

**IEEE Standard Methods of Testing
Amplitude-Modulation
Broadcast Receivers**

**IEEE Standard Method of Testing
Receivers Employing
Ferrite Core Loop Antennas**

SH11866



THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Inc.

ANSI/IEEE Std 186-1948
(Reaffirmed 1976)

An American National Standard
IEEE Standard Methods of Testing
Amplitude-Modulation
Broadcast Receivers

Approved December 12, 1972
American National Standards Institute

ANSI/IEEE Std 189-1955
(Reaffirmed 1972)

An American National Standard
IEEE Standard Method of Testing
Receivers Employing
Ferrite Core Loop Antennas

Approved December 30, 1976
American National Standards Institute

Published by
Institute of Electrical and Electronics Engineers
345 East 47th Street, New York, N. Y. 10017

Copyright 1949 and 1955 by The Institute of Radio Engineers, Inc.

An American National Standard

IEEE Standard Methods of Testing Amplitude-Modulation Broadcast Receivers

COMMITTEE PERSONNEL

Standards Committee, 1948–1949

A. B. CHAMBERLAIN, *Chairman*
L. G. CUMMING, *Vice-Chairman*

W. R. G. Baker
H. C. Black
G. P. Bosomworth
J. G. Brainerd
G. M. Brown
R. S. Burnap
Henri Busignies

W. G. Cady
P. S. Carter
H. A. Chinn
M. G. Crosby
A. E. Cullum, Jr.
Eginhard Dietze

D. G. Fink
L. R. Hafstad
Keith Henney
J. V. L. Hogan
L. C. F. Horle
A. G. Jensen

E. A. Laport
A. F. Pomeroy
J. R. Steen
W. O. Swinyard
J. R. Weiner
H. A. Wheeler
L. E. Whittemore

Technical Committee on Radio Receivers, 1948–1949

W. O. SWINYARD, *Chairman*
R. F. SHEA, *Vice-Chairman*

Jack Avins
G. L. Beers
J. E. Brown
W. F. Cotter

L. W. Couillard
A. R. Hodges
K. W. Jarvis

J. K. Johnson
B. D. Loughlin
C. R. Miner

Garrard Mountjoy
J. M. Pettit
F. H. R. Pounsett
J. D. Reid

Subcommittee

Methods of Testing Broadcast Radio Receivers

R. F. SHEA, *Chairman*

Jack Avins
J. D. Crawford

J. P. Grant
R. F. Hintz

A. R. Hodges
G. C. Larson

C. R. Miner
Garrard Mountjoy

1.00. INTRODUCTION

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 assemblies

and adjustments of input and output, the operating conditions, and the radio receiver adjustments as applied to any type of receiver. Then recommended procedures for measuring sensitivity, selectivity, and fidelity, and other characteristics, can be outlined.

2.00. DEFINITIONS OF TERMS

2.01. Standard Test Frequencies in the Broadcast Band

The standard group of seven carrier frequencies for testing is 540, 600, 800, 1,000, 1,200, 1,400, and 1,600 kilocycles. The standard group of three carrier frequencies for testing is 600, 1,000, and 1,400 kilocycles.

2.02. Standard Antenna Input Voltages

Four standard antenna input voltages are specified for the purpose of certain tests, as follows:

2.02.01. A "distant-signal voltage" is taken as 86 decibels below 1 volt, or 50 microvolts.

2.02.02. A "mean-signal voltage" is taken as 46 decibels below 1 volt, or 5,000 microvolts.

2.02.03. A "local-signal voltage" is taken as 20 decibels below 1 volt, or 100,000 microvolts.

2.02.04. A "strong-signal voltage" is taken as 1 volt.

2.03. Standard Loop Input Signals

2.03.01. A "distant-signal" loop input is taken as 86 decibels below 1 volt per meter, or 50 microvolts per meter.

2.03.02. A "mean-signal" loop input is taken as 46 decibels below 1 volt per meter, or 5,000 microvolts per meter.

2.03.03. A "local-signal" loop input is taken as 26 decibels below 1 volt per meter, or 50,000 microvolts per meter.

2.03.04. A "strong-signal" loop input is taken as 14 decibels below 1 volt per meter, or 200,000 microvolts per meter.

Note—The above loop field intensities are not equivalent to the standard antenna input voltages for the corresponding class of service. For example, the "mean-signal" voltage for antenna operation is 5,000 microvolts. This corresponds to a field intensity of 1,250 microvolts per meter assuming a standard 4-meter antenna (2.12), whereas the mean-signal voltage for loop receivers is arbitrarily taken as 5,000 microvolts per meter.

2.04. Antenna Sensitivity-Test Input

The sensitivity input is the least signal-input voltage of a specified carrier frequency, modulated 30 per cent

at 400 cycles and applied to the receiver through a standard dummy antenna, which results in normal test output when all controls are adjusted for greatest sensitivity. It is expressed in decibels below 1 volt, or in microvolts.

2.05. Loop Sensitivity-Test Input

The loop sensitivity-test input is the least signal field of a specified carrier frequency, modulated 30 per cent at 400 cycles, and applied as induced pick-up in the loop of the receiver, which results in normal test output when all controls are adjusted for greatest sensitivity. It is expressed in decibels below 1 volt per meter, or in microvolts per meter.

2.06. Interference-Test Input

The interference-test input is the least interfering-signal voltage or signal field, of specified carrier frequency, which results in interference-test output. It is expressed in decibels below 1 volt, or in microvolts, or in the case of loop measurements in decibels below 1 volt per meter or microvolts per meter.

2.07. Selectance

The selectance is the ratio of the ordinates of a selectivity graph, described in Section 4.05.03, between the resonant frequency and another frequency differing from the resonant frequency by a specified multiple of the width of one channel. (The width of one broadcast channel is 10 kilocycles.) It is expressed in decibels or voltage ratios. The ratio at a frequency n channels above the resonant frequency is denoted by S_{+n} and at a frequency n channels below the resonant frequency is denoted by S_{-n} . The geometric mean of these ratios is denoted by S_n . Expressed in decibels, the value of S_n is the average value of S_{+n} and S_{-n} . The terms "adjacent-channel attenuation" (ACA) and "second-channel attenuation" (2ACA) are used to refer to S_1 and S_2 , respectively.

2.08. Bandwidth

As applied to the selectivity of a radio receiver, the bandwidth is the width of a selectivity graph at a specified level on the scale of ordinates.

2.09. Normal Test Output

2.09.01. For receivers capable of delivering at least 1 watt maximum undistorted output, the normal test output is an audio-frequency power of 0.5 watt delivered to a standard dummy load.

2.09.02. For receivers capable of delivering 0.1 but less than 1 watt maximum undistorted output, the normal test output is 0.05 watt audio-frequency power delivered to a standard dummy load. When this value is used, it should be so specified. Otherwise, the 0.5-watt value is assumed.

2.09.03. For receivers capable of delivering less than 0.1 watt maximum undistorted output, the normal test output is 0.005 watt audio-frequency power delivered to a standard dummy load. When this value is used, it should be so specified.

2.09.04. For automobile receivers, normal test output is 1.0 watt audio-frequency power delivered to a standard dummy load.

2.10. Interference-Test Output

The interference-test output is 30 decibels less than, or 0.001 of the power of, the normal test output.

2.11. Maximum Undistorted Output

The so-called maximum undistorted output is arbitrarily taken as the least power output which contains, under given operating conditions, a total power at harmonic frequencies equal to 1 per cent of the apparent power at the fundamental frequency. This corresponds to a root-sum-square total voltage at harmonic frequencies equal to 10 per cent of the root-sum-square voltage at the fundamental frequency, if measured across a pure resistance. (The root-sum-square voltage

of a complex wave is the square root of the sum of the squares of the component voltages.)

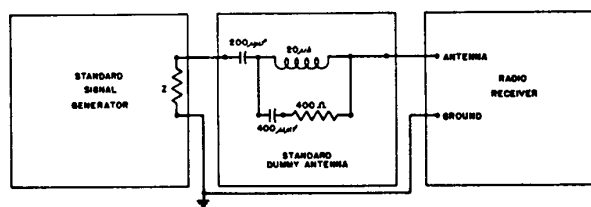


Fig. 1—Standard dummy antenna and method of connections.

2.12. Standard Antenna

A standard antenna is taken as an open single-wire antenna (including the lead-in wire) having an effective height of 4 meters. A dummy antenna which closely approximates such an actual antenna over a wide frequency range is shown in Fig. 1 and its impedance characteristics in Fig. 2.

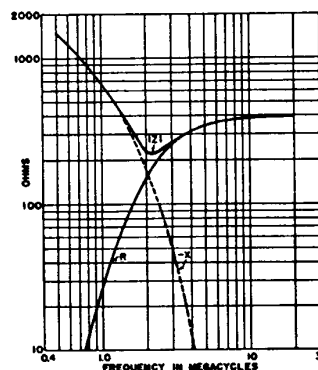


Fig. 2—Impedance characteristics of a dummy antenna.

3.00. REQUIREMENTS AND CHARACTERISTICS OF TESTING APPARATUS

3.01. Apparatus Required

The apparatus employed in the testing of radio receivers operating in the frequency range from 540 to 23,000 kilocycles has become fairly well standardized. The instruments are used in test procedures as described in Section 4.00 of this report which are intended to simulate as accurately as possible the operating conditions in actual service. The arrangement of the testing apparatus for many of the performance tests is shown in Fig. 3. The connections of the standard-signal generators for two-signal tests are described separately.

The principal measuring instrument is the standard-signal generator which is the source of controlled radio-frequency test signals. It consists of a radio-frequency oscillator of the electron-tube type which is adjustable over the entire radio-frequency spectrum in which the receiver under test is expected to operate. The radio-frequency oscillator is provided with means to modulate it to any desired degree at audio frequencies. The usual commercial instruments contain a fixed-frequency 400-cycle modulating system, which is standard for many of the performance tests. Connections are also usually

provided for external modulation adjustable over the audio-frequency spectrum from about 30 to 10,000 cycles.

Within the signal generator, the output of the modulated radio-frequency oscillator is attenuated by an adjustable and calibrated electrical network designed to vary the output-voltage level of the standard-signal generator over a wide range. Since the output voltage of the standard-signal generator is usually too low to be read directly, the radio-frequency voltage is measured at the input to the attenuator where the voltage and power levels are relatively high. A vacuum-tube voltmeter or a thermocouple is generally used for this purpose.

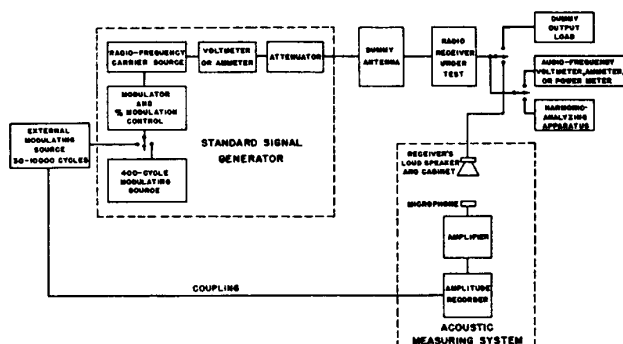


Fig. 3—Schematic arrangement of apparatus used in testing radio receivers.

Resistive, capacitive, and inductive types of attenuators are in general use, and each type has certain advantages.

The radio receiver under test is coupled to the output terminals of the standard-signal generator through a standard dummy antenna designed to provide impedances closely approximating the average of the impedances of antennas which have been found in actual use, or, in the case of loop receivers, through a radiating loop or the equivalent.

The audio-frequency electrical output of the receiver under test is measured in terms of the power delivered to a standard dummy load. The power may be indicated directly by a milliwattmeter or calculated from the voltage or current at the load. For measurements of electrical output when the background noise is appreciable in comparison to the desired-signal output, a band-pass filter, tuned to the desired audio-frequency signal, may be inserted between the standard dummy load and the indicating instrument.

Equipment for measuring the acoustic output of the receiver is of a special nature and is described in the Standards on Electroacoustics.¹

¹ "Standards on Electroacoustics: Definitions of Terms, Letter and Graphical Symbols, Methods of Testing Loudspeakers, 1938." The Institute of Radio Engineers, New York, N. Y.

The audio-frequency distortion introduced by the receiver is important and may be measured in two ways:

(a) By means of an instrument which measures the total root-sum-square value of all the audio-frequency components up to 5,000 or 10,000 cycles in relation to the amplitude of the fundamental frequency. This measurement is usually made at a fundamental frequency of 400 cycles.

The instruments commonly used for this measurement include an output meter and a band-elimination filter, inserted between the dummy load and the output meter, and of such characteristics as to attenuate the fundamental-frequency signal voltage to a negligible value and pass all of the harmonics with essentially no attenuation or discrimination between them. The root-sum-square value of the total output signal voltage or power with all the harmonics present is measured first. The filter is then inserted and a measurement is made of the root-sum-square harmonic components of voltage or power only.

(b) The second method employs an instrument which measures each harmonic component separately with respect to the fundamental component. This type of instrument has, in general, two forms:

1. One of these consists of a number of electric filters. One of these is tuned to the fundamental frequency, while the others are tuned to groups of three or four different consecutive higher harmonics. For the measurement of hum, one of the filters is tuned to the fundamental and the others are tuned to the harmonics of the power-supply frequency. Each component is measured separately at the output of the filters, which are connected in turn between the dummy load and the output meter to isolate the several frequencies for measurement.

2. The second type of instrument is devised to take advantage of the extremely sharp filters that can be provided for frequencies well above the audible. In this instrument, the group of frequencies to be measured is first converted into a group of frequencies in the super-audible band, having the same frequency differences and relative amplitudes as the original frequencies. This is accomplished through the process of the modulation of a variable-frequency carrier and the elimination of the carrier and one of the sidebands thus resulting. The remaining sideband is then applied to a suitably narrow-band filter, the frequency of the carrier being so varied that each component frequency in turn is passed by the filter and the frequency and relative amplitude thus made available for measurement.

Intermodulation is a form of audio distortion caused by cross modulation or intermodulation of the component frequencies in the signal, as a result of which new sum and difference frequencies are produced. Since these frequencies are not harmonically related to the original frequencies, they impair the quality of reproduction.

Both harmonic distortion and intermodulation dis-

tortion are caused by the same circuit nonlinearities, and, therefore, there is usually a good correlation between the amount of intermodulation distortion and the amount of harmonic distortion. Where high-frequency distortion is present, however, the intermodulation distortion will be high and yet the harmonic distortion will be very low because the harmonics are attenuated by the limited high-frequency response. In general, whenever the degree of nonlinearity is a function of frequency, it is to be expected that the correlation between harmonic-distortion and intermodulation-distortion measurements will be poor. It follows that intermodulation-distortion measurements will indicate the presence of significant distortion which may not be revealed by conventional harmonic-distortion measurements.

The equipment required for intermodulation-distortion is similar to that described above for audio-distortion measurement, with the additional requirement that the signal generator be simultaneously modulated at two different audio frequencies, with the percentage modulation from each adjustable. Methods for making these tests are given in the Appendix, Section 7.00.

3.02. Characteristics of Measuring Instruments

Measuring instruments must be so designed that their use will give a substantially correct idea of the receiver's performance. The following general limits are indicative of the tolerances which can be allowed without influencing the utility of the measurements. More specifically, the measuring equipment shall be sufficiently accurate so as not to introduce an error greater than 10 per cent in the quantity being measured.

3.02.01. Standard-Signal Generators

The output-signal voltage of the standard-signal generator for sensitivity tests should be adjustable from approximately 0.5 to at least 100,000 microvolts. For tests of selectivity, and to determine the performance of the receiver when operating in strong electric fields, a test voltage of at least 1 volt is required.

At frequencies in the broadcast band, an accuracy of indication of voltage output within 10 per cent is usually adequate. At higher frequencies, where the effect of the antenna becomes more and more marked, and where circuit stability is not so high, an accuracy of indication within 25 per cent is satisfactory. The electrical leakage, which is always present to some extent, should be sufficiently low so as not to affect measurements made at the lowest voltage levels; that is, at the highest receiver sensitivities.

The standard-signal generator should be provided either with direct-reading frequency scales or calibration charts. An accuracy of indication within 1 per cent is generally sufficient for the determination of operating ranges, coil-frequency overlapping, etc.

In the case of the standard-signal generator used in making selectivity tests and for the interfering-signal

generator used in two-signal tests, the radio frequency should be adjustable in small increments about the desired frequencies. Adjustment and indication to within 0.1 per cent of the carrier frequency are desirable.

The modulating oscillator should be reasonably accurate in frequency and low in harmonic content. A frequency accuracy within 2 per cent and a harmonic content of less than 2 per cent is generally satisfactory.

Unless otherwise specified, the standard level of modulation for all tests is 30 per cent. For certain overload and distortion characteristics, it is desirable to modulate the carrier up to 90 per cent or more. The percentage of modulation should be continuously variable and indicated by the instrument.

Frequency modulation should be kept as low as possible. The maximum permissible frequency modulation in cycles is given by $(50f_c + 100)m$, in which f_c is the carrier frequency expressed in megacycles and m is the modulation factor.

Whatever type of attenuator is employed, its output should be continuously variable over the entire range. The impedance of the attenuator, as viewed from the output terminals of the signal generator, should be negligible compared with that of the dummy antenna. The attenuator should be calibrated in microvolts or in decibels below 1 volt. The attenuating system must be so designed that adjustment of the test-signal voltage causes a negligible shift of the radio frequency.

3.02.02. Standard Dummy Antenna

The elements of the standard dummy antenna are capacitors (C_1 and C_2) of 200 and 400 micromicrofarads, respectively, an inductor L of 20 microhenrys, and a resistor R of 400 ohms, connected as shown in Fig. 1. The impedance characteristics of this network are shown graphically in Fig. 2. The effective values of R , L , and C should be within 10 per cent of the nominal values. The stray capacitance between any two points must be so small as to be negligible at operating frequencies, and the dummy antenna must be so devised as to avoid coupling to other equipment. If the output impedance of the attenuator of the signal generator is not negligible with respect to that of the dummy antenna, this impedance should be deducted from the respective constants thereof.

The leads used in connecting the standard-signal generator through the dummy antenna to the receiver should be so short as to introduce negligible voltage drop. They should be shielded to reduce external fields.

3.02.03. Output-Power-Measuring Device

The standard dummy load is a pure resistance which should be of sufficient power capacity to carry the maximum power output of the receiver without change in its resistance. If provided with taps, these should be sufficiently numerous to allow adjustment to within 10 per cent of the proper value. The precise value of the resistance of each step should be known.

Dry-rectifier-type voltmeters, vacuum-tube voltmeters, or thermocouple-type ammeters are suitable for measuring the power delivered to the standard dummy load. They may read root-sum-square values and be calibrated in current, voltage, power, or directly in decibels, the former units being more commonly used. While dry-rectifier-type voltmeters are subject to temperature and frequency errors, these are usually not of sufficient magnitude to affect the measurements seriously, so long as distortion is not high.

3.02.04. Distortion-Measuring Devices

The instrument used to measure the total audio-frequency distortion generated in the receiver should be capable of indicating the distortion with an accuracy within about 10 per cent between 0.5 and 30 per cent of the fundamental. It must not draw sufficient power from the standard dummy load to modify the magnitude of the distortion being measured. It is desirable that the instrument be of the square-law type for highest accuracy, but considerable deviation from square-law response will not result in serious errors because the second harmonic is usually predominant. Since distortion within the standard-signal generator will affect the measurements, it is obviously necessary that this distortion be kept at a minimum.

For making harmonic analyses by the measurement of each harmonic separately, an investigation of the frequency range from 30 to 10,000 cycles is desirable. The accuracy of measurement of each frequency should be within 5 per cent of the indicated harmonic amplitude, and sufficient selectivity should be available to prevent adjacent harmonics at any measured frequency from influencing the results. In this type of analysis it is, of course, necessary that the signal-generator harmonics be small in comparison with the harmonic distortion being measured. If an instrument is used which makes a lumped measurement of all distortion, by elimination of the fundamental, a high-pass filter should be used, in order to eliminate hum and similar low-frequency noise from the result.

3.02.05. Filters

Audio-frequency filters for the various uses discussed in this standard may be designed by conventional methods. Band-pass or band-elimination filters should preferably be provided with tuning adjustments to correct for drift with time. Iron-core inductances must be designed with an air gap and with sufficient iron so that, at the maximum output levels, harmonics are not generated by saturation of the iron. The filter attenuation at the desired frequency should be known and allowed for in the data.

3.03. Standard-Signal Generators for Two-Signal Tests

For certain tests of radio receivers, two radio-frequency input signals are required simultaneously and,

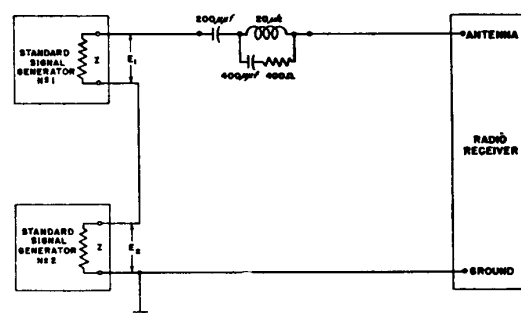


Fig. 4—Connection of two signal generators in a series circuit.

consequently, two standard-signal generators are employed. These signal generators are coupled to the receiver under test by any one of the three methods illustrated in Figs. 4, 5, and 6. If the connections of Fig. 5

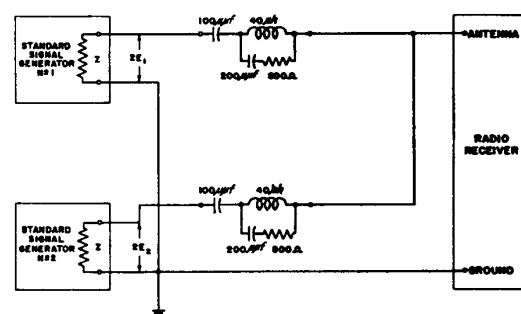


Fig. 5—Connection of two signal generators in parallel circuits.

are used, the dummy antennas each have twice the normal impedance and the signal voltage from each generator must be twice the recorded value. The signal generators may have resistive, inductive, or capacitive attenuators. The output impedance of the two attenuators, combined in either series or parallel arrangement, should be negligible in comparison with the series impedance of the dummy antenna or should be deducted from the respective constants thereof.

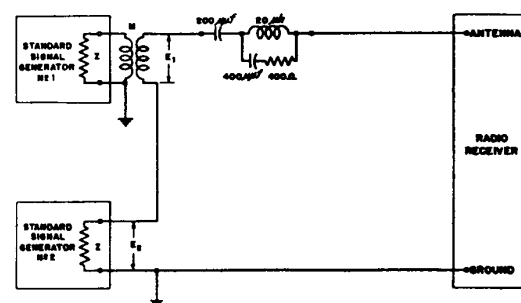


Fig. 6—Connection of two signal generators in a series circuit, one through an output transformer.