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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

TELEPHONE TRANSMISSION MEASUREMENTS

THE problem of measuring transmission loss over telephone lines has been greatly simplified in recent years by the development of inexpensive and simple instruments for the generation and measurement of electrical power at the usual telephone levels and frequencies.

As speech is transmitted over telephone lines the amount of power available for operating the receiver of course decreases as the distance between the transmitter and the receiver becomes greater. This decrease of amplitude follows a more or less logarithmic curve with distance, which has led to the adoption of a logarithmic unit for designating losses encountered in telephone transmission.

The unit is the decibel. It is an outgrowth of the original "mile of standard cable" which was later changed with modifications in value to transmission unit or TU, and finally to the decibel, db.

The losses that may be encountered in some of the usual telephone lines are given in the chart* following.

Line	*Loss in db per mile at 1000 cycles*
No. 12 iron wire (metallic circuit)	0.30 db
No. 12 copper wire (metallic circuit)	0.068 db
No. 24 gauge cable	2.10 db
No. 22 gauge cable	1.75 db
No. 19 gauge cable	1.20 db

These losses are given at 1000 cycles because this frequency is one of the most prominent in the voice-frequency band and is generally used when single-frequency tests are being made. Of course, all telephone systems transmit the various frequencies of the voice with different amounts of attenuation. For this reason, in order to determine the actual transmission characteristics of a given voice transmission system, tests must be made at several frequencies in the audio-frequency band, extending from about 150 to 3000 cycles, or from perhaps 50 to 5000 cycles for high quality circuits over which music and broadcast programs are to be transmitted.

However, the human ear is much more sensitive to frequencies between 800 and 1000 cycles than to any others, and commercial telephone transmitters and receivers have their best response

*B. C. Burden, *Telephony*, Oct. 10, 1931.

at these frequencies. It is because of such factors that 1000 cycles is chosen for the usual routine measurements.

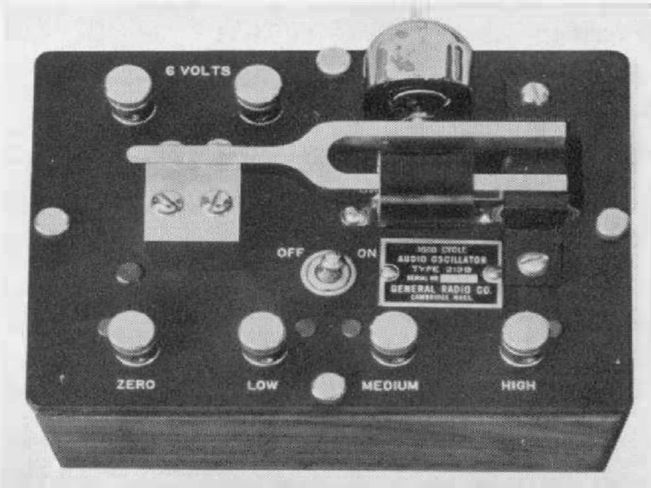


FIGURE 1. This electro-mechanical oscillator operates at 1000 cycles on power from 6 volts, direct current. The output circuit is a tapped transformer

A most convenient power source for such tests is the General Radio TYPE 213-B Audio Oscillator illustrated in Figure 1. This instrument has been described in detail in a previous issue.* The important characteristics that make it particularly applicable to the question under discussion are these:

1. It is simple and rugged.

2. Its power output is ample for any of the usual tests, 50 milliwatts or almost +10 db being available.

3. Its frequency is 1000 cycles to within very close limits.

4. It has a very stable output over a period of time, making the comparison of several readings a simple matter.

5. Its power supply is very simple. Four No. 6 dry cells are ample. The direct current required is only 130 milliamperes.

Three output impedances are available: 50, 500, or 5000 ohms. The 500-ohm tap is the most suitable for the usual telephone line measurements.

The question of how to measure these audio-frequency power levels has been met with complete satisfaction with the new copper-oxide rectifier type meter.

The rectifying unit itself consists of four copper-oxide to copper junctions arranged in the form of a bridge. Junctions of this sort conduct current from copper-oxide to copper much better than in the reverse direction from copper to copper-oxide. Therefore each unit has the properties of a half-wave rectifier. The four units in the bridge arrangement give full-wave rectification with resultant increased efficiency. Alternating current applied to the bridge results in a proportional direct current in the meter circuit. Such a-c indicators are very sensitive and respond readily to the low powers encountered in telephone practice.

A special application of this meter is the General Radio TYPE 586 Power-Level Indicator illustrated in Figure 2. This instrument is calibrated directly in decibels in order to facilitate measurements in this unit without any arithmetical calculations.

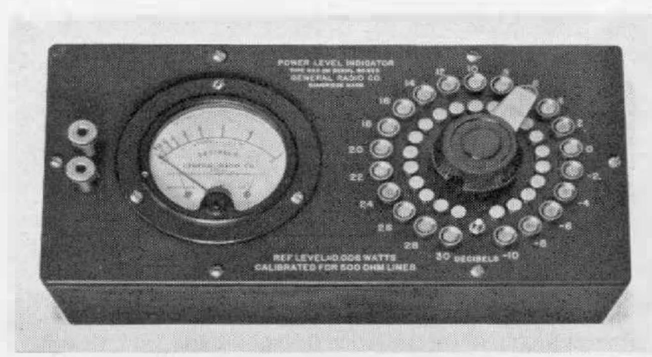


FIGURE 2. When bridged across the line, voltmeter fashion, this instrument indicates the amount of power that is being delivered to the 500-ohm line beyond the bridging point. It is direct-reading in decibels for a zero level of 6 milliwatts

*See General Radio *Experimenter* for April, 1930, copies of which can be supplied on request.

Since the impedance of the great majority of telephone lines is in the neighborhood of 500 ohms, the instrument is calibrated to read directly when used in circuits of this impedance. Six milliwatts is the zero reference level. There is a correction factor which is added or subtracted for lines of lower or higher impedance. Its value is given on a simple chart accompanying the instrument. In operation it is like any voltmeter; it is connected across the two-wire system under test and the power level read from the scale.

Two models of the instruments are available, differing only in sensitivity or range. The TYPE 586-A reads from −10 db to +36 db. The TYPE 586-C from −20 db to +36 db. Both are available for relay-rack mounting in permanent installations.

Many telephone companies maintain a regular check-up on the transmission characteristics of their lines. In this way any lines that are not satisfactory for commercial transmission are immediately detected and can be repaired before serious trouble results.

Such tests are so simple and inexpensive to make that the time expended is certainly well justified.

The 1000-cycle oscillator is connected to the pair under test at any convenient point, for instance, the main distributing frame, or the wire chief's desk. The power level at this point is read on the power-level indicator. A second power-level indicator is connected across the line at the remote point to which the test is being conducted. The difference in readings of the two indicating instruments in decibels gives the transmission loss directly.

The same test can be made on central office equipment to determine if all channels are operating properly. Cord circuits and repeat coils that become defective can be detected and located by this means before the trouble becomes sufficiently serious to interfere with satisfactory operation.

Some of the local-circuit losses that may be expected from normal equipment are given below:

Repeating coils for side circuits	0.70 db
Repeating coils for phantom circuits (two coils)	0.25 db
Magneto cord circuits	1.25 db
Common battery cord circuits	1.25 db

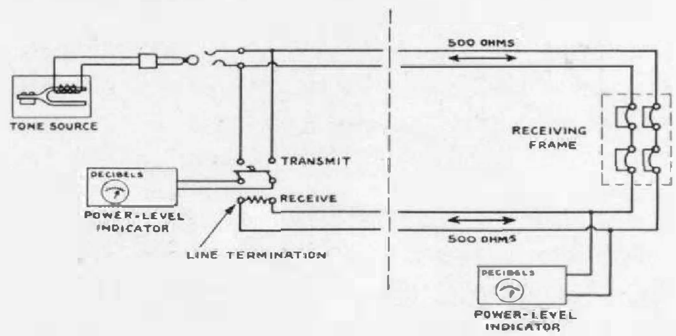


FIGURE 3. A convenient method of measuring line loss from one end when a duplicate pair of lines is available

Figure 3 shows a method for the measurement of long lines when two more or less similar pairs run between two distant offices. The two pairs under test are connected together at the distant end and the test equipment set up as shown. The power level at the transmitting end of the line is measured, then the switch is thrown to the receiving end and the level there measured. The difference in readings is the total loss of the loop. One-half of this value is the loss for the line in one direction only.

The maximum power level delivered by the oscillator is about +10 db and the lowest power that can be read on

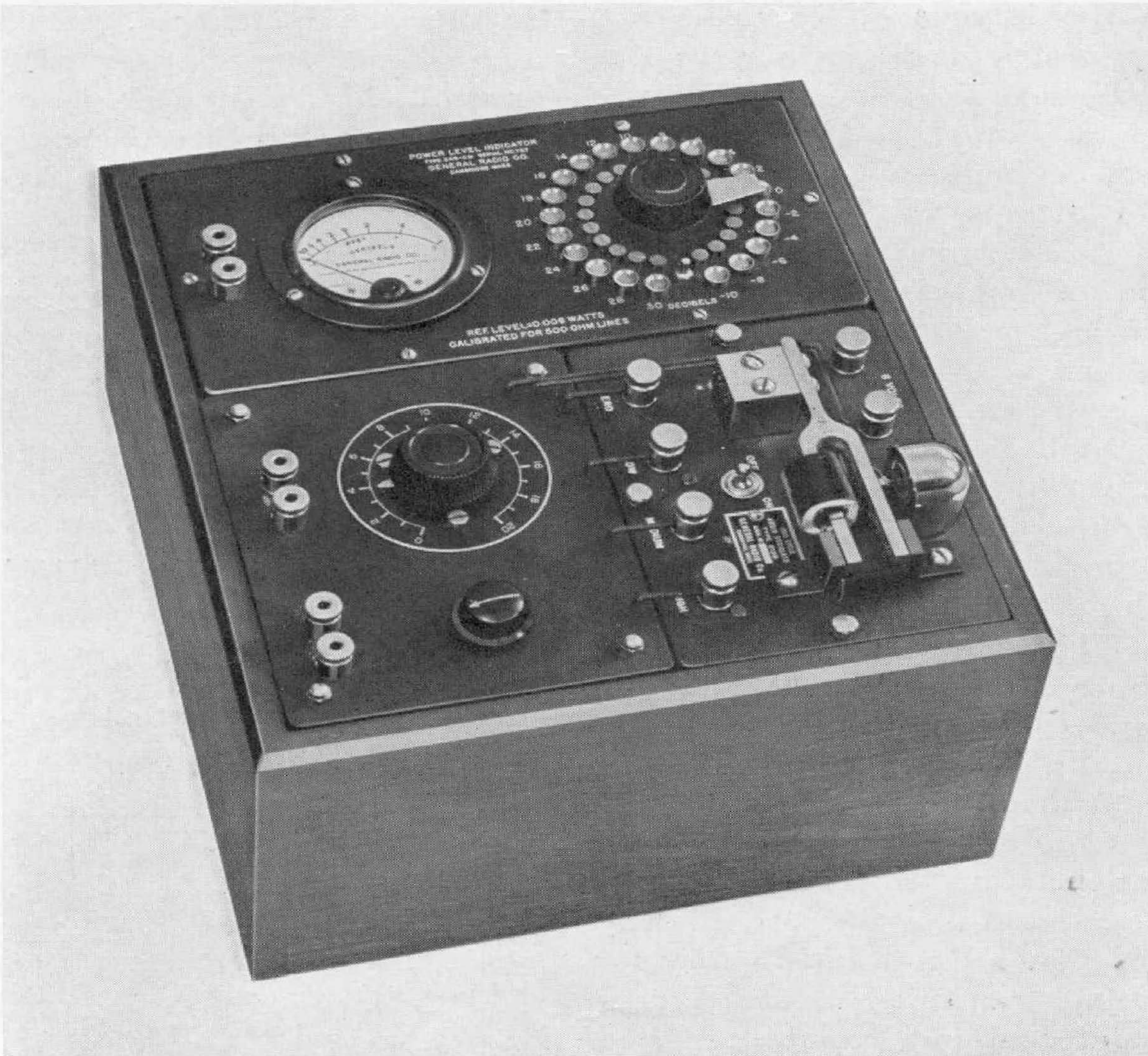


FIGURE 4. This assembly of a TYPE 213-B Audio Oscillator, a TYPE 586-CM Power-Level Indicator, and a potentiometer in a single unit makes a compact test kit for line tests. It can be made up to order, price on request

the more sensitive instrument is −20 db. Thus a total loss of about 30 db can be measured, corresponding to about 25 miles of No. 19 gauge cable, or 100 miles of No. 12 gauge iron open-wire circuit.

In order to make a check on the quality of speech and music transmission for broadcast lines, a variable frequency power source is substituted for the TYPE 213-B Oscillator. A beat-frequency oscillator such as the TYPE 613-A* is particularly recommended for this work.

The test frequency is set at a number of points from 60 to 6000 cycles and the loss at each frequency measured. A properly operating high-quality line should have a transmission loss that varies not more than 2 db to 4 db over this frequency range.

For the correct adjustment of line equalizers a test such as this is imperative.

In Figure 3 a power-level indicator is shown connected across the line at some distance from both ends of the line. This is to indicate that the power

*General Radio TYPE 613-A Beat-Frequency Oscillator. Frequency range, 10-11,000 cycles. Output power 35 milliwatts (+7.5 db). Price $210.00.

level at any chosen point on the line may be measured directly. Such tests are valuable as an adjunct to the linemen's usual tests. By such means a lineman can report to the office the exact power being delivered into a subscriber's loop for a given power supplied the line at the central office. Thus any faults in either central office or subscriber's loop equipment can be immediately uncovered by a much more precise and dependable means than by ordinary talking tests. The construction of the instrument is light and rugged enough to make it entirely suitable for such work.

Crosstalk tests can also be conducted by applying the tone source to one pair through a variable potentiometer that can be used to adjust the power level. The power-level indicator is used to monitor this level during the test. While listening on an adjacent pair, the power level is increased until the crosstalk heard in the adjacent pair under test becomes annoying. This level as read on the power-level indicator gives the information desired. On long repeater circuits levels from 0 db to +6 db are considered the maximum for safe transmission without crosstalk. Of course, on well balanced lines this level can be considerably exceeded before trouble results, and on short loops the limits are even higher.

The oscillator itself has, of course, many uses besides those mentioned above. It is widely used as:

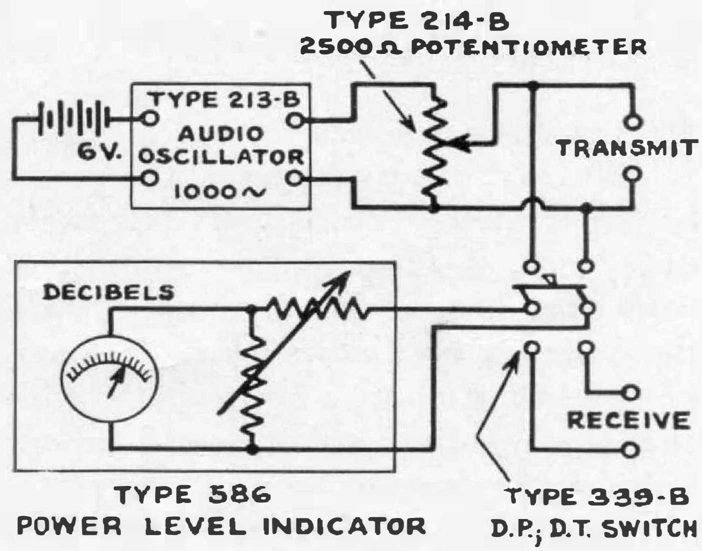


FIGURE 5. Wiring diagram for the test set shown in Figure 4

1. A tone source for use as an acoustic driver for testing telephone transmitters and similar equipment.

2. A tone source for identifying cable pairs.

3. A power source for the measurement of the gain in repeaters, public address installations, and other audio-frequency amplifiers.

Figure 4 shows a suggested arrangement for the audio oscillator, power-level indicator, and suitable auxiliary controls mounted in a cabinet for convenience and protection. The batteries for the oscillator are contained in the box, a potentiometer is provided to adjust the power output of the oscillator to any desired value, and a DPDT switch is used to transfer the indicator from TRANSMIT to RECEIVE as shown in Figure 3. A wiring diagram of such an assembly is given in Figure 5.

—ARTHUR E. THIESSEN

FREQUENCY STABILITY WITH THE SCREEN-GRID TUBE

IN the design of oscillators for use in frequency measurements, the problem of frequency stability is extremely important. A considerable amount of work has been done directed toward the design of oscillators whose frequency would not change appreciably with changes in supply voltages and tubes.

In single frequency oscillators stabilization of the frequency is not difficult. Usually a proper choice of circuit impedances is all that is necessary. It is considerably more difficult, however, to design a stable oscillator covering a frequency range of 50 to 1 with a single variable condenser.

It is generally conceded that the presence of harmonic voltages in the anode circuit of the oscillator is not conducive to frequency stability and, further, that an oscillator with good waveform is, in general, more stable than one with highly distorted plate and grid currents. An examination of the more common types of oscillator circuits indicates that the Colpitts circuit should have an advantage in this respect over other types, since the paths between plate and cathode and between grid and cathode offer low impedances to harmonics. This effectively short-circuits the harmonic voltages generated by the tube. Experimental work confirms this assumption, but, while it is better than most others, the Colpitts circuit is not inherently stable enough over wide frequency ranges to justify its use in precision apparatus unless some further stabilization is used.

It has been pointed out by Dow* that by properly proportioning the voltages applied to the plate and screen of a screen-grid tube, the oscillator frequency can be made nearly independent of changes in supply voltage. Figure 1 shows the variations in frequency resulting from grid- and plate-voltage changes in such a tube. Curve I is the change in frequency with screen voltage when the plate voltage is fixed at value B; Curve II shows the frequency change resulting from changes in plate voltage with the screen voltage held at A. Since the two curves have slopes which are approximately equal in magnitude and opposite in sign, it is evident that, if the tube is fed from a voltage divider so that normally the voltages on the screen and plate are A and B respectively, a change in total supply voltage can have no appreciable effect on the frequency. Any tendency toward a change in frequency due to a voltage change on one electrode is cancelled by an opposite change on the other.

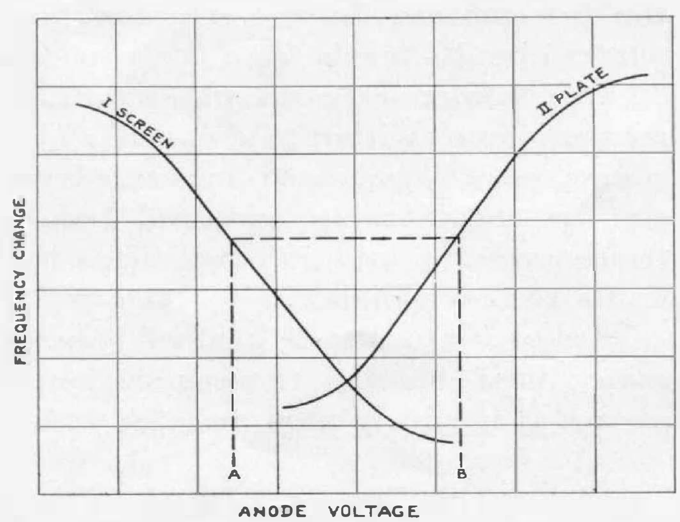


FIGURE 1. Effect on frequency of changing screen and plate voltages in an oscillator. In Curve I the plate voltage is fixed at B while the screen voltage varies; in Curve II the screen voltage is held at A and the plate voltage varies

*J. B. Dow, "A Recent Development in Vacuum-Tube Oscillator Circuits," *Proc. I.R.E.*, Dec. 1930.

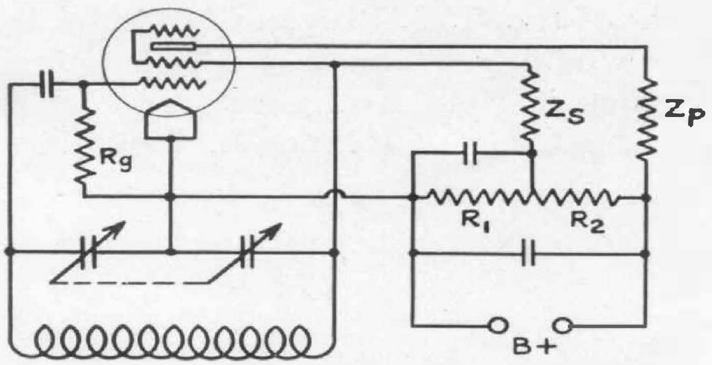


FIGURE 2. One form of voltage stabilized oscillator. The screen is used as the anode

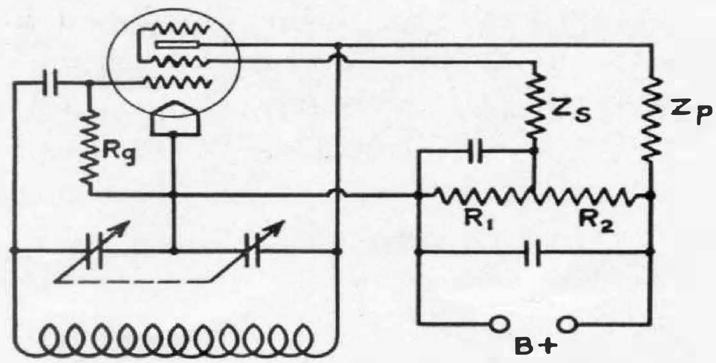


FIGURE 4. One form of voltage stabilized oscillator. The plate is used as the anode

When this stabilizing feature is applied to the Colpitts oscillator, the result is a system of unusual frequency stability. The effects of filament voltage and tube changes are greatly reduced, as well as those due to plate voltage. Figure 2 shows a simple form of this circuit. The impedances Z_s, Z_p, have some effect on the stabilization point, as does the grid leak R_g. The most stable operating point is found only by experiment, but can be located approximately by taking curves similar to those of Figure 1. Conditions differ between different types of tubes, but tubes of the same type are quite similar in operation. For optimum conditions with some tubes, the plate is at a lower potential than the screen, as shown in Figure 3.

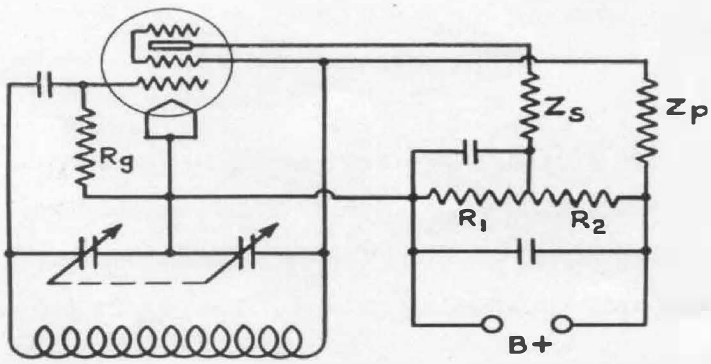


FIGURE 3. One form of voltage stabilized oscillator. Here the plate potential is lower than the screen potential

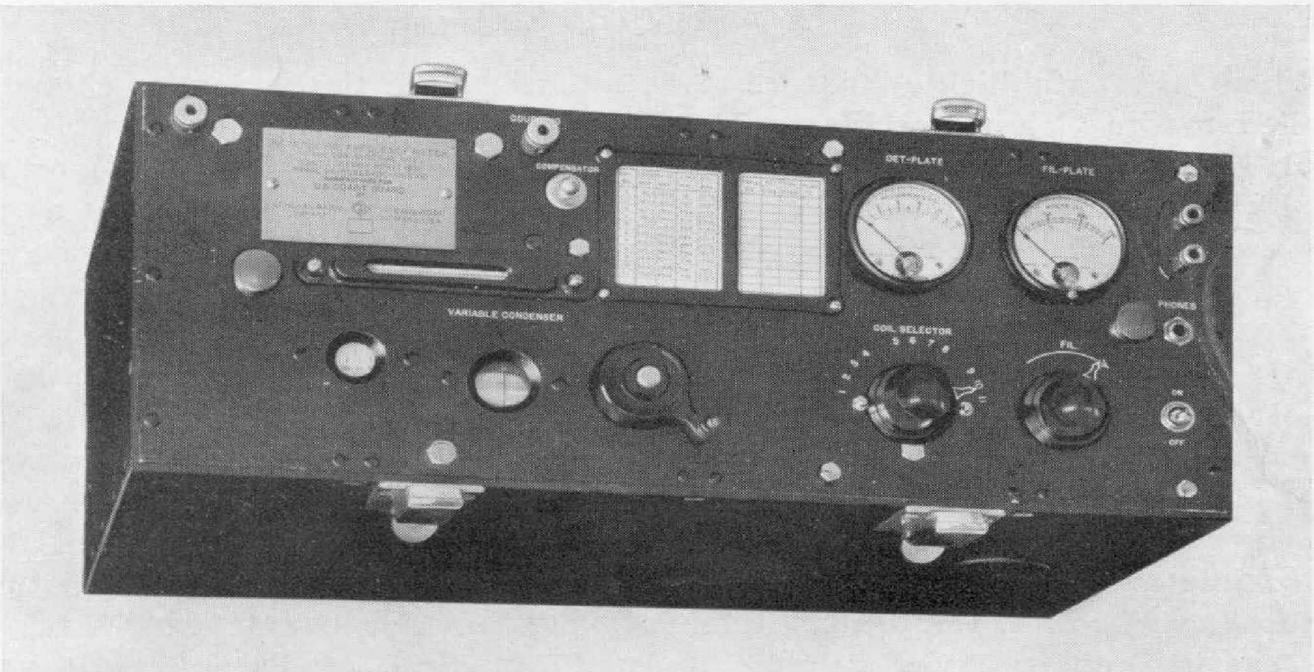
Either the plate (Figure 4) or the screen (Figure 2) may be used as the oscillator anode. When the screen is used, the plate circuit current wave is highly distorted, consisting of pulses at the oscillator frequency. Power may be drawn from this circuit at either the fundamental or a harmonic frequency without materially affecting the oscillator, particularly if the plate-screen capacity is neutralized.

The superior characteristics of the new stabilized oscillator circuit have been applied to a number of new General Radio instruments which will be announced within the next few weeks. A heterodyne-frequency meter covering all of the present commercial frequencies has been built around the new circuit. This instrument will be available in both alternating and battery-operated models, the latter being portable.

Another application of the new circuit is a linear-scale beat-frequency oscillator for measuring beats between standard harmonics and unknown frequencies. This instrument provides a means of interpolation between standard frequencies.

There has also been developed a combined oscillator and harmonic generator which is designed to take advantage of the 5-megacycle transmissions of the U. S. Bureau of Standards by providing a number of calibration frequencies based on the 5-megacycle standard. —CHARLES E. WORTHEN

A PORTABLE HETERODYNE FREQUENCY METER



A precision heterodyne frequency meter designed and manufactured by General Radio for the U. S. Coast Guard. This instrument covers a wide frequency range and employs a voltage-stabilized circuit like those described in the preceding article

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