The GENERAL RADIO EXPERIMENTER

VOL. VII. No. 6 NOVEMBER, 1932

ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

A SIGNAL GENERATOR FOR THE NEW RECEIVER TESTS

THE last few years have seen some great advances in the electrical design of radio receivers, particularly since the superheterodyne principle has been so widely adopted by many manufacturers. Both the type and technique of receiver measurements have undergone many changes since then, due partly to the general improvements in receivers and partly to the additional tests necessary with superheterodynes.

In measuring broadcast receivers a new method of measurement, the so-called two signal generator test, is receiving wide acceptance. With this method, two standard-signal generators are employed, one of which delivers to the receiver, through a dummy antenna, what is termed the "desired signal." This signal is a carrier to which the receiver is tuned and represents the program that is being listened to, to the exclusion of all others. Then, in order to determine how successfully the receiver eliminates the other undesired signals, a second signal generator is set up and also connected to the receiver. Its frequency is variable over a wide range and it represents any channel which might possibly interfere with the desired signal.

The requirements for the generator of the desired signal are very simple. Only three or four test frequencies distributed in the broadcast band are necessary. The three test frequencies recommended by the I. R. E. Committee on Standardization are 600, 1000, and 1400 kilocycles. Its amplitude need be adjusted to only three standard input voltages. Those recommended by the Committee are 50, 5000, and 200,000 microvolts, representing weak, medium, and very strong signals. Modulation at about 30% at 400 cycles is desirable for preliminary adjustment of the receiver.

The interfering signal generator is necessarily more complicated. In the first place, its frequency should be variable between approximately 100 and 5000 kilocycles. Its frequency calibration should be good (incidentally, the frequency calibration of the desired signal generator does not need to be particularly precise since it can be checked against the other instrument which must be calibrated). The frequency modulation must also be reduced to a low value; and the last and most important requirement is that its output be variable between 0.5 microvolt and 1.0 volt.

The method of making the test is simple. The desired signal is set at one of the test frequencies, for instance, 600 kilocycles, and adjusted to give an output amplitude of 50 microvolts. It is modulated so that the receiver may be tuned to it; the receiver's volume control is adjusted to give the standard 50-milliwatt power output. Once tuned, the modulation is turned off so that only the carrier is applied on the desired channel. The interfering signal generator is then turned on and its frequency is varied across a considerable frequency range. In most cases this should be about 100 kilocycles on each side of the desired channel.

The average user of broadcast receivers will find that, if his set is delivering an output power of 50 milliwatts, an interfering signal having a power of 50 microwatts is objectionable. On this assumption, the amplitude of the interfering signal is adjusted as it is swept across the undesired channels until an interference test output, that is, 50 microwatts, is observed from the receiver under test for points spaced every 10 kilocycles in the interference band. A curve can be plotted indicating the amplitude of the interfering signal necessary to give the 50-microwatts interference output. During all of these tests, the percentage of modulation of the interfering signal is kept at 30% at a frequency of 400 cycles. The test may also be repeated with the amplitude of the desired signal increased from 50 to 5000 and 200,000 microvolts.

One of the problems in the design of superheterodyne receivers is to elimi-

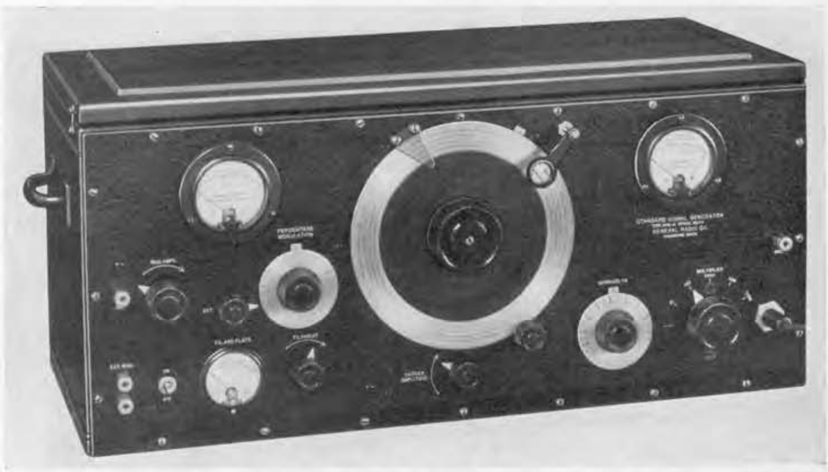

FIGURE 1. Panel view of a TYPE 603-A Standard-Signal Generator. The meters read the filament and plate voltages, modulation voltage, and carrier amplitude. Note the large frequency-control dial

nate various cross modulations which occur between the received signals and the local oscillator, particularly at the image frequency of the local oscillator. Other interference is due to direct pickup in the intermediate frequency amplifier. In order to determine the magnitude of this type of interference, a so-called "whistle interference test" is used. The tests are conducted the same as those described above, except that the interfering signal is unmodulated. Its frequency is varied across a wide band embracing the frequency of the intermediate amplifier and extending considerably above the frequency of the desired signal to include all possible points of cross modulation. In order that the audio-frequency system of the receiver shall not affect the test, a whistle when it occurs is adjusted to a frequency of approximately 400 cycles. The amplitude of the interfering signal generator is varied until the interference test output of 50 microwatts is obtained. Occasionally, it may be desirable, but it is not necessary, to vary the interfering signal by a very small amount so that the whistle frequency covers several points in the audio-frequency spectrum.

The requirements for the interfering signal generator are such that with a few additional controls it will also measure other important receiver characteristics. For instance, the over-all side-band response of a receiver can be determined by adjusting the frequency of the external audio modulation on the signal generator and noting the output-frequency characteristic of the receiver. The signal generator is set at one of the test frequencies in the broadcast band and 30% modulation at 400 cycles is applied. The gain of the receiver is adjusted so that the 50-milliwatt standard output is obtained. The audio modulation is varied from about 40 to 5000 cycles and the output power from the receiver is noted at various frequencies.

In making a test of this sort, the output load for the receiver can be either a rectifier-type meter having a resistance corresponding to the impedance into which the output tubes are designed to work, the output transformer having been removed or its secondary opened; or it may be a high-resistance output meter connected across the voice coil of the dynamic speaker. In the latter case, however, changes in the voice coil impedance due to its frequency characteristic and motional impedance will enter into the measurement. If the receiver is equipped with a tone control, the effect of this control on the frequency characteristic can also be observed.

Often it is very desirable, particularly when using pentode output tubes, to investigate the effect of various load impedances on the performance of the tubes. The General Radio Type 583-A Output Power Meter has an impedance which is variable between 2.5 and 20,000 ohms. It can be used either in place of the voice coil of the dynamic speaker or the primary of the output transformer. The difference in power delivered to varying loads for a given modulated radio-frequency input to the receiver can be noted by the various settings of the impedance switch.

With the general requirements in mind of the standard-signal generator necessary for the above tests the General Radio Company has developed the Type 603-A Standard-Signal Generator. This instrument is intended to

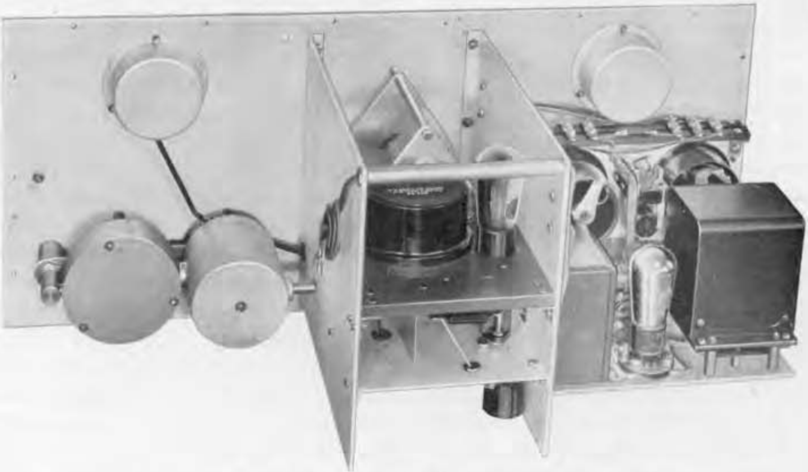

FIGURE 2. Rear view of the TYPE 603-A Standard-Signal Generator with the cabinet removed. The left-hand compartment contains the attenuator system and shielded thermocouple meter. The attenuator is divided into two sections, each housed in an aluminum casting

have the utmost flexibility. It is not restricted to the measurement of receivers in the broadcast band, but its frequency range has been extended to include most of the frequencies now in general use for radio transmission. As specifically applied to the requirements of the interfering signal generator and for the generator to be used for measuring the audio-frequency response, the TYPE 603-A Standard-Signal Generator has the following characteristics. The frequency range between 100 and 4400 kilocycles is covered by five coils. Two of these cover the broadcast band and have a combined range from 420 to 1900 kilocycles. The output voltage is continuously adjustable from 0.5 microvolt to 1.0 volt.

The ability to set and reset the carrier frequency of a standard-signal generator is of considerable importance. In order to facilitate this, a large and accurately engraved tuning dial is used. It is 8 inches in diameter and engraved around 270° of its circumference with 600 divisions. A magnifying glass is provided so that parts of a division may be read easily to improve the accuracy of setting. Fifths of a division can be very easily estimated. In the high frequency portion of the broadcast band, the coil has a range from 850 to 1900 kilocycles. The tuning dial has 600 divisions. This means a frequency change of about 1750 cycles per division for the coil span of 1050 kilocycles. Estimating fifths of divisions, the tuning can be set easily to within 350 cycles. The tuning condenser, incidentally, is straight-line frequency so that linear interpolation is possible.

The internal modulation system consists of a 400-cycle audio-frequency oscillator which delivers sufficient power for 90% modulation of the carrier. Its frequency is adjusted within ±20 cycles. The modulation percentage is continuously variable and the accuracy of calibration is such that when set for any given modulation it will be correct to within 10% of the percentage of modulation, using either internal or external modulation at 400 cycles.

The frequency characteristic of the modulation system is good and external modulation can be used with considerable accuracy over a wide frequency range. The highest audio frequency that can be used will depend upon the frequency of the carrier being modulated. The highest audio frequency that will produce an effective carrier modulation within 1 decibel of the modulation meter indication is about 1.5% of the carrier frequency. On low-frequency coils, this is the limiting factor. On higher-frequency coils, the radio-frequency filter and audio-frequency meter in the modulation circuit limit it to about 6000 cycles for an error of 1 decibel, or 10,000 cycles for an error of 2 decibels.

Very low power is required to modulate the instrument. Modulation at 30% is obtained by a power of about 60 milliwatts. The impedance at the external modulation terminals is about 5000 ohms.

The design of a flexible and accurate signal generator involves several important considerations. Two of the outstanding ones are the design of an attenuator that will operate successfully over a wide range of radio frequencies, and the reduction of stray fields to such a level that they do not enter into measurements when using the signal generator at very low output voltages. The attenuation system of the Type 603-A Standard-Signal Generator is such that essentially no measurable errors creep into its attenuation characteristics at frequencies up to and through the broadcast band. Some errors are involved in the actual direct-current calibration of the resistors and errors inherent in the direct-current d'Arsonval meter used with the thermocouples. These aggregate about 3%. At 10,000 kilocycles, the error in the attenuator becomes measurable and amounts to about 7%, which, together with the other errors mentioned above, give a total error at this frequency of perhaps 10%. At 25,000 kilocycles, all errors total to about 20%. By a careful design and layout of the oscillator and attenuator circuits, together with good shielding and use of toroidal coils in the oscillator circuit, the leakage is reduced to a point where it cannot be measured unless a highly sensitive receiver is connected directly to a multi-turn pickup coil, which is placed within a few inches of the panel of the instrument. These fields are in general so small that they do not affect measurements at 0.5 microvolt, even when using an unshielded receiver.

—A. E. Thiessen

* * * * *

The price of the Type 603-A Standard-Signal Generator is $600.00 with two calibrated coils for the frequency band from 420 to 1900 kilocycles. Additional calibrated coils for the complete frequency range of the instrument from 100 to 25,000 kilocycles are priced from $10.00 to $15.00 each, depending on the range. Calibration curves, if desired, cost $5.00 each additional.

A DIRECT-READING METER FOR POWER AND IMPEDANCE MEASUREMENTS

FIGURE 1. Panel view of a TYPE 583-A Output Power Meter, showing the available impedance settings and the meter scale

It has heretofore been necessary, when power measurements were to be made over a wide range of impedance values, to use a decade resistance box and a meter to indicate current or voltage. With data so taken, the power can be calculated, and from a plot of power delivered versus load resistance, the internal impedance of the source under measurement can be determined.

This is a laborious process and in addition it consumes a good deal of time, especially when data for several such curves must be taken as the characteristics of the circuit under measurement are varied. An instrument which indicates directly power and impedance enables these measurements to be made simply and conveniently and is an extremely useful tool in the communication laboratory.

In the May, 1932, *Experimenter* the TYPE 583-A Output Power Meter which was designed for this purpose was briefly described.*

This instrument consists of a variable ratio transformer, a loss adjusting network to give constant loss at all ratios, a meter multiplier network, and a copper-oxide rectifier-type meter.

The impedance range is extremely wide, extending from 2.5 ohms to 20,000 ohms. This is a ratio of 8000:1 and more than covers all the impedance values likely to be encountered in communication measurements.

The ratio of maximum to minimum power which can be read on the meter is 5000:1, extending from one milliwatt to 5 watts. An auxiliary scale in decibels referred to a zero level of one milliwatt is also included.

The input impedance of the instru-

*John D. Crawford, "A Power Meter with a Wide Impedance Range."

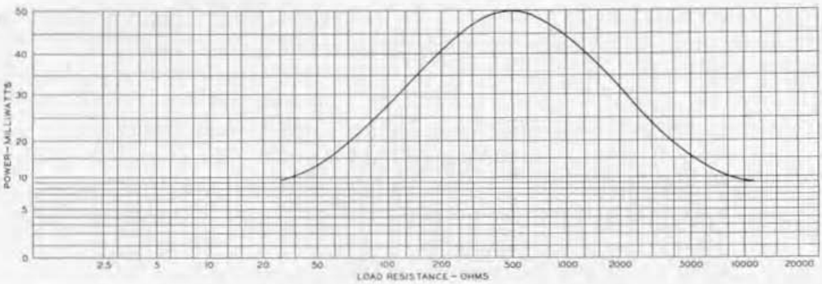

FIGURE 2. A curve of power output versus load resistance for a generator with a 500-ohm internal impedance

ment is adjustable in 40 steps spaced at approximately logarithmic intervals. This feature is of considerable importance. Figure 2 shows a plot of power output against load resistance for a device having an internal impedance of 500 ohms. The vertical lines on this plot correspond to the impedance values available in the power output meter, and these points are sufficiently close together so that the maximum power can be easily determined. Since the load impedance scale is logarithmic, the curve is symmetrical about the maximum power point. With logarithmic steps of impedance, therefore, the impedance corresponding to maximum power output can be closely estimated as the impedance switch is varied.

The vertical scale intervals of Figure 2 correspond to the angular deflection on the scale of the indicator. Since a copper-oxide voltmeter has an approximately linear scale, the scale for power calibration follows an inverse square law. This spreads out the low end of the scale allowing the meter to be read closely at low scale deflections.

Although the impedance can be varied by a ratio of 8000:1, a high accuracy of indication is obtainable over the greater portion of the useful frequency range. The error in full-scale power reading does not exceed 0.3 db between 150 and 2500 cycles per second and the average error between 30 and 5000 cycles is also not greater than 0.3 db. Since the variable-ratio transformer cannot be an "ideal" one, somewhat larger errors occur at the high and low ends of the useful frequency range. Between 20 and 10,000 cycles per second the average error is 0.6 db and the maximum error at any impedance setting at these extreme frequencies is 1.5 db.

The impedance error is also quite small over the greater portion of the frequency range. Between 150 and 3000 cycles per second this error does not exceed 7%. The average error between 30 and 5000 cycles per second is 8%. Since the accuracy of the best copper-oxide indicating element is only about 4%, these figures show that the other circuit elements are held to extremely small tolerances. At higher and lower frequencies, as might be expected, the impedance error increases, and the average error between 20 and 10,000 cycles per second is 20%. At the two extreme frequencies of 20 and 10,000 the maximum impedance error at any setting is 50%.

An analysis of these figures, particularly with reference to the curve of Figure 2, will show that they are, for the most part, negligible except at the highest and lowest frequencies.

The TYPE 583-A Output Power Meter is not intended to be a precision instrument and the uses for which it is designed do not usually justify precision methods. It combines convenience, wide range, and low price with a reasonable degree of accuracy and permits a high degree of accuracy over a somewhat smaller range.

To the communication engineer the uses of this instrument are obvious. Wherever power and impedance measurements must be made: in the design and testing of filters, transformers, and other networks; in measuring the power output of vacuum tubes; in making many of the standard tests on radio receivers; its use saves a considerable amount of time hitherto spent in manipulation and in calculating results.

It is useful in determining directly the power output of a generator or other source as a function of load impedance and the internal impedance of the source can be determined by means of the maximum power output point.

In matching loudspeakers to vacuum tubes, it is often necessary to make several series of observations in order to simulate the varying impedance characteristics of the speaker. For this purpose, the TYPE 583-A Power Output Meter gives the desired results very quickly. It is sufficiently sensitive to measure directly the output of a phonograph pickup in order to determine its internal impedance and output power level.

The price of the TYPE 583-A Output Power Meter is $95.00.

A NEW PLUG GROUP

674-D 674-J 674-P

TYPE 674 PLUGS AND JACKS

The prices of the TYPE 674 Plugs and Jacks were incorrect as listed in the October issue of the *Experimenter*.

The correct prices are:

TYPE 674-P All-Metal Plug	$0.35
TYPE 674-J Jack	.25
TYPE 674-D Insulated Plug	.50

THE GENERAL RADIO COMPANY mails the Experimenter, without charge, each month to engineers, scientists, and others interested in communication-frequency measurement and control problems. Please send requests for subscriptions and address-change notices to the

GENERAL RADIO COMPANY

30 State Street - Cambridge A, Massachusetts

PRINTED IN U.S.A.