Broadcast Engineering & Maintenance Handbook

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Preface

Radio is a very important part of life today. Since its beginnings in the early 1920s, broadcasting has undergone many changes, not only in its style of operation, but in its adoption of new technologies as well.

Although AM broadcasting is the older service—FM, after its faltering start in the late 1940s—caught its second wind in the 1960s, and today it is an important broadcast service. While different transmission techniques are required of AM and the FM stations, in every other aspect they are the same. In this book, they are treated as one—a radio broadcast station.

The role of individuals in broadcasting, including engineers, has also changed. While operational changes and new technologies have on the one hand, reduced the actual number of engineers required at a station, the need for greater knowledge and more maintenance by those remaining has increased.

From personal experience of 30 years as a broadcast engineer, I know that when problems develop or it is necessary to do major maintenance in the middle of the night, the broadcast engineer needs practical answers to problems rather than theoretical exercises. In this book, the material is presented with a practical view, little mathematics, and hands-on theory concepts. The engineer in the field needs to "put a handle" on the theory so he can produce practical results. And in the end, correct results are what count; and not the theories that led to these results.

My book views the station as a complete system and encourages the engineer to view his station and technical problems that develop in the same manner. So that maintenance is not done haphazardly or inefficiently, methods are suggested for planned routine maintenance that work for the engineer. Some general theory is presented on how equipment works, but the main emphasis is on operation and maintenance, including methods of performing required annual audio proof-of-performance tests.

Patrick S. Finnegan

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Chapter 1

Typical Broadcast Systems

Every broadcast station is shaped by its market, economic forces, programming type and style, environment, and many other factors. These factors result in each station becoming a unique entity. It is very doubtful that a typical or average station could be described with any degree of accuracy, but even though each station is unique, all stations have many things in common. And one thing all do have in common is the need for technical maintenance.

Because of this uniqueness of each station, the engineers charged with the installation, maintenance, and operation of a station must be able to shape general principles into a form that apply at that *particular station*. And to apply the general principles to that station, the engineer should have an understanding of its technical system.

In the discussions that follow, some of the factors which go into the shaping of a station are discussed briefly, and then a method is explained which can help the engineer bring the technical operation of his station into better perspective.

The physical arrangement of the station and many operational factors dictate some of the basic equipment requirements. These also contribute to the technical complexity of the station and the maintenance problems.

COMBINED STUDIO-TRANSMITTER

This arrangement is popular at many stations (Fig. 1-1), but all can use it. All of the studio and transmitting equipment

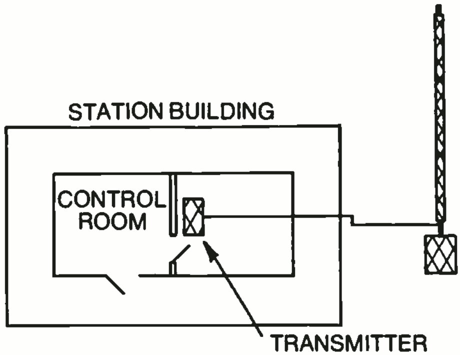
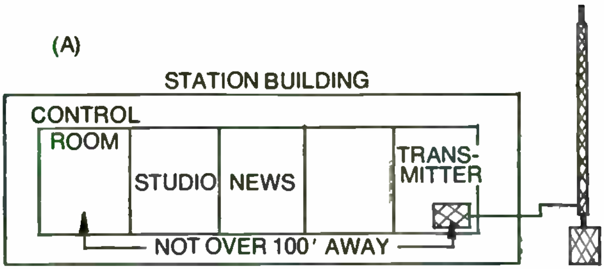


Fig. 1-1. Combined studio-transmitter arrangement. This is the simplest form and requires the least equipment.

is housed under one roof with the antenna nearby. The control room, studios, and transmitter are all clustered together for ease of operation. The transmitter may be located in the control room itself, or in an adjacent room where it can be observed through a soundproof window. This arrangement is the most efficient in operation and requires the least amount of equipment. Also, the job of maintenance and making measurements is easier to perform.

There are at least two variations of the combined studio-transmitter arrangement (Fig. 1-2). Although the studio and transmitter are combined under one roof, the transmitter may be located in another room or on another floor. The transmitter is no farther than 100 ft nor more than a floor away from the operator. Whenever the transmitter is moved away from direct visual and manual access by the operator, additional equipment is required and the system's complexity increases. Maintenance problems increase in direct proportion. The transmitter must have extension meters, and there must be a wired control so the operator can monitor and operate the transmitter.

In the second variation, the transmitter may be over 100 ft. and several floors away. Once the transmitter has been moved out past the limits described in the first variation, the station requires special FCC authorization, and a regular remote control unit must be used. Such arrangements are often found where tall buildings are available. The transmitter is located on the top floor and the antenna on the roof of the building. The



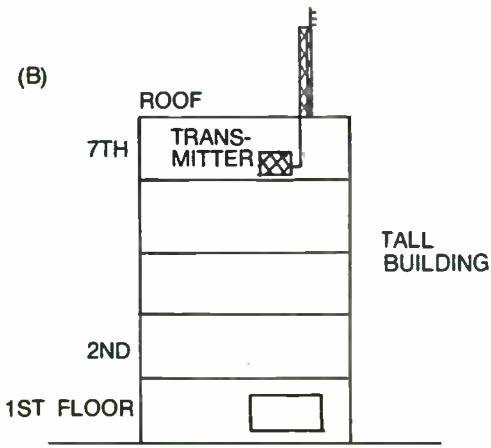


Fig. 1-2. Two variations of the combined studio-transmitter arrangement. In A, the transmitter is not over 100 feet away nor more than one floor away. In B, we have the second variation, in a tall building. This requires FCC remote control authorization.

building supplies tower height, and the use of a floor close to the tower will reduce the length of transmission line needed.

SEPARATE STUDIO-TRANSMITTER SITES

This is a very common arrangement (Fig. 1-3). The studios are located at some convenient place in the city, while the transmitter and antenna may be several miles away, usually out in the country. This is also the most complex of the arrangements and requires considerably more equipment. Maintenance and measurements are more difficult to perform, and travel time often becomes a factor. In those stations that do not have operators on duty at the transmitter site, security of the building also becomes a factor. Unmanned

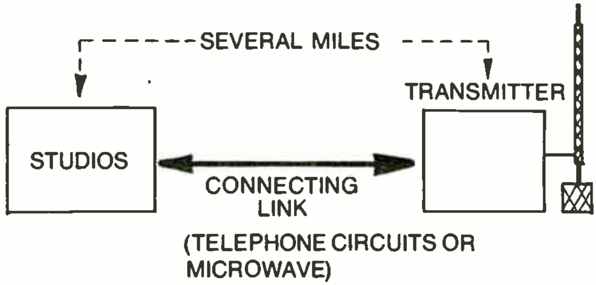


Fig. 1-3. A separated studio-transmitter arrangement. This is the most complicated and entails considerably more equipment and maintenance difficulties.

transmitters must have an FCC remote-control authorization and an approved remote-control unit in operation.

The two sites must have an interconnection link. There must be an audio circuit, a circuit for controlling functions of the transmitter, and provision for monitoring transmitter parameters. The interconnecting link is often provided by the telephone company, but it may also be a station-owned microwave link.

TYPE OF SERVICES

AM and FM stations, while both engaged in broadcasting, operate in different services. Everything at the transmitter and beyond is also different. So the service affects the equipment required, and maintenance problems are also different. The audio equipment can be the same for both types of stations, as long as the FM is a monaural service.

STYLE OF OPERATION

The "live" style of operation will dictate a certain number of equipment items as well as their arrangement. This type of operation is used by many stations. Typically, the majority of programming comes from records played on turntables in the control room, operated by a combo man (one who also acts as an announcer). In another live situation, there may be both an announcer and an engineer performing the work in two different rooms—that is, an announcer's booth and a control room working together. The combo arrangement usually requires the least amount of equipment.

STEREO OPERATION

For FM stations that operate in stereo, the equipment requirements literally double from those of monaural operation. And stereo places more exacting demands on equipment performance and operating practices. This also creates numerous maintenance problems. There must also be special stereo monitoring equipment and an FCC-approved stereo modulation monitor for the transmitter. And to convert the left and right audio channels to a composite signal which modulates the transmitter, a stereo generator is required.

At this time there are two additional stereo proposals before the FCC, but as yet there has been no approval. These are for quad stereo and AM stereo. The quad method uses four channels instead of the present two. Quad is being transmitted now, but it is converted to two-channel for transmission and then converted back to quad at the receiver.

The proposal for stereo on AM is for two-channel system. The main carrier would be amplitude modulated as is now done, and the subchannel would phase modulate the carrier.

ANTENNA SYSTEMS

The antenna system of a station is often a very strong determining factor in how the station is arranged and the equipment to be used. Besides the technical requirements, there are often site problems. And when an AM station must use a multitower, directional antenna system, the equipment, problems, and maintenance all multiply rapidly.

The FM antenna must have relatively great height because of the transmission characteristics at VHF The antenna itself is relatively small, so it must have some tower or other supporting structure for height. The antenna may be mounted on a short pole above a tall building, or on its own tower mounted on the ground. In either case, a transmission line is necessary to cary the RF from the transmitter to the antenna. Long lines in not-too-accessible locations make it difficult to perform maintenance, and when repairs are necessary, rigging equipment and tower crews must be called in to do the work.

While the tower is the supporting structure for the FM antenna, in AM the tower itself is the antenna. Although many stations can operate with only a single tower, a great many of them must use a multitower directional system. These systems require several towers working togeher to obtain the required radiation pattern. Still other stations use two different directional patterns, one for day and the other for night operation. The tower is actually only half of the antenna. The other half is the ground system underneath the tower, made up of many copper wires fanning out from the base of the tower at least as far from the tower as its height. These can be simple two-tower arrays or multitower arrays. They all increase the station's complexity.

To demonstrate how various factors can shape the station into a unique individual and affect its operation and complexity, one station with which I had a special problem required two different directional patterns for its day and

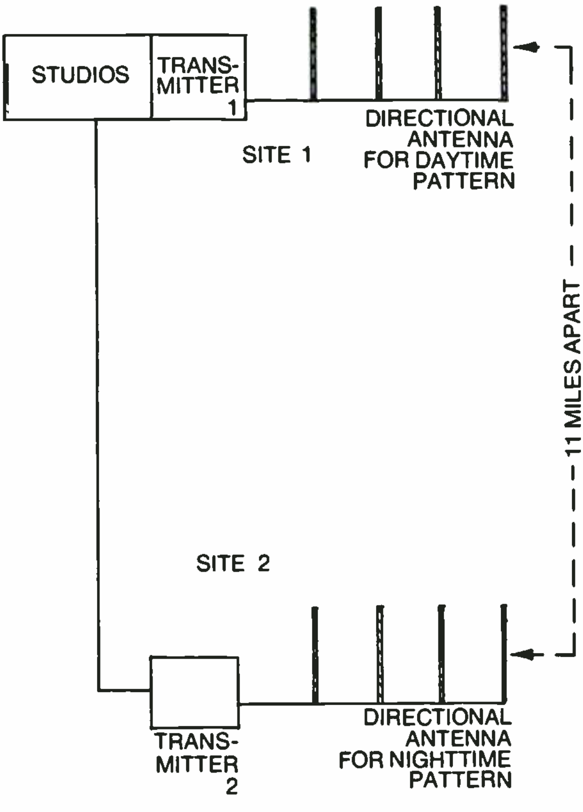


Fig. 1-4. A station with a real problem. It takes two separate transmitter sites and antenna arrays to solve it. The two were located 11 miles apart.

night operations. It wasn't possible to create these two patterns from the same set of towers at this site (Fig. 1-4). Consequently, it had to erect an *additional* multitower antenna system at another site 11 miles away! There are two different transmitter sites, one for the day operation and one for the night operation. Fortunately, there are only a few stations with problems such as this.

Directional antennas take up a lot of real estate, which is one of the reasons that most of them are located out in the country. There are many stations today that operate with a directional system within the city limits, but in most cases these stations had origionally built out in the country and the city grew out past them.

PERIPHERALS

Peripheral operations abound at any station. These are programming activities that cluster around the core of the station and make a heavy contribution to the station's programming. One important area is the news-gathering operations and the news room. Newsrooms today are often very well equipped with many electronic items.

Not necessarily associated with news, but often used by the news department, are the mobile remote pickup transmitters. Some stations have several of these units. The remote pickup requires its own peculiar methods of maintenance, and it generates its own problems as it also involves a somewhat different technology.

Additional program services—such as connection to a national, regional, or sports network, and the station's own remote broadcast arrangements—contribute to the station's complexity.

AUTOMATION SYSTEMS

Program automation systems, whether used on a part-time or full-time basis, rapidly multiply the needed equipment units, and if the system operates in stereo (Fig. 1-5) doubles its complexity and maintenance problems. When all the station's programming passes through an automation system, there is a need for recording booths for local production purposes. How well these are equipped depends upon how much of the automated programming is created at the station. In a station that uses full automation of its programming. there usually isn't a control room as this term is used in the general sense. One of the production booths must have some arrangement so that it can be placed on the air as a substitute for the automation system when the system fails.

COMPLEXITY AND MAINTENANCE

It should be very evident that whenever a station grows more complex for any reason there is a direct growth in the number of equipment items in use. And along with this growth in complexity and equipment numbers, there is a greater mumber of equipment failures. This is because there are just more things that can go wrong. Consequently, there is a need for more and better maintenance.

SYSTEM DIVISION

Although the discussions in this book must, of necessity, deal in generalities. the engineer on the job must always try relate these general discussions to the particular station for which he is responsible (Fig. 1-5). Even though one station

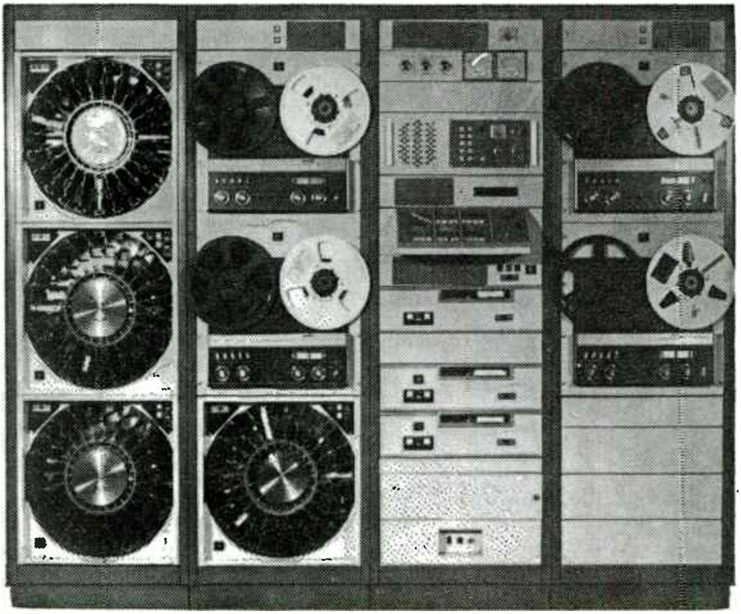


Fig. 1-5. Program automation systems increase the station's complexity and maintenance. Shown is a major program system by Systems Marketing Corp. (Model 3060), using a sequential programmer.

may have the same equipment lineup and may operate similarly to another, they will not necessarily have the same problems. Always remember that each station is unique. Each of its parts has its own stresses, wear, and possible abuses. For example, one station may have an operator who programs the automation computer keyboard with a feather touch, but another station may have an operator who pounds on the keyboard as if it were an ancient typewriter. It goes without saying that the latter station will soon have to replace keys on the keyboard.

So that engineer can develop a better understanding of his own station and its operation, the overall system should be divided into many separate parts. This does not mean that the equipment should be physically rearranged or even that the divisions need be written down on paper. However, drawing the divisions out in simple block diagram form could prove helpful, especially when new members are added to the staff. But the divisions should essentially be done in the engineer's mind.

THE MASTER SYSTEM

This is a term that can be applied to the station's complete, overall electronic operation, from its microphone inputs to its antenna outputs. Everything within this system must interface properly and work together as a single unit to produce the station's signal. This master system is made up of many parts that all dovetail together. And this master system can be divided into subsystems in a descending order of importance to master system. See Fig. 1-6.

Major Subsystems

The first division of the master system is the major subsystem. There can be several major subsystems of equal importance. A major subsystem can be described as an operational area in which a number of units work together to create a somewhat independent product or activity. One example would be the studio area of a station. All of its various subsystems work together to create the station's audio. This product is generally used to modulate the transmitter, but it can also be used for other purposes. It could, for example, be fed to a tape recorder. The recorded program could be sent to other stations or reserved for use at another time.

This same thinking can be applied in division of the master system into other major subsystems according to the particular station arrangement. But do not have divisions into major subsystems, than the particular situation warrants.

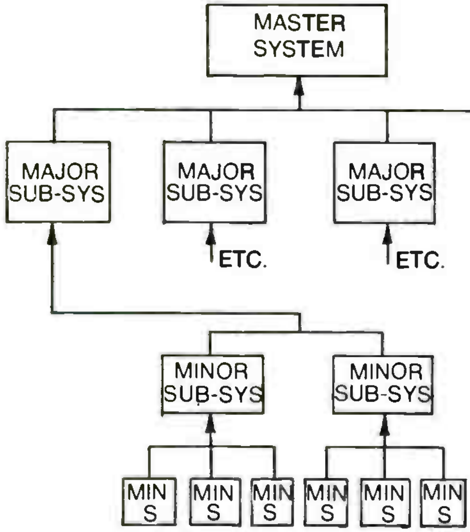


Fig. 1-6. Basic outline of the master system division into subsystems. This is similar to a company's personnel organization chart. Subsystems at the low end of the stack play the least role in the station's system.

Minor Subsystems

Each major subsystem can then be divided into minor subsystems, and, again, each of these ranked according to the importance of its role within that major subsystem. And each minor subsystem can be further divided into its own subdivisions. This dividing and subdividing creates a pyramid structure, all narrowing from a broad base to the single master system at the apex.

Many individual items that are low ranked in this particular arrangement are very expensive, high-quality units that can stand as master systems in their own right—but in other situations. A tape recorder, for example, is a complete unit in itself and can stand alone. But when used in the control room as a program source, it plays a lesser role and therefore is ranked as a minor subsystem. Thus, *use* in the operation determines the ranking.

Maintenance Aids

Dividing the station into its various parts proves very helpful to an engineer when problems develop and must be corrected in a hurry. It also helps the engineer visualize the total operation and not become confused by an apparent variety of independent operations. When he understands the total operation, he can quickly isolate problems to specific subsystems. Then another minor subsystem may be substituted, or bypass arrangements can be made so the station can continue its programming with little interruption.

COMMON DIVISIONS

As was pointed out earlier, each station is unique, but all have many things in common. In this chapter, we use the division method and discuss some of the equipment found in the various subsystems of a station (Fig. 1-7). In later chapters, those various equipments are discussed in more detail.

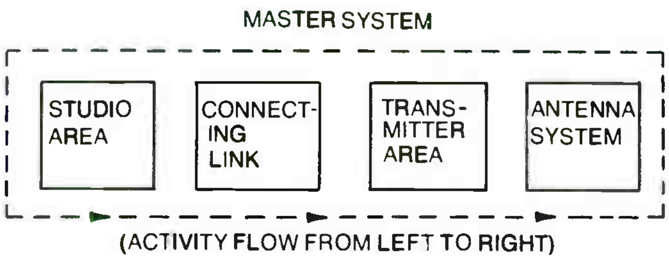


Fig. 1-7. The most common division of any station into four major subsystems.

Any station's master system can be subdivided into at least three or four major subsystems. Some stations may have more, but all will have at least this many. These major subdivisions are: studio area, connecting link, transmitter area, and antenna system.

THE STUDIO AREA

This major subsystem is composed of a variety of minor subsystems, surrended by many peripheral subsystems, all working together to produce the station's programming (Fig. 1-8). Further subdivision can be made in this manner: control room and its minor subsystems; recording booth and its

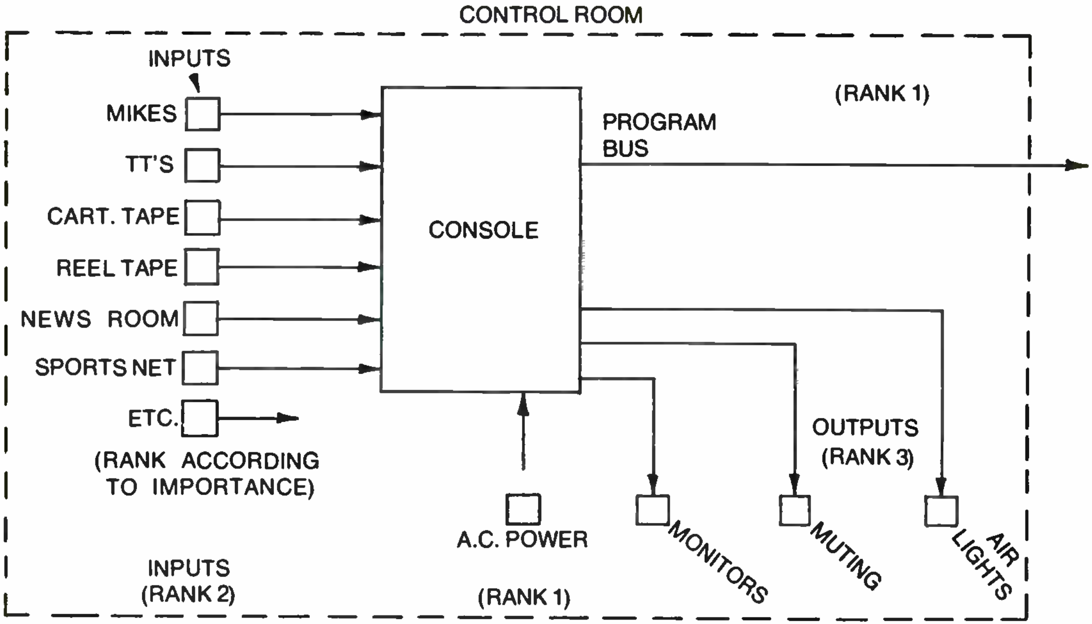


Fig. 1-8. Typical minor subsystem of the studio area. This is similar to a regular block diagram, except placement should be according to importance of role.

subsystems; second recording booth (if used); audio processors (if used at this location); peripheral systems, starting with the newsroom and its subsystems; remote pickup base transmitter and mobile units; network connection, regional network, and sports network; local remote lines and QKT circuits (voice coupler); and EBS (emergency broadcast system) equipment.

This is only a rough division, and each station should set its own order of priorities according to the actual equipment it has in use.

Control Room

This should be the highest ranking subsystem in the studio area of any station that uses a control room. (Automated stations may not.) In the control room, the highest ranking equipment item should be the control console. All other subunits feed into this console, there the programming material is mixed, blended, and controlled in the desired manner to produce the finished program product. The console is often referred to as the *control board*, or simple *board*.

Microphone System

Microphones originate a considerable amount of programming, whether live or recorded. For the live-tape operation, in which the main announcers work out of the control room, the microphones rank as a minor subsystem. There may be one or two located in the control room, one or two located in an announcing booth, and one or more located in each studio that is in operation. All of these feed directly to the console and are controlled by it. Microphones are low-level devices, so they must have preamplification. The preamplifiers are generally located in the console itself, although in some cases they are located in a rack.

Turntables

The second major source of programming is the turntables. There are a minimum of two turntables in the control room. It is extremely clumsy for a disc jockey to do a music show with only one turntable.

Although the term *turntable* is often applied to this program source, it is really a system made up of several subsystems: the turntable itself, drive meter, cabinet, cartridge and stylus, tone arm, equalizer, and preamplifier.

The signal output of the pickup cartridge is a low-level signal that requires amplification. The usual practice is to locate the preamplifier and equalizer in the turntable cabinet itself, close to the tone arm. The equalizer may be a separate unit, or it may be built into the preamplifier. The preamplifier brings the low-level signal of the cartridge up to program level of +8 dB (decibel) or the level desired.

Tape Recorders

Another important program source for the console is the tape machines in the control room. Tape machines may be of the open-reel type or the cartridge type. The cassette recorder is another type that is increasingly common.

In most cases, the open-reel machine is basically a two-system machine. That is, it is both a recording machine and a playback machine. It is the playback section of the machine that is used as a program source for the console. It may play tapes that have been recorded on this machine, other machines, or tapes that have been sent to the station. The playback amplifier can provide normal +8 dB program output levels.

The recorder section of the machine also has much use in the control room. The input to the recorder is often a selector switch so that the recorder can record from many sources.

Cartridge tape machines are newer than the open-reel machines, and all stations have two or more of these machines in use today (Fig. 1-9). Besides the different method of handling the tape, the configuration of these machines is often different. That is, many are playback-only machines which can play only prerecorded tapes. And there are often multideck machines that incorporate more than one playback section in the same unit. In the multiple units, some of the functions are shared, such as the cabinet, drive meter, etc. Ordinarily, each has its own head, playback amplifiers, and control circuit. When multideck units are employed, each slot is often referred to as a *tray*. For example, a machine may be a 3-tray unit or a 48-tray unit. The output of each of these trays or each unit is normally at program level of +8 dB.

A cartridge tape system is somewhat limited if only playback machines are used. So there is one or more recording units in the station, although the control room may have only one.

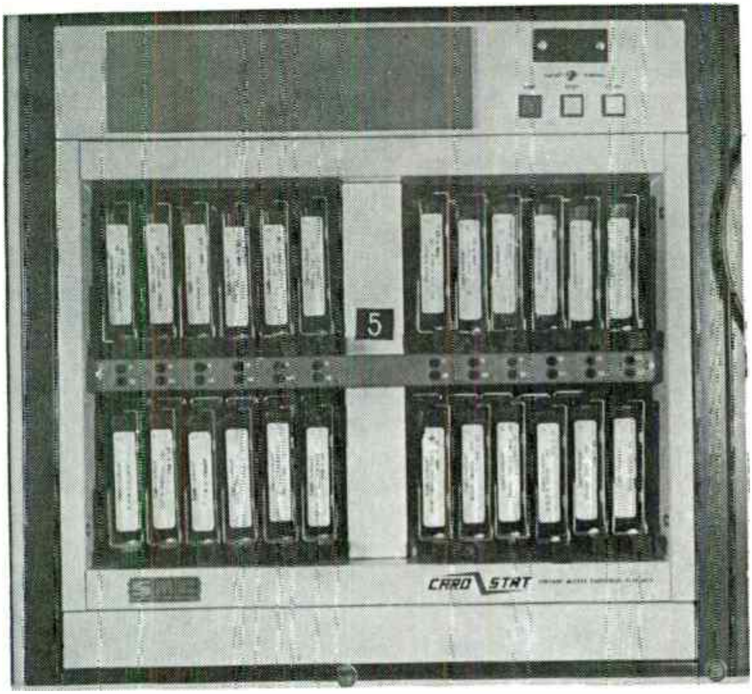


Fig. 1-9. Cartridge tape equipment comes in many styles, from the single tray unit to multitray units such as the 24-tray model shown here. (Courtesy Systems Marketing Corp.)

Peripherals

As mentioned earlier, there are usually many peripherals in the studio area. They vary from station to station, not only in type, but in numbers. Most stations have a newsroom. And how large this area is depends upon how much the station does in the news area. A major newsroom has a small console or mixing arrangement along with open-reel and cartridge tape recorders. There s a variety of electronic sources used in the news-gathering process; some may be portable and others are telephone circuits in the station. Most of these sources are channeled through the small console or mixer, so that editing can be done and completed news tapes produced. In many stations, the newsroom is well equipped so that it acts as a subsidiary control room for news programming. That is, when it comes time for the news, the newsroom is switched into the main control room as though it were a remote program, and the news is presented from the newsroom itself.

There are many other items that are helpful in the news-gathering process, such as receivers that monitor police, sheriff, and fire channels. There also may be a base transmitter-receiver located here for use of the remote pickup mobile units for news stories.

Remotes

Many program sources originate outside the station and are brought into the station over telephone circuits, or there may be remote pickup stations. Each of these is fed into the console in the control room for the switching, blending, and other processing needed. Programs may originate at stores, auto showrooms, fairgrounds, or any place that makes a good program or news source. These wire circuits are called *broadcast loops* and are leased from the telephone company for the occasion. Some may be equalized, others not, depending upon the quality of circuit required.

QKT Circuit

This type of circuit has become popular in recent years because it can be less expensive on a long-distance broadcast than regular broadcast loops. The QKT, also called a *voice coupler*, is supplied by the telephone company. It is a regular telephone that contains either an exclusion key, or a cutoff key, and a transformer to connect the station's remote amplifier to the telephone circuit. The broadcasts are handled as regular long-distance telephone calls. At the studio, it is necessary to arrange a connection to the telephone company circuit for the phone number in use, that is, a connection to the console.

Signal Processing

There may be several processors in the studio area. These are devices such as AGC amplifiers, peak limiters, equalizers, etc. They may be used at any place this action is required. In combined operations these follow the console output, but in separated operations they may be placed at either or both ends of the connecting link.

Processors are also used with production booths, and AGC amplifiers are often used to control incoming levels from a remote line. Here again, the use and location of the processor determines its ranking in your divisions.

Other Program Sources

There may be a variety of program sources feeding the console besides the equipment in the control room. Each station would apply a ranking to the source according to its importance to the station. That is, if the station carried a very heavy schedule from a sports network, this network is given a higher ranking that an occasional remote. Other sources can be from a sister AM, FM, or TV station the newsroom, or a production booth acting as a subsidiary control room.

EBS Equipment

All stations are required to have a receiver that receives the EBS alerts from key stations, and they must also send out EBS tests each week. The new FCC rules, which went into effect April. 15. 1976. require that a dual-tone system be used. That is, two tones—853 Hz and 960 Hz—are transmitted for 22 seconds. The receiver must be in operation all the time the station is on the air and must set off alarms when the alerting signal is received. There have been many changes in this system since its origination.

THE CONNECTING LINK

The second major subsystem that some stations have is the connecting link between the studio and transmitter. For stations with the transmitter in the control room, or in the next room, the connecting link is simply a pair of audio cables. A simple arrangement like that is hardly considered a major subsystem. But many stations have their transmitter out of sight and out of reach of the operator. The connecting link then does become a major subsystem.

Whenever the transmitter is far away from the operator, he must be able to monitor and control it, as well as feed the audio signal to the transmitter for modulation. There must always be an audio feed from the studio to the transmitter for the program audio. So let's consider that first.

Audio Circuit

The audio circuit is perhaps the most important subsystem of the link. The quality of this circuit must be as least as good as that required of the rest of the station itself. The audio-frequency response, distortion, and noise are the basic characteristics, although line losses are also a factor. A simple way to remember the quality of line needed is to consider the limits allowed when making a proof of performance. All the system audio must pass through this circuit. These are usually telephone lines that are equalized. And if the station transmits stereo, two identical circuits are needed for the left and right audio channels.

Transmitter Control

The operator must be able to do everything (almost) to the transmitter at a remote location that he can do to it while standing in front it—at least the controlling functions of turning it on and off, raisng power, etc. This involves a remote-control system. There are different models of remote-control units, and some of these use metallic telephone circuits. There is a sending unit at the studio which controls the different functions of the transmitter through a receiver unit at the transmitter site.

Metering

All of the important parameters of the transmitter must be metered. The parameter samples are sent from the unit at the transmitter site to a receiving unit at the control point, where they operate one or more meters. These devices usually scan the samples in sequence, and the unit at the control point is sychronized to this scan. In the simple units, these are stepping relays that send DC (direct current) voltage samples back to be measured. A single pair of wires is needed.

Sophisticated Units

Besides the simple control units, there are many modern, sophisticated units. These are basically digital devices that convert analog samples and control functions to digital signals. These use (frequency-shift keying) of an audio carrier signal to transmit information over the lines, if telephone company pairs, or the modulator of an STL (studio-transmitter link) microwave unit owned by the station.

STL

As just mentioned, these are microwave links. Such links are common in television stations and are becoming more common for FM radio. They are not as yet very popular in AM broadcasting. When the station uses its own microwave link, except for the quirks of Mother Nature on propagation, it places the control of the connecting link back in the station's hands. The STL, by the way, only replaces the telephone circuits that would otherwise be used. There must still be a remote-control unit for the transmitter.

Monitoring

Transmitter parameters must be monitored—also the antenna system, tower lights, and building security system (if used).

Transmitter modulation must be monitored by an approved modulation monitor. When the station is operating by remote control, the modulation monitor must be located at the remote-control point. When placed at the remote-control point, an RF amplifier is often required to increase the RF signal level so that the monitor can operate properly. When work must be done at the transmitter site that requires a monitor, there can be some extra difficulty in doing the maintenance.

Controlling and monitering the transmitter from any distance can become a rather complex operation (Fig. 1-10). When the more sophisticated remote-control units are employed, and a STL, then other technologies become involved: digital and microwave. When dividing by the subsystem method, the rank must be established according to that which is used at a station. Several of these technologies can be of equal rank. But always remember that the ranking is relative; it is designed to help the engineer quickly isolate problems that develop, as well as aid his understanding of the overall station operation.

TRANSMITTER AREA

This is the third major subsystem of the master system. This equipment receives the audio from the studio area, develops the RF carrier, impresses the audio on the carrier as modulation, and sends it to the antenna system for radiation. This area includes systems that could be classed as major systems, but in a station they work together as part of one major subsystem.

Transmitting Gear

Any transmitter is composed of many internal subsystems. Transmitters differ according to make, model,

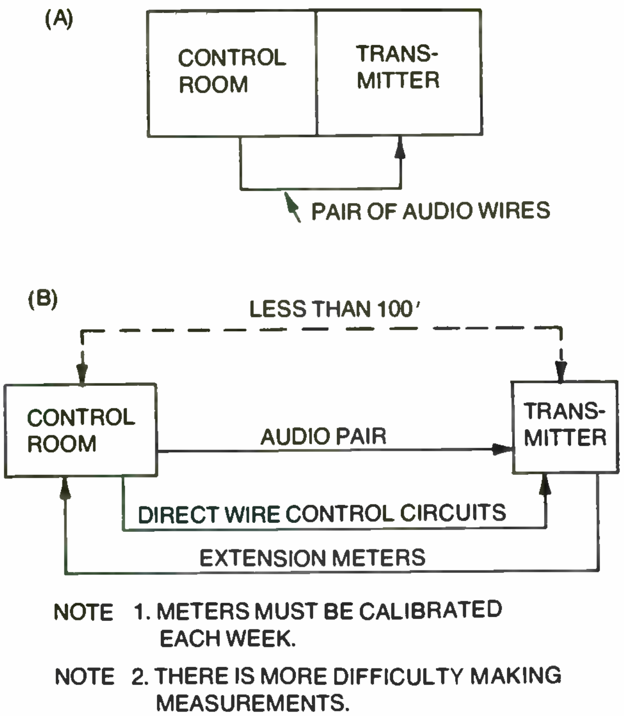


Fig. 1-10. Moving the transmitter out of direct visual view and control by the operator increases station complexity and requires more circuitry and routines. In A, the simple system requires nothing more than a pair of audio wires. In B, there must also be wire control circuits and extension meters. The further away the transmitter is moved, the more complex it becomes.

power range, and type of modulation. The transmitter is usually a self-contained unit that requires only an audio input and AC power input to provide a modulated RF output to the transmission line.

AC Power Input

Low-power units work on 230V AC, single phase, while high-power transmitter employ three-phase 230V AC. Very high-power units use 440V AC. this AC power is brought to the building over high-voltage mains, then stepped down to the 230V by transformers on a pole or on the ground. It is fed to a main power entrance, where there is fuse protection. Then it is distributed throughout the building. One of these circuits feeds the transmitter. In some of the older transmitters (and even some newer ones), the transmitter crystal is installed in an oven; this even usually has a separate AC circuit. The power feed should be through conduit.

Audio Input

The audio from the control room must be fed to the transmitter audio input. This audio is usually run through processors before it gets to the transmitter itself. There usually is an AGC amplifier to control program levels and a peak limiter right before the transmitter. There may also be speech enhancers or other dyamic equalizers in the line also. The AC and limting amplifiers may be combined in a single unit or may be separate units. When the transmitter is at a distance, these processors may be split up, or they may all be at the transmitter site. Much depends upon individual preferences and the particular situation. There are different types of processors used for FM and AM, as well as a different arrangement when stereo is in use. The same types can be used, but today the ordinary AGC amplifiers and peak limiters are giving way to more sophisticated ypes.

Peak limiters, designed for AM, switch the highest peak of a cycle to the positive modulation side before sending it into the transmitter. This allows the positive modulation to be higher than 100%, and at the same time limit the negative side to no more than 99% modulation. The output of these units are polarized.

FM peak limiters must contend with the 75 microsecond preemphasis in the transmitter. So some shape the audio to a true preemphasis curve by clipping, if need be, so as to attain a higher degree of modulation without overmodulating. Both stereo AGC amplifiers and limiters are strapped together so that they operate as a single unit, although controlling both left and right audio channels.

Stereo Generator

With stereo, the audio signals must be processed through a stereo generator before they are fed to the transmitter input. The generator is a very important subsystem in the stereo process. The composite output of the generator modulates the transmitter—not the audio signals themselves. The generator output contains both audio and supersonic signals that have been specially processed.

Monitoring

The monitoring of the transmitter can be classed in two categories: the modulation and the parameters.

Modulation—There must be an FCC-approved modulation monitor in operation. The AM monitor has provisions for monitoring the positive or negative modulation envelopes, provides audio output for speaker monitoring (after amplification), and provides outputs for measuring audio distortion during proof-of-performance measurements. The FM monitor provides the same capabilities as the AM monitor, except that the positive and negative modulation is not as important. The FM station does not use asymetrical modulation as do many AM stations. If the FM is stereo, there must be an FCC-approved stereo monitor. This monitor has many additional capabilities and provides many switching positions and pads for making the stereo proof measurements.

All monitors will have provisions for remote metering of its various functions necessary for the FCC-required monitoring of percentage of modulation. These functions can be routed over an extension-metering arrangement.

Parameters—Certain parameters of the transmitter must be metered and logged. When on remote control, or if extension meters are used, a sample of the parameter must be provided. Most modern transmitters already have the samplers built into them. Older transmitters, however, may not have the samplers, and these must be added. The output-stage power input—that is, voltage and current—and the transmitter power output must be logged. There may be other samplers provided also.

Transmission Lines

Once the RF signal has been generated and modulated, it is sent to the antenna over transmission lines. Some stations still use the old open-wire transmission line, but the majority use coaxial line. Coaxial lines come in different diameters, are either rigid or flexible, foam filled or air dielectric, and may be bare on the outside or jacketed. Air systems may use dry air or gas under pressure. Pressurization may be done by gas cylinders or an air pump.

The length of the line between the transmitter and tower is called the *horizontal run*. This may be suspended on posts or buried under ground. When the line feeds an FM antenna, it must also continue up the tower. This is called the *vertical run*.

When a transmission line is not properly terminated, *standing waves* are set up along the line. That is, some of the transmitter power is reflected back to the transmitter. The *standing-wave ratio* (SWR) is the ratio between the forward and reflected powers. If the *voltage* of the waves are used in the calculations, the term is VSWR.

Standing waves on the line can cause damage to the line itself or to the output stage of the transmitter. FM transmitters use a device that monitors this VSWR and shuts the transmitter off when VSWR reaches a predetermined value.

Cooling Systems

Transmitters must have cooling for proper operation. There is a subsystem built into the transmitter to provide its cooling. The air or water temperatures in the cooling system are sampled, and if the flow stops or decreases, an interlock shuts the transmitter down.

Transmitters are also designed to function within certain ambient temperature ranges, that is, operating temperatures. Either end of this range may be uncomfortable for humans. But if the ranges of air temperatures vary outside the transmitter limits, cooling or heating must be added.

ANTENNAS

The antenna system is the final point where the station has control over its signal. The antenna system is complex enough to be classed as a major subsystem; this is particularly true of the multitower AM directional systems. AM and FM antennas are classed in different categories. Their treatment is different because of the difference in frequencies. They require different operating and maintenance practices.

AM Antenna

This may be a single tower, or many towers in an array. The tower itself is the antenna, so its height has a definite relationship to the station's carrier frequency. Thus a vertical antenna is used, with the other half of the antenna system in its ground system. Primary coverage in AM broadcasting relies on the ground wave signals. The ground waves are more limited in distance but are more reliable than sky waves. But sky waves do enter the picture, and that is the reason stations cut back power at sunset and change to directional patterns, for the sky wave reaches farther after sunset.

Antenna towers may be either self-supporting or guyed. When guys are used, they are segmented with insulators so the guys do not affect the radiation of the signal. The guys are not part of the antenna; they are only for support.

The antenna may be series fed or shunt fed. There are some shunt-fed towers around today, but the majority are series fed. In this method, the antenna must be insulated from ground.

Coupling Units

When a series-fed antenna is used, a coupling unit must be used to match the transmission line to the antenna. This unit is usually a T-arrangement of coils and capacitors which matches the impedance transmission line to the tower, cancelling out any reactance of the tower itself.

In a directional system, each tower has a coupling unit, but there are also power dividers and phasers that divide and distribute the RF to the different towers in the array in the amounts needed to obtain the desired pattern. The whole system is interconnected with coaxial transmission lines.

Antenna Monitoring

In the single-tower, omnidirectional system, the power at the base of the antenna must be measured as the station output power. In a directional system, the power to the common-point feed of the system is measured for power output. And the phases and base current of each tower must be sampled and fed back to a phase monitor so that the proper operation of the antenna can be observed as an operational requirement. The samplers for this are usually small loops mounted at the appropriate place on each tower, or on poles away from the tower, yet close enough to get an adequate sample. The RF samples are fed back to the transmitter room over small-diameter coaxial lines.

FM Antenna

This antenna is small in physical size because of the carrier frequencies (VHF) used. Because of the small size, many antennas are often stacked one above the other, suitably spaced. This arrangement provides power gain. Each one of the units is called a *bay*; the whole array is the antenna. A directional pattern is possible when antennas are stacked, but the usual pattern is circular (but with increased power gain). Although each bay may be small, a typical 12-bay antenna can measure 100 feet in length.

FM Propagation—Signals at VHF behave far differently than those in the AM broadcast band. They tend to travel more in the line of sight, although they do get far over the horizon. They suffer more propagation losses. To overcome some of these factors, the antennas are mounted as high as possible within the limitations set by the FCC. This ordinarily requires a tall steel tower, unless a suitable building or other tall structure is available.

Weather Effects on FM Antennas—Weather affects the FM antenna far more than it will the AM antenna. Heating and cooling by the air or sun can cause the elements to expand or contract and detune the antenna. The most serious problem is sleet or ice forming on the antenna. This will seriously detune the antenna and cause serious VSWR losses on the transission line. To overcome this roblem, heaters are inserted in the antenna elements to melt any sleet or ice. These heaters are operated from 120V or 230V AC and are usually thermostatically controlled by a unit mounted near the base of the FM antenna. In some areas of the country, where icing is a very severe problem, the entire antenna is often enclosed in a radome.

Towers

Towers are used as supporting structures for FM antennas or as the antenna for AM stations, or a tower may serve in both capacities at the same time. Aside from the electrical characteristics and consderations as antennas, towers are large physical structures that require maintenance if they are to remain standing for many years.

Both for greater visibility and weather protection, the towers are painted. This painting and the colors used must conform with the FCC rules. The painting is mainly for visibility, but it does add increased weather protection. Other methods, such as galvanizing, will contribute the major share of weather protection. Weather is not the only thing the metal must be protected from, for these are other chemical elements. such as salt near the oceans and a variety of chemical elements added to the air in industrial areas.

Also for visibility. the towers must be lighted. and the lighting arrangement must conform to FCC standards. The rules specify a different arrangement for different tower heights. depending on whether the location is close to an airport or air lane. The lighting system requires 120V AC. and there must be one or more flashing beacons and side-marker lights at different levels. These lights must be turned on at a certain level of sky intensity (light). which is usually sensed by a photocell. This lighting must be observed each day for operation and then logged. If the tower cannot be visually observed. then samplers must be included that send data back to the control point to indicate that *all* lamps are operating properly. A new method of lighting recently developed is high-intensity strobe lighting. This type can be seen farther than conventional lamps.

Lightning Protection—Of course. a tall tower makes a likely target for lightning. Lightning develops tremendous forces. and the best we can do is divert it to prevent damage. Unless some precautions are taken. damage can result the elements in the tuning section. transmission line, transmitter, and transmitter building. Some very complex arrangements have been developed to prevent lightning strikes. Old-time remedies make use of lightning rods on the tower, ball gaps across the insulator of an AM tower. and static-drain chokes.

Isolation—The AM tower must be insulated from ground. But there are many metallic conductors that need to cross the base—or at least the signals they carry must cross the base—so special arrangements must be made.

Tower lighting and heaters for FM antennas require 120V AC. There are two ways to cross the base with AC power. The first is the large open-ring transformer. There is no connection except through the magnetic flux of the transformer windings. The second method feeds the AC power through large RF chokes.

FM antennas may be mounted at the top of an AM tower. The coax transmission line must cross the insulator at the tower base. Again. there are two methods of doing this. The preferable way is through an isolation unit. There is no direct connection to this unit. It maintains the impedance characterisic of the coax line. The second method makes use of an insulated quarter-wave section of the coax line. The quarter-wave length is figured at the FM carrier frequency.

When directional AM antennas are in use, the RF signals from the samplers are fed back over small coaxial lines. These must cross the base. Usually, large coils of the line are formed in an amount that creates an RF choke at the AM frequency to prevent shorting out the base. In another arrangement, the sample loops are on small wooden poles on the ground, but close enough to get an adequate sample from the tower.

Chapter 2

Maintenance Techniques

The term *maintenance* is a general term often used to cover *any* technical work on equipment. But there are different types of maintenance which can be divided into at least three general categories: troubleshooting. routine or preventive maintenance, and updating or modification.

TROUBLESHOOTING

Technical problems occur almost daily and may range from simple operational problems to major equipment breakdowns. The more units of equipment in a station, the higher the proportion of equipment failures. There are simply more things that can go wrong.

Troubleshooting is different from other forms of maintenance in that it is directed at failures in the operation, which often require attention.

Troubleshooting may be defined as: the application of general and specific knowledge, in a systematic manner, to an evident problem, so that data may be collected upon which a rational judgement can be made as to the solution and correction of the problem.

Each phrase of that definition has a special meaning and should be studied carefully (Fig. 2-1). For a better understanding, then, let's take each of the phrases and explore it more fully.

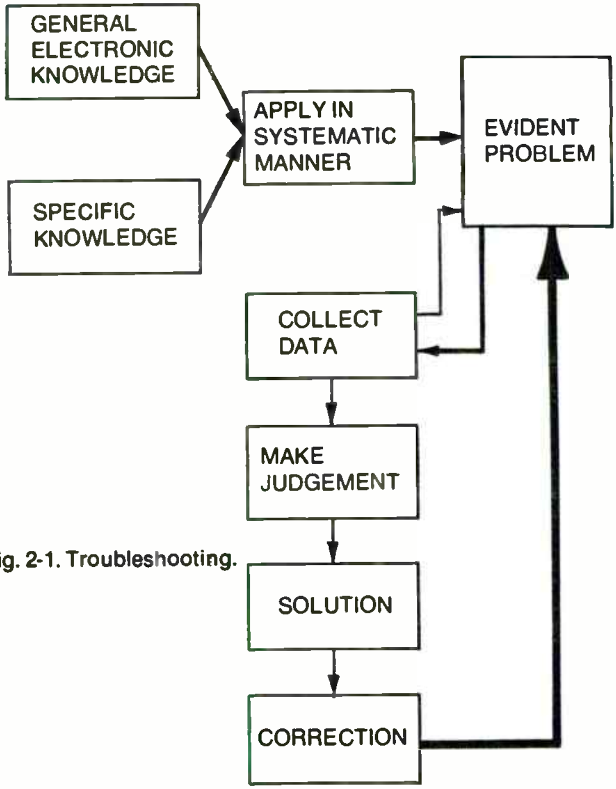


Fig. 2-1. Troubleshooting.

Application of General Knowledge

The troubleshooter must have a general understanding of basic electronics. He needs to know how components work and how they work in circuits, he must have some general knowledge of circuits and the particular technology in which the fault lies. For example, if it is an audio problem, he must understand audio systems, and if it is an RF problem, he must know general RF technology. Unless the troubleshooter has a good grasp of the fundamentals, he is groping in the dark! He could, in fact, cause more damage than he corrects. And in some sections of the system, such as high-voltage areas of a transmitter, he could cause himself harm.

Specific Knowledge

Although a good understanding of the fundamentals can go a long way in solving problems, efficiency dictates that the troubleshooter have a reasonably good understanding of the particular system and its equipment components. This is not about systems in general—for example, how transmitters work—*but how a particular one works.*

Systematic Manner

The engineer should follow definite routines or procedures in his search for the fault, rather than jumping around helter-skelter like a grasshopper. Without definite procedures, his efforts may be very inefficient, ineffective, and unproductive.

Evident Problem

This means that something in the system is acting abnormally or has failed. Actually, this is crux of troubleshooting. A problem already exists; it has happened and needs correction. Other forms of maintenance are anticipatory, but the troubleshooter must chase present realities.

Data Collection

One of the major aspects of troubleshooting is asking many pertinent questions and obtaining correct answers. Questions must be asked of those who were operating the equipment when it failed, and questions must be "asked" of the system by checking various meter readings and any other source that turns up data which helps in the solution of the problem.

Rational Judgement

Without facts, there can be no judgement—only guesswork. The gathering of data turns up facts and also turns up many irrevelant bits of information. These must be sorted out so that only pertinent facts remain upon which to make a judgement. When asking questions of nontechnical people who may have been operating the equipment at time of failure, extreme care must be used in assessing the answers they give so that real information may be uncovered.

The Solution and Correction of the Fault

In the sense used here, *solution* and *correction* are not the same thing. *Solution* means that the fault has been uncovered, and the engineer knows what it takes to restore the unit to normal. *Correction* means the steps taken to get the system operational again, even though this may be some temporary arrangement, such as bypassing the unit or substituting with a spare unit.

DEGREES OF TROUBLESHOOTING

There are degrees of troubleshooting just as there degrees of severity in problems. Consider a few examples that can help describe both.

In the first situation, the operator is sitting at the console ready to switch up a very important program coming in from a remote location. He is tense and doesn't realize he has his hand on the wrong key. When the time comes to switch, he throws that wrong key! Now he panics and calls for help. Technically, this is a simple problem (although it may not sound that way on the air). Solution calls for finding the correct key; correction calls for turning it on and the wrong one off.

In the second case, it is the same situation, but instead of the wrong key, he does throw the correct key—the console goes dead (the fuse blows). Technically, this problem is more severe and requires a little more troubleshooting.

Another example—assume that at the moment he throws the key, his air monitor goes dead and alarms warn that the transmitter is off the air! The fault this time is a burned-out section of rigid coaxial line, and there isn't a spare section in town. Technically, this is a very severe problem, and it requires considerably more expertise on the part of the troubleshooter in finding the fault. Besides that, in this case it also takes a considerable amount of latent ingenuity—or friends at a neighboring station with a spare section of line—if he is to get the transmitter back on the air with little loss of air time.

Troubleshooting can be translated into its long-term and its short-term aspects. Quite often, both of these aspects come into play when a problem occurs.

Short-Term Troubleshooting

In the *short-term* sense, time is usually a critical factor. That is, something fails and must be corrected immediately or within a short time. For example, a main program amplifier fails, shutting off the program that is on the air. This fault in the system must be found in a hurry and corrective steps taken immediately to remedy the situation. In this case, the defective amplifier is found and is bypassed with a patch cord, some level adjustments are made for the lack of gain, and the program is back on the air. Or the unit may be replaced with a spare unit, which is patched into place, and the programming resumes. Time is a critical factor in this example, since the programming must be restored quickly. This is the short-term aspect of troubleshooting.

Long-Term Troubleshooting

Whenever there is a defective equipment unit which is a low-priority item and the correction can be done whenever there are less pressing problems, then long-term aspects of troubleshooting come into play. Again a defective amplifier must be replaced with a spare unit or bypassed. But now time is not the critical factor that it was in short-term troubleshooting. With the system operating satisfactorily, using the substitute amplifier, the faulty amplifier can be repaired when time allows.

Although the short-term aspect took the master system or at least a major subsystem into consideration while isolating a defective minor subsystem (the amplifier), the same troubleshooting technique is used to isolated the defective component or fault in the amplifier. That is, for this problem, the amplifier now becomes the master system. All of its circuits and components become major and minor subsystems.

Mental Attitudes

Since time can be an important factor in short-term troubleshooting, additional elements enter the picture. One of these elements is *mental attitude*. Loosely translated, this means: the engineer's tendency to hit the panic button!

When one has allowed himself be drawn into a panic situation, his reasoning powers are severely hampered—he simply cannot think straight. Under such circumstances, much costly air time can be lost until the fault in the system is remedied and programming resumed. Besides that, there can be *additional* equipment damage caused by the engineer in a condition of mental panic. He may, for example, begin twisting every knob in sight, turning switches on and off, and even foul up special setup adjustments which can cause *other* units to operate far out of tolerance and even burn up components in them. In fact, anything can happen! To do his job effectively, the engineer who is naturally excitable must learn to discipline himself.

Lack of Knowledge

Besides an excitable engineer's natural tendency to panic, there are other possible causes of panic (Fig. 2-2). One cause is the lack of a good, basic technical knowledge—in particular, knowledge of the system and the parts with which he works on a regular basis.

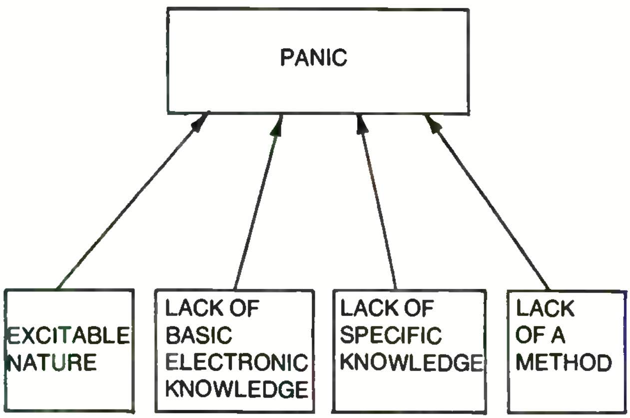


Fig. 2-2. Causes of a panic situation.

Another cause of panic can be the lack of a troubleshooting method. Without some method, the engineer may make much movement and effort but find it very unproductive of results. Over a period of time, most troubleshooters develop some method which they apply to help quickly isolate and correct a problem. One such method is described a little later on.

Decision Making

When short-term troubleshooting has isolated the fault in the system, decisions must be made in most cases. The decisions may not always be made by the troubleshooter alone, but he contributes his share to the decisions. And if he allows himself to become panicked, he probably won't be able to make a satisfactory decision or contribute logical information to the decision-making process of others who may make the final decision.

The scope of these decisions are tied to the facts in each case. He may need to decide alternate routes or alternate equipment for substitutions, or time may be an element in the correction and he may need to assess this aspect. For example, should he try to operate a faulty transmitter with the PA (power amplifier) plates glowing white hot, wedging in the circuit breakers, in hopes of staying on the air the last 5 minutes of an important broadcast? Will the tubes be damaged? The broadcast *could be* of great enough importance to warrant sacrificing the output tubes! Another example: A component has failed and a spare is not immediately available. Should he try to use one of less rating, and will it hold up? It may not last long, and the transmitter will be down again. So, would it take less time to dash off to the parts store to get a replacement, or take a chance that the low-rated part will hold up? Many such decisions must be made, and the engineer needs a cool head. If he doesn't have to make the desision himself, at least he should provide correct information on the situation and point out alternatives he can provide, so that others responsible can make the correct decision.

DEVELOP A METHOD

Any method eventually helps the engineer find the causes of problems and correct them. However, whatever method is used, it should be graded by its efficiency in terms of time, effectiveness, and productivity of results. And whatever method an engineer is using, he should review it from time to time to see if it really does the job for him. Is it really a method, or just a set of old habits? After all, what good is a method, when through its use, it takes an engineer all day to correct a problem that could have been corrected in a half-hour?

Whatever method you use, review it from time to time against changing technologies; make whatever adaptations or modifications that appear necessary.

One Method

The troubleshooting method described here is one that I have developed over the years It has proven itself successful in most cases.

When an equipment failure occurs, apply first the technique of taking a mental step back from the equipment. This mental step back is most important and is especially helpful to an engineer who tends to hit the panic button. The step back has the effect of mentally placing one *outside* the situation so that he can be *objective*. It also allows time for the reasoning machinery to get into gear. This mental step back should only take a few seconds to accomplish. It is somewhat akin to the saying, "Look before you leap."

Once the mental faculties are brought into proper receptive mood, careful observation is made of the events taking place. At the same time, proceed with the collection of data and other facts that provide clues. As the data and facts begin to pour in, the reasoning powers are brought to bear—sorting, discarding, and isolating data—until a solution is reached. As soon as a solution is reached, a decision is called for on the part of the engineer. Since the correction of the fault may not always be a simple matter, a decision must be made on what course of action to take. One usually needs to decide which course of action takes less time for correcting the fault, selecting alternate routes, substituting equipment, and so on.

Restating this method in condensed steps (Fig. 2-3): (1) Take a mental step back from the equipment, (2) Collect data and facts by a careful observation of what is taking place, (3) Arrive at a reasoned judgement based on the facts uncovered, (4) Make whatever decision is required.

The Wide View

Carefully observing events unfolding and collecting data and facts must be done in a systematic manner.

Once you have taken the mental step back from the equipment, look first at the overall system, that is, the master system or at least the major subsystem in which the events are taking place (Fig. 2-4). For example, if you were called about a problem in a recording booth, it is highly unlikely that you need to consider the station's overall master system. Consider only the recording-booth system. This initial wide view indicates that many parts of the master system *are functioning properly*.

Next, proceed to a narrower view of the system, scanning that section. With each step, make the view smaller in scope as data and facts indicate portions are working properly, until

Fig. 2-3. One troubleshooting method, in condensed form.

you finally arrive at a very narrow view, which is the particular fault or circuit in trouble itself. If the engineer has divided his station system in various sections or subsystems as described in the previous chapter, this scanning of the system can be done in a very short time.

This technique of starting with a wide view and narrowing the view progressively is similar to a TV cameraman covering a baseball game. When action is about to begin, since he doesn't know what will happen, he opens his lens to a wide-angle shot to cover a large area. As soon as the action breaks and he can determine the direction it is taking, he then begins zooming in with a progressively narrower view until he ends up with a very tight closeup of the outfielder catching the ball.

The Senses

All the senses should be brought to bear on the investigation of a problem, and this should also be done in a systematic manner. For example, suppose a defective

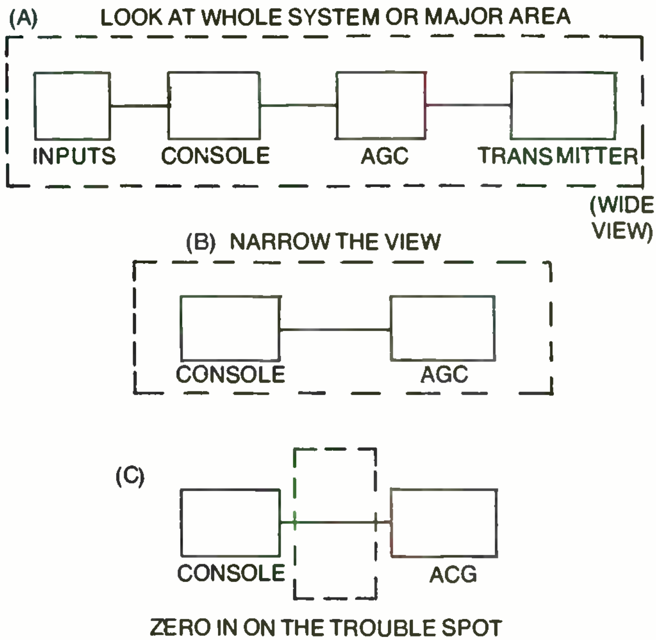


Fig. 2-4. Proceed from the wide view to a very narrow view.

amplifier has been pulled out of the system, and troubleshooting of the unit begins.

First, *visually* scan both sides of the chassis or circuit boards, but do this systematically (Fig. 2-5). Read it as you would a book or printed page. That is, start top left, read across, then move down a section on the left side, and again left to right, until the whole board is scanned. Continue this process until *both* sides of the chassis have been scanned. During the scanning, be on the lookout for obvious faults, such as discolored or charred resistors and other components, leaky capacitors, arc-over points, broken wires, etc. But even if you find something of this nature, continue the scan until the whole chassis is scanned. There can also be other defective parts on the chassis, but at some other place or on the other side.

Smell—Use your sense of smell at the same time you are scanning the chassis. Overheated components, burned or charred wiring and components, all give off distinctive odors. Although the component is not used as much today as it was a

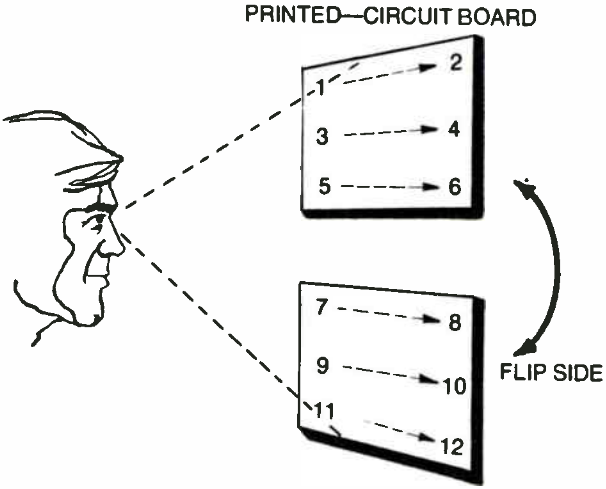


Fig. 2-5. Scan the chassis or printed-circuit board as you would a printed page.

few years ago, one needed only to step into the room where a selenium rectifier went defective to know what it was. The odor was very distinctive—rotten eggs. With a little practice and experience, the engineer can soon learn to distinguish these different odors, and they can be definite clues in locating the problem.

Touch—While the visual scan is taking place and you are on the alert for distinctive odors, the sense of touch can also be used. But be careful if the power is on the unit, and also be careful not to get burned.

Overheated components often radiate heat that can be felt without actually touching them. Do not touch large power resistors, as those normally run at a temperature that give a very bad burn. Other components, such as electrolytic capacitors, should run cool. If an electrolytic is leaking internally, it will run warm or hot. Many small transistors can normally run very hot. In all cases, be very careful.

Aside from heat, the sense of touch can also check for loose connections by *gently* wiggling components, cables, and other wiring. Do be gentle! Overworking and bending wires, terminals, etc. can *create* open circuits. If the connection is loose, gently pulling on it will show it up, or you may need to use a probing action. When power is applied to the chassis, it is wise to use some insulated tool,such as an RF alignment tool.

Hearing—Many defective components create noise; this may be either electronic, acoustical, or both. It is acoustical when it vibrates, buzzes, or gives off noise directly from the component or via the chassis. It is electrical when the noise becomes part of the electronic signal, for example, as hum in the program audio. Listen for noise, both from the chassis and from earphones or a loudspeaker. Microphonic components and noisy resistors often show up as noise in the speakers when the parts are probed or tapped with the alignment tool.

There are other noise sources that can be very misleading. These are the low-background/mechanical noises in a recording booth or studio. These noises are picked up by microphones. By the time they are processed along with other program material, their level may be much higher than was originally heard in the studio. Such noises come from air-conditioning units, heat ducts, turntables, tape machines, fluorescent-lamp ballasts, and elsewhere. When troubleshooting noise problems in the program material, listen carefully for this type of background noise. But listen in the studio or recording booth without any program running and with the speakers quiet. In other words, listen to the studio itself. You can turn tape machines into the "run" condition, then turn on the mike to mute the speaker. This will show up mechanical noise from the machine itself.

A systematic investigation making use of all the senses detects many of the areas in which the fault lies. But don't expect to find all problems this way. There are many problems that *do not* give off external clues, except through erratic operation of the equipment or the poor quality of the program sound. In those other cases, it is necessary to resort to making measurements of the signal, stage parameters, voltages, and

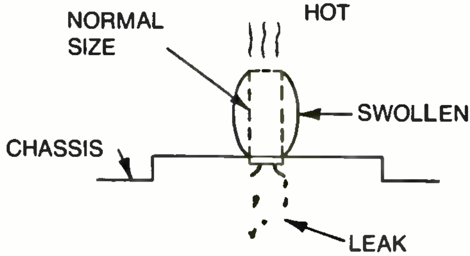


Fig. 2-6. Defective electrolytics can leak, swell, and get hot.

even checking out suspected components. Still, the habit of using all the senses during the troubleshooting process should be developed.

Brain Power

Systematic use of the senses may have uncovered a defective component, but it would be a mistake to assume that the component is the real fault or entire problem. On the contrary, it may only be one of the *results* of the real fault. Naturally, defective components must be replaced, but we must investigate *why* the part failed or burned up. If we simply replace the defective parts without correcting the real cause, the new parts will only burn up also. For example, upon investigation, suppose a burned resistor is found on a circuit board (Fig. 2-7). We assume this is the problem and replace the resistor with a new one. But if this resistor is in the

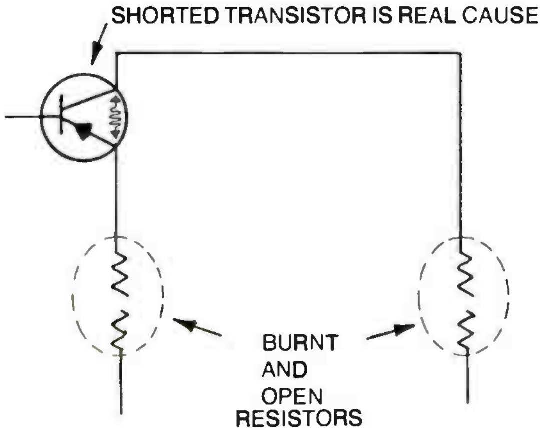


Fig. 2-7. Defective parts are not always the real cause. In this case, the shorted transistor burned out the resistors.

collector of a shorted transistor, it won't take long to burn up the new resistor. Go ahead and replace the defective parts; but before turning on the equipment, investigate the reason the part failed in the first place and correct that also. There can be many reasons for component failures. The part may have been underrated for its use in the circuit or may have simply worn out, but more than likely it was overloaded by abnormal circuit conditions or failure of another part. Reasoning must be used in making many of these determinations.

Reasoning

As discussed earlier, the investigation gathers facts about the problem and a reasoned judgement must be made. The reasoning applied should be *cause-and-effect* reasoning. This simply means that, when certain conditions exist—cause—certain results are obtained—effect. The same reasoning can be used in reverse order; that is, when certain *effects* are present, they have given *causes*. This is the usual reasoning in a troubleshooting situation, since the effects have already occurred, and now you must find the cause.

Knowledge

One cannot effectively bring reason to bear upon a problem unless one has some knowledge upon which to base the investigation. And this knowledge is of three types (Fig. 2-8). The first is *general knowledge* of electronic fundamentals that is acquired through schooling, home study

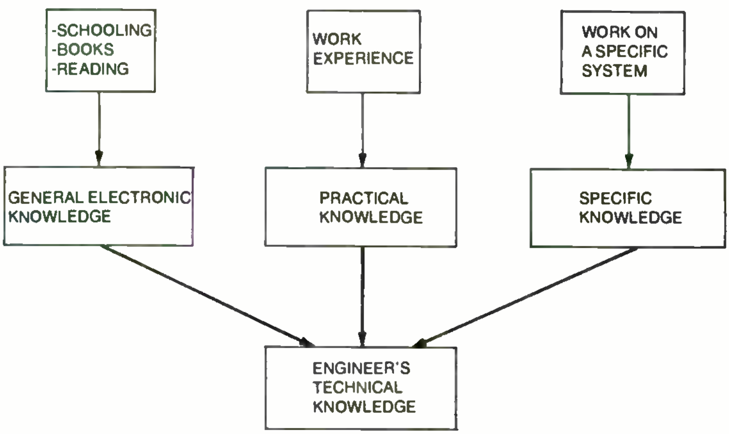


Fig. 2-8. Sources of technical knowledge.

courses, and books on electronics. The second is the engineer's *practical knowledge*, gained through a variety of working experiences with equipment and under a variety of situations. And third is *specific knowledge* of the system or equipment that now has a problem needing correction. The engineer can be weak in one or more of those areas and still do an acceptable job, but it takes longer to correct the problem.

If the engineer is weak in his knowledge of electronic fundamentals, there is really no excuse, since a wealth of technical knowledge is available through many good technical books, including many by TAB BOOKS, technical trade magazines, and information from equipment and component manufacturers.

As for specific knowledge of the system and its components in a particular station, any station with a reasonable amount of technical equipment in use has a wealth of technical information available in the equipment instruction manuals. And in the majority of troubleshooting cases, it is the practical information and knowledge that is used to find solutions and make corrections. The engineer does not need to know how to design the circuits in use—he need only have a fair understanding of how they work. As a matter of fact, the engineer who has only theoretical design knowledge, not tempered by practical knowledge, may have difficulty in troubleshooting problems because he always looks for the worst in any situation.

I know a broadcast engineer who once worked in equipment design for an equipment manufacturer. This fellow's hangup is capacitors. In his design work on critical circuits, he well knew the variations and caprices of capacitors in these circuits. Whenever he had a broadcast problem to solve at a station, he made a beeline to the capacitors in the unit at fault. He eventually got the real problems solved, but his equipment unnecessarily sported many new capacitors.

PRACTICAL PROBLEMS

Most modern equipment is stable and reasonably trouble free. During the first few weeks of shakedown, the weak or borderline components and transistors are weeded out. There can also be marginal or faulty designs that begin to show up with problems, or local situations may push some equipment into marginal operation—for example, high or low power line voltages on a regular basis put marginal components to the test. After the first few weeks, the equipment usually settles in and "purrs" along.

Still there are daily technical problems for the engineer to contend with. But a very high percentage of those day-to-day problems are usually minor in themselves, although it may not sound that way on the air. Wrong keys or switches thrown, a dirty jack, a sluggish relay or one with dirty contacts, a patch cord left out or plugged into the wrong jack, a transmitter left on the dummy load after nighttime maintenance—these are but a few of the more common problems the engineer is called upon to correct during the broadcast day.

Because so many of these problems are simple in nature and simple to correct, the engineer who looks for the worst or panics can cause a considerable loss of air time. The engineer who expects to find the worst situation imaginable, most often completely overlooks the fact that the problem could be simple! In a very short time, he has the system so completely disassembled that a considerable amount of time is required simply to put it back together again—and perhaps he still hadn't found the patch cord plugged into the wrong jack.

On the other hand, the engineer who panics starts twisting every knob in sight, twittering screwdriver setup adjustments, and really getting the system fouled up, sounding worse than it did before he leaped into action.

Major problems develop from time to time, but the wise and efficient troubleshooter expects and looks for the simple causes first.

An Illustration

A hypothetical troubleshooting situation should help illustrate many of the principles that have been discussed. Consider this situation: A station has its transmitter on remote control, located several miles from the studios. The only engineer on duty is also working the control room as an announcer. He spins a record, cues up the next one, and leans back—going to take it easy for a couple of numbers, simply segueing from one turntable to the next. Suddenly his monitor goes silent! Now anything in the system could be at fault—from the turntable itself to the antenna collapsed on the ground.

He should apply first the technique of a mental step back from the equipment, then observe the system—wide view—scanning the system in a systematic manner, gathering and sorting facts, and making judgements. First, he observes the console VU meter showing audio levels, and the meter is dancing along merrily. From his knowledge of the system, he knows the meter is at the output of the console, so he reasons that everything is okay to this point. He also knows there isn't much between the console and transmitter but a line amplifier telephone lines. He checks the transmitter readings and modulation monitor indications. All of these are normal. Since most of the system is operating properly, he reasons it must be the monitor amplifier itself, which is the last thing in the chain. There is a small portable radio in the control room, so he tunes in the station and in comes his music loud and clear. But now a decision is called for: what to do about the monitor. He makes a *decision*: He uses the small receiver with an earphone for monitoring the on-the-air audio and tries to see what is wrong with the amplifier when he gets free.

Thus, by the use of the *method*, he quickly runs down to isolate the problem and makes alternative corrections—all before the record runs out—and the listening audience never even knows he has a problem.

But consider what can happen if he panics. He may start flipping switches on and off, causing many disruptions to the program on the air. Worse, he may leave a switch off and then no program would be on the air. He could switch the transmitter on and off several times in quick succession, causing something to blow up and trip a circuit breaker. This necessitates a trip several miles out to the transmitter site—for the station is *now really off the air*.

Mark the Manuals

Another important aspect of troubleshooting is the matter of accurate circuit diagrams and equipment manuals. Since time is critical in many situations, the engineer must have *aid* from the prints and manuals and not *confusion*.

Most broadcast electronic equipment today has other applications or may be sold outside the U. S. Consequently, there must be some different circuitry for other applications and standards. There is a variety of instructions in manuals telling how to set up under these other conditions. And besides all this, the particular unit may have other possible configurations, for example, a tape machine may be either monaural, stereo, or multitrack.

An instruction manual, then, may have several different diagrams, different sets of explanations, and a variety of instructions to hook it up. From the manufacturer's point of view, this necessitates only one instruction manual to cover all these other usages and standards for the unit. But from the troubleshooters point of view, all this extra information and becomes a briar patch that he must wade through to find the current print or instructions he needs. It can be extremely frustrating. especially if the station is off the air and the fault must be corrected with as little time lost as possible. Under these circumstances. the engineer simply doesn't have time to sort out all these prints for the correct one.

When a new unit is installed and working. go through the instruction manual to *line out* all the information that does not apply. The information does not have to obliterated. simply lined out (Fig. 2-9). If it is an arrangement that may later be used. then the information can be restored.

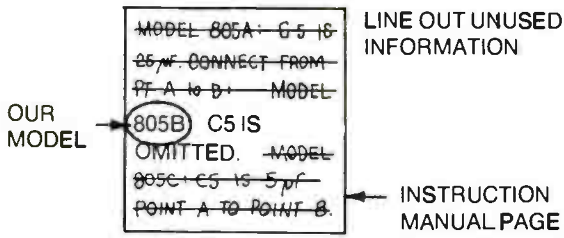


Fig. 2-9. Line out unused instructions.

On unused circuit diagrams, if they are detachable, remove them from the manual. Store them in a safe place. If not, then mark a large X across the diagram. On the correct print, out in the margin or in some other conspicuous place, write *OUR UNIT* in large letters. Any similar words can be used, but they should quickly identify the print.

In those sections which show different terminal connections, use a red pencil or some other color that stands out to show which arrangement is actually in use.

When a troubleshooting situation exists where time is at a premium, these markings help the engineer find the correct prints faster and save both time and frustration.

And one further word—don't use a pen to mark prints. Use a pencil or something that is easily erased. You may want to change the method of operation or hookup at some later time. If you have made changes in pen, you end up with a scribbled mess on the prints.

SIGNAL TRACING

A dynamic method for isolating faults and defective components is signal tracing. This method can be used only in those cases where the equipment is still operational. Naturally, if the equipment is smoking or operating in some other very abnormal manner, it must be shut down, or additional damage can be done. Signal tracing is not confined to a single unit. It can be used on the master system just as well, or on any subsystem. In the method of troubleshooting previously described, signal tracing is an important part. It is used in the area of collecting facts and data about the system or unit that is malfunctioning.

Signal tracing is rather simple in principle. The unit is placed in an operational mode, either in its normal location or on the workbench. An input signal of correct amplitude is applied, then some type of signal detector is used to follow the signal through various circuits of the unit until the output is reached. At the place where the signal fails to appear, becomes distorted, or seriously abnormal, the faulty circuit has been isolated. Although the technique is simple in principle, results depend upon near-correct operation of the unit in a test setup, correct signals, and interpretation of the results observed by the troubleshooter. Proper interpretation is very important, otherwise, the engineer may spend much fruitless time and effort running down false trails.

Signal tracing may or may not lead to the defective component itself. But it ordinarily leads to the defective circuit. How much further the signal tracing can go depends upon the circuit and the test equipment being used. When the signal tracing can go no further, then other methods are necessary to isolate the actual component at fault. For example, signal tracing may lead to a stage whose gain is far below normal. In a stage, as opposed to other nonspecific circuitry, there are many components which set its operating parameters. An oscilloscope can further the signal tracing, but this may not isolate the real fault. It is necessary to measure the DC operating voltages and perhaps check for shorts or component values that have changed. Although signal tracing does not always isolate the faulty component, it helps isolate the faulty stage—this is half the battle.

Test Signal

Signal tracing can be performed more efficiently if a test signal of steady amplitude is used, such as the sine wave from a signal generator. The steady sine wave, with its known amplitude and shape, helps in detecting variations through the unit under test by making comparisons easier. And as a *practical* matter, if the unit is on the workbench, connecting up the signal generator is easier than trying to "haywire" a connection to the program channel for a test signal.

Sine waves can also be used when signal tracing parts of the system itself. But for the program channels that have failed during programming, the more *practical* signal is the program itself. The sine wave does not have to come directly from a signal generator; it can be recorded on a tape or test record, then played by a tape machine or turntable.

The difficulty with a program signal is that its composition is constantly changing. This makes it difficult to get a correct level setting for comparisons and to compare input/output signals. For example, you set the correct input levels to start signal tracing. You suddenly find the signal very low. The program may be music that has hit a period of low-level passages, which can be embarrassingly misleading.

Signal Detector

Some detector is needed that gives an indication of what the signal is doing along the circuit path. The detectors in Fig. 2-10 all work well in audio circuits. If working with RF or digital circuits, different detectors as well as techniques must be used.

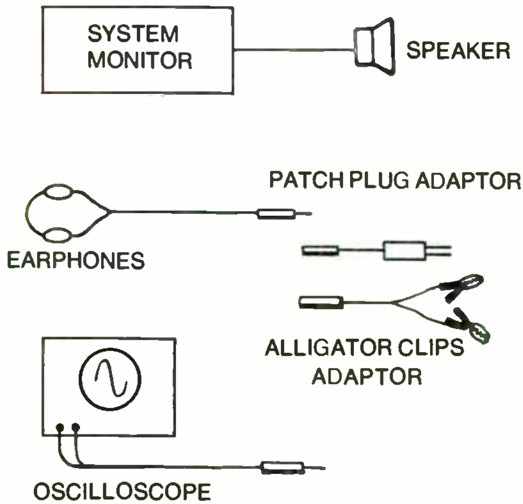


Fig. 2-10. Some audio detectors.

On the Bench

When signal tracing is done to a unit on the workbench there are several precautions to take in the test setup. The unit is always hooked up during the tests, even though it is faulty now, in its normal manner. Thus, the AC power to the unit, its input/output impedances, and signal levels should be those that are normal to its use in the system. And don't forget the grounding of the unit and the shields of the cabling.

Input impedances and levels should simulate those found in the amplifier's normal habitat in the system. For example, the bus which feeds the amplifier may normally run at +8 dB, but the level into the amplifier is lowered with a 20 dB pad, so that the input to the amplifier actually receives −12 dB. In determining what input level to feed the amplifier, find out where the pad is located. If it is external to the amplifier, then feed the amplifier at −12 dB. But if the pad is located inside the amplifier, then feed +8 dB to the unit. Also, during the test, make sure the amplifier is terminated in its proper load impedance.

Signal-Tracing Illustration

Assume that a self-contained audio amplifier which needs only AC power and input signals and output load (Fig. 2-11) is on the bench. A signal generator is used for the input signal and an oscilloscope is used for the detector.

First, set the input to the correct level, with the output impedance of the generator matching the input impedance of the amplifier. Place the oscilloscope across the input signal at the generator terminals. Observe the amplitude and waveform, calibrating the oscilloscope to some arbitrary setting. Next, move the oscilloscope to the *output* of the amplifier. This is important, for you may find that there is nothing wrong with the amplifier itself! The problem may be in the plugs and interconnecting wiring. This input-to-output look can then save signal tracing all through the amplifier only to find the fault is elsewhere.

But for our example, assume the output signal was low in level but not distorted. Proceed then to check stage by stage. The option is yours whether you move front to back or vice versa. But whichever method you select, be consistent and go stage to stage, that is, don't jump around.

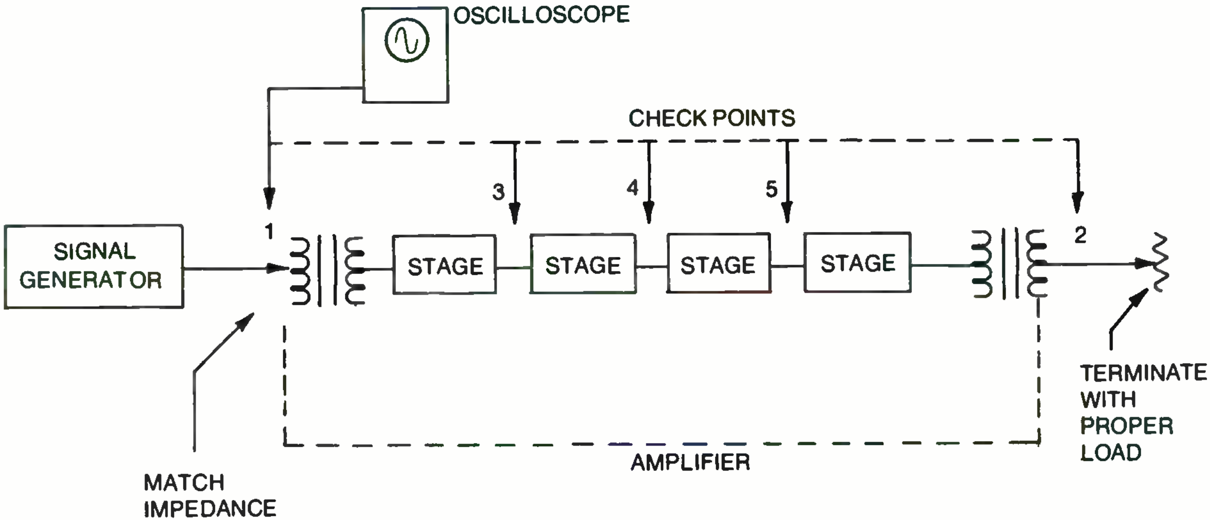


Fig. 2-11. Signal tracing. Measure the input first, then the output, then stage to stage.

Inside the amplifier, levels are high or low at different stages, but this does not necessarily mean that a stage is defective. This may be part of the amplifier's design. When you come across a spot where the levels vary considerably, move on to the next stage. If it is a design parameter, the levels probably come back to somewhat normal after the following stage. But, if the signal does not recover, then you have the faulty stage. If you can proceed into the stage itself, go ahead. But remember, even a normal stage can have a variety of different signal levels across components that can be misleading. For example, you may place the oscilloscope across a resistor in the emitter of the stage, finding the signal very low—lower than expected—or nonexistent. The resistor may be bypassed to eliminate any AC signal across it, or it may be used as part of an equalizing or shaping factor of the stage. All these things should be considered before taking components out and replacing them. Ordinarily, voltage measurements and checking components for shorts or value change do more for isolating the actual faulty component (Fig. 2-12).

Signal Tracing the System

Signal tracing the system is not difficult when the station has the foresight to install adequate monitoring and metering points during the installation.

When a fault occurs in the regular program channels, use the metering and monitoring positions throughout the system. If the problem is distortion, monitoring the audio is usually more effective, although metering indicates if levels are too high, overloading something and causing the distortion.

The procedure is the same as signal tracing a unit on the workbench, except that now the unit is spread out over a considerable area, and it is not always easy to see the results as easily as when everything is within arm's reach. Use the system's normal metering points (Fig. 2-13): the VU meter at the output of the console, meters on AGC amplifiers and peak limiters, and the modulation meter. There may also be a VU meter panel where several points of the system are tied up into a selector switch so that meter can quickly check levels throughout the system.

Use the system's aural monitoring arrangement. This is available at least at the console output. There may also be

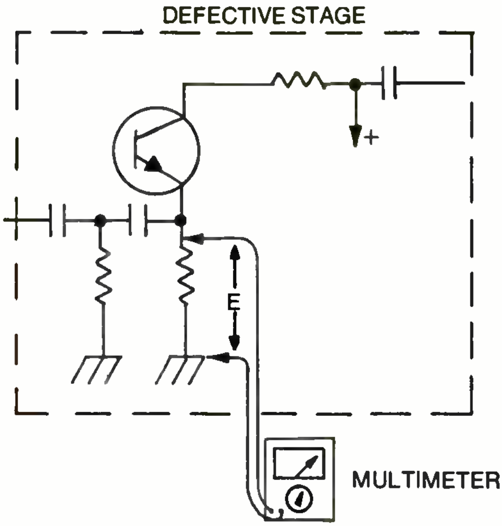


Fig. 2-12. When signal tracing has isolated a defective stage, use other methods to check components in the stage.

other parts of the system switched into a master-monitoring arrangement. A pair of headphones can be used in the circuit path at the patch panel.

Use care when patching the earphones into the patch panel, so that you don't take the program off the air—assuming the program is still on the air. Look for those positions which have a *multiple* jack wired to them. Tap into this multiple for the monitoring. If there aren't any multiples at the points you wish to monitor, here is a trick you can use: Take a patch cord, insert the plugs into both the input and output jacks, but don't push them in far enough to break the circuit. Next, with one motion, shove *both* plugs in very quickly, at the same time. There should be no break in the air signal, and if there is, it is so brief that no one notices it. This, of course, assumes the circuit is balanced. If it is not, make sure you have the correct polarity on both plugs or you will short out the circuit! Now that the patch cord is in place, it is taking the place of the "normals" (normally closed contacts) on the pair of jacks. Use the headphone either with the patch-type plug or alligator clips and pick up the signal at the pair of screws on either of the plugs of the patch cord (Fig. 2-14). By the way, this little trick with the patch cord does, in itself, locate many a problem with the normals on a jack! The

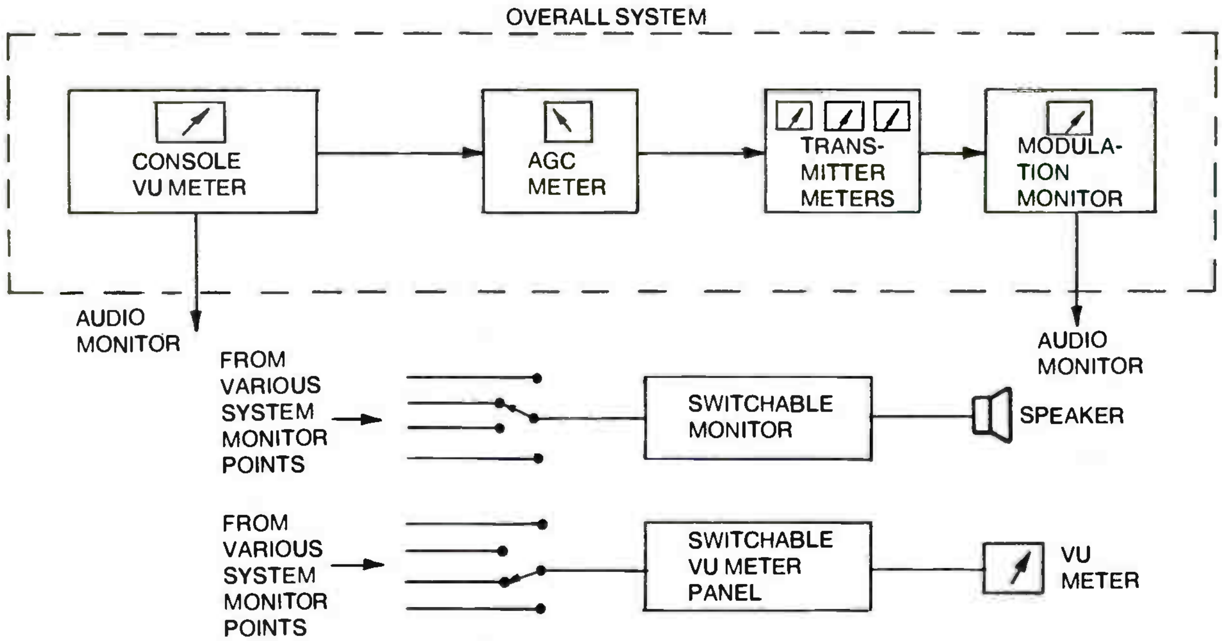


Fig. 2-13. Use the system's normal metering and monitoring when signal tracing.

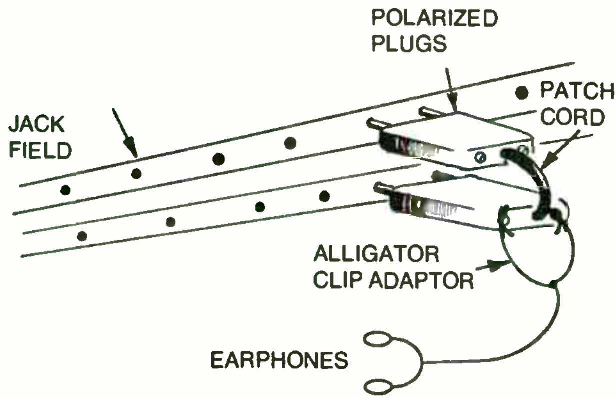


Fig. 2-14. When there is no multiple on a jack, use a patch cord to substitute for the jack "normals." Use earphones with alligator clips and attach to screws at rear of patch plug.

patch plugs either clean up the contacts or give a solid circuit that is lacking previously.

ROUTINE MAINTENANCE

Routine maintenance can be defined as the cleaning, oiling, testing, and adjustments made to the system on a regular scheduled basis, without being triggered by some fault or failure in the system.

In effect, routine maintenance looks ahead to eventual problems that can arise, and doing that which is necessary to forestall many problems. For this reason, routine maintenance is also called *preventive maintenance*. These routine procedures often detect small problems that are cured in their infancy, long before they develop into large, serious problems.

Fireman's Approach

There is another "method" of doing maintenance which is unfortunately, practiced at some stations. This can be called the *fireman's approach* to maintenance. In effect, *no* maintenance is done until something fails! Then, of course, the engineer goes to work correcting the problem. This is not the recommended way. But, unfortunately, many stations in smaller markets do not have adequate engineering personnel. There may be an engineer who takes care of the station on a contract basis, or there may be one full-time engineer who must devote the majority of his time to other matters at the station, such as announcing and programming. Even the station that does have adequate engineering personnel can find itself so covered up with problems or major construction that the routine maintenance suffers for periods of time.

When the fireman's method is practiced at a station, whether this be due to an engineer's own attitudes or as a result of station management, the results can often be costly, not only in replacement costs, but in station down time.

Although routine maintenance doesnot detect and cure all early stages of problems brewing it can catch many of them, minimizing headaches and ulcers.

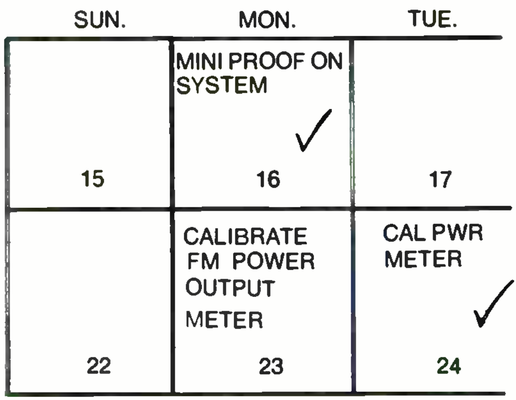
Scheduling

To be effective, routine procedures must be done on some regular basis and not in a haphazard manner; otherwise, some will get done and others may not get done at all. Memory can be a poor substitute for schedules and records. The station should decide which procedures to do on a regular basis, then set up schedules. Be realistic and practical in deciding what is to be done and how often. When setting up schedules, do not make them hard-and-fast rules that must be observed no matter what. Be practical and allow a certain amount of flexibility. What is necessary is the realization that schedules are important and things should be accomplished according to schedule whenever possible.

One scheduling means is the desk-type calendar. When a new calendar is obtained at the beginning of a year, go through the whole calendar and mark the dates in each month of the year when certain maintenance procedures are to take place. For example, if certain measurements should be made on the second Monday of each month, go through the calendar to mark each one. As the calendar page is turned for each month during the year, the entry will already be there to act as a reminder. But sometimes when the event is scheduled, some other important job must be done instead. This is where flexibility enters the picture. The scheduled procedure may be shifted to another day of that week, or may be even skipped until the following week. A week off the normal scheduling is still valid as far as routine scheduling is concerned.

Keeping Records

Scheduling ahead is one thing, but records also need to be kept which show that the maintenance was actually done. In the calendar, a small check alongside the scheduled entry can serve to indicate it has been done (Fig. 2-15). If the routine has to be done later in the week, a mark on the original entry is still adequate. But if the routine was bypassed for the month because of other things, then do not add the mark. The lack of the mark indicates the routine hasn't been done. If the date is important, then show the date it was actually performed even though that was not its regular scheduled date.



REGULAR CALENDAR

Fig. 2-15. Use a calendar for scheduling. In some cases, show date it was actually done, as here, on the 24th.

Reports

Whenever maintenance is done which is either routine or in correction of a catastrophic failure, a daily maintenance report is used (Fig. 2-16). These reports can be saved for several months or longer and can be a valuable reference when certain problems seem to come up often. For example, a certain capacitor has failed in a particular unit. But something tells the engineer that this was replaced only recently. With the report sheets, he can check previous reports. Checking further, he realizes the same part has been replaced twice this year already. This makes him take a harder look at the rating of the capacitor, and he may decide to use one with a higher voltage rating this time. Or perhaps there is an identical unit

TECHNICAL REPORT

DAY MONDAY DATE 7-7-77

TIME	TROUBLE	ENG.
9 AM	MODULATION MONITOR COMPLETELY DEAD.	S.V.
	REPAIRS	
9:10 AM	FUSE BLOWN IN MOD. MONITOR. COULD FIND NO OTHER FAULT. REPLACED FUSE. MON. BACK IN SERVICE.	P.F.
11:00 AM	MODIFIED JACK 2E8 ADDED A MULTIPLE 2E9.	J.J.

Fig. 2-16. Use some type of maintenance report daily.

that gets as much operation as this unit without failure. This leads the engineer to look for more subtle reasons why this unit has been failing so often.

There are a variety of records devised which cover maintenance situations or routines. The calendar and report sheet are but two. Other records can also be made, including those for transmitter power tubes and memory joggers for events that happen infrequently, such as a quarterly tower-lighting-equipment inspection (Fig. 2-17). Even though many of these inspections require maintenance log entries, there are separate records kept that consolidate those dates for easy review.

WHAT TO DO

What maintenance procedures that a station should set up depends a lot upon how much equipment is in use and how

FM POWER METER CALIBRATION		
1976	1977	1978
FEB. 3		
JUNE 10		
AUG. 25		
OCT. 1		

Fig. 2-17. Consolidate widely spaced entries made in maintenance log on a separate record for easy location.

sophisticated the equipment is. The station has to make its own decisions in this area.

Gradual Wear

Aside from catastrophic equipment failures that must be corrected, equipment that is in use for many hours a day simply wears out. This daily wear is not perceptible, because the increments are too small. It is only after many of these small increments add up that we begin to notice the fall in performance or mechanical wear. Because of this small daily drop in performance, different sets of measurements should be scheduled at intervals so that performance drops can be measured and replacement or correction can be made before the performance becomes bad or fails altogether.

Spot Checking

What is needed, then , is some method of spot checking the equipment performance from time to time (Fig. 2-18). For example, if response, distortion, and noise measurements are to be made on the system once a month, those need be only at a few audio frequencies that outline the system bandpass, rather than a full set of measurements as required in a proof of performance. In this way, the checks don't become cumbersome—but they give useful information.

FM SYSTEM TEST RUN

	RESPONSE	DISTORTION	NOISE
100 Hz	-1.0 DB	1.0%	
400 Hz	-0.4 DB	0.6%	-63 DB
REF. 1 kHz	0	0.3%	
10 kHz	+ 12 DB	0.5%	
15 kHz	+ 16 DB	0.7%	

Fig. 2-18. Use a few frequencies to spot-check the system. This cuts down the time to make measurements and outlines the system's behavior.

Areas for Routine Maintenance

As mentioned earlier, what specific routines to set up depends upon the equipment and how much there is of it, plus the usage it gets. Usage is a very important factor. Wear is directly related to how much use the equipment gets. For example, a small station with two tape machines that play a few spot announcements or other programs occasionally from the machines during the day doesn't have the same procedures as a station with several tapes machines—many of which may be in a large automation system where *everything* is played from tape all day long.

A few areas where routines can be advantageous are: periodic measurements on the master system; each tape machine; system level checks; individual equipment level checks (such as tape machine playbacks that feed a console); mobile radio transmitters, for power, frequency, and modulation; carrier frequency measurements; and power meter calibrations. Some of these are required by the FCC, others are required according to usage.

Other Maintenance

Besides making sets of measurements to keep tabs on performance, other maintenance should be done on a regular basis: Tape machine heads and pinch rollers need cleaning on a regular basis, meters in various machines and exhaust fans should be oiled or greased at intervals, air filters should be inspected. Some of these are important maintenance items.

For example, the bearings in tape machine drive motors can run dry, causing noise on the reproduced audio, and they will soon become totally defective having to be replaced. Without proper oiling, the bearings may run dry, freeze up, and stall the motor, burning it out also. Tape machine drive meters are expensive.

Fan motors can gradually become defective or ineffective in moving air (as can clogged air filters). Dirt may build up on the blades or squirrel cage so that the actual amount of air is reduced considerably. Or the bearings may dry up, get noisy, and put a drag on the motor. The lack of cooling air has many side effects in solid-state equipment. In transmitters, air flow interlock switches shut the transmitter down when the air pressure drops below its present control level.

All of these type measurements and routines should be scheduled in some manner, keeping records for reference.

UPDATING

With technology advancing so fast these days, a particular piece of equipment may have several modifications done to it within a year. Weaknesses of the original circuit design show up, bringing improvements by the factory. Updated parts, circuits, and similar information arrive in the mail from time to time.

As far as circuit weaknesses are concerned, the problem may never occur in the particular unit in your station. If the unit is performing satisfactorily there may seem to be no need to update the unit until the problem happens. The modifications, however, should be performed. When the modification is completed, be sure to correct the circuit diagrams and instructions where needed. There is nothing more exasperating in troubleshooting than to discover that the circuit diagrams do not match or agree with the actual circuit.

Spare Parts

Equipment updating through modification can change the stock of spare parts. Of course, good judgement must be used in this area.

When modifications require new specialized components, such as ICs or transistors, those on the shelf can become orphans unless they are used elsewhere in the system. And if the part is very specialized and costly, the dealer may not want it back.

There is usually another effect on spare parts—tubes, transistors, and ICs—by equipment modification. If the modification calls for a new type, the present stock may already cover it. But as it often happens, this usually is an altogether new type and you will want to stock some spares in the inventory. And if your luck runs like mine, it is a stock number that falls somewhere in between numbers in the parts drawers. So, all the drawers have to be shuffled down the line to make room for it. When you are setting up your initial inventory, leave a few open drawers at different places to take care of the new numbers. Then, many drawers do not have to be moved.

UPDATING YOUR KNOWLEDGE

Advancing technology has its effect on equipment obsolescence. It can have the same effect on the engineer's technical knowledge. The engineer must keep constantly abreast of changes or he will wake up some morning to find the field has passed him by, and he is now in a different technical world. True, many of the old principles are still in practice, but there are a great many new ones on the scene also.

The broadcast engineer must keep abreast of not only the new technologies, but also of components and equipments. There are ways he can do this:

First, subscribe to technical magazines relating to broadcasting, such as *Broadcast Engineering*. These magazines provide articles on operation, maintenance, new theories, and different types of broadcast equipment available.

Second, obtain specification sheets and literature on new broadcast equipment whenever possible. Write to equipment manufacturers for information and application notes on new equipment in your field of interest. Don't try to cover everything or you will be inundated. If you are in radio, get data on audio, radio transmitting, and test equipment; don't worry too much about the television aspect. Of course, you may desire to advance into another aspect and want to keep informed.

Third, obtain data sheets and application notes on new components whenever you can. These can be found in catalogs from parts dealers and manufacturers. There are also several trade papers available on a subscription basis that deal with components of all types. These are usually directed to purchasing agents of factories and other large component users, but read them whenever you can.

There may be times when the station's economic picture is not good so the station makes do with its old equipment until things get better. But don't allow this to discourage you from keeping up to date on what is available should the station decide to purchase. You should keep up to date so that when a purchasing decision is going to be made, you can make knowledgeable recommendations on what equipment should be obtained. Even if your recommendations are not considered, you will at least know what is going on in the industry. And should you move to a job at another station that is equipped with state-of-the-art equipment, the transition will not be difficult to make.

Chapter 3

Planning and Installation

Whenever new equipment is to be installed, changes made in the old, a complete remodeling, or a completely new station is installed, a certain amount of planning should come first.

PLANNING

Installation planning could be described as follows: carefully fitting together many equipment items so that they physically and electronically intermesh into a single master system that is efficient in its ease of operation and can be easily maintained.

We must distinguish between general planning and installation planning, as they are not the same thing. General planning concerns itself with such questions as what model to purchase, price ranges, station objectives, etc. Installation planning concerns itself with how the particular equipment that has been purchased will actually be wired into the system: What are the terminal numbers? Where must you drill the holes? And so on.

The amount of planning which must be done is dictated by the project at hand. Thus, there are both stages and degrees of planning. Major projects, for example, should receive much overall planning; and the multitude parts of the project must also have individual planning.

Small projects should receive their share of planning. There is a natural tendency to give small projects only cursory planning—with most of the planning actually occurring *after* the installation has taken place and failed! As the saying goes, "Back to the drawing board." In fact, most of these small projects never get on the drawing board in the first place.

Any project, regardless of its size, should be considered in relationship to the master system and what effects there may be when this project is completed. Even small system modifications can create large system problems. For example, an engineer designs an alarm device which contains several internal relays and incandescent lamps. No provision is made for power. It is expected to simply attach to the system power supply. But what is not known is that the power supply is loaded almost to its maximum capability. Any additional load will push the power supply into a near-overload condition. Consequently, the new alarm device loads the power supply so that parts of the master system become unstable, with some intermittent relay operation at various places. An engineer may spend much of his time searching for other problems in the system which are really caused by the overloaded power supply. Proper planning of this small project would have investigated the power source. Having found it loaded without spare capacity, the engineer could have provided another source of power for the alarm.

DRAWINGS

Drawings are the maps of a broadcast system. These drawings have many uses that, under different circumstances, provide different benefits. That is, they are used for troubleshooting problems, making system changes, and providing general information about the system. There are at least three types of drawings: block diagrams, schematic diagrams, and pictorial diagrams.

Block Diagram

The diagram of the overall system should be a single-line block diagram (Fig. 3-1). Block diagrams should also be made for each of the major subsystems and even minor subsystems, showing direction of the action flow, signal levels, and other pertinent data. Try to balance utility against clutter. It is possible the diagram can have so much information that it is difficult to use. Shoot for a happy medium.

Schematic Diagrams

The single-line block diagram is the best tool to obtain a wide view of the system. But for all the specialized areas of the

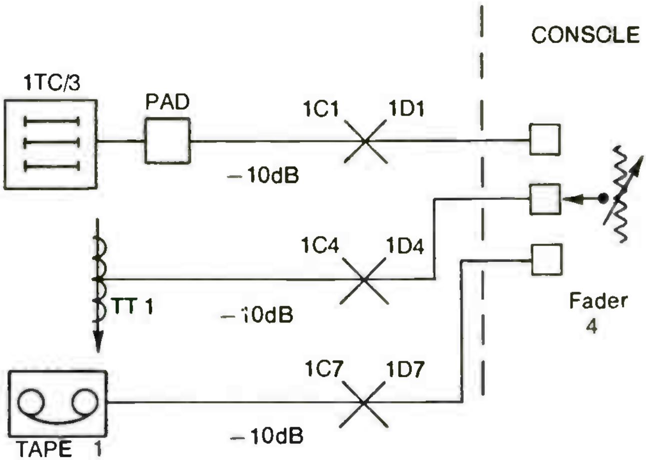


Fig. 3-1. Typical one-line block diagram (partial). Note the amount of information supplied in a simplified form.

system, it is necessary to employ the schematic for all the detailed information that is required.

All the individual projects within a large overall installation project, must have schematics drawn of the area involved (Fig. 3-2). These drawings provide the necessary detailed information required to complete the installation. Typical information must show terminal numbers, wire color coding, shield treatment, and similar information needed to get the job done properly.

When equipment units are to be modified through change of circuitry, or if additional components are to be added, schematics are a necessary requirement. For example, the console may contain one or two unwired lever switches so that the user may wire according to his own needs. If one or both of these switches are to be wired for station use, a schematic must be available—draw it now. And during the wiring operation, if any changes take place they should be entered on the schematic as they happen. Such specialized schematics should be preserved for future reference.

Regardless of how well the system installation may have been planned, the final results invariably contain changes from the original plans. No matter how much planning is done, it just isn't possible to foresee all contingencies—or a change of mind. Changes are to be expected. But when changes do

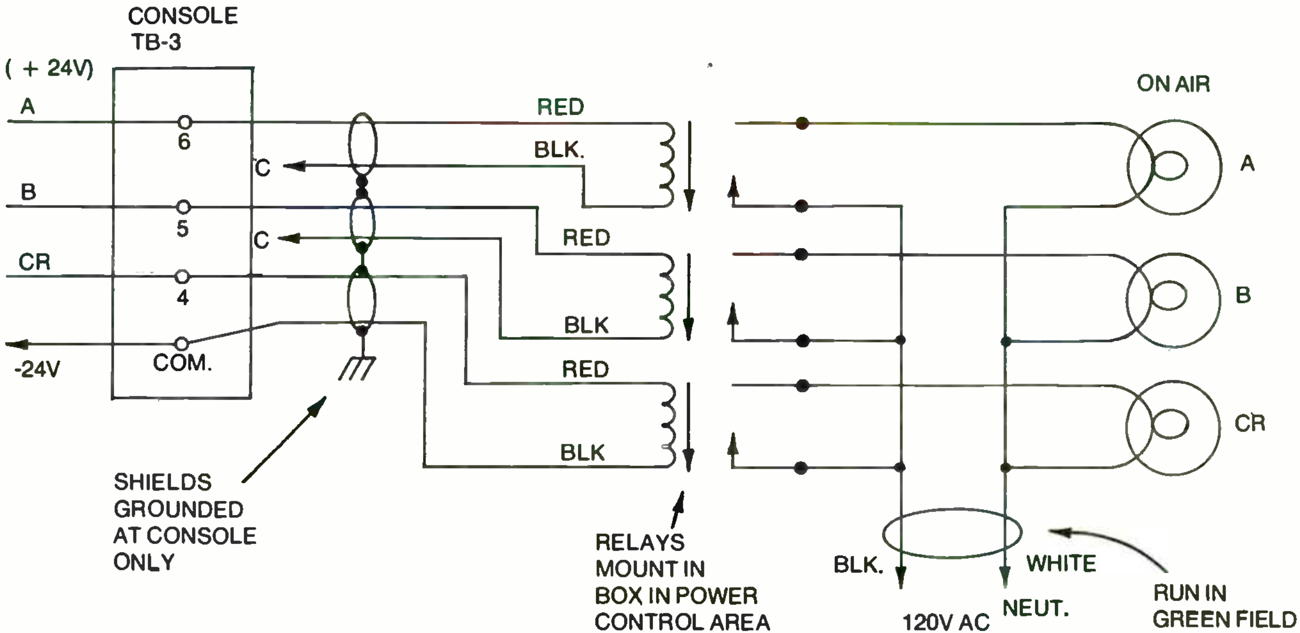


Fig. 3-2. Schematics are needed for specific sections to show the necessary installation data. Notice the information on shields, parts location, and other data.

take place, it is important that the diagrams are altered at the same time, not at some later date. Making changes to the drawings as the work progresses does tend to make the drawings look a bit shop-worn, but they are accurate!

Soon after the new system has been put into operation and is functioning as desired, make up a completely new set of drawings and records from the working set. If equipment modifications have taken place, correct the diagrams in the instrument's manual also. And while correcting the manual diagrams, also correct the other instructions, such as terminal numbers, etc. A good set of accurate drawings and correct circuit diagrams are far better for future use than a hazy memory.

Pictorial Diagrams

There are many occasions when simple sketches are very helpful during the installation. These need not be works of art but should at least be accurate enough that they convey the necessary information. Such diagrams can be very helpful when it is necessary to wire a multiple-leaf switch, since the terminals at the rear of the switch appear opposite to that of the actual switch arrangement from the front that is indicated on the schematic diagram. These diagrams are almost always used in conjunction with a schematic diagram. The schematic shows the actual circuit. while the pictorial helps with the physical arrangement.

WORK PATTERNS

We humans tend to develop patterns of doing things and then follow those patterns as a matter of habit. Many industry practices in regard to equipment layout have developed partly through utility and partly to agree with the way many people naturally do things. For example, we read a printed page left to right, line by line, from the top of the page to the bottom. Thus, most terminal boards are laid out in a left-to-right fashion. Everything, of course, can't follow such patterns and somethings must be designed for the specific usage. But you can expect to find many functions which follow natural human practices.

When laying out a new station, we must develop a number of patterns that are helpful for that station. Use standard industrial practices where they can be applied. But in the many other cases where it is purely a local situation, try to develop a practice that follows natural human practices when possible. But work at these beforehand. give them some thought. then be consistent when applying them throughout the construction.

OPERATOR'S VIEWPOINT

An example of a natural pattern translated into equipment is a row of leaf switches on a panel. These must be assigned their numbers from the operator's view standing in front of the rack, console, or whatever is holding the switches. The engineer wiring the switches from the rear must learn that his wiring pattern is always the reverse—right to left from the rear of the rack. While this may be a bit awkward for the engineer, the operator's position must take priority.

AUDIO CONNECTIONS

The audio throughout the system should be kept phased, just as a matter of good operating practice (Fig. 3-3). In a monaural system, there is no real burning issue why this should be done. As a matter of fact, the system works just as

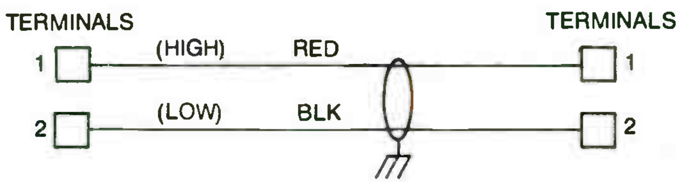


Fig. 3-3. It takes very little extra effort to keep the monaural system phased. Just be consistent in the terminal numbers and the color coding.

well regardless of phase. But it is just as easy to have a phased system as one that is haphazard by simply following a set pattern when wiring up the audio cables. It is simply a matter of assigning terminal numbers and maintaining color-coded wiring throughout.

Multiconductor Cables

Stations have many uses for multiconductor cables. These are not cables which come already wired with a particular piece of equipment, but rather those which the station wires. When possible, try to use regular industry color coding for the circuits. But when these are not suitable, assign colors—then stick to the pattern—especially when several cables perform the same functions on a number of different units, for example, remote-control panels.

The real danger in the use of the same cable for different circuits and functions without being consistent in the coding is that an engineer on a troubleshooting mission may follow the natural pattern. When arriving at the nonstandard cable, he starts checking it as per the previous cables. If +5V DC is on blue and −5V DC is on white, in the original scheme, he may want to pick up this IC supply voltage and use it as a pulse to send a trigger into the circuit. But, if the same pattern wasn't carried into the second cable, there may be +24V DC on the blue and −24V DC on the white. Feeding this into the IC could wreck it—be aware!

Jack Fields

The jack fields should be planned carefully. They should be assigned areas before the actual installation begins. This little exercise in planning often points out the need for more jacks than had been anticipated. Without this planning and assignment, installation can fill out the jack field long before all the necessary circuits have been completed, leaving no convenient space left in the rack to add additional jacks.

Jacks are operational units that must be viewed from the front of the rack. So, when making the assignments, remember this fact. From the front, they should read from left to right as far as their number assignment is concerned. As far as the actual circuit they carry, this must conform to other considerations.

Audio Terminal Blocks

As with the jacks, the main audio terminal blocks in each rack or major component should be assigned ahead of time. The main block in the console already has its own assignments since it came partially wired with the console.

When assignments are made on each block, give thought to the separation of various circuits according to the signal levels and functions the circuits carry. And give thought to the main circuits that need to pass along on these blocks. It is surprising the number of terminals that can be used when simple changes in the wiring are desired—for example, adding a jack to the output of an amplifier circuit. What may have been two terminals before the decision is now doubled to four terminals.

Planning and assigning ahead of the installation points out the need for more terminals in many instances, and it is handy to know this before actual installation begins. It is far easier mounting new blocks in an empty or unwired rack than to add new ones once there are bundles of cables in place. And it is especially important if holes must be drilled in the rack or frame to hold the additional terminal blocks. One thing more, always be sure to include many more terminals than are actually needed for the initial installation. There is always need for some spare terminals in future times.

Block Sheets

Assignment of the circuits on the terminal blocks can be done most efficiently if block sheets are used. There should be one sheet for each block. This form can be easily designed by the station to suit its own way of doing things. The important thing to remember is that the information must be readily determined from the sheet at some later time when a problem arises—the troubleshooter needs information in a hurry, or when there are to be circuit modifications or additions.

A simple way to design a form is to list the terminal block numbers from top to bottom of the page (Fig. 3-4), or perhaps to slit the numbers into two columns from top to bottom of the page. On the left side of the numbers, leave space to write in the name of the circuit or other pertinent identifying data. On the other side of the numbers, leave space for circuit and identifying numbers. Head the spaces to the left of the numbers as *external* and the spaces to the right of the numbers as *internal*. A normal block has 80 terminals, so leave space for all of these. At the top of the sheet, number or name the block and show its position, rack, and use. Use your own judgement. What is needed here is information that helps the troubleshooter find the correct block in a hurry when the information is needed. Always remember that in troubleshooting major problems there is no time for shuffling papers to find information. The information must always be in such a form and stored a place that the information can be readily found.

When wiring up the blocks and making the assignments, be consistent whenever possible. This is just another of these patterns we discussed earlier. If the external wiring is supposed to enter the block on the left side, then make sure

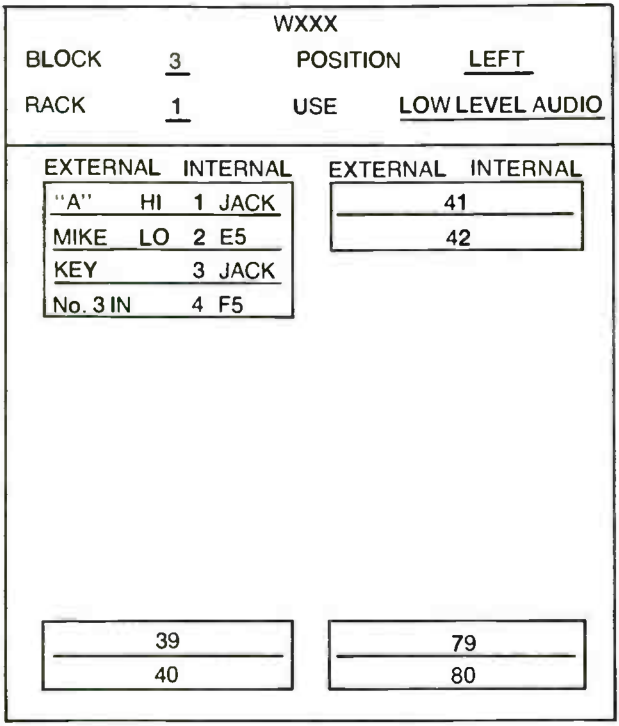


Fig. 3-4. Typical audio terminal block sheet. List all the terminals even though they may be spares at the moment.

that this is done in all cases where possible. Of course, this can't be done in every case, but try to be consistent. When the engineer comes along at a later date looking for circuits or chasing problems, he assumes that the input side of the terminals is on the left. If it is necessary to lift a terminal, he can do so with the expectation he is getting the correct one. Consistent wiring patterns are always a help to the troubleshooter (which may be yourself). This is particularly the case on terminal blocks because once all the wiring is in place and laced up, it is almost impossible to determine the actual physical direction individual cables are going. Of course, we are visualizing several blocks at the base of a rack and many cables. A single block and a few cables do not present so much of a problem. However, being consistent and following patterns always proves helpful later. So even though you are at the moment working in a unit with only a few circuits, stick to your established pattern. It is no more additional work to do it according to a standard pattern than to simply wire it without thought to a pattern.

EQUIPMENT PLACEMENT

The actual physical placement of the equipment is usually very different from that shown on diagrams. Diagrams are used to show circuits and similar information that is necessary; they can't always show physical placement. Sometimes units which are placed at a distance or in some other unit are shown on the block diagram by enclosing them in dashed lines (Fig. 3-5). This is very helpful if a unit is placed in another room and interwired.

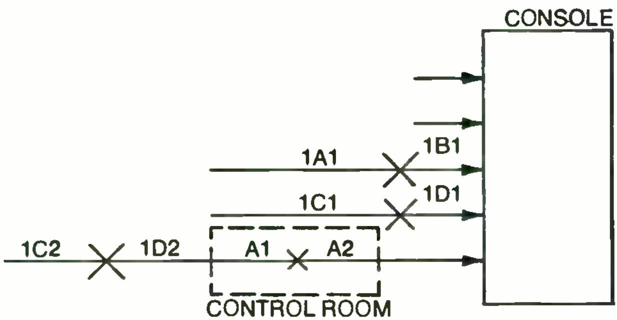


Fig. 3-5. Equipment location can sometimes be shown on the block diagram with a dashed-in box.

Careful thought should be given to the physical placement of equipment because thoughtless placement causes considerably more wiring, work, and maintenance difficulty. That is, the actual placement of a unit has a direct bearing on the number of jacks, terminals, circuits, and length of cables necessary to interconnect the unit.

To show how the placement of a unit causes considerably more circuitry and installation work, consider one of those optional-placement situations. A peak-limiting amplifier is to be used at the output of the console in a recording booth. Should the limiter be placed in the booth or in an equipment rack in another room? There may be no convenient place in the booth for mounting, but it could be arranged if desired.

Consider first the booth location: Input and output wiring should be direct from the console to the recorder selector switch. This places the operating controls in easy reach so that operation can be observed more easily. But on the other hand, there is no way to get into the input or output of the unit without actually disconnecting wires. Plus, it may not be such a good idea to have the unit within easy reach of the booth operators, who may twiddle the controls as an operational procedure.

This arrangement requires longwiring circuits from the booth to the rack and then back again. At the rack, at least four sets of block terminals are needed, and four sets of jacks. Four sets of terminals means eight terminals that must be accommodated on the terminal block. Of course, you could wire directly to and from the limiter in the rack without jacks or terminal blocks, but this is poor practice. If the unit is to be mounted in the rack, good engineering practice calls for test entry into and out of the unit.

As you can see from this example, adequate planning should be given to equipment physical location and to supplying the additional circuits, jacks, etc., that are needed to get the job done.

RACK SPACE

Adequate rack space seems to be a perennial problem, not only during an installation, but at later dates as well. It is wise, therefore, to carefully plan the efficient use of every inch of rack space carefully, then allow for additional space to take care of some of the future needs. Unless this careful planning is done, the engineer can soon discover that he has filled all the available space, leaving several more important units that must be mounted. This problem is really compounded if the empty racks are beautifully mounted or built into a wall during remodeling. The only way now to get additional space is to knock out some of those new walls. In the worst situation, a space is selected for racks that absolutely doesn't allow for additional racks unless outside building walls are knocked out. So, figure the space carefully ahead of time and then make sure there is additional space for future use.

Figuring the Space

As a first step in computing absolute rack space needed, total up all the panel heights of *all* equipment to be mounted in the racks. These figures can be found from equipment specification sheets, equipment manuals, or by actually measuring the panels if the equipment is on hand and uncrated. Figure the total space in inches. Figure *all* the heights, including all those fractions of inches. If the panel is $5\frac{1}{4}$ inches, you may call it a 5-inch panel, but in the measurement make sure it is figured at 5.25 inches. This gives the total vertical mounting space absolutely needed.

Next, measure the vertical panel space the particular racks permit. This may be taken again from the rack specification sheets. Be careful here. If the specification sheet says it can only mount so much, use that figure even though it *may appear* you can get in more equipment. Don't gamble on appearances. Now total all the available space for all the racks. This is the mounting space you have available. If the *required* absolute mounting space is more than the *available* absolute space—you are in trouble already! If these two figures are equal, then you are still in trouble unless you simply want a display of equipment. There are other factors which reduce the usable allocated space.

Most Efficient Use of Room

The rack space must be planned for its most efficient and practical use. As mentioned, other factors reduce the theoretical available space. The first is *spacing* of the bolt holes predrilled into the rack. These holes are drilled at intervals called *rack units*, each being 1.75 inches. The panel heights are in multiples of these rack units. For example, the 5.25-inch panel is three rack units, etc. By the use of standard racks and standard panels, all the panels fit snugly together, filling up the mounting space without gaps. If you start mounting equipment in the middle of the rack rather than at the top or bottom, make sure you line up the edge of the panel at the right location between the holes. You should notice that these are drilled in an uneven pattern. Place the edge of the panel so that it falls between a pair of the closely spaced holes. Then the holes in the panel line up with bolt holes. The opposite edge of the panel then should be done in a similar position. Be careful, as it is easy to start wrong. Then all the panel holes won't line up and you end up with gaps.

There are also racks and panels today that use different patterns. These have the holes at the edge of the panels. They don't fit the standard rack. Although you can mount them, you end up with many gaps between panels. If this type panel is used, the rack should be one that accommodates such a panel. Or you can drill holes to match, either in the rack or in the panel itself. It is best not to intermix too much, or there is too much waste space and a poor front appearance.

Another important factor which can affect the use of front-panel space is what is mounted *behind* the panels, particularly what is mounted at the base of the rack (Fig. 3-6). There must be room for such things as audio terminal blocks, transformers, AC power wiring, cables, and sundry other

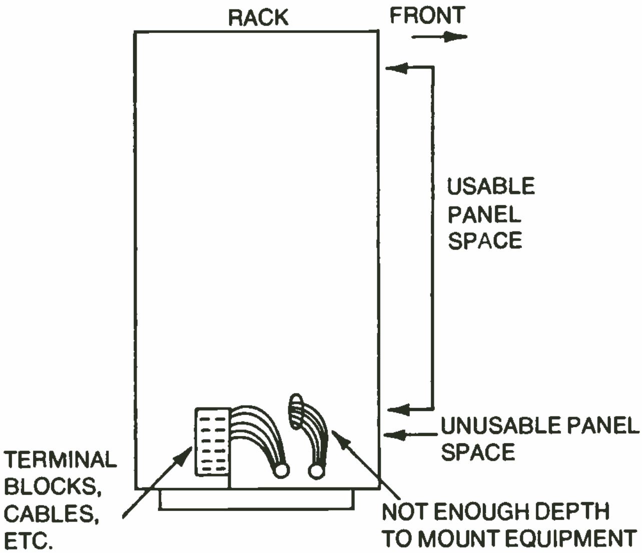


Fig. 3-6. Equipment, terminal blocks, cabling, etc. mounted in the rear of the rack will limit the usable panel-mounting space.

things mounted at the base of the rack in the rear. Ali these things make the front-panel space of little use for equipment mounting, as there is little depth left for the equipment to project back into the rack. In reality, those bottom panels are mere dress panels, covering up the front opening, hiding all the wiring at the base of the rack.

Thus, to be practical, the actual rack space provided must be reduced to a figure something like 75% of what is available. That is, if the rack has 72 inches of panel-mounting space, only about 54 inches of this can be used for equipment mounting. Of course, this figure can vary somewhat, depending upon what is limiting the bottom space.

Heat-Producing Equipment

There is still another factor which affects the practical use of rack space—the heat-producing equipment. Solid-state equipment is sensitive to heat. Care must be exercised when intermixing with heat-producing equipment such as tube equipment or power supplies. The solid-state units should be placed as far from the heat as possible; if they are in the same rack, they should be mounted lower in the rack. Heated air rises and accumulates more heat from other equipment as it does. The air at the top of the rack is hotter than that at the bottom of the rack. Everything that helps air circulation should be used, such as louvered doors, vented tops of the racks, an exhaust fan to remove the rack heat quickly, etc.

When you must intermix such equipment, give careful thought to its placement in the racks, and adjust your required rack space requirements accordingly.

Future Racks

After you have determined the practical amount of rack space required, then make the addition of one or two racks to the lineup for future expansion, even though these racks remain empty. Broadcast stations seem to be in a state of constant expansion, so it seems wise to provide additional space now when the racks are being built into a wall or similar arrangement. There is the tendency to use space right up to the amount provided. You have planned your present needs very carefully, now go ahead and use that planned space as if it is the only space available. Use it wisely and sparingly. As far as the spare racks are concerned, leave them empty. Simply close up the front with rack panels. A less-expensive method is done with regular pegboard material that is cut to fill in the full length of the rack. The pegboard can be painted to blend in with the rest of the surroundings.

WIRING

The air is filled with a great many signals and noise pulses. All these electromagnetic radiations are potential interference and noise problems for the broadcast system. And to compound the problem, all the solid-state devices used now are more susceptible to these interfering signals than old-style tube equipment. Careful selection of good shielded wire for use throughout the system helps immunize the system against interference. Equipment manufacturers realize the problems with the broadcast systems and are building protection circuits and components into the equipment so that they are less sensitive to RFI. But unfortunately, the interconnecting wiring often defeats what has been built into the equipment.

Shielded Cable

Select a basic audio cable that can be used in many applications throughout the station and can be bought in bulk at quantity discounts. The cable can be used for other applications such as low-voltage control circuits, pilot lamps, and many other low-voltage applications—these can all be shielded.

Of course, the cable should mainly be used for audio circuits. When selecting the wire, look over the specification sheets. Try to find one that provides 100% shield coverage and also a ground drain wire. Many of the audio cables today are available in this style. They cost a little more than those with a little less protection, but it will be well worth the extra cost to keep RFI out of the system.

Buy in bulk when you can. This is far easier than buying different varieties of cables. Stocking is simpler, and some can be kept on hand even after the installation has been completed.

Try to use the audio cable wherever possible in control and other low-voltage circuits. By the use of shielded cable, there is less chance of RFI entering the system through these *back doors*. Besides the RFI and noise problems, the shielded cables also reduces the possibility of crosstalk from these other circuits. Audio may be picked up and carried along a control cable, which does not affect the relay or similar control circuit, but it can carry the audio into another audio circuit, causing crosstalk or even oscillations.

Microphone cables must be flexible in use and still be shielded. So select a good microphone cable. This should be a three-wire shielded cable, using one of the wires as a solid ground.

Although shielding is an important specification in cable selection, another important factor is the capacitance within the cable. This capacitance is directly in parallel with the load impedance. It affects the high-frequency signals passing through the cable. In the specifications, try to select a cable with a low-capacitance-per-foot value. Remember that this capacitance is in parallel, which adds up as the length of the cable increases. At the end of a very long cable run, this capacitance is considerable. And there can be many long cable runs, even though the particular apparent run is short. For example, a cable may run from a console about 50 feet to a rack, then through several feet in the rack, then back 50 feet to the console output, and on to connecting circuitry. By the time the signal gets to its destination, it may have run through 200 feet of cable in what *appears* to be a 50-foot run.

Insulated Cable

Although shielding is important in keeping out unwanted signals from the circuit paths, these shields can themselves carry the unwanted signals. When selecting a basic cable, choose a type that has a plastic outer sheathing. This prevents individual cable shields from intermittently touching each other. When shields are bare, this intermittent contact of separate shields can create varying potential differences at various places on the shields—problems. Bare shielded cable should be tied together tightly in cables, so that the shields make a definite contact all along the way. But the better cable has an insulated outer sheath. This insulated sheath allows you to control over the points where the shields are grounded. The basic cable is used for purposes other than audio and can be routed into areas of low-voltage circuits; a bare shield could short out these circuits. The insulated shield prevents these problems.

Cable Separation

When many cables of different signal types and levels are run close together over long spans, there are all sorts of potentials for crosstalk, hum, noise, and other types of interference created. Shielding is a must, but in many cases additional techniques are also required. The cables should be segregated into types and levels. By *types* is meant control, power, and content.

Cables need physical isolation as well as signal separation. This can best be accomplished through the use of conduit or ducts. The conduits must be large enough to accommodate a number of cables of similar groupings. In a few cases, separate conduit for a single circuit is used, but for the main cable runs, several, large conduits are necessary.

When ducts are used, all the cabling run in the same duct, but they should be separated as much as possible. Some ducts have metal separators running lengthwise. If not, the cables can be anchored at various places to keep them apart.

Since broadcast stations have a propensity for quickly outgrowing their facilities, when making the basic decisions on conduit or ducts, be generous in the number provided. That is, try to look ahead for future needs. You can be almost sure your guess is wrong, but at least try to provide some extra capacity now. Ducts and conduits are some of the first items installed during construction of a new building or in a remodeling project. So try to get the added capacity now because it is very difficult and expensive to add at a later date.

Signal Levels

Separate cables according to signal levels (Fig. 3-7). Don't get carried away. What is important is that the principle of separation be kept in mind and applied within practical limits, not only during the initial installation, but at any time cable runs are made, now or in the future.

The usual cable groupings that I use are these: (1) microphone or similar low-level signals below −20 B, (2) mid-level signals in the range −20 dB to +18 dB, (3) high-level signals above +18 dB and speaker runs, (4) power and control circuits. These are relative groupings, so a few decibels one way or the other won't upset the pattern. Each of these groupings can be further subdivided if the situation seems to call for it. But as with all patterns, once you decide to use one, be consistent and stick with it whenever possible.

Fan-In

Although you maintain cable separation on the trunk lines, cables must eventually telescope back together as they arrive at their destinations, either in the rack or the console. Even so, the principle of separation can be maintained to some practical degree. For example, one rack contains high-level circuits and equipment, while the other rack contains low-level preamplifiers and similar circuits. Or a single rack may be divided, with high-level units at the top and low-level units at the bottom. Other similar separation can be done, such as one

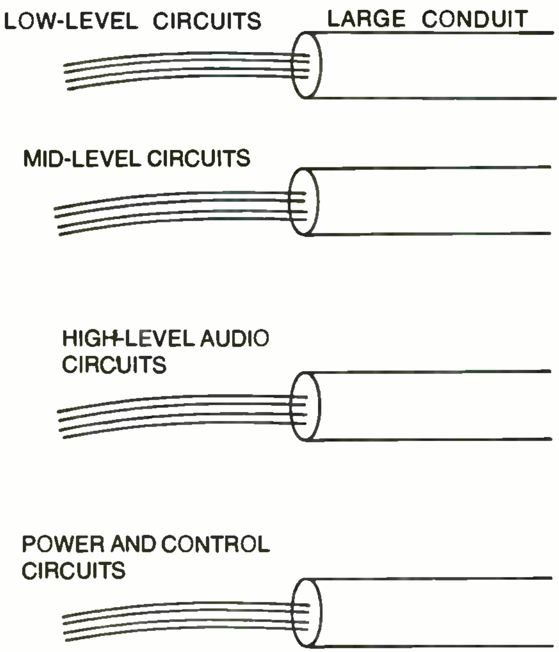


Fig. 3-7. Segregate cables by signal levels.

row of jacks for microphones, and another row, as far away as possible, for speakers; one audio terminal block at the base of a rack for low level, and another block for high level—or a single block with low level on one end and high level on the other end. The principle is simply keeping them apart whenever possible and practicable.

Internal Wiring

Cabling within a rack must also have separation. High-level cables must be laced together in one large cable, all midlevel cables into one large cable, and low-level cables into another large cable. Even these larger cables can be run separated. For example, dress the high-level and midlevel cables up one side of the rack, and the low-level cables up the other side of the rack.

GROUNDING

Throughout the station, a definite plan of grounding should be established, not only during the construction and installation stages, but at any time in the future when changes are made. This grounding can be divided into at least three main aspects: cable shields, common ground system, and the relationship of the grounds to lightning surges.

Controlled Shield Ground

The most successful method of handling the cable shields in the system is through the *controlled ground*. This method provides a positive control over the normal noise, crosstalk, hum, and similar interfering signals that crop up. The system is most effective when it uses a balanced system of wiring for all signal circuits. By *balanced*, is meant that both sides of the signal circuit are above ground potential.

The underlying principle is this: The shield of each cable is connected to the main ground *at only one place* on its run (Fig. 3-8). The shield must be insulated from all other shields except at that one grounding point. This means that jacketed cable

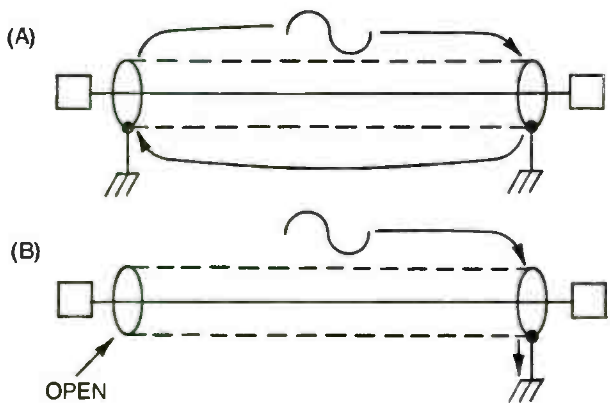


Fig. 3-8. Principle of the controlled shield ground. In A, when the cable is grounded at both ends, circulating currents can be set up in the shields. In B, the shield is grounded at one end only. Any currents picked up are routed to ground and can't circulate.

should be used throughout. By connecting the shield at only one place, there is an incomplete circuit path to any unwanted signal that may be induced in the cable shield. And any currents that are induced are carried to ground at the single grounding point rather than being allowed to circulate throughout the shield system. And these grounding points are only at selected points, not in some haphazard method. The majority of audio cables available today are jacketed and work with this method.

Ground Points

Actually, there are many grounding points within the overall system. But these are definite, selected points of contact with the main ground. Each major unit—such as rack, console, and transmitter—have a connection to the main ground. The control of the shield grounding must be planned ahead of time. A decision should be made ahead of time as to where the individual cables should be connected to the main ground. There are often questions during the installation as to which end of the cable gets grounded. So these should be anticipated and designated ahead of time. Consistency is important, or some cables may end up grounded at both ends. This allows a complete circuit path for unwanted signals carried on the shield, and circulating currents set up. Circulating currents must be avoided.

Make a Plan

To plan the shield system, draw a single-line diagram of the entire system. On this diagram (Fig. 3-9), show the points that shields terminate. A common grid can be set up when the

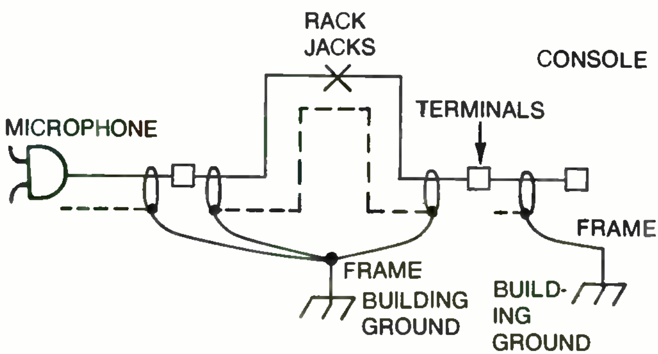


Fig. 3-9. Plan the control of shield grounding ahead of time.

overall system is laid out this way. For example, circuits that run *to a rack* ground *at the rack*. Circuits to a console, ground at the console. In other words, the grounding is always *at the end* of the cable run. A microphone circuit, from a studio that runs into a rack, through a jack field, and then back out to a console must have its shield grounded first at the terminal block as it enters the rack. The next grounding point is at the console terminal block. The shield of this cable leaving the rack has its shield cut off and insulated from other shields. In effect, this cable run has two grounding points: first at the rack receiving point, and second at the console receiving point.

Individual Projects

When schematics are drawn for the individual wiring projects and interface points, always add the shield information to that drawing. This answers any questions that arise during the actual wiring as to what to do with the shields. Except for the major wiring projects, such as the rack or a console, it is all these small interface areas where problems arise. So draw in the information to help the installer keep the system in order. Two installers may be working on the same circuit but at the different ends. If both are confused and tie down the shield, there is a ground loop provided, resulting in possible problems at some later date. Remember to retain this installation information for later reference when the system is in operation.

The controlled-shield-grounding method is only one of the methods in use. There are others that work as well in some situations, but the controlled method works the best when it is maintained.

Any grounding system is not a guarantee that there won't be problems in the system. By taking precautions with the grounding in the first place, you are at least providing a greater amount of protection against all these problems; and for most ordinary situations, you do, in fact, come up with a very "clean" system. But outside changes can alter the situation, and greater measures may be called for. For example, I installed a complete studio system that measured under 0.5% distortion and noise well below 80 dB. It sounded beautiful until we increased our FM power to 50 kW and added vertical polarization to the antenna by moving the antenna directly overhead. This subjected the audio system to a tremendous RF field. That blasted FM signal popped out of the least crack in the system!

Common Building Ground

So that a common reference for all signals and equipment in the station is obtained, a *common building ground* must be provided. This is the station's main ground. If this common ground is not provided, many possibilities exist for differences of potentials developing across any intermittent contact or irregular ground point that can produce problems of hum, crosstalk, transient noises, signal intermodulations, and system instability. At the same time, searching out and correcting problems that do develop is made more difficult.

The building ground should be a heavy copper strap run throughout the building and connected to ground at one or more places by copper rods driven several feet into the earth. Everything within the station is grounded to this strap.

There are many ground currents flowing through this strap and from many sources, so it must be a heavy strap and electrically one continuous piece. It must provide a very low resistance to all these currents. It should be at least two inches in width and wider if the expected currents are to be higher than average. Some stations with high-power transmitters nearby use a width of six inches or more for the strap. Remember that RF signals travel on the surface due to skin effect, so a wider strap is recommended with large RF signals close by.

Naturally, it is difficult to roll out a single strap to route throughout the station. It is normally several pieces connected together. But when connections or splices are made in the strap, make sure they are very low-resistance joints. Use a hard solder, such as silver solder, to make the electrical connection. Any resistance produces voltage drops. If the joint is a nonlinear resistance because of corrosion or other chemical action, intermodulation of signals occurs.

Each major unit of the system must connect to this main ground by another heavy copper strap. The strap at the unit need not be as wide as the main ground strap itself, unless the piece of equipment has heavy ground currents. Thus, each rack, console, transmitter, conduit, and power circuits must connect to this ground bus. At each unit, make sure the strap is bolted or soldered to the frame of each unit. On a rack or any other unit that is painted, scrape away the paint so that a good metal-to-metal contact is made.

Lightning and Grounds

Lightning generates enormous potentials and currents. Currents must flow to earth ground by the shortest route and as quickly as possible; they must not be allowed to circulate through the system ground. If these currents do circulate through any part of the ground system, there can be many unexpected results at the most unexpected places.

A surge or transient increases to a very high-potential peak value, then trails off to a lesser value that may oscillate into one or two overshoots or rings at the trailing edge of the transient. The duration of the transient is very short, in the order of milliseconds, with the rise time in microseconds. This sudden change has AC characteristics and can be translated into megahertz from a frequency standpoint. Since this is an AC signal, the *length* of the ground conductors takes on importance, since they exhibit inductance components at the high frequency of the transient (Fig. 3-10). And since this surge current is in the order of 20 kA, tremendous inductive voltages build up between the ground conductors and other

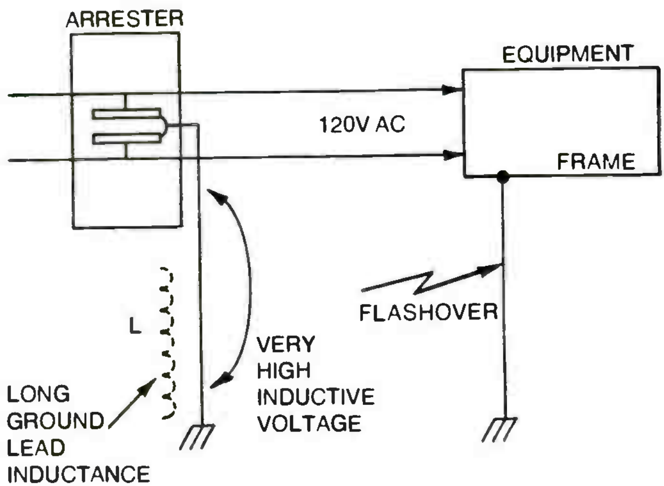


Fig. 3-10. The inductance of the long ground lead at the transient frequency generates dangerously high inductive voltages that arc over to adjacent units.

nearby objects such as racks or equipment. These potentials are dangerous; they create tremendous arcs just like the ones in science fiction movies. In our previous considerations of the building group strap, we were concerned with its low-ohmic values and the skin-effect RF resistance. But the length, in this case, should also be given full consideration when designing the ground.

When any length of the building ground bus must be more than 25 feet in length, try to break it up in some way. This may be done by running parallel conductors or some sort of grid system that breaks up all the runs into small segments. That is, run several crisscross members to the ground bus and make sure these are all soldered together. Take the ground bus to earth ground at as many points as you can. What you are trying to do here is break up the length so that is does not offer a suitable inductance to the current that may get into the system from the surge transient.

SURGE PROTECTION

The deadliest interference problem in the age of solid-state is the transient signal problem. Solid-state equipment is very suceptible to transients and most vulnerable to damage. The station must take adequate precautions to protect against this problem, or it will find its solid-state equipment on the bench for repairs more often than it is in the racks operating.

The transient can come from many sources, both within the station and outside the station. From inside, transients can be caused by heavy motors turning on and off, such as large air conditioners: switching of heavy current loads, such as in transmitters; and similar switching operations that cause an abrupt change in current flow. Studios have shown that the normal 120V AC power system can carry transient spikes of over 5000V for a very brief period. These spikes are so brief that they don't trip a circuit breaker or blow a fuse, but they can blow out solid-state equipment quickly.

From outside the station, transients can be generated by manufacturing plants and their heavy equipment or power lines swinging together in a windstorm, but the most common cause is lightning. The lightning does not need to strike the line. Nearby strikes induce large transients into the power lines.

Once a transient begins to build up, it needs to be routed to earth ground quickly. Let's consider the lightning surge over the power lines as our main problem. The best place to route it to ground is at the power entrance to the building. Some type of arrester or suppressor must be mounted directly to this primary entrance with a direct path to earth ground provided.

The alternative method is protection of each individual equipment item (Fig. 3-11). However, it is better to stop that surge at the door, rather than let it circulate, raining lightning bolts through the building. But if the incoming arrester is not totally effective, it won't be a bad idea to also protect some of the more sensitive equipment.

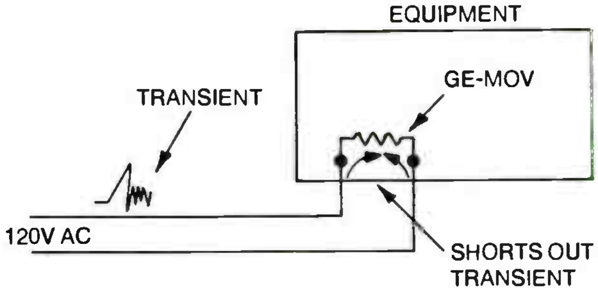


Fig. 3-11. Individual units can be protected from transients coming in on the AC power circuit by the use of devices such as the General Electric metal oxide varistor.

Lightning Arrester

There are several firms supplying arresters. While these different models try for the same end results, they are far from the same in their principles of operation. Each of the manufacturers has a different way of doing the job. But regardless of the method, all fall into the category of a "crowbar" circuit. That is, once the transient comes on the line, it turns on the arrester. The arrester shorts the power line to ground for the period the transient is in operation. Ordinarily, this is only for a few microseconds or perhaps milliseconds. At any rate, it is always less than a half-cycle of the power line frequency. But during the transient turnon, the power line itself is also shorted to ground. And it is important that the arrester shut itself off once the transient has passed. If it doesn't, the power line remains shorted to ground. The flow of current from the power line to ground is called *power follow*.

Fusing

Tremendous currents are flowing during a transient, but only for a very brief period of time. However, the circuit breaker or fuse of the power line itself must be such that it doesn't trip during this flow of current. If the arrester is wired into the primary ahead of the main fuse, the arrester itself must be fused. There must *always* be a fuse or circuit breaker between any load and the primary power. But the particular fusing must be of a special slow-blow type, otherwise the fuse or circuit breaker trips every time a transient comes on the line.

Grounds

As discussed earlier, very high currents flow through these grounds when a strong transient is present. The ground lead from the arrester to earth must be very short and direct. Besides that, this ground lead should also be insulated from nearby objects so that any potentials that build up will not also flashover. Avoid tying it into the building ground system.

Power Line Circuit

Power distribution throughout the country is not done in a uniform manner. It often depends upon practices in various parts of the country as well as the individual power company.

Selection of an arrester for your station requires information on the method of power distribution at your station. Unless this information is already on hand, a call to the local power company will probably obtain it for you. But stations which have been in operation for many years may have had many changes over the years, so the power company records may not be up to date. However, they wish to have their records up to date, so they usually send out an engineer to survey the system to give you the desired information.

A station can do its own investigation and come up with the information. This requires a visual inspection of the transformer banks as the power lines arrive at the station.

Take a paper and pencil and sketch the number of transformers in the bank. Take particular note of the secondary connections. It won't be difficult distinguishing which are primaries and which are secondaries. Observe how many wires go into a weatherhead (the down conduit to the station). There are several transformers in the bank, but each grouping feeds a power entrance to the building. There can also be more than one entrance from the same bank because very heavy equipment may have its own special feed directly from the bank. These additional feeds are easy to spot since they tie to the same place on the secondaries as do other

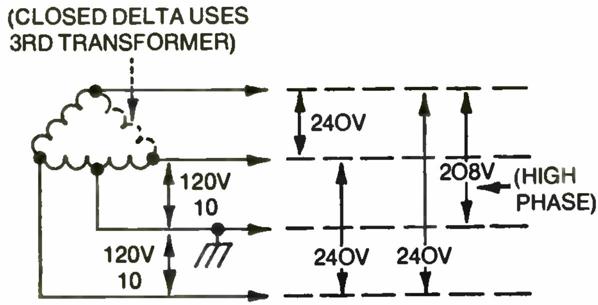


Fig. 3-12. Typical open-delta secondary connections for a 3-phase system. One transformer provides a 120V single phase. Voltages shown are the design parameters.

weatherheads. But observe carefully—one of the transformers may be a part of a three-phase bank but also providing a single-phase entrance. Also note the main power panels where these enter.

Measure the Voltages

Now that you have drawn a sketch of the transformer banks and the wiring of them, go to the power entrance panels and measure the actual voltages (Figs. 3-12 and 3-13). When three-phase and single-phase power are obtained from the same bank, the secondaries may be in either an open- or closed-delta configuration. If it is an open delta, there are only two transformers in use; one of these has a center-tapped secondary. This tapped transformer provides 120V AC single-phase power on each side of the tap. On a closed delta,

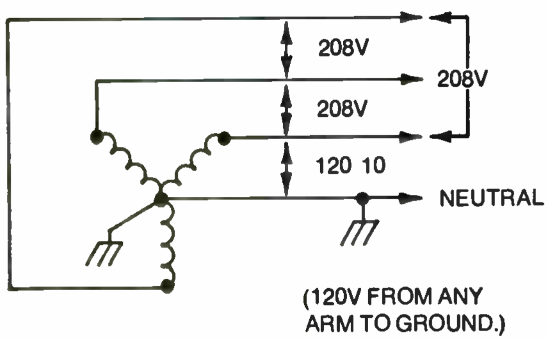


Fig. 3-13. Typical Y-connected secondaries of a 3-phase system. Voltages shown are design parameters.

the third transformer is used for the third phase, and the single-phase power is obtained from one of the transformers as is done in the open delta.

In either case, you should be able to measure 120V AC from center tap to either end of the transformer. From the end of the delta opposite the center tap to the center tap, the voltage measures 208V AC. End-to-end voltage measurement across each transformer in the bank provides 240V AC. That 208V is called the *high phase*, even though its voltage is lower than the end-to-end measurements.

These voltages are the design norms so they may or may not be the exact values that you measure at your installation. Actual voltages depend upon the voltage of the primaries themselves, but the ratios remain the same.

Selecting an Arrester

When selecting an arrester, the normal values of voltages you measured are important, as well as the fluctuations. However, the high excursion is the more important than the low one. This is because the arrester selected may be working near its maximum design limit. When a transient comes on and turns the arrester on, it may not be able to turn itself back off when the transient passes. When requested, the power company usually installs a recording device on the line to measure its high and low excursions during a 24-hour period.

Installation

This job is best left to an electrician, and in many areas of the country, only a licensed electrician can do the job anyway.

The arrester is normally connected directly to the incoming power line at the building entrance and ahead of the main circuit breaker (Fig. 3-14). If it cannot be mounted ahead of the breaker, you may have to change the breaker to a slow-blow type. If the arrester is connected ahead of the breaker, it must have a disconnect switch and its own fusing. When possible, add small neon lights to the input side of the arrester, so that these can be an indication that the fuse is okay and that the unit is connected to the power line. Without some indication, it is possible the arrester is open, the fuses are open, or the switch has been left open. In all these cases, the protection has been removed from the circuit.

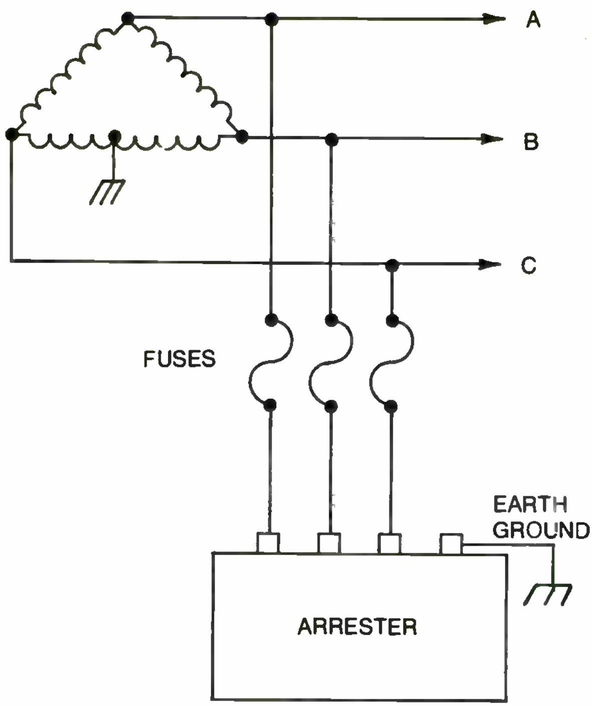


Fig. 3-14. Typical surge arrester installation on a 3-phase system.

The ground lead from the arrester should be as short as possible and should go directly to earth ground. This should also be an insulated wire to prevent flashovers to adjacent panels if high voltage builds up on the ground lead.

Maintenance

Actually, there is little to do in the way of maintenace of an arrester. One should check from time to time to see that it is actually in the circuit and that the fuses are still intact or circuit breakers not tripped. If there is dust collecting in the box, blow this out occasionally. But be very careful when doing anything around these circuits. A short across a pair of the buses creates a blinding flash that can damage the eyesight and cause serious burns.

INSTALLATION

After all the planning has been done, we must sooner or later get about the task of making the installation, and there are easy as well as hard ways of doing things. The following are few of the techniques I have developed and used with reasonable success:

Pulling Cable

On a large project, when many cables are run through conduit between two locations, it is difficult determining what length to cut the cable or cables.

First, run a "snake" through the conduit. Then tie onto the end of the spool to pull in one cable. Make sure it is adequate length to reach the desired location on each end of the conduit. If the distances vary, then make them all reach the farthest point. To accomplish this, pull the first cable back out of the conduit. Use that measured cable as the yardstick for the rest of the cables. Tie or tape them together every couple of feet, if desired, so that you don't end up with a tangled mess on the floor before they all get pulled into the conduit.

Now that you have made a large cable out of all the small cables, tie these onto the end of the snake. Make sure there is a good tie. The end of the snake should be bent over into a hook. There is tremendous pull on that joint; make sure it is tied down good and tight. Next, tape over the hook on the snake so that it can't hook a cable already in the conduit.

Of course, you should have decided which end of the conduit you will work from. It takes some elbow room for the cable when the pulling action starts; be sure to find the best way to pull. It doesn't matter as far as the wiring itself is concerned. Have someone feed the cable into the end of the conduit. He can keep any kinks straight and help keep the cable from binding on the edge of the conduit opening.

Identifying Cables

There are a couple of ways the cables can be identified. One method calls for tagging each cable before it is bundled into the large cable. But this can be time consuming, and if the tags are not the small roll-a-round type, they can become so mangled after the pulling operation that they are unreadable anyway.

The next method is the ringout. In this method, all the ends of all the cables are bared back so that you can get at the wires. Simply skin back the insulation a bit and keep the wires apart so they don't short to each other. You can use an

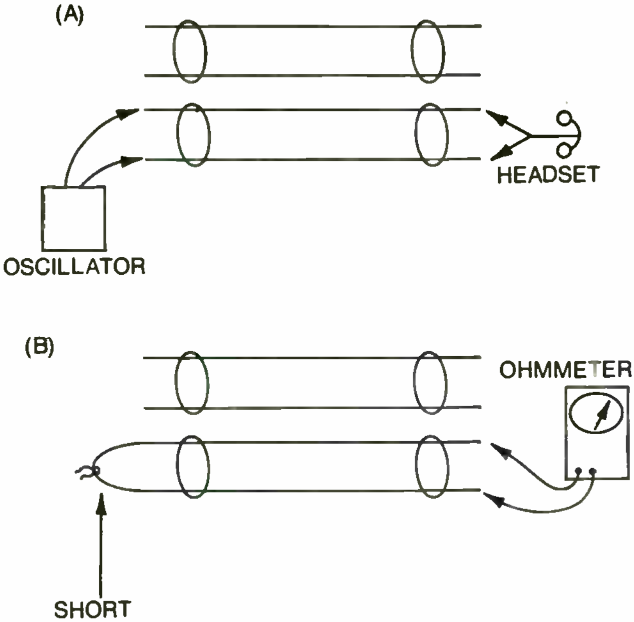


Fig. 3-15. Two different ways to ring out the cables. In A, an audio oscillator and a pair of headphones are used. In B, shorting one end of the cable and then using an ohmmeter at the other end is the method.

oscillator with a pair of headphones or use an ohmmeter. With the oscillator method. attach the oscillator to one pair of cables. then go to the other end and listen across various cable pairs until you find the pair with the tone. With the ohmmeter method. short one pair of wires; go to the other end with an ohmmeter and look for the short. If there is any doubt, make and break the short while watching the meter. Either of these methods works better when you have a helper. At least there is a lot less walking between the ends. If you have some intercom arrangement, use one of the cables for a communications pair until you finally wire all the others into the circuit. then do that one last. It is best to find a pair, wire in both ends to the terminal blocks. find another, and so on.

There is still one more way: Wire in all the cables to the terminal block at one end of the run; then ring them out. But be careful that you aren't reading the input resistance of a transformer or stage.

If you have many cables to check, another little trick can speed the process. Fan out all the cables on the floor, holding them with your foot. Then take the ohmmeter and quickly cross each pair until the shorted one is found.

Jack Fields

Wiring up jack fields is a tedious process; there are many connections to be made. Whenever there are many repetitious actions to make, always try to employ production-line techniques.

Many jacks are constructed so that a single piece of bare No. 14 wire will lay right across the ground terminal of each jack in the field. This makes a neat installation, but keep the wire straight. If it is bent in many places, it can be straightened by placing it between a couple of boards and giving a few taps with a hammer. Lay this bare wire across the ground terminals, but make it long enough so that it reaches to the main rack ground. Solder each of the jacks, then solder the end of the wire to the main ground. This is the only ground necessary at the jacks because all the audio cables are grounded at the terminal blocks at the base of the rack. The shield at the jack ends are cut off (on the cable).

Jumper Connections

There are many small jumpers to be made and wired in for the "normal" connections on the jack field. Do this: First deside on the length one of the jumpers should be. Don't install it, but instead use it as the measure. Then measure and cut off all the necessary jumpers for *all* the jacks. Install the jumpers on all jacks mechanically first. Next, solder all of them. It is less time-consuming to wire in all the normals than to wait and decide which will have normaled jacks and which will not. When the normal is not desired, it can easily be snipped off.

Wire Dress

Whenever there are hundreds of connections to wire and dress, practice motion economy. That is, use as few motions as necessary to do the operation. For example, first decide the length the outer covering must be stripped. Mark off the sample length near the spot you are working. You may be able to mark the length on the strippers themselves. Then it won't be necessary to actually measure each time—just use the marks each time to measure (without laying down the stripper). Do the same with the individual wires. Thus your operation should be simple motions—measure the outer shell, strip, measure the individual wires, and strip—all this without putting down the stripper or changing position in your hand. Practice the motion economy that works best for you; make it a habit. If you think this is a small point, observe other engineers in the way they dress the end of a wire cable. It can be amazing the number of motions some individuals make in this simple operation!

Fan-In

When dressing the cable into a jack strip, terminal block, or whatever connector, the cable must usually approach from one end of the terminal. A neat job can be done if the wires are measured and fanned into the connections.

Make sure all the cables are long enough to reach the greatest length, then tie the cable at the entrance to the terminal unit. Make sure it is tight so that individual cables cannot be pulled out. Again, the stripper may be used for a measure; decide the length of the first one, strip, and so on. This process can be measured for the first few, but it won't be long before the engineer can eyeball the length and come very close. Start with the shortest cable and work each one until the end one is reached. Work the length so that it is directly behind the jack before measuring the length into the jack.

Lacing

After the wires have been carefully dressed into position, lacing will make the finished product. You can either use a lacing twine or some of the cable ties. The twine makes a better looking job, but it takes a little longer to use. Use a good waxed lacing twine. Cut off a few feet; don't make it too long or it will be difficult to work. As each piece runs out, simply tie another piece to it. Make the loops so that each one pulls down tight and stays in place if let go. That is, lace over and under so that the tight straight piece is holding the loop in place. At the end, make three or four knots; snip off the excess. Another hint: Use a golfing glove or simply use a couple of Band-Aids over the little-finger joint where you naturally pull the string tight. After a couple of ties, you will be able to determine where this spot occurs. If you don't do this, the string eventually cuts through the skin and you will have some very sore fingers.

Chapter 4

Audio Characteristics and Problems

There are several important audio characteristics that affect the operation of a station's audio equipment. Many of the problems that arise and require maintenance can often be traced to these characteristics, which have either been ignored or inadvertently disturbed. Only a few of the main characteristics are discussed in the chapter, along with some problems and their sources.

LEVEL SETTING

There are two different aspects of signal levels that should be distinguished in these discussions. *Program* levels are those which occur during normal programming, caused by the program itself. *Standard* system levels are those around which the system has been designed, that is, the setup levels.

Program Levels

During operation, program levels vary according to the particular program, but the peaks should be maintained as read on the VU meter. When signal levels are very high, they should be adjusted back within limits by the gain control. The same can be said of low signal levels: Adjust upward to get them within limits. This is simply old-fashioned gain riding, which is a lost art today. This is so because too much reliance is placed on AGC (automatic gain control) and limiter amplifiers to take care of *all* gain problems. And secondly, many operators are basically announcers doing their own switching. Actually, AGC amplifiers do a fine job of riding gain—so long as signal levels are within their range. They cannot do the entire job; but when signals are within their range, they can often do a better job than an operator.

Meter Pads

The signal levels read on the VU meter are not necessarily the true signal levels of the bus they are monitoring. The VU meter itself has a definite full-scale range, just as any other meter. When the bus levels must be higher than the normal range of the meter, then pads must be inserted to bring these levels back into range. The pads, however, must only control the signal level to the meter, and must not affect the actual signals on the bus itself.

The range of the meter is approximately −20 dB to +3 VU, full scale. The meter can read bus levels that are within this range, but in many cases they are higher than this. A pad must be inserted to bring the bus level back within range of the meter. Consequently, the meter may be peaking at 0 VU, but the bus level may actually be +8 dB on the peaks.

The VU meter almost always has pads in its path (Fig. 4-1). The internal impedance of the meter is 3900 ohms, and if

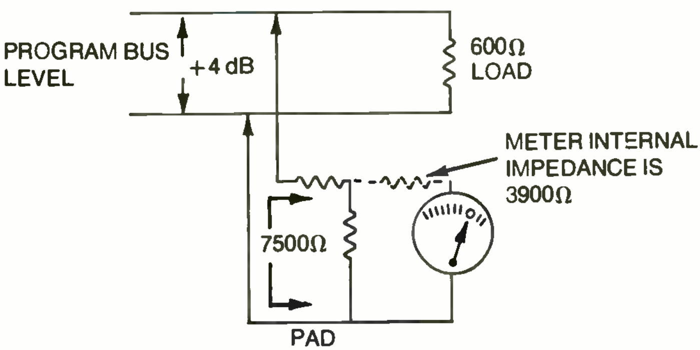


Fig. 4-1. VU meters always have resistance pads added, so they present at least a 7500-ohm bridging to the program bus. With a total of 7500 ohms for the pad and meter, the meter will indicate 0 VU when bus is +4 VU.

this is placed directly across a loaded 600-ohm bus, it will load the bus down a little (about 0.6 dB). Usually, there is enough resistance added so that the meter circuit appears to be approximately 7500 ohms. The meter will read lower, of course. It will be lower by approximately 4 dB, or to put it another way, it takes +4 dB on the bus to make the meter read 0 VU.

Standard Levels

The system is arranged to operate at certain levels, for example +8 dB. The VU meters are then padded to read 0 VU when these levels are present. That is, the system levels are +8 dB, and not the 0 VU that the meter-and-pad combination indicates. Every station should have its system set up around standard levels. Industry standards may be used, and this is preferable; but any standard can be set. Most broadcast equipment, however, is designed to operate at the nominal industry standard levels. Industry standards are essentially these: low-level microphones −55 dB; midlevel, −12 dB, program bus levels, +8 dB; other high-level monitor circuits +24 dB. The station standards need not be these exact values, but should be in the neighborhood.

Consumer Items

Many times, certain equipment items designed for the consumer or hi-fi market find their way into broadcast stations. This happens quite often in smaller stations, and even in some of the larger ones. This is not to say that such equipment should not be used, but the methods of designating input and output levels and impedances may be different. When mixing such equipment with regular broadcast equipment, look at the specifications carefully to determine what they mean. You don't want to compare apples and oranges. The broadcast standard is based on power and a definite impedance (Fig. 4-2). Program buses are at 1 mW in 600 ohms, representing a 0 VU level. This is also a voltage level of 0.775V across a 600-ohm impedance.

Sine and Complex Waves

The program signals are made up of complex waveforms and are far different from the sine-wave signal obtained from a signal generator. It is a paradox that our broadcast system must use the complex wave for all its program operations, but the majority of our test and setup adjustments must be made with the sine wave. This is necessary since many measurements require the signal to "stand still" long enough

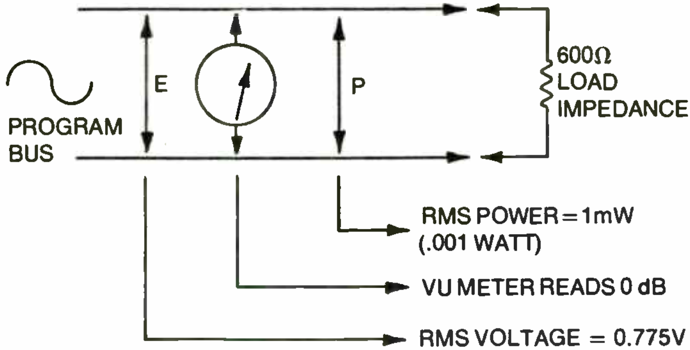


Fig. 4-2. The broadcast standard reference level is a measurement of power in a program circuit, with a specific 600-ohm load impedance. This is designated as 0 dBm (the small m means milliwatt reference).

so we can measure it. The unfortunate part of this is that the equipment often behaves differently when amplifying the complex wave than it does with the sine wave. Consequently, it is important that the engineer understands the differences between the two waveforms, and the different equipment reactions, so that more meaningful measurements and adjustments can be made to the system.

The *sine wave* obtained from a signal generator will provide those nice, symmetrical "text book" waveforms. The positive and negative halves of each cycle are identical in amplitude and beautifully shaped, and each cycle repeats itself until the generator is shut off. There are many things that can be said for the use of this test signal. It does meet all

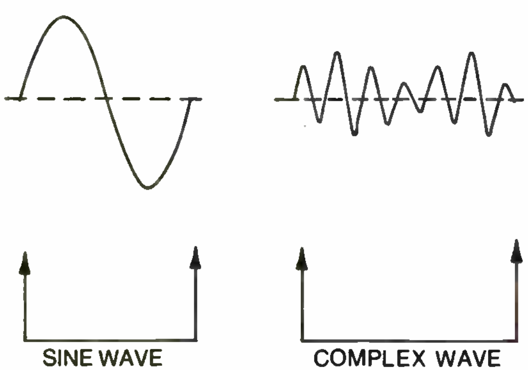


Fig. 4-3. The sine and complex waves.

the standard formulas for AC signals—peak-to-peak value, averages, etc.—regardless of the audio frequency that is used.

The *complex wave* is another story altogether. In the first place, very few of the cycles repeat themselves. Actually, there are many cycles mixed together as the sounds the wave represents occur. As a matter of fact, they bear little resemblance to cycles in the sense of a sine wave. Besides that, positive and negative portions are not always identical in amplitude. The term *complex wave* adequately describes this signal. Besides being so irregular in shape, the average, RMS, and peak values are constantly changing in relationship to each other, depending upon the program content at the moment. These relationships are further changed when the program signal is run through signal processors and equalizers.

Peaks and Averages

The average value of an unprocessed complex wave in relation to its peak value is almost always far lower than in a sine wave (Fig. 4-4). This change in relationship is due to the waveform itself. To get a higher average value, each cycle or time period must have more "body"; that is, cycle width in relation to peak amplitude. In a given time, say one second, the complex wave may run through a dozen or more cycles, each with a different width-to-peak ratio. Anyone familiar with pulse measurement, and particularly trying to rectify a pulse signal to obtain a DC voltage, knows what a disappointingly low value of DC voltage will be recovered from a high-amplitude, narrow-width pulse train.

The peak amplitudes of the complex wave can be 8 to 12 dB (or more) higher than the average value of the signal. And it takes a special meter to read these peaks with some degree of accuracy. This meter is the VU meter, and it is especially designed for reading the peak values of a complex wave. It has special damping to prevent overshoots and vibration of the meter hand, and other ballistics so that it can reasonably follow the wave. When it is measuring a complex waveform, it is indicating in volume units (VU), and not decibels. The standard AC voltmeter, as found on regular test sets or multimeters, does not have these characteristics and will not read correctly.

Any meter, including the VU meter, is an electromechanical device, so there is inertia present. Consequently,

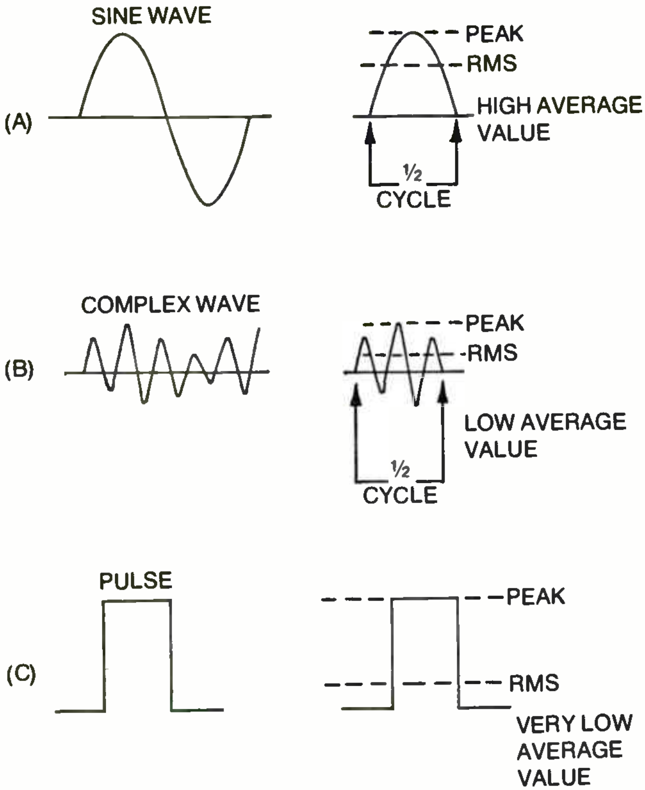


Fig. 4-4. Comparison of sine wave, complex wave, and pulse.

fast, narrow peaks arrive and go by before the meter can react. A sine wave, however, can be measured with the VU meter (Fig. 4-5). With symmetrical, repetitive sine waves, both the AC voltmeter and the VU meter will read the same. They will also both indicate in decibels. But even with all its special characteristics, the VU meter, on a complex wave, will still indicate lower than the true peaks of the signal. And these peaks will be far different than the decibels read on the VU meter with a sine wave.

An interesting test can be set up to verify the foregoing discussions on complex and sine waves (see Fig. 4-6). Use the console, and a remote amplifier or similar device that has a VU meter across its output. Make sure the output is properly terminated in 600 ohms and the input signal is not the type that has been processed. Use a microphone for best results, or use a record without any other processors. (The peak-to-average values will be somewhat distorted because of the processing of the program before recordings.)

Next, feed a signal generator into one input, making sure to use the correct impedance matching, and set the VU meter to read 0 VU. Select a frequency that will not fall within some equalizer range. Now, place an oscilloscope across the output resistor and set the signal display to some arbitrary value. However, make sure you leave plenty of space on both top and bottom of the trace. Do not change the scope input after this calibration.

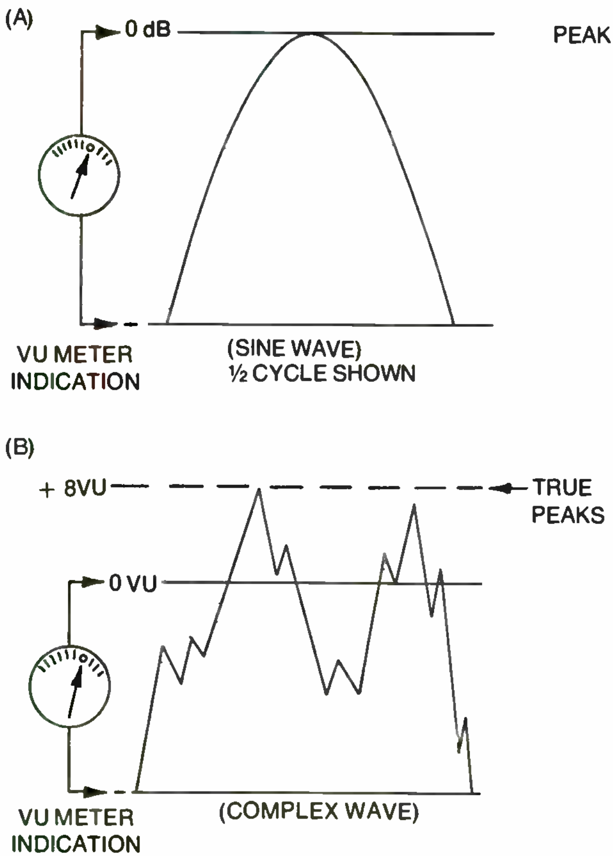


Fig. 4-5. When sine wave signal is used to set up the program level, (A) VU meter will read 0 on sine wave peaks but program peaks will be much higher. (B) The meter will indicate peak values as 0 VU, but the true peaks will be 8 to 12 dB higher.

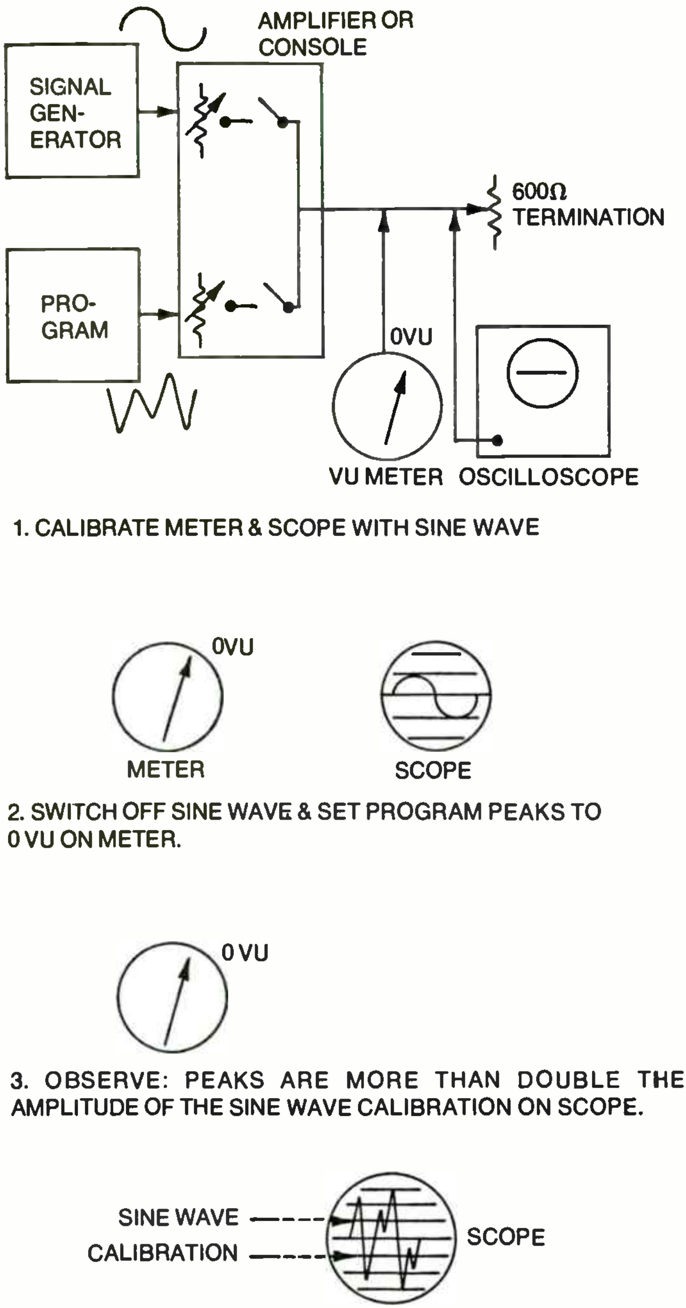


Fig. 4-6. A test setup to compare sine wave with complex program wave.

Do not change any gain controls, but switch off the signal generator. Feed the mike or program source into another fader and adjust the gain control of the channel so that the VU meter is reading 0 VU on the peaks. Observe the oscilloscope. The program peaks will be much more than double the peaks obtained with the sine wave. The scope, by the way, is indicating peak-to-peak values, but it will be the same for both signals, so the indications are still valid. The scope also reads voltage. Since the program peaks are more than double the sine wave peaks, they are more than 6 dB higher. Doubling the voltage is 6 dB, but since these peaks are more than double, the figure is more than 6 dB. This is only a relative test to visualize what is happening in the circuit. Compressors and peak limiters, of course, lower these peaks considerably.

Headroom

A very important aspect of level setting and control, which is often overlooked, is *headroom* (Fig. 4-7). The amplifier designers do give consideration to headroom; how much will

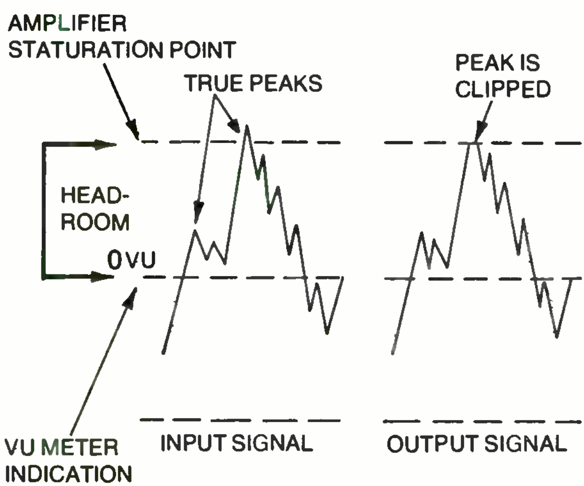


Fig. 4-7. Headroom is the space between the peaks as read on the meter and the amplifier saturation or overload point. Any peak past the saturation point will be clipped.

reflect the quality of the amplifier. In the previous discussions and demonstration, it was shown that the peaks of the program material are far more than what shows on the VU meter. The amplifier must be able to pass these peaks without going into nonlinear operation or clipping. The region between the peaks indicated on the VU meter and the point the amplifier goes into distortion is the headroom.

Lack of headroom can be due to poor amplifier design, or it can be due to an improperly chosen system standard level or improperly adjusted levels. For example, if +8 dB is chosen, make sure all VU meter pads are set to indicate 0 VU at this level. If they're set wrong, levels can be higher than indicated.

Check for headroom after the levels have been set up. Feed the signal generator at 10 dB higher to the system. Measure distortion first at the standard level, and then at the 10 dB higher level. If distortion increases at the higher level, then headroom is not adequate and the program peaks will be distorted. It will be necessary to choose a lower standard system level. In this case, perhaps 0 dB should be used as a standard system level.

DISTORTION

The signal going into a system should come out the other end unaltered in any way, except for an overall increase or decrease in signal amplitudes across the pass band. Whenever the signal is altered in some way, it is distorted. In practice, however, there may be many deliberate, controlled alterations of the signal. Although in a strict sense these are distortions, they are not necessarily bad. We don't usually think of these controlled alterations in terms of distortion, but those which are uncontrolled and detract from the signal are considered distortions. They fall into four categories: phase, frequency, amplitude, and intermodulation distortions. Whenever any one of these forms is present, other forms can also be present.

Phase Distortion

This type of distortion occurs when all signals in the pass band do not pass through the system in an equal time reference. That is, some frequencies may lead or lag other frequencies. Faulty components and stage overload can cause shifts in the phase. Small amounts of phase shift may not be detectable in a monaural system nor give any real problems.

FM stereo is a two-channel system that relies on the matrix action in the stereo generator and in the receiver for proper operation. Phase is very important, and varying amounts of incorrect phasing will cause deterioration of channel separation. Out-of-phase (180°) signals cause channel reversal and cancellation in a recovered monaural signal (Fig. 4-8). Each channel should be identical in the stereo system, and the patch length of each should be electrically the same.

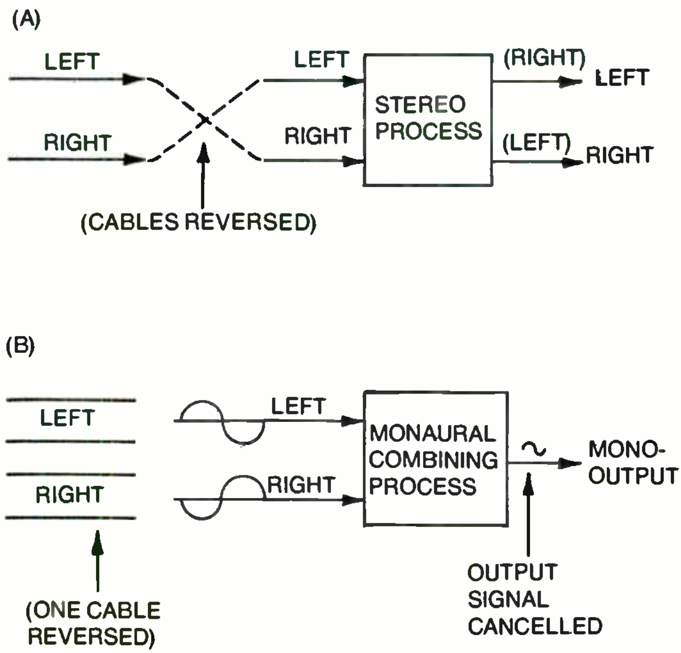


Fig. 4-8. When 180-degree phase shift occurs: In A, the cables in the stereo system are actually reversed, which interchanges left and right channels. In B, when one of the stereo cables is reversed and stereo is fed into a mixing process to produce a monaural signal, the out-of-phase signals cancel.

Both of these phasing problems can be caused in the installation as well as the operation. Path length problems often develop when telephone company lines are used for the connecting link to the transmitter. Both of these lines are equalized, and this in itself can cause phase shifts. The physical length of the individual line may vary considerably.

There are other forms of phasing problems, and from different sources, although we may think of these in terms of *feedback*. That is, output signals get back into the input stages in various ways, such as circuit capacitance, wiring capacitance between cables, input/output connectors too close together, or connections close together in jack fields, terminal blocks or elsewhere. If the output signals are in a phase direction to increase signal amplitude, this is *positive* feedback; and if they're in a direction to reduce or cancel amplitude, this is *negative* feedback. In positive feedback, oscillations can occur. However, if the feedback is not quite enough to cause the circuit to go into oscillation, circuit gain near certain frequencies can rapidly increase (Fig. 4-9). This is similar to the condition used in the superregenerative receiver. The *Q* of the circuit near the resonant frequency, however, may not be high enough, so the resonant curve will

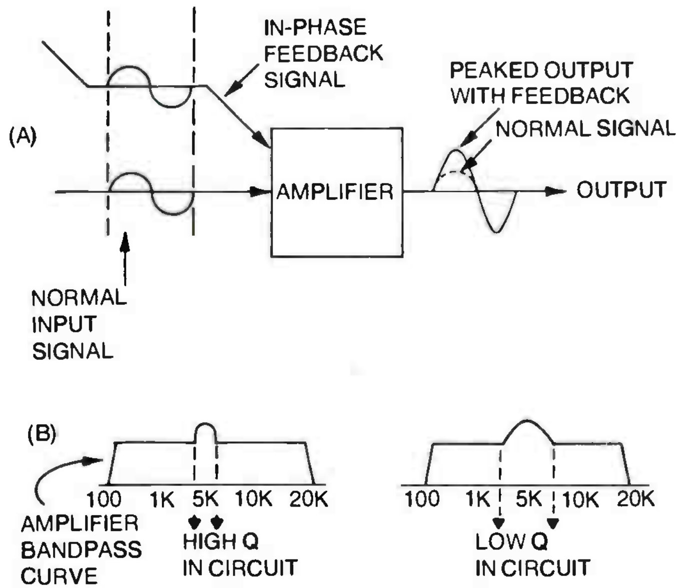


Fig. 4-9. (A) Positive feedback can create a signal boost or oscillation. (B) How wide the affected frequency area of the bandpass depends upon the Q of the audio circuits involved.

be broad. Only a few frequencies are affected, and this creates a peaking effect. In negative feedback, there is an opposite effect. That is, there is a cancellation of a few frequencies, or a notch effect. What actually occurs in each case will depend upon circuit conditions and the nature of the feedback signal itself.

RFI

Another source of feedback can occur when RF interference (RFI) is present from the transmitter being modulated with the *same* audio signal. The RF signal is picked up and demodulated by circuit components, and the resulting audio fed into the offending stage. The same conditions can exist as were discussed for regular audio feedback. But there can also be another type situation. In this case, there may be considerable delay (Fig. 4-10). The resulting signal then has an echo effect, and the greater this delay, the worse the effect. This is similar to the effect of the input/output signals from a tape recorder being fed into two open channels on the console.

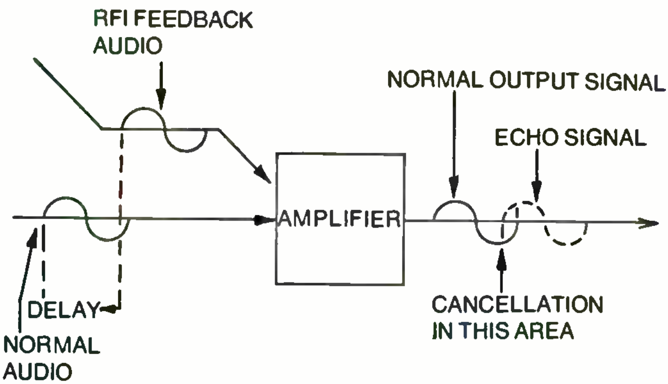


Fig. 4-10. RF feedback to the audio that is delayed can cause an echo effect.

Strong RF signals can be rectified by circuit components or the transistor itself. This can be converted to DC voltages by circuit elements filtering the rectified RF. This voltage may then be applied to a stage's bias, for example, and thus shift its operating mode into a distortion zone. The stage may be able to handle most of this, or the pickup may not be strong enough; but the shift can be to the point that the signal is being clipped on the peaks. This has its own peculiar sound in the audio, that of a severely overloaded stage.

Whether from shifting operating points or a strong audio input signal, the positive or negative peaks, or both, may drive a stage into saturation. This means outright clipping of the signal. There will be distortion because the output is not a perfect reproduction of the input, and a clipped signal will be very rich in harmonic content.

Frequency Distortion

This type of distortion occurs when all the audio signal frequencies are not amplified equally across the pass band. In other words, the response curve of the pass band is poor. This frequency discrimination can occur in any part of the pass band (Fig. 4-11). For example, if the discrimination occurs at high frequencies, there will be a rolloff or cutoff of the

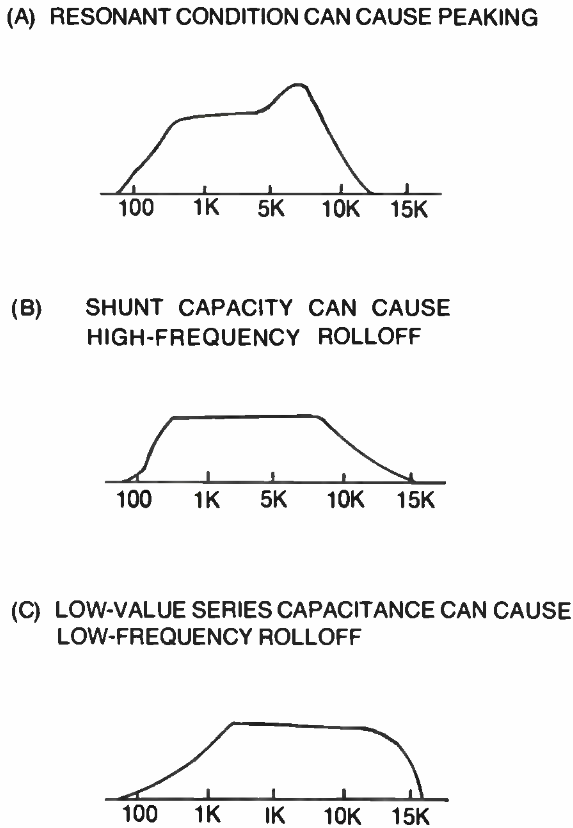


Fig. 4-11. Different ways frequency distortion can occur in the pass band of the unit or system.

response curve at the high end. And when it occurs at the low frequencies, the low end of the respone curve suffers in the same manner. If there is a sharp rise of a few frequencies at any place in the pass band, this is described as peaking or boost, and the opposite of this is a notch or cut. Naturally, equalizers do all of these things to a response curve; that is their purpose. It becomes distortion when the amplifier or circuit does it all by itself.

Reactance

Two factors which cause frequency distortion are the capacitance and inductance of circuits or components. Both of these have a reactive value that is frequency dependent. Perhaps the capacitive reactance is the biggest offender in audio.

Series capacitance will affect low-frequency audio. This is because the reactance increases at lower frequencies. For example, a large-value coupling capacitor with a several-microfarad value dries up or opens up, so that its effective value is now only a few picofarads. Only a few of the higher audio frequencies will get through, and none of the lows. This is, in effect, a differentiator circuit. The actual effect, of course, depends upon the actual values present.

High-frequency rolloff is usually caused by capacitance across a circuit. That is, the reactive element is parallel to the load. When the capacitance goes to ground, this is usually considered a bypass. Since the reactance of a capacitor becomes less as the frequency goes higher, the capacitor will provide a low-resistance path for the high frequencies; and if the values are such as to produce a very low-resistance path, it will short out the highs. One source of the problem is capacitance across the audio cable. This is also one of the reasons for low-impedance circuits, since this reactive path is parallel with the impedance.

Impedance Matching

Mismatching of impedances can also cause the frequency response to be affected. The mismatch will present a different impedance value to different frequencies. And unless the voltage developed across the impedance is the same for all frequencies, there is frequency distortion. A source of the problem can be the T-pad on a balanced circuit. The pad is intended for unbalanced circuits but is often used on balanced circuits because it is less expensive than an H-pad. (Here we are talking about the variable type used as a gain control.)

This pad will work all right, so long as it is kept in midrange. Toward the extreme sides, there can be serious response problems.

Defective Components

When circuit components become defective, they can change their characteristics drastically. These changes contribute to many distortion problems. Something may, for example, move a stage into a position of near oscillation. This could create a peaking condition in the audio. The same type of conditions that are caused by feedback can occur when components become defective.

Amplitude Distortion

One of the more common forms of distortion is amplitude distortion. This is usually caused by misadjustment or misoperation of the system. Whenever some stage does not amplify the audio signal in a linear fashion, the output is distorted, and there are usually second- and third-harmonic components present. Amplitude distortion is often called harmonic distortion.

Aside from simply overloading amplifiers by not adjusting gain as needed, there can be several other factors which can cause this type of distortion (Fig. 4-12). A stage's operating parameters may shift when components fail or change value. For example, a voltage-dropping resistor in series with the power load may go down in value, thus allowing more voltage to the stage than design permits.

Temperature Effects

Solid-state units are sensitive to temperature changes. Temperature effects can cause a transistor to shift to a different operating mode, and this can cause distortion. It is important that heatsinks be kept clear of air obstructions and that they are in place. It is easy to forget to replace one when changing a transistor. Another cause of heat buildup is the small ventilating fans often used and their filters. Filters can become clogged and shut off the air circulation of a unit, or the small motor can fail.

Push-Pull Stages

Stages in push-pull operation must be kept balanced or the output signal will be nonlinear. This is due to the nature of the

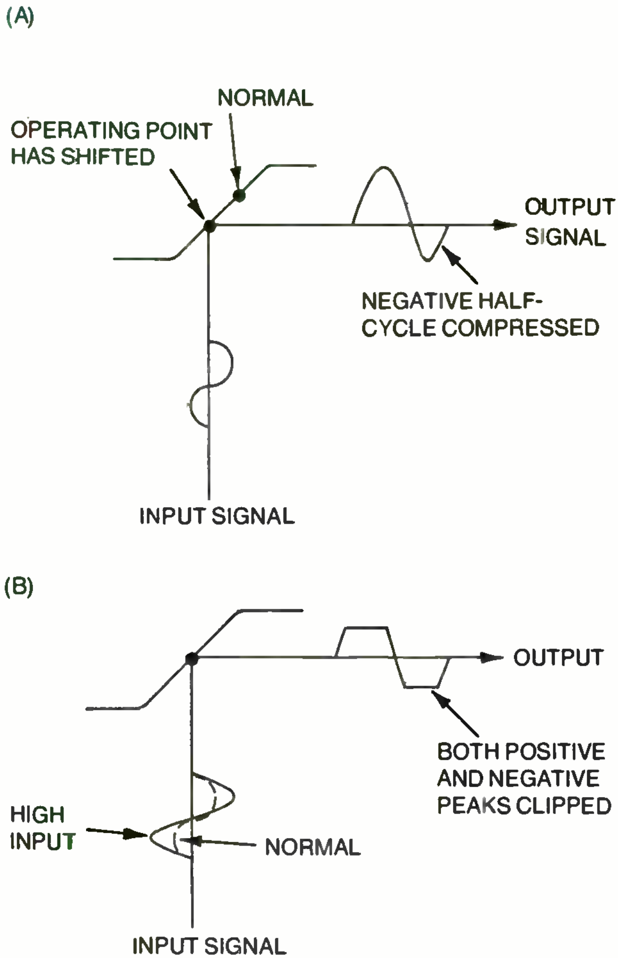


Fig. 4-12. Two ways amplitude distortion can occur: In A, stage operating point has changed on its input-output curve, causing output to be nonlinear. In B, input signal is too high, causing stage to be driven into clipping.

stage operation, as one side of the stage amplifies only one half of the cycle, the other half cycle being amplified by the opposite side of the stage. Both of the amplified halves of the signal are reunited in the output of the stage. Should components fail or change value, that would cause the two sides of the stage to unbalance and the output waveform to be distorted (Fig. 4-13). For example, both sides of a push-pull stage normally operate as a class B stage, but the bias on one

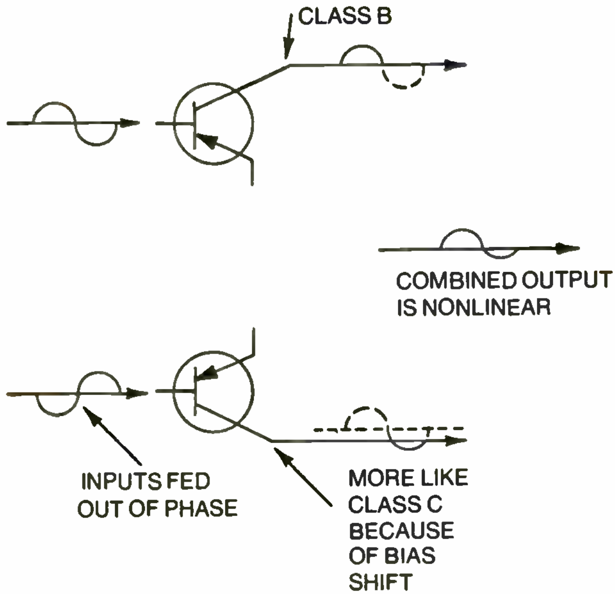


Fig. 4-13. Class B push-pull stages must be kept balanced. If bias should shift one half of the push-pull circuit so that one stage acts more like Class C, the combined output will be nonlinear.

side has increased so that side begins to act more like class C than B. The output waveform from this side is less than the other side, so the combined waveform is nonsymmetrical and distorted. Many complex waveforms are nonsymmetrical. That is, the positive side may be higher in amplitude than the negative, or the reverse of this. The human voice often generates such waveforms, and since these are natural, they are not considered distorted. The amplifier should reproduce them the same way they are received. Of course, shaping circuits may be used to make these waveforms symmetrical. At any rate, as long as the stage is faithfully amplifying what is at its input (even a distorted signal), that stage is not causing distortion.

Intermodulating Distortion

Whenever a stage is operated in a nonlinear manner or clips the signal *and* there are two or more signals present of different amplitude, intermodulation distortion will occur. A single tone passing through an amplifier and driving the stage into severe clipping will result in a very distorted output signal, but there will be no intermodulation distortion present. The conditions are right, but there can't be intermodulation distortion without a second signal present. When the conditions are such that distortion can occur, and the second signal is added, one signal will modulate the other. Note that this is a modulation process, and not simply a mixing process (Fig. 4-14). Signals can be mixed without modulation taking place; in fact, this is what the program material is—many mixed

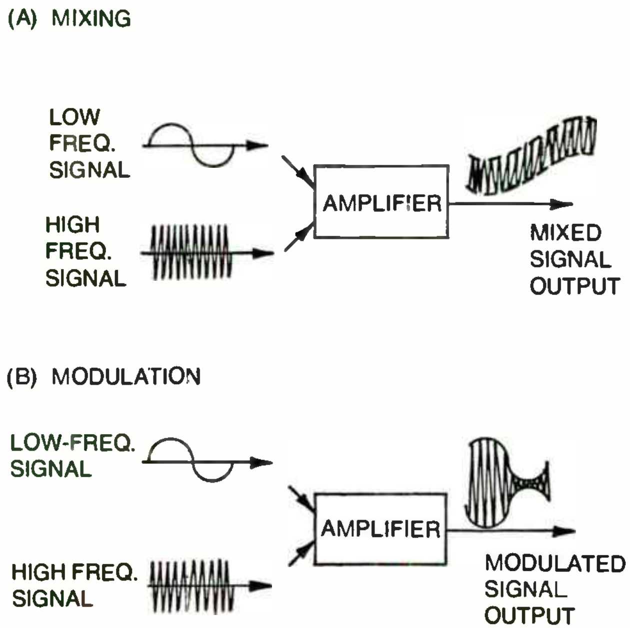


Fig. 4-14. Intermodulation distortion is a modulation process—not mixing.

sounds, all blended together. When a stage operates in a nonlinear fashion, however, and especially if clipping is taking place, then modulation will take place. This is similar to the process which takes place in the first detector or mixer stage of a superheterodyne receiver. The same results are obtained: Both original signals are present, plus sum and difference frequencies of both, and many harmonics are present. But the program signal has many different frequencies present at the same time. Many of these can be modulating each other and producing all the results, and all the additional harmonics are also tossed into the stew. The harmonics will be outside the system pass band, but the sum and difference frequencies will be in the pass band. They can't be removed. The sound of this defect on the air will depend upon the degree of distortion taking place. Small amounts may go unnoticed, but they tend to "muddy" the signal, or dull its clarity and brilliance.

Stereo Signal

Stereo signals that have been recorded with narrowly restricted bandwidth in the original material may be accompanied by high-frequency noise or other unfiltered signals. When this is fed through a limiter that also clips the peaks above a preemphasis curve, unexpected results can occur. Severe popping and cracking sounds can be heard in a monitor speaker causing the modulation meters to intermittently peg. In one situation where this occurred, news people had done some interviews with a small cassette recorder, dubbed this to a regular monaural cartridge, and then dubbed the monaural cartridge to a stereo cartridge. All of this dubbing certainly didn't enhance the quality of the signal, but on top of this, there was a very high-frequency hiss (probably tape hiss) in the background. Although barely audible, it did have a high amplitude, which kept the limiter continuously in a clipping condition. The pops on the air monitor speakers were not gentle pops, but more like the crack of a bullwhip.

GENERAL CAUSES OF DISTORTION

It is important to remember that the master system of the station must work as one unit, and no part of the system should contribute an inordinate share of the total distortion. Besides audio amplifiers, other parts of the system can contribute to distortion. Faulty components in a unit may cause distortion, as can power supplies, equalizers, signal processors, transmitter modulators, and RF tuned circuits that are of insufficient bandwidth. In sections of the book where individual units or parts of the system are covered, distortion possibilities with the unit and its operation will be brought out. For now, only a few of these general aspects are discussed.

Power Supplies

A power supply sets the operational parameters of all the stages in a single unit or units that it supplies. These may be regular or bipolar supplies, regulated or nonregulated. Even the regulated supplies can drift and need to be measured and adjusted from time to time. Most regulated power supplies today are solid-state units themselves, and the regulators are large power transistors or ICs. Temperature changes can affect these regulators just as much as they can affect signal transistors in the amplifier stages, and will cause the output voltages to drift or the supply to go out of regulation.

A power supply may have several different output voltages that are derived through resistor networks. Some fault in the load can cause higher than normal current through the current-limiting and dropping resistors for a given tap (Fig. 4-15). Two things can happen: The higher current will cause a greater voltage drop, so the bus voltage will be lower than normal. Second, the higher current may exceed the power rating of the resistor changing its value and eventually opening it up. During this time (which may be several days or weeks) that voltage bus is low. Consequently, other units or stages relying on the voltage bus to set their operating parameters will shift operation. This new mode of operation can be susceptible to overloads or other forms of distortion. With the stage operating with lowered voltages, even *normal* input signals may now be too high and cause it to overload.

Jacks

Either loose connections or dirty jacks can cause a form of distortion that is difficult to find. The difficulty in finding the culprit comes from our natural tendency to suspect an operating unit rather than a passive unit. As heard on a monitor speaker, this form of distortion sounds as though peak clipping were taking place in an amplifier. There can also be a loss of low frequencies because of the low value of capacitance that couples the signal across the contact.

In jacks, the "normal" contacts are usually at fault. The springs may not have enough tension, and oxidation may build up on the contacts, forming a high-resistance path for the signal (Fig. 4-16). The same situation can occur on a loose connection at a terminal board or any spot on a printed circuit board that didn't get soldered. When wiring up a new station or new jack field, there are many, many connections to be made. It is easy to overlook soldering one or two of these. In all cases, the oxidation will be resistive and will discriminate against all

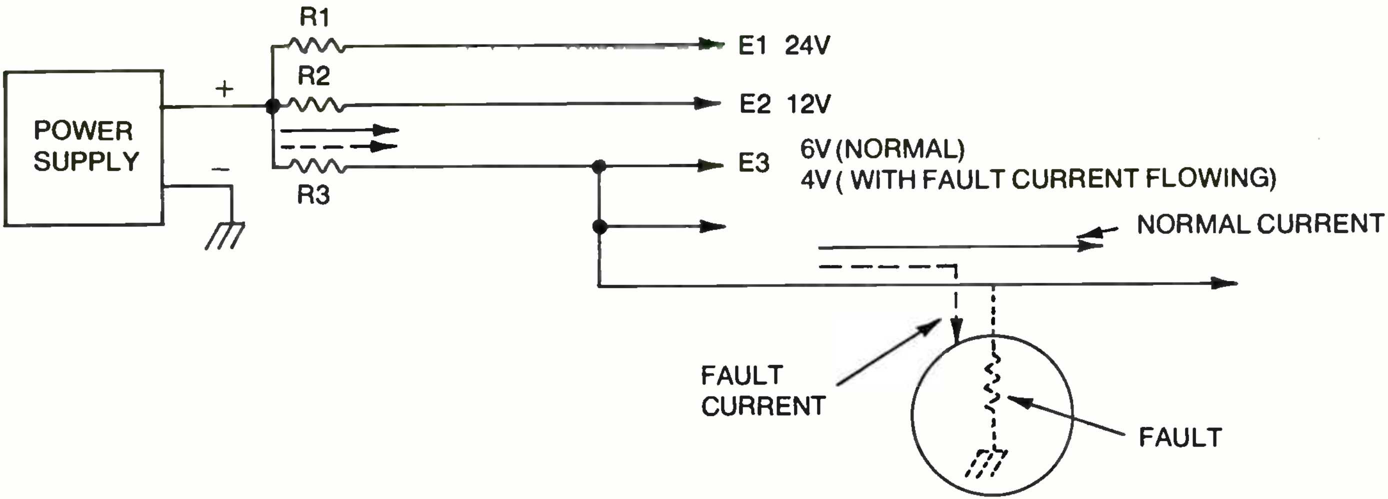


Fig. 4-15. Fault in circuit can increase current through R3, causing a higher voltage drop and lowering voltage bus E3. All circuits fed by E3 will be affected.

frequencies; and when the resistive value gets high enough, it becomes an open circuit to the signal. But the two conducting surfaces separated by a thin insulator will form a small capacitor. And only the very high audio frequencies get through.

Transistor Stage Design

Design problems are not ordinarily a problem for the engineer in the field, unless he is building his own circuits or remodeling other circuits. But a little knowledge of some of the factors important in circuit design are helpful. That is, the engineer can be on the lookout for those things which are important to the design and most likely upset stage operation when components change. And this is usually what causes distortion—a small shift in stage parameters.

Distortion is one of those subjective qualities about a signal. The hearer may not understand or recognize that he is hearing distortion, but instead, the distortion may be sensed or felt. (Serious amounts of distortion are something else and will require immediate correction.) Thus, a stage parameter may drift, resulting in a small increase in distortion, perhaps 1%.

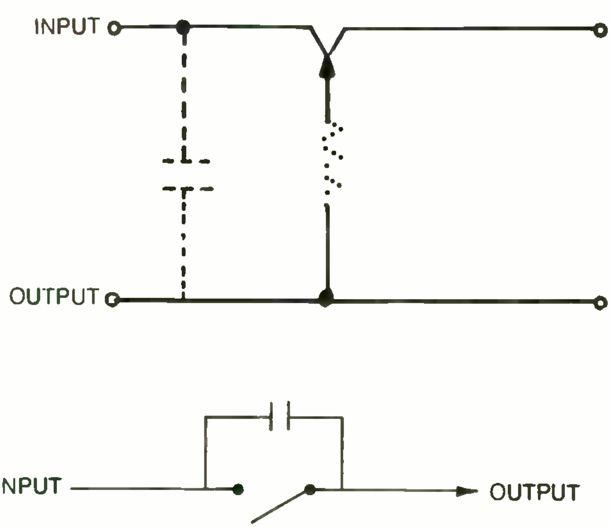


Fig. 4-16. Oxidation on jack "normal" contacts can create high series resistance and form a small capacitor. This is equivalent to an open circuit with a small capacitor across it. Only the very high audio frequencies will get through.

This additional 1% will add to the system's total distortion, and this may push the system out of FCC tolerances, even though that 1% would not be discernible by itself.

A transistor stage has two sets of conditions: DC, AC. The resistors around the stage and the DC power supplies set the DC parameters. In a sense, these values are noncritical. They are selected so that the transistor stage will operate within the range of the transistor itself and the stage gain desired. What is important about the resistors is that the *ratios* of these resistance values remain the same. All of these values can change a long way, just so long as they all change in the same direction and the ratio remains constant.

The change, however, must not move the operation out of the transistor's range. Under these conditions, there will be a change in the impedance and gain of the stage, and this could cause distortion in a following stage if the gain goes too high. What is important, from a distortion-and-troubleshooting viewpoint, is that *one* of the resistor values may have changed radically in a stage. This would definitely upset the stage parameters, perhaps its bias. So when troubleshooting resistor values around a stage, do not be concerned if all resistor values are off 10% or 20%, as long as they are all off in the same direction, either low or high. If one resistor has changed by 50% to 75% of its stated value, it should be replaced. The replacement should be as near the stated value as possible (assuming the other resistors are so). Thus, if the circuit calls for a 1000-ohm resistor and the closest value in the parts box measures 950-ohms, add a 50-ohm resistor in series with it to make 1000-ohms. The combination may not look as nice as a single resistor, but the stage will work as it should.

The DC operating mode is the *static* mode of the stage. The other mode is the AC, or *dynamic* mode. Control of the AC characteristics is just as important as the DC characteristics. The capacitor values around the stage are important, for if they change value, the AC characteristic will change, and on a frequency-dependent basis. Impedance and the AC gain will also change, and distortion may result. When a capacitor must be replaced, the replacement should be as near the stated value as possible. That is, the handiest value in the parts cabinet should not be used, simply on the theory that there ought to be *some* capacitance in the stage at this point and any value will do. If the correct value is not available, add capacitors in parallel to get more capacitance, or in series to reduce the value or get a higher voltage rating.

Equalizers

The excessive use of equalizers in a system can often lead to distortion. There may be too much boost to certain frequencies, which can overload following stages. There is no problem in this regard if the frequencies are lacking in the original signal (there could be noise problems) and the boost is required to bring the response back to normal. But when the original signal is not lacking in these frequencies, and the boost is done for effect, the boosted frequencies can overdrive other stages following the equalizer and create distortion.

IMPEDANCE MATCHING

A variety of equipment can be interfaced electrically and the most efficient transfer of signal power from one unit to the other is obtained through impedance matching. Impedances have been standardized in the broadcast industry.

Impedance is a term for an electrical value containing both resistance and reactance and is expressed in ohms. The amplitudes of signal levels in and out of an amplifier are directly related to the impedance value. To obtain the most efficient transfer of power from one circuit to another, impedances should be matched, and this match must hold across the pass band.

Impedance Mismatch

Mismatching always results in some penalties in terms of poor system levels, amplitude and phase distortion, and poor response curves across the pass band.

How severe the penalties will be depends upon the degree of mismatch and how critical the application. A source and its load should be matched. The source is called the *driving impedance*. This is the output impedance of the amplifier feeding a bus or other load. The input of the next stage, at the receiving end of the bus, is called the *load impedance*. The following are a few examples of how mismatching can become an operational problem.

When the load impedance is mismatched towards the low side of what it should be, the signal amplitude across the lower impedance will also be lower. To overcome this lower level, the operator may increase the driving-amplifier gain. This will cause the driving amplifier to work harder than normal. But the increased gain may affect the headroom designed into the amplifier so that it has all but disappeared, and clipping may take place, causing distortion. At the same time, the output stage of the driving amplifier is also working harder to deliver more signal current. This increase may be more than its design permits. This could damage the output transistor, or it may drive the stage into distortion.

When the *input impedance* of an amplifier is low in relation to the driving-amplifier impedance, a mismatch again occurs. (This is the same situation as in the previous example, except now we are discussing the other amplifier.) The mismatched impedance will provide low input voltages to the amplifier. And with a low input signal, the operator may increase the gain setting of this amplifier to make up for the signal loss. Now, however, the signal-to-noise ratio will suffer. At the same time, an amplifier running at high gain is susceptible to interference signals, especially RFI.

Reactive Components

If the reactive components of the driving and load impedances are not properly compensated (as during a mismatch situation), there are frequency-related effects. The type of frequency-related effects depends upon the type of reactance and how much is present. If there is a resonant condition, peaking of one or more frequencies will occur. Should there be shunt capacitive reactance, a high-frequency rolloff will occur. A typical example is a long cable run terminated in a high impedance rather than a normal low impedance. The capacitive reactance will be in parallel with this load impedance and the response curve will show high frequency rolloff (Fig. 4-17).

The Ideal and the Practical

Most theory and calculations are based on ideal conditions, but practice often falls somewhat short of the ideal. There are many cases where a mismatch does occur, and the theoretical penalties also occur; but in any particular situation they may have no real effect and may go unnoticed. Although mismatch will occur in some situations, how much penalty can be tolerated will depend upon the particular case. For

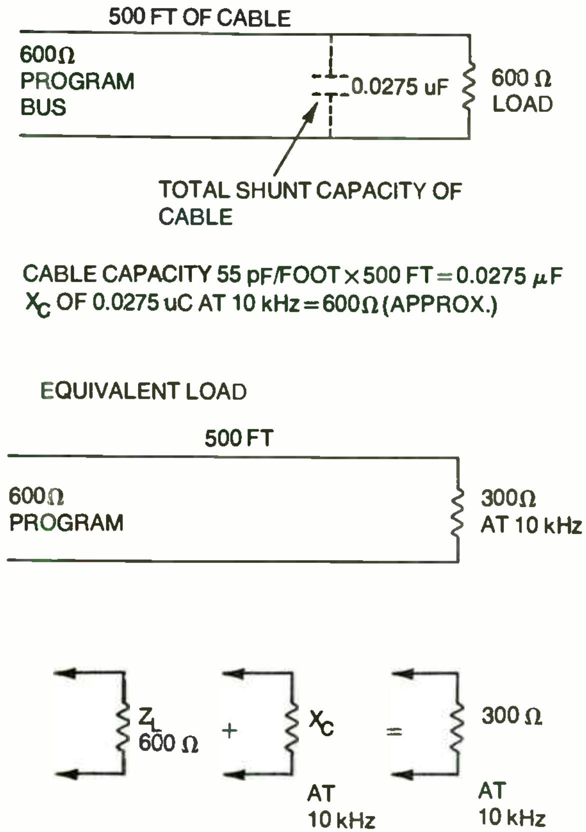


Fig. 4-17. Cable capacitance will shunt the high-frequency response. In the example, even a properly terminated cable will have a rolloff at the upper frequencies when the cable is very long.

example, a schedule E telephone company remote line has a very poor response curve. Even a loaded line has a pass band of approximately 200 Hz to 3 kHz. Now when the system receives a program over such a line, but mismatch occurred in the patchup that caused the audio to roll off above 10 kHz, the effect would be unnoticeable, since there isn't any signal frequencies left in this range after passing through the line. As a matter of good engineering practice, it is well to strive for the ideal, but also realize that there may be situations in which the ideal is not achieved, yet the results are acceptable.

Typical Cases

A usual situation where impedance mismatching can affect system levels is the overloading of a signal bus by too many circuits, so that the net load on the driving amplifier becomes a very low impedance. This can be a case of disregarding the impedance factor in the first place, or forgetting that all impedances in parallel compute the same as resistances in parallel. For example, a 600-ohm program bus is normally terminated at the end of the run by a 600-ohm load (Fig. 4-18). But at several places earphone outlets are tapped into the bus. Plugging in an earphone with a 2000-ohm

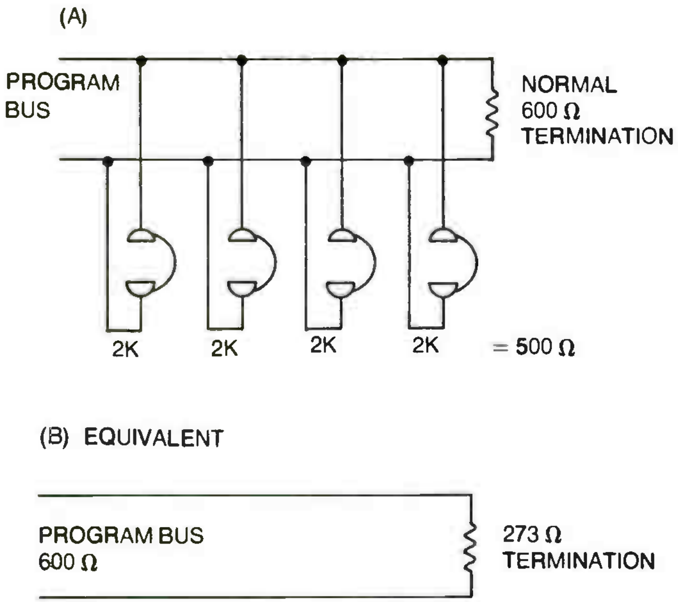


Fig. 4-18. Impedances in parallel figure the same as resistors. Here, the four earphones will cause double loading of the bus.

impedance will have little effect on the bus signal levels, but suppose during some special program there is an earphone plugged into four of these locations. Four 2K impedances in parallel represent an equivalent impedance of 500 ohms across the bus. Since the bus is already terminated in its normal 600-ohm load, the circuit is, in effect, double terminated. This will drop the bus level by 3 dB at least.

PADS AND TRANSFORMERS

Matching impedances and controlling signal levels throughout the system are usually done through the use of resistive pads and transformers. Transformers also provide circuit isolation, since there is no direct connection between the two circuits except through the magnetic fields of the transformer and its windings.

Most broadcast equipment is designed with standard input and output impedances. For high-level program units, this value is 600 ohms. Although designed for this standard impedance, the amplifier does not necessarily have a transformer on either end of it. Specification sheets are not always specific in this matter, but some sheets state that the amplifier is to have input and output transformers. The better amplifiers will have transformers, both for isolation and impedance matching.

Transformers

Isolation transformers have the same impedance on the primary and secondary. These are 1:1 transformers (Fig. 4-19A). They are not designed for matching, but solely for isolation. An isolation transformer can be a big help if wired to jacks on a patch panel. Whenever two incompatible circuits, such as a balanced and unbalanced one, must be patched together, inserting the isolation transformer between the two will make the circuit work without upsetting either. Many a hum problem can be corrected by the insertion of an isolation transformer.

Matching transformers (Fig. 4-19B) are similar to isolation transformers, except they have more than one winding on both the primary and secondary, or the primary and secondary may be tapped. Those with separate windings are usually strapped in series or parallel on the primary or secondary to obtain the desired impedance. Of course, there are many matching transformers that have a variety of taps available, but here we are discussing the usual type used for matching the standard impedances in the broadcast system. This same transformer can also be used as a 1:1 isolation transformer.

A *bridging* transformer (Fig. 4-19C) is often used in the broadcast system. The input of this transformer is a high impedance, while the output is a standard impedance. Some of

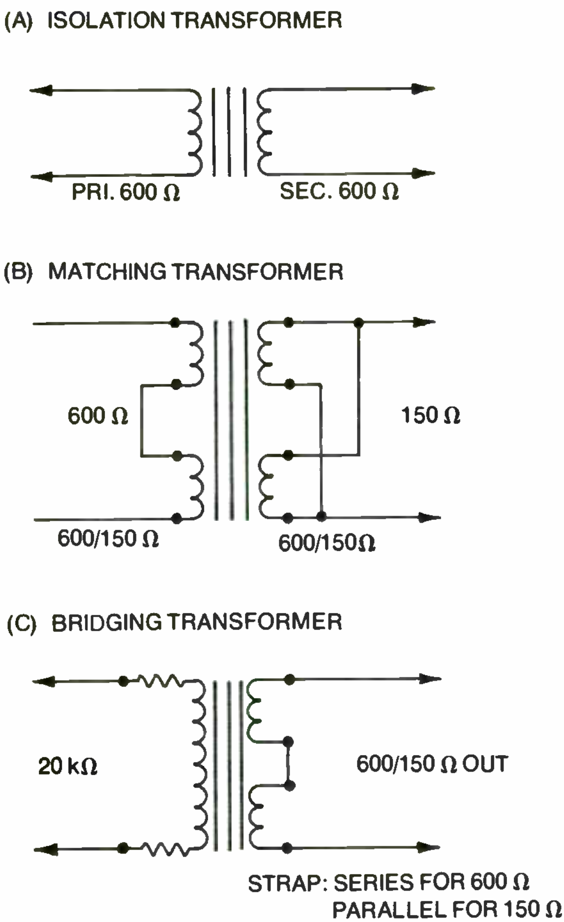


Fig. 4-19. Useful transformers for audio. Windings are strapped in series or parallel to get the desired impedance.

these have series resistors built into them and enclosed inside the case. The input side of this bridging transformer is 20K and the secondary is 600 ohms. When this transformer is used to bridge a circuit, there will be a 20 dB loss across the transformer, so the following circuit must be able to make up this loss. Often, however, the lower signal level is what is desired.

Resistor Pads

Pads used around the station are mainly of two types, bridging and matching. There is also the loss pad, which is often used. Resistors are always loss devices; even the minimum-loss matching pads have an insertion loss. So, whenever a resistor pad is to be used for matching, always consider this insertion loss and its effect on the system. There are many styles of precision commercial pads available in either balanced or unbalanced types.

Homemade Pads

For many situations around the station, homemade pads may be used successfully. They don't look as nice as the commercial models and aren't as precise in either loss value or the impedance. The lack of precision is because the exact value of resistors calculated will not be available in standard resistor values. Besides that, the standard values may be 10% or 20% of the stated value.

Building a Pad

When building a pad, consider whether the circuit is balanced or unbalanced. The input/output resistances of the pad will be the same in either case. However, if the circuit is balanced, the input resistance will be divided equally into two parts, that is, half on each side of the circuit (Fig. 4-20). The

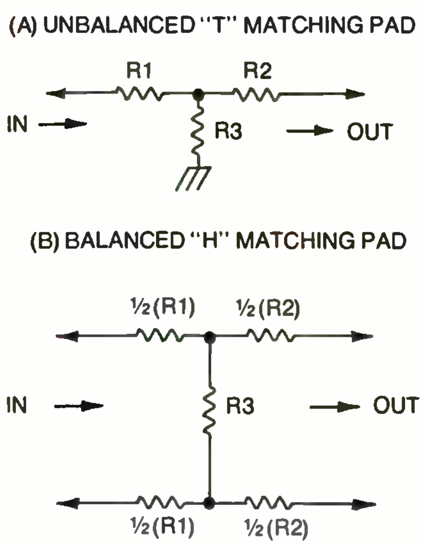


Fig. 4-20. To make a balanced pad from a T-pad calculated resistor values, divide R1 and R2 in half for each side of the circuit (R3 remains the same).

output resistance will be divided the same way. For example, suppose calculations show that the input resistance must be 100 ohms. If this is to be used on a balanced circuit, use a 50-ohm resistor on each of the input legs of the pad. In effect, this is converting a T-pad to an H-pad.

Don't accept the indicated resistor values on the resistors, that is, the markings. Actually measure each resistor for its true value and then select resistors which are as close as possible to the calculated values. Even though values found will not be exactly the calculated values, select *identical* values for each side of a balanced pad.

Once the pad has been constructed, make a test setup and actually measure the loss of the pad. This can be done by connecting a signal generator to the input side of the pad and measuring the level of the signal at the output of the pad (Fig. 4-21). Make sure the generator is driving with the correct impedance and that the pad is terminated with the correct

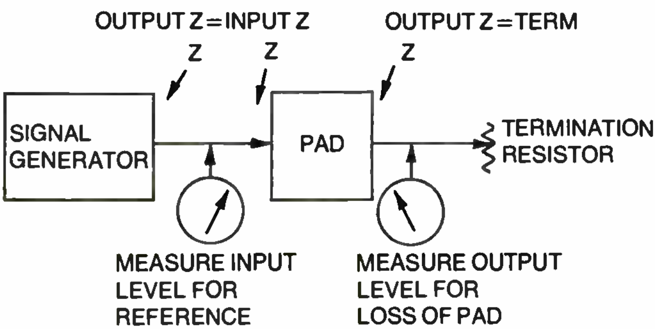


Fig. 4-21. Test setup to measure loss value of homemade pad.

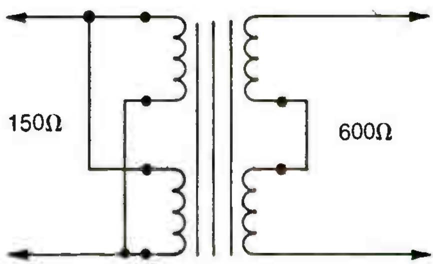
impedance. Unless the generator has a calibrated output meter/pad arrangement, the signal into the homemade pad must also be measured so that you have a reference. If the pad is removed to measure the output of the generator, make sure the generator is properly terminated. With this arrangement, the loss of the pad can easily be determined.

Because the standard resistance values didn't come too close to the calculated values, the loss of the pad will be off a few decibels from the calculated value, but it will work satisfactorily in most cases. However, when circuit values are critical, use the precision commercial pad.

Transformer Strapping

When different windings must be strapped in various manners to obtain the desired impedance of the input or output of the transformer, the values don't figure out in such a straightforward manner as with resistors. This is because of the construction of the transformer; whether the windings are separate or tapped, the turns ratio of primary to secondary, and the magnetic flux lines that affect all the windings. Thus if two windings on the primary are tied in series to obtain 600 ohms, when tied in parallel the result will be 150 ohms, and not 300 ohms (Fig. 4-22). But if two *separate* transformers have

(A)



(B)

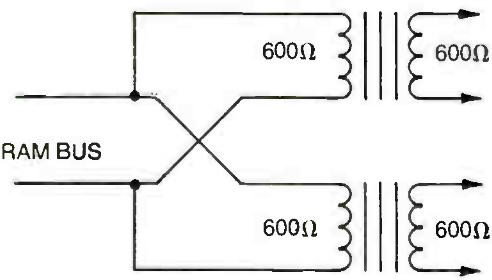


Fig. 4-22. When windings on a transformer are strapped in parallel, they usually provide one-fourth the impedance value of the series strapping. When two separate transformers are strapped in parallel, the impedance is halved.

the primaries tied in parallel, the two 600-ohm primaries will result in 300 ohms net impedance. With two separate transformers, the flux lines do not connect the windings of the transformers. Actually, this is what happens when two amplifiers with 600-ohm input impedances are placed across a 600-ohm bus; the resulting load is 300 ohms. It is the same situation when the inputs of the left and right audio channels are strapped together for test purposes in stereo. The resulting load on the signal generator is 300 ohms.

Making a Bridge

As mentioned earlier, bridging transformers are available. These usually have resistors built into the case and wired to the input winding to provide 20K input impedance.

A homemade variety can be created with a couple of resistors and an isolation or matching transformer. (This also has the advantage of converting back to a matching arrangement when bridging is no longer desired.) Simply insert a 5K resistor in each leg of the input of a 600-ohm transformer. This will provide a 20K bridging impedance and the loss across the transformer/resistor combination will be approximately 20 dB.

Ohm's Law

For operational purposes, impedances can be treated as if they were resistances. For practical purposes, this will be accurate enough, as long as the presence of the reactive component is recognized. Whenever several outlets are tapped off a circuit, remember to calculate the total value of impedance placed across the circuit (as was done with the earphones in an earlier example). There is often a tendency not to consider the values when the taps are bridging. Usually this is all right, as long as the standard 20K bridging units are in use. In that case, it would take approximately 33 of these units across a circuit to represent a 600-ohm load. This is not a likely situation. But when making use of homemade varieties, the resistor values are not always as high as the standard values of a bridge. In some cases, the circuit following the bridge cannot tolerate the 20 dB signal loss, so a smaller bridging value is used. Actually, such a bridge can be made with as little as 2K, and the effect on the bus will be less than 1 dB drop in the bus level. But care must be taken not to add any more such bridges to that bus. This 2K load is about the same as for a pair of headphones.

RF INTERFERENCE

There has always been a problem of RF signals getting into the audio system, but the problem in the past was not as severe as it is today. Tube-type equipment is not as susceptible to this type interference, and FM causes more trouble than AM. With certain precautions in wiring and a few corrective tactics, the problem could once be solved easily. But this is not the case today. In recent years, the industry has converted to solid-state audio equipment. And there has been a sharp increase in the number of stations operating, not only in broadcasting, but in all other services. So now a station must not only be concerned with RF signals of its own, but must also be on the lookout for a variety of other transmitters that may be nearby. In many cases, several stations share space on the same tower for FM, TV, two-way communications, etc., as well as AM. Interference, however, comes from very strong signals nearby, and not the usual clutter of signals that are picked up when tuning across a receiver band.

There are many ways that RF signals can get inside an amplifier. This can be direct radiation to an open chassis, carried on signal lines, shields, DC control circuits, and AC power circuits. Once the signal enters the amplifier, the basic reaction takes place at one or more transistors, and the results are amplified.

When a strong RF signal is presented at its terminals, a transistor can act as a diode and demodulate the signal through rectification. This is easily understandable, since the transistor is essentially two diodes back-to-back in the same case, sharing a common base. The most sensitive part is the base-to-emitter diode, and when detection takes place here, the results are amplified by the same transistor. In other situations, the bias shifts so that the stage acts like a class B detector; or slope detection may take place on an FM signal.

Detection of the RF signal's audio is not the only way RF can be a problem. Situations can exist where only rectification of the RF is taking place, but the audio is not recovered or is filtered out, and only a DC voltage remains. This DC voltage can shift the stage parameters so that the stage operates in a distorted manner. This is the same as operating the stage with improper adjustments. Although no audio is recovered from the RF signal, hum or other noise on the carrier may be added to the audio signal. The engineer troubleshooting the problem may be led down false trails attempting to find other circuit defects.

Another false trail can occur when the RF is demodulated and fed back into the audio. This is the same audio that is modulating the transmitter. If it is coming from another transmitter, this injected RF audio will appear as crosstalk. When it comes from the transmitter being modulated and the delay isn't so great as to create an echo, the audio heard from speakers may sound as if a stage is being overdriven slightly and is distorting on the peaks.

General Remedies

There are no surefire solutions to RFI, but there are a number of defensive measures that can be taken to reduce the possibilities of problems. Always keep in mind that the RF signal doesn't need wiring to enter a unit. An RF signal has both a magnetic and electrostatic field around it. A circuit carrying RF energy—whether this is a sampling-loop coaxial cable, open-wire transmission line, or even the terminal-type coaxial line end connectors—can radiate a signal.

When the transmitter is located adjacent to the audio equipment, there can be direct radiation from the cabinet of the transmitter unless it is kept tight. The actual amount of radiation from the cabinet must be kept very low so the transmitter will meet FCC type approval requirements. But this is for its manufacture. When it is in operation at the site, care must be taken that all the antiradiation devices built into the transmitter remain functioning. As a transmitter design engineer once told me during a discussion of this problem, the FCC type acceptance measurements are those of the electrostatic field only, although a transmitter cabinet may have a strong magnetic field radiated from it. And it is this magnetic field which is the biggest offender in RFI problems in the station.

Aside from the transmitter itself and the transmission line, there is, of course, the antenna. The very purpose of the antenna is to radiate a signal. Adjacent to an antenna there are very strong RF fields. The FM antenna that is only horizontally polarized provides less problems when the studios are located near it than does the same antenna with vertical polarization added. With vertical polarization, there is a strong field directly below the antenna.

A Clean Environment

The best defense against very strong RF fields is tightly screening the entire building, but this is also very expensive and many stations could not afford to do it. The next best defense is screening of the operational areas of the station. This method is also expensive unless the station is undergoing complete remodeling or it is a new station.

There is still another way of providing a clean environment for the audio circuits themselves, and this is through the use of conduits, metal ducts, enclosed equipment racks and equipment cabinets, and good shielding of the wiring throughout.

A Tight System

Whenever plans call for a complete or partial updating of the station, good shielding should be kept uppermost in these plans. A first step is a carefully controlled ground system throughout. This ground system should be consistent all through the system.

Very tight shielding is necessary for all wiring, racks, consoles, and other cabinets, and all of these should be given careful treatment throughout the installation. The audio wire itself should have a shield with 100% coverage; this information about a cable will be described in its spec sheets. Enclosed equipment racks should be used rather than open-frame racks. The steel panels and doors of an enclosed rack will divert quite a bit of the RFI.

Ground Leads

Ground leads from equipment to the main building ground should be kept as short as possible. Whenever this lead must be longer than a few feet, the ground lead should be shielded (Fig. 4-23). Now this may sound a little odd, shielding the ground lead, but RF at FM frequencies has short wavelength. The ground lead can actually become an antenna at the FM frequency. At 100 mHz, a quarter-wave antenna is about 2.34 feet long. At the upper FM channels, the antenna length becomes shorter yet. See Fig. 4-24.

Cabinets

Often, there is a single unit mounted in a cabinet by itself, rather than a rack. This cabinet must be kept tight, with all the

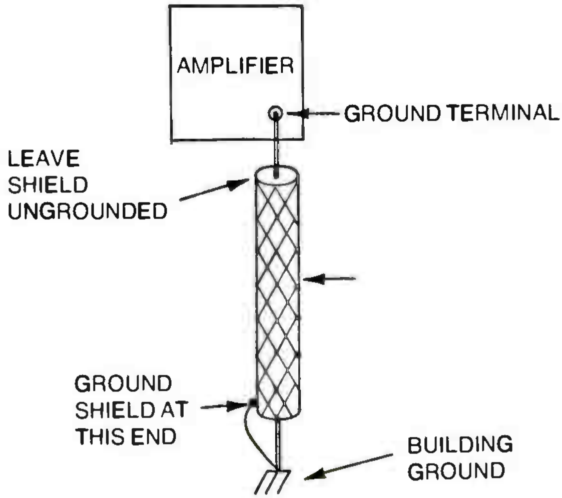


Fig. 4-23. Long ground leads at amplifiers should be shielded.

panels and screws in place. The cabinet itself must connect to the building ground, but paint can often insulate the panels (this can also be the case with anodizing processes). This makes an attractive cabinet, but is a poor shield since all the panels are insulated from each other. Remove paint, anodizing, or similar dress features so a good metal-to-metal contact is achieved.

Equipment manufacturers are aware of the problems with RFI in broadcast stations and are taking steps to make their equipment less susceptible to RFI by adding internal protection circuitry to and components. Although this RFI-proofing does do the job in most cases, it does not guarantee that a particular application or installation will not have RFI problems. Equipment made by other manufacturers who do not ordinarily make equipment for the broadcast market, but for consumer use, may not have any of this protection built in. If a station makes use of consumer-type equipment, caution should be observed in its specific application so that it doesn't introduce RFI to the rest of the broadcast system.

Brute Force Remedies

In spite of the best installation efforts, RF will find its way into equipment at some locations in the station. When this occurs, brute force methods may be necessary to eliminate the specific problem. But when such methods are used, care must be observed that the audio signal of the program does not suffer deterioration from the treatment. At the same time, do not forget that those old-fashioned problems of hum, shield buzz, crosstalk, and other interferences are waiting just outside the door.

Identification of RFI

The first step to take when a problem occurs is to identify both the offending RF signal and the affected stage. This is easier said than done! RF can usually be identified by its programming. Use any of the various signal-tracing methods and different test instruments to isolate the affected stage, but whatever instrument is used, make sure the instrument test leads themselves do not also pick up RF and feed it into the system. This will only contribute to confusion, rather than a cure. An oscilloscope is a good instrument to use, but it may not be sensitive enough, because the RF may be a very low level signal getting into a low-level, high-gain stage.

Bypassing

Once the offending stage has been located, try bypassing the base-to-emitter junction of the transistor (Fig. 4-25). Place

(A) $$\tfrac{1}{4}\lambda \text{ ANTENNA} = \frac{234}{\text{F IN MHz}} = \frac{234}{100 \text{ MHz}} = 2.34 \text{ FT.}$$

(B)

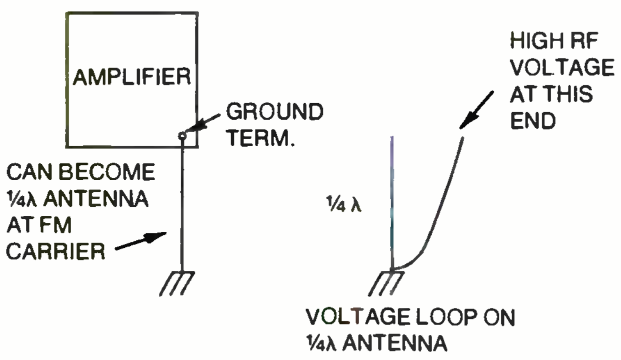


Fig. 4-24. Ground leads can become antennas at FM carrier frequencies.

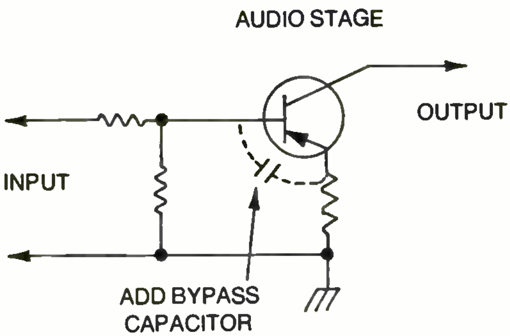


Fig. 4-25. Bypass the emitter to base at the transistor if this won't upset stage.

the capacitor directly on the transistor terminals. The value of this capacitor must be chosen so that it doesn't upset the stage operation or cause a rolloff of the higher audio frequencies.

Bypassing, when used as a defensive technique in any circuit, places a capacitive reactance across the circuit.

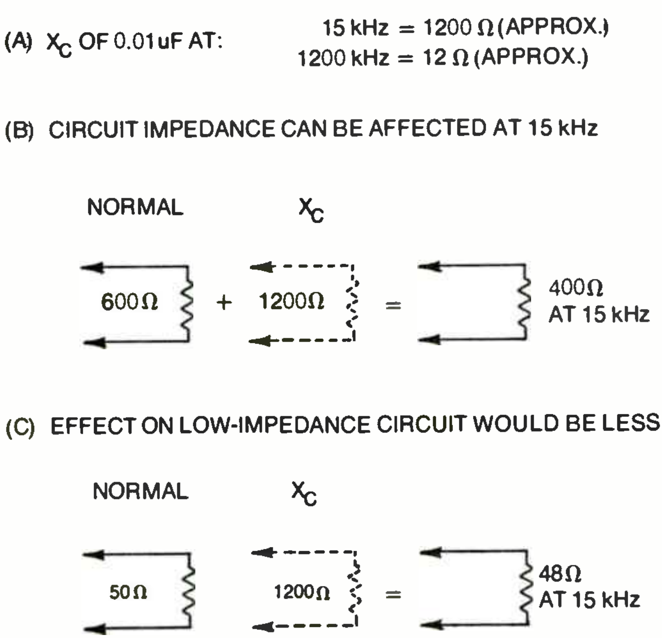


Fig. 4-26. Figure the value of the reactance of the bypass at both the offending frequency and at the highest audio frequency.

Before deciding upon the final value of this capacitor, always compute its reactance, not only at the offending radio frequency, but also at the highest audio frequency you want to preserve. And the capacitor should be one of the better ceramic or silver/mica ones. When bypassing to ground on a balanced circuit, use equal-value capacitors on each side of the circuit to ground. There is always the danger of rolling off the high audio frequencies when bypassing, and it is for this reason that the technique cannot always be used (See Fig. 4-26.)

Inductance

The pickup of RF may be due to a tuned situation in the input circuit of a transistor stage. That is, all the elements form the proper components of a resonant circuit at the offending RF signal and thus develop an efficient antenna. Small ferrite beads can be added to a circuit lead and cause a detuning effect on the RF signal. These beads have a small hole in the center and can be slipped over the wire lead and soldered in place. These are the same ferrite beads often used in video circuits to prevent parasitics.

T-Pads

On balanced circuits that use a T-pad type of gain control located on the line side of the input transformer, there can be RFI problems (Fig. 4-27). Grounding one side of the circuit can eliminate the RFI; but grounding one side makes the circuit an unbalanced circuit, so other problems can be created.

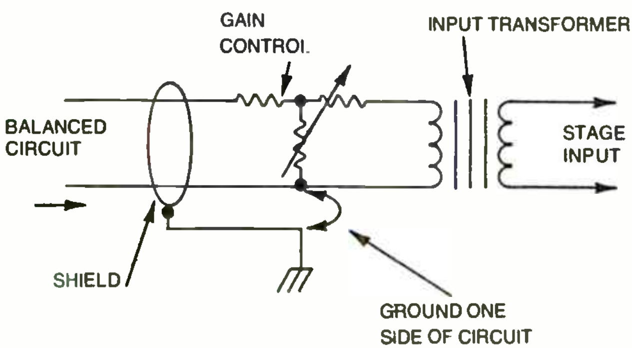


Fig. 4-27. When a T-pad gain control is used ahead of the transformer on a balanced circuit, it may be necessary to ground one side and run unbalanced.

There can also be problems if this circuit is patched into other balanced circuits. However, it works sometimes and is worth a try.

Power Circuits

Another port of entry for RFI is the AC power wiring to a chassis (Fig. 4-28). Each side of the power circuit should be bypassed immediately after it enters the amplifier. Additionally, series RF chokes may also be inserted in each side of the line. If chokes are used, be sure they can carry the

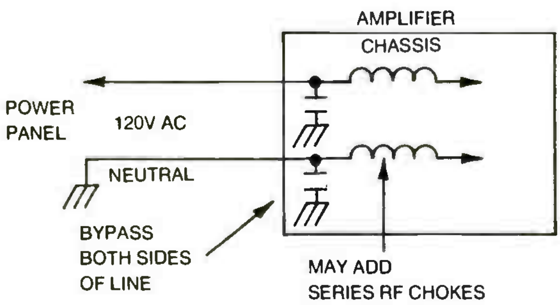


Fig. 4-28. Even though neutral is grounded at the power panel, treat AC power circuits as balanced circuits for RFI.

current drawn by the amplifier. The 120V AC power circuit is unbalanced, with the neutral grounded back at the power panel. When treating a power circuit, consider it as though it were a balanced circuit as far as RF is concerned. Although the neutral is grounded at the power panel, a long stretch of line is ungrounded as far as RF is concerned.

RFI is one of those phenomena that can't be pinned down to a simple theory. A theory can be developed for a *particular case* if all the elements of that case are known and can be accounted for. And that, perhaps, is the nub of the whole problem—identifying the elements that are peculiar to a specific case. If those are known, solutions can be derived. But the elements are not easy to identify. Consequently, after all the typical solutions are tried and fail, it then becomes a cut-and-try process until a set of techniques will eventually work. It can be a long frustrating operation.

Chapter 5

The Control Room

Most of a station's local programming will either originate in or pass through its studio area. There are many items of equipment working together in this major subsystem. The heart of the studio area is the main control room, and the piece of equipment of greatest importance in the control room is the console.

CONSOLE

The selection, mixing, controlling, and blending of all the program sources into the station's finished program product is the main purpose of the console (Fig. 5-1). To carry out these functions, the console must be able to select quickly a variety of program sources, mix them at will, amplify the mixture, and route it to some output receiving equipment. During the process, it must be able to monitor not only what is taking place within the console, but must be able to monitor other sources that are getting ready for the process. And at the same time, it must be able to send out warnings that certain functions are taking place and be able to mute selected speakers so that feedback does not occur with open microphones.

Although the basic console concepts are relatively simple, a console can become a rather complex unit with many interlocking switches, faders, relays, amplifiers and meters (Fig. 5-2).

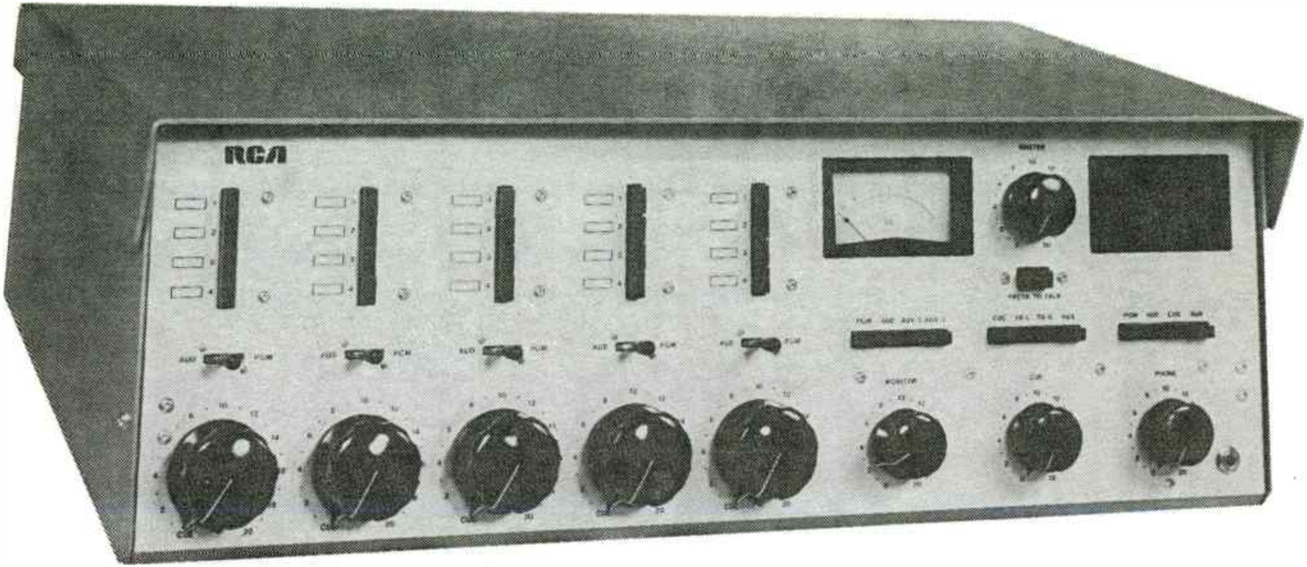


Fig. 5-1. A typical single-channel monaural console, the RCA BC-15 5- fader unit.

Input Selector

A console has a number of input selector switches, which may be either the lever type or push switches. In the usual arrangement, with a lever switch, the selector can select one of three sources to feed to the fader. The push switch can select perhaps five sources. The contacts of these switches perform many functions at the same time. They switch the audio from the desired source into the fader, back-load the unused sources, select and interlock the DC relay voltage for speaker muting, etc. Any additional functions taking place depend upon the particular console design.

The lever-type switch is a 3-position switch with all three positions active. That is, there is no OFF position. Each of the positions selects a source. The push switch is really several switches, but they are interlocked so that only one can be operated at a time. That is, when one is pushed "on," the previous switch will pop out and turn off.

The selector switch connects directly to the input sources. There are no transformers or pads between them (unless the station has added one). The purpose of the switch is to select one of those sources to feed into the console and maintain the load impedance on the unused sources.

Preamplification

Most consoles provide preamplification for low-level sources, while some provide preamplification on all the fader inputs. In the usual arrangement, only the faders designated for microphones have built-in preamplifiers. The other fader inputs have a plug-in assembly (usually a dummy cord) that directly connects the input/output terminals, or they may include an isolation transformer. Should the station desire preamplification in any of these other paths, they can plug in a preamplifier instead of the dummy cord. The output of the preamplifiers are at about −10 dB, which is compatible with the design of all faders. That is, each fader will need about −10 dB, whether from a preamplifier or from the source itself.

Mixer Bus

Once the source has been selected and routed through the preamplifier or dummy cord, it feeds directly to the fader input terminals. Each of the faders on the console is a part of its mixer system. The output of each fader is switched to a

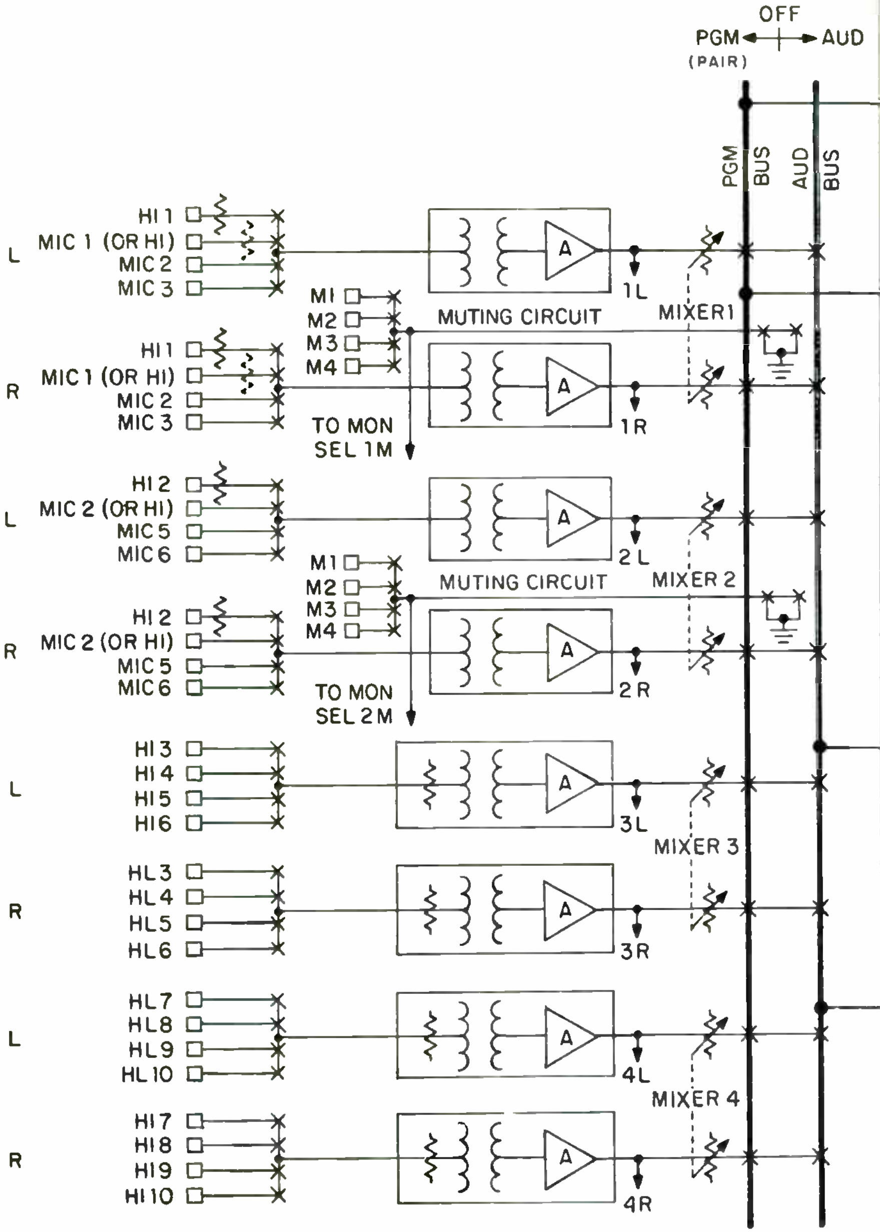
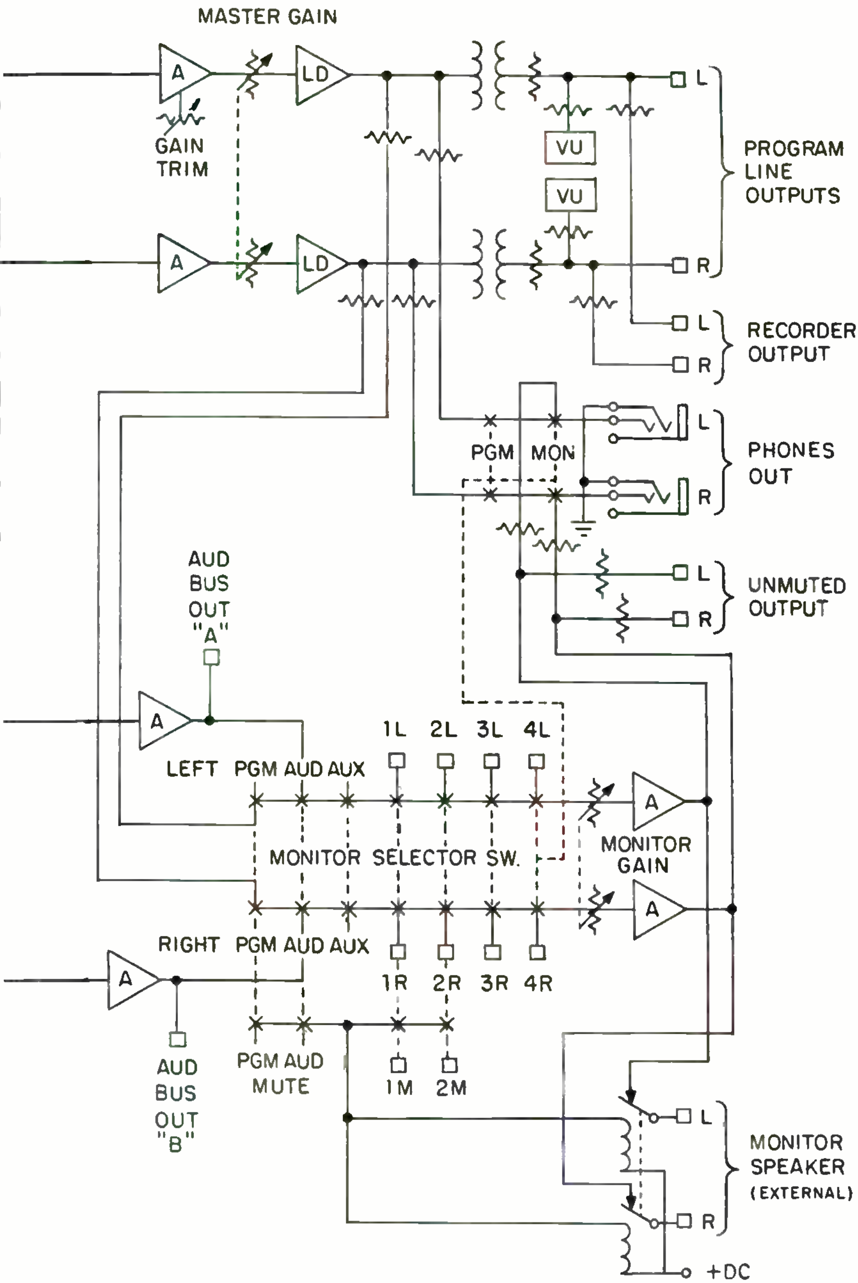


Fig. 5-2. Block diagram of the RCA BC-15 console.



(Illustration: Courtesy of RCA)

common mixing bus, and this is where the mixing action takes place. The fader maintains correct impedance with the selected source or preamplifier and attenuates the signal according to the setting of its control. At the same time, it maintains the impedance of the mixing bus.

Faders

A mixer system must be well designed if it is to control a variety of program sources and at the same time not interact with all the faders connected to the bus. That is, program levels should only change according to the setting of the individual faders, and not because impedances are shifting and affecting all the bus levels. The better consoles use precision faders in the form of ladder-type attenuators or similar precision units. Some of the less expensive consoles designed for the production booth often use an inexpensive potentiometer or wirewound control. The results are not always too predictable in these units.

Cueing

Another feature used on the precision faders is a CUE position. By turning the control all the way to OFF and then beyond, the fader switches into a CUE position. This position allows the output of the selected source be directed into a cue bus so that the source may be monitored prior to airing. This is a very handy feature, especially in the case of turntables or incoming remote lines and network lines.

Cueing can take place only from the one selected source, and the only time that cueing can be done is when that fader or source is not on the air or being routed through the console in the program mode. If you desired to cue any of the sources at any time, this would require a different type of cueing arrangement. However, this arrangement in the standard console is a very workable system.

Other Inputs

Besides the regular program inputs on a console, there are usually one or two faders designated for remote and network lines. The selector switches are usually somewhat different in the contact arrangement since they need to perform actions that are not necessary on the regular inputs. Some of the actions of the regular inputs are not needed here, such as, *on the air* lights and speaker muting.

Ordinarily, these circuits contain an isolation transformer between the selector and the fader, and there may be pads also since these are intended for high-level input signals.

Besides selecting one of the available sources for airing, the switches also have either contacts or positions which allow sending cue signals back out the line. They also permit talkback to the operator at the remote site before program airing.

Designation

Different terms are used to describe consoles, and I suppose the one used depends upon the way the operator thinks of his console—that is, as either a mixer or a switcher. Actually, it performs both of these functions and can be described either way.

Mixer—When the console is described by its *faders*, one is thinking in terms of the console as a mixer. The number of faders the console contains is a good indication of its capacity to handle a variety of program sources at one time. For example, if the console has eight faders, it can control eight program sources at the same time. Each one of the faders can be feeding program material onto the mixing bus at the same time. Naturally, if it has six faders, it has less capacity, and if it has ten faders it has a greater capacity.

Switcher—When described by *inputs*, one is thinking in terms of the console as a switcher. For example, the RCA BC-8 console has a capacity of 24 sources, or inputs. This does not mean that all 24 of those inputs can be used at the same time. What it does mean is that 24 sources may be wired to the console at one time, but only 8 of these 24 sources can be used at any one time.

Although the console does perform many switching functions, it is not truly a switcher as this term is used in other fields. The true switcher is merely a routing device that switches many inputs to a number of outputs. The console only has one output: All the inputs selected route to a mixer bus so that there is only one output of all the combined sources that have been selected.

Channel Selection

There are always two mixing buses in a console, although one may not be called such. There is a channel selector switch immediately following the fader which allows the operator to switch that fader to one of these two buses. In the normal single-channel console, one bus is designated the *program* bus and the other one is designated the *audition* bus. If it is a dual-channel console, there are two mixing buses plus an audition bus.

The channel selector switch is a 2- or 3-position switch, depending upon the console model. The switch routes the audio from the fader to the selected mixing bus, but there are other contacts which also control the DC relay voltages for speaker muting or *on the air* light relays. This voltage is interlocked and routed through the input selector switch so that only the affected studio is muted, not all of them.

Amplification

Mixers are loss circuits even though all the attenuation is adjusted out of each fader. There is an insertion loss, and of course, there will be the adjusted attenuation. Levels following a mixer are down in the low-level category. This requires amplification.

Immediately following the mixer bus, there are one or two amplifiers, again depending upon model. If there are two amplifiers, the first one is called the *mixer follower*. The next amplifier is called the *program amplifier*. If it is only a single, high-gain amplifier, it is called a program amplifier.

Each mixer bus must have amplification. In the single-channel console, there is only one program amplifier, and the audition bus may be either a similar amplifier or it may be the console's regular monitor amplifier. A dual-channel console has two separate program amplifiers, one for each channel. There may also be an audition amplifier, or at least the bus can be amplified or switched to the monitor circuit.

Master Gain

The individual faders are designed to control the level from the input source and adjust it to the correct ratio to other signals being mixed on the bus. But the overall levels must be adjusted also. Consequently, there is a MASTER GAIN control on the console. This control works in conjunction with the program amplifier or the mixer follower. It either works on the audio directly or on the parameters of the amplifier. In either case, it controls the overall console gain.

In the dual-channel console, there are two separate MASTER GAIN controls, one on each channel. Adjustment of either one has no interaction on the other; they are on independent channels.

Metering

Some means is necessary to measure the signal levels through the console, and this is done with a VU meter. The meter is connected into the circuit directly after the program amplifier. There will be meter pads so that the meter can be adjusted to hit 0 VU on the peaks, regardless of how much higher the overall level is. The normal output of the console is at +8 dB. There is usually a pad following the amplifier so the amplifier output itself is higher than +8 dB. The meter, however, is connected ahead of the pad on the channel, and it has its own pad to bring that level into range of the meter.

On the dual-channel console, there may be one or two meters. If there is only one supplied, there is some switching arrangement so that the one meter can be switched to meter either channel. Usually, there is an optional meter that can be purchased and added to the console. This is the preferred method, rather than switching the single meter for both channels.

Monitoring

Besides the VU meter, there are at least two other provisions for monitoring provided in the console itself. There are headphone and loudspeaker monitors.

Headphone jacks are supplied, and these normally have a series resistance for bridging. There is a selector switch so that many of the internal circuits can be monitored.

A monitor amplifier is provided to drive loudspeakers in the studios associated with the console and the control room itself. The output of this amplifier is routed through muting relay contacts that are controlled by the microphone selector switches. Whenever the channel key is thrown for the studio selected, the relay opens and prevents the speaker from operating. The contacts back-load the amplifier so as to maintain the proper impedance on it.

Air Cue

One of the selector switch positions on the monitor will provide for picking up audio from an outside source, such as the modulation monitor or a receiver. This will provide for listening to the program on the air with the console monitor. The switch position will be labeled AIR CUE.

Cueing Amplifiers

Cueing is necessary so that sources can be made ready prior to airing. Most of the faders have a CUE position on them. This position is connected to the cue bus. A special cueing monitor amplifier is normally provided and connected to this bus. Besides the cueing, the amplifier also has other uses. So, its input is usually on a selector switch. In this manner, it can receive cue from the fader positions and also receive cue from incoming remote or network lines.

By further switching arrangements, the input and output of this amplifier can be reversed so that the amplifier can be used as a talkback amplifier between the console and any of the studios or to remote locations. This allows for communications to the remote locations prior to air time. Of course, after the line is switched up for air, it can't be used for other purposes. This amplifier has its own GAIN control. By the way, when used as a talkback amplifier, the speaker mounted in the console is used as a microphone.

Stock or Custom

What we have been describing has been the general stock-type console. There are a variety of models to choose from and many manufacturers. Each one has some differences, but the basic concepts are there. Some may have more features than others. These standard consoles have been designed by the manufacturers in the hope they will satisfy a majority of the necessities of the regular station operation practices.

But there are also available component units that can be designed into a custom console. The station may select the individual units that more nearly satisfy the conditions at that station. Or the factory can make up this custom unit, using the station's requirements and putting it together with the component units. This service costs a little more, but the unit is all put together and checked out before shipment.

If these units still can't satisfy the station's needs, a thoroughly custom-built console can be bought. The station must supply the specifications and work with the factory engineers. Naturally, this type of console is far more expensive than the stock unit, but many of the very large stations must do this to fit their needs. For the average station however, the standard stock model usually comes close to satisfying their needs.

Dual Channel and Stereo

A dual-channel and a stereo console are not the same things (Fig. 5-3), even though they may appear alike from the

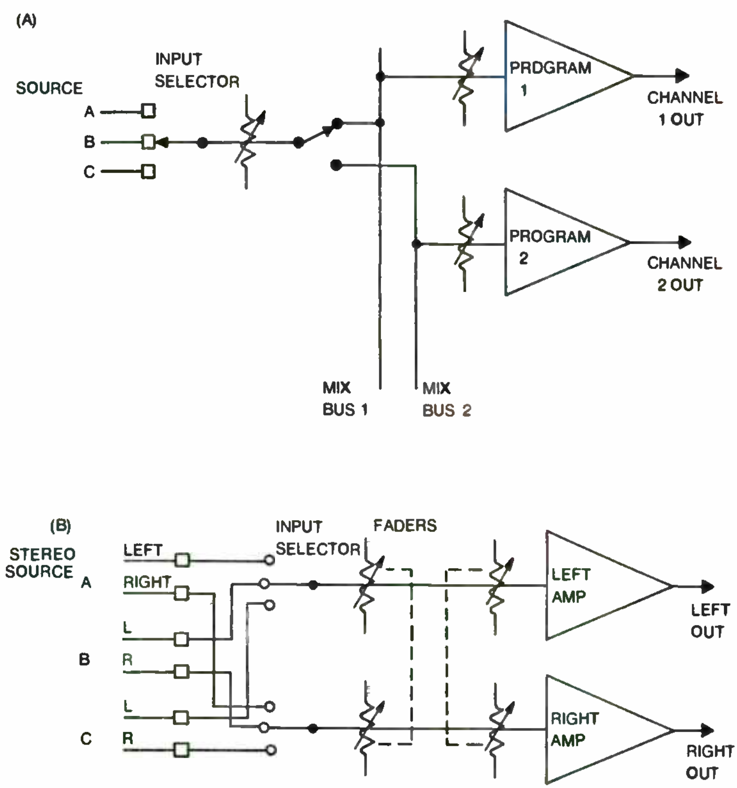


Fig. 5-3. (A) The dual-channel console selects and switches a source to either of two channels. (B) The stereo console selects the left & right channels of a source and carries this all the way through to the output.

outside. In the previous discussions, many mentions have been made of the dual-channel console as the conditions applied. In essence, the dual-channel console is simply two program channels *after* the faders. The inputs and faders may be fed to one or the other mixer buses and program channels. So there are simply two program channels.

The stereo console. however, is far different. It must have two identical channels all the way from the selector switches to the outputs; and these two channels must operate simultaneously. These two channels are for handling the left and the right audio channels of the stereo system. The input selector switch will select the left and right audio from the source and feed it to a dual fader. Two faders are ganged together so that one knob operates both. Then the signal goes on to the left and right buses, program amplifiers, and output.

The left and right channels must be identical to maintain stereo channel separation. The audio response curve through each channel, the noise, the distortion, and the phase shift should be identical.

CONSOLE INSTALLATION

The console is the focal point of the control room and the main operating position. Clustered around it are several equipment items that supply program signals which are mixed together into the final program. These must be within reach of the operator or announcer. The physical placement and location of the console should be given some very serious thought before the final position is decided on. When this consideration is taking place, give adequate thought to the maintenance of the console after the control room is in normal operation. Also think about the initial installation, when there will be many, many connections made to the console. And when it is necessary to troubleshoot problems, the engineer often needs to get to those terminals to signal-trace.

If at all possible, try to place the console out in the middle of the room. This will allow easy access to all sides of the console for maintenance. Unfortunately, the physical placement is often dictated by the room size and what other equipment must be placed in the room besides the console. If you are fortunate enough to get in on the planning of the building or remodeling, try to get a large enough control room. If you can't manage to come up with a decent physical size, at least try to get enough space to allow the console to be placed away from the wall. It is extremely difficult doing maintenance to the wiring side when the unit is against the wall.

Maintenance is done on the console in the majority of cases during programming time; something has failed or is failing and needs correction, but the console must continue in operation. We don't have the luxury of a spare console too often in the regular radio station. Of course there is some maintenance done after signoff when all is quiet, but expect most of the problems to occur during programming.

Grounds

The console should be the main grounding point for all the cable shields of circuits going to the console (Fig. 5-4). Make sure to get a good connection to the main building ground from

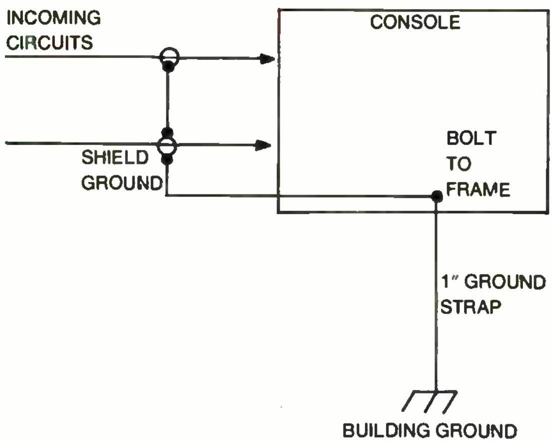


Fig. 5-4. Get good ground from the console to the building ground.

the console. Use at least a 1-inch strap for this connection, and solder to the building ground. Ground the console frame by bolting to the strap, and clean off paint to get a good metal-to-metal contact.

Jacks

Route all the audio circuits both in and out of the console through a jack field. This requires many jacks, but it increases the flexibility of the installation considerably and is a great help for troubleshooting. This flexibility extends to the operation itself. When all the circuits are on jacks, equipment may be substituted at will by the use of a patch cord. That is, you can bring the regular units in on different faders if the particular program calls for this arrangement; and if something fails, other units can be patched into the console in the defective unit's place. The substitute units may be left in their regular positions, such as, in a recording booth. Then, too, should it be necessary to have another tape machine—for example, during a special recording session in the booth—one of the control room machines can be patched in for the occasion. A jack field pays for itself many times during the lifetime of the equipment in a station.

MODIFICATIONS TO CONSOLE

Seldom do standard stock consoles exactly fit the needs of a station. Consequently, each station makes modifications which customize the console for that station. But when making modifications, be careful not to alter the normal performance of the console. The following are a few suggestions to follow when making modifications.

Power Supplies

Whenever some additional power-consuming modification is added to the console and it draws power from the console power supply, investigate the capacity of the supply and how heavy it is now loaded. There are two things to consider: is there reserve capacity, and what is its maximum capacity?

The power supply may have its own instruction manal, or at least there may be a section in the console manual that gives some specifications on the supply. Determine from this information what maximum load current the unit can supply (Fig. 5-5A). This is the starting point, but the figure may not be given in the manual, or at least not in a form that can be readily determined. There is a method that can be used to determine this maximum figure, but it does not give absolute figures. However, they are close enough to be practical. Look for a fuse on the DC load side. If there is one, this fuse will indicate the maximum current that can be supplied. The fuse is rated somewhat under the maximum value, but the load current should not exceed the fuse value. Do not increase the size of the fuse! If you do, the power supply may be damaged.

If there is no secondary fuse, then look to the primary fuse. Compute the primary power, using the primary fuse as the current value. Consider the power supply to be perhaps 70% efficient and multiply the primary power by 0.7 to give the secondary power. Then determine the maximum load current from the power formula, using the power figure just computed and the secondary DC voltage ($I = P/E$).

Next, open the output circuit of the power supply and insert an ammeter in series with the load. Turn the supply back on, and turn on as many functions as can be expected in normal use during operation, plus a couple more as a safety margin. Subtract this current reading from the maximum current that you computed. The difference in the reading is the reserve capacity. This assumes that the measured value was less than the calculated value. If it is not, that power supply is working at maximum now and you must go elsewhere for power.

Relays

When making modifications that require relay switching actions, look for relays or switches that operate in the way the modification requires and have some spare contacts. Make sure they are "dry" contacts—ones with no other connections to them (Fig. 5-5B). Also make sure that there isn't a contact with voltage that the spare contacts will make when the relay relaxes. This could place your modification across unwanted voltage, which can cause damage to the modification or the regular circuit. It is best to have the contacts completely clear of any connection to the console circuits. In this way, you use the action only but none of the circuits.

However, there may be cases in which you wish to pick up the switched voltage from the circuit; then it is okay to go directly to the desired contacts that have that voltage. Another source is across the relay coil. Whenever you tap into a circuit in this manner, always make sure the modification will not upset the regular circuits. There can be too much current drawn at that point through series resistors, and these may burn out. While we have been discussing relays, the same holds for switches as well.

Cabling

Modifications often call for running some outboard cabling into the console. There are some precautions to take in this regard.

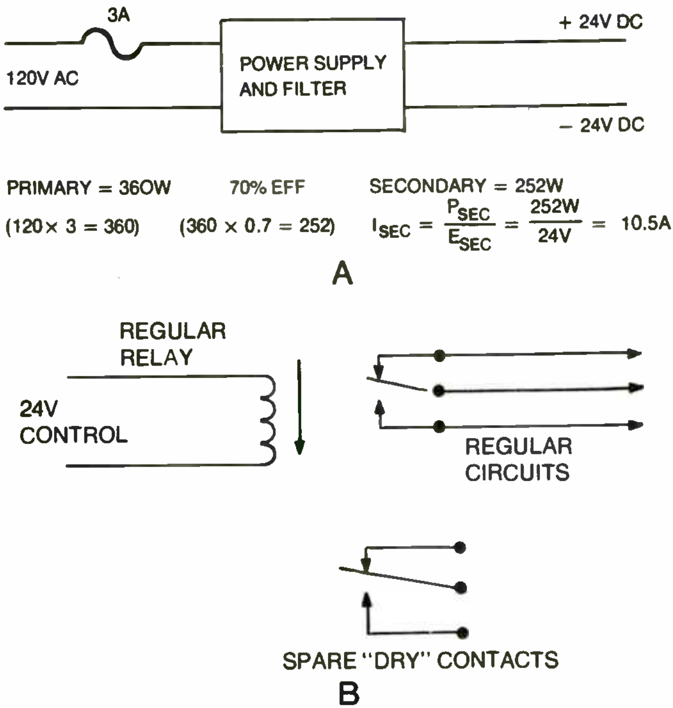


Fig. 5-5. Modifications to console. (A) Method of roughly calculating the maximum lead current of a power supply. (B) "Dry" contacts have no other circuits connected to them.

First of all, make sure the new cabling follows the regular console cabling, regardless of how irregular the path it may take. Remember that when the front panel is down, attached cables must bend back out of the way for the panel to close. So attach the new cabling to the regular cabling.

Also be careful of the path of the cabling. The new cabling may be carrying relay switching transients, hum, or other noise, so be careful to avoid low-level microphone or similar circuits. Remember, the circuits immediately following the mixer bus can be at a very low level also. Just because the new cables are carrying DC relay voltages does not mean that they can't carry other unwanted signals as well.

Switched Voltage

Another source of voltage that can be of use in modifications is the voltage that is switched to operate speaker-muting relays. This is often brought out to a handy connection board for selecting the keys to have the mute. At this point, the voltage can be picked up and used to operate external relays, such as a relay to start a turntable. This voltage will switch on and stay on when the channel key for that fader is thrown, so it works well for this use. But use an external relay. The contacts of that relay can carry the 120V AC to switch on the turntable motor. Use of an external relay avoids carrying the 120V AC into the console where it can introduce hum into various circuits.

When using external relays to be powered by the console, try to select those which have a low current demand for the coil. This makes less of a load on the power supply.

Add-Ons

There are often occasions when it is desirable to add switches to the console panel, for example, remote start switches for tape machines. This calls for drilling the front panel of the console.

First, the location: When a likely position is selected for the switches, open the panel and check the rear side. Quite often the reason the panel is clear is that there are components or cabling on the reverse side. Make sure there is clearance before deciding on the position.

Before drilling, measure off the panel space and use masking tape across the area to be drilled. Use a centerpunch, a small pilot drill and then a larger drill for the final-size hole. A large drill is difficult to start and can skip out across the panel, causing scratches that can't be removed. Remove the VU meter before hammering on the panel to set the centerpunch; a good jar can damage the meter. Before actually starting to drill, make sure the drill will not break through the panel and bore into a bundle of cables. If there are cables that can be reached with the drill, use a board as a shield between the drill and cables.

The drill spews filings over a wide area, so care must be taken to prevent these from getting into switches, circuit boards, etc. Tape some paper underneath the drilling area to catch the filings. If a vacuum is available, have it sucking in the filings right off the drill bit. This will save a lot of cleanup. When all is done, vacuum out any filings that have gotten into the console in spite of the precautions.

CONSOLE SETUP

When a new console has been installed, it needs the levels set, and measurements made to determine that it is working within specifications.

Levels should be adjusted so that the fader knobs and the MASTER GAIN control will normally operate at 12 o'clock, that is, half open. Use program material or tones through each of the input sources and set the output gain on each of the units so that the console is reading 0 VU on peaks. Try to adjust each of the sources that will be selected for a fader so that they balance well. In this manner, switching from one source to the other requires very little adjustment of the fader.

Make a set of measurements through the console, jacks, and wiring. There should be a set of response, distortion, and noise measurements. Also be on the lookout for RFI. In the area of noise and RFI, here is a little trick: With the sources attached to the console, but with no programming, turn the faders and MASTER GAIN control wide open (you should do the same with the monitor amplifier GAIN control); listen for background noises or RFI. In good installation you will not hear much of anything. The system is running at very high gain, and there is a possibility of feedback oscillations, so stay under this point.

CONSOLE MAINTENANCE

Consoles are generally trouble-free units, but there are problems from time to time. Amplifiers and components may fail occasionally. The points of greatest wear are the switches and faders, and here is where the majority of maintenance centers.

Switch Problems

The first problem area is usually switches not making proper contact. Even though these are self-cleaning contacts, oxidation, dust, or wear eventually makes the contacts intermittent. Clean these with a burnishing tool or coarse piece of paper. Place the tool between an open set of contacts, then close the switch. This will put pressure on the tool and clean both sides of the contact at one time. Rub the tool across the contacts several times, and then do the same to the other contacts. Use caution, as some of the switches also carry DC relay voltage on some of the contacts. If the power can be shut off, this is the best method. But if not, use paper to clean those contacts. Otherwise, the burnishing tool may short out the relay power and cause damage. Also, be careful not to bend springs on the lever-type switches.

Straightening Contacts

If the contact springs on a leaf-type switch have been bent or have lost some of their tension, be cautious in bending the contacts. It is best to use special adjustment tools, but it can be done with a pair of long-nose pliers. The best type has the nose bent at an angle. Bend the springs in small amounts only. Overbending can cause a change in pressure distribution so that adjacent contacts become intermittent.

Wiring Problems

When a switch or other component works loose, the component can have slight movement during operation, and this causes the wiring connected to it to flex. After a period of time, one or more wires break off. Unless the wire is sticking out in the open where it can be easily seen, this can be difficult to find. You must signal-trace the circuit. Follow it through all the interlocking switches. The troubleshooter may suspect a bad switch contact, but trace the signal—don't start bending contacts. If it is an audio circuit, feed program into that path and use a pair of headphones. Or you can use the monitor amplifier and a small jumper to complete the circuit from point to point. If it is open between the points of the jumper connection, you have the problem isolated. The same trick can be used by shorting across the contacts on a leaf switch with a screwdriver. But make sure you are on the correct contacts, and not on the relay voltage.

Fader Problems

Problems with step-type faders are usually noise or erratic operation. This is caused by the contacts becoming dry and oxidized. Of course, they may be wearing also.

Take the cover off the rear of the fader. Use the special fader cleaning oil. Apply a few drops of the fluid and operate the control several times through its full travel. Then, with a clean cloth, wipe off this fluid. Next, add a couple more drops of lubrication and then run the control through its travel to distribute the oil. Be stingy here and don't overoil. Replace the cover and send audio through the fader. It should now be clean and smooth in level adjustment.

Be careful of what type of material you use for a cleaner. Some solvents will leave the contacts very dry, and they will wear and become noisy again. Others may leave a gummy residue. When possible, obtain the special fader cleaning fluid from either the console manufacturer or the fader manufacturer.

Cleaning

The console needs cleaning from time to time. Clean the front panel with Glass Wax or a similar solvent. This will not only clean the panel of fingerprints etc., but will leave a nice polished look. But be careful of cleaning the face of the VU meter. This may be plastic and a strong solvent can fog the plastic so that it is difficult to read. Just use plain water or one of the regular window cleaners. Be careful not to get any fluid inside the meter.

Use a vacuum on the inside of the console. It is surprising the number of paper clips and odds and ends of audio tape that accumulate inside the console. Clean these out. But don't give in to the temptation of closing up the openings to prevent debris from getting in. These are also for ventilation, and to close them can cause the units inside to overheat and fail.

MICROPHONES

The microphone collects and directs sound waves in the air to a diaphragm. This diaphragm may be attached to a moving coil, part of a capacitor, or a ribbon suspended in a magnetic field. The sound waves cause this diaphragm to vibrate in a corresponding fashion, which generates an electrical signal at its output terminals that is a replica of the sound waves. The connections have been standardized so the forward pressure on the diaphragm will cause the "high" terminal on its output to go positive. This is a very simplified description, but getting the few simple components to reproduce the sound faithfully is another story.

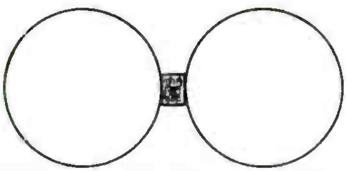
Over the years, much progress has been made in the development of microphones. Today, there are many, many models available that have excellent response curves and fit many specialized situations. But radio has also changed over the years, so that very little production work is done today.

Most of this has moved over to recording studios. In broadcast use, microphones are employed mostly for speech.

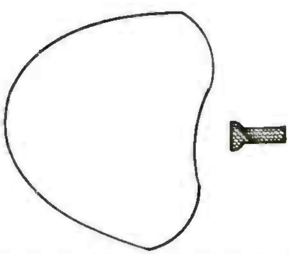
Patterns

An *omnidirectional* microphone picks up sounds equally without any directional effects (Fig. 5-6). But this holds true for only some of the microphones, while others may have some

(A) OMNIDIRECTIONAL—WILL PICK UP SOUNDS EQUALLY IN ALL DIRECTIONS



(B) BIDIRECTIONAL—MIKE WILL PICK UP EQUALLY FROM FRONT AND REAR, LITTLE AT SIDES



(C) CARDIOID—MIKE WILL PICK UP ONLY FROM THE FRONT, NO PICKUP FROM REAR OR SIDES

Fig. 5-6. The three most common microphone sensitivity patterns.

directional characteristics. A *bidirectional* mike will pick up equally from the front and back, and very little to its sides. This produces a sensitivity pattern that looks like a figure eight. The *cardioid* microphone will be sensitive at the front only, very little pickup from the sides and rear. The sensitivity pattern is heart-shaped.

The specification sheets that come with the microphone will show the patterns available for a particular microphone as well as its response curve. Before selecting a microphone for a specific use, look these over carefully.

Physical Structure

The physical structure has much to do with the performance of the microphone and its directivity. Internally, there are chambers in which the sound is controlled and directed. The sound enters the microphone not only through the front opening, but through slots or ports. By allowing the sound to enter these other openings, it is directed into various phase patterns to mix with the direct sound. This is what produces the various effects and patterns.

When the microphone case is to be refinished, care must be taken that these small ports are not covered over with paint; the same is true of dirt or other matter. In use, do not cover these ports with the hand. If the sound can't enter the ports or slots, performance of the microphone will deteriorate and the directional patterns will be lost.

Switched Patterns

Besides the fixed patterns, many microphones also have adjustable or switchable patterns and response curves (Fig.

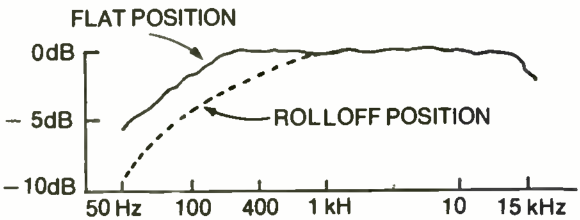


Fig. 5-7. Typical selective response curve of a cardioid microphone. When switched to its rolloff or cut position, the low frequencies are rolled off. This is useful in reducing unwanted, low-frequency room noises.

5-7). Control of the response curve is usually done at the low end, below 100 Hz. The rolloff is something in the order of 10 dB. This low-frequency rolloff can be a useful device when the room has much rumble, reverberation, or other low-frequency acoustical noises.

In other locations, it is necessary for the announcer to be very close to the mike. This causes a rise in the low-frequency response. In effect, it makes the reproduced signal sound very bassy and muffled. The rolloff helps in these situations. But some microphones are designed for close talking, and these have built into them the necessary chambers to cause the response curve to remain normal during close talking.

Wind Screen

Close talking on a microphone also brings up other problems. Certain sounds, such as a "p" sound, causes the microphone to "pop" each time the sound is used. When the microphone is used outdoors where there is wind, the sound of this wind rushing past the front of the microphone creates noises. All of these are objectionable sounds in the program. To overcome these, a wind screen can be used. This is a porous foam-plastic material that can be shaped to fit the front of the mike. This can be purchased in form-fitting units for a particular mike, or it can be purchased in flat sheets. In sheet form, cut it to size and staple the ends together so as to make a small sock to cover the mike. Microphones that have been designed for close talking already have materials built into them to prevent wind sounds or popping. If you are caught outdoors on a windy day, a handkerchief wrapped over the end of the mike will be somewhat effective.

Sports Microphones

These are always close-talking microphones. A regular mike will give problems. In most of these locations, there is much crowd noise, and unless the announcer works close to the mike, he won't be heard over the crowd. There are special sports microphones available that are also attached to a headset. This arrangement keeps the mike at a constant distance from the announcer's mouth and also provides for headset monitoring. Besides that, it allows both hands to be free. There is one drawback. If the announcer wants to do interviews, this type of microphone is not appropriate. The best thing to do is carry a regular hand-held microphone along for such occasions.

Impedance

The output impedance of microphones is important. They may be either high or low impedance. Almost all broadcast stations use the low-impedance arrangement. The capacitance across long cables seriously rolls off the response of a high-impedance mike, and it can be used only with a short cable. Broadcast situations often make use of very long cables.

Various microphone manufacturers have settled on their own impedance values. These may be 30, 50, 150, or 250 ohms. All of these values work into the normal low-impedance circuit with only a change of a few decibels in signal level.

Phasing

When only a single microphone is used at a location at one time, the phasing is of little consequence. However, when more than one microphone is used at the same location at the same time, phasing does become important. The phases being discussed are those which are 180 degrees in error, and not minor phasing problems.

When two microphones are 180 degrees out of phase and the same sounds are picked up and fed to the amplifier, these sound signals cancel each other in the amplifier; it is no different than connecting any other AC signals that are 180 degrees out of phase. The phasing is a matter of connection of the microphone cables and plugs to the microphone and to the amplifier or console. Even though all these factors are correct, it is still possible to get the mikes out of phase when they are patched in a jack field, by turning over one of the patch plugs.

The output of the microphone is a complex AC signal, and because it is an AC signal, the operator might give little consideration to the phasing. This is a mistake. Microphones should be phased just as a matter of good engineering practice, whether a multimike situation is expected or not. There is no great problem keeping the mikes phased if a standard wiring pattern is set up along with a color-coding pattern for the cables. The microphones have been standardized so that when the sound pushes the diaphragm forward, one of the terminals goes positive; this is the high terminal. Carry that through the wiring plan. If there is any doubt, check the specification sheet for the microphone. It tells what the numbers should be in the plug and the one which is high. This will be the #2 pin of the plug. The low side is #3, and the case of the microphone is #1.

Test Setup

A simple test setup can be arranged to check out the microphones for phasing (Fig. 5-8). This should be done when microphones have been sent in for repair also. Select two

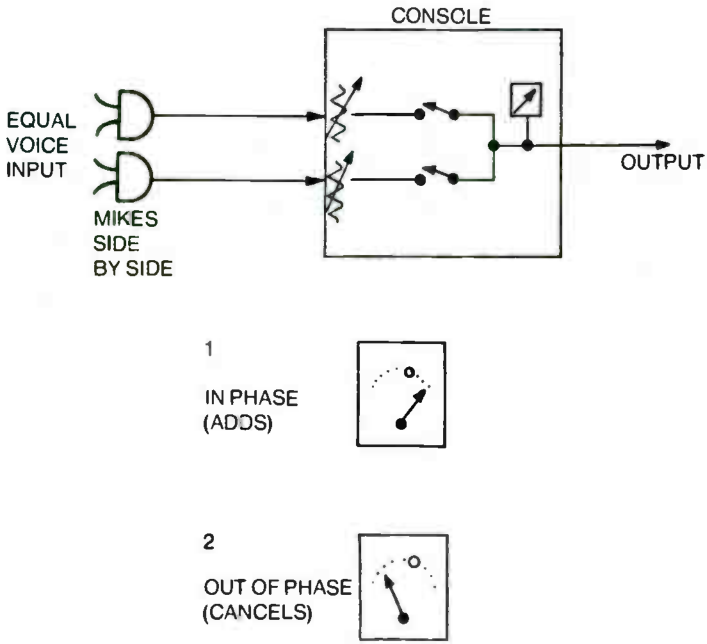


Fig. 5-8. Setup to test the phasing of two microphones.

microphones, plug them in to two different faders on the console or a remote amplifier. Hold the microphones side by side or have them on stands side by side, but very close together. What is needed is the same audio from approximately the same distance and direction hitting both of the microphones. Now, with someone talking continuously and at a steady level into both mikes (*mike 1 and mike 2*), turn off *mike 2*. Set *mike 1's* fader so that the peaks are 0 VU on the meter. Now turn off *mike 1*, and turn *mike 2* on. Set *mike 2's* fader so that the peaks are 0 VU. Turn *mike 1* back on. If these mikes are out of phase, the level on the VU meter will drop drastically. If they are in phase, the level should increase. In the out-of-phase situation, the signals are cancelling; but when in phase, the signals add together.

Problem Areas

The majority of microphone problems occur in the cables and plugs. In fixed locations, such as a control room, these do not occur too often, but in studios or out on remote locations, the cables and plugs get a lot of flexing and handling. Even in the fixed locations, problems can occur with the jacks in a jack field. These need to be cleaned from time to time.

Cables and Plugs—A regular routine maintenance program should be set up and followed in checking out mike cables and plugs. Flexing from remote locations often causes the shield to break. This often appears at about six inches from the plug itself. When a shield opens up, there is a buzz or sizzling sound in the audio. It sounds a little more like hum when the microphone is touched with the hand. The best repair is cutting off the cable past the shield break and redoing the connection. Once the cable has been repaired, check it out with an ohmmeter for continuity and for shorts across the connectors.

Plugs seem to have a penchant for losing those small screws that hold them together. The bad part of this is that they are not standard screws that can be picked up at a local hardware store. They are hard to come by. The station should have an assortment of these on hand. They can be purchased from the plug manufacturer.

Internal—Problems that develop internally are almost always caused by someone dropping the microphone on the floor or a similar mishap. Unfortunately, those who use the mikes often fail to report that the mike has been dropped. A sharp jolt, as can happen in a fall, can break the diaphragm or knock something out of place within the mike. When other outside tests of the cables and plugs do not correct the problem, look for internal problems. How far you can get into the microphone depends upon the type. Some you can't get very far into without special tools. But even if you can get it opened up, you may not be able to correct the problem anyway.

Most microphone manufacturers have repair stations, and there are some independent repair stations. Quite often these have a fixed fee for repair of the mike. It usually comes back as good as the original, and the case will be refinished. It is better to send in the mike for repair than to try to repair it yourself, unless of course, the fault is minor.

Room Noises—Room noises can sometimes be a real problem, expecially in a fixed location such as a recording booth. These noises may come from air-conditioner units, furnaces, motor vibration through the walls, and elsewhere.

Air ducts should be lined for several feet with a sound insulating material (Fig. 5-9). There are special ducts already prefabbed that include this soundproofing material. Even

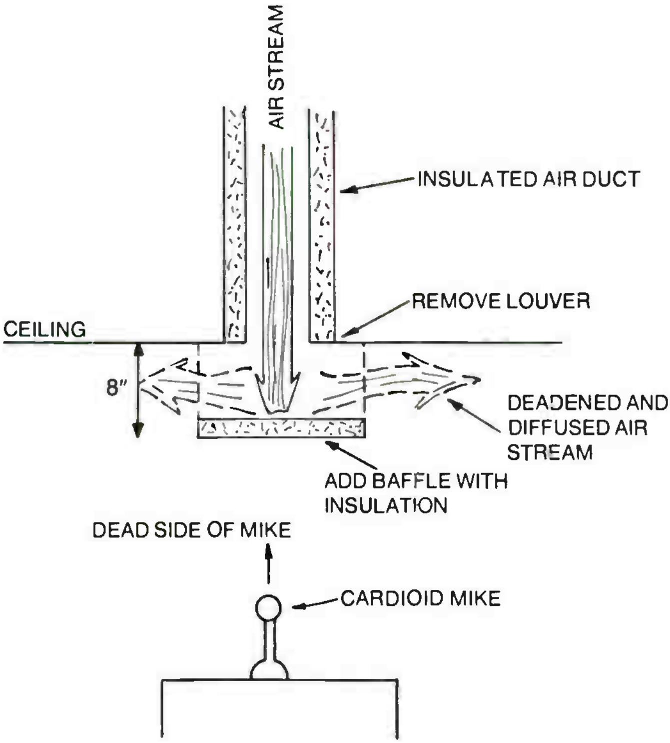


Fig. 5-9. Method of reducing noise from an air duct.

then, the actual movement of the air itself can cause noise as the air blows across a louver. Try to move the mike out of the direct path of the air blast or movement, as the sound carries stronger in the air stream. When this can't be done, take off the louver and add a baffle about six to eight inches away from the opening of the duct. This makes the air stream shoot into that baffle (which should be lined with soundproofing material) and thus absorb part of the rumble or other noises. There is still another trick: Use a cardioid mike and place it so that the dead side is towards the air sounds. This makes the mike less sensitive to the noise. For an electronic technique, use one of the mikes with low-frequency rolloff and insert a high-pass filter in the mike line (this should cut off below 100 Hz).

TURNTABLES

With music as the staple in many radio stations today, the turntable has become the station workhorse. The turntable is actually a system composed of several integral parts. There is the table itself, its drive motor and mechanism, and the cabinet to house and support the assembly. The electronics includes the stylus, the cartridge, the tone arm, the equalizer and preamplifier.

Recording

A master recording is made with a disc recorder. This is an amplifier system driving a cutter head and cutting stylus to cut grooves into a blank disc. The audio signal is pre-emphasized to overcome some of the inherent noise in the system.

NAB standards describe the width and depth of the grooves and the direction and angle of cutting (Fig.5-10). On the stereo disc, the left and right channels are recorded at 45-degree angles into the walls of the groove. The right channel is on the wall towards the outer rim, and the left channel is on the wall towards the spindle.

When the left and right audio channels are fed an equal inphase signal, the cutter modulates the groove laterally; and when fed an equal out-of-phase signal, the cutter modulates vertically.

The width of the stereo groove at the top is 0.001 inch, and at the bottom is 0.0002 inch. This is designed to take a playback stylus with a diameter of 0.0005 or 0.0007 inch. The monophonic groove is 0.0022 inch at the top and 0.00025 inch at the bottom, designed to take a playback stylus of 0.001 inch.

Reproduction

Very few stations today cut their own records. There was a time, before audiotape, when almost all stations had their own

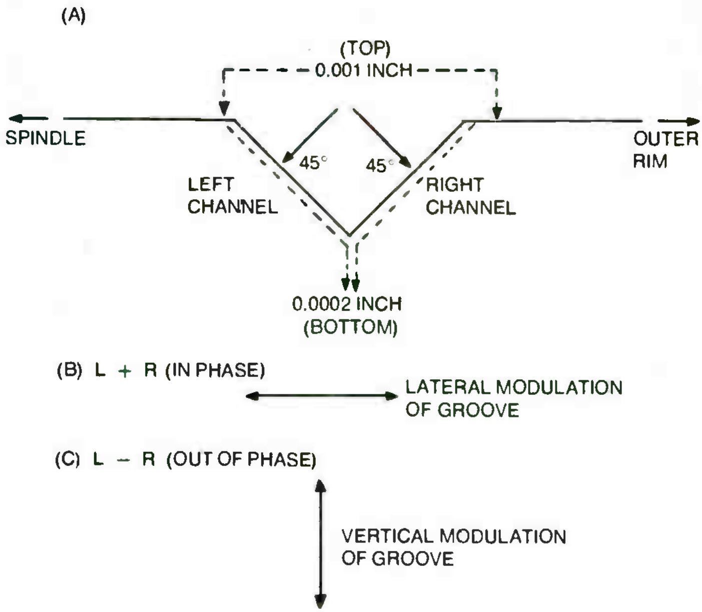


Fig. 5-10. In (A), the NAB groove standards for stereo. In (B), the result of in-or-out-of-phase signals to the cutter head.

disc-recording machines. But with audiotape so convenient, cutting of discs has fallen by the wayside. Today, the station is basically concerned with the playback of prerecorded records, which are really pressings made from a master. Some of these pressings are good, others not so good. Also, the majority of records made today are in stereo, so most of the following discussions will be directed toward stereo equipment, even though a station may be programming in monaural. It is a simple matter to combine stereo channels to obtain a monaural system.

Rumble

Very low frequency noise can be generated by the turntable and its drive mechanism. This is referred to as *rumble*. Mechanical resonance of the table itself can set up an often inaudible mechanical vibration. This vibration travels from the outer rim to the center spindle and couples to the stylus through vibration of the record.

The drive mechanism can become hard, develop flat spots, or be adjusted too tight, and this can set up vibrations. Since the drive is often at the outer rim, these vibrations travel across the table. Some models drive a special rim which has been forged into the table near the spindle area and out of the record playing area. Still other units make use of a bolt drive to soften and isolate noise coupling to the table.

These rumble noises can be annoying to a listener if they are audible. The broadcast audio system today has an extended range that amplifies these very low frequencies, and if they are high enough in amplitude, even though inaudible they can cause intermodulation distortion. This distortion degrades an otherwise good audio system. Special filtering is often incorporated, besides design considerations, to keep the rumble at a very low value. Measurements for rumble are made after the filtering and preamplification. This should be at least down 35 dB on each stereo channel, and preferably lower than that.

Stylus

The modern stylus is a precision-engineered device and is a far cry from the old needle of yesterday. The type of stylus to use will be dictated by the particular cartridge which will use it. Cartridge manufacturers will also make the stylus, but there are other manufacturers who make only replacement styli.

The diamond-tipped stylus is perferred over the sapphire. The diamond is more expensive, but it wears better and has a longer life. For stereo, use either the 0.5 mil or the 0.7 mil stylus, depending upon the equipment and the records the station plays. When only records are used, the 0.5 mil stylus will treat the record grooves more kindly. But if 45 RPM records are intermixed with LP's, then use the 0.7 mil stylus. The grooves in the 45s are not always the best nor hold too close to tolerance. Consequently, the 0.5 mil stylus will drop too deep into the groove, allowing the cartridge to drag along the top of the groove. A few plays in this manner and the distorted top of the groove has a permanent noise problem. Use the larger stylus for this application.

Cartridges

These are well designed units today, especially those for broadcast use. They may be dynamic, variable-reluctance, or ceramic. All of these types have somewhat different characteristics, but they all do an excellent job. All are designed for easy replacement of the stylus.

Replacement of the stylus is usually a simple matter of pulling out the old one and slipping in a new one...no screws or other parts to take apart. But do use the correct stylus with the correct cartridge; they don't interchange. Whenever possible, the station should use the same type of cartridge in all of its turntables, not only in the control room, but in the recording booths as well. Then only one type of replacement stylus need be kept in stock.

Output Connections

At the rear of the stereo cartridge there will be four pin connectors. This allows for a 4-wire output system, providing for both a high and low side of the left and right channels. They usually come with a strap across the low side, which grounds to the cartridge frame; but this can be removed when a 4-wire system is desired. Otherwise, the output is run as a 3-wire, unbalanced system.

Small pushon connectors are provided to attach the tone arm wires to the cartridge. These should be soldered to the wires, but away from the cartridge. After soldering, push them onto the cartridge pins. Heat from soldering can damage the cartridge, so do not solder or heat the pins.

Monaural or Stereo

When a station is in monaural, such as an AM station, the stereo pickup should still be used (Fig. 5-11). There are two ways to combine the stereo to produce monaural. In the first method, strap the output terminals of the left and right channels at the cartridge and feed to a monaural preamplifier. This places the two outputs in parallel and will affect the output impedance of each one, but it can be done in most cases without too much problem. The second method makes use of a stereo preamplifier, and the outputs of the preamplifier are strapped together in parallel. This method maintains the correct impedance load on the cartridge.

Installation

Proper tracking and record wear depend upon several things, and one of these is a level surface. Before making any adjustments, the cabinet itself should be leveled and resting on a solid base. Select a sturdy location or floor section on which

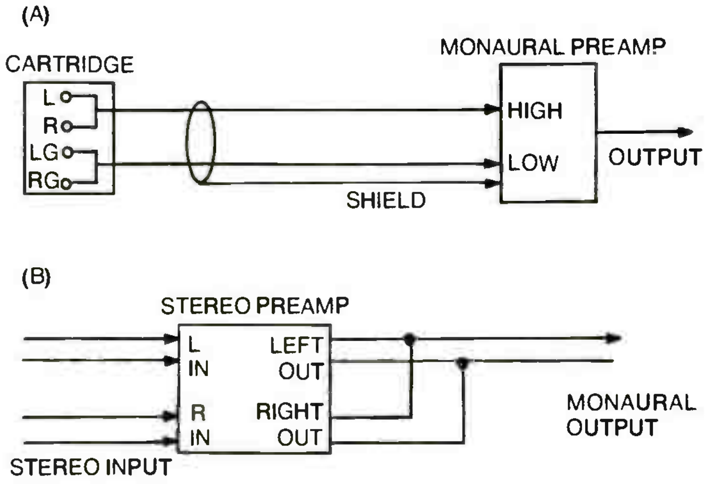


Fig. 5-11. Two methods of obtaining monaural from a stereo cartridge.

to place the cabinet. If the floor is not supported too well, someone walking across it can cause the floor to vibrate and the tone arm to bounce on the record. If necessary, add additional bracing to the floor.

Cabinets designed for broadcast use have four individually adjustable feet. Some level-measuring device is needed. A small carpenter's level will do, but a better one is the type that fits directly on the spindle and has a bubble in liquid, under a window with two crosshairs. Adjust each of the feet until the bubble is directly in the center, where the hairs cross, but make certain that all four feet are solidly on the floor at the same time this occurs. Whatever level device is used, always measure from the top of the turntable rather than the cabinet itself.

Tone Arms

Select a tone arm the same size as the table. These are available in both 12-inch and 16-inch sizes. Most stations use the 12-inch record or less, so the 12-inch arm and table will be sufficient. The 12-inch arm will be too short to work with a 16-inch table.

Before making weight adjustments to the tone arm, install the cartridge in final form on the arm. Use the special small scales designed for this purpose. Adjust the tone arm pressure as stated in the instructions for the stylus and cartridge in use. This will be somewhere between 1.5 and 4 grams. Try to set the weight at the lowest stated value that will track the disc.

Load Impedance and Wiring

Most cartridges are designed to work into a 47K load impedance. On the stereo cartridge, this means that the left and the right channel will each be loaded with a 47K load. The cabling to the preamplifier input should be as short as possible, as the cable capacitance is in parallel with this high impedance, and a long cable will roll off the high-frequency response. Mount the preamplifier in the cabinet itself, but keep it away from the magnetic field of the meter, which will produce hum in the amplifier.

The shield of the leads from the tone arm should be grounded at the preamplifier input only. There should also be a ground lead run from this point to the motor frame. It takes some experimentation to get the best grounding arrangement, and this is especially true when RFI is a problem. Without the proper grounding, there will be a sizzle or hum in the audio.

Signal Levels

Use a good test record as a signal source, such as the NAB or CBS test records. Those records provide a variety of test signals for both monaural and stereo.

Use the cut with the standard level and adjust the preamplifier GAIN control so that the feed to the console allows the console fader to be at 12 o'clock. This usually places the preamplifier GAIN control at about the same location. Ordinarily, there is ample gain in the preamplifier.

Run a set of measurements for response, distortion, and noise, using the test record as a signal source, and measure at the output of the console. The tests then indicates the system performance rather than the turntable performance only. You will also have a good indication of how well the interface to the console was accomplished.

Maintenance of Turntables

Most of the turntable problems are with the stylus. The stylus is a very delicate part of the system, and it is also the greatest wear point. It is subject to the most accidents and abuse. The tip is easily damaged if the tone arm is dropped on the table or cabinet, and it often loses the tip if scooted across the record. The operator needs a delicate touch, or accidents will happen.

Distortion

Inspect the stylus often, especially when all records played on that unit sound distorted (Fig. 5-12). A small pocket microscope is an excellent tool for this purpose. It has a very

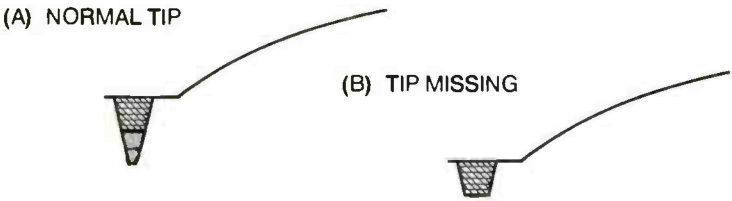


Fig. 5-12. Inspect the stylus with a microscope. If the tip of the stylus is missing, it will cause distorted sound and damage the records.

high power, so it takes some knack getting the tip into focus. This requires that the end of the microscope be almost touching the object, and this shuts out the light. Lay out a white sheet of paper on the desk to reflect plenty of light onto the hand-held stylus. It also gives backlighting and makes the point stand out.

Take a look at the tip. Often the tip is missing and the stylus has been playing records with the blunt stump. This will cause distortion and probable damage to the record grooves. If not missing, the point may be worn down. How much wear can easily be determined by making a comparison with a new tip—under the microscope.

The size of the stylus may be wrong for the type of record. Many of the 45 records, especially those with "top 40" music, have the grooves far overmodulated. Not only are the lands between grooves almost nonexistent in places, but they may be very wavy. This makes it difficult for the tone arm to track properly. The 0.7 mil stylus should be used on these records.

When poor tracking does occur, it may have many causes besides poor grooves. The record may be warped, and this causes the lightweight tone arm to bounce. Such records should be discarded, but unfortunately the operator often starts to tinker with the weight adjustment to make the arm track. The adjustments always end up far too heavy. So check the weight adjustment often to correct for this misoperation before damage occurs.

Record Cleaning

Records will accumulate dust, oil from the hands, and other foreign substances. This will build up on the stylus during play and prevent it from performing properly.

Records can be cleaned with warm water and a mild detergent, then rinsed with clean water and dried with a lint-free cloth. Commercial cleaners are also used, but experiment first, as some of these do not really do the job, and also leave a residue.

There is a small record-cleaning machine that is not too expensive and does a good job. The record is inserted in it, and it automatically spins the record while internal brushes clean out the grooves.

Speed

Speed of record rotation is very important to the reproduced audio. The table should run neither slow nor fast, and it should not waver. Small strobes are available that are placed on the turntable to check its speed. These work best under fluorescent lighting. The test is best done with a record on the turntable and the tone arm down and playing. This will put the normal load on the table. The marks on the strobe should stand still.

The marks will move either forward or backward, depending upon the incorrect speed. If you can't remember which direction is slow or fast, here is a trick you can use to make it definite: Place a finger along side of the turntable and apply a slight pressure, dragging the speed down. Then you can easily determine which way the marks move and whether the table has been running fast or slow.

Poor speed is usually due to problems in the drive mechanism or lubrication of the bearing at the base of the spindle. The drive puck may have hardened or become oily, or the table rim may be oily or gummy. Clean these off with alcohol and make sure the bearing doesn't run dry.

AUDIOTAPE MACHINES

The tape recorder is one of the most basic equipment items, in the control room, and in other areas of the broadcast station. Needless to say, when the tape equipment is inoperative, a severe bottleneck is placed in the normal daily operations.

Tape-Head Area

There are many electromechanical functions in a recorder, and these can cause problems during operation. The most critical section of the recorder, however, is the tape head. All other recorder functions support the tape head function. Many problems in this area not recognized as tape head problems are often blamed on other sections of the recorder. This area deteriorates and goes unnoticed for some time because the loss in performance is gradual. An example is a falloff in audio response. Proper tape head function is very important in both the open-reel and cartridge tape equipment.

Head

The head is a specially designed, properly shielded electromagnet. A coil of wire is wound on a magnetic iron core, which is shaped so that the pole pieces are separated from each other by a very fine gap. The signal current flows through the coil, producing magnetic lines of flux that are basically confined to the iron core. The lines of flux are continuous loops that cross the gap in the pole pieces even though the gap provides a greater resistance to their movement. The flux lines follow the signal current in the coil both in direction and intensity (Fig. 5-13).

Audiotape

The audiotape, with its iron oxide side held tightly across the pole pieces of the head, is pulled along at a constant speed. The iron oxide of the tape bridges the gap between the pole pieces, and this iron has less magnetic resistance than the air in the gap. Consequently, the flux takes the path through the tape. In so doing, the flux magnetizes the iron particles in a pattern that conforms to the flux lines in both direction and strength at any instant. Thus, the iron particles on the tape are magnetized in a pattern which is a replica of the signal current flowing in the head. The pattern is laid down on the tape in a track as the tape is pulled along.

Low Frequencies—For a given input signal, low frequencies magnetize particles more deeply in the tape than high frequencies. This is because the tape speed is constant

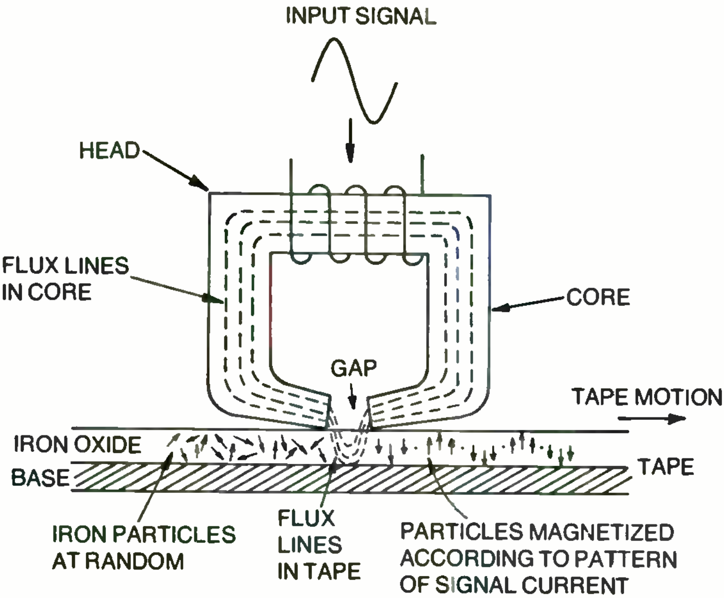


Fig. 5-13. The tape head system in an audiotape machine.

and a low-frequency portion of the tape is subjected to the signal for a longer period of time than high frequencies, and have a chance to penetrate deeper into the iron layer.

Signal Levels—Increasing or decreasing signal current flowing through the head causes a corresponding increase or decrease in magnetization depth. These factors affect the playback level recovered from the tape, because the greater the penetration of the flux into the tape, the stronger the magnetization of the particles, and the greater the recovered playback level.

Playback

During playback, the reverse of the recording process takes place. As the tape is pulled across the pole pieces of the head, the magnetic fields recorded on the tape induce currents in the playback head. The output voltage of the head is a replica of the signal that was recorded on the tape. The stronger the magnetic track on the tape, the greater the output voltage of the head, and thus the greater signal level.

Playback and Record Heads

The heads used for these two purposes have different characteristics. The record head must carry higher currents, and has a lower impedance than the playback head. The playback head usually works into a higher impedance, although there are some machines that are designed to use the same head in both positions. In the usual arrangement, they are different, and when replacing heads, care must be taken not to get the heads in the wrong positions. The results of misplaced heads can be disappointing. A record head used for playback produces a very low output signal.

Equalization

As discussed earlier, low frequencies record deeper into the tape high frequencies. From this it follows that the output of the playback head will vary in the same manner—the high-frequency response falls off. To correct this situation, it is necessary to preequalize the recording signal before it reaches the record head. The high frequencies are preemphasized according to a standard curve. The playback amplifiers use a standard deemphasis curve.

Erasure

A tape that has been recorded can be reused by erasing the recorded information. This is done by applying a strong AC field across the tape, which rearranges the iron particles in a random fashion on the tape. This field may be applied either by an erase head, as used on open-reel machines, or by a bulk eraser as used on cartridge machines. An erase head erases only the information on the section of tape that passes over it, while the bulk eraser erases the entire tape at one time.

How well the tape is erased depends upon how strongly the particles are magnetized and the strength of the erase field. Tapes that have been severely overloaded—that is, very strongly magnetized—will take many passes over the erase head to be completely erased. The portion that is not erased remains on the tape and appears either as crosstalk or background noise. With this in mind, caution should be taken in the use of bulk erasers, which develop strong magnetic fields. The tape should not be in the field at the moment of turnon or turnoff. This causes a magnetizing of the tape by itself that is difficult to erase. Instead, turn on the eraser, then bring the tape into the field. When done take the tape out of the field before turning the eraser off.

Residual Magnetism

There is another important problem in recording that must be overcome. The head is an inductive device and will not allow currents to flow through it in a linear manner. This is due to residual magnetism and the fact that magnetic fields are reluctant to change directions. Thus, as the current begins to flow into the head until it reaches it's maximum in one direction, the field will be established (Fig. 5-14). Now the current reverses itself and goes to the opposite maximum

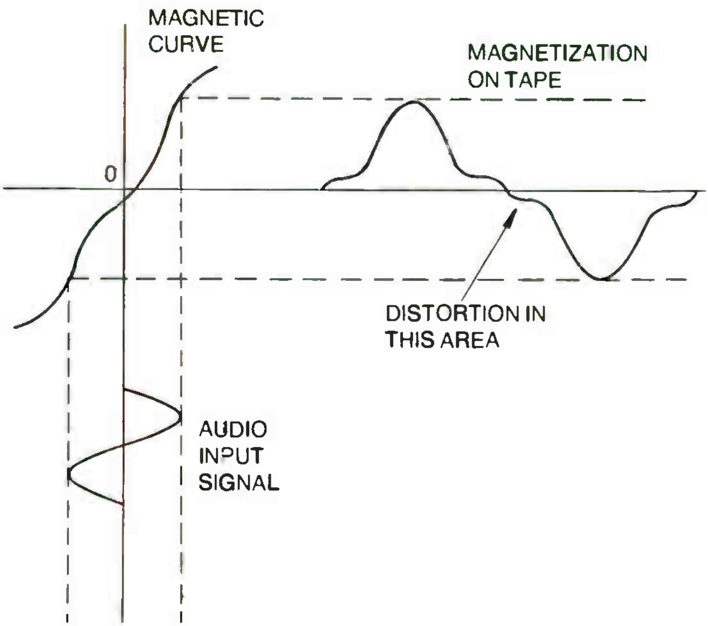


Fig. 5-14. Effects of the magnetic properties of the head and tape cause distortion near the zero-crossing line.

polarity. However, the reluctance of the magnetic field to change, along with the residual magnetism in the core and in the iron oxide on the tape, produces the familiar magnetic curve. This results in the signal current being distorted near the zero-crossing line.

To overcome this distortion, a high-frequency bias is used (Fig. 5-15). The bias is about 75 kHz and several times the amplitude of the signal current. This bias and the signal are mixed together before going to the recording head. The audio signal appears as twin curves riding the peaks of the bias

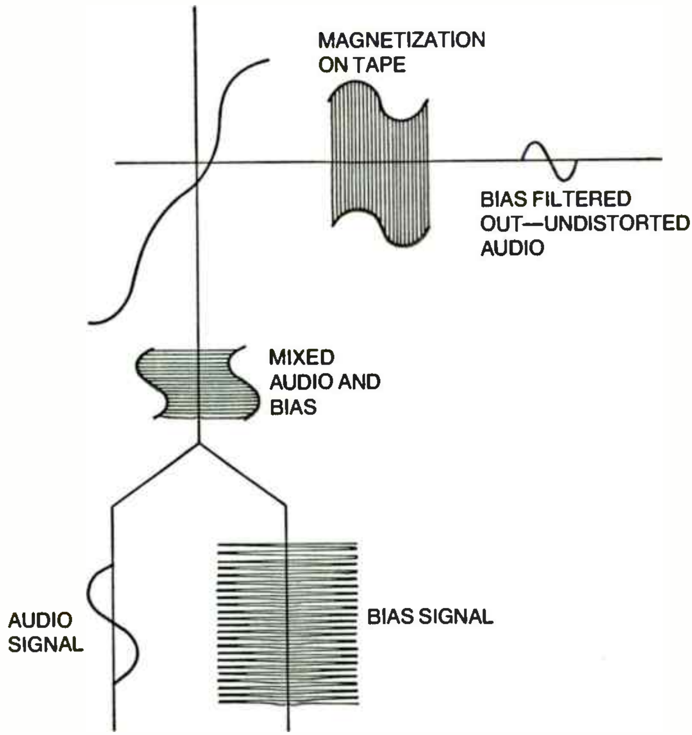


Fig. 5-15. Using bias to lift the signal into the linear area.

signal when viewed on an oscilloscope. During playback, the bias signal is filtered out, leaving the audio curve undistorted since the audio signal was lifted into the linear part of the magnetic curve.

Head Alignment

Head alignment is most important to assure that tapes are compatible from one machine to another, and output levels and frequency response are maintained. The face of the head and the tape must be aligned in their proper relationship. There are at least five requirements that must be met to obtain good alignment. These five positions are shown in Fig. 5-16. These requirements may not be met 100% and the results may still be passable; but the more accurate the settings, the more consistent the quality of the results. Head alignment is always necessary when replacing a head.

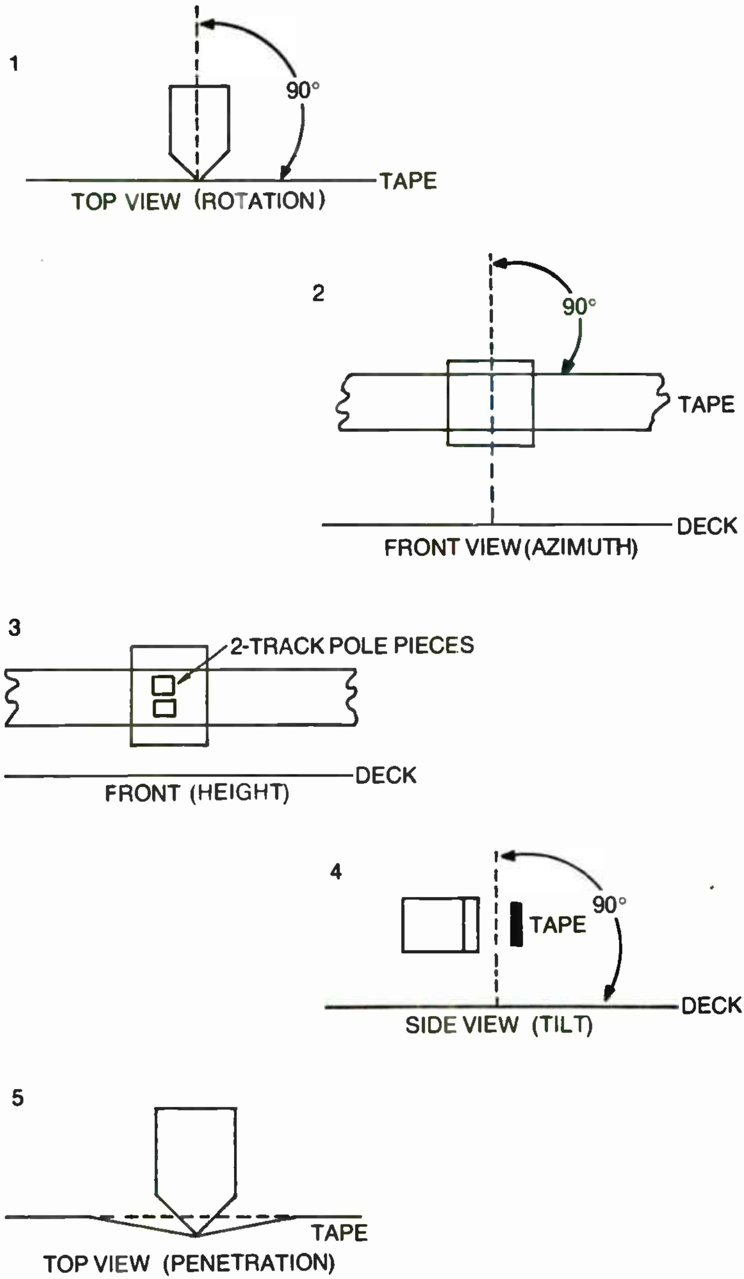


Fig. 5-16. The five conditions of head positioning which must be met in head alignment.

Removal and Replacement

Before removing the old head, note the markings and the positioning of the present head. Try to get the new head into the old position as closely as possible. Then the new head may require only a minimum of adjustment to bring it into full alignment. Some of the manufacturers have gauges and plates available to assist in the correct positioning of the heads. This is particularily true for cartridge equipment. These gauges can put the head into nearly the exact position. But there is always a need for final adjustment to bring the head into full alignment.

Playback Head—Always align the playback head first, while playing a standard NAB head alignment tape. (There is also a standard NAB cartridge-type alignment tape available.) Standard tapes should be handled carefully and stored separately. To prevent stretching, avoid using the fast-winding capabilities, and especially fast stops. Once the playback head is properly aligned with the standard tape, the playback will serve as the standard for the record section and head.

Record Head—Single tones are applied to the record amplifier input while adjusting the record head. Be careful to get the standard alignment tape off the machine before switching into a record mode, or the tape will be ruined. Another precaution concerns the signal levels into the recorder. These should be at least 10 dB below standard program-recording levels, and 15 dB lower is better if noise pickup is low. These lower levels are required because of the equalizer in the recorder, which boosts the high frequencies. If levels are too high going in, the boost causes the head to saturate at high frequencies, and this appears as a flat response—which it is not. In reality, the true response may be far from this indication. The reference level to use is between 200 Hz and 1 kHz. To be consistent, use the same tones that were used on the standard tape. There will be less confusion when this is done, and a better comparison can be made.

Cartridge Alignment

Head alignment in cartridge machines must meet most of the requirements as on open-reel machines, but there are a number of other requirements that must also be met. This is because the tape, guides, and pressure pads are within the cartridge itself. In cartridge alignment, consider these conditions: Pressure pads should be in good shape and press the tape against the head firmly; tape should fall easily and directly into the guides that may be on the head assembly; the cartridge should allow the head to penetrate into the tape deeply enough (check any depth adjustment that may be provided); the keyhole in the base of the cartridge should allow the pinch roller shaft to pop through without catching or pulling the cartridge to one side or holding the roller off the drive shaft (the cartridge should not touch the drive shaft); and side guides must be set to allow the cartridge to move directly into the head assembly. All of these conditions can be seen by careful observation and adjustments made accordingly.

On the Bench

It is often more convenient to take the machine to the workbench to make these alignments, provided that it's unnecessary to make many haywire hookups. Make up cables ahead of time that will fit the input and output plugs of your machines. These cables should also provide for the correct impedance matching, or at least allow for simply adding terminating resistors. Keep these cables along with other maintenance cables for future use.

False Indications

High input levels to the recorder can "ring" equalizers so that they oscillate, giving rise to spurious frequencies. The output meter can indicate these spurious signals rather than the input signal. Quite often these spurious tones will be lower in frequency than the input signal tone. If you have the output up on earphones or a loudspeaker, you can hear that the tone is wrong. Reset the input levels below the point where this can happen.

Worn Heads

The iron oxide on the tape is very abrasive and wears down the heads, and after much use, a groove or rut will be worn on the face of the head. These create ridges at the edge of the groove. Tape may fall so that its edge is riding atop this ridge and out of contact with the pole pieces of the head. The result is a pressure problem, and the output from that side of the tape can be low or nonexistent. On a full-track machine, this may not show up as a serious problem; but on a multitrack head, it produces serious problems. For example, on a stereo-plus-cue-track tape, the cue track is at the bottom edge of the tape. If it rides on top of a groove and has low output, the cue and stop tones on cartridge tapes are low and the machine will not operate properly.

Besides the erratic behavior of the signal from a worn head, the amount of wear can often be detected by either observation or feel. Shine light across the head. If it is worn, the light shows up the edges of the wear spot. Another method is to run your fingernail lightly across the face of the head. You can feel a groove on a worn head.

Clogging

When the head wears, it opens the head gap. Besides causing a falloff in high-frequency response, this also causes oxide from the tape to lodge in the gap and short it out magnetically. Shorting out the gap causes the output voltage to drop off to practically nothing. Heads in this condition should be replaced, but until they are, they must be cleaned often. If the output drops off while the machine is in operation, an emergency measure can be used. Squirt a head-cleaning solvent or alcohol onto the head while it is running. The movement of the tape and the fluid cleans out the gap.

Pressure Pads

Pressure pads must be kept in good condition or the machine will operate erratically, usually with weak output signals. All machines do not require pressure pads—it depends upon the head and the way in which the machine wraps the tape onto the face of the head. Cartridge machines have pads, and these should be kept in good condition. The pad maintains a constant pressure of the tape on the face of the head; but if it is worn or missing, the tape will flutter past the head or change pressure intermittently. All of these produce poor output results.

Capstan and Pinch Roller

Tape speed across the heads is determined by the capstan speed and the pressure of the pinch roller. The rubber in the rollers can become glazed from lubricant, or hardened and glazed with age. In all of these conditions, the roller can slip and cause speed variations. These show up as 'wows" in the program material. The rubber roller can be cleaned with alcohol or other solvent. If it becomes hardened, it must be replaced.

Capstan Motor

The motor often develops dry or bad bearings, and defects in the windings. With the power shut off, the motor or flywheel can be spun by hand. This should spin freely and coast for some time, and there should be no noise. One that is stiff or stops immediately after spinning needs to be taken out and reoiled or have the bearings replaced, if possible. If not, then the motor itself needs to be replaced. Many motor manufacturers have an exchange arrangement for capstan drive motors.

Bias Adjustment

The bias affects the output level and high-frequency response. The best way to adjust this, if metering is possible, is to record a high-frequency tone and then adjust the bias for the highest output level on playback. Playback must be observed while recording. Improper bias can produce some curious results, even showing up irregularities in brand new tape.

Chapter 6

Peripherals

Although the control room generates the bulk of the station's programming, there are many program segments gathered and prepared outside the control room. Besides the programming sources, there are auxiliary functions performed which either contribute to programming indirectly or facilitate the station's operation. In this chapter, we concentrate on newsrooms, recording booths, teleprinters, and house monitoring.

NEWSROOM

News-gathering operations in today's radio station are often hectic, fast moving, and require many electronic aids. The reporter out on the beat carries along an array of electronic aids. The advent of solid-state equipment, its corresponding reduction in size and weight, and its adaptability to battery operation, have enhanced portability to a high degree. For the first time, perhaps, since the early beginnings of radio, news gathering is able to make a greater use of broadcasting's own tools of the trade—electronic gear.

Whenever called upon to design or arrange equipment for use by the news department, always follow this basic concept—keep it simple, as simple as possible while still getting the job done. Remember that nontechnical people may operate the equipment. Complicated equipment arrangements that only engineers can operate will, when placed in the news department, probably fail, or at least fall far short of expectations. This is not intended to downgrade newsmen. On the contrary, news gathering is demanding work, and the electronic equipment must *assist* it, not impede it. During an interview, for example, the reporter must concentrate on developing pointed, probing questions, and listening carefully for shaded meanings in the answers given. He cannot also be trying to operate complicated equipment at the same time.

What Is Simple?

In this case, simple means ease of operation. Design and arrange equipment in this manner: cable plugs that can only go into a jack one way (color coding is helpful); simple switching that operates in a left-to-right fashion; switches that have straight on—off operation; functions all labeled clearly; on/off and nonlocking switches that must be pressed to operate. Perhaps these are rudimentary conditions, but they have a better chance of performing as intended. Remember that the newsman is concentrating on his story, not the operation.

Many recordings are made in the newsroom that end up on open-reel and cartridge tape. Consequently, there should be both open-reel and cartridge tape recorders in the newsroom. Since the product from these machines end up on the station's regular tape machines, the newsroom machines should be the same quality as the regular machines, and completely compatible.

Switching

Many tapes from cassettes and portable recorders are brought in for editing and dubbing onto larger machines, and other news sources feed into the newsroom. It is necessary to provide some *simple* switching arrangement so that all these sources can be edited and blended together into the final form desired. A small production console can be used, and some stations provide this. But a simple switching arrangement (Fig. 6-1) can be built that allow these sources to be wired in permanently, and only switching is necessary to pick up the desired source. In effect, this switcher will customize the arrangement for that operation.

When designing a switcher, keep in mind the output impedances of the various sources and try to maintain these as

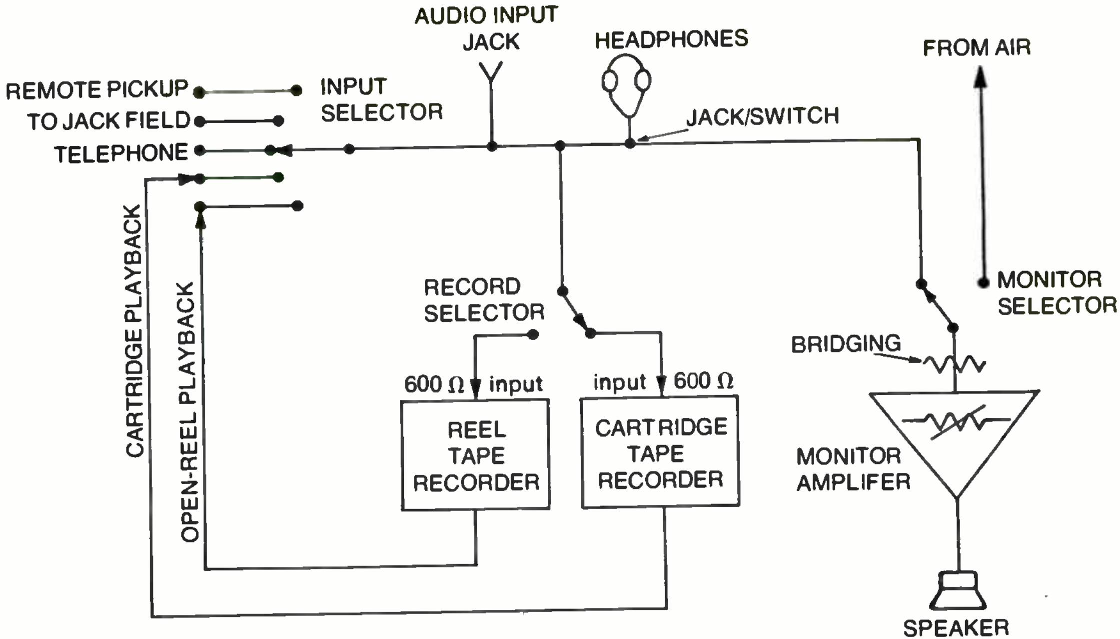


Fig. 6-1. Simple switching arrangement that can be built for the newsroom.

much as possible. Remember that when you simply parallel a couple of sources, you will affect the impedances and signal levels. If necessary, use bridging connections, and even use back-loading resistors on some of the switch terminals. Also, use pads to keep levels within reason.

Input Selection—Allow for the selection of several program sources, which can be permanently wired to the selector switch; for example, the telephone, remote pickup receiver, output of the cartridge tape machine, and output of the open-reel tape machine. Have one position that wires to a jack in the regular station jack field. This allows using any source in the station to feed to the newsroom. Also add an auxiliary jack so that small, portable equipment can be plugged into the switcher.

Recorder Selector—The output switch should be able to select the record input of either the open-reel recorder or the cartridge recorder. This allows for recording on either one. Between the switch and the recorders, an AGC amplifier can be used to good advantage in maintaining levels during recording.

Monitoring

There should be both earphone and loudspeaker monitoring. Add a small speaker amplifier and GAIN control for this purpose. During times that live recording is being done, the speaker can't be turned up, so earphones must be used. The earphone can be connected directly to the input selector bus or after the AGC. The earphones should be ahead of the monitor amplifier. A switch can be used to turn off the amplifier, or the GAIN control can turn it down. The earphone switch can be arranged so that it will automatically switch off the speaker when the plug is inserted into the jack.

Telephone Recording

Many interviews can be made over the telephone and recorded for use on the air. There are different ways this can be accomplished. In the direct method (Fig. 6-2), the recorder is connected directly to the phone line, but there should be 0.1 μF series capacitors in each side of the line for isolation of DC voltages. Use a 600-ohm transformer for other isolation.

Telephone recordings are not always the best, particularly when there is a poor line with low levels. When gains are

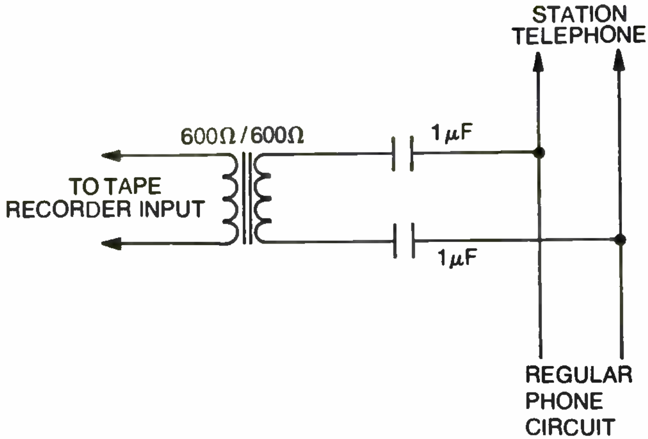


Fig. 6-2. A simple, direct connection can be made to regular telephone circuit, but use isolation.

turned up background noises increase, and the recording is very poor. An AGC amplifier can be of some value in leveling out the signals. In almost all cases, the local voice will be much stronger than that from the other end of the line.

The telephone company can lease a connection device that has an amplifier plus an AGC unit in it. I have had poor experience with these. They have regular AGC amplifiers that cause serious "breathing" or "pumping" effects on some recordings.

Whenever a telephone conversation is to be recorded or broadcast live, the person on the other end must be informed of this, and permission must be given. The rules are very strict about this. Anytime a phone conversation is to be recorded or broadcast live, first inform the party and get an okay—then turn on the recorder or put him on the air. (Stations have been fined for airing the initial "hello" of a conversation without first having informed the party he would be on the air.) There are exceptions, of course, such as your own reporter calling in a news story that he knows is supposed to be recorded or put on the air live. But don't become careless in this matter, or the station can get into hot water with the FCC and may face a lawsuit from the other party.

Other Monitoring

To keep in touch with activities occurring in the community, most stations monitor the police and fire communications channels. This may be done with a scanner-type receiver, or each channel may be monitored with a single crystal-tuned receiver. The scanner can only lock onto and monitor one channel at a time, but individual receivers can monitor all channels all the time. Individual receivers provide more information, as there may be events occurring on several channels at the same time.

Speakers

Live recording may be going on in the newsroom, so speakers can't be blaring. With a single-scanner, it can be turned down; but with several individual receivers, it is a chore to turn down all the speakers at one time. And if they are turned down, they may not get turned back up again.

A simple switching arrangement can be made that will switch off all the speakers at one time (Fig. 6-3). Run each

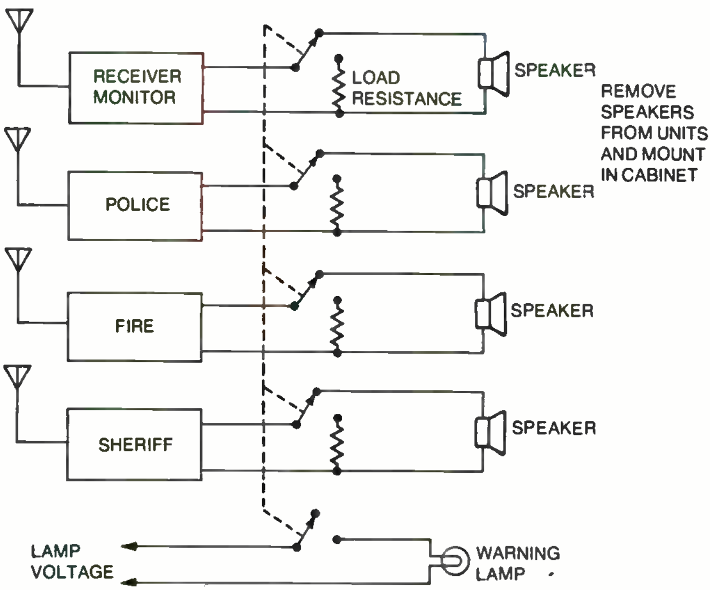


Fig. 6-3. A single multicontact or ganged switch can mute all the speakers at once. Lamp warns that the speakers are muted.

receiver speaker lead through a multicontact ganged switch on the speaker box. One turn of the switch turns off all the speakers at the same time. To make sure the speakers get turned back on, use a set of contacts on the switch to turn on a red pilot lamp to warn that the speakers are off.

Police and fire department channels are private communication channels. The Communications Act forbids use of their information in any way. When a station listens in on these channels for news events or news tips, it is making use of the information. This is not permitted *unless* the station has permission to do so. Therefore, the station must obtain permission from someone in the particular agency who has authority to grant permission, for example, the chief of police. Get these permissions in writing and keep them on file at the station. And if the individual changes, get the permission renewed by his replacement.

Maintenance

The majority of problems with news equipment are operator errors. Problems are also caused by dirty equipment, damaged plugs, cords, batteries, etc. There can be major problems in the equipment from time to time, but look for the simple problems first.

Operator Errors

Operator error is the first thing to look for when called in to correct technical problems in news equipment. Try to determine if the operation was done correctly. If the problem is an operator error and it is obvious the newsman does not know how to operate the particular equipment, explain its operation in simple, nontechnical terms.

Dirty Equipment

A lot of news work is done on tape, so the heads, pinch rollers, and drive shafts need cleaning often to remove oxide buildup and the bits and pieces of tape that accumulate. Clean the head with alcohol on a cotton-tipped swab. Clean out any bits of tape. Sometimes these wrap around the capstan drive shaft or the pinch roller causing a change in tape speed. Also look over any pressure pads that might need replacing.

A regular routine should be set up to clean the equipment. If the news people do this, fine; but even then, check from time to time that it is getting done. And don't forget heads on those cassette machines—they need cleaning too.

Cables and Plugs

Cables and plugs get a lot of use and abuse. Many times cables will fall on the floor and get stepped on. Look for broken leads and shields in the cables, bent plugs, or plugs that are falling apart. Some of these are molded types, and unless a replacement plug can be obtained, the whole cable will have to be replaced.

Microphones

Microphones for outside use must be rugged, for they take a lot of abuse. Unfortunately, much of this small equipment is intended for home use and not commercial use. These are often dropped on the floor or the concrete pavement. In many cases, it is cheaper to replace the whole mike rather than try to get it repaired. The fault may be minor, and if it can be fixed locally, go ahead. Small capacitor mikes used with cassette recorders have a separate battery that must be replaced occasionally.

Batteries

One of the big problems with portable equipment are the batteries. Instruction booklets that come with the instrument give the estimated life of batteries. This should be a reasonable estimate. Unfortunately, unless some type of log of the hours in use has been kept (hours add up quickly), the batteries may go dead right in the middle of an interview. Batteries should always be checked out before use. When possible, try to use rechargeable batteries.

Memory

Certain rechargeable batteries, such as nickel—cadmium, develop a "memory" if it is not used to full capacity at some regular interval. If only a small part of the capacity is used each day and then it's recharged, the battery will "remember" this small capacity, and if called upon for full design capacity, it my run down when it reaches the capacity it has become accustomed to. This can't be reversed, and the battery must be replaced.

Batteries should always be recharged after use, but set up some schedule to run the equipment on test. Run it until the battery is all the way down; then recharge it. Caution: Never leave fully discharged batteries on the shelf for very long. Only put fully charged batteries on the shelf.

Chargers

Keeping batteries charged depends upon the use of chargers. Small chargers are as delicate as some portable equipment. That is, the plugs and cables are easily damaged or pulled apart. When batteries fail to charge, check out the charger by measuring the voltage at the output plug. If the voltage is there in the correct amount, there are problems in the equipment or battery. If the voltage is missing, check the fuse if it has one. (Some small fuses are hard to come by and must be ordered.) If you have problems, change the fuse holder to take one of the larger, standard fuses. If it won't fit inside the case, use one of the line holders. Inside the case, short across the terminals so as to complete the circuit.

If the batteries still don't charge, check the socket pins, and especially the battery terminals and contact terminals inside the unit. These often corrode and develop high resistance.

Bulk Eraser

Most of the small open-reel portable recorders are half-track machines. Tapes are brought back into the newsroom for editing, and the tape is placed on the large machine. Of course, small machines can be used as a playback.

The tape may go directly to the control room for play. Most AM stations use full-track machines. So the other track of this tape must be clean. If there is recorded material on it, the full-track will play both tracks at the same time, and the tape can't be used.

Before going out on assignment, bulk-erase the tapes. In this way, the track will be clean, but the reporter must only record on the tape in one direction.

RECORDING BOOTH

Another area that contributes much to the station's programming is the recording booth. With so much program material on audio tape, a recording booth becomes an asset. Not only will the booth free the control room equipment, but it will allow the announcer to record announcements and other program material in a more relaxed atmosphere. If the AM station also operates a sister FM station that is fully automated, the recording booth becomes a necessity. For tape recording the booth should become the quality control center of the station.

Monaural or Stereo

The equipment used in the booth must match the type of service the station is supplying. If monaural, then only monaural equipment is needed, and if stereo, then stereo equipment must be used. A common combination is the monaural AM station and a sister station that is stereo. In this case, the booth should be made to do double duty. That is, use stereo equipment, but also have a monaural cartridge tape recorder.

More than one booth may be required if there is a great amount of recording. When additional booths are set up, they should all be made identical; but this is optional. One can be a straight monaural booth and the other stereo if desired.

Identical Booths

There are advantages to making all booths identical in equipment, layout, and functioning. This allows any recording in any of the booths and thus makes scheduling easier. Announcers can work any of the booths, as all the controls and equipment will be in the same configuration and in the same places.

There are also maintenance advantages. When one booth is down, it is easy to compare the faulty equipment with that which is working properly. This makes troubleshooting easier and bypasses some of the procedures. If one booth must be taken out of service, then either monaural or stereo recording can be done in the other booth. And there will be fewer spare parts required.

Basic Equipment

There are certain basic equipment items any booth should have (Fig. 6-4), and any additional needs can be met by adding specific equipment to fill those needs.

Cartridge Recorders—There should be one master cartridge tape recorder, and in a double-duty booth one should be monaural and one stereo. If the station uses the auxiliary switching tones, then the recorders should be equipped for these additional features.

Open-Reel Recorders—There should be at least one open-reel recorder, and if stereo recordings are done, then this should be double-track stereo. It would be well if this could also play back 4-track stereo. This recorder can be used for

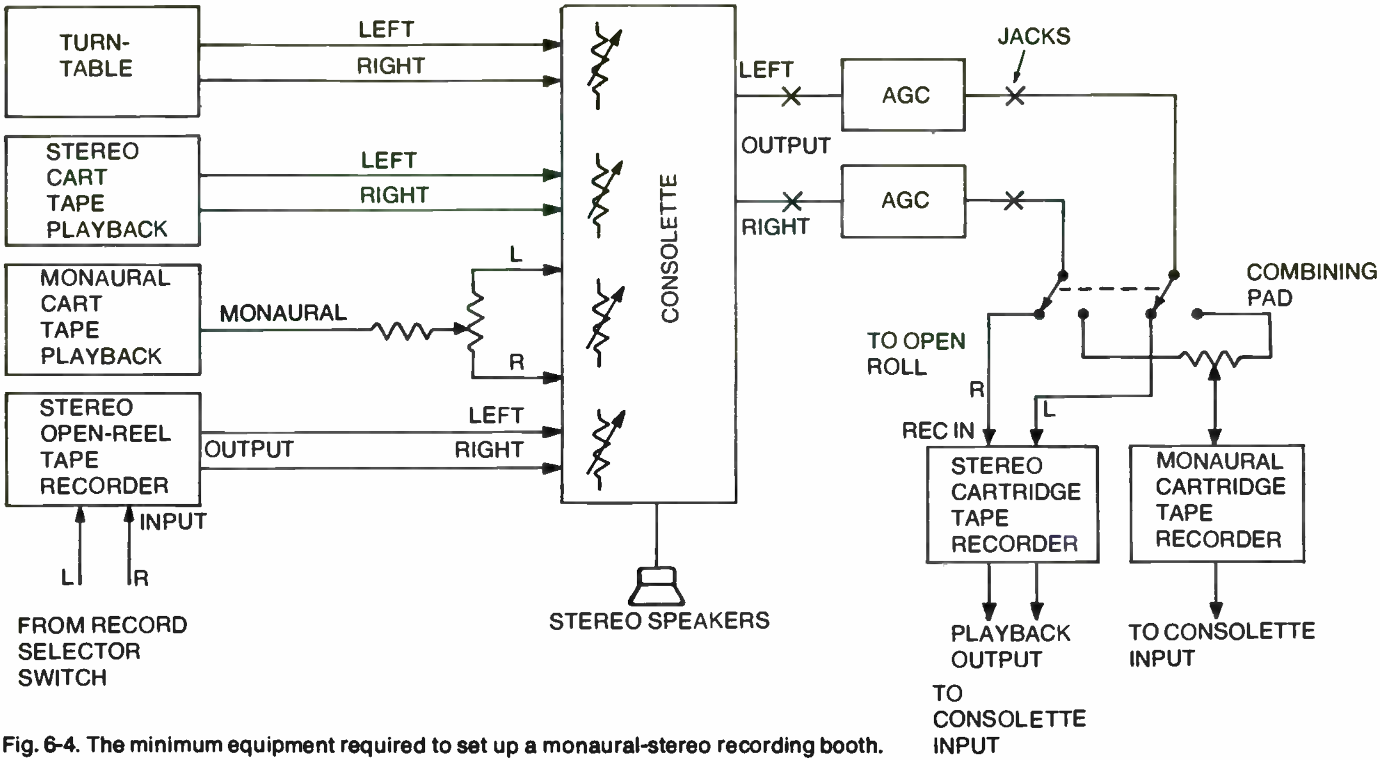


Fig. 6-4. The minimum equipment required to set up a monaural-stereo recording booth.

monaural. When doing so, feed both the left and right channels together. The resulting tape can play back on the control room full-track machines. If there is much dubbing done, then a second open-reel machine can be advantageous. These machines should be set up to act both as recorders and playback machines.

Consolette—There may be a need to do switching, mixing, and blending in the production of spots and certain other programming. A small production-type consolette should be provided. One of the larger control room-type consoles can be used, but these provide far more capacity than is really needed in the booth. Most of their features will not be used and are thus wasted.

Some production consolettes come as a package unit, that is, with a desk or table, integral monitor amplifiers, and turntables. These usually serve the purpose well and can save buying all the components and putting it all together.

Don't expect to get the same rugged quality in these small units as in the large consoles. Technically they are okay, but mechanically they leave much to be desired. The quality of components is not as good nor as lasting. For example, faders are often simple carbon or wirewound pots rather than step attenuators. And the equipment doesn't hold up as well. Expect to spend more time correcting problems here than in the large consoles.

Turntables—There should be at least one turntable in the booth. The output may be either stereo or monaural, but the cartridge should be stereo. The stylus size depends upon the records played—if only LP's, then use the 0.5 mil diamond. But don't skimp on the turntable. The turntable should be of the same quality as the regular units in the control room.

Cartridge Playback—There should be at least one monaural and one stereo playback machine for dubbing purposes. This, too, should be of the same quality as the master machines and preferably of the same manufacture.

AGC Amplifier—Following the consolette, an AGC amplifier or a combination AGC–peak limiter should be used. This will be of advantage in controlling signal levels and will prevent overmodulating the tape. In stereo, two identical units should be used for the left and right channels. Strap the control voltages together so that the units work as a single unit. By operating them in this manner, the original ratios of the left and right channels will be maintained.

Installation

Treat the booth installation just as you did the control room. Get a good, heavy ground connection to the building ground, and run a controlled shield ground on the cables. When wiring up small consolettes, expect to run into some other arrangements than with big equipment.

Terminal Boards—One of the first problems will be the audio terminal boards. These may be simple strip units with screws, and they may be mounted far inside the unit so that the outside cabling must run all the way into the equipment, rather than at a terminal block at the rear. When running the cabling inside the unit, try to follow the regular cabling routes. Avoid running high-level cables near low-level circuits, or low-level cables near high-level circuits.

Jacks—When possible, bring the outputs of the consolette to a pair of jacks on the station's regular jack field. If AGC amplifiers are used, bring their wiring to the jack field also. Should the amplifiers fail, they can easily be bypassed with a pair of patch cords. Jacks also provide an outlet for the booth to the rest of the station equipment. There may be times when the booth can operate as a subcontrol room, or even as the control room in an emergency. And in cases of an automated FM station, the booth can be used to go live if the automation fails or it is desired to remove the booth from programming for major maintenance.

Input Jack—Try to provide at least one of the inputs on the consolette as an external input by running this to the jack field. This will allow patching of any of the station's other equipment into the booth for use when needed, and it can serve such uses as recording from the telephone. A single jack used in this manner can expand the booth's flexibility considerably.

Standards

The master recorders should be the quality control standards for the station tape-recording facilities. The standard should be NAB standards, so that your standards will be compatible with industry standards.

For open-reel tape, use a NAB standard alignment tape to optimize the machine. Make sure this is the latest standard, as there have been changes in the past. These are full-track tapes.

Standard cartridge alignment tapes are available from NAB. There is only a monaural test tape. While work has been done toward developing a stereo test tape, as of now there is not one available. This monaural test tape has the same track configuration as regular cartridges. That is, it is not full-track.

The monaural test tapes can align the stereo machines. On the open-reel machine, since it is full-track, both tracks will play; but there is no way to actually check out the right channel head in the stereo cartridge machine. The nearest you can come is to feed the left head into the right audio channel. This allows tweaking up the equalizer, but it is being done against the left head, not the right head. When a monaural test tape is played on a stereo machine, there is an apparent rise in the low-frequency response (below 100 Hz) of 3 to 4 dB. This is a normal condition, so don't try to level out that tilt in the response. When a stereo tape is played, the response will be normal.

Some equipment manufacturers have developed their own stereo cartridge test tapes. These can be used if desired. In effect, your stereo tape standards are set to those tapes, but this is not necessarily an industry standard.

Local Standards

Once the master recorders have been optimized, make a number of different tapes that will be used for a variety of station tape standards, the first of which should be a *level set* tape.

Use the same tone as was used for reference on the NAB cartridge, or select your own somewhere in the range of 400 Hz to 1 kHz. Feed the tone into both channels of the consolette and set the fader so both meters read 0 dB. At this point you may discover the two meters on the consolette do not agree. Check with your standard test meter at the output of each channel (properly terminated) to see if they actually are different, or if it is the meters. In most cases, it will be the meters.

Adjust the recorder levels so that each one reads 0 dB, and then lock these controls or remove the knobs. These should not be regular operational controls. Any other adjustments for production should be done on the faders. Select a new blank cartridge (if possible) and run it through one time to settle the tape. Erase the tape to make sure it is clean. Then make the recording. First feed the left channel for awhile, then the right channel, and then both channels. Add announcements if desired, but don't stop the tape. The cartridge should be at least 2 to 3 minutes' running time.

When the recording is finished, play it back on the master recorder. Set its output meters to read 0 dB and lock these controls. You now have a basis upon which to check other cartridges in the future.

Make up a monaural tape in the same way, except use the monaural recorder. Be sure to properly label these tapes and store them with other test tapes.

Other Test Tapes

Once the equipment has been set up properly and the level tapes have been made, go ahead and make other test tapes that will help in the setup and test of station equipment. For example, an *auxiliary tone* test tape can be made at this time. Leave the audio channels blank and use only the auxiliary tones of 150 Hz and 8 kHz. If using two tones, set up some pattern in the way they are applied. Space the test bursts about five seconds apart. This will allow the circuits in the unit under test to settle down after being activated. If the equipment is set up for a variable-length auxiliary tone pulse, record several different lengths—those that will have particular application at the station. Label the tape; if special information is necessary, attach this to the top of the cartridge.

If you use a logging system that makes use of tone pulses on the cue track of the tape, make up a test of these. Try to get a variety of combinations that will put the logger through its paces. And make sure to place a label on top of the cartridge showing the numbers and the sequence that was recorded.

These tapes, by the way, not only will help in setting up adjustments on cartridge machines, but they can be used to measure the actual signal levels the machines put out.

Playback Comparison

When there are problems in station recording and some question is raised about a tape, the tape should be taken back to the master recorder and played on that machine. If the tape plays all right, there is something wrong with the station machine. If it doesn't, then it is probably the tape that's bad. There is a possibility, however, that something has happened to the master machine and it isn't recording properly. If there are identical booths, play the tape on the other master for a check. If there is no other booth, make another short recording on the master and try it. If it plays okay, the original tape is definitely defective.

Heads

When head replacement is necessary on the master machines, do this very carefully. Remember, these are the *masters*. Be careful not to get the record and playback heads interchanged, and replace them with the same quality and type of head that was taken out. Use premium heads. Be careful that the wiring to the heads isn't interchanged. If the wires are interchanged, phasing problems may occur. Always be conscious of the fact that these are the machines that set station standards, and make all the adjustments accordingly.

Track Identification

For heads used on broadcast recorders, the track placement is as shown in Fig. 6-5.

Head for Monaural Cartridge Tape—The program track is the one farthest away from the deck; the cue track is next to the deck.

Three-Track Stereo Cartridge Tape—The left channel is farthest away from the deck, the right channel is the center one, and the cue track is next to the deck.

Two-Track Open-Reel Stereo—The left channel is farthest away from the deck; the right channel is next to the deck.

Phasing

When changing stereo heads, there are two ways in which the phasing can be affected (Fig. 6-6). In the first case, the wiring is interchanged to the left and right channels so that the channels are reversed. In the second case, the high and low side of *one* of the heads is reversed. This will place that channel out of phase with the other channel, and when combined in a monaural system, the signals will cause cancellation and low levels.

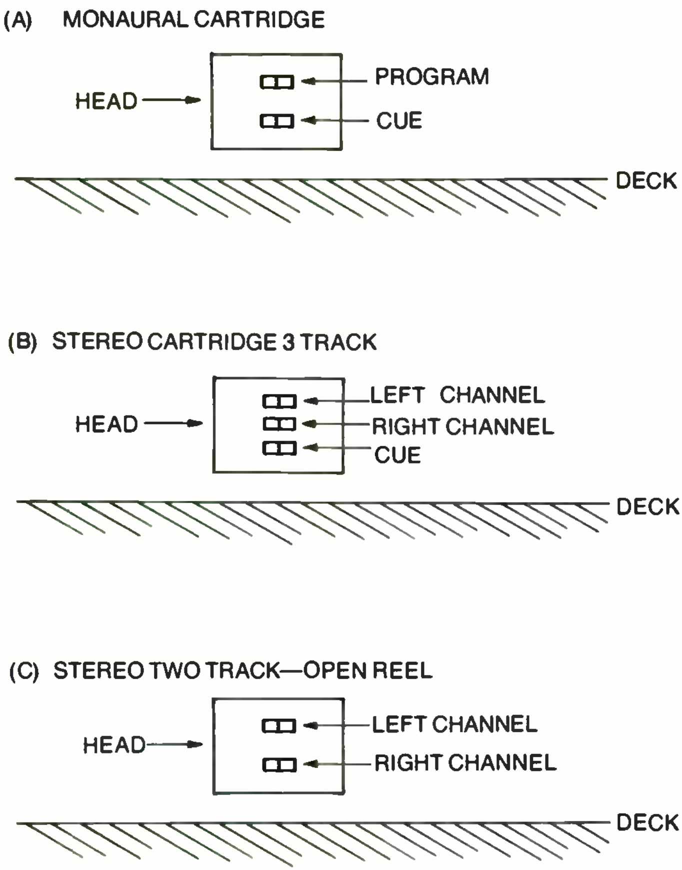


Fig. 6-5. Tape track identification on the heads.

Phasing is very important. Before taking the wiring off the heads, make notations of the wiring and color coding. Also, make sure the high and the low side remain as they were before removing, even though they may have been wrong in the first place—that is, both wires on each track were reversed. This should have been caught on initial setup, but to change after many tapes have been made could create problems. This is particularily true of the cue head. If the shape of the pulse is such that the leading edge is very steep (auxiliary tone) the cue circuit in some machines can interpret this as a cue tone and stop. So replace the wires on the heads just the way they came off.

Cartridges

Many poor recordings or failures in the system can be traced to negligence on the part of the announcer in not recognizing defective cartridges before they are recorded or failure to listen to the cartridge after the recording was made. A simple visual inspection of the cartridge will often detect faults such as wrinkled or worn tape, missing or defective pressure pads, a broken case, or missing parts. When a defective cartridge is recorded and fed to the regular system, problems are brewing. Expect to get a maintenance call that something is wrong with some of the program machines. Check the cartridge as a first step. When it is obviously defective—for example, in case of missing pressure pads—have

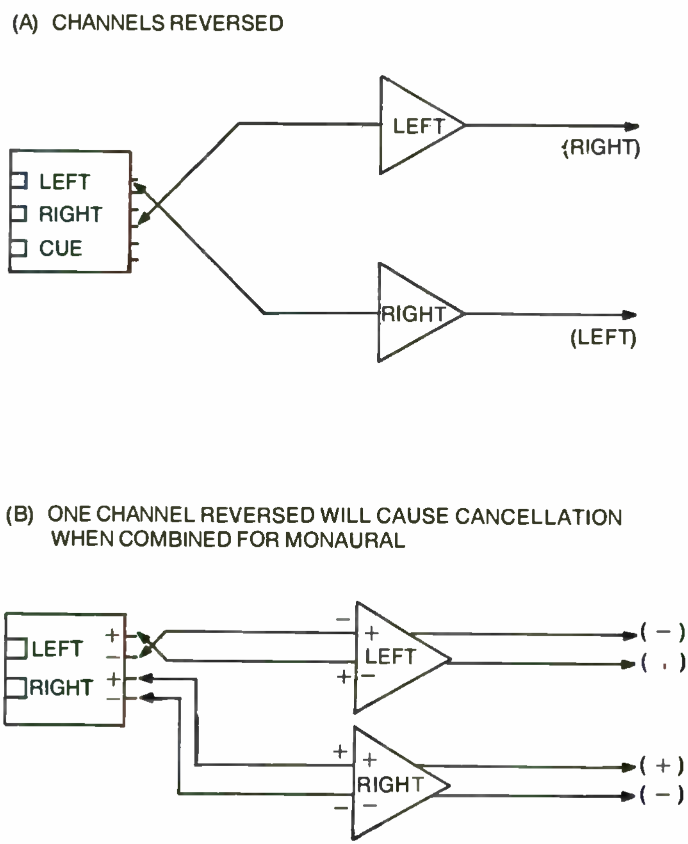


Fig. 6-6. Two different ways phasing can be incorrect in stereo.

a new spot recorded and take that cartridge out for repairs. Even adding pads will not help the poor recording that is already on the tape.

If the cartridge doesn't have any obvious defects, try it on the master machine or another regular machine. If it plays poorly on more than one machine, there is more than likely a cartridge problem or a bad recording. At least it is not the regular machine at fault. Make a new, short recording on the same master machine for comparison. Many problems could be eliminated, fewer spots lost, and tempers saved if the announcer would audition the tape after it is recorded. This should detect distorted audio, low signal levels, etc., before the cartridge is sent into regular program channels.

TELEPRINTERS

In the newsroom of every radio station, there are one or two teleprinters in operation throughout the day. One of these receives news from one of the news wire services, and if there is a second one, it receives weather information from the U. S. Weather Service. Just how involved the engineer becomes with these machines depends upon the station and what arrangements have been made. The news machine is leased and the service most likely done on it by some outside service company or the telephone company. The weather machine may be station owned and serviced, or it may be leased and serviced by an outside concern. If you do get to work with these units, you are involved with a different technology than broadcasting. This technology has its own way of doing things, as well as its own language.

Printer

Generally found at the station are receive-only units (RO), which do not have a keyboard. If a unit needs to send information, it must have a keyboard. Keyboards on sending units are not the same in character and symbol lineup as ordinary typewriters, nor are they the same on all teleprinters. The keyboard will correspond to the code in use, and there are several codes. The receive printer must also be arranged for the code in use on the circuit. A printer *can* work on all the usual codes but only works on the code it is adjusted for. That is, the unit must be adjusted for *one* of the regular codes; this is ordinarily done at the factory, although it can be done in the field.

Mechanical and Solid-State

Today there are many models with a varying degree of solid-state electronics incorporated in them. There are still those that are largely mechanical, and on the other end are those that are very high in electronics. The Extel Corporation printers are 80% electronic, and this is solid-state.

Input Circuitry

The printers normally found in the broadcast station for news and weather use have a DC input circuit. The DC must be supplied from the signal circuit itself. Look for a tag or sticker on the machine which will give this input current limit. The current should not exceed this limit, or the machine will be overloaded and develop problems, including burnout of some of the input circuitry.

Each printer is preset for a particular code, and this is ordinarily done at the factory; but the factory cannot set a printer to a code unless it has the information. If you are involved in ordering a machine, determine the code that will be used and supply the information to the factory.

Signal

The signal is a DC on-and-off type or pulse train. This is what the printer itself accepts. When the pulse is on (positive), this is called a *mark*; and when the pulse goes off (zero), this is called a *space*. The width of the pulses do not vary, but remain constant. There is no gap between pulses; these pulses line up side by side. Any gaps that appear are *spaces* and have a definite meaning in the train. For example, there may be several mark pulses in tandem. This would appear as a single wide pulse whose width is equivalent to the number of mark pulses involved. The number is what is important, not the apparent width.

Codes

The present codes are either updates or outgrowths of the old telegraph codes, and there are several of them. One of the more common codes used for communications is the ASCII. These letters are abbreviations for American Standard Code for Information Interchange. This code can accommodate 128 characters and is thus more flexible than the Baudot code. ASCII is an 8-level code, which means that there are seven pulses which define the character in the pulse train. Actually, there are 11 pulses in a group for each character sent. There will always be a space pulse to set up the machine to receive the pulse group, followed by a combination of 7 mark and space pulses, then a mark or space pulse for parity checking, and then two marking pulses (Fig. 6-7). The first pulse and the last two pulses are synchronization pulses. A group of seven

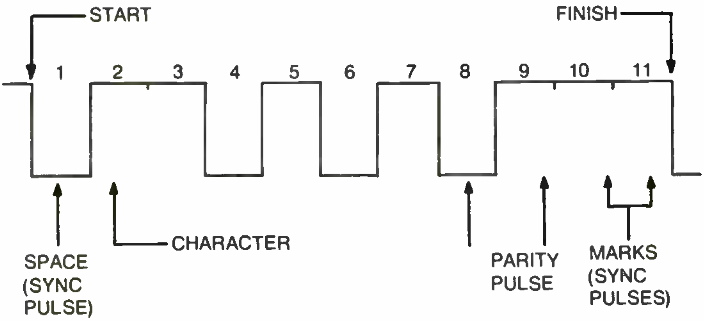


Fig. 6-7. ASCII 8-level code. The full 11-pulse group is used to define one character.

pulses in a variety of combinations defines the character or symbol. The pulse for parity is a method of checking the system for errors.

The news wire services use this code, and in some areas, the U. S. Weather Service is now using it.

Baudot Code

This is a 5-level code and is basically an old telegraph code. The *5-level* means that there are five pulses which define the character, plus the space and mark pulses for synchronization. Seven pulses in each group are sent. This code is limited in the number of characters and control functions it can accommodate and requires much shifting. This shifting is the same as on a regular typewriter when you need capital letters or symbols. These limitations are why the newer codes were developed and also why they contain more pulses in the group. More pulses simply allow more combinations of pulses and thus more functions. But for all its limitations, this code is still very much in use today in most parts of the country. The U. S. Weather Service uses this code.

Transmission

Codes can be sent over a variety of circuits, including radio channels. The teleprinter signal must modulate some carrier, and this is usually a midrange audio signal of 2 to 4 kHz. At the receiving end, the signal is demodulated back to its DC character and fed to the machine. These units are called *modems*, for modulator– demodulator.

For the weather service, this is accomplished at the telephone company's switchboard. They send the signal to the station over a local DC line. The news signal comes into the station as a modulated signal and has an outboard modem to convert the signal to the DC pulse input to the printer.

Ordering Weather Service

The services of the U. S. Weather Service are free since it is a public agency. They supply weather information and maintain a weather teleprinter network. There is a continuous stream of weather information sent out over this network 24 hours a day. To obtain this service, the station must provide its own printer and pay for a local line to the telephone company switchboard. No formal permission is needed from the U. S. Weather Service. Order a standard DC teleprinter circuit from the telephone company and tell them you wish to connect to the U. S. Weather Service network.

U. S. Weather Service

The U. S. Weather Service is divided into regions, states, and districts. Your contact will be in the office of the service in your state. You will need to obtain information from them about the code, speed of sending, and the *severe weather alert* signal used in your area. When ordering a teleprinter, the factory must have this information. In most areas, this will be: 5-level Baudot code, printing speed of 75 wpm, and the alerting signal of two or three uppercase *H*s followed by a lowercase *w*.

Weather Alert

The printout for the alert will appear something like this: ###Aw. The symbol # is what prints out when the shift signal is sent and the *H* key is pressed on the sending machine. The symbol has no significance in itself; its pulse train has simply been designated as the arming part of the alert signal. Shifting is the same as you would do on your regular typewriter. If you would press the carriage shift key and the key for the letter *H*, you would get the capital letter *H*. On the keyboard setup for the Baudot code, however, the uppercase is not a capital *H* but the symbol #.

Following the symbols ###, there may be other letters. In the preceding example, the *A* (in the state of Indiana) will open up all the machines in the state that are connected to the network. Other letters can follow, and these are used for selective signaling or for verification. Then the *w* is sent. When the *w* is sent, the alarm will sound. There must be some other character sent after the *w*, or the alarms will continue to sound. There is usually a space signal or something sent. Actually, the message will follow. This is pointed out here in case you are in a test setup and have the phone company testboard send a test signal.

When the signal is sent for weather alerts, there is also a 10-bell signal sent as is done with the EBS alert on the news machine. This bell signal can also be used to set off alarms, and in fact, that is the way the EBS alarm works.

Station Selector

To receive the special alerting signal from the Weather Service, or to turn on the motors in some machines and other special selective calling or signaling, a *station selector* is required. This is an outboard device that is located at the printer location. Servicemen call these *stunt boxes.* When the selector is an all-electronic device, it must be programmed *exactly* for the signal it is to accept and act upon. Take, for example, the alerting signal. If the code is ##Aw and the Weather Service sends ##AFw, the alarm will ignore the signal and not fire.

Installation

The input signal level to the machine is important, and it should not exceed the maximum current stated on the machine. The weather line is adjusted at the testboard to a fixed figure and maintained at that, but the level on the news wire is adjustable at the output of the modem. Too high an input signal will overload the machine, and the printout results will be garbled.

On the weather wire, if the standard current set by the testboard is too high for the machine, shunt a 50-ohm 5-watt resistor across the input of the printer itself (Fig. 6-8). This will provide a path for some of the current around the printer.

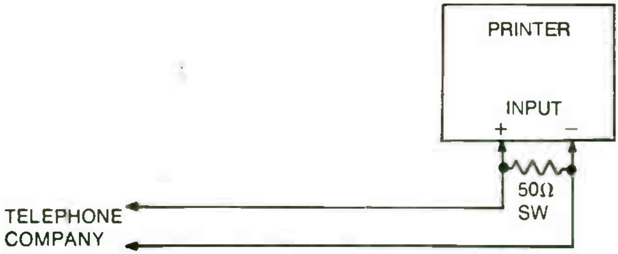


Fig. 6-8. When there is no way to adjust the signal current, add a resistor across the input of the printer to a provide a shunt path for part of the signal current.

Selector

When a selector is used, wire the input of this *in series* with the input of the printer (Fig. 6-9). This provides less of a load on the (telephone) circuit, and also provides an interlocking arrangement with the printer. The selector must be connected, or the printer will not work.

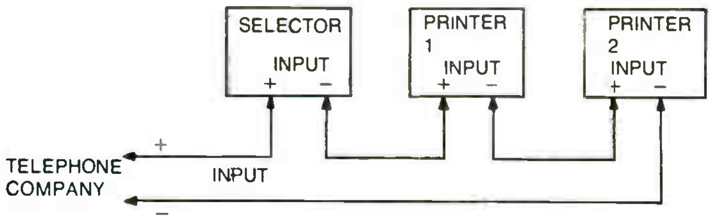


Fig. 6-9. When other devices or units are used on the same circuit, wire them all in series across the telephone line.

If it is necessary to shunt a resistor across the printer, make sure this is not shunted across the selector also, or the selector may not work properly. This would be the case if the resistor were shunted directly across the line.

Measure the Current

At the time of installation and at any time when garbling appears in the printout, measure the signal current on the incoming weather line or the input to the news machine (Fig. 6-10). Open one side of the line at the terminal block and insert a milliammeter in series with the line. You will not be able to get a good measurement until the line is idle. When messages are coming in, there are pulse trains on the circuit, and the meter will read very low and vibrate, as it cannot follow the pulses. Wait until the sending stops, then get the measurement. The signal current must be adjusted below the maximum value and should be set somewhere out in midrange. where the printer will work reliably The

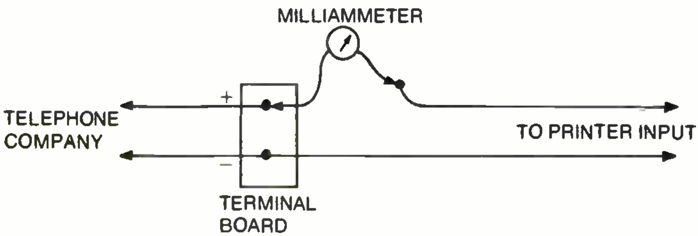


Fig. 6-10. Break one side of circuit and insert milliammeter in series with line to measure signal current.

maximum for the Extel solid-state printers is 60 mA. If the current is not there, the circuit is open. There will *always* be a steady line current of approximately 60 mA (or local standard) on the telephone circuit. Absence of current means the line is open.

Alarms

What type of alarm to use depends upon what is supplied with the machine and selector. For EBS on the news machine, a relay is added to the bell circuit. This relay provides dry contacts so that any external alarm device may be used. The relay will close each time the bell sounds. An external device must also sort out the five-bell bulletins from the ten-bell EBS signal. or the alarm will go off every time the bulletins come in. And there are many bulletin bells!

The ten-bell signal can also be used on the weather machine for severe weather alerts in the same way as the EBS is on the news machine. But if a selector is used for the special-alert signal. then the output of the selector will fire off the alarm. Some of the electronic selectors only provide an IC output of 5V DC at 3 mA. This requires an interface if something more than a simple electronic alarm, such as the Mallory Sonalert device, is to be used.

Maintenance

There may be times when the network is active, other times when it may be idle. The weather network can sometimes stand idle for perhaps an hour. The station must know if there is an idle network or if the circuit has gone open. There is a red circuit-alarm lamp on the machine. This is normally extinguished, or it flickers on and off rapidly during transmissions. These are normal conditions. If the circuit goes open, this lamp will come on at full brilliance. First, check the line for signal current. If the signal current is not there, the line is open. For the weather wire, call the phone company testboard. If the current is present and the lamp is lit, then there is an open circuit in the wiring to the machine. Check the connections and plugs.

Power

Of course, the machine can't print if the AC power is off or the fuse blown. On each machine, there is a power pilot lamp (usually green) which shows the power is okay. If there is no power lamp or if it is burned out, a quick check for power is to turn the machine power switch off and on. There will be a single bell when the power comes back on, and if the print head is out in midstream somewhere, there will be a carriage return back to the left margin.

Polarity

The input signal to the printer is a DC signal, and this means that the circuit must be polarized. If it is not, the printout will be severely garbled. During setup, the circuit and wiring is determined and polarized correctly. Check the tag on the machine to determine which terminal is plus and which is minus. At a later date, when maintenance is done or the wiring taken off for some reason, it might be reversed. During initial setup, mark the terminal boards for polarity and color coding of the wiring. A quick check can determine if the circuit has been properly restored.

Print Heads

There are a variety of print heads on various models of teleprinters. Some machines use ribbons and others use ribbonless paper. Print heads need to be cleaned from time to time as they may become clogged with paper, dust, and ink. Clean these with a stiff-bristled brush.

On the electronic type, the print head provides a 5×7 dot matrix to form the characters. A battery of small solenoids are clustered together. A needle-like plunger pops out of the individual solenoid to form its dot. These heads can become clogged so that the plungers can't operate properly. Clean out dust or debris from the face of the head with a brush or airblast. There is a small hole at the rear of each solenoid. Use a needle or similar small instrument to work the plunger mechanically. This will usually clean it. Don't take the head apart as it is difficult to put back together.

Ribbonless Paper

Ribbonless paper requires no ribbon on the teleprinter. The ink is imbedded in the fibers of the paper itself, and pressure from the print head releases the ink so that the character is formed.

When installed in the printer, the paper must be inserted so that it will unroll in the proper manner. If it does not, the wrong side of the paper will face the print head. At first glance it may seem difficult to tell which is the correct side. One side will be much darker, however, than the opposite side. If the paper is put in the wrong way, the printing will be faint and difficult to read.

There are both heavy-duty and light-duty machines available. When selecting a machine for station use, get a heavy-duty machine as it will get a workout in the station, and the light-duty machine might not hold up well.

AUDIO MONITOR SYSTEMS

All broadcast stations require audio monitoring for checking the air product, for auditioning, and for maintenance purposes. A good, reliable monitor system is similar to good test equipment in producing accurate results.

Classes of Monitors

Monitoring can be divided into four general classes: control room, house, special, and maintenance.

Control room monitoring includes the directly associated studios and the console. This monitoring is for the benefit of those involved in the production of the air product.

House monitoring is generally from the off-air signal, and distribution is made throughout the station at comfortable listening levels. Speakers are provided at many locations.

Special monitoring includes specific areas or circuits to be monitored, such as network or remote lines, or perhaps the signal from a sister station.

Maintenance monitoring encompasses all the special techniques and check-points used to listen in on the signal throughout the system.

Basic Ingredients of Monitors

Regardless of the size and complexity of the monitor system in use, there are some basic ingredients common to all.

In all cases, except headphone monitoring, there is a monitor amplifier. The power output of this amplifier is dictated by the amount of audio to be distributed and the levels. The control room console monitor is usually a part of the console itself, and its power output is specified by the console manufacturer. This amplifier is basically designed to supply three or four speakers only. These are located in the control room and the studios associated with the control room.

House monitor systems often make use of a high-power amplifier and, in some cases, there is more than one amplifier. Amplifiers for special-purpose monitoring, on the other hand, may use low-power units to supply a single small speaker.

Speakers

Speakers are needed at many locations. The power-handling ability of individual speakers depend upon how much signal level is required at a given location. The quality of the speaker and its enclosure will be subject to wide variation. Many inexpensive speakers and cabinets are available, and these have a reasonable quality. There are some locations, such as a client auditioning room, where a high-quality speaker is desired.

Level Control

It is most desirable to control the signal level at the individual speaker location (Fig. 6-11). These controls can have a knob mounted on the cabinet, or a setup control located inside the cabinet or on the rear, out of sight. Such controls permit the volume to be adjusted at each speaker location

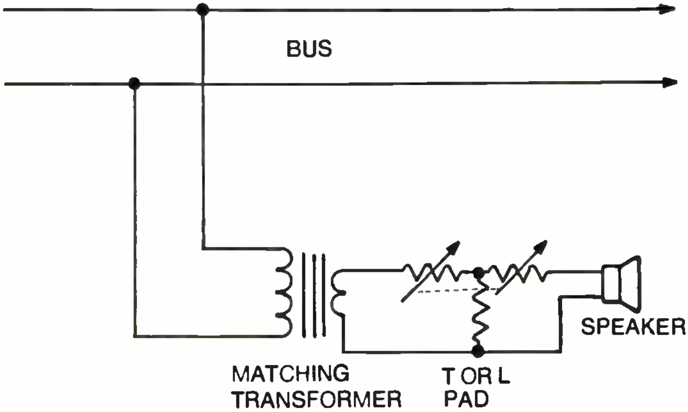


Fig. 6-11. Use an adjustable pad at each speaker to control volume.

without affecting the remainder of the system. In a house monitor system, once the main amplifier gain control has been set, there should be little reason for its readjustment.

The control room monitor will be used to monitor many circuits and programs, so its levels will be adjusted quite regularly. Even so, the speakers associated with the console should have an individual control at the speaker so that it can be adjusted to studio listening levels. A comfortable level in the studio may be entirely too low for control room use.

Speaker controls of both the *L* and *T* types are commercially available. The pad selected should match the speaker impedance and should be wired between the matching transformer and voice coil.

Impedance Matching

Impedance matching throughout the system is important. A matched system will give an efficient transfer of power and maintain correct frequency response. The amplifier output transformer will provide a number of impedance taps. A single system using one speaker would match or connect the speaker voice coil impedance to that impedance tap on the output transformer. As the system becomes more complex, the impedances become more important.

The speakers are the load on the amplifier and can be computed as any other parallel resistors. In the single-speaker system using an 8-ohm voice coil connected to the 8-ohm output tap on the amplifier, the system is matched and an efficient transfer of power will take place. Now, if a second 8-ohm speaker is connected in parallel with the first one, the combined load impedance is now 4 ohms, and a mismatch has occurred. Add two more speakers in parallel with these two and the load impedance becomes 2 ohms instead of the required 8 ohms. Power transfer is now very inefficient. This situation can be corrected in either of two methods. Either move the tap on the transformer to the appropriate tap (if such is provided), or add a matching transformer at each speaker.

Console Systems

Packaged systems supplied with the console have matching transformers in each speaker. The monitor output impedance of the console may be listed at 16 ohms. This is generally set up for four speakers. One might conclude from these specifications that the tap on the monitor output transformer is set for 16 ohms, but it is not. It is set for 4 ohms. This anticipates that the amplifier will see four 16-ohm speakers in parallel, or 4 ohms. Since most speaker voice coils are 6—8 ohm impedances, it would require a matching transformer to translate the 6—8 ohm voice coil to this 16-ohm value.

Mismatch

Amplifiers designed for use in broadcast systems usually have a large number of impedance taps available, while those designed for public address work often have fewer taps. Small amounts of mismatch are not noticeable, as the amplifiers usually have enough reserve gain to make up for the loss caused by mismatch. When the system becomes complex and there is careless attention to matching, problems can become more serious. If the mismatch is far off, the amplifier output stages may be seriously overloaded, which results in distortion and short life.

High-Current Circuits

The distribution system is very important in a complex monitor system. These are all very low-impedance circuits, that carry high currents. The resistance of the wire in the distribution system should be low, or power will be lost in long runs. As a matter of practice, these wires should be reasonably large in diameter, and not the ordinary audio cable. An alternative method is to keep the current lower by going to a higher impedance distribution system and matching transformers at the speakers. The higher impedance reduces the current, and the transformers will restore the impedance match. The impedance can be as high as 600 ohms if you obtain transformers to match the 600 ohms of the speaker voice coils. Going higher than 600 ohms creates other problems with high-frequency response due to capacitance in the cables.

CONSTANT-VOLTAGE SYSTEMS

The constant-voltage distribution used in public address systems can be used in a house monitor system (Fig. 6-12). In recent years, the 25V system has also come into use. Transformers in this system are marked in power taps rather

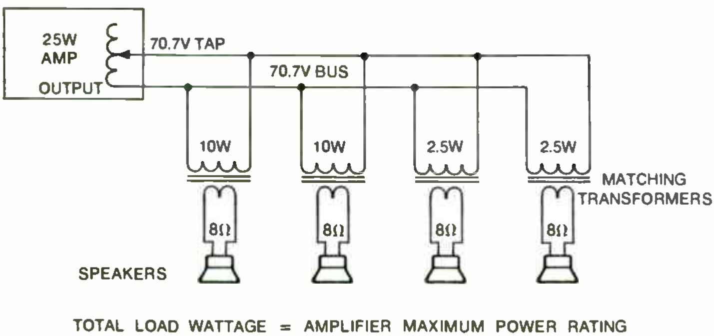


Fig. 6-12. The 70.7V distribution system. Matching transformer primaries are marked in power taps.

than impedance taps. These markings allow the system designer a simpler method and reduce computation to a minimum. The amplifier output transformer is marked for either a 70.7V or 25V tap. The system is based on a constant bus voltage at the maximum output power of the amplifier into a matched load. The amplifier usually does not operate at its maximum output power, as there should be some reserve in the system. In this system design, the total speaker load must equal the rated power output of the amplifier.

The design of a speaker distribution system is a simple matter if one selects components marked for this type of system. Each speaker transformer has its input taps marked in power, while the secondary have taps to match various speaker impedances. In system installation, simply connect each primary tap at the level selected for the speaker. The only requirement is this: *The speaker power taps must add up to the amplifier's maximum rated power output.* Assume, for example, that a 50W-rated amplifier and 10 speakers are used in a system, and each speaker receives equal power. The rated power of 50W divided by 10 gives 5W for each speaker. The tap on each transformer is set to the 5W tap. Unequal distribution of power can just as easily be made, as long as the total power taps equal the amplifier's maximum output rating. Don't worry about the power rating of the transformer itself, since no tap available would exceed its rating.

"Unmarked" Parts

A constant-voltage system can be designed even though components are not on hand or readily available which are marked for the 70V system. It requires more computation, some good-quality universal output-to-voice-coil transformers of adequate power rating, and an amplifier with a suitable impedance tap.

System Design

Figure 6-13 illustrates how to design a 70.7V system with unmarked components. First is the amplifier output transformer, and assuming that it has no tap marked 70.7V or 25V output, compute the impedance tap required by the use of the power formula $Z = E^2/P$, where P is the amplifier's maximum output rating, E is the bus voltage, and Z is the desired impedance tap. For example, we have a 50W amplifier and want a 70.7V line. Then,

$$Z = (70.7 \times 70.7)/50 = 5000/50 = 100 \text{ ohms}$$

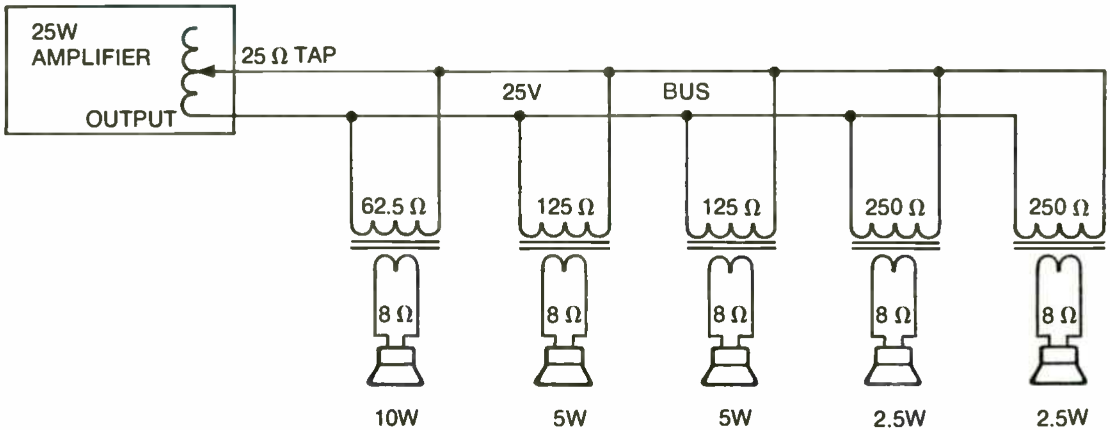
Find a tap as near to 100 ohms as possible and use that one. If there is no tap near 100 ohms, we can try for a 25V system. The impedance for a 25V system will be:

$$Z = (25 \times 25)/50 = 625/50 = 12.5 \text{ ohms}$$

The amplifier would most likely have a tap near this value, so a 25V system could be set up.

Design Variables

We will take a slight detour here from the system design to point out a few facts. You probably noticed that the impedance



(A) AMPLIFIER OUTPUT Z

$$Z = \frac{E^2}{P} = \frac{625}{25} = 25\ \Omega$$

Z = OUTPUT IMPEDANCE
E = BUS VOLTAGE
P = AMPLIFIER
MAXIMUM POWER

(B) SPEAKER-MATCHING TRANFORMER PRIMARY Z

$$Z = \frac{E^2}{P} = \frac{625}{10} = 62.5\ \Omega$$

$$\frac{625}{5} = 125\ \Omega$$

$$\frac{625}{2.5} = 250\ \Omega$$

Z = MATCHING TRANSFORMER
PRIMARY IMPEDANCE
E = BUS VOLTAGE
P = POWER TO
SPEAKER

Fig. 6-13. Design of 25V system with "unmarked" components. Compute output impedance tap of amplifier, and use universal output transformers at each speaker.

value changes for the different systems. Actually, there is *no standard impedance* for these systems. Since the system voltage must remain constant, the impedance depends upon the amplifier maximum power. For example, using the 70.7V system, the impedance for a system with a 50W amplifier is 100 ohms (5000/50 = 100). Now if a 25W amplifier is used instead, the impedance becomes 200 ohms (5000/25 = 200).

Another fact is that the voltage on the bus will certainly not remain constant, nor may it even reach the design figure. That is exactly what it is, a design figure, just as the maximum output of the amplifier is a design figure. For example, a 100W amplifier and a 70.7V bus will have an impedance of 50 ohms. In operation, the amplifier gain controls are set so that the amplifier is actually delivering only 50W to the line. By the power formula,

$$E = \sqrt{PZ} = \sqrt{50 \times 50} = \sqrt{2500} = 50\text{V}$$

Even though the design is for 70.7V, the actual bus voltage is only 50V. Also, in the computations, the figure 5000 is used as the square of 70.7. This figure is easier to remember than 4998.49, which is the true figure. The error is small enough to be ignored.

Back to Design

In our design example, we have a 50W amplifier and the 70.7V constant-voltage system. We have found the correct output tap on the transformer to use for this. Next, we need some good universal output-to-voice-coil transformers. We have eight speakers in the system, and there is unequal power distribution. Again, use the ordinary power formulas, except the power figure in our formula is the power we desire the particular speaker to have. The impedance factor is the primary impedance of our matching transformer at the speaker. Thus, $Z = E^2/P$, or $P = E^2/Z$. We want two 10W, one 7.5W, one 2.5W, and four 5W speaker locations. The total wattage is 50W, the maximum of our amplifier. Using this formula, the primary impedance tap for the 10W speakers will be:

$$Z = E^2/P = 5000/10 = 500 \text{ ohms}$$

For the 7.5W speaker we calculate: 5000/7.5 = 667 ohms. Of course, if we couldn't find an impedance value on the amplifier output transformer that would give us the 70.7V system and decided on a 25V system, the 25V figure would be used in the formulas.

Maintenance of Monitor System

Control Room Speaker System—There are three or four speakers fed from the console amplifier. It is necessary that studio and control room speakers are muted when a microphone is turned on in the particular room. Relays mounted in the console do this muting. When the relay operates, it disconnects the speaker and substitutes a resistor of equal resistance so as to keep the load on the amplifier constant. Should it be necessary to replace one of these resistors, the replacement should have a value equal to the speaker impedance. This value, remember, is the value of the input impedance of the matching transformer, and not the voice coil of the speaker. Thus, if the transformer input impedance is 16 ohms, this is the value to make the resistor. Make sure it has the correct power rating.

Switch Mute—There are times when it is desirable to shut the speaker completely off in the studio because rehearsals are going on. Many of the *T*-and *L*-pad controls used on the individual speakers will not shut off completely. A switch on the speaker cabinet can be installed that substitutes a load resistor on the amplifier when switched to remove the speaker. (See Fig. 6-14.)

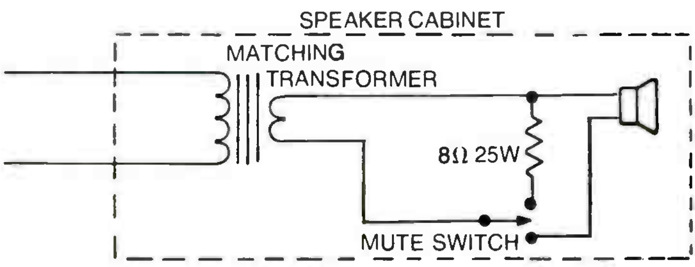


Fig. 6-14. Add a switch to speaker cabinet to act as a manual mute.

Jacks—If individual speakers do not have a cutoff switch, the speaker input leads should be routed through a jack field. Should the speaker mute become defective for any reason, a patch cord plugged into the jack will open the speaker leads.

A plug with a terminating resistor attached will both open the leads and terminate the amplifier.

Muting Relays—Contacts can become dirty and cause problems. The speaker will sound intermittent or distorted. Contacts should be cleaned with a small relay-burnishing tool if the monitor amplifier can be turned off; otherwise, use a piece of coarse paper run between the contacts. It is especially important with transistor amplifiers that the output does not become shorted. This will almost certainly blow the transistors.

Other Systems

There may be situations where a separate monitor is desired for a specific service or purpose. For example, the station may use a national network service and would desire to have constant monitoring of the network line. The amplifier should have a gain control near the operator, so the amplifier gain can be raised to listen for cues or lowered to a background for general monitoring. Unless the amplifier can be located at the control position, this should be a remote control. The control can be on the speaker itself, or the input, whichever is more applicable to the situation.

Bridging

Most monitoring is tapped into regular program buses, so monitoring should have a bridging arrangement so as not to load the buses. Buses are also balanced, so if the amplifier input is unbalanced, use an isolation transformer or a bridging transformer.

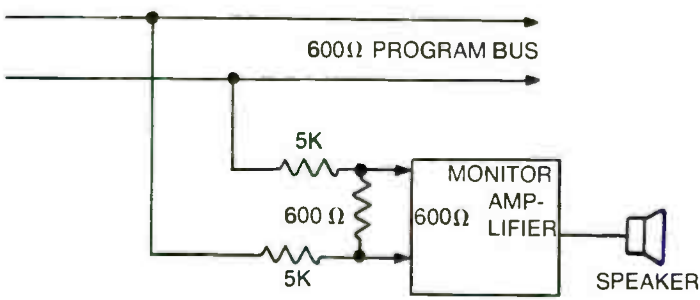


Fig. 6-15. Always use a bridging connection for the monitor amplifier.

Fixed bridging may be done in some applications (Fig. 6-15). If the amplifier is a 600-ohm balanced input, use fixed resistors in each leg. The value should be 5V to 10K in each leg. If only a single bridge is used on the circuit, the resistors can be as low as 2700 ohms in each leg. Don't go much lower than this and don't add any more bridges to the circuit if possible.

Chapter 7

Remotes

On-the-spot, live, remote broadcasts have been an integral part of radio since its infancy. Going outside the studios to do programming does present many engineering challenges. One major problem is how to get the program back to the studios. There are two ways to accomplish this: through the use of land lines or by a radio link. We consider these two methods in this chapter and also some of the equipment to take out to the remote. And we delve into the studio–transmitter link, which, although not a remote, does have many things in common with remotes.

LAND LINES

A wire circuit leased from the telephone company is a very common method used for remote broadcasts. The telephone company has a great many circuits, but only a few of these ever see use as broadcast channels. When a circuit is assigned for a broadcast loop, then it must meet the quality of the service ordered. There are several grades of circuits, each with a different bandpass. These are listed by the telephone company and are filed with the FCC.

Quality

The actual quality of a particular circuit depends upon the pair of wires assigned, and to some extent, upon the expertise of the local telephone company personnel—their understanding of broadcast needs. But at least the bandpass of the various local channels are listed; there are several grades. When ordering a circuit, the station must specify the grade of circuit desired; otherwise, the lowest grade circuit is assigned. Tariffs filed by Indiana Bell Telephone Company, for example, list nine different categories for broadcast channels, and these are divided into five grades. These range from the top-grade circuit, a schedule *AAA* line, which has a bandpass of 50 Hz to 15 kHz, to the lowest grade, a schedule *E* line, which has a bandpass of 300 Hz to 2500 Hz. The reason for the nine designations in only five grades is due to listing of each circuit by two designations according to usage. For the top grade, *AAA* is the designation given when this circuit is leased on a monthly basis. But if the circuit is leased only occasionally, this same grade of circuit is designated schedule *BBB*. A bit confusing, perhaps, but probably necessary as far as rates and tariffs are concerned. One thing to remember when ordering a circuit: Specify the grade of circuit you want. Contact the local telephone company and ask for the schedule of broadcast channels they have available. Don't be afraid to ask about the rates for the different grade of lines either.

Except for the individual drop from the pole, the circuit ordered is only one pair in multipair trunk and feeder cables. To keep the cable diameter within practical dimensions, the size of each wire is small, generally a 26-gauge wire. For the same reasons, the insulation around each wire may be a thin paper wrap or plastic. The small-gauge wire has high-series resistance, and the close spacing of the conductors gives high capacitance in shunt across the pair. Both of these factors add up to high losses for the signal as it passes through the cable.

Losses

The yardstick for measurement in telephone work is usually the mile. For an unloaded cable pair using 26-gauge wire, the signal loss for each mile of cable is approximately 2.9 dB at 1 kHz. The losses are worse at higher frequencies—about 9 dB at 15 kHz. Rates quoted are based on distance between the studio and the remote site, but this is not necessarily the actual cable routing. In most cases, the actual distance is less than the cable distance. But the signal must pass through the cable, wherever it meanders, and these losses add up. It is not uncommon to have three or four miles of cable in the routing. This means the losses are three or four times as great as they are at a mile.

Overcoming the Losses

Both equalization and amplification are required to overcome the cable losses. Just how much depends upon the circuit in question.

For ordinary telephone voice channels, the phone company adds loading coils at approximately each mile along the circuit. Spacing of these coils depends upon the cable, so the spacing may be at 3000, 6000, or 9000 feet. These coils are simply an inductance placed in series with the line at that spacing, cancelling the line capacitance to provide a degree of equalization. The typical loaded voice circuit has a bandpass of approximately 300–3200 Hz.

The broadcast channel, however, is not supposed to have any coils in the circuit. If there are loading coils, then the line cannot be properly equalized. The coils tend to peak the line at about 3200 Hz; there is a very rapid dropoff in response above this frequency. As a matter of fact, the higher end of the response curve drops into the cellar.

When a circuit is ordered, the phone company may not have any unloaded cable pairs in the area of the remote. If not, they assign one of the regular voice channels instead. This happens quite often these days because of the heavy demand for circuits. When a voice channel has been assigned, the phone company should go out to disconnect the loading coils along the way. They may forget to do this; if you try to equalize the line, the effort will be in vain. For practical purposes and when equalization is not going to be attempted, schedule E line with loading coils left in place provides a reasonably good circuit for many remotes where the programming is all talk—such as a sporting event or similar pickup.

Equalized Circuit

When music is part of the programming from the remote site, or if a better circuit is desired or required, then either equalize the circuit yourself or order a better grade line.

When a high-grade line is ordered, the phone company will equalize it. They use a self-contained equalizer-amplifier unit at the studio location. This provides both the equalization and high-gain amplification to make up the equalizer and line losses. These are portable units brought to the station for the occasion. If the station transmitter is at the same location, be on the lookout for RFI in these units.

Do-It-Yourself Equalization

Local equalizers may be used that are either the passive type or those more sophisticated units that allow for boosting or cutting the response curve in frequency bands. To equalize the circuit, someone must be at the remote location with a signal generator or a remote amplifier that contains a tone generator.

The passive equalizer does its job by *reducing* the low frequencies down to the level of the higher frequency point. This introduces a considerable amount of attenuation into the circuit. The farther you stretch the bandpass, the greater the loss becomes. So don't overdo it.

If you are going to equalize the line yourself, here is a little trick that helps the process: Insert a matching transformer at each end of the line. At the remote location, strap the secondary for 150 ohms (Fig. 7-1). Leave the primary at 600 ohms to match the amplifier output. At the studio end, strap

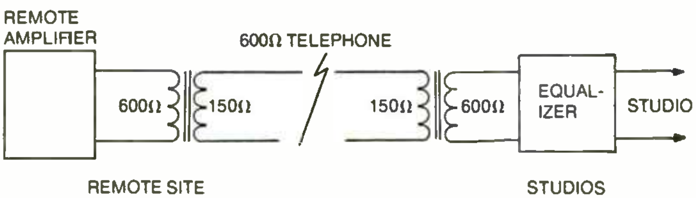


Fig. 7-1. Strap transformers as if the line were 150-ohms impedance. This makes equalization easier.

the primary for 150 ohms, again leaving the secondary at 600 ohms to match the studio equipment. The shunt capacitance is now across 150 ohms rather than 600 ohms. This has less effect and the line will be easier to equalize.

On-Air Equalization

Equalization and experimentation must be done before the program gets on the air. If there wasn't time to do it, some experimentation can be done while programming. However, do this gingerly, being constantly aware of the attenuation the equalizer adds to the circuit. Try to make adjustments in small increments. Keep one hand on the fader, trying to smoothly correct for the loss introduced. It really sounds bad on the air if the levels are varying all over the place. Gradually add small amounts and listen for the voice to crispen up.

Low-Level Output

Whenever equalization is done, whether with the announcer's voice or with a signal generator, remember that the equalization adds attenuation to the circuit. If there is much equalization, the output of the equalizer can be a very low-level signal, down at the microphone range or at least in the preamplifier input range. This makes the output circuit susceptible to noise pickup, hum, crosstalk from high-level circuits, and RFI.

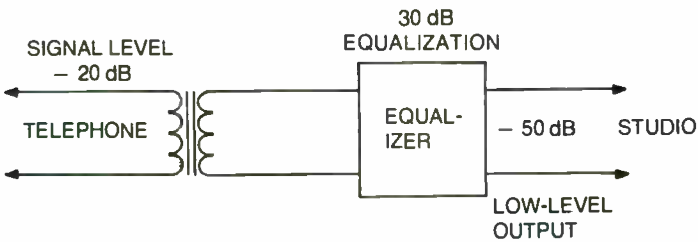


Fig. 7-2. When heavy equalization is done, the output of the equalizer may be at a low level.

When equalization is done, listen for noise in the background. A practical trick that gives a relative appraisal of the signal-to-noise ratio is this: First, set the levels in the remote system. Have the announcer talk into the microphone, or use the signal generator. Try to use the spare channel on a dual console or the console itself. Set the faders and master gain so the peaks hit 0 VU. If the fader is wide open, there can be problems, since the console gain is very high. Now take the signal off the channel and listen to the channel. Turn the gain on the console wide open and listen to the background noise; note any reading on the VU meter. The operator must make a judgement about how much noise is acceptable from the facts presented and the program to be broadcast. If the program is a basketball game in a gymnasium with a screaming crowd, the program can tolerate a higher noise level than a quiet pickup. While only a relative method, this can be useful for the occasion. For example, once you've calibrated for normal operation, and if the noise peaks do not move the VU meter at all, the noise is down at least 20 dB. You can estimate from there. The faders are usually 2 dB per step. So if you now open the fader 10 steps and the noise peaks start to jiggle the meter a little, the noise is down about 40 dB.

Jacks

When a station does many remotes, there may be several regular weekly remotes, such as churches. Rather than disrupt these circuits to handle a special remote, have several circuits from the jack field to the telephone terminal box. These should terminate on the station terminal board. Before a remote and after the line has been ordered, the telephone company usually supplies the information on circuit number and terminal numbers in the box. Then it is only necessary to cross-connect between your terminal board and the terminals on the telephone company board. Post the regular circuits that are in service so that you don't take down one of the active circuits. Post this right at the telephone company box.

Problems in Remotes

Many problems can happen to remote lines both before and during a program. Some of these are human errors, others are simply breakdowns in the circuits themselves.

At the Remote Site—One common problem is the connection of the remote amplifier to the telephone line. In many cases, there is a four-wire cable that connects to a four-post terminal block (Fig. 7-3). So the installer ties his four wires to the block even though only two actually are used. Now

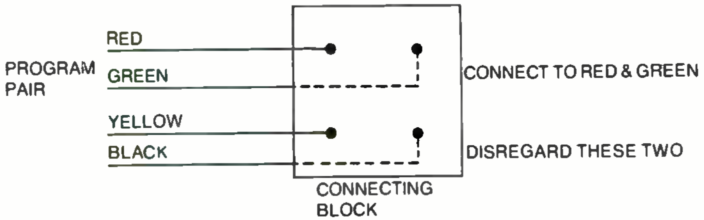


Fig. 7-3. Be sure to connect the remote amplifier to the correct pair of wires. Disregard any other wires.

the announcer comes along and ties the remote amplifier to the *wrong pair* of terminals. He simply isn't connected to the remote line at all, only to the cable. Do this: Ask the telephone personnel to instruct their installers to *use only two wires*, the active two. Cut the other two off. Also, find out which color code is used for the program pair. In the four-wire cable, this is usually red and green, but find out what it is in your area. When you find out the code, make a small tag. Tape it to the remote amplifier so the announcer can make sure he connects to the program pair.

Oscillators—In many cases, the phone company attachs a small oscillator or buzzer across the line. The battery lasts a couple of days. They can listen in on the line at the test board to know the line is still intact. The station can also listen in occasionally. If the tone disappears, call the telephone company and inform them. Some test boards are attached to an alarm at the downtown office; if the tone quits, an alarm goes off. Sometimes the batteries play out, but in many locations such as school gymnasiums, the little oscillators disappear...!

When an oscillator is used, make sure the announcer knows he is supposed to disconnect the oscillator before he attaches the remote amplifier. If he does not, there will be a low-level tone in the background of his program. It may not be *low* either, which will certainly make the program sound bad. In one case, the phone company thought they would play it wise and hide the oscillator so the kids wouldn't steal it. The installer mounted it at the terminal box located in a room somewhere else in the gymnasium. He used the other two wires in the cable to route the oscillator output back to the remote terminal, attaching them in parallel with the program pairs. This worked fine for line-continuity testing, but the announcer did not know it was there and attached the amplifier to the program pairs. The oscillator buzzed along for a large part of the first quarter, until the station could get the phone company (out-of-town game) down to the gym to cut the oscillator off. The announcer was not a technical man; he simply followed instructions. He saw the other two wires attached, didn't know what they were, so he left them connected. Watch out for the tricky installer.

Resistor Terminations—This is the most common method used for checking line continuity. The installer attachs a 10K resistor across the program line at the remote location. The test board personnel can check for line continuity by measuring across the line; the station can do the same thing. This is important for those circuits which are on a permanent basis. Simply measure the resistance across the line terminals at the telephone box at the station. You should measure the 10K resistor plus the line resistance. When the line is first set up and checked out, take a set of measurements with the ohmmeter to record these for future reference when there are line problems with the circuit. The announcer *should not* take this resistor off the terminals when he attaches his amplifier. The high-value resistance does not affect the circuit in any way. By the way, if the amplifier is attached to the line, you will not read the 10K resistance, but the low resistance of the output transformer. It still provides a continuity checkpoint, but at first glance, you may think the line is shorted. If there is any question, have the announcer remove the amplifier. Naturally, none of this can be done if the program is in progress.

Noise

Most problems found on the boradcast loop are noise, hum, and crosstalk. These are balanced lines, and if anything happens to upset the balance, noise problems occur. So when a line is first set up, measure each side of the line to ground with an ohmmeter. There should be an open (∞) reading. There is an initial kick of the meter pointer as it charges up the line capacitance, but this is normal.

When these problems show up, measure the line to ground again. If there is a reading or a short, check the carbon blocks that are mounted on each side of the line. Pull out the carbon; if the reading disappears, the carbon has arced through. These carbon blocks are protective devices against lightning or similar high-voltage surges that appear on the line. If one of the blocks has arced through, leave it out of the circuit unless a new one is available. It should be replaced as soon as possible.

Hum is another common problem. It happens if the line is unbalanced for any reason. There are other reasons for hum; it can be caused by connecting the amplifier incorrectly at the remote site; or it can be that one side of the studio equipment has been accidentally grounded. In either case, hum comes up as soon as the equipment is attached; but with the equipment off the circuit, the hum disappears. If the ground is in the console itself, then an isolation transformer inserted in the line corrects the problem for the moment (Fig. 7-4): At the earliest opportunity, the *real* problem or fault should be corrected. When hum is strong on the circuit, contact the local test board personnel to report the problem. Always check out your own connections and circuits first. It can be embarrassing to have telephone troubleshooters go out to the site or studios and find that the station equipment is at fault.

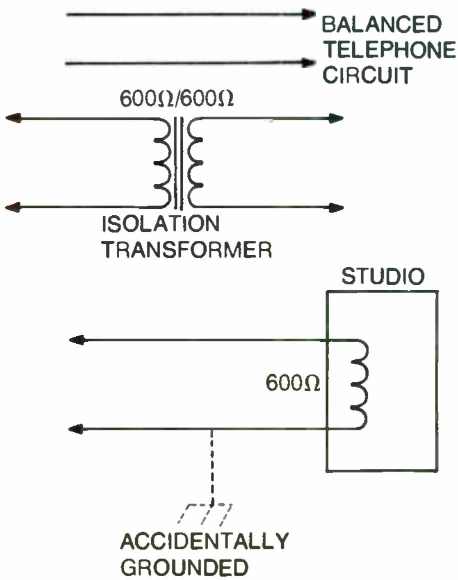


Fig. 7-4. If one side of equipment is accidentally grounded, insert an isolation transformer as a temporary measure.

In one case where hum was a real problem on a remote pickup, an announcer went to cover his first ball game. He was not accustomed to working with balanced circuits. He connected the line to *one* of the amplifier's output terminals and ground terminal, creating an unbalanced output. We lost a good part of the game before the hum problem could be corrected. The telephone man found that one.

Talk-back Hookup

In the ordinary loop, two-way communication is possible between the studio and remote site. The remote amplifier at the site and the talk-back amplifier in the console are used. Naturally, this can't be done during the program itself unless the station is airing a commercial or other announcements. This talk-back arrangement is very helpful in the preliminaries before broadcast time in setting up the cues, timing, instructions, and so on. But if the phone company has equalized the line, there are amplifiers in the circuit. Two-way communication is not possible on the equalized line. If communication is important enough, then order a regular business phone at the remote site. This is a little more costly, but there are shows where this is important enough to justify the extra expense.

QKT Circuit

The use of the regular telephone for remote broadcasts has flourished in recent years. As with many developments, this grew out of economic necessity.

Basically, the QKT, or *voice coupler*, is a convenient device for connecting the remote equipment to a telephone. Instead of using the phone instrument itself, regular audio equipment is used. The telephone contains a jack or an external box, which contains a transformer for isolation, and a push-to-talk switch or exclusion key. To do a broadcast, the announcer simply dials the station phone number. When the connection is made, he uses the phone in the regular manner. Without breaking the connection, he simply releases the switch or turns on the exclusion key. This places the amplifier output signal directly onto the phone circuit. The program goes over regular voice channels just as any other phone call. The station is charged for the phone call but there are no line charges. There is, of course, the installation charge.

There is one important difference to remember about a broadcast over a QKT and one over a regular broadcast loop: The QKT is a regular or long-distance phone call. Therefore, the announcer must dial the correct phone number at the station. And at the station, there must be a connection to the station equipment. Most stations have more than one phone number, perhaps an unlisted number. Cross-connect the phone circuits for those numbers in the telephone company's box to the station jack field. Use the isolation circuit as described in *Chapter 6* for the news recording.

Long-Line Network Hookups

Whenever the station is connected to a national, regional, or special network, the lines will be handled by the Long Lines Division of American Telephone and Telegraph Company. These circuits converge at and pass through the *toll-test section* of the local phone company. They may have a different name for it, but it is usually a separate part of the local phone company with its own personnel.

Generally, broadcast stations and the telephone companies work together well and have very good relations. Good relations with the local phone company pay off in the long run and in tight spots.

RADIO LINKS

In many locations land lines are not available or even practical, so the radio link is used. The remote pickup transmitter offers a flexibility not possible with fixed land lines. Use of remote pickup transmitters has been accelerating over the past few years, as has the use of all mobile communications systems. Some remote pickups operate in the shortwave band. There is also a heavy concentration in the VHF band along with an expanding use of the UHF band. These small systems, although flexible, are not a cure-all. They have their own problems and limitations and are not as reliable as the land line.

Propagation

With radio link, the propagation of the signal is an important consideration. Radio waves have different characteristics according to the frequency band in use. Shortwave signals travel a greater distance with less transmitter power, but they are subject to more *skip* than the higher frequencies. Atmospheric conditions skip the signal hundreds of miles, causing interference to other signals on the same channel. Theoretically, the VHF signal is line-of-sight transmission, but it does spread beyond the horizon and is subject to more skip than theory indicates. Signal attenuation along the path requires more transmitter power to deliver a strong signal where you want it to go. The higher the frequency band, the higher the path losses. At UHF, the signal does conform well to the line-of-sight theory, and propagation losses are more severe.

Transmitters and equipment operating in these different bands require different components, antennas, operating techniques and maintenance procedures. Since there is a very high concentration of remote pickups in the VHF bands, most of the following discussions applies equipment in this range.

Antennas

The transmitting and receiving antennas are the interface with the radio path, thus an important part of the system. These antennas must be as efficient as we can make them since we have no control of the signal out on the radio path. Once the signal leaves the transmitting antenna, it is subject to the foibles of nature, its own characteristics, and man-made interference. There are many elements which affect the antenna and signal propagation that should be weighed against the practical requirements of a particular system.

Height

In the VHF and UHF bands, height is a very important element in overcoming the line-of-sight characteristics in relation to the curvature of the earth. In fact, height is as important as transmitter output power and, in some cases, more so. Achieving ideal antenna height is not an easy matter. The portable transmitters, such as vehicular or walkie-talkie units, have antenna heights of only a very few feet above ground. This is typical of most of the remote pickup locations. To overcome this low height, the receiving antenna at the studios must be as high as possible. However, there are practical limitations to this also.

When the studio antenna is too high—several hundred feet—it becomes susceptible to skip signals. Although the high antenna enhances pickup from the remote locations, the skip signals boom in strong enough at times to wipe out local usage of the channel. Also, a point is reached in height where the transmission-line losses are greater than the advantage gained by height.

Gain

Different configurations of antennas collect more receive signal, reinforcing the signal by proper phasing, so that a power gain is realized. Actually this gain figure works in both ways, that is, in receiving and transmitting. The quarter-wave

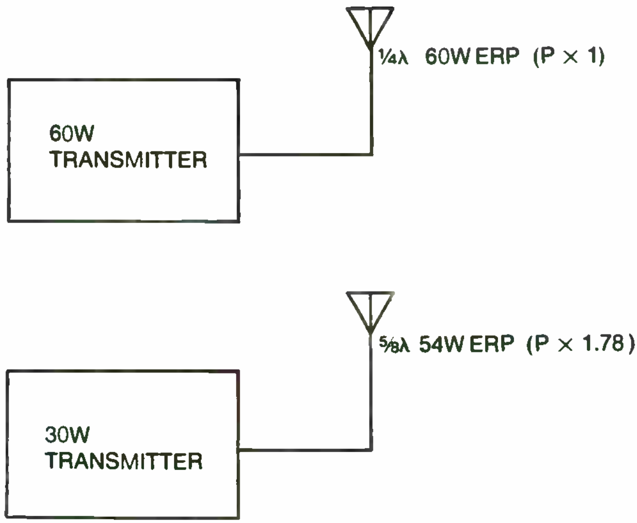


Fig. 7-5. The gain of the antenna effectively increases the transmitter output power.

whip anetnna is popular for vehicles and hand held units, having a power gain of 1 dB. So high-gain antennas should be used whenever possible. The ⅝-wave length whip antenna has also become popular. This antenna has a power gain of 2.5 dB, which is almost the equivalent of doubling the transmitter output power. For example, a 30W portable transmitter and the ⅝-wave length antenna radiate almost as much power as a 60W transmitter and quarter-wave antenna.

Higher gains than this can be achieved by stacking or using special antennas such as the yagi or collinear array. The yagi is also highly directional and can be used to advantage in areas where there is much interference, but it is much larger physically than the whip antennas, not lending themselves to portable use. They can be used to advantage at the base station.

Efficiency

Antenna systems are efficient or inefficient, just as any other electronic devices. *Efficiency*, as used here, means the input/output ratio. For practical purposes, the transmission line is considered as part of the antenna system. Efficiency is considered as the ratio of transmitter output power versus radiated power from the antenna. For example, if losses are 10% of the transmitter output power, the antenna system is only 90% efficient.

There are many factors that consume power before it is radiated: physical diameter of radiating elements (skin-effect resistance); resistance in coaxial connectors (corrosion, rust, or loose connections); resonant frequency of the antenna in relation to the carrier frequency (incorrect length); transmission-line losses (high-loss dielectric material or moisture in cable); standing waves (impedance mismatch); and other conditions.

Polarization

Another important factor relating to efficiency propagation is polarization of the antennas. Both the transmitting and receiving antennas must be in the same physical orientation, either vertical or horizontal. If one antenna is vertical and the other horizontal, theoretically, there is little or no reception. Practically, there are enough reflections that distort the original field so that reception is possible over a short distance, but the efficiency is far less than if both are polarized the same way.

Estimating Coverage

When setting up a system, a rough calculation of the coverage area can be made by use of FCC charts for either FM or the upper TV channels. These charts do not truly depict conditions of the 150 MHz band, but they can provide a rough idea of what to expect. They also consider the receiving antenna at a 30-foot height, which is seldom realized in mobile work.

You can expect at least coverage to the horizon or better, so if you want to compute this distance, this formula can be used: $D = \sqrt{2h_t} + \sqrt{2h_r}$ where h_t and h_r are the antenna heights at the transmitter and receiver. For a base station antenna height of 100 feet and a remote unit antenna height of 4 feet, we calculate $D = \sqrt{200} + \sqrt{8} = 14.14 + 2.83 = 16.97$ miles. These computations are theoretical and can only be used as estimates. They all consider the earth to be flat. Hills and obstructions will alter these figures.

System Bandpass

The next important consideration of the radio link is its bandpass. There are quite a few factors that affect the bandpass. Conversely, bandpass affects the quality of the audio signal that passes through the system. Bandpass is as much a design factor as an operational factor. Systems which are designed for communications work are intended for speech and provide the equivalent of a good telephone speech channel. Those designed specifically for remote pickup work have a bandpass equivalent to that of a class B (or better) equalized line. See Fig. 7-6.

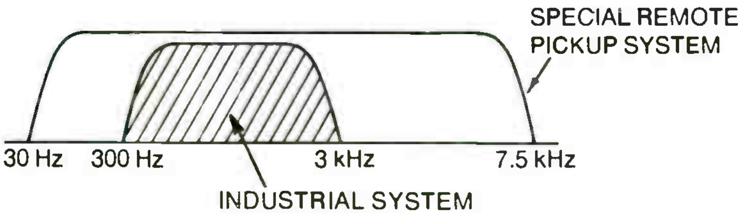


Fig. 7-6. There is a different system bandpass on narrowband industrial transmitters than on wideband special remote pickup transmitter systems.

Primary factors of design which determine bandpass are the audio and modulator section of the transmitter, and the bandpass filter and audio system of the receiver. Operational factors are the adjustments to these sections, as well as the tuning of various RF and IF stages in both the transmitter and receiver and the receiver's discriminator.

Industrial or Broadcast Equipment?

Transmitters that are used for remote pickup service may be either those designed for industrial services or specifically for remote pickup service. There are many manufacturers who build equipment for the industrial services, but only a very few who build equipment especially for remote pickup service. There are differences!

First is *duty cycle:* Industrial units are intended for *short* bursts of speech communication in which the transmitter is on for only a short time. The remote pickup units are designed for a *continuous* duty cycle; that is, they can transmit for long periods of time. This is important when program is to be transmitted. The industrial unit may overheat and deteriorate rapidly because the cooling system is not intended for this type of operation. For example, if the station is trying to broadcast a ball game over an industrial unit, odds are the unit won't make it to the end of the game. But for shorter programs, such as news interviews, they seem to work well.

Second is *bandpass*: Industrial units are *narrowband*, while the special remote pickup units are *wideband*. (Standard industrial units can be made wideband, but this is a modification done at the factory.) The audio system in the industrial unit is adequate to provide speech communications; however, special remote pickups have better audio systems. In the transmitter, there are provisions for two or more regular broadcast-type microphones; plus a mixer, peak limiter, and AGC amplifier built into the unit. It may also have a VU meter. The receiver audio section has audio filters and pads that may be switched in, and the output is a balanced 600-ohm transformer to match the studio equipment.

FCC Rules Regarding Remotes

Remote pickup systems come under the jurisdiction of the FCC. The technical requirements, operation, and other information about their use is found in *Rules and Regulations Part 74, Subpart D—Remote Pickup Broadcast Stations*. The remote pickup rules differ in many respects from the rules for industrial services, but stick to the remote pickup rules when the station has a system in operation; do not become overly concerned with the industrial services. In many respects, especially in bandwidth and frequency tolerance, the remote pickup rules are more lenient. But in operation, applications, and licensing, the remote pickup rules are more stringent.

At the time of this writing, the remote pickup rules are under consideration for extensive revision. Likely changes include a narrowing of the bandwidth, tighter frequency tolerance, and licensing of the system rather than each individual transmitter as is now done.

Maintenance of Remote Pickup System

Like any other electronic system, the remote pickup system must have a regular maintenance program. There are some required FCC checks, such as frequency and modulation, to make periodically; but the system deteriorates over a period of time, especially the antenna system, which is constantly exposed to the weather.

There are some general suggestions to be made about maintenance: First, become familiar with the particular units the station has in use—read the instruction manuals. These provide the specific tuning and adjustment information that is recommended for the units. Second, always be conscious of the system's bandpass when adjustments are made, whether to the modulator, speech amplifiers, or RF tuning. Many things affect the bandpass; unless major adjustments are required, it is best to leave the tuning alone. This is particularly true of the IF stages and discriminator in the receiver. If there is a problem, correct it; but that doesn't necessarily mean the unit needs a complete tuneup. If you farm out the work to some shop that does communications work only, make sure they don't narrow the discriminator bandpass.

Antennas

Many problems originate in the receiving and transmitting antennas. Be especially on the lookout for loose connections at or in the coaxial fittings of the transmission line. Also, look for rust and corrosion where the antenna mounts to the vehicle. Whenever poor signals are apparent, look over the antenna of the particular units involved. If the problem is common to *all* mobile units, then look at transmitting or base antenna. Mobile antennas can be bent or broken off. When the vehicle must be run through a car wash, try to remove the antenna whip if possible.

Field Strength

A relative measurement of the field strength of the signal can be made with one of the small kit-type field-strength meters (Fig. 7-7). These are not accurate or absolute figures, but do give a relative indication of how much signal is coming off the antenna. When a unit is first installed in a vehicle, set up some arrangement to make a field-strength measurement.

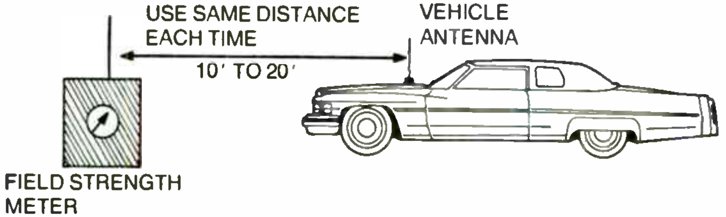


Fig. 7-7. Use a kit-type field-strength meter to measure radiated power. Do the procedure the same way each time.

Do this after the installation is complete and appears to be putting out a good signal. Save this reading for future reference. When there appears to be a poor signal output from the unit at a later date, then make another measurement for comparison, but use the same setup and procedure as in the original test. If the transmitter tunes up to full power in a dummy load, then take the coaxial fittings apart and check the antenna mountings for corrosion, open connections, and other problems.

Coaxial Line

When the coax line has fittings at both end, a simple check can be made of the line. Disconnect the antenna and attach a dummy load and wattmeter. Tune the transmitter directly into the load first for a comparison reading. Then move the dummy load to the end of the coaxial line. The readings should be essentially the same if the line is in good shape. Cable that is fished under carpets and seats of a vehicle can become damaged by crushing or abrasion, or it can simply be cut. This test will show it up.

Base Antenna

In most cases, the base antenna is mounted on a tall tower or the station's regular tower. Consequently, it gets less attention. If it is very high, then treat the antenna the same as you do the regular FM transmitting antenna. The best device for checking out an antenna system is the Bird Electronic Corporation's Mini-Monitor directional wattmeter. This

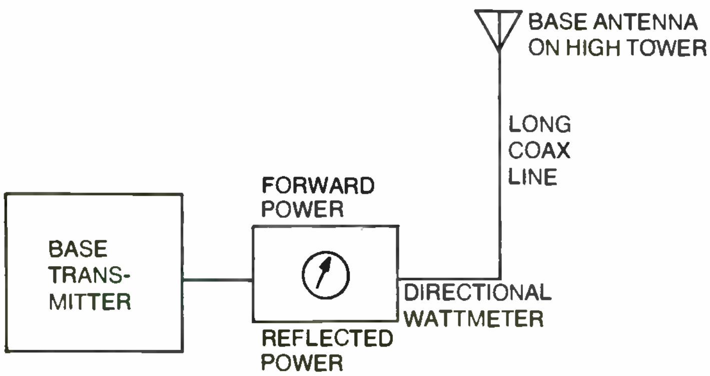


Fig. 7-8. On high base antennas use a directional wattmeter to measure power and tune to line.

instrument allows measuring the forward and reflected power at the transmitter end of the coaxial line feeding the antenna. If there is anything wrong with the line or antenna, power is reflected back to the input of the line. This unit does not read VSWR directly; it only gives you the two power measurements. To obtain VSWR, it is necessary to compute the value, using the measured powers. However, absolute VSWR figures are not really needed; what is important is that the reflected power is very small. When the station or antenna system is first installed, measure these values and compute the VSWR and save for future reference. At later dates, this should be checked and comparisons made. If there is any gradual increase in the reflected power, deterioration is taking place in the line, antenna, or both. But if there is a sudden increase in reflected power and the transmitter tunes oddly, something has happened to the system, and it should be checked out as soon as possible.

Transmitter Output

Getting a good match from the line to the antenna is important, but so is the tuning of the output stage to the load. The output tuning affects both the radiated power and the efficiency of the output stage. Most manuals say that the transmitter be tuned up into a dummy load and wattmeter, then connected to the antenna without further tuning. This is all right if the antenna and line have a good match and, in effect, offer the same load as the dummy load. But this may not be the case; the output stage can be operating detuned, thus dissipating too much power. Tune the transmitter into a dummy load and wattmeter, and load the transmitter to the correct current values in the output stage. Then attach it to the line and antenna. If these readings change appreciably, the antenna is not well matched. Touch up the output stage tuning in small increments, always keeping the stage current "dipped," until the readings approach those of the dummy load, or at least the maximum loading value.

Modulation Percentage

Even though a strong RF signal is received, the output audio signal can still be low and the signal-to-noise ratio poor. This can be the case if the transmitter modulation is not properly adjusted. To properly adjust modulation, a modulation meter is needed. The manual may instruct that this be set with tone modulation. This is okay as far as a preliminary adjustment is concerned, but it should really be set on voice peaks. First, adjust the speech clipper so that it is not in a position to affect the audio. Then use the microphone and talk into it at program level; that is, make the voice level at about the same level an announcer would talk at when giving a report. Set the level on the modulation meter to the desired amount on the peaks of the voice. If the output of the receiver (base station) audio can be observed with an oscilloscope, adjust the level to the point where clipping starts to occur on the peaks. Now, this may be much less than the deviation is supposed to be, but in that case, the system cannot handle the deviation. Back off below this clipping point, then adjust the regular speech clipper to clip at this point. While the level may be less than the system is designed for, the audio will not be distorted, although the output level is less than expected. If the transmitter cannot reach its required modulation, then other maintenance is called for.

PORTABLE EQUIPMENT

Doing a remote today is a pleasant experience compared to what it was years ago, when equipment was heavy, bulky, and tied to an AC power source. But with the light weight, solid-state equipment of today and its battery power, the whole remote kit can be carried in a small bag. Besides that, there need be no concern about how to find power at the remote site.

Portable Amplifiers

There are a variety of small, battery-powered remote amplifiers available today, and their quality is as good as the studio equipment. While all run on batteries, some can also be run on AC power if desired. They are all light weight and easy to carry.

There are some models which have a built-in telephone voice coupler. This type of remote is handy if you would rather not rent the equipment from the telephone company.

Aside from the desirability of the light weight and size, the amplifier should have two or more microphone inputs (Fig. 7-9). Although many broadcasts are single-mike situations, there are other occasions when more mikes are needed. If the station does many remotes, there should be more than one remote amplifier available. When there are several amplifiers, they should all be the same type. This makes it easier to stock batteries and parts and for announcers to operate the equipment. There can be a couple of the smaller amplifiers for the simple pickup occasions, but several should be of the multimike input variety.

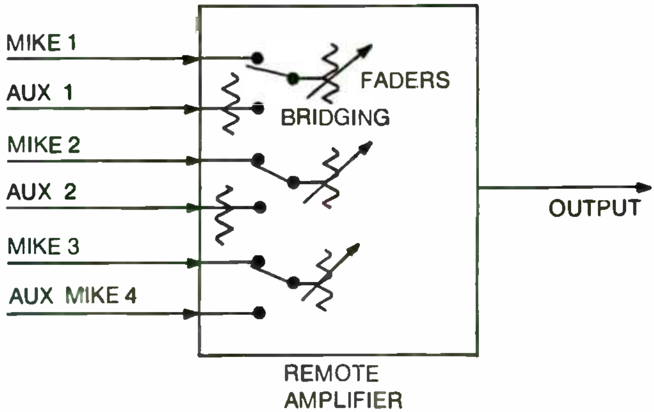


Fig. 7-9. The remote amplifier should have several input capabilities for flexibility.

Inputs

Besides microphones, other inputs are desirable on the amplifier. These other inputs may be on a switchable arrangement. The additional inputs can be used to obtain a feed from the local PA system, or portable tape recorders may plug into the amplifier to play back special types, such as interviews. By having a variety of input options on the amplifier—it doesn't need to be too complicated—can have more flexibility to cover more types of remotes.

Tone Generator

For test purposes on the line and for a rough equalization, an internal tone generator is also desirable. It should provide at least three audio tones: 100 Hz, 1 kHz, and 5 kH. By use of these three signals, a rough equalization of the line can be done before the program starts. There aren't enough tones to make a complete response run, but if these three are reasonably close in response, you can expect reasonably good results from the line.

Earphones

Many amplifiers provide a combination earphone jack and power switch. When the earphone is plugged in, the battery power is turned on. When the announcer has arrived very early at the remote site and has set up, he should pull out the earphones to conserve the batteries.

Many remote amplifiers only provide a single earphone jack. But on many remotes, more than one announcer may be involved, and each should have a headset. For example, a sports announcer and the announcer to do "color." So if the amplifiers do not have more than a single jack, add more jacks. Check behind the panels to see that there is clearance. Mount the additional jacks, and wire them in parallel. Make sure to use insulated washers on these jacks. The earphones are usually wired directly across the output of the amplifier, and if a noninsulated jack is used, it will unbalance the amplifier output and line.

Program Level

The program fed to the telephone line should be no higher than +8 dB on the peaks. Higher levels can cause crosstalk into other circuits in the cables. It the line is a clean line, then 0 dB on peaks will be sufficient. When the remote site is at a great distance from the station, such as over the long lines of AT & T, or if the line is equalized, there are amplifiers along the circuit. If the program level is too high, these amplifiers can be overloaded and distortion results.

Some remote amplifiers have a meter pad switch that allows adjusting the meter to read 0 VU on the peaks even though the actual output level may be +18 dB, for example. The announcer must make sure this meter pad is set correctly, or he will be feeding much higher levels into the line than is desirable.

Multimike Remotes

Some special remote programs may require more mikes than a particular amplifier has inputs, and these mikes must be available for immediate switching on and off. Such a program might be coverage of a special meeting of the city council or some public hearing. Such remotes require far more mikes than the normal multi-input remote amplifier can provide.

To solve the problem, two amplifiers can be used (Fig. 7-10). The outputs of the amplifiers may be mixed together in a simple pad to feed the remote line if the line can stand the 6 dB loss of the pad, or the two outputs may be simply strapped in parallel and fed to the line. I have used this technique on several occasions without apparent ill effect on the system

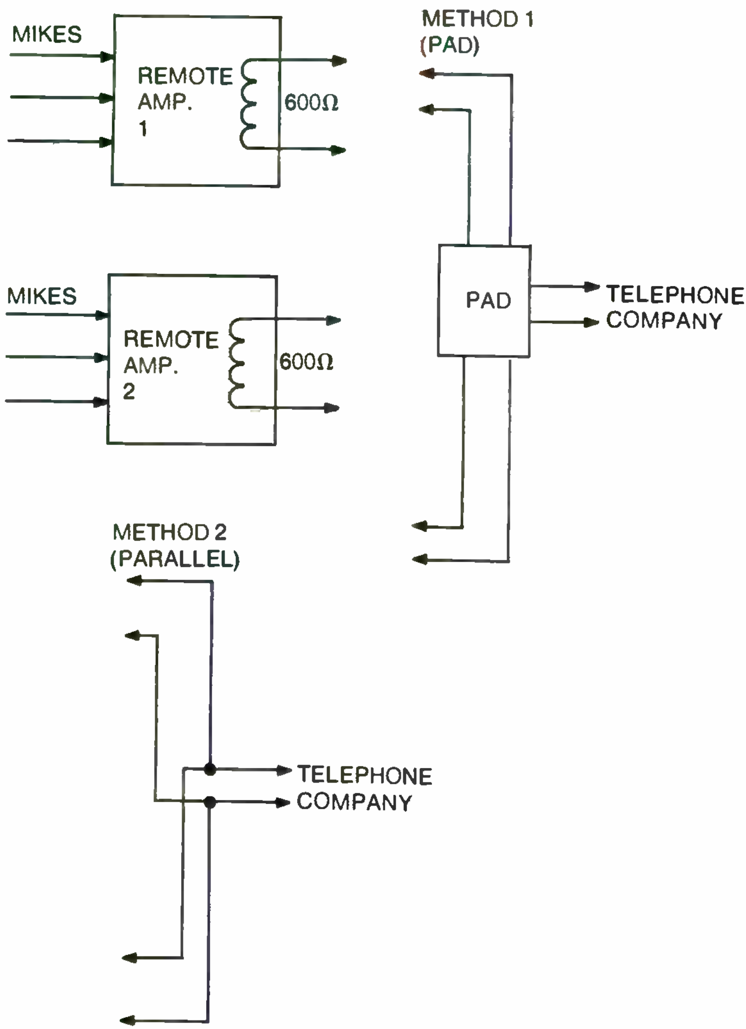


Fig. 7-10. When more microphones are required for the setup, use one or more amplifiers.

response effect except some level loss that could be made up. These were voice broadcasts similar to those mentioned.

Checkout

Before taking equipment out on a remote, it is a wise procedure to collect all the equipment, set it up, and check it out for proper operation. Besides determining if all the equipment works, the practice also determines that enough equipment has been collected to do the remote. There is nothing more disconcerting than to begin setup at a remote location only to discover that some important connector or adapter has been left behind. If there is no one at the studios to bring the part, the remote man has to go back after it, leaving all the equipment in an exposed, unprotected position. He could return to find his microphones missing! So gather everything up beforehand to check it out.

Batteries have a definite life span. Whether this happens right in the middle of a special broadcast or at some more convenient time depends upon how well someone keeps tabs on the hours of use the batteries have had. Some remote units do carry spare batteries internally, so if one set fails, the announcer needs only to switch in the good set. The instruction manual provides some estimate of the hours of battery life to expect. In estimating hours of use, include the time spent in the checkout of the equipment before the program began. On very special broadcasts, install a fresh set of batteries before the broadcast, especially if the program is a very long show.

Remote amplifiers should be ready to use and kept in some regular storage cabinet. If there is a problem in one of the units, send it to the shop. That is, keep the defective amplifiers separated from the rest. When the defective amplifier is repaired and checked, then it can be returned to the regular storage cabinet. With this method, there is less danger of someone using a defective amplifier on a remote.

Maintenance

Remote amplifiers and other components that have been out on remotes—especially if they have had hard usage over a period of time, for example, a week or two at the county fair—should be brought back to the shop on their return to the station. Here they should be checked out and any necessary repairs made before returned to the storage cabinet.

Equipment gets rough handling on remotes. Small things should not be allowed to accumulate. There are enough potential problems at the remote site without also having the knobs falling off the equipment.

Checking before and after use provides a double-check system. It's a little extra work perhaps, but if you have driven 150 miles to cover a ball game, only to discover the amplifier won't work or is missing, the precheck seems worth the extra effort.

Measure the Current Drain

Although the estimate of battery life is be reasonably accurate for equipment that is working well, battery life can be much shorter if there are circuit faults which cause a heavier current drain.

When the equipment is new and working well, install a new set of batteries and measure the current from the batteries with all the circuits in operation (Fig. 7-11). Save this figure for future reference. Either attach it to the unit's instruction

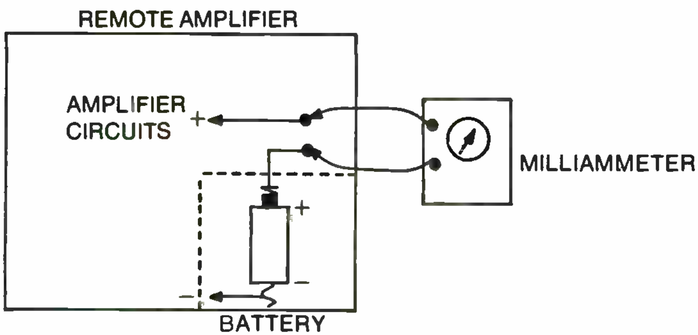


Fig. 7-11. Measure the current drain of a remote amplifier in full operation. Save the figures for later reference.

manual or keep it in the engineering files. When battery life seems to be much shorter than usual, remeasure the current. If the current drain is now much higher than the original figure. there is some fault in the amplifier that needs to be corrected.

Batteries

Batteries are composed of corrosive chemicals. Even though sealed, there can be leakage or "breathing" by the battery. These chemicals corrode the battery compartment voltage terminals.

As a safety measure, remove the batteries before the amplifier is placed in the storage cabinet, especially if it won't be used for some time. The batteries themselves can be kept alongside the amplifier or in a pocket of the carrying case. When the amplifier must go out again, then the batteries can be installed. By keeping the batteries out of the unit when in storage, there is less chance for damage to the battery compartment by corrosion.

Tag or label the batteries that have been removed from a particular amplifier, so that they are returned to the same unit. If the batteries of several units get mixed together then the estimates of life span become confused.

Type and size of battery to use is dictated by the particular unit. Although you may prefer to use the larger D-cell for its extra capacity rather than a C-cell as called for, there may not be enough space to handle the larger batteries. However, you can sometimes go to a different *kind* of battery, although it has the same physical shape and size. For example, instead of the regular zinc flashlight battery called for, you can use the alkaline battery. This is a heavier duty battery and lasts longer, although it is more expensive than the zinc battery. The manufacturer claims that this battery has ten times more energy than a comparable zinc battery. You may be able to go to the rechargeable battery. This must be recharged from time to time, but will last a long time before it needs to be replaced.

INTERCONNECTING LINK

Stations that must operate their transmitters at a great distance from the studios have a far more complicated system arrangement. There are considerably more initial engineering problems and potential operational problems; system maintenance is more difficult to perform. With the interconnecting link, as with remote broadcasts, the station has a choice of using land lines, microwave, or a combination of the two.

The first need is a routing of the station's audio from studio to transmitter. This circuit is an integral part of the station's audio system that must perform in all respects with characteristics comparable to any other part of the system.

A second important need is a control link the transmitter from the studio. The flip side of the coin is the need to monitor all the parameters of the transmitter from the control point. These two functions require special equipment at both the control point and the transmitter itself. The choice of this equipment and how it operates has a bearing upon the interconnecting circuits. There are many functions to perform; to route each one of these separately over miles of circuit path is uneconomic. With this in mind, the control units allow for selection of the control command functions and a sequential-scanning arrangement of the parameters so that all the information can be channeled over a single wire pair. The signal of the control unit may be DC, subaudible audio tones, or frequency-shift keying (FSK) of audio carriers with digital information.

FM Audio Line

The station needs a top-grade line for this circuit. This should be a schedule AAA or class AAA. Remember that the annual proof of performance must include everything from the microphone input to antenna output. This includes the interconnecting phone line. Since the system response must be within 2 dB of the reference at 1 kHz, the line must have a flat response. The telephone company equalizes the circuit, but a long circuit is not easy to equalize to 15 kHz or down to 50 Hz. Easy or not, do not accept a sloppy equalization job. It takes work, but this circuit should have a flat response within at least 1 dB of 1 kHz reference. It should not be "lumpy" nor roll off at either end. Always keep the master system in mind. If line response, for example, is down 2 dB at 15 kHz, the line itself meets technical specifications. But this requires the *rest* of the audio system to be flat at 15 kHz. Try to explain the purpose of the line and the severe requirements to the installers. Ordinarily, when they understand the need, most telephone people bend over backwards trying to achieve the desired results.

FM Stereo

The station that operates any part of its broadcast day in stereo has more severe requirements. There must be two identical circuits, one for the left and one for the right audio channels. The equalization process must take this into consideration. *Identical* means the same all the way across the bandpass. For example, if there is a 0.5 dB rise at 3 kHz on one channel, there should be a 0.5 dB *rise* on the other channel at the same frequency. If the response should *drop* at that point on the other channel, this is even worse. Even through each individual line is within specifications, the two together are not so good where stereo is concerned. This is a part you may have particular difficulty making the installer understand.

Path Length

The two lines should have equal path lengths, or there will be phase problems. Here again, try to emphasize when ordering the circuits that the two pairs should run side by side, if possible, and should certainly run in the same cable (Fig. 7-12). When the pairs run in the same cable and on the same frame at the testboard, there is a better chance that the two

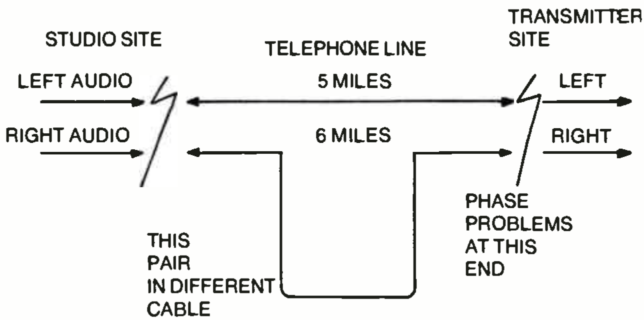


Fig. 7-12. If two audio circuits run in different cables, there can be different path lengths, which will mean phase problems in stereo.

circuits are nearly equal in length. In spite of all the efforts to achieve this, it may still be necessary to add some electronic device, such as the Garron phase corrector, to correct for path length.

AM Audio

System audio response for the AM station is not as stringent as for the FM station; if desired, a lesser grade line may be used. To meet proof-of-performance standards, the response need be only ±2 dB from 100 Hz to 5 kHz. A schedule A or class A line can be used. Although the class A line is less expensive than the class AAA line, the station may desire to keep the quality of its audio system intact and not allow the line to restrict the bandpass; all the rest of the audio equipment should have a response at least to 15 kHz or better.

Control Line

The type of line needed depends upon the type of remote control the station uses. If the unit is simply used for DC control and parameter measurements, the line must be a DC metallic line (Fig. 7-13). If transformers are in the line somewhere, it is no longer a DC line, and the remote-control

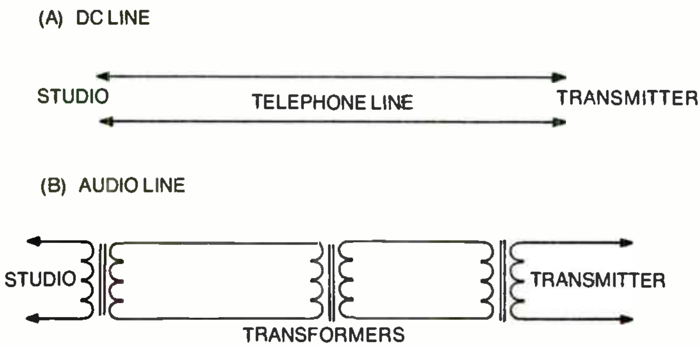


Fig. 7-13. A DC line is a metallic wire pair. An audio line might have transformers in it.

unit will not work. A line several miles long has considerable DC resistance in it, and this must be considered in the control unit design.

Audio Control Line

When the control signals can be sent in the form of audio carriers, then the circuit can be a regular audio channel. The more sophisticated control units do this by FSK audio carriers. These carriers range from about 800 to 2700 Hz. Since this is midrange audio, it passes through any transformers in the line. The control signals sent to the transmitter are only half the story.

Telemetry

Information about the transmitter must be sent back to the station control point so that the operator knows the transmitter is behaving properly and can log the meter readings. In units with audio carriers, the signals are subaudible tones in the neighborhood of 22–28 Hz. The ordinary line with transformers cannot pass this low-frequency audio very well, if at all. These tones *will* pass over a DC line. So when an audio-grade line is used for the control functions, these telemetry signals for the transmitter parameters are impressed as modulation on the main AM transmitter carrier itself, or in the case of FM, on a channel. The return route then is over the air from the main carriers to receivers at the control point. When the main transmitter modulation is used for telemetry, then consideration must be given to FCC standards relating to the use of these signals.

Maintenance

Actually, the land lines are outside the jurisdiction of the station personnel as far as maintenance goes. The maintenance is performed by telephone technicians. But these lines are very important to the broadcast operation, and station personnel should make continuing checks on these circuits, that is, on some periodic basis. A set of audio measurements should be made on a regular basis. These need not be a full set of response measurements, but only enough frequencies to outline the response of the bandpass. Also check signal levels, distortion, and noise. Cables may get moisture in them, or grounds may occur which increase hum level or crosstalk. There could also be problems with the telephone amplifiers, and distortion may increase. Whenever your measurements show a deterioration from the original measurements, notify the telephone company immediately to get them on the problem.

RFI

Modern line equalizers also contain a solid-state amplifier that is located at the transmitter site, where it is subject to strong RF fields. These amplifiers may also be susceptible to RFI, especially from the AM carrier. Some are more susceptible than others. Make sure the telephone company debugs any RFI that shows up in the unit. If need be, have them try other amplifiers. Debugging RFI may be a new experience for the telephone technicians, so you may have to pitch in and give them a hand. There can be problems in debugging since this is a 15 kHz circuit, and the brute force methods discussed earlier can't always be used.

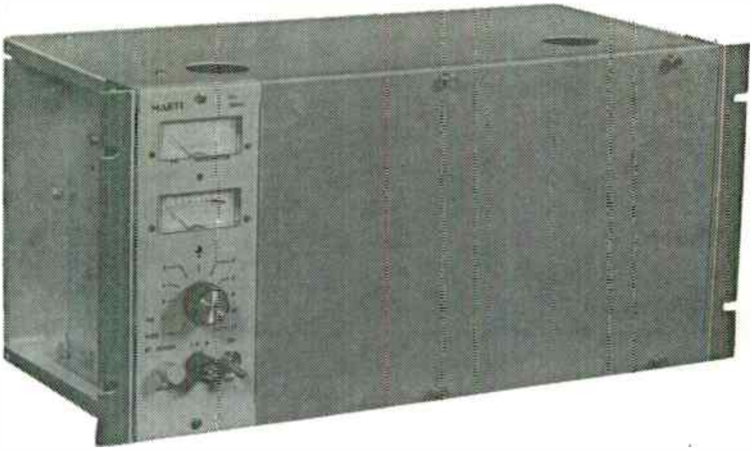


Fig. 7-14. The station may use a microwave unit instead of telephone lines for the interconnecting link. Shown is the Marti STL-8F transmitter unit, operating in the 950 MHz band.

Microwave

The station has the option of using a radio link instead of a land line for the interconnecting link (Figs. 7-14 and 7-15). This is a common practice with many TV stations, both for their remote sites and for the studio-to-transmitter link (STL). Although a radio link, this is not the same as the remote pickup transmitter used for remotes. Instead, it is a microwave RF

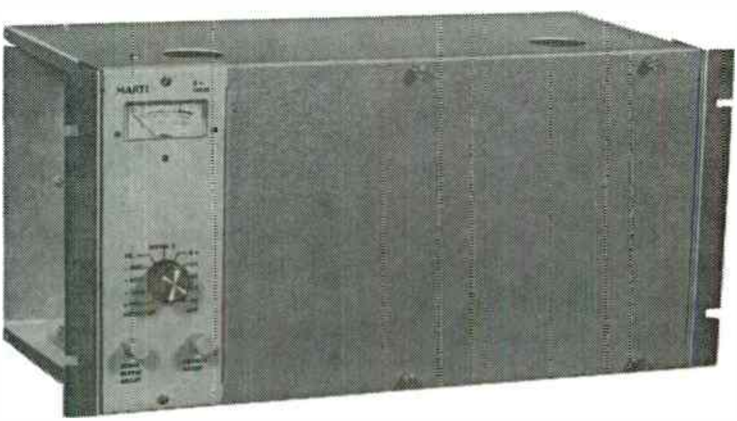


Fig. 7-15. The receiving end of the microwave link. This is the Marti Model R-200/950 F receiver.

signal focused into a very narrow beam pointed directly at the receiving location.

Microwave is a different technology that has its own very special techniques. There are several microwave bands allocated for different purposes. The frequencies for radio station STL are 947–952 MHz. Setting up a microwave link requires FCC applications, construction permits, licenses, and so forth, and the system must conform to the FCC standards for this service, found in *Part 74, subpart E—Aural Broadcast STL and Intercity Relay Stations*.

Unless the station engineers have a good working knowledge of microwave techniques and requirements when the station plans on switching from wire to microwave STL, have your consulting engineer or the factory application engineers design the system for your specific case. There are a number of manufacturers in the microwave business, but only a few, such as Marti Electronics, specialize in the radio station STL.

Signal Path

Microwave signals need a clear path to the receiving antenna. This must not be blocked by tall buildings, trees, or other structures. The beam should clear any obstruction by at least 100 feet.

A profile is needed of the terrain between the transmitter and receiver. This shows the contours of the ground and its elevations. To the eye, the ground may appear to be flat, but in reality there may be a gradual rise over a long distance. This stands out very clearly when a profile is drawn.

Large buildings, water towers, or antenna towers can cause real problems when they are directly in the beam path. Unless the transmitting and receiving dishes can be mounted high enough to clear these, then a multihop system must be installed. For very long distances, a multihop system may be required anyway.

Relays

When multihop systems are employed relay stations are required at various points along the path. Even a short path around a tall building may use a multihop system. In this case, the beam is angled off to one side of the building, to a relay station. The relay then shoots the beam to the receiving antenna. Of course, the relay may be installed on top of the tall building if permission can be obtained from the owners.

A relay is a receiver-transmitter unit, each with its own dish. The incoming signal is received and routed to the transmitter, which sends it out again from its own dish in another direction (or on ahead in the same direction).

Diffusion

It is not easy to keep the signal in a sharply defined beam. The signal always tends to spread out (Fig. 7-16). Some of the signals leave the beam at angles to the forward thrust, striking objects, water, or ground surfaces. Some of these stray signals reflect back into the beam, but not necessarily in the same phase.

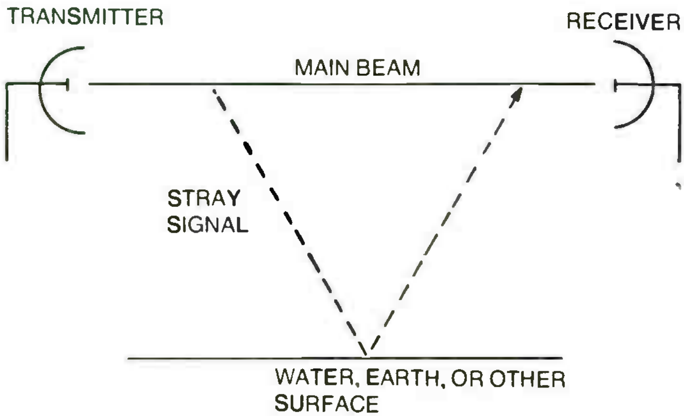


Fig. 7-16. Beam tends to spread out, and stray signal reflects off surfaces and back into beam with the wrong phasing.

There is considerable attenuation of the microwave signal along the path; the longer the path, the greater the attenuation. Weather elements also cause attenuation of the beam and signal fading. All of these factors must be considered in the design of the system, and proper compensations must be made to increase the reliability of the system.

Remote Control and STL

When an STL is used as the connecting link, both the station's audio program signal and the control commands for remote control are sent over the microwave beam (Figs. 7-17

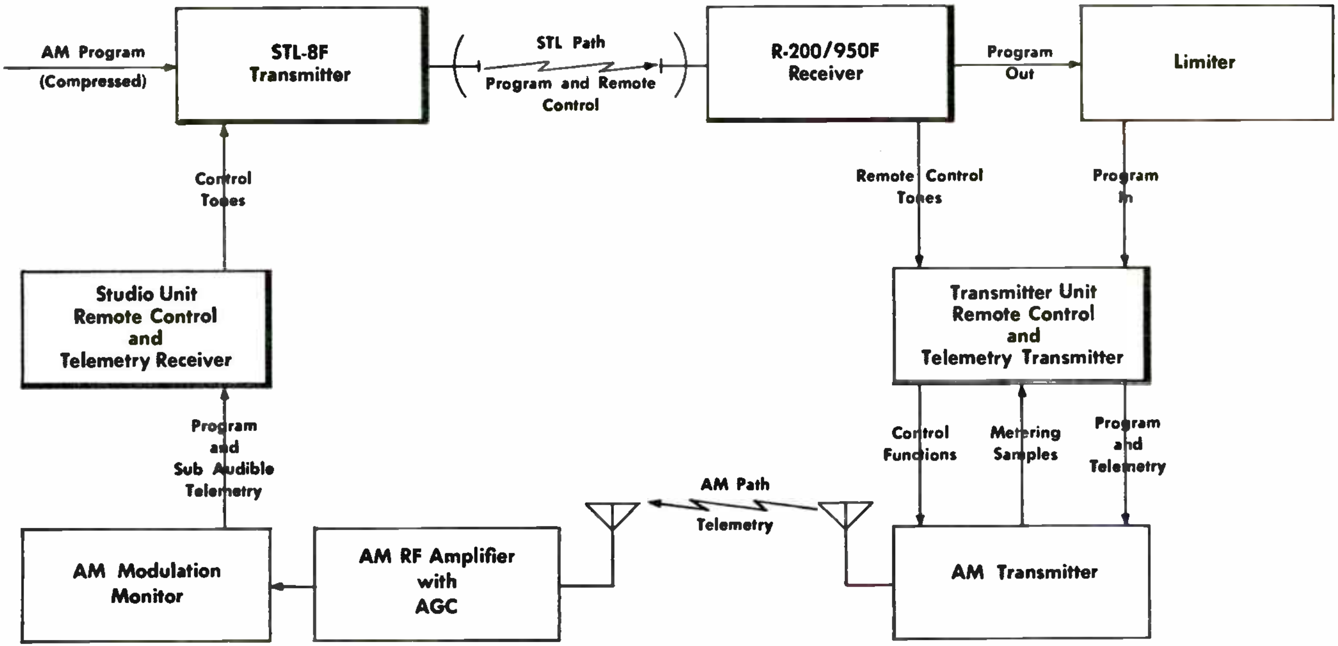


Fig. 7-17. Full over-the-air remote control for AM radio. (Courtesy Marti Electronics, Inc.)

and 7-18). At the receiving end, a receiver demodulates these signals and routes them to their proper functions. For this application, one of the more sophisticated remote-control units is used. The command signals are FSK, an ultrasonic carrier of 20 kHz to 27.5 kHz. This keeps it above the program audio.

For the telemetry of the transmitter parameters, the station's main transmitters are again used for modulation and sending the signals back to the control point over the station carrier.

The station may or may not desire a backup when an STL is used. This can be land lines or a dual system. In the latter method, there are dual transmitters at the control point and dual receivers at the receiving point. The transmitters are combined to feed a single dish. The receiving-dish output is divided into the two separate receivers. This dual system can be switched over should the first system fail. With this method, there is no need for a land line backup.

Stereo

There are two ways to handle stereo over the STL. In the first method, the stereo generator is placed at the studio, and the *composite* output of the generator is sent out over the STL to the transmitter. In the second method, program audio of the left and right channels is sent over a dual STL system. That is, the left audio is sent on one channel, and the right audio on the second channel. In effect, this is the same as is done with dual audio land lines. This is the method recommended by some manufacturers; however, there are proponents of the composite method.

Which way to go is the station's choice. Economics and reliability factors are involved, plus station expertise at maintaining an STL. These are questions only the station itself can answer, but here are a few points:

The reliability factor is important. When the link fails, the station is out of business until it can be restored. The land line does seem to have reliability factors in its favor, but telephone technicians can accidentally pull down patches, cable splicers may get into the wrong circuits, storms and vehicles can knock down poles and cables, and construction work can cut cables. While these don't happen too often, they are possibilities. On the other hand, Marti engineers claim 99.99% reliability in their STL system. According to their calculations, this means

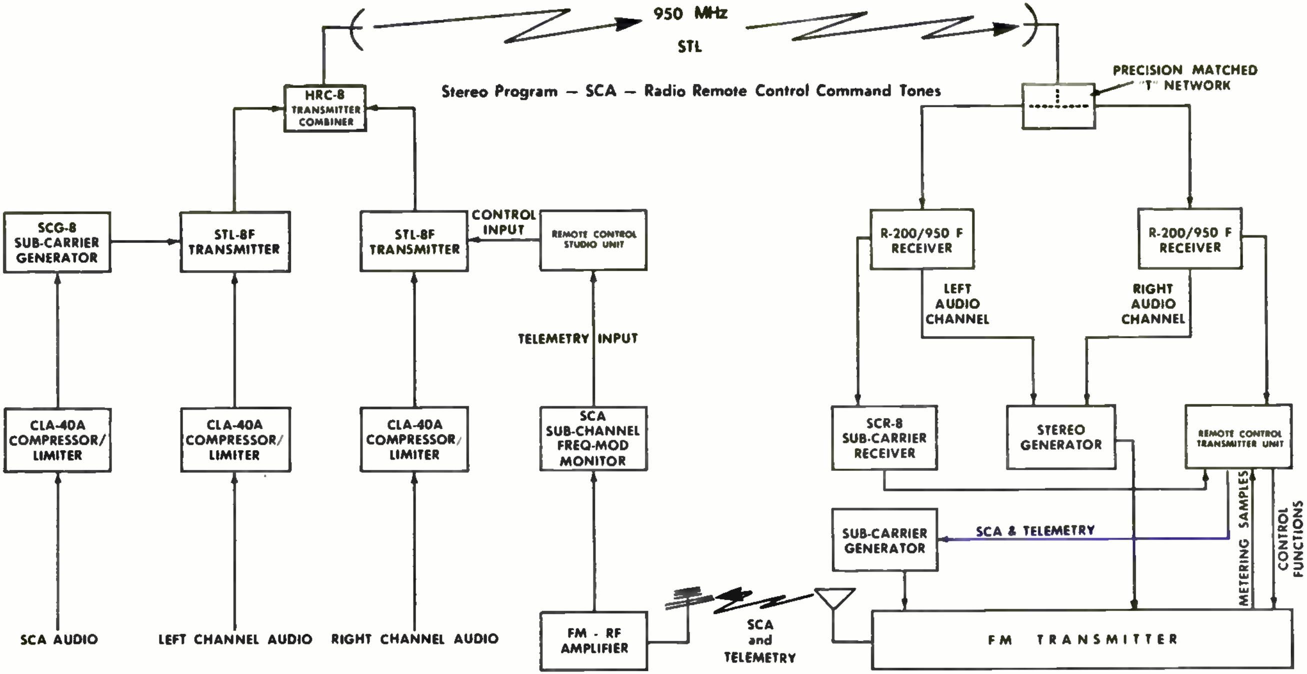


Fig. 7-18. Full over-the-air remote control for FM radio. (Courtesy Marti Electronics, Inc.)

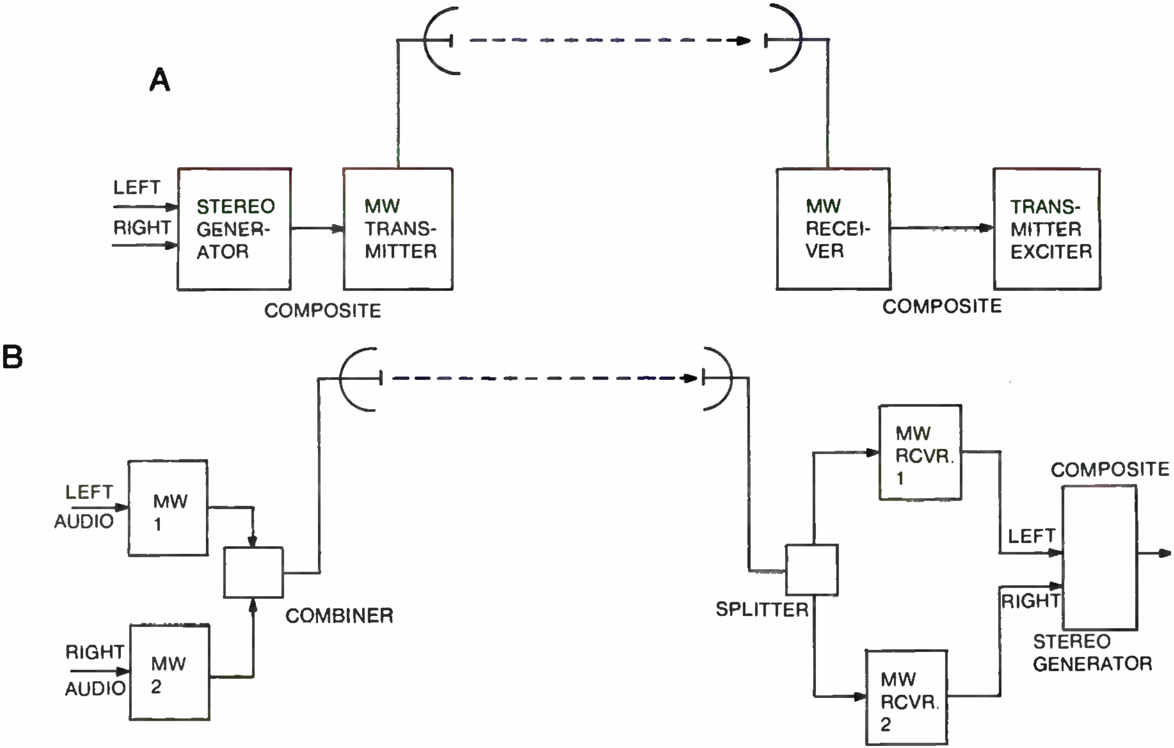


Fig. 7-19. Two ways to send stereo over the STL in A, as composite, in B, as the left and right audio.

that there *could* be 9 seconds of signal deterioration in a 24-hour period.

Economics is another factor. Land lines are less expensive to set up unless special cables have to be strung adding a construction charge, but the lease and rental goes on forever. And as telephone rates continue to climb, so will the future costs for the service. The STL is more expensive to set up, but its cost can be amortized in a three- to five-year period, depending upon how extensive the setup and equipment.

Maintenance expertise is simply a matter of learning. At the outset, maintenance on the STL could be done on a contract basis with an outside firm or with the factory service division. As experience is gained, it could then be done by the station.

Chapter 8

Program Automation

A number of radio stations, especially FM stations, use a major program automation system. All stations use some form or degree of automation. A major programmer is a complete system made up of many individual parts, all working together in a closely knit operation, which replaces both the control room equipment and the operator. To perform its functions as designed, it must meet two important conditions: Programming material for use by the system must be carefully prepared for that system, and the system's machinery and electronics must be kept functioning efficiently by adequate maintenance.

THE SYSTEM

All program systems are not the same, either in concept or in the equipment used. Methods also vary from one manufacturer to another. Systems can range from the simple sequential operation, wherein one event follows another according to a pattern preset by a multiple-switching panel, to the direct-access system with a multistep memory system that plays any source at any time controlling thousands of events before filling up the memory. In between these there are many combinations of some parts of both, such as, direct random access with sequential-subswitching arrangements or memories. In concept, the simpler system is essentially a single unit (although it will have several parts) that performs certain functions of the station's programming at different parts of the day. On the other hand, major memory systems replace all control room equipment and the operator.

For maintenance and troubleshooting, it is very important that the station engineer understand the particular system at his station. It is very easy to become wrapped up in the individual components of the system and become confused as to their role in the overall system. Study the components and their functions, but get a good overall view of them as a system.

The automatic programmer is a major subsystem in the station lineup, and it is made up of many minor subsystems that are still further divided into lesser subsystems. Use the method described in *Chapter 1* to develop a good understanding of the system and get the whole picture into focus.

Planning

No station should dive headlong into a major automation system without first doing much research and planning and knowing exactly what the system is supposed to do for them. This happens all too often and is generally the cause for disenchantment with the system's performance. But once the purchase decision is made for a particular system, there is still much planning to be done concerning its actual installation in the station. This planning is not much different than the planning required before installation of a new studio or a control room.

Space

In the installation planning, serious consideration must be given to the actual physical placement of the system. There must be adequate work space to the system. Consider the normal traffic patterns at the station. If this isn't given a thought, the equipment may be placed in a narrow area which is in one of the main traffic patterns of the station. When troubleshooting, the engineer and his test equipment may find themselves right smack in midstream of the traffic pattern, with people constantly crawling over them to get through. This situation is not conducive to the mental concentration required to isolate the problem.

Expansion

You can almost count on soon needing more rack space for expansion of the system. So plan at least two additional racks with the initial system to make sure there is room for further expansion. Use the rack space wisely and efficiently.

Efficient use of the space considers both the operation and maintenance. If all the racks are filled from top to bottom with tape machines, then when tapes must be changed the operator is down on hands and knees filling the floor-level machines. When trouble develops, the troubleshooter finds himself in the same awkward position.

Storage

There are many reels of tape and special program material that apply to the automation itself, and these should be stored in an area adjacent to the system. This allows for finding the replacement tapes when needed and keeps all the pertinent materials at hand. This storage area also separates the tapes which are to be used or saved for the programming away from tapes of a sister station, recording booths, and so on. This is no different than storing the current records or commercial tapes in the live control room or an adjacent room.

Recording Booth

A major automation system requires at least one recording booth to make up materials and announcement cartridges for the system. This booth should also be adjacent to the programmer. The booth is a very important part of such a station. By having it nearby, announcers can update materials quickly and can get the new one back into the system.

This clustering of the system and its peripherals into an operational area (Fig. 8-1) is no different from that which is done in clustering the peripherals around a live control room. When a major system carries the full day's programming of the station, this is in essence, replacing a live operation.

Turnkey or Station Installed

Most of the major system manufacturers install their equipment as part of a package price, but stations can select their own major components and develop their own automatic

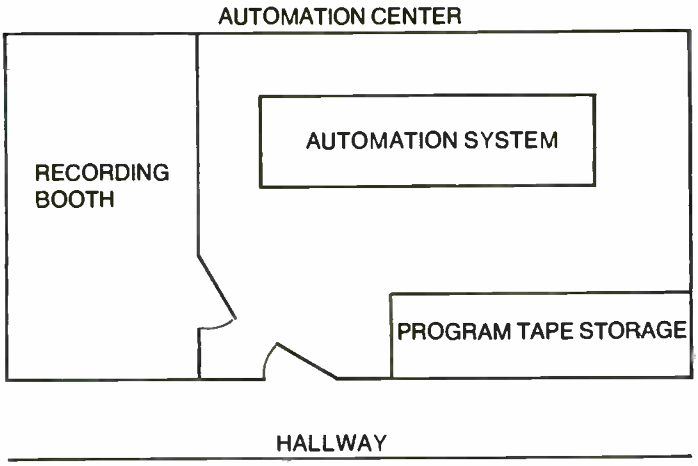


Fig. 8-1. Cluster the automation system and its peripherals together into its own operational area.

programmer. There are several manufacturers who sell the individual memories, switchers, and other components, working with station engineers in designing a system.

When the turnkey installation is done, work closely with the installer if you can. Have the installation conform to station standards. You will soon discover that not only do different companies do things in different ways, so do individual installers. Also, when the installer is being pressured by both the home office and the local station management to get the system operational in as short a time as possible, he may take the easy way out, doing a poor installation job. If you are tied up with trying to get a new transmitter on the air or technical problems with a sister station, you may not be able to spend any time with the installer. When things have all settled down, with everything working, you may discover the most tangled rat's nest of wiring you have ever seen. On the other hand, if the installer is not pressured and you can work with him, you have an excellent chance for getting an early insight into the workings of the system.

Installation

Try to keep the main power feed to the system separate from other power circuits, except perhaps, at the power panel. In each rack, use a plug-in strip for all the separate units to obtain power, and run the power feed through rigid or flexible conduit back to the power panel. If you have sufficient circuit breakers on the one panel, you can run each rack separately from a single breaker. It really isn't necessary with the plug-in strips. A single power feed can be run to the racks, then distributed from there.

Ground

A solid copper strap should tie all the racks together, or each rack may have a ground strap to the building ground. In either case, make solid connections to the building ground. The racks should also be bolted together. Where the ground strap connects to the rack, scrape off the paint to get a good metal-to-metal connection. Individual straps should be soldered to the building ground.

Surge Protection

If the station has not already installed surge protectors on the incoming power circuits, it should do so when an automation system is installed. At the least, these should be added to the power feed to this system. Most of these systems use solid-state electronics. Without surge suppressors, expect to have problems with the system after every electrical storm. Also remember that other sources of transients abound in a station, although these may not be the intensity of those from lightning, and these can cause many unexplained triggerings of the system.

Cables and Color Codes

Most of the individual units are connected into the system through multiconductor cables. It is important that color coding be kept as consistent as possible. Unfortunately, this is not always done by the manufacturer.

Cable sheets should be kept which not only give the function of each wire in the cable, but its color coding. If the color coding is not standardized, always keep this fact in mind when installing future equipment and troubleshooting. In this situation, cable sheets are very important. Standard practice dictates consulting these sheets before action is taken that involves the cables, rather than relying on memory.

System Phasing

Pay particular attention to the phasing of the left and right channels in a stereo system. This is the same attention you would give to phasing when installing a live control room or studios. But there is this difference. In a live studio you run your own audio cables, but with automation, most of the audio is routed through the multiconductor cables. Color coding may be different from your regular audio cables. Even worse, it can be different in cables from various units within the system. This allows more chances for errors in phasing. Remember to keep the high and low side of each channel the same and, of course, don't interchange the channels.

Setting Levels

Once everything is connected together and operational, set the audio levels throughout the system. Use test tapes that have been made up in the recording booth for a standard. Or you may use the *set level* tone on the NAB test tape.

Setting system levels is not as convenient as in a live studio arrangement, where all the console inputs are on jacks. There are far fewer test points on the automation system. You can expect to use some different techniques, but the requirements are the same; that is, each audio channel in stereo should have identical gain. If the initial setup is done from a tape machine, the master amplifier gains may be unbalanced. At each place along the route, channels should have the same gain—not only at the output of the system. There are at least two ways to set up the system levels.

Master Amplifier

If the input terminals of the master amplifier are available on terminal boards and can be easily disconnected from the system, feed a signal generator to the input of each channel separately with the correct driving impedance (Fig. 8-2). The driving impedance is usually 600 ohms. Make sure the output of the system is terminated at 600 ohms, and also connect your test meter to the output. Your test meter verifies that the VU meters are accurate.

Feed the input to the amplifier at 0 dB. Adjust the VU meters to read 0 dB. Check the test meter. If all is accurate, it too will read 0 dB.

Check for distortion. Now check for *headroom*. Change the meter pad or disconnect one side of the meter on the system (also the test meter). Without changing any amplifier gain settings, increase the input level from the generator to +10 dB.

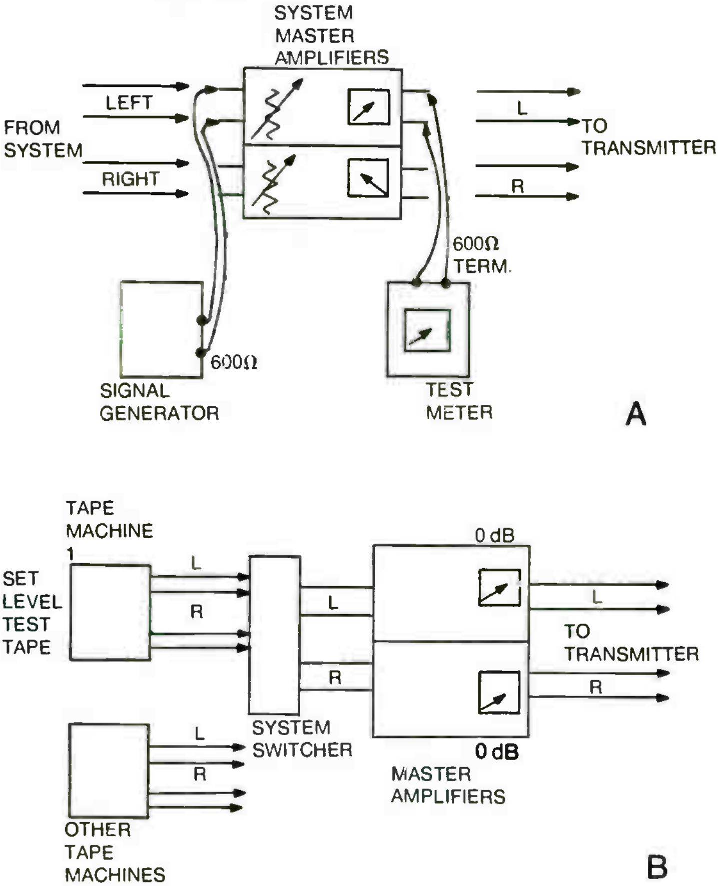


Fig. 8-2. Set the levels of the master amplifiers first (A), and then (B) the individual tape machines.

Measure distortion at this level to compare with distortion measured at normal levels. If there is an increase in distortion at +10 dB, the amplifier does not have adequate headroom—overloading is taking place. If that is the case, you should use a standard level which is 5–10 dB below the 0 dB levels. But most modern amplifiers are designed for at least +18 to +24 dB output, so that by setting the input to 0 dB or +8 dB, there is adequate headroom. Nevertheless, it is well to check this out and *know* what the amplifier will do—not what the specifications say it will do. If there is not adequate headroom and it is necessary to use a lower standard level, then make sure a note of this is placed in the instruction manual and the engineering files for future reference.

Playbacks

If you are able to adjust the master amplifier as previously described, it is now a simple matter of adjusting each playback unit. At this point, reconnect the master amplifier inputs into the system. Meters on the system can be used to set the levels; however, system meters may be at an awkward angle to be seen properly. Leave the test meter attached to the system output, and move it into a position more easily viewed. Set the output of each channel on the tape machine so the meters read 0 dB. Again check for distortion on each channel. You may wish to check each machine for headroom also. Do it the same as you did with the master amplifier. Set the levels of all the tape machines in the system to this standard.

System Response

Now that system levels have been set to a standard and balanced, check the system audio response and distortion. Run a standard NAB test tape through the system while using the test meter at the system output as before. You may wish to tweak the alignment of the tape machine heads at this time also. They will probably be on the button, but a simple check will tell. The response curve should be flat. If it is not, tweak the playback equalizers on the offending channel.

Alternative Methods

If it is not possible to get into the master amplifier inputs very easily—for example, if they are directly connected to a master printed-circuit board—then you will have to set levels a little differently. In this case work with the playback machines first. Set your test meter and connect it to the output of one machine. Disconnect the machine from the circuit and terminate the output. Or let the system terminate the machine and use your test meter as a bridging device. Adjust the output level of the machine to read 0 dB on both channels. Reconnect the tape machine. Move the test meter to the system output and terminate at 600 ohms. Now run the test tape again on the machine which has been calibrated to adjust the master amplifier gains for correct levels, and check VU meters as before. You can also check for headroom by adjusting the tape machine output 10 dB higher, checking for distortion. Remember to adjust the level back to normal. Don't change the master amplifier setting unless it is necessary to use a lower standard because of lack of headroom. With master amplifier now calibrated, you can use it or the test meter on the system outputs; adjust levels of each machine while it is playing a test tape. Also, the other measurements of head alignment, system response, distortion, and noise can be checked as discussed previously.

Control Tone Levels

The system usally relies on the control tones on the music tapes or the auxiliary 150 Hz tone on cartridge equipment to create the switching pulses. Unless these are set up accurately, the system can switch erratically or not at all. On cartridge equipment the tones are on a separate cue track of the tape, but in music machines, the tone is a subaudible tone in the left music track.

Music Machines

There are two different ways of handling the switching tones in different systems (Fig. 8-3). In one method, there is a single sensor that picks up the tone from the common left-channel audio bus from all the music machines. In the second method, each music playback machine has its own sensor. The single-sensor arrangement is more difficult to set up. In operation it must have enough leeway to accommodate all the machines, yet not trigger on music itself. It is a cut-and-try method. Even with an optimum setup, there can be an individual music number with many low-frequency tones that trip the circuit. A preferable method uses a single sensor at each machine. Then the adjustment of each sensor only involves the peculiarities of one machine, and the adjustments can be made accordingly. In either case, set the adjustment as insensitive as it can be and still trip reliably. Increase the sensitivity just a little beyond this point to allow for slight variations on music tapes. If you can create a test tape with these low-frequency tones of the correct lengths that corresponds with those the music library supplier uses, go ahead. But these companies often supply a test tape to adjust the sensors, which is compatible with the tones and level they use.

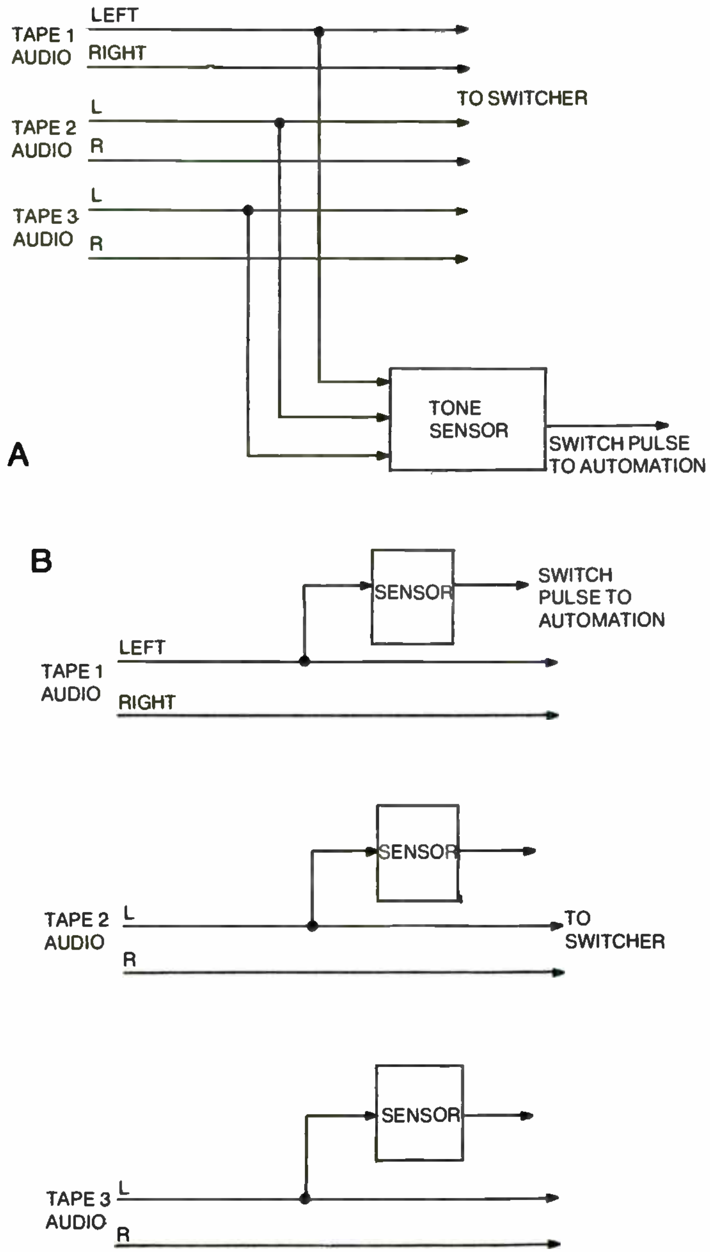


Fig. 8-3. Two different ways the control tones of music machines are handled. In A, one sensor handles all machines, and in B, each machine has its own sensor.

Cartridge Machines

Each playback machine should be set for reliable triggering on the auxiliary tone and for stopping on the cue tone. Again, set the sensitivity a little beyond the point at which the machines operate reliabily. Make up a test tape in the master recording booth to be used as a standard. Avoid running the sensitivity control wide open; there may be noise, transients, or other data recorded on the track if automatic logging is used. These spurious signals cause the machine to switch. Some models of playback machines are more sensitive than others in this regard. While you are doing this adjustment, attach an oscilloscope to the individual machine output to check the waveform of the switching pulses. Also observe for switching transients that occur when the machine starts up or shuts down. Any random transients cause erratic switching.

Maintenance

As mentioned earlier, it is unfortunate that these major systems do not have convenient test points throughout. There are test points scattered throughout the system, but most of these are on the individual units themselves, and they are not always convenient to get to. Besides that, they may be around the rear of the equipment, and it is necessary to be in front of the equipment to trigger equipment on or observe the action taking place. This makes troubleshooting and signal tracing a little more difficult.

There can be normal problems with the system in the area of audio—electronic and mechanical—but there will also be problems in the control, switching and memory circuits. One of the most confusing occurrences is when a number of different machines erratically fire on at the same time. That makes it difficult to get a good picture of what is really happening. That is, many uncalled-for events may be taking place that are seemingly unrelated to the actual fault. Transients on the switching bus are a likely cause of many unrelated events taking place all at the same time.

The system problems can be divided into two broad categories: improperly prepared program material or material in the wrong trays, and system electronic and mechanical problems.

Audio Problems

Audio problems are those associated with improper signal levels, which can cause overloading, distortion, low levels, noise, silence-sensor switching, or loss of one channel. For general level problems check out the tapes in question. If it is a cartridge, take it to the recording booth and play it on the master recorder. This should quickly determine if it is that tape or something in the system. If there is still some question, play another known-good tape in that machine to check performance. If the tape is at fault, have it redone. If it is a music tape from an outside library, complain to these people that the levels are not held consistently

If the poor levels appear to be the machine, check out the heads for oxide buildup, head wear, etc. It requires the same methods as for regular tape machines.

Head Cable

Sometimes the left or the right audio channel drops out when music is playing. One source of the problem is the cable plug that attaches to the tape head. Either the pins in the plug lose tension, or pins on the head are bent so that proper contact is not made. If the left channel is gone, the machine will not stop because the cue tones are not present.

Try to spring the contacts in the plug. This can be done successfully sometimes. Or straighten the head pins if bent. If the trouble can't be corrected in this way, then it is necessary to replace the whole cable because the plug is usually molded onto the cable.

Photoresistors

Losing one or both channels can be caused by photoresistor devices that are often used at various places in the system to switch the channels on or off when routed through some special unit, such as a network switcher. In the dual stereo units, there is a pinhole at one end where the light can be seen to glow when it is turned on. If the unit is supposed to be on and the light is not evident, substitute another unit. But if the unit is soldered onto the printed-circuit board, then make some other checks before unsoldering. You can use an oscilloscope to check for audio in and out of each channel, or you can measure the DC voltage and note if it is present or absent. If present but the light is still out, replace the unit. If the light is on and audio is still not coming through, check for input audio before changing the unit. In those systems which use single units, one on each channel, they run warm when the light is on for some time. Again, the checkout is the same, except there is no pinhole to observe the light. On both of these types, there is a terminal diagram on the body of the unit which shows the internal connections to the pins.

Other Causes

There are other causes for low levels or loss of either or both channels. Pressure pads on cartridge machines may be defective or missing (in some cartridges). The pull-in mechanism on a particular tray or on the single-head machine may be out of adjustment, or small parts may be missing. Unless the tape is held against the head with proper pressure, the output levels will be low, not only from the program tracks, but also from the cue track, causing erratic switching. Of course, worn heads or oxide buildup can create the same effects.

Failure to Switch

Anything along the switching-pulse route that is open can cause the switching pulse to fail to do its job. This can be caused by open circuits or loose plugs, a channel may not be ready, a machine may have blown a fuse, or developed some similar fault. It can also be caused by poor or no signal from the tape heads or failure in the machine sensor circuits.

Check the machine sensor circuits first by measuring the relay-contact output. Normally, the pulse itself does not do the switching; it turns on a relay that routes DC voltage to act as the actual control pulse. Make sure that there is no voltage on the contacts that can damage an ohmmeter. Otherwise, use the voltmeter on the output side of the contacts, checking to see that it is at the input contact before the test (Fig. 8-4). Play a tape, watch the meter, and listen for the relay to operate. If the relay operates but no voltage is switched, the contacts are defective. Replace the relay and try again. But if the relay does not operate, then look to the machine or sensor for fault. Check the actual tone pulse that is received from the tape machine. If it is strong and normal looking, then the sensor circuitry is at fault; but if the pulse is very weak, distorted, or missing, check out the cue circuit to the tape head.

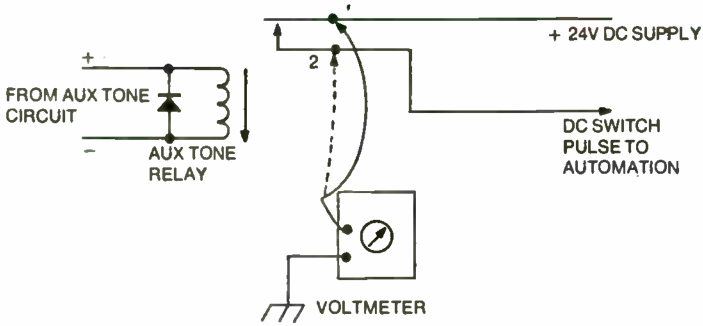


Fig. 8-4. If DC voltage is switched, measure the source voltage (1) first; then measure after the relay contacts (2) when the relay operates.

If the voltage is not present at the input of the relay contacts, look back into the circuit that is feeding the supply voltage. If the relay switches the voltage, trace the pulse on down the circuit path. Check for loose plugs or an open series diode in the circuit.

False Switching

Static electricity can be a real problem, producing false triggering of logic circuits. When carpeting is used, this situation in dry winter months can be very troublesome. Nylon indoor-outdoor carpeting is perhaps the worst for generating body static. If a memory-type controller is used, the best thing to do is go to special computer-room carpet. This has fine wires woven into fabric, providing a ground terminal. It is expensive, and perhaps the most economical and practical route is to forego the carpeting altogether. Many of the large industrial companies which have large computer systems have given up on the carpeting and installed asbestos or similar floor tile.

Static can be a real problem to either the memory unit itself or to individual machines which use a positive logic control. (By *positive* is meant that it takes a positive pulse to turn it on or cause the desired action.) Most solid-state equipment uses the negative logic, in that it takes a negative pulse or a ground connection to make the unit act. With one model of multitray cartridge machine using positive logic, an announcer walked across the room to place a cartridge in a tray of the machine. When he touched the machine, several trays turned on and ran. The turnon was caused by body static. Antistatic powders and other treatments for carpets either failed to do the job or were very short lived.

Head Replacement

When heads must be replaced on either the music machines or cartridge machines, always do this more carefully than one might do with regular machines in a standard live operation. Make sure the replacement head is correct; that is, don't get a record head instead of a playback head. Use the standard alignment tape. When removing the old head, physically displace as little as possible, noting the present mounting position of the head. The more precisely you install the replacement head, the easier it is to make the alignment.

Head Substitution

There may be a time that the station desires to change the heads on the music machines to a different type, or perhaps the factory might send a different head that is supposed to be a direct replacement. When this is done, check out the results very carefully. All heads do not have the same characteristics or response, particularly at the very low frequencies where the switching tones are carried. If the response below 50 Hz falls off rapidly, then be alert for switching problems; but check it out now, don't wait for switching failure. If you have a test tape with 25 Hz tones on it, use this on the machine to read the response on the system meters. It could be several decibels lower than the previous heads. Now this doesn't rule out the use of the heads, but the sensor will need some adjustment. In most cases, the individual sensor can be adjusted to accommodate the lower response, unless the response is unreasonably low or nonexistent at 25 Hz. The real problem can occur with the system that uses a single sensor for all the music machines. In this case, the best procedure is to change all the machines to the new type of head at the same time. Then the sensor can be adjusted to these new conditions. If the sensor is adjusted to accommodate this low-level machine, the sensitivity will be too high for the other machines, and it will trigger on music. For the single-sensor setup, all the machines must be reasonably close in low-frequency response.

PC Board Connectors

Another trouble spot can be the connections on edge-connected boards. This is the type where all circuits run to one edge of the board and the board plugs into a socket connector. The cards can work loose, or oxidation can cause resistance on the contacts. This causes intermittent switching, circuit failures, loss of channels, and other problems. Reseating the board if it is loose will correct this type of problem. If it is not loose, the board should be taken out; trace contacts on the card itself. Clean each contact with a pencil eraser. This will usually do the trick, but make sure the unit power is off before pulling out or replugging the card.

A similar situation can happen when a cable connects to pins projecting out of a board. This may be a continuation of a master board system from one chassis to another. In this case, the cable has many circuits and hence will be a large cable. The weight of this cable, plus occasional jarring, can cause the plug to work loose, and of course, certain functions fail or operate erratically. The best cure in this case is a good anchoring of the cable so that the weight is off the plug. Use some cable ties to anchor the cable down tightly, but make sure there is no strain on the plug.

Cable Abrasion

A similar situation can exist with units that roll in and out of the racks that are connected by flexible cables. If these units must have much movement during normal operating routines, the cables can drag across surfaces. Enough of this abrasion and the cable sheath and actual wire insulation wears through, grounding out to the frame. Check for these wear points. Also, make sure the cable is anchored well where it enters the chassis. Keep an eye out for abrasion where it may drag over rails.

Silence Sensing

Most systems provide a silence sensor that monitors the audio, then fires off an alarm and steps the system ahead if the audio fails. There is usually an adjustable time delay of three to six seconds before the unit reacts. This is normally connected to the monitor output of the system. In the usual station setup, there are signal processors, phone lines, transmitter, and much else beyond the automation itself. It is possible to have audio failures anywhere beyond the system resulting in no program on the air, although the automation may be purring along normally. The best monitoring point for the silence sensor is at the audio output of the modulation monitor or a receiver monitoring the station off the air (Fig. 8-5). Then if anything fails beyond the system, the silence sense alarm warns that there is no air program.

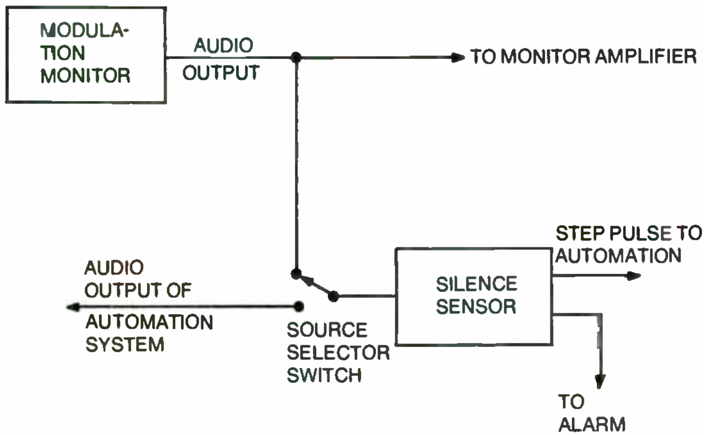


Fig. 8-5. Monitor the audio after the modulation monitor with the silence sensor.

Modifications

There are many modifications made to the automation both during the original installation and at later dates when the station trims the system to more specifically meet its needs. Regardless of when the modifications are made, the system diagrams should be updated with the new information. And if there is a change in the operation of a particular unit, then there should be modified instructions shown in the instruction manual. If the added circuit or modification is one of station design, then a complete schematic should be made along with its notation on the diagrams where it interfaces. Keep a regular file on these modifications along with the normal prints and manuals of the system.

Cleaning

A system that is in operation for all of the broadcast day runs miles of tape through the machines. Tape machine heads need regular cleaning to prevent oxide buildup. At the same time check on head wear. When there are many heads to be cleaned, these can be spread out over a period of a few days, but music machines should be cleaned at the end of each day. Those multihead cartridge machines do not have every head used as much as single-head types. Such machines can have the head cleaning spread out over a week without too much difficulty in operation, but that depends upon the actual operation of the machines in the system itself. The important point is that a regular head-cleaning routine should be set up and followed. At the same time, clean the pinch rollers and other tape-carrying surfaces.

Racks and Units

The rest of the system and the racks should be also on a regular cleaning routine. A vacuum should be used to clean out the dust before it is allowed to accumulate. During this time, check and clean any fans and air filters that may be used. Small fans can accumulate heavy layers of dirt on the blades which cuts down their efficiency, and the air filters can become clogged and reduce cooling. Also, check that these small fans are actually running.

Pilot Lamps

Major systems have many pilot lamps throughout. These are not there for cosmetic purposes, but serve a most functional end. When a number of these lamps are burned out, it may be difficult to determine which machine is running as programmed, which one is cueing, and what machines may be running due to some faulty switching. So it pays, from an operational viewpoint, to keep the lamps replaced and burning properly.

Readouts

Readouts serve a still more necessary function than the pilot lamps. Some larger readouts use small incandescent lamps for each one of the seven segments. Access to these is at the rear of the readout after some minor disassembly. But getting to the rear of the readout itself can be another problem. If some lamps are burned out, when an opportunity presents itself to open the unit, change the lamps. Replace all seven with new lamps. The ones still burning will not have too many hours left, and you would soon need to do the job again.

The lamps that are still good need not be thrown away. They can be used in other areas where it is much simpler to replace the lamp, for example, with the lighted switches on the music machines.

Transients

As mentioned earlier, transients can cause many problems. The relays and motors can kick up some unhealthy transients along the AC power circuits, and these can couple into control circuits and even the audio. Capacitors across relay contacts and diodes across relay coils reduce transients. Another device is the small surge suppressor made by General Electric Company for use on home equipment across the AC input. If the system worked reliably prior to this and now has transients, either the built-in suppressors have failed or defective components are now present. Check for burned relay contacts, as these can be a source.

MOS PROGRAM CONTROLLER

All major automation systems have a program controller. Smaller systems have mechanical switching matrices, and these are limited in size and action because of the physical limitations of the switches themselves. These are usually sequential in operation. Once the designers learned how to scale down computer technology and apply it to automation systems, the systems began to expand in size and flexibility. New devices have been also developed, such as the MOS (metal oxide semiconductor) field-effect transistor. The MOS-type program controller has become popular recently.

MOS

In the MOS field-effect transistor (MOSFET), the junction area is a very thin layer of metal oxide, acting as an insulator. The junction forms a small capacitor, which has the properties of memory. To store any appreciable amount of information, a large number of MOSFETs must be used. So the MOS IC was developed. On each IC chip, manufacturers have been able to squeeze in more and more memory cells so that present memories can store well over 4000 events.

Lineup

To obtain any number of events, the individual MOS units on each chip are arranged in series (Fig. 8-6). To further

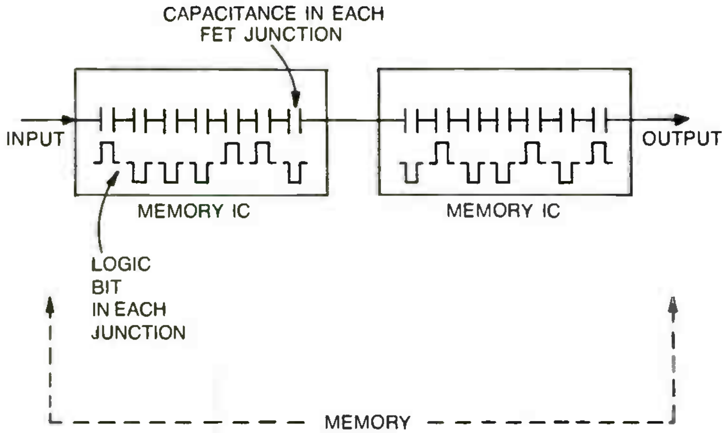


Fig.8-6. The MOS units are in series inside the IC, and ICs are wired in series to increase number of steps a unit can store.

expand this storage capacity, many chips are mounted on printed-circuit boards that are wired in series. How many events that can be stored in the memory is limited by the physical space required to handle the number of printed-circuit boards. But there are practical limitations because there are other peripheral circuits which process the data into and out of the memory itself. While the memory is a very important part of the controller, it is useless without the peripheral circuits, which process the data, control external equipment, and so on.

Binary-Coded Decimal

BCD stands for *binary-coded-decimal* and is a shorthand method used in computer technology to conserve space and components. There are several such codes possible, but the most common code used is the 4-line (8-4-2-1) code. Any digit from 0 to 9 can be formed by a combination of these four numbers. For example, the digit 9 can be formed by the 8 and 1; a 3, by 2 and 1. By the use of BCD, then, only 4 parallel circuits are required instead of 10. This conserves space and components.

Memory Storage

Information is stored in the memory in BCD form. The memory requires as many *parallel* paths as are necessary to handle the BCD profile for the particular digit in question. For example, a tape machine in the automation may be designated source #7. The memory must have a special section for the source information. The number of parallel paths required in the memory is determined by the highest number of sources the controller can handle. If, for example, it is a small unit that can only control seven sources, then there need be only three parallel paths, which could combine to make the number 7. This would be BCD 4-2-1. A fourth path for 8 would not be necessary since there is no number that high.

The storage and action of the memory can be compared to columns of soldiers on parade (Fig. 8-7). Each long, single column, marching forward in step, could represent a single

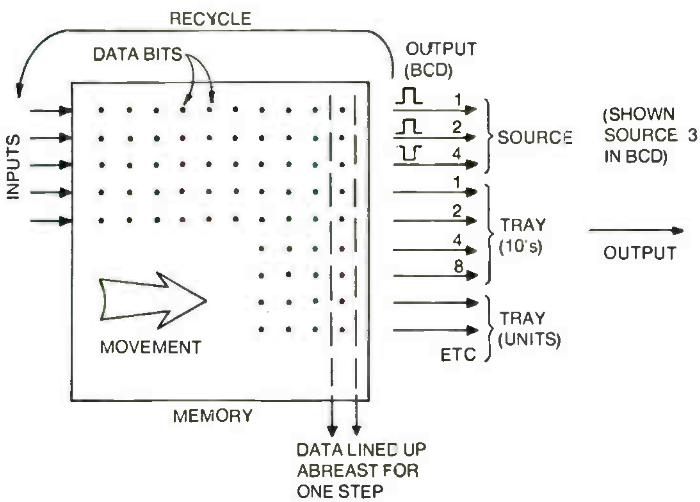


Fig. 8-7. All data bits lockstep abreast from input to output and then recycle.

BCD line. The number of soldiers in that column could represent the number of steps the memory can store. As the reviewing officer, you would look across these many columns and note how well each soldier from each column lined up shoulder to shoulder with the men on both sides. In the computer, there are as many "columns marching abreast" as there are requirements for data storage. In the source information we are discussing, the three parallel columns "march past in lockstep," one event after another. For example, if the source called for at this step in the memory is

#3, then the memory parallel BCD lines would be: line 4, low; lines 2 and 1, high.

The tray number for that step would also be lined up with the source lines. This section must have its own parallel BCD lines also. If there are code numbers or other data required at the same time, each of these must have its parallel lines. All of this informtion steps through the memory in parallel. The BCD lines in the memory are MOS chips.

The MOS is a *dynamic* memory with the storage in the capacitive element of each MOS unit. As with most capacitors, there is leakage, and the charge will "fade out." There is nothing to maintain the charge if power is removed, so the power must be on at every instant. Even under continuous power, the charge will fade, so the memory must be "refreshed." To do this, an oscillator *strobes* the memory, and each cycle of the oscillator frequency moves the columns ahead one step at a time. The memory is cycled from the output back into the input in a constant recycling process. The oscillator will operate at 1 or 2 MHz, so the data is cycled through the memory 1 or 2 million times each second.

When data is called for from the memory, the data that is stored does not get "used up." When a call comes in for a certain step, the output gating circuitry will wait until that step cycles to the output. At that point, a charge is transferred from all the columns to the output gating and sent on to the use intended. The memory data continues on its normal cycle back to the input of the memory. This is as if all the soldiers across the marching columns, on reaching a turning point, reached out and each pushed a *start* button simutaneously and then continued on their normal march.

The oscillator, or strobe, synchronizes all this activity as well as the recyling of the memory. You will find the oscillator feeding many parts of the computer as well as the memory.

Maintenance

Before attempting maintenance on the computer, study the workings of the model in use at your station. Some instruction manuals are nothing more than a sheaf of circuit diagrams with very little explanation of how the unit works. If this is the situation in your case, you will need to obtain data sheets on the various ICs used in the unit from the manufacturer. Work with the block diagram of the overall unit. Sometimes the instruction manual will supply this data also.

Troubleshooting

Use signal-tracing methods and keep the memory operating all the time (unless it is burning up). Once you turn the power off, the entire *memory* is lost and it will be necesary to reprogram. Use the logic probe at the test points of each board where they are provided. Some units may also include some small test lamps at various critical circuits. These lamps may be indicating in BCD, so take this into consideration when trying to figure out their action.

When possible, run the automation manually or switch it over to some other program source to play on the air. This will allow you to operate the memory at will, and you won't have to wait for long tapes to play through and cue up.

Cards

Follow the overall block diagram and check the input-output test points of each card (PC board) with the probe. (Refer to Fig. 8-8.) That is, determine if the input goes high or low as it is supposed to. Then move the probe to the

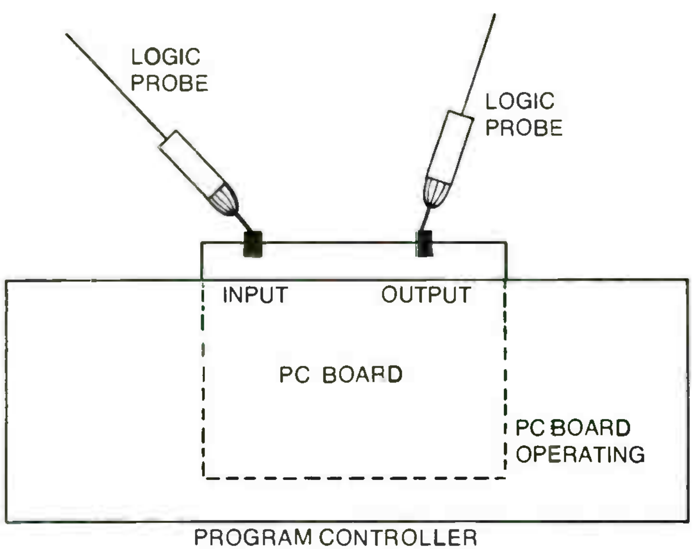


Fig. 8-8. Check the input test point and then the output test point of the card with a logic probe to isolate problem to the PC board.

output and check for the correct action. Two probes are better because then you can observe the input and the output at the same time. If the input indicates correct action but the output does not, then shut down the power and put the card on an extender board. Turn the power back on. Now the memory is lost, but only program around the particular steps or actions that were at fault rather than doing the whole memory at this time. You may have the power on and off several times before finding the fault. Now, with the card on an extender board, use a logic clip for the in-line ICs. The clip allows viewing the action of all the pins on the IC at the same time. Keep on tracing the signal until the fault is tracked down. To signal trace on the card, use the individual circuit or block diagram for the card itself. When using the probe, be careful not to short two pins of an IC together, or the IC may be damaged.

Memory

When problems occur, it may not be easy to determine if they are in the memory or somewhere else. If the memory has many *identical* cards on each side of it, the cards may be swapped around in an effort to get the fault to follow the position of the card (Fig. 8-9). This can help isolate the fault to

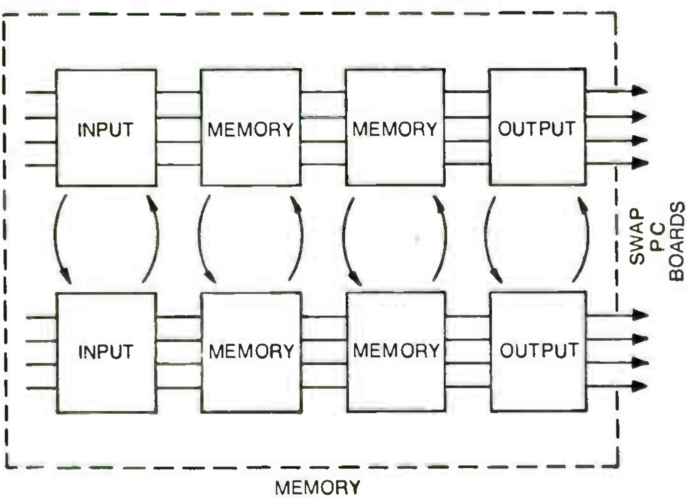


Fig. 8-9. Swap identical cards from one side of the memory to the other side in an attempt to isolate fault to memory itself or an individual PC board.

an individual memory card. For example, assume that a fault shows up as an incorrect number in the *unit* readout of the trays. Looking at the print, you realize there are enough circuits on the other side of the memory to swap some of the cards. With power down, trade a single card (or all, if trying to rule out the memory). Then reprogram some information. If the wrong number now moves over into, say, the source readout, the fault is in the memory. But if the fault remains in the tray's *units*, it is elsewhere. Swapping cards can be done anywhere there are identical cards on different circuits in the computer, *but make sure they are identical*. Plugging a card into a wrong slot can blow out all the units on the card. If the problem is determined to be the memory, then go through the process again; but this time, swap only one card at a time. This will isolate the problem to a single card.

Power

These dynamic memories must have not only continuous power, but well-regulated power supplies. Check the regulators and battery-charging voltages, and keep them set to the values shown in the instruction manual. Also check the air filters and blower if these are used. Air filters can clog up and fan motors can quit; and if the air is reduced, the power supplies may go out of regulation, and all sorts of erratic behavior can be expected from the memory.

Other Problems

Transients can be a real headache, both to the memory and the automation operation. Besides damage which can occur from strong transients, lesser transients can add spurious information to the memory, causing false switching of the automation by the controller. These transients can come from many sources: the power line, switching of tape machines, and static electricity from carpets.

Pushbuttons on the keyboard eventually wear out and need to be replaced, but before they fail altogether, they may become erratic or develop *contact bounce*. When this bounce is happening, the contact may send out two or three extra switching actions instead of the required one; this can add spurious information to the memory or step the system erratically.

Last, but far from least, is human error. Many problems will be the result of human error in programming the memory with wrong information. For example, the finger may slip on the keyboard and hit a 2 instead of a 3 for the source. So when this step comes around, it calls up and plays source #2 on the air instead of the #3 which was intended. Always remember, the memory calls up machines—not programs or announcements. It is up to the human operator to put the correct information into the memory and place the correct tapes in the correct trays of the tape machines.

Chapter 9

The Transmitter

A very important major subsystem in a station is its transmitter. This is the unit which puts the word *broadcast* in the term *broadcast station*. The transmitter must work reliably, for without it, the station is out of business. Reliability requires maintenance. When maintenance is performed, somewhat different techniques are necessary. This is because of the unit's RF nature, the dangerous high voltages involved, and the FCC Rules. It is not enough to simply make repairs and get the transmitter operating again. *Anytime* that the transmitter is in operation, it must comply with the Rules.

BASIC TRANSMITTERS

The AM and FM transmitters have many differences because of the methods of modulation and the different carrier frequencies. Even though they are different, they have very much in common. Both the AM and FM transmitter can be divided into at least six different systems: RF, the audio modulation, power supplies, control, monitoring, and cooling. Each of these systems are divided into a number of subsystems.

Techniques

Your troubleshooting and maintenance techniques need some modification when working with the transmitter.

Remember that you are dealing with RF and high voltages, so that some methods that work on studio equipment will not work here. Learn how the particular transmitter works, divide it up into its subsystems, fine-tune your techniques, and you can handle transmitter problems as easily as audio equipment problems.

AM Systems

The purpose of any transmitter is to convert the line power to an RF carrier so that it can convey the intelligence impressed upon it by modulation to all locations in the station's coverage area.

The AM transmitter carrier originates in a crystal oscillator stage and is amplified to the power output stage, where modulation usually takes place in the plate circuit. (See Fig. 9-1.) The modulated-carrier output signal then passes through a matching low-pass filter network to the transmission line and antenna.

The crystal itself usually operates at the carrier frequency, and the stability of this crystal controls the carrier within the required ±20 Hz tolerance set by the FCC rules. The crystal is mounted in an oven or a vacuum. Solid-state exciters use a higher frequency crystal, typically four times higher than the carrier, and then divide this down to the carrier frequency. The stages between the oscillator and PA (power amplifier) are straight amplifier stages, and they have high gain and very narrow bandwidth.

Modulation

Audio at a standard +10 dB input level is fed to one or more audio stages for amplification to the modulator stage. Plate modulation in the PA has been used extensively, although there are other methods in use. For plate modulation, the modulators must supply the sideband power, which is equal to 50% of the RF carrier's average power at 100% modulation, and more than this when 125% positive modulation is used. The modulator is simply a very high-power audio amplifier that is used to control the RF signal in the PA stage and produce modulation.

FM System

Although the carrier originates in the master oscillator, the oscillator itself operates at some submulitiple of the carrier

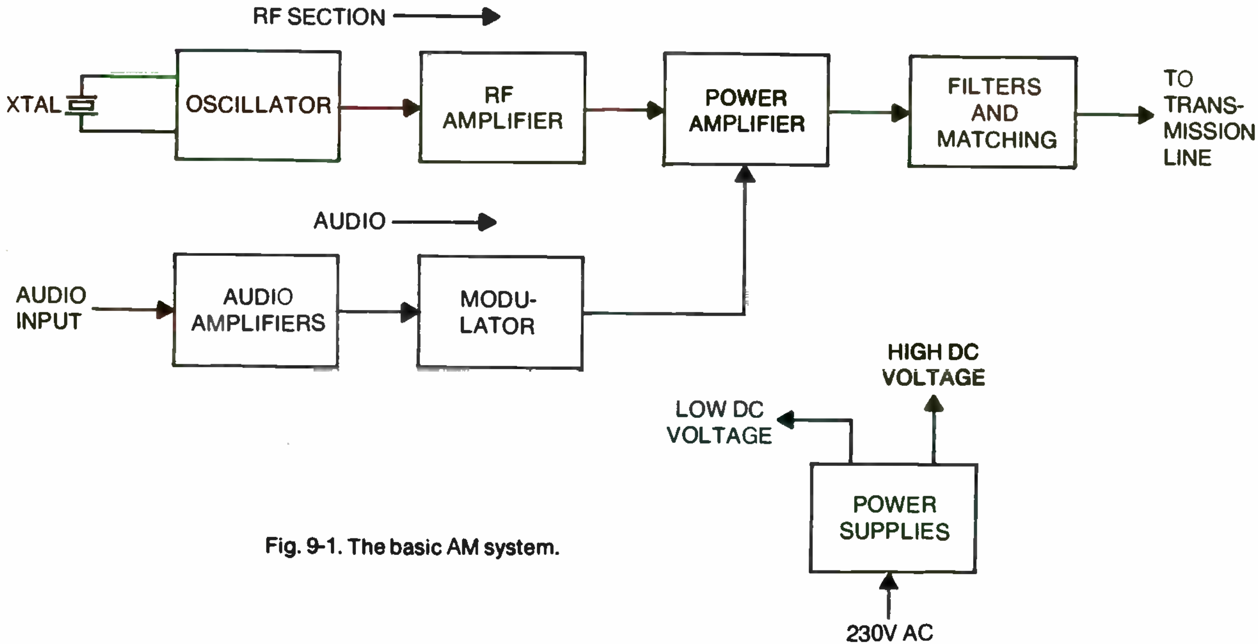


Fig. 9-1. The basic AM system.

frequency. This is because the carrier is in the VHF range, and oscillators at carrier frequency are impractical. The output of the oscillator then is multiplied until it reaches carrier frequency. This is done in several multiplier stages, and the frequency swing is also multiplied. Therefore, these stages must be more broadband than those in AM, for when a full carrier is amplified, the stage must be broadband enough to pass a carrier swing of at least 150 kHz (200 kHz would be better).

Oscillator Stability

The oscillator is far different from an AM oscillator. In most cases, the oscillator itself is modulated. This presents problems since a crystal cannot be used directly. There have been several methods used to produce frequency modulation but with the advent of stereo, most transmitters have gone to the direct FM, reactance-modulated oscillator (Fig. 9-2). Because a crystal cannot be used and the stage is modulated, its frequency stability is not very good. But indirect control is used so that crystal stability can be realized. This indirect control is called an automatic frequency control (AFC) system. The output of the main oscillator is sampled and mixed with a signal from a reference crystal oscillator to provide an IF (intermediate frequency) signal, as is done in a receiver. This IF signal is well filtered to remove audio modulation, and then converted to a DC control voltage that moves the master oscillator back on frequency when it drifts. This control system can maintain the carrier within the prescribed tolerance of ±2000 Hz.

Modulation

It requires very little audio signal power to provide 100% modulation in FM. The audio signal will be fed to the exciter input at the standard +10 dB for monaural. Or a composite signal from a stereo generator or SCA (Subsidiary Communication Authorization) signals, if they are used, may be fed in. These may or may not pass through an audio amplifier, and are routed directly to a pair of voltage-variable capacitors, which inversely change in capacitance when the DC voltage across them is changed. This varying capacitance is across the oscillator tank circuit, so the audio signal will modulate the carrier.

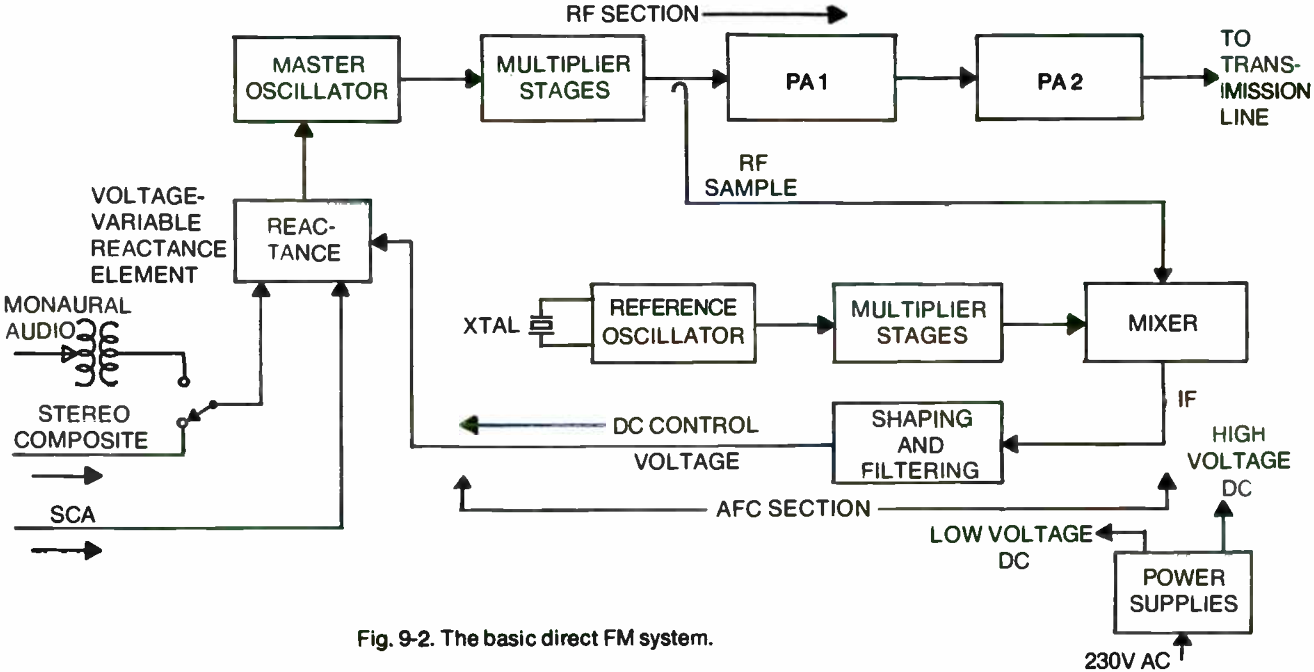


Fig. 9-2. The basic direct FM system.

Other Circuits

Power supplies convert the AC power line voltage into various levels of DC voltage as required. High-power transmitters require several thousand volts of DC for the power stages. These may be tube-type supplies, but most are now solid-state. Except for the voltages involved, they are somewhat conventional.

Control circuits operate all the various time delays, power contactors and other relays, and the blower system. This whole arrangement is called the *control ladder*, because all these various relays follow one another in the application of power to different stages.

Monitoring within the transmitter is done by various metering circuits. These usually measure only samples of the actual circuit currents or voltages. Some samplers supply low-voltage, low-current analog samples for external or remote control metering.

Rules and Regulations

Many things can be done to the transmitter *only after application has been made to the FCC and approval received.* Any engineer who is required to do maintenance or operate the transmitter should be well versed in the FCC technical standards. Many rule changes have been made and it is well to keep updated on these changes.

Some modifications require formal applications, others an informal letter to the FCC, and others simply notification to the radio inspector of the FCC district. Before deciding to make any change in the transmitter which would alter its operation in any way, consult the rules that apply in the case. These will be found in various sections of Part 73 of the FCC Rules and Regulations.

Installation

Prior to installing a new transmitter give much thought to the actual physical location. Consider operational factors *and* also what is required in peripherals. If the transmitter is a replacement for one that is already operating, don't plan to pull the old one out at signoff and have the new one installed in the same spot and back in operation by signon. This works on some occasions, but it is also possible that the station will be off the air for several days. Yet there are managers and owners who urge this approach to the installation.

Externals

Plan for the external connections that must be made. There will be AC power, audio input equipment, monitoring equipment, the transmission line, and perhaps a dummy load and external exciter for FM.

AC Power

AC power for the transmitter is usually 230V, or higher for larger transmitters. It is usually three-phase power, although in some low-power units, it may be single phase. This power should be run through conduit from the main power panel, and the wire used should be heavy enough to carry the expected current draw of the transmitter. The transmitter specification sheets give the total power required from the AC line at carrier only and at full modulation. Convert this power to current demand and select power cable heavy enough to carry this draw without overheating or producing a voltage drop. (FM has a constant power draw.)

Power Panel

The transmitter should have its own power panel, or at least its own circuit breaker. The size of this circuit breaker and panel must conform with the wiring codes for the size of wire used. If the transmitter must run from a general panel that supplies other units in the building, such as heaters, make sure the main breaker on that panel is heavy enough to carry the additional load of the transmitter. Don't overload the power panel, or intermittent outages result. If the load of the transmitter is too much for the main breaker, the transmitter must have its own panel.

Separate Power

For those transmitters (both AM and FM) which use a crystal or oscillator in an oven, a separate 120V AC source is required. This can be picked up from the main feed to the transmitter, but it is better if this is fed directly from the power panel and has its own circuit breaker. This allows shutdown of the main power to the transmitter back at the breaker panel and leaves the ovens operating on their separate circuit.

Transmission Line

Location of the transmitter in relationship to the coaxial transmission line is another important factor. High-power transmitters require large-diameter lines. When a dummy load external to the FM transmitter is used, mount a coaxial switch so that the switch from line to load is an easy matter and doesn't require disassembly of the normal line connections. Positioning of this coaxial switch and all the other coaxial plumbing should be given careful planning.

Phasors and Filters

When the AM station uses a directional antenna system, a phasor cabinet is mounted next to the transmitter. More than one coaxial line goes into this phasor from the antenna system. The transmitter output itself feeds into the phasor, and the phasor makes the distribution to the antenna system.

The FM transmitter has an outboard harmonic filter. These are in different configurations, but many are a rigid coaxial line section several feet in length. There must be room for this filter to project from the transmitter.

Racks

Besides the phasor (if used), there is at least one rack to hold the monitoring and audio input equipment. Such items as phase monitors, the modulation monitor, audio monitors, and audio-processing equipment are located here.

The FM transmitter generally has its exciter in an external rack adjacent to the main transmitter. The reactance modulator and especially the voltage-variable capacitors are very susceptible to vibration, so the exciter is mounted in a separate cabinet.

Grounds

Everything in the transmitter area should be bonded securely to a heavy building ground. There are strong RF fields from the antenna outside the building, so there are possibilities of feedback, and problems in the audio from the heavy AC drawn. All cabling is to be shielded for the same reason. The AM transmitter has a remote meter fed from the antenna base. If a directional antenna is used, a phase sample of each of the towers is fed back to the control position (transmitter location). All RF lines should be shielded to avoid piping these signals into the system.

Cooling and Heating

Consider the transmitter location in relation to the cooling and heating arrangements for the room or building. There can be air ducts, exhaust vents, and air inlets, and these ducts have to intermingle with coax lines. They should be arranged so that either can be taken apart for repairs without disassembling the other.

Putting It All Together

During or upon the positioning and connecting of the transmitter, check out the transmitter components and put all the pieces back together. How much was removed for shipping depends upon the transmitter and the manufacturer. Check for relays that have been removed and plug these back in. There may be power resistors either removed or tied down, so look for wood or other blocking that may have been inserted for shipping. Replace all tubes that have been removed, and make sure they are properly seated in their sockets.

Mount anything that has been been shipped separately, such as power transformers, modulation transformers, and cable harnesses or jumpers. On the power transformers, set the primary taps of each one for the local line voltages expected. Although the transmitter is set up and tuned up at the factory, check to see that taps on RF coils are still in place and tight. A tap may have popped loose during shipment.

Check for hardware that has been left loose at the factory or has come off during shipment. Check closely on terminal boards and across the terminals of voltage buses and capacitors. Loose hardware may be lying across a couple of voltage points waiting for you to turn on the transmitter and blow the circuit breakers.

TUNEUP

There are some important actions that must be taken before applying power to the antenna during the original checkout.

FCC Notification

The FCC must be notified before you begin equipment tests. Both the commission in Washington and the inspector in charge of the district must be notified. This notification is informal. Send a duplicate telegram to both offices, stating that you will begin conducting equipment tests according to construction permit number so and so, on a certain date. You may then proceed with the tests on that date without further authorization from the FCC.

Experimental Period

The time between 12 midnight and 6 a.m. local time is the *experimental period*. This period must be used by the AM station for equipment tests and regular testing unless it has special authorization to test in other periods. The FM station may test during the experimental period without authorization, but it can test at any other time *if* it notifies the commission in Washington and the inspector in charge of the district. In many cases, the experimental period is the only practical time to test, especially if the station is already operating a lower power transmitter on the channel. However, if you are operating on that channel and are going to use a dummy load, be careful that there isn't enough radiation from the load or other circuitry to cause interference with the operating transmitter. Go out and listen on a receiver for beat notes on the regular station carrier. If there is interference, then do the testing after signoff. Unless testing is done with a dummy load, the AM station must do its testing during the experimental period.

Best Efficiency

All the RF stages should be trimmed up in tuning and the antenna used as the load for the final testing. When you tune into the antenna, adjust for the best match to the load and the best efficiency of the PA stage. Adjusting for the best efficiency encompasses setting the input drive to the PA, matching the load, and tuning the plate circuit of the tube (or transistors).

AM Power Amplifier

Start the tuning by setting the controls to the markings shown on the factory checkout sheet. These are factory-tuned into a dummy load, and your antenna system has a slightly different load condition. So dip the plate current and adjust the drive and loading to obtain the required antenna current for the station's authorized power. Compare the readings obtained with those of the checkout sheet, and if comparable, go ahead and tune for best efficiency. This is called a *unity power factor* condition and does not occur at the resonance dip in plate current. Observe the antenna current meter and slowly adjust the PA plate tuning toward the capacitive side of resonance (more capacitance in the circuit). The antenna current will continue to rise without a corresponding rise in plate current for a short span of the tuning. Continue tuning in the same direction until the antenna current ceases to increase and the plate current begins to increase. This is the most efficient point of operation. Compute the PA efficiency by calculating output power divided by plate input power (voltage and current), times 100. If your tuning does not result in the efficiency as shown on the checkout sheet, there is something wrong. Check the remote antenna meter calibration before taking further action.

FM Power Amplifier

The output stage of the FM transmitter is different in its nature and tuning. It is a broadband stage, and tuning indications will not be as sharp as in AM. Standing waves on the transmission line and antenna present a somewhat different load than a dummy load. When first applying power into the line, check the VSWR on the line. If the indicator shows the standing waves to be low, then tune up. Set all the controls at the factory checkout settings. Normally, the PA input, plate tuning, and loading are tuned for a maximum power output rather than for a dip in plate current. Power output indication and efficiency depend upon some other important factors. If the output indicator is a properly calibrated reflectometer, then it will indicate true power; but if it is simply a sampling loop in the transmission line, it only indicates that RF is present. When the indirect power measurement method is used for operation, then the plate input power must be set for the prescribed efficiency, and not what can be realized.

Efficiency

The type of tubes and the circuit configuration of the output stage has much to do with the tuning, the indications, and the efficiency. Check the manual or schematic to learn about the transmitter you are to tune. When the output is a tetrode in a normal configuration and the screen current is metered, the screen current is the best indication of matching of the load and overall efficiency. When the load is properly matched, the plate circuit resonated, and the grid circuit peaked. the screen current will be at its lowest reading. Under these conditions. when the grid current is lower than required for a given plate input and output power, the stage efficiency is better than when the grid current is high. This is an indication of how much drive is required to get the power output.

Grounded-Grid PA

Many FM transmitters use a triode in a grounded-grid configuration for the output stage. This is a little trickier to tune up and the indications are not as clearcut. In this case, the IPA (intermediate power amplifier) driver stage also supplies part of the output power. The input tuning to the PA is actually the IPA plate tuning, so both stages must be at their peak to obtain the best output efficiency. Tune the PA LOADING and TUNING controls and the IPA TUNING controls for maximum power output. For best efficiency, consider not only the PA plate input power (voltage and current), but also the IPA plate current. If this is very high, the PA is actually supplying less power than it should. Try to tune for best PA efficiency at the same time the IPA efficiency looks good. This will give the most efficient operation.

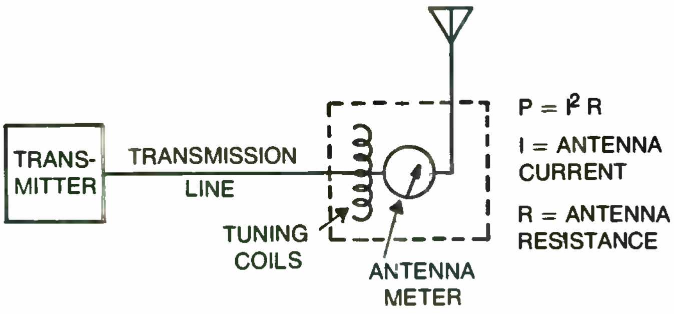
POWER MEASUREMENT

PA efficiency and transmitter power output depend upon the load itself. How the power output is measured and the accuracy of the instruments and the methods are the basic factors in determining true power output of the transmitter. True radiated power, however, must consider the efficiency of the radiating system, and the only way that it can be determined is through field strength measurements. For logging purposes, the transmitter and antenna parameters are used for indications.

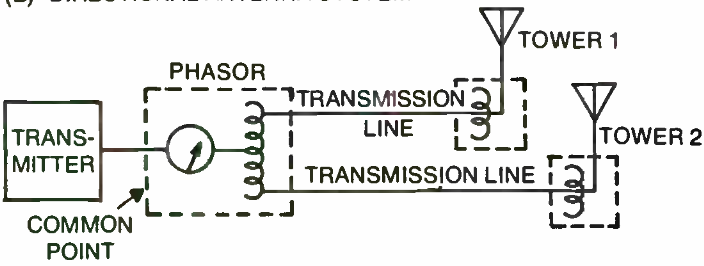
AM POWER

The AM station is required by the FCC to measure transmitter power output by the *direct* method (Fig. 9-3), and this must be maintained within the prescribed power tolerance of 90 percent to 105 percent of authorized power. Power measurement is based on the regular power formula, $P = I^2R$. This power is measured at the input to the antenna in a single-tower station, or at the input to the common feed point when a directional antenna is used. The current I is measured

(A) NONDIRECTIONAL ANTENNA



(B) DIRECTIONAL ANTENNA SYSTEM



$P = I^2R$
I = COMMON POINT CURRENT
R = COMMON POINT RESISTANCE

Fig. 9-3. Direct AM power measurement. Power is measured at base of single-antenna system or at common feed point to a directional system.

across the resistance *R* of that point. To obtain the resistance factor, a measurement must be made with an RF bridge. Both the resistance of the antenna and the reactance are measured. This requires special instruments and engineering knowledge, and the measurements obtained must be filed with the FCC. If there has been any change in the antenna—for example, adding an FM antenna at the top of the AM tower—then a new measurement of the base resistance must be made and filed. Any reactance that is present must be neutralized by tuning units to provide a good match, so that only the resistance factor remains. This is the resistance for the power measurement, and this figure along with the required current will be shown on the station license. Incidentally, the latest set of measurements must be kept available for the FCC inspector to look at during an inspection tour.

Meters

The meter at the base of the antenna (or common point) is a thermocouple-type instrument. It operates on the principle of heating by the RF signal, but since heat is the measured factor, ambient temperature also affects the indication of the meter. It would seem that in this day and age, a better way would be designed to measure the AM power. At the same time, it is worse than pulling teeth to get a meter manufacturer come up with figures as to *how much* ambient temperatures affect the indication. One manufacturer did show this effect as a 0.9 percent decrease in the indication for each 10°F rise in ambient temperature, and the reverse of this for temperature drops. Since when outdoor temperatures rise the indication is lower on the meter, this tends to show the transmitter efficiency as being lower in the summer than in the winter.

Calibration Charts

The antenna meter must be calibrated by the factory or a special meter shop and its accuracy certified. A calibration curve is supplied with the meter (or should be). The accuracy must be within two percent of full-scale reading. The station should also develop a temperature chart (unless it can control air temperatures in the vicinity of the thermocouple) and post this along with the calibration chart in the tuning house. When calibrating the remote meter against this base meter each week, or when reading the base meter itself, the indication should be modified to take into consideration both the calibration curve of the meter and the temperature chart to arrive at the true current in the circuit.

Expanded-Scale Meter

A station which operates at two different powers should use an expanded-scale meter so that both antenna current values can be indicated on a single meter. This would be the case for stations with a different day and night power. However, it must be a special meter that has been certified by the manufacturer to meet FCC Rules. Simply any expanded-scale meter will not suffice; make sure the one you use has FCC approval.

FM POWER

There are two methods permitted for power measurement in the FM station, indirect and direct. The power tolerance is the same as in AM, 90 percent to 105 percent of authorized power.

Indirect Method

This is the oldest method and is still common today. The PA plate input power times an efficiency factor is used to determine transmitter power output. The plate input power is the product of the PA plate voltage and the PA plate current. The efficiency factor which must be used is supplied by the manufacturer, and is found in the instruction manual or a chart supplied with the transmitter. This efficiency is not what you may be able to realize by fine tuning, but a fixed factor. This factor must be available to the FCC inspector upon demand. Stations have been cited when this factor was not available because the manufacturer did not supply it. Make sure you have this on hand.

Power Tolerance

Remember that the station must stay within the prescribed power tolerance. When line voltages change or there is some change in the antenna which affects the output stage tuning, a different plate input power will result and the operator must compute the power to make sure the station is within tolerance. To save a lot of later computation, do this: Compute the plate input power for different values of plate voltage change, perhaps 200V or 400V higher or lower than normal plate voltage, and compute the corresponding plate current required at each of these values. Also compute the tolerances according to input power. This takes a lot of computation at one time but saves a lot later. Pot these values at the operating position. A quick glance then shows what current should be present for a given plate voltage and whether the combination is within the power tolerance.

If these figures are not available and the transmitter goes out of tolerance, the station is open to a citation from the FCC either during an inspection or at license renewal time. People at the FCC *do* check the logs submitted at license renewal time, and if the figures show out-of-tolerance operation, there can be citations and even problems in getting the license renewed.

Direct FM Power Measurement

The direct method requires more accurate output measurements and calibrations (Fig. 9-4). To accurately measure the power, a *directional coupler* is used in the transmission line. This device picks up only the forward wave and feeds it back to a rectifier and then a meter (which must

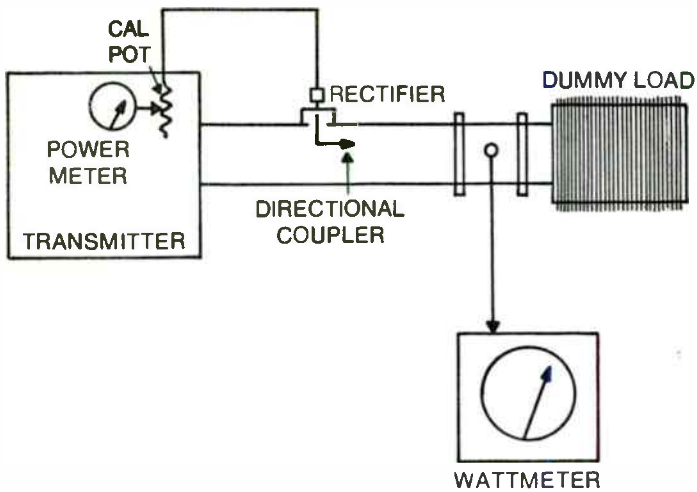


Fig. 9-4. Direct power measurement for FM. Power is measured with wattmeter with transmitter operating into dummy load. Only the forward wave is measured.

be calibrated). This directional coupler is far different than the old loop pickup in the line, which has been common for output meters. The loop will sample everything that is present at that point—both forward and reflected waves. The directional coupler, however, picks up only the forward or reflected wave (according to insertion method), and this is what makes it accurate for direct power measurement. The meter arrangement and two couplers used to measure both forward and reflected power, is called a *reflectometer*. Power output depends upon an accurate load of pure resistance without reactance. The meter must be calibrated against an outside standard, a wattmeter, which itself has been calibrated at the factory.

Power Meter Calibration

Terminate the transmitter with the dummy load and move the wattmeter into a position where it can be read accurately. Make sure the meter's mechanical zero is correct. Make sure the cooling system of the dummy load is in operation, or the dummy load will soon be damaged. Turn on the transmitter and adjust to the authorized power output as read on the wattmeter. If the authorized power is 10 kW, this is what the wattmeter indicates, although the meter on the transmitter may read anything at this point. Use the CALIBRATION control on the transmitter and adjust the meter to read 100 percent. Write down the plate voltage and plate current of the PA stage. Then raise the transmitter power to 105 percent as shown on the wattmeter. For 10 kW, this is 10,500W. Check the reading of the transmitter power meter; it should be 105 percent. If it is not, do not change the calibration. Instead, mark the meter face to show where 105 percent appears. Record the plate voltage and current at this power. Then do the same for 90 percent power. This will be 9000W on the wattmeter (for 10 kW). Again record the plate input power. Lock the CALIBRATION control so that it can't be accidentally misadjusted. Now turn off the power and switch the transmitter back to the antenna. Go through the same procedure at 100 percent, 105 percent, and 90 percent, and record the plate voltage and current for each. All of these readings must be entered on the station's maintenance log.

When switching back to the antenna, there should ideally be no change in the readings from what was obtained with the dummy load. But we live in the real world and there is some reactance in the antenna system. If the change is very great, there is high VSWR on the line and other problems that need to be corrected. Even a small VSWR changes the readings slightly, since you are not as well matched to the dummy load, but are matched to the line conditions.

Required Calibrations

When the direct method is used, the output meter must be calibrated as discussed. This procedure must be done at least once every six months, as required by the FCC, and the results entered in the maintenance log. This is the minimum calibration required, and the FCC man will want to see this information on an inspection tour. How well the meter holds calibration is something that is learned by experience with the particular unit. The calibration process should be done more often than required, until experience has shown that it isn't necessary. If someone should accidentally turn the CALIBRATION control at some other time, the calibration must be done over. Keep that control locked.

FREQUENCY MEASUREMENT

Anytime the transmitter is connected to the antenna system, its carrier frequency must be within the prescribed tolerances of the rules. This is ±20 Hz for AM, ±2000 Hz for FM. *Anytime* the carrier is out of tolerance and an FCC inspector or monitoring station measures the carrier in that condition, the station will be cited for violation of the rules. There is also a requirement that frequency measurements of the carrier be made at least once each calendar month. The interval between measurements may not be more than 40 days.

Just how the measurement is done is up to the station, but it must produce accurate results and must relate to signals of the National Bureau of Standards or to station WWV. In other words, the *measurement equipment* must be calibrated against WWV or Bureau standards. The old-style frequency monitor that was required for years cannot be calibrated in this manner and thus is not acceptable for the measurement. There are two ways the measurements may be made that will comply with the FCC: by an outside frequency-measuring service on a contract basis, or by a station-owned frequency counter that can be calibrated either directly or indirectly to WWV.

Outside-Service Measurement

There are a number of frequency-measuring services that will measure the station's frequency on a monthly basis. When possible, there should be direct telephone communication with the laboratory when the measurement is made. In some cases, when distance is too great or there are interfering signals on the channel, the measurement service will send out a portable unit on a regular tour. In this way, they can get good signals without interference, but in these portable setups, there may be no telephone handy. In any case, the service should call the station if they measure the carrier either out of tolerance or drifting close to the edge, so that it can be adjusted to authorized frequency.

Frequency Counter

A variety of accurate counters are now available at reasonable cost. The counter must be calibrated either by the station or an outside laboratory at sufficient intervals to insure its accuracy. To be calibrated locally, the counter must have an output signal from its internal oscillator for this purpose. Many counters do not have this feature, or enough stability or accuracy to meet FCC requirements. Those that do will normally have a temperature-compensated oscillator, and the spec sheets will state that it meets the FCC requirements. Often, one of the regular counters is modified with this type of oscillator so that it will meet the specs for FCC measurements. This is done by the factory, as is calibration.

Calibration

You can check the calibration (or recalibrate) against the signals of WWV with a communications receiver if the signal is sufficiently strong. It isn't possible to *measure* the carrier of WWV, because the local-oscillator signal in the receiver is too strong, and the counter locks onto the strongest signal. You can either beat the counter oscillator with the WWV signal or use the receiver BFO (beat-frequency oscillator). In either case, arrange the setup so that the output from the counter is comparable to the WWV signal strength. If the counter signal is too strong, it will be difficult to find the exact center of zero beat. To use the receiver BFO, tune in WWV and use the narrowest IF filtering the receiver will provide, and use the BFO to get a good beat on that signal. Remove the antenna and couple in a signal from the counter oscillator. If there is a beat note, the oscillator is off calibration slightly, so adjust its trimmer to bring it right into the center of zero beat. Check back and forth a couple of times, as the BFO may drift on you.

To beat directly against WWV, tune in the signal as before, but turn off the BFO and couple in a small amount of the counter signal. Listen for a distinct zero beat between the two signals. If there is a beat note, adjust the counter trimmer to get right in the center of zero beat. Make that final trim during the period that WWV is not sending voice or tone modulation.

Logging

The frequency measurement that is made must be entered in the station's maintenance log. The entry made must be of the actual frequency that is measured, and not the deviation from assigned frequency. Thus, if the FM center frequency were 200 Hz below the assigned frequency of 104.1 MHz, the counter would read 104099.9 kHz, and this is the figure that is logged. If you wish, you may show the difference from assigned frequency for your own information, but the required entry is the actual measured frequency.

Both reading the counter and logging the frequency can cause confusion. How many digits the counter displays depends upon the time base selected and the number of indicators provided. And at FM frequencies, to read or resolve all the way down to one hertz requires more indicators or readouts. What happens, however, is that the numbers which cannot be displayed slide to the left into *overflow* positions, and an indicator comes on to alert the operator to the fact. In our example above, to indicate all those numbers requires seven readouts on the counter. To resolve down to one hertz, the counter would have to have at least two more readouts. But with a seven-readout unit, when the time base is changed to read in hertz, the display shifts to the left, and the first two numbers on the left go into overflow, allowing two more numbers on the right of the display to be seen. The numbers would be displayed thus: 4099600 Hz. At first glance, this number doesn't seem to have any relationship to the station's carrier frequency of 104.1 MHz, but the leading digits 1 and 0 are implicit.

It is easier to determine that a carrier higher than its assigned frequency is out of tolerance than if it is the same number of hertz below. For example, when our 104.1 MHz carrier is higher than assigned by 2150 Hz, the counter will read 104102.1 kHz. This is obviously more than 2 kHz higher than tolerance. But now assume it is in the other direction; then the counter would display 104097.8 kHz. This is not quite as easy to evaluate at first glance. And if the measurement started out to measure with a time base for hertz resolution, the reading would be 4097850 Hz. To avoid confusion, here is a technique that can be used. Before taking the measurement, write down the carrier frequency out to one hertz. For example, 104.1 MHz would be 104100000 Hz. Then take the measurement, starting first with the megahertz time base to make sure the correct carrier is measured, and then change the time base to read out in hertz. Write down the measurement directly under that which you have written out for the assigned frequency. Add or subtract as needed, and this gives the difference from the assigned frequency and shows whether the station is out of tolerance or not. Write down on the log the actual measured frequency.

SIGNAL PROCESSING

Audio signals are always processed before they are fed to the transmitter. Similar units are used in the control room, in recording booths, and on remote lines. However at the transmitter, the regular AGC amplifiers and peak limiters are more sophisticated. This is because modulation processes offer different problems and they are different in AM and FM.

Basic Processors

In the basic AGC amplifier (Fig. 9-5), the audio signal passes through a variable-gain stage which is controlled by the audio itself. The audio signal farther down the line is rectified and converted to a DC control voltage that changes the stage's gain according to the signal levels. The time constant of the DC filter circuit determines the rate of change in gain that will occur. A long time constant causes slower action. This controls the average level of the signal and is too slow to follow peaks.

The regular AGC amplifier has many drawbacks, so a gated unit is used. This allows expansion of signals to take place only within certain ranges, and very low signals are not expanded. By properly setting the operating position, the same unit can act as a compressor also. This gives greater control over the average signal levels.

Peak Limiters

The basic peak limiter is the same as the AGC amplifier, with the exception of the time constant. This is made much shorter so that the control voltage can follow signal peaks. However, no expansion is used in a limiter, as only peak compression is desired.

Both the AGC and limiting action are often combined in a single unit. You will find modern units in both styles.

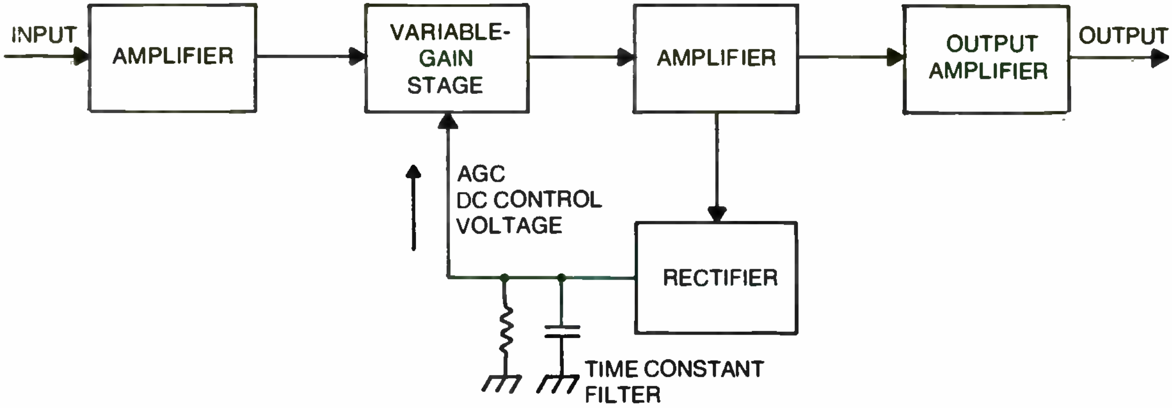


Fig. 9-5. The basic AGC amplifier. The only difference between an AGC amplifier and a peak limiter is the time constant on the control bus.

AM Processing

Recall from an earlier chapter that the peak level can be many decibels higher than the average level of a program signal. It is the peaks that cause overmodulation. The highest possible modulation that can be obtained on negative peaks is 100 percent. At this point, the audio modulation amplitude equals the RF carrier amplitude. Any increase beyond this and the carrier is actually shut off during that negative peak period. This severely distorts the audio signal and creates "splatter" outside the station's channel. (Both are FCC violations.) Since the signal peak is the controlling factor, the average of the signal is low; and out in the fringe areas, the signal will sound weak and not override receiver noise or interference.

The AM station uses both a peak limiter and an AGC amplifier. They may be separate or single units, but both functions are employed. The AGC holds the average modulation level high, and the peak limiter prevents overmodulation. This combination prevents overmodulation and increases the sideband power to override noise and interference in the fringe areas. This station's signal will sound louder. There is a tradeoff in dynamic range for increased sideband power.

Asymmetrical Modulation

This term simply means that the positive and negative modulation peaks are not the same amplitude (Fig. 9-6). It was discovered long ago that the human voice does not produce symmetrical peaks and these vary from one person to another. Consequently, when the high peak is in the negative direction at the modulator, the average signal is lower than normal. A device that many stations use electronically equalizes these peaks before they are fed to the transmitter, and many stations use them. Modulator unbalance as well as audio unbalances contributes to the same effect.

Forced Asymmetrical Modulation

Voice peaks are asymmetrical, and they arrive at the modulator in a random fashion. But the highest peak can *always* be shifted in the positive direction, and a consistently higher modulation level is achieved in both the negative and positive direction. Until recently, there was no limit set on positive

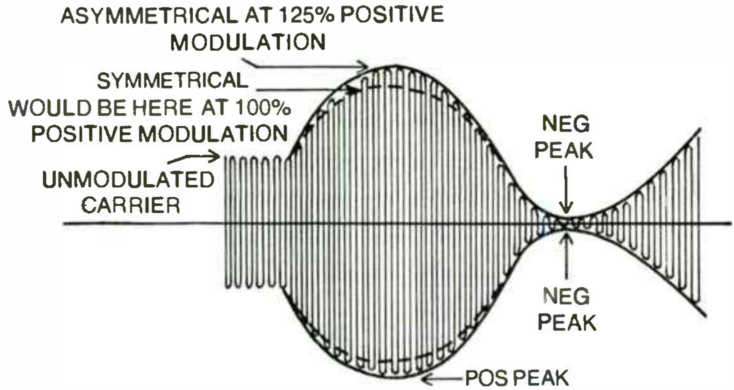


Fig. 9-6. Asymmetrical amplitude modulation. The positive and negative modulation peaks are unequal. Symmetrical modulation would have both peaks equal.

modulation—only the negative. Now the FCC set a limit of 125 percent in the positive direction.

AM limiters for transmitter use have circuitry that senses the highest audio peak and reverses its polarity if necessary, so that the highest peaks are always positive. By adjusting the negative peaks to no more than 100 percent, the positive peaks can be higher than 100 percent modulation.

When the modulation on the positive peak goes past 100 percent the sideband power is increased also. Consequently an additional processor may be used that deliberately creates this asymmetrical condition, even by clipping if necessary. This pushes the positive peak modulation to the 125 percent maximum. The output connections of such a limiter are polarized and must be connected correctly to the transmitter. If they are reversed, the high positive signal will go negative and severely overmodulate the transmitter.

FM Processors

The AGC amplifiers for FM are essentially the same as those for AM. When used for stereo, however, the two units should have identical characteristics. They are to be ordered as a stereo pair and tested together at the factory for stereo. This usually carries an additional fee, but it is worth it. The DC control circuits are to be tied together so the two units are synchronized. That is, the one with the highest amplitude signal takes over and controls both channels. This maintains the original balance between the two channels.

Limiters

The FM system presents a different modulation system and also a problem because of the 75 μsec preemphasis curve (Fig. 9-7). The 75 μsec preemphasis is prescribed by the FCC to overcome the energy distribution in the audio bandpass and the noise problem in the receiver. A different approach must be taken to the limiters. In some cases, the limiting is done in the usual fashion, but the signal is also run through a 75 μsec preemphasis network. After clipping, the signal is run through a complementary deemphasis network so that the effective overall response of the unit is flat. The clipping causes some distortion; how much depends upon the energy content in the signal. Stations with a rock or similar program format often use both limiters and AGC amplifiers in the same manner and for the same reason as AM stations—to hit the modulation hard, sound loud, and still not overmodulate. However, a large part of the dynamic range is traded off for loudness.

The big problem is the 75 μsec preemphasis gives a tremendous boost to the upper audio frequencies. Modern programming contains a considerably greater high-frequency content than when FM service was first approved years ago. While the preemphasis boosts the high audio, the modulation meter responds to a greater extent to the low-frequency, high-energy audio. To modulate the transmitter at 100 percent with these low-frequency peaks as read on the meter, the high-frequency audio causes severe overmodulation that is not indicated on the monitor. That modulation will show up on a spectrum analyzer, however. To avoid this overmodulation, it is necessary to modulate only 35 percent to 40 percent as shown on the modulation meter (there are peaks, remember). Out in the fringe areas, there are more problems from noise, possibly a six to eight decible loss in signal/noise ratio. Compared to a station using very heavy processing, this station will sound rather weak. But many "good music" and "classical" stations do go this route, as they desire the dynamic range.

Dolby B System

For FM use, the Dolby B system provides an alternative to the heavy-processing route (Fig. 9-8). This is now permitted on

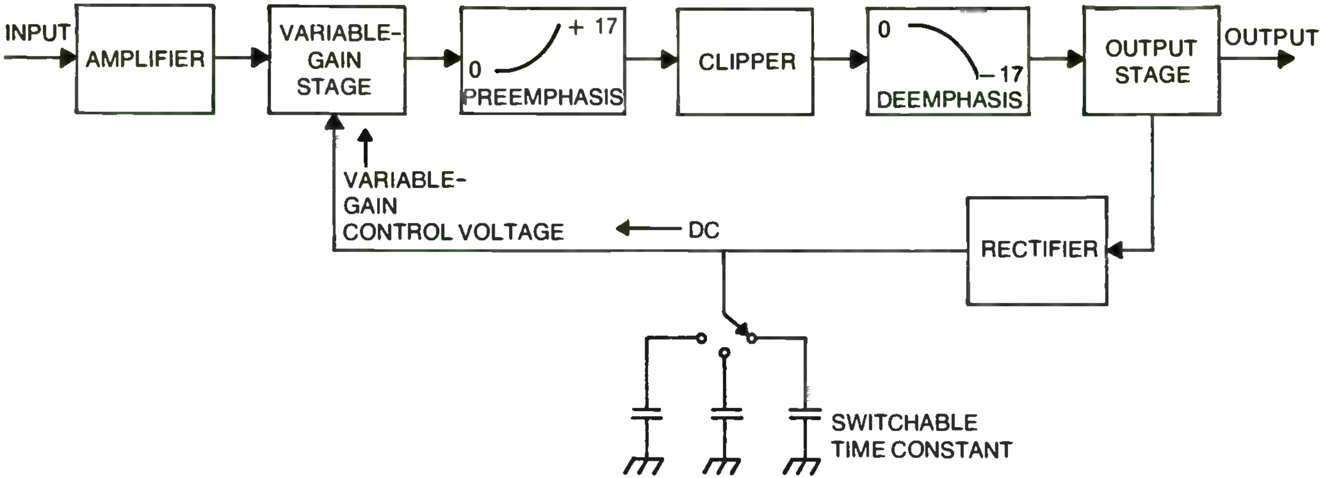


Fig. 9-7. The typical FM limiter also reshapes the audio to conform with 75 μsec curve, clips above the curve, and restores to a flat response.

FM. This unit uses controlled expansion of the upper audio frequencies. The audio is fed through a high-pass filter that has a ramped lower skirt starting at 200 Hz. Only the very lowest amplitude signals receive the expansion at its maximum. There are varying amounts of expansion up to 10 dB. Those on the ramp receive correspondingly less, as do all within the filter's bandpass, according to their amplitude. The higher level signals receive none.

All this filtering and expansion takes place in a side channel, and the expansion is controlled by the upper frequencies themselves. The original signal in its entirety passes right through the unit, but the processed part out of the filter/expander is then added back to the main signal. This combined, processed signal is then sent through a rolloff filter that will produce an effective 25 μsec preemphasis in the overall modulation system. The transmitter time constant is not changed; the processed signal is simply rolled off more, so that when the two are combined, the net result is a 25 μsec time constant.

When a station uses this system, it must be used in its entirety; both the expander section and time-constant-changing section must be used together. The FCC does not permit the station to change the time constant alone.

A station that does not use highly processed audio can now modulate to 100 percent as shown on the monitor, without overmodulating. But some peaks can still get through, so peak limiters used with the unit prevent any from passing through.

On the receiving end, to gain the most advantage, the receiver should be equipped with a decoder. This unit presents both a 25 μsec deemphasis and compression to restore the original program balance. A receiver without a decoder has a 75 μsec deemphasis, and this provides greater rolloff of the high-frequency audio, so the tone control will require some adjustment. The higher audio tones also are expanded, does not appear to bother the listener.

Setting Up Processors

Whatever the intended use, processors are set up with tones as a starting point. Remember, there is a difference between program peaks and the tone signal, so this must be considered as only preliminary. Make the final adjustments

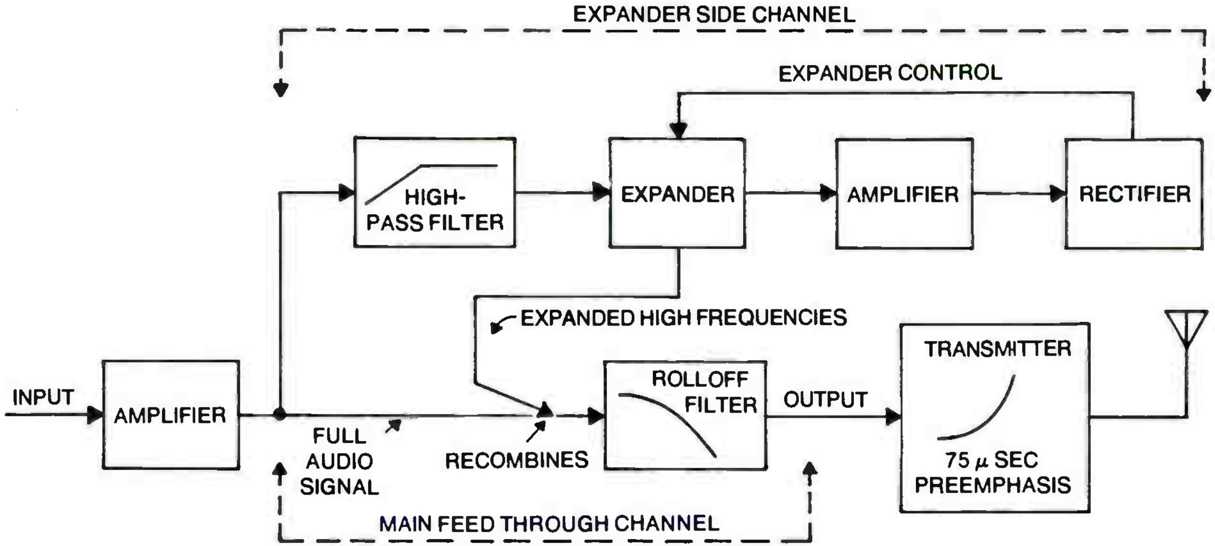


Fig. 9-8. The Dolby B system for FM.

with programming or program-type signals, and on the transmitter itself. Another thing to remember is this: the processing takes place inside the unit and presents a processed output at its terminals. This output is adjustable. Unless this output of the limiter is set in proper relationship to the transmitter, improper modulation levels occur. So adjust the output of the processor while observing the modulation monitor. On the AM system, an oscilloscope monitor is best.

Asymmetrical Identification

The polarity of the signal into the transmitter must be determined in AM when asymmetrical modulation is used. This is somewhat difficult to do with programming, so use a sine wave or other repetitive signal in which the two peaks can be changed so they can be identified. Here is a little trick that is used on a regular audio signal generator. Shunt a diode across the output terminals of the signal generator. Add an adjustable resistor in series so you can adjust the amount of clipping. A single diode will clip one of the peaks. It doesn't make any difference how you feed the output to the limiter, as the sensor will switch the nonclipped peak to the positive. Use an oscilloscope to monitor the amplitude-modulated carrier, and note the position of the peaks. If the nonclipped peak is in the positive direction, the connections are all right. But if it is

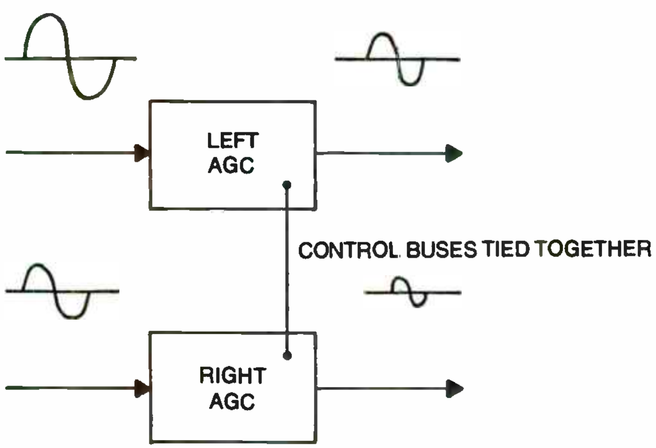


Fig. 9-9. Stereo AGC amplifiers or peak limiters should have the pairs synced together. The channel with the highest levels will control both channels.

in the negative direction, toward carrier cutoff, reverse the output leads of the limiter. Mark the output leads and connect to the transmitter input. If you desire to actually know which is positive and which is negative, then use the scope and look at the audio output of the limiter.

GENERAL MAINTENANCE

As mentioned earlier, due to the RF technology and high voltages in a transmitter, techniques must be developed so that the troubleshooter can perform maintenance with safety to himself and the equipment. The transmitter helps in this matter, for it is usually well metered and conditions at various points inside can be determined from the front of the transmitter. With a knowledge of the transmitter's workings and circuitry, these metering positions are very helpful in isolating problems to certain stages in a section. Another important thing to know are the limits, not only of operation (FCC tolerances), but also the limits of individual tubes and circuits. Without a knowledge of individual circuit parameters, the operator may be overworking stages until suddenly they fail catastrophically. For example, if he is concerned only with maintaining the output stage within its parameters, and it is working inefficiently, the IPA stage may be overworked, exceeding its ratings.

High-Voltage Precautions

Working around high voltages requires special techniques. Capacitors can retain a *lethal* charge long after power has been removed. Precautions must be taken in wiring and insulation to prevent arcovers and ionization problems. But the first order of business is personal safety. When you must go inside the transmitter for maintenance, know what you are doing, keep a cool head, and don't become careless. Develop good safety habits around the high-voltage circuits.

Confidence and familiarity with the transmitter are one thing, but when an engineer has worked around a particular transmitter for some time he must be careful not to become overconfident. There is an old saying "familiarity breeds contempt," but contempt for high voltage should never be allowed. These voltages are lethal, and one mistake can be the last one.

High-Current Precautions

Certain precautions should be maintained when working around high-current circuits, for they have their own brand of danger. As more transmitters go all solid-state, high current becomes predominant in developing the RF power output. This has been in trend in high-frequency RF circuits for the past several years anyway; that is, tubes are using lower voltages and higher currents.

Be especially careful with metal tools, rings, or other metal objects on the person when the voltage is on. These very-high-current circuits aren't much different from an arc welder. If you should accidentally brush a ring across a high-current circuit, it can instantly weld to the circuit and turn white hot. You can't get away from it, and it can burn clear to the bone. Further, high current generates much heat in the components through which it flows, so be careful not to touch them until they cool. Remember to make all circuit connections having very low resistance, so you don't create a heat hazard.

Basic Transmitter Divisions

As with the general functional divisions of a transmitter can be divided transmitter maintenance itself transmitters into four general categories: mechanical, electrical, electronic, and monitoring. *Mechanical* includes the cabinet, terminal boards, hardware, mountings, insulators, and blowers. *Electrical* includes the control ladder, relays, contactors, power supplies, and AC power source. *Electronic* includes the audio, RF, and modulation circuits; RF and audio filters; and all special circuits that generate the carrier and impress audio intelligence upon it for modulation. *Monitoring* includes the transmitter metering of parameters, samplers, other external metering, and also signal monitoring, such as modulation and audio monitoring.

Mechanical Maintenance

Blower motors and the amount of cooling air necessary creates vibrations and noise. This is both acoustical and electronic noise. Heating and cooling of parts will cause expansion and contraction. The net effect of all this is that the hardware tends to loosen up in the transmitter, both in the cabinet and the connections and terminal boards.

A general routine should be set up, based upon experience with a particular transmitter, to check out and tighten all the hardware and connections. Experience soon show those places or components that tend to loosen up more than others, so more attention is given to the trouble spots before something falls apart.

Loose hardware causes all sorts of problems. For example, a door with an interlock works loose, allowing the interlock to open and taking the transmitter off the air. If the transmitter is several miles away from the control point, much air time is lost.

Loose hardware in RF circuits causes arcing and burning of the contacts. If the hardware is at the grounding point, then parasitics, self-oscillation of a stage, feedback, or simply detuning and inefficient operation develop.

Blowers—The air-cooling system is important and it should be smooth running and quiet. The motor and fan bearings must be oiled or greased regularly, unless they are sealed bearings. Follow the instruction manual for the particular unit. Even sealed bearings will eventually fail.

Belts must be inspected to ward off sudden failure. They wear, and should be changed in due time. Also, the belts should be adjusted properly: too tight, they cause excessive bearing wear and vibration; and too loose, they slip and the air movement will not be sufficient as it should be.

When adjusting belts, set them according to the instruction manual. In general, without the blower running, you should be able to push on the belt in the center between pulleys and depress it about one-half inch. If you can't budge it, it is too tight, and if you can press it down an inch or so, it is far too loose.

Bearings—Bearings that are worn or dry are noisy and produce vibrations. Now when there are a number of bearings reasonably close together, it is difficult to detect which is the faulty one. A technique that can be used is an old mechanic's trick (Fig. 9-10). Take a long screwdriver and hold the blade against the bearing in question, and put the handle to your ear Be careful not to get tangled up in the rotating machinery or fan blades. You can hear distinctly a bad bearing through this mechanic's stethoscope.

Air Flow—Air acts in peculiar manners. It is easier to pull air than to push it. Actually, a blower creates a

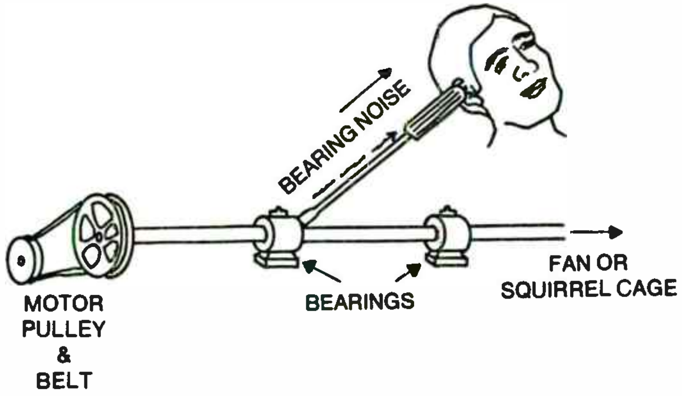


Fig. 9-10. Use a long screwdriver as a stethoscope to detect bad bearings.

low-pressure zone at its input and pushes air at its output, but back pressures can build up rapidly and reduce the flow. So it is important to keep the path clear of obstructions. And keep ducts tight, or the air will escape.

Air filters are directly in the air flow to filter out dust, and these do offer resistance. As dust builds up, greater resistance is presented, and the air flow drops. So filters should be kept clean. If they can't be cleaned, they should be replaced. Some filters are designed to be coated with oil. I can't vouch for their effectiveness, because they will eventually have everything inside the transmitter coated with a film of oil that collects dust and cooks into a gummy residue. I do not recommend these filters at all. If they are on the transmitter when you get it, replace them with dry filters.

Fan blades and squirrel cages will coat up with a layer of dirt after a while, and this reduces the blades' efficiency. Clean these before the dirt can build up.

Air Interlocks—Most high-power transmitters (and many low-power ones) will have an air interlock on the air system (Fig. 9-11). Anything that reduces the air flow and pressure below the preset value causes the interlock to open and shut the transmitter down. These are protective devices and should not be bypassed, except in an emergency and you are sure the air flow is high enough. Without adequate air flow, expensive power tubes can be very quickly damaged.

Besides the air filters themselves, check for leaks in the air system and that the air ports in power tube sockets or the

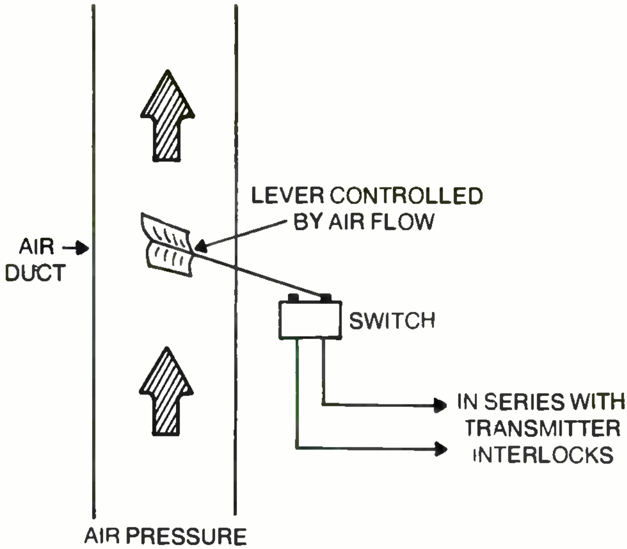


Fig. 9-11. Air interlock operation depends upon enough airflow in the duct.

cooling fins of power tubes are not clogged with dirt. In spite of the best working system, all of these things happen over a period of time. When there is reason to have a power tube out of its socket, take the opportunity to clean out the socket and tube fins. Use a vacuum to get what can be in this manner, and then use a blast of air from an air compressor or a blower with a small-port nozzle to blow the openings clear. Blow back through the tube fins or the socket ports in the opposite direction of the normal air flow.

Cleanliness—Even with air filters and tight cabinets, dust gets inside and settles on terminal boards, contacts, and insulators. High voltages attract dust particles like a magnet. All high-voltage terminals and insulators must be cleaned and kept that way to prevent arcovers. When an arcover does occur, a carbon path is formed that is very difficult to remove. In many cases, the insulator or other component must be replaced, for if the carbon cannot be removed, it arcs over again. Clean ceramic insulators with alcohol or clorothene. Minor cleaning can be done with a clean cloth dampened in water, but before applying the high voltage, let the blowers and cabinet fans run some time to make sure they are dry. Be careful about the cleaning fluid used when the insulator is polystyrene or other plastic. Many solvents will melt or fog them. Use only a mild cleaner, and in most cases, stick with water alone.

Electrical Maintenance

The control ladder will usually operate on either 120 or 230V AC and comprises many interlocking relays and contactors. The contacts of many of these relays carry heavy currents, so they are subject to arcing, burning, or welding together. For normal cleaning, use a burnishing tool or a fine emery cloth. These just polish and clean the contacts. Avoid using a point file, as this removes too much metal and changes the shape of the contacts. When burning or pitting does occur, (Fig. 9-12), then stronger measures are required. Use a point

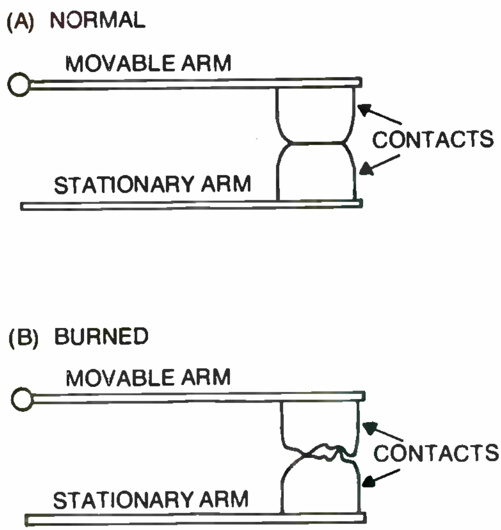


Fig. 9-12. (A) Normal contacts are shaped to make a good, low-resistance contact. (B) When contacts have been burned, they make a poor contact.

file and hone off the damaged area, but try to reshape the contact. That is, don't file it slat, as most contacts are somewhat crowned in the center. Contacts pitted so badly as to require reshaping will not last long and should be replaced as soon as possible. The majority of power contactors and large relays are designed so the contacts can be replaced, and spares should be kept on hand. The smaller relays do not usually have replaceable contacts, so these you have to coax along, since replacement usually means the entire relay.

Primary AC— Power cable connections between the transmitter and power panel should be tight. These carry high currents, and a loose connection will heat up. These cables should be heavy enough that they do not run warm with the normal transmitter load. After signoff and immediately after shutdown, feel the cable near the connections, both at the transmitter and at the power panel. This can be done during programming time if the cables are accessible. The objective is testing the temperature of the cable before it has time to cool off. Feel the cable within a foot of the connection. If there is a loose connection and it is heating, the cable will be warm or hot. Heat from the joint is conducted into the metal of the cable, so it isn't necessary to actually feel the connection itself. Also look for discoloration of the insulating material on the cable at that point, as that is another indication of overheating. If there is heating, take the connection apart with the power off. If it still looks clean and bright, tighten everything up. If the wire looks discolored or the connector is discolored, you may save it by cleaning and tightening, but it can require remaking the connection.

Balance—The load of the 230V single phase and the three legs of 230V 3-phase circuits should be balanced. During the initial installation, care should be taken to distribute the load equally. Although this may have been done, at later dates additional equipment may have been added, all on the same leg. When the power distribution becomes unbalanced in this manner, there can be problems from hum, because one side of the circuit is overloaded. To avoid this measure the current in each leg of the system with a clamparound AC ammeter. This shows the current draw in each single wire. If you discover that the system has become unbalanced, redistribute the load by shifting some of the units over to other legs.

Circuit Breakers—Inspect the power panels and feel the front of the breakers. If one is running warm, expect some outages. Measure the current against the rating. If the rating is adequate, the breaker itself may be going bad. It should be replaced at the earliest opportunity, before it shuts down some important item during broadcast time.

High-Voltage Supplies—A number of shorting devices are usually supplied which will either short out the high voltage when a door is accidentally opened or discharge capacitors after the high voltage is turned off. Some transmitters also supply a grounding stick, which is simply a wooden handle that has a metal hook on the end attached to a heavy ground strap (flexible cable). Whenever you work on high-voltage circuits, don't simply rely on automatic devices to short out the supply. Use the grounding stick, and touch it to all exposed high-voltage points, such as the capacitor terminals (Fig. 9-13). Leave the stick on the high-voltage bus until you are finished in the cabinet.

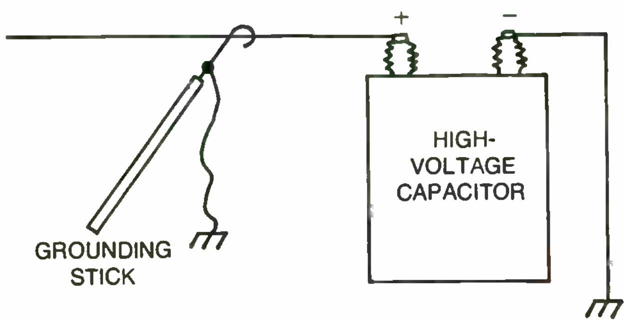


Fig. 9-13. When working in the transmitter, hang the grounding stick on high-voltage capacitors.

The grounding devices should be inspected, for remember they are safety devices and should work all the time. With power off check the grounding device on the doors or entries to high-voltage compartments. This may be a device that falls by gravity onto the bus, or it may a spring-loaded device that will ground the bus when the door is opened. Physically inspect to see that these do what they are supposed to. Something may cause them to hang up, so work them by hand and see if they operate properly. Also check the contact surface and make sure it is clean. On any of these devices, measure the high-voltage bus to ground with an ohmmeter with the safety device operated. There should be a solid reading to ground on the ohmmeter. If there is not, clean up the contact and try it again. It may also need some adjustment.

In the power supply, there may be a relay that will ground out the high-voltage capacitors after plate voltage is turned off. Inspect the contacts for burning. This relay should not fall too fast, as there is a full charge on the bus immediately after turnoff. If it hits immediately, the effect is the same as shorting the bus during operation; the contacts burn badly. Keep this relay's contacts clean and adjusted. Another check of this relay's operation: Observe the plate voltmeter. When the plate voltage is turned off, this meter indication should drop to zero immediately. If it hangs up or does a slow dropoff, the shorting relay is not working properly.

High-Voltage Capacitors—High voltage capacitors are usually filled with a special mineral oil for insulation. When this is beginning to break down or go bad, the capacitor may leak oil, get hot, or swell, or all three (Fig. 9-14). Immediately after turnoff, feel these capacitors. They may be warm from

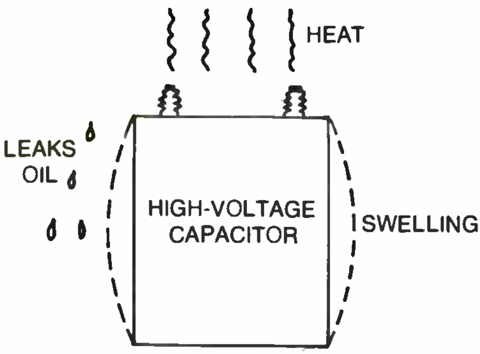


Fig. 9-14. Signs of high-voltage capacitors going bad. They may leak oil, swell, get hot, or all three.

other components nearby, but if they are warmer than expected, or hot, or if the other conditions are present, they should be replaced at the earliest opportunity, as they are going to fail soon.

A word of caution about measuring high-voltage capacitors. The dielectric molecules have been under severe stress from the high voltage and tend to take on a permanent charge effect. So even when a capacitor has been shorted and the short is removed, *the stressed molecules will build a charge right back up on the capacitor*. So don't try measuring these with an ohmmeter. The charge can become deadly after a period of time, so when the capacitors are to be discarded or placed on the shelf, wire the terminals together with a wire that will not come off by itself. Twist the wire on or screw it down with the capacitor terminal nuts.

Electronic Maintenance

Control of the RF energy is not an easy matter. Whenever given the slightest chance, RF will leak out of compartments and get into other circuits, causing crosstalk or feedback oscillations. Maintenance calls for keeping all the cabinets tight, all fasteners in place, and feedthrough capacitors grounded tightly.

Neutralization—When feedback occurs within the tube itself, the stage oscillates. Transmitters which require certain stages be neutralized provide instructions on how it is to be accomplished. Here is a general method you can use to check for the neutralization of a conventional RF stage, providing both the grid and plate currents are metered on separate meters. Tune the plate through resonance. The grid current should hit its peak at the same time the plate hits minimum reading. This may occur a little off the plate tuning, but when it occurs a long way from plate dip, the stage needs neutralization.

A stage out of neutralization can oscillate, and in the tuning process, the upper stages may be tuned to this rather than the carrier from the oscillator. The frequency will not be exactly correct, and of course, some tubes may burn out. Whenever a tuneup has been done, to make sure a stage hasn't "gone into business for itself," pull out the crystal. The RF output indication should immediately drop to zero. If it does not, an oscillating stage is supplying the RF. Shut the transmitter off immediately or something will burn up (and the station will be out of channel).

Multipliers—The FM transmitter exciter has a number of multiplier stages. These should be tuned carefully. In most cases, tuning is only a touchup job, but if there have been major components changed or a change of station frequency, then a multiplier can be tuned to the wrong multiplication factor; for example, tripling instead of doubling. It depends upon the leeway in the component values whether there is more than one possibility with the stage. If the tuneup is done with a wattmeter at the output of the exciter, there is zero power output when the wrong multiplication rate is used, since the upper stages are not tuned to that frequency.

PA Efficiency—Anything that adds resistance to the circuit, lowers the *Q* of the resonant circuit, or causes a mismatch to the load, causes a stage's efficiency to be poorer. The higher the efficiency of a stage, the easier it works in amplifying and passing on power to its load. The stage's efficiency when it is properly tuned can be an indicator of other problems either in the load or in the drive.

Contacts—The coils in the AM tuning box can be in a shielded compartment. The clips and other connections should be examined for looseness, signs of overheating, or arcing. A loose contact arcs or overheats when it is carrying an RF signal. If any are loose or burned, clean and tighten them. Such contacts will lower the tuned-circuit *Q* by adding resistance, and cause unstable operation.

Shorting Bars—In FM, the coils are somewhat different than in AM, and may not look like a coil at all. The tuned sections and their shorting bars provide the same action as the AM coils. Always remember that RF travels on the surface of the conductors. Keep the conductors clean and tight. When an arc has occurred, there will be bits of metal protruding from the surface of the conductor. Hone these off and polish up any carbon or smoke residue.

Capacitors—The AM transmitter or its tuning units may have air dielectric capacitors. Nothing should be allowed to accumulate in these openings or it can cause an arc. If an arc has occurred, clean up the surfaces so that there aren't any protruding bits of metal. These can cause further arcing.

Check sealed capacitors for overheating. They may become warm by conduction from power resistors or the cabinet, but if a unit is overheating, it will be hotter than the surrounding components. Check the current rating of the capacitor. It may have been underrated for the present conditions. There is a current rating on RF capacitors as well as a voltage rating. Circuit conditions may now be changed from the original, so that what was originally rated correctly is not now correct. Tuning conditions in a resonant circuit can produce much higher circulating currents than those of the overall circuit itself. Thus, mistuning can cause the capacitor to fail. If the tuning conditions haven't changed, then replace with a capacitor with a higher current rating (if it will physically fit, or a ratio combination of inductance to capacitance may be used.

When the output stages efficiency appears to get worse but the tuning and other parameters appear normal, this indicates either a drive problem or a load problem.

The drive from the preceding stages is intended to amplify the RF signal to the proper amount for the output stage requirements, so adequate drive will be indicated by the PA grid current. If this grid current is much higher than normal, the problem is either in the PA tube itself or its load. If the grid current is low, then look at the metering of the various stages down the line for one that is not indicating normally. Trim up the individual tunings, and if this doesn't do the trick, check the stage that shows abnormal readings. The grid current will be the most sensitive indicator of the workings of the previous stage.

Grounded-Grid Output Stage—Many FM transmitters use the grounded-grid configuration in the output stage. In this arrangement, part of the output of the driver goes into the load. Check the meter readings around this stage when the PA

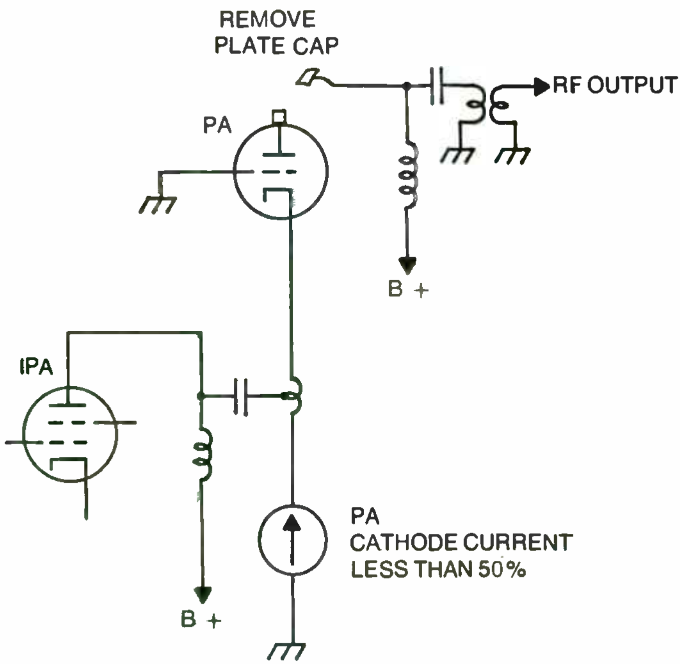


Fig. 9-15. In a grounded-grid output stage, remove the plate cap and check the PA cathode current. The PA should supply 50% or more of normal current, the IPA less than 50%.

efficiency appears low. If the IPA is not efficient, this affects the transmitter output and the apparent efficiency of the final stage itself.

Inefficiency of the IPA can be caused by PA, drive, or load problems. Here is one way to check out these stages. Remove the plate cap from the PA stage. Tune up the IPA stage and observe the PA cathode current. The normal cathode current should be roughly divided 50 percent for IPA and 50% for PA. If the ratio can be more for the PA than for the IPA, this is better. But if the IPA is supplying more than 50 percent, the PA tube is probably going bad. If this test is done when the transmitter is first installed, there will be a reference for later tests to judge the operation.

AM Loading—When the load changes, the stage must be retuned and rematched. On a single-tower AM station, for example, there may be some changes in the system which actually change the antenna resistance, but the same value of current is being maintained as per the license. In effect, the actual ouput power has changed, and this appears as a change in efficiency of the PA stage. Remember that the power is given by $P = I^2R$, so if the current remains fixed but the resistance changes, the power is different. If all other parameters appear normal except the PA stage efficiency, then look for a load problem. If the efficiency appears too good the actual output power is less than normal, and if worse, the output power is higher than normal. When these conditions persist and no other reason can be found, have a new measurement of the antenna resistance made.

FM Loading—FM load chenges affect the output stage, but such changes can usually be detected by a change in the VSWR reading of the line monitor. If the efficiency improves considerably, then it was the tube. But without this change, the tuning and loading positions will have changed, and this can be an indicator of load changes. If the output stage is a tetrode and the screen current is metered, this is a more sensitive indicator of load changes. Changes in the load will produce poorer plate efficiency, and this causes the screen to draw more current.

Tube Life—The hours of a tube's use should be recorded. This can be taken from the transmitter's running-time meter. If there is none, one should be added. Tie it into the circuit that will come on with the filaments. A record of total hours of life is useful for warranty purposes and is an indicator of average life expectancy of the system itself. It will take some time to develop experience; but if tube records are kept, in a couple of years or so, behavior can be established. Aside from particular tube failures, when the life expectancy seems to be shortening, look for leaks in the cooling system or changes in the operating parameters. Also look for worn or poor connections that cause burned contacts on the tubes, or something in the load that causes the tube to dissipate more power than the load (poor efficiency). These are long-term indicators, but show trends.

AM Modulators—The stage used for plate modulation is usually a push-pull arrangement. In such an arrangement, the stages should be balanced and linear. It is easier to balance two tubes that have about the same age than it is to balance one with many hours of use and a new tube. If one tube should blow in a pair having many hours, replace both of them. Save good one for an emergency spare or use with another tube of comparable hours.

Balance is usually done by adjustment of the bias on each tube, but this also affects the audio input to the transmitter. So go ahead and get a static balance on the plate current meters; then apply audio tone modulation, and use an oscilloscope to observe the envelope. Also, attach a distortion analyzer to the modulation monitor output. Null the distortion and do a dynamic balance for the minimum distortion. But observe the envelope. If the bias increases modulation, it can cause overmodulating and increase the distortion; or it can be too low and not give a good modulation figure in that 95 to 100 percent area. Reset the limiter output to provide the correct modulation values, and then run some programming material through and make the final adjustment.

AM Carrier Shift—Carrier shift is actually a good indication of the transmitter's ability to work under very heavy modulation. This will show up poor PA tubes, poor PA design, primary power source shortcomings, and undersized primary wiring. This condition can become worse when 125 percent positive-peak modulation is used (or attempted). Many of the older transmitters weren't designed for this type of modulation and can't handle it. The carrier shift limit set by the FCC is five percent maximum.

When carrier shift is present, first try trading out the PA tubes if they have many hours on them. Often this corrects the problem. If it doesn't, then observe the AC power line meter to see if the AC varies with modulation. If it does, the load is "dragging down" the power line. This may be because the primaries themselves are not adequate, but in most cases, it is the wiring to the transmitter. Also check the DC plate voltage for changes. Weak tubes in a power supply or defective series dropping resistors can affect the voltage, and lower voltage on the peaks will cause negative carrier shift. Still other checks to make are the grid current of the PA for drive, and the screen voltage. During peaks, and especially at 125 percent positive modulation, a very heavy demand is placed on the drive and screen circuits. Drive must be adequate or the peaks will flatten off, and if the screen isn't well regulated, its current

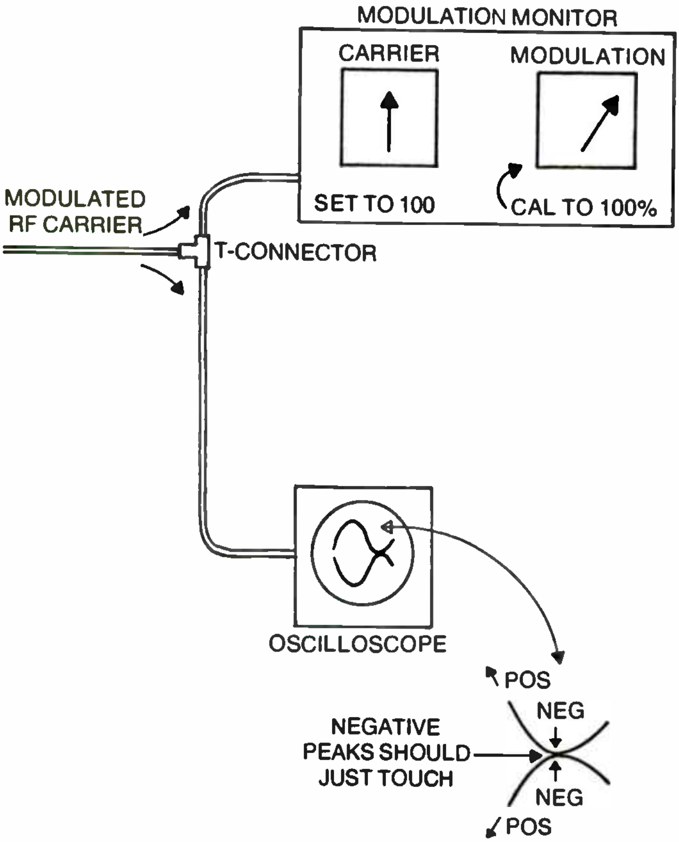


Fig 9-16. Use tone modulation on the carrier and oscilloscope to calibrate the AM modulation monitor for 100% negative modulation.

will rise on negative peaks. There will be a weaker output along with distortion.

Monitoring

A constant check must be maintained on all functions that affect the signal emanating from the station's broadcasting facilities. This is imperative not only to comply with FCC regulations, but also to present a clean signal to the listening public. The paragraphs that follow give the problems that are most likely to be encountered and their solutions.

AM Modulation Monitor—The AM monitor should be calibrated with tone modulation and an oscilloscope (Fig. 9-16). Use the same setup as when balancing the modulators and observe the modulation envelope. How often to check this calibration depends upon experience with the monitor and how well it will hold calibration. When you have reached 100 percent negative modulation on the scope, then adjust the meter to read 100 percent. This sets the accuracy of the meter. Adjust the peak flasher at the same time. Some of the newer monitors have a built-in calibrator, but always use the transmitter and a scope as the final authority. You can obtain the AM RF for the scope from the same input to the monitor. Add a coax T-connector so the line can feed both the monitor and the scope.

FM Frequency Problems—The carrier frequency can become erratic or unstable in a direct FM system. There can be many reasons for this, but generally there are problems with the oscillator, the AFC loop, or overmodulation.

The master oscillator should be working reasonably close to the carrier frequency without the AFC. When the basic oscillator frequency drifts so far that it is at the outer reach of the AFC, then it can be jumping in and out of control. Set it up as follows. Turn off the AFC switch, but observe the AFC meter. If this changes radically one way or the other, the master oscillator is far from carrier frequency. Adjust the master oscillator until it produces a reading on the AFC meter close to where it would be with AFC. What you are reading here is the error voltage caused by the oscilator when it is off frequency. When it is adjusted in this manner, switch the AFC back on. The frequency is now well within the capture range of the AFC.

Overmodulation—When the carrier frequency becomes erratic with modulation, it is possibly an overmodulation problem. Unless there is close control of the average and peaks in the audio overmodulation occurs, especially on the high-audio-frequency content. If only modest signal processing is used, pull the modulation *peaks* back to where they only indicate 35 percent to 40 percent on the modulation monitor. If overmodulation was a problem, the carrier frequency should stabilize.

Audio Filtering—Another cause of erratic carrier frequency in modulation occurs with the filtering in the AFC loop. The control voltage to the master oscillator from the AFC must be a pure DC voltage. If the modulation is not filtered out, this causes the frequency to shift. So check DC control bus with an oscilloscope. If there is modulation present, check out the filtering circuit.

AFC Loop—There can be a problem with the crystal reference oscillator in the AFC. It can be an oven problem, noisy thermostat, or low output. Any of these things will affect the ability of the AFC to control the carrier frequency. As a quick check, switch off the AFC and observe the carrier frequency. There will be some drifting around as the carrier is not stable anyway, but if the erratic conditions stop, there is a problem in the AFC. Check it out according to the instruction manual. If it is a logic-type circuit, check for the correct number and widths of pulses. Make sure the mixer is getting a good signal from both the carrier sampler and the reference oscillator chain. Look for a good, strong IF signal after the mixer, and at the correct frequency. At this point, the IF will be swinging with the carrier modulation, so if using a scope, wait for a pause in the modulation to get a stable waveform.

The sample of the carrier and the point in the circuit where it is obtained are important. In some exciters, this RF sample is picked up at the output of the exciter itself. This provides a good, strong signal, but it can be affected by the load on the exciter, and especially if a long coax cable is used, there may be standing waves on it. If there are erratic frequency readings of the carrier, check the output of the exciter. This will usually have a meter position. If anything on the load has affected the exciter output stage, this reading will be low. Consequently, there will be a weak sample to beat with the AFC oscillator. Retune and check the input tuning of the load stage. This tuning can affect the match and the VSWR, and thus the exciter load.

FM Monitor Calibration—Overmodulation causes problems of stability of the carrier frequency and also problems with the FCC. The modulation monitor should be calibrated so that it is indicating the correct percentage of modulation. There are a couple of ways to do this, depending upon the type of monitor that is in use.

Carrier Deviation—To actually measure the carrier deviation itself, you will need a communications receiver with a BFO and an accurate audio modulating frequency. With this method, you tune in the carrier and listen for the carrier to null as modulation is increased. Which null to use depends upon the modulating audio signal frequency and its amplitude.

This method is based on mathematical functions which predict where the carrier will go through nulls. The trick is to detect these nulls. The ratio of the carrier deviation f_D to the audio frequency f_A produces the modulation index M (Fig. 9-17). This factor will vary. At certain modulation indexes, the carrier will null. By use of the specific modulation index for

(A) BASIC FORMULA:

$$\text{M (MODULATION INDEX)} = \frac{f_D \text{ (CARRIER DEVIATION)}}{f_A \text{ (AUDIO MODULATING FREQ)}}$$

(B) CARRIER WILL NULL AT THESE VALUES OF M:

1st NULL	M=2.405
2nd NULL	M=5.520
3rd NULL	M=8.654
4th NULL	M=11.972
5th NULL	M=14.931

(C) THE BASIC FORMULA CAN BE TRANSPOSED SO THE VALUE OF MODULATING FREQUENCY CAN BE DETERMINED.

$$f_A = \frac{f_D \text{ (CARRIER DEVIATION)}}{\text{M (MODULATION NDEX AT DESIRED NULL)}}$$

$$\text{EXAMPLE: } f_A \text{ at 5th NULL} = \frac{75{,}000 \text{ Hz}}{14.931} = 5023 \text{ Hz}$$

(NOTE: 75,000 Hz IS 100% MODULATION FOR FM BROADCASTING).

Fig. 9-17. Table and formulas for determining the modulating frequency to use when calibrating the modulation monitor.

the null points and by transposition of the formula, you can compute what audio frequency is needed for a given null point.

Set up the receiver and tune in the carrier, preferably the IF in the monitor if this is the range of the receiver. Most communications receivers will not tune high enough to pick up the carrier directly, but most monitors have an IF that is suitable for use. If the monitor has an unusually low IF, the manual often describes another method that can be used. A frequency meter can sometimes be used if it is of a type that will give a beat note on the carrier.

First, tune in the carrier (without modulation) and set the receiver BFO to give a 400 to 500 Hz beat note. Decide which null you will look for and use the correct audio modulation tone to modulate he carrier. Apply the modulation very gradually and listen for the carrier to null or disappear. Listen closely, as these nulls are very sharp, and that first one comes up rather fast. There will be many other beats from the sidebands, but ignore these and listen for the carrier itself to null. When you have reached the desired null, observe the modulation meter. It should be reading 100 percent. If it is not, then adjust the appropriate control on the monitor. The accuracy of these readings depends upon the modulating tone, so check it with your frequency counter. Here the term *carrier* refers to the IF of the monitor.

Meter Calibrations—Remote meters that are logged for normal transmitter parameters, such as remote controls or extension meters, must be calibrated once each calendar week. The FCC requires such meters to be within two percent of the main meter they represent. Accurate calibrations depend upon how well the engineers read the meters and upon the samplers used. The remote meter and its calibration should not affect the main meter. This is not always the case, especially with extension meters. Regular remote control units have more isolation, and there is usually little effect. Much depends upon the unit and how it is wired and the samplers.

Reading the Meters Accurately—Some meters have many divisions on them, while others have relatively few. There are many times the pointer falls between divisions, and then interpolation is necessary. The remote meter, by the way, should have the same divisions as the main meter.

If the meter is a base current meter at the antenna, the engineer at the tower should take into consideration any calibrating factors and temperature corrections that must be applied. If these meters are slightly out of calibration, do this: First, take the temperature and the calibration chart figures and apply this to the true value of current that should be indicated for that power. Have the engineer increase or decrease the transmitter power to bring that meter into its correct reading if it is not already there. Then, check the remote meter reading and make the required correction. Before the correction is made these readings must be logged. If you desire to log what the base meter actually indicates without the correction factors, do so, but also show what the true current is. And, if using a temperature chart, show the ambient temperature on the maintenance log.

Sampler Problems—Direct-wired remote meters' calibration controls can affect the main meter, especially if the sampler is a series arrangement. This type of circuit is often used on remote power meters or modulation meters (Fig. 9-18). To calibrate the meters, first adjust the main unit without the remote meter connected. Then, adjust the

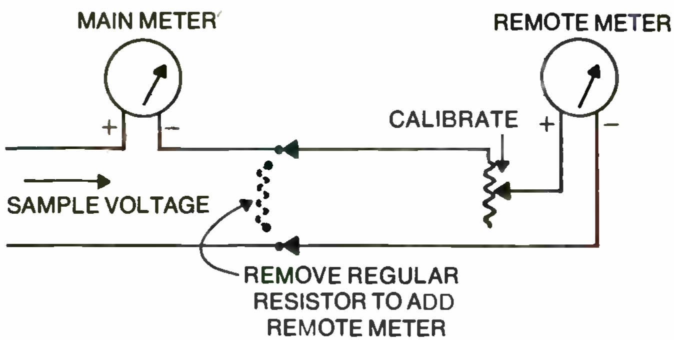


Fig. 9-18. When the remote meter and calibrating resistor are in series with the main meter, they are difficult to calibrate; the remote will affect the main meter.

calibrating control. There should be two people doing this so that both meters can be watched at the same time. The remote meter must agree with the main meter since they are measuring the same current. It takes much delicate juggling to get the two to read together and correctly. If you are not careful, the main meter will not read correctly. In the case of an FM power meter, have the dummy load and wattmeter on the transmitter, and then calibrate both meters at the same time. The wattmeter will show the correct value of power.

Dual-Power Operation—When an AM station operates at two different powers for day and night, it is difficult to get a remote meter to calibrate at both places with the same control (Fig. 9-19). In this case, arrange to have a switch and two calibrating controls at the remote meter. In this way, the

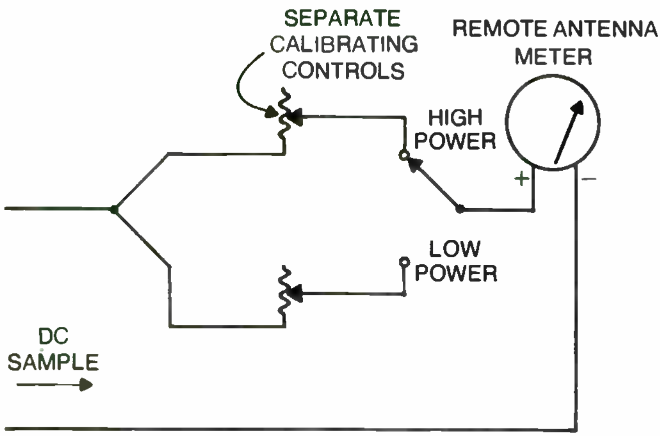


Fig. 9-19. When the remote antenna meter must read current for two different powers, add a switch and two different calibrating pots.

meter can be calibrated accurately for each power. In operation, of course, the switch must be thrown to the correct power so that the proper calibrating resistor is in the circuit.

Typical Meter Readings—A new transmitter (Fig. 9-20)—with the gleam of the new parts, the aroma of fresh paint and new insulation, and all—is a little like a new car. That first checkout of the transmitter should be a real pleasure, just like the first drive in a new car.

The instruction manual will show a complete set of typical meter readings for the transmitter. These have been obtained from a similar transmitter at the factory. Each transmitter is slightly different, and the meter readings can vary from the typical readings. Your transmitter will be checked out at the factory on your channel before shipment, and all the readings will be given.

When the new transmitter is installed, tuned up, and working properly, go through and take a complete set of meter

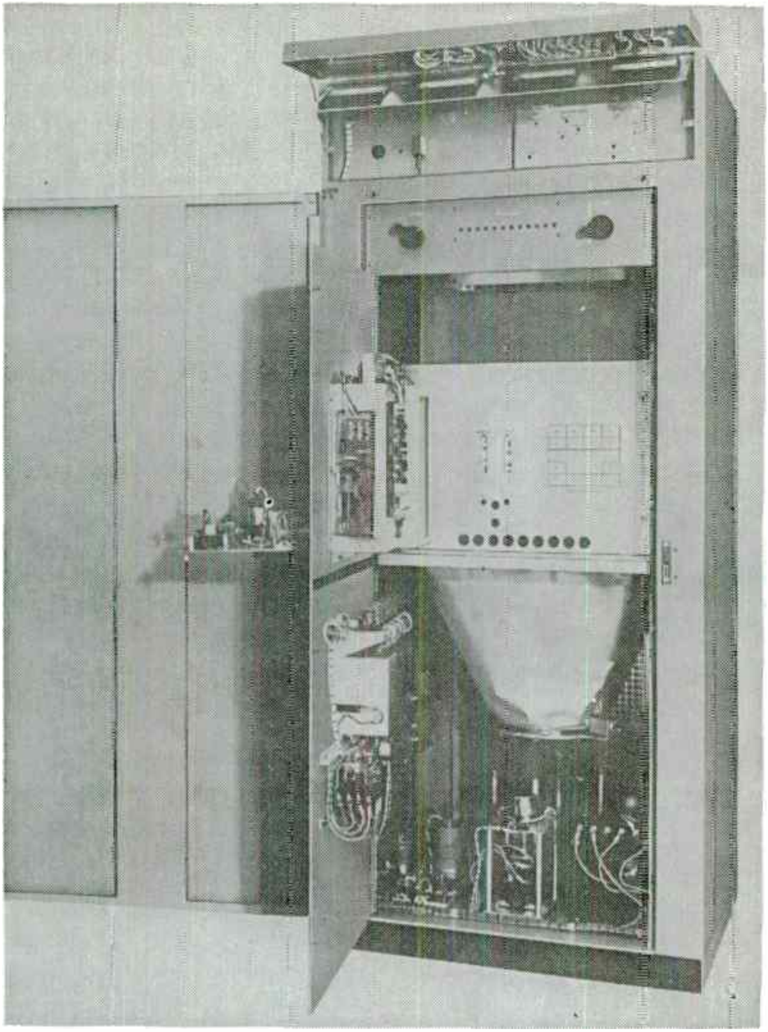


Fig. 9-20. Harris MW-1, solid-state AM transmitter with the front door and access panels open, showing the simplicity of layout and easy access for maintenance.

readings. The on-site operation will vary somewhat from the factory checkout conditions. This is due partly to different power line voltages. The load will be slightly different also, since the factory's dummy load and your antenna will present different situations. Thus, the on-site readings also vary. You can write of all these initial readings either in the instruction manual or on the checkout sheet alongside of the factory figures. This is a better reference than either the typical readings or the checkout readings. This is where the transmitter started at the station.

Reference Material

Drawings made of the wiring and jacks and any other pertinent notes about the installation should be saved for future reference. Note any special tuning done in the instruction manual, and if any modifications are made, show these on the prints. All this information will come in very handy when problems arise.

Chapter 10

Coax Transmission Line

The RF carrier from the transmitter will be routed to the antenna system over coaxial transmission lines. This is true for all FM stations and the majority of AM stations. There are many advantages in the use of this type of line, but it does have its own characteristics, and there will be problems when the operation is contrary to these characteristics. So when it is necessary to select a new line, replace a presently operating line, or troubleshoot problems that arise, a general understanding of the basic characteristics of coax line will help you make better decisions or solve problems. Although we will consider the larger diameter lines used for transmitting power, the same characteristics hold true for all coax lines.

CHARACTERISTICS

The line's special physical structure and the rigid control in maintaining the dimensions during manufacture are what create the electrical properties peculiar to this line and what makes it different from other lines or cables.

One conductor is mounted within the other conductor. The inner conductor is mounted exactly in the center of the outer conductor and is held in this position throughout the length of the line by insulators placed at regular intervals. The insulating medium may be dry air (along with the spacers), a solid material such as polyethylene, or a foamed polyethylene.

Natural Impedance

A coax line will have a natural impedance value that is called the *surge* impedance or *characteristic* impedance. This value is not the same for all coax lines but is dependent upon the diameter of each conductor, the spacing between the conductors, and the insulating material. Thus, by making the dimensions different, lines with different natural impedances can be created to suit different needs. There is a special formula for computing all this, but there is little need for it unless you plan to manufacture coax line.

In a practical field situation, you need only know which line is which. The important factor is the *ratio* of the diameters of the two conductors to each other. So, if you need a small section of line, and in the pile of line odds and ends you have, you find a suitable length but wonder about its impedance, then look at the inner conductor. The line with the larger inner conductor will have the lower impedance. Such situations often arise when the station may have several different coax lines and cables in use. Or it may have changed lines in the past—for example, from the old 51.5-ohm rigid line to the newer 50-ohm rigid line—and there are scrap pieces of both lines in the pile. The 50-ohm line will have a slightly larger diameter inner conductor. A similar situation in cables occurs with the RG-8 and RG-11 (50- and 75-ohm lines). The RG-8 will have a larger inner conductor.

Termination

The natural impedance of the line is its design impedance, and it is the *optimum* impedance at which the line should be operated. That is, the terminating load should be a pure resistance equal in value to this natural impedance. All the ratings in the spec sheets for any line are based on these ideal conditions unless stated otherwise. Consequently, if the load impedance has improper resistance value or if there is reactance present, standing waves will be set up in the line. When standing waves are present, all the design parameters change and the line values must be rated downward.

Peak Power

An important rating of a line is its *peak* power-handling ability. This is the ability of the line to withstand voltage stress across the conductors, and it also indicates the amount of voltage that can be present before an arcover occurs on the peaks. The basic factors which determine this rating are the spacing between the conductors and the insulating material used. The rating is not frequency dependent; the rating is the same for 60 Hz voltage as for a UHF signal. The stated rating in the spec sheet is based on dry air for the dielectric material. The rating can be increased by pressurization or if other gases are used instead of dry air. But when standing waves appear on the line, or there is moisture in the line, this rating will be quickly lowered.

Average Power

The second important power rating of the line is its *average* power rating. This rating is based on the temperature rise of the inner conductor before it warps or the insulators deteriorate or melt. Since RF power has a definite heating effect that increases with frequency, this rating is frequency related. The higher the frequency, the lower the rating. Remember that this is basically a temperature effect, so anything which can raise the temperature of the inner conductor will affect this parameter, such as direct sunlight or outside ambient air temperatures.

The heat from the inner conductor must be quickly transfered to the outside air, so anything that can hasten this transfer will improve the average power rating. Both pressurization and the use of a gas which has a better heat transfer characteristic than air will increase the average power rating. Standing waves, on the other hand, cause a rapid heat rise in the conductors, and so will quickly lower the rating of the line.

Attenuation

There will be a loss of power as the signal travels along the line. The determining factors for this loss are the resistance of the conductors and the leakage across the dielectric. Both the RF resistance and the leakage will increase as the frequency is increased, so the rating is definitely related to frequency. As a yardstick, the ratings are based on 100-foot sections of line.

There isn't anything you can do to improve this rating except to use a larger diameter line. The larger line will have a greater conductor surface and less RF resistance, and the wider spacing between conductors will reduce the leakage.

Although you can't improve the rating, standing waves will deteriorate the rating, by producing higher losses. Since the rating is based on 100-foot sections, the longer the line, the greater the total losses.

Velocity of Propagation

This rating only has utility in certain applications, but in those applications it is an important rating. The RF signal is slowed down as it passes through a coax line, so its physical wavelength is shorter than the same wavelength in free space (Fig. 10-1). The insulator or dielectric material is the basic cause of this. Lines with an air dielectric have only spacers to

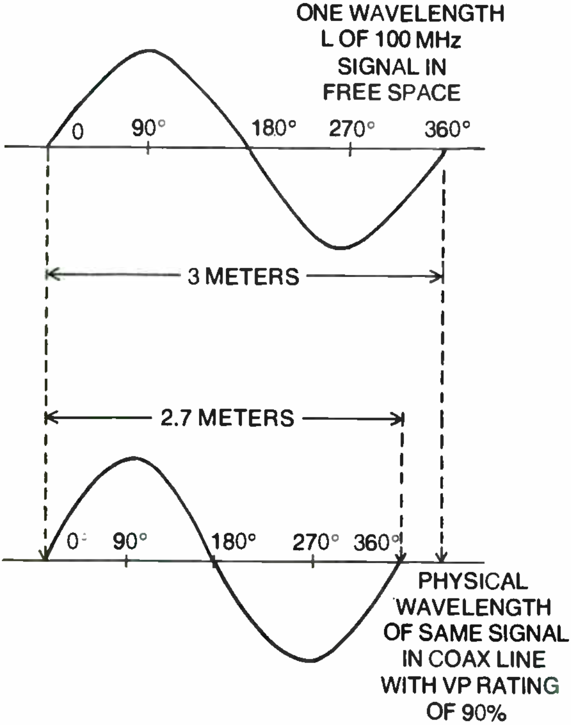


Fig. 10-1. The wavelength of the RF signal is shorter in the coax line than it is in free space. How much shorter is a function of the velocity-of-propagation (VP) factor of the line.

impede the wave and thus will have a higher rating. (The ratings are expressed in percentages.) Coax, with a solid dielectric, causes the wave to be delayed more, so it has a lower rating. For example, air dielectric lines will have a rating over 99 percent, while solid dielectric cables can have ratings as low as 60 percent.

The percentage velocity-of-propagation is used as a multiplying factor on the free-space wavelength of the RF signal. For example, a 100 MHz signal will have a free-space wavelength of three meters. But passing through a line with a velocity factor of 93%, the wavelength in the coax will be 2.79 meters (3 meters $\times$ 0.93 = 2.79 meters).

Phasing

From the previous discussion, it is obvious that the line's electrical length has a definite relationship to the RF wave it is transmitting. This is a useful factor to know when troubleshooting problems, cutting a line to avoid undesirable wavelength relationships, or using special lengths of line for phasing purposes. This latter is done in the feeder and intertower connections in AM directional antenna systems, and in joining the bays in a multibay FM antenna. For such purposes, the line length is often expressed in degrees of the RF wave rather than actual physical length. For example, a quarter-wave section is 90 degrees and a half-wave section is 180 degrees.

POWER DISTRIBUTION

When the line is properly terminated in a load resistance that equals the line's natural impedance, the power distribution at any place along the line will be equal (except for the gradual loss because of the line attenuation). The most efficient transfer of power takes place under these conditions.

Standing Waves

When the line is not properly terminated in a load which is a pure resistance equal to the natural line impedance, then all the power is not absorbed in the load, and some of it is reflected back towards the source end of the line. This reflection sets up standing waves on the line. Just how much power is reflected back to the source depends upon the degree of mismatch and what reactance is present.

The reflected power will have a different phase relationship to the forward power as it travels along the line. At some places the two powers are in phase and add together, and at other places they are out of phase and subtract. When the in-phase addition takes place, there will be a greater voltage stress or higher current than normal, which can cause arcovers from voltage or greater heating from the higher current. These phasing conditions will affect the signal's sidebands as well as the main carrier itself, so there can be distortions in the final received signal at the receiver location.

Standing-Wave Ratio

This is a figure that describes the conditions on the line and is a ratio between the forward and the reflected powers. Measurement can be made of either the voltage or the current components of the two waves, but most of the usual indicators in broadcast stations measure in terms of the voltage components. The term is then designated *VSWR* (voltage standing-wave ratio). The voltage must be measured with directional couplers that measure each wave separately, feed the voltages into a resistor arrangement so that they can be properly calibrated, and then read on an indicating meter.

Tuned Sections

Coaxial line sections are often used for tuning or matching sections, traps, and filters. In this application, very strong standing waves are essential to the tuning action. To create the desired effect, the line section is either shorted, left unterminated, or equipped with adjustable capacitors or shorting bars. When a line section is used for these purposes, it is a short piece of the correct physical length.

When trying to visualize the conditions taking place in a coax line, it is very easy to become confused with the conditions that prevail when the line is correctly terminated and when it is not (see Fig. 10-2). The two conditions are not the same at all. When correctly terminated, the line is simply a conductor for the signal, and except for slowing up the wave, it operates in the manner in which it is designed to. The voltage and current of the signal go through their normal rise and fall just as any other AC signal does, and there is only one wave in the line—the wave going forward to the load at the end of the line. Now, when the load is improper and some of the signal is reflected back to the source, there are two waves traveling in different directions, and their basic amplitude and phase are different. This is an altogether different ballgame, and all the

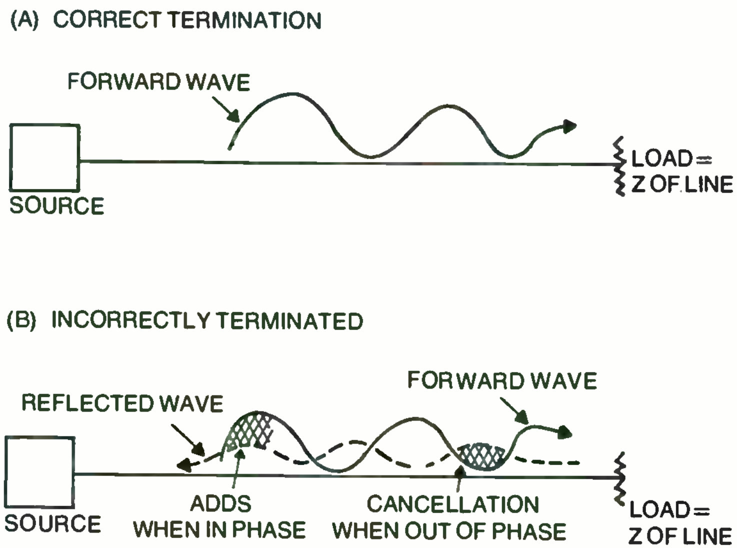


Fig. 10-2. Two entirely different conditions exist when the line is correctly terminated and when it is not.

line conditions change. For power transmission purposes, standing waves are very undesirable and should be kept as low as possible. But if you want to use the properties of standing waves to make a tuned section, then you create very strong standing waves deliberately.

DERATING

As previously discussed, when conditions other than the ideal occur in the line, just about all the characteristics of the line are altered in some manner. Since the design specifications are based on these ideal conditions, they must be derated. Standing waves on the line require that most of the parameters be derated by an amount related to the strength of the standing waves. Also, the specifications are based on a constant-amplitude signal, such as an FM carrier. When AM carriers are used on the line, the specs must be derated further.

Amplitude

When the station's carrier is amplitude modulated, the peak power rating of the line must be reduced to a lower figure. This is because the sideband power is transmitted along with the carrier itself. In amplitude modulation, the peak power of the signal at 100 percent modulation is four times the peak power of the carrier by itself. The peak power rating as given on the specification sheet must be divided by four to arrive at the rating for an AM carrier.

In the determination of the peak power rating of a line, there are many factors involved; but you are not designing a line, only trying to determine if a particular one can be used for the service you intend. All these other parameters will remain constant except the VSWR, so this simple formula will give the peak power rating for AM use.

$$\text{Derated peak power} = \frac{\text{rated peak power}}{(1 + M)^2 \times (\text{VSWR})}.$$

The modulation percentage M expressed as a decimal is 1.0, so $(1 + 1)^2 = 4$. Thus, the rated peak power is divided by 4. Of course, the VSWR enters the picture, and that value is also divided into the peak power to further derate the line. As can be seen by this simple formula, the peak power rating of the line quickly drops with AM.

"Super" AM

Now that AM broadcast stations are permitted to modulated to 125% on the positive peaks, the peak power rating of the line must be derated further. From the formula given then, $(1 + M)^2 = (1 + 1.25)^2 = 5.0625$, or about one-fifth the original rating. And this can be a problem for the AM station that can achieve that percentage of modulation.

Take, for example, a 1 kW AM station that is presently using a ⅞-inch foam-filled coax line. This line has a normal peak power rating of 44 kW, and since the line is solid dielectric, there is no way to use gas or a pressure to increase the power rating. On first glance, a 44 kW rating should be more than adequate for a 1 kW transmitter. With normal 100 percent modulation, the peak power must be divided by 4, so this brings the rating down to 11 kW. This is still plenty of room.

But now suppose the modulation is increased to 125 percent, which gives us 8.8 kW. The transmitted power under these conditions is 5 kW on the peaks, so the spread is getting closer. This is still adequate room so long as there are no standing waves on the line. If there are standing waves, then we must derate further. Let's assume the VSWR is 1.5; divide the 8.8 kW by 1.5, and the rating becomes 5.86 kW. What at first appeared as though we had the whole ball park to play in, now looks more like the infield only.

Average Power

When VSWR is present, the average power must be derated. This can either be done by computation or by a simple rule of thumb. If you want to compute, use this formula:

$$\text{Derating factor} = \frac{\text{VSWR}^2 + 1}{2 \times \text{VSWR}} + F\,\frac{\text{VSWR}^2 - 1}{2 \times \text{VSWR}}$$

The factor *F* is taken from a chart in the manufacturer's catalog sheets and is frequency dependent. For FM frequencies, the factor is about 0.4 or 0.5, and for AM frequencies, it is 1.

The rated average power of the line should be multipled by the derating factor. This will give the amount of power to subtract from the stated average power rating. Assume, for example, a line with an average power rating of 15 kW and a VSWR of 1.2. By use of the above formula, we find that approximately 4.17 kW must be taken from the 15 kW figure, so that the derated figure is now 10.83 kW. If the station had a 1 kW FM transmitter feeding this line, it is doubtful that that amount of power would cause any damage to the line. But if the transmitter were 10 kW, that is another story.

About the only time you might want to do all this computation is in an installation where you can't get the VSWR as low as you would like it. You must then derate the line for regular operation. When some unusual situation arises, such as ice on the antenna, simply divide the transmitter power output by the VSWR.

Besides the line, you also want to protect the transmitter output stages. In the previous example, if we divide the 10 kW output of the transmitter by the 1.2 VSWR, this will give a power figure of approximately 8.3 kW. Reduced transmitter power will give added protection to both the line and transmitter.

SELECTION OF TRANSMISSION LINE

There may be a time when you must select a line for a new station or a presently operating station that has been granted a power increase. The main factors in this selection (aside from economics) are the power losses and power-handling ability of the line.

Size

The two main factors which affect both the losses and the power-handling ability are the diameter of the line and the type of dielectric that is used. The larger diameter line will have less loss than a smaller diameter line of the same length. Lines which use Teflon spacers and air dielectric have the least loss for a given diameter. Use the charts supplied in the manufacturer's catalog to determine the size according to the amount of loss that can be tolerated and the required power-handling ability.

Losses

To determine how much loss can be tolerated in the system, use the transmitter power output and the power required at the input to the antenna. If this is an FM station,

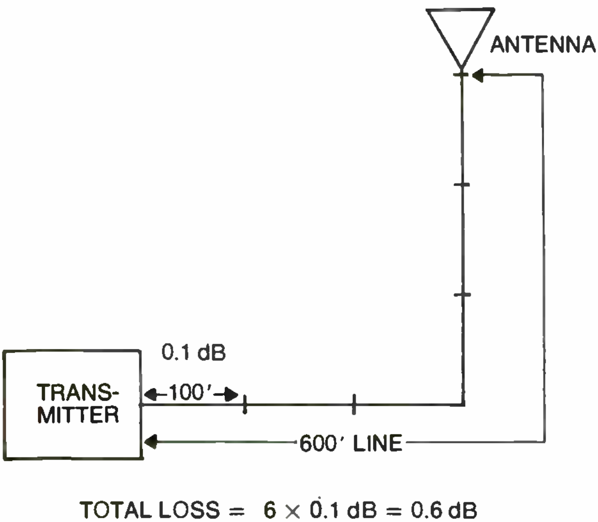


Fig. 10-3. Compute the loss for the total length of line, not just the 100-foot section.

divide the effective radiated power of the antenna by its power gain to arrive at the input required at the antenna.

The loss figures in transmission line charts are given in decibels per 100 feet, so you will need to convert power to decibels, or the other way around. You will want to know the total loss in the full line, not how much it will attenuate the signal every 100 feet. So divide the total length of the line by 100 to get the multiplying factor.

Multiply the decibel loss from the chart by the multiplying factor just derived. For example, a particular type of line has 0.1 dB loss per 100 feet on your channel. But your installation requires 500 feet of line. Since 500 divided by 100 equals 5, and since the loss is 0.1 dB per hundred feet, 0.1 dB $\times$ 5 = 0.5 dB. The total line loss then will be 0.5 dB. This is a power ratio of 1.12, so if the transmitter output power is 10 kW, there will be approximately 8929W at the end of the line to radiate from the antenna (10000/1.12 = 8929). The loss in the line is 10000−8929 = 1071W.

Power

Besides the loss in signal power, both the peak and average power ratings of the line must enter into the deliberations. Always try to select a line that will allow for some reserve capabilities, particularly if there are possibilities of the station increasing power at a later date. Working a line very close to its maximum ratings may save a little money on the initial investment, but it can sow the seeds of many operational problems in the future.

When estimating the size of the line for power rating, don't forget to derate the spec sheet figures for anticipated VSWR, and for the modulation if it is an AM station. Although a unity VSWR is very desirable, it is doubtful that this can be achieved with practical antennas, and if it is achieved it may not stay that way very long. Both the line and the antenna system are exposed to the weather, and they will both age, causing changes that increase the VSWR. But during unusual conditions, such as ice on the antenna or the removal of a bay of the FM antenna stack for repairs, the VSWR can rise. In your computations, allow at least for a possible rise to 1.5 VSWR. This is an arbitrary figure, but it will leave a desirable allowance and reserve in the line.

Type of Line

There are many choices when it comes to coax line, but basically these fall into two types, rigid or flexible. Each of these has its own advantages, disadvantages, and electrical characteristics. The rigid line will come in 20-foot sections that are bolted together at the flanged ends. This line requires elbows to turn corners or change direction, it and takes more installation time. But if repairs or changes must be made, they are easier.

The flexible line will be one continuous piece, flanged at both ends. This can make the installation go faster, and the mounting is simpler. But you must make sure of the length to order. And a large spool of this line is a bit clumsy to handle. If you guess wrong about the length (too long) you will need to cut off the factory-installed flange and redo it, unless you're lucky enough to find a suitable place where the excess can be coiled up out of the way. Also, repairs done on this line are far more difficult.

Don't Skimp

During the deliberations and calculations in trying to make the final selection, here is a thought to keep in mind. A good line and installation will last for many, many years, and with only a minimum of problems and very little maintenance. But a poor installation of an underrated line will be nothing but problems. So don't skimp on the line.

Select a good-quality line, allow for adequate reserve in the power ratings, and then make a good installation. Note that the statement said "adequate" reserve. You don't want to go overboard either. Use good judgement, and if the budget is tight, skimp on some other studio items and invest in a good line. When a problem arises in the studio gear, at least it is where you can get at it, and it probably would not affect the station's ability to operate. But if the line burns up, the station is off the air until it can be corrected. Correction can be costly, and worse if it is a vertical run up the tower that also requires tower riggers and their equipment.

INSTALLATION POINTERS

The installation should be planned well in advance of the equipment arrival at the site. If this is an FM line, then tower riggers and hoisting equipment are needed. In any case, the horizontal run can be made by station personnel. In this planning, give thought to storage of the line components before they are installed, and where you will work to cut the line and add flanges. Different techniques are required for rigid and flexible line. And, of course, there is some difference between AM and FM installations.

When the line is ordered, care should be taken to anicipate *all* the components needed, including all the small items, such as gas barriers, field flanges, etc. There is a variety of small components that go into the line installation. When all this arrives at the site, don't assume it is all there—check it out against the original order. If there are any shortages or wrong components, get replacements before construction begins. Once the construction begins, everything that will be needed should be on hand at the site.

INSTALLING RIGID LINE

In the FM installation, the antenna should already be in place atop the tower. This may be a presently operating antenna or a new antenna. By having the antenna in place, this gives a fixed starting place to begin the line, and at the same time, it will show up any problem in mating the antenna with the line. In many cases, the tower structural members at the top are close together, and routing the line can be a little tricky.

Have the tower riggers build the FM line from the top down. Some like to build from the bottom up to the antenna, especially with larger lines. There are two practical advantages to building from the top down. In the first case, the open end of the line will always be down, so there is less chance of getting rain or other materials in the line while it is being constructed. Secondly, it is a rare case when the distance between the antenna and the bottom of the run comes out exactly in multiples of 20-foot sections. There is always at least one piece to be cut and a field flange to be added. So, by constructing line downward, this cut piece will be at the base of the tower and not at the antenna. At the ground level, station personnel can get at it should later repairs be needed, but if it is at the antenna location, then tower riggers and their equipment will need to be called in to make the repairs. This is simply a bit of foresight that can save additional expenses at some later date.

Mountings

The line will be suspended by hangers every ten feet, and these will be either a spring hanger or some kind of movable hanger that will allow the line to move during contraction and expansion caused by temperatures. During the construction, however, the full weight is not yet on the line, so these must be compressed the correct amount when installed, according to the manufacturer's directions. This information will be found in the instructions that come with the hangers.

Rigid Mountings

At the top of the tower, the line should be anchored by at least two rigid hangers. These will support the line and, at the same time, prevent expansion from going past them. The antenna should not support the line. Allowing the antenna to support the line is poor practice, for all the tremendous pressures built up by contraction and expansion will push against the antenna, and it will be damaged. The FM antenna may have a matching transformer mounted at its input, so the rigid hangers should be below this; that is, right at the end section of the line itself. Consider everything above that point as the antenna.

Making Bends

It will be necessary to angle the line so that it can connect properly with the antenna flange and with the horizontal run at the base of the tower. There may be other problems on the tower itself that require the line to change directions. The rigid line cannot be bent, so both 90- and 45-degree elbows are available. The 90-degree elbow will handle most of this direction change if it is flanged at both ends with swivel flanges.

At the antenna junction and at the base of the tower, use two 90-degree elbows together (Fig. 10-4). This will allow for all angles and should meet the antenna feeder at the angle required. The use of two elbows also makes it easier to get the line apart when needed. If the line should run directly into the feeder, then it is necessary to loosen the rigid hangers and drop the line far enough to get them apart. Once the line is dropped, it will be impossible to get the line back together without hoisting equipment or some jack arrangement at the base of the line. Men could not lift the weight of the line by

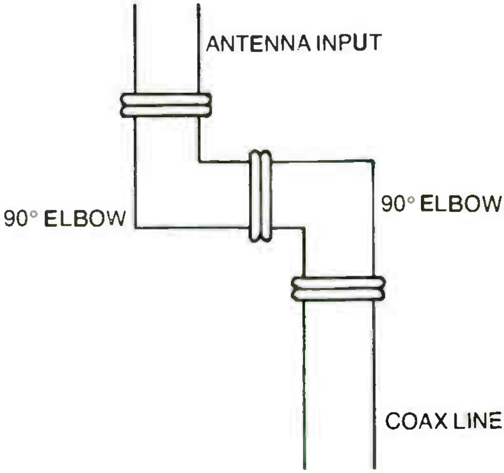


Fig. 10-4. Use two 90-degree elbows at the base of the antenna.

hand. Double elbows at the base of the tower also provide this facility at getting the line apart when needed.

Horizontal Run

Both the AM and FM station will have a horizontal run of line. The AM line will terminate in the tuning equipment, whereas the FM line will meet the vertical run. In this case, the AM line should have a rigid hanger at the tuning house.

Both the AM and FM runs should have a rigid anchor where the line enters the transmitting building. These rigid hangers allow the line to expand and contract between them but prevent the pressure from being applied to the equipment on either end.

Between the rigid hangers the line must be allowed to move. The hangers along the line are movable hangers that both support the line and allow it to move. These are different from the hangers for the tower but serve the same purpose.

Support and Shelter

The horizontal run must have support above the ground level. It should not be laid on the ground itself, nor should rigid line be buried. The supports may be steel pipes or fenceposts driven into the ground and tall enough for protection against mowing equipment, etc.

In sections of the country where ice is a problem in the winter months, a protective shield should be built over the line to protect it from ice falling from the tower. This shield will also protectthe line from tools or components dropped off the tower when workmen are on the tower.

Cutting the Line

As mentioned earlier, it is rare when it is not necessary to cut and flange at least one piece of line. There are always one or two pieces that need to be shortened, or small sections may be needed inside the transmitter building. When you make the cuts, do it carefully and survey the situation before diving in with a hacksaw.

First, make sure all the measurements are correct. This is very important. If you don't allow for the flanges, and the section is a snug fit anyway, you won't be able to get it in place—or it may come up short if you measured the other way. So get the measurements exact. The instruction sheet that comes with the flange will show all the correct allowances to make, including how much to undercut the line to allow for the flange. Measure the full distance that is needed for the line section—from flange face to flange face (Fig. 10-5). Use this as the required length and then allow for the undercutting as shown on the instruction sheet.

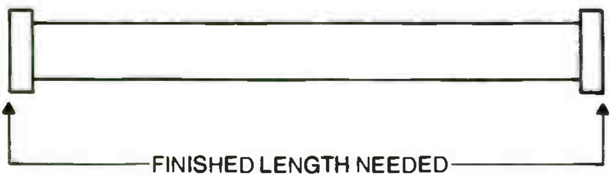


Fig. 10-5. Measure for the required finished length from flange face to flange face.

When you must cut a section, try to use an end that will already have one factory flange. In this way, you need only add one flange. Of course, there can be situations when the only piece of line left has no flanges on it at all. Then you must add two flanges. But a suggestion here: Assuming the line section is longer than needed and must be cut, go ahead and mount one of the flanges before cutting the line. This will then put the work in the situation as if the section already had a factory flange. By doing this, it will be necessary to cut only the one end of the line.

Outer Conductor

Before working with the outer conductor, pull out the inner conductor and put it in some safe place for protection. Then after careful measurement, mark the place you wish to cut on the outer conductor. Don't rely on your eye to make a straight cut; use a heavy sheet of paper that has at least two straight edges. Wrap this around the pipe, line up the straight edges, and mark with a pencil all the way around the pipe (Fig. 10-6). If done carefully, this will give a straight cutting guide.

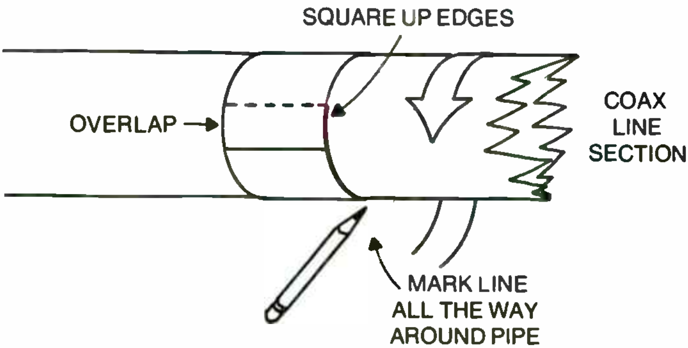


Fig. 10-6. Mark the pipe all the way around. Use a stiff piece of paper as a guide.

Now use a hacksaw with a good blade in it and cut through the line. But don't try to cut clear through the pipe. Only cut small sections, rotate the pipe, and cut some more. When nearing the end of the cut, hold onto the end piece so that it doesn't drop by its own weight and bend an edge at the cut surface. These are difficult to straighten out. During this time, keep the line section tilted at a slight angle so that the filings will fall out the open end and not back into the pipe.

When the piece has been cut off, clean up the sawed edge with a file. The inside rim of the cut can be cleaned up with a heavy pocket knife. Next, clean out the pipe so that there are no filings inside it. Take a clean rag and use something as a ramrod to push it through, or tie a clothesline to it and pull it through.

Soldering

With the cut made, check it out for straightness. It is important that the cut be straight, or the flange will fit at a slight angle. This will make it difficult to connect the section to the rest of the line, and if it is connected, there will be pressures against the solder joint.

Clean up the copper with steel wool or similar material so that it is polished bright. Then use a good hard solder such as silver solder. Some of the field flanges already have a ring of silver solder in them and need only be heated. If there is none, you must supply your own.

Use a medium tip on the torch, as silver solder requires more heat than soft solder. If there is a wind blowing and you are outdoors, set up some sort of wind shield. Wear gloves to keep from accidentally touching something with bare hands. Once heating begins, "wipe" the pipe with the flame for several inches from the flange. This will warm the pipe and cut down heat flow away from the joint. Once the solder has flowed evenly all around the seam, stop heating and let it cool. During this time before the solder sets, don't move the work. When it has cooled off, polish the joint with steel wool to clean away any burnt flux or torch residue.

Inner Conductor

The inner conductor must be measured carefully. This will be undercut more than the outer conductor. The inner conductor must accommodate the bullet or connector. So check the instruction sheet carefully for instructions on the measurements.

There will be insulated spacers on this conductor, so watch out that the cut does not come right on an insulator. If this is the situation, move your measurements one way or the other and then make a cut at both ends that will land between insulators (Fig. 10-7).

Skin Effect

One characteristic of any RF signal is *skin effect*. The wave will travel along the surface of the conductor and make very shallow penetration into the metal itself. So keep this in mind when making up flanges. Be concerned about the *inner surface* of the flange and make this a nice smooth surface from the pipe to the flange. Don't have gaps in the joint or large

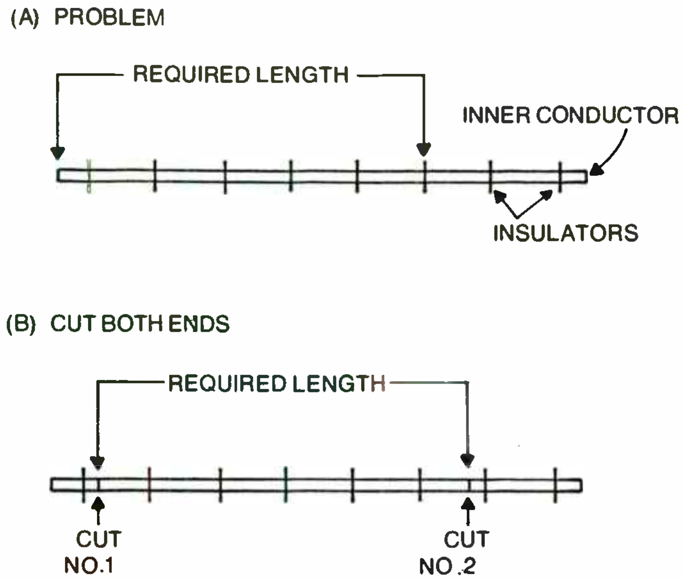


Fig. 10-7. Avoid cutting at the spacers on the inner conductor. If necessary, move the measurement down the line and make a cut at both ends.

blobs of solder protruding inside the line. Those are directly in the path of the RF signal and will increase the resistance and create standing waves.

Also avoid making dents in the line. Should a line section slam against the tower on its way up, have that section brought back down and a new section sent up. The dented one should be saved for making shorter sections.

INSTALLING FLEXIBLE LINE

The flexible line requires a little different handling than the rigid line. When planning the original purchase, make accurate measurements of the run for the whole line. The factory will cut the length you order and apply flanges. If you measure correctly, this will save putting on the flanges yourself.

Hoisting

A cable hoist should be ordered if the line will run up the tower to an FM antenna. This will attach to the end of the line and is pulled up by a winch. Leave this attached to the line and use it as the top anchor on the line. Make sure the cable is free to turn off its spool. Try to pick a day that is not windy.

If the tower is a "hot" AM tower, the hoisting should be done after signoff when possible, or shut down the AM transmitter long enough to get the line up the tower. If the AM can't be turned off and the line must be pulled up anyway, be prepared for many things. If it is a bare copper line, keep it away from the tower, or arcing will occur, which will put noise on the AM signal. The winch itself must use rope, not a steel cable. Also, wear the leather gloves, as the line will get plenty "hot" with RF as soon as it begins to stretch out.

In the transmitter room, look for much detuning of the tower and erratic operation of the transmitter. I had to do an installation in this manner one time, and the best recommendation that can be made is this: Don't!

Bonding

Some of these cables are sheathed with an outer polyethylene covering. This will insulate the line from the tower, but it will also upset the tower's electrical characteristics. So clean off the covering every so often and bond the coax to the tower. Pick spots that are not electrically related to the wavelength of the AM signal. That is, break up the coax into random lengths. The bare copper line is perhaps best for this type of installation, but it must be bonded tight to the tower so that arcing does not take place between the line and tower.

In either case, the line is bonded to a tower leg all the way down the tower. No other anchors or hangers are usually needed. But if the line must cross wide spaces on the tower, install angle iron for a brace and then bond the line to this. When a long stretch of line is not tied down, the wind will constantly flex it. This will lead to early metal fatigue, and the line will fail or fall apart.

Horizontal Run of Flexible Line

The best arrangement is the same as that for the rigid line, except different suspension is needed. Hangers can be used, but a piece of horizontal angle iron or a pipe is best and would require fewer hangers. There will usually be a large conduit that carries AC power for the tower lighting, and this can be used to support the line. Strap it to the pipe every two feet with banding. If the line is sheathed and long, again ground the outer conductor at intervals that will break up its relationship to the carrier wavelength (at an AM station).

There is no need to allow for contraction and expansion of this line, as the flexible line will adapt to these conditions.

PRESSURIZING THE LINE

When an air dielectric line is used, whether a rigid or flexible line, it should at least be pressurized with dry air. Without pressure, any small leak will allow outside moisture and dust to get into the line. Moisture will cause increased leakage of the RF across the dielectric. This will change the ratings, since they are based on dry air. Besides that, if there are any low spots in a horizontal run, water will collect there and build up until it shorts out the line. In the winter it will freeze and cause additional problems.

Breathing

A line that is not pressurized will "breathe." If there are any small openings, dust and moisture will be drawn into the line. This breathing is caused by pressure changes inside the line caused by the sun and air temperature changes. When the line is heated, pressure will build up inside, and the flow will be to the outside (Fig. 10-8A). But when the line cools, the pressure drops and the flow will be to the inside of the line (Fig. 10-8B).

If there are no leaks in the line, then there is no problem except for any condensation that might take place from moisture already inside the line. A line with even 1 psi inside pressure will always have a flow to the outside, as long as the inside pressure can be kept higher than the outside pressure, nothing can get in the line. So consider some pressurization of an air dielectric line.

Gaskets and Barriers

To be pressurized, a line must be sealed up. On the rigid line, an *O*-ring gasket is used at each flange for this purpose. The flexible line has no joints except at the ends, so it is automatically sealed unless there is a hole in it somewhere. On the rigid line, the gasket must be in its groove and not pinched, and the bolts must be pulled down tight.

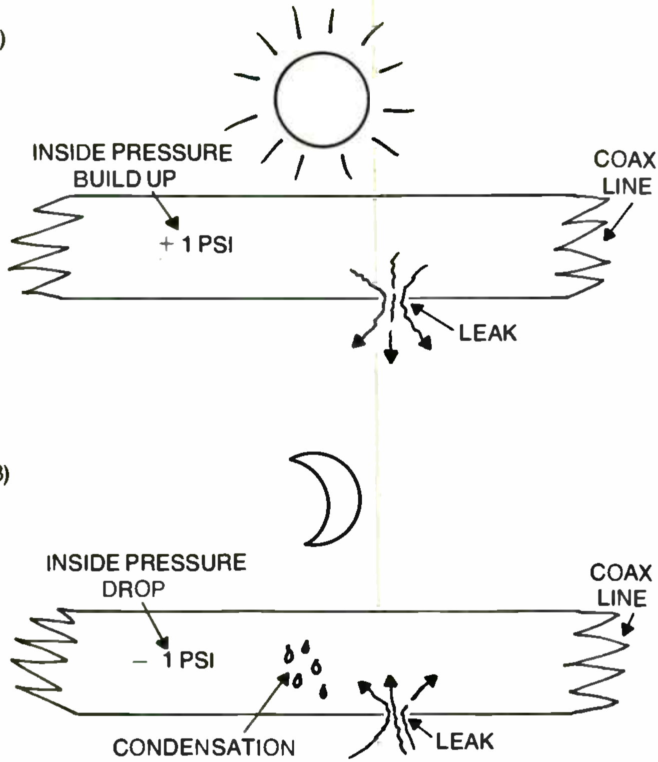


Fig. 10-8. An air dielectric line without pressurization and with a leak will breathe.

At the ends of the pressurized line, a gas barrier is needed. This is similar to a flange, except that the insulator is solid and does not allow gas to pass by it. It will also have at least two small ports with plugs screwed into them. These are for pressure gauges if desired, and as entry ports for the gas or dry air. They can also be used to bleed the line.

Pressurizing Equipment

Some method is required to pressurize the line after it is sealed. This may done with a dry air pump or a cylinder of gas. In either case, the pressurization equipment will have a regulator on it to maintain the line pressure and act as a buffer between the line and the source. In the dry air pump, air is filtered through a chemical that absorbs the moisture. The pump goes off at intervals, and a heater comes on to dry out the chemical and ready it for another cycle.

The gas cylinder has high pressure. The gas will automatically flow into the line until the cylinder pressure drops below the pressure in the line. Because of the high cylinder pressure, there must be a regulator between it and the line, or the line will be damaged.

Bleeding the Line

When a new line is installed and sealed up, it should be washed out with dry air or gas. Although dry air or gas will absorb moisture that is in the line, it can't get rid of it. But if you bleed the line (Fig. 10-9), the dry air will force the moisture to the outside, leaving the inside filled with dry air or gas. This same procedure should be done if the line has to be opened up for some reason, but it may not need as much bleeding as a new line.

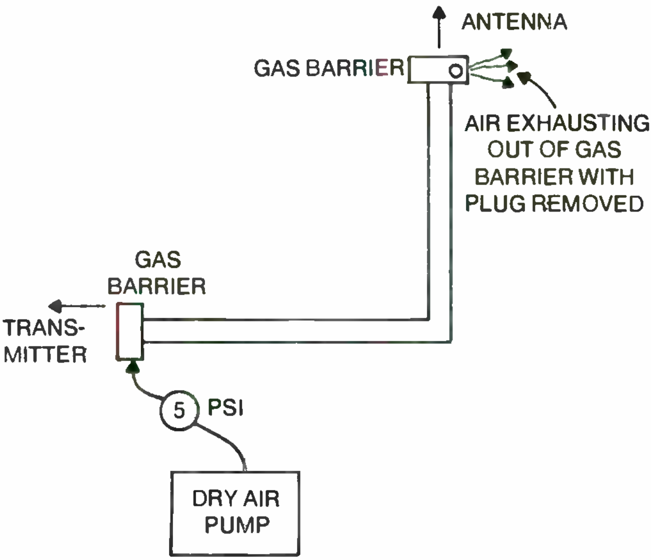


Fig. 10-9. Bleed the line by opening the plug at the end.

Pump up the line to at least five pounds pressure and let it set for a few minutes to absorb as much of the inside line moisture as it can. Then open the plug at the end of the line and let all this air out. The petcock at the input of the line should be closed. When the air quits blowing from the exhaust hole, put the plug back in the pump it up again. Do this two or three times.

Another way: After the first pumping up and bleeding, leave the plug open on the opposite end, and let the dry air pump continuously bleed the line for about five minutes, then seal it back up. If the end of the line is at the top of a tower, someone will have to climb the tower to open the line. Have one of the riggers do this since the job shouldn't be considered finished until the line has been checked out for leaks anyway. Give him a spare plug in case he drops the original. At other times, the line can be bled from the source end if necessary. This will do the job, but not as well as bleeding out of the opposite end of the line.

Checking for Leaks

When the line is first pressurized, check it for leaks. This can take place during the bleeding operation. Pump up the line to final pressure or a higher value, shut off the petcock and note the pressure gauge. Allow it a little time to settle down. Leave the line that way for several minutes or a half-hour and watch the pressure gauge. If it doesn't move, the line is tight; but if it drops off rapidly, there is a bad leak in the line somewhere.

Check all the flanges for a leak, especially the field flanges that were put on at the site. On these, also check the solder joint itself. Sometimes there is a pinhole in the solder and the line will leak. You can check these with a soapy water solution or one of the commercial leak-finding solutions. A leak will blow a bubble. If the line pressure is high, you can hear the air hiss out of the leak. By running a high pressure in the line (up to 20 psi) a small leak will become a large leak and will be easier to find.

There may be a pinched *O*-ring at one of the flanges. If there is, the flange will have to be opened. The ring may need to be replaced if it is flattened or cut.

CHECKOUT

A new line should have some preliminary checks before power is actually applied to it (Fig. 10-10). The first thing to check is continuity. This is important as an inner connector can be left out somewhere. Short-circuit the end of the line and measure with an ohmmeter. If there is an infinity reading, the line is open. If there is a short, the line is probably okay, but there may be a short somewhere in the line besides the end. If

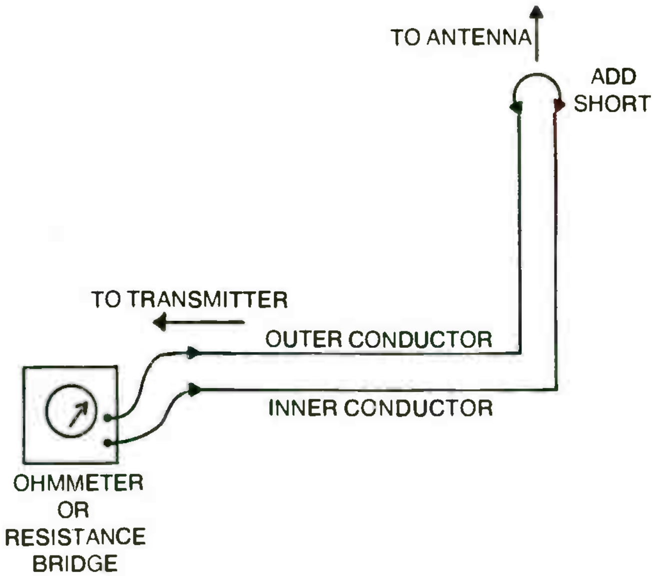


Fig. 10-10. Check line for continuity with an ohmmeter or resistance bridge.

you have a DC resistance bridge that can measure very low resistances (down in the hundredths or thousandths of an ohm), this will provide a reliable check, providing the resistance of the antenna is known.

The best procedure is to open the other end of the line. This is easy to do if it is an AM line, but not as easy when it terminated at an FM antenna. With the line open, the reading should go open, and if someone on the other end shorts across the conductor, then a low reading will be obtained. If using a resistance bridge, make sure a good solid short is placed on the other end, and measure the actual DC resistance. If it is an FM antenna, reconnect, and again measure the DC resistance.

Save these readings for future reference. These readings will typically be much less than an ohm, even on a long line.

Find the Missing Bullet

If your continuity check indicates the line is open, this presents something of a problem, more so if it is an FM line. There will be many sections of line and many bullets. Some isolating techniques will be needed to save opening every joint in the line.

First, open the line at the base of the tower and short the conductors together. By the way, the line need only be opened enough to slip some metal object in that will short the two. If there is continuity, the fault is up the vertical run; but if it is still open, the fault is in the horizontal run.

Now go open the horizontal run at midway and short the conductors. If the line is still open, it is in the quarter towards the source; but if a short occurs, then the opening is in the second quarter toward the tower.

The same procedure can be used if the fault is on the tower. And if a quarter-section of the run is long, you can use the same isolation technique. You will find the missing bullet much quicker this way than if you started opening each section of line.

Impedance Sweep

An impedance sweep of the line should be made on FM stations (Fig. 10-11). The station won't have the necessary

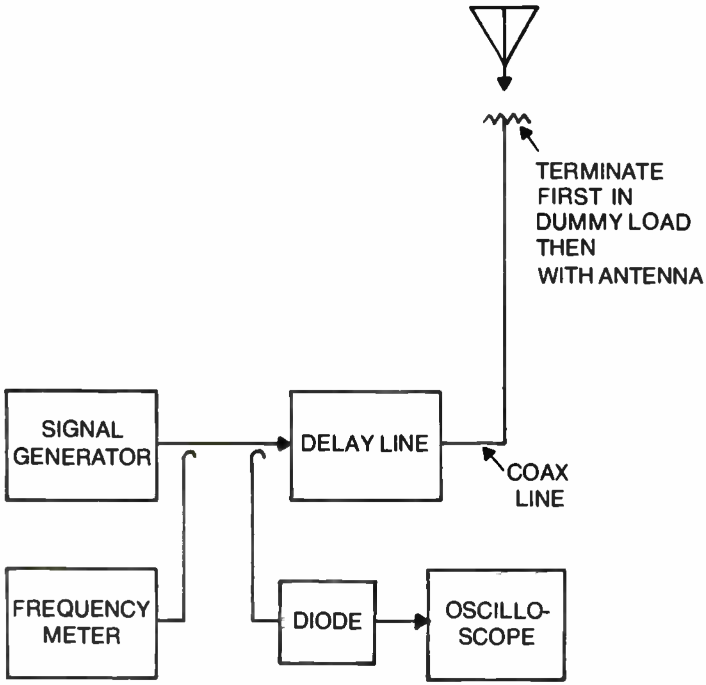


Fig. 10-11. Arrangement to sweep the line and the antenna across the bandpass for VSWR and impedance match.

equipment, but the consulting engineer or one of the service companies can do this for you. It will be a worthwhile investment.

This sweep will measure the impedance and the VSWR of the line across the bandpass of the station. This will be done first with the line terminated in a dummy load, and then with the antenna. Someone will need to be at the antenna to open the line to add the dummy load and then reconnect to the antenna. If there is anything seriously wrong with the line, it will show up on this sweep. When the antenna is connected, the transformer can be trimmed to get the best match across the bandpass.

Powered Checkout

Once these preliminary checkouts have been done, the transmitter can be connected up to feed the antenna through the line. Remember that this is as yet an untried line. It may have checked out okay with the other tests, but they were low-power tests.

The line may act differently under power, so feed the power gradually. Do it in steps. First, apply about one-fourth the regular power level. Check the VSWR indicator immediately for standing waves on the line. The indicator won't be properly calibrated yet, but it will give an indication if there are any standing waves. Let the system run this way for a few minutes and watch for any changes. Then, come on up to about half power, and repeat the procedures. Let the system run for about 15 minutes on half power. This will give all the line elements a chance to warm up.

If there isn't any indication of a serious VSWR problem, go on up to high power. But now, calibrate the VSWR indicator and check to see what the VSWR actually is. Save this figure for future reference. Let the system run for about a half-hour on high power before giving the line a clean bill of health. The preliminary checkout with the sweep will give a pretty good indication of line condition, but it is not the same as a check under full power.

LINE MAINTENANCE

A well selected line with adequate reserve in its specs and a careful installation will give good service for many years with only a minimum of maintenance. It does require some routine inspections from time to time and a daily check of the VSWR and gas pressure. Even a properly operating line can suffer physical damage from falling ice, tools, vehicles running into the supports, and other mishaps. And electrical damage can be caused by faults in the antenna itself.

Daily VSWR Checks

The VSWR should be read at signon and signoff. At signon, the line will be cold, but after a full day of operation under power, the line will be warmed up by RF heating, and perhaps the sun and outside temperatures. There may be slight changes between the two readings, and this is not a cause for concern. If these readings are gradually getting worse over a period of time, there is a gradual change in the system. But if the readings are normal at signon and poor at signoff, there is something heating up in the line, and problems are developing. There may be a poor connection that is overheating or burning, and it will soon break down. There may also be an antenna problem, and the problem should be uncovered and corrected as soon as possible.

Daily Pressure Checks

On pressurized lines, there should be a check of the line pressures each day. If this is a remote location, the line pressure should be part of the weekly transmitter inspection. An automatic dry air pump will continue to keep the pressure up in the line, but if there is a large leak, the unit may run continuously and burn itself out. If there is a large leak and gas is used, it can be expensive.

For a large leak, try this: Upon arrival at the site, shut off the source to the line at the petcock. Note the pressure gauge. Perhaps a half-hour later, again check the gauge. If there is no drop, the line is tight or at least the leak is slow. But if pressure is dropping significantly, there is a large leak. At least the horizontal run of line can be checked with a soapy water solution for a leak. If one is found, try tightening the bolts. This will often correct the leak, as the bolts may work loose. If it doesn't, then prompt maintenance will be called for after signoff.

Slow Leaks

It is difficult to detect and find slow leaks. A dry air pump will usually keep the line under pressure, even though it may work harder; but slow leaks usually soon develop into large leaks. When gas is being used, a slow leak can be detected by the amount of gas used over a period of time. When a new cylinder of gas is installed after the inital installation of the line, keep a record of the dates the cylinder is changed. A slow leak will use more gas, and it will be necessary to replace the cylinder more often. You can check the records and see what the normal usage is, and if the time between changes suddenly start to shorten up, a leak has occured.

Rigid lines put pressure on all the joints during expansion and contraction. This can help loosen some bolts. Any leak that is small in the summer, when the line is more expanded, will become a large leak in the winter, when the line is more contracted. Contraction pulls or attempts to pull the joints apart, while expansion pushes them tighter together.

Physical Damage

The line should be inspected occasionally for physical damage. If there has been severe icing, and when the melting comes and the field around the tower looks like an ice floe, keep an eye on the VSWR. Watch for sudden changes. If the VSWR suddenly jumps and stays up, at the next safe opportunity inspect the line for damage. I said *safe*, because it is dangerous to be wandering out under the tower if the ice is falling off in sheets or slabs.

Hot Spots

Another good indication of a high VSWR on the line are hot spots appearing at various multiples of the carrier wavelength. If the VSWR indicator is working and properly calibrated, it should be indicating this.

Aside from heating by the standing waves, other problems can be occurring that will produce heating. Check especially at the elbows and flanges on a line. When a flange or the area of the line within a foot of the line is hot, there may be a poor connection at the inner connector that is heating or burning. This can only get progressively worse until it fails. At the first opportunity, take the elbow or joint apart and check the bullet. Look for actual burning, but if the conductor hasn't progressed this far yet, check the copper inner conductor. The one running the hottest will discolor. Take the elbow apart if you can and check the inside of it. Replace the bullets or the whole elbow if necessary.

Intermittents

Intermittents in a line are just as much a headache as they are in any other piece of equipment. They are just as difficult to find and, in some cases, more so. I once worked at a 5 kW, 6-tower, directional AM station where an intermittent frying noise developed on the signal. After many and sundry checks, it was determined that the problem was in the antenna system somewhere. After signoff one night, I left the carrier on at the full 5 kW in the directional pattern, with no modulation, and took a transistor radio along on a tour of the antenna system, listening to the carrier. The frying noise would come and go.

Beginning at the one main feeder line, I banged on the coax line as I went, listening for something to happen. About halfway through the system, at or nearing one of the center towers, when the line was banged, the noise stirred up considerably and would occur every time the line was hit. (By the way, the banging was done with the heel of the hand, not the club I wanted to use.)

Going back and turning off the power, I opened up the line at that point. The end terminal had a bad solder joint inside and was burnt pretty badly. After cleaning this and resoldering, I found the noise was gone for good.

The technique was really no different than checking out a tube-type amplifier by going down the string of stages tapping on the tubes and listening for microphonics, except in this case, the "set" was spread out over a large area.

Chapter 11

Tower and Antenna

The final control a station has over its signal is at the antenna. A good antenna system is required so that the RF signal can be radiated in the most efficient manner. Antennas for AM and FM are physically different because of the carrier frequencies and propagation characteristics. They must also have somewhat different operating and maintenance techniques.

THE AM ANTENNA

Wavelengths in the AM band are rather long and require physically long antennas. One full wavelength in the middle of the AM band at 1000 kHz, for example, is 984 feet. This would require an antenna almost as long if full-wave antennas were used.

Propagation of the signal is by both the sky wave and ground wave. The ground wave is more reliable for local coverage, while the sky wave is best for long-distance communications. In broadcasting, the sky wave is undesirable, as it causes interference to stations on the same channel that are located many miles from the local station. The wavelength of the antenna that is used affects the direction of radiation of this sky wave, so a length is chosen that will reduce the sky wave as much as possible.

The Other Half

The antenna is actually made up of the antenna itself and its ground system. The ground system may be buried in the ground beneath a tower out in a field, or a counterpoise arrangement if located on top of a building. The ground system should always be considered as half of the antenna for maintenance and installation purposes. That is, half of the antenna is in the air, the other half under ground. This is somewhat analogous to a half-wave dipole stuck in the ground. Actually, it is only a loose analogy, for neither the actual shape or size approaches that of the dipole; but it does help illustrate the ground system as an important part of the antenna.

The ground system is not used in the sense that other grounds in the station are used. In those applications, we want to tie a shield or component to a zero-voltage reference point. At the antenna, however, we tie the tuning coils and coax outer conductor to the other half of the antenna. If you will visualize the antenna and ground system in this manner, then you will be apt to take as much care in making connections to the ground system as you do the antenna proper.

Electrical Values

The tower is insulated from ground, and its length is some part of a wavelength at the carrier frequency. It will exhibit RF resistance and reactance, depending upon this relationship. Besides the height, the actual physical shape of the structure, as well as large metals objects nearby, will affect these values. This is an important fact to remember when considering erecting another tower or some large metal object nearby.

Aside from the ability to tune or resonate the tower in use, power-consuming factors such as high-resistance joints can enter the picture, reducing the actual radiating efficiency of the antenna. So when making connections to the tower or ground system, remember to keep these as low in resistance as possible.

Tuning Unit

The RF power from the transmitter will be fed to the tower over a transmission line. When coax line is used (as in most cases), the line exhibits its own characteristics and "temperament" when not terminated properly. To obtain the most efficient transfer of power through the line, the line must be terminated in its natural impedance and with zero reactance.

It would be a rare case indeed to find an antenna that would exactly match the line directly. Consequently, a tuning unit is used to match the two together (Fig. 11-1). This unit will usually contain a T-network made up of series and shunt coils and capacitors. Besides matching the impedance of the line

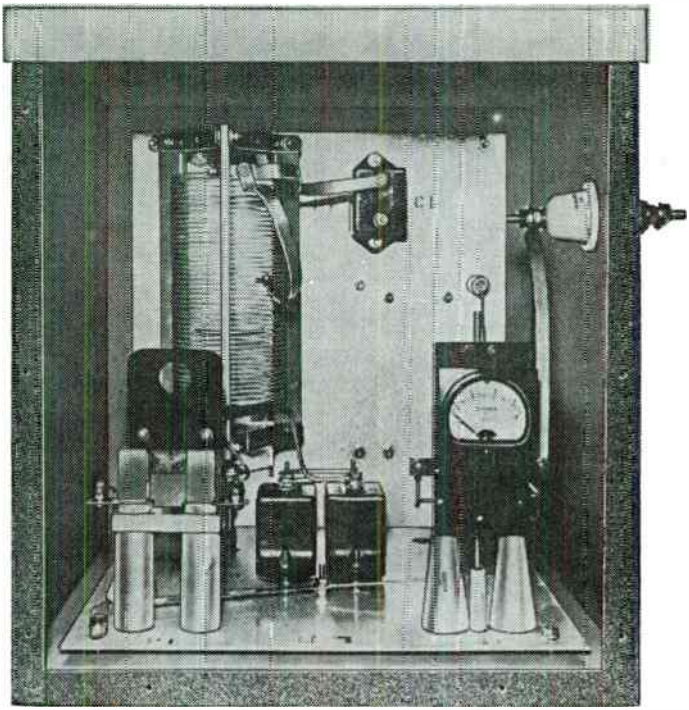


Fig. 11-1. The AM antenna must be matched to the transmission line at the base of the tower. Shown is a unit that contains a full T-network that can handle 1250W. (Courtesy Harris Corporation.)

and the antenna resistance, the circuit will also resonate the tower and act as a filter to attenuate any harmonics of the carrier that might be present.

Bandpass

Antennas are usually tuned to obtain the greatest efficiency in radiation. Tuning for greatest efficiency, while it will produce a higher radiated RF signal, will also increase the Q of the system. High-Q systems become narrowband, so sideband clipping will take place. This will limit the station's bandwidth.

The AM station is permitted an occupied bandwidth of 30 kHz. This means that, theoretically, the transmitter can be modulated out of 15 kHz audio. In practice, however, most of the older rigs will not pass this high an audio frequency. The new transmitters, however, can pass well over 10 kHz.

To obtain the greatest fidelity, the antenna system should be broadbanded. Included in this broadbanding are the harmonic filters and tuning coils at the output of the transmitter proper. The match at the tuning unit should also match the coax line impedance across the bandpass, or there will be a high VSWR at the unmatched areas of the bandpass. These can introduce distortion. Lack of broadbanding limits the station's potential fidelity.

Larger System

The antenna and its ground system are often a part of a larger antenna system. Many stations use directional antennas all or part of the time. While each tower in the system must perform its own role, the very close proximity of the towers make them all very interdependent. When something abnormal occurs on any one tower, whether this be a fault or a deliberate change, it will affect the entire system and the radiated pattern. This is something to bear in mind when making repairs to a directional antenna system.

Installation

Station personnel do not erect the towers, but they will very often install the ground system. The design of the ground system will be spelled out in the construction permit, so it must conform to this.

The installation should be done in a careful manner. If done in a haphazard manner, it is possible the finished job will end up with irregularly spaced radials, or worse, not enough. Before starting, plot out the installation and stake it out. The best way is with a surveyor's transit. If this is not available or you don't know how to use one, then it can be done another way.

First, compute the length of the *chord* between the two terminating points on the circumference of the circle described by the radials (Fig. 11-2A). Measure off a length of ground wire this length or use a tape measure. Next, measure off one length of wire for a radial. Take the end of this radial straight out from the tower until it is taut. Drive a stake into the ground. Now either use a tape measure or the other length of wire you measured and anchor this to the stake. Take the free end and the end of the radial wire and move to a point where *both* wires are taut. This is where the next radial belongs, so drive a stake in there. Continue this process until all the radials are plotted out.

Plow It In

The ground wires must not be left on top of the ground, but must be plowed into the soil about six to eight inches. Either construct a simple plow arrangement or use one of the commercial wire plows to do the job. All that is needed is a thin slit in the ground and something that will insert the wire in the bottom of the slit as the plowing is done.

Plow a straight line, and on the return trip, run the tractor wheel over the slit to close it back up. Make sure the end of the radial is buried and remove the stake. There is no point in advertising where the end of the wires are. If the stakes are left in or the wire ends sticking out, this is an invitation to thieves or vandals to pull up the ground system.

Connections

All the radials and the copper screen below the tower will have RF currents in them. The currents at the base of the tower will be high (just as they are at the base of the antenna proper). Wherever two wires cross or touch each other or the copper screen, make a good mechanical and solder connection. On the screen, make these at least every two feet. Intermittent or corrosive connections can cause arcing noise in the program or introduce an intermodulation components.

The ground system will be down for a good many years, so use a hard solder, such as silver solder. This is more difficult to work with, but it makes a stronger connection. If there is a wind, arrange some type of shielf, or the wind will slow up the process. Use a torch with a narrow flame for best and quicker results.

Tuning Unit

Take as much care with the connections to the ground system here as you do to the antenna proper. Use heavy copper strap and hard solder. And when attaching to the

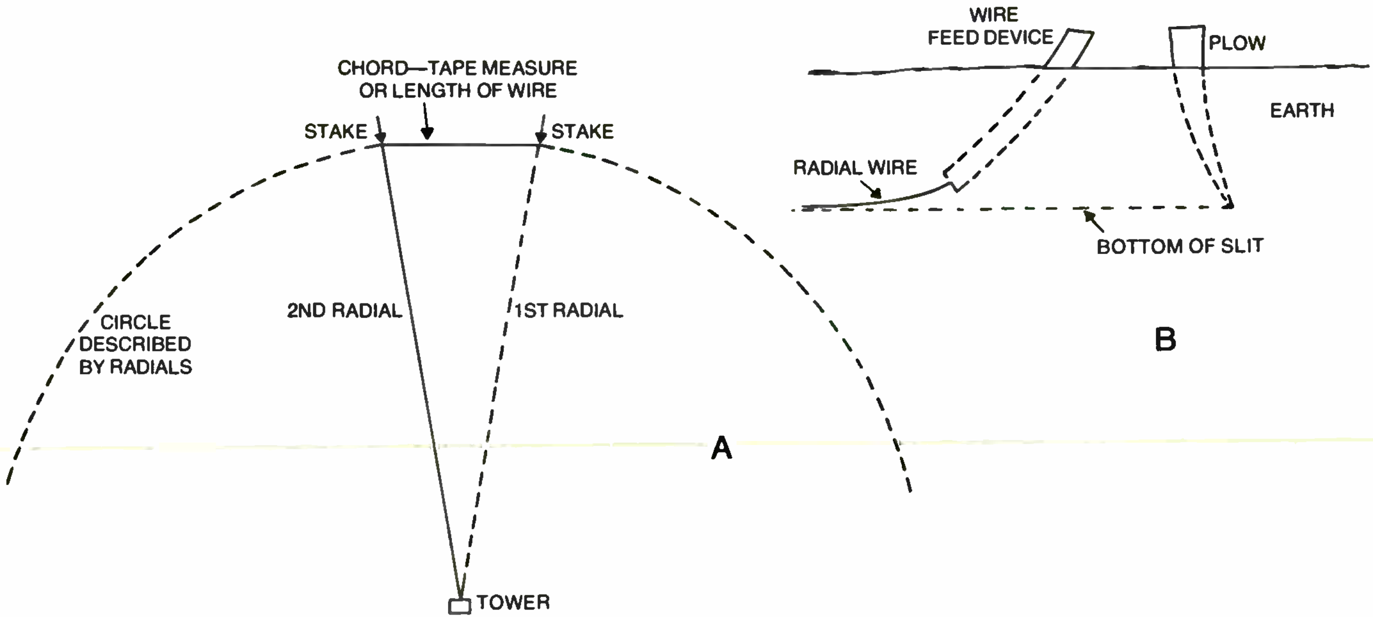


Fig. 11-2. Installing the ground system. (A) Plot out the ground system using one radial wire and either a tape measure or a wire the length of a chord to determine each terminating point. (B) Slit the soil and lay the radial wire in the bottom of the slit.

tuning-unit box, make sure the paint is cleaned off to get a good metal contact. Some boxes have a second inner chassis upon which the components are mounted, and their ground connections terminate on this chassis. Make sure this chassis and the outer box are securely bonded together and to the ground system. If there is a poor or loose connection here, the antenna system will become erratic or unstable. This is because half of the system is "floating" because of the intermittent ground connections.

FM ANTENNAS

The radiating elements of the FM antenna are much smaller than those in the AM system; the wavelengths are much smaller. For example, at 100 MHz, in midband, a full wavelength is 9.84 feet, contrasted with the 984 feet of the AM band.

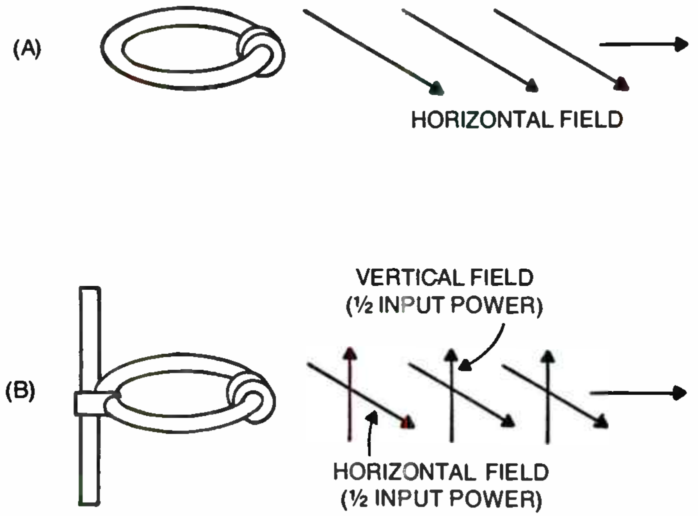


Fig. 11-3. (A) A single FM antenna bay has a power gain of 1 and radiates a horizontal field. (B) Adding vertical polarization will divide the bay input power into each field so that the gain in each field is 0.5.

Propagation characteristics are also different, in that the FM signal tends to travel in a straight line horizontally from the antenna. The FM antenna is required to be horizontally polarized, whereas the AM antenna is vertically polarized.

Other polarizations may be added to the horizontal polarization, but FCC approval is needed.

Power Problems

Each FM antenna is a dipole that is either formed into a circle, or into a *V*-shape. These are the basic shapes, but a vertical element may be added, or the elements may be bent into an oval shape. These additional shapings are used when additional polarization is added.

Each basic dipole has a gain of approximately 1. When vertical ploarization is added, the gain is reduced to 0.5 in each of the polarizations. The total gain for the antenna is still 1, but it will divide the power into two separate fields, the horizontal and vertical fields.

The receiving antenna will usually only receive one or the other field, depending upon its polarization. So the voltage in each field is now less.

You don't get something for nothing. If you want to divide the power into two fields, then you must double the input power to the antenna to recover the original radiated power in one field. Of course, some vertical polarization is most desirable because it provides a better signal to automobile FM radios.

Stacking

The small physical size of each FM antenna lends itself to stacking. When individual units (called *bays*) are stacked, each will contribute its gain figure to the total gain. Typical high-gain antennas of 12 bays are often used, and this will produce a power gain of approximately 12. Thus, if 1 kW was fed to the antenna, it would radiate 12 kW. This is called ERP or *effective radiated power*.

Stacking has its penalties also. The beam is more narrow, and it can become highly directional just like a multitower AM system. Directional FM antennas are not used (except in special instances), rather an omnidirectional antenna is desired.

Careful phasing of the individual elements produces an omnidirectional pattern. The narrow beamwidth can produce holes in the close-in coverage area. Again, special phasing is done to reduce this effect. Twelve bays seems to be about the practical limit for stacking, as the entire unit can become very long. A 12-bay unit for some FM channels can be well over 100 feet in length.

Pattern Distortion

Although all the bays are carefully phased to produce an omnidirectional pattern, this will only hold if the antenna is mounted on a very slim pole mounted above the tower. But a great many FM antennas are side-mounted on a tower. The proximity of the tower will affect this pattern considerably. So when an antenna is to be side-mounted, then the manufacturer must have the dimensions of the tower structure so that appropriate compensations can be made to the final tuning to produce the desired pattern. Remember that these are still only theoretical calculations, and when the actual mounting is made on your tower, there can still be some distortion of the circular pattern.

Matching

The antenna is fed by coaxial transmission line, so the antenna must present a purely resistive, zero-reactance load to the line. The tuning unit for this purpose is a coaxial transfomer, which will mount at the base of the antenna feedpoint. There are covered openings that can be taken off, and shorting or tuning slugs that can be moved to trim up the impedance match. Once the tuning has been accomplished, the covers are replaced and the line made gas tight so that the whole system can be gassed if desired.

The tuning should be done with special sweep equipment that will measure the VSWR across the bandpass of the channel. If only the VSWR indicator is used in the transmitter room, a match can be achieved; but this will be mainly at the carrier frequency. This is because the carrier is the main power element, and that is what the VSWR indicator will measure. Special test equipment will measure the match all across the bandpass, and this is important. If there is a mismatch in the outer reaches of the bandpass, there will be VSWR reflections to the carrier swing and sidebands when modulation is applied. This can cause amplitude response problems at higher levels of modulation, and phase shifts to the subcarrier and sidebands, which affect stereo signals.

Installation

The antenna is assembled at the factory and tuned up on the station's channel. Then it will be disassembled and shipped. During this process, it is possible some of the elements will be damaged or lost. So look all the components when they arrive. If tuned elements are bent, it will affect overall tuning the pattern of the antenna.

Where the bays were originally installed, there should be a mark of some kind. It is important that they are put back together, not only in their original line up, but so that one or more bays are not turned over. This reversal would reverse the phase of that bay by 180 degrees. Any of these situations will affect the pattern, impedance match, and operating parameters of the antenna. So put it back together carefully. Now, you won't be up the tower installing the antenna, but make certain the erection crew understands the importance of all these factors.

Alignment

Not only must all the parts of the antenna be put back together properly, they must be lined up perfectly in the vertical position, and the aperture at the face of the array should be straight (gap between the ends of the horizontal elements). If the whole antenna tilts forward or backward, mechanical beam tilt is introduced, and this is not permitted unless the construction permit specifically allows a definite amount.

Before everything is finally bolted tightly into place, use a surveyor's transit and view the antenna from the side. You should be able to tilt the transit from top to bottom of the antenna and find every bay on the same position of the crosshairs. Then go to the front of the antenna. Again, you should be able to tilt the transit top to bottom and find the gap at each bay on the same position on the transit's crosshairs. When this is the case, lock everything in place.

Transmission Line

The coax line will run on up the tower to the antenna matching unit. If this is a flexible line, band it to the tower leg every two feet. A rigid line must use hangers every ten feet. If the coax line has an outer insulating covering, then peel this off at several places and bond the copper outer conductor to the tower. If the tower is an AM antenna, the bare line must be connected tightly to the tower to prevent arcing, and if the line is insulated, then the outer conductor must be connected to the tower to break up its length relationship with the AM carrier.

Isolation

When the tower is an insulated AM tower, another problem presents itself. The coax line must be *isolated* or it will short out the AM antenna. This same holds true for *any* metallic conductors that cross the base, whether it is AC power or coax cable to a remote pickup antenna, or coax to sampling loops. These must be RF insulated, not simply DC insulated. The fact that there may be an insulated covering on the cable will not prevent it from shorting out the AM tower. There are at least two methods used to insulate the FM coax line.

Coupler Isolation

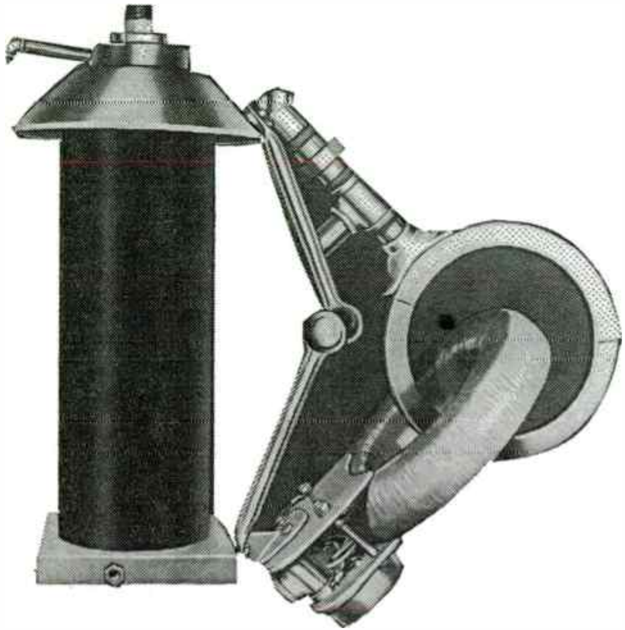
An isolation unit (Fig. 11-4A) is preferred. It is a metal box that is gas tight and completely insulated at its input and output. That is, both the inner and outer conductors of the transmission line are insulated. There is a loop coupling to the two sides of the circuit. By special design, the line impedance is not altered, so that the VSWR with the unit in the line is very small. Since there will also be RF voltage stress from the AM carrier across the unit, it is rated for different levels of AM carrier power as well as the FM power.

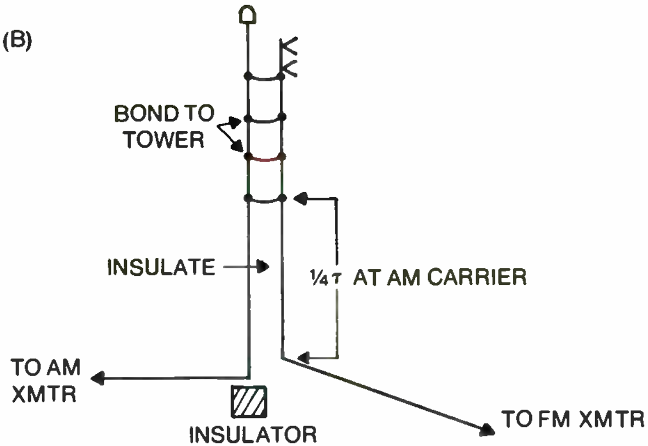
There are mechanical stresses as well as RF stresses on the unit. Pressure from the line expansion and contraction can break the insulation and allow a gas leak. And the RF carrier from the AM can melt the ceramic insulators. If the line is ungassed and a leak occurs, moisture can get in and rust the box.

Bazooka

This is a tuned line section and makes use of the high impedance of a quarter-wave line section that is shorted at one end. In this method, the coax line does cross the base insulator intact. But a quarter-wavelength up the AM antenna, the coax line must be insulated from the tower. This quarter-wavelength is figured at the AM frequency.

These tuned sections work out pretty well, but the spot where the coax shorts to the tower is reasonably critical if the full advantage of the section is to be realized. Past the quarter-wave insulated section, the line is bonded directly to the tower the rest of the way up to the FM antenna. The inner conductor of the coax is not affected, since it is shielded from the AM carrier by the outer conductor of the coax. As far as





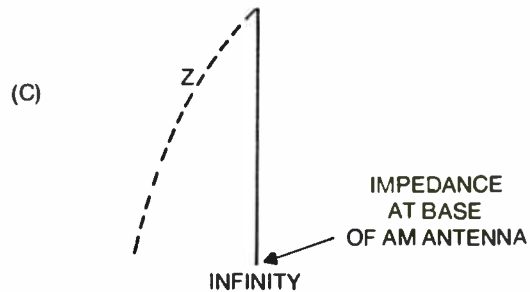


Fig. 11-4. Isolation techniques. (A) Crossing the base insulator of the AM tower with AC power requires isolation. Shown here is the Austin ring-type transformer. Also shown are lightning ball gaps. (B) Isolate FM coax line from the AM tower base with a quarter-wave tuned section. (C) The quarter-wave section presents infinite impedance to the AM carrier. (Photo courtesy Harris Corporation.)

the AM carrier is concerned, that coax line is open at the tower base.

Problems can occur if insulators break and allow the line to touch the tower, or if something shorts out an insulator. This destroys the tuned-line effect and, of course, the insulating qualities. When the tower is painted, these insulators must not be painted, and anything that can cause leakage, such as ice or corrosion across the insulators, can reduce the tuned line's effectiveness and affect the AM system.

Whenever an FM antenna is added to an existing AM tower, a new measurement of the base impedance of the tower is required, and this must be filed with the FCC. Additional equipment on the tower, plus crossing the base insulator, will probably affect the parameters of the antenna.

If the station is to be an AM–FM station, even though the FM may be some time later getting on the air, mount all the FM gear on the AM tower before the base measurement of the AM tower is made. If you do not, then when you do it some time later, a new set of measurements must be made.

TOWERS

The tower is an important structure that requires a large capital investment by the station. A properly designed and installed tower, given the usual care, will stand and serve for many years. There are many AM towers standing today that are over 40 years old.

Wind Loading

A tower is designed to withstand a certain amount of wind pressure, and this is figured with a certain amount of ice coating. The figures are usually conservative. The tower is usually specifically designed for heavy duty or light duty. As long as the original conditions exist, the tower will give many years of service.

But many factors can change these original conditions. One factor is additional loading on the tower. When antennas, microwave reflectors, and similar equipment are added to a tower, this changes both the weight-loading factor and wind-loading factor. Some of the smaller FM antennas don't weigh much or add much windloading, but microwave reflectors and heavy antennas do.

Dead weight—that is, the vertical weight of the equipment—is not as important as the wind-loading, unless of course, the tower is a very light-weight design and the load is a very heavy antenna. Most towers are carefully designed for the dead weight they can carry and are designed for certain specific purposes, such as mounting microwave dishes or heavy TV antennas. If a tower is loaded with all sorts of things it was not designed to carry, it may be overloaded, and a gust of wind may cause it to collapse. Before mounting anything large on the tower, consult the factory and get their opinion. They will be able to determine if the tower can carry the load or not.

Unless a tower is inspected at regular intervals and any faults corrected, it can deteriorate quickly. Remember that the tower is exposed to all types of weather, heating and cooling, wind stresses, chemicals born in the air, and salt near oceans. Rust can set in, braces work loose, bolts fall out. On guyed towers, the guys may lose tension or break. All these factors change the original conditions, and when a tower is neglected, these factors can weaken the tower and cause it to come down in a high wind.

Joint Use

It is common practice today for different broadcast companies to share the same tower, for example, a TV, FM station, or both, on an AM tower. In the past, each user of the tower was responsible for the lighting, painting, and other FCC requirements. Agreements must be worked out among all parties and approved by the FCC. The approved agreement must be kept on file at each of the stations for the radio inspector to see. All the other stations then don't have to concern themselves with the requirements of lighting, painting, and logging of the tower. The one that assumes the obligation (this is usually the tower owner) must comply with all the FCC requirements.

Painting

Towers must be painted in a prescribed manner to provide greater visibility to aircraft during daylight hours. The prescribed colors are international orange and white. All towers are not required to meet this section of the rules. (All these requirements will be found in part 17 of the rules.)

All towers more than 200 feet above ground level must be painted. Towers less than 200 feet may or may not be required to be painted. This depends upon their location in relationship to airports and air corridors. In all cases, the prescribed painting will appear in the station's construction permit and license. When the paint begins to fade, the tower must be repainted. If a station has approval to use the new high-intensity lighting, the tower need not be painted.

Even a short tower whose top is over 200 feet above ground must be painted. This would be the case if a large part of the support structure were a tall building.

Banding

The color of the paint bands and the number and width limits are prescribed in the rules. The bottom and top bands must be international orange. For towers up to 700 feet, there must be 7 equal bands of alternate orange and white. Towers of greater height than this must have additional bands since the maximum width can only be 100 feet, and at 700 feet, the maximum width—100 feet—has been reached. The minimum width is 1½ feet.

To compute the number of bands and their width (for towers up to 700 feet), divide the tower height by 7 to obtain the width of each band. For example, a 350-foot tower must have 7 bands of 50-foot width. If the tower is 700 feet, each band is 100 feet, the maximum. There will be 4 orange bands and 3 white bands.

Tall Towers

Since the maximum width of each band can be 100 feet, towers greater in height than 700 feet must have more than 7 bands. For these towers, the width of each band and the number of bands must be computed differently. To determine the total number of bands required, add two bands for each 200 feet of tower above 700 feet. If there is a fractional part less than 200 feet, add two bands for that fraction. In all cases, the top and the bottom bands on the tower must be orange, so there will always be an odd number of bands in the total figure.

For example, a 900-foot tower would have 7 bands for the first 700 feet plus 2 more bands for the next 200 feet, for a total of 9 bands. In another case, let's assume the tower is 990 feet. You have already worked out 9 bands for the first 900 feet. For that additional 90 feet, there must be 2 more bands. This would make a total of 11 bands for the 990-foot tower. The width of each band in the first case will be 100 feet ($900/9 = 100$). In the second case, the bands will be 90 feet wide ($990/11 = 90$).

STANDARD LIGHTING

A tower which is 150 feet or more above ground level must be lighted according to the FCC rules. The particular pattern prescribed will be determined by the tower height or special lighting requirements. Towers less than 150 feet may need lighting. In all cases, the prescribed lighting for the tower will be shown in the construction permit license.

Essentially, there is a flashing code beacon on the top of the tower, and at different intervals on the tower, side marker lights or additional code beacons are required according to the tower height. These side lights must be seen from all directions, so they will be mounted on the outside of the tower leg at each interval, one on each leg. For towers of 300 feet or less, there will be one flashing beacon at the top and a set of marker lights at midlevel. Changes occur in the requirements after every 150 feet of tower height, with a different arrangement of marker lights and additional code beacons.

Lamps

The flashing code beacons must contain two lamps wired in parallel. Each lamp must be rated at 620W or 700W. Having two lamps in parallel is a safety feature, for if one burns out, there will still be one lit even though the output will be cut in half. The lamps themselves have clear glass envelopes. The beacon contains a red screen to produce the red color, and the outside glass of the beacon is a lens which focuses the light into a horizontal plane.

The marker lights are single-lamp fixtures and must contain a 116W or 125W lamp. These also have clear glass envelopes. The fixture contains a red screen and the outside is a lens.

Lamp Control

The lamps may burn continuously, or they may be controlled automatically by a photocell control (Fig. 11-5). The photocell must face the north sky, and when daylight drops to 35 foot-candles, it should turn the lights on. When the north sky brightens in the morning to 58 foot-candles, then the photocell may turn the lights off.

The photocell must have an unobstructed view of the north sky. If it is shaded by a tall tree or building, it will turn the lights on too early and off too late. If the photocell should fail, it must turn the lights on, and they must burn continuously until the photocell is repaired. This is called a *fail-safe* arrangement. Towers which are less than 150 feet and which must be lighted may use a photocell, a clock, or manual control.

Flashing Beacons

The flashing of the beacons must be within the limits prescribed by the rules. There can be no less than 12 flashes per minute or more than 40. The *on* or lighted time must be twice the *off* or unlighted time. For example, if the lamp is flashing 20 times per minute, the total on—off cycle will be 3 seconds. The *on* time will be 2 seconds, and the *off* time will be 1 second. This 2-to-1 ratio must be maintained, as must the number of flashes within the prescribed limits.

The flashing mechanism will require some maintenance. Expect to have problems with the rotating mechanism and switching part of the unit. The flasher can get the station a citation if the code flashing is out of limits. The inspector *does* check this.

Installation

The tower lighting will draw heavy current. The wiring runs are long, so heavy cable should be used to prevent or reduce voltage drop at the top of the tower. Although 120V may be entering the cable at the bottom, several hundred feet later there may be only 100V left. When the system is first installed and in operation, have the voltage measured at the socket of each fixture in the system. The bulbs should be in place and drawing their share of current. Make a note of these measurements for future reference.

If the socket voltage is too low for the rating of the lamp, its light output will be lower than normal. The rules require that the rated voltage of the lamp be within 3% of the socket voltage. If the condition existed as just mentioned, the lamp must be rated within 3% of 110V and not 120V.

HIGH-INTENSITY LIGHTING

When a station desires to use high-intensity lighting, it must receive approval from the FCC. When the FCC does authorize the station to use this system, then it will replace the requirement for both the standard lighting and the tower painting requirements of the rules. It must, however, conform to the rules as they apply to high-intensity lighting.

The high-intensity lamp (Fig. 11-5) will produce a light that approximates daylight, with color response from infrared

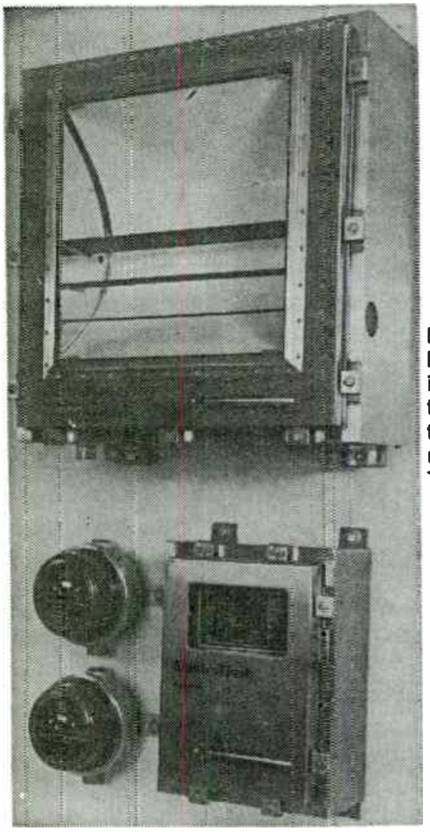


Fig. 11-5. Flash Technology's Model FTB-205 Electroflash units. Top unit is one of the lamp fixtures, and the lower unit is the control and photocell arrangement. (Courtesy Flash Technology Corp. of America.)

to ultraviolet. This daylight spectrum is what makes it so white and contributes to its brightness. The lamps are quartz lights filled with xenon gas. The presence of the gas and the pulsing of the light creates a high peak light output and high efficiency. The special fixtures with their reflectors also boost the light output so that it carries a terrific punch.

Light Pattern

The arrangement of lights on the tower depends as much upon the height above ground as it does in the conventional lighting (Fig. 11-6). Breakover points are at 300, 600, and 1000 ft. The height in this case is of the tower itself and does not include any antennas that are mounted on top of the tower. At each of the height levels on the tower where they are required, (including the top of the tower), at least three fixtues will be required, and maybe more.

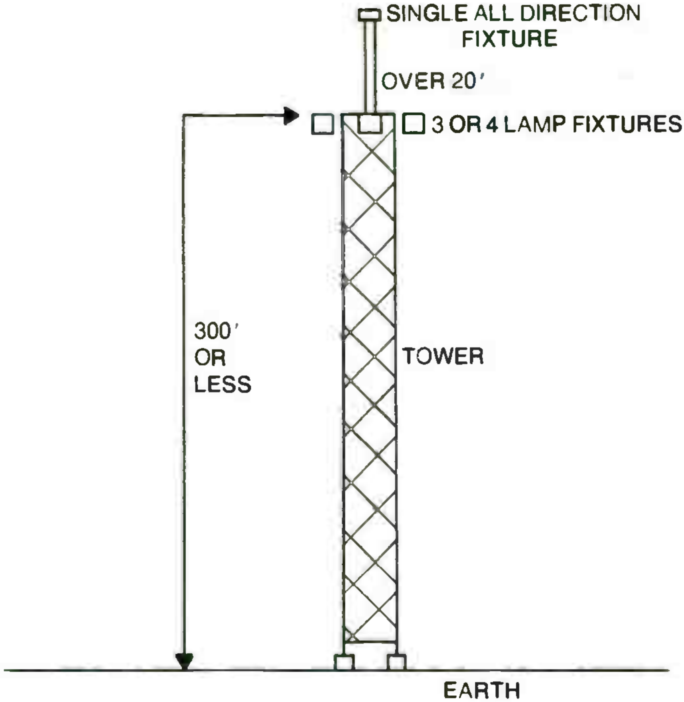


Fig. 11-6. High-intensity light system requires lights at the top of tower and at different intermediate heights on towers above 300 ft. If antenna projects above tower more than 20 feet, then an omnidirectional lamp must be used on top of the projection.

The same light output must be radiated horizontally from each level in a 360-degree circle around the tower without obstructions (Fig. 11-7). This typically requires three fixtures on a three-leg tower and four on a four-leg tower, but it depends upon the width of the tower and the ability of the particular fixtures to provide even lighting.

Figure 11-8 shows the relationship of the components of a strobe lighting system. If an antenna or anything projects

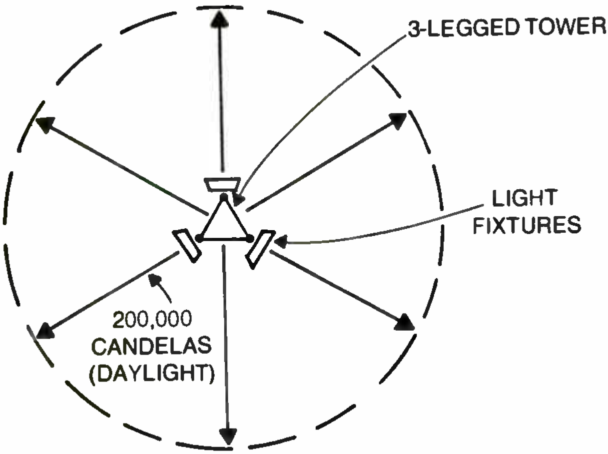


Fig. 11-7. Light must be distributed around tower equally in 360-degree horizontal plane.

above the tower more than 20 feet, a special, single, omnidirectional lamp must be mounted on the top of this projection. This is different from the other fixtures, since it projects light in a manner similar to the conventional code beacon.

Light Output

These lamps will burn continuously around the clock, but at different intensity levels. The intensities will change at twilight, at dark, and again in the morning. A photocell is required to monitor the north sky and operate an automatic changing device.

During daylight, the lamps must produce an output of 200,000 candelas in the horizontal plane, equally around the tower, at each level. (The candela is a measure of light *output*, as against the foot-candle which is a measure of illumination.)

At twilight, when the north sky dims to a light level between 30 and 60 foot-candles, the light output from the fixtures will be reduced to 20,000 candelas; and when the north sky dims to a light level between 2 and 5 foot-candles, the fixture output is reduced to 4000 candelas.

When a top omnidirectional lamp is required, its output will be 20,000 candelas during daylight and twilight hours and must drop to 4000 candelas at night. This light is controlled by the photocell as are the other lights.

Should the photocell or its control device fail, the lights must go to either the daytime brilliance of 200,000 candelas or the next light step higher than is required for that amount of daylight.

All the lights in the system must flash simultaneously. The prescribed flashing rate is 40 flashes per minute. The actual duration of the flash (*on* time) is 10 milliseconds during daylight and 250 milliseconds during night.

Power Supply and Control

High-intensity type of lighting requires a power supply and control circuitry. Both of these are solid-state units that mount at the ground level. They may be mounted in a building at the tower base or on the tower itself (at the base). The units are housed in a weatherproof cabinet so they can be mounted outdoors. Monitoring units are also available so that the lights can be monitored and operated by remote control.

TOWER AND ANTENNA ICING

In many areas of the country, sleet and ice can cause many problems with antenna systems during the winter months. Antennas for AM are not affected as much as FM antennas. Ice also presents a problem to the towers, guys, people and structures on the ground below the tower.

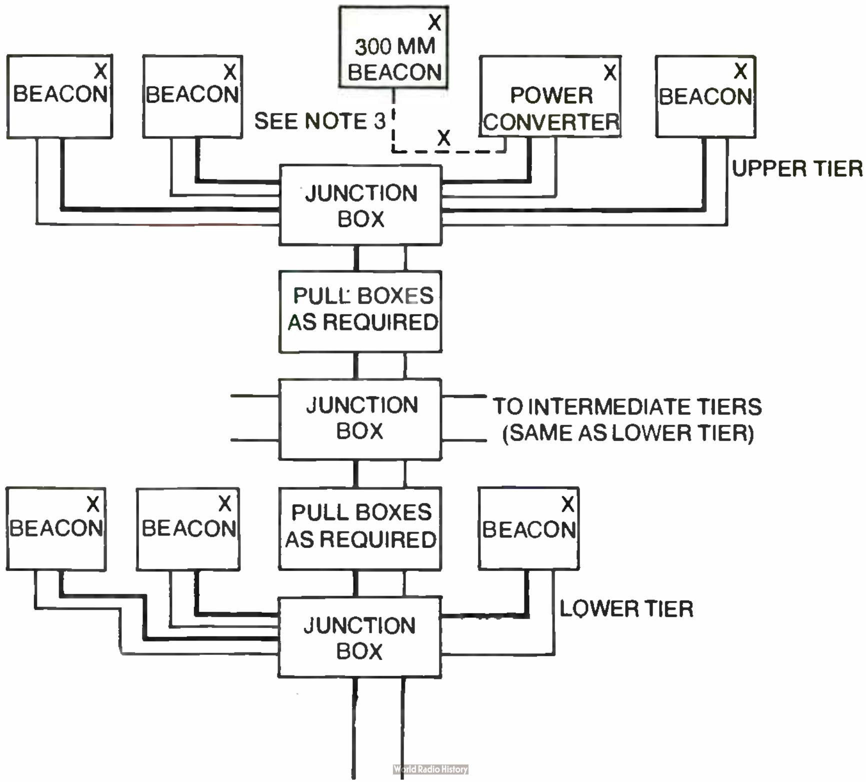
Physical Effects of Ice

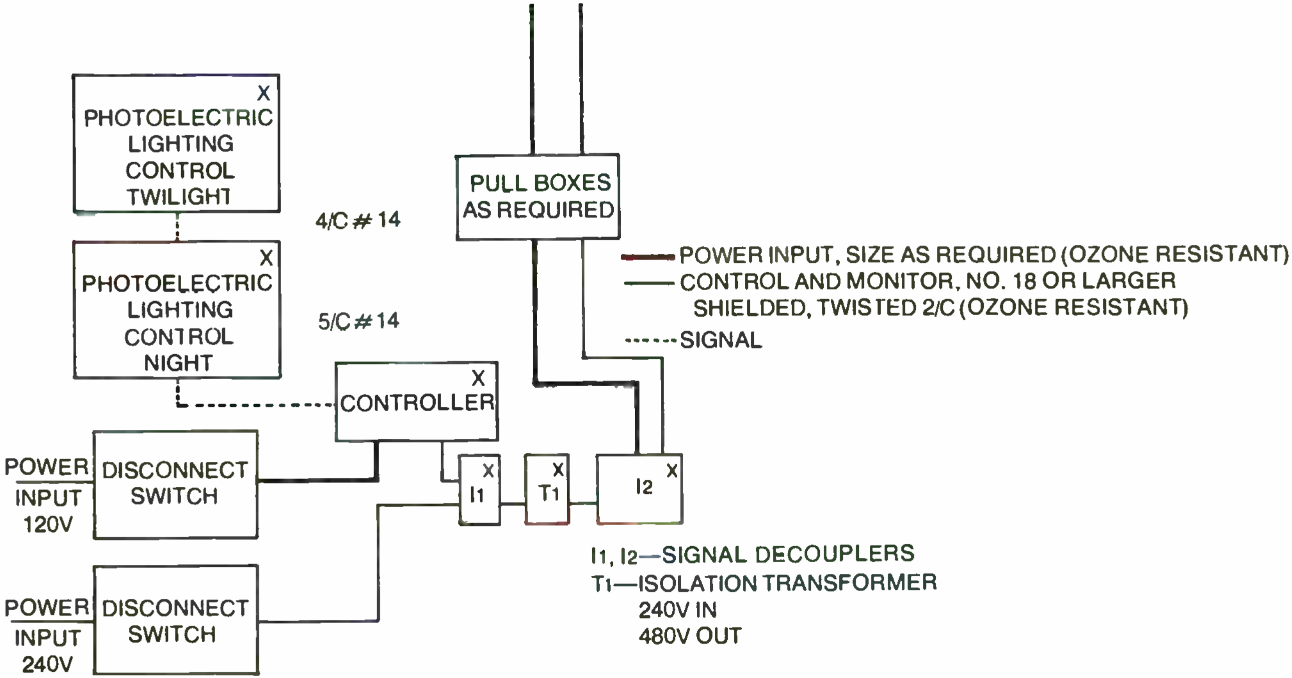
A heavy coating of ice increases the size of the tower members and changes the wind-loading rating. The tower members now offer a greater resistance to wind. Tower designs will take a certain amount of ice coating into account when developing the wind-loading rating of the tower. The real problem comes when a tower has been overloaded with additional elements it was not designed to carry, such as extra antennas and microwave dishes.

With a guyed tower, the guys can also become heavily covered with ice. This adds wind-loading to the guys and also extra weight on them. A tower that is overloaded and then becomes heavily coated with ice can easily collapse.

Electrical Effects of Ice

Many AM antennas can take ice in stride without any noticeable effect, yet others may go haywire. It depends upon


X
300 MM BEACON
X
BEACON
X
BEACON
SEE NOTE 3
X
X
POWER CONVERTER
X
BEACON
UPPER TIER
JUNCTION BOX
PULL BOXES AS REQUIRED
JUNCTION BOX
TO INTERMEDIATE TIERS (SAME AS LOWER TIER)
X
BEACON
X
BEACON
PULL BOXES AS REQUIRED
X
BEACON
LOWER TIER
JUNCTION BOX



1. ALL COMPONENTS MARKED X ARE SUPPLIED BY FTCA NOTES
2. ALL WIRES MAY BE RUN WITHIN THE SAME CONDUIT RISER
3. WIRING MAY BE RUN IN ANTENNA MAST—6 INDIVIDUAL CONDUCTORS

Fig. 11-8. Typical wiring arrangement for model FTB-205 strobe lighting system when the tower is a "hot" AM tower. Top beacon is only required in certain cases, and the intermediate tiers depend upon tower height. (Courtesy Flash Technology Corp. of America.)

the operating parameters of the particular antenna. Those with a very high base resistance will be significantly affected, as can those that use top-loading arrangements or an isolated quarter-wave section for the FM coax line at the base of the tower. On guyed towers, ice will bridge the insulators in the guys and create leakage paths, as well as coat the base insulator.

Icing of FM Antennas

Although FM antennas are broadband, heavy icing will cause some detuning. When the antenna detunes, it no longer presents the correct load to the transmission line, so the VSWR will increase on the line. The high voltages and currents set up in the line by standing waves can cause damage to the line and also to the output stage of the transmitter. These standing waves will also cause phase shifts in the carrier and its sidebands, and the phase shifts are detrimental to the stereo signal. The transmitter can become very unstable.

Ice Formation

Ice can form on the antenna even though there is none on the ground. Air temperatures at ground level are warmer than those at the FM antenna location on top of the tower. Moisture can be freezing on the antenna and tower even though that reaching the ground is in the form of mist or rain.

The mass of metal in the tower and the antenna are slow to change temperature. While the air temperature may be above freezing, that of the metal can yet be below freezing. Any moisture present will freeze on the metal surfaces. These same conditions can prevail for some time after the icing condition has passed on the ground.

The greatest icing occurs when a sleet or freezing rain is in progress. The antenna and towers will continue to build up a coating of ice all during the storm. The next day when the sun comes out, the whole tower may look as if it is made of glass.

Recognizing the Icing Problem

An AM system that is affected by ice will show inaccurate antenna current readings, and the transmitter output stage efficiency will deteriorate. The plates of the PA tubes can be running much redder than normal because the stage is detuned and dissipating more power within itself.

The output stage in the FM transmitter will become less efficient also, and its tuning may become unstable or erratic. The transmission line monitor will show an increase in VSWR on the line. If this rise in VSWR is high enough, the line monitor will shut the transmitter down.

Icing and Operating Techniques

The AM station that is affected should take some steps to protect the tubes in the transmitter and coax line. Pull the power back at least 10%. If the coax line has high standing waves on it, and if the modulation is at 125% positive and the line is normally close rated, pull the power back more than 10%.

You might try taking a wooden stick and chipping off the ice at the base insulator, but be very careful not to break anything or get burned by RF. If you try to chip ice off any of the low guy insulators, be careful not to set up vibrations on the guys or start them swinging. If the horn or ball gap is solid with ice, chip it out carefully, also the insulator to the tuning house. Retune the PA for its most efficient operation under the conditions present. It will need tuning as conditions change outside.

At the FM transmitter, pull back the output power. Derate the transmitter according to the VSWR figure. Even though the line may be heavy enough to carry the VSWR, the transmitter tubes must be protected. Simply divide the transmitter power output by the VSWR reading to get the operating power to use. Make sure the plate circuit is kept in resonance.

Ice Control Methods

There is no control equipment for AM antennas, but there is for FM systems. Control is in the form of heaters that melt the ice or keep it from forming. The entire antenna may also be enclosed in a radome. The heaters are the less expensive method and do not add to the wind loading. A station located in an area where ice will be experienced would do well to invest in heaters.

Heaters are installed inside the radiating elements of the antenna and are out of the RF field (Fig. 11-9). Melting of ice takes place by conduction of the heat from the heater to the outside metal of the antenna element. There are no heater

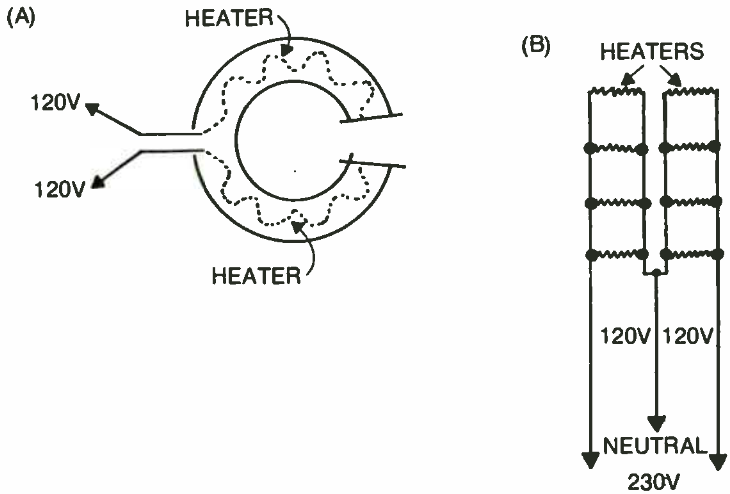


Fig.11-9. Each element of the FM antenna has a heater mounted internally. All heaters are connected in parallel. Divide load on both sides of a 230V circuit.

currents flowing in the metal of the radiating elements. Each of the heaters will operate on 120V AC and will be about 150W to 200W each, or 300-400W per bay.

There is a heater in each of the radiating elements of a bay, on both sides. The AC power is fed to the heaters at the rear of each bay, and the AC harness must be anchored so that it does not come loose and get into the RF field. This will also be shielded cable.

Heater Control

The heaters may be operated manually from the ground, or they may be tied into the tower lighting photocell so that the heaters come on at night with the lights. If this is done, then a manual shutoff should be provided so that the heaters do not run all during the summer months.

The best arrangement uses a thermostat control mounted at the base of the FM antenna. This will sense air temperatures at the antenna location and then turn the heaters on or off automatically.

Heater Power

When a multibay antenna is used, the heaters should have their own power circuit. If they are tied to the lighting power, they can reduce the voltage available to the lamps, and they may not work efficiently because of low voltages. If each bay draws 400W and there are 12 bays, that is 4800W. This is too much additional current to draw through the lighting cables. Run a new circuit all the way from the base of the tower to the heaters. This may be 240V, single phase, neutral ground. Balance the 120V heaters on both legs of the 240V circuit.

Heater Installation

When the antenna is first installed, turn on the heaters. A tower worker should feel each of the radiating elements in each bay to see if it is warm. Remember that each side of the bay will have separate heaters, so check them both for warmth.

After these have all been checked and they are working properly, measure the current drawn in each leg of the power feed at the base of the tower or in the transmitter room at the contactor. Then turn off the heaters and measure the DC resistance of the circuit on each leg. Make the same measurement after the heaters have been warmed up (and shut off). This will provide a hot- and cold-resistance measurement of the system. Save these resistance and current measurements for later reference. If any of the heaters burn out, the resistance figures will change and so will the current drawn.

LIGHTNING PROTECTION

Antenna towers are likely targets for lightning discharges. Such discharges can produce havoc with the equipment on the tower, at the tower base, and inside the transmitter building.

Static Drain

Protection is based on the static drain principle. That is, charges building up in the vicinity of the tower are drained off to ground before they can develop full damaging potentials. Lightning strikes nearby can also induce strong currents in the tower, so these currents must be drained off before they can cause damage.

Grounded Towers

The first requirement is a sharp, pointed lightning rod above the highest part of the tower and any equipment projecting above it, for example, the beacon. Some towers use three rods in a cluster. These rods must be securely bolted to the tower and should make a very good electrical contact. During tower inspections, these rods should also be examined for looseness. Constant flexing by the wind can sometimes work the bolts loose or cause the rod to break at the bolt connection.

Antennas and transmission lines for FM should be bonded to the tower at various places. At the tower base, a heavy copper strap, or one on each leg, should connect the tower to ground rods driven several feet into the soil. The concrete pier is not a good ground connection, so use copper strap. This connection to earth is very important, and it should be as low a resistance as possible.

Insulated Towers

The insulated AM tower presents more problems since the whole tower is insulated from ground (Fig. 11-10). Protection at the top and down the tower is the same as for the grounded tower, with lightning rods and good bonding. But now the problem is to keep the discharge out of the equipment and get it to earth without providing a metallic path across the insulator.

Lightning will follow the line of least resistance, so try to provide this. In the feed line between the tuning house and tower, add at least one or two loops about 12 inches in diameter. This will make that path slightly inductive. Across the insulator, provide horn or ball gaps. These gaps should be as close together as is practical; the closer the gaps, the lower the gap resistance. But you don't want modulation peaks to arc over, so adjust the gaps with full 125% positive modulation and set the gaps slightly beyond the point where they will arc over on peaks. The ground side of these gaps must be connected to the ground system with a heavy ground strap.

Lightning is unpredictable. It isn't possible to eliminate all current surges, so it is important that the antenna meter is removed from the circuit by its shorting switch and the line meter is not left active in the tuning unit. A heavy surge will invariably burn out these meters if they are left in the circuit. And this will take the station off the air, since the thermocouple is in series with the line circuit when active. If it burns out, the circuit will open.

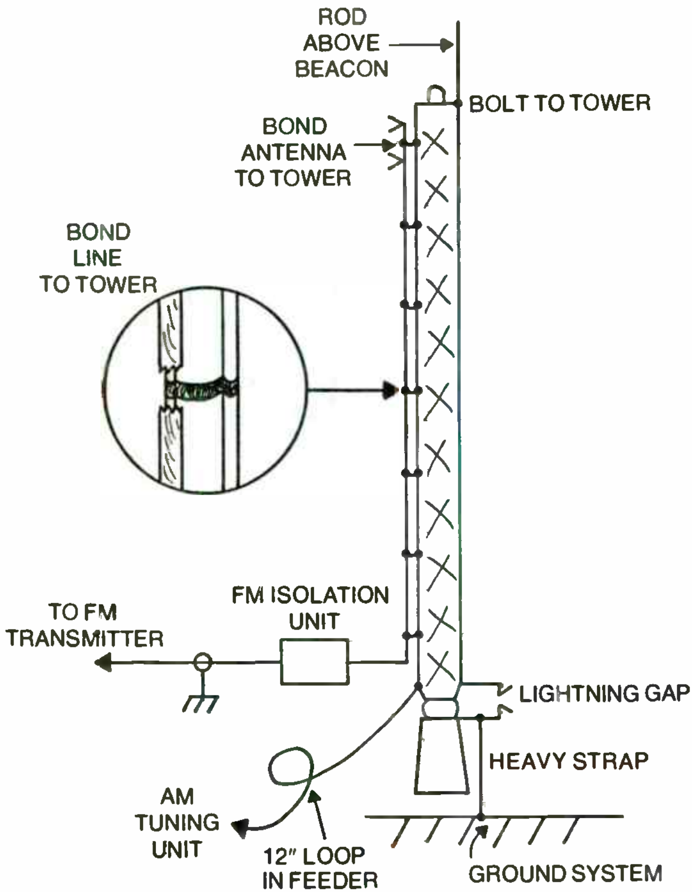


Fig. 11-10. Standard lightning protection.

Arc Suppressors

When a discharge does occur across the ball gap at the base of the tower, this will effectively short out the tower and put a load on the transmitter. The transmitter needs protection in the form of an arc suppressor or other means.

The arc suppressor is simply a relay circuit in the transmitter whose coil return is provided through the arc on the line when it occurs. That is, the arc across the ball gap provides the switch action. This relay doesn't shut the transmitter off, but it does remove the RF carrier by removing the RF drive or plate voltage.

Once the arc starts, the RF would sustain it unless the RF is shut off. During that brief period before the overloads can shut off, the output tubes take a heavy load. If this relay is DC operated, be careful when making changes in the tuning unit so as not to add series capacitors to the line, or the arc quencher will not work.

Lightning Protection for FM Antennas

Side-mounted antennas should be bonded to the tower with good electrical connections, and so should the transmission line. If the coax has an insulated covering, this should be opened at a number of places and the copper outer conductor bonded to the tower. (If the tower is an AM tower, this will have already been done for other reasons.) Where the line crosses the insulator at the base of an insulated tower, ground this outer conductor shortly after it crosses over the base (toward the transmitter) to the nearest ground point. If there are any currents flowing on this outer conductor, get them to earth immediately after leaving the tower so that they are not carried back into the transmitter building.

Guyed AM Towers

The guys should be broken up with insulators at various intervals for reasons already explained. Thus, there are insulated wires hanging up in the air, and they can have heavy currents induced in them from discharges. Since there is no place for it to go, it will jump the insulators. Carbon paths can build up from these discharges, or the insulators can crack and eventually fall off. Any damaged insulators should be replaced.

The techniques that have been discussed are not 100% guarantees there will be no lightning damage. Elements should be inspected from time to time in the AM tuning unit after there has been a heavy electrical storm. The tuning house or the ends of the guys are not a safe place to be during a storm or the period immediately preceding a storm. It is also unwise to have someone in the tuning house calibrating antenna meters or working on the tower itself during the period immediately preceding the storm—let alone during the storm itself. Very often the atmosphere is very highly charged just prior to the storm.

GENERAL MAINTENANCE

With the antennas and towers exposed to the elements, the system needs periodic inspections to detect damage or general erosion. When signs of failing are discovered, they should be corrected as soon as possible, or depending upon the problem, keep a closer check on its progress. Small problems in the antenna system can suddenly become very large and expensive problems. The following are a few areas to consider in the station's outside maintenance program.

Transmission Lines

The horizontal run can be inspected more often for physical damage. Look for dents, holes, loose ground straps, and faulty conditions of support posts and hangers. All this requires is a walk along the line, watching closely for anything that may be out of normal. Some problems, such as large dents in the line, can show up as high VSWR. And if gas leaks occur on a gassed line, then the gas consumption will increase or the dry air pump will run continuously. Check and correct as discussed in the chapter on lines.

Tuning Unit

Inside the tuning unit, check for loose and burned connections on the coils and ground connections. Observe for tar or other dielectric and sealing material leaking from capacitors. If these checks are made immediately after signoff, then feel for heating of capacitors and connections. A poor connection will show signs of heating without showing signs of burning. Capacitors going bad can also be heating without showing other signs yet.

Also check for the presence of mice. If there are holes in the tuning box, mice will get in. Close up the openings, or if they are needed for air circulation, then use screen wire.

Grounds

Keep a check on all ground straps around the tuning unit of the AM tower. These are necessary to tie the ground system into the antenna and to provide a low-resistance path to earth for lightning discharges. If any of them breaks, replace it as soon as possible, and if a solder connection comes loose, get it resoldered. Keep all the grounds tight. If these become loose, the antenna system will become unstable.

Gaps

Check out the ball or horn gaps at the base of the tower. Insects will build nests here and then get scorched. This can also provide a leakage path across the base of the antenna. Other debris may also accumulate and do the same thing. If leakage paths aren't created, then the gap width can become more narrow and arcovers can occur on modulation peaks. Clean out these gaps with a wooden stick. Be careful when the power is on so as not to get an RF burn. When the debris has been cleaned out, check for carbon or metal deposits from lightning that may have gone across the gap. When power is off, clean out or polish up the gap with emery cloth.

Arc Quencher

If the transmitter has an arc quencher, check it out occasionally. This will take two people, and it is best to test with the RF power off but the transmitter otherwise turned on. Take a large screwdriver and short the gap momentarily and have someone observe the relay in the transmitter for operation. If it doesn't work, check out the relay circuit. Also check the tuning unit to see that no series capacitor has been added.

Grounds Keeping

The fence around the base of the AM tower must be kept in good repair so that unauthorized personnel cannot touch the tower and perhaps get a RF burn. The FCC requires the fence, and that it be in good condition. When the inspector is around and goes down to read the antenna meter, he will also observe the condition of the fence. If it is falling down or the gate missing, the station will get a citation. Also, make sure it is kept locked, just as the tuning house must be kept locked.

Another thing the inspector will look for is weeds growing around the base of the tower. The weeds must be kept down. If they grow up over the insulator and get wet, leakage paths are created for the RF, and this can affect the tower operation. Getting rid of weeds is easier said than done. Most chemical treatments are temporary. If nothing else works, at least take a whip and cut them down.

Construction

If any construction takes place at the base of an existing AM antenna, such as a sewer line run across the field, the wires in the ground system can be cut off. It is important that these be soldered back together, or part of the system is left floating. Explain the purpose of the wires to the workmen doing the job. They may not understand, but make them at least understand you want to resolder any wires that are cut.

Turnbuckles

Guyed towers have some type of tension-adjusting arrangement at the anchors. If this is a turnbuckle, the flexing of the guys have a tendency to turn them loose. These must be kept at the proper tension for tower support. One technique for this is to run a loop of the guy wire through the turnbuckle after it is properly tensioned (Fig. 11-11). This can be a scrap of the guy or the loose end of it. After looping through the turnbuckle, clamp it together. This will keep the turnbuckle from being turned, and the guy will stay at the proper tension.

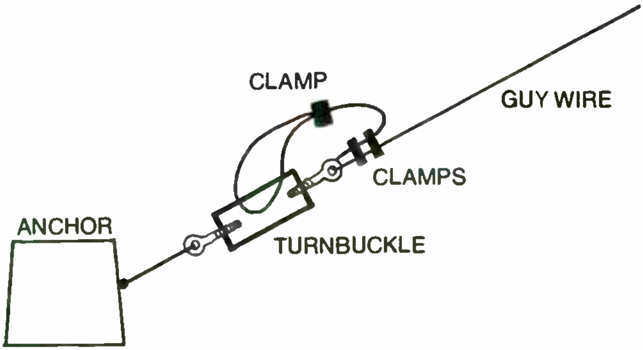


Fig. 11-11. Use a scrap of guy wire or the end of the guy to loop through the turnbuckle to keep it from turning.

Corona Discharge

This is a condition that can take place with high-power FM transmitters and when vertical polarization is used. Unless the tips of the vertical units are rounded or capped off with a spherical device, corona can take place at the end. It can also happen at the gap in the horizontal part. This will usually happen during misty weather or when it is raining. Corona can be seen from the ground as a white light at one place on the FM antena.

At the transmitter, corona discharge will affect the loading, and the VSWR will change erratically. If this happens, pull the transmitter power back below the point where the corona ceases. At the earliest opportunity, have someone inspect the antenna for a missing end cap.

High VSWR

If the VSWR is intermittent or just plain high, and there is no apparent reason, such as a damaged line or antenna or moisture in the line, have someone check out the system with sweep equipment for VSWR across the bandpass. It will be necessary to open and terminate the line at the antenna so that a determination can be made as to the source of the problem, the antenna or the line. A station will seldom have this test equipment available, so the work will need to be hired out.

Don't let the system operate too long if the VSWR is running consistently high. Much permanent damage can be done to the lines, antenna, or the transmitter.

Chapter 12
Required Inspections

All broadcast stations are required to make certain inspections periodically. These inspections are essentially for preventive maintenance, and the FCC does not spell out the exact procedures to use. The station can make the time spent productive if these inspections are carried out in some systematic manner geared to the station's needs, rather than simply fulfulling a legal requirement. In the pages that follow, a variety of suggested procedures are offered that you may find useful at your station.

TRANSMITTING-EQUIPMENT INSPECTION

The station is required by the FCC to inspect its transmitting equipment and associated monitoring equipment once each calendar week. There must be at least five days between each inspection. The inspecting operator must hold a valid first class radiotelephone license. At the completion of the inspection, he must make an entry in the station's maintenance log which certifies that the station is operating within the technical requirements of the FCC as determined by the inspection. When any adjustments or repairs are required, that also must be included in the log entry.

Routine Inspection

While the inspection can be made only of those components of the system that would fall in the category of transmitting equipment and associated monitoring equipment and still fulfill the requirement, I suggest broadening this inspection so that it may be more productive as a routine maintenance practice of the station. That is, include the *entire transmitter plant* in the inspection. If done in a systematic manner, this would require very little extra time but yield far more information. Inspecting in a systematic manner requires planning. Develop a regular routine in a checklist form. This will serve as a reminder of what to inspect and later as a reference. Make up copies of the form. Leave a blank space so the operator can check off each item and a space for comments or notations beside each item. For the transmitter proper, make up a meter-reading sheet of all the meter positions on the transmitter, plus a few others for its operation (Fig. 12-1). Again have copies run off for worksheets. All that should be necessary are blanks along side each item to enter the meter reading, the rest should be printed out on the form. Other simple forms may be added and left at the transmitter site.

Keep a File

Aside from the maintenance log entries that must be made, all these other forms should be kept in a file for future reference. They can be of great value when troubleshooting, and many months later they can show definite trends or deteriorations in the system. Even on a short-term basis these week-to-week comparisons can show problems developing (or now present). These comparisons are easier if the sheets, such as the meter-reading sheets, are so arranged that each week's set of readings are in a vertical column and that several of these weekly columns are on one page. This places a meter position's readings directly across the page, and any changes will stand right out. If the set of readings that were taken for the transmitter when it was installed are available, present readings can be compared against those to indicate what changes have taken place. If major modifications are made to the transmitter, that may change some of the meter readings; the new set taken immediately after the modifications will then serve as the latest reference.

Transmitter Inspection

The first thing to do with the transmitter is to observe its physical appearance and listen to its sounds, that is, its

AM TRANSMITTER METER READINGS

DATE		2-2-77	2-9-75	2-16-77	
MULTIMETER AUDIO I_K	mA				
OSC I_K	mA				
1ST BUFF I_G	mA				
1ST BUFF I_K	mA				
807 I_G	mA				
807 I_K	mA				
PA I_K	mA				
MOD I_P	mA				
PA I_P	mA				
PA E_P	V				
RF I	A				
FIL E	V				
TIME	hr				
COMMENTS:					

Fig. 12-1. Typical transmitter meter-reading sheet. Make up one that suits your particular transmitter.

acoustical sounds. After an engineer becomes familiar with his transmitter and has made a number of inspections, he can quickly sense when something is not normal. A slight change in the sounds might indicate the air system problems, such as plugged air filters or back pressure from a building exhaust fan. Or he may detect relays beginning to hum, buzz, or chatter.

Many transmitters provide small windows or observation ports so that tubes and other components can be observed while the transmitter is in operation. Look at the power tubes and modulators (if AM). Observe the redness of the plates, the brightness of the filaments, and note especially if there is any blue glow among the elements. This would indicate the presence of gas (in a "hard" vacuum tube) and that the tube is going bad. If the PA plates are redder than usual (or white), the stage is either out of tune, or something has happened to the load. If the tubes are modulators and the plates are running hotter than normal, the tube or bias characteristics have changed, and those tubes are also dying. If the tubes are ceramic types, look for discoloration of the plate or cooling fins, which can indicate excessive dissipation. Observe if there are any burn or arc marks where flashovers may have occurred around the tube or socket. Then observe any other components that may be seen through the windows. Again, look for signs of overheating, arcing, insulation peeling off wiring, and other abnormal conditions.

The transmitter cabinet should be checked by placing a hand on its panels and feeling for vibrations, heating, and air leaks. A relay or contactor, for example, can be developing loose laminations or the mounting screws may be loose, and this can set up vibrations that may as yet not be very loud but can be felt through the panels. If heating is abnormal, components inside may be overheating and radiating the heat to the panel; or the air exhaust or internal air system may be faulty, making the inside cabinet temperature hotter than normal, and this is transferred to the metal panels. Air leaks at the seams or joints in air ducts will soon develop dust streaks on the outside surface of the duct near the leak. Look for such dust streaks when observing through the window as discussed earlier. If the duct is accessible, you can feel for the air leak. Leaks in the system should be tightened up as soon as possible and not allowed to get too large. If the air pressure drops too low, the air interlocks can open and shut the transmitter down.

Meter Readings

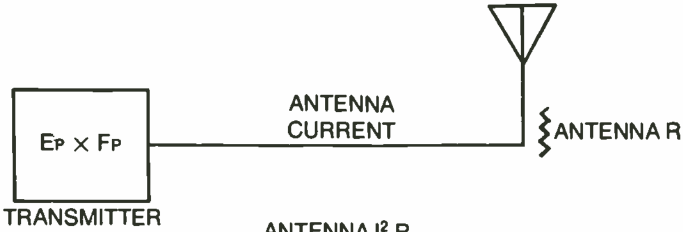
Naturally you will observe the PA voltage, current, output power, and antenna current to see if these are within specifications. There should be places on the meter sheet for these entries since the sheet should record *all* the meter readings that are occurring at that time.

Take a full set of readings of the transmitter and record them on the meter-reading sheet. There will usually be a switchable meter that can monitor most if not all of the lower stages in the transmitter and, perhaps, separate filament voltage and line voltage meters and a running-time meter. The sheet should be laid out so that the entries required are in the same direction as the rotation of the selector switch. Lay out the sheet in the same order the meters appear on the transmitter, also. In this way a straightforward routine can be used to take all of the readings without jumping back and forth between positions or meters.

As discussed in the chapter on transmitters, the original set of readings should be those that are realized in the specific, on-site installation, rather than the factory checkout sheet. This set should be the standard for comparison, and comparison can prove invaluable in maintenance and troubleshooting. For example, some lower stage may be far off its reading from the previous week (although the transmitter output appears normal) and may require maintenance before the stage fails altogether, taking the station off the air.

PA Efficiency

Always compute the PA stage efficiency after taking the meter readings. This output efficiency figure is a good barometer of changes that have taken place. There may be a load problem, a drive problem, an output meter out of calibration, or simply deterioration in the tube itself. So compute the efficiency—but don't become elated to discover the old rig seems to be improving with age, delivering a better efficiency than it ever has in the past. Don't believe it. Remember that efficiency is a ratio of power output to plate power input. An efficiency that looks "too good" can mean the output meter or the remote antenna current meter is out of calibration, thus not telling the true facts. If the meters are in calibration, then something in the load may have changed. In this case, that super efficiency actually means that the station is radiating *less* than normal power, and not the indicated power you used in the formula (Fig. 12-2). If the efficiency



$$\frac{\text{ANTENNA } I^2 R}{E_p \times I_p} \times 100 = \text{EFFICIENCY}$$

ORIGINAL: ANTENNA R = 50 Ω P = I^2R = 1000W
ANTENNA I = 4.47 A

ANTENNA R HAS CHANGED: ANTENNA R = 45 Ω P = I^2R = 900W
ANTENNA I HELD CONSTANT: ANTENNA I = 4.47 A

Fig. 12-2. The PA efficiency can be a good barometer of problems. In this example, if the antenna resistance changed from 50 to 45 ohms but the original antenna current were maintained, the efficiency would look good, but the output power would actually be 10% less.

looks especially good or bad, this calls for some after-signoff maintenance, or it may call for outside help to measure the load with special instruments. Always investigate a change in efficiency, whether a gradual trend or a sudden event.

Coax (Indoors)

Depending upon the type station and its operation, there may be only a single line, or there may be a maze of coax sections, elbows, and other fittings in the transmitter room (Fig. 12-3). Check the lines for hot spots caused by standing

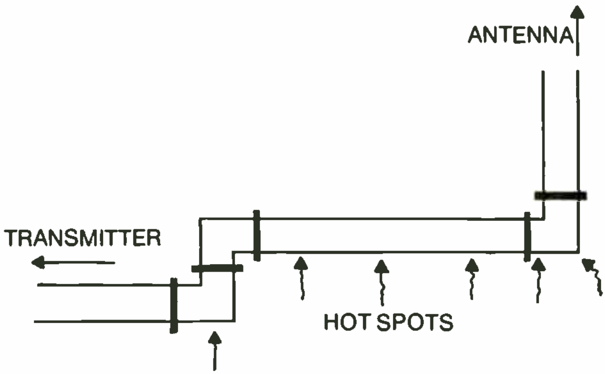


Fig. 12-3. Check the line, flanges, and elbows for heating and hot spots.

waves. Because of the long wavelength for AM, there would be one at most, but at the shorter FM wavelength you can have one or several inside the building. You need to feel the line for this, and also feel all the flanges and similar connections. If there are any problems, including high VSWR, there can be heating at the flanges. If you detect places that are abnormally warm, you may have some serious problems that require early maintenance before something burns up. Room temperatures as well as conducted heat in the copper can warm the lines, but after a few inspections, the operator will soon learn what is normal.

Harmonic Filter

The FM transmitter will have a harmonic filter immediately following its output. Since this unit is dissipating any harmonic content in the signal, it will run warm. If the unit is running hotter than normal, look for problems. This can mean that there is a problem inside the filter itself, but it can also mean that there has been a change in the transmitter tuning or other filtering units that are now either generating harmonics or allowing others to get through. If the units running hotter than normal, look critically at the meter readings that have been taken and note the position of the tuning controls. This can call for some after-signoff maintenance. You may need to check out the multipliers and other internal filter circuits.

VSWR Indicator

The VSWR indicator may be part of the output-measuring arrangement, or it may be a separate line monitor. At least one AM transmitter now has a built-in VSWR indicator, but generally these are found in FM stations. These indications should also be observed and noted on your record sheet. Show both the forward and reflected power if it is not a calibrated VSWR indicator.

Whether or not the unit is a calibrated one, the important thing is the reflected-power reading and its trend. Take into consideration the weather at the time of the reading. During cold or very hot weather, the metal in the FM antenna can expand or contract a small amount so that there is some slight detuning, thus a little higher VSWR. Of course, if it is raining and the VSWR is high, that indicates a problem also. Be on the lookout for a drift to higher readings from week to week; there may be problems developing on the antenna or in the line. You can make DC resistance remasurements on the line and antenna (after signoff) to compare with the original measurements. If this doesn't show much change, then plan on getting some outside help to check out the system with specilized test equipment. Don't allow the situation to go on too long, or it can get to the point that line or antenna damage is caused, resulting in the line monitor intermittently shutting down the transmitter.

Line Pressures

When pressurized coax line is in use, then the line pressures should be on the list for inspection. Check the line gauges for pressure. If this is zero and the pressure pump is running continuously, there is a wide-open leak in the line. Shut off the line petcock; the unit should shut off. If a gas cylinder is used, you will hear the gas hissing into the line. The line has opened up in some manner. This will call for checkout and repair. The repairs may have to wait until signoff, but check it out before leaving the site.

When the coax line is leaking pressure slowly, this is more difficult to detect. Notice if the pressure pump seems to run quite a bit when you arrive, and listen for it during the time you are at the site. The pump may be on and off several times during the inspection. Suspect a medium-to-small leak in the line. If it hasn't run at all and the pressure is up, the line is tight. When a gas cylinder is used for pressurizing the lines, keep a chart next to the cylinder. Show when it was installed and the pressure in the tank. You can make an entry on the chart each week of the pressure. This chart, then, can be a good indicator of gas usage. By having the chart right at the cylinder, it will be easy to compare from week to week, and also, when a cylinder is exchanged, there will be little excuse for not putting the pressure reading on the chart.

Power Panel

Inspect the power panel for tripped circuit breakers. There may be some that have tripped, even though they do not directly affect on-the-air equipment. For example, they may be on room heaters. Reset any that have tripped and check why. Aside from breakers that may have tripped, feel the front of the breakers in the panel. Some may be overheating. Sometimes breakers will run hot before they fail.

The Building

A number of things should be inspected or observed about the building itself, both inside and outside. This is particularly important for the remote, unattended transmitter site. Inspection of the building should be a part of the regular inspection routine. When approaching the building, be alert and have your mind on the inspection and not occupied with other matters. Look over the building, the grounds, the tower, etc., as you make the approach. Before going into the building, take a walk around the outside. Observe the windows, doors, or any opening or ventilator for signs of attempted forced entry or plain vandalism.

Once the door is unlocked and unlatched, let go of the knob and pause momentarily. If the building has an air exhaust system that is intermeshed with the transmitter cooling system, the system may be fouled up and two things can happen: (1) If the system is in full exhaust, but the outside air intakes are closed or clogged, the room pressure will be low. When you let go of the door knob, the rush of outside pressure to equalize that lower pressure in the room will cause the door to swing inward. (2) If the thermometers are calling for full exhaust and the outlets are closed, then the room pressures will build up. When you let go of the door knob, nothing will happen; but when you push the door open, you will feel resistance against the door swinging into the room. By being

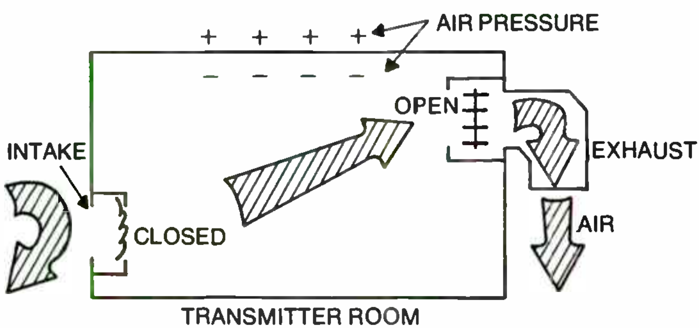


Fig. 12-4. An air system in full exhaust but with its intakes closed will create a low pressure in the room.

alert to such things you can quickly gain clues that something is amiss.

Temperatures and Odors

At your first entrance into the transmitter, be alert for abnormal room temperatures and odors. These can be clues of problems either present or developing. If the room temperatures are too warm or too cold, something is wrong with the heating and cooling systems. A circuit breaker may have tripped, or there may be mechanical problems with the louvers—a motor burned out, etc. When components are overheating, they will give off odors. If the odors are very strong, then something is in the process of overheating; but also be alert for fainter odors. Something may have burned out a couple of days earlier.

Water Leaks

The roof may have sprung a leak, or there may be leaks around outside air vents, windows, or doors. Observe the ceiling for water stains or wetness, and the same around any of the openings. Leaks in the roof can allow rainwater to drip (or run) into the transmitter and equipment. The leak itself doesn't have to occur immediately above the equipment; it can run down rafters from some other section. And the opening it finds may be right over the transmitter. Roof leaks can occur at any time, but be especially alert in the spring. Falling ice from the tower may have damaged the roof, and with the spring rains, come the large leaks.

Security Lights

When all has been inspected inside the building, it is time to go out to the tower. Turn on the outside security lights first. These may normally come on with the photocell, but you may wish to check them by turning them on manually. This may require a pass around the outside of the building, and if any are out, they should be replaced. If you wish, go back in and turn them off, and when you get to the tower (assuming the photocell is here), cover up the photocell to note if the security lights do come on.

Walk the Line

On the way out to the tower, walk the transmission line run. Observe the supporting posts or structure, the ice shield over the line, the line hangers, and the line itself. If everything inside the building looked okay, then the line check can be casual. But if there were indicated problems, then take a close look. If VSWR was high, feel the line for hot spots and the flanges for heating. If there were pressure leaks, check the flanges and solder joints for leaks with a soap or chemical solution.

Doghouse

The AM station may or may not have a "doghouse" (house for the tuning apparatus), but it will have a tuning unit at the base of the tower. For a doghouse, inspect the outside and the door for signs of attempted entry or vandalism. If the tower-lighting photocell is on the tuning house, inspect it also. An unprotected photocell can become the target for stone-throwing vandals. If the photocell is okay, cover it up to see if the tower lights come on; if the security lights are also connected to this circuit, note if they come on also. Note if the door is actually locked—the last one at the tuning house may have forgotten to lock it! The FCC requires that the tuning house and gate around the tower be kept locked and that the key be accessible to the operator. There should be a key at the control point and also one inside the transmitter building—in case whoever came out to check the place forgot to bring the key along.

Be alert for things amiss, just as you were in the transmitter building. Odors can warn that something is overheating, such as a capacitor or lighting choke (if used). There can also be other odors: mice that got into the unit and were roasted. Feel any coax lines near their end terminals or flanges for heating. Inspect all the ground straps for tightness and see that they are in place. Remember that these tie the system to the antenna ground system and are very important.

Tuning Unit

Open up its door and take a look inside. Note if the antenna meter switch has been left in a position that would allow the meter to read. Check the antenna current while you are at it, and note any calibration charts that are present. Calibration charts should be posted at the tuning unit or in the doghouse, although this can be a copy of the actual chart.

Leaving the line meter active in the circuit is just as hazardous as leaving the antenna meter active. Lightning discharge can blow both of them out and take the station off the air. If this meter has been left in the circuit and it doesn't have a switch arrangement but a plug instead, then before you leave, arrange with the control room to turn off the transmitter long enough to make the change. If you work out your cues properly, it should only take a few seconds. Then observe the capacitors for overheating or leaking. With power on, don't feel the capacitors. As a matter of fact, it is best to keep your hands out of the box altogether. Also note the coils, especially the taps, for discoloration or signs of burning and arcing. There may be discoloration, or there may be soot from an arc. Observe the static drain choke; this may be cooking down. Before leaving, make sure the antenna meter and line meter are out of the circuit.

QUARTERLY LIGHTING-EQUIPMENT INSPECTION

There must be a daily observation of the operation of the lights and if any are out, this must be reported to the FAA tower or Flight Service Station. The FCC also requires that all the tower-lighting equipment receive an inspection at intervals not exceeding three months. This is a preventive maintenance requirement. The fact that the light operation is observed every day and that it is operating *will not* substitute for this quarterly inspection. Either the station personnel may make this inspection, or an outside service company may be hired.

Outside Service Companies

There are many companies that specialize in tower-lighting service and maintenance. As in anything else, there are some good ones and some not-so-good ones. Always keep in mind that it is the licensee that is held responsible for compliance with the FCC—not the outside service company. The licensee's responsibilities cannot be delegated to anyone.

Check up on the work done by the service company, and don't pay for work unless you are reasonably certain it has been performed. I had one experience where the serviceman who was supposed to inspect and relamp the tower simply drove by after dusk when the lights were lit. He noted that all were lit and filed his report as having inspected and changed all the lamps. An easy way to make a buck, but he didn't get away with it. They had to send a man back and actually do the job.

Don't let anyone on the tower unless he reports to the control operator why he is there. The serviceman should come to the control room and talk to the operator. If the transmitter is an unattended site in the country, then someone from the station should go to the site and observe that the work is being done. In all cases, check on the work being done. Many of these service companies will leave the old lamps that were taken out during the relamping.

What to Inspect

The FCC requires that all mechanical or automatic controls and other devices associated with the tower lighting be inspected to insure they are operating properly. So what to inspect actually depends upon the individual system in use at the station. There are relays, contactors, transformers, circuit breakers and panels, flashers, and the associated wiring (Fig. 12-5). If there are other relays that tie into the lighting control, they should be inspected so that a malfunction will not adversely affect the tower lighting. If the station has a contract with an outside service company, they will also relamp the tower each time they inspect the fixtures.

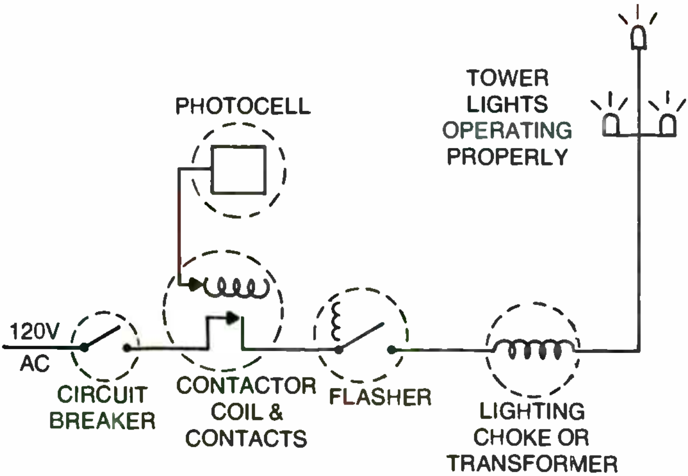


Fig. 12-5. Things you are required to check on inspection.

Photocell—All towers except those under 150 feet must have a photocell to control the lighting. This is for standard lighting as well as high-intensity lighting. Cover up the photocell to observe that it does turn on the lights. Listen for any noisy internal relays. Look over the glass enclosure for cracks, and note if there is moisture condensation on the inside of the glass. These are designed to mount outdoors, being sealed with gaskets. If the gaskets have deteriorated, moisture may be getting inside.

Relays—The photocell does not usually switch the lighting directly. It uses relay interfacing that operate contacts. The photocell operates the coil of the interfacing relay. Check out the appearance of the 120V coil for heating signs. The coil changes color or the wrappings crack when overheated. You can feel the coil also, but be careful of the 120V. If the mountings or laminations become loose, the relay can hum and buzz. This is no real problem, but it can be a nuisance if the relay is mounted where someone has to listen to it all day. Tighten down any loose mountings and inspect the contacts. The contacts switch the load, producing a high-current drain. So check for burned and pitted contacts. Clean and dress them as needed, or replace the contacts if they are beyond repair. Check all of the relays that are directly associated with the lighting. If the system is a complicated one, then a checklist should be made up so as to not miss any.

There will most likely be other relays connected to the photocell which interface to other functions, such as outside

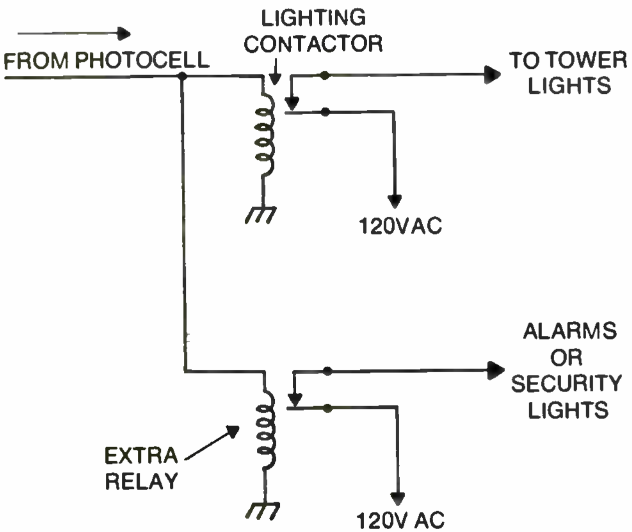


Fig. 12-6. Check other relays that may operate from the photocell.

security lights and alarm systems (Fig. 12-6). Having security lights tied to the photocell insures they will turn on automatically at dusk. Alarms will warn the operator that the lighting has turned on. It is important that any additional relays that are attached to the photocell control be inspected, especially the coil. If this coil should short out, it will short out the photocell and lighting control. If it opens up, the security lighting or alarms won't work.

Flasher—Code beacons require a flasher unit. This may be mounted at the tower base or off the tower. Listen to its operation. The rotating machinery can become dry and noisy. Add a drop of oil or grease where required and observe the mechanical operation to see if it is smooth or jerky. The motor or bearings may be becoming defective and may soon need replacement. Check out the fail-safe features on the particular unit. If the unit has dry contacts, inspect these for pitting and burning. Replace any defective contacts.

A simple test device can be made up to test the flasher unit (Fig. 12-7). At the base of the tower or in the tuning house, it is difficult or impossible to also see the top beacon while observing the flasher unit. Get one of those rubber-covered outdoor sockets that has pigtails on it. Attach alligator clips or test leads to the pigtails and insert a regular light bulb. Attach the leads to the load output of the flasher to observe the operation of the test lamp. If the light only flickers on and off

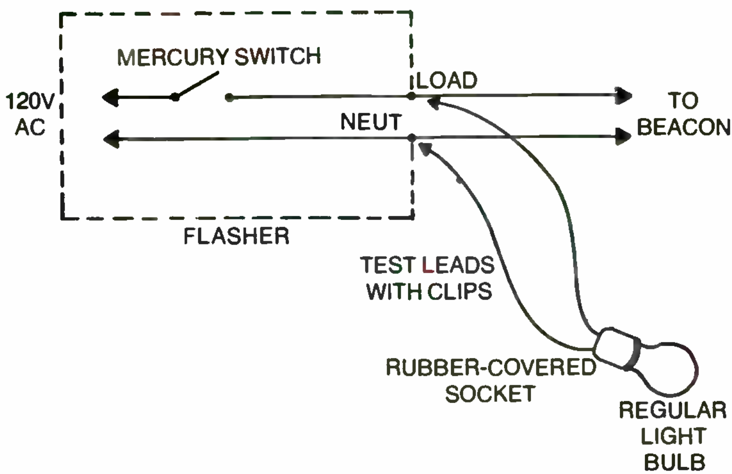


Fig. 12-7. A simple flasher test unit.

and the switch is a mercury tube, the mercury is probably parted or the tilt mechanism is improperly adjusted. Take a stopwatch along to time the flashes. The *on* time should be twice as long as the *off* time, and there should be no more than 40 nor less than 12 flashes per minute.

Lamps & Fixtures—When the towers are relamped, the serviceman will also inspect the fixture, socket, wiring, lenses, and color screens. If any are cracked or broken, they should be replaced. Moisture in the unit can cause shorts. If a drop of cold rain water splashes onto the lamp while it is lit, it will shatter. Any condensation that occurs should be allowed to leak out, or at least the unit should be allowed to "breathe." There will be small "weep" holes for this purpose. These should be kept open.

Logging

When the lighting-equipment inspection has been made, an entry is required in the station's maintenance log showing when it was done. If there were any repairs necessary, then these should be part of the entry. If the problems were found that couldn't be corrected immediately, this should be entered on the log also. When the necessary parts are installed, make an entry on that day's maintenance log.

Besides the log entry, you may desire to make a notation on your calendar or similar record of the date the inspection was made. This method will serve as a reminder of when the next one is due and saves leafing through a stack of logs to find some specific date or entry.

ANNUAL INSPECTION

The station has a large investment in its tower, antenna, and transmission line. That these expensive system items are constantly exposed to the elements 24 hours a day would seem to indicate that they should receive close attention and periodic inspections to insure they will serve faithfully for many years. The tower and antennas should be inspected at least once a year.

It is doubtful the station would have either the equipment or competent personnel to do an adequate inspection. Consequently, a tower erection company or service company should be retained to do the work. Spell out what you want done. Ask for bids from at least three companies. Major companies will bid reasonably close so long as you state what is to be done. When the bids come in, make certain they spell out what they are proposing to do. Be careful of a very low bid. This outfit may not be planning to do half of what you want. Don't accept a simple term such as "tower inspection" on the proposal; have it spelled out. Then there is no question, either when the work is in progress or afterwards.

Include in your letter asking for bids the height, number of towers, and whether they are guyed or self-supporting. Specify what you want done: Inspect the condition of the paint; inspect tower members for rust, galvanizing condition, loose or missing bolts, and bends; check the lightning rod, lighting fixtures, conduit, guy insulators, and guy condition; measure tension and adjust guys; check the plumb of guyed tower; inspect the condition of the FM antenna, grounds, transmission line, and hangers. Specify the time of year to do the work (allow some leeway) and that evidence of adequate insurance coverage be provided. Also state that a full report must be made after the inspection has been completed.

Repairs

Ordinarily, this will only be an inspection and will not include any repairs (except minor ones). The service company will not have the equipment along to make any major repairs. Some work requires winch trucks and tower-rigging equipment. Such equipment is only sent to the job sites when needed. If you know ahead of time that some major work must be done, then advise them of this in your request for a quote. This work will usually be quoted separately. If there are needed repairs, detected by the inspection, that can be done without additional equipment, you will be charged extra. So make sure all this is clear in the contract.

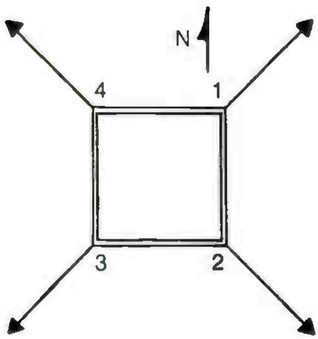
The best time of the year to have the tower inspected is during the summer months. Not only does the work go faster, but if there are any major repairs needed, time is allowed for obtaining any necessary parts before bad weather sets in. Try to spell the time out in the inspection contract.

Guys

These cables are what keep a guyed tower standing. They should be inspected for rust, missing clamps, broken strands, missing or cracked insulators, and proper tension. Insulators are used only on towers where it is necessary to break up the electrical length of the guy. If an insulator breaks and falls off, the guy will not come apart, but there will be slack in the guy. If there are broken strands, the strength of the guy is weakened; if clamps are missing, the remaining clamps are carrying the full load.

Tension—It is important that guys at every level have the correct amount of tension so that the pull is the same on all sides and levels of the tower. If they are improperly tensioned, they will affect the plumb of the tower or cause the tower to be S-shaped. That is, if all guys on one side of a tower are too tight and those on the opposite side too loose, the tower will tilt. If they are different tensions at different levels, the tower will be as crooked as a snake. All these are bad for the tower, reducing its ability to stay standing during high winds.

Measure the Tension—The tension is measured with a special device called a *dynamometer*. If the wind speed is more than 20 mph, the contractor will not measure the guy tensions. Measurements will not be accurate if there is too



GUY	1	2	3	4	
BOTTOM					
2ND LEVEL					
3RD LEVEL					
4TH LEVEL					

Fig. 12-8. The tension on each guy should be measured and recorded on the report sheet.

much wind. Measuring guy tension should be part of the contract, plus any adjustments that may be required. These measurements should be a part of the final report (Fig. 12-8).

Shoot the Plumb—*Plumb* means that the tower is standing straight from bottom to top and does not tilt in any direction. The plumb is measured with a surveyor's transit. It should be measured from two different locations (two sides of the tower) that are 90 degrees apart (Fig. 12-9). The transit should be set up no closer to the tower than the farthest guy, nor should there be a building or tree in the way to obscure the view. The operator must be able to observe each leg of the tower from

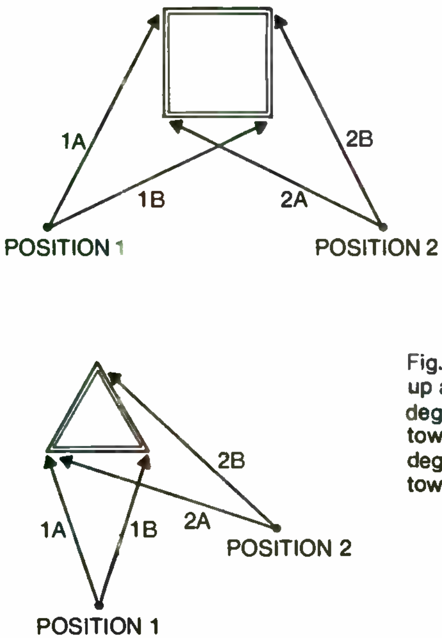


Fig. 12-9. Transit should be set up at two different positions 90 degrees apart. On a triangular tower, this may be less than 90 degrees. Check opposite legs of tower in each position.

bottom to top through the transit. At each of the locations, two opposite legs are observed (one at a time. The crosshairs of the transit are centered at the outside edge of one leg, then tilted up through the full length of the tower to note any deviation from the starting position. Then the same is done on the opposite leg. Special note is made of the levels where the guys attach; improper tensioning can pull the tower out of plumb. The same procedure should be followed at the other location 90 degrees from the first transit position. This time the other pair of opposite legs are measured.

FM Antenna

It is important to have the FM antenna system inspected. Changes will show up as VSWR, pressure leaks, and gas consumption; but there are many mechanical factors which can be operating that don't show up until failure occurs. Some of these can be detected from the ground with a pair of binoculars, but they are not always readily visible even then.

A careful inspection should be made of the antenna for loose connections, bent elements, discolorations (from arcing or corona), and parts missing. Check that the heaters are working properly. Observe carefully the actual feed to each bay, that is, the strap or short stub which feeds from the center conductor to one side of the horizontal element. The bolt may be loose or missing that would seriously affect that bay. For those stations using vertical polarization also, observe the horns of the vertical elements for discoloration, which can be a sign of corona. Corona can also take place across the ends of the horizontal rings. Look for any missing anticorona devices.

Heaters should be turned on while the man is on his way up the tower. This will give the elements time to warm up. He should actually feel each element to make sure it is heating. The RF power should be turned off for this check. Remember, there are two heating elements in each bay, so make sure he checks both sides of each bay. At the ground level, the current drain of the heaters can be measured and compared against previous readings.

Transmission Line

The line can be checked on the way up the tower. In an AM station, check the isolation unit. If an isolation section is used, it is important that insulators are in place and that none are painted, cracked, or missing. Any problem here will detune the AM antenna. Then check the flanges for heating, loose bolts, hangers, and ground clamps. Also look for dents in the line due to ice falling. If an isolation section is used, carefully inspect that important first strap where the coax bonds to the tower.

Chapter 13

Tests and Measurements

A station has a sizable investment in its equipment. In order that this high-quality technical equipment can be properly maintained, it is only logical that test equipment of comparable quality and variety be owned by the station. For it to be of any real value, however, station engineers must understand how to use the test equipment to its fullest capabilities.

TEST EQUIPMENT

Any test unit is basically a device that is external to a circuit and compares samples of the operating circuit to some outside value or standard. The test unit should not affect the operating circuit in any way.

Testing is essentially comparing some value against another standard or an arbitrary value, then detecting the deviation. The values may be normally accepted values—voltage, current, resistance, or waveforms—for the type of equipment; or they may be more rigidly controlled standards, such as the frequency of WWV. Throughout the broadcast station, there are a variety of degrees of accuracy required. Some may be loose go/no-go comparisons, and others for strict tolerances, such as the carrier frequency measurement. The majority will fall somewhere in between these extremes.

Portable and Fixed

Measuring devices may be either fixed or portable. Both types will be in use at the station. Those in the fixed category will be factory-installed meters on units such as the transmitter multimeter and the console VU meter. There are others which station engineers install for remote-metering purposes or for a running measurement on some unit.

Selecting Instruments

When selecting portable test instruments, there are several factors to consider. One of these is the quality of the instrument. Quality depends upon the accuracy of the end results and the ability of the instrument to withstand the handling necessary in portable use. Test equipment is available in a wide range of accuracies, beginning with those intended for the home hobbyist to laboratory standards. Most broadcast instruments fall somewhere out in the middle of this range.

What test equipment to purchase is often dictated more by preference than need. But we need to be practical, balancing preference and need against the budget. The end results are what should be the controlling factor.

Many tests are of the simple go/no-go variety or simple comparisons that do not require absolute values. For example, when measuring a 24V power supply bus to operate relays, it is immaterial if the meter indicates 22V or 26V instead of the true 24V. When erratic switching occurs, however, and measurement shows the bus indicating 14V instead of the true 16V, this is really material. A standard multimeter will help the engineer troubleshoot this problem; it is not necessary that a lavoratory instrument be available to indicate the precise voltage.

Most of the test instruments for broadcast work are the better instruments used in service shops. Seldom are laboratory-accuracy instruments required. When some particular measurement *does* require such accurate measurements, accurate instruments can be rented, the work performed by the station's consulting engineer, or one of the service companies can be contracted. Making the measurement of the AM antenna resistance, for example, requires accurate, specialized equipment. A number of stations with a directional antenna do own an RF bridge; this has operating utility and helps in keeping the system tuned and matched. But for making a new determination of the antenna resistance, the FCC will not accept the measurements made by the average station engineer. He has to demonstrate his qualifications satisfactorily to the Commission before his measurements are accepted.

Another factor in the selection process is whether an instrument has most or all of its features used on a regular basis. Many instruments have many features that do not get used; if the station has invested in those extra features, the money is actually wasted. For example, a good-quality service-type oscilloscope handles almost all the oscilloscope measurements in a radio station. It would be simply wasteful to invest in one of the more sophisticated oscilloscopes that cost at least five times as much. A large percentage of the extra features of the scope will never be used in a radio station. The additional money spent could be invested in other needed units.

Equipment Use

Even the best test instrument is of no real value unless the station engineer can operate it correctly. Unless he can operate the unit correctly and interpret the results correctly,. the engineer may diagnose problems that do not exist. That is, his misinterpretation of the indications can lead him to perform adjustments to the operating equipment that are just plain wrong. More often, wrong interpretations produce wrong clues and inaccurate reasoning by the engineer. In effect, he can be led down many false trails when troubleshooting problems if he doesn't understand his test equipment.

Study the instruction manual to know the equipment's limitations and proper use. Practice with the instrument on circuits that are working normally so that when problems do develop you will have a reservoir of experience in the use of the instrument and know how normal circuit parameters run on that instrument. This is important. In the first place, each operating-equipment item is individual; its operational parameters can deviate from design norms or the ideal. It is well to know this in advance of problems because you may obtain measurements that appear to deviate from design norms but *may be normal* for that unit, having nothing to do with the problems at hand. If the engineer is familiar with the operating norms of the program equipment and the normal indications of the test instrument, the test equipment can become a useful tool in the reasoning process. But if the engineer must devote a considerable amount of reasoning power trying to figure out how the test equipment operates, then interpreting the results, he cannot devote enough concentration to solving the problem. Test equipment then becomes a hinderance instead of a help.

What Equipment?

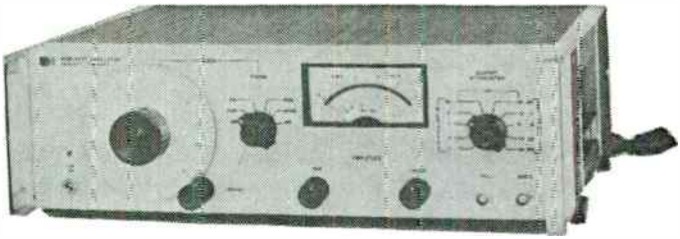
Types, quality, and accuracy of portable test instruments in a station will depend on what operating equipment is in use, but a few basic items are generally required. There must at least a standard multimeter (VOM), an FET VOM or VTVM (for more critical measurements), an oscilloscope, a frequency counter, and a proof package—consisting of a good audio signal generator with calibrated pads and a good noise-distortion analyzer. When there are many units containing digital equipment and circuits, there should be a logic probe and a logic clip. Figure 13-1 shows two instruments suited to broadcast work.

MEASUREMENT BASICS

It is important to know in what *terms* the test instrument will register. If this is not known, the engineer may be comparing two different sets of values, coming up with wrong conclusions. There are number of factors, both inside and outside the unit, that can affect the indications.

RMS and Peak Values

The RMS value of a sine wave is equal to 70.7% of its peak value. The standard AC voltmeter contains a modified bridge circuit which will rectify and convert the sine wave or AC voltage to a DC equivalent to the RMS value, and this is the indication. RMS is the normal expression for AC voltage on the specification sheets and in literature, so that is what the meter will indicate. When other values are required, such as the peak value, they will be specified. If the instrument doesn't have a switch position that will povide the peak value of the measured signal, then you can multiply the RMS value (as indicated on the instrument) by 1.41 to obtain the peak value. However, this only holds true if the voltage is a sine wave. Program signal



A

B

Fig. 13-1. (A) Hewlett-Packard Model 651B is a suitable audio oscillator for test purposes in the station. Various options are available that will tailor it to the particular application. (Courtesy Hewlett-Packard.) (B) Various special instruments can make the maintenance job easier. The SMC tape head meter can measure the output directly off the audiotape head. (Courtesy Systems Marketing Corp.)

amplitudes are a different story altogether. If you try to measure a program signal with an ordinary voltmeter, the indications will be far from accurate. The regular meter can only indicate that some signal is present, and not how much.

Peak-to-Peak Values

In the RMS and peak readings on most meters, only a half-cycle of the voltage is actually measured; the other half-cycle is removed by rectification. But instruments that read in peak-to-peak values, such as FET VOMs and VTVMs, indicate the full AC cycle from its positive peak to its negative peak.

The oscilloscope will only indicate peak-to-peak values. This is very important to remember when comparing signal amplitudes on different instruments. If the stated value is RMS, such as 6.3V in a tube filament circuit, the indication on the oscilloscope will be 17.76V. As discussed earlier, the peak value is 1.41 times the RMS value. These peak indications are only for a half-cycle. Since peak to peak is the full cycle, this value is twice the peak value, or 2.83 times the RMS value. Figure 13-2 illustrates the relationship between these values.

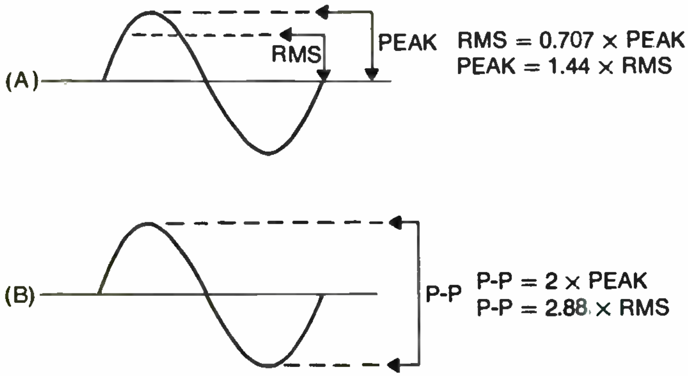


Fig. 13-2. The RMS and peak-to-peak values of a sine wave.

Voltmeters and Audio Measurements

The ordinary voltmeter is unsuitable for audio because of the waveform difference between program and sine wave signals. There is also another reason. The standard voltmeter has a frequency response about 800 Hz. While this is adequate for line power and similar low-frequency sine waves or power supply ripple, it is inadequate for audio. The voltmeter found on the noise-distortion analyzer or an audio voltmeter will have a much wider bandpass. Its actual bandpass may be well into the RF range.

Low Power Ohmmeter

Solid-state components such as transistors, diodes, and ICs require only a very small amount of voltage to turn them on. So when attempting to measure resistance values in a circuit that has these components, the devices can be turned on by an ohmmeter's internal battery. This creates a number of shunt paths, making actual measurement considerably inaccurate. Some test instruments, such as meters, provide a *low-power ohms* function. This supplies a very low voltage and current, so that the resistors can be measured in the circuit without turning on the solid-state device.

Input Impedance

For voltage measurements, all instruments have a high impedance input. The question is: How high is high? This is a relative matter. Another aspect is shunt capacitance. Shunt capacitance becomes increasingly important as the circuit frequency becomes higher, and especially at RF. Instrument impedance is relative because, if the circuit being measured is very high impedance, the meter impedance, especially for a VOM, may not be so high, causing circuit loading. This loading will affect both the circuit under test and the measurement.

Probes

For greater circuit isolation and for voltage reduction to the instrument, multiplier probes are used. For example, the compensated 10X probe for an oscilloscope (Fig. 13-3) offers a 10M (10 megohm) impedance to the circuit under test, and the compensation reduces the shunt capacitance to a very low value. Without the probe, the input impedance would be 1M.

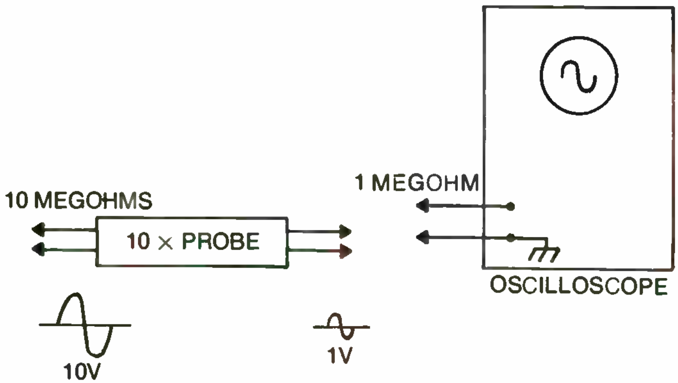


Fig. 13-3. A 10X probe on oscilloscope will provide circuit isolation, but also reduces signal amplitude to instrument.

Remember that this probe reduces the voltage to the instrument by a factor of 10 also. For example, if the circuit under test has a signal voltage of 50V, the probe will divide this by 10 so that 5V will be available to the instrument. This means the probe has the effect of reducing the instrument's sensitivity. When the signal level is very low and you need the probe isolation, the instrument sensitivity can be reduced below the point where it can make useful measurements.

A variety of other probes are available. Some are designed especially for a particular instrument, while others are more general and can be used with many different instruments. Two such probes are the RF probe and detector probe. The RF probe will rectify RF signals and reduce them to DC equivalents so that the regular DC meter can measure RF. Detector probes can be used to remove the modualtion envelope from the RF, such as in a sweep envelope, and allow the scope to measure the bandpass of an RF circuit.

Panel Meters

The panel meter cannot always be used by itself as a regular test instrument. Unless the panel meter is measuring current within its design range, then there must be external multipliers to isolate the meter from the circuit and limit the current. Some special meters may have these limiting resistors built within the case so that the measured signal is applied directly to the meter's external terminals, but these are not ordinary panel meters.

Basic Meter Movement

The basic meter movement is an electromagnetic device that operates on DC. If this is to be used to measure voltage in a circuit, then enough series resistance must be added to limit the current to the natural limits of the basic meter. Since the meter measures *current*, the internal resistance is low, so the external resistors also provide isolation. The dial face can be marked in any value, for example, RF current. In such a case, the meter is actually still measuring DC, which has been derived by an external rectifier from the RF voltage.

Each meter is designed around its full-scale indication. For example, if the movement is designed for 1 mA, then when 1 mA of current flows through its coil, the pointer will move to its extreme right limit. Meters are available in many other ranges, from microamperes to amperes. Look on the lower edge of the dial face. Many meters will have the full-scale value for the meter movement shown here.

Since the meter movement is an electromagnetic device, the panel itself can affect the movement. When ordering a panel meter, check the specification sheets. If the meter is designed to mount on a magnetic panel (steel), this will be stated. The meter should be mounted on a steel panel, or the indications will not be correct. By the same token, if the meter is for a nonmagnetic panel (aluminum or nonmetallic material), then don't use a steel panel for mounting. The actual amount of error introduced will vary. For those cases where the indications are only relative, it is not too important. The factory makes compensations in the meter for the type of panel mounting. Some meters have built-in shielding so the panel material has no effect on the meter.

Checking a Meter

Sometimes it is desirable to check a meter. You may suspect its accuracy, or you may want to replace it but the full-scale value is not shown on the dial face. A simple test setup can be arranged to do this (Fig. 13-4), but don't check a meter for continuity with an ohmmeter. The internal batteries of the ohmmeter may send too much current through the meter and damage it. Instead, use the milliammeter section of your multimeter. Connect the meter under test in series with the multimeter, a 1.5V flashlight battery, and a

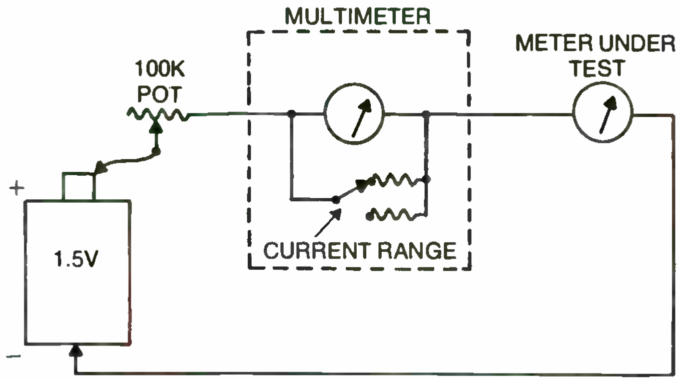


Fig. 13-4. To check unknown scale of a meter, use the ammeter section of a multimeter as a comparison. Start with a high-resistance value in the pot.

high-resistance pot. Start out with a high value of resistance in the order of 100K to limit the current (the meter under test may be a microammeter). Lower the resistance while observing the current in the two meters. When the meter under test is at full scale, observe the multimeter and its range selector. This will give the full-scale value of the meter. When making the initial setup, measure the resistor (if it is a pot) to make sure it is in the maximum-resistance position.

Station engineers add meters to many circuits either for remote metering or as a constant monitor of a circuit. In many of these cases, a standard panel meter is used, and the dial reading is purely an arbitrary value. For example, a 0–1 mA DC meter can be used with enough series-limiting resistance to indicate voltages on a 10V DC bus. Now this might confuse others, but so long as those who work with the circuit know what it means, it is immaterial that the dial reads milliamperes.

Correct Dial Face

On some meters the station may add, the dial face must have the same markings, divisions, and accuracy as the original meter. This would be the case if meters were added to the transmitter and the indications used for logging purposes. The FCC requires this. There are a number of meter shops around the country which can do this type of work at a nominal fee.

RF Pickup

Our old enemy RFI haunts meter circuits also, and both the panel meter and test instruments are affected. In one case, our station sent an announcer to do a ball game broadcast in a distant town. Our man was using a phone line, but a local station came in to do a broadcast using a remote pickup transmitter. As soon as that transmitter was turned on, the VU meter on our amplifier hit solidly on the right-hand pin and stayed there throughout the broadcast. The RF was not affecting the audio, only the meter circuit. Gain control for that broadcast was done by *guess-and-by-gosh*, setting the controls where they normally were and backing them off if distortion was heard. Meters mounted in a transmitter will have a 0.01 or 0.001 μF capacitor across the meter terminals to keep the RF out of the meter movement. If you have a problem in an audio circuit, use a higher value that won't affect the audio and still will cut the RF.

For test instruments that are being affected by RF, be sure to get a good ground to the case along with shielded test leads. Even this may be a marginal situation, and it may be necessary to keep clear of the instrument so that body capacitance will not introduce more RF to the meter—that is, set the range and then back off from the meter to make the measurement.

Accuracy

When an instrument must be accurate, then either calibrate it yourself or have it calibrated. Many meters can't be calibrated properly in the field since there aren't appropriate standards available. Meter shops will calibrate panel meters and certify their accuracy. Instruments can be sent to meter shops or the factory for calibration or repairs. The accuracy of some meters must be maintained, and if it is in question, they cannot be used. For example, the FCC specifies that the antenna meter can't be used if the certification seals have been broken.

PROCEDURES

Whenever a test arrangement is set up and instruments attached to an operating circuit, there should be as little effect on the circuit as possible, ideally none. Unless precautions are observed, the test arrangement can affect the operating circuit or introduce spurious interference. In all these cases, not only will the indications be in error, but the circuit will be operating improperly. This is another reason why the operator should have an understanding of how test equipment works.

Comparisons

Perhaps the quickest way to troubleshoot problems is to compare the inoperative equipment with another unit of the same kind that is operating properly. The test instrument then makes a comparison against an operating unit as a standard rather than some outside standard of voltage or current. Of course, this can't always be done since there may be no other unit available to make the comparison. When there is such a unit, there is no need to interpret waveforms that deviate from the ideal. The fact that the comparison unit is operating properly makes it a good standard of comparison. Thus, if the test setup or test equipment is loading the circuit, it will be doing the same thing to the operating circuit, and the effects will show up in both units. Only when there is a wide difference are you close to the problem.

Balanced or Unbalanced Input

The majority of test instruments have an unbalanced input, that is, one side is grounded. Others may have an isolated ground and a jumper that allows the option of grounded or ungrounded operation. The instrument with an unbalanced input grounds one side of the balanced circuit, and this can cause operational problems that introduce hum or other interference. If the circuit is *on the air*, then that is a very undesirable condition.

If the balanced circuit has a grounded center-tapped transformer, then the unbalanced input of the test unit will short out half of the circuit (Fig. 13-5). This will cause a change in impedance and operating conditions as well as interference. In any case, the meter indications can be far from accurate.

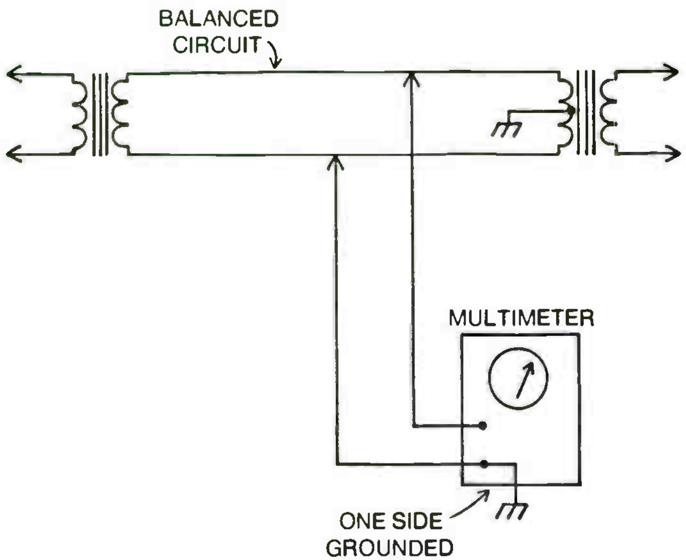


Fig. 13-5. The unbalanced input of meter can short out half of a balanced circuit. This will affect both the circuit and the readings. To avoid this, float meter case.

Terminations

Amplifiers and other units are generally designed to operate into a definite terminating impedance, or the signal levels will be in error. When patching into a jack field or when a unit is on the bench, it is possible the load or termination has been lifted off the unit. In the jack field, the "normal" contacts will lift when a patch plug is inserted, so that the unit now only has the high impedance of the test instrument input as the load. Check the diagrams to see how units are wired into the system. Add a proper termination at the test unit if necessary.

The opposite condition can happen if there is a termination on the test instrument. Should the patch plug be inserted into a multiple jack, the normal load is not lifted, and now the unit is double terminated. This will make the output signal low.

When measuring RF in coaxial cables, always make sure the correct termination is used, or there will be standing waves on the cable, which cause unusual indications as well as operation.

Transformers

When working with balanced circuits, run the connection to the test instrument through an isolation transformer. If a signal generator is feeding the unit, then levels will be incorrect if the amplifier does not present a correct load to the generator. In some generators, where the output pads are balanced to ground, an unbalanced input of an amplifier can short out half of the attenuator, causing signal levels and tests to be far from correct.

Excessive Voltage

When a unit is operating improperly, during tests be on the lookout for higher-than-normal voltages. Ordinarily, we think excessive voltage in relation to the high voltage in transmitters. But comparatively low DC voltages can be just as detrimental to the test instrument. For example, you may be expecting to read 5V on a bus for logic circuitry, but now a 24V relay voltage is appearing on the bus. As a precautionary habit, always start with the instrument set for a higher voltage range, then adjust downward as it becomes evident the circuit voltage is well within range of the meter. This is particularly true when first moving into a problem. A high percentage of test equipment damage comes from excessive voltage.

Wrong Function

A second type of damage comes from placing the ohmmeter across a circuit that has voltage on it.

When a multimeter is connected to a voltage source, care must be taken not to rotate the function switch through the current ranges. There won't be any series resistance to protect the meter. If switched into current ranges, the low impedance of the meter will also put a low-resistance path to ground on the equipment; the equipment can be damaged or its fuses blown.

Another wrong-function situation that can give incorrect indications is having the meter switched to measure AC voltage when trying to measure a DC bus. On some not-too-well-filtered relay supply buses, ripple can be relatively high and cause the meter to read high. For example, a 24V DC bus could read about 40V in the AC position. This sort of reading can lead the troubleshooter to search for the wrong problem.

Panel Meters

When setting up permanent metering of a power supply, for example, use enough series-isolation resistance so that the current drain of the power supply is very low (Fig. 13-6). The smaller the current drain, the less effect it will have on the power supply. How much current drain depends upon the power supply voltage and the series resistance. You may wish

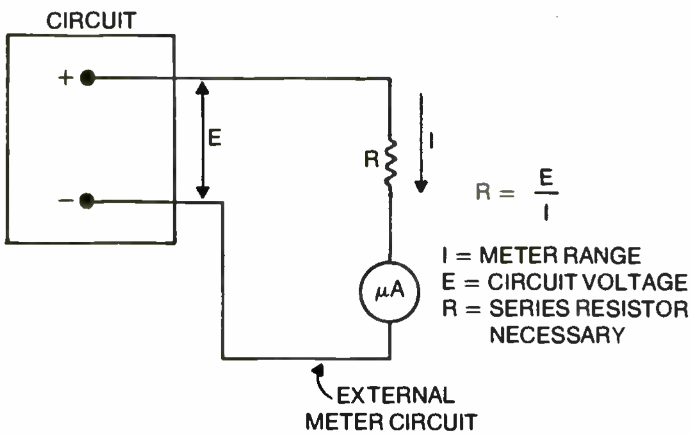


Fig. 13-6. When adding a panel meter to make a voltmeter, add enough series resistance to limit current through meter and drain from circuit. Use Ohm's law to figure resistance.

to use a meter in the microampere range. Use Ohm's law to compute the resistance required. This is essentially what the high-quality test instruments use, although they use precision resistors for the job. In a 20K-per-volt meter, that means there are that many ohms for each volt. If it is the 100V range, then there is 2M of resistance between the meter and source. The meter will draw very little current from the source.

Printed-Circuit Boards

Many circuit boards have wiring traces on both sides of the board. When making measurements to ground of boards that have ground traces around the edge of the board, don't clip the instrument ground clip over the edge of the board unless you are certain the trace on the opposite side of the board is the *same* ground. With many circuits using bipolar power supplies on the same board, there may be two or three different ground buses. The trace on the opposite side of the board may be a signal line or a different ground.

TEST EQUIPMENT MAINTENANCE

To do the job that was intended, test equipment, whether instruments or panel meters, must be kept in good repair. Unfortunately, test equipment repair is often a low-priority item because there seem to be too many pressing operational problems. Erratic test equipment can be a real headache, often worse than no equipment at all.

Erratic Operation

The majority of these problems will be external, that is, in the test leads and clips. Look for broken shields or conductors, loose connections in the tips and probes, or parts that have separated in a probe.

Inside the instrument, there may be loose hardware or broken insulators. There can be defective or damaged components, such as the input circuit burned out from overload—or burned printed-circuit boards, shorted transistors, defective ICs, etc. In other words, test instruments are subject to the same type failures as operating equipment. The circuits may be different, but they are subject to the same ills.

When components are defective, you may be able to replace them, but in the process, the accuracy may be impaired. Multiple switches may be cleaned with a contact cleaner. Check with the instruction manual for the instrument. There are often instructions on how to adjust the unit after a component or transistor has been replaced. If the corrections can be made at the station, this is all to the good.

Reduced Accuracy

If the instrument has been damaged so that its accuracy is impaired, recalibration may require standards that are not available in the field. Then it must be sent back to the factory for recalibration, repair, or both. When precision parts are required, factory repair may be the best route to take when the accuracy of the instrument is important.

All this depends upon the instrument. Many tests are simple and don't really need a calibrated instrument, for example, checking the continuity of cables, or checking to see if voltage is present or not. But if the calibrated output pads in an audio signal generator are burned out or damaged, it should be sent to the factory for repair and recalibration.

Batteries

Many portable instruments today operate on batteries. The batteries may be rechargeable *secondary* batteries, or nonrechargeable *primary* batteries. Treat the batteries of test equipment the same as those of the portable operating equipment. Keep the battery compartments clean of corrosion. If a particular instrument sets on the shelf for some time between uses, take its batteries out as you would do with remote amplifiers.

Some meters have a *battery test* position on them. Use this on each occasion the instrument is used. If the battery is low, the meter indications can be in error.

High-Voltage Meter

A transmitter high-voltage meter must be mounted in a recessed location so that it is not accessible to the operator. This is a safety precaution. There will be an additional glass or plastic window on the front of the panel. In effect, you read through a double glass. The meter itself will be mounted on standoff insulators. It may be difficult to read the meter if the room lighting is not good; when dust accumulates, it may become impossible. And high voltages do attract dust. The equipment must be turned off to clean this meter because you need to get behind the panel. In some instances, you may need to dismount it from the insulators. Try not to get things too wet, and also clean off the insulators. Make sure everything is dry before turning on the high voltage. Run the cabinet fans awhile to help dry it out.

Probes

A probe is basically just another test lead, although it is a little more complicated than a wire with test clips. Probes on oscilloscopes and others use a shielded lead. Look for breaks in the shield near the connection at the test instrument, where it gets a lot of flexing. Screws that hold the probe together may come loose, or the connections inside may become loose or ungrounded. Take the probe apart carefully. There may be a small printed-circuit board with components on it. Check for loose joints.

USEFUL TECHNIQUES

The engineer should learn to obtain the most out of each test instrument. By learning and discovering various ways an instrument can make measurements, tests can often be done quickly. Following are a few tests or methods that can be helpful.

Oscilloscope DC Voltage Measurement

The oscilloscope is primarily designed to measure waveforms of AC signals, but it can measure DC voltage also (Fig. 13-7). Of course, we don't set the oscilloscope just to measure voltage, but if it is desired to know the DC voltage on the point and we don't want to get out the voltmeter, the oscilloscope can measure it accurately.

Set the input to DC coupling. Remove the probe and short the input to ground to provide a reference trace on the CRT. If the voltage is positive, it will deflect the trace to the top of the tube; if negative, the trace will go toward the bottom. Set the base reference line according to the anticipated polarity of the voltage. Reinstall the probe. Now place the probe on the terminal to be measured. The trace will deflect upward or downward. Use the calibrated attenuators to keep the trace on the CRT. Calculate the DC voltage from the attenuator settings and the vertical deflection on the tube. If the graticule

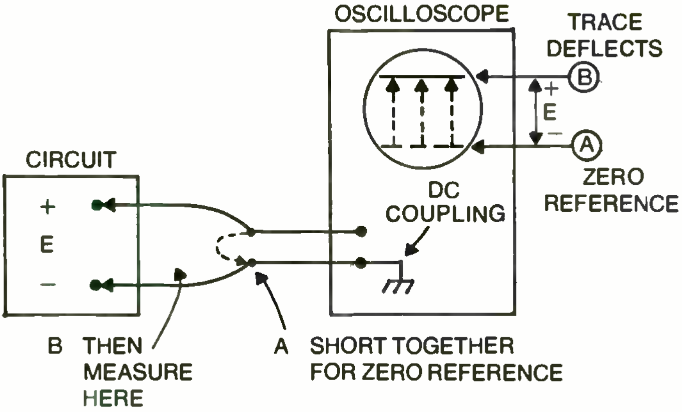


Fig. 13-7. Making DC voltage measurement with the oscilloscope. Use DC coupling and short the probe to ground for reference. Distance between zero reference and deflection of trace is directly proportional to the DC voltage.

(scale on the CRT) and attenuators are not calibrated, then use the internal calibrator.

With a signal present, the DC voltage can still be measured. In this case, the DC voltage will be the zero axis for the AC signal, which will be superimposed. Calibrate the reference line as was done before, but allow space on the tube for the AC signal also. Use DC coupling; the DC value will be given by the deflection of the AC zero axis from the reference position.

Check Polarity

Some oscilloscopes have a phase or polarity reversal of the displayed trace. That is, if the input signal is a positive-going pulse, the display can be switched to show it as a negative-going pulse. With AC signals, polarity is no problem, but with pulse or TV signals, this is a nuisance.

You can check your oscilloscope for polarity reversal. Use a regular flashlight battery and measure its DC voltage as described earlier. The trace should deflect to the top of the CRT. If it deflects towards the bottom of the tube, the oscilloscope is inverting the signal. Remember this when you have to measure pulse or DC voltages.

Measure Decibels

The oscilloscope can also measure decibels, but it will take some calculation. Rough calculations are often made to compare the signals in a test arrangement. First, let's review a few facts about decibels. The oscilloscope measures voltage, so the voltage formula for decibels must be used. The impedance of the circuits tested must be the same, or the simple formula can't be used. The formula is $d = 20 \log (E_1/E_2)$.

In most situations, we need only rough estimates of decibels, hence the computation need not be done. For example, you may be working on an amplifier and measure its input and output signals. If both are say, 600-ohm impedances, the decibels can be computed. Assume the output is one-half of the input. This is a 6 dB loss. After adjustments and repairs have been made, you check the signal again. This time the output is twice as much as the input signal. This is a GAIN of 6 dB. Your repairs improved the amplifier gain by 12 dB. In another situation, you may be reading the output of a stage, where the oscilloscope is calibrated to that AC signal. But now the gain is changed so that you have to change the attenuators on the oscilloscope. You can use the values on the attenuator (usually given in voltage) to compute the decibels change.

AC Ripple

The AC ripple on the DC output of a power supply can be measured with the oscilloscope, providing the actual percentage (Fig. 13-8). Measure the DC voltage, then use the

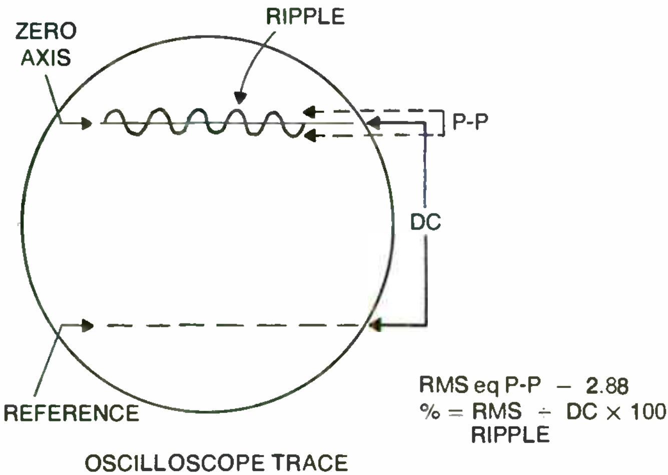


Fig. 13-8. Use the scope to measure and compute the ripple on a DC bus. Ripple must be RMS value.

AC axis through the ripple as the DC line. Measure the peak-to-peak value of the ripple from the graticule markings. Ripple is the ratio of the RMS value of the AC signal to the DC voltage. So compute the RMS value first. Divide the peak-to-peak ripple value by 2.83 to obtain the RMS value. Divide this RMS voltage by the DC voltage, then multiply by 100. That will give the percent of ripple on the DC bus.

Hum

The oscilloscope can be used not only to measure the hum amplitude in relation to the signal but also identify its source. The simplest method is to attach the oscilloscope to the amplifier output and remove the input to the amplifier. If the hum disappears with the signal, it is not in the amplifier at all. But assume it is present. Without the signal present, it is very easy to identify the hum, whether it is 60 Hz, 120 Hz, a clean or a raspy signal, etc. This can point to the source. Use the horizontal sweep to determine the hum frequency. If this isn't calibrated, then set up on the 120V power line and get one full cycle displayed. This is 60 Hz. Now, if the trace of the hum shows two cycles, it is 120 Hz and probably coming from the power supply.

Noise

When measuring noise with the noise-distortion analyzer, use the oscilloscope output to identify the nature of the noise. The noise will be a part of the high-distortion figure indicated in the measurement. The oscilloscope will identify it as "white" noise, transients, hum, RFI, or whatever. This is a big help in locating the source of the problem. If the measurement is made on the overall system, use a terminating plug while going down the jack field from unit to unit. This eliminates part of the system which could be amplifying the noise. If the noise is originating in a certain unit, the figure will drop markedly as soon as you terminate the input of the next amplifier.

This same identification process can be done on AM checks of the FM carrier, a measurement required in an FM proof of performance. Attach the oscilloscope to the output of the meter that is used to measure the noise on the carrier. Identification of the noise will help you know where to look for the problem. If it is 60 Hz, it is cathode-to-filament leakage in a tube, or primary AC coupling. If 120 Hz, then look at the power supplies.

Transistor Switching

In many solid-state circuits, a transistor is used as the switch to operate a relay. This may be an interface between a relay and IC. This transistor will have its collector tied to the "low" end of the relay coil. When the pulse turns the transistor on, it conducts, taking the "low" end of the relay to ground. If erratic operation is noted, use the FET multimeter to check the voltage at the collector of the transistor. Without an *on* pulse, this collector should be at the full relay voltage. The full voltage will appear here because there is no current to produce a drop across the coil. If the voltage is not present, the relay coil is open, assuming the supply voltage is okay. If the voltage is present, use the low scale of the meter to measure the base of the transistor. It should be perhaps 0.2V or less. Now pulse is passed into the circuit. If this goes positive to about 0.7V or more (in an NPN transistor), the transistor should turn on. Measure the collector again. If the relay voltage is still present, the transistor hasn't turned on and needs to be replaced. The collector voltage should go to zero at turnon.

Identifying Lines

There may be cases when an uncoded audio line will be run for speakers when it is desirable to have the installation properly phased. For example, you may need to set up a number of speakers around a large room with proper phasing so they are not "fighting" each other with sound waves. Here is an old trick that public address installers have used. When you run the line and before anything is connected to it, including the source, attach a regular 1.5V flashlight battery across the two wires of the cable (Fig. 13-9). Then, at each location, bare the wires; with your voltmeter, measure the voltage. The positive and negative voltage on the line will identify each wire. Mark the wires for later identification. Do this at each location, and don't forget to mark the feed end of the line.

Monitor Test Point

The AM monitor will usually be rack mounted. There are often occasions when it is desirable to measure the modulation

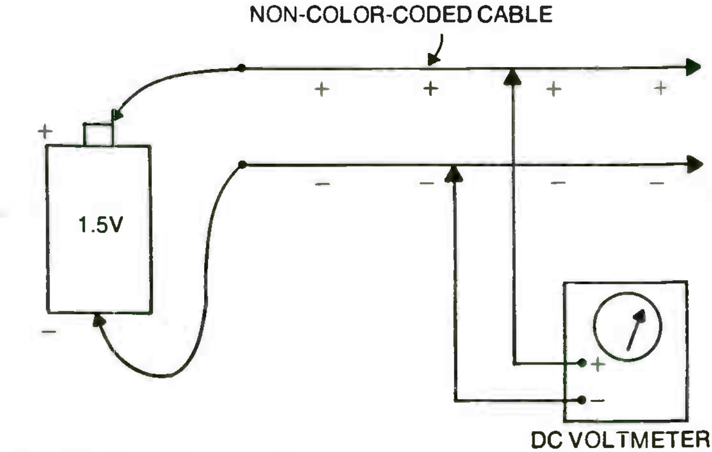


Fig. 13-9. Use a flashlight battery and voltmeter to identify the wires in an uncoded cable.

envelope of the RF itself to make comparisons with what the monitor is indicating. So that you don't have to make a special setup each time, a simple test point can be setup as follows. Use a T-connector in the RF feed line. Add a ground lug on the front of the panel for the oscilloscope ground clip. Then when you desire to check the envelope, simply connect the oscilloscope to this test jack and measure. There will be no disassembly or a special setup needed. The monitor will continue to operate as it was. Make a shield cap to cover the jack to prevent RF radiation into the audio gear.

Stereo Pilot Frequency

When there is a strong main-carrier signal floating around the area, it may be difficult measuring the stereo pilot frequency because the counter will lock onto the strongest signal. If you can arrange a test jack out of the stereo generator that will not upset the circuit, do so. But if the modulation monitor has a coax output on the front so that the composite and pilot can be switched, use this for your test point. This will provide the isolation and, at the same time, provide an amplified pilot signal that is separated from the composite. Check out the circuit to make sure this is actually the pilot and not a reconstructed signal.

Counter on Cable

Perhaps the best place to pick up a carrier signal to check for frequency is on a cable that feeds a sample of the RF to a monitor. In this way, the coax can connect directly to the counter, and the cable will shut out any interfering signals. But signal levels in the cable may be higher than the counter input circuitry can tolerate. For those locations where you make regular measurements, measure the RF in the cable. Use a small load and wattmeter if available. If it is an AM carrier, you can measure that with the scope. Or if it is FM, you need an RF probe on your regular meter (this may not be too accurate). Remember to terminate the coax line, otherwise, there will be standing waves. This termination and isolation can be done with RF pads, which are available in several loss values, such as 6, 10, and 20 dB. When working with RF circuits, a few of these in the test gear box are handy to have around. Use isolation in the line to keep the signal level below the counter maximum. Once you have determined the correct value for the line, then use the appropriate pad in the counter lead each time a measurement is made on that line.

VCC Isolation

When some digital unit is on the bench and it is necessary to use a logic probe to troubleshoot the unit, a pulsing device is needed. The VCC (semiconductor supply voltage) bus can be used to create artificial pulses. When this is done, isolation should be used to prevent shorting the bus and to limit the current sent into an IC (Fig. 13-10).

Solder a resistor to the VCC bus on the board and bend it away from the board. Use a regular test clip attached to the

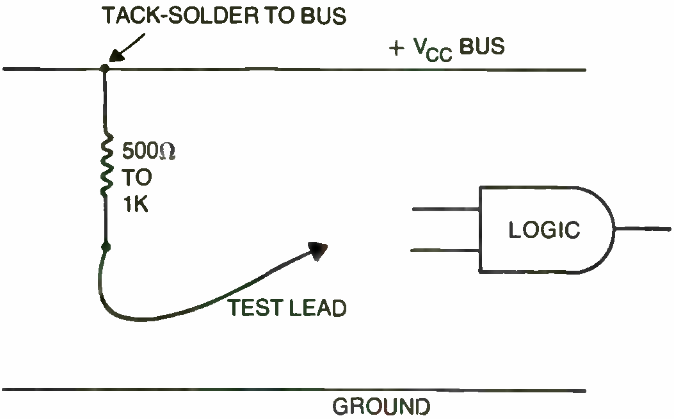


Fig. 13-10. When using the VCC voltage to create an artificial test logic pulse, use a current-limiting resistor for protection of the logic as well as the VCC bus.

end of this resistor; use the other end as your pulser. Compute the value of resistor from the VCC voltage and the allowable current for the type of ICs or transistors is use. For a 5V VCC, this will run about 500 to 1000 ohms.

Contact Bounce

This is a situation that can foul up automation systems and can turn two or three program units on in very quick succession. Contact bounce occurs in a switch or a relay where the tension of the springs is getting weak; instead of one solid make, they momentarily break the circuit, then make contact again. There may be two or three pulses formed this way. The same thing can happen in the keyboard of a programmer. In this case, it programs unwanted information into the memory.

Detecting bounce is not easy, and it depends upon how fast the instrument can respond. A oscilloscope may not be much use here because the pulse may be too fast for you to spot it on the trace. The logic probe is a better indicator. It will have a pulse stretcher in it that will allow it to blink on at least a couple of the bounces. Attach the probe to the bus where bounce is suspected, and pulse the unit. If contact bounce occurs, the probe will blink more than once very rapidly. You can signal trace in this manner until you chase down the offending unit. There isn't any repair except replacement of the particular relay or switch.

Isolating a Defective IC

When troubleshooting has isolated a problem to a pair of ICs, the logic probe can help isolate the faulty one if there is a current-limiting resistor between them. First, place the probe at the output of the driving IC and pulse the unit. If the pulse is normal (a normal pulse will light the probe), then move over to the load side of the resistor to measure the pulse. If the probe doesn't light, either the resistor is open or the load IC is shorted. A low-range voltmeter can also be used for this test. The voltmeter will indicate if there is voltage or not, and how much. If the voltage is present but low, then the load IC either has leakage or is shorted. If the pulse is low from the driver and about the same on the other side of the resistor, there is something wrong with the driving IC. If there is no resistor in between, there is no way of isolating the defective unit since they are directly tied together. But you can find a faulty trace between the two to be the problem. So if the pulse out of the driver is okay, but nothing at the load, then slide the probe tip or meter probe along the trace. As soon as the break is passed, the probe will go out or the voltage will disappear.

Signal Indicator

When a remote pickup system is in use, if the pickup antenna can be rotated, then the best signal-strength location can be determined as follows. Connect a 50 μA DC meter to the grid-current test jack of the first limiter. (You may wish to add a switchable isolating resistor for very strong signals.) The transmitter is turned on at the remote site and the antenna rotated until the meter peaks. This is the best pickup and is a good indicator of signal level.

High and Low Side

As mentioned earlier, many automation systems switch the "low" side of the circuit (Fig. 13-11); that is, they switch the ground of the relay or bus. When troubleshooting the system, you may desire to artificially switch the system by

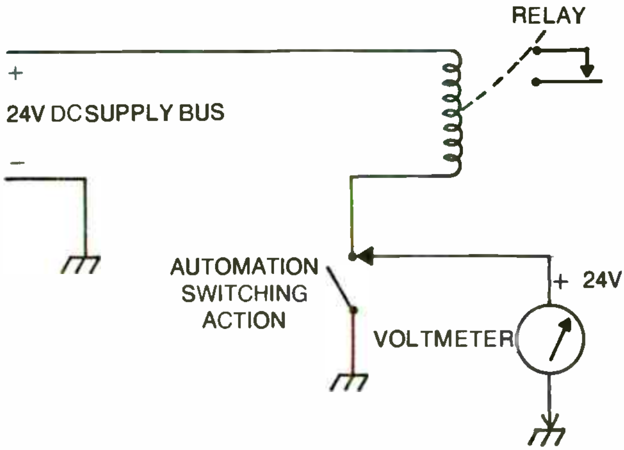


Fig. 13-11. Automation switches the "low" side of a circuit. Without current flow, the supply voltage will be measured at the "low" end of the coil.

grounding the bus, but the meter will read the supply voltage on the bus until the switch occurs. Unless you know for certain this is the ground side, don't do it. If it is the "raw" bus, you will blow the circuit breaker and perhaps a few series diodes to boot.

The best way to identify the bus without actually running down the cable is to wait for a normal switch pulse or have someone step the system through its normal switches. Have the voltmeter across the bus and ground. On low side, the voltage will drop to zero during the switching action since it is now at ground. If the voltage doesn't change, you have the high side of the circuit. For later reference, mark the terminal and perhaps the prints to show this information.

Transients

A logic probe can be used to detect transients on logic-level circuits, but don't use it in relay circuits where the voltage is out of its range. The oscilliscope is the better instrument for this, but you will have to observe quickly because the trace will flash on and off the screen very fast. Connect the scope across the bus, and set the sensitivity so that the 24V DC will only deflect one or two divisions. When the circuit is turned on, there may be a positive-going overshoot that is about four or five times the relay voltage. The deadliest one will come at turnoff, and this will go in the opposite direction, that is, negative. It may be more than 20 times the relay voltage. If your transient suppressors are working, the pulses won't appear at all, or only slightly. One word of caution: If you find such transients on a switching bus, try not to make too many switches without correcting the problem. As you keep turning the relay on and off, these transients are belting the solid-state units on the receiving end. You can blow out a whole bank of solid-state units in one shot.

Chapter 14

Proof of Performance

The station's operation must be in compliance with the FCC Rules, and within the tolerances specified in the technical standards *at all times* the station is in operation. Aside from that, the rules require that each station make a comprehensive set of measurements at least once each calendar year to demonstrate that the station is capable of operating within the standards. This required set of measurements is called the *annual audio proof of performance*, or *proof* for short.

COMMON ASPECTS

Although the AM and FM measurements are somewhat different, there are many factors common to both proofs. These will be discussed in this section.

Meaningful Measurements

For the engineer to make meaningful measurements, he must understand the test equipment that will be used and the methods the particular instruments require. If the equipment is new to the engineer, he should practice with the test instruments and read their instruction manuals until he feels confident he can use them properly and can obtain accurate results.

Test Equipment

If you are in a position to select the equipment that will be purchased for the proof package, select only quality equipment. Equipment with the necessary accuracy, wide bandpass, and stability will have its price, but avoid the "cheapies" and kits. Now, you may have difficulty selling the nontechnical, cost-minded station manager on the price tag, but give it a good effort. In a sense, this equipment will be providing an independent standard against which the station will adjust its operating equipment. If this standard is inaccurate, so will the station's adjustment, permitting it to operate outside the rules' tolerances.

Special Arrangements

The station engineer may find it convenient to make up special patching arrangements or perhaps switching units which will make the tests easier in some cases. These can avoid a lot of "haywiring" during the tests. But when you plan to build a special switching unit or use special patchups, check these out well ahead of time. Actually make some test setups either in the shop or on some part of the system that is idle at the moment. Especially measure the signal output levels, for it is possible the particular arrangement is affecting the loading on the oscillator or changing the impedance of the system.

As you will recall from an earlier chapter, the mismatch of impedance can affect both signal amplitude and response. Also check out any such arrangement carefully. Naturally, this checkout is only required when a new arrangement is set up, but if there is anything special about it that can't obviously be repeated the next time, make a note for future reference.

Inverse Function

Audio proof response measurements are made differently than in ordinary cases. In the ordinary case, the audio generator would supply a reference tone and various other tones to the input of the amplifier *at a constant amplitude*. The output of the system or amplifier would be measured directly and compared to the reference. If the response were down, then the output signal for that tone would be down so many decibels.

In the proof measurement, the measurements are the inverse of this procedure in that *the output of the system is held constant*, and the input amplitudes from the signal generator are adjusted to make the output constant. In this case, the output is the required percentage of modulation for a particular set of measurements.

Since the output is held constant, the intput signal amplitude is what's measured. The changes of the input signal will be the inverse of the system response (Fig. 14-1). For example, the input signal variation in the FM proof will actually describe a *deemphasis curve* instead of the system's 75 μsec preemphasis curve. To plot this curve for a proof, all the signs of the input signal curve must be changed to the opposite value. That is, if the figure is plus, then it must be changed to minus. Needless to say, in the small hours of the morning this can become confusing.

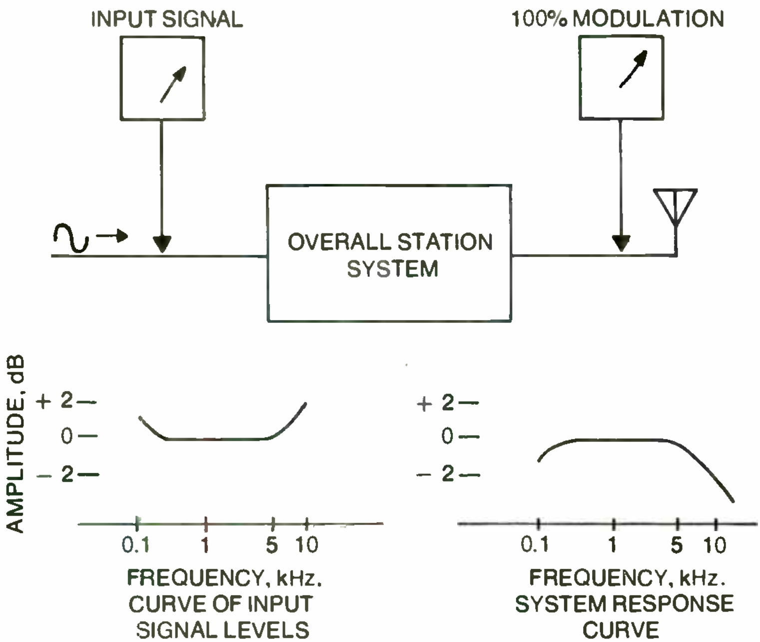


Fig. 14-1. A plot of the input signal levels for different tones while holding the output of the system constant will describe a curve exactly opposite that of the system response.

Measuring the Input

Since the input amplitudes are what is used to plot the system response (Fig. 13-2), then it is important that an accurate measurement be made of these levels. There are at least three ways of doing this. In the first and simplest method, a variable attenuator is used at the output of the signal oscillator to control the level into the audio system. An audio

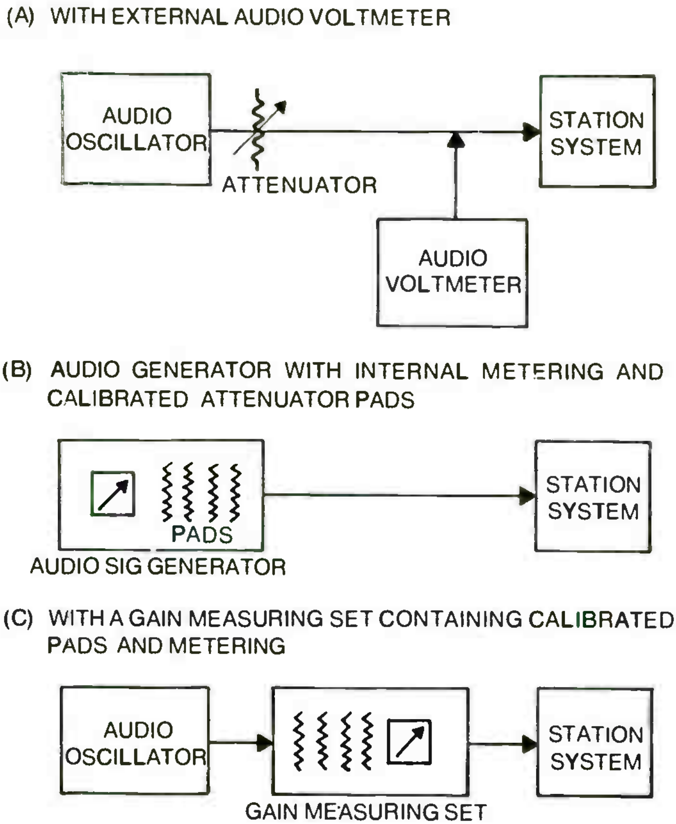


Fig. 14-2. There are at least three ways of measuring the input signal levels.

voltmeter with internal calibrated pads is used across the input of the system to actually measure the signal amplitudes directly. The usual audio voltmeter is calibrated to read in decibels. If your meter is not, then the method is not simple, as you would have to calculate all the decibels, since the rules' specs are given in decibels.

The second method is to use a signal generator that has its own internal metering and calibrated output pads. The output of the oscillator is adjusted to a given value each time, usually +10 or +15 dB, and then the desired attenuation is applied by internal calibrated output pads.

The third method uses what is called a *gain measuring unit*. This is a unit with metering and calibrated pads and switching. The signal generator is fed into the unit, attenuated properly, and measured there before feeding to the audio system.

Signal generators and attenuators are designed to operate at some given impedance value, usually 600 ohms. In many cases, although the unit may have switches to select other output impedances, the actual signal level will not be the same as at 600 ohms. Consider for example, a signal generator with internal meter and calibrated output pads. The unit is calibrated in decibels referred to 1 mW (dBm), which means 1 mW into a 600-ohm load. With a 600-ohm load, then, when the internal meter is set to it normal operating value, the pads will attenuate the correct amount, and the output signal will be the indicated value of the pads and meter.

But if a 150-ohm output is selected and properly terminated with 150 ohms, the actual output signal level will be much less than before, something on the order of 6 to 8 dB less. Check the instruction manual for a conversion chart that can be used; or simply measure the output in this mode, but have it properly loaded. This difference will be a constant and will hold across the bandpass. It can be misleading though—another reason why the engineer should know the instrument he is using.

Plotting

The amplitude response and the distortion measurements can be more effective when they are plotted in graph form rather than in a long vertical row of figures. The graph will show the whole system response or distortion at one glance (Fig. 14-3). A full set of measurements must be made at three or five percent modulation. Plot the response curves for each of these percentages on the same page, not on the same reference line, but three or four separated curves on the same page. The FM response can't be done this way because of the preemphasis curve, but the distortion measurements can.

If you will also mark in the limits of tolerances permitted (also in graph form), one glance can show whether the system is making specs easily or just barely.

Forms

No standard form is required, but the presentation must be readable and obvious—especially to the inspector. You may use any form that someone may advance as a standard (there

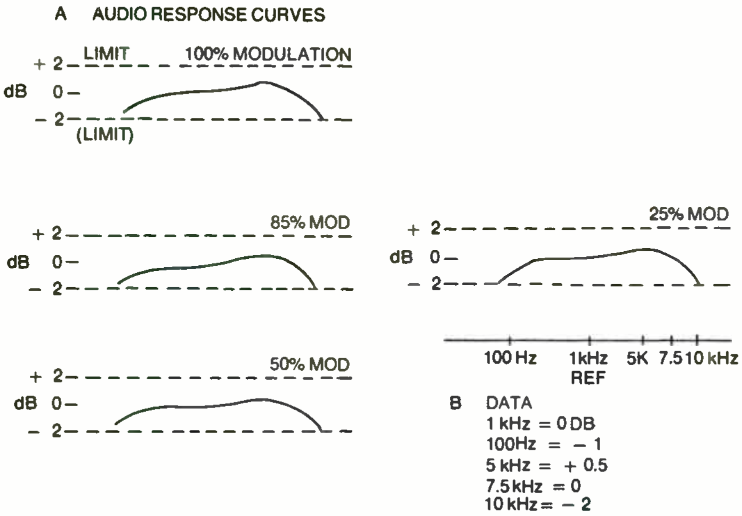


Fig. 14-3. A graph (A) is more expressive of results than a vertical row of figures. (B) Plot similar results on the same sheet.

is no FCC standard), or you may make up your own. Actually, forms are not difficult to make. I simply used semilogarithmic graph paper that is available at any drafting supply house and many book stores. By use of such paper, the spare sheets can be used for a variety of purposes. When used for the proof, a few simple limit lines and division values are added, along with pertinent data such as name of curve, etc. This is not much work. However, for plotting the FM audio, I do use a preprinted form that has that 75 μsec curve and limits drawn in. Whatever form you use, make it clear and label it for what it represents.

Records

The rules require that a description of the equipment and procedures used be explained in the proof. Use your own words to describe how you made the particular measurement. You may do this on the sheet with the measurement, or on an adjacent sheet if the measurements and results take up the whole sheet. If the measurement is something very special, then this procedure is important for your own information and will help you repeat the same measurement at some later date.

As part of your description, it is helpful to draw a block diagram of the equipment as it is arranged in the measurement. Show jack numbers and pertinent signal levels where this is appropriate (Fig. 14-4).

Keep a Log

A log of the transmitter operation must be kept during the measurements, just as it is required during programming. Station identifications must also be made on the hour. So arrange a tape machine that can be switched into the system (or patched in) to play a prerecorded station identification. Don't change any of the other system adjustments, or the calibrations will be out of kilter.

Rather than keep a *program* log, show when these identifications were made in the *remarks* area of the transmitter log itself. And if it was necessary to make major changes to bring the system into tolerances, such as changing the PA or AM modulator tubes, then make these entries on the maintenance log.

The operating log during the proof period should be kept with the proof itself, rather than placed in the regular log files.

When all the graphs are drawn, combine all the pertinent sheets into a single volume or package. The engineer making the measurement must sign and date it. He may do this on a title page, or each individual sheet can be signed and dated. The proof is not acceptable to the FCC without this signature and the date the proof was made.

Preliminaries

The proof itself will require many measurements, and this will be time-consuming. The system should be in correct operation before the actual measurements begin. Some preliminary measurements should be made on the system before the proof itself begins. Run a few measurements that outline the system conditions (about what was recommended for regular maintenance checks).

To do an outline, run response measurements for at least three audio frequencies. Use the 1 kHz data for reference, then the lowest audio and the highest audio frequencies that will be used. Check distortion at these frequencies also, and make a noise measurement. If all these are in their normal range, then you can expect the rest of the measurements to fall into line. If

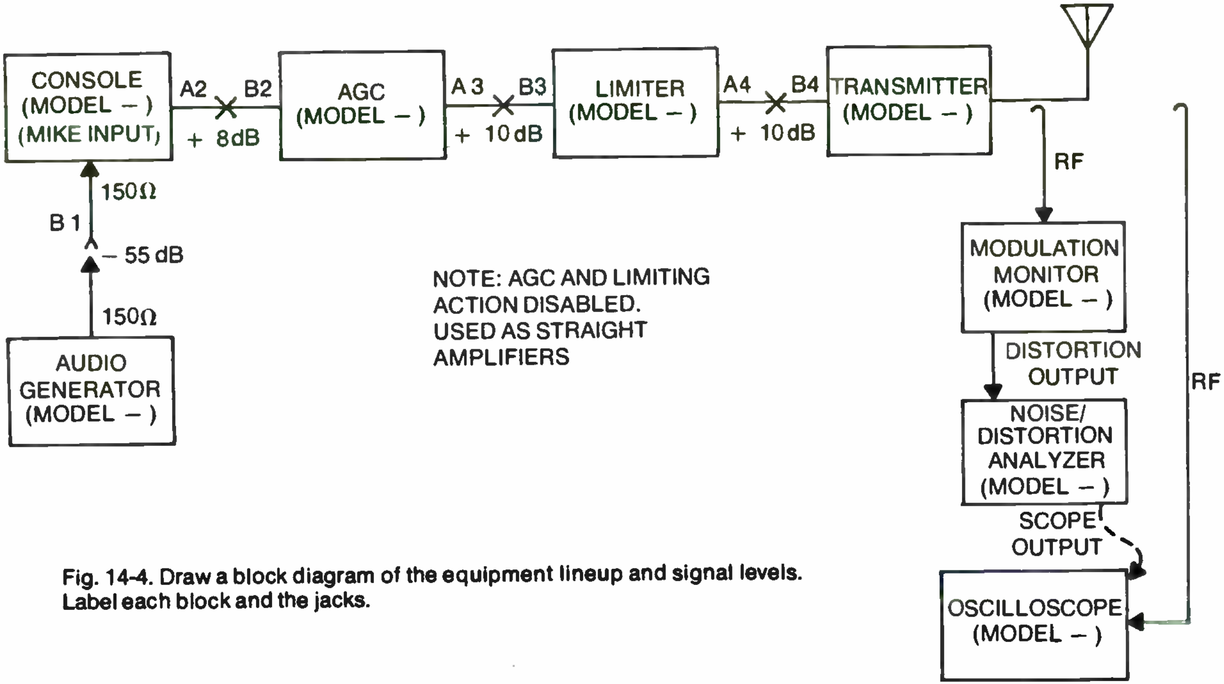


Fig. 14-4. Draw a block diagram of the equipment lineup and signal levels. Label each block and the jacks.

any are borderline or actually out of tolerance, correct these problems before doing the proof. It may be that the PA or AM modulator tubes must be changed or noise problems corrected.

Noise and Distortion

The usual distortion meter is a bridge arrangement which cancels out the fundamental tone and reads all that is left over as distortion (Fig. 14-5). Part of this figure can be noise in the system, so if the distortion readings are coming out high, use the oscilloscope to identify what is actually being measured on the meter.

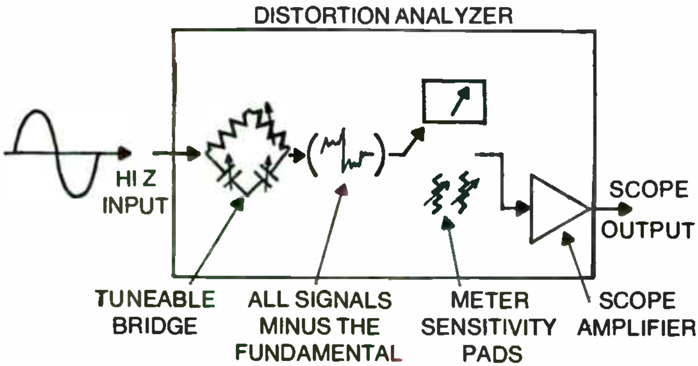


Fig. 14-5. Basic distortion analyzer. Bridge circuit cancels the fundamental tone, and the meter reads everything remaining, including noise. Analyzer will also contain an amplifier to feed an oscilloscope the same information the meter is indicating.

If the scope is synchronized or swept with the power line frequency, hum will show up as a single loop for 60 Hz, a double loop (figure-eight) for 120 Hz, etc. Some supplies (three-phase) will produce three loops or seven loops, depending upon the type of supply. Solid-state supplies may have switching transients at the leading and trailing edge of each half-cycle in the ripple pattern. Other noise, such as high-frequency shot noise, will be evident as "grass" throughout the pattern on the scope, while distortion will be various parts of cycles which are severely misshaped.

By interpreting the noise pattern on the oscilloscope, the direction or location of the required maintenance can be pinpointed. But clean up this noise problem, or all the distortion measurements as well as the noise measurements themselves will be higher than they should be, and out of tolerance.

Calibrations

Since the modulation monitor will play an important role in both the AM and FM proofs, make sure it is in calibration. The AM monitor can best be checked against an oscilloscope and the FM monitor as described in an earlier chapter. The percentage of modulation is important; it is the reference against which the response of the system is measured. If the AM monitor is out of calibration, then at the high percentages of modulation the transmitter may actually be overmodulated, and this will yield high distortion readings.

System Aspects

The proof must be made with the system in its normal operational mode and with the same equipment lineup. The only exemption to this is that AGC amplifiers, peak limiters, and similar processors must have their special action disabled and the unit run as a straight amplifier. If this can't be done, then the unit must be patched out of the circuit. To run response measurements through such processors would be meaningless, as the AGC units would correct the levels.

Now if telephone circuits are used as STLs and these have fixed equalizers (which they should), then these must be left in the circuit. Dynamic equalizers, which are really signal processors, should have their action disabled.

Normal operation also means that the transmitter is connected to its antenna system. Although a dummy load may be used for maintenance purposes, it is not permissible to run the proof on a dummy load.

Gain Change

All stations use some form of signal processing. By switching out the special action, the system gain will increase because most AGC amplifiers are normally in compression by 10 or 15 dB. When this is removed, the system gain will increase by the same amount. So allowance must be made for this change in gain.

Everything in the system could be left as it is, minus the processing action, and the input signal level run that much lower. But this will make the system ahead of the processors work much easier than normal. It will also degrade the signal-to-noise ratio. Nor will it show up headroom problems in any of the amplifiers.

I recommend that all the amplifiers be run in their normal modes. To take care of this increase in system gain, correct it at the processors themselves. That is, reduce their gain. If these units must be patched out of the circuit, then the last amplifier in the chain should have its gain adjusted the correct amount. Most modern processors, however, have a switch to disable the special action so that the amplifier acts as a straight amplifier. This is the better procedure, as the measurements will then include those amplifiers which are normally in the chain during programming.

Components

If the preliminary checks indicate problems, correct them. But make sure the corrections are permanent, not just some special adjustment to make proof figures. For example, suppose the preliminary AM tests show an excessive carrier shift, with perhaps high distortion also. The engineer changes out the PA tubes and the modulator tubes, and now the measurements are what they should be. It is not permissible to run the proof through these new tubes and put the old tubes back in the transmitter.

Remember, the proof is a certification by measurements that the system is in compliance with the technical standards. But the station must be in compliance with these technical standards all the time—not just at proof time. To put those old tubes back in operation places the station in noncompliance with the rules. Should the inspector walk in the next morning and observe the out-of-tolerance carrier shift, or perhaps *hear* the serious distortion that showed up last night, the station is in for a citation.

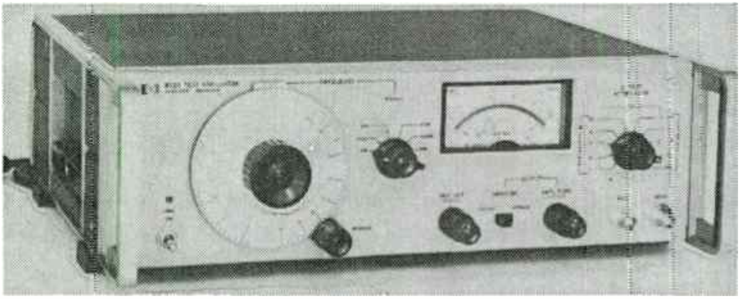
Proof Package

The basic test equipment required for the AM and FM proofs is the same. This will consist of an audio signal generator, audio voltmeter, calibrated pads, and a noise-distortion analyzer.

The audio signal generator (Fig. 14-6A) should be of high quality, with very low internal noise and distortion, and good stability. A quality instrument will easily have specs of better than −90 dB noise factor, and distortion of less than 0.5%. It may contain its own voltmeter and calibrated output pads.

If the voltmeter and pads are not built in, then an external voltmeter and calibrated pads are required. You must be able to accurately measure the input signal amplitudes to the system.

A noise-distortion analyzer is required (Fig. 14-6B). This may be a combined unit or separate units. Quite often, the same instrument will measure both noise and distortion. The analyzer must pass a wide band of audio frequencies and their harmonics. The unit is measuring harmonics, and if the highest audio frequency used (in FM) is 15 kHz, the second harmonic is 30 kHz. The rules require that harmonics be included in the measurements to at least 30 kHz. Accurate pads must be provided internally to calibrate the meter.



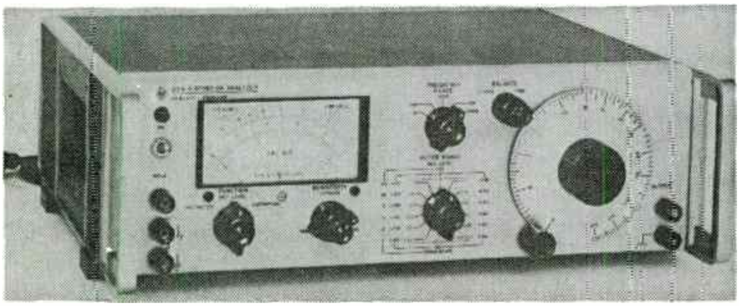


Fig.14-6. (A) Half of the proof package is the audio signal generator and attenuator pads. Shown is the Hewlett-Packard Model 625A test oscillator. When selecting a unit for the proof work, obtain the various options which make it more suitable to this use. (B) The other half of the proof package is the Hewlett-Packard Model 331A distortion analyzer. This unit has several options that should be obtained to make it more suitable for proof work.

Additional Equipment

A good wideband oscilloscope will prove very useful to both the AM and FM proofs and when making stereo measurements. In AM use, the scope can be used to calibrate the modulation monitor and identify what the distortion analyzer is indicating. For FM, it will serve the same identification purpose and will help set up the stereo generator and stereo phasing adjustments.

A regular shortwave communications receiver will be necessary in the AM proof to check for spurious and out-of-band emissions. This receiver can also be used to check FM transmitter deviation and calibrate the FM modulation monitor.

THE AM PROOF

Part 73.47 of the FCC Rules describes the specific measurements that must be made during the proof, while Part 73.40 outlines the tolerances or limits within which the measurements must fall. Both of these requirements are highlighted in Table 14-1 for your convenience. Since the rules are undergoing many changes these days, before actually conducting a proof, check the current rules.

Preliminaries

As discussed earlier, before diving into a proof, check out the test equipment, the setups, and similar arrangements in the shop first. Feed the signal generator's output directly into the distortion analyzer. If the noise and distortion are out of tolerance, it won't be possible to measure system values very accurately. If distortion is high, use the scope and look at the audio signal. It may have the peaks clipped. A clipped signal will create very high distortion figures.

During this checkout, make sure all the test leads, patch cords, jacks, and other accessory equipment used will work. There is nothing more frustrating than to try to make measurements when the test leads are erratic or ground connectors keep falling off. By making sure all the equipment is actually working correctly, you can devote your attention to making the proof measurements.

Check out the system itself with some spot measurements. Adjust the modulator biasing for minimum distortion, as well as the RF drive, etc. If there are any hum-balancing pots,

Table 14-1. AM Proof Requirements

AUDIO RESPONSE

- Set of measurements made at 100%, 85%, 50%, and 25% modulation.
- Each set to include: 100, 400, 1000, 5000, and 7500 Hz.
- 1 kHz must be used as reference.
- Limits: ± 2 dB from 100 Hz to 5 kHz of the 1 kHz reference.

AUDIO HARMONIC DISTORTION

- Set of measurements to be made at 100%, 85%, 50%, and 25% modulation.
- Each set to include: 50, 100, 400, 1000, 5000, and 7500 Hz.
- Limits: 7.5% when modulating 85-100%. 5.0% when modulating 0-84%.

CARRIER SHIFT

- Measurement to be made at 100%, 85%, 50%,and 25% modulation.
- Limit: 5%.

NOISE

- Measurement of noise to be referenced to 100% modulation with audio modulating tone of 400 Hz.
- Limit: − 45 dB (below 100% modulation).

SPURIOUS RADIATIONS

- Between 15 kHz and 30 kHz from carrier: − 25 dB (unmodulated carrier reference).
- 30 kHz to 75 kHz from carrier: − 35 dB
- Any emmission higher than 75 kHz from carrier:
  The lesser of: 43 + 10 log (power in watts).
  − 80 dB.

CERTIFICATION

- Description of equipment used, procedures, date measurements made, and signature of engineer making the measurements are required.

adjust these for the lowest hum value, but balance these against the overall system. If any of the spot measurements shows up as marginal, check it out. If this requires the modulator and PA tubes to be changed, then do so and make all the necessary adjustments required by the change.

When the modulator bias is changed, this will change both the audio input requirement and the modulation percentage. If you get halfway through the proof and decide these must be done to make the rest of the measurements fall in place, then the whole proof will need be done over since the levels and other calibrations will now be different. Adequate time spent on the preliminary checkout and maintenance will be time well spent.

Monitor Calibration

The modulation monitor can be used as the detector to make noise and distortion measurements, or a separate detector can be used. Some distortion analyzers have an RF detector built into them to make an AM proof. You may use either one, so here are some factors to consider.

When the monitor is used, if it has a high noise and distortion level internally because of some problem, these will be added to the measured results of the system.

An RF detector must have the correct RF input level or it can become very nonlinear. Its output under these conditions can be distorted or noisy, or both, and these will be added to the measurements.

I have used both but find the monitor itself far more convenient, and seldom are the internal problems bad enough to detract from the proof measurements. Besides that, the monitor is a normal unit used in the everyday operations, and it needs a checkout also. If there are any problems in the monitor, correct them as you would problems in the audio system.

The modulation monitor will be used to check the percentage of modulation. So check this with tone modulation and an oscilloscope. Run the three measurements (1 kHz for reference) and make any adjustments needed to make the monitor meter agree at 100% modulation as indicated on the scope. Then try 100 Hz and 5 kHz to see if the meter tracks properly. While you are at it, set the peak flasher adjustments.

When the AM transmitter is modulated 100% with tone modulation, some very high currents and RF voltages are being developed. The modulator and PA tubes can overheat by sustained tone modulation. Remember that tone has a higher average value than program material, so these stages are working very hard. Be intermittent with the measurements. That is, modulate with tone to the correct percentage of modulation, make the calibrations and measurements for the tone, and take the modulation off to allow the equipment a brief rest period between measurements.

Ball Gaps

Modulation transformers, RF coils, and capacitors have ball gaps across them for protection against too-high voltages that could cause them to exceed their ratings. During tone modulation, at 100% modulation, the instantaneous peak voltage on the positive peak of modulation will be twice that of the peak RF voltage alone (Fig. 14-7). Besides that, these peaks will be recurring continuously until the tone is removed. These high peak voltages can cause the ball gaps to arc over. If they do arc over, check out the setting of the gap for the proper spacing. There may be dust or other debris in the gap. If the gap is improperly set, adjust it according to the spacing given in the instruction manual. Don't simply open the gap as far as it will go just to prevent arcing. That defeats the purpose of the gap, and the component can be damaged.

What Power?

Many stations are licensed to operate at two different output powers, one for daytime and another for nighttime. You are required to make the proof only at the highest licensed power of the station. If this is the daytime power (usual case), then operate at that power for the proof.

The transmitter should be tuned and peaked up to its most efficient operation, and the output power should be right on 100% of its normal licensed power. Remember that you must also keep a transmitter log during this period.

Plan Your Program

Determine ahead of time the routine you will follow in making the measurements. If you do this, the measurements can be made in an orderly fashion. There will be less likelihood of forgetting a particular measurement that would require you to remake the arrangement and calibrations just for that measurement.

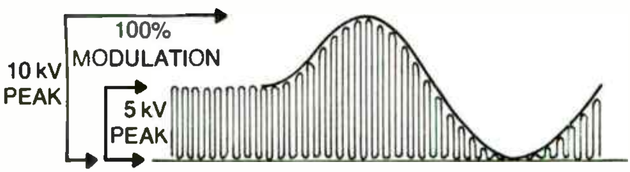


Fig. 14-7. In AM, the peak positive voltage at 100% modulation is twice that of the unmodulated carrier. Incorrectly set ball gaps will arc over.

Do this planning on paper—use a tablet. First, draw a block diagram of the equipment lineup as it will be used, show the jacks throughout the chain, and label the blocks for the equipment units they represent. If you plan to use matching or isolation transformers, then draw these in also, and show the impedances. All this need only be readable; you can make the pretty pictures later.

Next, line in two vertical columns for each percentage of modulation. As the main heading, show the modulation percentage, and subhead each column RESPONSE and DISTORTION. You will need four pairs of columns. Over in the left margin, show the audio tones that will be used. If you are going to make any in-between measurements, place them in order with the other tones.

Alongside the 400 Hz figure, write NOISE-CARRIER SHIFT. This is a reminder to make these measurements at that frequency. Down below the vertical columns, show NOISE and a blank line to write in the noise figure, and make four entries for carrier shift. The noise is made only at 100% modulation, while carrier shift is measured at each percentage.

Setup and Levels

Go through and switch out the AGC, limiting, and other processing action. Terminate the input to the transmitter for this initial setup, so as to keep modulation off the air.

Feed 1 kHz at the proper impedance into the main microphone input on the console. This will be a jack in the jack field in most instances.

Switch the tone up on the console and adjust the faders to the normal settings. Adjust the input signal from the generator to −50 or −55 dB as measured on the external voltmeter or signal generator metering. The faders should be approximately in the normal positions. That is, the fader and the master gain control.

The VU meter should be reading 0 VU. If it is not, then tweak up one or the other controls to get it on zero. But with step faders, they may jump 2 dB at a time, so avoid being on a "crack." Get a solid reading. Keep the input signal at an even value of −50 or −55 dB. This makes it easier to calculate any differences during the run.

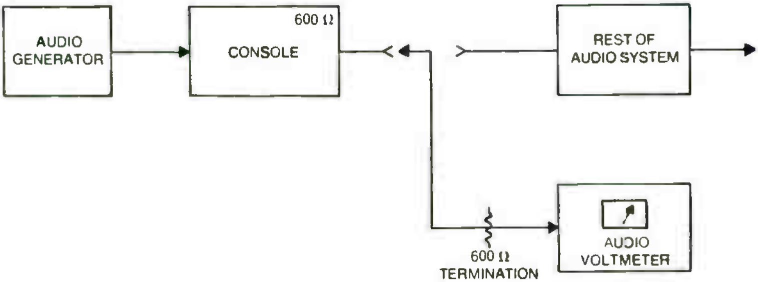


Fig. 14-8. Use the audio voltmeter to measure output of each unit in chain. Add proper termination to input of voltmeter.

The signal level recommended here is approximately 10 dB higher than normal microphone levels, which are usually −60 to −65 dB. This level will check out the headroom in the system and makes up for the difference between signal peaks and sine wave.

Measure the Levels

Now measure the levels throughout the chain by patching in the the audio voltmeter with a proper termination on its input so as to provide a load for the measured amplifier (Fig. 14-8). Adjust each amplifier to its normal range setting. If some have been badly misadjusted, this is a good opportunity to restore them to their normal range. The final amplifier should have an output of approximately +0 dB, which is a standard transmitter input level.

Now, allow this signal onto the carrier and check the percentage of modulation. The particular modulator bias adjustment may require a little different signal than +10 dB, so adjust the output amplifier to make up this small difference. Again go back and measure that level with the voltmeter after 100% modulation is reached. At the jacks on your block diagram, you should have listed each of the levels measured at 1 kHz.

The system is now set up and calibrated to begin making the measurements. Do not change any of the settings from here on, or the calibrations will be destroyed. The only signal level change to make will be at the signal generator itself and its attenuator pads.

Audio Response

This measurement is made by adjusting the input signal amplitude, which is feeding the main microphone input on the console, until the correct percentage of modulaton is indicated on the calibrated modulation monitor. This input voltage must be measured accurately. As mentioned earlier, there are at least three ways to do this, depending upon the equipment used. For an example, a signal generator with an internal meter and calibrated output pads can be used. First, set the generator to the correct audio frequency, and for the reference, use 1 kHz. Adjust the generator output control until its meter reads +10 dB. (This is the calibrating point for this instrument in the example.) The output signal amplitude will be the algebraic sum of the meter reading and the total of the pads inserted. So add all the pad values used to the meter reading. If your meter now reads +10 dB and there are enough pads used to produce a −65 dB loss, the +10 dB added to the −65 dB produces a −55 dB output level to the equipment.

The question at this point is: Is that actually −55 dB? This is something you should have checked out in the preliminaries. Remember, the output impedance is adjusted for perhaps 150 ohms. Let's assume for our example that it is correct. Now write this down on the tablet, as this is the reference of 0 dB. But write in the actual value of −55 dB. In effect, you have now made the response measurement at 1 kHz at 100% modulation. Next switch the generator to another of the required tones, adjust the pads for 100% modulation, and write down the input value. Do this for all the required tones for 100% modulation.

Other Modulation Percentages

When you have finished all the measurements required at 100% modulation, then switch the oscillator back to 1 kHz. Adjust the generator output level by adding more pads until 85% modulation is reached. Again, write down the intput level; this is the reference for the 85% modulation run. Do the same at 50% and approximately 25%. I generally use 30%, because modulation meters don't have a mark to indicate 25%, so most of the adjustments for level must be by eyeball. The 30% figure does give a line on the scale to set up on.

Distortion

The distortion measurement should be made immediately following the audio response measurement. That is, once you have set the tone to reach the appropriate modulation level and have recorded the input level setting, don't change anything. Move into the distortion measurement. This will save both time and adjustments.

The input to the distortion analyzer should be connected to the distortion output terminals of the modulation monitor, or across the wideband detector if you are using one. In both cases, the circuit will be an unbalanced, high-impedance one, but so will the analyzer input. Make sure there is no loading resistor across the input of the analyzer, and since it is unbalanced, be careful of the polarity of the connection or patch plug.

To make the measurement, set the analyzer function switch to its *set level* position and the meter pads to the correct position for this calibration. Once calibrated, place the function switch into *distortion* mode and then set the frequency balance adjustments to null the meter reading to its minimum. Continue the null adjustment, removing pads from the meter circuit to increase its sensitivity. When the point is reached that the meter reading cannot be reduced further, then the meter reading and meter sensitivity pads show the distortion value of the system.

When the meter is very sensitive, tune the nulling controls very slowly. The null is very sharp and it takes very little to tune out of the null and perhaps damage the meter by overload. Another habit the engineer should develop is to immediately switch the meter sensitivity pads back to the calibrating value as soon as the measurement is made. If the analyzer is left in this position (very sensitive) and the frequency of the signal generator is changed, the meter can be damaged. This is no different than a regular test meter which, for example, is set to the 1V range and then placed across 120V.

Noise

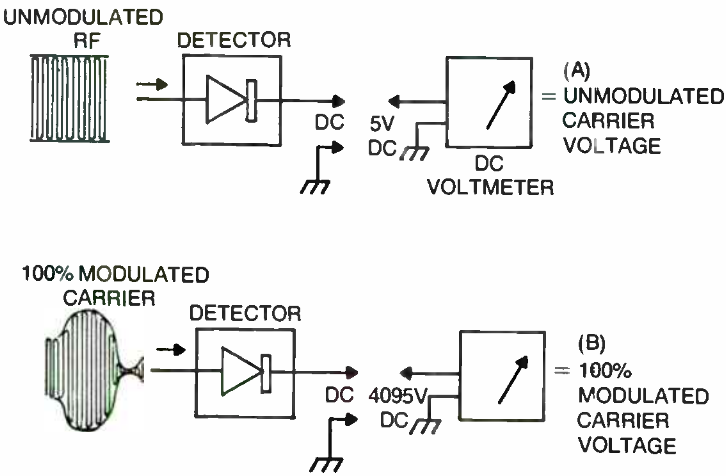
When the measurements at 100% modulation get to the 400 Hz tone, take a noise measurement. But do this after making the response and distortion readings, as there will be some slight change in the analyzer calibrations. When the other two measurements have been made, leave the modulation on the system, but now calibrate the noise meter to 0 dB. You may wish to increase the range of the meter circuit so as to allow for room to read the noise figure.

Once the meter has been calibrated, then remove the tone modulation and terminate the input of the system with a resistor equal to the value of the input impedance. The noise meter will drop to zero. Take out meter pads to increase the meter sensitivity until there is an indication on the meter. The sensitivity pads and the meter indication give the noise figure of the system in decibels.

Carrier Shift

The carrier shift can be read with a DC voltmeter across the output of the detector (Fig. 14-9), or can be read from the carrier meter on the modulation monitor. In most cases, the carrier meter on the modulation monitor is nothing more than a voltmeter across the internal RF detector, and it is calibrated in percent. So this is very convenient to use for the measurement. In either case, the voltage of the unmodulated carrier is read first.

On the monitor, the meter is set to 100%. Then the carrier is modulated 100% with 400 Hz tone and the rectified DC



THEN: $A - B = C$

AND: $\frac{C}{A} \times 100 = \%$ CARRIER SHIFT

EXAMPLE: $5V - 4.95V = 0.05V$

$$\frac{0.05V}{5V} = 0.01 \times 100 = 1\% \text{ CARRIER SHIFT}$$

Fig. 14-9. Carrier shift is the change in rectified DC voltage out of the detector between the unmodulated and modulated-carrier conditions.

voltage is again measured. With a regular meter the percentage of change must be calculated, but with the carrier meter the percentage is read directly off the calibrated meter scale. This measurement must be made at each of the percentage ranges when the 400 Hz tone is used. Thus there will be four measurements for carrier shift.

Out-of-Band Measurements

These are measurements of spurious radiations and harmonics from the transmitter. They may be made with a communications receiver (Fig. 14-10), but if there is a controversy or complaints, the Commission may require that field strength measurements be made.

If the receiver has an S-meter, this may be used, but you can make some small modifications and actually measure in decibels, although you must do some calculations. For this modification, bring out the AVC bus to a pin jack on the receiver (Fig. 14-11). Pick up the bus ahead of the AVC switch. The receiver gain must be controlled manually and not by the AVC, which must be switched off. Although not controlling the RF stages, the bus is still active, and this is where you want to tap in to measure the AVC voltage. Measure this voltage with a regular DC voltmeter.

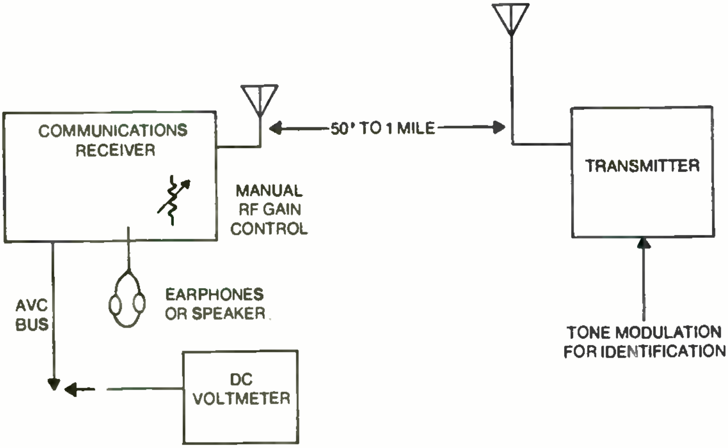


Fig. 14-10. Setup for measurement of out-of-band radiations. Depending upon how well the receiver is shielded, you may have to move away from the transmitter site up to 1 mile.

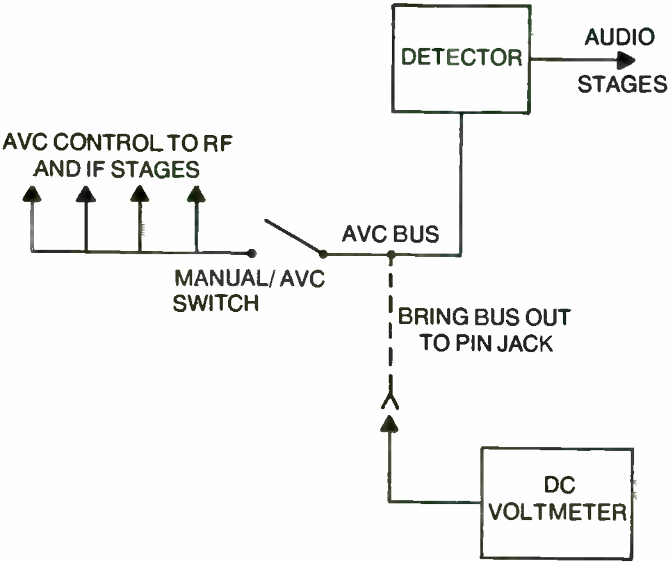


Fig. 14-11. Modify the receiver so that AVC bus can be measured.

The receiver may be used at the transmitter site if it is well shielded. Be careful of overloading the front end with signal. An overload condition will create spurious signals within the receiver which will be deceiving. If shielded well, the antenna terminal itself will often be a sufficient antenna. If there are overload problems, move away from the transmitter as far as one mile if need be.

Modulate the transmitter with tone for identification purposes. Search the broadcast band and all the other bands on the receiver for any readings. Those which are multiples of the carrier frequency are harmonics, while any in between are spurious emissions. First tune in the carrier on the receiver and measure the AVC voltage on the voltmeter. This should be set to approximately 40V or higher by the manual GAIN control on the receiver. Avoid setting the receiver gain in the overload or distorted mode. Once this is set, do not change the RF gain setting, as the arrangement is now calibrated. That 40V becomes your 0 dB setting at carrier. Now search all the bands carefully and note any readings on the voltmeter.

The tolerance for out-of-band measurements is a little confusing at first reading. First of all, it is doubtful the ordinary communications receiver can tune within 15 kHz of the carrier to check the bandwidth. This calls for a very high degree of selectivity and rejection of the carrier. You may be able to get a reading at 75 kHz if there isn't some all-night station booming in at that spot. The tolerance for harmonics and other spurious frequencies in decibels is:

$$43\ \text{dB} + 10 \log (\text{power in watts})$$

or 80 dB, whichever is less. In this formula, the "power in watts" is the station carrier power and, in effect, reduces the station power to decibels.

The logarithm for a 250W station is 2.398; for 1 kW, 3.0; for 2.5 kW, 3.398; and 5 kW, 3.699. Multiply each of these by 10 to determine the decibel term for the power and add it to the 43 dB figure. Thus, for 250W, the tolerance is:

$$(2.398 \times 10) + 43\ \text{dB} = 23.98 + 43\ \text{dB} = 66.98\ \text{dB}$$

For the 5 kW station:

$$(3.699 \times 10) + 43 = 79.99\ \text{dB}$$

All higher power stations would only have to meet the 80 dB spec. as this would be the lesser figure.

To measure with the setup described, once you have calculated the tolerance, work backwards through the formula to find what voltage is the tolerance level as measured on the AVC bus voltage. For example, assume yours is a 1 kW station and the tolerance is 73 dB. You are working with voltages, so use the voltage formulas. Assume you decided to set the carrier at 40V on the meter.

$$73\ \text{dB} = 20 \log 40/E_2$$
$$73/20 = 3.65$$
$$\text{antilog } 3.65 = 4467$$

This provides the voltage ratio of the formula. Since we used 40V as E_1, then $E_2 = 40/4467 = 0.009\text{V}$. You need a DC voltmeter with a sensitive scale, but any readings higher than 0.009V and the station is out of tolerance.

Wrapup

If all the measurements have been within tolerance, all you have to do now is the paper work. Plot or graph all the curves, draw the block diagrams, describe the procedures, and, in general, package the proof into a presentable single volume. Don't forget to date and sign the proof and number all the pages in the volume. The transmitter log that was kept during this period should also be combined with the proof as another page of the package. The proof must be kept at either the transmitter or the control position and be available for the radio inspector to review when he makes an inspection of the station. The proof must be retained for a period of two year.

You have worked all night; you are tired and want to get home and go to bed. But make sure all the program equipment is restored to its normal operational mode and all the processor actions restored. Check for switches left open or off, and check the jack fields for patch cords or terminations plugged in. If the transmitter was connected to the dummy load for any reason, make sure this is back on antenna.

FM MONAURAL PROOF

The FM proof of performance requires tighter tolerances than the AM proof, and since the bandpass is greater, there are more measurements to make. Part 73.254 of the Rules details the required measurements, and Part 73.317 describes the various tolerances permitted. These requirements are combined and highlighted in Graph 14-1 and Table 14-2. Check the current rules for any changes that may have occurred.

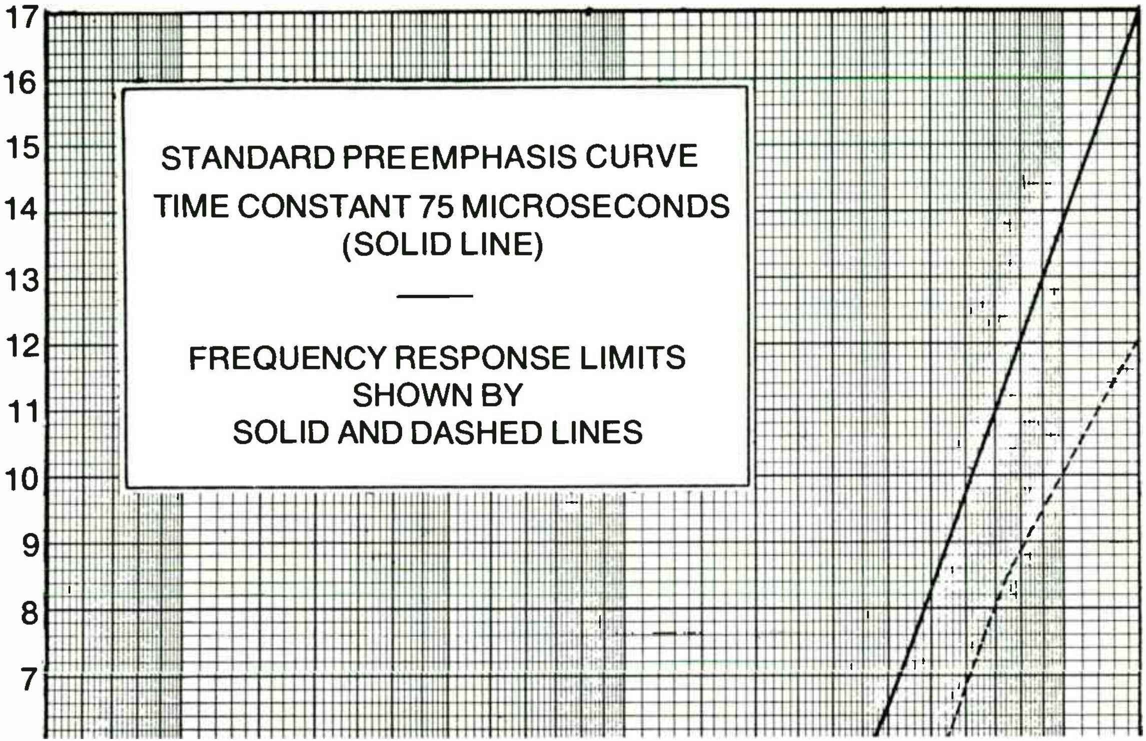
Main Mike Input

The proof is required to include all equipment between the main microphone input and the antenna. For many stations which operate with full-time automation, the location of the main mike terminals is a good question. Where are they? Most of these stations will have some standby live arrangement which can be used should the automation fail. This may be the recording booth, or it may be the control room of a sister AM station where simulcasting takes place. The station must decide how its own operation fits into the situation. The live type operation is no problem since it will have a regular control room.

Preliminary Checks

Check out the test equipment ahead of time, along with the test leads, plugs, cords, and anything else that will be used to make the measurements. This can be done in the shop, and anything that is faulty should be repaired.

Graph 14-1. FM Monaural Requirements



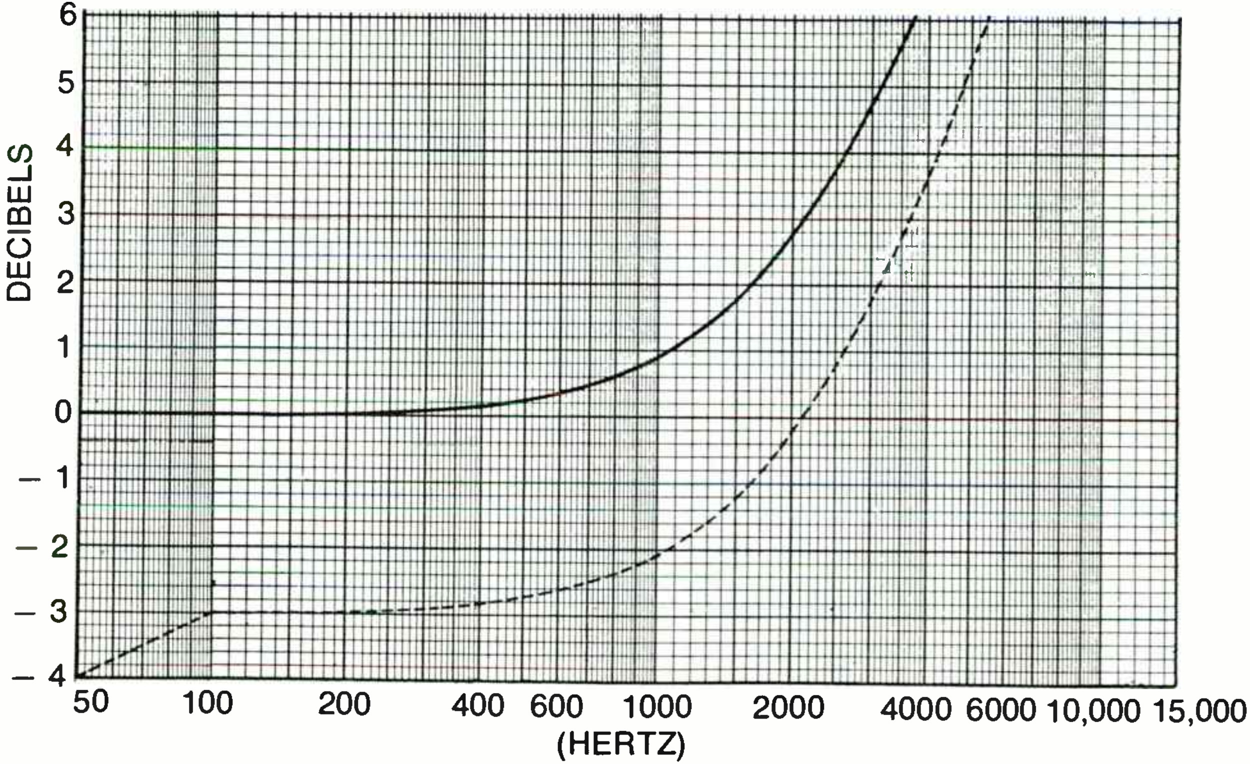

DECIBELS
6
5
4
3
2
1
0
– 1
– 2
– 3
– 4
50
100
200
400
600
1000
2000
4000
6000
10,000
15,000
(HERTZ)

Table 14-2. FM Monaural Requirements

AUDIO RESPONSE

- Set of measurements to be made at: 100%, 50%, and 25% modulation.
- Each set to include: 50 Hz, 100 Hz, 400 Hz, 1 kHz, 5 kHz, 10 kHz, and 15 kHz.
- Measurements to be made without deemphasis.
- Limits: System curve must fit within the standard FCC 75 μsec preemphasis curve.

AUDIO HARMONIC DISTORTION

- Set of measurements to be made at: 100%, 50%, and 25% modulation.
- Each set to include: 50 Hz, 100 Hz, 400 Hz, 1 kHz, 5 kHz, 10 kHz, and 15 kHz.
  Except: at 50% and 25% modulation, no measurement required at 10 and 15 kHz.
- Limits: 50 Hz, to 100 Hz, 3.5%, 100 Hz to 7500 Hz, 2.5%; 7500 Hz to 15 kHz, 3%

(note: 75 μsec deemphasis used in measuring equipment).

FM NOISE

- Measurement of noise to be referred to 100% modulation with audio modulating tone of 400 Hz.

(note: 75 μsec deemphasis must be used in measuring equipment.)

- Limit: − 60 dB (below 100% modulation).

AM NOISE

- Measurement to be made, referenced to 100% amplitude modulation of carrier.
  (note: 75 μsec deemphasis must be used in measuring equipment).
- Limit: − 50 dB (below level representing 100% AM).

CERTIFICATION

- Description of test equipment used, procedures, date measurements made, and signature of engineer making the measurements are required.

Check out the station equipment, especially any temporary hookup arrangement such as patching the recording booth into the system to replace the automation system. Be especially careful about impedance matching, and watch out for hum or other noise problems or faulty jacks. The jacks may not see too much use and can be dirty, and this can result in erratic measurements.

Run a few outline measurements to see if the system is going to fall into place or if there must be maintenance first. The tolerances are going to be tighter than in the AM proof, so look over these preliminary measurements very carefully, and if anything is borderline, correct the faults.

Modulation Monitor

If there is any question about the calibration of the modulation monitor, check out the carrier deviation with the shortwave receiver and carrier nulls as described earlier. The engineer may do this as a matter of practice, but if experience shows that the monitor remains stable, then there is no real need to make this calibration every time. Since the percentage of modulation is the reference point, this should read accurately.

Monitor Noise

All of the noise and distortion measurements will be made through the modulation monitor, so any internal noise or distortion will add to the system measurements. This monitor must have low noise and distortion figures of itself, because the system tolerances are very tight, and the preemphasis in the audio system places a greater stress on the noise factor.

Because of the preemphasis of the system, distortion readings are not required above 5 kHz on percentages of modulation less than 100%. The recovered audio becomes so low that it is not far away from the monitor noise factor. If the preliminary checks show high noise or distortion figures at the high audio tones, check the audio system itself right before it enters the transmitter. If it checks out okay here, there could be transmitter problems, but more than likely the problem is in the monitor circuits. Check the factory instruction manual for any maintenance tests they may suggest to determine this. Check out especially the audio circuitry in the monitor that feeds the distortion output terminals. This is usually on a different circuit than the audio monitoring (Fig. 14-2).

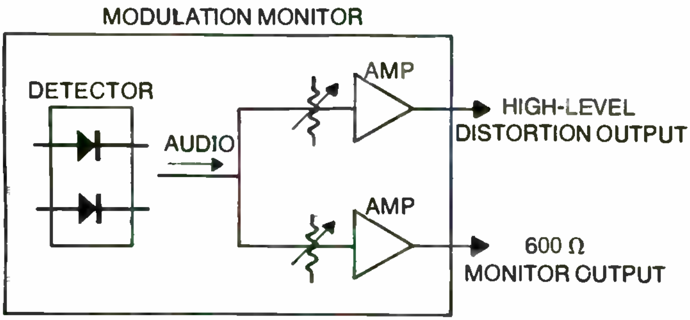


Fig. 14-12. The distortion output of the monitor often uses different circuitry than the audio monitor output.

Plan the Program

Plan out your methods and approach on paper. There will be more measurements to make, so allow for these. That is, you must measure at audio frequencies out to 15 kHz, so add these to your response and distortion columns. Draw up a block diagram of the equipment lineup and label the blocks and jack numbers.

Set Up the Reference

First, go through and switch out the AGC, limiting, and similar processing action. Again, terminate the input to the transmitter until the levels are set correctly in the audio system, making the adjustment at the processor to make up for the gain increase that occurred when the AGCs were removed from the circuit. Make sure the proper impedance match is used throughout, and especially between the signal generator and the system input. You are going out to 15 kHz, and an impedance mismatch will seriously affect the higher tones.

Set the signal generator for 1 kHz reference and then set up all the levels throughout the audio system as was discussed for the AM proof. It is the same procedure and will require approximately +10 dB at the input of the transmitter for 100% modulation.

Preemphasis

The audio system itself will have a flat response curve (or should have) across the bandpass; the 75 μsec preemphasis in the transmitter will produce a very steeply rising response curve as the signal passes through the transmitter. The modulation meter circuit does not have deemphasis, so when the measurements are made and the modulation meter is held at a constant percentage of modulation, the resulting audio curve will describe this preemphasis curve.

Perhaps it should be pointed out here that if the station is using the Dolby B noise reduction system, which effectively reduces the system time constant to a 25 μsec curve, this must be switched out of the system (the same as any processor) and the proof run at the standard 75 μsec time constant.

With this steep system gain at the higher audio tones, the engineer must be careful when switching from one tone to another on the signal generator. If, for example, he were making a measurement at 1 kHz and then accidentally switched the frequency multiplier to 10 kHz on the generator, the transmitter would be seriously overmodulated. This could cause damage to the modulator, the modulation meter, and distortion analyzer. So make it a habit to automatically switch in 10 or 20 dB of loss pads before switching to a higher audio frequency. Once the tone is correct, then take out enough pads to obtain the correct modulation figure.

Response Measurements

The output of the system is held constant—that is, the percentage of modulation is— and the input signal amplitude is adjusted to obtain that percentage of modulation. Once the system levels have been calibrated, don't make any adjustments except to the signal source and its output. The output of the generator as it goes into the station must be measured and recorded. But this is an inverse condition, and the signal levels describe a curve which is exactly opposite of the system response. So the sign must be changed when plotting the curve. For example, when the system gain increases (a plus sign) the input signal level must be reduced (a minus sign).

With the steep 75 μsec preemphasis, the input signal will be reduced as much as 17 dB at 15 kHz. This can be a bit confusing, but it is not very much different from running the "flat" curve of the AM proof. To help quickly determine if the system is falling within tolerances, have a preemphasis curve handy to make comparisons, or jot down the limits somewhere. Show both the upper and lower limits.

Distortion Measurements

The distortion measurements are made with the analyzer input connected to the modulation monitors distortion output terminals. Again, these are high-impedance, unbalanced circuits. The distortion measurements are made with 75 μsec deemphasis, so if this is a switchable function on the monitor, make sure it is switched in.

Make the distortion measurements immediately after making the response measurement for that percentage of modulation, using the procedures described in the AM proof. The distortion measurements are at very low levels, so be especially careful making the nulling adjustments so you don't pin the meter of the analyzer. In most cases, those final measurements will be on the 1 percent scale, on which the meter circuit is very sensitive. Also, if these measurements seem higher than they should be or out of tolerance, use the oscilloscope on the scope output terminals of the analyzer to identify the character of the noise or distortion that is measured on the meter.

Noise

There are two types of noise measurements that must be made. The first is normal system noise in the audio, simply called FM noise. This is required at the 400 Hz audio tone and 100% modulation only. This is performed exactly the same as in the AM proof, except no external detector can be used, as the modulation monitor is used to make all these measurements. Calibrate the noise meter when the system is 100% modulated with 400 Hz tone, remove the tone, and terminate the input to the system with a resistor of the correct value as the input impedance. Reduce the noise meter pads to increase its sensitivity and read the noise.

The requirement here is far more severe than in AM. The FM system must meet at least a −60 dB noise factor. So allow enough room on the noise meter gain when calibrating that the measurement can go down this low.

For proof purposes, noise figures are always given in decibels, so if your noise meter is reading only in RMS voltage, it will be necessary to compute the decibel value from the RMS values measured. The normal audio noise meter is usually calibrated in decibels also, so use this and save all the computations.

AM Noise on FM

The second type of noise measurement required is that of anything which may be amplitude modulating the carrier, whether it be hum, other noise, or modulation components. All this is undesirable and is termed AM noise. To measure this factor, a regular AM detector is required. Any AM noise modulation components recovered through the detection process are then measured on the noise meter. Some modulation meters have a rectifier circuit built into them for making this measurement. If so, use the procedure described in the instruction manual. If it does not, then you will need to construct a circuit that will do the job.

First, a few factors involved. In the AM process, the peak of the audio signal will be exactly equal to the peak of the RF signal at 100% modulation. To derive a noise figure, a 100% reference point is necessary. The regular AC voltmeter and the noise meter will read in RMS voltage; they have been modified so they indicate in this fashion. The detector will be a peak-reading device, and the DC output voltage will be equal to the peak RF carrier voltage.

Making the Noise Measurement

First, use the detector and measure the RF carrier voltage in the recovered DC value by a regular DC voltmeter (Fig. 14-13). Adjust the RF input coupling to produce approximately 3V to 4V DC. This represents the peak RF carrier. Now multiply 0.707 times this DC value to derive the RMS value. Use the signal generator with a low-frequency audio tone and feed this to the noise meter until that computed RMS value is obtained. Then read this value on the decibel scale. This calibrates the noise meter with an audio signal whose peak is equal to the RF carrier peak (100% AM modulation).

Do not change any setting on either the detector coupling or the noise meter, since both are now calibrated. Remove the audio tone from the noise meter and connect the calibrated noise meter to read the output of the detector rectifier. Reduce the meter sensitivity pads until a reading is obtained on the meter. The meter reading and the pads will then give the noise value. If this is high or borderline, use the scope on the output of the meter to identify the noise element. In the majority of cases, it will be coming from the power supplies, although it can be from cathode-to-filament shorts in one of the power tubes.

Graphs

The audio response curves of the system will follow the standard 75 μsec preemphasis curve. That curve is not easy to draw. As a suggestion, you may have the standard curve as shown in the FCC Rules taken to a print shop and have them print you up a batch of sheets which have both the graph divisions as well as the curve tolerances drawn in. Or if you are good at this type of drawing, then make up a master form by drawing the curve limits on a graph sheet and run this through a copy machine for worksheets (save the master).

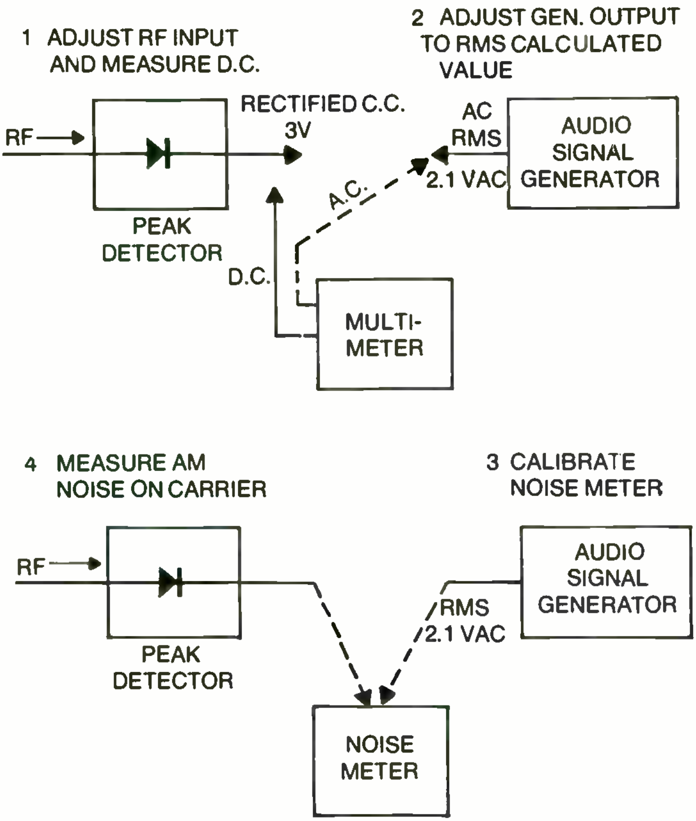


Fig. 14-13. To measure AM noise on FM carrier: (1) Measure DC output of the peak detector. (2) Compute 0.707 of this DC value and set output of signal generator to this value. (3) Use this AC signal to calibrate the noise meter. (4) Connect calibrated noise meter to detector to measure any modulation components on carrier. For example shown, RF was adjusted to obtain 3V.

When drawing in the actual curve you measured, remember that the input levels actually describe a 75 μsec *deemphasis* curve, the opposite of the system response. But you must plot the system response. So change every sign to the opposite sign. For example, if your measured signal level were −15 dB (from 1 kHz reference) at 15 kHz, change this to +15 dB for plotting purposes.

Other Measurements

Besides the required measurements, you may make any other measurements you desire. One good example is a power measurement. If the station uses direct power measurement, then the output power meter must be calibrated at least every six months. There is no requirement that it be done at proof time, but this seems like a logical time to make one of the required calibrations.

Remember to restore all the equipment to its operational mode. Switch the processors to their active mode, and make sure all patch cords and terminating plugs are out of the system. If the transmitter was switched to the dummy load to make a power measurement, restore it back to the antenna. If a temporary patchup of the recording booth or similar source was used to replace an automation system, then it is advisable to run a little music programming through the system after it has been restored to make sure that it really is restored. You can use an audio identification out of the system for the final station identification also.

STEREO PROOF

The technical requirements for stereo are found in Part 73.322 of the rules and highlighted in Table 14-3.

Proof Requirement

The rules do not require that an annual proof be made for stereo. When a station is operating in stereo, the technical requirements of Part 73.322 must be met all the time, just as must all the other technical requirements of the rules. But the only proof requirement is that of the monaural proof as described in Part 73.254. The actual wording is somewhat vague in this regard. After consultations with several people at the FCC and in the industry, I learned that the only requirement for a proof is that of the monaural proof.

Good Engineering Practice

It would seem that a variety of measurements must be made to demonstrate (under controlled conditions) that the stereo system does meet the technical requirements of the rules, especially if the station is full-time stereo. During the annual monaural proof of performance, there is no prohibition against making additional measurements to the system for the station's own purposes. It would seem logical that a set of stereo measurements be made at this time to obtain a broader view of the technical operation than that derived from the

Table 14-3.

STEREO TECHNICAL STANDARDS.

AUDIO RESPONSE, DISTORTION, NOISE

- Identical with those of monaural except modulation percentages include 10% pilot.

SEPARATION

- Measurement to be made of left and right audio channels, 50 Hz to 15 kHz.
- Limit: − 29.7 dB (each channel).

CROSSTALK

- Measurement of the crosstalk from the main channel into the subchannel.
  (Main channel modulated with 400 Hz, subchannel unmodulated.)
- Measurement of crosstalk from subchannel into main channel.
  (Subchannel modulated with 400 Hz, main channel unmodulated).
- Limit: − 40 dB below 90% modulation.

SUBCARRIER SUPPRESSION

- Measurement of the degree of suppression of the subcarrier (38 kHz) without modulation and with modulation of the subchannel.
- Limit: 1% (or less) of main carrier modulation.

PILOT

- Within 2 Hz of 19,000 Hz.
- Modulation: 8%-10% of main-carrier modulation.

SUBCARRIER

- 38 kHz, 2nd harmonic of 19 kHz Pilot.
- Amplitude modulation, double sidebands with suppressed carrier.

mono proof. For our purposes, we will call this a "stereo proof," but remember that it is not required.

Method of Operation

As with the monaural proof, it may be difficult for automated stations to find their main microphone input, but if the station is on full-time automation, this is really a moot question anyway. Of course, if the operation is live, then there is no problem, and the test should be run through the console microphone input jacks.

For full-time automation, I would recommend that the signal be applied to the input of the system where the automation system feeds it. That is, substitute the test generator for the automation system (Fig. 14-14). I do not

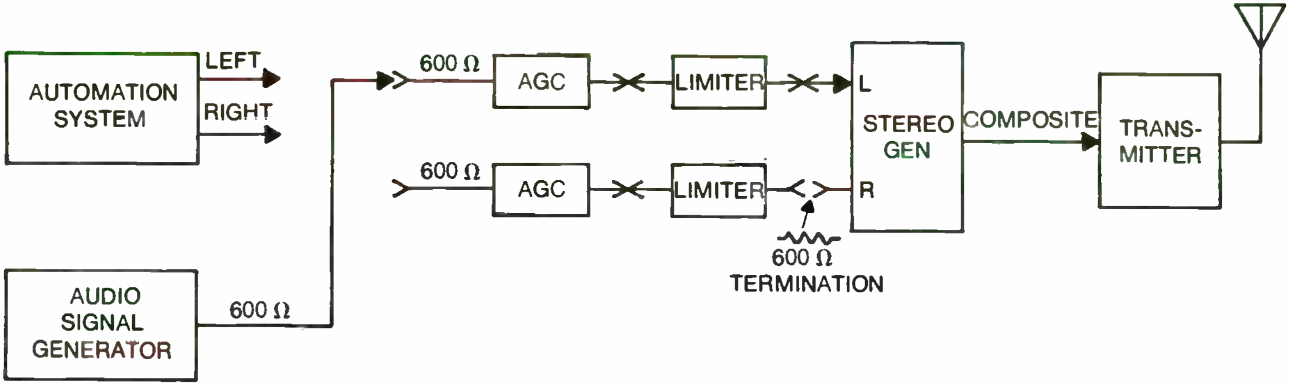


Fig. 14-14. For full-time automated stations, feed the test generator to the same point where the automation feeds the system.

recommend running test tapes through the automation system for the proof figures. Test tapes are subject to stretching, edge damage, etc., so that the results are not always repeatable or accurate, and they rely on the head and characteristics of the particular machine that is playing the tape. Check out the automation system by itself and get it where it should be in technical specs; but for the stereo part of the system, feed the signal in place of the automation system.

Equipment Required

The test equipment required is the same as for the AM and FM proofs, that is: the signal generator, audio voltmeter and pads, and noise-distortion analyzer. The station in stereo must have a FCC type-approved modulation monitor in use. To obtain type approval, the monitor must also include special test provisions so that the stereo measurements can be performed. An oscilloscope is also necessary for phasing adjustments of the stereo generator and can be used for the other purposes described earlier.

Special Arrangements

The test equipment is monaural, so to make some of the special stereo measurements, some means must be provided that will allow the monaural test signal to feed both channels at the same time. At other times, phase reversals will be necessary to make some measurements. The engineer may find it desirable to build up a switching arrangement in a box to handle these functions, or they can be done with patch cords.

When patch cords are used, there should be at least three jacks wired together, which will, in effect, place the two stereo inputs in parallel across the single output of the signal generator (Fig. 14-15). This is the method I use, and I find it practical and easy to set up. Make sure the test cords are the same length and mark the plugs to show which will be *right* and which *left*. Use the notch on the side of the plug for polarization.

One more precaution: Use an ohmmeter and check through the patch cords to make sure the plugs haven't been put on in reverse. This can happen if they were apart for repairs and the engineer was careless about polarity when putting them back together.

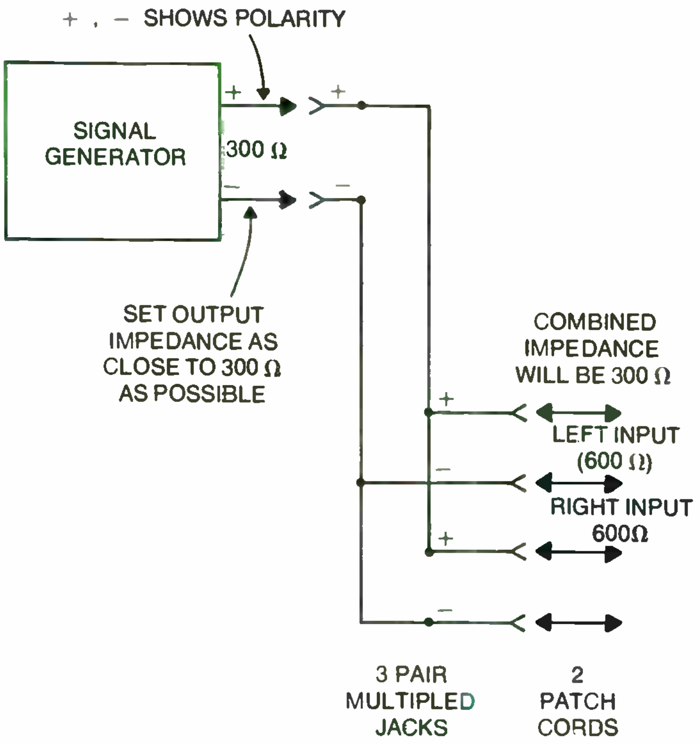


Fig. 14-15. Use patch cords and multiple jacks to strap generator output to feed both left and right channels together. Change generator output impedance to match the resulting impedance as closely as possible.

There is also an impedance problem when paralleling the two 600-ohm stereo inputs. This results in a load impedance on the generator of 300 ohms. So use the 150-ohm or nearest impedance available on the signal generator output.

Phasing

The first preliminary checks of the system should be of its phasing. The phasing is of two types: 180-degree phasing and lesser degrees of phasing. The 180-degree phasing will switch channels if the channels are both reversed; but if the polarity of one channel is 180 degrees out from the other, this can shift the audio of one into the other channel (according to the phasing), leaving little or nothing in the opposite channel. Lesser degrees of phasing will affect the separation measurements and the actual channel separation.

The channel phasing should be checked first. Set up the signal generator to feed the left input of the system with a very low-amplitude 400 Hz tone. Connect the vertical input of the scope to the stereo generator composite output, and synchronize the scope horizontal sweep with 19 kHz. This may be obtained from the 19 kHz test jack on the generator. Adjust the horizontal sweeps so that only one cycle of the 19 kHz is displayed. If you do not use too much audio input to the left channel and the phasing is correct, then small sections of the 400 Hz will be seen in the first and third quadrants of the 19 kHz cycle (Fig. 14-16). Observe the modulation monitor. It should show that the audio is in the left audio channel.

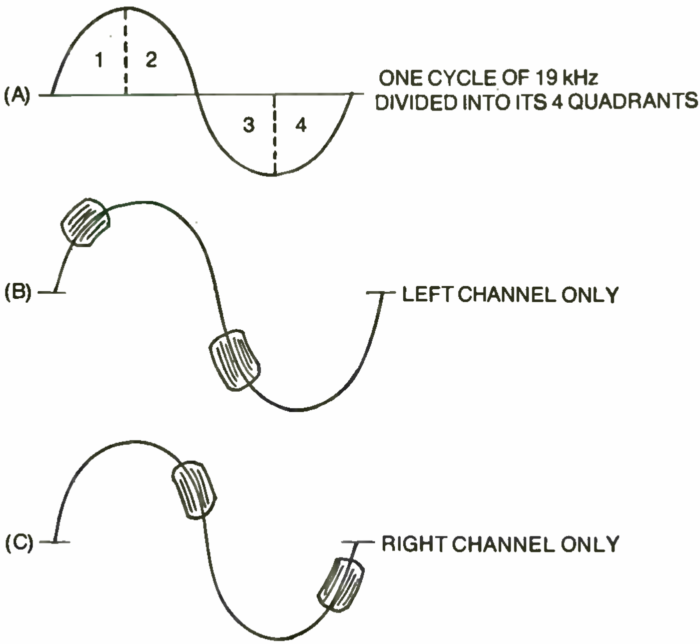


Fig. 14-16. (A) Divide one cycle of 19 kHz into its four quadrants. (B) Modulation will appear in quadrants 1 and 3 when left-channel-only signal is fed. (C) Modulation will appear in quadrants 2 and 4 when right-channel-only signal is fed.

Now you may check out the right channel if desired. This time, feed the audio to the right audio input of the system. The audio will appear in the second and fourth quadrants of the 19 kHz cycle displayed on the scope, and the audio will indicate on the right-channel meter of the modulation monitor.

Polarity

The previous test showed that the audio channels were in the correct position but didn't show if one of the channels had its polarity reversed. This can be checked at the output of the stereo generator or at the composite output of the modulation monitor. Since you are already set up with the generator, go ahead and use that. First, feed 400 Hz to both the left and right channels simultaneously, in phase; that is, $L = +R$. When both channels are in phase, the matrix in the stereo generator will sum the two and send them into the main channel of the transmitter. That is, they will be an audio signal only to the transmitter. So the output of the stereo generator will supply an audio sine wave of 400 Hz, equal in peak-to-peak value to the normal composite output. But if one of the channels is out of phase, then the matrix will see out-of-phase or $L = -R$ signals at its input and will send these all into the subchannel.

At the output of the stereo generator, you will have displayed two halves of the 400 Hz cycle, but each half-cycle will be filled in with 38 kHz waves (really sidebands of the subcarrier). If there is a polarity problem, go down the jack field and feed the in-phase audio to both channels at different places, and this will quickly run the problem down to the offending unit. Look for the wiring to have been replaced incorrectly either at the input or output terminals.

Pilot Phasing

The pilot and 38 kHz switching must be properly phased, or there will be separation problems. Leave the scope monitoring the composite output of the stereo generator and synchronized to the 19 kHz. Feed audio to the left and right channels out of phase, that is; $L = -R$. (Simply turning over one of the channel patch plugs will do this.) This produces the typical butterfly pattern on the oscilloscope. Expand the scope display so as to better view the center, where the wings connect together. The horizontal points of each wing should face each other and be lined up on the horizontal axis through the display. If they do not, there is a phasing problem. Adjust the pilot phasing control on the stereo generator to align these two points.

If you have already run the monaural proof, then the system is within normal tolerances; but you may still want to

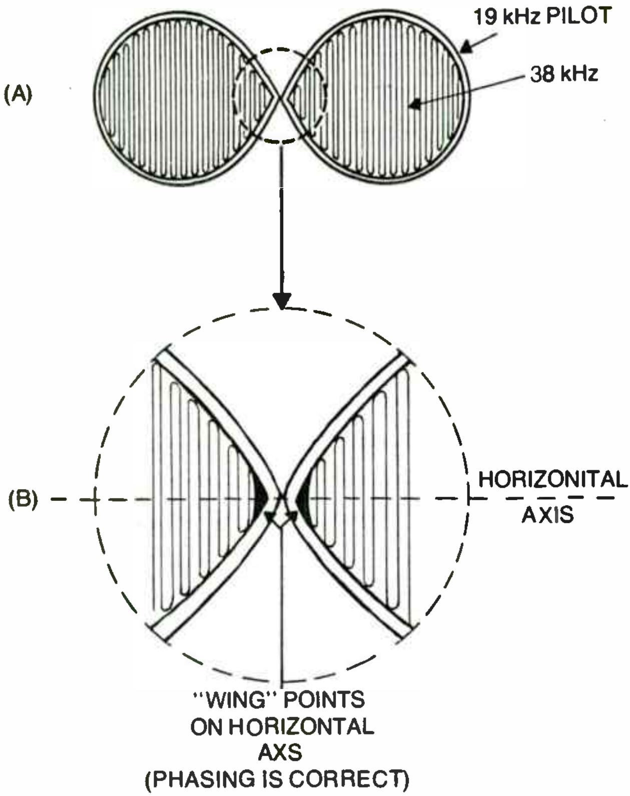


Fig. 14-17. Measure composite output of stereo generator. (A) Obtain the typical butterfly pattern. (B) Expand center area. Points of wings should be on the same horizontal axis. If not, adjust pilot phasing in generator.

take a couple of sample measurements to make sure the new arrangements have not affected impedances or introduced noise or hum into the sytem.

Level Setting

Set signal levels throughout the audio system so that the left and right audio channels are balanced throughout. First, feed a 1 kHz tone into the left-channel input. Have the correct impedance matching. This level should be at −50 to −55 dB, as in the monaural proof. Use the audio voltmeter and measure the output of each unit in the left chain so that it is within its normal range. The output signal will probably be 0 or +4 dB, depending upon the stereo generator. Now allow this to modulate the transmitter, and adjust for the correct percentage of total modulation This will be 100%, which also includes 10% pilot.

With the left channel properly calibrated, move the generator to the right-audio-channel input and again measure and adjust levels throughout the channel. But this time, adjust each unit so that its output matches that of the level you measured on the left channel at that point. In this way, the two audio channels will apply equal-amplitude signals to the stereo generator. Once the two channels are set up and calibrated, do not make any changes in them.

Separation

Now that the audio levels throughout the left and right channels have been calibrated, you may wish to check out the separation. To do this, feed 400 Hz to either the left or right channel and measure the composite output of the stereo generator with an oscilloscope (Fig. 14-18). If desired, you may shut off the pilot for this check, as that will make a clearer pattern on the scope.

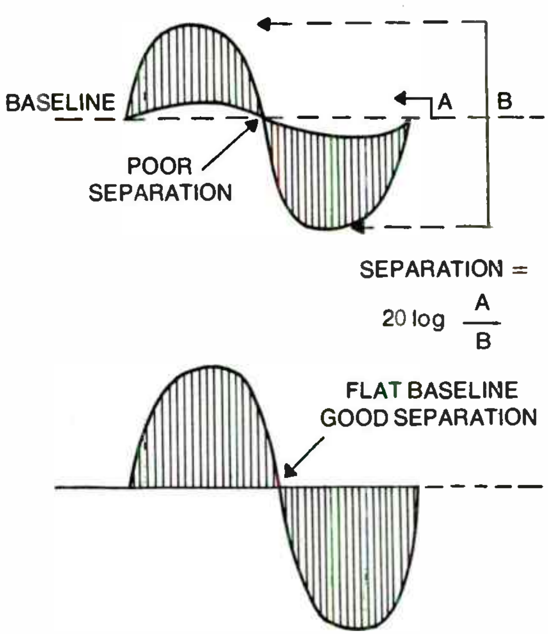


Fig. 14-18. Check the separation of the stereo generator with a scope. Feed left or right channel. Base line should be flat for good separation. Adjust separation controls on stereo generator to flatten baseline.

Check the baseline of the pattern. It should be perfectly flat. If it is not, touch up the separation controls in the generator to flatten out the line. Now feed the other channel and again flatten out the line if necessary. It may take a few tries, as the two channels and the adjustments are interrelated. Restore the pilot to its normal value.

Stereo Monitor

If there is any question about the stereo monitor, then go through the appropriate checkouts and adjustments as recommended in the instruction manual. If it does need adjustment, then the composite output from the stereo generator will be needed for a direct feed to the monitor. If the preliminary test runs check out okay and the stereo generator itself seems to be in correct adjustment, then the monitor is probably okay.

It is important that the stereo generator be adjusted for separation and phasing with a scope, and not the monitor. If the monitor is out of adjustment and the stereo generator is adjusted to the monitor, it is a case of the blind leading the blind. The measurements may appear okay, but they are not. Once the generator checks out all right with the scope, go ahead and adjust the monitor against the generator.

Response and Distortion

These measurements are made in the same way as in the monaural proof, with the exception that the left or right channel is measured singly (Fig. 14-19), and the total modulation will be 10% less; that is, there will be 90% modulation and 10% pilot. When you do make the measurements, terminate the input of the opposite audio channel with a resistor so that the channel does not allow open-circuit hum to foul up the measurements. Actually, it is best if this termination is applied at the input of the stereo generator.

For the distortion measurements, connect the distortion analyzer to the distortion output of the left or the right channel, as the case may be, on the modulation monitor. Make sure to switch in the 75 μsec deemphasis on the monitor, if it is a switchable item.

Separation

The separation measurements should be made immediately following the response and distortion

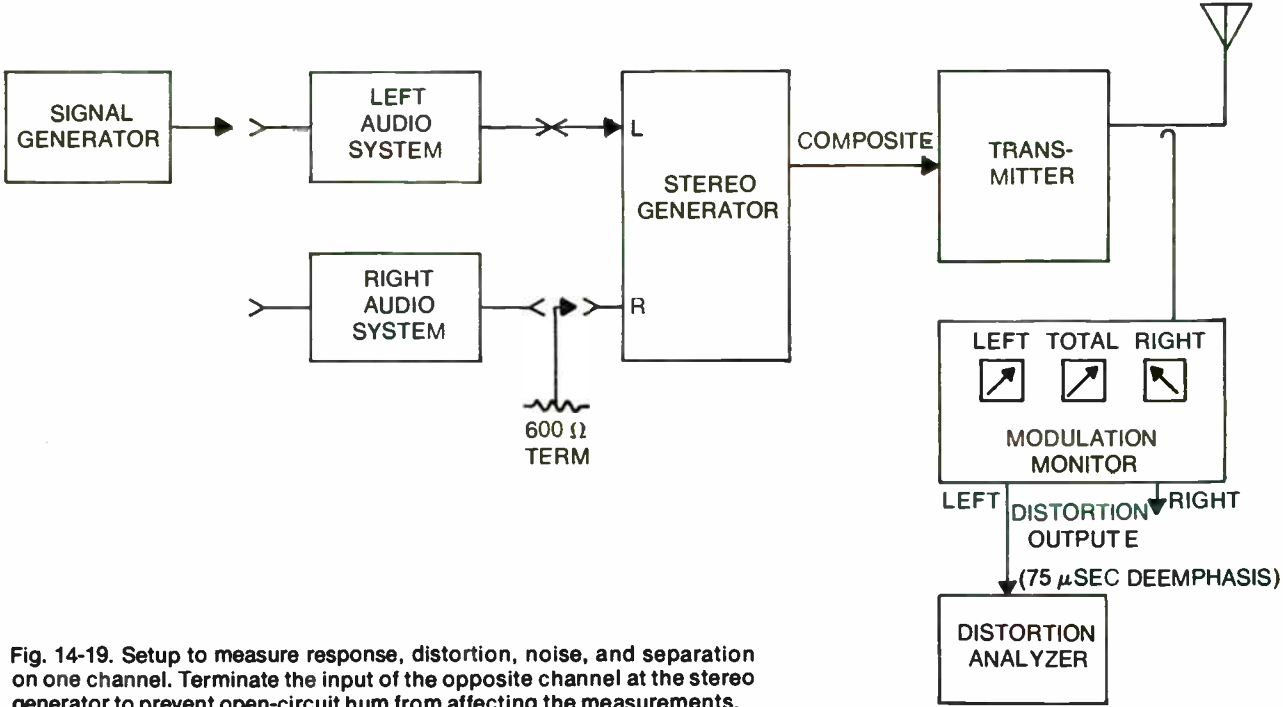


Fig. 14-19. Setup to measure response, distortion, noise, and separation on one channel. Terminate the input of the opposite channel at the stereo generator to prevent open-circuit hum from affecting the measurements.

measurements. You measure the response at 100% modulation. After recording the input level, check the distortion for that frequency. Without changing anything, make the separation measurements on the monitor. How they are actually performed may vary from one monitor make to another, but with the modulation at 100%, the separation switch is placed in the opposite channel, and the meter pads are reduces so as to measure whatever audio is in the idle channel. So if you were feeding the left channel, then the right channel would be read for any residue (Fig. 14-20). The meter sensitivity pads and the meter reading will give the value of separation in decibels. Separation measurements are only made at 100% modulation.

Crosstalk

Crosstalk is measured in two directions—that is, the crosstalk from the main channel into the subchannel, and the

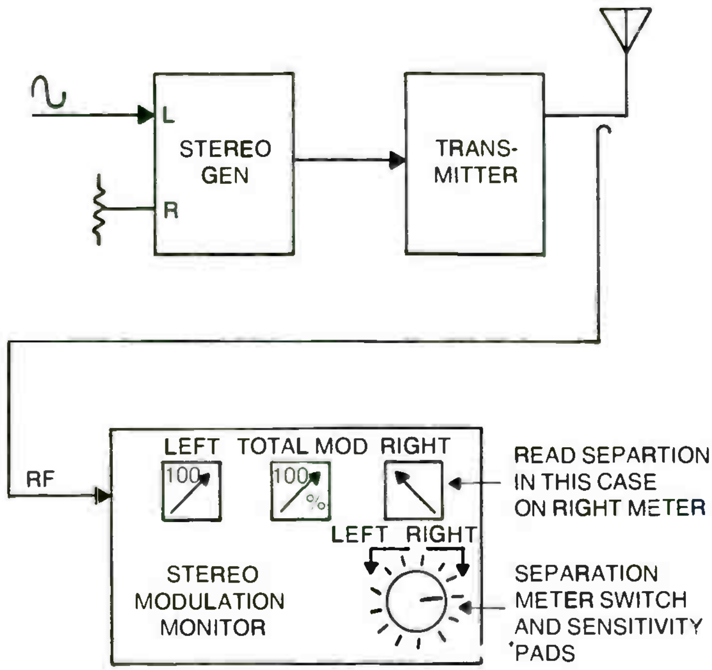


Fig. 1-20. Measure separation according to the monitor in use. Shown is a typical monitor measuring the separation of the right channel from the left channel.

crosstalk from the subchannel into the main channel (Fig. 14-21). During these measurements, only the main channel or subchannel is modulated; the other is idle. The *main channel* here is the modulation spectrum of the main carrier in the audio region of 50 Hz to 15 kHz. The *subchannel* is that spectrum area of 23 kHz to 53 kHz. What is being measured is spillover, harmonics, or spurious signals that may originate in one channel and cross over into the other channel.

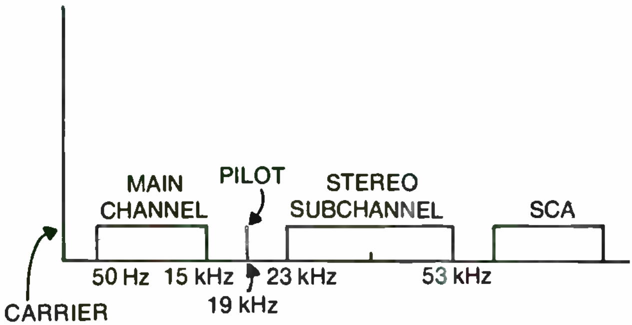


Fig.14-21. The sideband spectrum of composite modulation of the FM carrier. Crosstalk is the spillover of spurious and harmonic elements from the main channel into the subchannel, or the subchannel into the main channel.

Feed audio at 400 Hz into both audio channels in phase ($L = +R$). The matrix in the stereo generator will cause all this to appear in the main channel, and nothing into the subchannel. The total modulation should be at 100%. Set the function switch on the monitor to read crosstalk of main channel into subchannel, and then on the appropriate meter (usually right) of the monitor, set the meter pads to increase meter sensitivity until a reading is obtained. The meter reading and the pads will give the value of crosstalk from the main channel into the subchannel.

Then reverse one of the input patch cords so as to feed the 400 Hz into both channels out of phase ($L = -R$). This out-of-phase signal will be sent into the subchannel, and nothing into the main channel. At the modulation monitor, set the function switch to measure crosstalk of subchannel into main channel, and then adjust the meter sensitivity pads (usually the left meter) so as to obtain a reading. The meter pads and meter reading will give the value of crosstalk from the subchannel. All these readings are in decibels.

Subcarrier Suppression

The 38 kHz subcarrier itself is not transmitted, only its sidebands (Fig. 14-22). This test will show how well the stereo generator is performing this function. The tests are made first without modulation of the subchannel, and then with modulation of the subchannel with audio tones from 5 kHz up to 15 kHz.

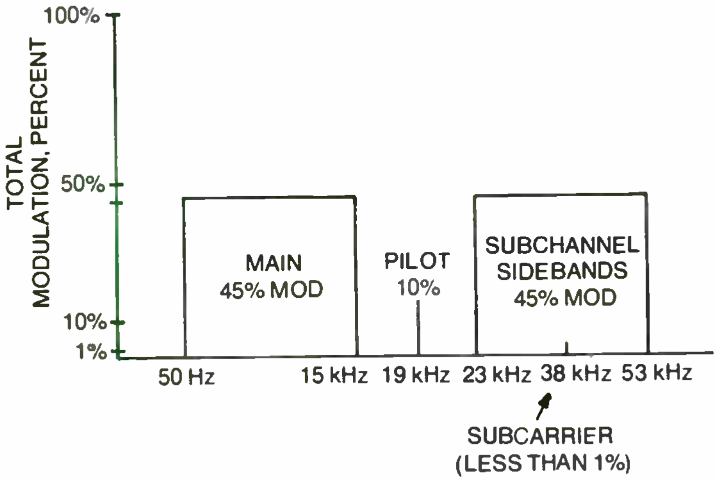


Fig. 14-22. The 38 kHz subcarrier must be suppressed to less than 1% modulation of main carrier's total modulation.

For the first measurement, terminate both inputs of the stereo generator with a resistor. At the monitor, set the function switch to measure 38 kHz suppression. Then adjust the meter (usually right) pads to increase the meter sensitivity and obtain a reading. The meter reading and pads will give the value of subcarrier remaining, or rather how well it is suppressed, in decibles.

Using the same setup on the monitor, feed 5 kHz out of phase to the left- and right-channel inputs and modulate to 100%. Read the subcarrier suppression as was done without modulation. Make this measurement for each of the modulation tones.

Noise

You may now make the noise measurements. Actually, they could have been made during the response and distortion measurements, when the routine got around to 400 Hz. The noise measurements are made in exactly the same way as in monaural, but in this case all measurements are made on the left channel, and then on the right channel. Expect to lose 1 dB of noise in these measurements as compared to the monaural measurements. This is because you are now only modulating 90% (plus 10% pilot), whereas in the mono proof you used the full 100%. Look at the modulation meter—this 10% represents 1 dB.

You may make AM noise measurements if you wish, but I have never seen any change between the measurements made in composite modulation and monaural modulation.

Putting It All Together

When you plot the graphs, plot the left and right channels on the same curve (Fig. 14-23). To identify the curves, either use different colors, or draw one curve in a solid line and the

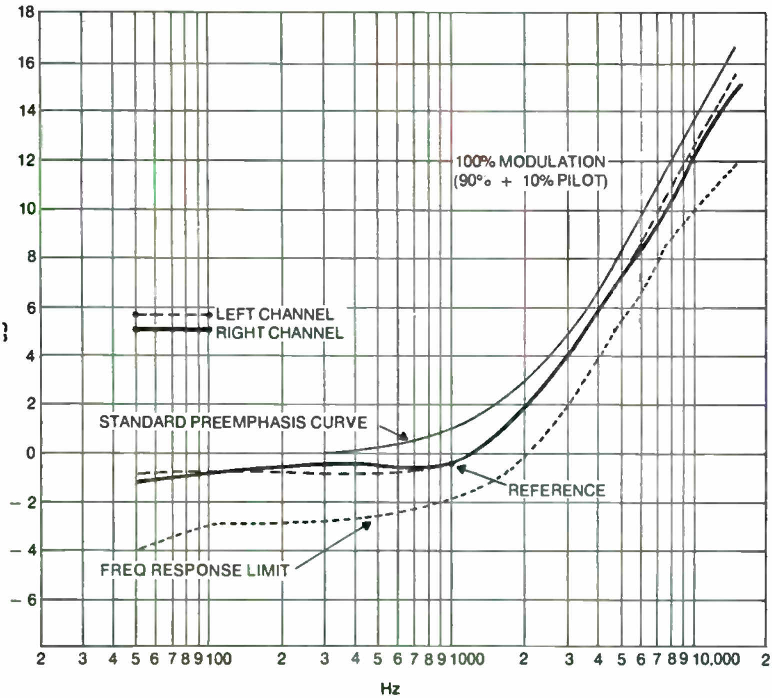


Fig. 14-23. Plot the left and right channels on the same graph. Use two colors, or make one a dashed and the other a solid curve. This will make the difference stand out.

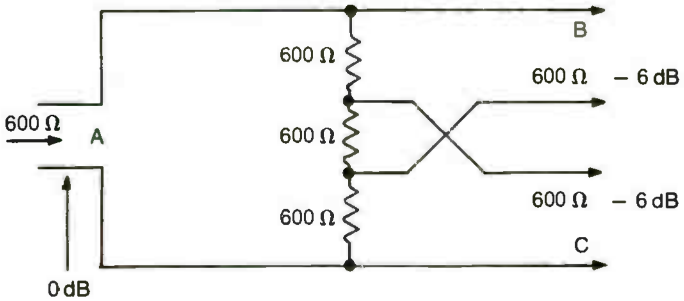
other in a dashed line. When two colors are used, any difference between the curves will be very striking.

Don't forget to restore everything for normal program operation. Check the AGCs, limiters, and other processors to see that their action is switched back on. Check the patch panels for stray cords or plugs, the console for switches open, and, especially, make sure the transmitter is not on dummy load. If there is an automation system, make sure it works normally. After being up all night, you certainly don't want the signon man getting you out of bed because the system won't work!

Appendix A

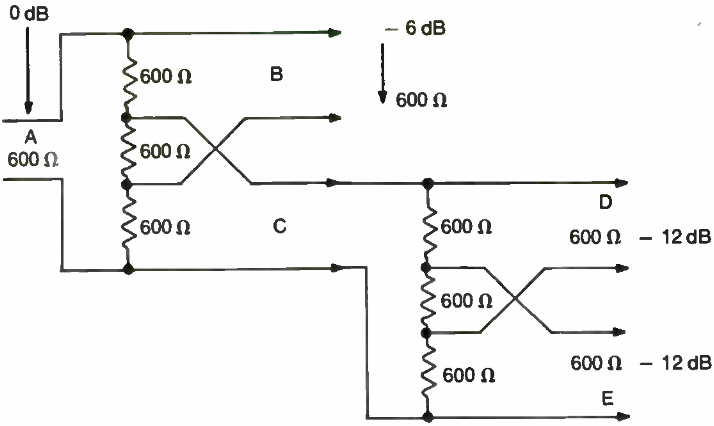
Simple Resistor Branching Pad

This is designed for 600-ohm balanced circuits. Signal at input *A* will divide equally into outputs *B* and *C*. The three resistors should be identical. There will be a loss of 6 dB from the input level to either output. The pad will work in the reverse direction equally well, and there will be no crossover between *B* and *C* inputs when used in this manner. Circuit is useful when a single output must be fed to two different buses, and when used in reverse, will mix two sources into a single bus.



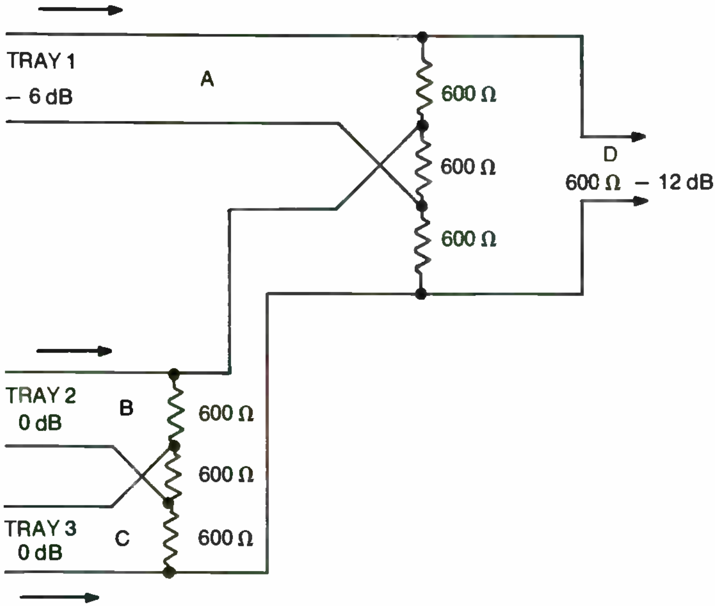
PADS IN TANDEM

When it is necessary or desirable to split a signal into three channels, then the simple resistor pad can be used, that is, two pads in tandem. The signal loss is 6 dB across each pad, so the output level at *D* or *E* will be −12 dB.



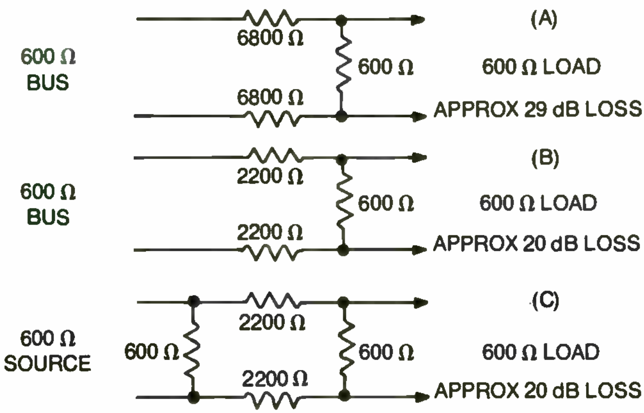
THREE-INTO-ONE ARRANGEMENT

The simple resistor pad can also be used to mix three sources into one input. Two pads are worked in reverse. There is a 6 dB loss across each pad, so the output at *D* is down 12 dB. The output of one source must be adjusted 6 dB lower than the other two if the levels at *D* are to be the same. This is useful when it is desired to feed a three-tray cartridge machine into a single fader on the console, for example.



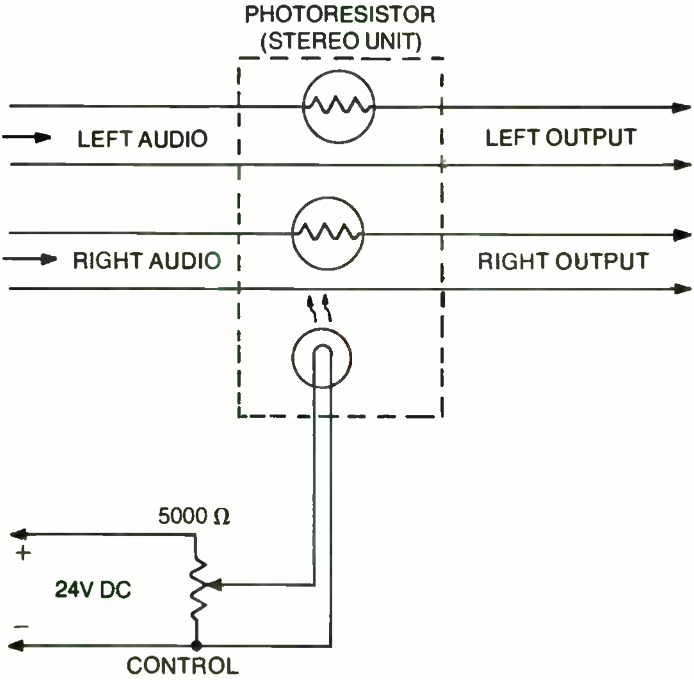
BRIDGING PADS

When a transformer is not available, or if not needed for the application, simple bridging pads can be used. The pad in A will produce a loss of approximately 29 dB at its output. It bridges a normally terminated program bus. The pad in B will produce a loss of approximately 20 dB, under the same conditions as in A. When the bus does not feed anything else but the level is too high, then the bridging pad can be used with a 600-ohm resistor across the input of the pad, as in C, to properly terminate the source.



PHOTORESISTOR AS GAIN CONTROL

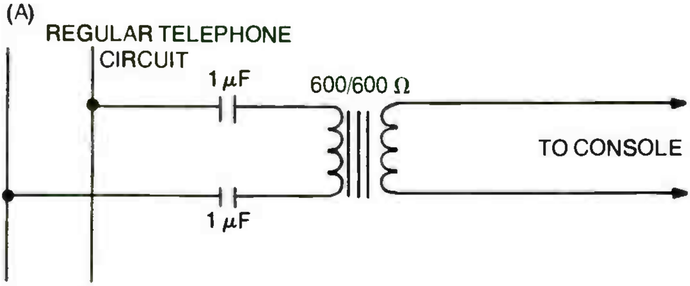
The photoresistor can be used as a remote gain control. If stereo circuits are involved, then use a dual or stereo unit. The audio circuits themselves do not have to be routed away from the amplifiers or the rack. All that is needed is a DC control circuit which controls the voltage to the lamp in the photoresistor. This allows the control to be placed at any location—for example, at the console—while the photo unit is at the amplifiers in the rack or even another room



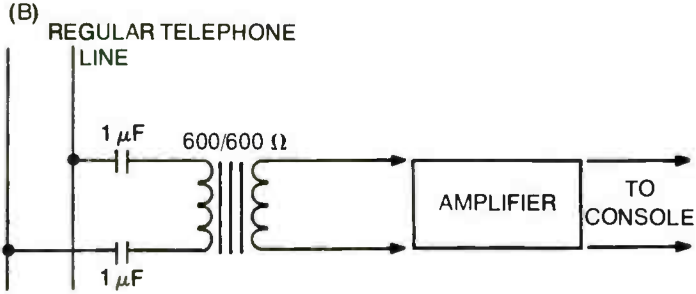
RECORDING FROM REGULAR TELEPHONE LINE

For news reports. remote broadcasts, and others that are done over the regular telephone, a simple connection can be arranged at the studios. In A is a simple connection. The series capacitors block out any DC voltage on the line, the 600–600-ohm transformer provides isolation. If there is not enough level then an amplifier can be inserted as at B. It is often desirable to play back a commercial announcement to a client over the phone. The circuit in A can be used in reverse, as is shown at C.

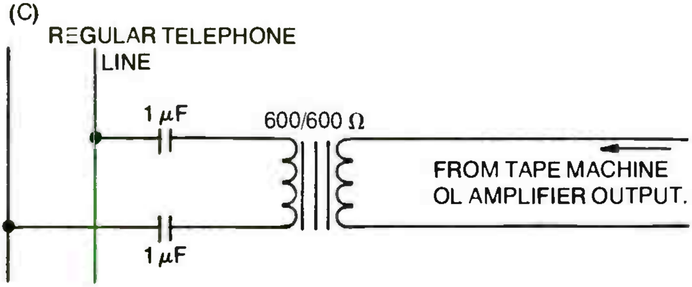
(A)



(B)

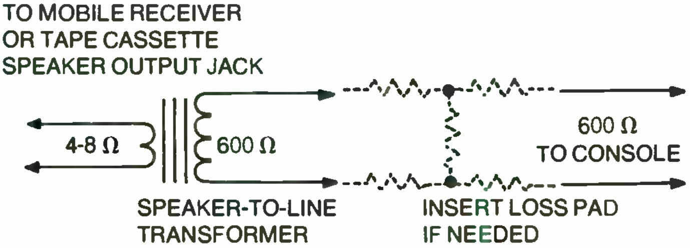


(C)



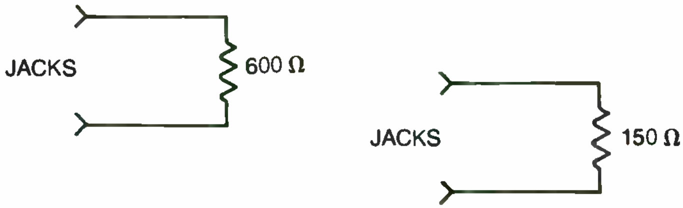
CASSETTE OR MOBILE RECEIVER MATCHING

The simple circuit shown will match the speaker output of a cassette tape recorder or the receiver output of a mobile unit to the station's regular equipment. Use a speaker-to-line transformer, which will provide isolation. If the level is too high, insert a balanced loss pad between the transformer and the audio system.



TERMINATIONS

For test purposes, a handy termination at the jack field can be a big convenience during maintenance or even for operation. Simply wire a resistor across either the jack terminals themselves or down on the audio block. Have one of each of the common impedances that are most likely needed at the jack field, that is, of those used in the station. A patch cord can then easily patch in the termination when needed.

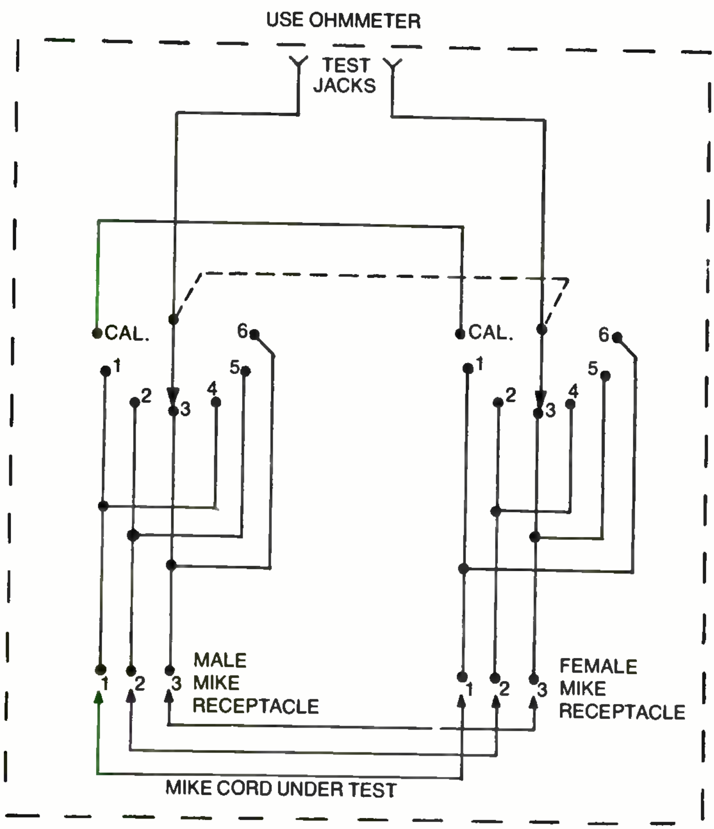


MICROPHONE CORD TESTER

This simple test unit can be built up to test for continuity of each wire in a mike cable and also to check for shorts across the cable wires.

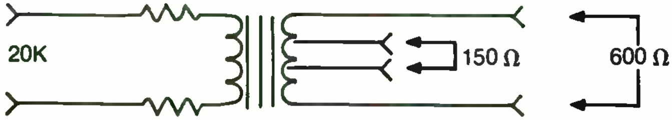
Use a two-layer rotary switch of at least seven positions. The whole unit should be mounted in a metal box and attached to the wall at the workbench. Use a regular ohmmeter for the test.

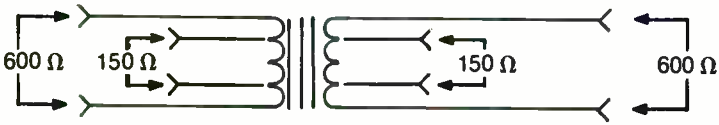
- In CAL position, a short is provided to calibrate the ohmmeter.
- Positions 1-2-3 checks for continuity of cable wires 1-2-3.
- Positions 4-5-6 checks for shorts across the wires in the cable.
- Flex the cable throughout its length during each test to check for intermittents



TRANSFORMERS ON JACKS

For isolation and bridging purposes, transformers mounted in a rack and with all their windings appearing on jacks can be very helpful both in operation and for test purposes. Bring both the primary and secondary windings to jacks, but do not try to use more than one set of taps at a time.



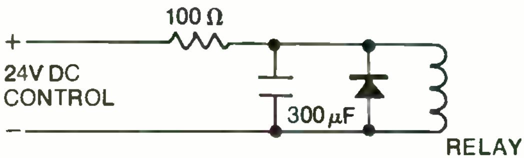


CAPACITORS AS TIMERS

The charge stored in a capacitor can be used for timing purposes in control circuits. Estimate approximately two seconds of delay (or hold) per 400 uF. Use good electrolytics.

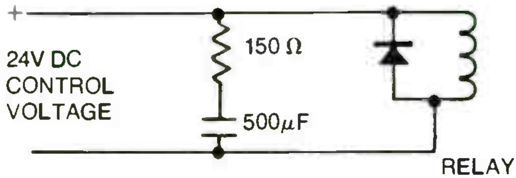
Capacitor and Resistor to Delay Pull-In of Relay

The circuit shown is designed for a continuous control voltage applied. The RC combination will provide approximately two seconds of delay before relay will pull in and operate.



Capacitor and Resistor to Delay Dropout of Relay

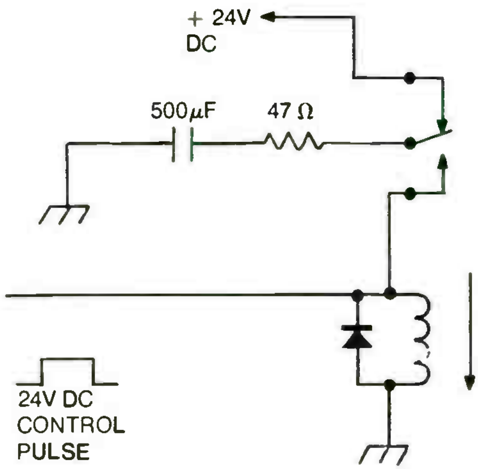
The circuit shown is for a continuous control voltage. Values should provide about a 1½-second delay in dropout. Increase size of capacitor to obtain a longer delay.



Capacitor to Delay Dropout of Relay

The circuit shown is for a pulse-type (DC) control. The capacitor should provide for a little over one second of delay in the relay dropout. Increase capacitor value for longer delay.

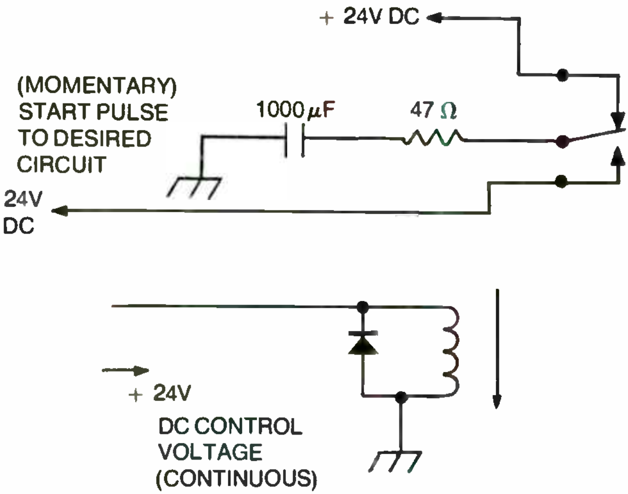
(C)



CAPACITOR AS MOMENTARY START CIRCUIT

This circuit is useful when the control voltage is on continuously, but the circuit requires only a momentary start pulse. In effect, this circuit transforms a continuous control to a momentary control.

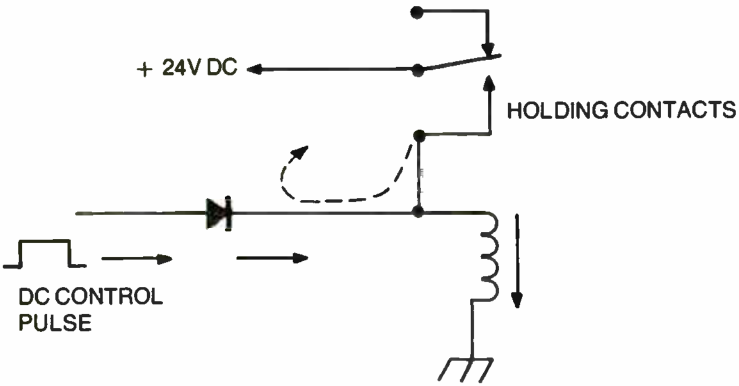
While the relay is idle, the capacitor charges from the 24V DC supply voltage. When the control voltage comes on, the capacitor is transferred to the outgoing control line, and the charge in the capacitor is dumped into that line. Value shown will provide approximately a 2½-second DC start pulse for whatever is desired to be started. Since relay stays on while the continuous control is on, capacitor cannot recharge and thus cannot provide additional pulsing to the momentary circuit. When relay relaxes, capacitor will charge again, awaiting for the next call.



DIODE AS GATE

The diode will act as a one-way gate in DC circuits. This property can be very useful in control circuits where it is not desirable to have the DC circuit voltage feed back into the control circuit.

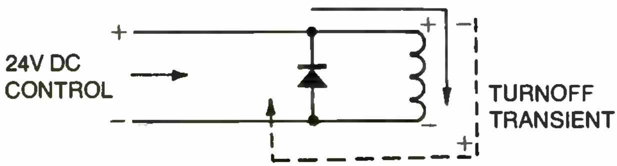
In the circuit shown, the start pulse will pass through the diode to the relay coil. When the coil pulls in, the holding voltage will be present, but this holding voltage cannot feed back into the control circuit. If the control voltage is negative, reverse the diode.



DIODE AS TRANSIENT SUPPRESSOR

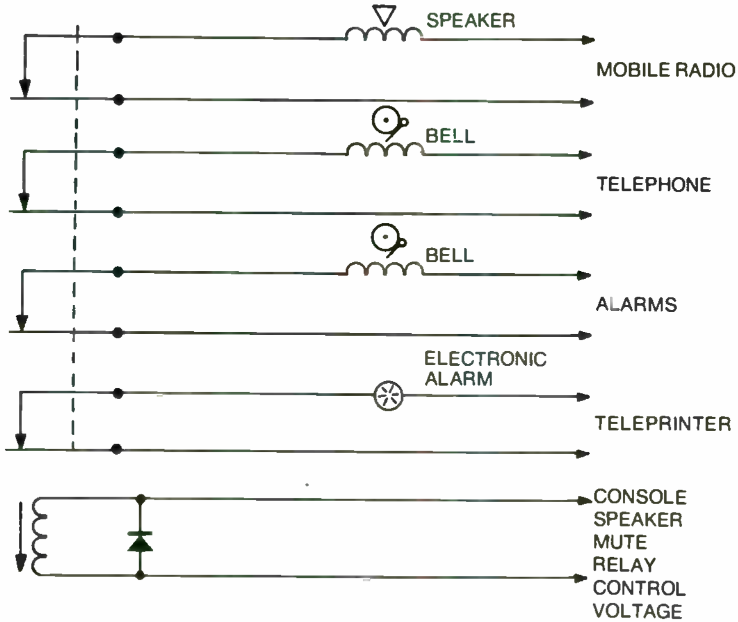
Inductive devices will kick up a strong transient at turnoff. The diode can be used as a suppressor. The diode must be placed in the circuit properly or it will conduct on the control voltage. As shown, the diode will not conduct when the control voltage is turned on. But when the control turns off, the inductance will try to maintain the status quo and will create a voltage from its collapsing field that is opposite to the control voltage. The polarity of this transient voltage will be such that the diode will conduct and short it out.

Always remember to place the diode in the circuit so that the cathode is facing the positive side of the control voltage.



ALARM MUTE CIRCUIT

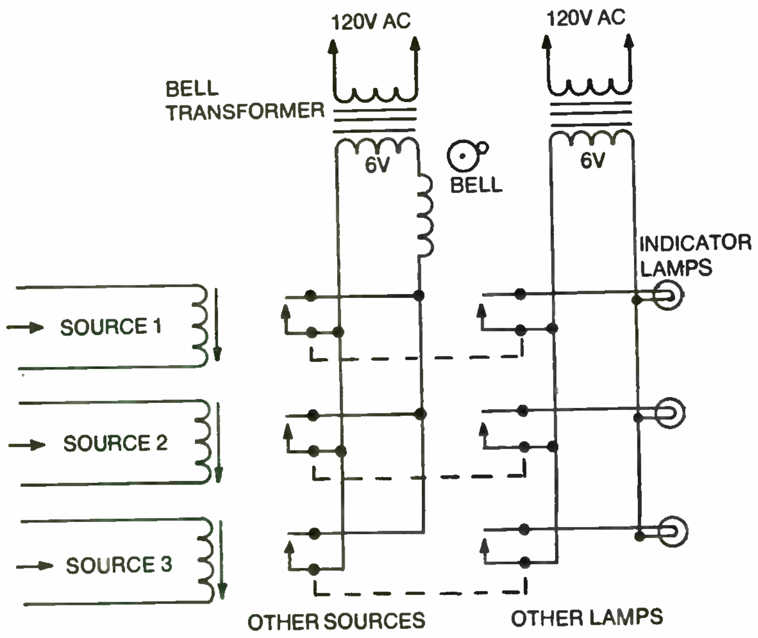
When announcing takes place in a control room it is undesirable for acoustical alarms to go off in the middle of an announcement when the mike is open. All alarm devices can be run through relay contacts on a relay that is operated from the regular speaker mute relay voltage for the control room. When the mike is on, the alarm bells cannot sound. The alarms should also have a visual indicator so that the announcer knows the alarm is sounding.



ALARM SYSTEM

A variety of functions may have alarms, and when more than one fires at a time, it can be difficult determining which one is on.

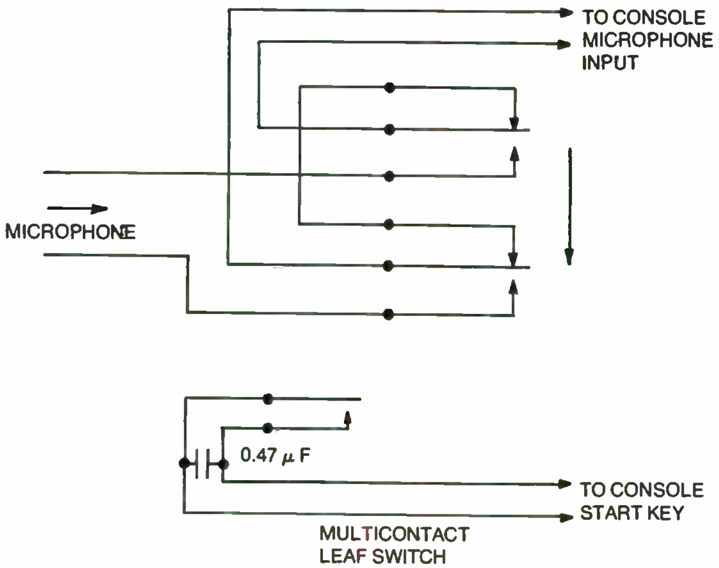
In the circuit shown, only one bell (or electronic alarm) is needed, and each alarm circuit has an indicator lamp to visually indicate which circuit has alarmed. The coil of the relay for any alarm source can have the desired voltage value for the circuit, since the source supplies the relay voltage.



REMOTE MICROPHONE SWITCH

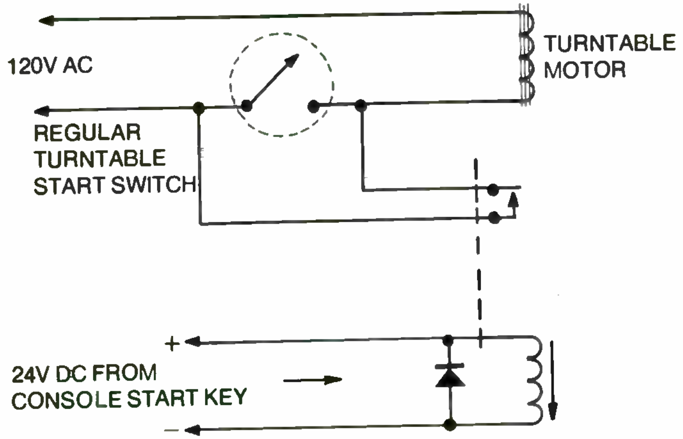
There are several places where it is desirable that the announcer be able to switch his mike on and off, such as in an announce booth. The circuit shown will permit this. The console key must be on and the fader open. When the key is in its *off* position, a short is placed across the audio input to the console, thus not allowing hum or noise. When the key is thrown, the short is removed and the mike is fed into the console through the switch.

The additional set of switch contacts operate the channel mike mute and other relay functions associated with the console switch. A capacitor is placed across the contacts to soften any "pops" that might occur.



TURNTABLE REMOTE START SWITCH

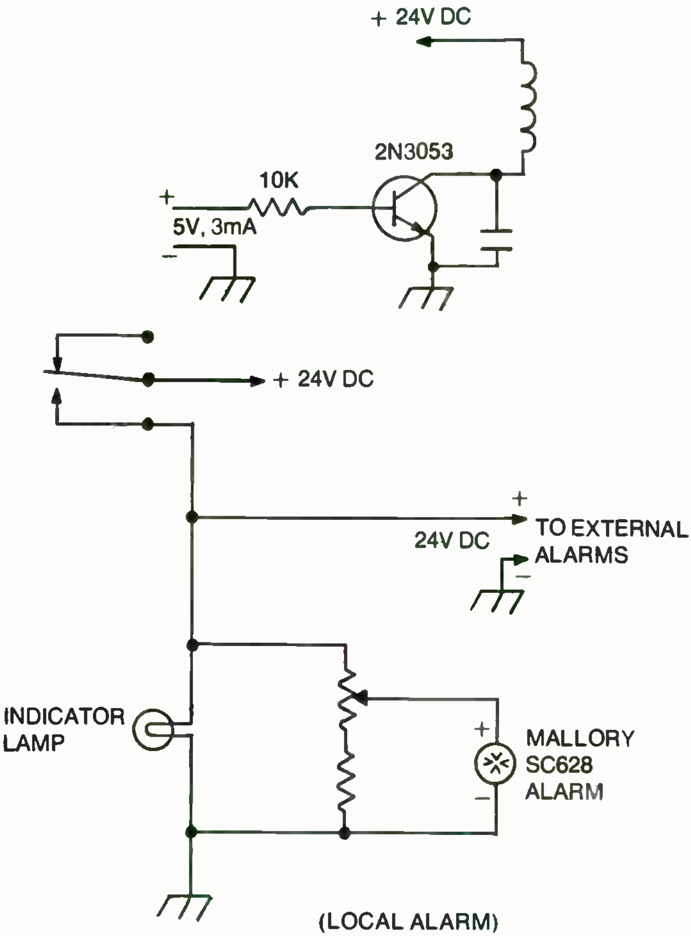
This circuit will allow the turntable be started from the regular key on the console. The circuit is simply an outboard relay whose contacts supply the same action as the normal turntable start switch. Mount the relay in the turntable cabinet. The normal start switch can still be used for cueing, etc.



ALARM WITH IC INTERFACE

This is a suitable alarm circuit when the source is an IC which can supply only low voltage and low current. The transistor is used as the interface and as the switch to turn on the relay. Contacts on the relay supply 24V to both external alarms and to a local alarm. The variable resistor will control the loudness of the local electronic alarm.

The circuit as shown assumes that the reset is done to the IC source itself. If the initial alarm is only a single pulse, then add holding contacts to the relay, and bring the return for the relay through a normally-closed switch which can be used as a reset button.

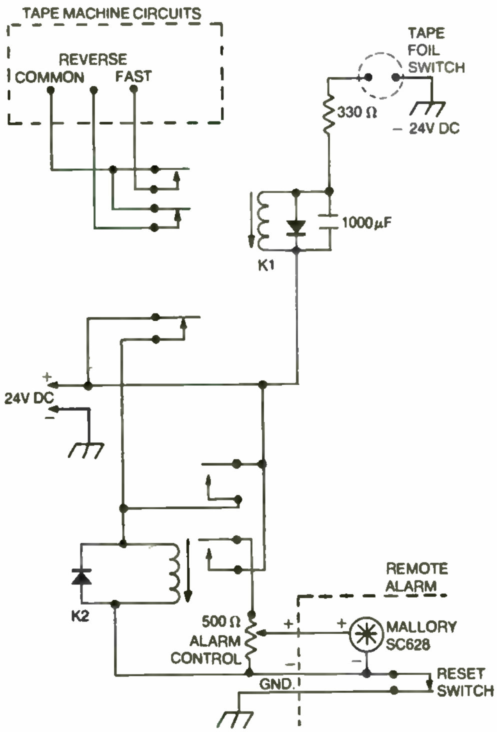


AUDIOTAPE MACHINE AUTOMATIC REWIND

In those cases where a tape machine is unattended, the circuit as shown can provide for automatic rewind at the end of the tape and, at the same time, provide an alarm to warn the operator that the tape is rewinding.

A foil switch must be added to the tape machine, and a length of conducting foil applied to the tape at the position the tape normally stops. This provides the start of the switching action. The capacitor and resistor on *K1* provide a delay of 24 seconds, approximately, which allows the machine to come to a full stop. After the delay, *K*1 will operate, and its contacts will switch the machine into reverse and apply a *start* impulse to the *fast* control position. (These contacts do the same as the machine pushbutton switches.)

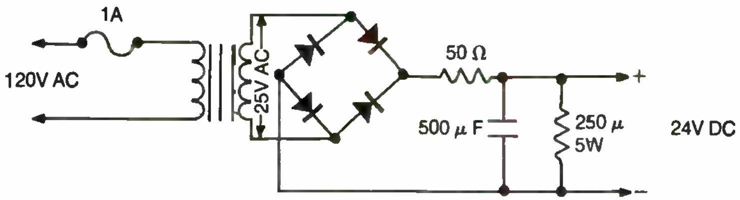
Contacts on *K*1 also apply supply voltage to *K*2, which sends out an alarm voltage to a remote alarm at the operator's position. The loudness of this alarm is adjustable. Alarm reset is through the normally closed ground return circuit (switch).



RELAY POWER SUPPLY

The station will build many small alarms, indicators, or relay circuits that need power, and it is not always possible or desirable to obtain power from the regular power supply in some unit.

A small power supply can be built for this purpose. Use a transformer which has a 1A, 25V secondary. The bridge reduces the amount of ripple. The bleeder is not necessary, but does hold the unloaded output voltage down. If better regulation is desired, then a zener can be added. But for most common purposes, the circuit as shown is adequate. If the circuit is often unloaded, use a 50V capacitor, as the DC voltage can rise to about 40V (depending upon line voltage).



Appendix B

Useful Formulas for Broadcast Engineers

Ohm's Law

DC Circuits	AC Circuits
$E = I^2 R$	$E = I^2 Z$
$R = \frac{E}{I}$	$= \frac{E}{R}$
$Z = \frac{E}{I}$	$I = \frac{E}{Z}$

Power

$$P = I^2 R = \frac{E^2}{R} = IE$$

Impedance

Series Circuits

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Parallel Circuits

$$Z = \frac{RX}{R^2 + X^2}$$

Equal Resistors in Parallel

$$R_t = \frac{R\text{(value of one resistor)}}{n\text{ (number of resistors)}}$$

Two Unequal Resistors in Parallel

$$R_t = \frac{R1\ R2}{R1 + R2}$$

Power Factor

$$\text{pf} = \frac{R}{Z} = \frac{P\ (\text{true power})}{EI\ (\text{apparent power})}$$

Q of Circuit

$$Q = \frac{X}{R}$$

Reactance

$$X_L = 2\pi fL \qquad X_C = \frac{1}{2\pi fC}$$

Transformers

$$\frac{N_p}{N_s} = \frac{E_p}{E_s} = \frac{I_s}{I_p} = \sqrt{\frac{Z_p}{Z_s}}$$

Decibels

$$\text{dB} = 10 \log_{10} \frac{P_1}{P_2}$$

$$\left.\begin{aligned} \text{dB} &= 20 \log_{10} \frac{E_1}{E_2} \\ \text{dB} &= 20 \log_{10} \frac{I_1}{I_2} \end{aligned}\right\} \text{(Equal resistance or impedance)}$$

Sine-Wave Relationships

$$\begin{aligned} \text{RMS} &= \text{peak} \times 0.707 \\ \text{Average} &= \text{peak} \times 0.637 \\ \text{Peak} &= \text{RMS} \times 1.414 \\ \text{Peak} &= \text{average} \times 1.57 \end{aligned}$$

Constants

$$\pi = 3.14159$$
$$2\pi = 6.28319$$
$$\text{Fahrenheit} = (\text{Celsius} \times 9/5) + 32$$
$$\text{Celsius} = (\text{Fahrenheit} - 32) \times 5/9$$

Wavelength (Free Space)

$$\lambda\,(\text{meters}) = \frac{300}{f\,(\text{MHz})}$$

$$\lambda\,(\text{feet}) = \frac{984}{f\,(\text{MHz})}$$

Antenna Length

$$\text{Quarter-wave (ft)} = \frac{234}{f\,(\text{MHz})}$$

$$\text{Half-wave (ft)} = \frac{468}{f\,(\text{MHz})}$$

Antenna Electrical Length in Degrees

$$\text{Length (degrees)} = \text{length (feet)} \times f(\text{kHz}) \times 1.016 \times 10^{6} \times 360^\circ$$

Chord of a Circle

$$c^2 = a^2 + b^2 - 2ac \cos C$$

where a and b are the two sides, C is included angle

Bandwidth

AM: $\text{BW} = 2M$
FM: $\text{BW} = 2M + 2D$

where M = highest audio-modulating frequency
D = deviation to one side of carrier

Loss Pads

Formulas are for a *T*-pad. For balanced circuits, use an *H*-pad: divide the input resistor value in half and place half in both legs (do the same for the output side).

$$R_3 = \frac{2\sqrt{NZ_1Z_2}}{N - 1}$$

$$R_1 = Z_1 \frac{(N + 1)}{(N - 1)} - R_3$$

$$R_2 = Z_2 \frac{(N + 1)}{(N - 1)} - R_3$$

where N = desired loss (dB)
Z_1 = input impedance
Z_2 = output impedance

Index

U

V

W