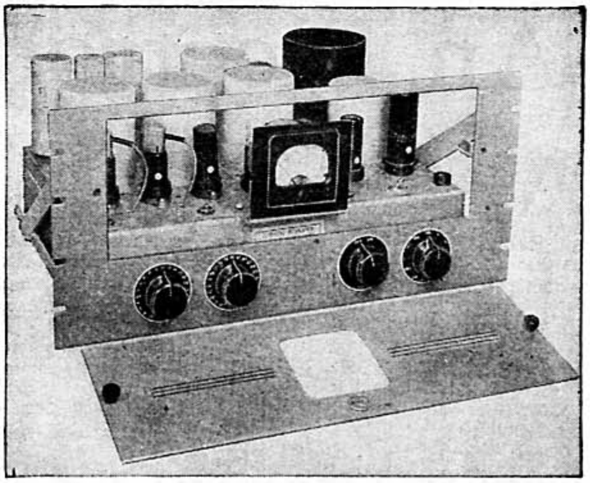
BROADCAST EQUIPMENT



PART VI—TRANSMITTING-STATION EQUIPMENT

By DON C. HOEFLER*

EVER since the inception of radiotelephone broadcasting, on that evening in 1907 when Dr. Lee DeForest demonstrated his great achievement before several guests atop New York's old Parker Building, a problem of ever-increasing consequence has been that of adapting the widely varying range of the program material to the fixed volume range of the amplitude-modulated transmitter. The volume range of the transmitter lies between that point corresponding to the innate noise level of the equipment and that level which corresponds to maximum (100%) modulation. This range is usually about 30 or 40 db, while the dynamic range of the program may be as great as 60 db or even more. Furthermore, the coverage of the transmitter is partially dependent upon its average degree of modulation. Volume compression and the technique of "riding gain" are therefore necessary adjuncts to the modern standard broadcast system.

The monitoring engineers at the control booth, master control room, and transmitter must compress the volume range by inserting loss during the exceedingly loud sections and removing loss during the passages at and below the inherent noise level. When this operation is accomplished efficiently, the modulation level is never low enough to harm satisfactory reception nor high enough to cause distortion. Despite the fact that the program level is monitored and controlled at several different points, this process remains very delicate and rather unreliable, requiring of the operator keen perception, physical co-ordination, and familiarity with musical compositions. It is further complicated by the fact that the higher the average degree of modulation is maintained, the oftener the peaks will override the maximum of 100%, causing distortion in the transmitted carrier with resultant distortion in the receiver. Since these overmodulation peaks occur with great rapidity, it is practically impossible for the monitoring engineer to compensate for them properly unless he knows beforehand exactly when they will occur. (The subject of modulation will be discussed in some detail in a future installment.)

It was with these inherent difficulties in mind that manufacturers developed the limiting amplifier. This is an amplifier so designed that its output cannot be increased beyond a predetermined maximum value. This desirable function permits the monitoring engineers to relax their diligence with assurance that the transmitter cannot be badly overmodulated, with the result that the average degree of modulation is raised and the station's coverage is thereby improved. Representative types of this equipment are the Western Electric 110-A and the R.C.A. 96-A, now succeeded by the 86-A. The former is shown in Fig. 1 and the latter in the photo above.

The gain of this unit is automatically lowered whenever the program peaks become excessively high. The basic principle of operation is similar to that of receiver automatic-volume-control, in that a small portion of the signal input is rectified to provide a bias control voltage to the amplifier input. Thus 6K7s are utilized in the input, exhibiting the variable-mu characteristic which is particularly useful for such operation.

The volume-compression circuit consists of the 6R7 duplex-diode triode, in which the triode amplifies a portion of the signal, which is rectified by the double diode, with the result that a varying D.C. bias voltage is produced across the resistance in series with the fixed bias on the grids of the first stage. As the signal increases, the bias becomes more negative and the gain decreases. This action is like delayed AVC in that it does not take effect until the audio signal level applied to the limiter tube exceeds its own fixed bias. It should be understood that this operation does not introduce excessive distortion by merely clipping the signal peaks, but rather it actually reduces the overall gain and then permits it to return slowly to normal. It must function quickly in order that sudden peaks may be efficiently compressed. However, much trouble would be experienced if the gain were able to fluctuate due to low-frequency audio notes. The circuit components are therefore so chosen that volume compression becomes effective in 0.001 second, but the gain is not fully restored to normal for about seven seconds. The compressor circuit may be removed by opening switch S1, in which case the unit operates as a straight linear amplifier.

The remainder of the circuit is quite conventional, with the 6N7 twin triode operating push-pull into a resistance-coupling circuit to drive the push-pull output. The 89 power pentodes are triode connected and thus operate class A1. A single meter, in conjunction with suitable shunts and multipliers and a switching arrangement, performs all the measuring functions indicated. With this equipment it remains necessary for the monitoring engineer to increase the gain whenever the signal gets "down in the mud," i.e., when it enters the area comprising the inherent noise level of the equipment.

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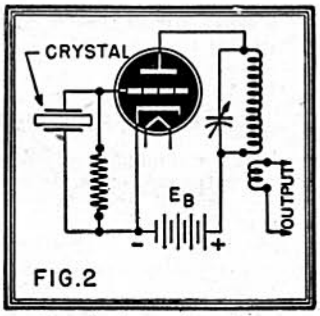

Fig. 2—Standard crystal oscillator circuit.

*Broadcast Engineer, ex WJLB-WLOU, Detroit, Mich.

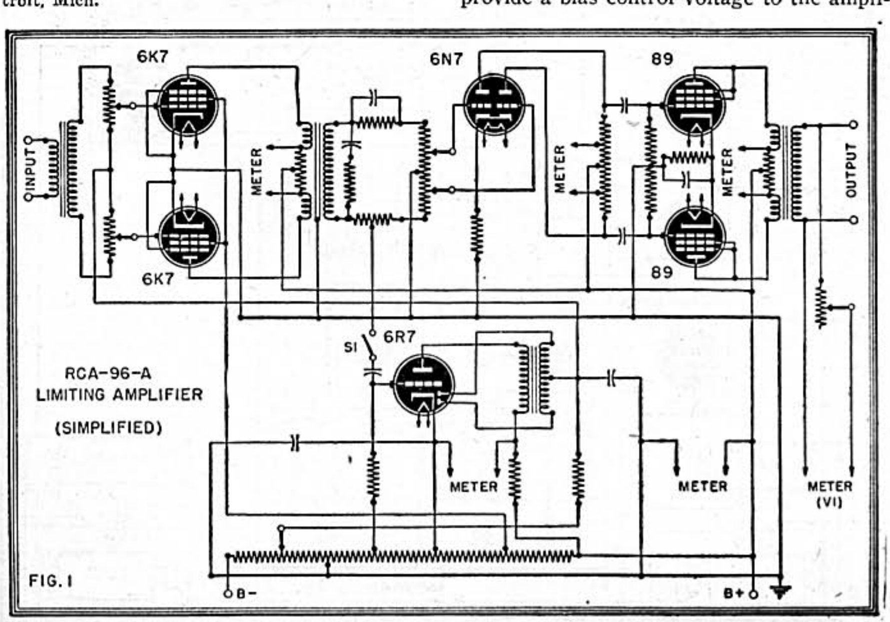

Fig. 1—A typical limiting amplifier, which automatically keeps program level within bounds.

An Electronic Mineral Locator

MANY methods, such as seismographic means and resistance measurements, are in use for determining the nature of the earth below its surface. A new principle, simple and effective, is now available in the field of prospecting, for locating surfaces of discontinuity and strata interfaces such as "marker beds" in oil fields. The inventor, Gary Muffly of Penn Township, Pa., has discovered that at such interfaces, distortion of an applied EMF takes place. Two low frequencies are transmitted through the earth and because of resulting distortion at surfaces of discontinuity, rectification and modulation occurs. Additional frequencies (sum and difference) are therefore present and may be detected and measured.

Previous difficulty due to natural ground currents is eliminated, since the latter are usually direct current or slowly fluctuating and cannot interfere with an A.C. detector. Frequencies used may be 100 and 80 cycles per second and voltages in the neighborhood of 1000. Modulation frequencies are therefore 20 and 180 cycles.

Fig. 1 shows the basic arrangements, wherein the electrodes in the earth form a square about 1000 yards on each side. The resultant current paths, both on the surface and below, form melon-shaped figures between electrodes. In a vertical plane half way between them the current path will be horizontal and cannot intercept any horizontal interface which may be present. The straight line joining a set of electrodes is therefore always in a neutral zone. If it exists at all, the modulation effect will be present in the intermediate zones, denoted by dotted lines.

To operate, a fixed electrode is set into the ground some distance from the square while a probe electrode is moved from one position to another. Voltages picked up are filtered (to remove the original 100 and 80 cycles), amplified and indicated on a meter. Equipotential lines and points of maximum potential may then be plotted in the area.

Fig. 2 shows what may be expected when different horizontal interfaces are encountered, for example that between a limestone stratum and one of sandstone. Plotting of voltages will result in a figure such as shown. Note that the voltages at opposite sides of the square diagonals are out of phase.

If the potential curve takes the form of curve A, it will be found that the interface is shallow, if the curve is like B, the interface is deeper and if like C, the discontinuity is very deep. For determining depth the important measurement is the *position* of the potential maximum rather than its value, which varies with the type of interface. The potential curve corresponds to points on a line through the center of the square and parallel to its sides. Fig 3 shows a sloping interface and resulting curve.—*I.Q.*

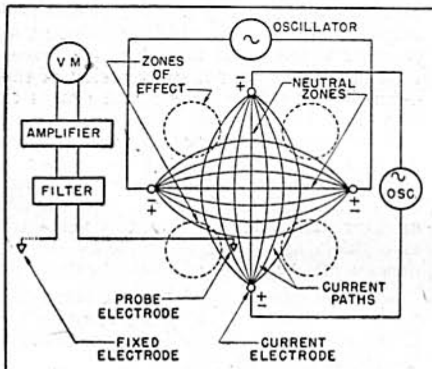

FIG. 1

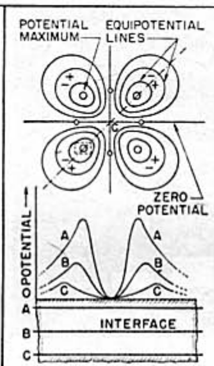

FIG. 2

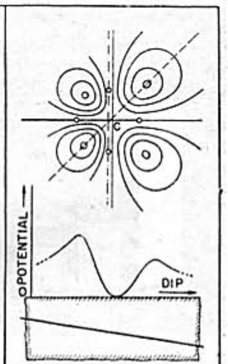

FIG. 3

BROADCAST EQUIPMENT *(Continued from page 283)*

As we have seen, the creation of a broadcast signal which will convey speech and music to the listener's receiver involves the production of a continuous R.F. carrier upon which there is superimposed the program, the wave-shape of whose signal is as nearly identical as possible to that of the original sound produced in the studio. The standard broadcast radiotelephone transmitter is that apparatus wherein a fundamental R.F. wave is generated, amplified, amplitude-modulated, further amplified (sometimes depending upon modulation level), and finally delivered into the radiating system.

The first consideration in the transmitter equipment is the oscillator, which originally generates the R.F. carrier. The F.C.C. requires that ". . . the frequency of all stations shall be maintained within 20 cycles of the assigned frequency." This means that a maximum frequency drift of ±10 c.p.s. is permitted. Oscillators controlled by crystals have the greatest frequency stability and are always used in broadcast transmitters.

In its simplest form the crystal oscillator appears as at Fig. 2. It utilizes the crystal's piezoelectric effect, which was previously mentioned in the discussion of the crystal pickup, wherein it was stated that an E.M.F. is generated between the faces of a crystal when a mechanical strain distorts its shape. The converse is also true—an electrostatic charge impressed across the faces will cause the crystal to change its shape. It is this latter property which causes the crystal to behave exactly like an ordinary tuned circuit, the equivalent of which is shown in Fig. 3. L represents the crystal mass which is effective in the vibration, C represents the mechanical compliance or rigidity, R represents the internal resistance due to friction, and C1 is the capacitance due to the holder electrodes and the crystal dielectric.

Several crystalline substances exhibit this piezoelectric effect; among them are quartz, Rochelle salts, tourmaline, and cane sugar. Rochelle salts are the most active in this property, but quartz is used almost exclusively for controlling the frequency of oscillators because of the important advantages it offers. It is inexpensive, has a low temperature coefficient, and is practically impervious to light, shock, moisture, and aging. Furthermore, due to its extreme hardness and low frictional coefficient, it has very low internal resistance, with the result that the circuit has a very high Q. Thus the resonance curve of a quartz plate is extremely sharp. It is this characteristic of the crystal that makes it particularly desirable for use in controlling oscillator frequency. In practice, the selectivity of a crystal circuit may be around 100 times that which can be obtained with an equivalent LC circuit.

It must be borne in mind that although the slab of quartz used as a resonator is usually referred to as a "crystal," it is not actually an entire crystal, but only a section of one cut to certain dimensions and specifications. Plates are cut from a natural quartz crystal at various angles to its electrical, mechanical, and optical axes, resulting in varying electrical and mechanical characteristics.

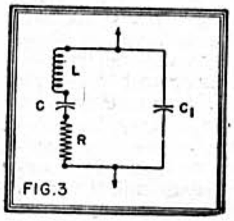

Fig. 3—The quartz crystal acts like a very high-Q coil-condenser combination.

Frequency stability of a quartz plate resonator depends upon the tuning of the output circuit, oscillator tube operating voltages, power taken from the tube, type of crystal cut, and ambient temperature. The first three factors depend upon the design and operating characteristics of the circuit, and are usually maintained constant. The latter two, however, are inter-related variables of considerable importance. The type of cut of the quartz plate determines its "temperature coefficient of frequency," which is usually expressed in terms of frequency change in cycles per second, per megacycle, per degree Centigrade. This coefficient may be either positive, i.e., frequency varies directly as the temperature, or negative, with frequency decreasing with increasing temperature. This calculation is not quite as complicated as it may first appear, and this can be best demonstrated by an actual example.

Suppose we have a 1,400-Kc. X-cut crystal, calibrated at 50° C., having a negative temperature coefficient of 20 cycles per megacycle per degree Centigrade, and we desire to find at what frequency it will oscillate at 60° C. First we see that the temperature has increased 10° C. Then at one megacycle the frequency would change by (10 x 20), or 200 c.p.s. Since the calibrated frequency is 1.4 megacycles, the frequency departure from this frequency would be (1.4 x 200), or 280 c.p.s. The temperature has increased and the coefficient is negative; hence the drift is minus and is subtracted. The new frequency is (1,400 –0.28), or 1,399.72 Kc. Any such calculation is made in this way, with due regard for the polarity of the coefficient.

Practical means of eliminating crystal drift will commence our discussion next month.

(To be continued)

NEW FM RECEIVING SYSTEM

(Continued from page 279)

features include an input impedance characteristic designed to improve lock-in operation of the oscillator. The discriminator also, by its narrow response range, shares some of the work of reducing response to amplitude variations in the signal.

The new system is not only likely to offer an improvement in FM reception—it will also render a service in pointing out that improvements may often best be made by attacking the problem from a new and unexpected direction.

Abstracted from "A Frequency-Dividing Locked-In Oscillator Frequency-Modulation Receiver" by G. L. Beers in the December, 1944, *Proceedings of the I.R.E.* Drawings are also reproduced by courtesy of the Institute of Radio Engineers.

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Dr. Frederick E. Terman, author of the standard works *Radio Engineering* and *Radio Engineers Handbook*, has been appointed dean of the School of Engineering of Stanford University at Palo Alto, California.

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1	14	15	4
12	7	6	9
8	11	10	5
13	2	3	16

ANSWERS TO ELECTRONIC PUZZLE

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The numbers add up to 34 in every direction, if answers are correct.

Industrial Electronics has achieved sufficient importance to warrant opening a school for training in that subject alone. The school is an activity of Industrial Electronics, Inc. and the Visual Training Corp., both of Detroit. Designed primarily for returning veterans, instruction is open to any qualified person.