The RADIO ENGINEERS' DIGEST

APRIL 1945 VOL. 1., NO. 9

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The Price of Freedom

The dictators thought we were soft, luxury-loving, we Americans. They thought we were so devoted to our high standards of living, that we wouldn't — or perhaps couldn't — do without these things to challenge their attempt to rule the world by force.

But now as they await their final hour of doom, they know at last how badly they misjudged the American character.

There's no doubt we Americans like our high standards of living; we like our luxuries, too, when they are possible. But not at the price of losing our independence or endangering our national security.

As a people, we Americans are slow to rise to anger; we hate the thought of war. But once we realize that our nation is in peril, we forget about luxuries and gird ourselves for war. We can and we do eliminate every non-essential to pay the price of freedom.

THE RADIO ENGINEERS' DIGEST

JOHN F. C. MOORE, *Editor*

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EASING MULTIPATH PROBLEMS

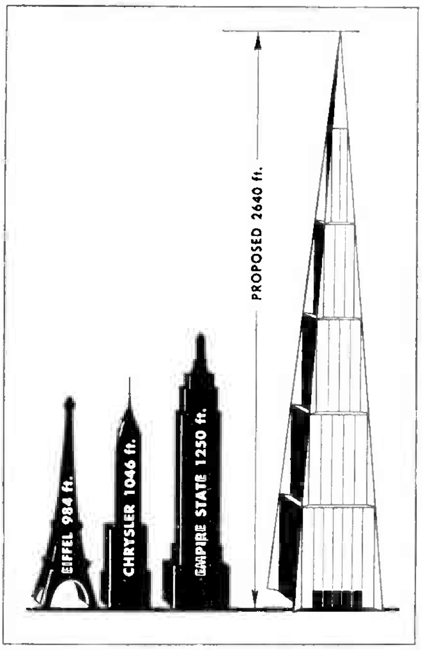
Reprinted from Electronic Industries

IN METROPOLITAN New York, television has received as thorough a workout as anywhere in the world. There the needs were discovered and improvements worked out for the continued upgrading of quality. There, some of the original television enthusiasts have seen all picture quality levels from 30 lines upward. However, the upper limit of quality now depends on the observers' good luck in being located in a ghost-free position.

Within a range of say five mile radius from the midtown section it is common experience to be able to get any one of the several programs with only a minor amount of multiple path distortion, and with a lot of patience in setting up an antenna it is possible for one to pick out which of these stations he can receive well, but it is nearly hopeless, except by elaborate multiple antenna means, to get them all.

Ghosts persistent

All viewers are acquainted with the appearance of these multiple images—double "reflections" of the same picture a little ways left or right away from the



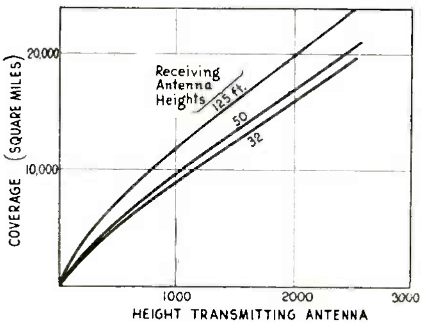
Indicating high tower possibilities, this design was proposed in 1939 for the N. Y. World's Fair. From a base 400 ft. square, it rises about 500 ft. to the first setback, providing ample pace for many uses besides housing television systems. Each setback is 50 ft. in depth. Courtesy Wm. Van Alen, architect, and Ralph W. Squire, engineer

main image. Many do not realize that multiple reception over substantially identical path lengths can reduce the quality or the effectiveness of the number of lines used to what would be received with half the lines, or less, even though no actual ghosts might be in evidence.

There are about 580 picture elements per line in the present system, so the spot jumps from one picture spot to another in about one-tenth microsecond. An alternate path only 100 feet longer will fill in and destroy the contrast that would have existed between adjacent points, since the second signal arrives one picture element away.

The ease with which signals at these frequencies bounce around is astonishing. They are as energetic in this regard as are light waves— and the whole science of vision is based on light being reflected from all materials into the eye.

"Just put up a directional antenna." This sounds nice and simple until a service man is called in to figure how to direct toward three (and there will soon be more) stations at once and still avoid ghost signals coming from all sides. However, there are no known methods of avoiding such interference in other ways except by this method of directivity. Here the results depend entirely on the sharpness of the reception angle.



Coverage is closely proportional to height

Directivity a solution

This introduces the one greatest need of the television system for anticipating and alleviating to the greatest possible extent the problems that will confront the many thousands of potential television set purchasers when sets are available: getting single path reception with a low cost antenna; and in many places even getting good reception at all, no matter what the cost. The following suggestion is made:

Based on the metropolitan New York area: Immediate steps should be taken to work out a plan for erecting a single television tower to serve as many transmitters as can to join in cooperation. A tower, with say a 2,000 foot elevation erected above the Palisades, would accomplish the following direct results:

1. Give all receivers a single point to aim at.
2. Avoid reflection surfaces of the Palisades rocks.
3. Be high enough to give some chance for elevated directivity at the receiver to shoot over surrounding roof structures. This upward tilt would be quite effective in Manhattan where multiple path difficulties are greatest.
4. Increase the coverage to roughly double the present. If the effective height is roughly doubled, the area covered is also doubled.

Towers of this nature are unusual but entirely practicable. In fact, a 2,500-foot tower was designed some years ago for use at the New York World's Fair but never built. Whether or not the structure is designed to handle a sightseeing "load" as well is a matter or cost economics.

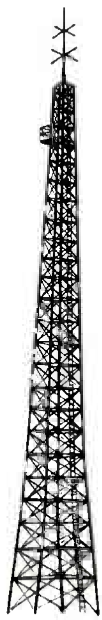
From a technical standpoint, many separate antenna arrays could be installed with little difference in their effective height. Or else a single antenna broadened to cover the whole television spectrum range could be designed with necessary filters and fed with coaxial cables from the ground or lower level. A third method would place a single broadband power amplifier at the top, fed by dc vertical cables and modulated by coaxial down leads of suitable construction. These methods are all technical possibilities and the various phases of the plan will be discussed in these columns by experts in those fields.

There are many side issues that would need consideration, such as a flying hazard. From one viewpoint, a beacon having a chance of giving above-the-clouds visual guidance would have many advantages when needed. As an in-the-clouds collision hazard, the application of modern radio services, wherein a signal emitted in the neighborhood to operate one of the numerous radio receivers with which the planes are to be equipped, would give ample warning.

As to the cost, it would be large, but might be distributed among several stations possibly on the leased service plan.

The development of the necessary wide band phone cables has progressed so that there is no handicap in transmitting signal bands of any width necessary for future quality and color services.

There can be no forced requirements that a station must utilize this universal transmitting point. If several stations did cooperate, it would give the set owner and the installation man something to point to with best assurance of good results. Signals coming from other directions would have to be just as satisfactory as those from the master tower, or they would remain unheard.—R.R.B.



Its Wired for Color

The human eye can detect at best only 10,000 colors. The electronic spectrophotometer — or color analyzer — can detect and record more than 2,000,000 different colors.

PLANNING AN F-M STATION

Reprinted from Electronics

By P. B. Laeser

FM-Television Engineering Supervisor
WMFM-WTMJ
The Milwaukee Journal Radio Stations
Milwaukee, Wisc.

A practical discussion of the problems confronting a-m stations contemplating the new service. Notes on the selection of sites, estimation of coverage, determination of required transmitter power, choice of antennas, and building layouts.

AFTER THE decision is made to enter the f-m field, the broadcast station engineer is confronted with the job of satisfying management as to the cost of serving the proposed market area. Can he use any of his present a-m facilities? What are the possible sites for the transmitter and antenna? Are suitable wire lines available or does he have to resort to a studio-to-transmitter (STL) link?

Basically, the problem settles down to taking inventory of the present transmitter site, determining whether a signal can be propagated from there over the territory specified, and deciding what will be necessary to feed a high-quality program service from the studio to the transmitter.

Determination of Coverage Area

In the majority of cases an entirely new transmitter location will be chosen for the f-m installation because good locations for broadcast band antenna systems are not often satisfactory for f-m.

Many a-m stations are located in lowland or swamp areas to provide a ground system with good conductivity. This particular consideration is not an

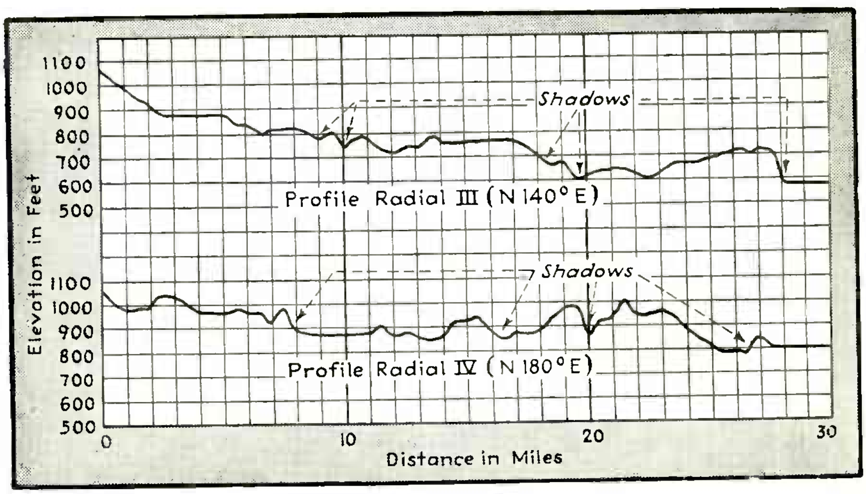


Fig. 1—Profile of the land elevation above sea-level along each of two radials centered on Richfield, Wisc. Note that a number of points, even within the primary service area, are in shadow.

important factor in the f-m band. More important is the elevation of the terrain with reference to the area to be served, and a site overlooking as much area as possible is needed.

Signal propagation over the broadcast band shows a wide variation between extreme frequencies for a given power and antenna system. This is in direct contrast to the f-m band, where substantially the same results are had on any frequency within the band. Very high-frequency signal propagation results in coverage more definitely related to specific areas than standard broadcasting. Recognizing this, the FCC is authorizing applicants to apply for specific trading areas and has set up the following four classifications of coverage:

Class A. An area comprising a limited trade area and a city, usually composed of one small city and adjacent area.

Class B. An area comprising a basic trade area and a principal city, usually composed of a principal city, one or more smaller cities and the areas adjacent to these cities.

Class C. An area of at least 15,000 square miles, comprising primarily a large rural area and that part of basic trade areas which cannot be served by stations assigned basic trade areas due to economic and technical limitations.

Class D. An area having substantially different characteristics (social, cultural and economic) from those specified in classifications A, B and C, where the establishment of a special program and technical service is in the public interest.

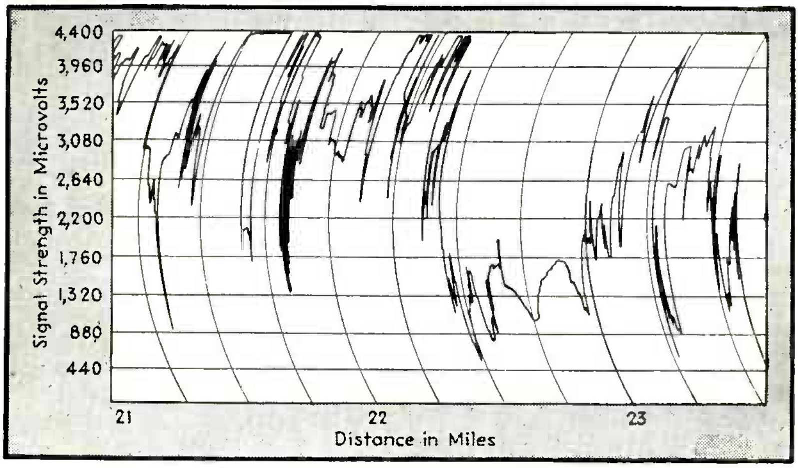


Fig. 2—Shadows such as those shown in Fig. 1 produce marked variations in signal strength, as shown on this graph obtained by continuous recording while driving through a hilly area

Five channels are at present set up for non-commercial educational stations. Since a request for other frequencies and additional channels has been made by the RTPB, the present allocations for the various classifications may be modified in the near future.[1]

Complete data on trade areas can be obtained by referring to available maps.[2]

Transmitter Sites and Shadow Effect

Many cities have unusually tall buildings which are well suited for f-m installations. However, the location of such buildings in relation to the service area should be considered, especially if a circular pattern is contemplated. As an illustration, cities on the seaboards and on the Great Lakes in some instances are adjacent to large water areas.

If the initial outlay is for a class A station and plans are not for a large rural coverage, the transmitter should be placed at a point where the noise level is highest and population most dense. At the outskirts of the area, probably, the population will be sparse and noise levels low. Lower signal intensities will therefore be tolerable. Adequate lines between the studio and transmitter generally are available for a 50 to 15,000-cps circuit when the transmitter is located in a city.

There will be installation difficulties but these are not insurmountable. For example, it may be necesary to hoist material outside a building in a busy area or dismantle large units to fit the elevators. Steel beams may have to be cut in two, transported to the roof and welded together again. Such work is generally best carried out on a Sunday, roping off the street below to minimize danger to the populace. In negotiating for building space, the lease should clearly specify the extent of the roof rights for the antenna system.

To cover a large metropolitan area and large rural areas or large rural areas plus several metropolitan areas (Class B or C) it is necessary in most cases to locate the transmitter at a point quite remote from the studio. Fortunate is the station that is located on high ground overlooking its principal city and trade areas. In choosing this site several factors must be considered, elevation being the prime requisite.

TABLE 1—MULTI-ELEMENT ANTENNA GAIN, COMPARED WITH DIPOLE

	TURNSTILE			CIRCULAR		
Layers	Field Gain	Power Gain	D*	Field Gain	Power Gain	D*
1	0.707	0.50	0.0	0.89	0.79	0.0
2	1.12	1.25	0.5	1.28	1.66	1.0
3	1.41	2.00	1.0	....	....	2.0
4	1.66	2.75	1.5	1.86	3.47	3.0
5	1.87	3.50	2.0	....	....	4.0
6	2.06	4.24	2.5	2.45	5.25	5.0
7	2.26	5.05	3.0	....	....	6.0
8	2.40	5.76	3.5	2.66	7.08	7.0
10	2.69	7.24	4.5	....	....	...

* Distance in wavelengths between top and bottom elements.

Obstructions such as hills, cliffs, or buildings, when present in the transmission path, introduce attenuation and these zones are known as shadow zones. The area encompassed in a shadow will receive only a fraction of the signal intensity available at other equidistant points, the actual signal strength depending on the degree of shielding. Examination of the elevation along sample radials shown in Fig. 1 will reveal cases where line-of-sight transmission is not obtained. It is not unusual to find shadows such as these in the primary area of existing f-m stations. Fig. 2 shows a sample recording of signal strength made while driving through such a shadow.

If the station is planned for the northern states or mountainous country, a location on a main highway or at least a good secondary road maintained in the winter is advantageous, making it possible for the operating personnel to gain access to the property on an all-year-round basis. A hill reached by a good highway has an advantage over one of somewhat higher elevation but inaccessible, because the cost of additional tower height sometimes is less than laying out a new road. Also, by staying close to highways, advantage can often be taken of power facilities which interconnect cities. Dual power service from separate feeders is desirable. Too great a distance from power lines may require the installation of an independent emergency generating plant. Furthermore, complete dependence on local power facilities may not be advisable in all cases.

Another qualifying factor in choosing between two sites is the nature and and elevation of the land in their immediate vicinity. A sharp drop-off on all sides is to be desired, especially in the direction of the major market area.

A considerable amount of time and effort can sometimes be saved by procuring quadrangle maps for the various sections of the country under scrutiny. Immediately it will become apparent which of several likely spots has greater elevation above sea level and sites can be evaluated accordingly. If there is any doubt, an altimeter should be obtained and checks made to verify.

Telephone service may be obtained in some locations not too far from intercity trunk systems by branching off with underground circuits. In one instance a line was laid underground for four miles after easements from property owners

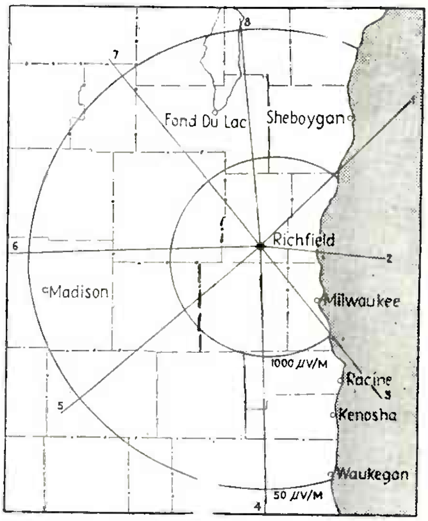


Fig. 3—Map showing predicted 1000 and 50-microvolt contours around WMFM. Radials on which signal-strength measurements were later taken are numbered

had been obtained. Lines in cables are preferred to open-wire circuits because of the latter's susceptibility to atmospheric noises. Where telephone service is not practical a station-to-transmitter-link must be installed.

The possibility of a water system should not be overlooked, especially if a high-powered transmitter is planned which necessitates auxiliary cooling of the air plasts and a constant supply of water for the evaporator.

Signal-Strength Contours

After the most suitable site has been chosen and all the factors related to the site are set down and evaluated, the next step is to determine what size transmitter, what antenna height and what antenna gain is needed.

The FCC has set up the standard for good reception as 1000 microvolts for urban listeners in areas having high noise levels and 50 microvolts for rural listeners in areas having high noise levels. It is possible by referring to FCC Chart 41722,[3] to predict at what distance the 1000-microvolt and the 50-microvolt points occur on various radials with assumed transmitter powers and antenna heights. Since these are only predictions, it will be necessary after the station is in operation to procure measuring equipment or engineering service to prove that the contour lines are as calculated. Adjustments compensating for either under or over-estimates can then be made.

Surveys made on v-h-f stations sometimes show great discrepancies in the pattern compared to the predictions. This, no doubt, is due to irregularities in the terrain involved. Mountainous country and large cities show great deviations compared to the surveys made in country more level and densely populated. Figure 3 is an illustration of the predicted contours of WMFM, Milwaukee (formerly W55M).

After establishing the two contours, the area in square miles can be measured by the use of a planimeter. Population analysis of the service area can then be carried out.

In the majority of cases it is probable that the f-m transmitting antenna will be independent of other antennas and on its own supporting structure. However, a question arises and will come up again and again in the future regarding the possibility of mounting an f-m antenna on the tower of an active a-m station.

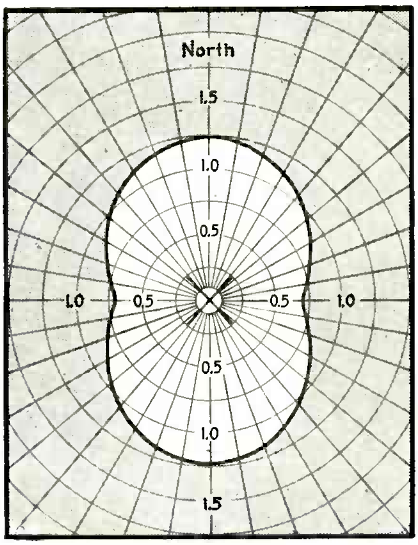


Fig. 4—Radiation pattern of a 60-deg phased turnstile called a "dumbell", having equal currents in all elements, showing north-south directional gain over a 90-deg turnstile

Where this is contemplated each tower will present its own structural problems and these will have to be analyzed by the manufacturer. The effect of loading the a-m tower with a heavy f-m array will, particularly, have to be carefully calculated. There is also the possibility that adding an f-m radiating structure might change the a-m antenna current distribution, and the phase angle in the case of a directional array.

Antennas

Horizontal polarization of the f-m antenna is recommended because of the high power-gain attainable while maintaining a structure rugged enough to combat the elements. Vertically-polarized antennas giving high power-gain are comparatively difficult to construct, whereas stacked horizontal units giving appreciable gain are readily obtained.

There are several ways of accomplishing antenna power-gain, namely, by stacked circular antennas commonly known as "donuts", by "turnstiles" using successive layers of arms radiating from the mast, or by square loops stacked one above the other and known as Alford loops. There are also several other suggested methods of securing horizontal directivity, such as corner reflectors and spiral antennas. Such antennas effectively increase the power by reducing the signal radiated vertically and concentrating it in the horizontal plane, i.e., along the earth's surface.

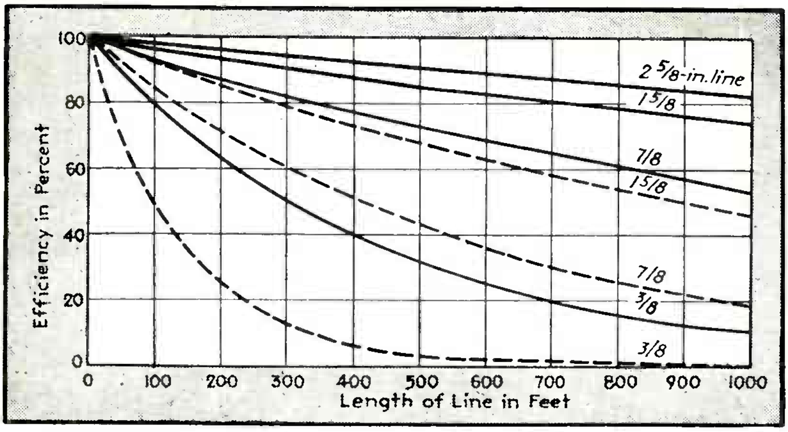


Fig. 5—Graph illustrating the percent efficiency of various sizes of coaxial transmission line using Isolantite insulation. Solid lines show efficiency at 50 Mc. Dashed lines show efficiency at 300 Mc. (General Electric)

The effective signal radiated (ESR) is the all-important factor in evaluating an f-m system and, therefore it should be determined whether a high-gain antenna system and a low-powered transmitter or a low-gain antenna and a high-powered transmitter are to be used. For example, for one typical transmitter site a calculated 4000 watts of effective signal is needed to assure a 1000-microvolt contour at 20 miles. This can be accomplished with 4000 watts of generated power using an antenna with a power gain of 1, or by using a more complex antenna system giving a gain of 4 and reducing the generated power to 1000 watts. The results in either case are theoretically identical. By referring to the following table of more or less standardized transmitter sizes it will be noted that 4000 watts falls between 3 and 10,000 watts, making it necessary to install a 10-kw transmitter.

TABLE 2—TURNSTILES VS DIPOLE

90-DEGREE		60-DEGREE	
		Field Gain	
Layers	Field Gain	North-South	East-West
2	1.12	1.36	0.79
4	1.66	2.02	1.19
6	2.06	2.51	1.44
8	2.40	2.93	1.68

250 watts
1,000 watts
3,000 watts
10,000 watts
25,000 watts
50,000 watts
100,000 watts

It is obvious that the most economical approach in this case would be to use a 1-kw transmitter with an antenna having a gain of 4 since the cost of the antenna would not approach the cost of a 10-kw transmitter. In addition, the maintenance and upkeep would be very much in favor of the smaller transmitter and the more complex antenna system.

Table I gives a comparison between two popular high-gain antenna types and a dipole having a gain of one. Comparative values of antenna gain for equal mast height are in favor of the turnstile, as the distance between layers of the turnstile antenna is ½ wavelength and of the circular antenna one wavelength. This corresponds to approximately 10 and 20 feet respectively, depending on the exact frequency used. In the event of CAA restrictions on height of the tower structure this represents an important factor.

Some modification of pattern can be obtained with a turnstile by either phasing or varying the current relationship of the elements in quadrature to obtain an elliptical pattern if it is desired to cover an elongated market area. Using a 60-deg phased turnstile, with equal currents, an increase of about 22 percent in one direction can be obtained with a loss of approximately 30 percent in the other direction. Figure 4 shows the pattern of a 60-deg turnstile that has been dubbed the "dumbbell." Table II shows the relative increase in field gain over a 90-deg turnstile for various numbers of layers. Note that the desired north-south field gain of a four-layer turnstile 60-deg phased is 2.02 compared to a standard 90-deg turnstile of six layers giving a gain of 2.06. Thus the 60-deg turnstile will provide a solution to some of the cases where an irregular trade area cannot be served adequately with a circular pattern.

Transmission Lines

Considerable trouble has been experienced in the past with transmission lines. Open-wire and coaxial lines are in use and both require careful matching to obtain a reasonably low standing-wave ratio. Ratios of 1 to 1.25 have proven satisfactory for coaxial lines. A somewhat higher value can be tolerated on open lines.

Sleet and ice formation has been the most troublesome condition, resulting in flashover and occasional burn-out of the feeder system, a situation not too easy to repair under adverse conditions. De-icers have been built into some antenna installations and are especially valuable in zones subject to sleet formation. They are controlled from the power panel inside the buiding or can be made to operate automatically within the temperature range of sleet formation, and in no way affect the operation of the antenna. Without such protection it would be necessary to reduce the input power for transmission line protection.

The erection of coaxial lines sometimes is extremely difficult, especially vertical runs up a tower. Great care is essential to prevent solder and dirt from entering the line while under construction. Solderless inner and outer couplers have helped this situation considerably but on smaller sizes of line the inner couplers should probably be of the solder type. Several sections of line may be assembled on the ground and then hoisted into place, resulting in a minimum number of connections to be made up on the tower where it is harder to do good work.

Experience has shown the following transmission line sizes to be adequate for transmitter power outputs as listed below, assuming that the line is correctly terminated to eliminate standing waves:

250 watts or less	70 ohms	⅜ in. OD
250 watts to 1kw	70 ohms	⅞ in. OD
1 kw to 3 kw	70 ohms	1-⅜ in. OD
3 kw to 10 kw	70 ohms	1-⅝ in. OD
10 kw to 25 kw	70 ohms	3-⅛ in. OD
25 kw to 50 kw	35 ohms	2:3-⅛ in. OD

Lines somewhat larger than are strictly necessary are suggested, giving additional safety factor. Larger lines also result in lower losses and may be advisable if the length of line is unusually long. For the STL transmission line sizes should be especially generous because at the higher frequencies involved losses

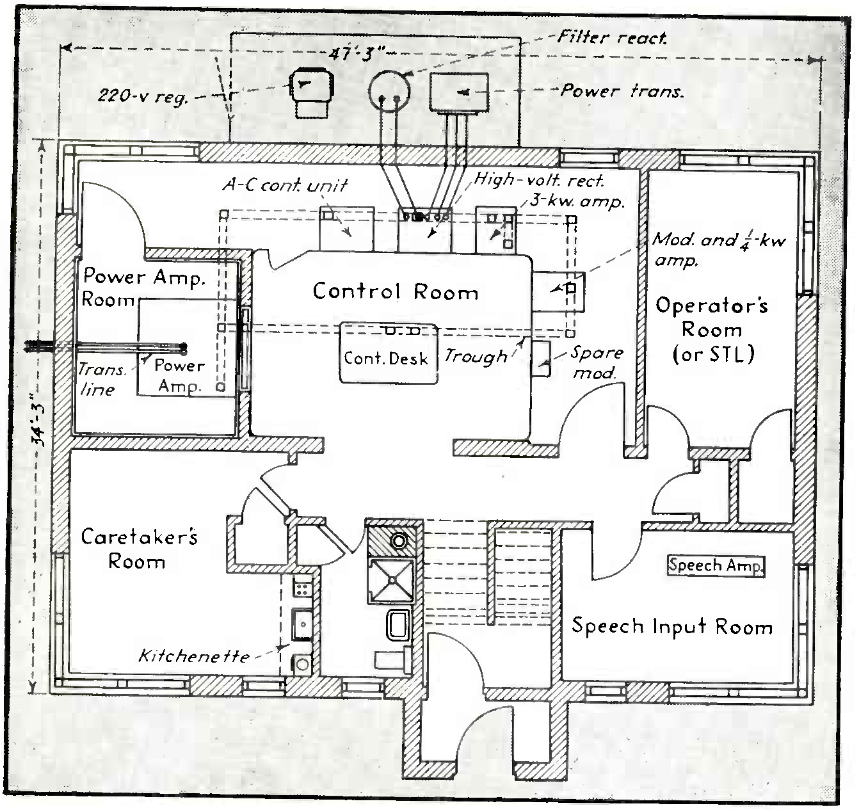


Fig 6—First-floor plan of the WMFM transmitter building at Richfield, Wisc.

increase appreciably and power is more difficult to generate. Figure 5 shows relative line loss at 50 Mc and 300 Mc for various sizes and lengths of typical coaxial line.

Transmitter Building

An f-m installation does not require as large a space as its a-m counterpart. A typical 1-kw f-m transmitter is a completely self-contained unit including blower and power supplies, occupying a space approximately 72 by 30 by 72 in. over all. A floor space as small as 350 square feet would be sufficient to accommodate the transmitter, and a room adjacent to the transmitter suitable for audio console, turntables, line amplifier, frequency and modulation monitor, and monitoring receiver. A typical 50-kw transmitter occupies space comparable to the average 5 and 10-kw a-m station now in service.

A typical 50-kw installation is the Milwaukee Journal f-m station WMFM, which houses its transmitter in a two-story building 47 by 34 ft. in size. On the first floor shown in Fig. 6, is the transmitter, speech and test room, STL receiving room, caretakers quarters and toilet. The basement, shown in Fig. 7, is devoted to the cooling and pump room, heating plant, work shop, tube storage and building utility. Rectangular steel ducts 4 by 6 in. are placed along the ceiling of the basement to house the inter-connect wiring between the various transmitter units directly above. All motor-generators, blowers, water pumps, etc. are mounted on rubber rails to minimize the noise transmitted through the building foundations.

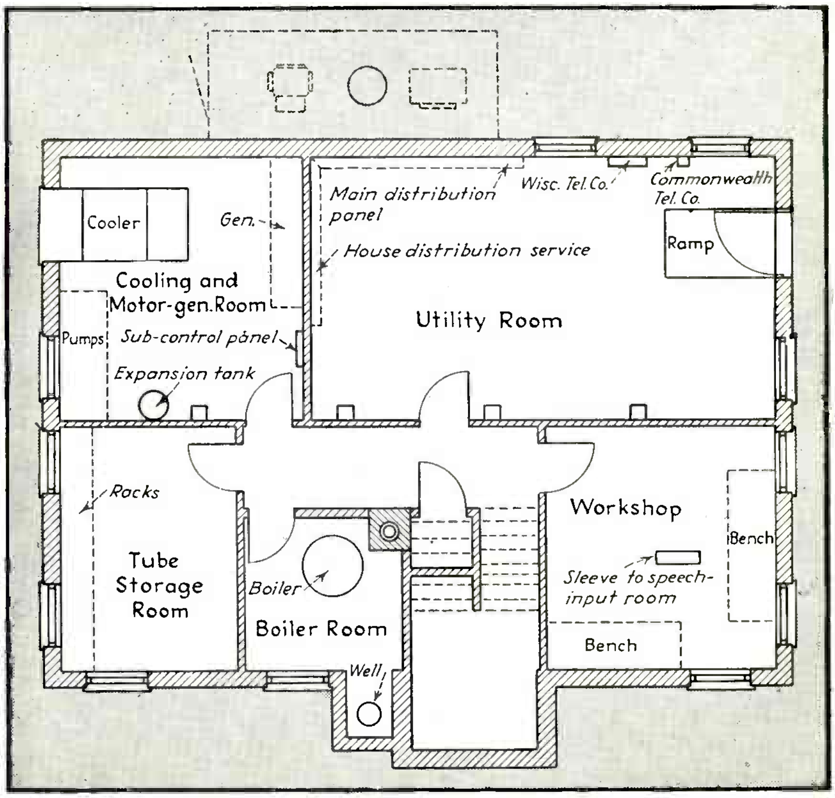


Fig. 7—Basement floor plan of the WMFM transmitter building

The 50-kw transmitter comprises five units. The modulator is incorporated in the 250-watt unit, and followed by a 3-kw amplifier in a cabinet directly alongside, with its associated rectifiers and blowers. Following this is the high-voltage rectifier and power-control units mounted in racks somewhat larger. The plate transformer for the 100-kw rectifier, with its voltage regulator and reactor, is mounted directly outside the building on a raised concrete block platform for protection against snow. The 50-kw power amplifier is installed in a separate room which is completely shielded by 0.006-in. thick copper, including the floor and door.

A balanced concentric line consisting of two 3⅛-in. lines is inductively coupled to the power amplifier. These lines are mounted on an elevated trough spanning the distance between the tower and transmitter building. To minimize sudden differential changes between the inner and outer conductors, the trough is covered with a sectionalized removable shield. Mounted directly at the trans-mission-line end-seals are two diodes which act as a vacuum-tube voltmeter reading the relative voltage for daily comparison and reference purposes. For the present, indirect measurement of power output is used and calculated at 60 percent of the plate input of the final stage.

The ground system deviates greatly from a-m band practice insofar as radial wires were not buried as a part of the radiating system and only sufficient copper was laid for equipment grounds and protection against lightning. The ground system consists of sheets of expanded copper screening each 6 by 10 ft. in size, laid around the entire building and covered with eight inches of soil. The tower ground is made up of similar pieces forming a mat 30 by 30 ft. overall and tied to the building ground by several two-inch copper straps.

During the period of construction, the entire building metalwork, such as conduit, water pipes, reinforcing steel, metal lathe, was bonded together and spot-welded. Every 10 feet, four-inch copper straps were brought out of the masonry slightly below ground level and joined to the screening.

Power

The WMFM a-c power requirement for the transmitter itself is about 102 kva with the transmitter operating at its licensed power input of 60.5 kw. When the amplifier is running at full 50-kw r-f output, the a-c power demand rises to 135 kva. Power requirements given here do not include equipment such as the electric stove, building heating, water pump, tower and building lighting.

The local utility supplies service from either of two 26,400-volt lines, each line coming from a different direction on separate feeders. Three 50-kva transformers feed 240-volt, 3-phase power into the building through an underground duct.

Transmitters of various sizes will use approximately the following a-c power:

250 watts	1.2 kw
1,000 watts	3,5 kw
3,000 watts	7.5 kw
10,000 watts	24.0 kw
50.000 watts	135.0 kw

The power used by associated equipment such as speech input, monitoring, and lighting, should be added to the above estimated power requirements.

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(2) "Retail Shopping Areas," J. Walter Thompson Co., New York; "Four-Color Retail Trading Areas," Hagstrom Map Co., New York; "Trading Areas," Rand McNally & Co., Chicago; "Consumer Trading Areas." Hearst Magazines Inc., New York.

(3) "Standards of Good Engineering Practice for High-Frequency Stations," Federal Communications Commision, Washington, D. C.

The most powerful weapon of ignorance—the diffusion of printed matter.
COUNT TOLSTOI.

A STABILIZED NARROW-BAND FREQUENCY-MODULATION SYSTEM FOR DUPLEX WORKING*

Reprinted from Proceedings of the I.R.E.

By E. E. Suckling†

Nonmember, I.R.E.

Summary—A system is described whereby the two terminals of a duplex radiotelephone channel are stabilized against each other by the use of standard automatic-frequency-control circuits and the common use of an oscillator for both transmitting oscillator and superheterodyne high-frequency oscillator. The send and receive frequencies are separated from each other by an interval which is the frequency of the intermediate-frequency channel. The system can be designed to give adequate frequency stability** for most applications without the use of crystal control.

Introduction

A MAJOR difficulty in the design of ultra-high-frequency communication systems is the attainment of sufficient frequency stability of the transmitter and of the receiver.

The use of a wide band with either a superregenerative receiver or a wide-band superheterodyne circuit permits some variation in frequency but with the increasing use of the ultra-high-frequency spectrum these methods are no longer available and communication channels must be maintained within as narrow a band as can be used to convey intelligence. In the case of both amplitude- and frequency-modulated systems this requirement often means the use of crystal stabilized oscillators with numerous frequency multiplying stages and perhaps also a phase modulator.

In a remotely switched radio terminal it is usually necessary that whenever the unit is switched on, the assigned frequency be always available without any possiblity of variation and in this case it is practically essential that a crystal-controlled oscillator be used. If the channel is frequency modulated, the Armstrong system[1] or some modification of it will be preferable, as the controlled reactance tube oscillator, although stabilized once it has been tuned to its stabilizing source, does not necessarily start oscillating at the frequency required and the commencing frequency of such an oscillator may be beyond the control limits of the automatic-frequency-control circuit. In many installations conditions are not

* Decimal classification: R414. Original manuscript received by the Institute April 29, 1943; revised manuscript received, August 14, 1944.

† Radio Section, Chief Engineer's Office, Post and Telegraph Department, Wellington C. 1, New Zealand.

** Editorial Note: The term "stability" is not used in this paper in its usual sense, that is, as the ability to maintain a given carrier frequency at a constant value. The method described in the paper relates instead to the maintenance of a fixed-frequency relation, or difference of frequencies, between the two carriers involved in one system; accordingly both carriers can drift equally in the same direction without bringing the corrective means into play.

1 Edwin H. Armstrong, "A method of reducing disturbances in radio signaling by a system of frequency modulation," Proc. I.R.E., vol. 24, pp. 689-740; May, 1936.

2 D. E. Foster and S. W. Seeley, "Automatic tuning, simplified circuits, and design practice," Proc. I.R.E., vol. 25, pp. 289-314; March 1937.

(Proceedings of the I.R.E., January 1945)

as rigorous and preliminary tuning may be permissable. In such cases, as the use of crystal control involves considerable complication of equipment, this factor, together with the difficulty of altering frequency when it may be required, opens the field for the development of a system which, while easily variable in frequency, has both stability and also simplicity of circuits.

The arrangement to be described incorporates these features and provides for a simultaneous two-way radio-telephone link with the characteristics which can be expected when using a frequency-modulated transmitter and a sensitive receiver.

PROPOSED SYSTEM

In the usual system of stabilized frequency modulation the transmitter frequency is stabilized against a crystal oscillator. The arrangement is very similar to the automatic-frequency-control circuits[2] used in some domestic receivers whereby the receiver oscillator is maintained at a required frequency by reference to an incoming carrier.

In both cases the oscillator to be controlled is arranged with an electronic reactance connected across its tuned circuit which enables the frequency of oscillation to be varied by an alteration of the bias on the reactance tube. Bias for the reactance tube is derived from a frequency discriminator connected in an intermediate-frequency channel. When, due to a drift in the variable oscillator, the frequency in the intermediate-frequency channel has deviated from the center frequency of the channel a steady voltage is obtained from the discriminator and this voltage applied as bias to the reactance tube alters the oscillator frequency in such a way as to correct the original drift. As a result, the drifting oscillator is constantly corrected and brought back towards the correct frequency since any deviation produces a direct voltage which will tune the oscillator back towards the original condition.

There cannot, of course, be perfect correction as a small frequency deviation is required to produce a correcting voltage. This deviation need only be a few hundred cycles to produce sufficient voltage to correct what would otherwise be an off-frequency condition of many kilocycles.

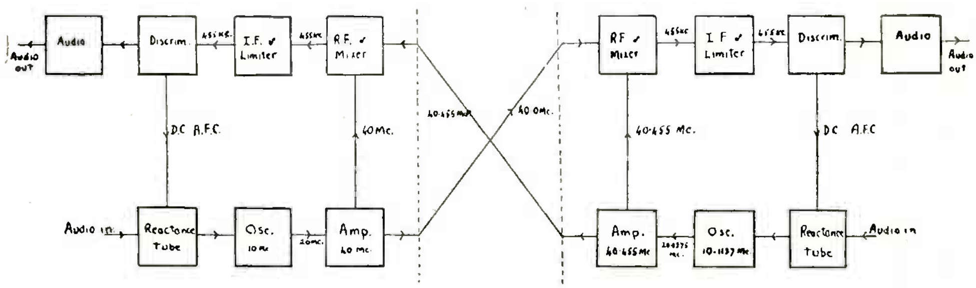
In the system here described the frequency used to control the oscillator is that of the incoming carrier. It is, in fact, a standard automatic-frequency-control system using a superheterodyne receiver, the oscillator of which is constantly corrected to maintain the intermediate frequency at the correct value. The oscillator of a superheterodyne receiver can be used as the basis of a transmitter when it is satisfactory for the receive and send frequencies to be separated by an interval which is the frequency of the intermediate channel.[3] This principle is used and as both send and receive channels are in simultaneous operation the automatic frequency control applied to the receive oscillator gives stabilitity to the out-going frequency. As the receiver oscillator (or its harominc) is actually radiating, the transmitted frequency will have a stability similar to that of the incoming frequency (maintained by the automatic-frequency-control system), but spaced from it by the receiver intermediate frequency. The incoming carrier which supplies the stabilizing frequency for the transmitter-receiver arrangement can originate in a crystal-controlled transmitter in which case the frequency stability of the whole system will be approximately the same as that of the crystal oscillator. It is, however, possible to use at either end of the channel a transmitter-receiver arranged as described with, in each case, an automatic-frequency-controlled receiver oscillator working also as transmitting oscillator. In this case, absolute frequency stability will not be attained but the system will in itself be stable in

[3] W. W. Honner, B. E. and T. E. Trew, "A low power installation for ultra-high frequency radio telephone links," *A.W.A. Tech. Rev.*, vol. 5, pp. 287-293; 1941.

that the two oscillators will be maintained at a frequency separation from one another which is the common frequency of both of the intermediate-frequency channels. A block diagram below shows the complete duplex-channel arrangement.

Drift of the two oscillators simultaneously is possible and is not corrected. This, of course, may cause interference with the adjacent channels, or it may involve working with receiver radio-frequency tuned circuits slightly out of alignment, but actually is unlikely to be of sufficient magnitude to give trouble due to either effect. As long as the two oscillators are maintained at the corerct frequency separation the correct intermediate frequencies will be developed and the major requirement for receiver tuning will be satisfied.

It can be seen that either frequency or amplitude modulation can be used with the system but in view of the necessity for a discriminator and a reactance tube to effect automatic frequency control, the use of frequency modulation is



the obvious choice as it involves merely the use of a microphone transformer with the reactance tube. Frequency modulation permits a closer spacing of transmitter and receiver frequencies with a lower intermediate-frequency channel and a more stable discriminator.

Equipment Design

The efficient operation of the system depends upon the automatic frequency control and the design must therefore center about the automatic-frequency-control circuits. As a standard for commencement it was considered that a frequency variation due to external causes such as thermal, voltage variation, etc., of an uncompensated oscillator of reasonably careful design would be of the order of 0.1 per cent at 10 megacycles and that the consequent carrier drift to be encountered was up to 40 kilocycles at 40 megacycles. It was also considered that for a 10 kilocycle per second modulation deviation, an off-center tuning of $\pm$ 1 kilocycle was tolerable when the discriminator characteristic was linear to $\pm$ 12 kilocycles per second. The design of the automatic-frequency-control circuits must therefore be such that the discriminator reactance-tube combination produces sufficient reactance across the oscillator tuned circuit to cause a frequency deviation of 40 kilocycles when the intermediate frequency is 1 kilocycle off center.

In an experimental setup 2-watt carriers were used spaced 455 kilocycles apart, the working frequencies being 40 megacycles and 40.455 megacycles. Concise measurements of the performance of the system were not taken but the action of the automatic frequency control in "locking" the two carriers was very evident. The complete units each about the size of a domestic receiver enabled good quality duplex telephone conversation to be maintained over a distance of several miles. An interesting feature was the incorporation of single-dial control by which the radio-frequency and oscillator circuits were ganged. This enabled a wide choice of channel frequencies to be used but also gave the effect that on tuning around the dial and hearing the other station communication was then immediately possible as the local carrier was by the action of tuning the receiver set to and locked at the correct frequency for the remote station's receiver.

CONCLUSION

The principle used appears to have application in many cases for duplex ultra-high-frequency radiotelephony where high stability is required without the refinements (and also limitations) of crystal control. Tests indicate that as long as the signal received is sufficient to actuate the limiter, frequency stability is maintained despite variations in power-supply voltage and despite the usual thermal variations in the oscillator circuit.

Routing Cabs by Radio

Great Lakes shipping losses have been reduced by ship-to-shore-radio-telephone service. In Cleveland, post-war plans include routing cabs by radio.

FUTURE OF THEATER TELEVISION

Reprinted from Television

By Dr. Alfred N. Goldsmith

TELEVISION broadcasting for the home audience has partly diverted attention from another promising field of television development, namely, theater television. Theater television bears somewhat the same relationship to home television that theatre motion pictures bear to home movies of professional films.

Recently the Society of Motion Picture Engineers, through its Television Committee, asked the Federal Communications Commission to provide experimental facilities for the development of theater television by radio methods. It is not certain whether theater programs will be distributed by conductors or by radio, but the Society's proposals indicated the line of thought of the motion-picture engineers. They envisioned, in each city, a group of distributors of theater television entertainment. Each of these distributors would have a television transmitting station from which the program would go to the receivers in a group of theaters within the service area of the transmitters. The programs would come from three possible sources. They might originate at the transmitter studios, as live talent performances or even as film presentations. Alternatively, they might be outside events picked up by a mobile unit or two in the field and relayed to the main transmitting station. Or, as another method, they might reach the transmitting station by a nationwide wire or radio-relay system which would enable syndication of all programs throughout the country. This might mean that each distributor would thus require a group of frequencies. Since there might be quite a number of distributors in the larger cities, the need for frequencies would rise correspondingly. And since high-detail color television might ultimately be required, the channel width would be considerable — perhaps 40-60 megacycles or even more. The sum total of the Society's request for allocations was therefore thousands of megacycles and, accordingly, such operations could be placed only on the frequencies of the order of 10,000 megacycles or more! Only a minor fraction of the frequencies were requested at present or experimental test, but the basic planning was clearly an ambitious and imaginative one.

It is obvious that the theater audience has a different psychology and scope from the home audience. The intimacy of home television presentations will probably be greater than that of the theater programs. This will influence the nature of the dialogue, the proportion of close-ups and medium shots, and other production factors.

It is also known that the timing for a home program will, to advantage, be different from that which is desirable in the theater and that the length of a program may also be different for the two types of show. Much thoughtful experimentation will be necessary to get all the guiding facts.

Consequently, theatre television to a large extent, will need its own source of programming. Naturally, outstanding events addressed to the home might find their way to the theater screen, but this would account only for a relatively small percentage of theater programs. There have been proposals that such events as racing, boxing and many other sports which will make top theater television fare should be specially picked up for television. The question which must arise is whether theater interests will be able to tie up events exclusively for their use. There is also the possibility that the theater television transmitter might thus partly replace the film projection rooms of the various theaters it services.

If radio is used for the distribution of the theater-television programs, some additional interesting problems will arise in connection with the protection of property rights in the program. Perhaps such protection can be secured by copyrighting the programs. Or further, they may be transmitted as multiple-addressee messages of private nature on a point-to-point basis rather than as broadcast messages. This suggestion was made by the representative of the Society of Motion Picture Engineers at the recent Federal Communications Commission hearings. Secret methods of transmission have also been proposed, and their utility and desirability in the theater field awaits analysis.

Given good engineering, clever showmanship, and a guiding vision, theater television promises to be not only an interesting addition to the entertainment arts of the future but a definite economic asset to the box office.

The greatest discovery of all time — man's ability to think.

ANONYMOUS

FACSIMILE NEWSPAPERS

Reprinted from FM and Television

*By Lieut. Col. Robert D. Levitt**

Predicting a Shift from Mechanical to Radio Distribution, and the Manner in Which It Will Be Accomplished as Soon as Equipment Is Available

AMONG the developments in the field of communications is one which offers a particular challenge to the enterprise and vision of the newspaper publishers. That is the radio-operated facsimile process of transmission, reception, and reproduction of graphic images, by which it is possible to create permanent, identical, black-and-white copies of photographs, drawings, printed material—even entire newspapers!

Facsimile has already progressed to the point beyond which the only further development needed is that which may be dictated by consumer demand, and such development invariably comes with astonishing speed. Before the war, this new service could have been started with equipment then available. The period of wartime postponement, during which facsimile development has been accelerated for military use, will have served public interest by making superior instruments available when facsimile broadcasting can be launched on a postwar basis.

> THIS discussion of facsimile is of particular interest and significance because it was not written by a radio engineer, but by a newspaper man whose knowledge of publishing was gained with one of the largest newspaper organizations in the world.
>
> Col. Levitt lays down a challenge to the most progressive minds in the fields of engineering, publishing, and broadcasting. The idea of shifting from mechanical to radio distribution is entirely sound, and the plan of employing both methods, as is projected for AM and FM broadcasting, until the new can supplant the old, represents a reasonable and logical advance in service to readers and advertisers alike.
>
> While it is startling to think that simple home facsimile machines can take the place of those amazing machines that print and fold thousands of newspapers per hour, this is no more amazing than the contrast between those machines and the crude hand presses used not so many years ago!

To the newspaper publisher, facsimile is either a threat or a promise. If it is set up intelligently and enterprisingly on a commercial basis, it is a promise of a wonderful refinement and advance in present newspaper publishing techniques. But, ignored by newspaper publishers and exploited by others, it is a threat of deadly competition.

To begin with, facsimile, as it affects newspapers, must be regarded only as a

* 25 Central Park West, New York City. Former promotion director, New York Journal American and circulation promotion manager, The American Weekly.

new, superior method of distribution. It is not a newspaper; it is merely a means for delivering newspapers to the home.

For the purpose of this analysis, let us divide the operation of publishing a newspaper into two basic phases. The first phase, which includes the gathering and writing of news and features, obtaining photographs, solicitation of advertising, typography, engraving, composition, and make-up, we may call the "production phase." The second phase, onward from the stage at which page forms are locked up, including the familiar progression to presses, to mail room, to delivery trucks, and to dealers or carriers, we may call the "distribution phase."

Facsimile, then, offers a modern substitute for the conventional "distribution phase" of newspaper publishing. Once the page forms are locked up, completing the "production phase," facsimile takes up the task of distributing the newspaper. At this point, instead of continuing with the present succession of printing and distribution stages, reproduction proofs of the pages will be inserted into transmitting mechanisms and broadcast direct to recording units in the homes of newspaper readers.

The economics of substituting radio for mechanical distribution offers a most interesting study. Annual cost per family for a facsimile reception is no more than the price of daily morning and evening papers, yet facsimile distribution eliminates the newspaper publisher's largest factors of labor, cost, expense, and capital investment.

Obviously, facsimile is useless without the organization and equipment to accomplish the "production phase." Without reporters, photographers, writers, editors, advertising solicitors, and all the rest of the complex creative set-up, facsimile is an empty vehicle. It is a train without freight. But it is a beautiful, streamlined, air-conditioned train, and if the present-day newspaper publisher doesn't provide the freight, it is an odds-on bet that someone else will.

The publisher who has spent years in perfecting the "production phase" of his paper to suit the reader-market he serves must either extend his usefulness by utilizing the new substitute for his old 'distribution phase" or resign himself to the inevitable consequences. Others, perhaps the radio broadcast station operators themselves, can, and undoubtedly will, set up organizations to accomplish the "production phase" of newspaper production, and employ facsimile as a dramatic substitute for the "distribution phase" of the old-style newspaper. When facsimile has developed into an economically sound enterprise, and there is every indication that this can happen very quickly, its competition will render obsolete the newspaper as we know it today.

Analysis of the present competitive position of the newspaper further emphasizes the significance of facsimile. At present, the only important competitor of the newspaper in the dissemination of current information is standard-band radio. The newspaper has two major advantages over radio: the advantage of visual presentation over auditory; and the advantage of permanence. But both of these are merely temporary. With the development of facsimile, not only will the visual advantage be lost, but also the advantage of permanence, and new factors of speed and convenience will operate to the distinct disadvantage of the conventional newspaper.

It is apparent that unless the newspaper publisher swims with the technological current, he will find himself submerged. The current is rising behind the dam of wartime restrictions, and there are cogent reasons why the newspaper publisher had best prepare to swim with it now, instead of letting someone else take the initiative when peace releases the commercially profitable torrent.

Of course, facsimile transmission of newspapers cannot be a profitable enterprise until there are in American homes enough facsimile receivers to support an economically sound advertising rate structure for participating newspapers. It is assumed that facsimile will afford no sources of revenue to newspapers other than paid advertising. But, profitable or not, preparation for the transmission of newspapers by facsimile broadcasting will have to start before the first recorders are offered for sale, because that is the only way to create a demand for recorders. No one will buy a facsimile machine unless something he wants to receive is being broadcast.

Who will broadcast the first regular facsimile newspapers which will create the demand for facsimile recorders? In the answer to this question is contained the destiny of the newspaper business

The facsimile newspaper which is used to create a demand for facsimile reception will simutaneously create a demand for itself. As the product improves and the promotion effort increases, the sale of receiving equipment will grow. Concurrently, the chances of competitive success for belated entries in the field will diminish in inverse ratio to the multiplying acceptance of the pioneer.

This natural law of competition is the most obvious argument for early, foresighted action by newspaper publishers. As the slow but inevitable transition from mechanical to electrical distribution progresses, the laggard publisher will see his reader market lost, probably beyond any belated effort to recapture it.

Government regulation will undoubtedly establish standards of transmission so that any recorder can be operated by facsimile signals from any station to which the receiver is tuned. It appears that there will be ample facilities available for facsimile transmission, which is another reason for early enterprise. Only by early entry into the facsimile field can the newspaper publisher assure himself of a leading position. He must have a part in the formulation of the master plan if he hopes to derive any benefit from its ultimate realization. He must be there when the regulations are made or he may be regulated out of business.

The soundest course for the newspaper publisher seems clearly indicated. It closely parallels that taken by standard-band radio broadcasters in dealing with Frequency Modulation. They have decided to make FM an accessory to standard-band broadcasting until it assumes the stature of a substitute. They channel their standard-band programs over FM as well, offering this as a plus value to their advertisers. As the use of FM receivers grows, the broadcasters will constantly be in the sound position of deciding at what point they will abandon standard-band broadcasting in favor of exclusive FM broadcasting, without any disruptive or costly transition.

Similarly, the newspaper publisher should use facsimile as an accessory to his "distribution phase" until it has become an economically feasible substitute. The moment there is one facsimile receiver offered for sale in the circulation (or, in this case, broadcast) radius of the newspaper publisher, he should commence facsimile transmission of his newspaper. By doing this, he himself will be able to decide at what time, be it a year or a decade later, he will shut down his presses and sell his trucks, or take any intermediate action. It will not be decided for him, with disastrous consequences, by irresistible competition.

At this point it should be considered that FM broadcast stations can transmit sound and facsimile signals simultaneously, by the mere addition of a scanning machine and its associated electrical circuits. Similarly, FM receivers can operate loud-speakers and recorders simultaneously or separately. This fact, considered in connection with the manifest interest of many publishers in sound broadcasting, suggests new avenues of mutual radio-newspaper enterprise. The vast possibilities inherent in the simultaneous transmission and reception of sound and facsimile are not properly a part of this discussion, but rather serve to emphasize the broader significance of its theme.

Now is the time for the newspaper publishers to decide not how they are going to combat facsimile, but how they are going to use it. In speaking of newspaper publishers, it has been intended to include them all, for facsimile is clearly an instrumentality for newspaper publishers collectively. It does not set one publisher against another, although it does set publishers as a group against non-publishers who may enter the newspaper field.

Facsimile can probably be of greatest service to newspaper publishers if employed in a manner that will neither disrupt their present competitive positions in relation to one another nor destroy the stability of their economic structures.

This can be done. But it can be done only by intelligent, cooperative, planned action—and, above all, by early planned action, now! That is possible because if, in any area, there is more than one facsimile broadcasting service, the "readers" will be able to choose their newspapers by tuning to the transmission they want, just as they now select their papers from the stands. Moreover, the same receiving equipment will produce the morning paper from one publisher and the evening paper from another.

All this can be done. It calls for prompt and careful planning between the publishers and the manufacturers of broadcast transmitters, radio receivers, and facsimile scanners and recorders.

Blessed is he who has found his work; let him ask no other blessedness.
THOMAS CARLYLE.

HIGH FIDELITY AND TONE CONTROL

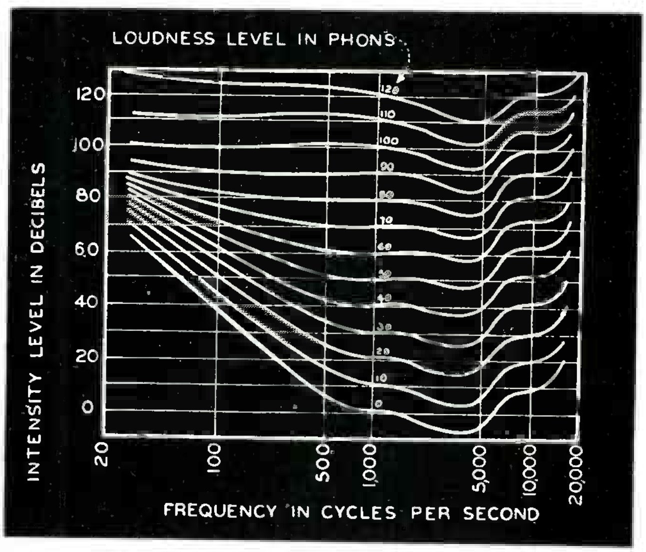
Reprinted from Service

By Edward Arthur

POSTWAR receiver plans indicate that tone quality will be quite a major feature. F-m, of course, will contribute its share toward tone quality emphasis. The projected interest in this phase of receiver design will prompt many problems that only a substantial knowledge of sound will solve. A review of some of the basic principles of sound and application data that would be of assistance in solving these problems therefore appears to be a *must* on the Service Man's program.

To assist in this important program, a brief review of the essentials are offered in this article. In our approach we will review the physical aspects of sound from the time it originates in the broadcast studio, trace its path through the transmitter and receiver into the sound reproducer, the room in which the receiver is installed, and, finally, the ear of the listening public. In addition, design methods of tone control will be discussed, as well as an analysis of some commercial systems.

Any audio frequency has two important characteristics, its frequency and its amplitude, or volume level. For high fidelity, it is important that the final signal contain all the audible frequencies of the original signal transmitted at



their relative amplitudes. Again, frequencies not present in the original, should not appear in the final signal. For *best* or *ideal* reproduction of both speech and music, a frequency range of 30-15,000 cps is essential.

The relative amplitude range at the point of transmission varies from 70 watts for a full orchestra, to .05 watt for a triangle. However, the limitations imposed by the components involved in both transmission and reception, limit both the frequency range and the amplitude range.

A high fidelity a-m broadcast station is limited in its audio frequency range of transmission to 30-9,000 cps, because of federal regulations limiting the side band transmission to ten kc. In addition, the amplitude range must be compressed, since background noises would override the low intensity audio signals, and the high amplitude levels would tend to overmodulate the transmitter, creating serious audio distortion, or causing possible station failure. Other

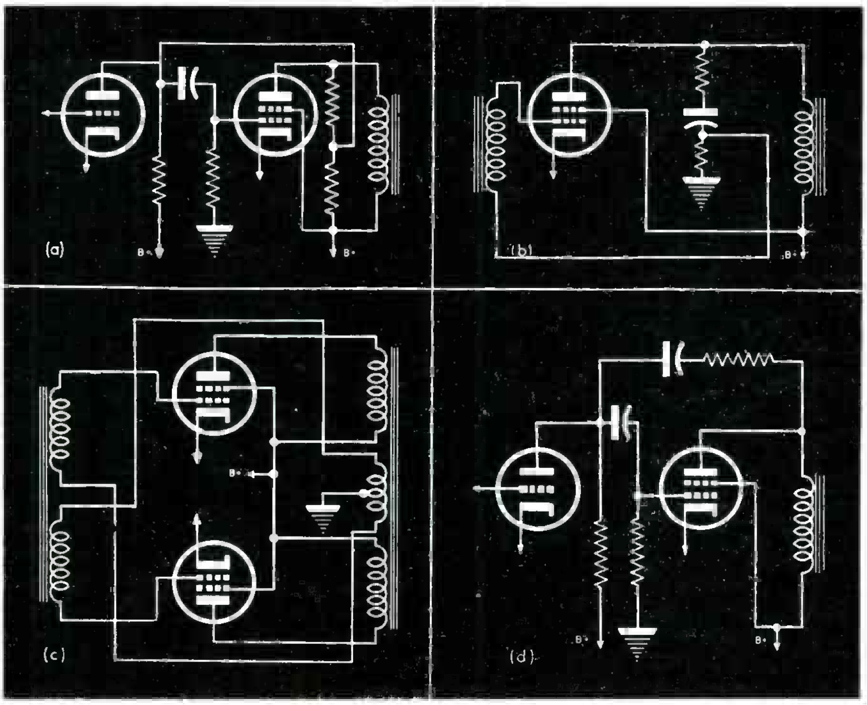


Fig. 2. Various systems of inverse feed-back. Most of these systems operate in the final stage of the a-f amplifier

factors influencing the fidelity of transmission are the particular microphone used by the studio, the studio from which the transmission takes place, and the attenuation factor and frequency characteristic of the lines over which the signal is piped from the studio to the transmitter.

F-m transmitters have a *possible* audio range of transmission of 30-15,000 cps. Because of the limiter action of the f-m receiver, the signal-to-noise ratio is better than in a-m systems, and the signal distortion less than 2%.

A-m receivers limit the ultimate audio-frequency response. Detuning effects in the r-f and i-f sections of the receiver due to variations in signal amplitude, avc action, and the voluntary limiting of side-band response to reduce monkey chatter, or cross talk, create signal distortion even before detection takes place. In f-m receivers, the r-f distortion is reduced so as to be a negligible factor.

Audio amplifiers may be designed to have a flat-response characteristic from 30-15,000 cps, so that distortion in this part of the circuit can be ignored. Modern diode-detector circuits can be controlled, so that the distortion in this part of the receiver is also a negligible factor.

The loud speaker and its associated equipment, such as the cabinet in which it is mounted, or the sound diffusers used with it, is the final unit associated with the electrical system of sound reproduction. The fidelity of this unit can be controlled within fairly narrow limits by design and construction. Multiple speakers, to give adequate response to the entire audio spectrum, or sound diffusers incorporated in the cabinet design to permit more uniform distribution of energy, are essential components of all high-fidelity systems.

The final factors involved, are the room in which the loud speaker has been installed, and the hearing ability of the person or persons listening.

The furniture, rugs, and draperies in a room, the size of the room, the position of the listener with reference to the sound source, all exert a great influence

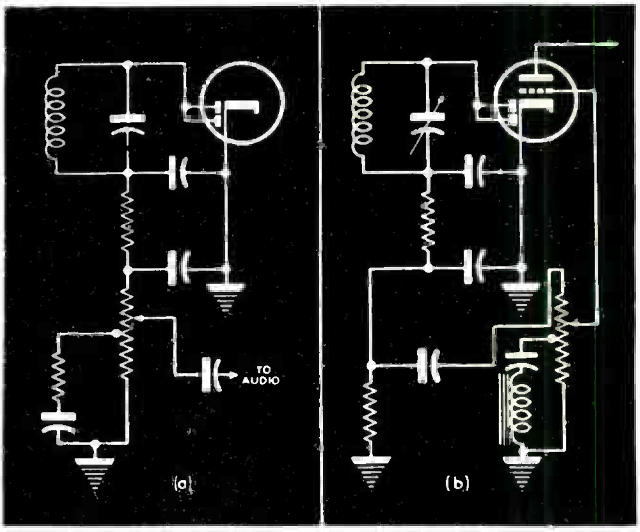


Fig 3. Two methods of bass compensation on volume control are shown in a and b. Method shown in a is a popular method; b method offers both treble and bass compensation.

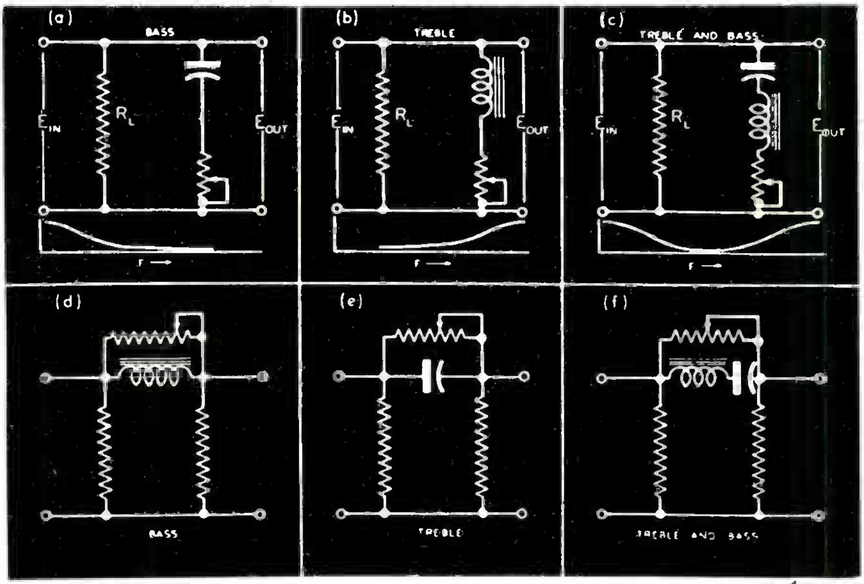


Fig. 4. Six basic methods of tone compensation are illustrated here. Frequency response curves of methods shown in a, b and c also appear. All of these systems are of the losser type, with boosting provided by reducing level of unwanted frequencies

on the audibility of various portions of the audio spectrum. It should be noted that the relative amplitude of the various audio frequencies is here involved, and not the fidelity of the frequencies themselves. In general, it may be said that more uniform response is obtained when the sound source is installed in a corner facing the center of the room.

One factor not previously discussed, and possibly the most important, is the hearing ability of the listener. Individual abilities vary widely. There is a progressive deterioration of hearing ability with age. This is particularly true of the ear response to the upper registers. A suprisingly large percentage of people are tone deaf in varying degrees.

Given a person of normal hearing, the response of the ear to frequencies between 30-15,000 cps varies, so that maximum response seems to lie between 3,000 and 4,000 cps. The second and more important factor in relation to receiver design, is that this variation in ear response is a function of volume level,

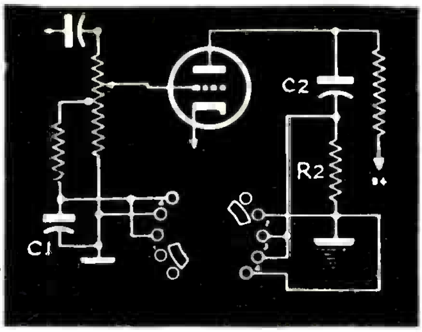


Fig. 5a. (above) Tone-control system used in General Electric 35 receiver. Point switching is used for tone control. Circuit is normal in position 1, with bass compensation operating in the volume control. This position is called brilliant.

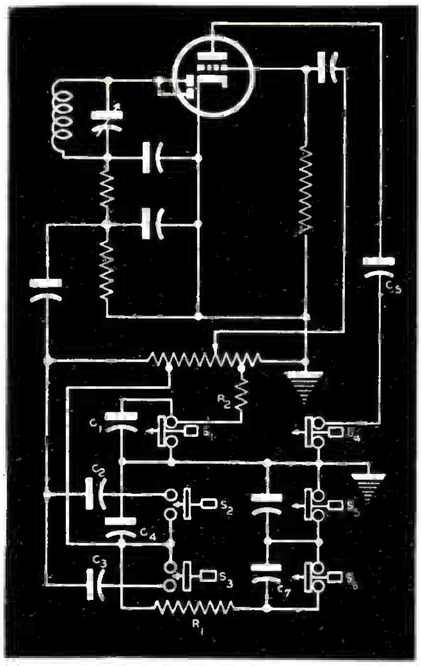


Fig. 5b (right) Tone-control system in Zenith 8S647 This type of control is used in most of their console models. When the Switch S_1 is opened, bass boost is applied for low volume settings.

Fig. 1. From this empirical chart, it can be seen that hearing response is poor at low frequencies at low levels, and improves as the amplitude is increased. High-frequency response likewise improves with amplitude, but not as rapidly.

A third factor is the influence of the duration of listening. Hearing acuteness decreases with time, due to fatigue.

The enumeration of these problems is not intended to discourage, but rather to point out the obvious need for some system of audio-amplitude control, which would control the relative respons of the various portions of the spectrum, in order to overcome these problems.

It is quite difficult to determine just what high-fidelity reproduction means, since there are so many factors affecting a signal between the time it first is produced at the studio, and finally arrives to the listener. Two facts should be noted. Poor fidelity tends to tire the listener. Again, the listener, individually, is the final judge of whether the reproduction is good or bad. Here, the hearer may be influenced, since he will recognize better fidelity when it is compared to poor tone.

There are three factors that influence fidelity:

(1)—The percentage of the frequency range of the original present in the final signal.

(2)—The frequencies not present in the original, but found in the final signal (harmonic distortion).

(3)—The relative amplitudes of the various frequencies in the orginal, and their relative amplitudes in the final signal.

As previously stated, *perfect* reproduction involves a frequency range of 30-15,000 cps. However, the extreme frequencies may be eliminated, and satisfactory reproduction will still be obtainable. To gain some idea of this, 95% quality may be obtained in orchestral music with a frequency range of 70-10,000 cps, 90% with a range of 90-8,000 cps. Authorities differ, but the limits for good reproduction would seem to lie between 90 and 100 cps for the lower end, and 9,000 and 10,000 cps for the upper end. A note should be made that satisfactory *speech* reproduction limits are 200-3,000 cps.

Harmonic distortion may also be tolerated within limits. These limits depend, to some extent, on the frequency bandwidth being used. A narrower bandwidth permits more harmonic distortion, since not only are the higher frequencies

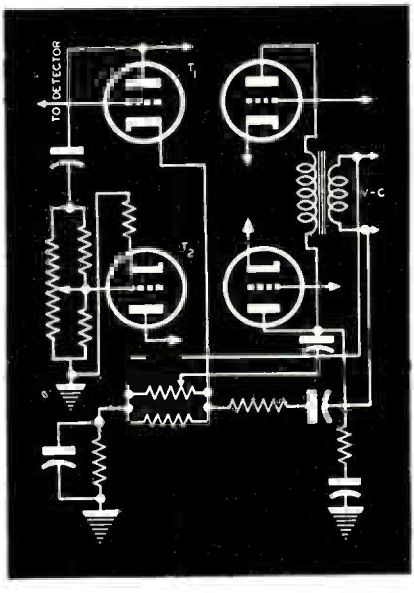


Fig. 5c Tone-control method used in f-m model 12 of Pilot. Inverse feedback is incorporated to provide high-fidelity response.

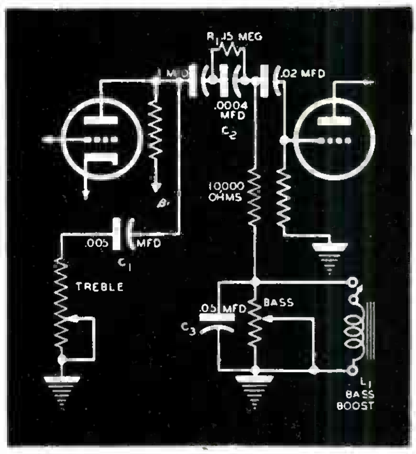


Fig. 5d. Stromberg-Carlson model 35 tone-control system. Bass-boost inductor and RC network coupling system is featured.

removed, but the harmonics of the lower frequencies present in this upper range are also silenced. For high fidelity, the total harmonic distortion (that is, 2nd, 3rd, . . . 6th) should be less than 5%. This range may vary to 10 to 12% for fair fidelity.

Amplitude distortion is not necessarily an evil, since it is a function of tone control. As shown in Fig. 1, the ear responds unequally to both ends of the tone scale, depending on the amplitude. Since most music is produced at higher levels than it is reproduced, it becomes necessary to compensate for the frequency characteristic of the ear with a change in level. It is important that we do *not* over-emphasize the non-linear ear reaction at a particular reproduction level, since the reaction of the ear to the original signal would have the same non-linear frequency characteristic. Therefore, it should be borne in mind that the difference in audibility for both extremes of the audio range accompanying a change in level, is the most important characteristic of the ear.

It is an anomaly that for high fidelity, it is necessary to have an amplifier with a flat response characteristic to the audio range, and then proceed to distort it with tone control. Tone control, in other words, is a method for compensating for:

(1)—The non-linear ear characteristic.

(2)—Amplitude distortion inherent in both the transmitter and the receiver.

(3)—The room in which reproduction takes place.

(4)—The individual hearing ability and taste of the listener.

A flat-response characteristic is obtained by proper design of the audio components. To facilitate this design, and reduce harmonic distortion, negative or inverse feedback is often employed, Fig. 2. This is accomplished by feeding back a portion of the output of a tube to the input of that tube in such a manner as to cancel, or buck out, a portion of the input driving power. It is usually employed in the final stage. The benefits to be derived from this procedure are, more uniform frequency response, reduction of stage hum and harmonic distortion, and reduction of *hangover effect*. A secondary result is the reduction of stage gain, which is not necessarily detrimental, since most receivers have more than ample output. This latter effect is usually overcome by increasing the driving power to that stage. (The average radio is operated in the home at a volume level of less than 2 watts, and generally, less than 1 watt).

Hangover effect is due to a speaker cone resonating at its natural period. It is most prevalent when the output tube has a high plate resistance. Since inverse feedback also reduces the apparent plate resistance, the shunting, or loading effect of the tube is increased, with a consequent reduction in hangover or speaker boom. Some receivers use transformer coupling for inverse feedback, Fig. 2*c*. The theory is still the same; feeding back a cancelling voltage out of phase with the input voltage. Bass compensation, to give a rising characteristic to the low frequencies, may be incorporated in the feedback circuit, by the proper proportioning of the resistive and capacitive elements, Fig. 2*d*.

Bass boost, as differentiated from bass compensation, is the accentuating of frequencies in the range of 60-250 cps. Most bass-boost systems involve the use of inductance to give a sharply rising characteristic to those frequencies below 250 cps. This is necessary, particularly at low volume settings, because of the ear response.

Bass or treble compensation for low level operation is usually incorporated in the volume control, Fig. 3*a*,*b*. The particular point on the volume control where it is installed is a function of the level of the incoming signal, and is determined from tests conducted by the design engineers. For this reason, it is important that an identical control be used where replacement is necessary. Fig. 3*a* shows a bass compensation system, and Fig. 3*b* a more ideal system for both bass and treble compensation.

Tone controls may be divided into two classes. One is the fixed type where point switching changes the response; the other is the continuously variable type where potentiometers are used to regulate the amount of bass or treble compensation. Console models sometimes use one or the other or a combination of both methods.

Tone control circuits are a combination of resistance, capacitance, and inductance, in such relation, that their loading effect on a circuit varies with frequency, Fig. 4.

Resistors, at audio frequencies, display no frequency characteristic; that is, their resistance remains constant over the frequency spectrum.

Condensers vary in reactance (a-c resistance) inversely with frequency; that is, their resistance increases as the frequency decreases.

Inductances vary in reactance directly with frequency; that is, their resistance decreases as the frequency decreases.

Since the gain of an amplifier stage is a function of the load across the output of that stage, it is possible to vary the stage gain for various portions of the audio spectrum by the appropriate association of resistance, capacitance, and inductance. The above is true where the control is in parallel with the load. By the same reasoning, the transfer characteristic of an audio stage may be made nonlinear by the introduction of capacitive and inductive elements, in inverse position to their parallel operation. This is demonstrated in Fig. 4, where the function of an inductive element in parallel operation is duplicated by a capacitance in series operation.

Fig. 4 shows six basic types of tone control. It will be noted that all of these types are losser systems. That is, the boosting is accomplished by reducing the level of unwanted frequencies. The resistors act as variable controls to influence the amount of bass or treble boost desired. The same circuits may, by inverse reasoning, also be designated as damping circuits; bass-boost may be called treble damper.

Tone circuit designation is a function of the frequency characteristic of the amplifier. For example, a bass-boost system may actually be a treble control, if the bass-boost position is the zero spot on the control. An advance of the potentiometer may introduce resistance into the circuit, reducing the by-pass effect of a condenser, thereby increasing the treble response.

The circuits shown in Fig. 4 are basic, and are usually present in one form or another in the tone-control systems of most receivers.

Incidentally the values associated with a tone-control system are a function of the tube input and output impedances. Since the action of a tone control is a function of constant voltage, the load presented by the tone circuit must be several times as great as the plate resistance for a triode, or the plateload resistance for a pentode.

In Fig. 5 appear some typical examples of tone-control systems. Fig 5*a* shows the tone control system employed by G. E. in their model 35. In position 1, the circuit is normal; that is bass compensation is operating in the volume control and bass boost in the audio. This might be compared with the system shown in Figs. 3*a* and 4*a*. In position 2, R_2 is shorted, and the treble is further attenuated by having the full effect of C_2 from plate to ground. Position 3 shorts out C_1 removing the bass boost in the volume control. Position 4 grounds C_2 and shorts out C_1, thereby attenuating both ends of the audio spectrum. These

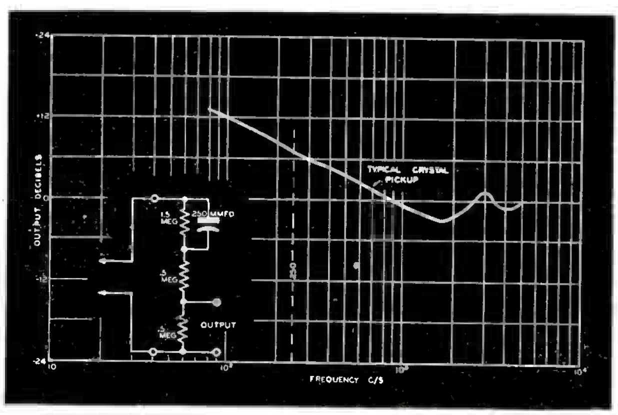


Fig. 6 Typical response curve for a crystal pickup and tone compensation system used with the pickup

positions are called: 1—brilliant; 2—bass; 3—treble; 4—mellow.

Fig. 5*b* shows a system used by Zenith in model 8S647. In this diagram S_1 to S_6 represent six tone switches in their normal or off positions. When S_1 is opened, bass boost is applied for low volume settings; compare this with circuit of Fig. 3*a*. When S_2 is closed, C_2 is applied across the volume control, acting as a high-frequency shunt; compare with Fig. 4*e*. When S_3 is closed, this effect is further pronounced. With S_4 opened, the shunting effect of C_5 is removed, thereby increasing the treble response. Opening S_5 boosts the bass, and opening S_6 boosts the treble. There are two-boost networks involved in this system. One consists of R_1 in association with condensers C_2, C_3, C_6, and C_7. The other consists of R_2 in association with C_1. The third element is the plate shunt condenser, C_5. It can be seen from the action of these circuits that bass or treble boost is a matter of relative level.

Fig 5*c* illustrates an inverse feed-back circuit used in Pilot FM 12, that also acts as a tone control circuit. Audio voltage from the voice coil is fed back to the cathode of T_1 resulting in high attenuation of high intensity voltages, and lower attenuation of low intensity voltages, providing more uniform gain. The tone control is a two-section affair, one section using the inverse feedback network, and the other the input to the inverter grid. By a combination of these circuits acting simultaneously, a sharp high-frequency cutoff is effected. This is an excellent feature, since it reduces the high-fidelity response when signals of limited frequency range are being received, thereby reducing background noises.

A tone-control system used in the Stromberg Carlson 935 is shown in Fig. 5*d*. The treble control is quite simple; compare with Fig. 4*a*. While most tone networks would designate this as a bass compensation system, when acting in reverse, it may be considered as a treble control. It then is a function of the original respouse curve without tone compensation, which may show a marked high—or low—frequency characteristic instead of a flat one. In this particular case, increasing the resistance in series with C_1 increases the treble response. The network consisting of R_1 and C_2 (compare with Fig. 4*c*) is a treble-boost network. Since the a-c resistance of condenser C_2 decreases with frequency, high frequencies pass more readily than low frequencies. The network consisting of R_1, R_3 and C_3 is a bass-boost system (compare with Fig. 4*a*) with the control across the condenser instead of in series. The addition of the inductance across this circuit introduces a resonant network that is quite broad in response. This increases the low-frequency response quite rapidly at very low frequencies.

Tone controls associated with phono pickups are similar in action to receiver tone systems, and component values again are a function of the input impedance, in this case, the pickup. Magnetic pickups are generally low-impedance devices, and crystal pickups high-impedance sources. Additional factors in the design of phono-tone controls and compensation systems are the frequency range of recording and the amplitude contraction (as opposed to expansion) practiced by the recording studio.

In recording, the low-frequency response is attenuated rapidly to prevent needle jumping and distortion at high amplitude levels. For this reason, pickup tone control circuits are generally heavily bass boosted. The highest recording frequency for general sale records is in the neighborhood of 8,500 cps, and varies with the manufacturer. Pickups also have frequency characteristics. Therefore most phono-tone systems are characterized by sharp bass boost and sharp cutoff above 8,500 cps.

The response of an average crystal pickup is shown in Fig. 6. It will be noted that the rise in amplitude toward the low-frequency end starts at 900 cps. This response is too gradual for good bass response. In order to flatten the response curve, Stromberg Carlson uses system shown in insert of Fig. 6. It is a version of Fig. 4*e*, in that it is a treble-boost system. Bass boost below 250 cps is then accomplished in the receiver tone system.

WHAT'S BEING READ THIS MONTH

As a regular feature of our magazine, we take pleasure in presenting each month a complete list of the articles which have appeared in the current issues of the leading trade and professional magazines. The list for this month is as follows:

COMMUNICATIONS (MARCH 1945)

TELEVISION ENGINEERING
A Television Studio Installation Designed for Research and Instruction........*Albert Preisman*

V-H-F ANTENNA COUPLING
An Improved Antenna Coupling Circuit for 30-40 mc........*H. J. Kayner*

AERONAUTICAL COMMUNICATIONS
Design of Broad-Band Aircraft Antenna Systems........*F. D. Bennett, P. D. Coleman and A. S. Meier*

CIRCUIT ANALYSIS
Cathode Followers and Low-Impedance Plate Loaded Amplifiers........*Sidney Moskowitz*

MILITARY COMMUNICATIONS
British Army Communications' Equipment Developments........*Capt. Andrew Reid and H. W. Barnard*

TRANSMITTING TUBE DESIGN AND APPLICATION
External Anode Triodes (Part III)........*A. James Ebel*

TRANSMISSION AIDS
Approximate Losses for Various Sizes of Concentric Transmission Lines at 46 mc........*Willard H. Wood*
A Volume Level Control for Audition Amplifier........*Harry E. Adams*

COMPONENT APPLICATIONS
Combining Components to Obtain Exact Specification Values........*Raymond P. Aylor, Jr.*

FILTERS
Filter Analysis and Design........*C. E. Skroder*

ELECTRONICS (April 1945)

THE RADAR EQUATION
Radiated power and receiver sensitivity are related to the distance and size of the detected object

HUMAN CENTRIFUGE
Aircraft pilot blackout conditions are reproduced and reactions measured electronically in AAF aero-medical lab

PRACTICAL ELECTRONIC INDUSTRIAL CONTROLS
A consultant tells what tubes will and will not do........Paul G. Weiller

A 50-kw F-M TRANSMITTER
WMFM, and particularly its phase-shifting modulator, is described in detail........*Phil B. Laeser*

ELECTRONICS (April 1945) *continued*

ELECTRONIC IGNITION SYSTEMS
A survey of the development of various circuits and a comparison of their functions........*G. V. Eltgroth*

TEST SET FOR QUARTZ CRYSTALS
Stable a-c operated unit can be set to check many types of crystals against requirements........*W. E. McNatt*

DIELECTRIC-CONSTANT METER
Magic-eye tube is used as indicator-oscillator in a simple, unique differential-capacitance meter........*Frank C. Alexander, Jr.*

AUTOMATIC LIQUID LEVEL CONTROLS
Industrial electronic equipment provides accurate automatic control of liquid level and other process variables........*Theodore A. Cohen*

RECEIVER WITH 2-Mc I-F
Complete circuit of five-tube receiver for high-quality local reception, having several novel features........*Harvey Kees*

GEIGER COUNTER SPECTROMETER FOR INDUSTRIAL RESEARCH
New instrument measures X-ray intensities of rotating powder samples directly, for speedy analysis........*H. Friedman*

GASEOUS RECTIFIER CIRCUITS—PART I
Voltage and current wave forms of commonly used single-phase circuits, with pertinent equations........*P. T. Chin*

DESIGN OF L-C PHASE-SHIFT NETWORKS
Graphical analysis simplifies design of phase-shift networks for power circuits........*Robert W. Woods*

HYPERBOLIC CHART
Speeds conversion of complex numbers from hyperbolic to rectongular form........*Perry Ware*

ELECTRONIC INDUSTRIES (April 1945)

DESIGNING FILTERS FOR SPECIFIC JOBS........*Arthur H. Halloran*
THE VIBRATRON
WIRE FOOTAGE COUNTER
OWI-CBS 200 KW WEST COAST TRANSMITTER........*Robert N. DeHart*
MODERN LABORATORY SETUP
ALLOCATIONS NEARER
INTERFERENCE PROBLEMS........*John H. Bose*
MULTI-CHANNEL SOUND RECORDING ON FILM
ELECTRONIC TRAINER
RCA REVEALS PROJECTION TELE
THERMAL STABILITY IN RECEIVER OSCILLATORS........*Ralph R. Batcher*
REPEATER AMPLIFIER
ELECTRONIC RECORDER FOR FLIGHT TESTING........*Thomas A. Dickinson*
NINE PRODUCTION LINE SHORTCUTS
CAVITY RESONATORS........*W. Daellenbach*
DC PICTURE TRANSFER........*Henry N. Kozanowski*
NAVY RADIO EQUIPMENT
TUBES ON THE JOB

FM AND TELEVISION (March 1945)

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NOTES ON INDUCTANCE CALCULATION

A simplified method of designing a coil to give a desired value of inductance..........*William Vissers, Jr.*

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Practical data on setting up a high-power transmitter and getting it into operation..........*Harold E. Ennes*

MEASUREMENT OF RECEIVER CHARACTERISTICS, PART III

Information on approved receiver test methods..........*A. C. Matthews*

DIFFICULTIES IN MULTIPHASE FILAMENT OPERATION

An analysis of troubles encountered in operating filaments of transmitting tubes and how difficuties may be minimized..........*H. W. Baker & A. K. Wing, Jr.*

COMMUNICATION AND CONTROL RELAYS

A survey of relays with practical data regarding the characteristics and applications..........*Geoffrey Herbert*

MEASURING RESISTANCE OF HOT FILAMENTS

Describing a resistance bridge to test elements whose resistance changes with heat..........*A. K. McLaren*

PARALLEL RESISTANCE CHART

This chart differs from others in that the error in the resultant resistance shown is constant and within 1% of the indicated value..........*C. J. Merchant*

RADIO CRAFT (April 1945)

V.H.F. RADIO RANGE..........*Raymond Lewis*
FUTURE ASPECTS OF TELEVISION..........*Dr. Lee DeForest*
RADAR PRINCIPLES..........*R. L. Smith-Rose*
THE VISIE-TALKIE..........*Grego Banshuk*
RADAR, BATS AND SUPERSONICS..........*Dr. Robert Galambos*
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ROBOT TELEVISION TANK..........*Hugo Gernsback*
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A SIGNAL TRACER AND MULTITESTER..........*Harold T. Glenn*
TEST OSCILLATOR..........*Homer Davidson*
VOLTAGE DIVIDER DESIGN..........*Jack King*
CARRIER COMMUNICATOR..........*Bob Melvin*

RADIO NEWS (April 1945)

COMMUNICATIONS ON THE WORLD'S GREATEST AIRLINE..........*Lt. Col. Howard J. Haines*
DAD'S ADVICE TO G.I. JOE..........*Russell J Paige*
PHASING OF LOUD SPEAKERS..........*Nicholas B. Cook*
THE TELEVISION RECEIVER..........*Edward M. Noll*
A NEW PORTABLE DISC RECORDER..........*P. Peters*
EMERGENCY RADIO RECEIVER TESTS..........*Capt. Stuart D. Distelhorst*
DIRECT-READING IMPEDANCE METER..........*Guy Dexter*
SERVICEMEN'S GUIDE TO PRIORITY PURCHASING..........*Eugene Carrington*

RADIO NEWS (April 1945) *continued*

RADIO NEWS - Radio Electronic Engineering Edition (April 1945)

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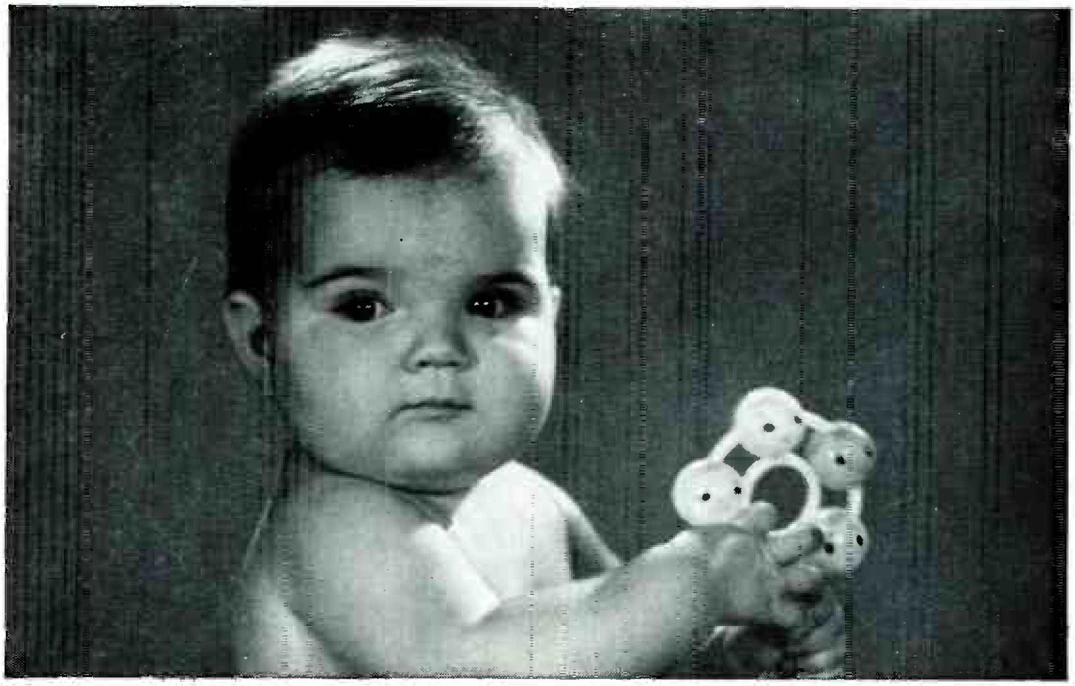
TELEVISION (April 1945)



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Chances are you're already on the Payroll Savings Plan. Saving as you've never been able to save before. This is fine *provided you keep on saving.*

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