STANDARD TESTS OF BROADCAST RADIO RECEIVERS

A. General

The purpose of the standard tests here proposed is to provide by general agreement a basis upon which the complete normal performance of any broadcast radio receiver may be reasonably predicted. It is believed that no simple "figure of merit" can properly be derived that will by itself give an index of complete performance. This follows from the varying weights that may be applied at different times and in different services, to the fundamental properties of Sensitivity, Selectivity, and Fidelity. Consequently it is believed to be essential to define and to provide for the separate measurement of each of these fundamental properties. Such information is of a somewhat too highly technical nature to appeal directly to the average user of broadcast radio receivers, but is thought to be useful to radio distributors and dealers in guiding their selection of apparatus for specific service conditions, and to engineers and manufacturers in aiding the comparison and improvement of their products.

It is recognized that the tests do not comprehend the entire range of service conditions that may be met in practice, and that peculiarities of design not reflected in the test data may in special cases affect the deductions properly to be made from the test results. It is also recognized that the three basic properties of Sensitivity, Selectivity, and Fidelity are in some radio receivers dependent upon adjustments that will change the relative prominence of each, and consequently the three factors should be invariably measured at the same settings of the radio receiver adjustments. Nevertheless, it is thought that acceptance of the procedure outlined, together with proper interpretation and correlation of the results obtained by the tests, will serve to permit a standard comparison of normal radio receiver performance.

B. Definition of Terms

1. Sensitivity. The degree to which a radio receiver responds to signals of the frequency to which it is tuned. It is measured quantitatively by the reciprocal of the Normal Radio Field Intensity (definition, page 107).

2. Selectivity. The degree to which a radio receiver is capable of differentiating between signals of different carrier frequencies. This

characteristic is not expressible by a single numerical value, but requires one or more graphs for its expression.

3. Fidelity. The degree to which a system, or a portion of a system, accurately reproduces at its output the signal which is impressed upon it. As applied to a radio receiver, fidelity is measured by the accuracy of reproduction at the output terminals of the modulation of the received wave.

4. Normal Test Output. As applied to the testing of a broadcast radio receiver, this term represents an audio-frequency power of 0.05 watt in a non-inductive resistor arranged to carry alternating current only and connected across the output terminals of the radio receiver (usually the loud speaker terminals), the resistance of the resistor having been adjusted to give maximum power output per volt input for the type of vacuum tube intended to be used in the radio receiver, with normal adjustments of this vacuum tube. If the radio receiver is not arranged to filter out direct current from its output circuit, then an external filter system shall be employed, of such character as to introduce negligible resistance to direct current, to have negligible loss, and to have negligible shunt admittance and negligible series impedance relative to the output resistor.

5. Normal Radio Field Intensity. As applied to the testing of a broadcast radio receiver, this term represents the radio field intensity of a received signal modulated 30 per cent at 400 cycles per sec., which results in Normal Test Output (definition 4, page 107) at resonance. If the radio receiver does not include a self-contained antenna, then the signal is to be impressed on a real or artificial Standard Antenna* (definition 6, page 108).

For data on various methods of measuring the percentage modulation, the reader is referred to reference R275(b), page 137. The method described in this article has much to recommend it from the point of view of simplicity, and with proper care the method is sufficiently accurate and reliable for general use. The method involves calculation of the percentage modulation from measured values of the peak voltage on the radio-frequency oscillator output under modulated and unmodulated conditions. The voltage measurements are made with a

* Experience has indicated that with some radio receivers, an artificial antenna adversely affects the stability. In such cases it is necessary to employ a real antenna.

vacuum-tube peak voltmeter. The author states that this method is capable of giving an accuracy of only about 4 per cent. For use in calibrating the percentage modulation of a radio-frequency oscillator for radio receiver measurement work, however, this accuracy is generally sufficient.

6. Standard Antenna (Real or Artificial). As applied to the testing of a broadcast radio receiver not having a self-contained antenna, this term represents an artificial antenna having in series a capacity of 200 micromicrofarads, a self-inductance of 20 microhenries, and a resistance of 25 ohms. In computing the radio field intensity of an impressed signal, the effective height is to be taken as 4 meters—that is, the radio field intensity (in microvolts per meter) is equal to the impressed radio-frequency voltage (in microvolts) divided by 4.

7. Standard Test Frequencies. In the testing of a broadcast radio receiver, the five standard carrier frequencies are 600, 800, 1000, 1200 and 1400 kilocycles per sec. When tests are required at only three carrier frequencies, the values 600, 1000, and 1400 kilocycles per sec. are recommended.

C. Test Outlines

1. Sensitivity. This is determined by impressing a radio-frequency voltage in series with the self-contained antenna, or by impressing a known radio field intensity on the self-contained antenna, if the radio receiver is so provided, or otherwise in series with a Standard Antenna (definition 6, page 108), and measuring the Normal Radio Field Intensity, under the conditions stated in definitions 4 and 5, page 107, for carrier frequencies from 550 to 1500 kilocycles per sec. A graph is plotted with carrier frequency as abscissa and Normal Radio Field Intensity as ordinate. A uniform scale should be used for the abscissas, and either a uniform or logarithmic scale (or a uniform scale with transmission units) may be used for the ordinates, depending on the range of radio field intensities which the graph is required to cover.

2. Selectivity. This is determined by tuning the radio receiver to each Standard Test Frequency (definition 7, page 108), in succession, with the receiver in the same condition as in the Sensitivity Test, and measuring the radio field intensity necessary to give Normal Test Output at a series of carrier frequencies in steps not greater than 10 kilocycles per sec. at least up to 100 kilocycles per sec. on each side of resonance or until the radio field intensity has increased to at least 100

times its value at resonance. The conditions of modulation of the radio-frequency oscillator are to be the same as given under the definition for Normal Radio Field Intensity, (definition 5, page 107). For each Standard Test Frequency, a graph is plotted with carrier frequency as abscissa and radio field intensity as ordinate. The scale for ordinates should be logarithmic and the most accurate representation is secured by plotting the graphs for Selectivity with separate enlarged frequency scales, which should be uniform and alike.

3. Fidelity. This is determined by tuning the radio receiver to each Standard Test Frequency (definition 7, page 108) in succession, with the receiver in the same condition as in the Sensitivity and Selectivity tests, adjusting the impressed radio field intensity to the Normal Radio Field Intensity (definition 5, page 107) and then varying the modulation frequency from 40 to 10,000 cycles per sec. at 30 per cent modulation and constant radio field intensity throughout, taking readings of relative output voltage at convenient modulation frequencies. For each Standard Test Frequency, a graph is plotted with modulation frequency as abscissa and as ordinate the ratio of the output voltage at the modulation frequency of measurement to the output voltage at the modulation frequency of 400 cycles per sec. A logarithmic scale should be used for the abscissas and a uniform scale for the ordinates.

D. Requirements and Characteristics of Testing Apparatus

The apparatus employed in testing radio receivers should be as simple as is consistent with accurate performance of the necessary functions. As far as possible, the same apparatus should be used in the different tests. The values of the electrical quantities and the calibrations should not change with time; or if some change is unavoidable, means for checking should be provided.

The required apparatus, for Tests of Sensitivity, Selectivity, and Fidelity, is indicated schematically in Fig. 7. Both frequency sources should be calibrated so that separate measurement of frequency is not needed. The requirements of the separate elements are stated in the following paragraphs.

1. Audio-Frequency Source. For Sensitivity and Selecti
this may be a mechanical oscillator of fixed frequency (4
sec.); but a vacuum-tube oscillator having a frequ

from 40 to 10,000 cycles per sec. is preferred and for the Fidelity Test is necessary. The total harmonic content in the output of this oscillator should not exceed 5 per cent. The audio-frequency oscillator is arranged to modulate the radio-frequency oscillator by a known amount and preferably should furnish the same degree of modulation without readjustment at all carrier frequencies and all modulation frequencies. Means should be provided for adjusting the degree of modulation for at least the normal value of 30 per cent.

2. Radio-Frequency Source. This consists of a vacuum-tube oscillator supplied preferably from batteries, either fully shielded in itself or so shielded from the radio receiver under test that there is no

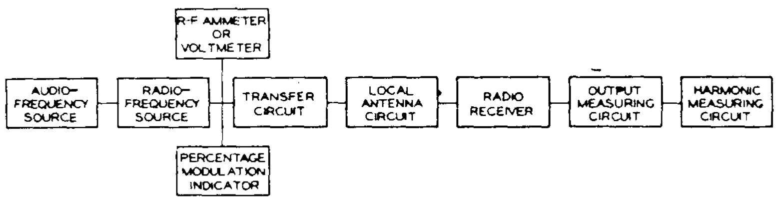

Fig. 7—Schematic Arrangement of Apparatus Used in Tests of Radio Receivers.

direct radiation to the receiver. If the power supply is external to the shielding system which encloses the oscillator, all ungrounded leads to the oscillator should pass through shielded low-pass filters. The frequency should be adjustable by an external control to any desired value between 500 and 1500 kilocycles per sec., and the frequency should not be affected by changes in output power. Means should be provided for varying the frequency in small steps immediately on each side of any specified frequency. A second external control should be provided for varying the modulated radio frequency output supplied to the transfer circuit, and an instrument should be provided which indicates the effective value of this output. The oscillator in conjunction with the transfer system used (see part 3 below) should be capable of supplying in series with the receiving antenna system at least 200,000 microvolts at all carrier frequencies.

3. Transfer Circuit. The radio receiver under test is provided with a local antenna circuit consisting of either a loop antenna (which may be self-contained) or an artificial antenna. In determining the significant characteristics, as outlined in the preceding sections, modulated radio-frequency voltages of known value are impressed in the

local antenna circuit through the transfer circuit which should assume one of two forms as follows:

(a) A coupling coil fed from the radio source and mounted in inductive relation with the loop antenna or with the 20-microhenry inductance coil of the artificial antenna. In the latter case, the coupling coil is used as the primary of a calibrated mutual inductor, the secondary of which is the 20-microhenry coil.

(b) A calibrated attenuator of the resistance type terminating in a low impedance of known value (usually a resistance of about one ohm) which may be inserted in series with the artificial or loop antenna. This attenuator should be so constructed that all attenuation ratios are substantially independent of frequency within the broadcast band. It is preferably made variable in steps with additional provision for continuous variation between the steps. As an alternative to continuous variation within the attenuation network, provision may be made for continuously varying the measured current or voltage supplied from the source to the attenuator over a sufficient range to cover all values of receiver input voltage which lie between the steps of the attenuator. Design details of attenuators fulfilling these requirements are available in the literature. The combined range of ratios on the attenuator and variable currents from the source should be such as to allow a range of voltage across the terminal unit which feeds the receiving set of 1 microvolt to 200,000 microvolts.

4. Output Measuring Circuit. The components of the output measuring circuit should be as follows:

A non-inductive load resistor adjustable by calibrated taps and covering a range of 1 to 10,000 ohms and capable of dissipating 0.1 watt at any setting.

An output filter to be used with radio receivers normally having d.c. in their outputs. This filter should fulfill the requirements given under definition 4, and a recommended form consists of an inductance of not less than 100 henries (with 10 milliamperes d.c. in the winding) and a capacitance of not less than 8 microfarads arranged as shown in Fig. 11.

A vacuum-tube voltmeter or an equivalent device which will accurately measure the r.m.s. values of output voltage. At Normal

Test Output the voltage is of the order of from 10 to 20 volts for ordinary output vacuum tubes. For the Sensitivity and Selectivity Tests the output meter need be calibrated only at these values. For the Fidelity Test continuous calibration is required, and for Overload Level Test calibration for much higher values is needed.

E. Test Procedures

1. **Preliminary.** The present day radio receivers vary so greatly in their manner of operation that it is difficult to set down a single test procedure for each fundamental characteristic and have the procedure include all the allowances that should be made for the peculiarities of different sets. It is simpler to describe in general the test setups and adjustments of input and output; the operating conditions; and the radio receiver adjustments as applied to any type of receiver, and then standard procedures for measuring Sensitivity, Selectivity, and Fidelity, can be outlined.

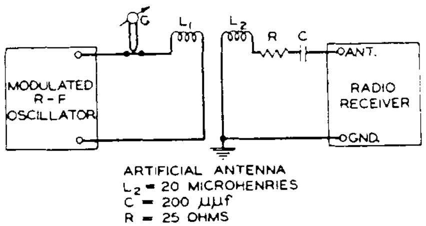

Fig. 8—Standard Input Circuit—Mutual Inductive Coupling.

2. **Input Measurements.**

(a) Radio Receiver Without a Self-Contained Antenna

Standard input circuits are shown in Figs. 8 and 9. Either circuit may be used depending on whether an impedance device or a mutual inductance (see section D, page 109) is used to attenuate and introduce the radio-frequency voltage in the artificial antenna circuit.

The mutual inductor is used as shown in Fig. 8. The input to the receiving set is controlled by adjustment of either the coupling between coils L_1 and L_2 or the current through L_1. The assumed value of radio field intensity impressed on the radio receiver is determined from the formula.

$$\mathcal{E}=\frac{2\pi f M I}{h} \text{ microvolts per meter where,}$$

f is the carrier frequency in kilocycles per sec.,
M is the mutual inductance between L_1 and L_2 in millihenries;
I is the current through L_1 in microamperes;
h is the antenna height in meters (4 meters for the standard antenna).

The circuit for use with an impedance coupling device is shown in Fig. 9. The voltage impressed in series with the artificial antenna is brought to the desired value by selecting the proper degree of attenuation and accurately adjusting either the current or the voltage

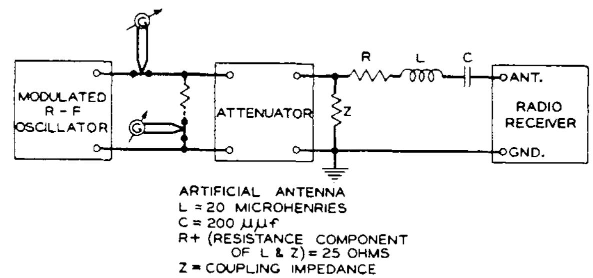

Fig. 9—Standard Input Circuit—Impedance Coupling.

input to the attenuator. If the attenuator is calibrated in terms of current, the radio field intensity impressed in the artificial antenna may be expressed as,

$$\mathcal{E}=\frac{KZI}{h} \text{ microvolts per meter;}$$

where,

K is the attenuation factor;
Z is the impedance of the coupling device;
I is the measured value of current fed to the attenuator in microamperes; and
h is the assumed antenna height in meters (4 meters for the standard antenna).

If the attenuator is calibrated in terms of voltage and includes the impedance Z then,

$$\mathcal{E}=\frac{KV}{h} \text{ microvolts per meter:}$$

where,

K is the attenuation factor;
V is the measured voltage input in microvolts;
h is the assumed antenna height in meters. (Four meters for the standard antenna.)

(b) Radio Receiver with a Loop Antenna

An arrangement of apparatus as shown in Fig. 10 is recommended.

A known radio field intensity is impressed on the loop antenna by adjusting the distance X and the current through the coil L. The coil and loop antenna centers are kept on a common axis, and the distance X kept large as compared with the dimensions of the loop antenna.

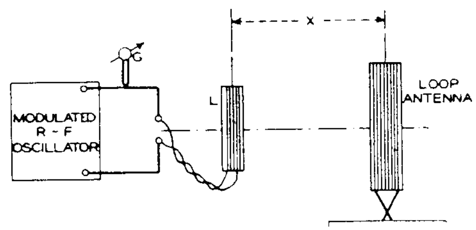

Fig. 10—Radio Receiver with Loop Antenna.

The radio field intensity is,

$$\mathcal{E} = \frac{18{,}850\, NA^2 I}{(A^2+X^2)^{3/2}} \cos B \text{ microvolts per meter}$$

where,

N is the number of turns in the coupling coil L;
A is the radius of the coupling coil, in centimeters;
I is the ammeter reading in microamperes;
X is the distance in centimeters between the center of the coupling coil and the center of the loop antenna; and
B is the angle, if any, between the axis of the loop antenna and the line between coil centers.

The radio-frequency voltage may be introduced in the loop antenna by inserting the terminal impedance of a resistance type attenuator in series with the loop at a point of ground potential in a manner similar to that shown for an artificial antenna in Fig. 9. In this case, the equivalent radio field intensity is given by the expression,

$$\mathcal{E} = \frac{E}{Q}, \text{ in microvolts per meter,}$$

where E = the voltage across Z in microvolts, and

Q = reception factor in meters of the loop antenna employed.

The factor Q may be calculated approximately for a rectangular loop from the relation,

$$Q = 2NH \sin \frac{\pi f s}{300{,}000}, \text{ where,}$$

N = the number of turns;
h = the height of the loop in meters;
s = the length of the loop in meters; and
f = the frequency in kilocycles.

It is not appropriate to specify a standard loop reception factor because the loop antenna is frequently a characteristic element of the radio receiver under test.

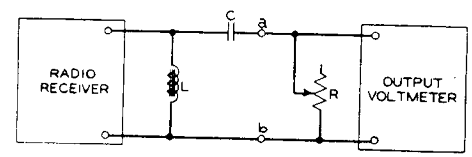

Fig. 11—Radio Receiver with Direct Current in Its Output.

The method first described adapts itself best to the testing of loop receivers because it leaves the loop circuit in its normal form. If the second method is applied to the testing of a loop radio receiver, the output terminal unit of the attenuator should be of low impedance and have a resistance which is low compared with that of the loop.

3. Output Measurements.

(a) Radio Receiver with D. C. in its Output

If the radio receiver is not equipped to filter direct current from its output, the circuit which should be used in making output measurements is as shown in Fig. 11.

The specifications for the components of the above circuit are given in Section D, page 109.

The value for R is dependent on the operating conditions of the output tube used in the radio receiver and is arbitrarily taken as the plate resistance value given by the tube manufacturer for that tube under the given conditions. In the case of a radio receiver having an output transformer, R is taken as the reflected value of the tube resistance, or

$$R = \frac{R_p}{A^2}$$

where,

A = the transformer ratio of primary to secondary turns; and
R_p = the value of tube plate resistance.

The voltage across R for Normal Test Output is,

$$V_n = \sqrt{(0.05) \times R}.$$

(b) Radio Receiver with No D. C. in Output

If the radio receiver has a device eliminating direct current from its output, (referring to the circuit of Fig. 11) L and C are removed and the points a and b connected directly to the output terminals of the receiver.

(c) Radio Receiver with Extraneous Voltages in the Output

The voltages due to a-c hum, tube noises, etc., that may exist across the output of some radio receivers must be considered where the output voltage to be measured is small. For example, if these voltages are comparable with the Normal Test Output Voltage, let the voltage across the resistor R for Normal Test Output be,

$$V_t = \sqrt{V_1^2 + V_2^2}, \text{ where}$$

V_1 is the r.m.s. voltage due to extraneous effects, and

V_2 is the value for Normal Test Output Voltage which gives 0.05 watt power in R.

In any case, if the extraneous voltage is appreciable, the measured voltage across R (see Fig. 11) should be considered as the vector sum of the extraneous voltage and that due to the desired signal.

4. Operating Conditions.

(a) Battery-Operated Radio Receivers

The "A" and "B" battery voltages supplied to the radio receiver should be held constant at the values specified for the receiver. If a battery cable is not furnished with the receiver, the leads to the batteries should be as short as possible. The batteries used should be in good condition.

(b) Socket Powered and Electric Radio Receivers

The a-c or d-c voltage input to the radio receiver should be held constant at the value specified for the set or at 115 volts. If the receiver is provided with adjustments for reducing hum or ripple in the output, such adjustments should be made.

(c) Tubes

The tubes used should have characteristics which represent the arithmetical mean value as regards filament emission, plate current, plate resistance, amplification factor, and mutual conductance for that type of tube.

5. Radio Receiver Adjustments.

(a) General

The Test Frequency adjustment is normally obtained by adjusting all the external tuning and volume controls, with which a radio receiver is equipped, until maximum response is had at its output for a given signal impressed on its input.

(b) Regenerative Radio Receivers

All tests should be made for each of the following conditions:

(1) With the radio receiver adjusted as in part (a) without causing oscillation at radio or audio frequencies to occur within the receiver.

(2) With the receiver adjusted as in part (a) with the minimum of regeneration that can be obtained by adjustment of the external controls only.

(c) STABILIZED RADIO RECEIVERS

If a radio receiver is provided with external stabilization controls that are to be used in the normal operation of the receiver, it should be tested as a regenerative receiver. No other modifications of the general instructions of part (a) are necessary for the testing of stabilized radio receivers.

(d) SUPER-HETERODYNE RADIO RECEIVERS

If a super-heterodyne radio receiver has a separate control of its oscillator frequency, all tests should be made with the oscillator adjusted to the higher frequency above the signal, unless the instructions accompanying the receiver specify other conditions for operation. Selectivity tests should include the response at the lower frequency. In making selectivity tests the radio-frequency oscillator should be moved over twice the intermediate frequency. If this falls outside the broadcast band it should not be ignored. Otherwise, tests are to be in accordance with part (a).

6. Sensitivity and Tuning Range Tests.

(A) SENSITIVITY TEST

The radio-frequency source with 400-cycle, 30 per cent modulation is adjusted to a given Test Frequency, the receiver tuned to the signal and the input radio field intensity adjusted until Normal Test Output is had. The value of radio field intensity is noted and the same process is repeated at the remaining Test Frequencies. A graph is plotted with Normal Radio Field Intensity as ordinate and carrier frequency as abscissa. A linear ordinate scale is ordinarily used, although in comparing receiving sets of widely different sensitivities it is sometimes advantageous to use a logarithmic ordinate scale. The abscissa scale used should be linear.

(B) TUNING RANGE TEST

In conjunction with the sensitivity test it is convenient to make a test of the tuning range of the radio receiver. Using the same test conditions as for the sensitivity test, the radio receiver tuning ad-

justment should be set for the lowest carrier frequency it is capable of receiving under normal operation. The radio-frequency oscillator is then adjusted in frequency until it is at that frequency which gives maximum output in the output meter. The output signal used should be approximately Normal Output, to avoid inaccuracies due to overloading. The radio-frequency setting of the oscillator is then recorded as the lower frequency limit of the tuning range. If the radio-frequency oscillator is incapable of reaching the low limit frequency of the receiver, the oscillator should be set at its minimum frequency and the receiver tuned to it. The dial scale reading of the radio receiver is then recorded for that frequency. The process is then repeated at the high-frequency limit of the range. The maximum and minimum frequency settings of the tuning control will generally correspond to the maximum and minimum dial scale markings. If they do not, the dial settings corresponding to the limit frequency settings should be recorded.

If a calibration of dial setting versus carrier frequency is desired, it can be obtained by adding to the limit values a set of readings of the dial settings for each of the Standard Test Frequencies used in the sensitivity test. The dial calibration is plotted in the form of a graph with carrier frequency as abscissa and dial setting as ordinate, both to a linear scale.

7. Selectivity Test. The radio-frequency source with 400-cycle, 30 per cent modulation is adjusted to a given Test Frequency, the radio receiver tuned to the signal and the input radio field intensity adjusted until Normal Test Output is had. The value of radio field intensity is noted and the radio-frequency oscillator is adjusted in steps of at most 10 kilocycles on either side of the Test Frequency and at each setting of the radio-frequency oscillator the radio field intensity necessary to give Normal Test Output is determined and recorded. The readings are taken until the radio-frequency input is at least 100 times its value at resonance or until a range of 100 kilocycles either side of the Test Frequency setting has been covered. The same procedure is repeated at the remaining Test Frequencies. A graph is plotted for each Test Frequency using the radio-frequency input as ordinate to a logarithmic scale and carrier frequency as abscissa on a linear scale. The scales used for each graph for a given radio receiver should be uniform and alike.

8. Fidelity Test. The radio-frequency source with 400-cycle, 30 per cent modulation is adjusted to a given Test Frequency, the receiving set tuned to the signal, and the input radio field intensity adjusted until Normal Test Output is had. Then the modulation frequency is varied from 40 to 10,000 cycles continuously or in steps, the modulation percentage being maintained constant at 30 per cent and the outputs recorded for each modulation frequency. This procedure is repeated for each Test Frequency, and then curves are plotted with the per cent of the voltage output at 400 cycles as ordinate to a linear scale and modulation frequency as abscissa on a logarithmic scale.

F. Additional Tests

The tests outlined in this section are to be regarded as tentative only. They are included for the purpose of bringing before the industry the need for tests of certain other factors of performance, in addition to the major radio receiver tests which have been outlined in the preceding sections.

In some of the following tests, limits have been set in a somewhat arbitrary manner for the purpose of providing a basis for experimentation and further development. After some general experience has been had in making these additional tests, it is intended that definite standards for procedure in investigating these factors of radio receiver performance shall be drawn up. The Committee will be greatly assisted to this end if those laboratories finding a use for such tests will try out the methods outlined, and send in their comments and criticisms.

The tests which have appeared necessary thus far under this heading include:

1. Tests for overloading of radio receivers.*

2. Tests for volume controls of radio receivers.

3. Tests for hum produced in radio receivers.

* In the opinion of the Committee overload tests are considered worthy of a place among the preceding standard tests, but it is felt that there has not been sufficient experience with this test by various laboratories to warrant the setting up of a definite standard test for this characteristic of radio receivers. The following paragraphs on "Overloading of Radio Receivers" are therefore placed in the section on "Additional Tests," pending the collection of further data. It is expected that the material will be revised in further editions of this report.

1. Overloading of Radio Receivers. It is conceded that the effect of distortion on the human ear is highly variable, and dependent upon many conditions which cannot be specified in any manner which shall be standard practice for any length of time. There is a basis on which overloading can be defined from the technical viewpoint, however, that may be used for the purpose of comparing radio receivers with respect to this factor of performance. A radio receiver can be said to be overloaded when distortion is manifested in the output, i.e., when the electrical output differs in wave form from the electrical input by a specified amount. The output of the radio receiver should be tested for the introduction of spurious frequencies, that is, those not present in the input.

Because of the fact that an amplifier may, and usually does, overload at one or more frequencies more readily than at others, the overload test should be conducted either at all frequencies over the audio range, or at those particular ones where overloading occurs with least input. Determination of this point, or points, is therefore the first step in the test. To do this, it is recommended that the output be examined with a cathode ray oscillograph by a method such as that described in "Notes on the Testing of Audio-Frequency Amplifiers."* The two voltages applied to the deflection plates of the oscillograph would be the a-f voltage used to modulate the r-f oscillator, and the radio receiver output voltage, respectively.

When the critical overloading frequencies have been found they are to be used to measure the overload level of the receiver, as follows:

The test apparatus will be that used for the "Fidelity" test, except that a harmonic measuring instrument is to be connected across the standard output load, and this instrument so chosen as to constants, that it exerts negligible effect on the load circuit. For this purpose the instrument described in "The Alternating Current Bridge As a Harmonic Analyser"** is recommended.

The radio-frequency input (with the modulation adjusted to the critical overload frequency and 30 per cent modulation) is to be increased in steps until a value is reached, which causes the output voltage to contain 10 per cent of total harmonics.

* See reference R342.7 (b), page 138.
** See reference (R800) 537.7(a), page 142.

When this input value has been reached, the output voltage is to be measured (as in Fidelity test) and the power in the output circuit calculated. The overload level of the radio receiver shall then be considered to be that value of power output.

2. Volume Control Tests.

Briefly, the most important of these are:

(a) Tests of the effect of the volume control on the sensitivity, selectivity, and fidelity of the radio receiver.

(b) Tests of the effect of the radio-frequency field to which the radio receiver is exposed (input signal not subject to the volume control in some radio receivers).

(a) 1. Effect of Volume Control on Sensitivity

The radio field intensity required to produce Normal Test Output should be measured at various volume control settings. These can be plotted in the form of a graph using percentage of maximum setting of volume control as abscissa, and Normal Radio Field Intensity in microvolts per meter as ordinate. This graph can be plotted on the same type of paper used for selectivity graphs with the logarithmic axis as ordinate. The graph should be taken all the way to the minimum end of the volume control unless impossible with the available equipment. In the latter case the graph should be taken at least to a radio field intensity of 50,000 microvolts per meter. This graph can be taken at any one or more of the Standard Test Frequency settings desired, and enough points should be taken to show the graph shape accurately.

(a) 2. Effect of Volume Control on Selectivity

In addition to the usual inverse resonance graphs, a selectivity graph should be taken with a radio field intensity at resonance of 1000 microvolts per meter. This signal is to be reduced by means of the volume control until it gives Normal Test Output at the receiver output. One or more such selectivity graphs should be taken at reduced volume control as required in the opinion of the test engineer, and in cases of apparent erratic behavior of the volume control, graphs may be taken at higher values of radio field intensity.

(a) 3. Effect of Volume Control on Fidelity

In addition to the usual fidelity graphs, one should be taken with a radio field intensity of 10,000 microvolts per meter, with the radio receiver output reduced by means of the volume control to give Normal Test Output at 400 cycles. Such curves should be taken at 600 and 1400 kilocycles, and at other standard test carrier frequencies if thought desirable.

(b) Effect of the Radio-Frequency Field to Which the Radio Receiver Is Exposed

It was intended that this test should evaluate the pickup by the radio receiver circuit, of radio-frequency fields through unshielded or poorly shielded coils or wires, within the radio receiver, and through the power line in the case of radio receivers deriving part or all of their power supply from that source, under conditions where the volume control was set at minimum. Such a test appears desirable, but the committee knows of no satisfactory way of making such a test quantitatively at the present time, and recommends that the various laboratories keep in mind the need for such a test. If a method is later developed which permits results of a useful quantitative nature to be obtained, it is requested that this be brought to the attention of the Subcommittee on Radio Receivers.

3. Tests for Hum.

Radio receivers of the type which derive their power from an a-c supply generally produce in the output circuit a certain amount of audio-frequency voltage, composed of a combination of various harmonics of the a-c supply frequency, and occasionally containing the fundamental. This voltage is commonly called the a-c hum voltage, and this section is intended to outline certain tests for evaluating it.

A measure of the r.m.s. hum voltage across the output terminals of the radio receiver is not an indication of its quantitative effect on the ear, since the audio response characteristics of a-f amplifiers and loud speakers, and of the human ear, cause the higher harmonics of the a-c power line to result in more sound response from the loud speaker than do the lower harmonics or the fundamental. Therefore it is desirable to evaluate the various harmonic components of the hum voltage in order to obtain a useful conception of the degree of unpleasantness which the hum from a particular radio receiver will create. A simple way of doing this would be to construct a filter network having an attenuation characteristic which would take account of the dropping off in loud speaker response and ear response below 1500 cycles. (It is felt that frequencies above 1500 cycles can be disregarded in the hum measurement.) This network should be connected between the radio receiver output, and the output voltmeter. If the voltmeter is calibrated in r.m.s. volts it will then measure the square root of the sum of the squares of the various hum harmonic voltages, each harmonic being attenuated to a percentage of its actual value, corresponding to its importance from the point of view of the loud speaker and ear response characteristics. Thus, a single voltage measurement is made to give a measure of the degree of unpleasantness

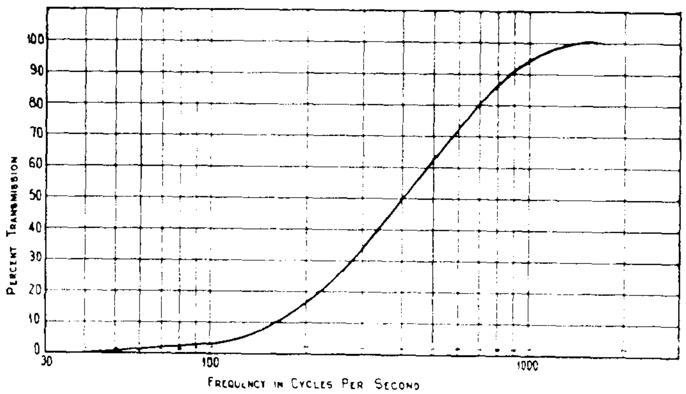

Fig. 12—Possible Attenuation Characteristic of Arbitrary Network for Use in Hum Measurement.

which the hum from a particular radio receiver would create with an average loud speaker. From this voltage measurement, and the value of the radio receiver output resistance, the hum power should be calculated.

While the ear characteristic is fairly well-known, the preparation of a network which would include the response characteristic of an average loud speaker would, of course, necessitate the measurement of all the loud speakers upon the market at the present time, and for some time past. It would also require the use of sound measuring equipment, and measurement conditions whose absolute accuracy has been proven. These requirements are impossible of complete realization at the present time, but it is felt that some valuable experience

in the field of hum measurement can be obtained by the adoption of an arbitrary network, having characteristics which appear, in light of present knowledge, to be of the general order of magnitude of the frequency attenuation factors involved, and to approximate an average loud speaker characteristic. A possible attenuation characteristic for such a network is shown in Fig. 12, and a network having approximately this characteristic is shown in Fig. 13.

It should be emphasized that the graph of Fig. 12 is not intended to include an accurate representation of an average loud speaker frequency response characteristic. The network characteristic is only tentative, and has been prepared as a guide for those desiring to make investigations in the field of hum measurement.

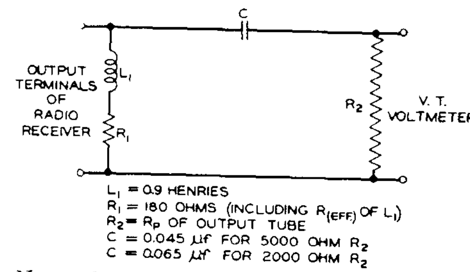

Fig. 13—Network Intended to Approximate An Average Loud Speaker Characteristic.

Other conditions which must be considered in connection with the measurement of hum from a radio receiver are:

(1) Use of an a-c power supply having known and definitely limited harmonic characteristics.

(2) Adjustment of any devices provided on the receiver for hum regulation, such as filament mid-tap potentiometers, for minimum hum.

In connection with condition (1) above, it is suggested that use be made of the differential distortion factor circuit, which has been used in the past in the electrical art in evaluating the harmonic content of a-c power lines. The circuit is shown in Fig. 14. The constants of the circuit are governed by the relation:

$$R = \frac{1}{2\pi f C}$$

where f is the fundamental frequency of the a-c line. The value of R

can be chosen to suit the particular thermocouple meter available. The resistance of the thermocouple should be, of course, small compared with R.

The differential distortion factor is then given by the following relation:

$$d.d.f. = \frac{I_c}{I_r}$$

where I_c is current through condenser and I_r is current through resistance.

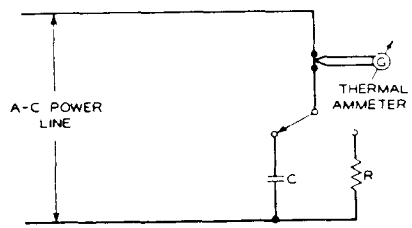

Fig. 14—Differential Distortion Factor Circuit.

It is recommended tentatively, in making measurements of hum on a-c radio receivers, that the power line have a differential distortion factor not greater than 1.05.

It should be noted that in some radio receivers, more hum will be produced when a carrier is tuned in. On this account it is necessary to measure the hum under two conditions of the radio receiver, unless only the value of the worst hum condition is desired, in which case that one of the following receiver adjustment conditions should be used which gives the greater hum:

(1) No incoming carrier frequency, and no other voltages such as static, induction, etc., in the output circuit. In radio receivers where the position of the volume control does not affect the hum with no incoming carrier, the last condition may be most easily complied with by setting the volume control to zero.

(2) With an incoming unmodulated carrier having a radio field intensity of 10,000 microvolts per meter impressed on the radio receiver input circuit, and with the volume control so set that were the incoming carrier to be modulated 30 per cent with 400 cycles, it would give normal output power in the radio receiver output circuit. Here, as in condition 1, static and induction voltages in the output voltage should be reduced to a negligible percentage.

METHODS OF MEASURING THE PROPERTIES OF RADIO CIRCUIT ELEMENTS (SEE NOTE 1)

Unit	Methods	Frequency Range: Direct Current	Power Frequencies 10 – 100 Cycles	Speech Frequencies 50 – 10^4 Cycles	Radio Frequencies $10^4 - (3 \times 10^7)$
Frequency	Approximate		Reed-Type Frequency Meter R800 (530)	Comparison Methods (Audio Tuning) (See Note 2)	Frequency (Wave) Meter R200b, R213a; Piezo Crystals R214a, R214b
	Laboratory		Comparison Methods (See Note 2)	Comparison with Acoustical Standards (See Note 2)—Resonance Circuits R200b	Comparison with Harmonies of Acoustical Standards R213a—Resonant Circuits R200b
Voltage	Approximate	Voltmeter	Voltmeter	Vacuum-Tube Voltmeter (5) and Thermovoltmeter R261b	V. T. Voltmeter (5) Thermovoltmeter R261b
	Laboratory	Potentiometer Methods R800 (530) or Precision Voltmeter	Precision Voltmeter Potentiometer R800 (530)	Standardized V. T. Voltmeter (5)	Standardized V. T. Voltmeter (5)
Electric Field Intensity	Approximate				Calibrated Radio Receiver R270e
	Laboratory				Comparison with Measured Voltages R270e
Current	Approximate	Ammeter	Ammeter	Thermoammeters R200b	Thermoammeters R200b
	Laboratory	Potentiometer R800 (530) or Precision Ammeter	Precision Ammeter	Standardized Thermoammeters R200b	Standardized Thermoammeters R200b
Resistance	Approximate	Wheatstone Bridge R800 (530) Current-Voltage Measurement (See Note 3)	Wheatstone Bridge (DC) R800 (530) Current-Voltage Measurement (See Note 3)	H-F Bridge (14) Current-Voltage Measurement (See Note 3)	H-F Bridge (14) Reactance Variation Methods R200b Dielectric Loss R200b
	Laboratory	Wheatstone Bridge R800 (530) and Kelvin Double Bridge (17)	Wheatstone Bridge R800 (530) (DC)	H-F Bridge (14)	H-F Bridge (14) Resistance Substitution Methods R200b Dielectric Loss R200b
Impedance	Approximate		Current-Voltage Measurement (See Note 4)	Current-Voltage Measurement (See Note 4)	Current-Voltage Measurement (See Note 4)
	Laboratory		Current-Voltage Measurement (See Note 4)	Bridge-Current Voltage Measurement (See Note 4)	Measurement of Resistance and Reactance Components (See Note 5)

METHODS OF MEASURING THE PROPERTIES OF RADIO CIRCUIT ELEMENTS (SEE NOTE 1) *(Continued)*

Unit	Methods	Frequency Range			
		Direct Current	Power Frequencies $10-100$ Cycles	Speech Frequencies $50-10^4$ Cycles	Radio Frequencies $10^4-(3\times10^7)$
Capacity	Approximate		Ballistic Methods R800 (530) Bridge R800 (530) or Current-Voltage Frequency Determination (See Note 6)	Current-Voltage Frequency Bridge R800 (530)	Substitution in Resonant Circuit R200b (Dielectric Loss) R200b
	Laboratory		Ballistic Methods R800 (530) Bridge R800 (530) Current-Voltage Frequency Determination (See Note 6)	Bridge R800 (530)	Substitution in Resonant Circuit R200b
Inductance	Approximate		Bridge Methods R800 (530) Current-Voltage Frequency Determination (See Note 7)	Bridge R800 (530) Current-Voltage Frequency Determination (See Note 7)	Substitution in R200b Resonant Circuit
	Laboratory		Bridge Methods R800 (530) Current-Voltage Frequency Determination (See Note 7)	Bridge Methods R800 (530) and (14)	Substitution in Resonant Circuit R200b (Distributed Capacity of Coils) R200b

Note 1—Numbers in parentheses refer to references in the bibliography which follows.

Note 2—Comparison with standard tuning fork. See reference R213a.

Note 3—Resistance may be determined from measured value of voltage drop and current $R=\frac{E}{I}$

Note 4—Impedance may be determined from measured value of voltage drop and current $Z=\frac{E}{I}$. The vacuum-tube voltmeter may be used at the higher frequencies.

Note 5—Measurement of resistance and reactance components

$$Z=\sqrt{(\omega L-\frac{I}{\omega C})^2+R^2}$$

See references R210(e), R240(d), R220(g), R230(d).

Note 6—Capacity may be determined from measurements of current, voltage, and frequency $C=\frac{I}{\omega E}$

Note 7—Inductance may be determined from measurements of voltage, current, and frequency $L=\frac{E}{\omega I}$

REFERENCES RELATING TO THE MEASUREMENT OF THE CHARACTERISTICS OF RADIO RECEIVERS AND ASSOCIATED APPARATUS

These references are classified according to the extension of the Dewey Decimal Classification to radio subjects contained in Circular 138 of the U. S. Bureau of Standards.* An outline of this classification was published in the PROCEEDINGS of the Institute of Radio Engineers, **16**, 1423; October, 1928.

Abbreviations for the titles of the publications referred to in these references are as follows:

Amer. Acad. Arts and Sci. *Proc.*	*Proceedings* of the American Academy of Arts and Sciences.
A.I.E.E. *Jl.*	*Journal* of the American Institute of Electrical Engineers.
A.I.E.E. *Trans.*	*Transactions* of the American Institute of Electrical Engineers.
Archiv f. Elek.	*Archiv für Elektrotechnik.*
Bell Sys. Tech. Jl.	*Bell System Technical Journal.*
Cir. B. of S.	Circular of the Bureau of Standards.
Elec. Comm.	*Electrical Communication.*
Electrician	*Electrician* (London).
Exp. Wls. & Wls. Engr.	*Experimental Wireless and Wireless Engineer.*
Fr. Inst. *Jl.*	*Journal* of the Franklin Institute.
G. E. *Rev.*	General Electric *Review.*
I.E.E. *Jl.*	*Journal* of the Institution of Electrical Engineers.
I.E.E. *Jl.* (Japan)	*Journal* of the Institution of Electrical Engineers, Japan.

* Copies of Circular 138 of the Bureau of Standards can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. for 10 cents per copy.