# SECTION 6: REMOTE PROGRAM ORIGINATION

6.1

# Radio Field Production

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Radio stations have used the remote location broadcast for decades to bring the listener an added sense of realism and excitement. Although the concept of the remote—as it is better known—has not changed substantially over the years, the means to accomplish the task has been quantum leaps in performance, ease of operation and reliability. Radio Electronic News Gathering (RENG) systems of today can be configured to provide virtually any degree of sophistication required by the station. As with any other area of broadcasting, the key to a successful RENG system is thoughtful planning.

## PLANNING THE NETWORK

The importance of careful planning of a RENG system cannot be over emphasized. The network should be configured based on the precise needs of the station. All persons that will be involved in the use of the system should be consulted to determine just what type of arrangement will be needed. Whether a station's format is "all news" or, "AOR," all persons in the news, production and engineering departments should sit down and define the requirements of the network. Whatever is heard at such gatherings, resist the urge to be negative when someone asks for a level of performance that is not practical. Hear everyone out. Even though the engineers present at the meetings may know that it is impossible to provide every reporter on the staff with a separate frequency that can be received at the studio from anywhere in town, at least listen to what the users would *like* the system to do. The realities of station economics and the laws of physics can be explained after the desires of the participants have been outlined. Many—perhaps most—RENG systems were built on a piecemeal basis, as needs dictated and economics allowed. The lack of a unified plan has often lead to RENG systems that are cumbersome to operate and—in the long run—more expensive than necessary to build for a given level of performance.

The size and layout of the station's market will have a substantial effect on how the RENG network is designed. A system intended to cover a sprawling urban area of 10,000 square miles will be configured much differently than a tightly clustered urban center covering 2,000 square miles. The number of stations in the market that are involved in RENG activity may also affect how a system is designed, and what types of equipment are used. Stations in major metropolitan areas may find that few, if any, frequencies are available for RENG activity.

Additional information for this chapter was provided by Richard A. Rudman; Engineering Manager, KFWB Radio; Los Angeles.

Program material can be returned from the field to the studio though either of two common routes—wired telephone lines or wireless transmission systems of various types. The route back to the studio will depend upon a number of factors, including the location of the event, the availability of telephone lines, the amount of set-up time provided and the duration of the broadcast.

### Wired vs. Wireless

Until the 1960's, the word "remote" was rarely spoken without reference in the same sentence to "the telephone company." Wired systems, either using the dial-up network or leased broadcast loops, provided the vast majority of interconnections from remote broadcast sites to a station's studio facilities. Since that time, however, radio systems have assumed an important role in remote activities because they inherently offer greater flexibility and generally provide the user with a higher-quality audio link.

Radio systems are ideally suited for broadcasts of relatively short duration from a variety of locations (during the course of a week's time). Meetings, speeches and sporting events, however, are probably best handled by a wired arrangement. The amount of frequency congestion in the origination area will also have an effect on which method a station will choose for the greatest reliability. Urban areas in which secure RPU channels are difficult to find may be best-suited to a wired link.

The amount of lead-time given the station before various events that need to be covered will also have a significant effect on the route taken by the program audio back to the studio from the remote site. Broadcasts that are scheduled weeks in advance are obvious candidates for use of a telephone company loop. Spot news events, on the other hand, do not lend themselves to planning days in advance, let alone weeks in advance. In such applications, therefore, a radio system is most practical.

The cost of telco facilities must also be considered. Unless the loop is to be left in place for a long period of time, installation charges can become prohibitive, especially if high-performance equalized lines are needed for the application. Many stations are able to justify the cost of a RENG radio system based solely on the telco savings that can be anticipated.

This discussion does not mean to imply that stations should choose between *either* a wired link or a wireless system. Large-scale systems are often built using both interconnection methods, either as various links in the chain or as back-up protection, in the event of a partial system failure.

## WIRED SYSTEMS

Wired communication systems for news, sports or programming can take a number of different forms, from basic telco equalized loops to sophisticated single or multi-line frequency extension systems using the dial-up network. An equalized line offers the user a simple, reliable link to the studio. The drawbacks include inflexibility, installation lead-time and installation or rental costs. Using the dial-up network gives the user a greater degree of flexibility than with standard equalized loops, however the level of performance (when a bandwith extension system is *not* used) leaves a great deal to be desired. The most popular way around this problem is through the use of a 2-line frequency extender system, as illustrated in Fig. 1.

There are a wide variety of extension methods, each with a different way of accomplishing the task. Generally speaking, however, audio from the remote source is split into two frequency bands by a filtering network. The higher frequency components are shifted lower by a conversion circuit for application to the telephone company dial-up network. The lower frequency components are shifted upward by a second conversion circuit and applied to a second telephone line.

At the studio demodulator end, the two signals are frequency-shifted back to their original values, filtered and re-combined to form the output of the system. Variations on this method include the use of single or multi-band compressors, variable equalization and compandor circuits. The use of audio compression at the transmitting (remote) point, and reciprocal expansion at the receiving (studio) end, can provide a substantial reduction in apparent line noise.

An interesting application of a single-line encoder/decoder is shown in Fig. 2. Audio from a news or sports story is recorded at high speed on a two-speed tape recorder. When the material is fed to the station, the low speed is used and the recorder output is fed through a single-line bandwidth extension system. At the studio end, the feed is recorded on the low speed of another 2-speed machine. When the program material is played back on high speed at the studio, an effective doubling of frequency response at the high end is achieved. With this arrangement, it is thus possible to squeeze a signal bandwidth of 100 Hz-5 kHz through a single dial-up telco line. Companding circuits, if used in the bandwidth extension unit, will also improve the line's apparent signal-to-noise (S/N) performance.

### Setting Up a Wired Remote

If a wired remote is chosen for a particular broadcast, the station has a number of options

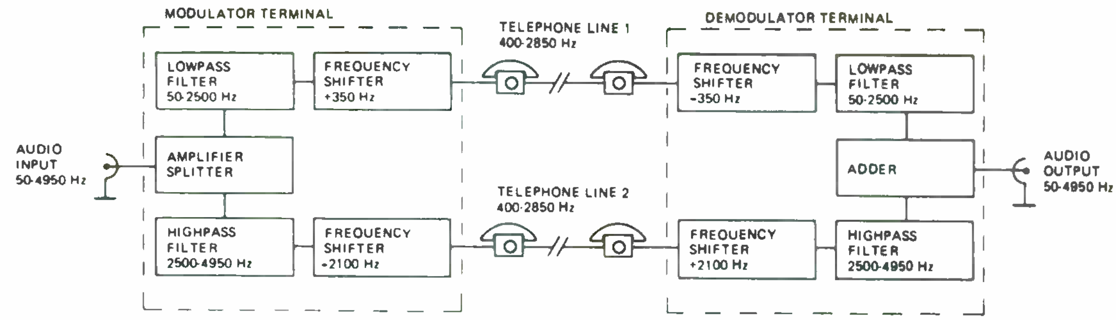



**Fig. 1. The basic two-line frequency extension process for dial-up telephone links. (Courtesy of C. N. Rood.)**

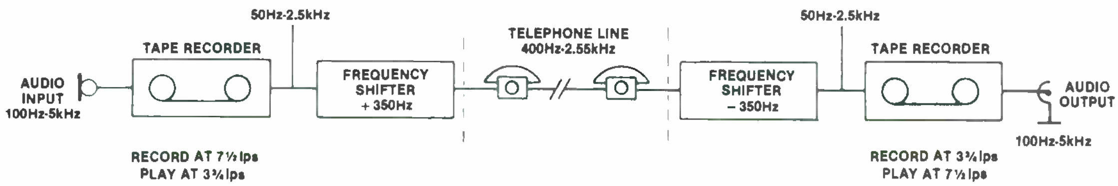



**Fig. 2. A frequency doubling technique using 2-speed tape recorders and a single-line bandwidth extension system. (Courtesy C. N. Rood.)**

in terms of equipment and configurations. The decision on how to originate the remote location programming will depend upon the requirements of the particular broadcast. Some generalizations can be made, however, that apply to most events.

A program transmitted back to the studio via a standard dial-up telephone company line—without any bandwidth extension—will usually be brief in duration, if for no other reason than the poor audio quality typical of such an arrangement. Spot news reports are common examples of this method of program return.

Small, battery-powered mic-to-line amplifiers are available to drive dial-up telephones through direct connection to the *tip* and *ring wires* of the phone company cable or through clip leads at the handset microphone pins. The direct connection method of coupling is preferred over the handset connection because the former by-passes the telephone hybrid coil assembly with its associated level loss. The broadcaster's motto when it comes to dealing with telco equipment is usually, "the more you can bypass, the better off you will be."

A broadcast transmitted to the studio over one or two dial-up telco lines using bandwidth extension equipment can provide impressive audio quality. Reasonably flat frequency response from 50 Hz to 5 kHz is possible using a two line system.

The equalized broadcast loop is probably the most popular method of relaying lengthy remote programming to the studio. Some stations prefer to order unequalized lines and adjust the loop themselves for the required frequency response. This procedure can be effective on relatively short telco lines. Generally, however, any audio loop that goes through more than one exchange should be left to the phone company, which has had decades of experience in making miles of twisted pair cable sound decent.

If a station decides to equalize the line and not rely on telco, equalization should be applied only at the studio (receiving) end. Applying frequency selective boost to a telephone line input can raise components of the signal to a point that will cause crosstalk into other lines or clipped audio due to the action of network protection devices.

The receiving equipment for a wired remote broadcast should be given careful consideration. Sophisticated telephone interface equipment is available today from a number of manufacturers. This hardware can ensure that maximum audio fidelity is recovered from the line. Some new generation interface equipment includes automatic gain control circuits, equalization and dynamic noise reduction systems.

## Remote Site Equipment

The audio equipment used at the site of the remote will vary as widely as the types of programs broadcast. Fig. 3 illustrates a typical application for either a wired or wireless relay system.

A four channel audio mixer is used to mix the sources and drive the telco loop, phone or RPU transmitter. Careful attention should be given to the connection of the mixer output to the telephone line. A phone coupler should be used be-

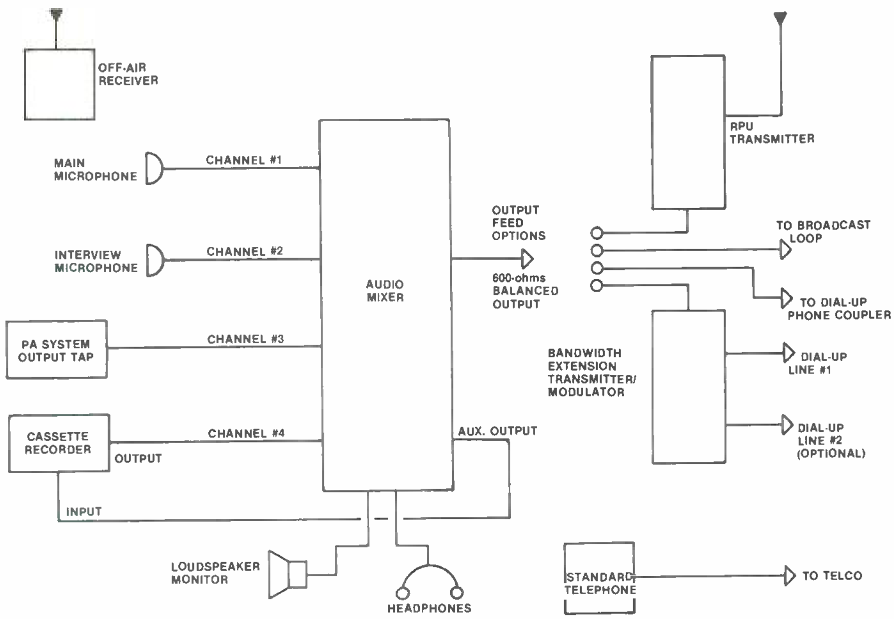



**Fig. 3. A typical equipment configuration for a medium scale RENG broadcast.**

tween the mixer and the telephone unless the mixer is specifically designed to work directly into a *hot dial-up line* (one with dc voltage across it). This caution applies to a connection made either to the phone line tip and ring wires or to the telephone set through the microphone terminals.

As shown in Fig. 3, two microphones are used —one for the announcer and another for interviews. An output is taken from the local PA system to pick up audio from meetings, speeches, music or whatever. A cassette recorder is often useful at a remote broadcast because it gives added flexibility to the remote crew. The recorder input signal can be taken from an auxiliary output on the audio mixer, allowing interviews or material from the PA system to be mixed and recorded for later use on the air.

A tone oscillator is useful in setting up the remote broadcast. Most mixers designed for remote applications include an oscillator that can be switched on to the program channel. This feature is especially useful when a telco line is employed to return program audio to the studio.

Having the proper monitoring facilities is important to the success of any remote broadcast. A loudspeaker and set of headphones should be provided for the remote crew. It is often desirable to have several headphones available for use by personnel at the remote site. Not all portable mixers can support a loudspeaker and multiple headphone outputs, and so a separate power amplifier and headphone booster may be needed.

An off-air receiver is a requirement for nearly all remote broadcasts. The receiver gives the remote crew a way of checking the total link and allows easy cueing of talent at the event.

A separate dedicated telephone set is suggested for complicated remote broadcasts. The phone provides an easy means of communicating with the studio. It can also serve as a backup line for program audio in case the RPU system or telco loop should fail.

## WIRELESS SYSTEMS

RENG has come a long way since the narrowband walkie-talkie days, when a 5 watt "portable" unit would be as big as a briefcase and weigh 35 pounds. Today's gear is small, lightweight and can deliver excellent audio quality. Stations can now go into the field for news and special event programs and maintain studio-like sound. The audio quality of remote broadcasts is more important now than ever before, because radio station transmission systems and consumer receivers are constantly improving. Further, the listening audience is becoming more discriminating and demanding of news operations. Today's competitive marketplace requires more than just sound from the field. It demands clean audio with good frequency response and low distortion. TV news has shown the public that this is possible, and has conditioned consumers to expect it.

Radio channels typically used for RENG work are used on a shared basis, and so receipt of a license is no guarantee of unlimited interference-free operation. Indeed, an unused channel is the exception—not the rule—in most larger urban areas of the United States. The frequency coordination process is a complicated procedure that requires careful thought and planning, and generally a great deal of lead-time. Broadcasters in a given geographical area rarely have to decide whether they wish to become involved in frequency coordination efforts. Usually the need for coordination is painfully obvious to all persons involved in RENG activity in the region.

The main driving force behind coordination efforts has been the Society of Broadcast Engineers, which has set-up a National Frequency Coordinating Committee to encourage and support local coordination efforts, and to provide whatever support might be needed in this regard. The subject of frequency coordination is discussed in detail in Section 1. Spectrum congestion is a sad fact of life to many stations engaged in RENG today. Users must recognize that coordination is vital to the reliable operation of remote broadcast systems, since spectrum congestion will no doubt become worse in the future, rather than better.

## Licensing Procedures

RENG work is done on two primary bands of frequencies set aside by the FCC for Remote Pickup Unit (RPU) operation. A number of frequency groups are allocated near 150 MHz and 450 MHz. Some assignments are also made on frequencies in the 25 MHz region. A particular broadcast station is not restricted to a maximum number of RPU systems that it may put into operation. The needs of the station and the budget available for equipment purchase are, instead, the major controlling factors.

Most RENG activity is currently centered in the 150 MHz and 450 MHz bands. In these slices of spectrum, three major license classifications exist—Automatic Relay Station (ARS), Base Station and Remote Pickup Mobile Station.

ARS systems are designed to receive program material on one frequency and retransmit on another. In this way, the average area of the RENG system can be extended considerably.

Base stations are, as might be expected, fixed-position transmitters used for communication between the central point and one or more remote points. Base stations may, in the event of emergency conditions, be used as a program relay channel for Emergency Broadcast System information.

Remote Pickup Mobile Stations consist of vehicle-mounted and portable (hand-carried) transmitters. They are usually licensed as a system in conjunction with a principal Base Station, or Stations. Remote Pickup Mobile Station licenses generally specify a minimum and maximum number of mobile transmitters allowed in the RPU system. Standard divisions include from 1 to 4 stations, from 4 to 12 stations, from 10 to 20 stations and from 20 to 50 stations.

The Commission's Rules require that the transmitter power for a RPU station be limited to


a level necessary for satisfactory coverage of the service area. In any event, not more than 100 watts of transmitter power output will be licensed. RPU transmitting equipment operating onboard an aircraft is normally limited to a maximum transmitter power of 15W. A Mobile Station consisting of a hand-carried or pack-carried transmitter is restricted to not more than 2.5W power output.

All RPU transmitting equipment must be type accepted by the Commission and checked each year (for units with more than 3W output) for frequency accuracy, deviation and RF power output. FCC Rules also require that RPU transmitters rated for 3W or greater must be equipped with a circuit that will automatically prevent modulation in excess of the authorized limits. In other words, an audio limiter must be built-in to the unit.

There are virtually no operator requirements for the use of a unit in the RPU service. Any person designated by and under the control of the licensee of the station may operate the equipment. An operator's license, as detailed in Part 13 of the Commission's Rules, is not required.

## Building a RPU System

In view of the serious spectrum congestion problems that exist today in many areas of the country, any RPU/RENG system should be designed to be as spectrum-efficient as possible and—equally important—to be as immune to undesired transmissions as possible. Even if the system will be operated in an area that currently does not have a spectrum congestion problem, there is no guarantee that such a problem will not surface in the near future. In any event, a well engineered system is also a spectrum-efficient system.

The first rule of spectrum-efficiency is to use only the effective radiated power (ERP) necessary to do the job. There is no justification for putting 15W into the air when 5W will provide the desired (or acceptable) signal-to-noise figure from the receiver. Ideally, all transmitters in a RENG system would, therefore, be equipped with continuously-variable power output stages. The operator at the remote site would then run the transmitter with only enough power output to reach the required S/N figure at the receive (studio) point. With some types of units this method of operation is possible, but in the majority of cases, continuously-variable power output transmitters are not available. User modification of existing equipment is not an acceptable solution, since such work would most likely invalidate the transmitter's FCC type acceptance.

A more logical solution, therefore, is to purchase RENG transmitters of several different power levels operating on the same frequency (or frequencies). All of the popular RENG broadcast equipment manufacturers offer units with different power output levels. With some equipment, a low-power transmitter is used and an optional power amplifier module is added between the transmitter and the antenna to give the needed RF output.

Directional receive and transmit antennas are a good idea for both an efficiency and coordination standpoint. The use of a pair of high gain antennas makes it possible to achieve a much greater ERP for the same transmitter power. Of equal benefit in a crowded urban area is the elimination of any non-essential radiation. Through the use of directional transmit and receive antennas, stations can establish more secure channels by placing the radiated energy where it will do the most good (from the transmit end), and rejecting unwanted signals from other directions (at the receive end).

A simple and sometimes effective coordination tool is cross-polarization. Two stations on adjacent frequencies may achieve as much as 25 dB isolation through the use of different polarizations of transmit antennas, matched by like polarization at their respective receive antennas. Cross-polarization results in varying degrees of success, depending upon the frequency of operation and the surrounding terrain. Line-of-sight paths usually will provide good results, but urban centers with their highly-reflective buildings, generally cause polarity shifts in the transmitted signal that may significantly reduce the benefits of cross-polarization.

## Path Engineering for Fixed Stations

Careful path engineering should be performed prior to any licensing work to determine if the proposed locations of Base Station and ARS installations will be able to achieve the desired results without using excessive amounts of transmitter power. There is much more to path engineering for a RENG system than simply pointing the transmitting and receiving antennas at each other (when directional antennas are used) and turning the equipment on. Base Station and ARS systems are fixed-position installations that cannot always be located in the best possible geographic locations because of space availability problems, excessive construction or site rental costs, or local/federal licensing difficulties. In such cases, the required path is not the ideal path and the link will have to be engineered around the fixed points.

The site selection process for repeaters and receivers should also take into consideration the RF environment in which the equipment will be working. Multi-user locations, such as the World

Trade Center in New York City or Mount Wilson near Los Angeles, are very good talk-out sites, but terrible receive sites. For such situations, a remotely-located receiver (in the case of a repeater system) should be considered. The two sections of the ARS station would then be tied together with telco facilities.

The use of a telco loop to feed a remotely-located transmitter introduces several familiar problems, such as noise, crosstalk, distortion (if repeated several times), limited frequency response and installation/service delays. In some arrangements, the use of a telco loop to the transmitter (or receiver) is the only economical way to complete the link. Although such a hybrid system is not the ideal configuration, it will get the job done.

Planning for any RENG system should begin with an accurate, detailed U.S. Geological Survey (USGS) map covering the proposed path. Note should be made of any natural obstructions or Fresnel clearance obstructions (such as mountains, hills or vegetation) or man-made obstructions (such as buildings, water tanks or transmitting towers) in the proposed path. The transmitting and receiving antennas should be plotted so that a minimum of .6 Fresnel Zone clearance is obtained over 4/3 earth. Information on obtaining USGS maps may be found in the chapter on Information Sources in Section 1; Fresnel zone clearance is covered in more detail in the chapter on Microwave Engineering in Section 4.

When planning a RENG path, a profile drawing of the transmitting and receiving antennas, the terrain and any obstructions in between should be made on graph paper set to 4/3 earth radius. The use of such graph paper will compensate for the curvature of the earth and the normal refraction of VHF and UHF frequency signals when determining Fresnel Zone and obstruction clearance. Simple height above sea level is insufficient to determine whether a natural or man-made obstruction will interfere with the RENG signal on a long-distance path. Once a proposed path has been drawn, a visual inspection should be made of the area for any problems that could degrade the performance of the system. Particular attention should be paid to items not documented on the USGS maps, such as unforeseen hills, high-rise buildings or point obstructions, such as radio towers.

The terrain from the transmitting antenna to the receiving antenna must be examined not only for obstructions, but for reflection possibilities as well. A large body of water will usually cause problems for a RENG system operating in the UHF frequencies. If the water is an even number of Fresnel Zones from the direct path, signal attenuation will likely occur at the receiver. Temperature changes and tidal conditions will also have an effect. Likewise, thick vegetation or forested areas can be reflective to RF signals when wet, creating a similar (but not so troublesome) problem. Generally the solution to reflection problems is to change either the transmitting or receiving antenna height or to employ a diversity reception system, if a long-term solution is needed.

## Determining the Fade Margin

A gain and loss balance sheet should be computed to determine the *fade margin* of the proposed system. An adequate fade margin is vital to reliable performance of the system because a link that is operating on the edge of the minimum acceptable receiver quieting will encounter problems later down the road. Normal component aging in the receiver or transmitter can cause a loss in received signal level and thus degrade the system performance. Likewise new construction near the transmitting or receiving site can degrade the path, resulting in poor performance. Atmospheric conditions, usually severe weather in the area or ice on the transmitting or receiving antennas can also cause sharp fading, and even a complete loss of signal, if an adequate fade margin above minimum receiver quieting is not provided. The RENG system fade margin can be computed by using the following equations:

$$G_s = G_t + G_{ta} + G_{ra} \qquad [1]$$

Where: $G_s$ = total system gain (dB)
$G_t$ = transmitter power output (dBm)
$G_{ta}$ = transmit antenna gain (dBi)
$G_{ra}$ = receive antenna gain (dBi)

The values for $G_{ta}$ and $G_{ra}$ are gathered from the antenna manufacturer's literature.

(Note: $dBi = dBd + 1.1\ dB$, approximately.) The value for $G_t$ is given by the following formula:

$$G_t = 30 + 10 \log P_o \qquad [2]$$

Where: $G_t$ = transmitter power output in dBm
$P_o$ = transmitter power output in watts

Next, the system losses are computed:

$$L_s = L_p + L_l + L_c + L_m \qquad [3]$$

Where: $L_s$ = total system losses (dB)
$L_p$ = path loss (dB)
$L_l$ = transmission line loss (dB)
$L_c$ = connector loses (dB)
$L_m$ = misc. loses (dB)

The values for $L_l$ and $L_c$ can be determined from the manufacturer's literature. Fig. 4 shows typical loss values for ½-inch foam-filled transmission line. A reasonable value for connector loss with components normally used in ½-inch transmission line installations is 0.5 dB. The value for $L_p$ can be found by using the following formula:

$$L_p = 36.6 + 20 \log F + 20 \log D, \quad [4]$$

Where: $L_p$ = the free space attenuation loss between two isotropic radiators (dB)
$F$ = frequency of operation in MHz
$D$ = the distance between the antennas in statute miles

Now, the fade margin can be calculated:

$$\textit{Fade Margin (dB)} = G_s - L_s - R_m \quad [5]$$

Where: $G_s$ = total system gain (dB)
$L_s$ = total system losses (dB)
$R_m$ = minimum signal strength required for target $S/N$ (*dBm*, a negative number)

$G_S$ and $L_s$ are determined by the equations previously shown. $R_m$ (receiver sensitivity) is determined from the receiver manufacturer's specifications. If the manufacturer gives a receiver sensitivity figure in microvolts, the following formula can be used to convert to *dBm*:

$$R_m = 20 \log \frac{V_r \times 10^{-6}}{.7746} \quad [6]$$

Where: $R_m$ = minimum required signal strength (*dBm*)
$V_r$ = Receiver sensitivity (microvolts)

$R_m$ can also be found by using a communications receiver test set, available at most commercial and industrial communications radio service shops.

In order to predict accurately the performance of a RENG radio link, the value of $R_m$ must be determined carefully. Many receiver manufacturers specify $V_r$ for 20 dB of receiver quieting. This level is a convenient reference point; however, it should not be used for fade margin calculations. For maximum system performance and reliability, the fade margin determination should be made based upon the signal level required to provide the minimum acceptable receiver signal-to-noise performance.

The recommended fade margin for a 150 MHz band RPU system is at least 10 dB plus 2 dB for each 10 miles of line-of-sight path distance greater than 10 miles. At 450 MHz, the fade margin should be increased to a minimum of 15 dB plus 3 dB for each 10 miles of path distance greater than 10 miles. These fade margins are designed to limit periods of performance degradation of the radio link to 1% or less during worst-case environmental conditions. The fade margin assumes transmit and receive antenna clearance above the ground and all obstructions of 50 to 100 feet.

While it is important to provide an adequate fade margin, needlessly high fade margins should be avoided because of the spectrum congestion problems that may result. Variable power output transmitters give the user the ability to adjust for an optimum fade margin, while keeping radiation toward other stations at a minimum.

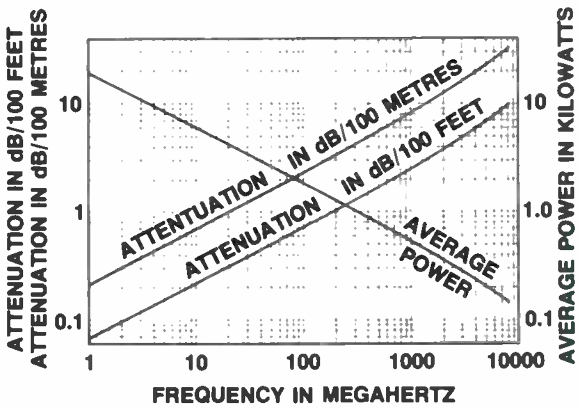



**Fig. 4. The attenuation and power handling ratings for 1/2-inch foam dielectric coax. (Courtesy of Andrew Corp.)**

## Other Planning Considerations

Path engineering for remote-location broadcasts is seldom done for RENG activities because of the transient nature of such events. Rough estimates should be made, however, of the geographical areas of interest before attempting remote feeds. It is well worth the time spent to conduct a coverage survey of the primary areas of interest for RENG activity when planning an overall system to determine which locations provide good or marginal performance. A little planning and work ahead of time will save many problems (and probably dead air) once the system is put into operation.

For base or relay installations that, for one reason or another, cannot use frequencies in the RPU bands for program or control data interconnection, there is often an alternative to the telephone company audio loop back to the studio. Private common carriers in many markets are installing competitive audio circuits, which can be leased. If the RENG installation is co-located with a television relay station, it may also be possible to back-haul the RENG audio on one of the TV microwave system's subcarrier channels.

The selection of receiving sites must be made with care, keeping in mind the area of coverage required of the receiver. The best location for a RENG system is not always the highest building in town. Placing a receive antenna at a high elevation in a metropolitan area can result in poor performance of the system in the downtown area, since the gain of many omnidirectional vertically polarized antennas decreases as the antenna is raised above the transmitting point. Tall buildings are excellent for point-to-point relay transmissions, but are generally unsatisfactory for wide-area coverage in a metropolitan region.

An inexpensive installation option is available to AM broadcast stations that do not want to erect a separate RENG transmitting tower at the main transmitting site. An isocoupler can be installed at the AM tower base that will pass the RPU transmitter frequency with good efficiency (90% is typical), while at the same time presenting a high impedance to the AM band energy. Isocouplers are available in various frequency and power ranges. Installation of these devices may change the base impedance of the AM tower slightly thus an engineering consultant should be contacted before installation work begins.

Every effort should be made to locate the receiving antennas of a RENG system as far away from high power transmitting antennas as possible. This should be attempted regardless of the frequency separation between the receive unit and the suspect high power transmitting antenna. Failure to achieve adequate separation may require the installation of filters of various types on the receiver front-end.

In order to keep system losses to a minimum, a low loss transmission line should be used, such as the 1/2-inch foam-filled coax shown in Fig. 4. The advantages of using a low loss line are illustrated in Table 1. The two ends of the transmission line (at the receiver and transmitter) are probably the easiest parts of the hardwired system in which loss can be introduced, and so care should be taken to install the lines and connectors according to good engineering practice. The line should not be bent in a smaller radius than that recommended by the manufacturer. Excessive bending can cause a kink in the outer conductor of the coax, reducing the power handling capability of the line and (more importantly in most cases) changing the characteristic impedance of the line at that point. This will result in increased VSWR (and therefore, power loss) at the transmit end, and greater signal loss at the receive end (if bent there).

The transmission line and connectors must be made watertight if exposed to the elements. Each connector should be sealed with a silicone dielectric compound and then wrapped with good quality tape. Unless this is done, rain may eventually work its way into the connector and cause signal loss or VSWR problems. The line should be grounded (using a recommended grounding kit) at the point where it leaves (or enters) the equipment building and where it starts its climb up the tower (unless the vertical distance to the antenna is less than 10 feet). This will prevent any high voltage transients caused by lightning from entering the equipment building, and thus the RENG equipment. A short length of flexible coax is generally used on each end of the two transmission lines for connection to the equipment and antennas (when 1/2-inch or larger coax is used).

**TABLE 1. Typical cable loss for popular types of transmission line. Note the poor performance figures for RG-58/U. LDF4-50 is 1/2-inch foam-filled line, LDF5-50 is 7/8-inch line and LDF7-50 is 1-5/8-inch line. (Chart courtesy of Scala Electronics.)**

TRANSMISSION LINE LOSS COMPARISONS

L = Loss in dB per 1ØØ feet
E = Approximate power transmission efficiency of 1ØØ foot length

| | 15Ø Mhz | | 45Ø Mhz | | 95Ø Mhz | |
|---|---|---|---|---|---|---|
| | L | E | L | E | L | E |
| RG-58/U | 6.Ø db | 25% | 12.Ø db | 6.3% | 2Ø db | 1% |
| RG-8/U | 2.5 db | 55% | 5.Ø db | 31% | 9 db | 13% |
| LDF4-5ØA | Ø.85 db | 83% | 1.7 db | 67% | 2.5 db | 55% |
| LDF5-5ØA | Ø.48 db | 9Ø% | Ø.9 db | 85% | 1.55 db | 71% |
| LDF7-5Ø | Ø.28 db | 94% | Ø.56 db | 88% | Ø.88 db | 84% |

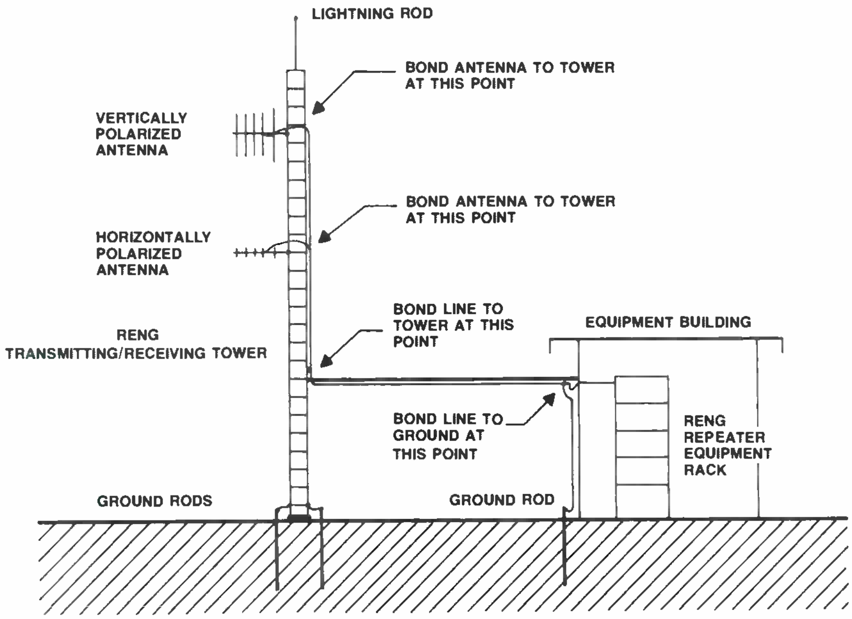



**Fig. 5. The recommended installation practices for RENG antennas and transmission lines.**

This "pigtail" is normally no more than 18 inches long. See Fig. 5.

## Antenna Considerations

The selection of an antenna for use in a RENG system is an important decision because of the effect the antenna has on system performance and spectrum usage. The usual RENG antenna has, until recently, been the omnidirectional vertical whip with a small amount of gain. Many system planners, however, are now being forced by interference concerns to use directional antennas with moderate amounts of gain. The low power levels commonly used with RENG equipment and the RPU band frequencies make it possible to economically achieve increased effective radiated power (ERP) through the use of high gain transmit antennas. The use of high gain antennas also concentrates the radiated signal where it will do the most good, and minimizes radiation in directions that may adversely affect the RENG activities of other stations in the same, or nearby, communities.

The omnidirectional base station antennas commonly used in the 150 MHz and 450 MHz bands are vertically polarized units with 4 to 6 dB gain. Electrical beam tilt is sometimes available. Depending upon the manufacturer, up to 20 degrees downtilt can be provided on 150 MHz antennas, and up to 11 degrees is common for 450 MHz omnidirectional units. Large amounts of beamtilt are normally used when the antenna is to be mounted on a structure that is substantially above the surrounding terrain, thereby improving the antenna's close-in coverage.

The typical directional RENG antenna is a medium gain 5-element Yagi. Such a unit provides about 9 to 10 dB gain over a reference dipole, with a front-to-back ratio of approximately 14 to 18 dB. Fig. 6 shows the radiation pattern for a commonly-used 5-element 150 MHz Yagi. This particular antenna measures 40″ × 40″ × 4″ and weighs 8 pounds. It is, thus, small and light enough to be used on remote broadcasts. It is also suitable for permanent installations using either horizontal or vertical polarization. These antennas may be stacked in two and four bay arrays (with suitable phasing harnesses) for additional gain and directivity.

Most Yagi antennas are made to match the specific frequency requirements of the user. Multiple frequency operation using a single antenna is possible with reasonable VSWR numbers, though, as long as the operating frequencies are not removed from the cut center frequency by more than 1 to 2 percent.

A recent addition to the RENG user's bag of electronic tricks is the broadband log periodic antenna, which can be used on any channel within a wide band of frequencies. Such antennas provide a smooth pattern with minimal sidelobe radiation and a high front-to-back ratio (typically 25 dB in the 150 MHz band). Nominal gain for 150 MHz operation is 7 dB. Units can also be stacked to provide additional gain and directivity. Such antennas are usually larger and heavier than the familiar Yagi, however they allow use of the antenna for virtually any frequency within the specified band at low VSWR levels (a maximum of 1.5-to-1 is typical). Fig. 7

shows the radiation pattern of a log periodic antenna designed for use in the 450 MHz band. Horizontal or vertical polarization is available. The antenna shown in Fig. 7 has a gain of 8 dB and a front-to-back ratio of 35 *dB*. Such a unit is, thus, ideally suited for operation in areas with high spectrum congestion.

Just as a TV or FM broadcast antenna must be protected against icing problems, so should antennas used in RENG applications. Although antenna de-icers are not used in RENG installations, a radome is often available for an antenna to protect it from damage or degradation in performance due to snow, ice or salt spray.

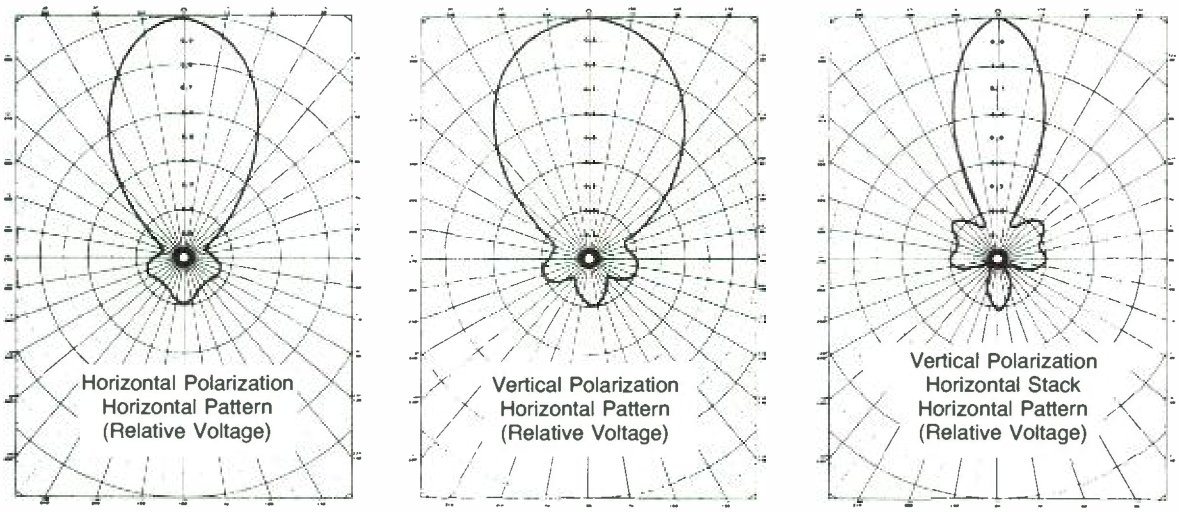



**Fig. 6. Radiation patterns for the CA5-150 5-element yagi antenna made by Scala Electronics for use in the 150 MHz frequency band.**

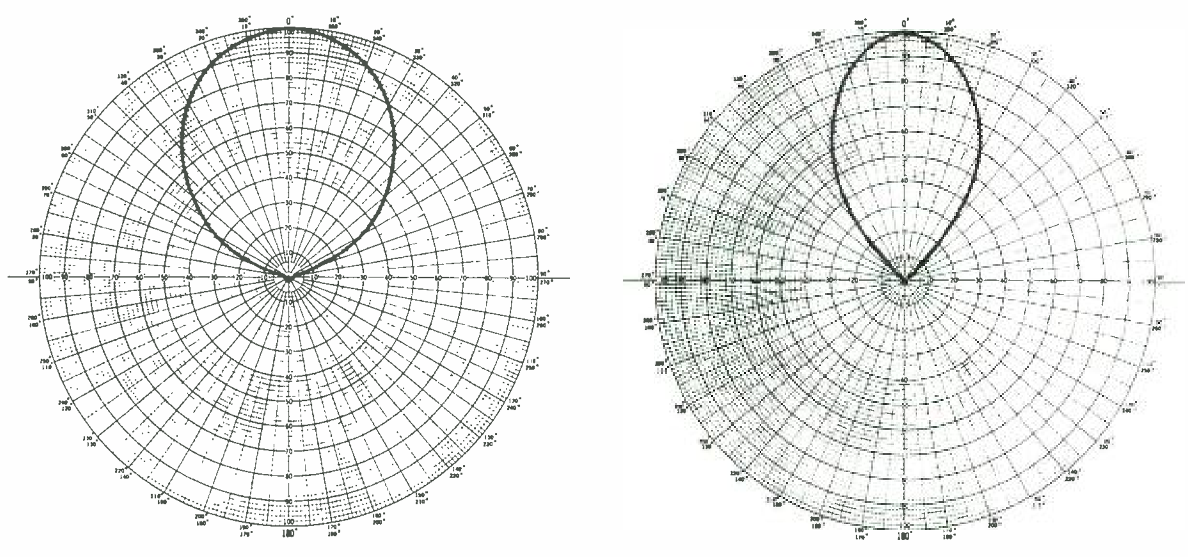



**Fig. 7. The radiation patterns for the Scala CL-400 broadband log periodic antenna, designed for use in the 450 MHz RPU frequency band. (Courtesy of Scala Electronics.)**

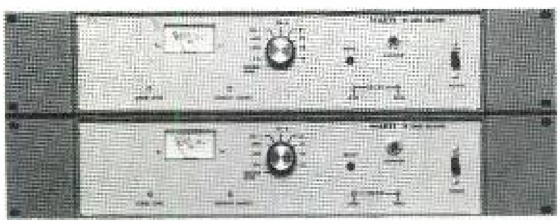
## Transmitter-receiver Considerations

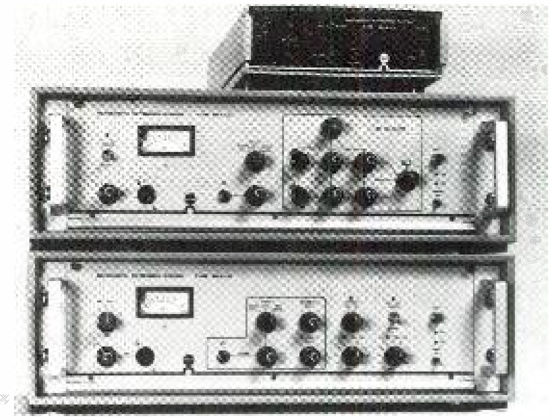
Whatever the configuration of the planned RENG system, there are several important points that should be considered. Most of these items apply to receiving equipment, which usually present the greatest problems to a system designer. Transmitting equipment must also be selected with care, but the receiving links in a RENG system are the ones most often subjected to conditions that may make good performance difficult.

A receiver should be selected that has sufficient dynamic range and headroom to allow the system to deal with strong adjacent-channel signals, as well as very weak and very strong co-channel signals from transmitters in the network. A receiver with inadequate headroom will clip and yield distortion. Wide dynamic range active devices should be used in the receiver front-end, such as gallium arsenide field effect transistors (GAsFETs).

The need for a preamplifier or cavity preselector network ahead of the first RF stage should also be considered. RF preamplifiers can add sensitivity, but they can also cause overload conditions in the presence of medium-level co-channel signals. Preselectors are often necessary at mountain-top or antenna farm locations because of the high-level RF signals present at such sites. It is not uncommon to have a 1 kW land mobile paging transmitter operating in the 454-455 MHz range located nearby a RPU band receiver that is working in the 455-456 MHz frequencies. High power FM or TV transmitters can also cause desensitization of the receiver front end, unless adequate bandpass filtering has been included in the receiver design.

The locations commonly used for relay sites are seldom ideal from an environmental standpoint. They are often inaccessible during portions of the year, very hot in the summer and very cold in the winter. For this reason, equipment that is rugged should be selected, if downtime is to be minimized. Temperature extremes can also cause problems for frequency-determining elements, as well as accessories such as cavity filters, preselectors and preamplifiers. Since relay sites are often difficult to reach, equipment should be designed for easy maintenance, preferably through module replacement. A spare stock of modules should be kept at the site so that the system can be quickly returned to operation. The defective module can then be serviced at the studio, or returned to the factory for repair. It makes little sense to haul a truck full of test equipment up to a remote site whenever a problem occurs. It is not cost-effective either.





Regular performance tests should be made of the RENG system, just as an engineer would do with any other important chain of equipment at the station. Regular checks and measurement often allow the engineer to spot problems that could cause a total system failure if left unattended. If trouble is experienced with a piece of receiving equipment, the possibility of interference from other services should not be overlooked. A spectrum analyzer is invaluable for such work.

## System Configuration

The requirements of users will vary greatly from one station to the next and from one market to the next. There are, however, several standard system configurations that can be modified to fit the requirements of most users. These range from the simple point-to-point program relay system common in many small-scale operations, to complicated multi-point relay installations with automatic signal quality voting circuits.

Fig. 8 shows the basic RENG program relay system in which one (or more) transmitter(s) on a particular frequency is (are) used in the field, and a single receiver is located at the studio. All

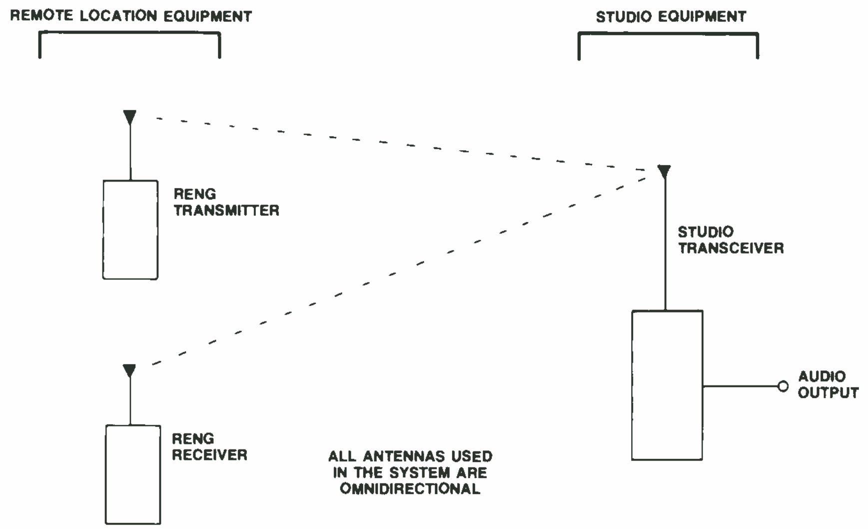



**Fig. 8. The basic RENG program relay system using a single hop from the remote location to the studio.**

antennas used in the system are omnidirectional. While there is much to be said for system simplicity, such an arrangement is not practical in an increasing number of urban areas because of spectrum congestion problems and the need to cover large geographical areas.

The system configuration shown in Fig. 9 overcomes the geographical coverage area problem through the use of an Automatic Relay Station. The range of a RENG system can be greatly extended through the use of an ARS. Such systems also make it possible to use lower power transmitters in the field, since the transmitter at the program origination point need only be powerful enough to reach the ARS site. This often allows the use of smaller and lighter remote transmitters, usually hand-carried or pack-carried units. The arrangement shown in Fig. 9 will satisfy the requirements for wide area coverage and is sufficient for radio markets where spectrum congestion is not a problem. Because all antennas in the system are omnidirectional, however, the con-

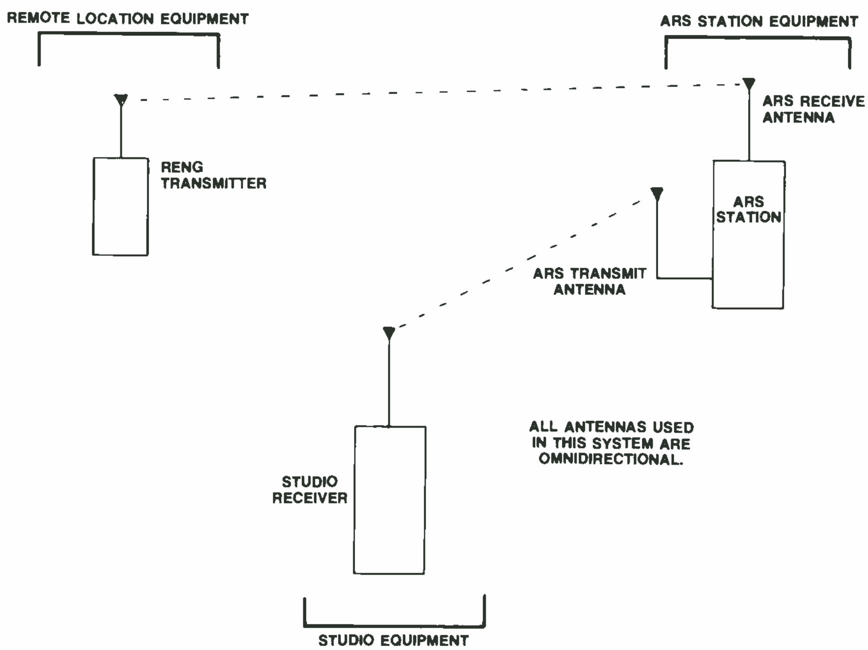



**Fig. 9. The basic RENG program relay configuration using an ARS station between the remote location and the studio.**

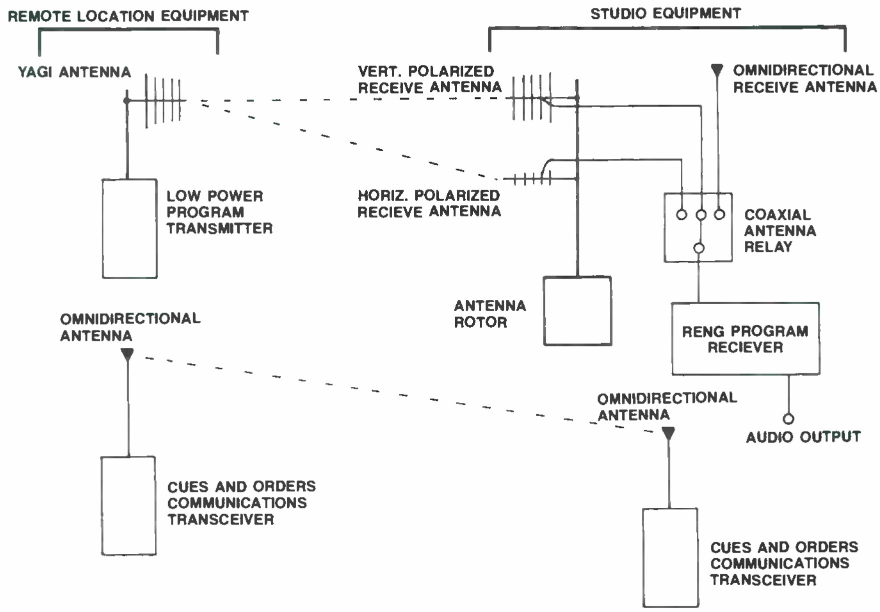



**Fig. 10. A high-performance two-point RPU system designed for operation in frequency-congested areas.**

figuration is not suitable for use in larger urban areas which are experiencing frequency allocation problems. For such applications, a more sophisticated approach is needed to RENG activity.

Fig. 10 shows a high-performance two-point RENG system designed for operation in spectrum-congested areas. At the remote site, two transmitters and two antennas are used. The communications transceiver is used to set-up the program audio link and to relay cues and coordinating information. The low power transmitter and its associated directional transmit antenna are used to relay the program signal to the studio. At the studio site, a communications transceiver, feeding an onmidirectional antenna, is used for set-up information, cues and coordination work. The multi-antenna receive system is used for program audio pickup.

The "cues and orders" radio system shown in Fig. 10 is used for general purpose communications not requiring wide frequency response and a high signal-to-noise ratio. The lower power program relay transmitter and directional receive and transmit antennas provide a secure and quiet channel, without causing interference to other RPU band users in the area.

Between remote broadcasts and when beginning the initial set-up procedure for a remote, the omnidirectional antenna is patched into the broadcast-quality RPU band receiver at the studio through the coaxial switch, K1. Once contact has been established with the remote crew, one of the directional antennas—which are mounted on a common mast driven by a remote-controlled antenna rotor—is switched into the studio receiver. The polarization of the transmission from the remote site is planned before the remote crew leaves the studio. Selection of either horizontal or vertical polarization is made during the frequency coordination process, or at the discretion of the user. Engineers may find that a particular polarization may yield better results from certain geographical areas, and in such cases, that polarization would be chosen. Once the proper antenna has been selected, the antenna rotor is adjusted for maximum received signal strength. The studio operator then talks the remote crew into the best position for its Yagi transmit antenna. At this point the antennas are locked-down and the link is ready for the remote broadcast.

If a variable power transmitter is used at the remote site, or transmitters of various power levels are available, the transmitter power would next be adjusted to the point necessary to achieve the required S/N performance at the receiver. After power output adjustment, the antennas on both the receive and transmit ends should be checked again for correct positioning.

While this process may be time consuming and require the purchase of additional equipment, it will assure a high quality, secure, RF link from the field to the studio. This system will also result in a minimum of unwanted radiation to other RPU band users.

Fig. 11 shows a high-performance, secure-channel Automatic Relay Station. The same antenna selection and positioning procedure is used in the ARS installation as was used in the two-point system of Fig. 10, except that the antenna switching and positioning work is done by remote control. The link for this remote control system can be a subcarrier on the main station broadcast signal, a separate dedicated radio link, a dial-up telephone patch or a leased telco data or voice loop. A standard broadcast transmitter remote control system is used, with the common channel on-off/up-down functions performing the necessary switching and positioning work at the ARS site. For stations with multiple site capability on the main transmitter remote control system, the ARS remote points can be simply treated as other "transmitter sites" and controlled as such from the master unit.

A monitor receiver is included at each ARS installation to inhibit activation of the ARS transmitter if a transmission is already in progress on that frequency. As shown in Fig. 11, the control commands are received over a subcarrier receiver from the main station transmitter. The relay station logic interfaces the remote control unit with the receive antenna coaxial switch and the antenna rotor control box. During set-up, the telemetry section of the remote control unit provides an audio FSK signal that is sent back to the studio control unit via a telco line or the relay (ARS) transmitter, as shown.

The SCA, omnidirectional program, monitor and relay transmit antennas are all fixed in position. Only the directional receive antennas, one set for horizontal polarization and the other for vertical polarization, are movable. An arrangement such as that shown in Fig. 11 will provide maximum flexibility and minimum risk of program audio disruption.

In a system where two or more of the ARS stations shown in Fig. 11 are used, an arrangement such as that shown in Fig. 12 may be implemented. The studio remote control unit is used to determine which of the ARS stations is allowed to repeat the program traffic. Those stations which will not be used to repeat the program material would be instructed by the studio operator to remain inactive. For multiple site ARS operation, as shown in Fig. 12, individial directional receive antennas, or a single directional receive antenna mounted on an antenna rotor, may be used to receive the ARS traffic at the studio.

For protection against system failure, an equalized telco loop can be installed between each ARS point and the main studio. With this backup provision, an equipment failure in the relay gear would not interrupt a remote broadcast.

One of the problems sometimes experienced with ARS equipment is the possibility of a desired signal opening the system, and an undesired signal keeping it open after the desired traffic has ended. This can occur if the tone burst method of repeater keying is used. For example, a valid tone burst signal unlocks the ARS system and then undesired noise or traffic holds the channel open after the desired traffic has ended by prohibiting a loss-of-carrier indication from the receiver. The ARS will thus be stuck open until the level of the interfering signal drops to a point that allows the receiver to squelch and generate a loss-of-carrier command to the ARS system logic. In order to maintain positive control over the system, a means should be provided to override the ARS logic by remote control from the studio.

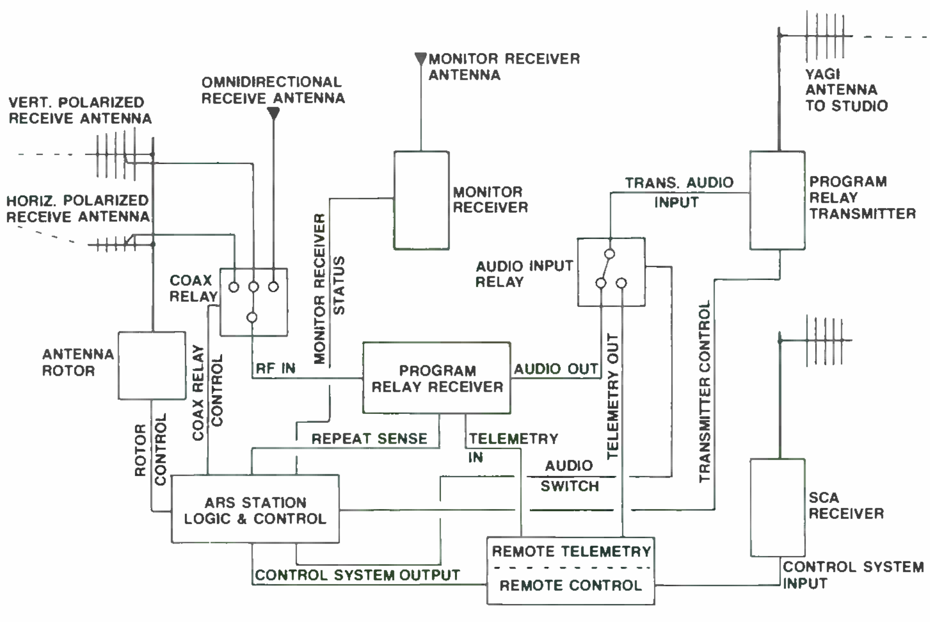



Fig. 11. A high-performance secure-channel ARS station with remote control of system functions.

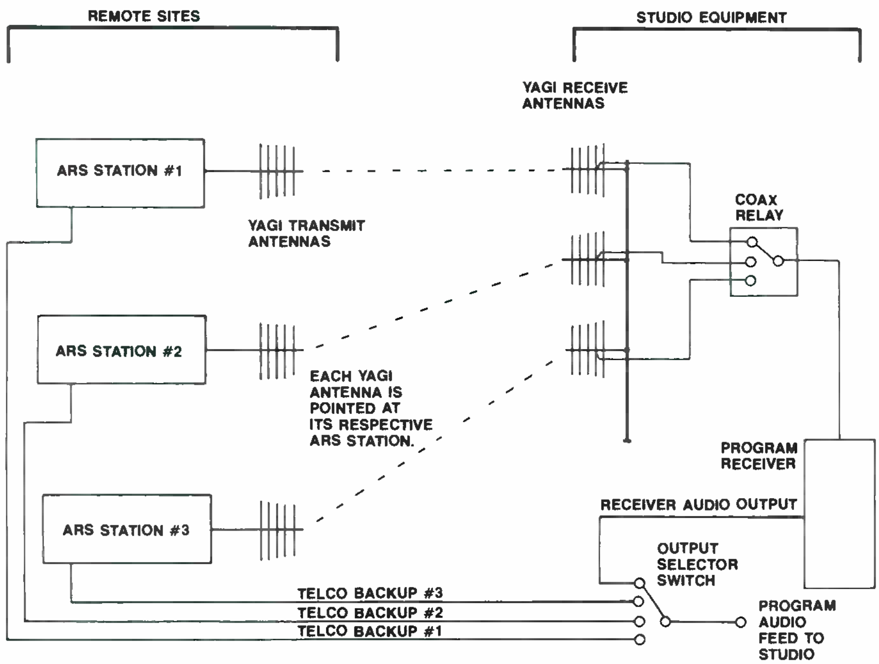



**Fig. 12. A multiple site ARS network feeding a central studio control point. Note each ARS station is also connected to the studio via a land line for backup protection.**

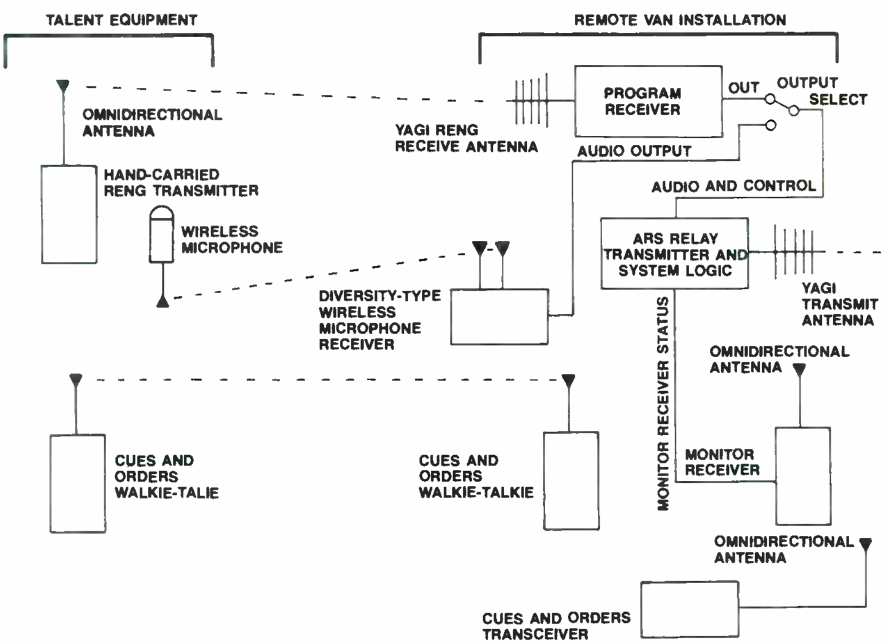



**Fig. 13. The use of an ARS system at the event site for added range and talent flexibility.**

Fig. 13 shows some of the ways the remote location program audio can be transmitted. As mentioned previously, the communications transceiver is used for cues and orders from the studio location. The program channel signal can consist of a hand-or pack-carried transmitter, which directly feeds the studio receiver or one or more ARS systems. Fig. 13 also shows a repeater station configuration that can be used when a high-power transmitter is required to reach either the studio or the ARS relay point. The use of a repeater—configured as a standard ARS station—in a car or van outside the remote location also gives the talent at the event greater flexibility, since a small hand-carried transmitter can be used, rather than a larger unit with antenna and power cables attached. This arrangement is also ideally suited for use with a wireless microphone, which gives the talent an even greater degree of flexibility. The receive antenna at the remote van can be either an omnidirectional unit, or a Yagi. The system shown in Fig. 13 includes a monitor receiver to prevent ARS transmission over traffic already in progress.

There is a limit, of course, to the number of times a signal can be repeated and still maintain good audio specifications. Moreover, each added hop in the path between the remote site and the studio increases the chances of a spurious signal interrupting the remote feed. Each additional hop also increases the complexity of the system and the vulnerability of the link to equipment failure. The design goal for any RENG system should be to keep the arrangement as simple and direct as possible, while still providing talent flexibility, backup protection and high performance.

## Wireless Microphones

The use of wireless microphones to free-up the talent at a remote broadcast is gaining popularity with stations involved in RENG activity. The advantages to the talent are obvious: complete freedom of movement and nothing to carry around but a microphone and air monitor receiver. There are no controls or meters for talent to worry about. The range of a wireless mic is somewhat limited, but a properly designed system for remotes that are more-or-less stationary can provide simple set-up and coverage of an event.

The receiver used in conjunction with the wireless microphone may use either diversity or non-diversity reception techniques. A non-diversity receiver is used where multipath cancellation is not a problem, such as in open areas or when conducting fixed-position interviews. If, on the other hand, the wireless mic is to be used in several places and the possibility of multipath cancellation exists due to nearby reflective objects, a diversity receiver is recommended.

The diversity receiver uses two antennas, located in different areas of the event site. A minimum separation of 20 feet is usually recommended. The receiver automatically selects the stronger of the two signals for demodulation. The switching of RF sources occurs silently without any "squelch type" noise bursts.

Many wireless microphone systems include audio companding circuits to extend the dynamic range and lower the apparent noise floor. A properly engineered wireless microphone system can be treated by engineering personnel as essentially a piece of wire between the microphone and the audio console input.

## Remote Cues and Orders

Communications with a remote crew from the studio can be accomplished in one of several ways. The simplest method is an over-the-air cue in which the talent simply listens to the station's air signal and takes his (or her) cue from the studio announcer or a pre-recorded introduction cart. Other methods include use of the station's subcarrier signal for cueing information or a separate, dedicated, radio link specifically used for cueing instructions, either from the remote truck (as shown in Fig. 13) or from the main studio.

If a station needs a more sophisticated intercommunication system, a trunked 800 MHz radio system can be considered. A 5 or 10-channel trunked repeater acts like a small telephone exchange in which the number of users (telephones) exceeds the number of channels (trunk lines). Telephone system theory is used to predict the busy level that can be expected during periods of heavy radio traffic. Three minute time-out timers are usually included in mobile transmitters to enforce time limits.

These trunked systems can tie into the regular telephone system at hilltop repeater sites or at trunked base stations. Broadcasters interested in 800 MHz trunked radio should contact their local area land mobile operator to see if such a system is available.

In certain situations, a station may be able to design and license a UHF business radio system for dispatch and coordination of RENG crews. These systems offer the user the luxury of not encountering a busy signal, as may occasionally happen in a trunked system. As with the trunked network, no programming is allowed on a UHF business radio system.

One of the problems often encountered when carrying remote broadcasts on an automated station is the need to have an operator stand-by during the broadcast to trip the automation system to the next event when the talent at the remote site gives the proper cue. The simplest way around this problem is through the use of a sub-audible tone that is high enough in frequency to not interfere with the ARS sub-audible tone that may be used for repeater equipment, and low enough in frequency so that it does not interfere with normal program audio. For example, in a system where the ARS access sub-audible tone is 25 Hz, an "advance system" control tone of 45 Hz could be used. In order to prevent premature automation system trip commands, the program audio input to the remote location transmitter would be passed through a high pass filter to remove any audio components below about 60 Hz. At the studio, the receiver audio output would run through another high pass filter to remove any control tone signals from the automation system program channel feed.

## In Conclusion

A RENG network should be planned and constructed with long-term service and frequency coordination requirements in mind. Areas that currently do not experience spectrum congestion problems may encounter them in the near future. It pays, therefore, to design a system that is spectrum-efficient and relatively immune to interfering signals. It is always easier—and cheaper—to do the job right, the first time.

# 6.2

# Microwave Electronic News Gathering (ENG)

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## INTRODUCTION

Electronic News Gathering (ENG) and Electronic Field Production (EFP) are standard operating networks in most broadcast stations. Rapid advances in equipment and system designs have contributed in making fast coverage to on air possible and opened the doors for more and better field operations.

Close cooperation between the news department and the engineering department is now demanded and the technology is there to assist.

This section of the *Handbook* will address the microwave portion of News and Field Productions. Other support equipment, Vans, Cameras, VCR's and the like are covered elsewhere.

## FREQUENCY CONSIDERATIONS

Microwave bands available for the Broadcast Auxiliary Service in Television Remote Pickup applications are the same as in fixed link service; i.e., 2 GHz (1990-2110 MHz) plus the non-exclusive, shared band 2450-2500 MHz, 7 GHz (6875-7125 MHz) plus frequencies shared and coordinated with common carriers in the band at 6425 to 6525 MHz*, and 13 GHz (12.7-13.25 GHz). Analysis of the options is similar to the discussion in the STL sections of the Handbook, plus some additional considerations.

The 2 GHz band has been the predominant selection because of overall path performance, antenna design, transmitter power, receiver sensitivity and general reasonable electro-mechanical configurations.

In comparison, the 7 GHz Band can be supported; however, propagation through adverse path conditions, trees, etc. is more difficult and corresponding antenna configurations with narrower beamwidths make path alignment more difficult. Band D (13 GHz) is proportionately more difficult than 7 GHz.

These interrelationships for remote performance will be more evident as one becomes aware of the following arguments.

Some additional considerations for band selection that should be reviewed are as follows: Which band is in service for STL Relay operation in your neighborhood region? How far away are you planning to go with your remote system? What STL Relay activity is present in these areas? Which mechanical configuration can you support? Which mode of operation is planned, i.e. News Gathering or Planned Field Production?

Obviously, mutual interference with other participants in the same band must be considered. Channels 8, 9, and 10 of the 2 GHz Band (2450-2500 MHz) are available on a shared, non-exclusive basis. The shared users at this time include microwave radar ovens, industrial heating

*Not available for Broadcast Auxiliary fixed link service.

systems and medical diathermy, etc. This means broadcasters can license for operation in this band and equipment is available; however, if any interference is realized in generation, the FCC will not take any action to alleviate the interference.

Systems have been used successfully in these channels. Selection of a receive site in a remote area is possible. Narrow beamwidth antennas can be employed and acceptance of some interference in limited azimuth positions can be tolerated.

## RECEIVE SITE SELECTION

Receive site selection is an analysis encompassing the full spectrum of broadcast operations. Some considerations are as follows:

Downtown site—high rise building: How will it support local urban activities, hospitals, court houses, city hall, mayor's office, school committee offices, police stations, parks, etc. Do not forget the path for relay back to studio. Discussions with the News Department and Production Department should be conducted to identify other important points of potential interest. Roof top configurations can play an important role in the selection of the class of receive antennas. Naturally, the building management restrictions relative to aesthetic factors, as well as window washer activity, fire and helicopter access, structural integrity and a host of other factors all bear on these considerations.

**23 GHz ICR Transmitter. (Courtesy M/A-COM MAC)**

Quadrant selectable horn antennas have been used successfully in many downtown sites that have demanded invisible installations. Antennas can be finished in the color of the building, they can be flush mounted on penthouse walls, parapet corners or mullions. If visibility and profile integrity are not the overriding issues, a stub tower installation on the roof top can support any of the available ENG antennas. Specifics of these antennas will be discussed in a later section.

Internal installations on high-rise buildings have been constructed with special attention to the type of glass the antenna must look through. Leaded glass must be avoided. Tinted glass, depending on technique used in tinting, should be checked closely for propagation loss.

The selection of high rise building relative to other stations in town can be a problem and an aid. All stations on the same roof present a conflicting situation relative to mutual interference. At the same time, it can be a compatible situation for pooling activities with subsequent distribution to each station over its respective relay.

## TRANSMITTER TOWER

The TV transmitter tower is probably the most universally used ENG receive site. It is not necessarily the first site, but eventually it emerges as the most logical. Typically, the tower site provides the long range performance.

Depending on tower load budget, antenna selection can range from the earlier four quadrant horn or omni antennas, both approximately 13 dBi gain, up to the higher gain, 26 to 29 dBi, steerable reflector antennas.

Two basic tower configurations have emerged over the years. The most prevalent configuration places the antenna with low noise amplifier at the highest available position on the tower, with the RF and control lines run down to the receiver and control system in the transmitter room. The received signal is then coupled back to the studio over a duplex channel with the STL.

A second configuration places the antenna, along with a tower mounted repeater box at the highest point. In this configuration, only control line or VHF/UHF radio control is coupled to the repeater and the output is coupled to the fixed relay antenna for routing back to the studio.

Some considerations for tower systems are: tower loading, lightning protection, icing conditions, elevator or climb, and environmental extremes. Tower sites, with their associated long range capabilities, can support regional interchange of news.

A projection of receive site height versus horizon distance is plotted in Fig. 1.

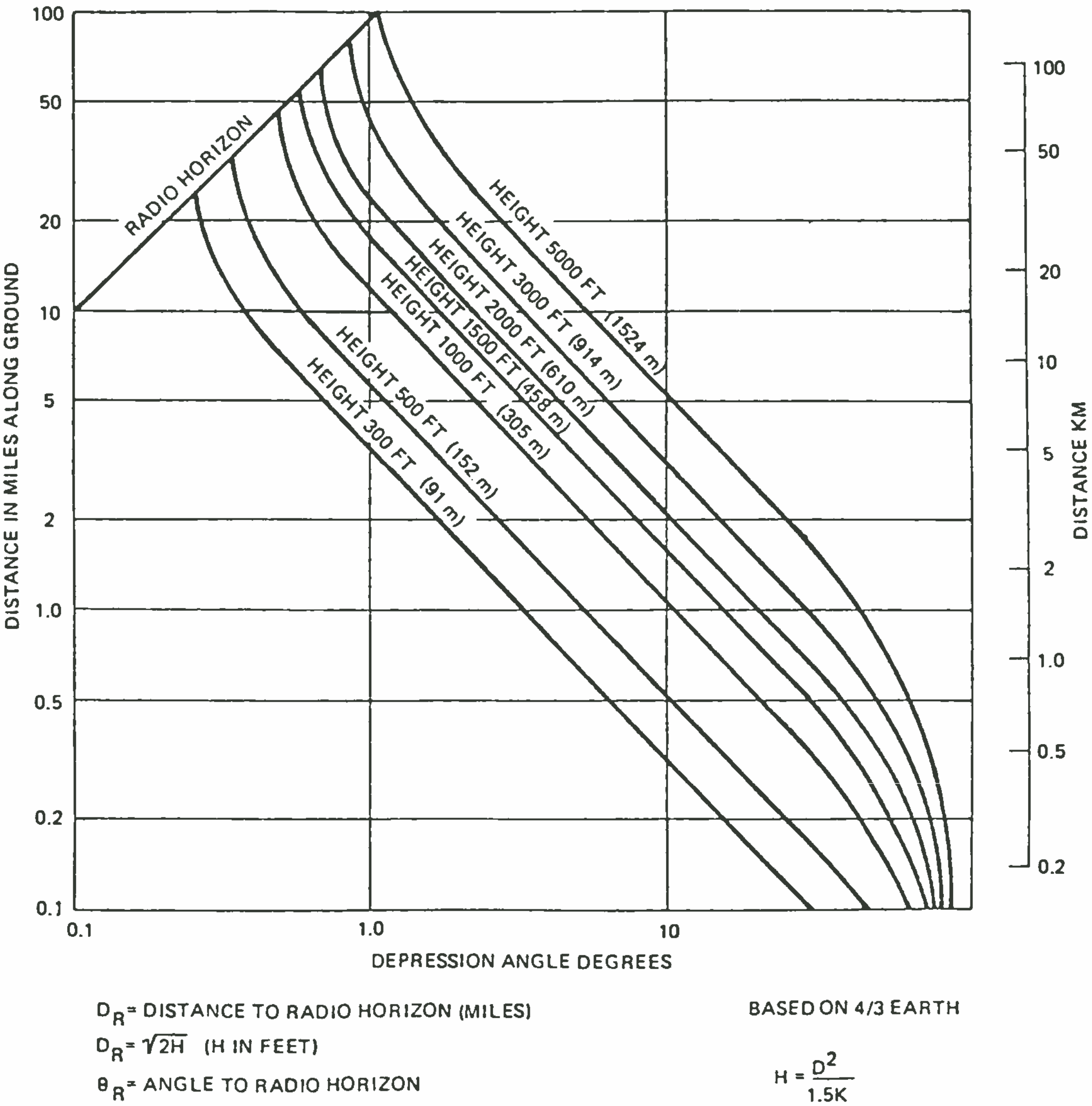



**Fig. 1. Conversion of antenna angle to distance miles for different antenna heights.**

## THE ENG VAN

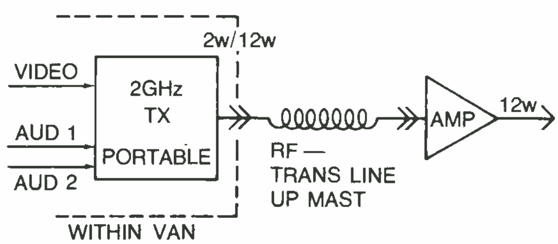
The ENG Van is a study in the evolution of human engineering. Each van design reflects changes peculiar to the people involved. We will restrict our discussion to the microwave content.

Transmitter systems at 2 GHz take a number of approaches, all aiming to provide the maximum 12 watts allowed by the FCC for mobile input to the transmitting antenna.

Maximum flexibility is provided by the following Block Diagram A. This configuration allows for full power at the antenna on the van mast as well as full power when the transmitter is removed from the van and used externally, e.g., on a roof top for a more direct shot to the receive site.

A second configuration is detailed in Block Diagram B. This configuration is used for a more

**Block Diagram A:**



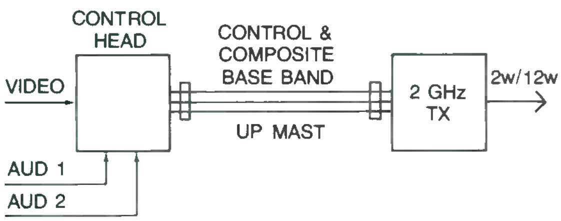

**Typical Van Tansmitter Configuration**

economical design when the transmitter is expected to remain devoted to the van and only employed as a separate portable on rare occasions.

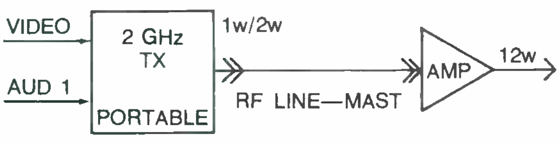
A third configuration represents the earlier van designs and is detailed in Block Diagram C. Essentially, all the basic transmitter-amplifier

Typical ENG Van. (Courtesy M/A-COM MAC)

**Block Diagram B:**




**Block Diagram C:**




systems cover the standard seven channels plus offsets (½ channel frequency up or down) of the 2 GHz band and operate from either +12V to +31 VDC or 115 VAC.

Various telescoping masts have been employed ranging from 15 feet high to greater than 50 feet. Many operators in (metropolitan) environments feel the shorter masts are just as effective to get above local traffic and to set up a reflective "bounce" path. The taller masts have proved effective in treed areas, enabling the antenna to get up to the thinner portions of vegetation.

Typical van-transmitting antennas are detailed in Table 1. Gain, wind load, mast stability, and stored configuration are some of the considerations.

**TABLE 1**

**Van-Transmitting Antennas at 2GHz**

Single Disc Rod — 18 dbi — Circ. Pol. — 6.1″×6.6″
Dual Disc Rod — 21 dbi — (2 Element) — 6.1″×22″
Golden-Rod — Dual — 21 db — 4.25″×20″
Quad Rod — 24 dbi — (4 Element) — 6.1″×54″
Silhouette — 20 db — 20″×30″
2-Foot Parabola — 19 db — Circ. Pol.
4-Foot Parabola — 25 db — Circ. Pol.

The interrelation between van and receive site is obviously important. We have noted that multiple channel (frequency agile) equipment is employed to help avoid interference among users. Multiple polarized antennas are also used to assist in this interference avoidance as well as helping self-generated interference to our own signal.

Circular polarization has been promoted for many years as a technique to reduce multipath signal reception which in turn generates many ghosts in a conventional video system. The basic theory shows that if a transmitted signal is launched from a "right circular" polarized antenna, a corresponding "right circular" polarized receive antenna will couple the incoming signal to the signal input receiver at maximum power transfer.

Conversely, if a transmitted signal is launched from a "left circular" polarized antenna, a "right circular" polarized receive antenna will accept this signal at a dramatically reduced power transfer efficiency, on the order of 20 dB below the correct mode.

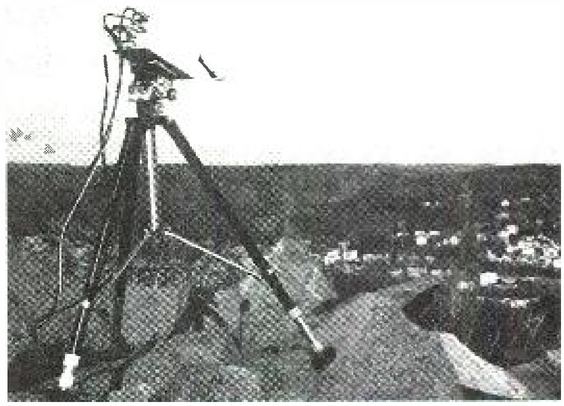
A characteristic of circular polarization is that *"right circular"* wave reflecting off a reflective surface will become, effectively, a *left circular* wave. As described above, this reflected wave, as a multipath signal, is now reduced dramatically at the receiver front end, helping to make a cleaner desired signal. This antenna performance is used constructively in ENG operations. In one sense, "multipath", the undesired reflected signals, is reduced by the polarization isolation of the receive antenna. In the opposite sense, intentionally reflecting, or "bouncing", the signal is used to reach the receive antenna from blocked van positions. In this mode the receive antenna is switched or tuned to the opposite circular polarization from the transmitting antenna, optimizing the input.

In contrast, a "linear" polarized signal, be it horizontal or vertical, has no reversal of apparent polarization when reflected off a reflective surface. This passive discrimination of circular polarization has been a vital ingredient in ENG operations. Fig. 2 is a graphic display of the benefits of circular polarization.

Most receive site antennas are configured with continuously variable polarization or switchable polarization, right circular, left circular, horizontal, and vertical. This design flexibility allows the studio operation to optimize the reception.

The basic function of the ENG/EFP microwave van is to couple the remote camera origination back to the studio. Another function that often occurs is as a repeater van. Some consideration in configuration should be given to this use. There are a variety of combinations that allow a van to be used as a repeater. A typical mode is to extend the position of the cameraperson beyond the hard wired video/audio lines by the use of a 13 GHz mini portable. A small 13 GHz transmitter with 3 inch horn antenna allows the cameraperson to extend the coverage over one mile from the van. Obviously, alternate antenna sizes are available that further extend these possibilities. Another van repeater configuration is as a 2 GHz in-band repeater. Situations arise that call for long distance coverage which in turn requires the employment of two vans in tandem.

In this mode, care must be taken to provide sufficient isolation to the receiver system. The unknown conditions of relative positioning of receive antenna to transmitting antenna can be a problem.



**13 GHz Mini Portable. (Courtesy M/A-COM MAC)**

Consider a configuration wherein the optimum receive antenna position ends up looking right at the outgoing transmitting antenna. Front end overload will severely limit the receive path range. The latest receiver designs have addressed interference rejection with some dramatic improvements, however this adverse proximity to high power transmitters will most likely require selective channel filtering. Both transmitters and receivers need this filtering.

The transmitters typically employ wideband power amplifiers to support high power along with full band frequency operation. These amplifiers produce an undesirable noise level across the full bandwidth therefore acting as a noise generator to the nearby receiver. Channel filters must be employed, one tuned to the

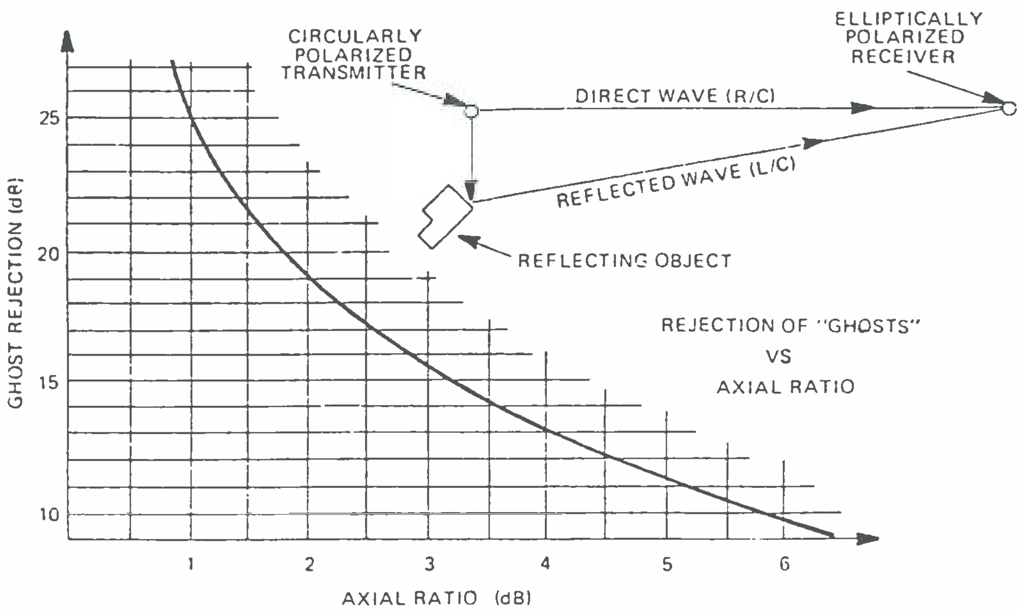



**Fig. 2. The benefits of circular polarization.**

transmitter frequency to limit out-of-band noise, and one to the receiver, to reduce the unusually high level of interference signal to the receive signal. This reduces the frequency agility somewhat, but is a reasonable compromise under these adverse configurations.

The 13 GHz mini portable system mentioned above has been joined by new system combinations at 38 GHz. At this high-frequency, compact transmitters have somewhat limited range, approximately one mile with reasonable performance and horn-type antennas. This flexibility is valuable in cutting the umbilical cord to free the cameraperson from the van. With proper choice of antenna, these signals can also be "bounced" when line of sight is not possible.

Full van-type vehicles have been the primary remote vehicles for the early news gathering systems. In a conventional van configuration, the microwave content is typically a mini portable 13 GHz system, comprising a comera cable extension, a 2 GHz transmitter, a 30- to 40-foot telescoping mast and a circular polarized transmitting antenna.

The "news car" concept is another type of remote unit. This is a streamlined vehicle similar to the film car of earlier days. In the news car, the microwave content is basically a 2 GHz low-power/high-power transmitter, a tripod or short bumper mount, manual telescoping pipe, and a small transmitting antenna. The combination allows for quick and simple set up, by snapping the antenna to the transmitter and then to the tripod, or by putting the transmitter in the trunk to a coaxial line to a quick-connect antenna on a pipe mount.

## CENTRAL RECEIVE SITE

ENG central receive design configurations employ a variety of antennas; some of these are as follows:

a. Omni-directional dipoles—6 to 13 dBi

b. Quad horn-switched 90 degree sector—13 dB per sector

c. Directional nominal gain—16 to 20 dB

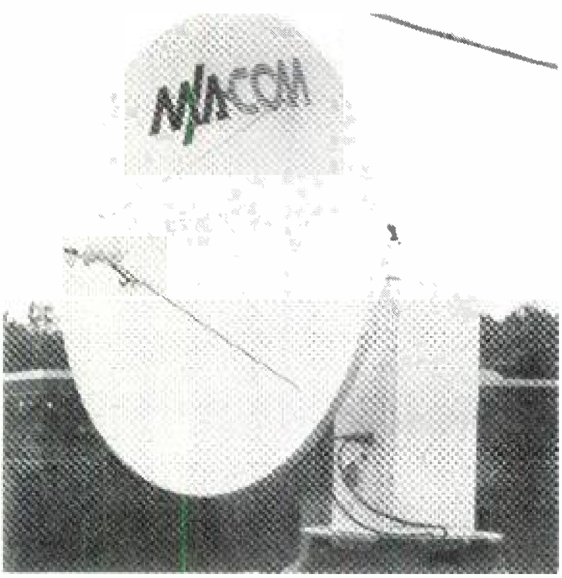
d. High gain steerable—22 to 24 dB

e. Higher gain—narrow beamwidth steerable and auto-track—25 to 29 dB

f. Dual band 2 and 7 GHz or 2 and 2.5 GHz directional—steerable 22 to 25 dB

The omni class of antenna can be varied in gain versus length with corresponding reduction in vertical beamwidth. Omnis serve the necessary functions and allow for essentially lower cost, low wind load and simpler installations. The inability of the omni to reject multipath or interference is a drawback. A relatively clean receive site—high tower, flat terrain—coupled with clear, narrow beamwidth, transmitting antenna positions can support the omni configuration.

The quad horn-switched 90 degree sectors provide the full complement of polarization selection (horizontal, vertical, left circular, right circular) along with direction discrimination. The multiple, four separate quadrant elements allow for a variety of installation configurations. They can be grouped in a cluster, as on a tower, or separated far apart, as on the corners of a roof top. This flexibility of placement along with the



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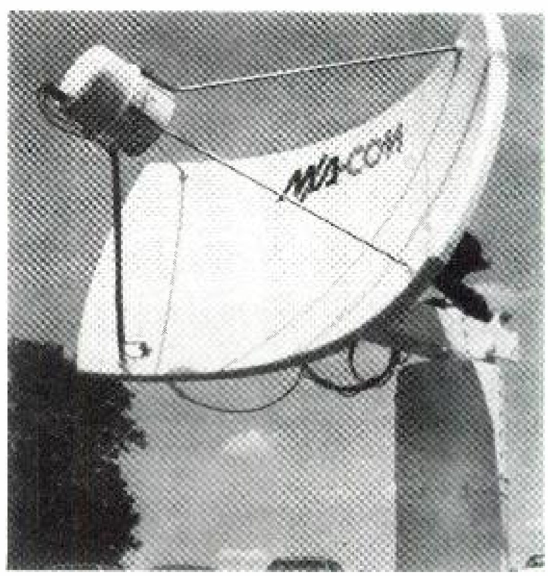

**Miniscan™**

selectable sector discrimination has led to wide use in downtown, high rise and roof top installations. Bounce (reflected) shots are easier to set up with horn antennas, versus steerable, since only one antenna, the van, is essentially panning and the studio observer has the ability to select the optimum polarization and sector. Control systems with quad horn antennas provide two-way control command and confirmation feedback of sector (N,S,E,W) polarization, (H,V,RC,LC) receiver AGC and frequency channel.

High gain, steerable antennas combine the standard antenna technologies of aperture (size) and phasing (numbers of elements) to provide the higher gain, 20 to 29 dB. This higher gain dramatically increases system sensitivity (double range per each 6 dB increase). However, the narrower beam width and panning at both ends of the path introduce some complexities in optimum path alignment.

## REMOTE CONTROL

Remote receive sites require control from the studio. The control systems are typically designed to operate over standard voice circuit lines (Telco 300-3400 Hz), 2 wire and/or 4 wire. If subcarrier capacity is available over existing microwave paths (STL/TSL) then the control circuits can be carried on these networks. Some standard telephone lines can exhibit noise conditions creating false inputs to and outputs from the control system. Care should be taken to note this, as opposed to assuming there is a fault in the antenna system.

The control functions from the studio vary somewhat versus the class of receive antenna, but basically are: Antenna direction—Azimuth and elevation in steerable systems, Quadrant (N, S, etc) in sector systems. Polarization—Right Circular/ Left circular Horizontal/Vertical or any in between mode on continuously variable systems. Other functions provided are Frequency Channel selection and AGC indication of Received Carrier Level.

Studio observation of optimum receive signal on a video monitor and speakers is conventional. Maximum AGC feedback is not always synonymous with optimum video/audio.

## INTERFERENCE AND CENTRAL RECEIVERS

Rejection of interference from other originating systems has been addressed by suppliers and operators: Local frequency coordination and planning are a must. Planned antenna polarization can help. Diverse receive site selection is possible. In most markets an optimum common site usually emerges and interference grows.

Receiver design has evolved focusing on rejection of undesired signals while preserving the desired signal to the extent possible. The essential compromise that has emerged is reflected in the common baseband loading of standard color video with audio subcarrier at 4.83 MHz. This close-in subcarrier frequency has led to narrow IF bandwidth designs. Naturally, the ability to pass multiple subcarriers suffers under these limitations. Variable bandwidth control is effective in supporting configurations that call for field production as well as news gathering.

### Remote Van Positioning Considerations:

Line of sight from the transmitting antenna to the receiver antenna is the desired optimum configuration. Many situations preclude this, and trial and error situations must be evaluated. The studio controller is an active participant in this activity. Quadrant awareness of the geographical terrain relative to the remote vehicle position is obvious. Topographic overlay mapping of the area with respect to the receive site antenna has been successful. Trial and error experimentation along with recorded results has been very effective. Computer inventory with recall coordination has been implemented at many stations.

Bounce shots can be a solution to a blocked path. Any reflective surface can act as a beam redirection. It is helpful if the van crew is aware of their relative elevation to the receive site. The reflected signal can be considered similar to a handball trajectory—the angle of incidence determines the angle of reflection. Exaggerated elevation of the van antenna can easily cause the reflected signal to pass high over the receive antenna. Multiple bounce conditions can be set up; however, energy disbursement loss must be considered and long range success is doubtful. Fig. 3 presents an effective configuration versus respective antenna gains; note this assumes no obstructions.

## AIRBORNE CONSIDERATIONS

Helicopter use by news departments for video coverage can be supported by standard ENG microwave hardware. The helicopter used as a camera platform transmitting to the studio and as a long range microwave repeater platform, can be readily implemented.

Omni antennas (see photo) have been mounted below helicopter frames with varying degrees of success. The omni (360 degrees) patterns coupled with adverse terrain, high hills, buildings etc., result in troublesome multipath. Steerable and

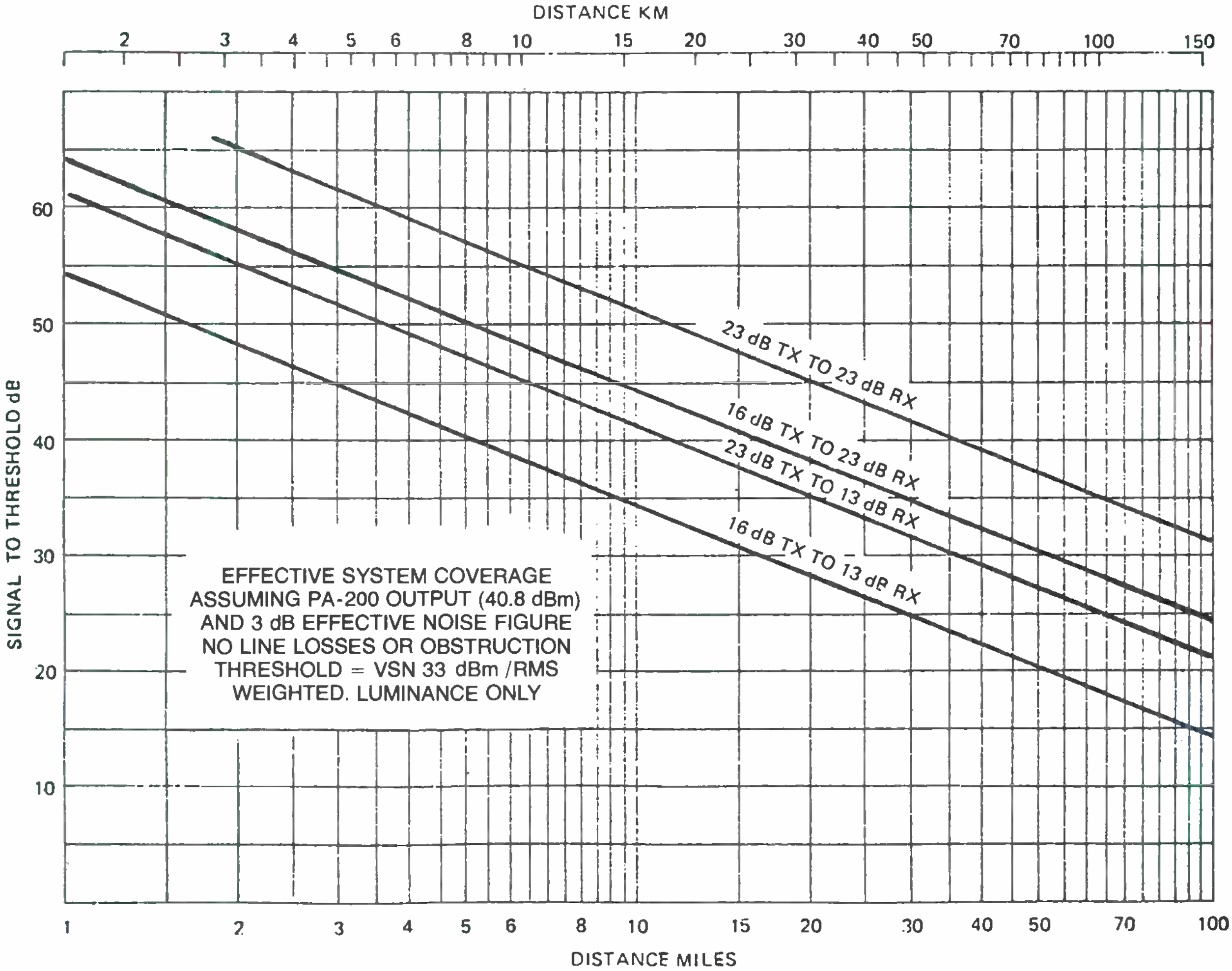


**Fig. 3. Effective system coverage.**

autotrack receive antennas help reduce this problem but do not eliminate it.

Examination of the omni patterns and the interrelation of gain and elevation patterns demonstrates other performance characteristics that must be addressed. Nominal gain, omni designs (4-6 dBi) have relatively narrow elevation angles resulting in dramatic drop-off of signal strength when the helicopter executes a relatively sharp-angled turn.

Directional transmitting antennas can dramatically reduce the multipath problems prevalent in the omni antenna. Steerable high gain, directional airborne antennas are available with sophisticated automatic steering and/or manual steering. The manual steering configurations require constant attention and relative bearing inputs.

One class of automatic steering system employs a magnetically stabilized gyroscope. A Horizontal Situation Indicator (HSI), coupled to the gyroscope can be set on the correct bearing, steering the directional transmitting antenna to the receive site. As the helicopter maneuvers about this setting, the system automatically holds the directional antenna on the preset bearing. The set antenna bearing will be effective with no further update until the aircraft moves so that the antenna beamwidth falls off the receive site. A manual reset of the new bearing must be initiated at this time.


**Skypod-Airborn Antenna System. (Courtesy M/A-COM MAC)**

A further sophistication of this steerable system can be implemented with the incorporation of a microcomputer and Loran-C or Omega navigation network. The navigation system provides a continuous update input to the HSI correcting the relative azimuth on a full time basis. Receive site coordinates can be entered in the minicomputer and the system programmed to hold the directional antenna to the required bearing.

Fig. 4 is a nomograph of respective antenna heights for helicopter and receive site versus distance. It should be noted this is based upon a 4/3 earth radius and represents a grazing condition. It also assumes a smooth intervening terrain. Terrain roughness will result in the need to elevate site end points.

**Bell Jet Ranger helicopter in flight with retractable antenna mount extended.**

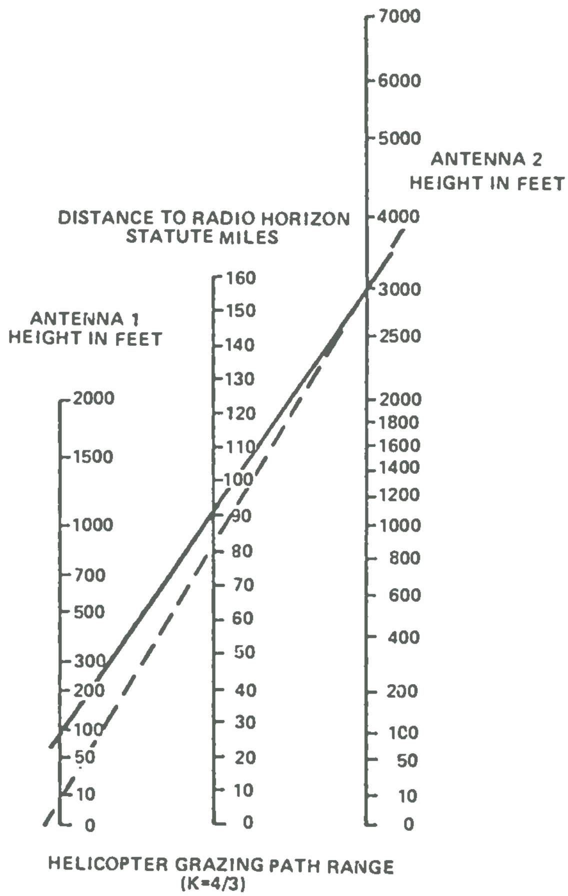


**Fig. 4. Helicopter grazing path range (K = 4/3).**

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Reference:
Forbes, E. J., *An ENG/EJ Handbook*, Microwave Communications Company, Burlington, MA, 1980.

# Television Field Production: An Overview

Carl Bentz
*Television Editor,*
*Broadcast Engineering Magazine*
*Overland Park, Kansas*

Television made a major change in our lives. We no longer had to be content with listening to Ted Mack's Amateur Hour; suddenly the contestants were in our living room. Our imagination could paint the scene as the Lone Ranger met Tonto in a radio studio cottonwood grove; but the magic of TV, through film, proved beyond a doubt that Silver was a magnificent white horse. The excitement of a tie-breaking World Series homer was unquestioned from the radio commentator's voice; however, seeing the action live from the stadium in New York brought new meaning to the game.

Not only has 'remote' taken us from the studio, it has taken us across town, across the country, around the world and into space. The ultimate ENG experiences to date must include the closeup images of Saturn's rings and the sight of Earth and men working in the cargo bay of the Space Shuttle. What better TV coverage than showing such far reaching successes of mankind!

## What is Field Production?

Whether we call it ENG, EFP, OB or remote, the concept of field production is the same. Escape the confines of studio walls. Find, and take advantage of, the reality of the outside world.

ENG (electronic news gathering), the simplest means, overcomes our dissatisfaction with talking-head newscasts. We see the first place marathon runner cross the finish line; the biggest catch of a local fishing contest pulled in; the result of a neighborhood effort to aid the elderly. We experience the terror of fires, tornados, war, etc. Our preference is to see it from a live camera via microwave to the studio. But we are content to see it by tape-delay during a regularly scheduled time, so our favorite weekly series is not interrupted.

The demands on ENG equipment are dictated by the needs for immediacy and flexibility. The


**Fig. 1. The JVC ProCam series offers lightweight, easy operation, even by unskilled ENG operators. (Courtesy JVC)**

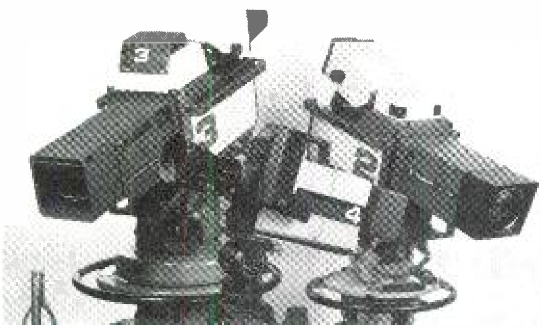


Fig. 2. Philips LDK-6 automatic camera family includes compatibility and adaptability to any use. (Courtesy Philips)

equipment must be rugged, easily portable and easily set up and used. The news director is interested in having useable pictures and sound in a hurry. The subtleties of gamma and signal-to-noise are of little importance, particularly in the case of a live news feed or where the footage will only be used one time. Simplified controls and automatic circuitry save time and reduce the chances for error even though they may not produce the best quality under all conditions.

EFP (electronic field production) expands our view. Whether the program is one of the soaps or a documentary feature, being there, even by TV on tape, is better than staying inside the studio. EFP is not bound to videotape; it can be live. Production, however, suggests that post-production may follow the shooting.

EFP crosses a hazy boundary into outside broadcasting (OB), as we televise live remotes. We expect the pagentry of the New Year's Day Rose Bowl Parade; political conventions; a Presidential Inauguration; the Super Bowl game; or a royal wedding. Seeing is believing. Immediacy enhances and satisfies our interest to share happiness and sorrow with our fellow man.

Here the demands on the equipment are for ruggedness and flexibility, but performance quality is more important than with ENG. News production may accept noisy pictures with poor color balance and distorted sound if the content is urgent and the exposure is brief. For longer segments or full-length programs, particularly where considerable expense is involved in acquiring rights, setting up and post production, producers and sponsors are looking for close to studio quality. On the other hand, there is usually more time, in EFP, to set up and adjust equipment to achieve good quality. If equipment is highly automated, it may be desirable to have overrides allowing manual tweaking for optimum performance.

What does field production offer to the station? Viewer satisfaction is one thing, but the visibility of the TV crew at an event heightens the station's committment to, and involvement in, the community. The station becomes more a part of the locality and increases the community's acceptance of the station and its products—communications and programming.

## Planning for Field Production

Because preparing for remote capabilities is a major step in station growth, planning is essential. Obviously a primary concern must be budgeting. Management will want the most for the least, but cost effectiveness and reliability are critical. Both personnel and equipment considerations will bring all station departments into the final decisions. Programming and production may know what they want to do, but it will be up to engineering to make it work, to the sales department to earn extra revenue, so that accounting can make payments on the new equipment and perhaps new salaries.

The planning phase considers pie-in-the-sky dreams, as well as down-to-earth realities and limitations. Compromises will be required, and, from them, decisions made on the proposed extent of field production activities and the preferred approach to acquiring equipment.

Who will operate what equipment? Labor agreements may dictate that engineering staffers handle all camera and recording operations. In other stations production people may do some of the technical work. But one question remains—are there enough people now on staff to handle extra assignments?

To what extent is remote operation expected? Do plans warrant purchasing a production vehicle? Should the purchase be a customized system? The bigger the remote vehicle, the more sense a


Fig. 3. Midwest Corporation custom design for TCS Productions. (Courtesy Midwest)

custom system makes. Outfitting a vehicle takes time, and splitting the station staff between construction and regular duties may not be feasible. There are many companies that are well versed in building to given specs. All choices may be left to the buyer, or standard packages of equipment may be offered.

## To Lease or To Buy

Leasing might be a more practical approach to start with. It could allow a trial period, so to speak, to check out production concepts and feasibility of remote activities for your station. Keep in mind that if you own your own, you are also responsible for continuing equipment maintenance, upkeep of the vehicle itself and the financing of the system.

Leasing costs for production equipment will vary with area of the country, availability of the equipment and the size of the system needed. A ball park price for a complete 40-foot van, including six or more cameras, several VTRs, all audio and video switching equipment and monitoring, will average about $13,000 per day. In general, a price of $600 per equipment item is a guide line. Still-store systems will possibly be more. The daily amount covers a 10-hour day and takes into account an operating crew of from 18 to 20 people.

The purchase of a turnkey production system will be expensive. The simple ENG super-van configuration is commonly priced from $100,000 to $250,000. If the purpose is strictly ENG, perhaps a 4-wheeled vehicle would be a better solution. Protective containers for the camera, recorder and microwave wave system could be installed, still leaving room for the camera operator, a microwave technician and the reporter/talent.

The stepvan or straight truck system will include more equipment and is geared more toward full production, i.e., several cameras with CCU

**Fig. 4. A transportable elliptical system from GEC-McMichael. (Courtesy GEC-McMichael)**

control positions, several recorders, monitoring equipment, audio and video switching systems and perhaps microwave for going on the air live. Costs of such systems will start upward of $150,000 and could surpass $500,000.

The 40-foot van trailer is the epitomy of production units, and carries a fitting price tag. Except for actual floor space, it is a studio on wheels and requires an equipment complement that resembles or exceeds a normal studio. Vans similar to those used by the major networks will have multi-million dollar tags for a complete studio vehicle with multiple cameras, audio and video recorders, audio and video switching, appropriate audio, pulse and video distribution amplifiers, audio and video monitoring equipment and sufficient air conditioning to cover the heat rise of equipment and personnel.

## Making the Mobile Unit Mobile

The cost of the 40-foot van system will probably not include a tractor to transport the system from one production site to another. Tractors may be leased on short-term plans for an average cost of $116 per day or more economical long-term bases. The leasing plan usually includes any emergency or normal mechanical repairs, licensing and taxes required for the tractor.

Alternatively, the tractor could be purchased ranging from the mid $60,000 to mid $70,000s, for a cab-over unit including a sleeping berth for those trips that require a long haul situation. Used tractors may be found in the $30,000 to $45,000 range and could probably provide the required service. Maintenance, operation, licensing and taxes for the tractor must be included in any plans for purchase.

Keeping the mobile unit in top operation requires a maintenance plan. The plan followed by ABC Sports, for example, involves over-maintenance of the fleet of 18 tractor/van production systems. In 1984 terms, the cost of the program is a ballpark total of $200,000 for the entire fleet. Each of the #362 Peterbilt tractors is rated to handle loads to 80,000 lbs gross weight, so the load presented by the 68,000 lb van systems offers no difficulties.

A reliable driver is also a must. Again referring to the ABC Sports organization, a driver must prove a 250,000 mile successful driving experience. His record must be spotless and involve all types of driving conditions, including all four seasons and preferably all areas of the country. Because the driver is in charge of a multi-million dollar package of equipment, he must have a highly professional attitude. The success of the network's sports programming is dependent upon the remote vehicles being in place at specified times. It is the driver's duty to have the equipment there—on schedule.

## Lease-Outs Aid Financing

If you decide to buy, leasing the system to others could provide aid in financing it. The status of owning your vehicle and the convenience of not having to arrange for a leased system are plus factors. If you consider allowing others to use your system, however, two additional questions need to be answered. Will the truck need a staff on lease-out assignments? Will the equipment complement make the truck desirable to others?

If the plans include live remotes, the remote van will require microwave systems to feed signals back to the studio. Some type of 2-way communications is required in the truck for cueing purposes. New subcarrier applications for TV would allow cueing to be provided through multiple aural subcarriers of the station. Frequency coordination is important, particularly in larger markets, and should be part of the planning process (see the chapter on Frequency Coordination in Section 1). Depending on how remote the production location is, transportable uplink and satellite reception capability could be employed. An alternative might be to contract for a common carrier service through one of the newly formed "bypass" microwave companies.

It quickly becomes obvious that planning for remote operation requires answers for four basic questions. What is desirable; what is feasible; what is acceptable; and what is affordable?

## Selecting Equipment

Shopping for remote equipment is just as critical as purchasing for the studio. Signal quality is a major consideration, but cost, unfortunately, has some control over quality. The equipment should be as simple to operate and maintain as possible, particularly since non-technical personnel could be involved. Logic suggests compatibility is desired between the new remote items and existing studio equipment.

## Cameras

Probably most stations already have one or more basic ENG systems (one camera, one portable video recorder), which see hard treatment in the news department. If all cameras are the same brand, perhaps even the same model, maintenance expense and operator confusion will be reduced. Identical recorders will avoid format interchange problems, large parts inventories and extra operator training time. This approach provides compatibility between ENG systems.

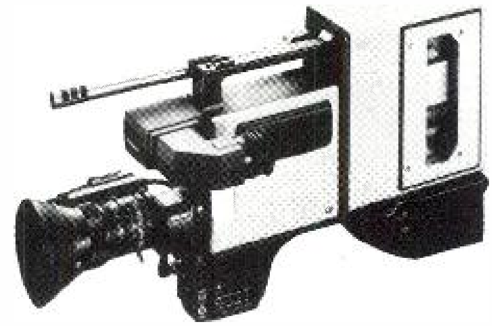


**Fig. 5. The Panasonic RECAM and Sony Betacam products include complete systems of cameras, recorders and editing equipment. (Courtesy Panasonic, Sony)**

What kind of equipment do we want in our remote system? Nearly any camera could be used for remote production. Other sections of this handbook will give specifics on different products. But let's look at few of the factors which may determine the choice.

- Pickup type—Plumbicon or Saticon tube or CCD
- Three tube or single tube with striped faceplate filter.
- Optical format—½", ⅔", 1" or 1¼"
- Configuration—hand-held, tripod mounted, pedestal mounted.
- CCU/remote panel—required or option.
- Output signal—composite or component video. (PAL, NTSC, Betacam, M, Lineplex, etc.)
- Link to production control—coax, triax, multicore, fiber optic, microwave or none.
- Automatics—black/white balance, iris, registration, centering, etc.
- Detachable recorder unit.
- Digital memory of setup parameters.
- Computer setup system.

- Viewfinder diagnostics.
- Available lens systems.

## Some Camera Specs Specifically:

Sensitivity is defined as that amount of light falling upon the scene to be televised (i.e., a standard test chart) that produces an output video signal of 1V peak-to-peak (p-p) including sync or 0.707V p-p non-composite. The value may be given in foot-candles (lumens per square feet) or lux (lumens per square meter), where 1 fc = 10.76 lux (1 lux = 0.0929 fc). The sensitivity specifications should include the lens f/stop, the scene reflectance percentage and the video gain setting. The color temperature of the light on the scene is typically specified at 3200 K.

A data sheet for the Philips LDK-614 ENG camera lists 1300 lux, f/2.8 and 60% reflectance. The incident light falling upon a scene (or test chart surface), 1300 lux, which reflects 60% of that light toward the camera, with a lens set for f/2.8 and video gain at 0 dB, should produce a standard TV video signal.

Maximum sensitivity (or minimum illumination) goes a bit farther. ENG cameras include a video gain control. Actual gain figures vary, but 0, +6, +12 dB and 0, +9, +18 dB are common values. We now are given the amount of light with an f/stop, reflectance % and gain figure, all of which still give the standard video output signal.

For the Panasonic AK-3010 camera head, sensitivity is 2000 lux, 89.9% reflectance chart, f/4.5 and 0 dB gain for standard operation. Under low light conditions, the maximum sensitivity is rated 24 lux, f/1.4 and gain at +18 dB, still using the 89.9% reflectance chart.

**Fig. 6. Wireless microphone equipment attaches to the camera to free talent and camera operator from microphone cabling. (Courtesy Panasonic)**

It should be noted that in the two examples, the reflectance is different. The camera rated with a 60% figure should be more sensitive than that with the 89.9% value, if the other parameters are the same. Recall that as the lens setting moves from f/4 to f/5.6, the relative aperture is getting smaller, or less light is entering the camera. The larger the number in the "f/" rating, the more sensitive the camera. Finally, the smaller the lux value (which may be estimated to be foot-candles x 10), the more sensitive the camera.

Color temperature of the incident light will have some effect on the output signal level, but its primary effect will be upon the white and black balance. Color temperature is based upon a rather esoteric concept from physics. The color temperature is that temperature to which an "ideal black body radiator" must be heated to radiate a specific color of illumination. The greater the degrees Kelvin specified for color temperature, generally the more blue the light becomes. For example, some idea of the variation is seen in the following color values. Actual numbers will vary from reference to reference, but these serve as indicators.

| | |
|---|---|
| Candle flame | — 1,850°K |
| Sunrise | — 1,900°K |
| 500W incandescent lamp | — 2,960°K |
| TV studio lamp | — 3,200°K |
| Photographic flood lamp | — 3,400°K |
| White fluorescent lamp | — 4,500°K |
| Average 12-noon sunlight | — 5,350°K |
| Daylight fluorescent | — 6,500°K |
| Blue sky | — 11,000°K to 25,000°K |

Color monitors will also be factory aligned in accordance to color temperature. One common "white" value is noted as D-6500, meaning that a white raster is equivalent to a 6,500°K average daylight white. Some monitors are set for a white reference C, which is approximately 7,000°K.

ENG cameras must be capable of handling a much wider range of lighting conditions than their studio cousins. The camera that goes to the baseball park may need to shoot a segment in full sun, then another in the shade. On the way back to the station, the assignment might require working in an interior artificially lighted area. For an idea of the variation, consider the following lux values.

| | |
|---|---|
| Full sun | — 100,000 lux |
| Overcast at noon | — 10,000 lux |
| Interior by window | — 1,000 lux |
| Interior work area | — 100 lux* |
| Full moonlight | — 0.2 lux |

*(Artificial light, considered the minimum for working, closely lighted)

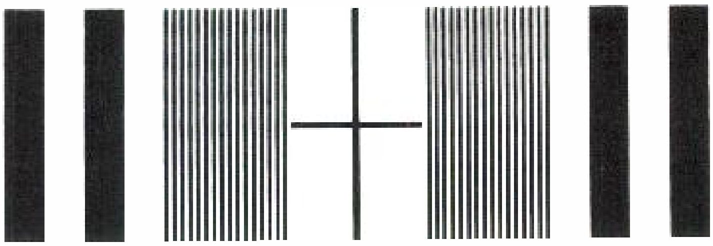



**Fig. 7. Modulation depth test chart.**
**(Courtesy Telecommunications Industries Ltd.)**

Again, reference sources will no doubt vary on the luminance values for any given situation, due to the many subjective variables that will come into play.

In order that the camera can begin to accommodate the possible range of light conditions, two types of filters are available in the camera's optical system. First, color filters compensate for the color temperature of the incident light. One will allow a studio light temperature to be changed to daylight color; another, for outdoor use, converts light to the 3200K studio condition.

Neutral density (no color) filters are included to compensate the wide range of illumination. Some are rated by a percent density. Others are graded by a logarithmic scale. In conjunction with the auto iris feature found on most cameras, the neutral density filter allows the camera to better handle wide illumination variations.

Horizontal resolution can be confusing, as specified by the manufacturer. Typically the value is given for the green channel only. The specs should indicate if the values are given for a camera with no enhancement applied or with detail circuits active. The specification may be noted in TVL (television lines at center of screen) or in % depth of modulation. Depth of modulation compares the ability of the camera system to respond to segments of a test chart that are equivalent to frequencies of 5 MHz and 0.5 MHz, i.e., a comparison between 400 TVL and 40 TVL. If the amplitude of the waveform produced by the pattern shown on the modulation depth chart marked 5.0 (a value "b") is compared too that from segments marked 0.5 (a value "a"), then

$$\text{Depth of Modulation} = (b/a) \times 100\%.$$

## Recorders

Video recorders also offer a great deal of variety. (As this material is written, there has yet been no agreement as to a standard 1/4" format. The 1/2" format remains divided between Beta and M.)

- Portable or mounted use.
- Format—1″ B or C, 3/4″ U-matic, 1/2″ Beta or M and 1/4″ Lineplex.
- Recording format—Composite video, color under or component video.
- Confidence heads.
- Playback electronics.
- Field editing accessories.
- Weatherization
- Battery or ac operation.

For EFP material planned for post production, the 1-inch B and C formats continue to hold ground. Although the 1/2-inch system quality rivals the larger formats, 1-inch retains an edge in picture quality. Portable recorders are available in B and C, 3/4″ and 1/2″ formats.

In the production vehicle, 1-inch, 3/4-inch and 1/2-inch systems are found. The two larger types are more popular, probably because they are more established and have included dynamic video head tracking features for a longer time. Dynamic tracking, with appropriate timebase correction, allows the still frame and both forward and reverse slow motion features, which are of prime interest in sports coverage.

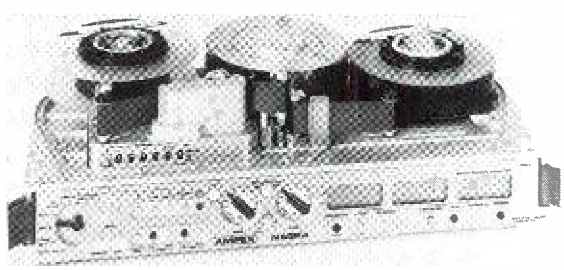


**Fig. 8. The Ampex/Nagra VPR-5 system uses lightweight alloys for critical framework stability. Extendable reel support arms allow longer play-time reels, if the machine is used in a van. (Courtesy Ampex)**

## Other Recording Media

In any size production vehicle, the magnetic disc medium is possible, occasionally with effects capabilities. Ampex in the US and TEAC in Japan (for the Tokyo Olympics) developed disc-based slow motion products which doubled as still-frame storage units.

With floppy disc technology, the Arvin/Echo EFS-1 videodiscassette unit allowed much less expensive still-frame pictures and stepped slow motion during Monday Night baseball games in 1976. Several models later, Precision Echo continues the dual-sided, discassette concept to store 200 images per disc side in a table-top package.

As rigid Winchester disc technology shrank in size, the higher density medium allowed digital disc recording techniques to appear in the Abekas VSP42 Video Slide Projector (later the A42). The rugged system, requires only a few rack units of space, stores 100 frames, expandable to 300 frames, and provides a streaming cassette system for off-line storage. At NAB '84 the A42 was shown with a companion A52 video production effects unit designed around the same limited space feature. Other such systems may be expected in the future.

Other hard disc-based systems, generally requiring larger spaces, are available from ADDA, Ampex, ASACA, Harris Video, MCI/Quantel and NTI.

Film continues to play a role in production for television. While Sony, Ikegami and others have developed interesting products for HDTV applications, film presently maintains an edge in production, particularly for prime time TV presentations. The name of Arriflex is one of the best known for film cameras in the US. A recent introduction by Aaton/Zellan, Clear Time Recording, allows time code information to be printed directly on the film. With multiple cameras involved, this system makes post production editing much easier without the use of slating.

## Switching, Etc.

With multiple camera systems, video switching is a must. Every switcher manufacturer offers several system sizes, one of which should work nicely in a vehicle. Most are composite video products. Grass Valley Group and Shintron were the first to introduce component video switching systems in small formats that allow mixing of both types of video signals. Plan for an effects section with at least the typical wipes, keys, etc. Remember that inputs should be available for all possible cameras as well as other sources. You may want to use roll-ins from video tape, the still store and even a graphics system.

Audio, too, must be controlled. Whether the need is for simple or automatic mic mixing, up to a multi-track recording system, the range of products is unlimited. Even with the approval of stereo aural TV broadcasting, the choice should not be limited, as most mixing consoles offer at least a stereo mix.

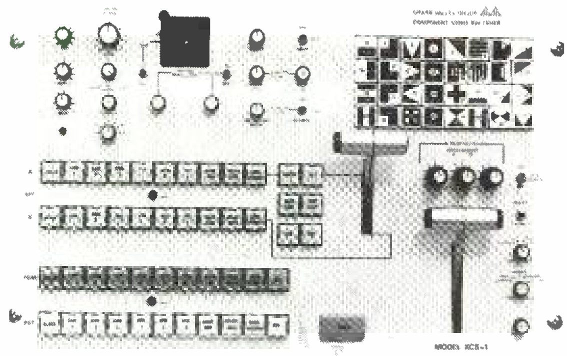


**Fig. 9. The GVG 1LTV and 1XTV component video switchers differ little from this developmental model introduced at NAB '83. (Courtesy Grass Valley Group)**

Audio facilities should include recording and playback capability. For extended periods, reel-type units may be preferred. Voice over announcements will probably be added for cartridge systems. With improvements in head technology, cassette systems have found some popularity. Studer and TASCAM systems have both been used in production systems, including network vehicles.

A compact disc player would probably be preferred over phono equipment, if the desired material is available on a CD disc format.

Titling is often desirable for the remote event. A variety of character generators provided the basic TV typewriter function. The choices may allow simple type faces in various font sizes to special characters and logos. Other systems require that each face/font size is loaded into the generator memory. Free form electronic graphics systems and graphics options, tied to video disc-based still stores add the flexibility of incorporating a variety of titling and other graphic extras from the remote site.

Interfacing through special data buses on switchers, character generators and graphics systems for digital effects units allow a variety of image manipulations to be accomplished in real time during the production. Try to imagine a remote event without flips, tumbles, spins, compressed images, etc.

Timebase correction is necessary if any inserts from videotape are planned. Many 1-inch tape machines include a system TBC, but other tape formats may require external units. Both composite signal units, and others specifically for the M and Beta component formats are on the market.

When a source provides a signal that does not require time base correction for use into the remote switcher, perhaps the frame synchronizer is more desirable. Cameras operating via individual microwave links to the central production van might be connected to the switcher through individual synchronizer units. Not all synchronizers offer feedback signals commonly used for timebase correction. Check the specifications closely to make sure the operation you want will be possible.

Synchronization of audio may also be required on signals from external sources where the video has been highly processed, i.e., from satellite linked sources. Such audio synchronizers will more commonly be used at the studio location to make the necessary correction prior to airing the signals.

Modern equipment allows an entire production system to be driven by the sync from one of the portable cameras. Still, a master sync generator, including auto-switchover to a backup generator is advisable in the production system. A reliable system will cover all bases with redundant functions.

Distribution, monitoring and test equipment are musts. The plans should include audio, video and pulse DAs, good quality audio and video monitoring units and sufficient waveform and vector monitors for video. Along with single function systems, several manufacturers offer units with switch selection of waveform and vector functions. Such a dual purpose product may be important where available space is critical.

Signal generators and vertical interval test signal insertion allows automatic correction systems to correct video signals whose parameters fall outside of preset limits. Source ID functions may also be provided by the test generators. With appropriate decoders on the video monitors, the

**Fig. 10. TEK offers portable signal monitors that offer test oscilloscope as well as waveform and vector functions. (Courtesy Tektronix)**

**Fig. 11. Wireless microphone systems may double for audio and for intercommunications needs. (Courtesy HM Electronics)**

origin of each camera's signal is automatically noted on the video monitor screen in the production vehicle.

Inter-communications between various areas within the vehicle and with the staff members outside is essential. The intercommunications may include a link to the local telephone system.

Microwave equipment should also be considered. Armed with a portable microwave transmitter, even the single camera ENG system can go on-air live from the scene to good effect. A choice in microwave frequency bands is available. Most systems are in the 2 GHz band, which covers from 1.990 to 2.110 GHz. Increasing use of the 7 GHz band (6.875 to 7.125 GHz) has been found, as microwave paths become more congested in major markets. In both the 2 and 7 GHz spectra, a secondary band is available on a shared basis with other services.

The 13 GHz band is also available, but has seen limited use for ENG. That frequency is more commonly used between fixed locations, such as STL and intercity relay functions. Prior to determining which microwave bands to operate for remote production, it is wise to find out what fixed services are involved in any given area. Special path arrangements may be required for getting the EFP signal back to the station.

If the production plan might involve helicopters, as has been done at auto racing, additional microwave systems, with auto tracking antennas, could be suggested. Satellite uplinking is also desirable when events of network interest are to be covered.

Human comforts must be considered. Not only is heating and cooling advised to make the operators' production time more pleasant, the equipment requires environmental control for best results. The vehicle may be used in all weather extremes, so insulation is valuable. The insulation will also be important in keeping external noise from interferring with activities inside the vehicle.

Working space, both for operation and technical needs, must be provided. Operators that must function in cramped quarters will not work efficiently for long periods of time. Cables, no matter how well prepared, when forced into insufficient space, will fail at the most inconvenient time. The space needed for technical reasons also allows good circulation of cooling air in and around equipment.

On board power for equipment operation may not be essential. At nearly any event for which a 40-foot trailer is scheduled, power should generally be available. It is possible, however, that local power might not be available at setup time. As a result, a small portable or integral power generator could prove most helpful in getting all systems checked out. A backup generator is advisable, in case the local power fails. The portable can be the primary power supply for out-of-the-ordinary locations where commercial power is not available.

For smaller vehicles, some type of power source may be required. News does not occur in close proximity to a power distribution panel! For ENG, be prepared with plenty of fully charged batteries for cameras and recorders. For small EFP systems, plan ahead. If the event is scheduled, local power will probably be available. But not always.

Using an integral power generator does present problems. In a small vehicle, an inverter, providing ac from the vehicle battery is possible, though the purity of the ac power waveform is often questionable. Most equipment no longer requires highly pure sine wave ac power at exactly 60 Hz, but every attempt should be made to provide proper power, rather than betting against fate.

For larger systems, a gasoline-powered engine system is preferable. The engine, however, is also a source of noise. Special care should be taken in insulation, if the generator is a part of the main vehicle. The generator should be mechanically isolated from other parts of the vehicle, to avoid conduction of noise. Alternatively, the power generator could be a tow-along unit that could be separated from the main vehicle.

Connections into and out of the vehicle should be provided at a convenient location. All ports should allow quickly connected, but secure, fittings for each cable. The panel should be permanently well labelled, so fast setups can be done with a minimum of effort, time and interconnect errors.

Outfitting the production vehicle is perhaps more demanding than setting up a new studio. The most capability within money and space

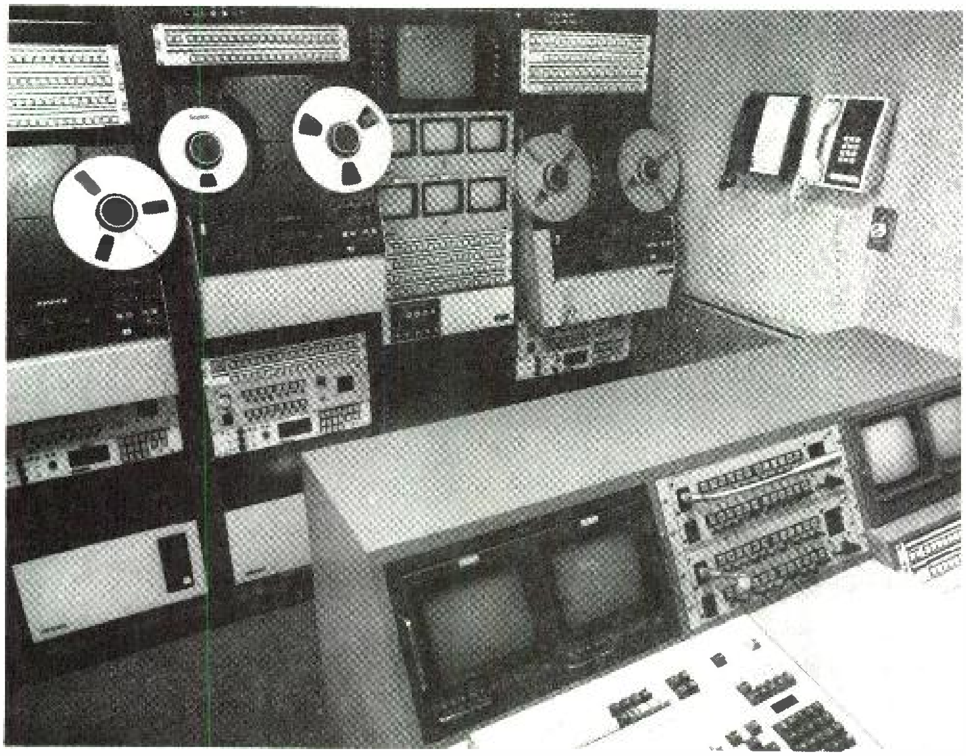


**Fig. 12. Typical production control area in a medium size vehicle.**

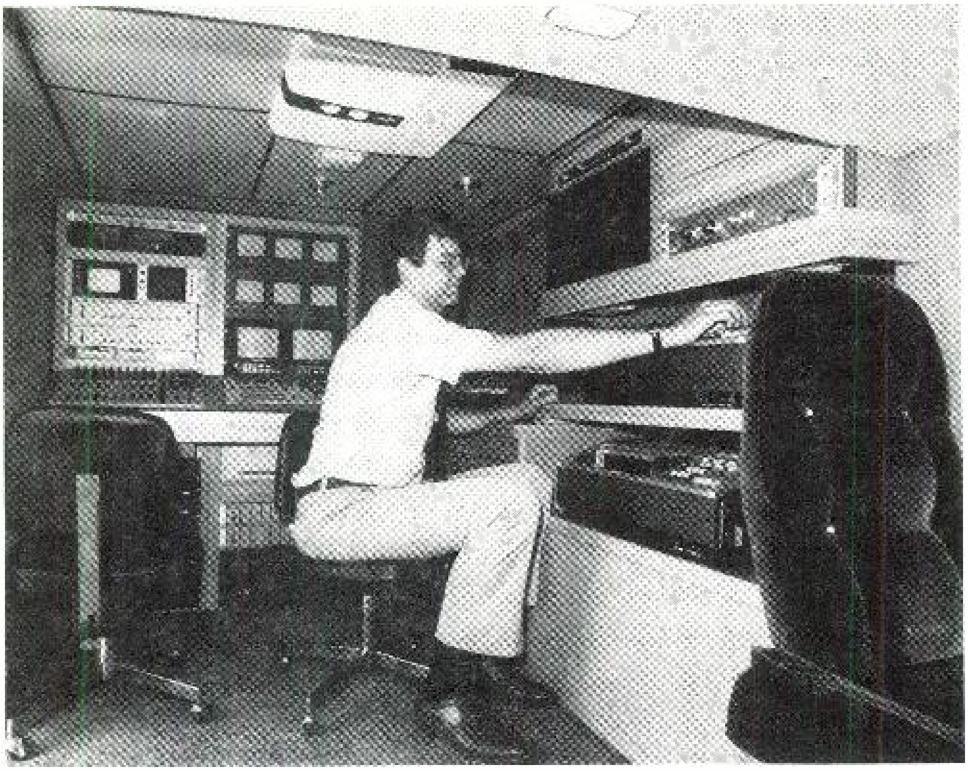


Fig. 13. A production system in a smaller vehicle can still be versatile.

limitations is the ultimate aim. Some degree of compatibility with existing studio equipment should be attempted. The facilities needed to meet the field production expectations will not be planned overnight.

## Operation, Tips and Techniques

### *Preparing for a Remote*

With the production vehicle ready and the date of the event set, many small items will still require attention. A checklist is one suggested method to make certain that everything is on schedule. Another good approach to any production is an operations manual. The manual, like the script for a play, includes all information that is pertinent to the production. A copy of the manual is provided to each member of the production staff.

As a case study, the Table of Contents from the July 4, 1984, WGBH/Mugar Productions "Live from the Esplanade," carried on PBS, gives a good example of making certain the annual Boston Pops Concert went smoothly from the television point of view.

### Table of Contents

- Program Order/Timings
  A program log
- Schedule
  Calendar of all events involved with the production
- Contact List
  Telephone numbers of all individuals connected with the production
- WGBH Fax Orders
  Station equipment that will be needed for the production
- Camera Positions
  Layout of production area, showing camera locations with lens and support equipment for each location
- Production Microwave
  Special camera microwave equipment needed, locations, special conditions.
- Transmission Microwave, Uplink, Rain, Transmission Contingencies
- Microwave link assignments, satellite transponder assignment, times, signals to be transmitted, what happens if it rains!
- Communications
  2-way radio, wires intercoms, etc.
- Helicopter
  All arrangements for helicopter with cue sheet for chopper crew and camera

- Who is where
  Production staff assignments
- Food & Transportation

The production involved five cameras in and around the Hatch orchestra shell. In addition the layout included one at the Prudential Tower (about ¾ mile away), one on a boat in the Charles River beside the Esplanade park area and one in a helicopter made available by station WNEV-TV7, Boston.

The crew had to work around tens of thousands of spectators gathered for the annual orchestra performance. The scheduling had to meet with the PBS network timing. Helicopter activity was restricted in time and place by local ordinances and required special coordination.

The major items in the equipment complement for this production included:

In the audio remote vehicle—

- Mixer—API 40inX24out
- ATRs - Otari MTR-90 24-track and Ampex ATR-100
- Monitors—UREI and Aurotone, driven by RTS and Bryston amps
- Lexicon 224 reverb
- dbx limiters
- Dolby-A noise reduction systems
- Mics—Schoeps, AKG VR2 and others

In the video remote vehicle—

- Cameras
  - 4 Ikegami HK-312, with triax, equipped with three Fujinon 16-1 lenses and one Canon 40-1 lens
  - 4 Ikegami HL-79D cameras with EFP lenses
- Switcher—CDL CD480
- Video Effects—Quantel DPE5000SP
- Synchronizers—DVS
- Camera microwave—M/A COM 2 GHz
- VTRs—Sony BVH2000 playbacks and BVH500A overlapped backup recording
- Video monitors—Barco CM55 and Conrac
- Audio mixer—NEVE 20in
- Intercoms—RTS, HME wireless mic, 450 MHz walkie talkies, standard business telephones
- Transmission microwave—M/A-COM 2 GHz and 12 GHz systems

A cooperative effort between WGBH and other Boston TV stations (WBZ, WCVB and WNEV) helped to make the production successful. Not only was equipment shared, but microwave channels were made available to WGBH through a frequency coordination effort between the four stations. With only seven 2 GHz channels available for the Boston stations, arrangements allowed only the WGBH operation to use the frequencies during the televised concert.

In providing the information on the production, the engineer-in-charge stressed that cooperation between the various segments of the production and the other local TV stations was the key to a successful event.

## On-Air from the Air

Going live from the production site may be only part of the requirement. Such was the situation handled by WHIO-TV7, Dayton, OH, for the International Air Show. Opening ceremonies and five hours of live coverage were provided, as well as a 1-hour documentary within three days of the event.

WHIO has carried the event previously, so parts of the preparation were not new. Special needs included two 150kW diesel generators, telephone lines, scaffolding and the remote vehicle. Equipment included items borrowed from other Cox broadcast stations and rental arrangements.

One major problem encountered during air show production was RF interference. In addition to microwave at the site to bring signals from two portable BVP-330s and one helicopter mounted BVP-3 camera to the production truck, an assortment of communications frequencies were required for the aircraft. Also, microwave carried signals to WHIO for the life feed. Two other stations also covered the event. Add to all those radio systems, radar adding its own touch of pulsed signals!

The syndicated documentary material was taped on another day of the event, simplifying production problems. In addition to activities in the air, special arrangements were needed for interviews. To achieve the most natural sound, a special audio system was used to record the aircraft on a separate audio channel for later mixing into the final program.

## For Other Field Productions

Such efforts would hardly be needed for a simple ENG feed into the news, but EFP and OB events require the added planning. For a dramatic production, camera and mic locations would typically be included in a technical copy of the script. Camera movements and shots should be noted according to directorial edicts. Any changes from original plans during rehearsals should be noted as well, to make the final shooting go smoothly.

In OB production such as the WGBH example, convention coverage, sporting events or a space shuttle launch, the basic placements may need to give way to circumstances at the time. Still, all possible pre-planning is a good idea.

## Conclusions—Combatting Murphy

One of the greatest difficulties in any field production attempt is getting around Murphy's law and its many corollaries. "If it can go wrong, it will!" It is up to the engineering department to be prepared for all of the inevitable problems. Equipment redundancy is one possible solution. A full complement of test equipment for any eventuality is another.

There is, however, no solution as a propos to avoiding trouble as good planning. Care in decision making toward the remote equipment and compatibility with the studio system will ease possible equipment failures. Keep in mind that a studio camera could become a last minute sub for a defective ENG camera, even with a greatly reduced portability and flexibility.

If the primary remote recorder goes down minutes before the event begins, have another recorder available. A lesser quality machine is preferred to no machine at all. Keep contingency equipment in top condition. The primary equipment only fails when the possible backup systems are not in top condition!

Make sure that everyone involved in the production is prepared for failures. The production handbook or a check list helps. More experienced groups may find a rehearsal unnecessary, but an inexperienced crew could benefit if problems occurred (on purpose) during technical rehearsals. Finding the time for such rehearsal luxuries is seldom possible, but a 'rigged' run-through could pay off.

A complete signal flow chart of the production system should be conveniently located in the vehicle at all times. The staff should know the system without referring such a layout. In the heat of trying to get around a failure, however, the signal map can save valuable time. The smallest item causes the greatest amount of trouble the most number of times, so the more comprehensive the equipment layout and interconnection diagrams the better.

Whether you are in the planning phase or under the stress of a complicated production, stay calm and logical. Panic situations cannot be averted by panicked staffers.

The comments in this section are intended to be only an overview of the world of TV field production. Hopefully some of the comments will give an insight into aspects that you have not considered for your particular needs. Many additional excellent products are available besides those mentioned or pictured. Other sections of this handbook will aid in making decisions for your system.

Best of luck in your endeavours and happy TV field production!

# 6.4

# Telephone Systems and Interfacing

Chapter 6.4:
**Part I: Interfacing to the Dial-Up Network**
Part II: Telco Audio Program Service

## Part I: Interfacing to the Dial-Up Network

Steve Church
*WHK, WMMS*
*Telos Systems*
*Cleveland, Ohio*

Why are the people who run local TV news so concerned with avoiding the dread "talking head" — that is, the anchor simply reading a story into the camera? Because they've discovered that *being there* is better. The same is true for radio, and most often that means "The Telephone Company" and its lines will be involved. Many stations make listener call-ins an important format element. News departments rely extensively on "phoners" to get reporters and newsmakers on the air in a timely fashion. And, despite the recent complications resulting from AT&T's breakup, equalized phone loops are still an important means of moving high-fidelity audio from place-to-place for broadcast use.

### INTERFACING TO THE DIAL-UP NETWORK

#### Introduction to the Switched Network

In order to make the best use of phones on the air, it is helpful to understand how the telephone system works, so that we have an idea of what we can expect from a typical dial-up circuit.

The phone pairs provided us by the phone company are known officially as "subscriber loops." On standard subscriber loops, the phone company specifies a frequency response of 300 to 3,000 Hz. In the not too distant past, when all local calls were connected at the exchange by relay contacts, better frequency response was likely to be had on many conversations. Long distance calls, though, have almost always gone by way of band-limited microwave or satellite links so frequency response on them has never been better than the promised 300 to 3,000 Hz.

Even on local calls, however, the latest generation exchanges convert the phone audio to digital using devices called CODEC's (CODer/DECoders). As with any analog signal to be digitized, anti-aliasing filters must be used to limit frequency response to less than one-half of the sampling rate employed. Since phone CODEC's use a sampling rate of 8 kHz, response is absolutely limited to less than 4 kHz. In practice, filters with steep cutoffs above 3.4 kHz are used, and these are the limiting factor with regard to phone line audio response.

A current-limited dc voltage and the conversation audio appear together on each phone pair. The dc leaves the exchange at 48 volts and is limited to 6-80 ma by a series resistor. Often, the resistor's value is selected depending on the resistance of the loop itself. A little known fact is that a standard plain AT&T telephone incorporates a varistor which, by sending loop current, automatically adjusts voice level to compensate for various loop lengths. The dc resistance of loops varies from a few to 1,300 ohms depending on length.

The incoming audio level varies from approximately -30 to -15 dBm. Send audio is required

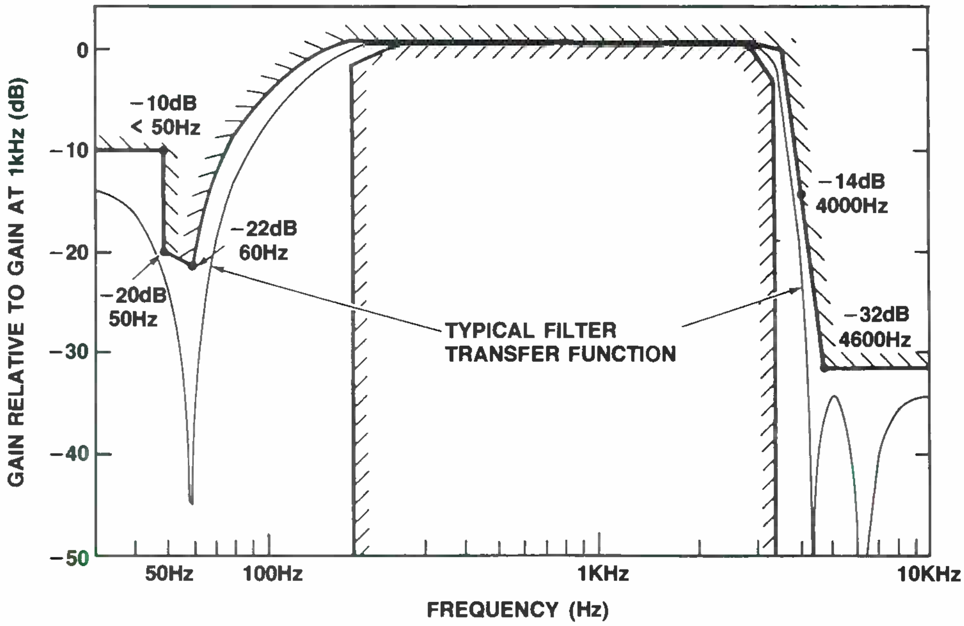



**Fig. 1 Anti-alias filters limit phone line response.**

to be limited to -9 dBm. Loop audio loss from the exchange to the subscriber location is supposed to be kept to 8 dB or less. Ring voltage is around 90 volts and varies from 10 to 60 Hz.

The telephone company uses a special weighting curve called "C-message weight" to determine the signal-to-noise ratio on a phone line.

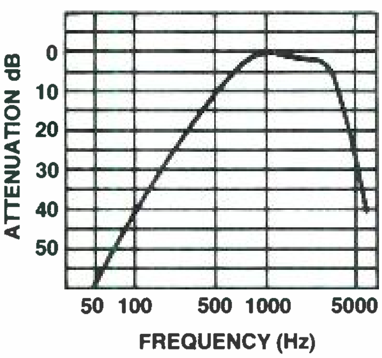



**Fig. 2. C-message weight curve.**

As you can see, this weighting curve has considerable low-frequency roll-off. This, of course, allows a line to have a lot of hum and other low-frequency noise and still meet the officially mandated noise specs. While this makes life easier for the phone company, it can be troublesome when you are using phone audio on the air. If you are having noise problems, you might try to get the telephone company to switch their noise meter to the "flat" position, since their gear usually does have this option available. Incidentally, the C-message curve was developed years ago to simulate the frequency response of an old-style telephone earpiece!

The FCC rules for connection of equipment to the phone company lines can be found in The Rules and Regulations of the Federal Communications Commission, Part 68: Connection of Terminal Equipment to the Telephone Network. The rules can be ordered from the government printing office, or can be found reprinted in the Code of Federal Regulations in the reference section of most larger libraries.

## Terminal Equipment

Now that we know a bit about the nature of the phone network, we can explore what happens after the lines become "ours." "Terminal Equipment" is the equipment we connect to the lines after the official "Customer Demarcation Point," and includes PBX and Key systems as well as simple single-line phones. Of course, we'll also explore specialized broadcast interfacing systems.

PBX, or Private Branch Exchange systems are used where there is a need for a large number of extension phones. PBX's are sort of miniature central office exchanges, allowing local phones to call each other as well as being able to access "trunk" lines for incoming and outgoing calls. PBX systems often have a number of specialized features for call routing and control.

"Key Systems" are used where the number of extensions is smaller. Key systems are generally distinguished from PBX systems by the presence of incoming CO (Central Office) lines on individual buttons on each extension phone. The common standard 5-line and 10-line phones connected to a central Key Service Unit are of this type.

With the newer phone systems, the distinction between PBX's and Key Systems has begun to blur. Some PBX system phones now can button-access individual lines, and some of the newer "Key" systems have PBX-like features. When selecting a system, however, it is very important to determine whether it is classified officially as PBX or Key, since, as of this writing, business line charges in some states are considerably different depending on which type system will be connected. Lines destined for PBX connection can cost twice that of those wired to key systems.

### *Key System Nuts and Bolts*

While newer, sophisticated electronic phone systems are quickly replacing the old-style key systems in radio station "front offices," the old reliable "1A2" key systems are still used in the on-air studios by the vast majority of stations. These offer the advantage of providing a solid contact-closure connection between studio equipment and incoming lines for least quality degradation, as well as high reliability and relatively simple interfacing.

Understanding how a Key System works, if you have one, will be useful if you intend to make use of commercial telephone-to-broadcast equipment which connects to this kind of system or if you desire to build your own interfacing devices.

Leading from the Key Service Unit to each phone is a thick cable with a number of wires, usually "25 pair" or 50 individual wires. Understanding the function of each wire is the key to understanding how key systems work. See Box, this page.

**Tip/Ring**—The name originated with the tips and rings of the patch cords telephone operators first used to connect callers. The tip/ring pair is the actual telephone line connected through from the incoming lines. They may be located with headphones or a telephone.

**"A" leads**—These tell the key system which lines are off-hook. Any time a line is selected on a phone and taken off-hook, a connection is made from that line's "A" lead to another wire called "A common." The "A" lead is at -24 volts, and "A common" is at ground potential, so when a line is selected, the "A" lead goes from -24 V to ground.

If the "A" lead connection is broken before the tip/ring is disconnected, the system puts the line on HOLD.

These wires may be located by using a volt meter while selecting lines on a nearby phone.

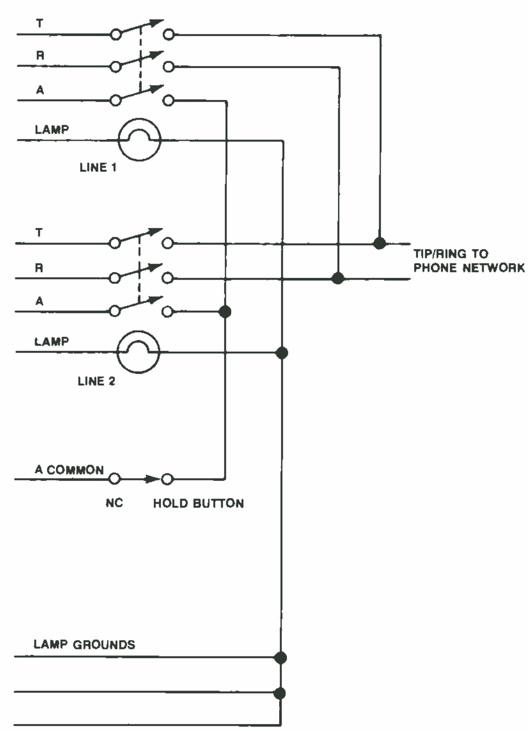
There is usually only a single "A common" wire for all lines in a system.

**Lamp leads**—These light the lamps on the phone's line buttons. The lamps use 10 volts ac. The lamp circuit is completed through the "LG" lamp ground wires.

All of the LG wires are connected together at the KSU. Multiple wires are used to distribute the current to reduce the voltage drop when a number of lamps are lit.

In the great majority of systems, the lamp grounds and the "A" common are connected to ground, and are effectively the same.

In standard old-type "six-wire fan-out systems," the A common is renamed "A1" and bussed to each line so that there are a full six leads devoted to each line—Tip/Ring, A/A1, and L/LG.




TELEPHONE SWITCHING CIRCUIT

| 6-wire fanout | 5-wire fanout | Color |
|---|---|---|
| Line 1 Tip | Line 1 Tip | white/blue |
| Line 1 Ring | Line 1 Ring | blue/white |
| Line 1 'A' | Line 1 'A' | white/orange |
| 'A' circuit common (gnd) | 'A' circuit common (gnd) | orange/white |
| Line 1 lamp ground | Line 1 lamp ground | white/green |
| Line 1 lamp | Line 1 lamp | green/white |
| Line 2 Tip | Line 2 Tip | white/brown |
| Line 2 Ring | Line 2 Ring | brown/white |
| Line 2 'A' | Line 2 'A' | white/slate |
| 'A' circuit common (gnd) | Usually line 9 'A' | slate/white |
| Line 2 lamp ground | Line 2 lamp ground | red/blue |
| Line 2 lamp | Line 2 lamp | blue/red |
| Line 3 Tip | Line 3 Tip | red/orange |
| Line 3 Ring | Line 3 Ring | orange/red |
| Line 3 'A' | Line 3 'A' | red/green |
| 'A' circuit common (gnd) | Usually line 8 'A' | green/red |
| Line 3 lamp ground | Line 3 lamp ground | red/brown |
| Line 3 lamp | Line 3 lamp | brown/red |
| Line 4 Tip | Line 4 Tip | red/slate |
| Line 4 Ring | Line 4 Ring | slate/red |
| Line 4 'A' | Line 4 'A' | black/blue |
| 'A' circuit common (gnd) | Usually line 7 'A' | blue/black |
| Line 4 lamp ground | Line 4 lamp ground | black/orange |
| Line 4 lamp | Line 4 lamp | orange/black |
| Line 5 Tip | Line 5 Tip | black/green |
| Line 5 Ring | Line 5 Ring | green/black |
| Line 5 'A' | Line 5 'A' | black/brown |
| 'A' circuit common (gnd) | Usually line 6 'A' | brown/black |
| Line 5 lamp ground | Line 5 lamp ground | black/slate |
| Line 5 lamp | Line 5 lamp | slate/black |
| Line 6 Tip | Line 6 Tip | yellow/blue |
| Line 6 Ring | Line 6 Ring | blue/yellow |
| BL, AG, or spare | BL, AG, or spare | yellow/orange |
| SG, LK, or spare | SG, LK, or spare | orange/yellow |
| Line 6 lamp ground | Line 6 lamp ground | yellow/green |
| Line 6 lamp | Line 6 lamp | green/yellow |
| Line 7 Tip | Line 7 Tip | yellow/brown |
| Line 7 Ring | Line 7 Ring | brown/yellow |
| B or B1 | B or B1 | yellow/slate |
| R or R1 | R or R1 | slate/yellow |
| Line 7 lamp ground | Line 7 lamp ground | violet/blue |
| Line 7 lamp | Line 7 lamp | blue/violet |
| Line 8 Tip | Line 8 Tip | violet/orange |
| Line 8 Ring | Line 8 Ring | orange/violet |
| Line 9 lamp ground or T1 | Line 9 lamp ground or T1 | violet/green |
| Line 9 lamp or R1 | Line 9 lamp or R1 | green/violet |
| Line 8 lamp ground | Line 8 lamp ground | violet/brown |
| Line 8 lamp | Line 8 lamp | brown/violet |
| Line 9 Tip | Line 9 Tip | violet/slate |
| Line 9 Ring | Line 9 Ring | slate/violet |

**Fig. 3. Standard 25 pair color-code.**

If you ever need to deal with a key system, the standard 25 pair color-code and function chart should help you. Notice that in addition to these basic connections, there will also be some special wires devoted to intercom audio and control. These vary widely from system to system.

## Audio Interfacing

### *One-way Audio Interfacing*

Often, there is a need to take audio in only one direction at a time from a phone for broadcast. Newsroom phoners are a common application. Since there is no requirement that a two-way conversation be recorded, a simple interface will do. One approach is to obtain the common Voice Coupler, or "QKT" arrangement from the phone company. This small box is permanently wired into a phone instrument or line, and provides a quarter-inch phone jack output for feeding a line-level signal to a console or recorder input. When using a coupler, it is most convenient to have the telephone instrument on-line with it equipped with a push-to-talk switch on its receiver. This is because the phone's receiver has to be off-hook while a feed is coming in, and the switch turns off the receiver's mouthpiece microphone when it is not depressed, thus insuring that noise from the studio side will not be included in the recording. Since a QKT works in both directions, you can use it to send audio down the phone as well, very useful in the production studio for letting clients hear commercial masterpieces before they go on the air.

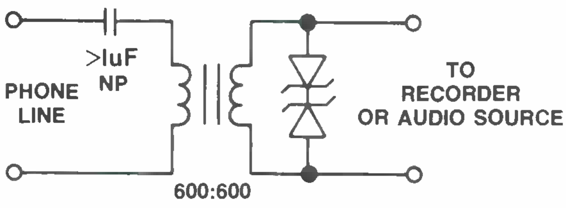



Fig. 4. Homebrew "QKT".

Since a QKT is nothing more than a transformer, a capacitor and a zener diode limiter, you can build your own.

The capacitor provides dc blocking so that the transformer does not become saturated with the phone line's dc potential. If you are sending audio into the phone line, remember you'll have to limit audio level to -9 dBm. The QKT has back-to-back zeners for this purpose; you may want to add them to your home brew interface if you expect audio levels to get out of hand.

If you are hooking up to a multi-line phone, you'll have to connect to a point where the selected tip/ring is present after line selection. The most convenient place is usually right at the phone network. Using headphones you should be able to find the spot.

### *Two-Way Interfacing Schemes*

For on-air use when it's necessary for the caller to hear the announcer and the audience to hear the caller, you'll have to implement a more complex scheme. You will need some way to separate the "send" and "receive" audio paths. There are two basic methods for accomplishing this: the Switching method and the Hybrid approach.

#### *The Switching Approach*

This technique uses simple switching to keep the send audio from appearing at the receive output. Two electronic switches are used in such a way as to ensure that either the send or the receive path is closed at any given time, but never both simultaneously.

A decision circuit compares the send and receive levels, with the direction of transmission being determined by the relative signal strength.

Often, Voltage Controlled Amplifiers (VCA's) are used in place of the switches to provide soft-

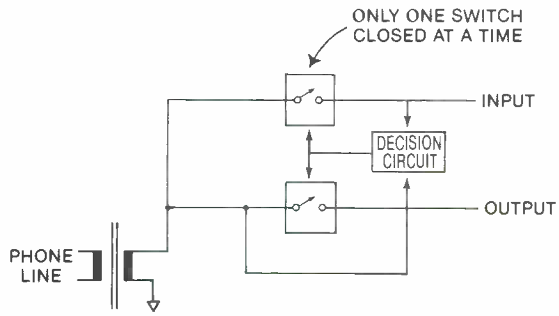



Fig. 5. Switching-type circuit.

switching rather than the absolute on-off of simple switches. The common telephone company-supplied speakerphones work this way.

The disadvantages of the switching technique result from the uni-directional nature of these systems. The primary problem is that the caller cannot be heard while the announcer is speaking —or laughing! Also, noises in the studio can sometimes cause a caller to "disappear" momentarily, especially on weak calls.

#### *The Hybrid Approach*

Hybrids were invented by the phone company many years ago in order to separate the send and receive signals from a standard two-way phone pair. Long distance calls went by microwave, and, of course, microwave links only go one way. Thus, the need for some way to split the two signal directions.

The first hybrids were made from transformers with multiple windings. Nowadays, most hybrids are made with active components-operational amplifiers (op-amps) or transistors-and are known as "active hybrids." Both circuit types use the same principle, and achieve the same effect. An op-amp version is shown in Fig.7.

The first op-amp is simply a buffer. The second is used as a differential amplifier, the two inputs are added out-of-phase (or subtracted, if you prefer). If the phone line and the box labeled "balancing network" have identical characteristics, then the send signals at A and B will be identical, and no send audio will appear at the output of the second op-amp.

The balancing network is a circuit consisting of capacitance and resistance, and sometimes inductance, forming an impedance network. Depending on the hybrid's application, this circuit can be very simple, or be made of a large number of components, with a very complex impedance characteristic. For more information on op-amps, see Chapter 7 of this Handbook.

Notice that R1 and the phone line form a voltage divider, as does R2 and the balancing network. If you think of the phone line and balancing network as pure resistances, then it is apparent

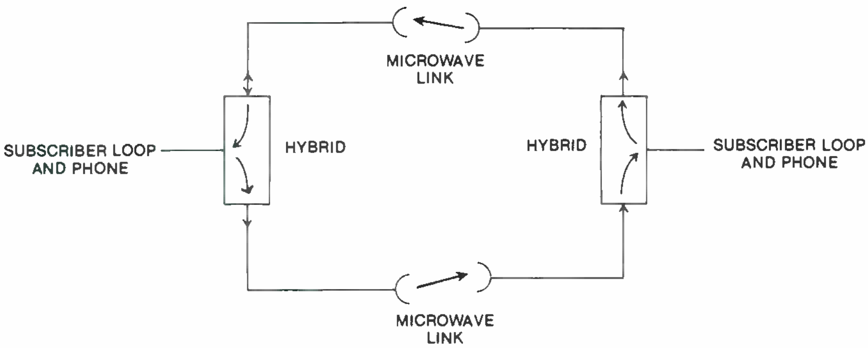



**Fig. 6. Hybrid/microwave signal path.**

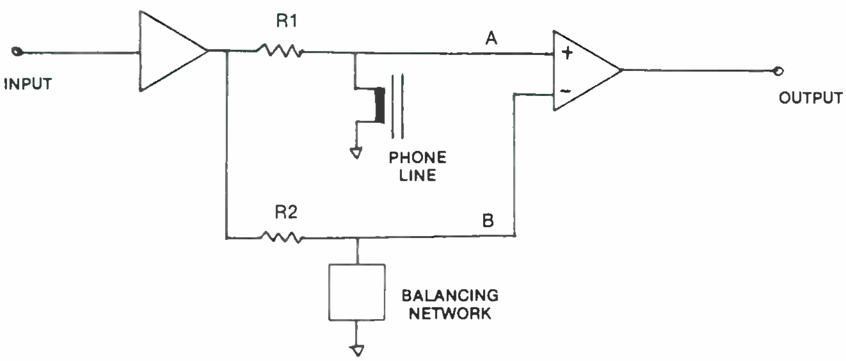



**Fig. 7. Op-amp hybrid.**

that the phone line and the balancing network must have the same value in order for signals at A and B to have the same amplitude, and full cancellation to occur.

In the real world, the phone line is not purely resistive, but rather a complex impedance, causing both the amplitude and phase to vary at A as the send signal frequency varies.

Only when the impedance of the balancing network is the same as the phone line, and the signal at B is matched to that at A in both amplitude and phase, will full cancellation of the send signal be achieved. Otherwise, leakage results, the scourge of hybrid circuits.

Since the phone company's requirements were not generally too stringent, they usually used (and still do) a simple network with compromise values of resistance and capacitance. The phone company's design goal is to get an average of about 12 dB rejection, with 6 dB acceptable on difficult lines. When better performance is required, modules with a number of R and C elements which can be switched in or out are employed, the switches being set to match the network to a particular line.

The amount of hybrid rejection is sometimes called "trans-hybrid loss". Trans-hybrid loss is *not* the loss from the phone line audio to the output.

Incidentally, while we're talking terminology, a standard phone pair is called a "two-wire" circuit in telephone engineering jargon, and the hybrid has two ports, send and receive (in addition to the telephone line and balance network connections), requiring four wires to connect, thus, a hybrid is sometimes called a "two-to-four wire converter."

## Hybrid Application

In broadcast application, the telephone audio, including hybrid leakage, consisting of the local announcer audio phase-shifted because of the phone line reactance, is mixed with the original announcer audio.

If the amount of the leakage is too great, and the phase shift too extreme, the announcer audio will suffer degradation. When this occurs, the announcer most often sounds "hollow" or "tinny" as the phase cancellation affects some frequencies more than others. Also, feedback can be a problem when it is desired to have the caller on a speaker in the studio. Clearly, a hybrid will be useful only when leakage can be kept acceptably low.

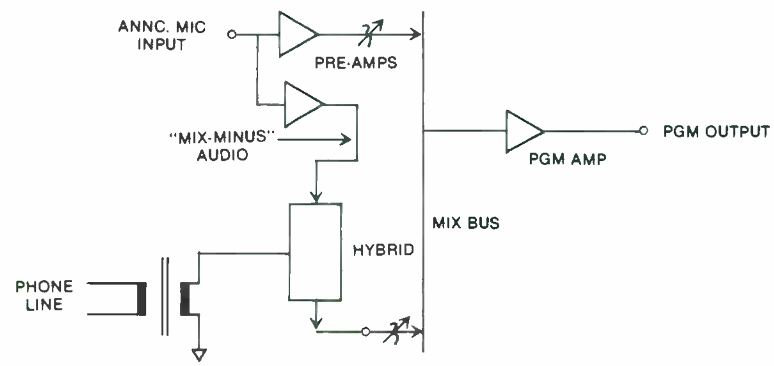



**Fig. 8. Console/hybrid mix path.**

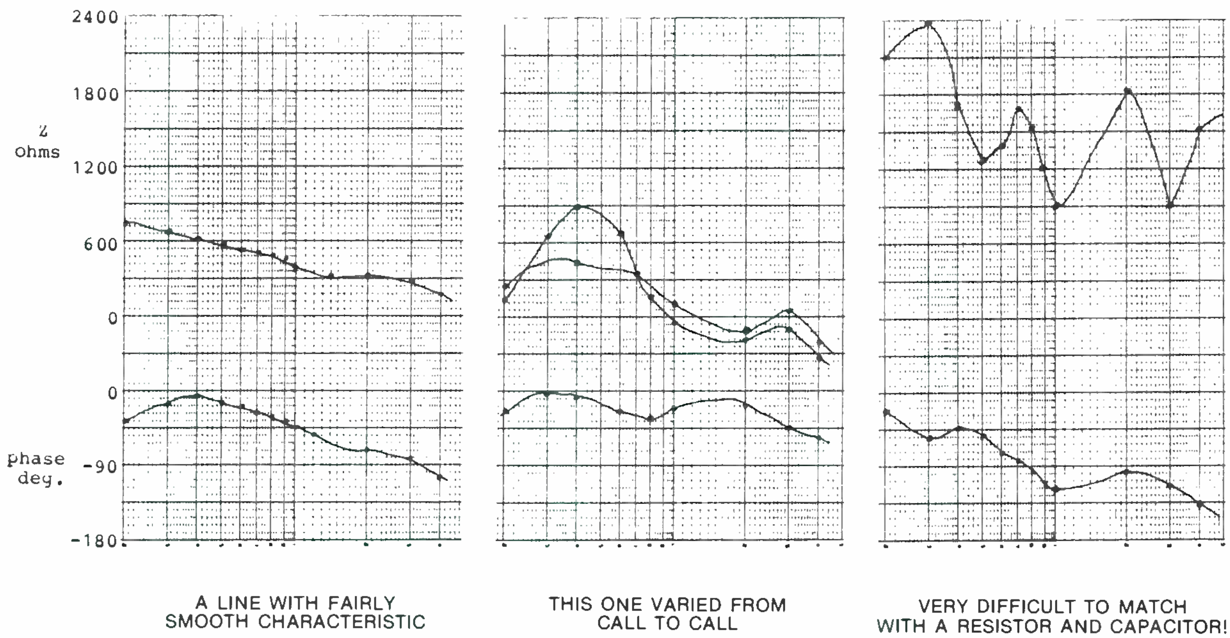



**Fig. 9. Phone line graphs.**

Fig. 9 shows some graphs of impedance vs. frequency and phase shift measured for some phone lines.

The lines with the smooth curves have impedance characteristics which can be simulated with a simple resistor-capacitor combination. These lines would work very well with a hybrid type interface device, since a practical RC balance network would make the cancellation of send audio at the receive output port high enough to prevent announcer audio coloration. Of course, if the hybrid is to be switched among a number of lines, they would all have to have nearly the same curve. Another consideration: the line characteristic would have to be consistent from call to call.

While it would theoretically be possible to make a balance network to match the more difficult lines, practical considerations usually keep this approach from being used, the line impedances are often inconsistent from call to call, or the impedance characteristic required is too difficult to produce.

Interfaces with an automatically-adjusted resistor-capacitor balance network work well when the phone lines to be used have a smooth impedance curve, but poor performance will still result when the line impedance characteristic is not a simple first-order RC curve and cannot be adequately matched by a simple RC network.

Another way to improve hybrid performance on widely varying or difficult lines is to trade single-frequency rejection for wide-band loss by making the phone line look less reactive to the hybrid with some series resistance.

Before leaving the subject of hybrids, another point should be made:

*The true test of hybrid performance is determined by measuring the amount of rejection across the entire audio frequency range, preferably with pink noise as a test signal at the send input.*

Any hybrid with an adjustable R and C balance network can claim high rejection at any given frequency, since both phase and amplitude at a single frequency can be tweaked for good cancellation. Voice is rarely a single-frequency source.

*Combination Systems*

The best systems for broadcast use combine the hybrid and VCA-type switching techniques. Here is one such configuration: The hybrid is used to produce as much send-to-receive isolation as can be achieved. The "override" or "caller-control" VCA causes the "dynamic" rejection to be greater than the hybrid alone can produce. When send audio is present, the VCA reduces the gain of the receive signal. Thus, leakage is reduced on a dynamic basis. However, it should be apparent that the level from the phone is also reduced when the announcer is speaking. A control pot in the VCA control signal path is often used to adjust the amount of receive ducking, allowing full duplex operation (when the hybrid alone produced sufficient rejection), or a speaker-phone-like effect whereby the caller is turned-off when the announcer speaks. As a practical matter, this control is usually set to provide the minimum amount of ducking which provides adequate send-to-receive leakage.

*Digital Signal Processing Hybrid*

One interface device (developed by the author) uses Digital Signal Processing to reduce hybrid leakage so that simultaneous conversation is possible without distortion of the announcer mike send audio. Phone audio is digitized and processed in a high-speed signal processor chip. The signal processor software produces good cancellation of send audio due to its adapting the balance network to an optimum value for each phone line to which it is connected. The hybrid is automatically adjusted to account for even very complex phone line impedances. Fig. 11 shows a block diagram of this device.

## Improving Phone Audio Quality

As studio and distribution quality improve modern broadcast audio, it has become more important that we do what we can to make telephone audio less of an "earsore." Filtering and equalization are the primary tools.

On a standard phone line, there is little or no audio above three to four kHz, but there is noise. Thus, a filter device with a very steep roll-off above 3 kHz can be employed to reduce phone line noise significantly without affecting conversation audio.

The low-end can be improved as well. On dial-up lines, low-frequency hum is often a problem. The hum is usually 60 Hz mixed with the second harmonic, 120 Hz. Thus, it is important to have a sharp roll-off starting at 200 Hz, or so. Again, there is very little phone audio present at these frequencies.

An inexpensive filter may be constructed using an IC filter intended for digital telephone exchanges and PBX's. The telephone filter IC used in the example in Fig. 12 has both a 5th order

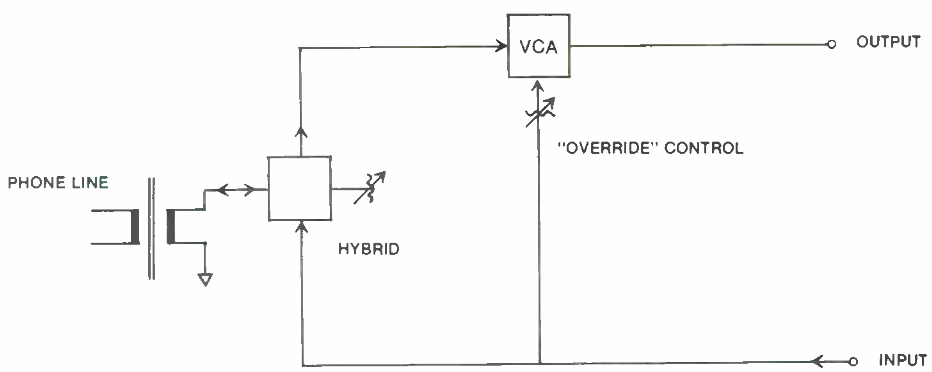



Fig. 10. Combination-type interface circuit.

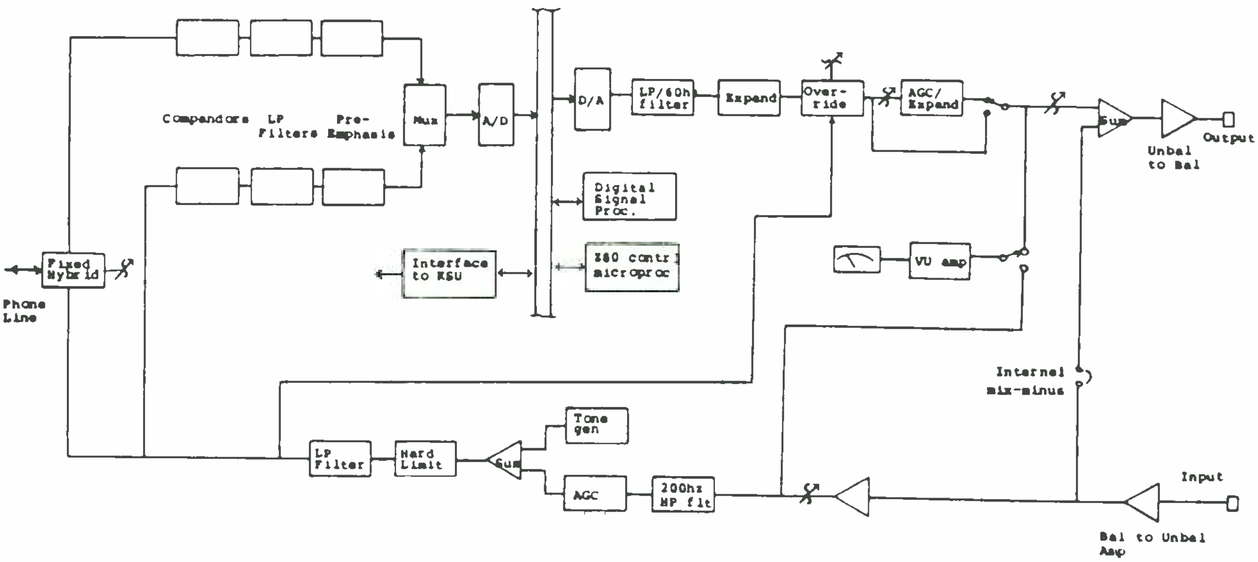



Fig. 11. Telos 10 digital interface block diagram.

elliptical low-pass section and an effective 60 Hz hum filter.

Since it is a switched-capacitor type filter, the 2912A needs an oscillator to operate. Also, note that the supply voltages are plus and minus *five* volts rather than the usual ±15.

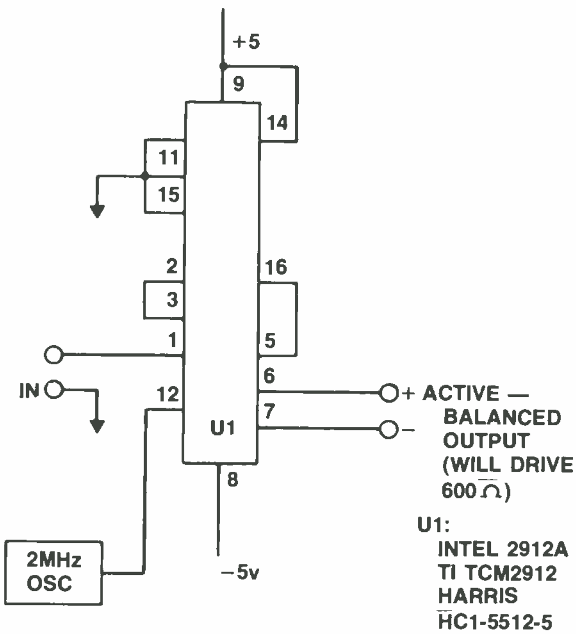



Fig. 12. Telephone audio filter using 2912A IC.

## *Additional Processing*

The next step is equalizing the phone line to improve quality and increase intelligibility. Using an equalizer to shape the frequency response of the phone line within its audio bandwidth can result in marked improvements in perceived quality. A typical phone line has an excess of energy at around 400 Hz and considerable roll-off at both the top and bottom ends of its passband, so the idea is to compensate by adding gain at both. Try boosts at 2.5 kHz and 250 Hz, a cut at 400-500 Hz, or some combination. Parametric equalizers are the preferred device for achieving the proper sound. Since every phone line is different, the ear is usually the best instrument to evaluate the results.

Another effective processing device is the expander, or noise gate. These devices may be used to reduce gain "between the words" of a conversation, thus making phone line noise less objectionable. On extremely noisy lines, though, the gating action may make the noise *more* distracting by its coming and going with the word than if it were there at a constant level all the time. A unit with adjustable threshold and duck ratio can be set so that the optimum compromise may be achieved between the benefit of reduced noise and audibility of the effect.

## *Bandwidth and Signal-to-Noise Extension*

So far, this chapter has covered processing at the studio-end only. We will now consider the situation where we have a planned remote origination using dial-up phone lines. Until recently, broadcasters could count on the phone company to provide high-quality equalized loops at moderate cost. In addition to the increased cost of equalized loops, there have always been problems when short-notice remotes were required, or when remotes were to be originated from an area where equalized service was unavailable. One solution is to make use of the dial telephone system for remote broadcasts. The problem here is the 300 to 3 kHz and 35 dB or so S/N that the dial network provides is not adequate for modern broadcast needs. Frequency shifting and amplitude companding can be used to make the dial-up network acceptable for some kinds of remotes.

## Frequency Shifting

### *Frequency Shifting Using One Line*

Frequency shifting offers a way to squeeze more *frequencies* into a line than it will normally pass. Or, more accurately, the process allows *different* frequencies than the usual 300-3,000 Hz to be passed through a standard phone line.

The popular Comrex unit shifts all audio frequencies up by 250 Hz in the encode mode (going into the phone line) and down by 250 Hz in the decode mode. The result is a 250 Hz improvement at the low end at the expense of a 250 Hz loss on the high end. This means a typical phone line's response will be changed by the shifting process to be 50-2750 Hz. The 250 Hz loss at the top is not very significant due to the logarithmic nature of audio frequency response.

The Comrex and similar units perform the shifting function by heterodyning the input audio with a low-frequency carrier. The "phasing" SBB (Single SideBand) generation method is employed to allow only one sideband to emerge at the output; the carrier and other sideband having been cancelled in the SSB process. Encoding and decoding can easily be accomplished in the same unit, since only a simple signal path change is required to cause an encoder to decode, and vice-versa.

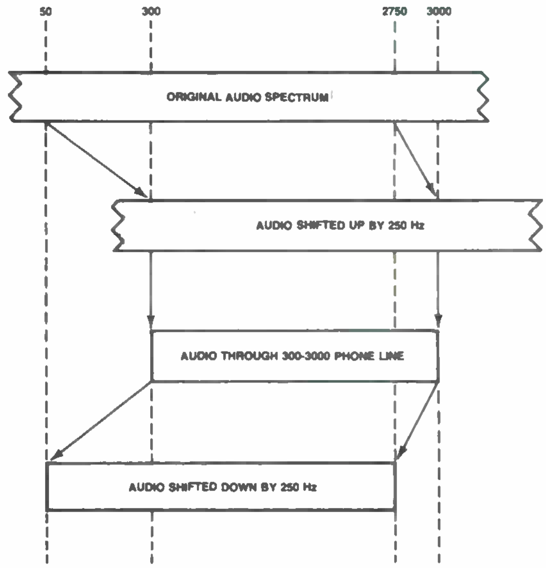



**Fig. 13. An audio frequency shifter allows transmitting an improved low end response with only a small loss at the upper end.**

Subjectively, frequency-shifter feeds sound less "telephone-like". However, the result of improvement at the low end without high-end enhancement is often a somewhat muddy or "flat" sound.

One approach to improving subjective quality is to boost the high end that you *do* have with a sharp EQ rise above 2 kHz. A parametric EQ

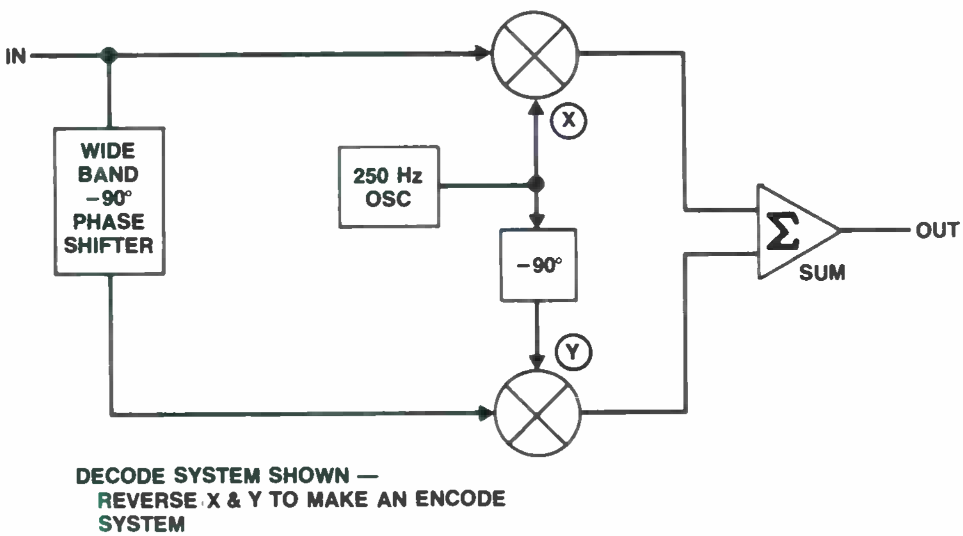



**Fig. 14. Frequency shifter block diagram.**

or custom filter would be preferred so that the desired high-Q curve can be obtained.

Another way to improve the subjective high-end quality is with the application of Aphex or EXR "exciter" equipment. These units generate harmonics of the input audio, which are then combined with the input to produce a "harmonically-enhanced" output. This output will have new high-frequency information above the 3 kHz phone line bandpass, so, the generator unit should be placed after any HF roll-off filters.

Yet another, more elaborate, approach to high-end improvement is the half-speed transmission technique. With this approach, another encode process is used in addition to the frequency shifting already described; this time operating to improve high-end response rather than low-end. A phone line with fixed bandwidth can be made to have more if we are willing to trade-off transmission time for better fidelity.

The technique is very simple: the recorded material is played back at half-speed; after reception, the received material, having also been recorded, is played back at twice the record speed. What goes through the phone line is nearly unintelligible, since it is half-speed audio. Of course, this method cannot be used when real-time transmission is desired, and toll calls cost twice as much—another example of the futility of expecting something for nothing!

The combined shifting and half-speed techniques result in an effective bandpass of 100 to 5,500 Hz.

One note regarding frequency shifting: decoding must be done from a direct input. That is, frequency-shifted audio should be decoded as it comes out of the phone line, before it goes to tape. If the shifted audio is recorded un-decoded, with the intention of later playing the tape back through the decoder, interesting but unairable results may occur. These are due to the additional slight frequency shifts introduced by the recorder. The decoder is not expecting to see these, and is quite intolerant of them.

### *Frequency Shifting Using Two Lines*

Despite the benefits derived from extending the frequency of a phone line to 50 Hz, the frequency response obtained from a single phone line is still limited to a very "low-fi" 3 kHz. Response to 5 kHz is, however, possible with the use of two phone lines (the half-speed transmission technique described above extends response, but, cannot be used when "real time" transmission is required).

In a two-line extension system, highly selective crossover networks split the program audio into two bands each of about 3 kHz or so in width. These bands are then heterodyned to occupy the available phone bandwidth using the same kind of process as in the single-line shifters. In the Comrex unit, input audio is separated into bands of 50 Hz and 2400 Hz and 2500 to 5000 Hz. The first band is then shifted up 250 Hz, while the second band is down-shifted 2 kHz. A five-band

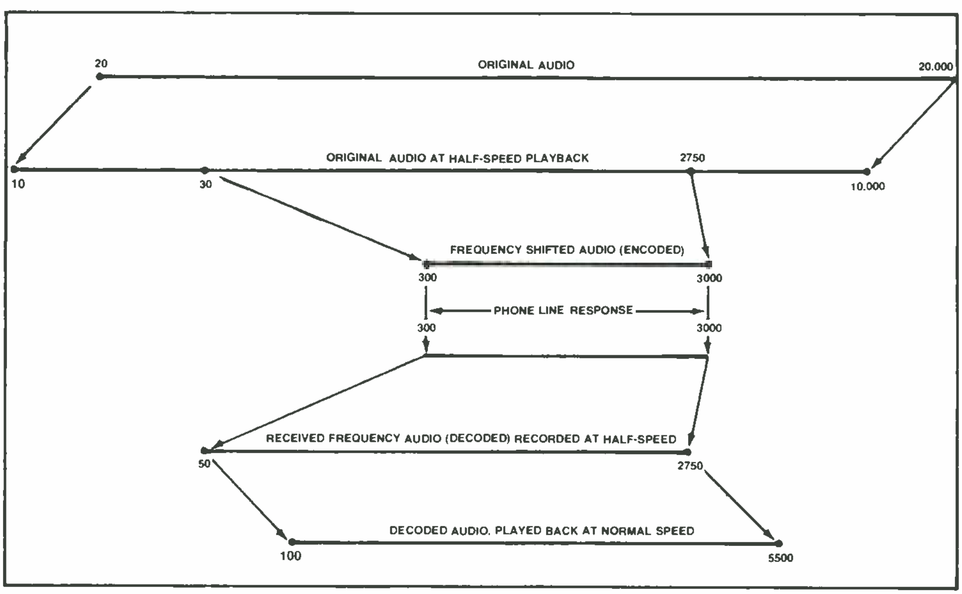



**Fig. 15. Combined half-speed, frequency-shifted transmission offers a playback response of 100 Hz to 5.5 kHz.**

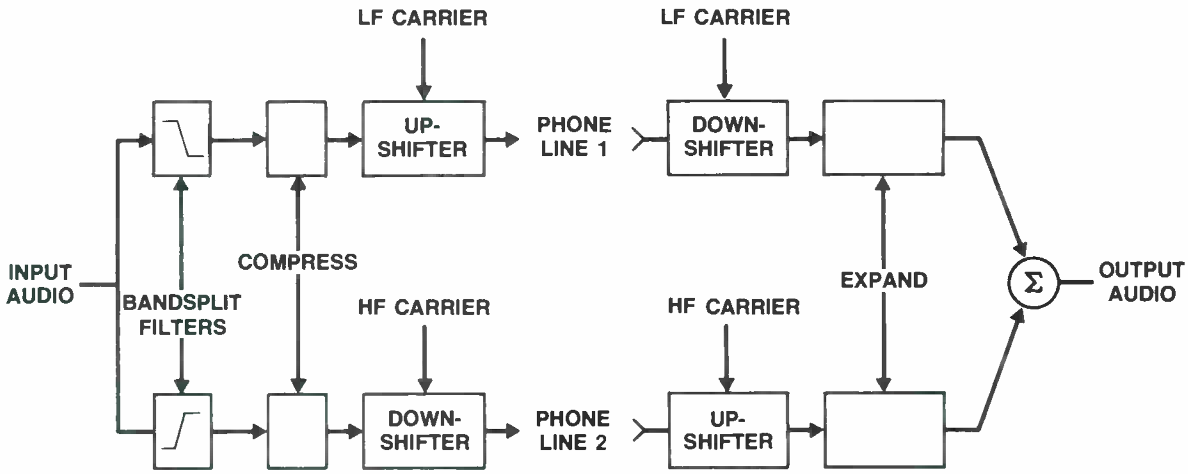



**Fig. 16. Two-line shifting scheme.**

companding system is employed to improve signal-to-noise performance.

## New Technology

### *Cellular Telephone*

Many cities now have access to the new cellular telephone service. Cellular telephones are perfect for use as communication/cueing channels during full-fidelity remote broadcasts, and can be used for originating low-fi telephone-grade location broadcasts, such as might be appropriate for news reports.

The audio quality of cellular phones is generally comparable to that of the standard wired network. Of course, all of the phone quality enhancement techniques described above may be applied to feeds originating from cellular phones. It would even be possible to combine a two-line frequency extender with two cellular phones for higher-fidelity remotes.

### *Digital Phone Services and ISDN*

With the current explosion in the area of computing technology and the resulting demand for computer-to-computer communication, phone companies are gearing-up to provide end-to-end digital transmission service. Someday these new services may be useful to broadcasters as replacements for equalized loops.

AT&T has experimented with a digital switched network system called "Accu-Net." This system operates at 56K bps (bits per second). Unfortunately, 56K bps is not fast enough for high fidelity audio transmission. At 12 bits and a 32 kHz sampling rate, hi-fi audio needs at least a 384K bps data rate. New technologies for data compression, though, may eventually allow this kind of service to be used for transmission of program audio.

Then there's the Integrated Services Digital Network, or ISDN. The ISDN was devised by The United Nation's telephone committee, and has been endorsed by AT&T and a number of IC manufacturers. It comprises a set of specifications that define standards to permit interconnection of a wide range of digital voice and data equipment to the telephone network. Since the ISDN specifies a bit rate of 192K bps, remote-quality audio is a possibility. As this is written, the potential for broadcast use of ISDN services is unclear. What is certain, however, is that the technology of telephony and the technology of radio will continue to grow and evolve—together.

# 6.4

# Telephone Systems and Interfacing

Chapter 6.4:
Part I: Interfacing to the Dial-Up Network
**Part II: Telco Audio Program Service**

## Part II: Telco Audio Program Service

Skip Pizzi
*Technical Director*
*National Public Radio*
*Washington, DC*

Telco lines are used in most remote broadcasts and as STL's (studio-transmitter links) for many radio and television stations, and for the interconnection of many radio and television networks, so it is clear why they are such an indispensable part of broadcasting as we know it. This heavy reliance by broadcasters on telephone company services can cause catastrophic results when something goes amiss at Telco, and every broadcast engineer has his or her share of horror stories to tell on that topic. Nevertheless, if the truth be told, the majority of the time, service is rendered promptly, and the Telco installation staff are often quite helpful and reasonable in most broadcast service divisions.

### Dealing with the Phone Company

The best way to minimize problems with your telephone company is to establish a good working relationship with the appropriate personnel, and to understand as much as possible about their operation. If your people come across as friendly and knowledgeable, but also professionally firm and businesslike, things should go well.

#### *Obtaining and Testing Your Lines*

For a local, stereo pair, order two type 6008 or 6009 lines, specifying "stereo conditioning." This incurs a one-time additional charge on each stereo pair, which can be hefty, (around $300 or more in most places, currently), but without this, there is no guarantee that the two lines will travel similar routes, and if they are sufficiently different in path length, significant phase errors can occur, wreaking havoc on your stereo image and mono compatibility. Some broadcasters always order *three* lines and have them all stereo-conditioned, so there is always one backup. Others forego the extra charge and try conditioning themselves with a very high resolution DDL or similar device at the receive end. (Approximately five microseconds time difference occurs for every mile of path length difference.) Although linear distances between ends of the circuits might be short, actual circuit routing may be much longer, and these miles of path length difference may mount up quickly in an unconditioned pair. Nevertheless, even with conditioned pairs, it seems that about half the time, the polarity between lines is inverted as installed. This is of course a simple matter for the broadcaster to fix, but it is one of the first things to be checked after stereo lines are installed. Other items to be checked, for *all* lines, are frequency response (should be well within ±3 dB of ordered response), phase response, S/N ratio, distortion, and headroom. (When spare lines are ordered, all should be measured, and the poorest delegated for "back-up.") Regarding flat response, check well outside the cutoff frequencies, because it is not always safe to assume that response *rolls off* beyond them. Occasionally in order to get a line to pass specs, Telco equalizers are used to boost the extreme frequencies and if this is not done properly, the response may indeed be flat up to the specified frequency, and then *rise* for another octave or two before finally rolling off. Obviously, this reduces headroom and alters frequency response, and is also a particular problem when lines are being fed with noise-reduction-encoded (i.e. HF pre-emphasized) audio.

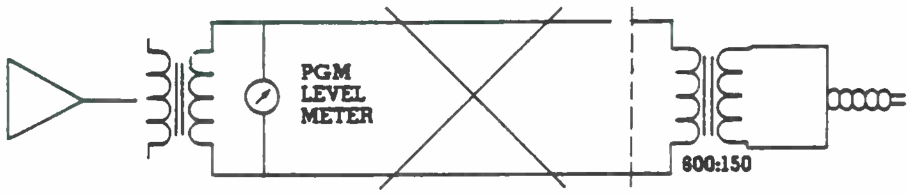



Fig. 1. DON'T meter the signal across the input to the repeat coil (transformer at rt.) and DON'T feed the repeat coil directly from another transformer, if possible.

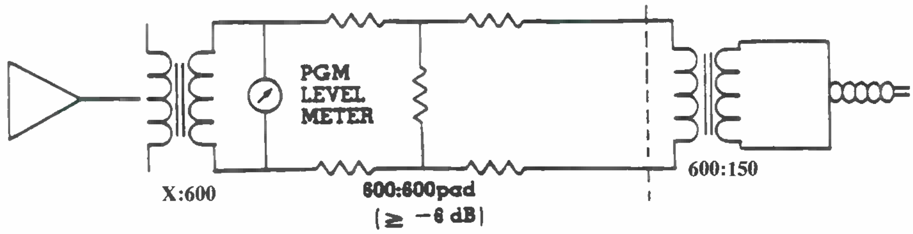



Fig. 2. DO place a pad between the output device's transformer and the repeat coil; and DO place a level meter before the pad, calibrated for the voltage across the pad's output when terminated with a 600 ohm resistor.

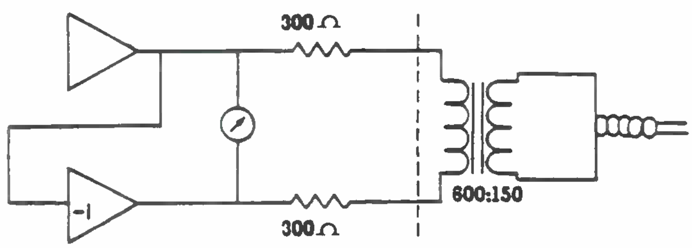



Fig. 3. DO feed low-impedance sources (e.g. op-amps) through a 600 ohm differential balanced pad; and DO place the level meter before the pad, calibrated as above.

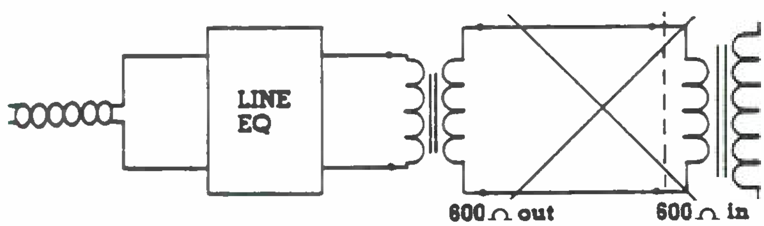



Fig. 4. DON'T terminate the receive-end repeat coil (transformer at right) with another transformer, if possible; its loading may vary with frequency from the true 600 ohm resistive termination used in line-up causing level and frequency response variations.

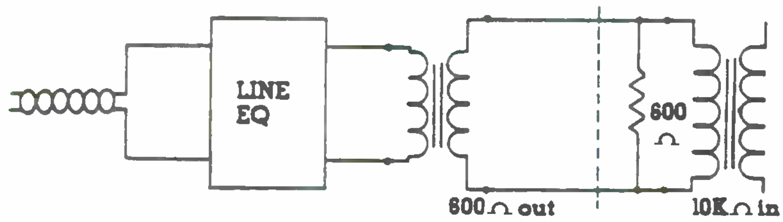



Fig. 5. DO terminate the receive-end of a program circuit with a 600 ohm resistive load and bridge the load with a high-impedance transformer or active balanced input. Note: Common mode rejection of the transformer or active input must be considered if the distance from the repeat coil is great or is near other lines which induce cross-talk. Ideally, the secondary of the repeat coil should be resistively terminated. An active, balanced input circuit does this nicely, provided any RF is bypassed before the first stage of amplification. An alternative is the use of an input transformer with a high-impedance, bridging input. This allows the 600 ohm resistor, as shown in Fig. 5 to match the repeat coil. Another version, often seen on the input of broadcast line amps and modulation limiters is a 600 ohm H-pad; effectively the reverse of Fig. 2. Following the above steps at both ends usually insures that transmission loss and frequency response closely match those of the phone company set up.

## Proper Interfacing

For testing circuits, sinewave frequencies of 400 Hz and lower may be fed at Telco "P.O.L." (program operating level) of +8 dBm, but frequencies above 400 Hz must be fed at "Telco test" level of 0 dBm. Recording type consoles whose reference levels (0 VU) are +4 dBm can operate well into these circuits, and gain an additional 4 dB of headroom while losing 4 dB of S/N. However, it is essential that any mixer used to feed a Telco line directly is capable of driving a 600 ohm balanced load, the standard impedance of all Telco lines (150 ohm lines are available upon request in most areas). Many consoles—even expensive ones—cannot do this, in which case a distribution amplifier is the best solution. Often, a variety of tape recorders, IFB, mults, etc. are also being fed by the mixer at the remote site, so an audio distribution amplifier (DA) is essential in providing isolation between all these (usually Hi-Z) inputs, as well as proper drive for the 600 ohm phone line. When this is the case, always try to have the phone line driven by its own DA output, with no other (even bridging) inputs attached.

Remember that dc voltages may appear across the phone line, and the isolation that the DA provides is useful in protecting the inputs to all the other devices as well. For this reason it is also wise to *not* use transformerless DA's in this application. A *good* transformer can be your friend on remotes, especially when interfacing with Telco. Nowadays, a good installation will commonly be provided by Telco with repeat coils, however, which serve this purpose well, so an active-balanced output capable of driving at least +18 dBm (preferably higher) into 600 ohms would work well in that sort of application. See Fig. 3.

Note well that Telco equalizes its lines for flat response with a 600 ohm source impedance and 600 ohm termination. If any other impedances are used by the customer, flat response is *NOT* guaranteed. In today's equipment it is common to see bridging conditions, so most consoles' output impedances are lower than 600 ohms. This will usually cause a high-end rise on the receive end, if such a console is used to feed telco lines directly.

The "H"-pad in Fig. 2 above does NOT provide a 600 ohm source to the line by itself. Note in this diagram that the secondary of the output transformer on the left is 600 ohms. If it is not, the pad will not set things right; it is there to provide isolation of the meter or an oscillator from the repeat coil. Optimally, in such a case, the output of the feeding device should be modified to provide a 600 ohm source impedance. The situation in Fig. 3 *does* provide both isolation and proper source impedance.

To determine the source impedance of a device's output, place a bridging input meter across the output while feeding 1 kHz. (No other inputs should be attached.) Terminate the output with various resistances; the source impedance is the value of the resistor which drops the level by 6.02 dB. Check at other frequencies—level shouldn't change.

Finally, the meter on the xmit end should be used only for initial absolute level calibration (as shown in Figs. 2 & 3). Relative levels for frequency response tests are not valid from such a meter connection, and oscillator level at different frequencies should NOT be re-zeroed based on this meter's readings. To correct for any oscillator drift, use a more isolated meter such as the meter on the oscillator itself, which feeds a console or D.A. which in turn feeds the phone line as shown in Fig. 2 or 3.

### *The Specs*

In terms of S/N ratios, the telephone company uses a peculiar sort of measurement. They declare a noise level of −90 dBm as "absolute quiet" and measure a noise *up* from there, using the unit dBrn. Therefore a circuit with a Telco noise spec of 40 dBrn would have a noise level of −50 dBm which, if the Telco reference level of +8 dBm is used as P.O.L., gives the user a 58 dB S/N ratio on the line. The longer a line travels, the noisier it gets, of course. Telco specs for local circuits (varies with location and local operating company) usually call for a S/N ratio of 65 dB or better (33 dBrn) for 15 kHz lines. "Interexchange service" (IXC), to use predivestiture terminology, which entails the inclusion of AT&T Long Lines (generally microwave) service, had a S/N spec of 57 dB or better (41 dBrn) for 15 kHz lines. The local 5 kHz spec was 52 dB S/N, long distance 5 kHz was 42 dB.

Another option offered by many telephone companies is the so-called "loss-less" or "zero-loss" line, where the Telco line acts as a unity gain device. Normally, signal provided to the customer on the receive end may fall to as low as -30 dBm when 0 dBm is being fed from the transmit site. (Audio signals in copper cable lose about 1 dB/mile). A line amp on the receive end can bring the signal up to house P.O.L. If the customer so desires, however, Telco will provide (at an additional cost) a loss-less line, so that +8 in gives +8 out. This is achieved by the insertion of additional Telco amplifiers along the route, and is not always desirable, since these amps are of unknown quality and reliability, and your line amp is a single, known, and easily accessible unit. Nevertheless, if the line is long, and the Telco amps are OK, a loss-less line may give you a few dB quieter performance, although with perhaps a slightly higher distortion spec. This may be advisable in places like New York City where crosstalk and impulse noise from old, waterlogged and densely trafficked lines is quite common. In most cases, however, fewer amplifiers used in regular lines (there may indeed be none at all in short hops within one exchange or service area) provide better overall sound. In cases where both regular and loss-less lines were ordered from the same site, in my experience, the regular lines were almost always chosen.

Gaussian or random noise is of course far less objectionable than the coherent noises sometimes found on Telco lines, such as the above mentioned crosstalk, impulse noise (clicking from dial pulses and other switching), and the so-called "sings" or tones caused by carrier beating and other nefarious sources. For this reason, lines should be monitored on the receive end for a good while after they are installed without any audio being fed from the remote site. They should also be turned up and auditioned as early as possible before their on-air use. Call Telco at the earliest sign of trouble.

Although there are no published Telco specs to be met for distortion or phase response, distortion should be 0.25% THD or better for 15 kHz local lines. For stereo pairs, relative phase response should be within 30 degrees across the passband. Widely divergent frequency response across the stereo pair is a tip-off to check phase response carefully. When spare lines are ordered, the two closest to each other in frequency and phase response should be made the main pair, assuming all other specs are equivalent.

The published headroom spec is only 10 dB on most lines (+18 dBm maximum). Using a P.O.L. of +4 dBm instead of Telco's +8 will give you 14 dB of headroom, at the expense of S/N, which is a more prudent approach in most cases.

## Communication Lines

Whenever ordering program circuits for live remotes, always order an "MB" or "PL" to the site as well. This is a standard dial-up telephone line for use in voice communication between the studio and the site. Stations equipped with RF communication systems may want to use these instead if they are within range, but these may leak into the program audio, prohibiting communication while the site is on the air. This "MB" service is relatively inexpensive, and usually well worth the cost. A way to save, however, is to provide your own telephone instruments (with visual ring/bell cut-off if desired), and just order the line from Telco. Normally this will be a regular seven digit telephone number, but other variations such as dedicated "PL" (private line, also known as "ringdown") or OPX (off-premises extension) services are possible. PL is a non-eq line with dialless instruments at each end; one end rings whenever the other is picked up (also called "PLAR"—private line with automatic ringdown—in some areas). OPX is an extension of a customer's PBX system placed at a permanent remote site. The terms "MB" and "PL" are often used in the broadcast industry to indiscriminately refer to any sort of regular telephone at the remote site for communications purposes. This is all well and good until actual Telco orders are being placed; then exact terminology becomes important. Telco lives by abbreviations, and a single misplaced letter could cost you a lot of time, hassle and money. Additionally, these sorts of services are ordered from a different office and are installed by a different crew than the broadcast program lines, so careful coordination on your part is required. This is the area where most problems occur, in my experience, since these folks are not working only with broadcasters but are usually the regular telephone service office and installation staff, so they are dealing with you as just another regular customer. It may be advisable to order this service earlier, and request it to be in place sooner than your program lines. Since it is generally a much cheaper service than the program lines, the extra cost isn't very much, and no matter how well the program circuits are functioning, lack of communications can seriously compromise a remote broadcast's quality.

## The Final Frontier

For longer-haul circuits or networking, satellite hook-ups have become commonplace in recent years. For network distribution, it is a particularly cost-effective method (especially in the long term), but it is also a useful and high quality method for remote feeds ("back-hauls") to a station or network hub as well. Various broadcast organizations now have satellite networks in place, and most offer their excess space on these to outside customers. These networks have leased their satellite space from the satellite owners, the "common carriers" such as Comsat, AT&T, Western Union, RCA and others. Individuals can also lease satellite space from the common carriers, but for one-time, point-to-point needs, it is usually better to go to one of the networks, since the common carriers generally prefer dealing with the big, full-time, mass users, and their sales offices will often freely admit to prospective customers that price and service might be better from one of the smaller, more broadcast-oriented companies as the excess-capacity selling networks. Among these, an example is National Public Radio. NPR leases a full video "transponder" (satellite channel) on Western Union's Westar IV satellite, and uses the rather wide spectrum provided therein for dozens of frequency-modulated analog audio channels of various bandwidths. This so-called "multicasting" approach allows a network to offer several choices of programming to its stations simultaneously (in mono or in stereo pairs of channels, without the need for "stereo conditioning" since all satellite path-lengths among the audio channels are identical), and have excess space left over which it may sell to other customers. Regional "uplinks" (satellite earth stations with receive and transmit capability—also called "RT's") can feed to these several channels, while "downlinks" (receive-only earth stations—"RO's") at each of the network's stations can be tuned to the channels desired at the time. Since noise is a big problem in satellite transmission (40 dB is considered good in many cases), most analog satellite systems use some sort of companding to achieve reasonable S/N (65 dB or higher) for wideband audio. Some systems use the video transponder for a smaller number of digital audio channels. Even with all this variation, there are some reasonably priced, off-the-shelf "fully-agile downconverters" which can handle most of the analog frequencies and companding systems in use, when hooked up to a dish pointed at the right bird, equipped with sufficient LNA's (low-noise amplifiers). The digital systems are still a bit more proprietary, but probably not for too much longer.

A third more recent option is to obtain the services of a satellite communications contractor. These companies have as their sole function the selling of satellite hook-ups for point-to-point or network use, one-shot or permanent. They utilize both existing earth stations and "portable uplinks" (mobile satellite transmitters), and provide customized service to the individual customer's request, using their own or subcontracted facilities.

For live remote transmissions on satellite circuits, terrestrial Telco lines, microwave or VHF-band RPU's (remote pick-ups) are usually employed to get audio to the nearest uplink (except when a portable uplink is used), and again, if necessary, from the nearest downlink to the end-user (so-called "handoff" service). These "first-mile" and "last-mile" hookups are often on Telco program lines, so although satellite technology is well in place in the broadcast audio world, until the portable uplink becomes as commonplace as the telephone, Telco lines will be a part of the typical live remote.

One other thing to remember about satellite service that differs from the terrestrial, is the element of time delay. Because geostationary satellites are used, the distance from earth to satellite is over 23,000 miles. Signals travelling up and back from that satellite take about 1/4 second. (Terrestrial line delays rarely exceed 100 ms., except on long network lines). If satellite back-haul *and* satellite network feeding is used, there is about ½ second delay. In any case, this provides for more difficulty in monitoring. The remote site cannot simply monitor off-air on the network affiliate in that town. More lines—terrestrial ones—must be used for "backfeeding" the remote site with a "mix-minus" program feed and any IFB (interruptable foldback) or other cueing. Again, these are usually Telco lines of a lesser quality (5 kHz or non-eq).

## What Next?

Aside from the price increases, the future holds great promise for this technology. Copper wire is being replaced by fiber optic in many areas,

## LEGEND

CM - Channel Mileage (per air-mile basis)
CT - Channel Termination (flat rate)
IOC - AT&T's Interoffice connection (mileage rate)
LATA - Local Access and Transport area (service area)
LEC - Local Exchange Company (local Telco)
POC - Program Operating Center (old name for Telco "Toll")
SO - AT&T's Serving Office
SWC - Serving Wire Center (new name for Telco "Toll")

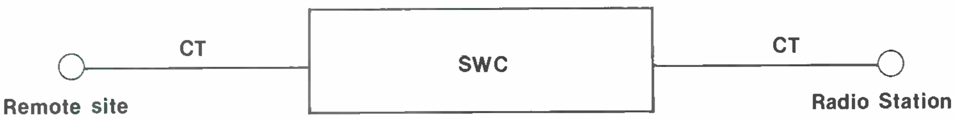



Fig. 6A. Typical intraLATA service.

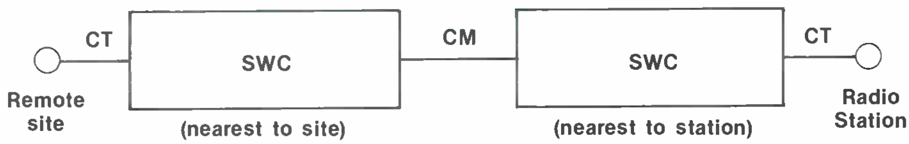



Fig. 6B. IntraLATA service where site and radio station are in different "rate centers" of the same local exchange company.

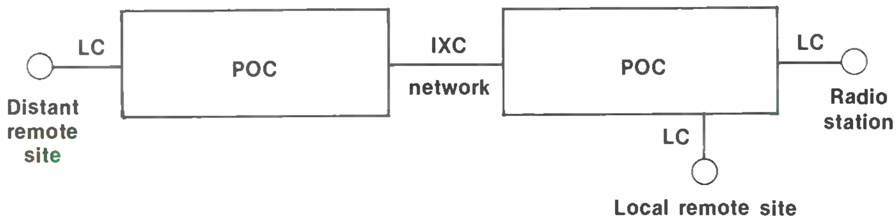



Fig. 7A. Typical pre-divestiture arrangement for distant & local remotes.

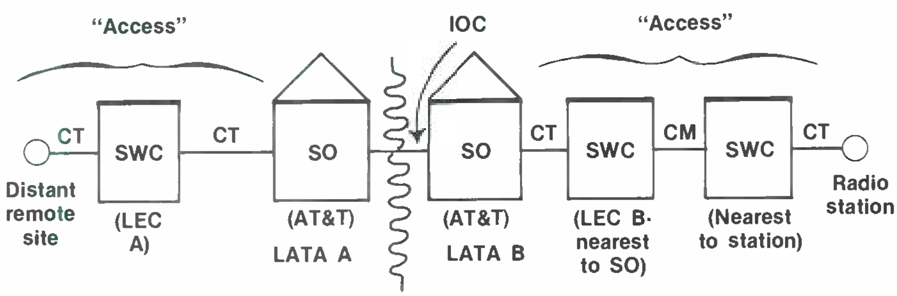



Fig. 7B. Typical (post-divestiture) intraLATA service. In this example, access charges in LATA B will be higher than in LATA A, since radio station is in a different rate center of LEC-B than AT&T's SO.

improving fidelity and reliability, and providing much greater capacity to areas of high traffic. (The most obvious improvement is in terms of freedom from hum, buzz, impulse noise and crosstalk in downtown areas, due to the system's operation in the digital and optical domains, rather than the analog and electrical). Cellular phones are beginning to be used for com-links and back-feeding, along with more sophisticated RF equipment, replacing the traditional dial-up phone at the remote site. Noise reduction on Telco lines has been in use by some broadcasters for years (with varying results), but more recently, stereo radio remotes using PCM or CPDM digital encoding on a single NTSC video circuit have provided excellent results, albeit at a higher cost for the line and the hardware. The work gets harder, the costs go up, but the results improve.

## Postscript: Local Access and Transport Areas

To understand the basics of post-divestiture private line operation, it is important to understand the concept of LATA's, Local Access and Transport Areas. These LATA's are the boundaries of operation for each of the local operating companies. These companies were formed when the Bell System was broken up and AT&T divested itself of its local telephone operations. (AT&T kept its Long Lines, Western Electric (manufacturing), and Bell Labs (R&D) divisions.) Along with the former Bell System, there are several areas that have always been served by independent, non-Bell companies (such as GTE, Continental and the like), and these also have been assigned LATA's corresponding to their former operating areas.

Broadcast circuits within a LATA (the old "LC," now called "intra-LATA service") will operate technically as before, but with different billing mechanisms. Instead of a single, fixed rate LC charge, the line will be billed as shown in Figure 6A. The part of the circuit from the remote site to the nearest Telco "Toll" office (now known as a "Serving Wire Center"—SWC) is called a "Channel Termination" (CT). The line from this SWC to the radio station's studio is also billed as a CT. CT rates range up to almost 300 percent higher than the corresponding old LC rates, but as you can see, each intraLATA circuit is billed as *two* CT's, so actual costs for these lines will be twice that. There may also be a "Channel Mileage" (CM) charge for local circuits in which the SWC for the remote site is different from the studio's SWC, over and above the two (fixed rate) CT charges, see Fig. 6A. The air-mile distance between the two SWC's (also called "rate centers") is tacked on at "X" dollars/mile.

Circuits which extend across a LATA boundary (the old "IXC," now "interLATA service") get even more involved. Your local company will charge you a CT for your connection to their nearest SWC and then another CT for a connection from SWC to the AT&T service office (SO) in that LATA. Those two circuits are called "access" to the AT&T network. AT&T then provides the inter-office circuit (IOC) between that SO and their SO in the LATA where the remote site is. The local exchange company (LEC) for that LATA provides "access" from the AT&T SO to the remote site. "Access" charges may vary depending on the distance between SO and SWC in each LATA. See Fig. 7.

Multi-point networking set-ups follow this same basic building block and "access" billing approach, with additional "secondary service functions" by AT&T for switching, direction-reversal monitoring, etc.