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The Standard-Signal Method of Measuring Receiver Characteristics

By Charles T. Burke

THE "standard signal" method of rating radio receivers has met with general acceptance since its proposal several years ago. This method of receiver evaluation requires an accurately known voltage of known degree of modulation adjustable over a wide range, including values of very small magnitude. The input to the receiver is adjusted until a standard output power is obtained and the input voltage is taken as a measure of the receiver sensitivity.*

The functional diagram of Figure 2 illustrates the arrangement and use of the equipment required by these tests. The output of the modulated radio-frequency oscillator is passed into an attenuator consisting of a resistance

*L. M. Hull, *Proceedings of the Radio Club of America*, October, 1928; *I. R. E. Yearbook*, 1929, pp 106–128.

Figure 1. Type 403-C Standard-Signal Generator, front of panel view

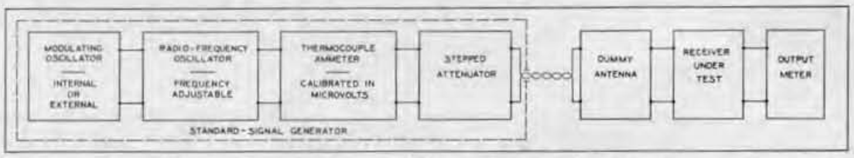


FIGURE 2. Outline showing component parts of the standard-signal generator and auxiliary equipment required for making sensitivity, selectivity, and fidelity characteristics on radio receivers

network so designed that its attenuation over the operating frequency range can be calculated from its constants. The attenuator is coupled to the receiver through a dummy antenna of prescribed constants. The power output of the receiver is measured by any one of several satisfactory methods.

The method of measurement outlined above forms the foundation for a complete test of receiver performance. In establishing the rating of a receiver, a series of sensitivity measurements at frequencies including the entire operating band would be taken. Selectivity curves, i.e., curves of sensitivity for signals differing in frequency by increasing amounts from that to which the receiver is tuned, at a number of frequencies throughout the band can be plotted from data obtained in the same manner. The output of the radio-frequency oscillator is adjusted as the oscillator frequency is changed in small steps, so that the receiver output is kept constant. The frequency to which the receiver is tuned, the frequency of the oscillator, and the voltage input to the receiver are recorded. From these data, a selectivity curve may be plotted showing the strength of interfering signal required to give the standard output as the separation between the received and interference signals is increased.

The same principle of measurement and type of equipment can be used in investigating the operation of portions of the receiver circuit. Thus a single radio-frequency stage or the entire radio-frequency amplifier could be measured, or detector characteristics could be investigated.

The principal component of the equipment required for these tests is a modulated radio-frequency oscillator provided with means for adjustment of its output voltage to known values over a wide range. The essential requirement of a generator for this purpose is that it produce an accurately known voltage between its output terminals and nowhere else. It is readily realized that if the receiver picks up energy from the generator in addition to that measured at its input terminals, the test will be of no value. The first two requirements of the generator are, therefore, adequate shielding and a means of adjusting and accurately determining its output voltage over a wide range including very small magnitudes. The problem of shielding, while quite troublesome, involves only the application of known principles.

It is necessary to obtain output voltages of a few microvolts. Since there is no known method of measuring such voltages directly, it is necessary to attenuate a measurable voltage by means of a calculable network in order to obtain voltages of this magnitude. The design of an attenuator which is accurate at broadcast frequencies is a problem of considerable difficulty. The voltages involved at the lower ends of the attenuator are so small that minute pickups and ground currents will greatly affect the output voltage. The design of such an attenuator involves not only the design and layout of units which will have negligible reactance in themselves, and between units in the attenuator assembly, but also the location of grounds and return conductors.

The General Radio Company in coöperation with the Radio Frequency Laboratories, Inc., brought out its original Standard-Signal Generator, the Type 403, in June of 1928. This instrument provided a modulated output in the broadcast range adjustable between 2 and 200,000 microvolts. Complete shielding of the generator permitted its use with unshielded receivers.*

While the Type 403 Standard-Signal Generator proved entirely satisfactory for the uses for which it was designed, development work directed particularly at the elimination of its three principal limitations was continued. First, and probably most important, it was not readily adaptable for use at frequencies outside the broadcast band. Second, the radio-frequency oscillator was required to deliver so much power that external batteries were necessary, which seriously impaired the usefulness of the instrument for such purposes as field-strength measurements where portability is an important consideration. Third, the elaborate shielding made the process of changing tubes or making other adjustments inside the generator excessively involved.

As a result of this program, the new Type 403-B Standard-Signal Generator was placed in production last summer. The most radical design change was the lowering of the power in the oscillating circuits. The older model used 112-type tubes with 135 volts on the plate, and its radio-frequency oscillator delivered 100 milliamperes to the attenuator system. In the Type 403-B Standard-Signal Generator 12-type tubes were used with a plate-battery voltage of only 45 volts; the input to its attenuator was only 5 milliamperes. This reduction in level of the power input to the attenuator accomplished two of the objects of the redesign. Since the amount of shielding largely depends upon the power level in the oscillator circuit, the change permitted a very extensive simplification of the shielding system. The smaller batteries could be

*"Rating of Radio Receivers," *General Radio Experimenter*, November, 1928.

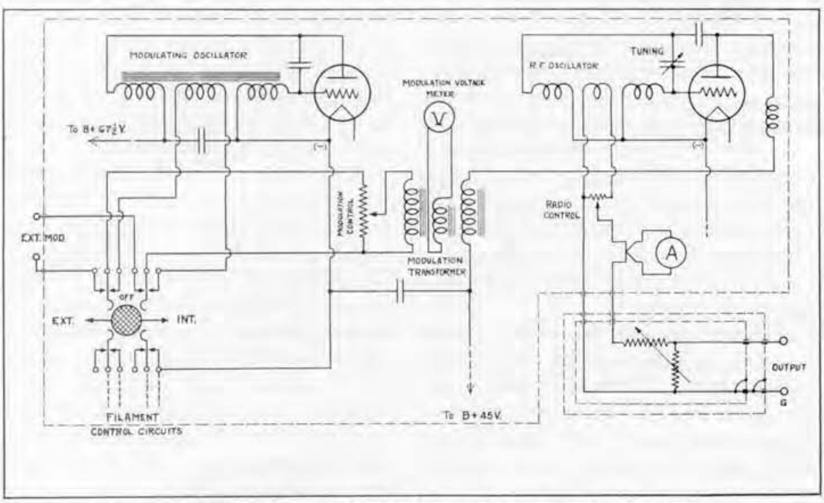


Figure 3. Functional schematic of Type 403-C Standard-Signal Generator

placed inside of the instrument without increasing the cabinet size. The oscillating circuit was also redesigned to permit the use of plug-in coils, thus extending the frequency range of the instrument.

Development work on the generator, particularly on attenuator systems, was actively continued, even after manufacture of the new instrument was started. The problem of attenuator design is peculiar in that it is more difficult to check the performance of attenuators at low output levels than to design them. The attenuator system had a total voltage attenuation ratio of 20,000 to 1 with minimum outputs of a few microvolts at radio frequencies. There is no known method of measuring a microvolt of alternating current directly. All methods of measurement of voltages of such magnitude are comparison methods and involve at least as great a possibility of error as does the attenuator system being checked. Four methods of comparison are available. Two attenuators of different construction but identical ratios may be connected in cascade. As the attenuation of one is increased and that of the other is decreased by the same amount, the output should remain constant. The validity of this method rests on the reasonable belief that two attenuation systems of different construction would not have compensating errors at all attenuations and at different frequencies. It is subject to the disadvantage that there is no direct indication as to which attenuator is responsible for any error that may appear.

Another method varies the current input to the attenuator as the attenuation is changed. This method is necessarily confined to a limited range of attenuation steps, since the current input to the attenuator must be kept within the operating range.

A third method of attenuator calibration is to observe the output of a radio receiver as the input is increased. This involves a knowledge of the detector characteristic of the receiver amounting to a calibration of the receiver. The difficulty of such calibration without a source of known input voltage is obvious.

A fourth method is to heterodyne the output of the attenuator under test, and amplify it at a lower frequency. An attenuator, calibrated at the lower frequency included in the low-frequency amplifier, is used to check the high-frequency attenuator.

All four methods depend upon an unknown receiver characteristic to determine the amount of difference in the two voltages compared. If there is no difference, however, the receiver characteristic does not enter the measurement except when the third method is used.

It is the opinion of those most familiar with the problem that it is impossible to obtain a voltage attenuation ratio of 2 to 1 at 1000 kilocycles with a smaller probable error than 1 per cent. The range of the attenuator used in the standard-signal generator includes fourteen 2 to 1 ratios. The probable error of such a system may, therefore, be about 15 per cent. It should be noted that this is a limitation of the method of checking the attenuator, not necessarily of the attenuator itself.

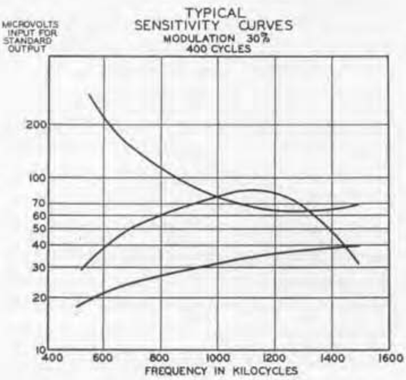
With improved methods of checking the attenuators, several sources of error were discovered, necessitating changes in the attenuator system. Coupling to the attenuator leads was found to exist, as well as coupling between input and output sections of the attenuator, which had a total voltage attenuation ratio of 20,000 to 1 in a single shielded compartment. It was also found that heavy currents flowing in the shielding about the attenuator set up fields which coupled into it.

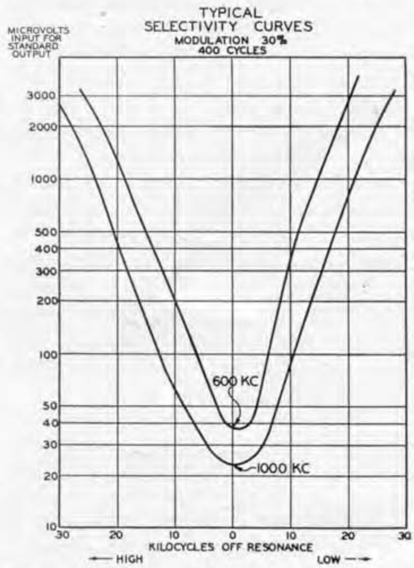
Several measures were adopted to

overcome these difficulties. The use of a type of concentric conductor in which the low potential side of the circuit forms a shield for the high potential side eliminated the trouble due to voltages induced in the wiring. Capacity coupling between the two ends of the attenuator was eliminated by dividing it into two sections and shielding them from each other. The entire assembly was then placed in a separate shielded compartment electrically isolated from the main shielding except for a connection at one point.

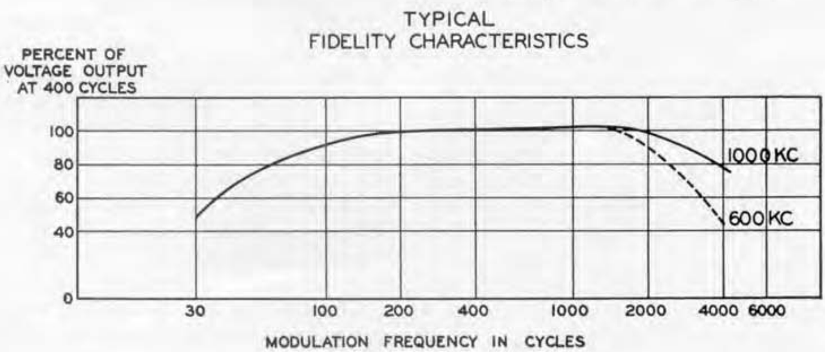
With the new attenuator, which is a conventional **L**-network, a maximum total probable error in the attenuator system of less than 15 per cent. is indicated. In other words, the error in the smallest output voltage due to the attenuator is less than 15 per cent. if all of the individual errors between steps were cumulative. The possible cumulative error, of course, decreases as more sections of the attenuator are removed from the circuit to obtain the higher voltages.

The Type 403-C Standard-Signal





Typical broadcast receiver characteristics: Figure 4—Sensitivity curve; Figure 5—Selectivity curve; Figure 6—Fidelity curve



Generator, as the latest design of the new instrument has been designated, consists essentially of a modulated radio-frequency oscillator. The tuning range covered by five coils extends from 15 to 1500 kilocycles. In addition to the main tuning condenser, a secondary frequency control is provided for use in taking selectivity curves, where a small change in frequency is desired. This control consists of a copper sector which moves in the field of the tuning coil and changes its inductance.

Since the frequency change due to this adjustment results from a change in inductance, the percentage change in frequency for a given setting is not directly affected by the setting of the main tuning control, which changes the capacity in the circuit. Modulation is provided for with a 400-cycle vacuum-tube oscillator included in the generator. Terminals for external modulation with input leads properly filtered to eliminate radio-frequency leakage are also provided. The external oscillator should be capable of maintaining about 15 volts across 2500 ohms in order to produce 30 per cent. modulation.

The input current to the attenuator is read on a thermocouple meter calibrated in microvolts, and the attenuator is calibrated as a multiplier. The attenuator has a non-reactive output impedance of approximately 10 ohms at all steps except the two corresponding to greatest output voltage.

The entire assembly is enclosed in a shielded cabinet. Filter circuits are included in the leads to the meters, making screening in front of the meters unnecessary. The instrument can be used with unshielded receivers without any pickup from the generator. The most sensitive receivers available have failed to detect any signal voltage when connected to the generator with the generator output switch set at zero.

A standard dummy antenna made in accordance with the specifications of the Institute of Radio Engineers is available. Its constants are:

Inductance . . .	20 microhenrys
Capacitance . .	200 micromicrofarads
Resistance . . .	25 ohms

The effective height is taken as four meters.

The TYPE 403-C Standard-Signal Generator requires two 12-type vacuum tubes for operation. Space is provided in the cabinet for the necessary batteries; i.e., 1.5 volts for the filament, and 45 volts and 67.5 volts for the plates of the radio- and modulating-oscillator tubes, respectively.

The TYPE 403-C Standard-Signal Generator possesses the features required for the measurement of receiver characteristics with facility. The voltage of the output system is continuously variable over a wide range. Leakage is reduced to a minimum, permitting the measurement of very sensitive receivers. Selectivity curves may be rapidly run by use of the fine adjustment on the frequency control. The use of external modulation makes over-all characteristics readily obtainable.

The curves of Figures 4, 5, and 6 are illustrative of the type of receiver data that is obtainable with the signal generator. The effect of side band cutting is noticeable on the audio-frequency characteristic of Figure 6.

While the standard-signal generator is used extensively in receiver testing, both in the laboratory and the production line, its uses are not limited to receiver performance tests. Another wide range of usefulness of an instrumnet of this sort, producing a known voltage of small magnitude, is in the measurement of the radio-field intensity (field strength) of transmitters. The portability of the instrument, with all batteries contained in the cabinet, is of particular advantage in this connection.

Straight-Line Wavelength, Straight-Line Frequency, and Straight-Line Capacitance Condensers

By John D. Crawford

FOR experimental work in the laboratory when an exact capacitance calibration is not required, high-grade variable air condensers built for sale to the radio broadcast and radio amateur experimental fields may often be used. This saves wear and tear on the calibrated instruments and materially reduces the investment in equipment. Most of the experimental condensers now on the market have been designed for use as tuning controls in oscillatory circuits where it is desirable that the angle of rotation be proportional either to wavelength or frequency. Since condensers with straight-line wavelength and straight-line frequency plates do not have their

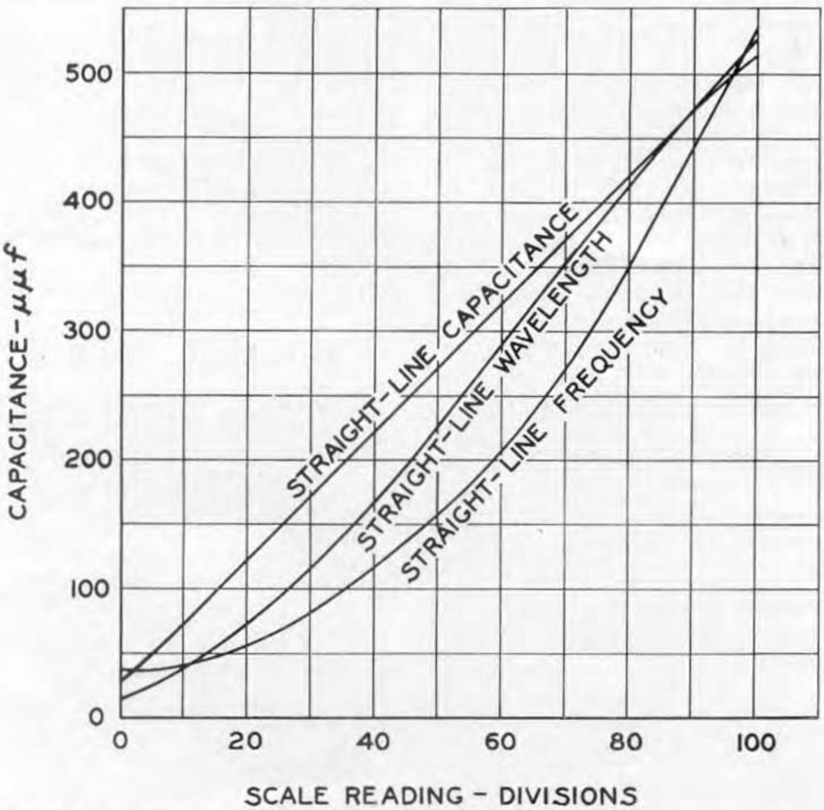


FIGURE 1. Capacitance calibrations for three typical General Radio condensers: (a) Straight-line capacitance, TYPE 247-G; (b) Straight-line wavelength, TYPE 247-F; (c) Straight-line frequency, TYPE 374-F

capacitances proportional to setting, one often wants to know how much the capacitance varies from the straight-line law.

It is obvious, of course, that the total capacitance in a circuit is directly proportional to the square of the wavelength and inversely proportional to the square of the frequency. A condenser to follow either a straight-line wavelength or a straight-line frequency law must have the slope of its capacitance calibration curve smaller during the first part and larger for the second part of the scale than for a condenser following the straight-line capacitance law. The curves of Figure 1 show better than words this difference. They are actual calibrations for three General Radio condensers, each of which has a nominal maximum capacitance of 500 micromicrofarads.

MISCELLANY

By THE EDITOR

THE TYPE 403-C Standard-Signal Generator described by Mr. Burke in this issue of the *Experimenter* is supplied with one TYPE 403-Q2 Inductor for covering the frequency band between 500 and 1500 kilocycles and with a TYPE 418 Dummy Antenna. The cabinet size is 27¼ inches by 13 inches by 10½ inches, the weight is 41 pounds, and the Code Word is SCALY. The price of $600.00 includes no tubes.

Plug-in coils are available for extending the operating range to other frequencies as follows:

Type	*Frequency Range*	*Price*
403-P2	500–1500 kc.	$12.00
403-P3	165– 500 kc.	12.00
403-P4	60– 175 kc.	22.00
403-P5	27– 60 kc.	22.00
403-P6	15– 33 kc.	22.00

Frequency calibrations for these are supplied only when ordered at an extra charge of $8.00 per inductor. The type numbers for the calibrated coils are 403-Q2, 403-Q3, 403-Q4, 403-Q5, and 403-Q6. The generator with which calibration coil will be used must be submitted with the order so that we can make calibrated and check the performance of the instrument.

The TYPE 403-C Standard-Signal Generator can be shipped from stock. Calibrated inductors for other frequency ranges will require another ten days.

CONTRIBUTORS

The contributors to this issue of the *Experimenter* are both members of the General Radio Company's Engineering Department:

CHARLES T. BURKE, S.B., Massachusetts Institute of Technology, 1923, S.M., 1924. ⁓ Engineering Department, General Radio Company, 1924 to date.

JOHN D. CRAWFORD, ⁓ Editor, *General Radio Experimenter*.

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