MEASUREMENTS ON RADIO RECEIVERS

35. Receiver Characteristics and Their Determination.[1]—Radio receivers are tested by employing an artificial signal from a standard signal generator to provide a voltage corresponding to that induced in the receiving antenna. This voltage is ordinarily applied to the receiver through a network, termed a dummy antenna, having characteristics such that the receiver views substantially the same impedance as it would in normal operation with an actual antenna. The receiver output is then observed by replacing the loud-speaker or telephone receivers by a suitable resistance load, with which is associated a power indicator.

The dummy antenna recommended for use in testing broadcast receivers is given in Fig. 78.[2] The impedance of this network in the frequency range 540 to 1,600 kc approximates that of the typical open-wire antenna resonant at about 2,500 kc, and having a capacity of the order of 200 μμf. At higher frequencies the network approaches a constant impedance of 400 ohms, and so resembles a nonresonant transmission line of corresponding impedance.

1 Many of the tests and test procedures commonly used with radio receivers, particularly broadcast receivers, have been standardized to ensure uniformity. These standards are described in " Standards on Radio Receivers," Institute of Radio Engineers, New York, 1938.

The standard test procedures used in England are described in the paper R. M. A. Specification for Testing and Expressing the Overall Performance of Radio Receivers, *Jour.* Vol. 81, p. 104, 1937 {*Wireless Proc.*, Vol. 12, p. 179, September, 1937).

2 **Where tests are to be made only in the standard broadcast frequency range, an alternative network consisting of a capacity of 200 μμf, resistance of 25 ohms, and an inductance of 20 μh, all connected in series, is commonly used. Such a dummy antenna has practically the same impedance as the recommended network in this frequency range.**

With loop antennas, the signal-generator voltage can be introduced into the receiver loop by use of a known mutual inductance, as in Fig. 79a, or can be inserted directly in series with the loop circuit, as in Fig. 79b.[1] The former arrangement is preferable, because it requires no correction for distributed capacity of the loop. In this mutual-inductance method, if the reactance of the primary inductance X_p is at least three times the internal impedance R_p of the signal generator, then the strength

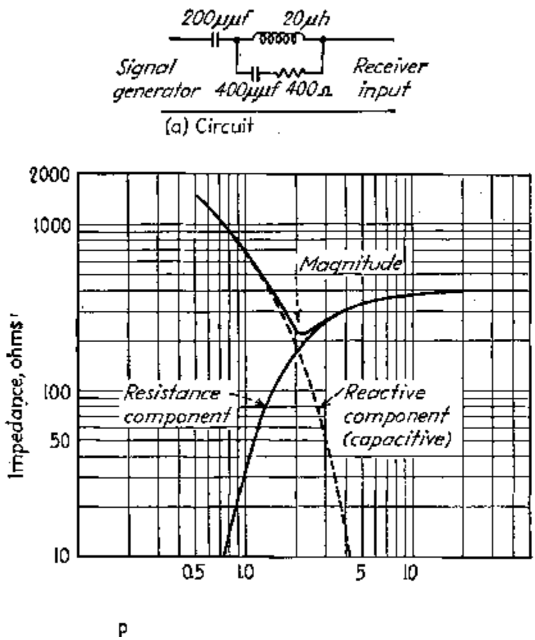

FIG. 78.—Standard dummy antenna used for testing broadcast receivers, together with its impedance characteristic.

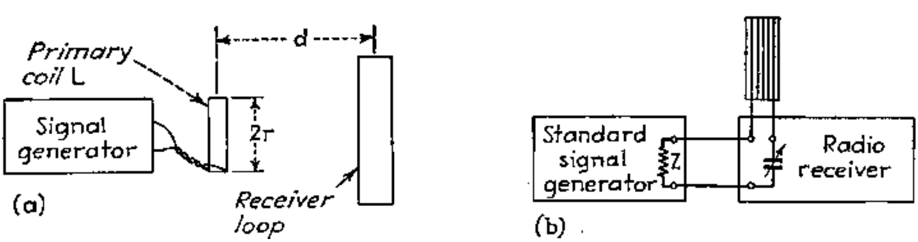

FIG. 79.—Methods of introducing signal-generator voltage into a loop antenna.

of the radio field E required to induce in the loop the same voltage as does the signal generator is[2]

$$\epsilon = \frac{18.85 N_p r_p^2}{d^3} \frac{E}{X_p} \tag{42}$$

where ϵ = strength of radio field, microvolts per meter.

N_p – number of turns in primary coil L_p.

[1] Further details on receiver measurements when loop antennas are used are given by W. O. Swinyard, Measurement of Loop Antenna Receivers, *Proc. I.R.E.*, Vol. 29, p. 382, July, 1941.

[2] When this relation is not satisfied, then one should substitute $\sqrt{X_{p^2} + R_{p^2}}$ in place on X*p* in Eq. (42).

r_p = radius of primary coil, cm.

d = distance, meters, between center of primary coil L and center of loop antenna.

E = signal-generator voltage, millivolts.

X_P = reactance of primary coil L.

The distance d should be at least twice the largest dimension of the loop or primary coil, but should be much less than a wave length.

When the signal-generator voltage is inserted directly in series with the loop, as in Fig. 79b, then the intensity of the radio field that would produce the same effect in the radio receiver as does the signal generator, is

$$\epsilon = \frac{47,750E}{N_2Af} \tag{43}$$

where ϵ and E have the same meaning as in Eq. (42), N_2 is the number of turns in the loop antenna, f the frequency in kilocycles, and A the cross-sectional area of the loop in square meters.

Sensitivity.—The sensitivity of a radio receiver is defined in terms of the voltage that must be applied by a signal generator to the receiver input to produce a specified output. In the case of broadcast receivers, the conditions of the sensitivity test have been standardized on the basis of a signal modulated 30 per cent at 400 cycles, with the standard output to be delivered by the receiver into a dummy load taken as 0.5 watts.[1] The sensitivity is normally expressed either in microvolts, or in decibels below 1 volt. Unless otherwise stated, the sensitivity test is taken with the receiver controls adjusted to give maximum sensitivity. A typical sensitivity curve of a broadcast receiver is shown in Fig. 80.

Selectivity.—The selectivity of a radio receiver is that characteristic which determines the extent to which the receiver is capable of distinguishing between the desired signal and disturbances of other frequencies. Selectivity is expressed in the form of a curve that gives the signal strength required to produce a given receiver output as a function of the cycles off resonance of the signal, with the response at resonance taken as the reference (see Fig. 80).

The selectivity curve of a radio receiver is normally obtained by disabling the automatic-volume-control system (or replacing the A.Y.C. bias by a fixed bias), setting the signal generator to the desired frequency, tuning the receiver to this frequency, and adjusting the signal to give a convenient output when modulated 30 per cent at 400 cycles. The carrier frequency of the signal generator output is then varied by progressively increasing amounts from the frequency to which the receiver is tuned, and the signal-generator voltage increased as necessary to maintain constant receiver output. Selectivity curves should be carried to 100 kc off resonance or to 80 db above the response of resonance, whichever is encountered first.

Selectivity curves with the automatic-volume-control system operative can be obtained by employing two signal generators, one to represent the desired signal to which the signal is tuned, and the other to represent the interfering signal. In such an arrangement, the "desired" signal is adjusted to the amplitude desired for purposes of the test, and the modulation of this signal is then removed. The "interfering" signal generator is then turned on and modulated 30 per cent at 400 cycles. The selectivity is then expressed as a curve showing the amplitude of tjie interfering signal required to produce a standard 400-cycle output, as a function of the difference between the frequency of the interfering signal and the frequency of the desired signal. The selectivity curve obtained from a two-signal-generator test of this type

[1] This assumes that the receiver is capable of delivering an output of at least one watt. If the maximum receiver output is between 0.1 and 1 watt, the standard output is 50 milliwatts.

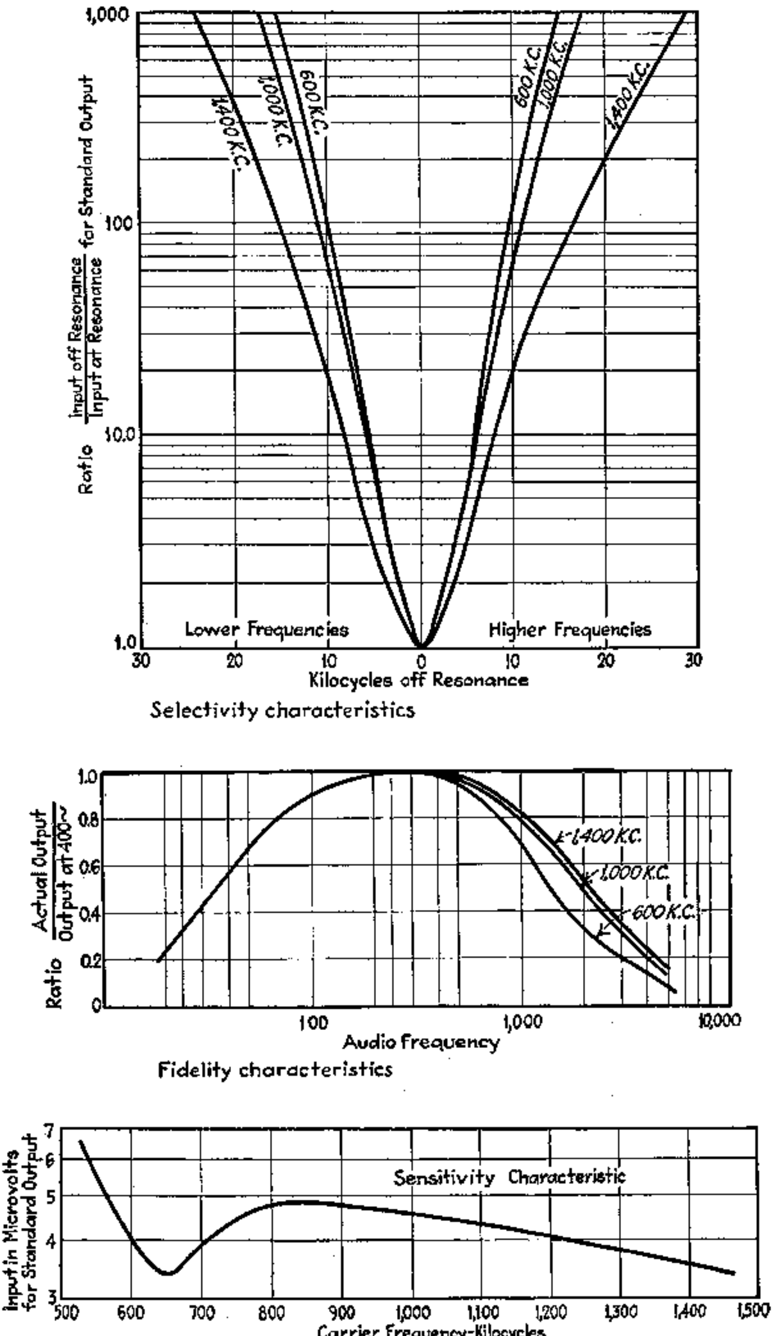

FIG. 80.—Typical sensitivity, selectivity, and fidelity curves of a superheterodyne receiver.

takes into account not only the selectivity of the resonant circuits of the receiver, but also any cross-modulation effects that occur in the receiver. These cross-modulation effects commonly dominate the situation when the desired signal is large and the frequency difference between the two signals is not too small.

Fidelity.—The fidelity of a receiver shows the manner in which the electrical output at a dummy load depends upon the modulation frequency. Fidelity is measured by setting the signal generator to a desired carrier frequency, tuning the receiver to this signal, adjusting the signal generator until a convenient output is obtained, and then observing the variation in receiver output as the modulation frequency of the signal generator is varied, while keeping the degree of modulation constant at 30 per cent. The results of a fidelity test are expressed in the form of a curve, as shown in Fig. 80, with the output at 400 cycles taken as the reference value. In making fidelity tests care must be taken to avoid applying so much input to the receiver as to overload the output. Also, in the event that the noise and hum voltages in the receiver output are appreciable, it is necessary either that the signal be strong enough to override these interfering effects, or that their power be subtracted to give the true output.

Fidelity tests as outlined above using a dummy load do not include the characteristics of the loud-speaker, or the acoustics of the space in which the sound is reproduced. These factors can be taken into account by over-all tests in which the relative sound output of the receiver is measured.[1]

Miscellaneous Receiver Characteristics.—In addition to selectivity, sensitivity, and fidelity, a number of other characteristics are often of interest. These include the maximum undistorted power that the receiver can develop, the hum and noise level, cross-talk, spurious responses, automatic-volume-control characteristics, etc.

The maximum undistorted output that a receiver can develop is arbitrarily defined as the maximum power that can be delivered to the load with an rms distortion not to exceed 10 per cent. Undistorted power is commonly measured with a signal modulated 80 per cent at 400 cycles, although other conditions of degree and frequency of modulation may be specified.

Noise and hum may be objectively measured in several ways.[2] One procedure consists in applying an unmodulated carrier of appropriate amplitude to a receiver from a signal generator and observing the hum and noise output on a square-law indicating device. The signal is then modulated and the degree of modulation adjusted until the square of the rms output, as indicated on the instrument, has been doubled. The hum and noise present under the given conditions can then be expressed in terms of decibels below 100 per cent modulation.

Spurious responses are investigated by the use of one or two signal generators, as the case requires, and are evaluated in terms of the amplitude of the undesired signal required to give a specified output, compared with the amplitude of the desired signal required to give the same output. Thus if an image voltage must be 1,000 times as strong as the desired signal, to produce a given output, then the image discrimination is 60 db.

Operation of Two Signal Generators in Parallel.—Certain receiver tests necessitate the use of two signal generators acting simultaneously on the receiver input. When both generators have one terminal grounded, as is usually the case, this presents a special problem.

[1] Such tests are described by Stuart Ballantine, High Quality Radio Broadcast Transmission, and Reception—II, *Proc. J.R.E.*, Vol. 23, p. 618, June, 1935; H. A. Wheeler and Y. E. Whitman, Acoustic Testing of High Fidelity Receivers, *Proc. T,R.E.,* Vol. 23, p. 610, June, 1935.

[2] For further information on this subject, see "Standards on Radio Receivers," *loc. cii,;* F. B. Llewellyn, A Rapid Method for Estimating the Signal-to-noise Ratio of a High Gain Receiver, *Proc. I.R.E.*, Vol. 19, p. 416, March, 1931; S. Ballantine, Fluctuation Noise in Radio Receivers, *Proc, T.R.E,,* Vol. 18, p. 1377, August, 1930; H. O. Peterson, A Method of Measuring Noise Levels on Short-wave Radiotelegraph Circuits, *Proc. J,R.E.,* Vol. 23, p. 128, February, 1935.