# COMPILATION OF IEEE STANDARDS ON BROADCAST AND TELEVISION RECEIVERS

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## NOTE ON THIS SPECIAL BTR STANDARDS ISSUE

For some time the Administrative Committee of the Group on Broadcast and Television Receivers has felt that a collection of IEEE Standards pertinent to the radio and TV industry might well serve G-BTR members in a number of ways:

1. To familiarize the group, especially the newer members, with those IEEE Standards relating specifically to the receiver industry.

2. To provide a convenient reference source, under one cover, for these Standards.

3. To stimulate interest among G-BTR members in participating in Standards Committee activities, particularly in serving to keep the Standards up to date.

With these purposes in mind, the Administrative Committee decided to issue this special COMPILATION OF IEEE STANDARDS ON BROADCAST AND TELEVISION RECEIVERS. As new or revised Standards become available, they will be carried in the regular G-BTR publications.

We are grateful to IEEE Headquarters for the help that they have provided in making this project possible.

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## IEEE STANDARDS ON BROADCAST AND TELEVISION RECEIVERS

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Acknowledgment is made of the work of former chairmen and members of the Technical Committee on Radio Receivers and the Sub-Committee on Frequency Modulation Receivers, who are responsible for initial drafts of this standard. These include Messrs. D. E. Foster, L. F. Curtis, R. M. Wilmotte, A. W. Barber, J. E. Brown, C. C. Chambers, W. F. Cotter, V. D. Landon, C. F. McCoy, and Dale Pollock.

# Standards on Radio Receivers

## METHODS OF TESTING FREQUENCY-MODULATION BROADCAST RECEIVERS (1947)

### 1.00. INTRODUCTION

The first report on definitions of radio terms, letter and graphical symbols, and methods of testing and rating equipment was published by the Institute in 1913. This report has been revised and expanded since that time, and special reports have been published dealing with the principal types of equipment commonly used in radio.

The last report dealing with radio receivers was published in 1938.

The present report deals with the testing of frequency-modulation broadcast receivers in the range between 88 and 108 megacycles.

These Standards cover definitions of terms and methods of testing receivers designed to receive frequency-modulated (FM) waves in order to establish standards similar to those already in use for receivers designed to receive amplitude-modulated waves.[1] In view of the many uses to which such receivers may be put, the report has been limited to broadcast receivers designed to operate at carrier frequencies between 88 and 108 megacycles and having characteristics required to receive transmissions in accordance with the Federal Communications Commission standards for such service.[2] The methods may be used for frequency-modulation receivers for other services by applying the proper system requirements.

[1] "Standards on Radio Receivers," The Institute of Radio Engineers, New York, N. Y.; 1938.

[2] "Standards of Good Engineering Practice Concerning FM Broadcast Stations," Federal Communications Commission, September 20, 1945.

### 2.00. DEFINITIONS OF TERMS

#### 2.01. Standard Test Frequencies

The standard group of three carrier frequencies for testing is 88, 98, and 108 megacycles. The standard mean-carrier frequency, for use when measurements are to be made at a single frequency only, is 98 megacycles.

#### 2.02. Test Input Signals

Input-signal intensities may be expressed in either of two ways: (a) In terms of available power, in which case the input is expressed in decibels below 1 watt. (b) In terms of input voltage, in which case the input is expressed in microvolts.

#### 2.03. Available Power

The available power is the power delivered by a generator to a matched load. It is equal to $E^2/4R$ where $E$ is the equivalent open-circuit voltage of the generator and $R$ is the internal resistance of the generator (including the dummy-antenna resistance). It is expressed in decibels below 1 watt. A signal generator may be calibrated in terms of the available signal power and used on that basis even though not matched exactly by the load impedance. If a signal generator is to be used with various values of dummy-antenna resistance, it should be calibrated in terms of the open-circuit voltage and the available power should be calculated from the above formula. In this report, when values of power input are spoken of, it should be understood that the available power is meant.

#### 2.04. Standard Input Values

Five values of standard input are specified for the purpose of certain tests. The values of standard input voltage are equivalent to the corresponding values of standard input power for a receiver designed for an input impedance of 300 ohms.

(a) *Standard Input Powers*

(1) 130 decibels below 1 watt
(2) 110 decibels below 1 watt
(3) 90 decibels below 1 watt
(4) 50 decibels below 1 watt
(5) 30 decibels below 1 watt

(b) *Standard Input Voltages*

(1) 11 microvolts
(2) 110 microvolts
(3) 1,100 microvolts
(4) 110,000 microvolts
(5) 1.1 volts

(c) *Standard Mean-Signal Input*

The standard mean-signal input is either 90 decibels below 1 watt, or 1,100 microvolts.

#### 2.05. Standard Test Modulation

Standard test modulation in tests on frequency-modulation receivers refers to a signal that is frequency-modulated at 400 cycles with a deviation of 30 per cent of maximum rated system deviation. In this report, maximum rated system deviation is taken as 75 kilocycles, so that the deviation due to standard test modulation is 22.5 kilocycles.

### 2.06. Maximum-Sensitivity Test Input

The maximum-sensitivity test input is the least input signal of a specified carrier frequency having standard test modulation which, when applied to the receiver through the standard 300-ohm dummy antenna, results in standard test output when all controls are adjusted for greatest sensitivity. It is expressed in decibels below 1 watt or in microvolts. If necessary, a 400-cycle filter may be used to minimize the noise output.

### 2.07. Maximum-Deviation Sensitivity Test Input

The maximum-deviation sensitivity test input is the least input signal of a specified carrier frequency having full rated system deviation at a 400-cycle rate which, when applied to the receiver through the standard 300-ohm dummy antenna, results in 10 per cent root-sum-square of noise and distortion in the output (Section 2.11) when the volume control is adjusted for standard output. It is expressed in decibels below 1 watt or in microvolts. This test discloses the influence of the selective circuits of the receiver and of internal receiver noise on the usable sensitivity of the receiver.

### 2.08. Deviation-Sensitivity Test Input

The deviation-sensitivity test input is the minimum deviation at 400 cycles of a carrier wave of standard mean-signal input value (Section 2.04(c)) required to give standard test output (Section 2.10) when all controls are adjusted for greatest sensitivity. The deviation sensitivity is expressed in kilocycles or as a percentage of maximum rated system deviation.

### 2.09. Quieting-Signal-Sensitivity Test Input

The quieting-signal-sensitivity test input is the least unmodulated signal input which, when applied to the receiver through the standard 300-ohm dummy antenna, reduces the internal receiver noise to the point where the test output rises 30 decibels when standard test modulation is applied to the input signal. It is expressed in decibels below 1 watt or in microvolts.

### 2.10. Standard Test Output

For receivers capable of delivering at least 1 watt of maximum undistorted output, the normal test output is an audio-frequency power of 0.5 watt delivered to a standard dummy load. For receivers capable of delivering 0.1 watt but less than 1 watt maximum undistorted output, the normal test output is 0.05 watt of 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.

### 2.11. Maximum Undistorted Output

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

### 2.12. Standard 300-Ohm Dummy Antenna

The standard 300-ohm antenna comprises a pair of resistors, one connected in series with each terminal of the signal generator, of such value that the total impedance between terminals, including the signal generator, is 300 ohms. It is intended to simulate the mean value of the impedance of a typical transmission line connected to an antenna. (Fig. 1.)

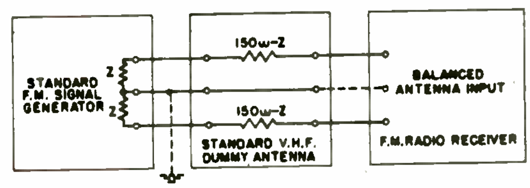


Fig. 1—Standard v.h.f. dummy antenna and method of connection.

### 2.13. Standard Pre-Emphasis Characteristic

The standard pre-emphasis characteristic has a rising response with modulating frequency, equivalent to that provided by a simple circuit in the modulating source having a time constant of 75 microseconds. The characteristic may be obtained by taking the voltage across an inductor and a resistor connected in series and fed with constant current. The inductance in henries is 0.000075 times the resistance in ohms.

### 2.14. Standard De-Emphasis Characteristic

The standard de-emphasis characteristic has a falling response with modulation frequency, the inverse of the standard pre-emphasis characteristic, equivalent to that provided by a simple circuit having a time constant of 75 microseconds. The characteristic may be obtained by taking the voltage across a capacitor and resistor connected in parallel and fed with constant current. The capacitance in farads is equal to 13,333 divided by the resistance in ohms. The standard de-emphasis characteristic is usually incorporated in the audio circuits of the receiver.

### 2.15. Frequency Deviation

Frequency deviation is the difference between the instantaneous frequency of the modulated wave and the carrier frequency.

### 2.16. Maximum System Deviation

Maximum system deviation is the greatest deviation specified in the operation of the system. It is expressed in kilocycles. In the case of frequency-modulation broadcast systems in the range from 88 to 108 megacycles, the maximum system deviation is 75 kilocycles.

# 3.00. REQUIREMENTS AND CHARACTERISTICS OF TESTING APPARATUS

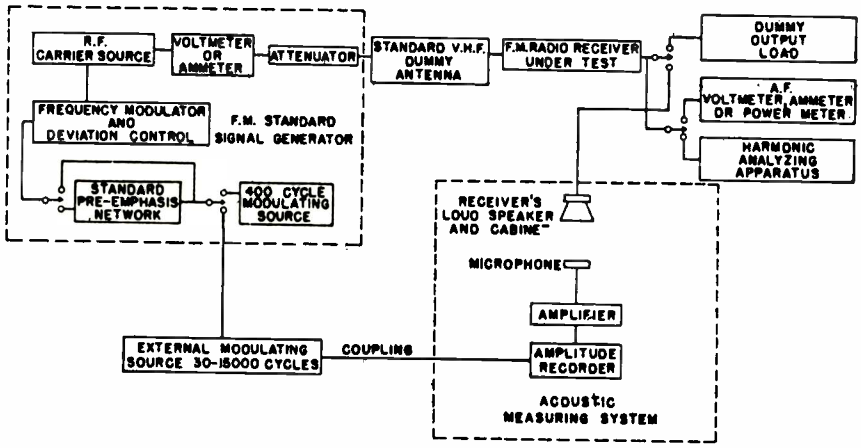


Fig. 2—Schematic arrangement of apparatus used in testing f.m. radio receivers.

### 3.01. Signal Generator

A frequency-modulated signal generator is required for testing frequency-modulation radio receivers.

The signal generator should cover at least the carrier-frequency range from 88 to 108 megacycles. It preferably also covers the intermediate-frequency range and frequency ranges required for spurious-response tests.

The generator output should be controlled by a calibrated attenuator, and the output should be adjustable over a range of at least 1 microvolt to 100,000 microvolts, and preferably from 0.1 microvolt to 1.1 volts. Balanced output terminals should be provided for the radio-frequency ranges, and single-sided output terminals for the intermediate-frequency range. It may be desirable to provide single-sided output terminals for the radio-frequency range also. All of these terminals should be provided at the end of a flexible cable.

The output meter of the signal generator should indicate the open-circuit voltage at the terminals, and the internal impedance should be stated.

The generator should be capable of being frequency-modulated at rates from 30 to at least 15,000 cycles per second, and at deviations from zero to at least rated system deviation and preferably to twice that value. It should be provided with a deviation indicator reading from not more than 5 kilocycles up to the maximum deviation.

The modulation circuit of the generator should be provided with a standard pre-emphasis network. A switch should be provided for cutting this pre-emphasis network in or out of the generator circuit at will.

The generator should provide a frequency-modulated signal at 400 cycles up to maximum rated system deviation with less than 2 per cent, and preferably less than 1 per cent (root-sum-square), distortion. Amplitude modulation resulting from the frequency modulation should be kept to a minimum.

The frequency and amplitude modulation of the output voltage due to power-supply ripple should be negligible, in comparison with the effects under observation. The proper connection of a balanced-output signal generator for testing a balanced receiver is shown in Fig. 1.

### 3.02. Audio-Output- and Distortion-Measuring Devices

Apparatus for the measurement of audio output and distortion is the same as that required for the testing of amplitude-modulation receivers.[1] (See Fig. 2.)

### 3.03. Standard-Signal Generator for Two-Signal Test

For certain tests of radio receivers two radio-frequency input signals are required simultaneously, and consequently two standard-signal generators are employed. The recommended method is to use dummy antennas of twice the standard 300-ohm value with each generator. The calibration for open-circuit voltage of each generator is made before further connection. The terminals of the two dummy antennas are then connected in parallel and to the input terminals of the receiver. By this arrangement (shown in Fig. 3), the

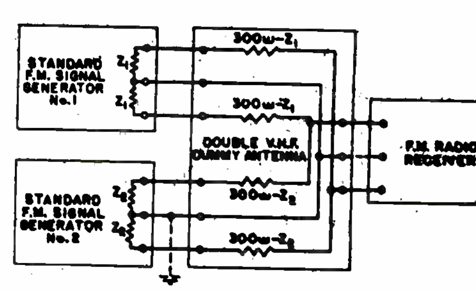


Fig. 3—Standard v.h.f. dummy antenna for two-signal test and method of connection.

[1] See Section III, "Requirements and Characteristics of Testing Apparatus," in "Standards on Radio Receivers," (pp. 17–18, 21.) The Institute of Radio Engineers, Inc., New York, N. Y.; 1938.

impedance connected across the receiver input terminals is the normal value and the open-circuit signal voltages are half the values indicated by each generator.

### 3.04. Standard-Signal Generators for Amplitude-Suppression Test

The measurement of amplitude-modulation suppression (Section 4.05.06) requires a standard-signal generator capable of simultaneous amplitude and frequency modulation. The generator should be capable of being modulated in amplitude at a 400-cycle rate and frequency-modulated at a 1000-cycle rate. Precautions must be observed to keep incidental frequency modulation in the amplitude-modulation process to a minimum, preferably less than 1 per cent of maximum system deviation. Similarly, precautions must be observed to keep the frequency modulation free from amplitude-modulation effects. The signal generator should have an attenuator for adjustment of signal input to the receiver over the range of standard input-signal values. (Section 2.04.)

# 4.00. TEST PROCEDURES

## 4.01. Input Measurements

*4.01.01. Radio Receiver Designed for a Balanced Antenna*

The input power is introduced into the radio receiver through the standard 300-ohm dummy antenna.

When the receiver requires the use of an antenna having an impedance other than that of the standard dummy antenna, the impedance of the dummy antenna used will conform to that required in the receiver specification.

If only a single-sided signal-generator output is available, one terminal of the input circuit of the receiver is connected to the grounded terminal of the generator output circuit, and the correct value of dummy-antenna resistance must be used.[4]

It is also well to make two simple tests to be sure that measurements are free of errors because of unbalance. First, the balanced receiver input coil is reversed, and second, the power-line connection for either the receiver or the signal generator is moved to a different outlet. Any change in the sensitivity observed on alternating these connections indicates an error due to unbalance.

## 4.02. Output Measurements

*4.02.01. Choice of Load*

Output measurements of a radio receiver are made in terms of the power delivered to a standard dummy load, except in special cases where other terms are specified. Some tests will be described which must be performed with a loudspeaker.

The standard dummy load is a pure resistance whose value is equal to the 400-cycle impedance of the loudspeaker which is (a) contained in the radio receiver, or (b) supplied therewith, or (c) recommended for use therewith. Where an output transformer is connected between the radio receiver and the loudspeaker, the output transformer is to be treated as part of the radio receiver.

If the loudspeaker impedance has pronounced irregularities at frequencies in the vicinity of 400 cycles, or if the preceding rule cannot be complied with, the standard dummy load is determined by one of the following rules:

(a) The load resistance which gives the greatest value of maximum undistorted output.

(b) The load resistance recommended by the manufacturer of the radio receiver or of the vacuum tubes used therein.

In case the latter rule is to be followed and there is a transformer between the output vacuum tube and the load, the load impedance should be

$$R_2 = R_1 N_2^2 / N_1^2$$

where

$R_2$ = standard dummy-load resistance in ohms

$R_1$ = load resistance recommended for the output vacuum tube, in ohms

$N_2$ = number of turns on the transformer secondary

$N_1$ = number of turns on the transformer primary.

In case $n$ output vacuum tubes are connected in parallel, the standard dummy load is $R_2/n$.

*4.02.02. Radio Receiver with Background Noise in Its Output*

(a) If the background-noise power is smaller than the output power being measured, the incremental reading of the output meter may be used to measure the incremental output power resulting from a given external cause. If a thermocouple output meter is used, the incremental output power is equal to the observed total power minus the observed noise power. If another type of output meter is used, a calibration should be made in terms of incremental power. Using a thermocouple meter, the incremental output power or voltage in the presence of the noise background can be obtained from the following formulas:

$$E_0 = \sqrt{E^2 - E_n^2}, \qquad P_0 = P - P_n$$

[4] J. A. Rankin, "Input Connections for Ultra-High-Frequency Measurements," *RCA Rev.*, vol. VI, p. 473: April, 1942.

where

$P_0$ = output power being measured
$P$ = total power observed
$P_n$ = noise power observed
$E_0$ = output voltage being measured
$E$ = total voltage observed
$E_n$ = noise voltage observed.

(b) If the background noise power is greater than the output power being measured, it is desirable to use a band-pass filter tuned to the test audio frequency to remove the background noise partially or wholly from the output meter. This filter should be connected between the load and the output meter.

(c) An excellent method of selecting a locally generated signal from noise and other disturbances of different frequencies is by the use of a synchronously excited electrodynamometer. The field is excited from the original source of the modulation, such as the 400-cycle generator, and the phase of excitation is adjusted for maximum deflection when the signal output of the receiver is applied to the armature. The average deflection then depends only on the signal output corresponding to the excitation. Other output merely causes slight fluctuation of the deflection. This method is especially well adapted to the selection and individual measurement of hum components and harmonic-distortion components, the field being excited by synchronized current of the desired harmonic frequency, with other components thoroughly filtered out. Vacuum-tube electrodynamometer circuits have been described in the literature and are all well adapted for this purpose, if care is taken to avoid overloading.[5,6]

## 4.03. Operating Conditions

### *4.03.01. Choice of Operating Conditions*

The operating voltage applied to a radio receiver should be held constant at the specified value during measurements of receiver characteristics. The operating voltages given below for the various receiver classes are the values for normal testing of receivers. If the operating voltage of a receiver is specified, the tests should be performed at that voltage; otherwise the normal test voltage should be used. Certain receiver characteristics may be desired at other than normal test voltage or over a range of operating voltages, in which case a statement of the voltages used should be included in the test data. In any case, tests should be made to check if the receiver operates satisfactorily over the full range of operating voltage that is likely to be encountered in practice.

If the receiver is provided with adjustments for reducing hum or ripple in the output, such adjustments should be made.

[5] H. M. Turner and F. T. McNamara, "An electron tube wattmeter and voltmeter and a phase-shifting bridge," Proc. I.R.E., vol. 18, pp. 1743–1747; October, 1930.

[6] J. R. Pierce, "A proposed wattmeter using multielectrode tubes," Proc. I.R.E., vol. 24, pp. 577–583; April, 1936.

### *4.03.02. Socket-Power Radio Receivers*

(a) *Alternating-current-operated receivers:* The normal test voltage is 117 volts, r.m.s.

(b) *Direct-current-operated receivers:* The normal test voltage is 117 volts, d.c.

(c) *Alternating-current- or direct-current-operated receivers:* The normal test voltage is 117 volts.

Any characteristic of this type of receiver which is affected by power supply should be tested with both alternating and direct current.

### *4.03.03. Battery-Operated Radio Receivers*

(a) *Automobile receivers:* The normal test voltage is 6.6 volts at the receiver battery terminals. This voltage should be obtained from a 6-volt storage battery subject to steady charging at the required rate rather than by the use of a dropping resistor.

(b) *Farm-lighting-plant receivers:* This class of receivers includes those designed for operation from the so-called 32-volt farm-lighting system. The normal test voltage is 36 volts.

(c) *Radio receivers operated from batteries of specified voltages:* This class of battery-operated receivers is intended to comprise those not included in classes (a) or (b). Batteries of the type and voltage specified for use with the receiver should be employed for normal tests. The batteries used should not have abnormally high internal resistance. Tests should also be made with batteries which have voltages of two-thirds of their original rated values. If a battery cable is not furnished with the receiver, the leads to the batteries should be as short as possible.

### *4.03.04. Vacuum Tubes*

The vacuum tubes used should have standard rated values of those characteristics which most affect the performance of the receiver.

## 4.04. Radio-Receiver Adjustments

### *4.04.01. Tuning Controls*

A receiver is *tuned approximately* to a desired signal by adjusting the tuning controls until the desired audio-frequency output is obtained either with the least possible radio-frequency input power or with the lowest possible setting of the volume control.

The range switch is regarded as a tuning control.

A receiver for frequency-modulated waves is *tuned accurately* to a desired signal by first tuning it approximately and then adjusting the tuning controls until either the undesired noise is a minimum or the harmonic distortion of the demodulated desired signal is a minimum. In many receivers these two tuning positions coincide. When they do not coincide it should be stated whether the tuning is for minimum noise or for minimum distortion.

To tune a receiver to the position of minimum noise, the receiver is tuned approximately as described above. A signal of the desired frequency, having a strength corresponding to the average signal strength to be received or to the standard signal-input power if this signal strength is not specified, is amplitude-modulated at 400 cycles and 30 per cent modulation and fed to the input terminals of the receiver. The tuning controls are then adjusted until the audio output of the receiver is a minimum. It is important to insure that the input signal has a negligible degree of frequency modulation.

To tune a receiver to the position of minimum distortion, the receiver is first tuned approximately as described above. The signal of the desired frequency, having a strength equal to the standard signal-input voltage, is frequency-modulated at 400 cycles with maximum rated system deviation and fed to the input terminals of the receiver. The tuning controls are then adjusted until the root-sum-square of the harmonic components of the 400-cycle tone (sine wave) in the output of the receiver is a minimum. In many receivers, the minimum-distortion tuning point may be readily located by observing the audio wave form on a cathode-ray oscilloscope while increasing the deviation somewhat beyond 100 per cent.

*4.04.02. Volume Controls*

The adjustment of a single main volume control requires no special instructions. Where a receiver has in addition a sensitivity control, special instructions are required. Any sensitivity control is to be set as described in the test.

*4.04.03. Tone Controls*

During tests requiring output measurements at the standard test modulating frequency, the tone control is adjusted to give maximum modulation-frequency output. During other tests, the tone control must be adjusted as described in the test.

### 4.05. Performance Tests

The performance of a radio receiver is determined by measurement of the several individual characteristics. The foregoing sections have specified the setup of measuring apparatus and the receiver under tests; in addition, it is necessary to follow standarized test procedures in order that measurements made in different laboratories will be comparable. These test procedures serve to measure the individual characteristics of the receiver.

*4.05.01. Tuning Range*

The radio-receiver tuning control is set for the respective minimum and maximum carrier frequencies in each tuning range which it is capable of receiving with normal operation. At each setting, the signal generator is tuned to the resonant frequency of the receiver and the carrier frequency recorded. This procedure may be extended to obtain a frequency calibration of the dial, if this is required.

*4.05.02. Sensitivity*

There are three sensitivity values of general interest in relation to frequency-modulation receivers. Each gives information as to the usefulness of the receiver, and in expressing results the type of sensitivity should be specified.

*4.05.02(a). Maximum Sensitivity.* The maximum sensitivity (Section 2.06) is measured at each test frequency by means of a standard signal generator. The receiver under test should be connected to the signal generator through the 300-ohm dummy antenna. If the input impedance for which the receiver is designed is known, a dummy antenna of that impedance should be used; otherwise the standard 300-ohm dummy antenna (Section 2.12) should be used.

At each of the test frequencies, the signal generator is frequency-modulated 22.5 kilocycles (30 per cent) at a 400-cycle rate. All receiver controls are adjusted for greatest sensitivity and the signal-generator output adjusted to obtain standard test output (Section 2.10) from the receiver.

In very sensitive receivers the signal output may be largely obscured by internal receiver noise. This fact should be noted in expressing the results of this test.

If the receiver is provided with an adjustable squelch control, the sensitivity is observed when it is set to just quiet the receiver with the signal generator connected, but in the absence of any signal, and also when the control is disabled.

When the tuning for minimum noise does not coincide with that for minimum distortion, the above test should be repeated with the receiver tuned for minimum noise.

*4.05.02(b). Maximum Deviation Sensitivity.* The maximum-deviation sensitivity is measured at three test frequencies applied through the 300-ohm dummy antenna. The signal generator should be frequency-modulated at 400 cycles with full rated system deviation of 75 kilocycles, and the volume control adjusted to standard output with a strong signal input tuned for minimum distortion. The output distortion should be observed and the signal input reduced, keeping the indicated receiver output constant by readjusting the volume control, if necessary, until the output distortion reaches a value of 10 per cent, or until the input is below that required for standard output. The signal input at which the distortion reaches 10 per cent is the maximum-deviation sensitivity input and is expressed in decibels below 1 watt or in microvolts.

When the tuning for minimum noise does not coincide with that for minimum distortion, the above test should be repeated with the receiver tuned for minimum noise.

*4.05.02(c). Deviation Sensitivity.* The deviation-sensitivity test serves to determine whether the useful sensitivity of the receiver under test is limited by the audio gain. It is usually sufficient to measure this characteristic at only the mean carrier frequency. With the volume control set at maximum, the receiver should be connected to the signal generator through the standard 300-ohm dummy antenna, and a signal of mean-signal input intensity with standard test modulation at a 400-cycle rate applied. The deviation is then adjusted to the value which gives standard test output. The value of deviation required is the deviation sensitivity, and it is expressed in kilocycles or as a percentage of rated system deviation.

*4.05.02(d). Quieting-Signal Sensitivity.* This test is performed at each of the standard test frequencies with the signal generator connected to the receiver under test through the standard 300-ohm dummy antenna. The signal generator should be frequency-modulated with standard test modulation (Section 2.05) and the volume control adjusted to a convenient output value below audio overload, with a signal of mean value. The modulation should then be switched off and the signal intensity reduced to the least value which will produce a 30-decibel rise in indicated output with standard test modulation as compared with the indicated output with the unmodulated carrier.

This test serves to indicate the relative freedom of the receiver from objectionable internal receiver noise during pauses in modulation when receiver noise is least likely to be masked by modulation.

The results are expressed in decibels below 1 watt, or in microvolts.

### *4.05.03. Co-Channel Interference Test*

This test is intended to show the effect of an interfering signal of the same frequency as the desired signal, and includes the inherent effect of the detector, the limiter, and the automatic volume control.

Two signal generators are required, only one of which need be capable of frequency modulation. The output of both are applied simultaneously to the receiver under test at the mean carrier frequency of 98 megacycles.

With the desired signal frequency having standard test modulation and an intensity equal to one of the standard input values, the audio-frequency output of the receiver is adjusted by means of the volume control to the standard test output.

The modulation of the desired signal is then removed, keeping the intensity of its carrier unchanged, the interfering signal, frequency-modulated with standard test modulation, is turned on and the output of the receiver read as the level of the interfering signal is increased from zero to 1 volt or more.

The result of the test includes the effects of both the cross-talk and the beat-note components of the interference. If the results are desired for the cross-talk only, a 400-cycle filter is used in the output.

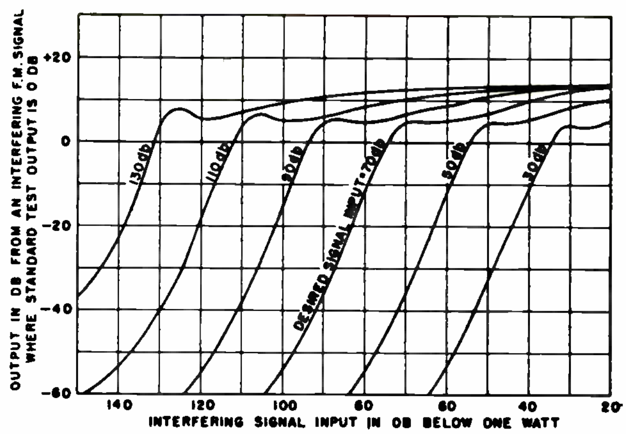


Fig. 4—Co-channel interference.

The test should be repeated at each of the standard-signal input levels of the desired signal.

The values of output may be plotted with the ratio of the output from the interfering signal to the standard test output expressed in decibels as ordinates (see Fig. 4). Either the interfering signal or the ratio of the interfering signal input to the desired signal input expressed in decibels may be plotted as abscissas.

The co-channel interference characteristic may also be expressed as the interfering-signal input, in decibels below the desired-signal input, which produces an output 30 decibels below the standard test output.

### *4.05.04. Masking Interference Test*

The masking effect of an unmodulated interfering signal is obtained by a test similar to that for the co-channel interference but with the desired signal modulated with standard test modulation and with the interfering signal left unmodulated. The test is performed at each of the standard input levels of the desired signal, the output signal being noted as the level of the interfering signal is increased from zero. The results may be plotted in the same way as the co-channel interference (see Fig. 5).

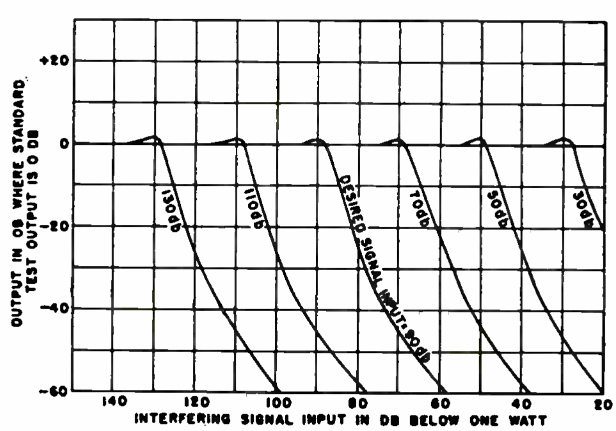


Fig. 5—Masking interference.

### 4.05.05. *Selectivity Test*

This test is intended to show the effect of an interfering signal differing in frequency from the desired signal, and includes the inherent effects of the selective circuits, the limiter, the automatic volume control, and the detector. This test is useful in describing adjacent-channel and second-channel interference.

Test conditions are the same as those described in Section 4.05.03 for co-channel interference except that the interfering signal generator is separated in frequency from the desired signal by one standard channel separation. The desired signal, unmodulated, is applied at the lowest value of standard input and the output of the receiver is recorded as the level of the interfering signal, frequency-modulated with standard test modulation, is varied from zero to a value capable of producing standard test output. This procedure is repeated for all

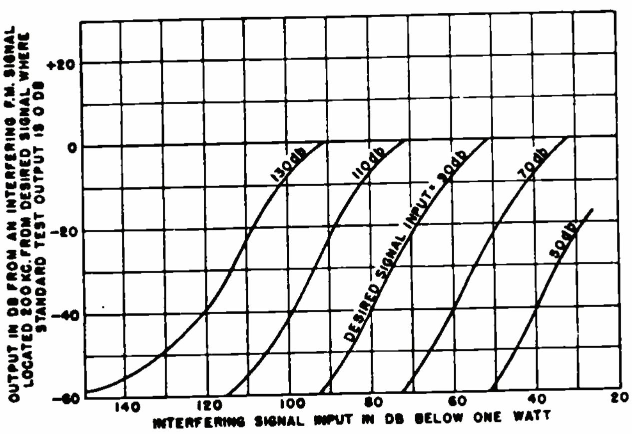


Fig. 6—Adjacent-channel interference.

values of standard test input. (See Fig. 6 and Section 2.04.) The measurements are then repeated with the interfering signal generator separated from the desired signal by twice standard channel separation. (See Fig. 7.)

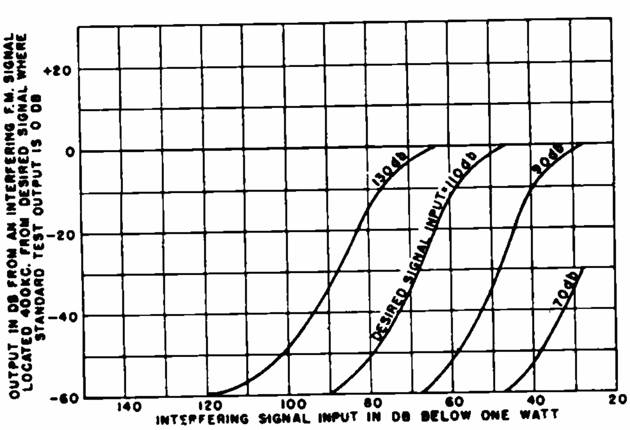


Fig. 7—Second-channel interference.

Curves may be plotted using interfering-signal input level as the abscissa, and the audio output power as the ordinate for the several standard input-signal values.

The adjacent-channel and the second-channel interference may be expressed as the interfering signal input, in decibels below the desired signal input, which produces an output 30 decibels below the standard test output.

### 4.05.06. *Amplitude-Modulation-Suppression Test*

This test measures the suppression of amplitude modulation which may be present in a frequency-modulated signal. It is carried out at the standard mean carrier frequency. The frequency modulation is at a 1000-cycle rate with a deviation of 30 per cent of maximum system deviation. The standard mean input-signal value having this modulation is applied to the receiver in the usual manner. The volume control is adjusted to produce standard output. The input signal is then amplitude-modulated at 400 cycles and 30 per cent modulation. The intensity of the undesired output of the receiver is measured by filtering out the 1000-cycle frequency.

The amplitude suppression is the ratio of the undesired output to standard test output expressed in decibels (see Fig. 8).

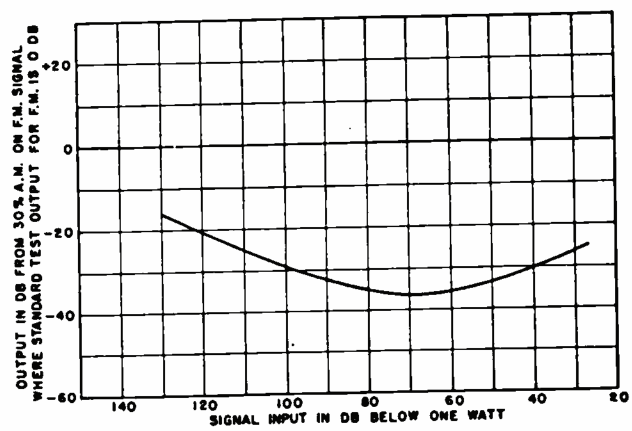


Fig. 8—Amplitude-modulation suppression.

In order to determine the variation of amplitude-modulation suppression with input, the test is repeated with the other standard input-signal values.

If a signal generator capable of being simultaneously amplitude and frequency modulated is not available, two signal generators may be used, one amplitude-modulated and one frequency-modulated, with signals from both simultaneously impressed on the receiver. If two signal generators are used they should be connected as described in Section 3.03 and precautions must be observed that the beat note between the two carriers does not influence the undesired output. Precautions must be observed to keep the amplitude-modulated signal free from incidental frequency modulation. One means is the use of piezoelectric control of the frequency of the signal to be amplitude-modulated.

#### 4.05.07. *Electric Fidelity*

The electric-fidelity test shows the manner in which the electric output of a radio receiver depends on the modulating frequency. It takes into account all characteristics of the receiver except those of the loudspeaker.

The radio receiver is tuned (as described in Section 4.04.01) to a signal at standard mean carrier frequency and of standard mean signal-input value, frequency-modulated with standard test modulation. The receiver output is measured in terms of current or voltage in a standard dummy load. The data should state the load which is used. The receiver volume control is adjusted to give normal test output with 400-cycle modulation. The output variation is observed while the modulation frequency is varied continuously from 30 to 15,000 cycles. The standard pre-emphasis characteristic is to be employed in the standard-signal generator and the modulating voltage is to be maintained constant at that value which provides a modulation of 30 per cent of maximum rated system deviation when the modulation frequency is 400 cycles.

If the electric-fidelity curve has decided peaks, there may be a tendency toward overloading, and the observations should then be repeated with a lower output.

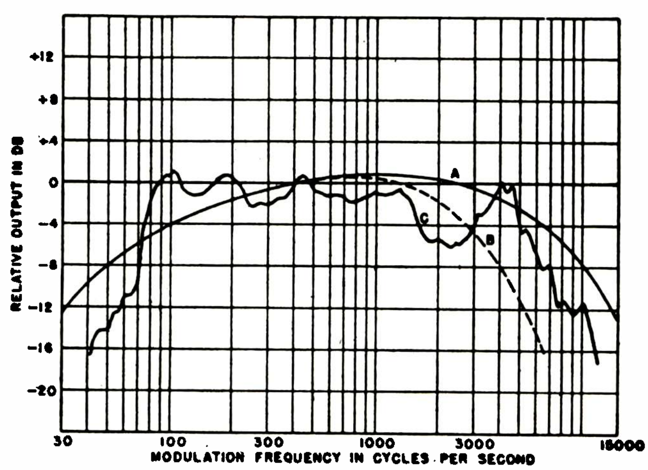


Fig. 9—Fidelity curves.
A—Electric-fidelity curve with tone control for maximum response.
B—Electric-fidelity curve with tone control for minimum response.
C—Acoustic-fidelity curve for one condition.

A statement of the level at which the measurements are made should be included in the data.

The electric-fidelity curves are plotted with audio frequencies as abscissas and relative output voltage or current values as ordinates (Fig. 9). The ordinates are plotted in decibels or in per cent of voltage or current, taking normal test output at 400 cycles as zero decibels or 100 per cent. In the former case, the scale of ordinates should be uniformly divided; in the latter case, the scale may be logarithmic or uniformly divided. The scale of abscissas should be logarithmically divided.

It is frequently unnecessary to make or plot these observations below −20 decibels or 10 per cent, although further observations may be desirable for special purposes.

If hum or noise is present in an appreciable amount during the fidelity test, a suitable correction should be made to prevent its affecting the accuracy of the fidelity observations.

If the fidelity changes substantially with the volume-control setting, this test should be repeated at selected power levels differing in steps of 10 decibels and the resulting curves plotted at levels differing by 10 decibels to show the changes in the variation of output with audio frequencies for selected output levels.

If the receiver has one or more manual tone controls, tests should be made with the standard signal input voltage and with settings of the tone controls which will give maximum and minimum response at high and low frequencies. If overloading is observed at any frequency, the curve should be taken at a lower level and a statement of this fact included in the data.

In order to determine the volume-control effect of the manual tone controls, the tone controls are first set to give maximum response at 400 cycles with the volume control adjusted for normal test output. The fidelity curve for each setting of the tone controls for the same setting of the volume control is obtained and plotted as the ratio of the observed output to the normal test output.

If the fidelity of a receiver having other automatic controls is affected by parameters other than those already noted, additional tests to show the effects of such parameters should be made.

#### 4.05.08. *Acoustic Fidelity*

The acoustic-fidelity test shows the manner in which the acoustic (sound) output of a radio receiver depends on the audio frequency of modulation. It takes into account all characteristics of the receiver, including the radiation of the loudspeaker. For this reason, it is more valuable than an electric-fidelity test. The acoustic-fidelity test cannot easily be performed with high accuracy, nor is this generally required, since the performance of the loudspeaker depends on its surroundings to a great extent.

The procedures for acoustic-fidelity tests are described elsewhere.[7]

The radio receiver is tuned (Section 4.04.01) to the standard mean carrier frequency, modulated with standard test modulation and having mean-signal input intensity. The receiver volume control is adjusted to give normal test output with 400-cycle modulation. The sound-pressure variation is observed while the modulation frequency is varied continuously from 30 to

[7] "Standards on Electroacoustics," 1938, The Institute of Radio Engineers, Inc.

15,000 cycles while maintaining 30 per cent of maximum rated system deviation from 30 to 400 cycles. For frequencies above 400 cycles, the deviation is increased from 30 per cent of maximum rated system deviation in accordance with the standard pre-emphasis characteristic.

The acoustic-fidelity curve is plotted with values of audio frequency as abscissas and relative sound pressure as ordinates. The ordinates are plotted in decibels relative to a chosen zero sound-output level. This level should be the same for all tests on a given radio receiver and on the several receivers if they are to be directly compared. The curves for the response in different directions from the loudspeaker should be plotted on the same sheet in such a manner as to facilitate comparison. The scale of ordinates should be uniformly divided and the scale of abscissas logarithmically divided.

If the receiver has a tone control, a set of curves should be taken for the settings which produce maximum low- and high-frequency response, and at least one curve for each of the other settings.

Other conditions for acoustic-fidelity tests may be chosen according to the suggestions made for electric-fidelity tests.

The acoustic fidelity of automobile receivers is observed by the same procedure, except that the receiver is mounted normally in the car and the microphone is located in the position of the head of the occupant of the car. The window conditions also affect the observations. If only one curve is to be observed, the microphone should be in the position of the driver's head, and all the windows should be halfway open.

### *4.05.09. Harmonic Distortion*

The test is intended to evaluate the spurious audio-frequency harmonics which appear in the electric output of the radio receiver during normal operation. Care should be taken to avoid appreciable harmonic distortion occurring in any part of the signal-generating equipment or in the output-measuring circuit. Harmonic-measuring equipment is required in the output circuit, which should not appreciably affect the output load conditions. This equipment may measure each harmonic individually or may measure all harmonics collectively. The proper tuning of the receiver is important in making distortion tests.

No one complete set of conditions can be prescribed for this test, because harmonic distortion depends on so many details of radio-receiver design and operating conditions. Harmonic distortion is caused by overloading and many other phenomena and is present under various operating conditions, especially at high degrees of modulation. The following series of tests is intended to show the effect of operating parameters on distortion.

(a) *Variation of Output.* The receiver is tuned to the standard mean carrier frequency, and the standard mean signal input with standard test modulation is applied. The distortion is noted as the output of the receiver is varied by means of the volume control.

(b) *Variation of Modulation.* At the standard mean carrier frequency with the standard mean signal input and a 400-cycle modulating signal, the modulation is varied from a deviation of 10 to 100 per cent of maximum rated system deviation and the distortion observed. The output is maintained at normal test output by the volume control for this test, or as near this value as possible.

(c) *Variation of Input Signal.* The distortion at normal test output, obtained after readjusting the volume control if necessary for each observation, is recorded as the signal-input level, at the standard mean carrier frequency and deviated at 400 cycles, is varied. The test is made at both 30 per cent and 100 per cent of maximum rated system deviation. The distortion should be recorded as the input is varied over the entire range of standard input values. This test indicates distortion due to inadequate bandwidth.

(d) *Variation of Modulation Frequency.* To disclose the effect of the modulation frequency on distortion, tests in paragraphs (a) and (b) should be repeated at several modulation frequencies throughout the audio-frequency range. The maximum modulation frequency of which harmonic distortion can be detected by this method is one-half the maximum frequency which can appear in the output.

In making distortion tests at the higher frequencies, special apparatus or special test methods (such as simultaneous application of two modulating tones) may be required.

The harmonic distortion is measured across a standard dummy load and may be measured as either root-sum-square total harmonic distortion or each harmonic may be measured separately. It is expressed as the ratio of the harmonic voltage to the fundamental voltage either in per cent or decibels.

*4.05.09(a). Deviation Distortion Test.* The maximum-deviation distortion test is the measurement of the distortion due to inadequate bandwidth and/or inadequate amplitude-modulation rejection. It is measured at 98 megacycles with the signal generator connected to the receiver through the 300-ohm dummy antenna. Distortion at standard test output is measured at full system deviation over the range from maximum sensitivity level to 30 decibels below 1 watt.

### *4.05.10. Maximum Undistorted Output*

This test is intended to indicate the maximum power output which the receiver will deliver under given conditions, before appreciable overloading or other forms of distortion occur. The maximum undistorted output may be determined under given conditions by observing the total harmonic distortion, and continuously increasing the output from zero up to the least value which contains a total harmonic distortion of 10 per cent (root-sum-square voltage). This value is the maximum undistorted output under the given conditions.

The data should include a statement of the operating conditions, including which condition was varied in order to increase the output during this test. It is suggested that the volume control of the radio receiver be varied, the other conditions being unchanged during a single test and being chosen as suggested for the harmonic-distortion test. Freedom from distortion depends on the radio-frequency input and on the frequency and percentage of modulation.

It is understood that there is no sharp dividing line between appreciable and negligible distortion. The figure of 10 per cent has been chosen somewhat arbitrarily as a reasonable basis for the definition of maximum undistorted output as affected by all operations in the receiver.

*4.05.11. Maximum Output*

This test is intended to show the maximum power output delivered from a radio receiver, without regard for distortion. The conditions for obtaining this output and the general behavior of the receiver under overloading conditions should be included in the data.

The radio receiver is tuned to a signal of standard mean carrier frequency and modulated with standard test modulation. With the receiver adjusted for greatest sensitivity, the percentage of deviation is set successively at 0, 10, 30, and 100 per cent of maximum rated system deviation, and the 400-cycle power output is observed with signal inputs varied over the whole range of standard input values. Suitable 400-cycle filters may be used for the elimination of noise background and harmonic output at low signal-input levels except for the 0 per cent deviation curve.

The maximum-output curves are plotted with values

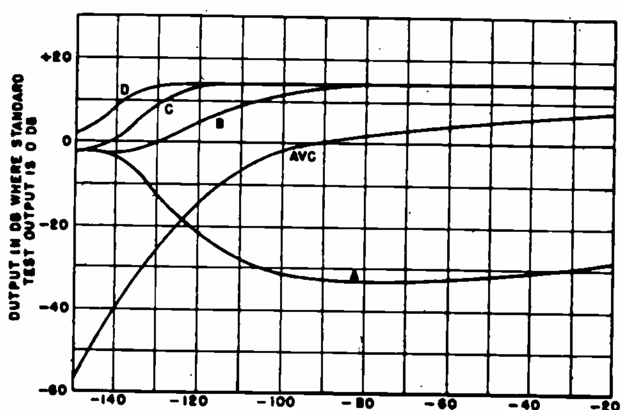


Fig. 10—Maximum-output and automatic-volume-control curves.
A—Maximum output for 0 per cent of maximum deviation.
B—Maximum output for 10 per cent of maximum deviation.
C—Maximum output for 30 per cent of maximum deviation.
D—Maximum output for 100 per cent of maximum deviation.
AVC—Automatic-volume-control curve.

of input power as abscissas and output-power values as ordinates. The scale of abscissas should be uniformly divided for decibels or logarithmically divided for power (see Fig. 10).

*4.05.12. Automatic-Volume-Control Characteristic*

This test is intended to show the manner in which the receiver output varies, due to automatic volume control and/or limiting, with changes in input under conditions where the audio-frequency system does not overload. The test is performed in the same manner as the maximum-output test for 30 per cent modulation (Section 4.05.11) except that the volume control is retarded so that audio overload does not occur. For the purpose of this test, freedom from audio overload is taken as the volume-control setting which reduces the power output to one-half its maximum value for any input below 1 volt. The automatic-volume-control characteristic is plotted in the same manner as the maximum-output characteristic.

*4.05.13. Spurious Responses*

With the radio receiver tuned in turn to each of the test frequencies, the signal generator should be continuously varied over a wide frequency range to discover if the receiver is simultaneously responsive at frequencies other than the test frequency. These other responsive frequencies are called spurious-response frequencies and are most often found in superheterodyne receivers. Each spurious-response frequency is noted and the spurious-response sensitivity test input is measured as in the maximum sensitivity test, provided it is smaller than 30 decibels below 1 watt or 1.1 volts. Its ratio to the desired-signal maximum-sensitivity test input may be computed, and is called the spurious-response ratio. This test is properly classified as a selectivity or interference test, although its procedure is that of a sensitivity test. Care should be taken that the harmonic output of the signal generator is attenuated sufficiently so that it does not affect the observation of the spurious response of the receiver.

(a) *Image Response.* A superheterodyne receiver is generally responsive to two frequencies whose difference from the local-oscillator frequency is equal to the intermediate frequency. One of these is the desired-signal frequency, and the other is called the image frequency. This is a special case of a spurious-response frequency and is tested as such. Its observed characteristics are referred to as the "image-sensitivity test input" and "image ratio."

(b) *Intermediate-Frequency Response.* Another special case of a spurious-response frequency in the superheterodyne receiver is that due to the sensitivity to an intermediate-frequency signal input. One test procedure is the same as for the other spurious responses, except that the input is adjusted to the intermediate frequency.

A second test procedure is to inject the intermediate-frequency test input signal, amplitude-modulated 30 per cent, between the two antenna terminals of the receiver, connected in parallel, and ground, through a standard 300-ohm dummy antenna. The frequency of the test signal is adjusted for maximum receiver output.

The observed characteristics are referred to as the "intermediate-frequency-response sensitivity" and the "intermediate-frequency-response ratio."

*4.05.14. Hum*

Hum is the low-pitched composite tone generally produced by alternating-current socket-powered radio receivers and electric radio receivers obtaining plate supply from vibrators or dynamotors. The tone may include a component at any integral multiple of the alternating-current or pulsating-current frequency. The hum is due to either of the following causes:

(a) Residual hum is produced when the volume control is at the minimum setting and no signal is being received. It is caused by disturbances in the audio-frequency circuits of the receiver.

(b) Hum modulation is produced by disturbances which modulate a carrier being received, and its intensity generally increases with increasing carrier voltage.

Except where otherwise recommended, the individual components are measured with a loudspeaker load connected. A tuned filter or other harmonic analyzer is used to measure individually the hum-output current at each integral multiple of the alternating-current power-supply frequency which is below 300 cycles. When 60-cycle power is used, the 60-, 120-, 180-, and 240-cycle components are measured. The observations should be converted to power output. If a reactive loudspeaker load is connected, the apparent power (volt-amperes) is preferably computed after observing at each frequency the voltage and current, the voltage and impedance, or the current and impedance. (The impedance at any frequency is easily measured by the voltage-current method.)

Acoustic measurement of hum output is desirable but is very difficult by available methods. The results of the electric measurement must be interpreted with reference to electric and acoustic-fidelity curves and the characteristics of audition.

*4.05.15. Measurement of Hum*

*Residual Hum.* The residual-hum test is intended to evaluate the hum component in the output of a radio receiver when no signal is being received and the volume control is set at minimum. If the receiver has a tone control, it should be set in the position for maximum hum. The procedure depends on whether any part of the hum originates in the loudspeaker. The observations should be converted to apparent power output.

If there is no appreciable hum voltage across the loudspeaker terminals when they are disconnected from the radio receiver, the hum components may be measured in the standard dummy load with the output-measuring equipment as in the distortion test.

If there is an appreciable hum voltage across the loudspeaker terminals when disconnected from the radio receiver, the hum components are measured in terms of the hum current through the loudspeaker voice coil itself and not in terms of the voltage across the loudspeaker. The loudspeaker is connected in the normal manner to the radio receiver when the observations are made. The current-measuring equipment introduces into the voice-coil circuit an impedance which is negligible as compared with the voice-coil impedance. In the case of a loudspeaker having a field coil carrying hum current, this procedure evaluates the combined effect of hum originating in the radio receiver itself and hum induced in the voice-coil from the field coil, with due regard to their phase relations.

*4.05.16. Hum Distortion*

Hum distortion is produced by disturbances similar to those which produce hum, where such disturbances in either radio-frequency or audio-frequency amplifiers modulate the audio-frequency tone produced in response to a frequency-modulated radio-frequency carrier.

The hum distortion is measured and expressed as the root-mean-square total per cent modulation of the audio-frequency tone by the hum disturbance.

*4.05.17. Noise Audibility*

The actual audibility of random noise, hum, and miscellaneous noise is best determined by a listening test. Such observations are not capable of precision, but are fundamentally sound, as distinguished from less direct electrical observations. The completely assembled and operating radio receiver is placed in a quiet room and an experienced observer with normal hearing notes the greatest distance at which the noise is audible under stated conditions. The distance is used to express the audibility of the noise. The room is preferably large, or treated to minimize reverberation. This method takes into account noise produced by both loudspeaker radiation and by mechanical vibration of parts. A brief description of the sound heard is useful, in addition to the audibility observation. Obviously this method is suited only for observing a small amount of noise, audible for only a short distance.

The noise-audibility test is intended to evaluate collectively random noise and hum under operating conditions. The radio receiver is tuned in the normal manner to each of the seven standard values of input power at the standard signal-carrier frequency. If the receiver has a tone control, it is set in the position for maximum hum. The volume control is adjusted to give normal test output with standard test modulation; then the modulation is reduced to zero. The audibility of remaining noise is then observed. The residual noise audibility is likewise observed, with no signal and with the volume set at minimum.

### *4.05.18. Tuning Characteristic Test*

The tuning characteristic shows the variation in audio output of the receiver as it is tuned through a signal. This characteristic is of importance in frequency-modulation receivers since they may have spurious output responses adjacent to the correct tuning point. The effect is usually more easily measured by variation of the signal-generator frequency than by variation of receiver tuning, since the signal generator usually has better frequency control and calibration than the receiver.

The receiver is tuned to the mean carrier frequency for each standard input signal value with standard test modulation and the volume control adjusted to standard output. The output is then measured as the signal is detuned to each side of the receiver frequency.

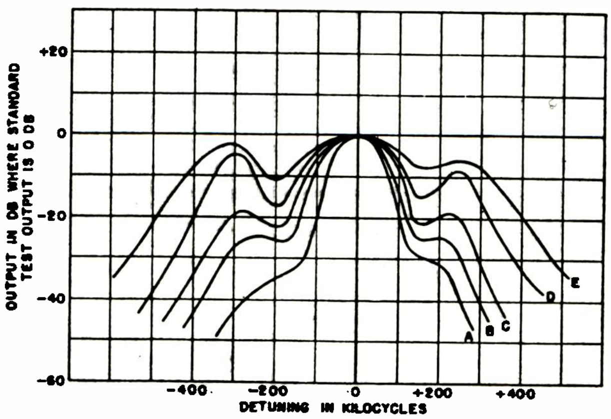


Fig. 11—Tuning characteristics.
A—Input power 130 decibels below 1 watt.
B—Input power 110 decibels below 1 watt.
C—Input power 90 decibels below 1 watt.
D—Input power 50 decibels below 1 watt.
E—Input power 30 decibels below 1 watt.

For each input signal value a tuning curve is plotted, having as abscissas the frequency difference of detuning and having as ordinates the ratio of the observed output to normal test output (see Fig. 11).

### *4.05.19. Tuning Indicator*

This test is intended to show the effectiveness of any indicator as an aid in tuning the receiver accurately. The procedure is the same as that employed in the tuning characteristic test except that the indicator is observed instead of the audio-frequency output. The deflection is plotted on a uniformly divided scale of ordinates and with the frequency of detuning as abscissas.

### *4.05.20. Frequency Drift*

This test is intended to show the variation in the frequency of the oscillator of a superheterodyne receiver. The tests are normally performed with the receiver tuned to the standard signal carrier frequency.

The variation of frequency is observed with the aid of a beat signal obtained between the oscillator under test and another oscillator of constant frequency. For example, the frequency of the beat signal may be observed by comparison with a calibrated audio-frequency oscillator.

The test should cover the following causes of frequency drift and the results should describe the operating condition.

(a) The frequency varies with time during the warming-up period of the receiver. A curve of frequency drift with time is plotted with time in minutes as abscissas on a logarithmic scale and frequency drift in kilocycles as ordinates on a linear scale (see Fig. 12). The time is measured from switching on the receiver but observations are ordinarily started one minute later.

(b) The frequency varies with power-supply voltage in a manner that depends on the rate of variation of this voltage. The major change course occurs almost

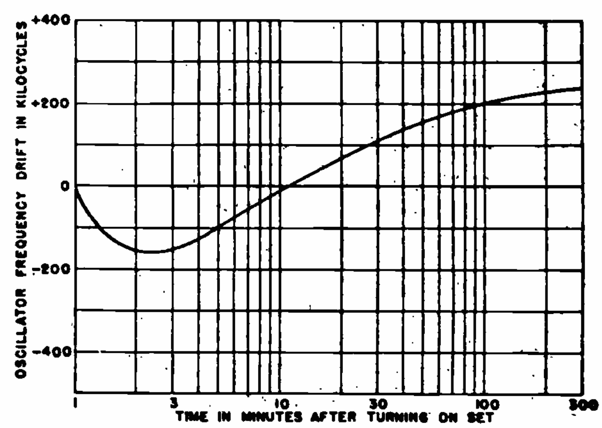


Fig. 12—Frequency drift with time.

instantly following a change of power voltage. Therefore the test is performed as quickly as possible to minimize other effects. In the case of operation from a 120-volt power line, the line voltage is varied at least between 100 and 130 volts and the resultant frequency drift is observed. The amount of frequency drift is expressed in cycles per one per cent change of line voltage, as an average value over the specified range of line voltage.

(c) If the receiver has automatic volume control, the variation of signal-input power affects the oscillator frequency indirectly by way of the control circuit. The frequency drift with variation of signal-input voltage is observed after the receiver has been in operation a sufficient length of time to reach temperature stability.

The signal-input power values are plotted as abscissas on a uniformly divided scale of decibels below 1 watt. The frequency drift in kilocycles is plotted as ordinates on a uniformly divided scale. (See Fig. 13.)

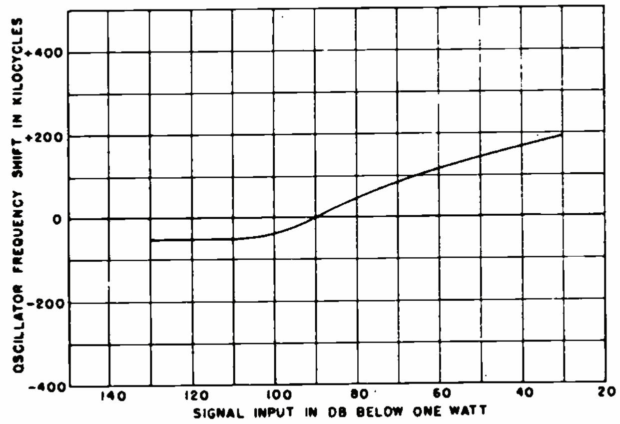


Fig. 13—Frequency shift with change in signal-input power.

### *4.05.21. Low-Frequency Instability*

This test is intended to evaluate the limiting conditions for unstable operation of the receiver, as affected by low-frequency feedback which may be electric or acoustic in nature, and which may involve both carrier frequency and audio frequency and the audio-frequency circuits. At any given frequency, the variables employed to induce instability are the signal-input power, the tuning control, the manual volume control and tone control, the modulation frequency and degree of modulation, and, in battery receivers, the age and condition of the batteries. All parts of the receiver, including the loudspeaker, are mounted in their normal relations.

The test is performed at the standard test frequencies. The receiver is tuned to a modulated test signal, after which the modulation is switched off. The conditions most conducive to the detection of any tendency to instability are found by trial. It is suggested that the frequency of the signal be varied manually over a range of about 100 kilocycles above and below the normal test frequency as the test input power is varied from zero to a maximum of 0.01 watt. An observation is made of the minimum signal-input power at which any unstable operation appears. The maximum of such input power is also recorded if less than 0.01 watt.

### *4.05.22. Direct Radio-Frequency Pickup*

This test is intended to evaluate the effects of pickup of the desired signal or of undesired signal through coupling to parts of the receiver other than the input terminals. Such pickup of desired signals affects the volume-control characteristics. Such pickup of undesired signals affects the selectivity characteristics.

Capacitive pickup is usually more important, and may be tested more simply, than inductive pickup. One or both of the desired and undesired signals are applied to a large capacitor to provide a field intensity whose value can be computed. This capacitor comprises a pair of large horizontal plates displaced vertically, the intervening space being much larger than the receiver. The receiver is set on the lower plate and is grounded thereto. The input terminals of the receiver are connected to a dummy antenna which is shielded from the large capacitor. This test then evaluates the direct pickup of the vertical electric field of a signal wave.

A superheterodyne receiver may be sensitive to direct pickup at the intermediate frequency, and therefore should be tested for this.

### *4.05.23. Radiation from Local Oscillator*

A local oscillator, such as employed in a superheterodyne receiver, may radiate sufficient power to cause interference in other radio receivers operating in the vicinity. Such radiation may be caused by coupling to the antenna or the power line or by incomplete shielding of the oscillator and the circuits coupled thereto.

The receiver is connected to its proper antenna and the electric-field and magnetic-field intensity in the neighborhood observed by any of the known methods. Observations are made with the receiver tuned to each of the standard test frequencies. Results are expressed in field intensity as a function of distance from the receiver under test.

# TESTS FOR EFFECTS OF MISTUNING AND FOR DOWNWARD MODULATION, 1949*

## Supplement to Standards on

# RADIO RECEIVERS: METHODS OF TESTING FREQUENCY-MODULATION BROADCAST RECEIVERS, 1947

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## 1. MISTUNING

1.1. The degree of mistuning is represented by the total signal output distortion resulting when the receiver is adjusted to a frequency other than the desired signal frequency. The measurement is made by setting the signal generator to standard input voltages successively, modulating the signal generator to 75 kc deviation at standard test output. The signal generator is then adjusted off tune by successive increments, the volume control is adjusted for standard test output, and the total distortion in per cent (or db) is measured. For each value of input signal a curve is plotted, having as abscissa the frequency difference of detuning, and as ordinate the distortion expressed in per cent, or db. Distortion components will comprise all frequencies present except the fundamental frequency of the modulating tone. In these tests the signal generator is adjusted off tune on each side of the signal frequency.

1.2. The standard measurement will comprise setting the signal generator on each side of the signal frequency and noting the amount of mistuning that will produce 10 per cent distortion, expressing the degree of mistuning as the average of the measured plus and minus frequency excursions. The signal input for this test shall be the standard mean signal input (1,100 microvolts).

This mistuning test should be correlated with the frequency drift test, Sec. 4.05.20.

## 2. DOWNWARD MODULATION

2.1. This test will define the ability of the receiver to withstand the effects of downward amplitude modulation. In this test it is assumed that the principal forms of distortion are caused by the downward component of modulation.

2.2. The test is made at the standard mean-carrier frequency (98 megacycles). Frequency modulation is impressed at a 400-cycle modulation rate at 30 per cent of maximum rated system deviation and the volume control is adjusted for standard output. The input signal is then simultaneously amplitude modulated at a 100-cycle rate. By means of a band cut-off filter, the 100-cycle modulation is eliminated in the receiver output. The amplitude modulation is then increased until the total distortion reaches 10 per cent. The percentage modulation at this point is the downward modulation capability of the receiver. The test is made at all values of standard input signal voltages.

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# *Standards on* RADIO RECEIVERS

## METHODS OF TESTING AMPLITUDE-MODULATION BROADCAST RECEIVERS (1948)

### 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.

IEEE Standard #186.

### 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.)

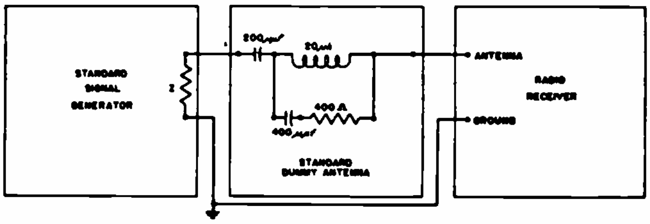


Fig. 1—Standard dummy antenna and method of connections.

### 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.

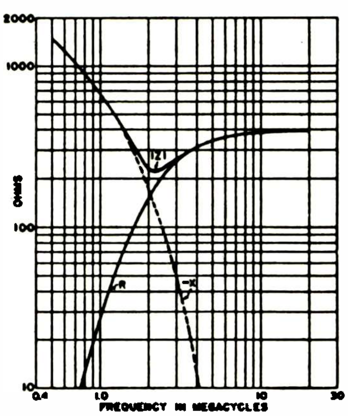


Fig. 2—Impedance characteristics of a dummy antenna.

## 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.

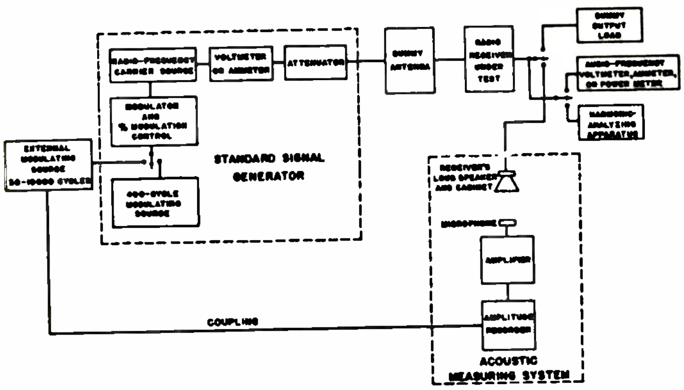


Fig. 3—Schematic arrangement of apparatus used in testing radio receivers.

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 distortion 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, 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 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.

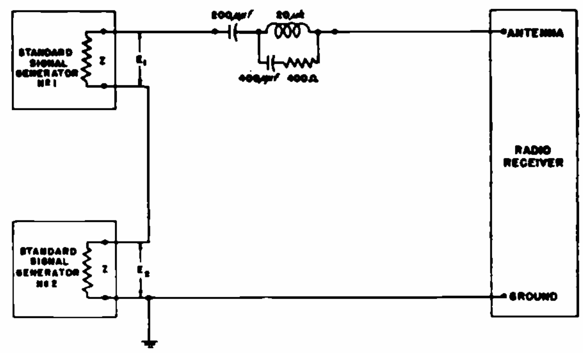


Fig. 4—Connection of two signal generators in a series circuit.

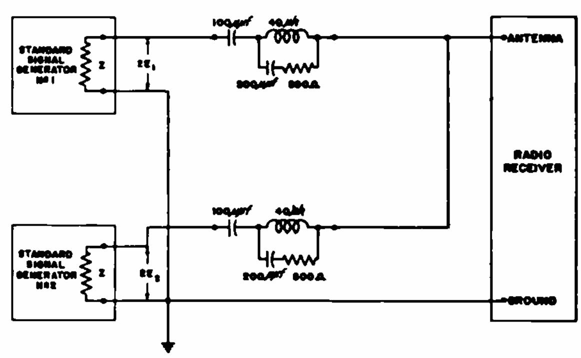


Fig. 5—Connection of two signal generators in parallel circuits.

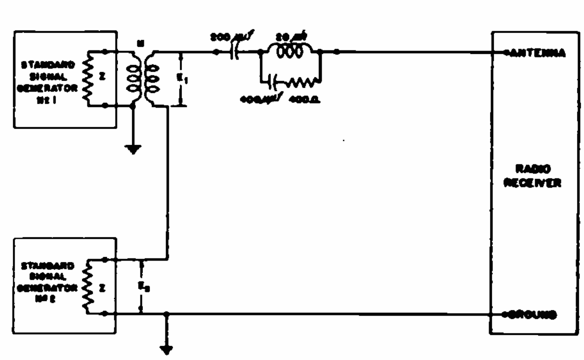


Fig. 6—Connection of two signal generators in a series circuit, one through an output transformer.

The standard-signal generator providing the interfering signal must conform to the general requirements for standard-signal generators and, in addition, must be capable of operating at frequencies well above and well below the frequency of the desired signal.

The radio-frequency harmonic content of both signal generators either must be negligible or must be filtered out, since, when the interfering-signal generator is operated at integral multiples or submultiples of the desired-signal frequency, spurious responses otherwise may be produced which are not chargeable to the receiver.

# 4.00 TEST PROCEDURES

## 4.01. Input Measurements

### *4.01.01. Radio Receiver Designed for a Standard Antenna*

The input voltage is introduced in the radio receiver from the standard-signal generator in series with a standard dummy antenna as shown in Fig. 1. The output circuit of the standard-signal generator should have negligible impedance compared with the standard dummy antenna, unless the output-circuit impedance is included as a part of the dummy-antenna network. The effects of leads between the signal generator and dummy antenna must be taken into account unless such effects are negligible.

### *4.01.02. Radio Receiver Designed for a Special Antenna*

A receiver designed for use with a special antenna is tested with a special dummy antenna designed to simulate the special antenna. Care should be taken that the method of introduction of a signal voltage, as well as the impedance characteristics, simulate conditions existing in the special antenna. Where a special dummy antenna is used, a statement of the constants employed should be included in the test data.

The input to the receiver should be expressed as the root-mean-square voltage in microvolts, or alternatively in decibels below 1 volt, applied to the input terminals of the dummy antenna, the output terminals of the dummy antenna being connected to the receiver.

### *4.01.03. Radio Receiver with a Loop Antenna*

Such receivers are tested like receivers designed for use with a standard antenna, except for the method of introducing and measuring the input voltage. The induced signal in the loop antenna should be expressed in terms of the equivalent field intensity of a received signal. The induced signal in the loop antenna may be introduced and measured by the following methods.

*4.01.03.01.* Voltage may be induced in the loop antenna from a coaxial coil inductively coupled thereto, as shown in Fig. 7. This method is preferred because it is independent of distributed capacitance between the turns of the loop. The natural frequency of coil $L$ and its leads must be much greater than the signal frequency. The distance $X$ should be at least twice the largest dimension of either the coil $L$ or the loop antenna, but much less than the wavelength at the signal frequency. The distance to surrounding objects, such as the walls of a screened room, should be much greater than $X$. The relation between the observed current in coil $L$ and the equivalent field intensity is given by the formulas

$$E = \frac{188.5 N_1 A_1^2}{X^3} I_1$$

$$I_1 = \frac{E X^3}{188.5 N_1 A_1^2}$$

where

$E$ = equivalent electric-field intensity in volts per meter at the loop antenna
$N_1$ = number of turns of coil $L$
$A_1$ = radius of coil $L$ in meters
$X$ = distance in meters between the center of coil $L$ and the periphery of the loop antenna
$I_1$ = current in coil $L$ in amperes.

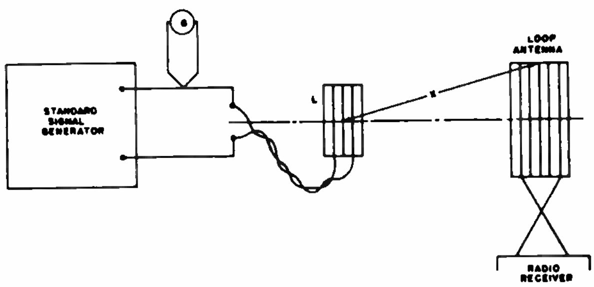


Fig. 7—Standard input to a radio receiver with a loop antenna. A plan drawing of the loop is used to better illustrate the relative dimensions of the coupling devices.

In loop measurements on high-frequency bands, precaution must be taken to insure that the current through all turns of the loop is uniform and accurately measured. If the loop impedance is accurately known, the loop applied voltage may be measured and the current calculated, for use in the above equations.

In the Appendix, Section 5.00, will be found detailed data on the design and use of suitable radiating loops for simplified use in testing loop receivers.

*4.01.03.02.* While the above method of measurement of a loop receiver is most commonly used, there are other methods which have special application and possibly advantages for particular measurements. Another such method is described in the Appendix, Section 6.00.

*4.01.03.03.* For making two-signal tests of receivers having loop antennas, the signals should be coupled into the receiver by one of the methods shown in Figs. 8, 9, and 10. These arrangements correspond to those of Figs. 4, 5, and 6 for conventional antenna-input connections. While these drawings show the low-inductance, series-resistance test loop, described in the Appendix, Section 5.00, they are also directly applicable to the more general case of the high-inductance coil. The value of *R* is determined by the design of the test loop. The equivalent field strength radiated from the test loop is calculated in the same manner as given in Section 5.00. It will be noted in Fig. 9 that, for parallel operation of the two signal generators, the voltage of each is doubled, as is the value of *R* for each generator.

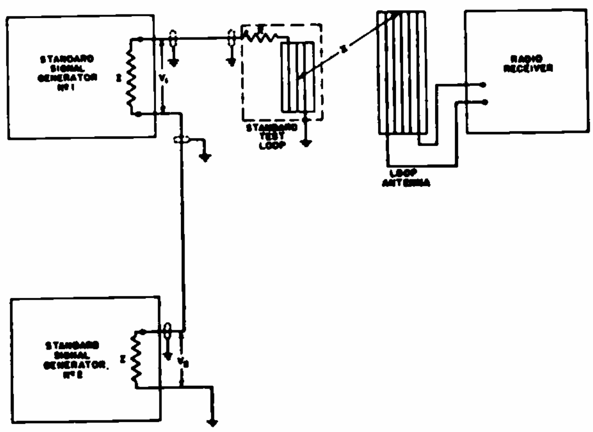

Fig. 8—Connection of two signal generators in series circuit, No. 1 output not grounded.

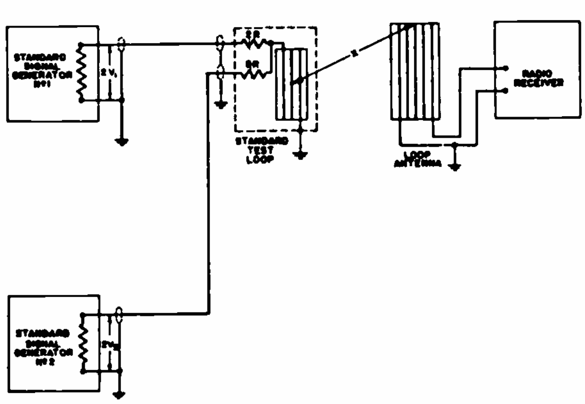

Fig. 9—Connection of two signal generators in parallel circuits, both outputs grounded.

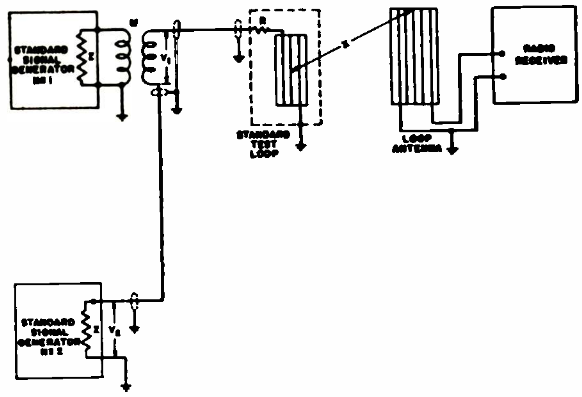

Fig. 10—The two grounded signal generators in series, one through an isolation transformer.

### 4.02. Output Measurements

*4.02.01. Choice of Load*

Output measurements of a radio receiver are made in terms of the power delivered to a standard dummy load, except in special cases where other terms are specified.

The standard dummy load is a pure resistance whose value is equal to the 400-cycle impedance of the loudspeaker which is (a) contained in the radio receiver, or (b) supplied therewith, or (c) recommended for use therewith. Where an output transformer is connected between the radio receiver and the loudspeaker, the output transformer is to be treated as part of the radio receiver.

If the preceding rule cannot be complied with, or if the loudspeaker impedance has pronounced irregularities at frequencies in the vicinity of 400 cycles, the standard dummy load is determined by measuring the load resistance which gives the greatest value of maximum undistorted output, this load resistance not to exceed one and one-half times the direct-current resistance of the voice-coil winding.

*4.02.02 Radio Receiver with No Direct Current in Its Output*

If the output of a radio receiver is free of direct current and is insulated from high direct voltages, a dummy load may be connected directly to the output terminals in place of a loudspeaker.

*4.02.03. Radio Receiver with Direct Current in Its Output*

If the output of a radio receiver contains direct current, or if it is connected to high direct voltages, the standard dummy load should be insulated from each output terminal by capacitors, as shown in Fig. 11. The values of *L* and *C* should be sufficiently great not to have appreciable effect on the output to be measured. Static charges on the dummy load should be removed by a leak resistance *r* sufficiently large not to affect the output to be measured.

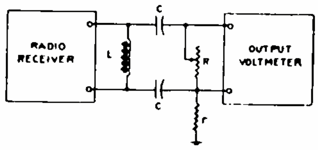


Fig. 11—Radio receiver with direct current in its output circuit.

*4.02.04. Radio Receiver with Push-Pull-Amplifier Output*

If the output of a radio receiver contains direct current, as obtained from the plates of two tubes operating as a push-pull amplifier, the standard dummy load and the inductance may have center taps. It is then advantageous to connect the ground-potential side of the voltmeter to the center tap and observe directly one-half of the load voltage.

*4.02.05. Radio Receiver with Background Noise in Its Output*

*4.02.05.01.* If the background-noise power is smaller than the output power being measured, the incremental reading of the output meter may be used to measure the incremental output power resulting from a given external cause. If a thermocouple output meter is used, the incremental output power is equal to the observed total power minus the observed noise power. If another type of output meter is used, a calibration should be made in terms of incremental power.

Using a thermocouple meter, the following formulas give the incremental output power or voltage in the presence of the noise background:

$$P_0 = P - P_n$$
$$E_0 = \sqrt{E^2 - E_n^2}$$

where

$P_0$ = output power being measured
$P$ = total power observed
$P_n$ = noise power observed
$E_0$ = output voltage being measured
$E$ = total voltage observed
$E_n$ = noise voltage observed.

*4.02.05.02.* If the background-noise power is greater than the output power being measured, it is desirable to use a band-pass filter tuned to the test audio frequency to remove the background noise partially or wholly from the output meter. This filter should be connected between the load and the output meter.

*4.02.05.03.* An ideal method of selecting a locally generated signal from noise and other disturbances of different frequencies is by the use of a synchronously excited electrodynamometer. The field is excited from the original source of the modulation, such as the 400-cycle generator, and the phase of excitation is adjusted for maximum deflection when the signal output of the receiver is applied to the armature. The average deflection then depends only on the signal output corresponding to the excitation. Other output merely causes slight fluctuation of the deflection. This method is especially well adapted to the selection and individual measurement of hum components and harmonic-distortion components, the field being excited by synchronized current of the desired harmonic frequency, with other components thoroughly filtered out. Electron-tube electrodynamometer circuits have been described in the literature and are all well adapted for this purpose if care is taken to avoid overloading.[2,3]

## 4.03. Operating Conditions

*4.03.01. Choice of Operating Conditions*

The operating voltage applied to a radio receiver should be held constant at the specified value during measurements of receiver characteristics. The operating voltages given below for the various receiver classes are the values for normal testing of receivers. If the operating voltage of a receiver is specified, the tests should be performed at that voltage; otherwise, the normal test voltage should be used. Certain receiver characteristics may be desired at other than normal test voltages, or over a range of operating voltages, in which case a statement of the voltages used should be included in the test data.

If the receiver is provided with adjustments for reducing hum or ripple in the output, such adjustments should be made.

*4.03.02. Socket-Powered Radio Receivers*

*4.03.02.01. Alternating-Current-Operated Receivers.* The normal test voltage is 117 volts, root-mean-square.

*4.03.02.02. Direct-Current-Operated Receivers.* The normal test voltage is 117 volts, direct current.

*4.03.02.03. Alternating-Current- or Direct-Current-Operated Receivers.* The normal test voltage is 117 volts.

Any characteristic of this type of receiver which is affected by power supply should be tested with both alternating and direct current. The wave shape of the supply should not be distorted sufficiently to affect measurements such as power output.

*4.03.03. Battery-Operated Radio Receivers*

*4.03.03.01. Automobile Receivers.* The normal test voltage is 6.6 volts at the receiver battery terminals. This voltage should be obtained from a 6-volt storage battery subject to steady charging at the required rate rather than by the use of a dropping resistor. In making hum or distortion measurements, care must be exercised that the battery charger does not introduce an error due to ripple in its voltage.

[2] H. M. Turner and F. T. McNamara, "An electron-tube wattmeter and voltmeter and a phase-shifting bridge," Proc. I.R.E., vol. 18, pp. 1743–1747; October, 1930.

[3] J. R. Pierce, "A proposed wattmeter using multielectrode tubes." Proc. I.R.E., vol. 24, pp. 577–583; April, 1936.

*4.03.03.02. Farm-Lighting-Plant Receivers.* This class of receivers includes those designed for operation from the so-called 32-volt farm-lighting system. The normal test voltage is 36 volts, but the actual voltage is variable over a wide range.

*4.03.03.03. Radio Receivers Operated from Batteries of Specified Voltages.* This class of battery-operated receivers is intended to comprise those not included in classes 4.03.03.01 or 4.03.03.02. Batteries of the type and voltage specified for use with the receiver should be employed. The batteries used should not have abnormally high internal resistance. If a battery cable is not furnished with the receiver, the leads to the batteries should be as short as possible.

*4.03.04. Electron Tubes*

The electron tubes used should be selected to have the rated values of those characteristics which most affect the performance of the receiver.

## 4.04. Radio Receiver Adjustment

*4.04.01. Tuning Controls*

A receiver is tuned to a desired signal by adjusting the tuning controls until the desired audio-frequency output is obtained, either with the least possible radio-frequency input voltage, or with the lowest possible setting of the volume control. When the receiver is tuned to a signal, any appreciable change of either the signal frequency or the tuning controls should cause diminution of the output. Special care is required in accurately tuning receivers having automatic gain control; in such cases, the receiver may be tuned to a relatively weak input voltage, with the manual volume control at maximum, after which the input voltage may be increased to the desired value. In some cases, however, this procedure cannot be followed, as the tuning is affected by the magnitude of the signal input voltage.

The band switch is regarded as a tuning control.

The following tuning adjustment is to be used for fidelity tests, in the absence of special instructions furnished with the receiver. If the receiver under test has automatic gain control, it is tuned first by adjusting the tuning control of the receiver, or that of the signal generator, for maximum output from the receiver with the signal modulated at 400 cycles. The modulation frequency is then increased until the output is decreased about 14 decibels or to 0.2 of the 400-cycle voltage. The tuning control is then finally readjusted slightly for minimum output at this frequency. The tuning is now correct for fidelity tests. If there is difficulty in following this procedure, the receiver probably has an unusual selectivity characteristic requiring further instructions for tuning, or requiring correction of the tuning circuits.

*4.04.02. Volume Controls*

The adjustment of a single main volume control requires no special instructions. Where a receiver has, in addition, a sensitivity control or "local-distance" switch, special instructions are required. Where sufficient instructions accompany the receiver, they should be followed. Otherwise, the following rules should be observed, insofar as they are applicable.

*4.04.02.01.* A "local-distance" switch should be set in the "distance" position for all tests except those in which the receiver is tuned to a local-signal or strong-signal voltage, as herein defined. In this case, the switch is set in the "local" position.

*4.04.02.02.* Any other sensitivity control is set at maximum sensitivity for all tests except where it is needed to control the volume further, or except where the test is made to determine the effects of the sensitivity control.

*4.04.03. Selectivity Controls*

Many receiver characteristics are affected by the setting of the selectivity control, on a receiver having such control. For initial tuning and performance tests, the selectivity control should be adjusted to give the highest degree of selectivity. To determine the effect of the selectivity control, tests whose results are affected by its setting should also be performed at other settings.

Receivers having automatic selectivity controls operated by the strength of the received signal require special tests not specified in these Standards.

*4.04.04. Tone Controls*

During tests requiring output measurements at 400 cycles only, the tone control is adjusted to give maximum 400-cycle output. During other tests, the tone control must be adjusted to meet the requirements of the test.

Receivers having automatic tone controls operated by the strength of the received signal, or by some characteristic of the audio output, require special tests not specified in these Standards.

## 4.05. Performance Tests

The performance of a radio receiver is determined by measurement of the several individual characteristics. The foregoing sections have specified the setup of measuring apparatus and the receiver under test; in addition, it is necessary to follow standardized test procedures in order that measurements made in different laboratories will be comparable. These test procedures serve to measure the individual characteristics of the receiver.

*4.05.01. Tuning Range*

The radio receiver tuning control is set for the respective minimum and maximum carrier frequencies in each tuning band which it is capable of receiving with normal operation. At each setting, the signal generator is tuned to the resonant frequency of the receiver, and the signal frequency recorded. This procedure may be extended to obtain a frequency calibration of the dial if this is required.

#### 4.05.02. *Sensitivity*

The sensitivity-test input is measured at each test frequency with the aid of a standard-signal generator. At least three test frequencies should be used in each tuning band, one near the middle and one near each end of the band.

The sensitivity graph is plotted with test frequencies as abscissas and sensitivity-test-input voltages or field intensities as ordinates, as illustrated in Fig. 12. A uniformly divided scale of ordinates should be used if the input is expressed in decibels below 1 volt, or 1 volt per meter. A logarithmically divided scale of ordinates is preferable if the input is expressed in microvolts, or microvolts per meter. A logarithmically divided scale of abscissas should be used to show all of the data on one graph if the receiver covers more than one tuning band. A uniformly divided scale of abscissas may be used to show the sensitivity characteristic in any one tuning band.

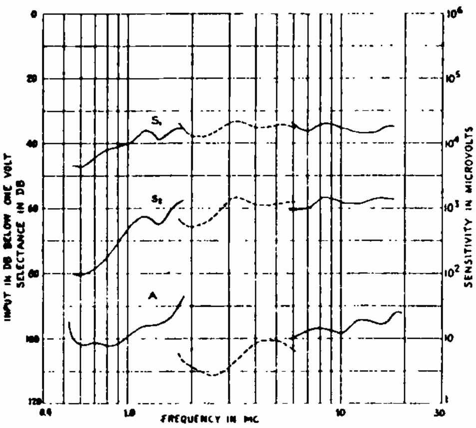

Fig. 12—Sensitivity and selectance curves.

#### 4.05.03. *Selectivity*

The radio receiver is tuned in succession to each test frequency, as in the sensitivity test. The signal generator is then detuned each side of resonance, the radio-frequency input voltage which results in normal test output is observed, and its ratio to the sensitivity-test input is computed. Observations are made at least every 10 kilocycles up to 100 kilocycles off resonance, or until the ratio exceeds 10,000 times, or until the observed input voltage exceeds 1 volt, whichever requires the least departure from resonance.

If, in superheterodyne receivers, this test is made at only one frequency, it is recommended that this be 1,000 kilocycles. It is sometimes not feasible to conduct the selectivity test on all bands, in which case the approximate selectivity may usually be deduced from the results of measurements made at lower frequencies, particularly from measurements of selectivity of the intermediate-frequency amplifier.

If the receiver is provided with a manual selectivity control, the selectivity should be measured in the positions of maximum selectivity and minimum selectivity, the selectivity in intermediate positions of the control also being measured if desired.

If the receiver has an automatic-gain-control circuit with the same degrees of selectivity as the signal circuit, no special precautions are necessary. However, if the automatic-gain-control circuit selectivity differs appreciably from that of the signal circuit, it is advisable to maintain the automatic-gain-control voltage at that value obtained at center frequency. It should be noted that this method provides an indication of the circuit selectivity, rather than of the discrimination against interference, which can be measured more accurately by the two-signal method detailed below.

For each test frequency, a graph is plotted with carrier frequencies as abscissas and ratios of input voltage off resonance to input voltage at resonance as ordinates, as illustrated in Fig. 13. The scale of abscissas should be uniformly divided and enlarged. The scale of ordinates should be uniformly divided when the ratios are expressed in decibels, or logarithmically divided when the ratios are expressed numerically.

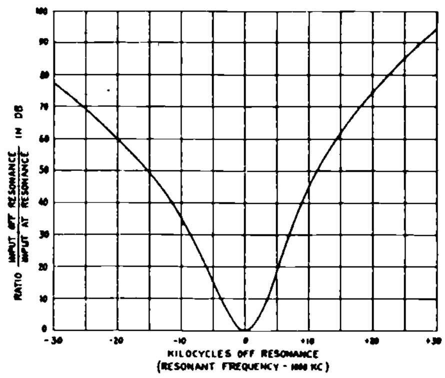

Fig. 13—Selectivity curve at 1,000 kilocycles.

The results of the selectivity test may alternatively be expressed in tabular form or graphically in terms of selectance or in terms of bandwidth.

To express the selectivity in terms of selectance, a graph is plotted with resonant frequencies as abscissas and corresponding values of selectance as ordinates, as illustrated in Fig. 12. One graph is plotted for each of $S_1$, $S_2$, etc., or for each of $S_{+1}$, $S_{-1}$, $S_{+2}$, $S_{-2}$, etc. The scale of ordinates should be uniformly divided if selectance is expressed in decibels, or logarithmically divided if selectance is expressed numerically.

To express the selectivity in terms of bandwidth, a graph is plotted with resonant frequencies as abscissas and with bandwidths as ordinates. A graph may be plotted for each of the levels, 3 decibels or 1.41 times, 6 decibels or 2 times, 20 decibels or 10 times, 40 decibels or 100 times, etc., referring to the selectivity curves. Both scales may be uniformly divided, or the scale of ordinates may be logarithmically divided. Alternatively, the selectance or bandwidth may be given in tabular form.

If the volume control or signal level substantially affects the selectivity curve, this test should be repeated with the volume control reduced until the signal input equals the "mean-signal" input voltage, and, if desired, the other standard input voltages. If the radio receiver has automatic gain control, this test with reduced manual volume control should be performed with the automatic-gain-control voltage held constant, as described above.

If the radio receiver has automatic selectivity control, selectivity curves may be taken in the usual manner by supplying to the automatic-selectivity-control device several fixed control potentials to obtain representative operating characteristics.

On loop receivers employing highly selective loops, the over-all selectivity may differ from that obtained with antenna operation, in which case the above measurements should be repeated, using induced loop pickup.

*4.05.04. Electric Fidelity*

The electric-fidelity test shows the manner in which the electric output of a radio receiver depends on the modulation frequency. It takes into account all characteristics of the receiver except those of the loudspeaker, although the latter are of major importance. Because of this weakness, the test is essentially analytical in nature. Its value resides in the ease and accuracy with which the test is performed, and in its usefulness for comparative purposes.

The radio receiver is tuned (as described in the last paragraph of Section 4.04.01) to a signal at 1,000 kilocycles, modulated 30 per cent at 400 cycles, having a mean-signal voltage 46 decibels below 1 volt or 5,000 microvolts, or 46 decibels below 1 volt per meter or 5,000 microvolts per meter for loop sets. The receiver output is measured in terms of current or voltage in a standard dummy load, or in terms of the voltage across or of the current in the voice coil of the loudspeaker. In the latter case, the loudspeaker should be located in its baffle or cabinet, with the receiver chassis in place. The data should include a statement of which load is used. The receiver volume control is adjusted to give normal test output. The modulation frequency is then varied from 30 to 10,000 cycles while maintaining 30 per cent modulation, and the output variation is observed.

If the electric-fidelity curve has decided peaks, there may be abnormal tendency toward overloading, and the observations may have to be repeated with reduced output, which output should be recorded with the data.

The electric-fidelity curves are plotted with audio frequencies as abscissas and relative output voltage or current values as ordinates, as illustrated in Fig. 14. The ordinates are plotted in decibels or in per cent of voltage or current, taking normal test output at 400 cycles as 0 decibels or 100 per cent. In the former case, the scale of ordinates should be uniformly divided; in the latter case, the scale may be logarithmically or uniformly divided. The scale of abscissas should be logarithmically divided.

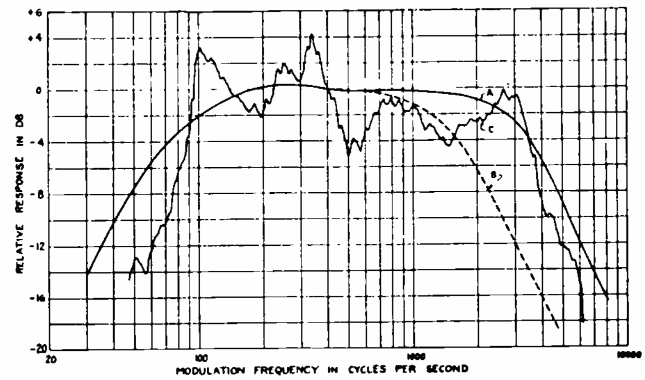


Fig. 14—Fidelity curves; (a) electric-fidelity curve with tone control for maximum response, (b) electric-fidelity curve with tone control for minimum response, and (c) acoustic-fidelity curve for one condition.

When the output is measured across the loudspeaker, the relative output in decibels is taken as 20 $\log_{10}$ of the voltage ratio.

It is frequently unnecessary to make or plot these observations below −20 decibels or 10 per cent, although further observations may be desirable for special purposes.

If hum or noise is present in an appreciable amount during the fidelity test, a suitable correction should be made to prevent its affecting the accuracy of the fidelity observations.

If the fidelity changes substantially when the receiver is tuned to signals of different frequencies or voltages, this test should be repeated at 600 and 1,400 kilocycles, or at distant-signal and local-signal voltages. Such tests are essential to show the effects of automatic selectivity or automatic tone controls.

If the fidelity changes substantially with the volume-control setting, this test should be repeated with power-output levels differing by 10-decibel steps, and the resulting curves plotted at levels differing by 10 decibels to show the changes in the variation of output with audio frequencies for selected output levels.

If the fidelity changes substantially with loop operation, this test should be repeated, using loop-induced signals.

If the receiver has one or more manual tone controls, this test should be made at 1,000 kilocycles with mean-signal voltage and with settings of the tone controls which will give maximum and minimum response at high and low frequencies. If overloading is observed at any frequency, the curve should be taken at a lower level and a statement of this fact included in the data. A manual selectivity control may be considered as a high-frequency tone control for the purpose of this test.

In order to determine the volume-control effect of the manual tone controls, the tone controls are first set to give maximum response at 400 cycles with the volume control adjusted for normal test output. The fidelity curve for each setting of the tone controls for the above setting of the volume control is obtained and plotted as the ratio of the observed output to the normal test output.

If the fidelity of a receiver having other automatic controls is affected by parameters other than those already noted, additional tests to show the effects of such parameters should be made.

*4.05.05. Acoustic Fidelity*

The acoustic-fidelity test shows the manner in which the acoustic (sound) output of a radio receiver depends on the audio frequency of modulation. It takes into account all characteristics of the receiver, including the radiation of the loudspeaker. For this reason, it is more valuable than an electric-fidelity test. The acoustic-fidelity test cannot easily be performed with high accuracy, nor is this generally required, since the performance of the loudspeaker depends on its surroundings to a great extent.

The procedures for acoustic-fidelity tests are described in the contemporary Standards on Electroacoustics.[1]

The radio receiver is tuned (as described in the last paragraph of Section 4.04.01) to a signal at 1,000 kilocycles modulated 30 per cent at 400 cycles, having "mean-signal" input. The receiver volume control is adjusted to give normal test output. The modulation frequency is then varied from 30 to 10,000 cycles while maintaining 30 per cent modulation, and the sound-pressure variation is observed.

The acoustic-fidelity curve is plotted with values of audio frequency as abscissas and relative sound pressure as ordinates. The ordinates are plotted in decibels relative to a chosen zero sound output level. This level should be the same for all tests on a given radio receiver and on different receivers which are to be compared. The curves for all directions should be plotted on the same sheet in such a manner as to facilitate comparison. The scale of ordinates should be uniformly divided and the scale of abscissas logarithmically divided.

If the receiver has a tone control, a set of curves should be taken for the settings which produce maximum low- and high-frequency response, and at least one curve for each of the other settings. One typical curve is illustrated in Fig. 14.

Other conditions for acoustic-fidelity tests may be chosen according to the suggestions made for electric-fidelity tests.

The acoustic fidelity of automobile receivers is observed by the same procedure, except that the receiver is mounted normally in the car and the microphone is located in the position of the head of the occupant of the car. The window conditions also affect the observations. If only one curve is to be observed, the microphone should be in the position of the driver's head, and all the windows should be halfway open.

*4.05.06. Harmonic Distortion*

This test is intended to evaluate the spurious audio-frequency harmonics which appear in the electric output of the radio receiver during normal operation. Care should be taken to avoid appreciable harmonic distortion occurring in any part of the signal-generating equipment, or in the output-measuring circuit. The required harmonic-measuring equipment in the output circuit should not appreciably affect the output load conditions. This equipment may measure each harmonic individually or may measure all harmonics collectively. The proper tuning of the receiver is important in making distortion tests.

No one complete set of conditions can be prescribed for this test, because harmonic distortion depends on so many details of radio receiver design and operating conditions. Harmonic distortion is caused by overloading and many other phenomena, and is present under various operating conditions, especially at high degrees of modulation. The following series of tests is intended to show the effect of operating parameters on distortion.

*4.05.06.01. Variation of Output.* The receiver is tuned to 1,000 kilocycles and a "mean-signal" input, modulated 30 per cent at 400 cycles, is applied. The distortion is noted as the output of the receiver is varied by means of the volume control.

*4.05.06.02. Variation of Modulation.* With a "mean-signal" 1,000-kilocycle, 400-cycle-modulated input, the modulation is varied from 10 to 100 per cent and the distortion observed. The output is maintained at normal test output by the volume control for this test, or as near this value as possible.

*4.05.06.03. Variation of Input Signal Level.* With a 1,000-kilocycle signal, modulated at 400 cycles, the distortion at normal test output is noted as the input signal voltage is varied. This test is to be performed at both 30 per cent and 80 per cent modulation. It is usually sufficient to take distortion at the standard input levels which fall within the limits of the receiver. When a standard-signal level exceeds the limit of the receiver, a measurement should be made at that limit.

*4.05.06.04. Variation of Modulation Frequency.* To disclose the effect of the modulation frequency on distortion, tests in Sections 4.05.06.01 and 4.05.06.02 should be repeated at several modulation frequencies throughout the audio-frequency range. The maximum modulation frequency at which harmonic distortion can be measured is one-half the maximum frequency which can produce any appreciable output.

The harmonic distortion is measured across a standard dummy load and may be measured as either root-sum-square total harmonic distortion or each harmonic may be measured separately. It is expressed as the ratio of the harmonic voltage to the fundamental voltage either in per cent or decibels.

*4.05.06.05. Acoustic Measurement of Distortion.* Acoustic measurement of harmonic distortion is desirable but is very difficult by available methods. The results of the electrical measurement must be interpreted with reference to electric- and acoustic-fidelity curves and the characteristics of audition.

Subharmonic distortion usually occurs only in the loudspeaker, and, therefore, must be measured acoustically. The building-up time is a characteristic in which subharmonic distortion differs essentially from harmonic distortion. Also, it is more critical as to frequency of excitation, and may be unstable in amplitude. The general procedure of paragraph 4.05.06.01 is followed for this test. The subharmonic distortion need not be observed for electric output exceeding the maximum undistorted output evaluated by electric tests.

*4.05.06.06. Intermodulation Distortion.* As described in Section 3.01, intermodulation distortion will not correlate with harmonic distortion when the nonlinearity present is a function of frequency.

Inasmuch as there is no general agreement on the best method of measuring intermodulation distortion, a brief description of the current methods of measuring this form of distortion is given in the Appendix, Section 7.00.

### *4.05.07. Maximum Undistorted Output*

This test is intended to indicate the maximum power output which the receiver will deliver under given conditions, before appreciable overloading or other forms of distortion occur. The maximum undistorted output may be determined under given conditions by observing the total harmonic distortion, and continuously increasing the output from zero up to the least value which contains a total harmonic distortion of 10 per cent (root-sum-square voltage). This value is designated the maximum undistorted output under the given conditions.

The data should include a statement of the operating conditions, including which condition was varied in order to increase the output during this test. It is suggested that the volume control of the radio receiver be varied, the other conditions being unchanged during a single test and being chosen as suggested for the harmonic-distortion test. Freedom from distortion depends on the radio-frequency input voltage and on the frequency and percentage of modulation.

It is understood that there is no sharp dividing line between appreciable and negligible distortion. The figure of 10 per cent has been chosen somewhat arbitrarily as a reasonable basis for the definition of maximum undistorted output as affected by all operations in the receiver.

### *4.05.08. Maximum Output*

This test is intended to show the maximum power output delivered from a radio receiver, without regard for distortion. The conditions for obtaining this output and the general behavior of the receiver under overloading conditions should be included in the data.

The radio receiver is tuned to a 1,000-kilocycle signal modulated at 400 cycles, and is adjusted for greatest sensitivity. The modulation is set successively at 0, 10, 30, and 80 per cent, the signal input voltage is varied from 120 to 0 decibels below 1 volt (1 to 1,000,000 microvolts), and the output power is observed. Suitable corrections may be made for noise background and harmonic output, if present in amounts sufficient to affect the observations, or a 400-cycle filter may be employed.

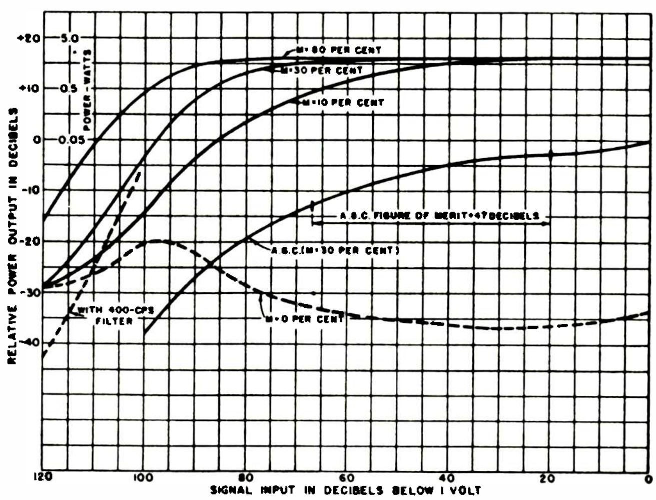


Fig. 15—Maximum-output and automatic-gain-control characteristics; input is an all-wave dummy antenna; 1 megacycle, 400-cycle modulation; 0 decibel output = 0.05 watt in a 3-ohm load.

The maximum-output curves are plotted with input voltages as abscissas and output-power values as ordinates, as illustrated in Fig. 15. The scale of abscissas should be uniformly divided for decibels or logarithmically divided for microvolts. The scale of ordinates may be either uniformly divided for decibels or logarithmically divided for watts.

### *4.05.09. Automatic Gain Control*

This test is intended to show the operation of automatic gain control under nonoverloading conditions in the audio-frequency amplifier. In the case of receivers intended for antenna operation, the receiver is connected as shown in Fig. 1 and tuned to a mean-signal input voltage at 1,000 kilocycles, modulated 30 per cent at 400 cycles. The output is first adjusted by means of the volume control so that maximum output for any input less than 1 volt does not give audio-frequency overload. For the purpose of this test, the overload limit may be considered as one-half the maximum power output.

The output is then read as the input is varied from 1 microvolt to 1 volt. The output is recorded in decibel variations from the maximum output obtained with this volume-control setting. This test should preferably be repeated at the middle frequency of each band.

For receivers intended for a wide range of signal input voltage, the automatic-gain-control figure of merit is the number of decibels maximum reduction of input, below 100,000 microvolts, for which the maximum change of output is 10 decibels. For receivers primarily intended for small values of signal input, such as automobile receivers and the short-wave bands of broadcast receivers, the upper limit should be 5,000 microvolts instead of 100,000 microvolts.

In the case of loop receivers, the connections shown in Fig. 7 are used. In this case the strongest signal used, in taking the continuous automatic-gain-control curve, is 200,000 microvolts per meter, or 14 decibels below 1 volt per meter. The procedure followed in obtaining this curve is similar to that described above.

For loop sets, the automatic-gain-control figure of merit is the number of decibels maximum reduction of input, below 50,000 microvolts per meter, for which the maximum change of output is 10 decibels.

If an automatic quieting control is incorporated in the receiver, these tests should be performed both with and without this control in operation.

### *4.05.10. Spurious Response*

With the radio receiver tuned to each of the test frequencies, the signal generator should be continuously varied over a wide frequency range to discover if the receiver is simultaneously resonant at frequencies other than the test frequency. These other resonant frequencies are called spurious-response frequencies and are most often found in superheterodyne receivers. Each spurious-response frequency is noted and the spurious-response sensitivity-test input is measured as in the sensitivity test, provided it is smaller than 1 volt. Its ratio to the desired-signal sensitivity-test input may be computed, and is called the spurious-response ratio. This ratio may be expressed in decibels or as a numerical ratio of voltages. This test is properly classified as a selectivity or interference test, although its procedure is that of a sensitivity test. Care should be taken that the harmonic output of the signal generator is attenuated sufficiently not to affect the observation of the spurious response of the receiver.

In the case of loop receivers, various spurious-response ratios may be materially different on the loop from those obtained with antenna operation and should be measured on the loop as well as the antenna.

*4.05.10.01. Image Response.* A superheterodyne receiver is generally responsive to two frequencies whose difference from the local-oscillator frequency is equal to the intermediate frequency. One of these (usually the lower) is the desired-signal frequency, and the other is called the image frequency. This is a special case of spurious-response frequency, and is tested as such. Its observed characteristics are referred to as "image-sensitivity test input" and "image ratio."

*4.05.10.02. Intermediate-Frequency Response.* Another special case of a spurious-response frequency in a superheterodyne receiver is that due to the sensitivity to an intermediate-frequency signal input. The test procedure is the same as for other spurious responses, and the observed characteristics are referred to as the intermediate-frequency-response sensitivity and the intermediate-frequency-response ratio.

### *4.05.11. Random Noise*

Random noise having a continuous frequency spectrum is produced in the electrical circuits of a radio receiver. Such noise as is produced in the radio-frequency circuits and greatly amplified appears most prominently in the output of the receiver. In the presence of a signal carrier, such noise appears as sidebands of the signal, but the noise sidebands on each side are unrelated in phase, whereas the signal-modulation sidebands are related in phase. The amount of noise in the output of the receiver depends on the filtering action of the selective circuits, tone controls, etc., in the receiver. The noise power in the output is proportional to the effective bandwidth of the receiver with respect to both of the noise sidebands.

The random-noise output is measured with the load and output-measuring equipment connected as in the electric-fidelity test, but with the modulation reduced to zero, because the proper interpretation of the noise observation requires some reference to the electric-fidelity curve. The meter used should be chosen to have small wave-form error, or should have a noise wave-form correction factor determined by comparison with a meter having small wave-form error. If appreciable hum is present at the same time, it should be filtered out before measuring the noise. This may be accomplished by the use of a high-pass filter with a sharp cutoff below 300 cycles, which has very little effect on the random-noise measurements. See Fig. 15 for a typical random-noise curve (0 per cent modulation).

*4.05.11.01. Equivalent-Noise-Sideband Input.* The equivalent-noise-sideband input (ENSI) is the equivalent input magnitude of all random noise which is transferred to the output circuit, and, therefore, of all such noise within the frequency sidebands passed by the receiver. This expression of noise has the advantage that its value in most receivers does not depend critically on the carrier input voltage, the sensitivity of the receiver, or the volume-control setting. Also, its value can be compared directly with the carrier input from a desired signal. It is most easily observed, and is most important, in highly sensitive receivers.

For purposes of measurement, the equivalent-noise-sideband input is taken equal to the input of a single sideband of 400-cycle modulation which will produce an equal output from the receiver, other conditions being the same. The identification of the noise of both sidebands with a single-sideband component of modulation is necessitated by the random-phase relation among the noise sidebands and the signal carrier, as distinguished from the specific phase relations among the carrier and each pair of sideband components of modulation. This measurement theoretically requires the presence of a carrier much greater in amplitude than the peak value of noise and 400-cycle sidebands present. The value of equivalent-noise-sideband input, computed by the following equation, is then substantially independent of the detection characteristics of the receiver:

$$E_n = mE_s(E_n'/E_s') = mE_s\sqrt{P_n'/P_s'}$$

where

$E_n$ = equivalent-noise-sideband input voltage
$E_s$ = signal carrier input voltage
$m$ = signal modulation factor
$E_n'$ = output voltage of noise only
$E_s'$ = output voltage of signal only
$P_n'$ = output power of noise only
$P_s'$ = output power of signal only.

The signal carrier input is present and constant during all observations. Its voltage $E_s$ should be at least three times, and preferably at least ten times, the computed noise voltage $E_n$. The carrier input is modulated at 400 cycles to the extent of the factor $m$, which should not exceed 0.3 (30 per cent). The audio-frequency noise output may be measured alone by switching off the modulation. The 400-cycle signal output may be measured alone with the aid of a 400-cycle sharply selective filter. Alternatively, the 400-cycle signal output in the presence of the noise may be measured and corrected for the noise component. Noise from hum or such other causes is not intended to be included in this test, and should not be allowed to affect the final result. Low-frequency hum components, if excessive, may usually be filtered out by the use of a 300-cycle high-pass filter, without materially affecting the random-noise output. It is especially important that the output meter should indicate correctly the root-sum-square values of the noise, which has a very irregular wave form with great ratios of peak-to-mean amplitude. Thermal instruments are the most reliable in this respect. Overloading conditions should be avoided, and normal operating conditions of the receiver should be employed.

The random noise originating in a receiver limits its useful sensitivity, so that the sensitivity test should be interpreted with reference to the equivalent-noise-sideband input.

*4.05.12. Hum*

Hum is the low-pitched composite tone generally produced by alternating-current socket-powered and converter-powered radio receivers. The tone may include a component at any integral multiple of the alternating-current frequency. The hum is due to either or both of the following causes.

*4.05.12.01.* Audio hum is produced by coupling between hum sources in the supply or rectifier circuits and the audio amplifier, and its intensity generally increases with volume-control setting.

The audio-hum test is intended to evaluate the hum components in the output of a radio receiver when no signal is being received. If the receiver has a tone control, it should be set in the "high" position. The procedure depends on whether any part of the hum originates in the loudspeaker.

If there is no appreciable hum voltage across the loudspeaker terminals when disconnected from the radio receiver, the hum components may be measured with the load and output-measuring equipment connected as in the electric-fidelity test, thus measuring the total hum consisting of the power-supply fundamental and all its harmonics.

If there is appreciable hum voltage across the loudspeaker terminals when disconnected from the radio receiver, the hum should be measured in terms of the hum current through the loudspeaker voice coil itself, rather than in terms of the voltage across the loudspeaker, and the total hum calculated using this current and the loudspeaker voice-coil impedance. The loudspeaker is connected in the normal manner to the radio receiver when the observations are made. The current-measuring equipment should introduce into the voice-coil circuit an impedance which is negligible as compared with the voice-coil impedance. In the case of a loudspeaker having a field coil carrying hum current, this procedure evaluates the combined effect of hum originating in the radio receiver itself and hum induced in the voice coil from the field coil, with due regard to their phase relations.

The audio-hum output will usually vary with volume-control setting, depending upon the relative effects of the various sources of hum pick-up. To evaluate these factors, hum measurements should be made:

(a) With the volume control at minimum.

(b) With the volume control left at that setting which would produce normal test output with mean-signal input, but with the intermediate-frequency-amplifier circuits inactivated, as by by-passing the last intermediate-frequency plate to ground.

(c) With the volume control at full volume and the intermediate-frequency system inactivated.

In the case of phonograph combinations, audio hum should also be measured with the phonograph pick-up connected to the audio amplifier under the following conditions:

(a) With the phonograph motor de-energized, the pick-up on the rest, and the volume control at minimum.

(b) Same as (a) but with the volume control at maximum.

(c) With the volume control adjusted, while reproducing the outside 1,000-cycle band on RMA Frequency Test Record No. 1, to give normal test output, the needle then lifted not more than $\frac{1}{4}$ inch above the record, with the motor still running. The above test record is described in greater detail in Section 4.05.26.

*4.05.12.02.* Hum modulation is produced by hum sources which modulate a carrier being received, and its intensity generally increases with increasing carrier voltage.

The hum-modulation test is intended to evaluate the hum components introduced in a radio receiver by hum disturbances modulating the received carrier. In order to measure hum modulation, as distinguished from audio hum, the former is accentuated by the adjustments of the receiver. The receiver is tuned in the normal manner to each of the four standard input voltages at 1,000 kilocycles. If the receiver has a tone control, it should be set in the "high" position. The volume control is first adjusted to give the normal test output with the given signal voltage modulated 30 per cent at 400 cycles, and the modulation is then reduced to zero. The hum is measured with the load and output-measuring equipment connected as in the electric-fidelity test, and is expressed in terms of reduction in decibels below standard test output.

### *4.05.13. Hum Distortion*

Hum distortion is produced by disturbances similar to those which produce hum, where such disturbances in either radio-frequency or audio-frequency amplifiers modulate the audio-frequency tone produced in response to a modulated radio-frequency carrier. It is identified as sidebands of frequencies differing from the audio frequency of modulation by an amount equal to the frequency of the hum disturbance causing the distortion.

The hum distortion is measured and expressed as the root-sum-square total per cent modulation of the audio-frequency tone by the hum disturbance. The hum modulation of the audio-frequency tone may be measured by any method used to measure the audio-frequency tone, in this case acting as the carrier, and the hum disturbance acting as the cause of modulation. No specific test procedure for measuring hum distortion is outlined in these Standards.

### *4.05.14. Whistle Modulation*

In superheterodyne radio receivers receiving only a single unmodulated carrier frequency, a whistle whose pitch varies rapidly with tuning may be produced by interactions between various parts of the receiver. Such a whistle occurs most often when the received carrier frequency is near an integral multiple of the intermediate frequency, but it may occur when the received carrier frequency is near a simple fractional multiple of the intermediate frequency, such as 3/2 or 5/2.

The whistle-modulation test is intended to evaluate the whistle noise which may be introduced in a superheterodyne receiver. In order to measure whistle modulation, it is accentuated by the adjustments of the receiver. The receiver is tuned in the normal manner to a signal at one of the standard input voltages. If the receiver has a tone control, it should be set in the "high" position. The volume control is adjusted to give approximately the maximum undistorted output obtainable with the given signal voltage modulated 30 per cent at 400 cycles, and then the modulation is reduced to zero or to a very small value so as not to mask the whistle. The loudspeaker load is used, with output-measuring equipment, to enable the observer to listen for whistles. The signal generator and receiver are tuned together over the entire frequency band, and each frequency is noted where a whistle is heard near zero beat at the same time the receiver is exactly in tune with the signal. At each frequency noted, the signal input voltage and the volume control are again adjusted, and the whistle output is measured electrically with the whistle tuned to about 400 cycles and the modulation reduced to zero. The whistle modulation is computed by the equation

$$m = 30E_w/E_s$$

where

$m$ = whistle modulation in per cent
$E_w$ = whistle output voltage
$E_s$ = signal output voltage when modulated 30 per cent at 400 cycles.

This procedure usually is followed with each of the three lower standard input voltages. The whistle modulation need not be measured if it is so small as to be masked by random noise or hum output.

### *4.05.15. Noise Audibility*

The actual audibility of random noise, hum, and miscellaneous noise is best determined by a listening test. Such observations are not capable of precision, but are fundamentally sound, as distinguished from less direct electrical observations. The completely assembled and operating radio receiver is placed in a quiet room, and an experienced observer with normal hearing notes the greatest distance at which the noise is audible under stated conditions. The distance is used to express the audibility of the noise. The room is preferably large, or treated to minimize reverberation. This method takes into account noise produced both by loudspeaker radiation and by mechanical vibration of parts. A brief description of the sound heard is useful, in addition to the audibility observation. Obviously, this method is suited only for observing a small amount of noise, audible for only a short distance.

The noise-audibility test is intended to evaluate collectively random noise and hum under operating conditions. The radio receiver is tuned in the normal manner to each of the four standard input voltages at 1,000 kilocycles. If the receiver has a tone control, it is set in the "high" position. The volume control is adjusted to give normal test output with the signal modulated 30 per cent at 400 cycles, and then the modulation is reduced to zero. The audibility of the remaining noise is then observed. The residual noise audibility is likewise observed, with no signal and with the volume control set at minimum.

*4.05.16. Two-Signal Crosstalk Interference*

In order to observe correctly the interference between two received signals, both desired and interfering signals must be present during the test. The crosstalk test deals with the type of interference in which the modulation of the interfering signal is heard in addition to that of the desired signal. This test is intended to indicate the greatest interference input which may be permitted without the interference-modulation output power exceeding 0.001 of the desired-modulation output power, assuming that both signals are modulated to the same degree.

The radio receiver is tuned to the desired signal set at one of the standard test frequencies and at one of the standard input voltages. The receiver volume control is adjusted to give normal test output when the signal is modulated 30 per cent at 400 cycles, after which the modulation is switched off. If the receiver has a manual selectivity control, this test is performed at both maximum and minimum selectivity.

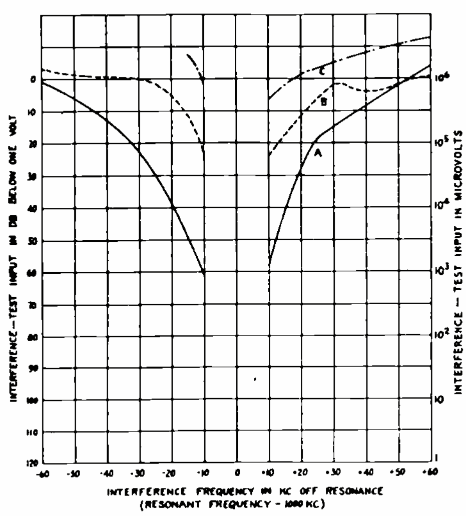


Fig. 16—Crosstalk-interference curves; (a) desired signal, 50 microvolts; (b) desired signal, 5,000 microvolts; and (c) desired signal, 100,000 microvolts.

An interfering-signal input voltage is applied to the receiver in addition to the desired-signal carrier, which remains unchanged. The interfering signal is tuned through a wide frequency range, and the interference-test input voltage, which gives interference-test output at 400 cycles, is observed wherever its value is less than 1 volt, or 200,000 microvolts per meter for loop receivers. In particular, observations are made at least every 10 kilocycles up to 100 kilocycles above and below the desired-signal frequency.

For a given standard test frequency and for the several standard input voltages, crosstalk-interference curves are plotted, having as abscissas the frequency difference in kilocycles between the interfering signal and the desired signal, and having as ordinates the observed interference-test inputs in decibels below 1 volt, or in microvolts, and, in the case of loop measurements, in decibels below 1 volt per meter or microvolts per meter. The scale of abscissas should be uniformly divided. The decibel scale of ordinates should be uniformly divided and should increase in the downward direction on the page. The microvolt scale of ordinates should be logarithmically divided and should increase in the upward direction on the page. Typical curves are illustrated in Fig. 16.

It is ordinarily of no value to observe crosstalk with the interfering frequency less than 5 kilocycles from the desired frequency or frequencies of whistle interference, because more serious interference is caused by the beat notes.

The two-signal crosstalk-interference test is the only type of selectivity test which shows correctly the selectivity curve, at reduced sensitivity, of a radio receiver having automatic gain control. Also, this is the only method whereby the selectivity of a receiver having automatic selectivity control can be tested directly.

The presence of the interfering signal may also reduce the desired-signal output, which would not be apparent from the crosstalk-interference curve. This effect is blocking interference (see Section 4.05.18) caused by the interfering-signal carrier, and is most likely to occur when the two signals are on adjacent channels. The cause may reside in automatic control or in overloading. If this effect is substantial, a blocking curve is plotted to accompany each crosstalk curve. After observing each point on the crosstalk curve, the interfering-signal modulation is switched off, the desired-signal modulation is switched on, and the desired-signal output is observed. Values of the relative desired-signal output are plotted as ordinates on the same scale of abscissas. The scale of ordinates should be divided uniformly for decibels or logarithmically for voltage ratio.

*4.05.17. Two-Signal Whistle Interference*

This test deals with the type of interference in which a beatnote whistle is heard, which depends mainly on the carriers of the desired and interfering signals, and on the radio receiver. It is especially applicable to superheterodyne receivers. More specifically, this test is intended to indicate the greatest interference input which may be permitted without the interference output exceeding the equivalent of approximately 1 per cent modulation of the desired signal. If the desired signal is modulated 30 per cent, the permitted interference output power is 0.001 of the desired-modulation output power.

The signals are the same as for the crosstalk test, except that the interfering signal is unmodulated. The interfering signal is tuned through a wide frequency range, and the interference-test input voltage, which gives interference-test output at 400 cycles, is observed wherever its value is less than 1 volt.

For a given standard test frequency and a given standard input voltage, a whistle-interference spectrum is plotted, having as abscissas the interfering frequency, and having as ordinates the interference-test input in decibels below 1 volt, or in microvolts. The scale of abscissas should be logarithmically divided to cover a wide range and the scale of ordinates should be uniformly divided for decibels, or logarithmically divided for microvolts. An example is shown in Fig. 17.

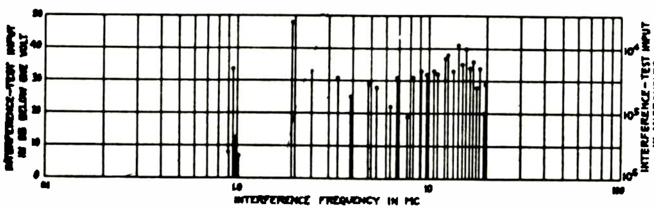


Fig. 17—Whistle interference spectrum. Desired signal, 50 microvolts at 1,000 kilocycles.

It is ordinarily of no value to observe the whistle with the interfering frequency 400 cycles from the desired frequency, because this observation is independent of the radio receiver characteristics, the interference-test input being 40.4 decibels below or 0.95 per cent of the desired-signal input voltage.

At any interfering frequency where whistle is observed, the observation may be extended to give interference-test output at other audio frequencies besides 400 cycles, and these observations may be on an enlarged scale of abscissas.

*4.05.18. Two-Signal Blocking Interference*

This test deals with the type of interference in which the undesired-signal carrier affects the desired-signal output of the receiver. The cause may reside in automatic control or in overloading. More specifically, this test is intended to show the amount of variation of the desired-signal output with input voltage and frequency of the undesired-signal carrier.

The radio receiver is tuned to the desired signal set at one of the standard test frequencies and at one of the standard input voltages. The receiver volume control is adjusted to give normal test output with the signal modulated 30 per cent at 400 cycles.

In addition to the desired signal, an unmodulated interfering signal is applied to the receiver. This signal is set at various predetermined values of input voltage or frequency, while the other of these quantities is subjected to continuous variation. One of the standard input voltages may be used, and the frequency varied, or the frequency may be set at intervals of 10 kilocycles either side of the desired-signal carrier frequency, and the input voltage varied.

For a given frequency and input voltage of the desired signal, a blocking-interference curve is plotted, having as ordinates the ratio of the desired-signal 400-cycle output to the normal test output obtained in the absence of interference. The ordinates are plotted in decibels on a uniformly divided scale, or as voltage ratios on a logarithmic scale.

The interfering-signal frequency or input voltage, whichever is subjected to continuous variation, is plotted as abscissas. The frequency difference in kilocycles may be plotted on a uniformly divided scale. The input voltage may be plotted in decibels below 1 volt, on a uniformly divided scale, or in microvolts on a logarithmic scale.

It is ordinarily of no value to observe blocking with the interfering frequency less than 5 kilocycles from the desired frequency, because more serious interference is caused by the beat note.

A special blocking-interference curve is prescribed above (Section 4.05.16) to accompany each crosstalk-interference curve.

*4.05.19. Tuning Characteristic*

The tuning characteristic shows the apparent selectivity of a receiver, as distinguished from the actual selectivity. This effect is the variation of signal output while tuning the receiver through the carrier frequency of the signal, but it is usually more easily measured by variation of the signal frequency, since the signal generator has better frequency control and calibration than the receiver.

The receiver is tuned to a signal of each standard input voltage and of a frequency in the middle of each tuning band, such as 1,000 kilocycles for the broadcast band. The signal is modulated 30 per cent at 400 cycles and the volume control is set for normal test output. The 400-cycle output is then observed with detuning of the receiver or of the signal carrier.

For a given frequency and input voltage, a tuning curve is plotted, having as abscissas the frequency difference of detuning, and having as ordinates the ratio of 400-cycle output to normal test output. The former is taken as positive when the receiver is tuned to a frequency greater than that of the signal. The scale of abscissas should be uniformly divided. The scale of ordinates should be divided uniformly for decibels or logarithmically for voltage ratio.

If the receiver has automatic frequency control, the extent of such control is indicated by the width of the tuning characteristic, observed at given values of input voltage and frequency. If the "tuning-in" curve differs from the "tuning-out" curve, both should be plotted and marked with arrows denoting the direction in which they were traced.

*4.05.20. Tuning Indicator*

This test is intended to show the effectiveness of a visual tuning indicator as an aid in tuning the receiver accurately. The procedure is the same as that employed in the tuning characteristic test, except that the deflection of the indicator is observed instead of the audio-frequency output. The deflection is plotted on a uniformly divided scale of ordinates.

*4.05.21. Frequency Shift*

This test is intended to show the variation in the frequency of the oscillator of a superheterodyne receiver. The tests are normally performed with the receiver tuned to a frequency in the middle of each tuning band of the receiver. If observations under the worst conditions are desired, the receiver should be tuned to the highest frequency of each band.

The variation of frequency is observed with the aid of a beat note obtained between the oscillator under test and another oscillator of constant frequency. For example, the frequency of the beat note may be observed by comparison with a calibrated audio-frequency oscillator.

*4.05.21.01.* The frequency varies with time during the warming-up period of the receiver. A curve of frequency shift with time is plotted with time in minutes as abscissas on a logarithmic scale and frequency shift in kilocycles as ordinates on a linear scale. The time is measured from switching on the receiver, but observations are ordinarily started 1 minute later.

*4.05.21.02.* The frequency varies with power-supply voltage in a manner that depends on the rate of variation of this voltage. The major change occurs almost instantly following a change of the power voltage. Therefore, the test is performed as quickly as possible to minimize other effects. In the case of operation from a 117-volt power line, the line voltage is varied at least between 105 and 130 volts and the resultant frequency shift is observed. The amount of frequency shift is expressed in cycles per 1 per cent change of power-line voltage, as an average value over the specified range of power-line voltage.

*4.05.21.03.* If the receiver has automatic gain control, the variation of signal-input voltage affects the oscillator frequency indirectly by way of the control circuit. The frequency shift with variation of signal-input voltage is observed after the receiver has been in operation a sufficient length of time to reach temperature stability. The signal-input voltage values are plotted as abscissas on a uniformly divided scale of decibels below 1 volt or on a logarithmic scale of microvolts. The frequency shift in kilocycles is plotted as ordinates on a uniformly divided scale.

*4.05.22. Automatic Frequency Control*

The simplest test indicating the effect of automatic frequency control is the tuning characteristic, performed in the manner described in Section 4.05.19.

A receiver having automatic frequency control has abnormal operation in other respects when the receiver is detuned to the extent permitted by such control. The electric-fidelity test and the two-signal tests are among those whose results are affected by such detuning, and which should, therefore, be repeated with detuning. The range of permissible detuning, for the purpose of such tests, may be taken as the range within which the tuning characteristic varies less than 3 decibels.

*4.05.23. Low-Frequency Instability*

This test is intended to evaluate the limiting conditions for unstable operation of the receiver, as affected by low-frequency feedback which may be electric or acoustic in nature, and which may involve both carrier-frequency and audio-frequency circuits. At any given frequency, the variables employed to induce instability are the signal-input voltage, the tuning control, the manual volume control, the tone control, and, in battery receivers, the age and condition of the batteries. All parts of the receiver, including the loudspeaker, are mounted in their normal relations.

The test is performed at least at a frequency in the middle of each tuning band, and preferably also at the minimum and maximum frequencies of each band. A modulated signal is tuned in and the modulation is switched off. The conditions most conducive to instability are found by trial, and an observation is made of the minimum signal-input voltage with which unstable operation can be obtained. The maximum of such input voltage is also observed if less than 1 volt.

*4.05.24. Radiation from Local Oscillator*

A local oscillator, such as is employed in a superheterodyne receiver, may radiate sufficient power to cause interference in other radio receivers operating in the same neighborhood. Such radiation may be caused by coupling to the antenna, power line, or other external leads, or by incomplete shielding of the oscillator and the circuits coupled thereto.

The receiver is connected to its proper antenna, and the electric- and magnetic-field intensity in the neighborhood is observed by any of the known methods. There is no simple form for expressing the results. Observations are made at least at the middle frequency of each tuning band, and preferably at the extreme frequencies of each band.

*4.05.25. Phonograph Combinations*

In addition to the above tests on radio receivers, there are several special tests which reveal useful information on the operation of the phonograph portion of combination receivers. Hum measurements which may be made on such combinations have already been described in Section 4.05.12.01. In addition to hum, the following characteristics should be measured:

(a) Electric fidelity
(b) Rumble
(c) Maximum output
(d) "Wow" or flutter.

Definitions of these characteristics, with methods of measurements, are given below.

*4.05.25.01. Fidelity.* The fidelity of a phonograph reproducer corresponds to the audio fidelity described under Section **4.05.04**, except that RMA Frequency Test Record No. 1 is used instead of a modulated carrier. This RMA Frequency Test Record No. 1 contains, on side A, a gliding frequency from 10,000 to 30 cycles for usual nominal level testing. Side B contains five 1,000-cycle bands, recorded at 0, 2, 4, 6, and 8 decibels above the 1,000-cycle reference on side A, and a gliding frequency 6 to 8 decibels above side A in the range between 3,000 and 30 cycles for checking pickup tracking at various levels.

In making the fidelity test, side A is used, and the output is first set at standard output using the outside 1,000-cycle band. Readings of output are then made at all announced frequencies, including the 1,000-cycle bands at start and finish. The data are plotted as in Section 4.05.04, using the 1,000-cycle output as zero reference.

Suitable correction usually must be made for noise resulting from needle scratch to provide accurate data above 1,000 cycles.

*4.05.25.02. **Rumble.*** Rumble is a low-frequency tone or series of random pulses generated at the phonograph pickup as a result of vibrations of the record player. It is generally a maximum when the needle is near the outside of a 12-inch record.

Rumble is measured with the load and output-measuring equipment connected as in the electric-fidelity test, except that a low-pass filter is used with a sharp cutoff at 300 cycles. The measuring equipment should have low wave-form error.

Side A of the test record is also used in this test. The volume control is adjusted to give normal test output while reproducing the outside 1,000-cycle band and with the low-pass filter disconnected. The filter is then reconnected and measurements made of rumble components while the needle is in the region between the 1,000-cycle tone and the 10,000-cycle tone.

In some cases, a particular rumble frequency may predominate, resulting from motor vibration or pickup-arm resonance. Measurements of such a frequency may be accomplished by means of a tuned filter or harmonic analyzer.

*4.05.25.03. **Maximum Output.*** The maximum audio output on phonograph may be less than that obtained on radio, because of the absence of automatic-gain-control voltage which normally causes a rise in plate and screen voltages in the audio amplifier.

The test is made by reproducing the 1,000-cycle tone on side A of the test record and adjusting the volume control to produce maximum output. The measuring equipment used must give an accurate indication of root-sum-square independent of wave form.

*4.05.25.04. "Wow" or **Flutter.*** "Wow" or flutter is caused by minute imperfections in the motor and/or transmission means used to drive the phonograph turntable; and, if present to an appreciable extent, may noticeably impair the quality of reproduction. It is usually evident when a steady note is being reproduced, such as the 1,000-cycle band, and evidences itself as a cyclic variation in pitch; hence the name "wow." While there is no great distinction between "wow" and flutter, the former is usually applied to very low cyclic variation, the latter to the more rapid type.

"Wow" or flutter is measured as a percentage of root-mean-square deviation in frequency of a tone to the average frequency. Special equipment is required to make such a measurement, this equipment being capable of responding uniformly to all flutter rates up to 200 cycles, and of measuring to a precision of 0.02 per cent flutter.

Care should be exercised to insure that the method of measurement permits normal conditions to exist as when playing a commercial pressing.

# APPENDIX

# 5.00. DESIGN AND USE OF SHIELDED TEST LOOP

## 5.01. Shielded Loop with Series Resistance

The type of transmitting loop to be considered is completely shielded electrostatically. A diagram of it is shown in Fig. 18. This loop is 0.25 meter (10 inches) in diameter and consists of three turns of No. 20 solid tinned copper wire with celanese insulation. These turns are placed in a copper tube which is bent into a circular form having 0.25 meter (10 inches) as the mean diameter. The copper tube is prevented from acting as a short-circuiting turn by attaching one end only to ground and insulating the other end. Through the gap between the two ends of the copper tube are brought the

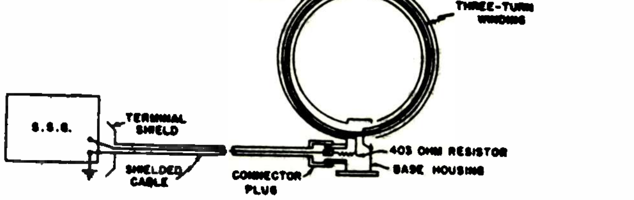


Fig. 18—Diagram of three-turn shielded loop with 403 ohms in series.

start and finish connections of the loop. A small housing at the base of the transmitting loop contains a 403-ohm resistor which is connected in series between the ungrounded end of the loop and the high side of the shielded cable leading to the standard-signal generator. A 0.0064-meter (¼-inch) shielded microphone cable, 1.2 meters (4 feet) long, is used; this terminates at the loop end in a single-connection-and-ground microphone plug, which screws into a jack in the base of the transmitter loop. At the other end, the cable is connected to the ground and high sides of the signal generator by a plug combined with a metal shield sufficiently large to prevent capacitive coupling between the generator output terminals and the receiver loop. For convenience of manipulation, the loop and housing are designed to be mounted on a regular microphone stand.

The series resistance is proportioned to make the field strength in volts per meter, at an arbitrary distance of 0.6 meter (24 inches), equal to one-tenth of the signal generator reading in volts. The value of 403 ohms is calculated by the use of the equations in Section 4.01.03.01. Set $E$ equal to 0.1 volt per meter or one-tenth of the maximum output of the signal generator. Then substitute the known values of $N_1$, $A_1$, and $X$, and solve for $I$. Knowing the output voltage of the signal generator, the value of $R$ may then be obtained. If center-to-center separation is used instead of center-to-periphery, the error will be approximately 9 per cent for this case.

It is to be noted that, if the output impedance of the signal generator is high, the loading effect of the resistor upon the generator must be taken into account in determining the voltage across the coil, and hence the field strength.

Where broadcast receivers having loops with a dimension exceeding 0.3 meter (12 inches) are to be measured, the transmitting loop should be separated from the receiving loop by a distance which is at least twice the maximum dimension of the receiving loop. The field strength produced at the receiving loop is inversely proportional to the cube of the distance, so that at 0.9 meter (3 feet) separation (suitable where the maximum dimension of the receiving loop is 0.46 meter (18 inches)) the field strength in volts per meter is no longer one-tenth the output of the signal generator in volts, but is 1/33.7 of the volts' output.

The maximum frequency at which this equipment can be used is limited by shunt capacitance in the shielded connecting cable and the series inductance of the cable and loop. Measurements have indicated that, with the cable length of 1.2 meters (4 feet) and a constant-voltage input to the line, the rise in voltage at the end of the cable, as the frequency is increased, is sufficiently balanced by the drop due to the increasing reactance of the loop to provide nearly uniform current through the loop up to a frequency of 20 megacycles. The capacitance of the 1.2-meter (4-foot) length of cable is approximately 120 micromicrofarads, and the series inductance of the cable and loop is approximately 7.5 microhenrys.

### 5.02. Error Due to Leakage Field

In making measurements on sensitive loop receivers, trouble due to generator leakage is often experienced. It is necessary that this be minimized by proper orientation of the receiver or generator, or by further shielding of the generator, if accurate results are to be secured. The presence of leakage fields can readily be detected by repeating the measurement with the transmitting loop rotated 180 degrees. If this produces appreciable change in the measured sensitivity, the cause is likely to be leakage of some type.

One other precaution should be mentioned. It is important to keep both the transmitting and receiving loops well away from any large metal objects which would distort the magnetic field. This applies to the conducting walls of shielded rooms. A clearance around each loop equal to twice the distance between loops is considered a satisfactory minimum value. The receiving loop is generally left in place in the receiver cabinet because the effect of the conducting chassis is desired, since it is present in normal operation.

## 6.00. TRANSMISSION-LINE METHOD OF TESTING LOOP RECEIVERS

### 6.01. General

In the testing of loop receivers by means of a shielded radiating loop, as described in Sections 4.01.03 and 5.00, several precautions are required if the results are to be accurate. A separation of at least twice the diameter of the largest loop should be used between loops, and a separation at least twice this value between either loop and the nearest metallic object. These restrictions frequently make it difficult to make accurate measurements of console receivers employing large loops inside the normal-size shielded room.

An alternative method which lends itself readily to use inside such a screen room employs a transmission line as a radiating means. This method has the additional advantage of being easy to set up using readily available laboratory apparatus.

### 6.02. Description of Apparatus

A detailed description of the method and the field equations involved will be found in the two references given in the Bibliography at the end of this section. The method consists of stretching a single, solid wire of No. 12 to No. 16 B & S gauge tightly between two insulators at a uniform distance below the roof of the screen room (the inner shield) and parallel to the longest dimension of the room, as shown in Fig. 19. In order to prevent standing waves on the line, it must be terminated in its characteristic impedance, which is given by

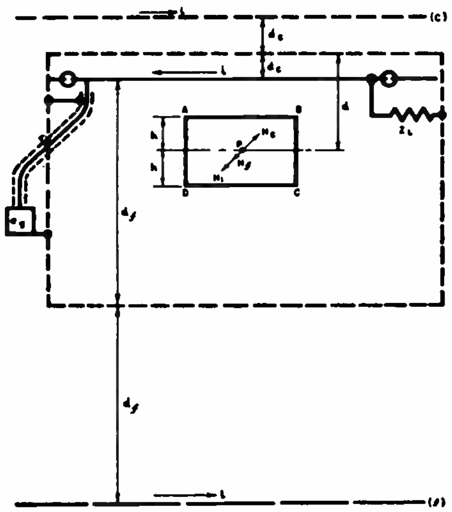

Fig. 19—A single, solid wire stretched between two insulators at a uniform distance below the roof of the screen room.

$$Z_0 = 138 \log_{10} \frac{4d_c}{a}$$

where

$d_c$ = distance to the ceiling

$a$ = diameter of wire.

A variable 1,000-ohm resistor may be used for this termination and adjusted as described below for proper termination.

A conventional signal generator is located outside the screen room and connected to the other end of the transmission line through a shielded lead, the low-potential terminal being grounded to the shielded room.

To determine the proper line termination experimentally, the generator is adjusted for maximum power output at its highest frequency (say, 20 to 25 megacycles) and a high-frequency vacuum-tube voltmeter is used as a standing-wave indicator by sliding its probe along the wire. The terminating resistance is adjusted until the line voltage is uniform along its length.

The receiver to be measured is located directly below the transmission line, as near the center of the screen room as possible, and is tuned to the radiated signal in the normal manner. The field intensity at the receiver loop is given in the section below.

### 6.03. Formulas for Field Intensity

The field strength in volts per meter at a point $P$ near the center of the wire and in a vertical plane directly below it is

$$E=\frac{60E_g}{Z_g+Z_0}\left[\frac{1}{d}-\frac{1}{2d_c+d}+\frac{1}{2d_f-d}-\frac{1}{2d_f+2d_c-d}+\frac{1}{2d_f+2d_c+d}-\frac{1}{2d_f+4d_c+d}+\frac{1}{4d_f+2d_c-d}-\frac{1}{4d_f+4d_c-d}\cdots\right]$$

where

$E$ = field strength in volts per meter

$E_g$ = signal-generator voltage in volts

$Z_g$ = signal-generator impedance

$Z_0$ = line impedance as given in Section 6.02 above

$d$ = distance in meters from wire to point $P$

$d_f$ = distance in meters from wire to floor

$d_c$ = distance in meters from wire to ceiling.

The first term corresponds to the direct radiation from the wire, the successive terms being due to the multiple reflections from roof and floor.

If a square loop is used with the height of one side equal to $2h$, the average field strength around the loop is given approximately by

$$E_{AVE}=\frac{60E_g}{Z_g+Z_0}\left[\frac{d}{2h}\log_e\frac{d+h}{d-h}\right]\cdot\left[\frac{1}{d}-\frac{1}{2d_c+d}+\frac{1}{2d_f-d}-\frac{1}{2d_f+2d_c-d}\cdots\right].$$

Using the first four terms of this expression is usually accurate enough for most purposes.

Neglecting all terms beyond the fourth and converting to common logarithms, the above equation may be reduced to the following approximate form

$$E_{AVE}=\frac{69E_g}{h(Z_g+Z_0)}\log_{10}\left[\frac{(d+h)(2d_c+d-h)(2d_f-d+h)(2d_f+2d_c-d-h)}{(d-h)(2d_c+d+h)(2d_f-d-h)(2d_f+2d_c-d+h)}\right].$$

# 7.00. INTERMODULATION DISTORTION

## 7.01. General

It has long been recognized that nonlinear elements in a radio receiver may produce considerable distortion which will not show up in harmonic-distortion measurements. This distortion takes the form of crossmodulation 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 distortion 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 may be high, yet the harmonic distortion is 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.

## 7.02. Methods in Use

*7.02.01.* Two general methods for measuring intermodulation distortion are in use at the present time. In the first method described in Bibliography reference 4, the signal is modulated simultaneously with a low audio-frequency $f_1$ of the order of 100 cycles and a high audio-frequency $f_2$ of the order of 5,000 cycles. The amplitude of $f_1$ is chosen to have a definite ratio to the amplitude of $f_2$; usually, this ratio is 4 to 1. If nonlinearity is present, $f_2$ can be considered as being modulated at a frequency equal to $f_1$ and, therefore, the intermodulation products are $f_2-f_1$, $f_2+f_1$, $f_1-2f_1$, $f_2+2f_1$, $f_2-3f_1$, $f_2+3f_1$. . . . The per cent intermodulation distortion is referred to the upper audio-frequency $f_2$ and is given by

$$\text{per cent } IM \text{ distortion} = \frac{\sqrt{(E_{f_2-f_1}+E_{f_2+f_1})^2+(E_{f_2-2f_1}+E_{f_2+2f_1})^2+(E_{f_2-3f_1}+E_{f_2+3f_1})^2\cdots}}{E_{f_2}}.$$

*7.02.02.* In another method of measuring intermodulation distortion, described in Bibliography reference 5, measurements are made at a number of points throughout the audio-frequency range. The amplitudes of $f_1$ and $f_2$ are usually equal, and their frequencies are varied in such a way that the difference frequency $f_1-f_2$ is held constant. The relative amplitude of the intermodulation component at the difference frequency $f_1-f_2$ is then considered a measure of the intermodulation distortion. The difference frequency $f_1-f_2$ may be chosen equal to 400 cycles if a wave analyzer is not available. Further measurements to indicate the presence of significant higher-order intermodulation products may be necessary, particularly where the nonlinearity is symmetrical.

## 7.03. Existing Problems

Among the problems which prevent the fixing of rigid standards at the present time is a lack of agreement among the principal workers in the field as to the best method of making intermodulation measurements.

Measurements made on two representative makes of standard-signal generators show an internal intermodulation distortion of the order of 10 per cent. It appears, therefore, that standard-signal generators will require an improvement in design before reliable overall receiver intermodulation-distortion measurements can be made.

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# Standards on Radio Receivers: Open Field Method of Measurement of Spurious Radiation from Frequency Modulation and Television Broadcast Receivers, 1951*

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# Standards on RADIO RECEIVERS:

# Open Field Method of Measurement of Spurious Radiation from Frequency Modulation and Television Broadcast Receivers, 1951

## 1. INTRODUCTION

Modern broadcast radio receivers of the superheterodyne type are frequently sources of spurious radiation from the local oscillator, which radiation may cause severe interference with other services. In addition, in the case of television broadcast receivers, there may be radiation of power from other sources beside the local oscillator. This Standard describes the potential sources of spurious radiation from frequency modulation and television broadcast receivers and sets up methods of measurement whereby the strength of some of these radiations may be determined. Where the methods for the two classes of receivers differ, the specifications for each are outlined.

## 2. SOURCES OF SPURIOUS RADIATION

**2.1** The local oscillator fundamental and harmonics.

**2.2** Intermediate-frequency amplifiers which may radiate spurious signals at the fundamentals, and harmonics or combinations of the intermediate frequencies.

**2.3** In some television receivers, the high voltage for the cathode-ray tube is obtained by means of a radio-frequency oscillator, which is then a potential source of radiation at its fundamental and harmonic frequencies.

**2.4** In television receivers the sweep circuits may radiate harmonics of their fundamental frequencies.

**2.5** In television receivers the video amplifier and any nonlinear circuit elements which may produce signals by demodulation of the radio or intermediate-frequency signals.

## 3. MODES OF RADIATION OF SPURIOUS SIGNALS

**3.1** Spurious signals emanating from any source, such as those described in Section 2, may appear on the receiver antenna terminals and be radiated from an antenna system attached thereto. Such signals may be balanced or unbalanced to ground.

**3.2** Radiation from the sources enumerated in Section 2 may occur in the vicinity of the receiver due to direct electric and/or magnetic fields created by the components assembled on or within the chassis, or by cavity resonances of the chassis itself.

**3.3** Radiation from any of the sources may be propagated through the power supply cord. Such radiation may be due to balanced or unbalanced currents flowing in the line cord. This Standard does not cover measurement of spurious radiation from this source.

## 4. METHODS OF MEASUREMENT

### 4.1 General

This Standard establishes a system whereby the radiation described above may be measured, and sets up operating conditions and specifications for equipment for accomplishing these measurements. In this method, the receiver and measuring equipment are set up under reproducible conditions as described below, and the field strengths of the various radiations are measured under specified conditions.

The method described herein is primarily applicable to the measurement of spurious radiation in the uhf and vhf bands from those sources producing an appreciable field at 100 feet. For sources producing radiation in other bands or those producing comparatively insignificant fields at 100 feet other methods of measurement may be necessary.

### 4.2 Equipment Required and Setup Details

#### *4.2.1 Receiver Platform and Antenna*

The platform upon which the receiver under test is to be mounted shall be located on relatively level ground, free of any obstruction to a distance of at least 100 feet from both the receiver and the field strength meter, and away from reflecting objects. This platform shall carry a nonconducting rotatable antenna mast. For convenience, it may be desirable to have the mast and the platform rotatable as a unit. This mast shall carry at a height of 30 feet a single straight dipole antenna constructed of ½-inch od tubing. A transmission line of the type and characteristic impedance for which the receiver under test is designed, shall be attached to this dipole at its center and shall be vertically disposed under the center of the dipole with the plane of the maximum cross sectional dimension of the transmission line parallel to the dipole. This transmission line shall be secured to the pole at sufficiently frequent intervals to insure mechanical stability against movement.

When testing receivers designed for use with unbalanced shielded transmission line, the antenna may be connected to the transmission line through a balanced-to-unbalanced transformer of the type, if any, specified by the manufacturer. If the receiver is designed to operate from either an unbalanced transmission line or a 300-ohm balanced line, the latter shall be used in these measurements.

If the receiver under test is a table model, it shall be placed upon a table, the top of which is 48 inches above ground. If the receiver is a floor model, it shall be located on a platform, the top of which is 18 inches above ground. In the case of those receivers where the lead-in does not reach the antenna terminals when mounted in accordance with Section 4.2.1.3, the receiver shall be raised the necessary amount. The plane of the front panel of the cabinet shall be parallel to the dipole, and the center of the cabinet shall be directly below the center of the dipole.

*4.2.1.1* For vhf television receivers the dipole antenna shall measure 88 inches from end to end. For uhf television receivers the length shall be 12 inches from end to end.

*4.2.1.2* For frequency modulation receivers having terminals for an external dipole, the length shall be 58 inches from end to end.

*4.2.1.3 Disposition of Transmission Line.* The transmission line shall be 28 feet in length and shall proceed horizontally directly back from the antenna terminals of the receiver, then vertically upward to a height of 84 inches above ground, and finally, again horizontally, to a position vertically disposed under the center of the dipole; and after the first bend, shall not approach closer than six inches to the cabinet at any point. Fig. 1 illustrates a possible method of routing the transmission line.

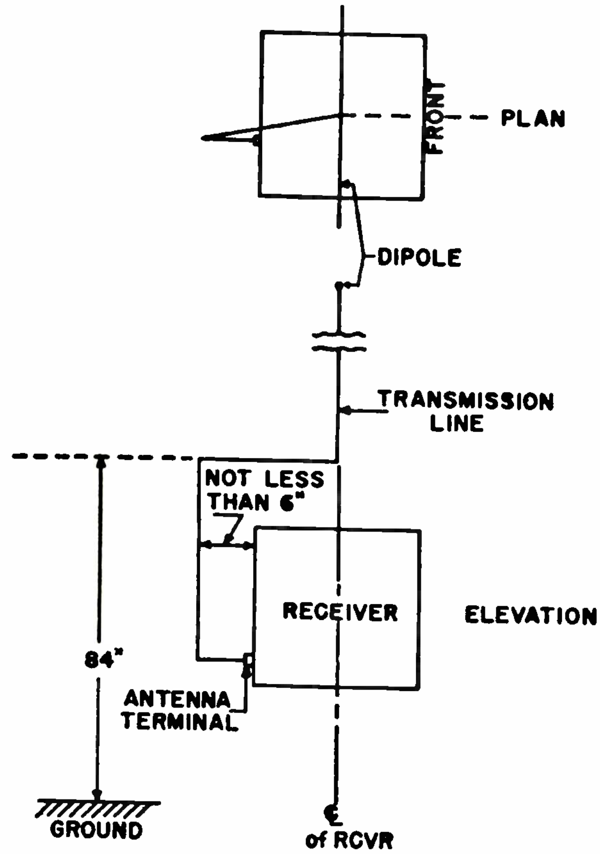



Fig. 1—Possible method of routing transmission line.

#### *4.2.2 Field-Strength Meter*

A suitable field-strength meter shall be provided, equipped with an antenna capable of being adjusted for horizontal or vertical polarization. The field-strength-meter antenna shall be located at a distance of 100 feet horizontally from the antenna of the receiver under test.

The transmission line from the field-strength-meter antenna shall be disposed horizontally for a distance of 24 inches in a direction directly away from the receiver under test, then dropped approximately vertically to the field strength meter.

Provision shall be incorporated whereby the height of the antenna above ground may be varied from seven feet to twenty feet.

#### *4.2.3 Power Supply*

Power lines to both the receiver under test and the field strength meter shall be buried to a depth of 12 inches or more, and the power outlet at each location shall be at the top of a metal conduit which extends not more than 18 inches above the level of the ground, and at the receiver location shall be not more than 12 inches from the vertical axis of the antenna. The power cord of the receiver under test shall be short and as vertical as possible, with any excess length bundled up as close as possible to the plug end.

Adequate isolation shall be incorporated in the supply line to the receiver so that a negligible amount of signal will appear at the field strength meter from this source. Each side of the line shall be by-passed to the conduit at the receiver outlet.

*4.2.3.1* Unless otherwise specified, the line voltage shall be maintained at within 2 per cent of specified line voltage during all measurements.

*4.2.4*

No extraneous metallic object having any dimension in excess of 6 inches shall be in the vicinity of the set under test, or of its antenna. The platform, antenna mast, guys, and tables shall all be fabricated of non-conducting materials. The antenna mast and other associated equipment at the field strength meter shall likewise be free of metallic objects.

The ground at the site shall be as homogeneous as possible, with special effort being made to avoid gravel paths and other similar low-conductivity features.

### 4.3 Measurements To Be Made

*4.3.1*

The receiver under test shall be tested with the transmission line from the dipole connected directly to its antenna terminals. A second set of measurements shall be made either with these connections reversed or, in the case of coaxial lines, with the receiver antenna rotated 180 degrees with respect to the receiver chassis.

*4.3.2*

If the receiver is supplied with a built-in antenna, measurements shall also be made with this antenna connected to the antenna terminals. Any adjustment provided for tuning this built-in antenna shall be set at that position producing maximum radiation. If it can be demonstrated that the disconnected standard dipole antenna and transmission line mounted on the platform affect the field strength, they shall be removed for this test. In the case of receivers utilizing the power line as an antenna, separate tests, other than the open field measurements, may be necessary to determine the amount of potential radiation due to voltages existing on or between the wires of the cord.

*4.3.3*

As a means of measuring direct chassis radiation, the receiver shall be tested with the antenna terminals terminated in a noninductive resistor equal to the impedance for which the receiver is designed. A precaution with respect to the disconnected antenna, similar to that in the above Section, shall be observed.

### 4.4 Method of Measurement

The receiver under test shall be checked over the frequency range to which it is intended to be tuned. The number of test frequencies shall be adequate to insure measurement of maximum radiation within this range.

With the field-strength meter tuned to the frequency of the spurious radiation being measured, and with its antenna aligned broadside to the receiver under test and 20 feet above ground, the receiver under test and its dipole antenna shall be rotated together in a horizontal plane until maximum signal at the field-strength meter is obtained. The antenna of the field-strength meter is now varied in elevation from twenty feet to seven feet, holding it broadside to the receiver under test, and the maximum reading of field strength so obtained is recorded as the radiation strength of the receiver under test. These tests are now repeated with the receiver antenna reversed, as in Section 4.3.1.

The above tests shall be repeated with the field-strength-meter antenna aligned for vertical polarization.

If reversing the antenna of the field strength meter produces an appreciable difference, the results so obtained shall be averaged.

SUPPLEMENT TO STANDARDS ON RADIO RECEIVERS:
OPEN FIELD METHOD OF MEASUREMENT OF SPURIOUS RADIATION FROM FREQUENCY MODULATION AND TELEVISION BROADCAST RECEIVERS (1952)

# PRACTICAL CONSIDERATIONS IN MEASURING VHF RECEIVER OSCILLATOR RADIATION

## INTRODUCTION

During recent years a considerable number of open-field spurious-radiation measurement stations have been placed in operation. The sites selected and the method of measurements used at all of these stations have been in substantial accordance with 51 IRE 17. S1 or the preliminary drafts which were its forerunners.

The following information is intended to assist in the selection, equipping, and putting into operation of new sites, and in the calibration of existing and new sites. By calibrating sites in accordance with the method described, it is possible to determine whether the test equipment is operating properly, and the correction which must be applied to standardize the readings obtained on a set under test.

## SITE SELECTION

In selecting a site location, it is desirable that it be as far as practicable from all transmitting stations, yet be conveniently reached by car. In order to avoid interference with the measurements by car and tractor ignition, the site should be located at some distance from highways and cultivated farm land. Airports present difficulty both from ignition and from reflections from planes. Because reflections have been experienced from planes at high altitudes and quite distant from the site, it is desirable to locate away from main airlanes as well as airports. Locations near engineering laboratories or factories are likely to suffer from a high level of interference from sweep oscillators and other test equipment.

## TOPOGRAPHY

The soil at the site should be homogeneous in composition and free of surface discontinuities in the area between test locations. The surface should be reasonably level, while permitting drainage, yet avoid focusing or dispersion of the ground-reflected waves. A sod surface, free of shrubs and trees, has generally been found best. It is very convenient to have the site fixed; cars and trucks may then be driven up to test locations to permit easy handling of heavy console receivers, as well as test equipment. Parking areas should be located at least 200 feet away from the test location.

Supplement to IEEE Standard #187.

## STRUCTURES

### RECEIVER LOCATION

The standards specify a turntable and dipole to be rotated as a unit at the receiver test location. In order to permit tests of large console receivers, the turntable should be large and of heavy construction, with a clearance above the top of the table of about six feet to permit routing the transmission line in the prescribed manner. A method of supporting the dipole, which has been used successfully at many sites, is the use of plywood tubing through which the transmission line has been run. With this construction it is necessary that the transmission line be maintained taut and centered. The bottom of the tubing is supported above the center of the receiver by arched columns from the turntable, and bearings used at one or more points to keep the tubing vertical. This prevents the wind from whipping the transmission line and shelters it from the rain. Ventilation of the tubing to keep the inside free of condensation is desirable. The dipole must be accessible in order to permit changing the length, and this is most easily done by use of a ladder, although means for lowering the supporting structure may be provided instead. The supports for the tubes forming the dipole should be constructed so as to keep the capacitance across the dipole low and to keep changes in the capacitance, due to moisture and temperature, at a minimum. Rotation of the turntable and dipole should be controlled from the field-strength meter location. The turntable and receiver under test can be protected from the weather by a wooden-frame housing. Heating of this shelter may be necessary in extremely cold areas, but heaters should be below ground level at this test location.

### FIELD-STRENGTH METER (FSM) LOCATION

At the FSM location, the standards call for adjusting the antenna height between 7 and 20 feet and for rotating it between horizontal and vertical positions. The transmission line from the antenna to the measuring equipment runs horizontally for 2 feet before dropping vertically. The antenna supporting pole must be located so that the FSM dipole is 100 feet horizontally from the axis of rotation of the turntable. Housing for the FSM and operator must clear the FSM antenna, but the controls for the height and polarity of the FSM antenna should be located inside the house. Stops at the two extremes of antenna height, and detents at the horizontal and vertical polarity positions, are helpful. Rigid support of the antenna to prevent swaying with the wind is desirable, and a free-running carriage important. A power switch at the FSM location, to permit the operator to turn off momentarily the power to the receiver under test, is helpful in assuring him that the FSM is tuned to the right signal and that no interference is present. At some locations, thermal insulation of the house and electric heating may prove worthwhile.

### SERVICES

An adequately regulated power supply for both the FSM and receiver is highly recommended. Electronic type AC regulators have been found to be satisfactory. Since isolated, elevated conductors are used and the hazard may be higher than normal, lightning protection should be incorporated as a safety measure. Drinking water and toilet facilities are items to be considered. Bench space at FSM location is needed for maintenance work on equipment or modification of receiver design at the site location. Telephone connections between the test locations are helpful, and a regular phone line to the FSM location will often save much time. Such a phone line should be buried, or so located as to have no effect on the measurements.

## PERSONNEL

Measurements are usually made faster and more accurately when the FSM is operated by someone regularly assigned to use and maintain the test equipment; but the assistance of an engineer familiar with the receiver under test is valuable. A form to be filled out during the measuring may speed up the work on routine measurements.

## SITE CALIBRATION

### MEASUREMENTS

The operating characteristics of the site may be determined by using a signal generator as a substitute for the radiating receiver. For the condition of all radiation taking place from the dipole at the receiver location, the method described below permits measurement of site attenuation. The steps for site calibration are as follows:

1. A signal generator is put on the turntable at the receiver location, and its output fed (through isolation pads if necessary) through a balun or other transformer to match the generator to the line and through the specified transmission line to the standard dipole. The field strength (horizontal component) is measured in the prescribed manner.

2. The signal generator is removed to the FSM location and connected to the calibrating input terminals of the FSM through a suitable network. The signal generator attenuator is adjusted to give the same FSM reading. The site attenuation is the difference between the two signal-generator attenuator settings, with due allowance for the loss resulting from the use of any isolation pads.

## CALCULATIONS

The theoretical site attenuation has been calculated for an 88-inch dipole at 80, 100, 120, 200, 220, and 240 mc, and the resulting points plotted on the attached figure. The points are connected with a heavy line to facilitate interpretation of the graph.

Certain known factors (e.g., the capacitance of the dipole mount) and certain unknown factors (e.g., the loss in the balun transformer used) have not been considered, but all are believed to be minor and noncumulative.

The theoretical site attenuation for each frequency was calculated from the usual formula for isotropic antennas in free space

Attenuation db = 37.0 + 20 log f(mc) + 20 log d (miles).[1]

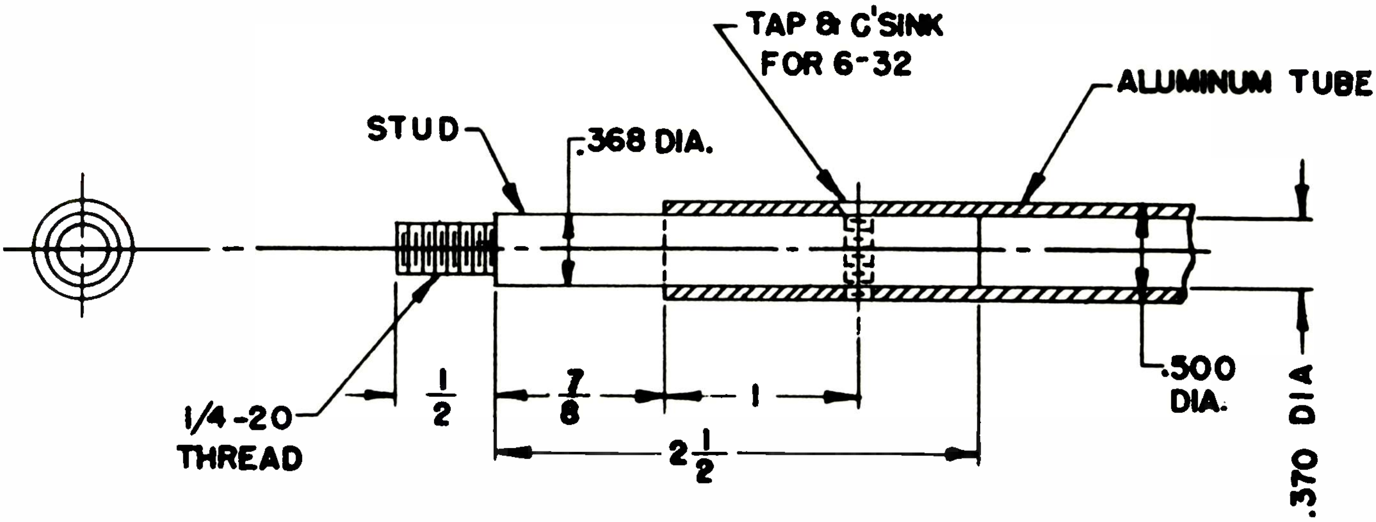
Correction in each case was made for ground reflection, actual antenna gain, and impedance mismatch. The resulting calculations are shown below in tabular form:

SITE-ATTENUATION CALCULATION

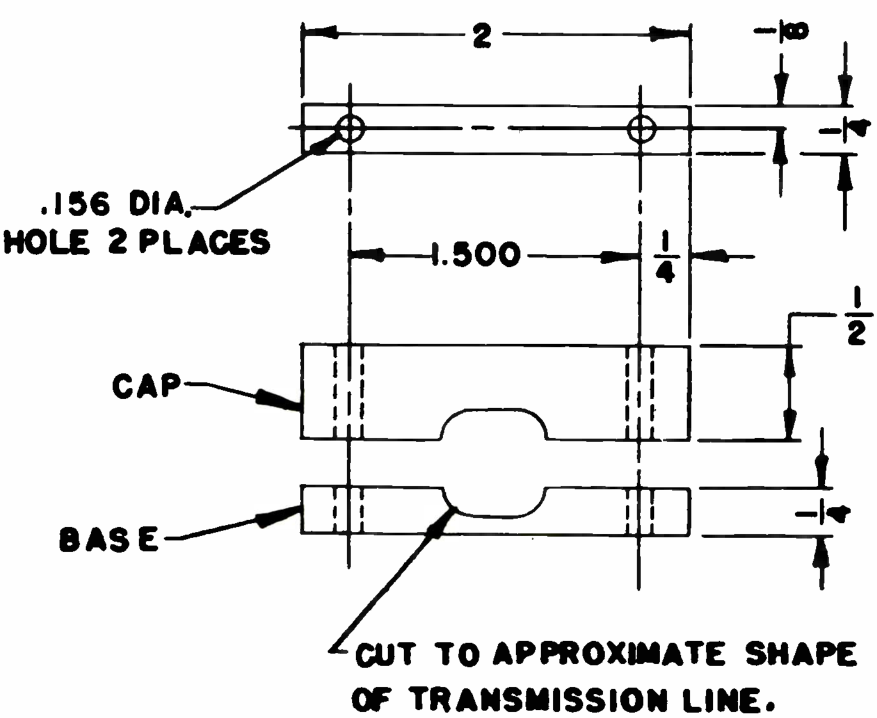
| Frequency - mc | | 80 | 100 | 120 | 180 | 200 | 220 | 240 |
|---|---|---|---|---|---|---|---|---|
| Free space - isotropic antenna att. | -DB | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 |
| Freq. factor = 20 log (mc) | -DB | 38.1 | 40.0 | 41.6 | 45.1 | 46 | 46.9 | 47.6 |
| Radiating antenna mismatch & line loss | -DB | 3.0 | 4.3 | 4.9 | 6.9 | 4.6 | 4.8 | 7.0 |
| Distance factor = 20 log (miles) | -DB | -34.4 | -34.4 | -34.4 | -34.4 | -34.4 | -34.4 | -34.4 |
| Ground reflection (representative value) | -DB | - 4.7 | - 4.7 | - 4.7 | - 4.7 | - 4.7 | - 4.7 | - 4.7 |
| Half-wave dipoles over isotropic | -DB | - 4.3 | - 4.3 | - 4.3 | - 4.3 | - 4.3 | - 4.3 | - 4.3 |
| 88-inch dipole over half-wave | -DB | - 0.1 | - 0.3 | - 0.4 | - 0.9 | - 1.1 | - 1.2 | - 1.3 |
| Voltage to 95 ohm FSM input by FSM antenna instead of to a matched load ($Z_a$ = 73 + 42.5 ohms) | -DB | - 0.8 | - 0.8 | - 0.8 | - 0.8 | - 0.8 | - 0.8 | - 0.8 |
| Theoretical attenuation | -DB | 33.8 | 36.8 | 38.9 | 43.9 | 42.3 | 43.3 | 46.1 |

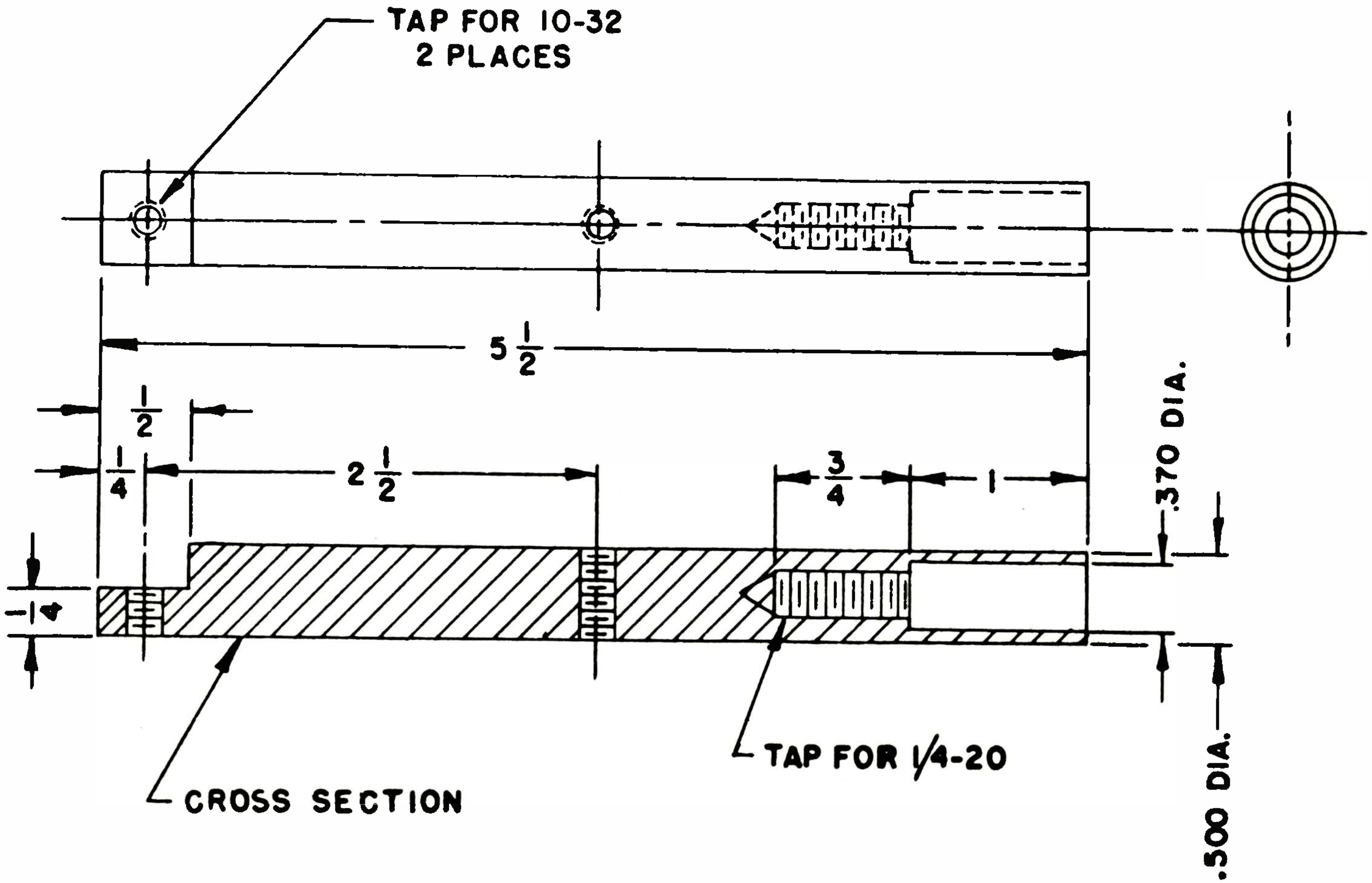
[1]Reference data for radio engineers, Federal Telephone and Radio Corp; 3rd ed. p. 436.

VHF DIPOLE EXTENSION
MAT'L:- DURAL OR ALUMINUM
DIM. IN INCHES




TRANSMISSION LINE CLAMP
MAT'L:- LUCITE OR PLEXIGLASS
DIM. IN INCHES



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# Standards on Television: Methods of Testing Monochrome Television Broadcast Receivers, 1960*

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# Standards on Television: Methods of Testing Monochrome Television Broadcast Receivers, 1960

## Part 1—INTRODUCTION

### Chapter 1—General

*1.1 Object*

THIS standard replaces IRE Standard 48 IRE 22. S1, "Standards on Television: Methods of Testing Television Receivers, 1948."

At a later date, a standard for color television receivers will be introduced. Reference will be made in that standard to many portions of the present standard which are applicable to color television receivers as well as to monochrome receivers.

*1.2 Scope*

This standard describes procedures for measurement of the performance characteristics of the picture and sound sections of television receivers. Where specific test conditions are stated, these apply to home broadcast receivers designed to receive transmissions in accordance with the specifications of the United States Federal Communications Commission.[1] Where other conditions apply, appropriate modifications must be made.[2]

Emphasis is placed on over-all receiver performance. Internal characteristics such as the gains and bandwidths of individual stages are not generally considered.

*1.3 Standard Test Frequencies*

The range of standard test frequencies includes all of the allocated television channels. The present television channel allocations, where $A$ includes frequencies from $470+6(C\text{-}14)$ to $470+6(C\text{-}13)$, and

$$P = 471.25 + 6(C\text{-}14)$$

$$S = 475.75 + 6(C\text{-}14),$$

are as follows:

| Channel No. | Channel Allocation mc | Picture Carrier Frequency mc | Sound Carrier Frequency mc |
|---|---|---|---|
| 2 | 54– 60 | 55.25 | 59.75 |
| 3 | 60– 66 | 61.25 | 65.75 |
| 4 | 66– 72 | 67.25 | 71.75 |
| 5 | 76– 82 | 77.25 | 81.75 |
| 6 | 82– 88 | 83.25 | 87.75 |
| 7 | 174–180 | 175.25 | 179.75 |
| 8 | 180–186 | 181.25 | 185.75 |
| 9 | 186–192 | 187.25 | 191.75 |
| 10 | 192–198 | 193.25 | 197.75 |
| 11 | 198–204 | 199.25 | 203.75 |
| 12 | 204–210 | 205.25 | 209.75 |
| 13 | 210–216 | 211.25 | 215.75 |
| 14 | 470–476 | 471.25 | 475.75 |
| 15 | 476–482 | 477.25 | 481.75 |
| . | . | . | . |
| . | . | . | . |
| C | A | P | S |
| . | . | . | . |
| . | . | . | . |
| 82 | 878–884 | 879.25 | 883.75 |
| 83 | 884–890 | 885.25 | 889.75 |

When measurements are not performed on all VHF channels, they should be made on Channels 4 and 10. The picture and sound carriers of these two channels are referred to as the *VHF standard test frequencies.*

Receivers which cover the entire UHF range should be measured on Channels 18, 48 and 79. The picture and sound carriers of these three channels are referred to as the *UHF standard test frequencies.*

*1.4 Standard Test Input Levels*

Input signal levels may be expressed in either of two ways:

a) In terms of available power (Section 1.4.1), in which case the input is preferably expressed in decibels below one watt.

b) In terms of input voltage, in which case the input is frequently expressed in microvolts or in decibels below one volt and the intended source resistance is stated.

When a standard composite picture signal is used, input level refers to the value during the synchronizing pulse interval. Where a picture carrier with sine-wave modulation is used, the input level is the value of the carrier in the absence of modulation.

Normally, two signal generators will be used so as to to supply both the sound and picture carriers. Unless otherwise specified, the outputs of these generators will be maintained equal.

*1.4.1 Available Power.* The available power is the power delivered by a generator to a matched load. It is equal to $E^2/(4R)$, where $E$ is the rms open-circuit voltage of the generator and $R$ is the internal resistance of the generator (including the dummy-antenna resistance). It is preferably expressed in decibels below 1 watt. The signal generator may be calibrated in terms of the available signal power and used on that basis, even though not matched exactly by the load impedance. If a signal generator is to be used with various values of dummy-antenna resistance, it should be calibrated in terms of the open-circuit voltage and the available power should be calculated from the above formula. When reference is made to values of power input, it is understood that the available power is meant.

*1.4.2 Input Voltage.* Input level in terms of voltage refers to the open-circuit voltage of a generator with an internal resistance, including the dummy-antenna resistance (Section 1.7), equal to the nominal input resistance of the receiver. By this definition, when the receiver input impedance is a resistance equal to the nominal input resistance, the input voltage (open-circuit voltage) is twice the voltage appearing across the antenna terminals of the receiver.

[1] Rules and regulations of the Federal Communications Commission, pt. 3, Sec. 3.682.

[2] A related IEC Standard, "Recommended Methods of Measurement on Receivers for Television Broadcast Transmissions," is published by the International Electrotechnical Commission, 39, rue de Malagnou, Geneva, Switzerland.

Since the input impedance of television receivers built in the United States has been standardized at a value of 300 ohms, it has become common practice to express the input in microvolts, or in decibels below one volt. However, voltage measurements made on receivers designed for a different input impedance will not be directly comparable to those made on receivers designed for the standard 300-ohm impedance unless correction is made for the difference in input impedance.

*1.4.3 Values of Standard Test Input Levels.* Standard input levels are specified in Table I. Corresponding to these values of available power, which are independent of the receiver input impedance, are shown the approximate equivalent values of open-circuit voltage for the standard impedance level of 300 ohms.

TABLE I

| Available Power, db below 1 watt | Approximate Equivalent Input Voltage for $R=300$ Ohms | |
|---|---|---|
| | microvolts | db below 1 volt |
| 131 | 10 | 100 |
| 121 | 32 | 90 |
| 111 | 100 | 80 |
| 101 | 320 | 70 |
| 91 | 1000 | 60 |
| 81 | 3200 | 50 |
| 71 | 10,000 | 40 |
| 61 | 32,000 | 30 |
| 51 | 100,000 | 20 |

*1.4.4 Standard Mean-Signal Input Power.* The standard mean-signal input power is 81 db below 1 watt, corresponding to 3200 $\mu$v at 300 ohms.

## *1.5 Standard Picture Test Modulation*

*1.5.1 Sine Wave.* The standard test modulation for sine-wave modulated signals shall be 30 per cent amplitude modulation at 400 cps.

*1.5.2 White-Pattern Modulation.* The standard test modulation envelope for white-pattern modulation shall be an RF signal modulated by the waveform standardized by the Federal Communications Commission and shown in Fig. 1.5.2 with the picture portion of the signal constant at 15 per cent of the carrier level during the synchronizing peaks.

*1.5.3 Gray-Pattern Modulation.* The standard test modulation envelope for gray-pattern modulation shall be an RF signal modulated by the synchronizing waveform of Fig. 1.5.2 with the picture portion of the signal constant at 40 per cent of the carrier level during the synchronizing peaks.

*1.5.4 Test-Pattern Modulation.* The standard for test-pattern modulation shall be an RF signal modulated by the EIA (Electronic Industries Association) test pattern (Fig. 1.5.4) with the white peaks at 15 per cent of the carrier level during the synchronizing peaks.

## *1.6 Standard Sound Test Modulation*

Standard test modulation of the sound carrier is frequency modulation at 400 cps with a deviation of 7.5 kc; this is 30 per cent of the maximum system deviation of 25 kc.

The standard transmitter pre-emphasis provided by a time constant of 75 $\mu$sec is normally not employed in fidelity testing of the sound channel. Instead, the corresponding standard de-emphasis characteristic, shown in Fig. 1.6, is applied as a compensating correction to the amplitude-vs-frequency response. This procedure is described in Section 10.2.2.

## *1.7 Standard Dummy Antenna*

The standard dummy antenna presents a balanced, resistive, 300-ohm source impedance to the antenna terminals of the television receiver. Signal generators that do not have these properties must be provided with an external network which may consist of resistors or of a balun.

The resistors used should have negligible reactive components, and in the case of two or more generators, the resistance networks should be located at the signal generators with a 300-ohm balanced line to the receiver. Most of the networks used with two or more signal generators require a correction factor for determining the open-circuit voltage from the generator voltage.

If a balun is used in place of a resistance network, its voltage transformation and impedance characteristics must be known with respect to frequency. If either of these characteristics is not reasonably flat, an iterative resistance attenuator network may be used to minimize departures from uniform transmission or termination.

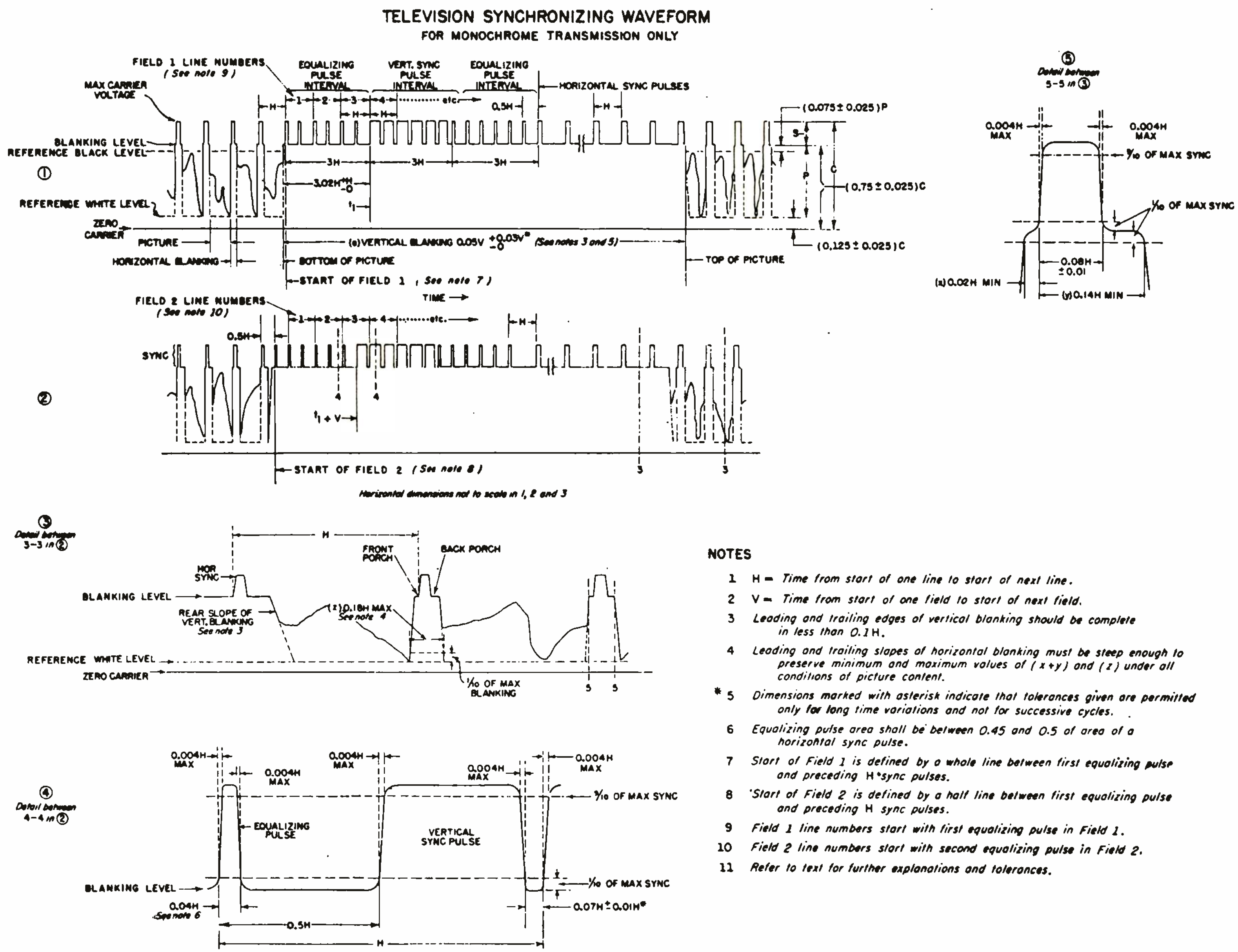
The effect of reversing the connections to the receiver antenna terminals and reversing the power-line connections of either the signal generator or the receiver or both should be noted. A change in the receiver output is an indication of unbalance in the dummy-antenna system; however, no change in receiver output does not necessarily indicate a balanced dummy-antenna system.

When more than one signal generator is used, a comparison should be made of the relative receiver output as each signal generator is tuned in turn to the same frequency, to obtain the appropriate correction.

The following paragraphs describe several examples of dummy-antenna configurations. In many instances, balun transformers can be used advantageously, particularly where it is desirable to effect impedance matching with a minimum power loss, or when the receiver has little unbalanced signal rejection.

*1.7.1 Single Balanced Signal Generator.* The network consists of two resistors of equal value, one connected in series with each terminal of the signal generator and of such value that the total output impedance, including the signal generator, is 300 ohms.

*1.7.2 Single Unbalanced Signal Generator.* The network consists of two resistors, a 150-ohm resistor connected in series with the "ground" terminal of the signal generator and a resistor (equal to 150 ohms minus




NOTES

1 H = Time from start of one line to start of next line.

2 V = Time from start of one field to start of next field.

3 Leading and trailing edges of vertical blanking should be complete in less than 0.1 H.

4 Leading and trailing slopes of horizontal blanking must be steep enough to preserve minimum and maximum values of (x+y) and (z) under all conditions of picture content.

* 5 Dimensions marked with asterisk indicate that tolerances given are permitted only for long time variations and not for successive cycles.

6 Equalizing pulse area shall be between 0.45 and 0.5 of area of a horizontal sync pulse.

7 Start of Field 1 is defined by a whole line between first equalizing pulse and preceding H sync pulses.

8 Start of Field 2 is defined by a half line between first equalizing pulse and preceding H sync pulses.

9 Field 1 line numbers start with first equalizing pulse in Field 1.

10 Field 2 line numbers start with second equalizing pulse in Field 2.

11 Refer to text for further explanations and tolerances.

Fig. 1.5.2—Television synchronizing waveform for monochrome transmission.

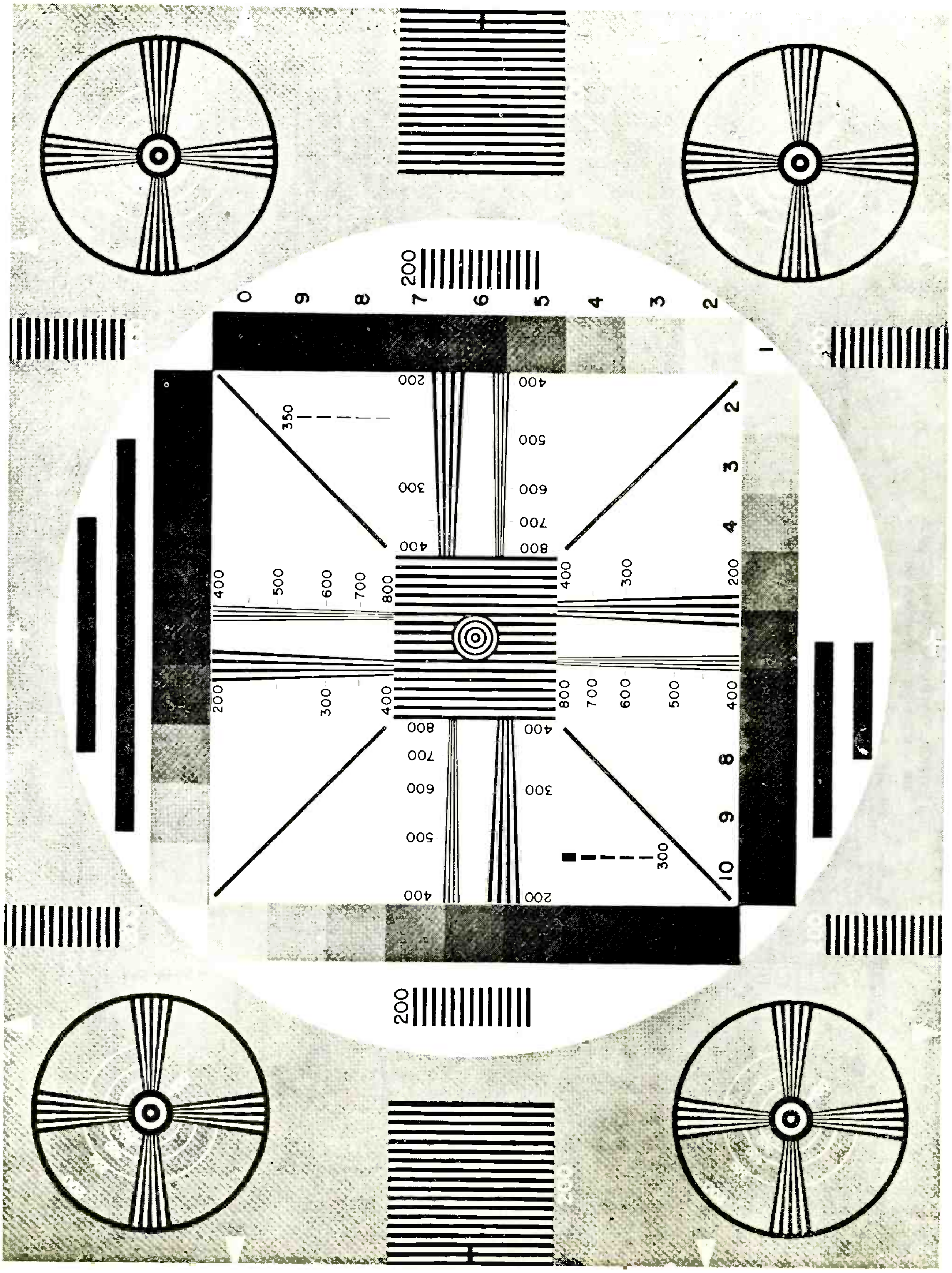



Fig. 1.5.4—EIA resolution chart.

the generator output impedance) in series with the output terminal of the signal generator.

*1.7.3 Two Signal Generators.* Separate picture and sound signal generators may be connected as shown in Fig. 1.7.3. The open-circuit voltages obtained from the connections of Fig. 1.7.3(a) and 1.7.3(c) are one-half the generator open-circuit voltages.

Fig. 1.7.3(c) illustrates a special case in which signal generators with 300-ohm output impedance are employed. The dummy-antenna network provides an impedance match to the signal generator outputs as well as the required source impedance to the receiver

*1.7.4 Three Signal Generators.* For certain measurements, a third signal generator may be required. The two connections shown in Fig. 1.7.4 provide an open-circuit voltage that is one-third the generator open-circuit voltage.

Fig. 1.7.4(b) illustrates a special case in which signal generators with 300-ohm output impedance are employed and the dummy-antenna network provides an impedance match to the generator output.

## *1.8 Standard Picture Test Output*

The standard picture test output as delivered by the receiver to the controlled element of the picture tube shall have an amplitude of 20 volts between blanking level and white, as determined by a cathode-ray oscilloscope when using the standard white-pattern modu-

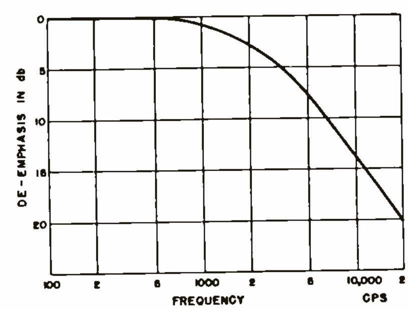



Fig. 1.6—Standard de-emphasis curve.

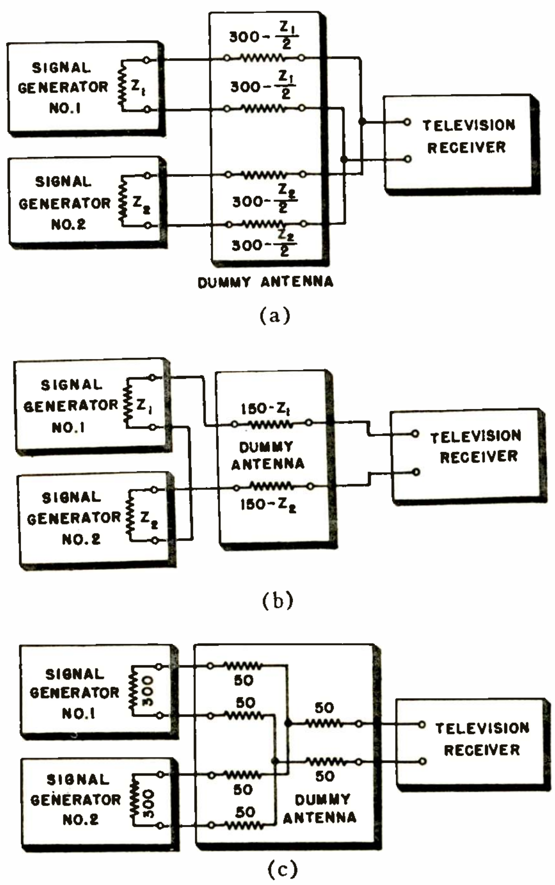



Fig. 1.7.3—Dummy-antenna connections for two signal generators. (a) Two signal generators in parallel. (b) Two signal generators in series. (c) Two 300-ohm signal generators in parallel.

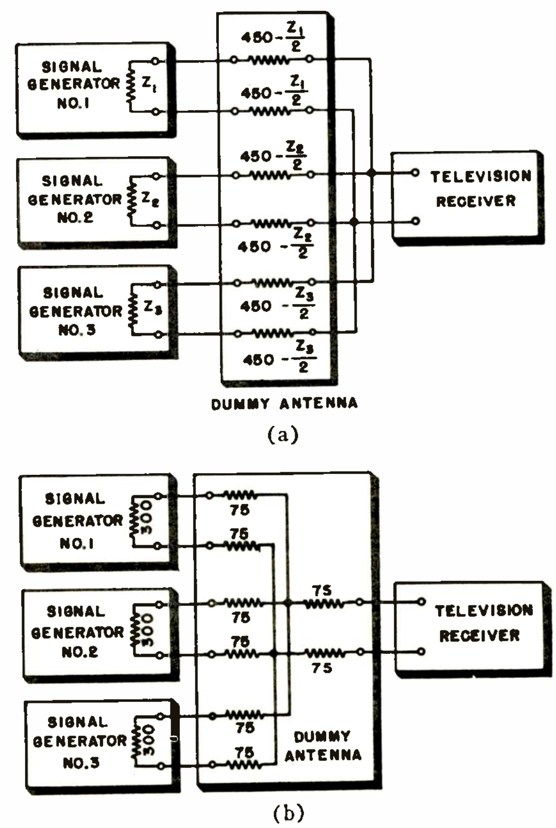



Fig. 1.7.4—Dummy-antenna connections for three signal generators. (a) Three signal generators in parallel. (b) Three 300-ohm signal generators in parallel.

lation (Section 1.5.2). When using symmetrical sine-wave modulation (Section 1.5.1), the standard output shall be 20 volts peak-to-peak. These outputs are equivalent for a receiver having a linear relationship between input and output over the amplitudes involved, as shown in Fig. 1.8. If the particular receiver being measured has been designed to operate with a picture device whose operating voltage requirements are so different from the conventional picture tube as to make the above value of 20 volts unsuitable, a value should be chosen to be approximately one-half of the normal maximum input voltage for the particular picture device being used. The value so chosen should be included in the data.

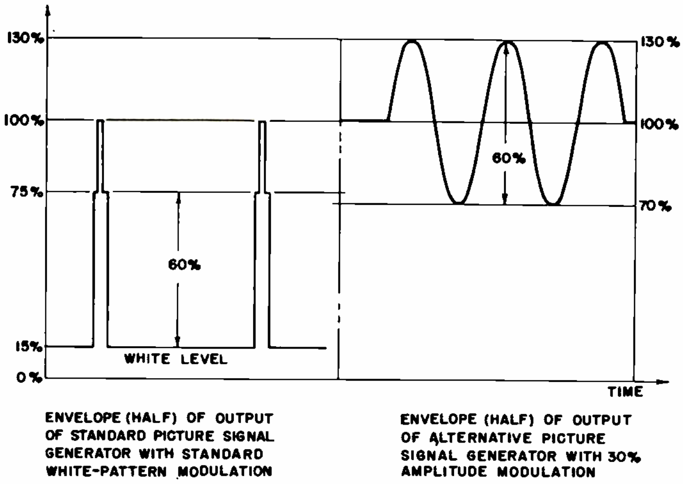



Fig. 1.8—Equivalence of output from standard white-pattern modulation and alternate 30 per cent amplitude modulation.

### *1.9 Standard Sound Test Output*

*1.9.1 Standard Test Output.* For receivers capable of delivering at least 1 watt at 10 per cent distortion (Section 10.3), the standard test output is an audio-frequency power of 0.5 watt delivered to a standard dummy load. For receivers capable of delivering 0.1 watt but less than 1 watt at 10 per cent distortion, the standard test output is 0.05 watt of audio-frequency power delivered to a standard dummy load. When this latter value is used, it should be specified.

*1.9.2 Standard Dummy Load.* Output measurements of the sound section of a television receiver are made in terms of the power delivered to a standard dummy load substituted for the loudspeaker, except in special cases where other terminations are specified. The standard dummy load is a pure resistance whose value is equal to the absolute value of the 400-cps impedance of the loudspeaker. Where an output transformer is connected between the receiver and the loudspeaker, the output transformer is treated as part of the receiver.

### *1.10 Standard Test Conditions*

*1.10.1 General.* It is assumed that the following standard test conditions are in effect during all tests unless noted otherwise.

*1.10.2 Power Supply.* Receiver measurements are made at the supply voltage for which the receiver is designed. Mean values of voltage and frequency are arbitrarily selected, such as 117 volts and 60 cps for ac operated receivers. Certain receiver characteristics may be desired at other than standard supply voltages and frequencies, or over a range of operating values. Tests should be made to check whether the receiver operates satisfactorily over the range of operating voltage and frequency likely to be encountered in service.

*1.10.3 Ambient Temperature and Humidity.* The ambient temperature should be between 20° and 35° C, and the relative humidity should be below 90 per cent.

*1.10.4 Electron Devices.* The electron tubes or other devices used should have standard rated values of those characteristics which significantly affect the performance of the receiver.

*1.10.5 Television Receiver Adjustments.*

*1.10.5.1 General.* All control settings not otherwise specified should be adjusted for normal reception. The synchronizing controls are adjusted for proper synchronization and best interlace. The contrast control is adjusted for maximum focused luminance (Section 3.9), unless otherwise stated, and the brightness control is set so that the line structure just disappears in the darkest portion of the gray scale. The scanning linearity, the scanning amplitude, and the focus adjustments are optimized.

*1.10.5.2 Tuning adjustments.* The receiver is normally tuned so that the local oscillator operates at the correct frequency, corresponding to the selected channel. This adjustment can be made by measuring either the local oscillator frequency or the picture carrier intermediate frequency (nominally 45.75 mc) with a frequency meter.

When measuring peak picture and peak sound sensitivity, the receiver is tuned as described for these tests (Sections 4.3 and 8.4).

## Chapter 2—Requirements and Characteristics of Test Apparatus

### *2.1 Standard Picture Signal Generator*

The standard picture signal generator should provide a signal with the following characteristics:

a) The generator should be capable of modulation by the waveform of Fig. 1.5.2 to produce a modulated signal whose characteristics are in accordance with the Rules and Regulations of the Federal Communications Commission.[1]

b) The amplitude-vs-frequency characteristic should display less than 0.5-db response difference for any two modulating frequencies in the range from 30 cps to 4.5 mc. The time-delay errors should be negligible within this frequency band. Ideally a vestigial-sideband filter is required; however, most receiver tests can be made without this filter (Section 6.2.2).

c) The output voltage should be adjustable to any value over the range between 1 and at least 200,000 $\mu$v. Higher outputs up to 2 volts are desirable. The output-level indicator should measure the output during synchronizing peaks.

d) Incidental phase modulation of the carrier should not exceed 10 degrees swing at full video modulation at any carrier frequency.

e) Extraneous frequency modulation (hum) of the carrier should be negligible with respect to the characteristic under observation, especially when the generator is to be used in connection with the sound signal generator (Section 2.3) for tests on the sound channel.

*2.2 Alternative Picture Signal Generator*

Although the complete performance testing of the picture section cannot be accomplished without the use of a standard picture signal generator and a pattern generator, as described in Sections 2.1 and 2.4, many tests can be made with a standard signal generator producing a sine-wave 30 per cent amplitude-modulated signal. Furthermore, certain of the standard tests can be facilitated by the use of this type of signal generator. This generator should have a frequency range extending from below the intermediate frequency up to the highest television channel plus twice the intermediate frequency of the receiver under test, should be capable of amplitude modulation at 400 cps, and should have a variable output voltage up to at least 200,000 $\mu$v and preferably 2 volts.

Extraneous frequency modulation of the carrier should be negligible with respect to the characteristic under observation, especially when the generator is to be used in connection with the sound signal generator (Section 2.3) for tests on the sound channel. The carrier frequency stability should be consistent with the requirement of Section 2.3(d).

*2.3 Sound Signal Generator*

The sound signal generator should have the following characteristics:

a) The output should be calibrated from 1 to 200,000 $\mu$v with a constant source impedance.

b) It should be capable of frequency modulation at rates of 30 to 15,000 cps to a deviation of at least 25 kc and preferably to 50 kc with negligible distortion, and negligible incidental amplitude modulation.

c) Amplitude and frequency modulation at power-line frequencies should be negligibly small.

d) The carrier frequency should be sufficiently stable to maintain an accuracy of $\pm 5$ kc in the 4.5-mc difference frequency between the sound and picture carriers.

*2.4 Pattern Generator*

This equipment, which supplies a modulating signal to the picture signal generator, must contain means for generating a composite signal which will contain not only those picture elements which comprise a test pattern, but also correctly timed blanking and synchronizing pulses. The characteristics of the standard synchronizing waveforms are given in Fig. 1.5.2.

The pattern generator must be provided with the necessary controls and monitoring means to assure the correct levels of the various components of the composite picture signal. It must be free of hum, noise, and other extraneous components.

In addition to the standard synchronizing-signal waveforms, the pattern generator should be capable of providing the following composite picture test patterns:

a) The white-pattern modulation of Section 1.5.2.

b) Gray-pattern modulation of Section 1.5.3.

c) Sine-wave modulation for frequencies of 100 kc to 4.5 mc.

d) Square-wave modulation of variable repetition rate capable of being synchronized with the sweep frequencies.

e) Staircase patterns arranged to appear as vertical stripes and to be movable over the entire picture.

f) The monoscope type of test pattern (Fig. 1.5.4).

g) A cross-hatch pattern in which the video component consists of two sets of synchronized narrow rectangular pulses at time intervals equal respectively to not more than $\frac{1}{16}$ of the vertical and horizontal scanning intervals. These pulses produce a cross-hatch pattern of stationary vertical and horizontal lines.

*2.5 Wide-Band Cathode-Ray Oscilloscope*

A calibrated wide-band oscilloscope is required for testing the performance of the picture circuits of a television receiver. Its phase and amplitude response must be such as to avoid significant distortion of any waveform of interest; the major requirements are that the deflection sensitivity difference between any two frequencies from 30 cps to 4.5 mc should be less than 0.5 db and that the time-delay error be negligible.

The input impedance should be high enough so that the performance of the circuits to which the oscilloscope is connected is not affected by the resistance or capacitance of the oscilloscope input circuits.

*2.6 Audio-Output and Distortion-Measuring Devices*

Apparatus for the measurement of audio output and distortion is the same as that required for the testing of frequency-modulation receivers.[3] The output meter should measure true rms values.

*2.7 Measurement of Luminance*

The photometer used in all luminance measurements should be capable of operating over a small area of the image. An instrument having an acceptance angle of 1

[3] See Section 3 of IRE Standards, 47 IRE 17. S1, "Standards of Radio Receivers: Methods of Testing Frequency-Modulation Broadcast Receivers, 1947."

degree operated at a distance from the image equal to four times the picture height is suitable. The instrument should preferably be of the objective type and should simulate the color response of the average human eye. If the instrument is of the subjective matching type, a calibrated filter should be fitted to secure optimum color match.

Since ambient lighting is variable, the effect of this should be assessed separately. Ambient lighting includes reflections of the television picture from surrounding objects, and a check should be made with the receiver operating at maximum brightness to verify that the luminance of the light reflected from any object does not exceed 0.2 foot-lambert.

When subjective methods are used, sufficient time should elapse before measurements are taken in order to condition the eye to the low level of ambient illumination. Unless otherwise stated, all luminance measurements should be taken at the center of the relevant area in a direction parallel to the optical axis of the picture screen.

### *2.8 Shielded Enclosure*

A shielded enclosure is required for some television receiver measurements in order to attenuate external signals that might otherwise affect the measurements.

## Part II—PICTURE SECTION OF RECEIVER

## Chapter 3—Picture Quality

### *3.1 General Considerations*

Picture quality depends on characteristics which include size, resolution, contrast range, transfer characteristic, geometric distortion, interlace, luminance, and focus. These may be measured or evaluated by viewing the image of suitably designed test charts. One test chart recommended for this purpose is shown in Fig. 1.5.4 and is described in Standard RS-170 of the Electronic Industries Association. Other useful charts are described under the applicable sections of this standard.

The pattern generator (Section 2.4) makes use of a camera or scanner focused on the chart, or a monoscope containing a copy of the chart. The modulation level of the picture signal generator is set with the whitest portion of the gray scale of the chart at reference white level (15 per cent) and the darkest portion of the gray scale at reference black level (Fig. 1.5.2).

The receiver is tuned in accordance with Section 1.10.5.2 with standard mean-signal input, and the controls are adjusted as in Section 1.10.5.1.

### *3.2 Picture Size*

*3.2.1 Definition.* The picture size is described by four projected quantities: Picture diagonal, maximum picture height, maximum picture width and picture area. Linear dimensions are specified in inches and area in square inches.

*3.2.2 Method of Measurement.* The projected dimensions are determined by means of a sliding gauge or other suitable device. Another method consists of photographing the picture area from a point situated on the optical axis of the area at a distance equal to at least five times the maximum picture height. From this photograph, the projected dimensions, as well as the picture area, are determined.

### *3.3 Curvature of Picture Screen*

*3.3.1 Definition.* The curvature of the picture screen is defined by the ratio between the picture depth and the maximum picture height. The picture depth is defined as the distance between two geometrical planes, both perpendicular to the optical axis, one going through the image point nearest to the observer and the other going through the most distant image points of the picture area.

*3.3.2 Method of Measurement.* The picture depth is measured with the aid of a traveling microscope or other suitable means.

### *3.4 Geometric Distortion*

In the television transmitter, the coordinates of the picture elements are translated into time differences in the television signal. In the receiver the reverse process must take place in order to obtain undistorted reproduction. Any deviation from the desired linear relationship between timing and position due to the receiver is defined as geometric distortion.

Geometric distortion is measured by using an electrical time pattern generator [Section 2.4(g)] in which the video information consists of two sets of synchronized pulses, at equidistant time intervals, representing a cross-hatch pattern of horizontal and vertical lines. Detailed procedures for measuring geometric distortion are given in IRE Standards, 54 IRE 23. S1.[4]

### *3.5 Nonlinearity*

*3.5.1 Definition.* Scanning nonlinearity is defined in terms of the pattern of horizontal and vertical lines produced by the cross-hatch pattern generator [Section 2.4(g)]. The horizontal nonlinearity is the departure of the spacing between any two adjacent vertical lines from the mean spacing between the lines expressed as a percentage of the mean spacing between the lines. Vertical nonlinearity is defined similarly. Both horizontal and vertical nonlinearities are measured along projected horizontal and vertical lines through the center of the picture area.

*3.5.2 Method of Measurement.* A cross-hatch pattern generator is used [Section 2.4(g)]. To determine the nonlinearity, a photograph of the reproduced pattern may be taken as in Section 3.2. Alternatively, a traveling

[4] "IRE Standards on Television: Methods of Measurement of Aspect Ratio and Geometric Distortion," Proc. IRE, vol. 42, pp. 1098–1103; July, 1954.

microscope or other suitable means may be used to measure the distance between adjacent intersection points of the projected pattern.

*3.5.3 Presentation of Data.* The nonlinearity is plotted on a linear time scale as abscissa and a linear percentage scale as ordinate. The equal time intervals corresponding to the divisions of the picture area as transmitted are marked on the abscissa.

The difference between the mean distance and the distance between adjacent points is plotted as a percentage of the mean distance, at the center of each time interval. Graphs are plotted for both vertical and horizontal nonlinearity.

Short-time nonlinearity of scanning, such as results from yoke ringing, may not appear. To measure such deviations a more closely spaced pattern is necessary.

### *3.6 Raster Distortion*

*3.6.1 Definition.* Raster distortion is the deviation from a true rectangle of the largest completely visible contour of approximately the correct aspect ratio formed by the test pattern.

*3.6.2 Method of Measurement.* An electrically generated cross-hatch test pattern [Section 2.4(g)] is used.

A photograph of the reproduced pattern may be taken under the same conditions as specified in Section 3.2.

On this photograph, or a similar projection of the reproduced pattern on a plane perpendicular to the optical axis, the distorted reproduction of the contour of the largest completely visible rectangle formed by the test pattern and having approximately the correct aspect ratio is traced (Fig. 3.6.2). This contour is normally an adequate description of raster distortion.

If one form of distortion predominates, it may be measured in accordance with the following methods. Fig. 3.6.2 represents a generalized contour. The corner points $A$, $B$, $C$ and $D$ are marked, and the auxiliary lines $AB$, $BC$, $CD$, $DA$, $KF$ and $HE$ are then drawn so that $AE=EB$, $BF=FC$, $CH=HD$, $DK=KA$.

The greatest distance between the line $AB$ and the contour section between $A$ and $B$ lying outside the quadrangle $ABCD$ is called $a_2$.

The distance between $AB$ and the point of the contour section lying farthest away from $AB$ inside the quadrangle $ABCD$ is called $a_1$. The distances $b_1$, $b_2$, $c_1$, $c_2$, $d_1$ and $d_2$ are similarly defined.

The following distortion percentages are specified:

*Horizontal Trapezoid Distortion*

$$T_H = \frac{AD - BC}{AD + BC} \cdot 100 \text{ per cent}$$

and

*Vertical Trapezoid Distortion*

$$T_V = \frac{AB - DC}{AB + DC} \cdot 100 \text{ per cent.}$$

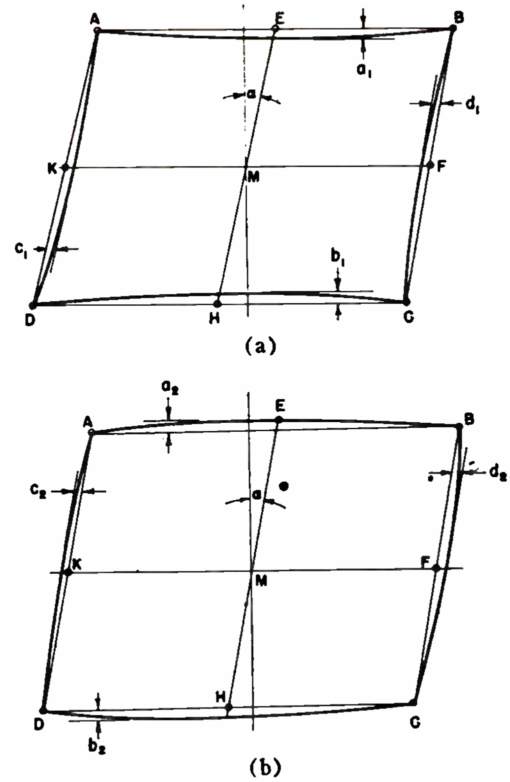



Fig. 3.6.2—Raster distortion measurements. (a) Pincushion distortion. (b) Barrel distortion.

If the contour sections $AB$ as well as $DC$ lie completely *outside* the quadrangle $ABCD$, the

*Horizontal Barrel Distortion*

$$B_H = 2\frac{a_2 - b_2}{AD + BC} \cdot 100 \text{ per cent.}$$

If the contour sections $AB$ as well as $DC$ lie completely *within* the quadrangle $ABCD$, the

*Horizontal Pinchushion Distortion*

$$C_H = 2\frac{a_1 + b_1}{AD + BC} \cdot 100 \text{ per cent.}$$

Similarly, the

*Vertical Barrel Distortion*

$$B_V = 2\frac{c_2 + d_2}{AB + CD} \cdot 100 \text{ per cent}$$

and the

*Vertical Pincushion Distortion*

$$B_V = 2\frac{c_1 + d_1}{AB + CD} \cdot 100 \text{ per cent.}$$

*Parallelogram Distortion* is expressed by the angle in degrees.

*Ripple Distortion* of the contour is present when the raster contour sections $AB$, $CD$, $BC$, $DA$ show undulations. The peak-to-peak value of such undulations may be expressed as a percentage of raster height or width.

## 3.7 *Influence of Hum on Geometric Distortion and Brightness*

Geometric distortion and brightness irregularities may occur as a result of power-supply voltages and power-supply magnetic and electric fields. These effects can be distinguished by operating the receiver from a supply having a frequency differing slightly (*e.g.*, 1 cps) from the field frequency. Alternatively, if the receiver uses a power supply to which the picture synchronizing-signal generator is locked, the necessary relative phase changes may be obtained by rotating a suitable manual phase shifter in the lock-in circuit of the synchronizing-signal generator through 360 degrees.

With respect to geometric distortion, the excursion of the points in the picture which have the greatest vertical and horizontal movements are noted. The picture center should be offset (and the background brightness increased) so that the raster edges can be observed. This enables a determination of the degree of raster motion and synchronizing timing variation.

Brightness variations normally appear as moving horizontal bands. The receiver contrast and brightness controls may be adjusted to produce a gray background to facilitate observation of the shading.

The faults observed in this section are described together with the conditions of measurement.

## 3.8 *Luminance*

For a specified set of conditions, the maximum luminance of a television picture may be limited by factors which include deterioration of focus, geometric or size distortion, inadequate video drive, and the relative area of the picture at the peak white level. Flicker, which is generally not a limiting factor, is not considered here. See Section 2.7 for method of measurement.

## 3.9 *Maximum Focused Luminance*

*3.9.1 Definition.* This is the maximum luminance at which the focus is sufficient to resolve the line structure.

*3.9.2 Method of Measurement.* Apply to the receiver the standard test-chart modulated signal (Fig. 1.5.4) at mean-signal input level. Increase the luminance level to obtain the maximum luminance at which the focus is still sufficiently good to show line structure in maximum luminance areas near the center of the raster, with the focus control optimized.

*3.9.3 Presentation of Data.* The luminance is expressed in foot-lamberts, together with a description of the uniformity of focus over the raster.

## 3.10 *Maximum Usable Luminance*

The maximum usable luminance is measured with the same setup used to measure maximum focused luminance (Section 3.9.2). The luminance level is increased until significant degradation of the picture occurs for reasons other than defocusing. This luminance value is recorded as the maximum usable luminance together with a statement of the limiting condition.

## 3.11 *Contrast*

*3.11.1 Introduction.* Contrast is the ratio of the luminance of a peak white area of the picture screen to the luminance of a black area of the picture screen. Contrast may be limited by halation effects in the display device, by ambient illumination, or by severe nonlinearity in the luminance transfer characteristic. The first two are considered in this section and the third in Section 3.14.

*3.11.2 Halation-Limited Contrast.* The degree to which contrast is limited by halation effects is influenced by the following factors:

a) The relative size of black and white areas. In general, contrast decreases as a greater portion of the screen is excited by electrons. See Fig. 3.11.2(a).

b) The relative distance between points at which contrasting luminances are measured. In general, the contrast decreases as the distance between the measurement points decreases. See Fig. 3.11.2(b).

c) The presence of high luminance areas at the corners or edges of the picture. Scattering of electrons from the neck or sides of the picture tube may limit contrast. See Fig. 3.11.2(c).

*3.11.2.1 Method of measurement of halation-limited contrast.* Halation-limited and electron-scattering contrast are measured using the test charts shown in Fig. 3.11.2. The picture-tube beam current must be cut off in the black (shaded) areas of the picture. The white areas of the picture are at maximum focused luminance. The ambient illumination should be negligible.

a) Halation-limited large area contrast ($\alpha_l$) is measured with the test chart shown in Fig. 3.11.2(a):

$$\alpha_l = \frac{2L_2}{L_1 + L_3} .$$

b) Halation-limited detail contrast ($\alpha_d$) is measured with the test chart of Fig. 3.11.2(b):

$$\alpha_d = \frac{L_2 + L_3 + L_4 + L_5}{4L_1} .$$

c) Electron-scattering-limited large area contrast ($\alpha_s$) is measured with the test chart of Fig. 3.11.2(c):

$$\alpha_s = \frac{L_2 + L_3 + L_4 + L_5}{4L_1} .$$

*3.11.3 Contrast Limited by Ambient Illumination.* With ambient illumination the luminance values of the black and white areas of the picture are increased by an equal amount, thus reducing the contrast. If, without ambient illumination, the luminance of a black area is $L_b$ and the luminance of a white area is $L_w$, the large area contrast is

$$\alpha_l = \frac{L_w}{L_b} .$$

With ambient illumination, an amount $L_r$ is added to

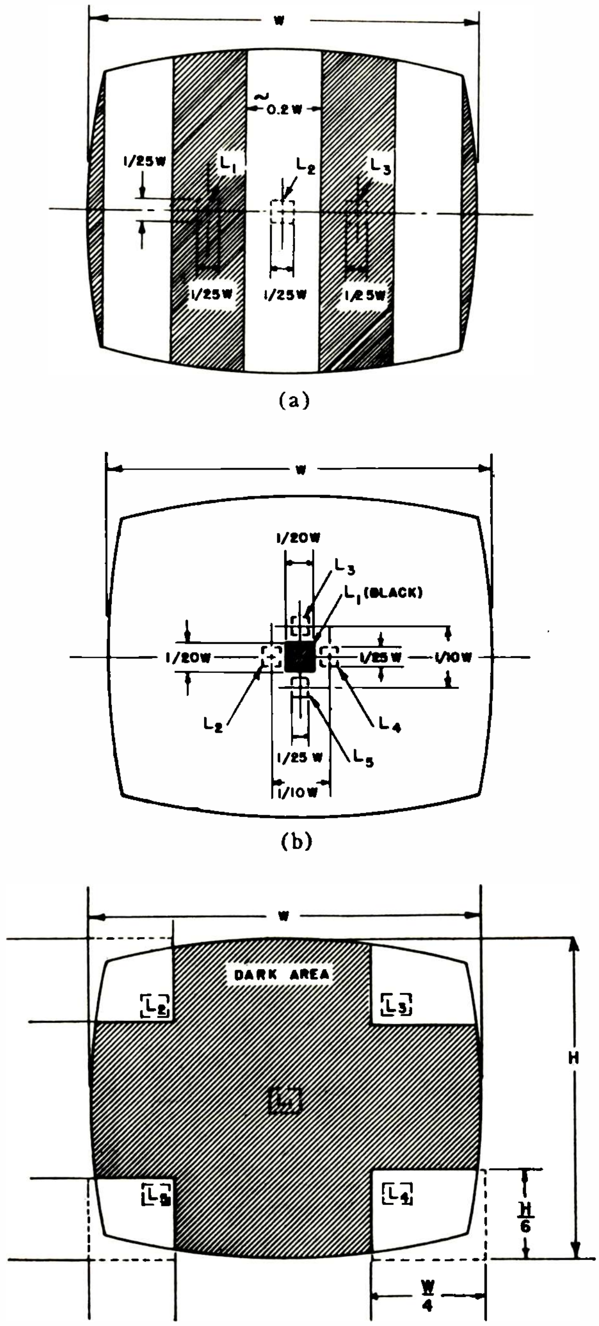



Fig. 3.11.2—(a) Test pattern for measurement of halation-limited large-area contrast. (b) Test pattern for measurement of halation-limited detail contrast. (c) Test chart for measurement of electron-scattering-limited large-area contrast.

$L_b$ and $L_w$. $L_r$ is the luminance due to the ambient light reflected by the picture screen. If $\rho$ is the reflection coefficient of the picture screen (Section 3.11.4) and $L_0$ is the luminance caused by the ambient illumination with $\rho = 1$, then

$$L_r = \rho L_0.$$

Thus the contrast with ambient illumination ($\alpha_i$) becomes

$$\alpha_i = \frac{L_w + L_r}{L_b + L_r} = \frac{L_w + \rho L_0}{L_b + \rho L_0}.$$

*3.11.4 Reflection Characteristic of the Picture Screen.*

*3.11.4.1 Definitions.* The reflection characteristic of the picture screen is the luminance value in the direction of the optical axis as a function of the angle of incidence of the ambient illumination relative to the luminance value of an ideally diffuse surface with the same ambient illumination, the receiver being switched off.

*3.11.4.2 Method of measurement.* The front of the receiver is illuminated by a source of light equivalent to Standard Illuminant *C*. A magnesium carbonate block is placed on the optical axis in contact with and in front of the optical surface nearest to the viewer.

The luminance values of the magnesium carbonate block and the face of the receiver adjacent to the carbonate block are measured. The measurement is repeated as the angle of incidence of the light is varied.

*3.11.4.3 Presentation of data.* The results are expressed as the ratio between the luminance of the face of the receiver and that of the magnesium carbonate block corrected for its known reflectance. This ratio is plotted as a function of the angle of incidence.

### *3.12 Resolution and Focus*

*3.12.1 Definition.* The vertical and the horizontal resolution is expressed as the maximum number of lines which can be resolved in the vertical and the horizontal directions as read from the resolution wedges on a reproduction of the standard test chart, Fig. 1.5.4.

*3.12.2 Method of Measurement.* The receiver is set up as in Section 3.1 with standard test-chart modulation. The focus should be adjusted in such a manner that the best over-all compromise is obtained. The nominal resolution is read at the point along the converging lines beyond which each individual line cannot be recognized with certainty. The resolution is recorded in the center and in the four corners of the picture. The highlight luminance should be specified.

### *3.13 Electrical Fidelity*

The electrical fidelity is measured in Chapter 6, which describes measurement of the high-frequency step response (Section 6.4) and the line and field-rate step responses (Section 6.5). These data should be supplemented by a description of the test-chart reproduction, with the receiver adjusted as in Section 3.1. Ringing, overshoot, smear, and line or field shading should be described qualitatively.

### *3.14 Luminance Transfer Characteristic*

*3.14.1 Definition.* The luminance transfer characteristic represents the relationship between the luminance and the corresponding picture modulation percentage.

*3.14.2 Method of Measurement.* A television signal at standard mean-signal level, modulated with the staircase pattern of Section 2.4(e) consisting of vertical bars equally distributed through the gray scale, is applied to the receiver terminals. The dimensions of the gray scale pattern should be approximately one-fourth of the respective picture dimensions. The modulation is adjusted so that the lightest bar corresponds to 15 per cent of the carrier level during the synchronizing peaks and the darkest bar to black level. Black level is defined as 70 per cent of peak-synchronizing amplitude for this test only. The contrast and brightness controls of the receiver are adjusted so that the scanning lines just disappear in the darkest bar and the lightest bar is at maximum focused luminance (Section 3.9). The luminance of each bar is measured with the gray scale pattern centered in the picture. The measurements should be repeated with the gray scale at the sides and corners of the picture and may also be repeated with higher or lower background brightness.

*3.14.3 Presentation of Data.* The luminance of each bar is plotted against the modulation level expressed as a percentage of the blanking level to peak white amplitude. 8.3 per cent on the abscissa corresponds to black level (70 per cent of the peak-synchronizing amplitude) and 100 per cent corresponds to reference white level (15 per cent of the peak-synchronizing amplitude). Logarithmic scales are used. See Fig. 3.14.3 for typical data.

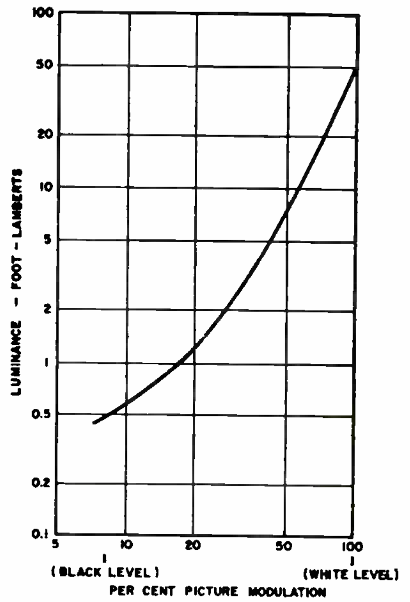



Fig. 3.14.3—Luminance transfer characteristic.

### *3.15 Interlace*

The quality of the interlace is described by the ratio of the distances between one scanning line and the two lines adjacent to it which belong to the interlaced field, each expressed as a percentage of the distance between two consecutive lines in a single field (Fig. 3.15). A test should be made to determine whether the interlace is affected by the vertical hold control, the type of picture modulation, or other control settings, and the results noted in the data.

### *3.16 Effect of Vertical Synchronizing Pulse on Horizontal Synchronization*

Rotation of the horizontal hold control may produce a relative displacement of the upper part of the picture. This effect is described by noting the deformation of a vertical line, as described by $\delta_1$ and $\delta_2$ in Fig. 3.16, as the horizontal hold control is rotated through the pull-in range. The resulting displacements are expressed as a percentage of the picture dimensions:

$$\frac{\delta_1}{w} \times 100 \quad \text{and} \quad \frac{\delta_2}{h} \times 100.$$

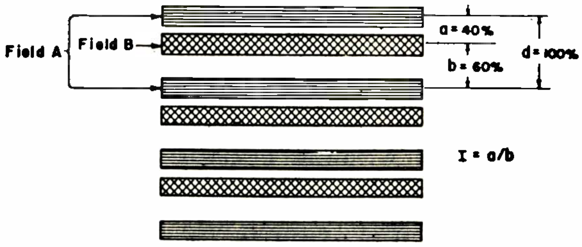



Fig. 3.15—Quality of interlace.

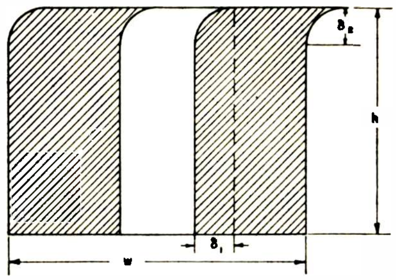



Fig. 3.16—Pulling on vertical synchronizing pulses.

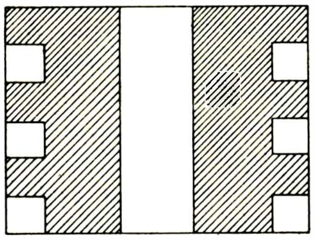
### *3.17 Effects of Picture Information on Synchronization*

Picture information in the form of large area black-to-white transitions frequently has adverse effects on synchronization. These effects may be measured by the use of a test chart as shown in Fig. 3.17(a). The receiver is adjusted as in Section 1.10.5. The resulting displacements [Fig. 3.17(b)] are expressed as a percentage of the picture width:

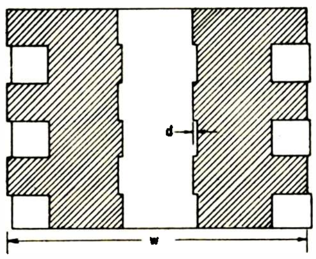
$$\text{Pulling on picture content} = \frac{d}{w} \times 100.$$

If no displacements result, the synchronizing-signal amplitude is reduced until measurable displacements occur. The data must include a statement of the reduction in synchronizing signal used.

Other test charts than the one shown in Fig. 3.17(a) may be used to advantage. For example, the polarity of Fig. 3.17(a) may be reversed, or the relative black and white areas varied. Due to the subjective nature of these data, the results are best reported as a side-by-side comparison, rather than as absolute data.



(a)




(b)

Fig. 3.17—Effects of picture on synchronization. (a) Test chart. (b) Typical results.

*3.18 Subjective Examination of Picture Quality*

Degradations of picture quality which are not described by the tests specified in this standard may be detected by subjectively examining the picture over a wide range of operating conditions. Particular emphasis should be given to the effect of variations in the settings of the receiver controls.

The following types of degradation should be looked for:

a) Luminance irregularities due to extraneous signals at the picture device control electrode, scanning velocity variation, or fold-over.

b) Interference generated internally such as extraneous oscillations in the deflection system (Barkhausen or other retarding field oscillations), shock excitation of incidental resonant circuits by sudden start or cessation of deflection currents, or crosstalk of sound into the picture.

c) Unstable synchronization, characterized as jumping, jittering, rolling, etc.

The above conditions can frequently be described best by a photograph of the phenomenon. When this is not possible, a subjective description of the extent, direction, size, shape, frequency and seriousness of the fault should be given.

## Chapter 4—Sensitivity, Picture

*4.1 Picture Sensitivity*

The sensitivity of the picture channel may be limited either by the available gain or by internal (thermal-agitation) noise originating principally in the tuner.

The "nominal sensitivity" and the "peak sensitivity" describe the extent to which the receiver performance is limited by the available gain. The "noise factor" is a measure of the internal receiver noise.

The nominal sensitivity (Section 4.2) is a measure of the receiver gain when the receiver is tuned normally to produce the nominal picture carrier intermediate frequency.

The peak sensitivity (Section 4.3) is a measure of the receiver gain when the receiver is retuned so that it has maximum gain at the picture carrier frequency. The sound channel performance and the adjacent-channel selectivity under this retuned condition are dependent upon the required amount of retuning of the local oscillator and the amount of shift in the IF amplifier selectivity as a function of AGC voltage.

In actual use, the receiver may be tuned to achieve a compromise between picture sensitivity, sound sensitivity and adjacent-channel rejection, depending on local conditions. This yields an effective value of receiver sensitivity which depends upon how closely the nominal sensitivity approaches the peak sensitivity.

In addition to gain and internal receiver noise, the effective receiver sensitivity is influenced by other characteristics such as weak-signal IF selectivity, transient response, gamma, contrast, luminance, screen persistence, clipping levels, and synchronizing performance.

*4.2 Nominal Picture Sensitivity*

*4.2.1 Definition.* The nominal picture sensitivity is the lowest input signal which results in standard picture test output when the receiver is tuned to produce the nominal picture intermediate frequency (Section 1.10.5.2).

*4.2.2 Method of Measurement.* The picture signal generator is connected to the receiver as described in Section 1.7. Standard white-pattern modulation (Section 1.5.2) is used. The receiver is tuned to produce the nominal intermediate frequency (Section 1.10.5.2) and the receiver controls are adjusted for maximum sensitivity.

The input signal is increased until the standard picture test output (Section 1.8) is obtained. This value is the nominal picture sensitivity.

If the video output is obscured by noise, sufficient filtering should be added so that the blanking level and peak white are delineated.

Where a television signal generator is not available, a 30 per cent sine-wave modulated signal (Section 1.5.1) can be used. This alternative procedure requires that the normal AGC voltage which would be produced by standard white-pattern modulation be simulated. A low-pass filter is used to reject thermal noise, and the input level is adjusted to produce standard test output.

*4.2.3 Presentation of Data.* The sensitivity is measured on the channels of interest and the results expressed in microvolts or in decibels below 1 volt.

*4.3 Peak Picture Sensitivity*

*4.3.1 Definition.* The peak picture sensitivity is the lowest input signal which results in standard picture test output when the receiver is tuned for maximum picture output.

*4.3.2 Method of Measurement.* The procedure is the same as in Section 4.2.2 except that the receiver is detuned the minimum amount required to produce peak output in the vicinity of the normal tuning position; if the output continues to increase as the receiver is detuned from the normal setting (as defined in Section 1.10.5.2), the peak sensitivity is measured with the receiver tuned so that the intermediate frequency produced is 1.5 mc lower than the nominal value.

*4.3.3 Sound Sensitivity.* The peak sound sensitivity, as described in Chapter 8, is measured for the same receiver tuning used in measuring the peak picture sensitivity.

### *4.4 Noise-Limited Sensitivity—Noise Factor*

*4.4.1 Introduction.* Provided a receiver has sufficient gain, its usable sensitivity is primarily limited by its noise factor.[5] The noise factor is a significant and reproducible measure of the noise performance of the input portion of the receiver, as compared with that of an ideal noise-free receiver. Other factors influence the noise-limited sensitivity as described in Section 4.1.

*4.4.2 Definition of "Noise Factor (Noise Figure), Average.* Of a linear system, the ratio of (1) the total noise power delivered by the system into its output termination when the noise temperature of its input termination is standard (290°K) at all frequencies, to (2) the portion thereof engendered by the input termination. For heterodyne systems, portion (2) includes only that noise from the input termination which appears in the output via the principal frequency transformation of the system and does not include spurious contributions such as those from image-frequency transformations."[6]

*4.4.3 Method of Measurement.* A random noise generator, which usually consists of a temperature-limited thermionic diode, is employed as a calibrated source of random noise. This noise generator is matched to the nominal 300-ohm input impedance of the receiver.

In order to compare the receiver noise with that of an ideal receiver, the receiver detector is linearized by injecting an auxiliary unmodulated signal at either the signal or the intermediate frequency. The noise factor is then determined by noting the amount of noise which must be added by the noise generator to produce a 3-db increase in the noise measured at the detector output.

The detailed measurement procedure is given below:

a) The test equipment is connected to the receiver.

b) The receiver is tuned as described in Section 4.3 for measuring peak picture sensitivity.

c) The AGC voltage applied to the first amplifier in the receiver is replaced by a fixed bias equal to that existing at the amplifier when the input is connected to a standard dummy antenna, with no applied signal. An adjustable bias source is connected to replace the AGC voltages on the later IF amplifier stages. The AGC voltages normally developed in the receiver should be rendered completely ineffective.

d) The waveform at the output of the video detector is examined with an oscilloscope to establish that only noise is present (no hum or other signals). If it is necessary to disable the vertical or horizontal sweep circuits to eliminate interference, the power supply should be loaded so that operating conditions of the rest of the receiver are normal.

e) A high-impedance video voltmeter is connected across the video-detector output to measure the noise output. If an averaging type of meter is used, precaution should be taken that it does not overload on the upper part of the scale because of the high ratio of peak-to-rms value of the noise voltage. The technique outlined in the following steps must be carefully followed so that the noise peaks are not clipped in the receiver itself. To observe whether nonlinearity is present, the video-detector output should be monitored on the oscilloscope throughout the test.

Care should be taken that no regeneration is introduced as a result of connecting the video voltmeter and the oscilloscope to the output of the detector.

f) An unmodulated carrier at either signal or IF frequency is coupled loosely into the receiver. The signal is tuned to the picture carrier frequency (normally the center of the band for this measurement) and its amplitude is increased to the point that *just* produces maximum output reading on the video voltmeter. This amplitude is the amount required to linearize the detector. The reading on the video voltmeter is then observed.

g) The noise generator is then turned on and its output increased until the noise output meter reading increases 3 db above that of step f). The noise factor is then read from the calibrated noise generator scale. If the noise factor for a 3-db increase in receiver noise output is not indicated directly on the instrument, or if the noise factor of the receiver is beyond the range of the instrument, making it impossible to increase the noise output by 3 db, then the following formula for the noise factor is applied:

$$NF \text{ (in db)} = 10 \log_{10} \frac{20IR_a}{M-1}$$

where

$I$ = dc current through the noise diode,
$R_a$ = noise generator source resistance,
$M$ = relative increase in receiver noise output power.

h) The effect of spurious responses, principally the image response, is usually negligible in television receivers, provided the image rejection is greater than 6 db.

i) The noise factor should be measured as a function of input signal level or alternative means should be

[5] This definition is from 57 IRE 7. S2 "Standards on Electron Tubes: Definitions of Terms, 1957," vol. 45, pp. 983–1010; July, 1957.
[6] 53 IRE 7. S1 "Standards on Electron Devices: Methods of Measuring Noise," Proc. IRE, vol. 41, p. 896; July, 1953.

used to establish that the noise factor for maximum sensitivity conditions is indicative of the signal-to-noise ratio at higher signal levels. For example, if shorting the AGC bias applied to the tuner improves the signal-to-noise ratio, this indicates that the noise factor is poorer at the higher signal levels.

*4.4.4 Presentation of Data.* The noise factor, for each channel measured, is given in decibels. A statement of whether the signal-to-noise ratio is degraded by the AGC voltage is included [see Section 4.4.3 (i)].

### *4.5 AGC Characteristic and Figure of Merit*

*4.5.1 Definition.*

*4.5.1.1 AGC characteristic.* The AGC characteristic describes the dependence of the picture output and the sound output levels on the input signal.

*4.5.1.2 AGC figure of merit.* The picture AGC figure of merit is the number of decibels reduction of the input signal, below 100,000 μv, required to reduce the picture output voltage by 10 db. The sound AGC figure of merit is defined in the same manner.

*4.5.2 Method of Measurement.* The picture and sound signal generators are connected to the receiver as described in Section 1.7. Standard white-pattern picture modulation (Section 1.5.2) is used. The sound carrier is modulated 30 per cent at 400 cps. The picture-to-sound carrier ratio is unity.

The receiver is tuned to produce the nominal intermediate frequency (Section 1.10.5.2), and the contrast and volume controls adjusted for standard test output with an input signal of 100,000 μv. The input signal is then varied from 10 μv to 2 volts (if available), without altering the controls, and the picture and sound outputs measured as a function of the input level. The measurement is repeated with the controls adjusted for standard test output with input signals of 10,000 and 1000 μv, as in Fig. 4.5.3.1.

If the video output is obscured by noise, sufficient filtering should be added so that the blanking level and peak white are delineated.

If the receiver has a "local-distance" sensitivity switch, its position should be noted. If the sensitivity or contrast controls significantly influence the operation of the AGC circuit, the measurement should be repeated for appropriate settings of the controls.

*4.5.3 Presentation of Data.*

*4.5.3.1 AGC characteristics.* This is plotted as in Fig. 4.5.3.1 for picture and sound outputs.

*4.5.3.2 AGC figure of merit.* This is noted as in Fig. 4.5.3.1 for both the picture and sound outputs.

### *4.6 Maximum Usable Input Signal*

*4.6.1 Definition.* The maximum usable input signal is the highest level of input signal for which the receiver gives acceptable performance under specified conditions.

*4.6.2 Method of Measurement.* The same test conditions are used as in Section 4.5.2.

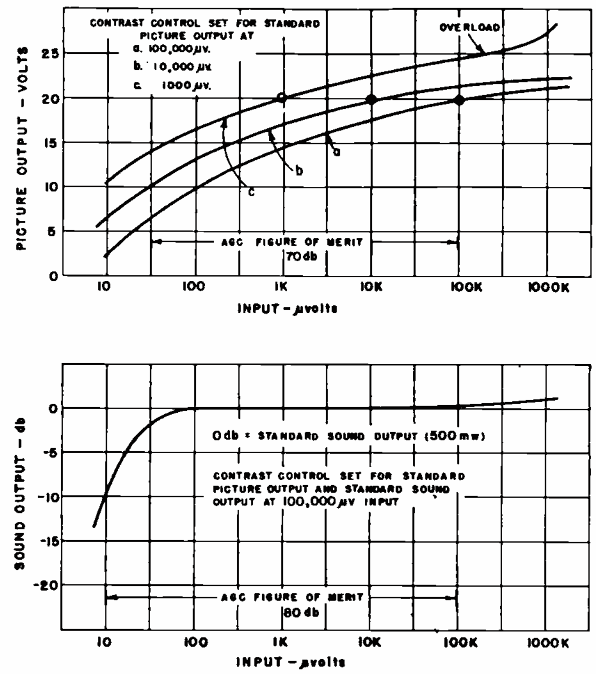



Fig. 4.5.3.1—AGC characteristics for the picture and sound channels.

1) The input level is gradually increased and the receiver controls and switches are adjusted to maintain optimum performance. The highest input signal level for which the performance remains acceptable is noted.

2) The measurement is repeated to find the highest input signal level which will just cause the receiver to operate abnormally (*e.g.*, "lock-out" by AGC blocking) when the channel selector is switched, or when the receiver power is turned on with the input signal applied.

*4.6.3 Presentation of Data.* The lowest of the values determined in the preceding three tests is recorded with a description of the effect which causes impaired performance.

### *4.7 AGC Speed*

*4.7.1 Definition.* Amplitude modulation of the composite input signal (airplane flutter) produces amplitude modulation at the picture tube to a degree which depends upon the characteristics of the AGC circuit. The AGC speed is described by a plot of the residual amplitude modulation at the picture tube against the frequency of the amplitude modulation, the per cent modulation of the input signal being maintained at 30 per cent. The AGC speed figure of merit is the frequency at which the per cent modulation of the signal at the picture tube is reduced from 30 per cent to 10 per cent.

*4.7.2 Method of Measurement.* The picture signal generator is connected to the receiver through an auxiliary RF amplifier, the gain of which can be varied by the application of a sine wave. The percentage modulation is maintained at 30 per cent, while the frequency of modulation is varied from a few cps to several hundred cps. Standard white-pattern modulation (Section 1.5.2) is used. The receiver is tuned to produce the nominal intermediate frequency (Section 1.10.5) and the receiver controls are adjusted for standard test output.

The detector output is observed on an oscilloscope. At each frequency of modulation, the percentage amplitude modulation at the detector output is recorded.

The test is performed at an input level of 3200 $\mu$v and 100,000 $\mu$v. If the reduction in amplitude modulation percentage is observed to depend significantly on the contrast or AGC controls, the tests are repeated with representative settings of these controls.

*4.7.3 Presentation of Data.* The amplitude modulation at the picture tube input is plotted against the frequency of the modulation. The AGC speed figure of merit is noted on the curve.

## Chapter 5—Interference, Picture

### *5.1 Introduction*

Interfering signals which affect the picture may be generated externally or may be generated by the receiver itself. These undesired signals may enter the receiver through the antenna, the power line, and in some cases, may be picked up directly by the circuit components.

The receiver selectivity characteristics (Section 5.2) indicate the susceptibility of the receiver to undesired signals whose principal path includes the antenna.

Internally generated interference (Section 5.3) can best be measured by observation of the reproduced picture under conditions of controlled input signals.

Separate tests are included for compatibility with color signals (Section 5.4) and the effects of impulse-noise interference (Section 5.5).

### *5.2 Selectivity Characteristics*

*5.2.1 Combined Radio-Frequency and Intermediate-Frequency Selectivity Characteristic.*

*5.2.1.1. Definition.* The combined radio-frequency and intermediate-frequency selectivity characteristic is a measure of the relative gain vs frequency from antenna to video detector.

*5.2.1.2 Method of measurement.* It is desirable to take data under various conditions of receiver gain in order to show possible effects of regeneration and circuit detuning. Since the automatic gain-control circuits are disabled for this measurement, the desired receiver gain conditions are selected initially and the corresponding RF and IF gain-control voltages are measured. The following conditions of receiver gain are suggested:

a) Gain at nominal sensitivity level (Section 4.2.1).

b) Gain with input signal 20 db above nominal sensitivity level.

c) Gain at standard mean-signal level.

The procedure described in Section 4.2.2 is followed and the RF and IF gain-control voltages are measured and recorded for the picture carrier input levels referred to in a), b), and c) above.

The picture carrier modulation is then changed to 30 per cent 400-cps modulation. The gain-control circuits are disabled and RF and IF biases, as determined in the previous measurement at the nominal sensitivity level, are provided from an external source such as a battery. The contrast control remains at its maximum setting for the remainder of the measurements.

The signal generator, with just enough output to give a readable indication at the picture tube, is varied in frequency over the pass band and set at the trap frequency of highest attenuation. At this frequency, the signal generator output is adjusted to give a selected reference level at the picture tube. This reference level should be as high as possible without encountering overload.

The output indicating device may be an oscilloscope or a voltmeter. A 400-cps band-pass filter will prevent thermal noise or hum from affecting the readings.

The signal generator frequency is then varied over the pass band of the receiver and data are taken at enough points to define the selectivity characteristic. At each frequency of measurement, the input level is adjusted to give the previously selected reference output at the picture tube and this input level is recorded.

This procedure is repeated for the receiver gain conditions of b) and c) above with the gain-control biases adjusted to the appropriate values. The same reference output level is used for the three sets of measurements. When making the measurements at reduced receiver gain, it may not be possible to obtain data at the trap frequencies due to overload of the RF or IF circuits.

Because the selectivity is normally measured at an abnormally low detector level to prevent overload, it is desirable to make an additional test to determine whether the response in the pass band changes significantly with detector level.

The selectivity characteristic should be measured on at least one of the standard VHF and one of the standard UHF test channels (Section 1.3).

*5.2.1.3 Presentation of data.* The combined radio-frequency and intermediate-frequency selectivity characteristic of the receiver is plotted as in Fig. 5.2.1.3.

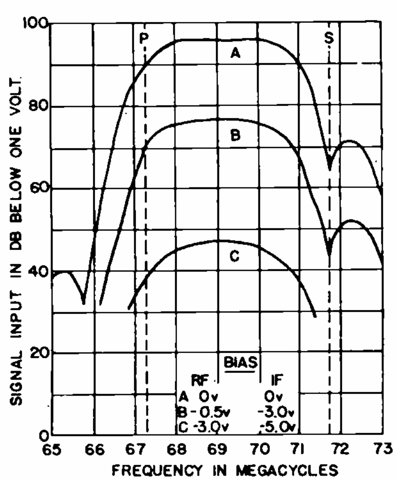



Fig. 5.2.1.3—Typical RF-IF selectivity characteristic.

*5.2.2 Intermediate-Frequency Selectivity Characteristic.*

*5.2.2.1 Definition.* The intermediate-frequency selectivity characteristic is a measure of the selectivity of the receiver circuits from the converter input to the video detector.

*5.2.2.2 Method of measurement.* The procedure of Section 5.2.1.2 is repeated with the signal generator tuned to the intermediate-frequency range and connected to the converter input instead of to the antenna. Measurements are made for the same receiver gain conditions as in Section 5.2.1.2 and the same reference output level is used.

Precautions must be taken to prevent feedback as a result of the signal generator connection.

*5.2.2.3 Presentation of data.* The intermediate-frequency selectivity is plotted as in Fig. 5.2.1.3 with the appropriate change in the frequency scale.

*5.2.3 Rejection of Predictable Off-Channel Signals.*

*5.2.3.1 Introduction.* A television receiver, tuned properly to a desired channel, is subject to interference from a number of specific signals having predictable frequencies. Interference from these signals occurs often enough to warrant individual measurements of the ability of the receiver to reject these specific frequencies. The following measurements are usually made:

1) Lower-Adjacent-Channel Sound-Carrier Rejection Ratio
2) Upper-Adjacent-Channel Picture-Carrier Rejection Ratio
3) Accompanying-Sound-Carrier Rejection Ratio
4) Intermediate-Frequency Rejection Ratio
5) Image Rejection Ratio.

The rejection ratios are ratios of the over-all gain of the receiver at the desired picture carrier frequency to that at the interfering signal frequency of interest.

*5.2.3.2 Method of measurement.* The test conditions for these measurements are the same as those described in Section 5.2.1.2 except that here the relative gain of the receiver is measured at the picture carrier frequency and at the interfering signal frequency of interest only (as enumerated in Section 5.2.3.1).

In the case of intermediate-frequency and image rejection ratios, the measurements of gain are made at the frequencies within the intermediate- and image-frequency ranges which produce the greatest receiver output.

The intermediate-frequency rejection ratio is usually made for both balanced and unbalanced signal input conditions as follows:

*Balanced Input.* The signal generator is connected to the receiver through the standard dummy antenna (Section 1.7).

*Unbalanced Input.* The intermediate-frequency signal is applied unbalanced to the receiver antenna terminals as shown in Fig. 5.2.3.2. However, the desired picture carrier signal is applied balanced through the standard dummy antenna. The unbalanced input voltage is the voltage across the resistor at the output of the resistive pad. When making the unbalanced connection, one should connect the generator ground terminal to a receiver ground terminal which is as near as possible to the antenna connections to the tuner.

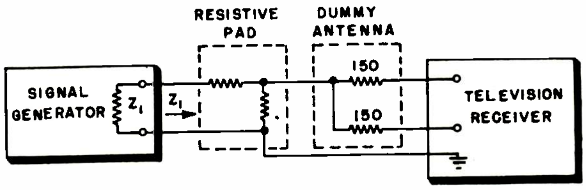



Fig. 5.2.3.2—Connections for unbalanced intermediate-frequency interference ratio measurement.

These rejection ratio measurements are normally made at the receiver gain setting corresponding to nominal sensitivity level.

The measurements should be made on at least one of the standard VHF and one of the standard UHF test frequencies.

*5.2.3.3 Presentation of data.* The ratio of the input signal level at the interfering frequency of interest to that at the desired picture carrier frequency is expressed in decibels.

*5.2.4 Spurious Responses.*

*5.2.4.1 Introduction.* In addition to the interfering signals described in Section 5.2.3, there are other frequencies at which interfering responses may occur. Spurious responses can be caused if external signals or one of their harmonics in combination with the receiver local-oscillator frequency or one of its harmonics produce an interfering signal in the intermediate-frequency pass band. Spurious responses may also be caused by cross modulation.

Because of the extreme frequency range involved, it is generally impractical to test for all possible spurious responses. The test described in Section 5.2.4.2 specifies a limited frequency range which is adequate to cover most of the possibilities likely to be encountered.

In general, the interfering signals existing at the lower end of the frequency range specified in Section 5.2.4.2 will appear as unbalanced signals at the receiver input terminals, while those at the higher end appear as balanced signals. Because the balanced or unbalanced signal condition is a function of many unpredictable factors, the test specifies that measurements be made for both conditions.

*5.2.4.2 Method of measurement.* For this test a signal source capable of supplying a harmonic-free interfering signal output from 10 $\mu$v to at least 2.0 volts is required. This source should cover the frequency range of 0.5 to 1000 mc. To fulfill these requirements, more than one generator may be necessary, and low-pass filters may be required to attenuate harmonics.

The interfering signal generator and the picture and sound signal generator are applied to the receiver in balanced connection through the dummy antenna described in Section 1.7.3. The resolution chart is applied as modulation to the picture signal generator, standard sound modulation is applied to the sound generator, and the interfering signal generator is amplitude-modulated 30 per cent at 1000 cycles. The picture and sound signal generators are adjusted for an input approximately 10 db above the nominal sensitivity input (Section 4.2), the receiver is adjusted for normal operation, and the interfering signal generator is set at maximum output.

The frequency of the interfering signal is varied over the range from 0.5 to 1000 mc while the picture is under observation. Any interference to either picture or sound should be noted together with the frequency at which it occurs. If any interference is noted, the interfering signal level at that frequency is reduced until the interference is just perceptible and this signal level is noted.

The test should be repeated with the picture and sound signal input 10 db below the maximum usable input level (Section 4.6).

These tests should be repeated with the interfering signal applied in the unbalanced connection, as shown in Fig. 5.2.4.2.

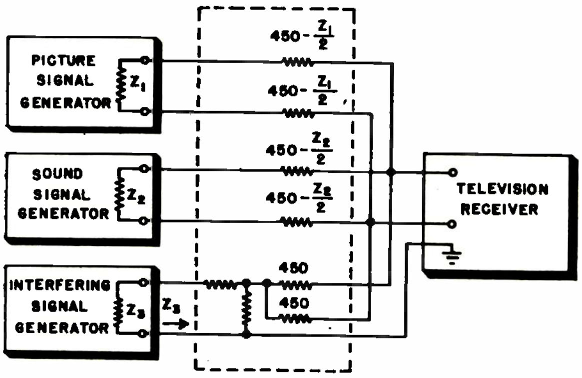



Fig. 5.2.4.2—Generator connections for unbalanced-input spurious-response measurement.

*5.2.4.3 Presentation of data.* The ratio between the interfering and desired signals in decibels is tabulated where the interference for the condition is just perceptible. The frequency of the interfering signal, the channel to which the receiver is tuned, the level of the desired signal, and the type of interference are noted.

### *5.3 Internally Generated Interference*

#### *5.3.1 Radio-Frequency and Intermediate-Frequency Harmonic Interference.*

*5.3.1.1 Definition.* 1) In a television receiver tuned to accept an RF signal which is a harmonic of the intermediate frequency, the harmonics generated by the IF amplifier may be of sufficient amplitude to be reamplified by the tuner and mixed with the desired RF signal. A beatnote having a frequency equal to the difference between the desired RF carrier and the IF harmonic is produced. If this beat frequency lies within the receiver video pass band, it can be observed on the picture tube screen. This is intermediate-frequency harmonic interference, sometimes referred to as "tweets," and is usually more troublesome with weak input signals.

2) Picture interference may also be caused by harmonics of the desired input signal mixing with harmonics of the local oscillator and producing signals that fall within the intermediate-frequency pass band of the receiver. This interference is more likely to appear with strong input signals.

*5.3.1.2 Method of measurement.* The picture and sound carrier generators are connected through the standard dummy antenna to the receiver. The picture modulation consists of standard white-pattern modulation and the sound generator is unmodulated. The receiver is adjusted for normal operation.

Observations are made on an oscilloscope connected to the picture tube input. The signal input levels are varied from 10 $\mu$v to the maximum usable signal input level (Section 4.6), and the input level and receiver tuning for the most objectionable interference within the usable (neglecting the tweet) picture range are noted. At this level, the peak-to-peak beat output during the picture interval and the blanking level to peak white amplitude are measured.

*5.3.1.3 Presentation of data.* The peak-to-peak beat output is expressed as a percentage of the blanking level to peak white output and recorded with the input signal level for the channels of interest. Where a subjective evaluation is necessary, a description of the perceptibility of the beat and the effect of receiver tuning should be included with the pertinent test conditions.

#### *5.3.2 Sound into Picture*

*5.3.2.1 Definition.* This type of interference is a result of either the coupling of the sound modulation or 4.5-mc intercarrier signal from the sound channel circuitry to the video circuitry, or intermodulation between sound and picture carriers in the RF or IF circuits. The result is an undesired pattern on the picture tube screen.

*5.3.2.2 Method of measurement.* The sound and picture signal generators, at standard mean-signal input, are connected to the input of the receiver (Section 1.7.3). The receiver is tuned and adjusted for normal operation (Section 1.10.5). White-pattern modulation (Section 1.5.2) is applied to the picture carrier generator and 100-cps modulation is applied to the sound carrier generator at maximum system deviation. The receiver volume control is adjusted for standard test output (Section 1.9). The speaker should be electrically connected to the receiver and in its normal position with respect to the receiver chassis. The signal source must be free of cross modulation between picture and sound signals.

The sound-to-picture carrier ratio is then increased from unity, maintaining the picture carrier constant, until 100-cps bars are just perceptible on the picture tube screen and the corresponding value of sound-to-picture carrier ratio is recorded.

The test should be repeated with sound modulation removed, and the sound-to-picture carrier ratio increased until the effect of the sound carrier becomes visible in the form of a fine-grain 4.5-mc beat pattern. The corresponding sound-to-picture carrier ratio is recorded.

The preceding tests should be repeated at maximum usable input signal to detect cross-modulation effects.

With unity sound-to-picture carrier ratio at standard mean-signal level, the volume control is advanced until interference is again observed. The power output at which this occurs is noted.

*5.3.2.3 Presentation of data.* The sound-to-picture carrier ratio in decibels which results in just perceptible interference, together with the picture carrier level, is tabulated for the tests described in Section 5.3.2.2. The sound power output corresponding to just perceptible interference is also noted.

*5.3.3 Interference from Horizontal Deflection Circuits.*

*5.3.3.1 Introduction.* This interference is usually caused by bursts of RF energy generated in the horizontal deflection system and coupled into the signal circuits at either the incoming signal frequency or intermediate frequency. The visual effects usually consist of a vertical bar in the picture or horizontal synchronization instability, or both. The interference may appear on one or more channels and is usually more severe at weak signal input levels.

*5.3.3.2 Method of measurement.* The receiver is tuned to a channel where the interference is noted. The appropriate picture carrier signal with white-pattern modulation (Section 1.5.2) is connected to the receiver through the dummy antenna, and the receiver is tuned normally. The transmission line to the tuner should be in its normal position for this measurement since the results are affected by the location (and the balance) of the input system.

The level of the picture carrier signal is then gradually increased until the interference is no longer perceptible. This signal level is recorded. The test should be repeated for all channels where the interference is noted.

### *5.4 Compatibility with Color Signal*

*5.4.1 Introduction.* The purpose of this test is to determine subjectively whether the monochrome receiver under test is capable of receiving a color signal without producing undesirable beatnote patterns in the picture.

*5.4.2 Method of Measurement.* For this test a laboratory-generated color signal is required. The picture and sound carrier signals at standard mean-signal level are connected to the receiver. Standard sound test modulation is applied to the sound carrier and the picture carrier is modulated with video information corresponding to a color bar pattern. It is desirable to have full-purity (or "saturated") color bars corresponding to each of the primary colors as well as the complementary colors, and in addition one white bar. The white bar is transmitted as a peak white signal at full intensity, and the color bars are transmitted at 75 per cent of their maximum possible amplitude in order to avoid over-modulation effects on certain colors. These levels are chosen as representative of the most severe conditions ordinarily found in natural scenes.

With the receiver controls adjusted for normal operation, the picture is observed in each of the bar areas for the presence of spurious patterns resulting from the 3.58-mc chrominance signal, or a 920-kc beatnote between the chrominance signal and the sound carrier. Effects of variations in the tuning should also be noted.

The test should be repeated with the sound carrier level maintained at twice the picture carrier level. A check should be made to determine whether the results vary significantly with signal level.

*5.4.3 Presentation of Data.* The presence of a 3.58-mc or a 920-kc beat should be recorded, together with the corresponding input signal conditions. The effect of variations in the receiver tuning control should also be noted.

### *5.5 Impulse Noise Interference Susceptibility*

At present no instrument is available which closely simulates the interference generated by automobile ignition systems, vibrators, shavers, and similar sparking devices. Lacking such equipment, receiver performance under impulse-noise conditions is usually evaluated by making comparative performance tests using an actual noise source coupled to the receiver input.

The receiver under test and the comparison receiver are placed in a shielded room and connected through a dummy-antenna network so as to receive equal signals. The noise source is mounted outside the shielded room and coupled to the single cable which feeds both receivers.

The receivers are adjusted for normal operation using standard test-pattern picture modulation and standard sound modulation. Initial tests are made at a level 10 db above nominal sensitivity level.

The susceptibility of the receiver is tested by observing the performance as the interference input level is increased. Observations should be made for the following defects:

a) Disturbance of the luminance during and immediately after the interfering pulses. Note should be made of whether the interference is predominantly black or white, the duration of the interference, the presence of blocking, and AGC disturbance.

b) Disturbance of the horizontal synchronization.

c) Disturbance of the vertical synchronization.

d) Disturbance of the sound output.

The relative performance of the receiver under test with respect to the comparison receiver is described. The observations are repeated at various input signal levels and with various types of noise sources.

## Chapter 6—Electrical Fidelity, Picture

### *6.1 Introduction*

The electrical fidelity is the over-all response of the receiver to the electrical variations which make up the signal present at the picture tube input. This involves two broad characteristics:

One is the ability of the receiver circuits, as the scanning spot travels horizontally, to reproduce a transition representing an abrupt change from black to white (or vice versa) and to resolve fine horizontal detail. This ability is dependent on the amplitude and phase response of the receiver to frequencies above 100 kc. In a monochrome receiver the phase response need not be measured directly since adequate information may be obtained from measurement of the amplitude response (Section 6.3) and the step response (Section 6.4).

The other characteristic is the ability to reproduce the electrical variations which correspond to the shading in the picture. This involves the response to frequencies down to the field repetition rate. The information may be obtained by observing the low-frequency square-wave response (Section 6.5) at both the field rate and the line rate.

### *6.2 General Measuring Techniques*

*6.2.1 Picture Signal Generator.* The signal source for measuring the electrical fidelity must have sufficiently low distortion so as not to interfere with the receiver measurements. In addition to the test modulation, the picture carrier should be provided with composite sync modulation. This is desirable so that the AGC, sync, and dc restorer circuits function normally. If composite sync modulation is not used, these circuits should be biased in such a way that the normal picture signal response is not distorted. For additional requirements of the picture signal generator, refer to Section 2.1.

*6.2.2 Vestigial-Sideband Filter.* To exactly simulate the television broadcast transmission characteristic requires the use of a vestigial-sideband filter. However, most receivers have sufficient selectivity so that this relatively complex filter can normally be omitted with negligible distortion of the amplitude response and the step response.

*6.2.3 Standard Envelope-Delay Predistortion Network.* To simulate television broadcast transmissions, a standard envelope-delay predistortion network (Fig. 6.2.3) is inserted ahead of the modulation input of the picture signal generator. (This network is designed to compensate for the high-frequency phase distortion introduced by the relatively sharp cutoff in the picture IF amplifier of color receivers.)

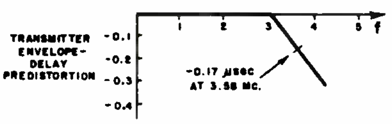



Fig. 6.2.3—Response of the standard transmitter envelope-delay predistortion network.

*6.2.4 Receiver Input Connections.* The output of the picture signal generator is supplied to the receiver as described in Section 1.7.

*6.2.5 Selection of RF Channel.* The measurements are normally made on a single channel having a relatively flat RF response.

*6.2.6 Receiver Tuning.* The receiver must be carefully tuned. If the tuning differs from that in Section 1.10.5.2, the tuning criterion should be described in the data.

*6.2.7 Signal Input Level.* The standard mean-signal input level is used.

*6.2.8 Picture Signal Generator Modulation.* The picture signal generator modulation is specifically described for each of the three measurements in Sections 6.3.2, 6.4.2, and 6.5.2.

*6.2.9 Test Output Level.* The nominal test output level is the standard picture test output (Section 1.8). However, other levels may be used where the modulation percentage or the contrast control has a significant effect on the response.

*6.2.10 Adjustment of Receiver Controls.* The receiver controls are adjusted for normal operation. In each of the measurements the effect of the contrast control on the response should be observed and, where significant, measurements should be repeated for representative settings of this control. The brightness control should be adjusted for normal operation for each of these contrast control settings so that picture tube overload will not distort the response. Where overload occurs in the video amplifier, it may be necessary to reduce the percentage of the picture signal modulation. Deviations from the specified measuring conditions should be included in the data.

*6.2.11 Oscilloscope Connection.* The response at the input of the picture tube is observed using a wide-band oscilloscope (Section 2.5). A probe having negligibly small input capacitance may be used; alternatively, the picture tube may be disconnected and its capacitance replaced by that of the oscilloscope in such a way as not to alter the original response.

### *6.3 Amplitude Response*

*6.3.1 Definition.* The amplitude response is the sine-wave modulation-frequency response characteristic at the picture tube input as a function of the modulation frequency.

*6.3.2 Method of Measurement.* The picture signal generator is modulated with a composite sync signal and a sine-wave picture signal as shown in Fig. 6.3.2. The sine-wave modulation frequency is varied between 100 kc and 4.5 mc while maintaining the modulation constant at the level where the peaks of the sine waves correspond to 15 per cent and 70 per cent of the synchronizing signal peaks. A video sweep generator may be used for this modulation.

The receiver contrast control is adjusted for standard picture test output at the input of the picture tube for the lowest modulation frequency (100 kc). Where contrast control settings have a significant effect on the response, the response should be measured at several

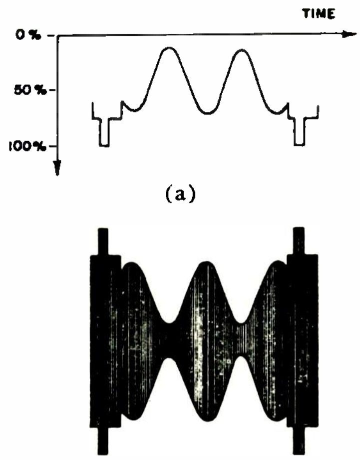



Fig. 6.3.2—Sine-wave picture signal used for measuring the amplitude response. (a) Picture-tube signal. (b) Modulated RF picture signal.

representative settings, observing the precautions of Section 6.2.10.

The amplitude response may be dependent on the percentage modulation of the sine-wave picture signal. If the response is observed to change significantly as the percentage modulation is reduced, the measurement should be repeated with the modulation of the sine-wave envelope reduced by 6 db.

*6.3.3 Presentation of Data.* The amplitude of the sine wave at the input to the picture tube is plotted as a function of the modulation frequency as shown in Fig. 6.3.3.

### *6.4 Step Response*

*6.4.1 Definition.* The step response is the waveform measured at the picture tube input when the picture modulation is a rectangular pulse having sufficient duration for steady-state to be reached.

*6.4.2 Method of Measurement.* The standard picture signal generator is modulated with a rectangular pulse and composite sync [Fig. 6.4.2(a)]. The rectangular pulse is synchronized to the line scanning frequency and phased so as to produce a black vertical bar. The step response is described by the waveform at the picture tube input corresponding to the black-to-white and white-to-black transitions. This contains the desired information on rise time, overshoot, ringing, smear, etc., as defined by Fig. 6.4.2(b). (This differs considerably from a typical receiver response.)

The step response may be dependent on the percentage modulation. If the response is observed to change significantly as the percentage modulation is reduced, the measurement should be repeated with the modulation reduced by 6 db.

When the contrast control is observed to have a significant effect on the step response, the measurement should be repeated for representative settings of the contrast control.

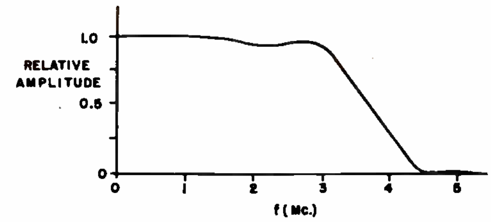



Fig. 6.3.3—Over-all receiver amplitude response.

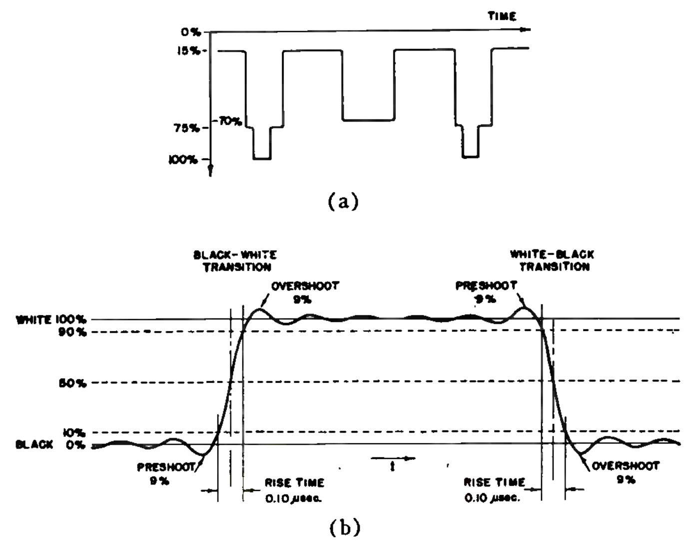



Fig. 6.4.2—(a) Rectangular pulse modulation for step-response measurement. (b) Nomenclature for specification of high-frequency square wave (response shown is that of ideal band-pass filter with rectangular cutoff).

### *6.5 Low-Frequency Square-Wave Response*

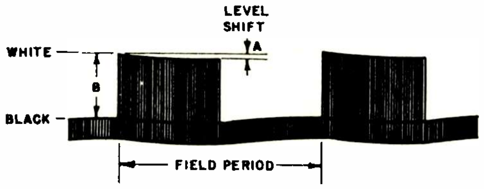
*6.5.1 Definition.* The low-frequency square-wave response is the waveform produced at the picture tube input, at the field rate and the line rate, when the input signal modulation corresponds to a pattern the lower half of which is black and the upper half white.

*6.5.2 Method of Measurement.* The picture signal generator is modulated with white at 15 per cent and black at 70 per cent of the peak of sync. The waveform at the picture tube input and the level shift are observed as in Fig. 6.5.2.

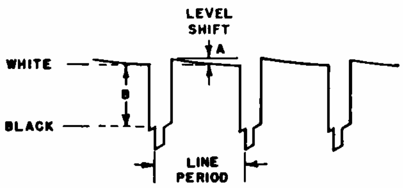
Frequently measurement of the low-frequency square-wave response is complicated by the presence of other low-frequency voltage components at both the grid and cathode of the picture tube, including blanking components. In such instances, the resultant output waveforms must be determined with due consideration for these components.

Hum voltages associated with the power supply may lead to errors in the measurements. These can be identified by operating the receiver from a supply which is asynchronous with the field frequency.

*6.5.3 Presentation of Data.* The low-frequency square-wave responses, including the white-level shift, are shown as in Fig. 6.5.2(a) for the vertical rate, and Fig. 6.5.2(b) for the horizontal rate. Significant power supply hum components should be noted.




(a)




(b)

LEVEL SHIFT PERCENTAGE $= \frac{A}{B} \times 100$

Fig. 6.5.2—(a) White-picture level shift during the field period, and (b) same but during the line period.

*6.6 Electrical Transfer Characteristic*

The electrical transfer characteristic may be plotted following a procedure similar to that described in Section 3.14 for measuring the luminance transfer characteristic.

## Chapter 7—Stability

*7.1 Stability of Local Oscillator*

*7.1.1 Introduction.* These tests are designed to show variations in the frequency of the local oscillator of a television receiver resulting from receiver warm-up and changes in line voltage and signal input level.

*7.1.2 Warm-up Drift.*

*7.1.2.1 Introduction.* The local-oscillator frequency usually varies with time for a period following receiver turn-on because of slight changes in component values and tube characteristics with rising temperatures. Ideally, this test is made under controlled humidity conditions and a statement of the existing humidity is included with the test data.

*7.1.2.2 Method of measurement.* Local-oscillator frequency drift can be measured by measuring the variation of the intermediate frequency produced in the receiver when receiving a stable RF signal. If a suitable frequency counter is available, the intermediate frequency is measured directly at the output of the IF amplifier.

Lacking a frequency counter, the measurement may be made by injecting a signal into the IF amplifier from a stable signal generator covering the intermediate-frequency range. The beatnote produced is monitored at the picture tube and measurements are made by reading the signal generator frequency required to maintain zero-beat output.

The RF picture signal is applied at standard mean-signal input on one of the standard test frequencies.

The receiver is turned on and the fine tuning control is quickly adjusted to place the produced IF signal at the nominal picture intermediate frequency of the receiver. In taking the succeeding measurements of local-oscillator drift with time, the fine tuning control is left untouched.

Frequency readings should be started at one minute after turning on the receiver and continued at suitable intervals until the frequency is stabilized.

The test should be repeated for all channels of interest, always allowing sufficient time for the receiver to cool off completely.

*7.1.2.3 Presentation of data.* Curves of local-oscillator frequency drift with time are plotted as in Fig. 7.1.2.3.

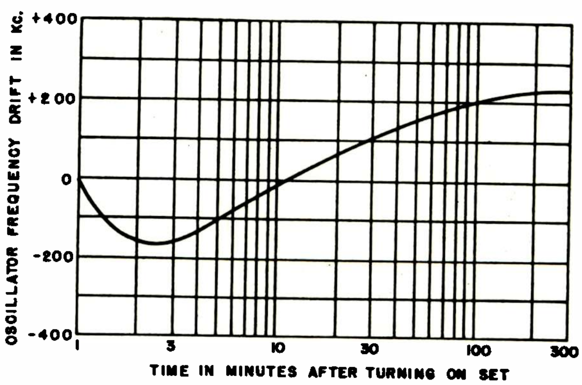



Fig. 7.1.2.3—Local-oscillator warm-up frequency drift characteristic.

*7.1.3 Drift with Line-Voltage Variation.*

*7.1.3.1 Method of measurement.* The procedure used to measure drift with line-voltage variation is similar to that described in Section 7.1.2.2. Before this test is begun, however, the receiver should have been in operation long enough to reach temperature stability as determined in Section 7.1.2.2. The fine tuning control is adjusted to produce the nominal oscillator frequency at a line voltage of 117 volts.

The deviation from nominal oscillator frequency is read as the line voltage is varied in 5-volt steps from 105 to 130 volts. Allowance of approximately half a minute should be made after shifting the line voltage so that the cathode temperature stabilizes.

The test should be repeated for all channels of interest.

*7.1.3.2 Presentation of data.* Curves of frequency drift vs line voltage are plotted as in Fig. 7.1.3.2.

*7.1.4 Drift with Variation in Signal Input Level.*

*7.1.4.1 Introduction.* Variations in signal input level may affect the oscillator frequency indirectly by way of the automatic-gain-control circuit. Because of the internal power-supply impedance, variations in AGC voltage may significantly change the dc voltage applied to the oscillator circuit.

*7.1.4.2 Method of measurement.* The measurement procedure used is similar to that described in Section 7.1.2.2 except that the receiver should have reached

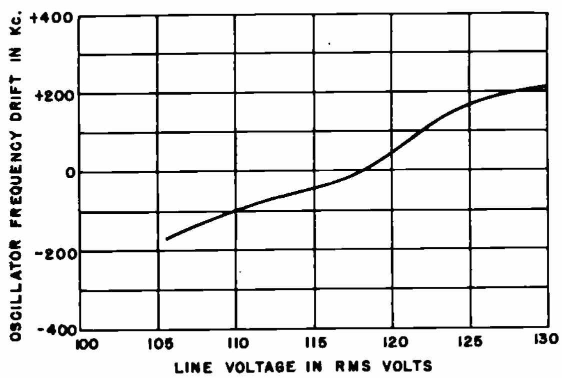



Fig. 7.1.3.2—Local-oscillator frequency drift with line-voltage variation.

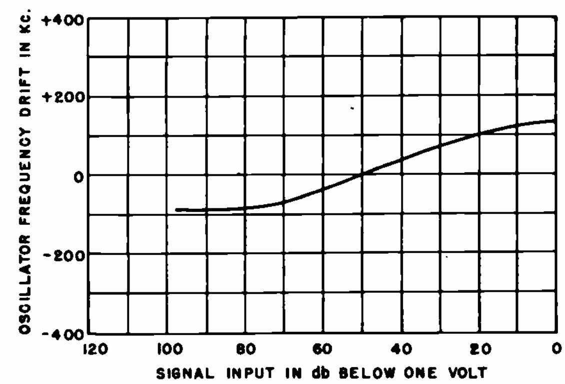



Fig. 7.1.4.3—Local-oscillator frequency drift with signal-input level variation.

temperature stability before readings are taken. The fine tuning control is adjusted to produce the nominal oscillator frequency at a line voltage of 117 volts.

Readings of deviations from nominal oscillator frequency are made as the signal input level is varied from 10 $\mu$v to 1 volt.

*7.1.4.3 Presentation of data.* Curves of local oscillator frequency drift vs signal input level are plotted as in Fig. 7.1.4.3.

### *7.2 Stability of Deflection Synchronization*

*7.2.1 Range of Hold Controls.*

*7.2.1.1 Introduction.* It is necessary in the case of automatic-frequency-controlled oscillators to differentiate between pull-in range and hold-in range. Hold-in range is the range of applied frequencies over which the oscillator will hold synchronism once it is synchronized. Pull-in range is the range of applied frequencies over which the oscillator will pull into synchronism as the signal is initially applied. The hold-in range is greater than the pull-in range. Operation of scanning systems beyond the pull-in range but within the hold-in range is normally not satisfactory, since any momentary interruption in the signal will cause the receiver to lose synchronism. Pull-in range is, therefore, the important factor.

With vertical synchronizing circuits, which are usually triggered, the hold-in and pull-in ranges are substantially equal.

*7.2.1.2 Method of measurement.* For pull-in range measurements, the picture carrier with white-pattern modulation (Section 1.5.2) is applied through the standard dummy antenna to the receiver. The receiver is tuned as described in Section 1.10.5.2. Measurements are made at nominal picture sensitivity level (Section 4.2), standard mean-signal input level, and maximum usable signal level (Section 4.6). The contrast control is set for standard picture test output.

*7.2.1.2.1 Horizontal pull-in range.* The horizontal hold control is used to throw the receiver out of horizontal synchronism and then is slowly returned to the position where the picture just returns to synchronization. The frequency of the scanning oscillator, just before pull-in occurs, is measured. This measurement is made with the hold control moving in from both sides of center frequency, and the difference of these two frequencies is the horizontal pull-in range.

*7.2.1.2.2 Vertical pull-in range.* The vertical hold control is used to throw the receiver out of vertical synchronism, and then returned slowly to the position where the picture just returns to synchronization. The synchronizing voltage is then removed from the vertical oscillator, permitting it to free-run, and the frequency of the vertical oscillator is measured. The measurement should be repeated for the other setting of the hold control where synchronization just takes hold. When removing the synchronizing voltage care must be taken that the frequency-determining circuits of the oscillator are not affected.

*7.2.1.3 Presentation of data.* The frequency difference between the two extremities of the pull-in range is tabulated for the horizontal and vertical pull-in measurements together with the signal input level at which the measurement is made.

*7.2.2 Scanning Oscillator Stability.*

*7.2.2.1 Introduction.* These stability tests are designed to show variations in the frequencies of the horizontal and vertical scanning oscillators resulting from receiver warm-up and variations in line voltage.

*7.2.2.2 Warm-up drift.*

*7.2.2.2.1 Method of measurement.* For these measurements the synchronizing channel of the receiver is suitably disabled so as to allow the scanning oscillators to run free. An RF input signal is not required for this test but care should be taken that any stray input signals do not change during the measurement.

Frequency measurements of the horizontal and vertical scanning frequencies are made by means of a frequency counter. Alternatively, oscilloscope Lissajous patterns using a calibrated audio-frequency generator and loosely coupled signals from the horizontal and vertical scanning circuits can be used. These measurements are made for the same time interval described in Section 7.1.2.2.

*7.2.2.2.2 Presentation of data.* The horizontal and vertical scanning oscillator warm-up drifts are plotted as in Fig. 7.1.2.3 with the appropriate changes of the frequency scale.

*7.2.2.3 Drift with line-voltage variation.*

*7.2.2.3.1 Method of measurement.* The procedure used to measure scanning oscillator drift with line-voltage variation is similar to that described in Section 7.2.2.2.1 except that the frequency readings are taken as a function of line voltage. The line voltage is varied in 5-volt steps from 105 to 130 volts.

Before this test is begun, the receiver should have reached temperature stability as determined in the measurement of Section 7.2.2.2.1.

*7.2.2.3.2 Presentation of data.* The horizontal and vertical scanning oscillator frequency drifts are plotted as in Fig. 7.1.3.2 with appropriate changes of the frequency scale.

*7.2.3 Static Phase Accuracy of AFC Loop.*

*7.2.3.1 Definition.* The static phase accuracy is a measure of the change in relative phase between input and output of the AFC loop which accompanies a change in either input frequency or local-oscillator frequency.

*7.2.3.2 Method of measurement.* To measure the static phase accuracy, a picture signal generator, modulated with the resolution chart and having an output amplitude equal to standard mean-signal input level, is applied through the dummy antenna (Section 1.7) to the receiver. The receiver is tuned according to Section 1.10.5. The contrast control is adjusted for standard test output.

The horizontal hold control is moved first clockwise and then counterclockwise to the extremes of the pull-in range as defined in Section 7.2.1. The location of a fixed point of the test pattern is observed on the picture-tube screen and the horizontal displacement of this point is measured as the horizontal hold control is moved through the pull-in range. The static phase accuracy in degrees per cycle per second is given by

$$\frac{\text{Observation Point Displacement (inches)} \times 360 \text{ (degrees)}}{1.15 \times \text{Trace Width (inches)} \times \text{Pull-In Frequency Range (cps)}}.$$

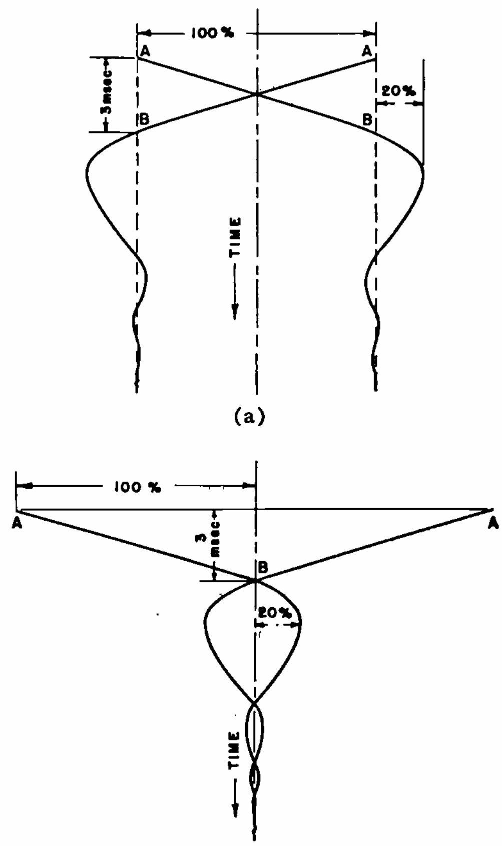
The factor 1.15 in this equation allows for a retrace time of 13 per cent. Trace width refers to the length of horizontal travel of the forward trace of the electron beam. If the scanning width is so great that the picture tube is overscanned, the trace width should include that portion of the trace which lies beyond the edge of the picture tube.

*7.2.4 Phase Step Response of AFC Loop.*

*7.2.4.1 Definition.* This test is a measure of the response of the horizontal AFC loop system to a step of input phase. This response is indicative of the system's ability to integrate the incoming synchronizing information over a given period of time. Systems with the same step response will, in general, show comparable performance under the influence of random noise.

*7.2.4.2 Method of measurement.* Method 1: The horizontal synchronizing signal is phase-modulated at the sync generator with a 30-cps square wave synchronized with the sync generator. The receiver is synchronized both horizontally and vertically and is adjusted for best linearity. The horizontal hold control is set at the center of its pull-in range. A stationary video pulse is transmitted during each horizontal line so that a vertical white line appears in the center of the picture tube screen when the phase modulation is removed from the synchronizing signal. With the phase modulation applied, the white line traces the positive and negative step response of the AFC loop on alternate fields as a stationary pattern on the picture tube screen. In this display the vertical axis is the time axis and the horizontal axis displays the output phase amplitude. A special signal generator has been developed for this test and is described by Gruen.[7] In this method, the synchronizing signal, but not the video pulse, is phase-modulated. To insure linear operation of the AFC loop, the phase-modulation amplitude should not exceed ±30 degrees.

A typical step response is shown in Fig. 7.2.4.2. Rep-




(b)

Fig. 7.2.4.2—Typical phase step response of horizontal AFC loop.

[7] W. J. Gruen, "Test generator for horizontal AFC scanning system," IRE Trans. on Broadcast and Television Receivers, vol. PGBTR-5, pp. 36–43; January, 1954.

resentative ranges of values of overshoot are 15–25 per cent, and of rise time from the start of the transient to the first crossover (point $A$ to point $B$) are 2–4 msec. The start of the transient should be smooth as shown in the figure; an abrupt change at this point is indicative of direct sync getting into the horizontal oscillator.

Method 2: If the composite sync generator of the picture-signal generating equipment is accessible, a 30-cps square wave may be introduced into the reactance tube of the sync generator to obtain the desired phase modulation. (The sync generator's 31.5-kc oscillator should operate as a locked oscillator controlled by a fixed frequency.) With this method, both the video and sync signals are phase-modulated.

*7.2.4.3 Presentation of data.* The results of this measurement consist of photographs of, or plots derived from, the picture-tube screen and will be of the form of Fig. 7.2.4.2.

*7.2.5 Interference Affecting Synchronization.* Receivers are tested for vulnerability to impulse-noise interference as described in Section 5.5.

It is possible for picture or sound information to affect the synchronization. This is checked by subjecting the receiver to a wide range of operating conditions, including operation at minimum and maximum contrast, high brightness, high sound output, etc.

Any impairment of synchronization is reported along with a description of the test conditions.

## Part III—SOUND SECTION OF THE RECEIVER

### Chapter 8—Sensitivity

*8.1 General*

This section includes procedures for the measurement of the over-all performance of the sound channel. Receivers employing a separate sound IF channel have not been produced for some years and therefore are not considered.

In all tests, it is assumed that the input signal consists of both the picture and sound signals, and that the ratio of the sound-to-picture carrier is unity, unless otherwise specified. The difference frequency between the carriers must be maintained accurately at 4.5 mc ±5 kc.

All measurements described are on the basis of an over-all test. However, particularly in making design rather than performance measurements, it is frequently advantageous to check the 4.5-mc intercarrier sound channel by breaking into the receiver at the video detector output with a 4.5-mc signal. Adequate isolation is required in this case to prevent loading and regenerative effects.

*8.2 Sound Sensitivity*

The sensitivity of the sound channel is measured under the same conditions as the nominal picture sensitivity (Section 4.2) and the peak picture sensitivity (Section 4.3). The corresponding sensitivities for the sound channels are termed the nominal sound sensitivity and the peak sound sensitivity, respectively.

*8.3 Nominal Sound Sensitivity*

*8.3.1 Definition.* This is the lowest input signal required to produce standard sound test output when the receiver is tuned to produce the nominal intermediate frequency.

*8.3.2 Method of Measurement.* The receiver under test is connected to the sound and picture signal generators through the standard 300-ohm dummy antenna (Section 1.7.3) and tuned as described in Section 1.10.5.2 to produce the nominal intermediate frequency. Unity ratio is maintained between sound and picture carriers. The sound signal generator is frequency modulated 30 per cent (7.5-kc deviation) at a 400-cps rate. The picture-signal generator is modulated with standard white-pattern modulation (Section 1.5.2), and the receiver controls are adjusted as in measuring the picture sensitivity (Section 4.2). The volume control is at maximum and the tone control is set for maximum 400-cps response. The signal generator outputs are adjusted to obtain standard sound test output (Section 1.9) across the dummy load. The output meter should be connected across the load through a 400-cps band-pass filter to reject the random noise output (Fig. 8.3.2).

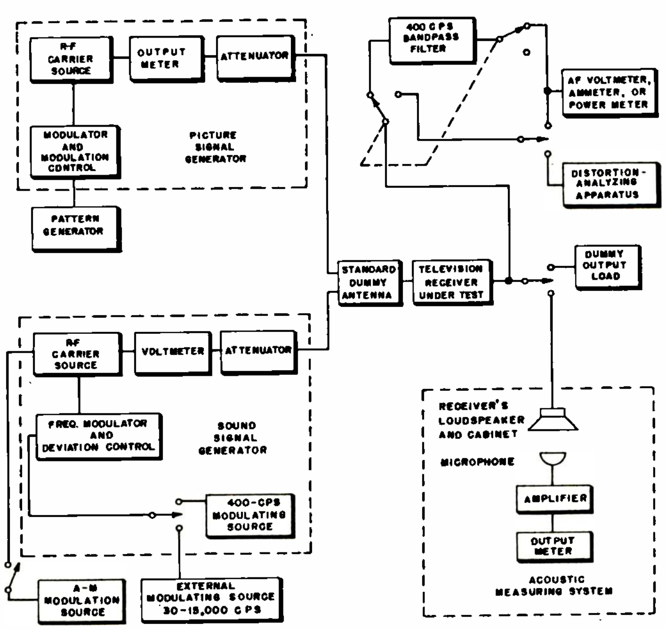



Fig. 8.3.2—Block diagram of equipment for testing the over-all performance of the sound section of a television receiver.

*8.4 Peak Sound Sensitivity*

*8.4.1 Definition.* This is the lowest input signal required to produce standard sound test output when the receiver is tuned as in measuring peak picture sensitivity (Section 4.3).

*8.4.2 Method of Measurement.* The procedure is the same as Section 8.3.2 except for the receiver tuning.

*8.5 Quieting Sensitivity*

*8.5.1 Definition.* The quieting sensitivity is the lowest input signal required to reduce the noise output to a value which is 30 db below the output obtained when standard test modulation (Section 1.6) is applied to the sound carrier.

*8.5.2 Method of Measurement.* The procedure is similar to that for measuring nominal sound sensitivity (Section 8.3) except that the volume control is adjusted to maintain standard sound test output (Section 1.9) and the tone controls are adjusted to provide a flat over-all response (allowing for normal transmitter pre-emphasis). The standard sound test modulation is then switched on and off, while the input signal is reduced until a value is reached at which a 30-db difference in indicated output is noted between the modulated and unmodulated conditions. This value of input signal is the quieting sensitivity.

*8.6 Signal-to-Noise Ratio*

To supplement the quieting sensitivity (Section 8.5), it is desirable to measure the signal-to-noise ratio as a function of input signal. The picture and sound signal generators are connected to the receiver as described in Section 1.7. White-pattern modulation (Section 1.5.2) is used for the picture and 400-cps 30 per cent modulation for the sound. The receiver controls are adjusted for normal operation. At each input level the sound output is observed with the volume control set for standard output and the tone controls adjusted as in Section 8.5.2. A 400-cps band-pass filter should be used to reject noise (Fig. 8.3.2). The modulation is then switched off, the filter removed from the circuit, and the noise output measured. The signal-to-noise ratio is expressed in decibels and plotted as a function of the input signal (Fig. 8.6). Hum, deflection voltage pickup, and video interference should not be included in this noise measurement; these are separately evaluated (Section 10.4).

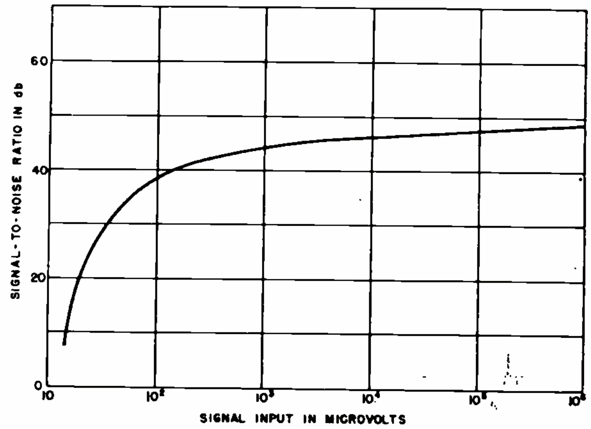



Fig. 8.6—Signal-to-noise ratio.

*8.7 AGC Characteristic*

Refer to Section 4.5.

*8.8 Limiting Characteristic*

*8.8.1 Introduction.* The limiting characteristic shows the variation in the sound output as the sound carrier amplitude is varied, the picture carrier amplitude being maintained constant. The degree of limiting affects the variation in sound output with receiver tuning. It also affects the suppression of amplitude modulation and interference (Section 9.2), although this suppression is accomplished by other than static limiting in many receivers.

*8.8.2 Method of Measurement.* The limiting characteristic is measured by connecting the picture and sound signal generators as in Section 1.7, using standard mean-signal input level. Standard gray-pattern modulation is used (Section 1.5.3). The sound carrier is 30 per cent modulated at 400 cps, and the volume control is set for standard output at the maximum point on the output characteristic. The sound carrier amplitude is varied below and above the nominal 1:1 sound-to-picture carrier ratio and the sound output is plotted against the sound-to-picture carrier ratio.

## Chapter 9—Interference, Sound Section

*9.1 Selectivity and Spurious Responses*

The over-all selectivity curve (Section 5.2.1) provides a measure of the susceptibility of the sound channel to interference from adjacent-channel signals and other undesired signals. For example, the susceptibility to adjacent-channel picture carrier interference is usually determined by the selectivity for a signal 1.5 mc above the desired sound carrier frequency.

The test procedure used to check spurious responses in the picture channel is applicable to the sound channel as described in Section 5.2.4.

The sound IF circuits which are tuned to the 4.5-mc intercarrier frequency are sufficiently selective with conventional design so that measurement of their selectivity is not normally required.

*9.2 Amplitude-Modulation Suppression Ratio*

*9.2.1 Introduction.* The AM suppression ratio is a measure of the ability of the sound channel to reject undesirable amplitude modulation of the sound carrier. This amplitude modulation can occur, for example, as a result of cross-modulation of the sound carrier with the modulated picture carrier.

Two methods are described for measuring the suppression of amplitude modulation: 1) the meter method (Section 9.2.2) and 2) the oscilloscope method (Section 9.2.3). The meter method has the advantage of being more sensitive and providing a more quantitative measure of amplitude-modulation suppression for receivers which have a high degree of suppression. The oscilloscope method, although less sensitive, frequently provides useful design information not directly obtainable from the meter method.

*9.2.2 Meter Method.* The picture and sound signal generators are connected to the receiver as described in Section 1.7. Standard white-pattern modulation (Section 1.5.2) is used for the picture carrier. The receiver controls are adjusted for normal operation with the generators set at standard mean-signal input level.

The sound carrier is simultaneously frequency- and amplitude-modulated. The sound carrier is 30 per cent frequency-modulated at between 50 and 70 cps and 30 per cent amplitude-modulated at 400 cps. A 400-cps high-pass filter is used to measure the output resulting from the amplitude modulation. This choice of AM and FM frequencies has the advantages that harmonic distortion of the FM output and incidental undesired frequency modulation of either the picture or sound carriers at power-supply frequency are rejected by the high-pass filter.

The sound signal generator must have negligible incidental frequency modulation when it is amplitude-modulated. The picture signal generator must also satisfy this requirement. Unless the equipment is known to have negligible incidental frequency modulation, an external amplitude modulator, adequately isolated, should be used.

The output resulting from the 30 per cent frequency modulation is measured with the amplitude modulation removed. The 30 per cent amplitude modulation is then simultaneously applied to the sound carrier and the 400-cps high-pass filter is used to measure the output resulting from the amplitude modulation. The ratio of the two outputs, corrected for the filter attenuation, and expressed in decibels, is the AM suppression ratio.

The measurement is normally made on one channel for various input signal levels. Repetition of the measurement for higher percentages of amplitude modulation and at other amplitude-modulation frequencies provides useful data.

To eliminate the effect of noise, it is frequently desirable to carry out the measurement at mean-signal level with unity sound picture carrier ratio, and to repeat the measurement with the sound carrier amplitude as the parameter. Alternatively, the measurement can be made at the 4.5-mc intercarrier beat frequency (Section 8.1).

*9.2.3 Oscilloscope Method.* In the oscilloscope method, the procedure is similar to that for the meter method. However, the sound output is connected to the vertical plates of an oscilloscope, while the AF generator which frequency-modulates the sound carrier is connected to the horizontal plates so as to produce the display shown in Fig. 9.2.3. Correction for phase shift may be required to close the pattern.

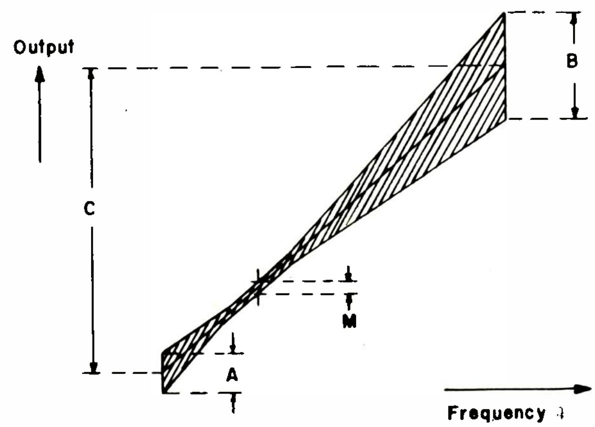



Fig. 9.2.3—Display of amplitude-modulation-suppression ratio on the oscilloscope.

The formulas shown below define an unbalanced suppression ratio, a balanced suppression ratio and a maximum suppression ratio:

$$\text{Unbalanced suppression ratio} = R_u = 2\left|\frac{C}{A-B}\right|$$

$$\text{Balanced suppression ratio} = R_b = 2\left|\frac{C}{A+B}\right|$$

$$\text{Maximum suppression ratio} = R_m = \left|\frac{C}{M}\right|.$$

The expressions for $R_u$ and $R_b$ are applicable only when the pattern is as shown in Fig. 9.2.3. When the crossover point is outside the displayed pattern, the expressions for $R_u$ and $R_b$ become:

$$R_u = 2\left|\frac{C}{A+B}\right|$$

$$R_b = 2\left|\frac{C}{A-B}\right|$$

The procedure described in connection with the meter method is applicable to the oscilloscope method.

Although 30 per cent frequency modulation is used in measuring these suppression ratios, as in the meter method, it is desirable to increase the frequency modulation to at least 100 per cent in order to view the complete discriminator characteristic.

## Chapter 10—Fidelity, Sound Section

### *10.1 Electric and Acoustic Fidelity*

This chapter describes methods for measuring the electric fidelity, including the amplitude-vs-frequency response, harmonic distortion, and power output of the audio signal delivered to the dummy load which replaces the speaker. The acoustic fidelity is measured by applying the same signal generator and receiver procedures, with the speaker in the completely assembled cabinet replacing the artificial load. Acoustic measuring procedures are described in other IRE standards.

### 10.2 *Amplitude-vs-Frequency Response*

*10.2.1 Definition.* The amplitude-vs-frequency response shows the manner in which the electrical output delivered to the dummy load reproduces the modulating audio signal. It takes into account all characteristics of the receiver except those of the loudspeaker.

*10.2.2 Method of Measurement.* The picture and sound signal generators are connected to the receiver which is adjusted for normal operation as in Section 1.10.5. Mean-signal input level and 30 per cent sound modulation are used. The receiver volume control is adjusted so that the point of maximum response in the audio frequency range gives standard sound test output. The output is observed while the modulation frequency is varied continuously from 30 to 15,000 cps.

If the receiver has one or more tone controls, the response is plotted for the adjustment which gives the maximum bass and treble compensation. The tests should be repeated for minimum and mean settings of the tone controls.

If the response changes substantially with the volume control setting, this test should be repeated at selected power levels.

Since no pre-emphasis is employed in the sound signal generator, the measured power output values should be corrected by adding the values corresponding to the standard receiver de-emphasis curve, which has the absolute values shown in Fig. 1.6.

The presence of overload at any point should be noted.

*10.2.3 Presentation of Data.* The results are plotted with the frequency as the abscissa on a logarithmic scale and the power output in decibels as the ordinate on a linear scale. The 400-cps output is taken as the 0-db reference level and the corresponding absolute power is noted on the graph.

### 10.3 *Harmonic Distortion*

*10.3.1 General.* The over-all harmonic distortion in the electrical output is measured for a wide variety of signal and operating conditions. From these measurements it is possible to determine the part of the receiver which is responsible for the distortion.

Nonlinear distortion in the signal generating and measuring equipment must be negligible.

*10.3.2 Definition.* The harmonic distortion is determined by the percentage of the rms value of the harmonics in the output when a pure sinusoidal modulating signal is used, the formula being

$$K = \frac{\sqrt{E_2^2 + E_3^2 + E_4^2 + \cdots}}{\sqrt{E_1^2 + E_2^2 + E_3^2 + E_4^2 + \cdots}} \times 100 \text{ per cent.}$$

$E_1$ is the fundamental-frequency voltage and $E_2$, $E_3$, $E_4$, etc. are the voltage values of the individual harmonics present across the dummy load.

Hum, deflection, and video components are not included in harmonic distortion.

A distortion analyzer will read the rms value of the total distortion, while a wave analyzer is required if the individual harmonics are of interest.

*10.3.3 Method of Measurement.* The picture and sound signal generators are connected to the receiver as described in Section 1.7. Standard gray-pattern modulation is used. Unless otherwise specified, standard mean-signal input level is used and the controls are adjusted for normal operation. If interference from either the power supply, video, or deflection system is encountered, suitable precautions are taken so that the harmonic distortion measurement is not affected. A wave analyzer may be used to measure the individual harmonics.

The distortion is measured with the following characteristics as the principal parameters:

*10.3.3.1 Distortion vs power output.* The modulation is fixed at 30 per cent, the modulation frequency at 400 cps, and the harmonic distortion is plotted as the output is varied by means of the volume control.

The ***power output for 10 per cent harmonic distortion*** and the ***maximum power output*** without regard to distortion are individually noted.

The ***residual power output*** is the output corresponding to minimum setting of the volume control.

*10.3.3.2 Distortion vs percentage modulation.* The modulation frequency is fixed at 400 cps and the output is maintained at standard test output by adjustment of the volume control (where possible). The harmonic distortion is plotted as the modulation is varied from 10 per cent to 200 per cent.

The procedure is repeated with the output held at a level 10 db below standard test output so that output-stage distortion is minimized.

*10.3.3.3 Distortion vs modulation frequency.* The modulation is fixed at 30 per cent and the output is maintained at standard test output. The modulation frequency is varied and the harmonic distortion is measured.

The preceding measurements are supplemented where necessary by measurements which show the effect of power output, tone control setting, input signal level, and sound-to-picture carrier ratio. In particular, the presence of distortion due to stray coupling at low volume should be noted.

### 10.4 *Power Supply (Hum), Deflection, and Video Interference*

*10.4.1 Introduction.* The tests in this section are designed to detect interference in the sound output which may arise from causes such as inadequate power supply filtering (hum), coupling to the deflection circuits, and coupling to the video circuits (buzz).

The nuisance value of this interference depends upon its waveform as well as its rms value and the acoustic frequency response of the receiver.

*10.4.2 Method of Measurement.* The picture and sound signal generators are connected to the receiver as described in Section 1.7. Except where otherwise specified, standard white-pattern picture modulation and 30 per cent 400-cps sound modulation are used, and the receiver controls are adjusted for normal operation. The sound output delivered to the dummy load is observed with both a meter and an oscilloscope.

*10.4.2.1 Interference output—volume control at standard test output setting.* The volume control is set at the position which produces standard test output and the sound modulation is switched off. The amplitude and waveform of the interference output is noted for the worst setting of the tone controls.

The receiver contrast control and the depth of picture modulation are increased and the conditions resulting in interference are noted.

*10.4.2.2 Interference output—volume control at minimum setting.* The volume control is set at minimum. The sound modulation is switched off and the interference output is noted.

*10.4.2.3 Hum modulation.* With the sound modulation on and standard test output, the waveform or spectrum of the sound output is observed to detect the presence of intermodulation, including power supply, hum, deflection, or video components.

*10.4.3 Presentation of Data.* The amplitude, waveform, and source of the interference should be specified and the conditions of measurement.

These interference measurements in particular should be supplemented by listening tests to evaluate qualitatively the interference under normal operation.

## Chapter 11—Radiated and Conducted Emissions

### *11.1 General Considerations*

Television receivers which cause interference to other receivers and services generally have been found to produce it in either of two ways: at higher frequencies by waves radiated from the chassis, transmission line and antenna; and at lower frequencies by waves conducted over the power line.

### *11.2 Radiated Interference*

The method of measurement is given in IRE Standards 51 IRE 17. S1.[8] The results are stated in microvolts per meter at a distance of 100 feet, at each frequency.

### *11.3 Conducted Interference*

The method of measurement is given in IRE Standards 54 IRE 17. S1,[9] in the supplement to these standards 58 IRE 27. S1,[10] and in IRE Standards 56 IRE 27. S1.[11] The results are stated in microvolts, at each measurement frequency, across the standard power-line impedance network..

## Chapter 12—Miscellaneous

### *12.1 Receiver Input Impedance*

*12.1.1 Introduction.* Although the magnitude and phase angle of the complex impedance at the input terminals of the receiver can be measured, it is usually of more interest to know either the voltage standing wave ratio, VSWR, produced in the transmission line, or the absolute value of the reflection coefficient, $\rho$, which are related as follows:

$$\text{VSWR} = \frac{1 + |\rho|}{1 - |\rho|}.$$

When the imput impedance varies across the channel, the VSWR for frequencies in the region of the picture carrier is of primary interest. The input impedance is often a function of signal level.

*12.1.2 Definitions.* The voltage standing wave ratio is the ratio of the maximum to the minimum voltage that appears at points along the transmission line. The reflection coefficient is the complex ratio of the voltage of the reflected wave to the voltage of the incident wave.

*12.1.3 Method of Measurement.* A long transmission line of the specified characteristic impedance is connected to the input terminals of the receiver, which is switched on and tuned to the appropriate channel. The AGC voltage applied to the first amplifier in the receiver should be stabilized at the value corresponding to a weak applied signal. A signal generator is connected to the other end of the transmission line. The generator applies an unmodulated radio-frequency signal of constant voltage (open-circuit) and variable frequency to this end of the transmission line. The strength of the signal at this end is measured with a detector. The combination of the signal generator and the detector must terminate the transmission line accurately with its characteristic impedance [see Fig. 12.1(a)]. The signal strength is plotted as a function of the input signal frequency, first with the receiver end of the transmission line short-circuited and secondly with the receiver end of the transmission line connected to the antenna input terminals of the receiver. From these two curves, the VSWR is derived, using the relation

$$\text{VSWR} = \frac{V_2 + V_1}{V_2 - V_1}.$$

[8] "IRE Standards on Radio Receivers: Open Field Method of Measurement of Spurious Radiation from Frequency Modulation and Television Broadcast Receivers, 1951," PROC. IRE, vol. 39, pp. 803–806; July, 1951.

[9] "IRE Standards on Receivers: Methods of Measurement of Interference Output of Television Receivers in the Range of 300 to 10,000 kc, 1954," vol. 42, pp. 1363–1367; September, 1954.

[10] "Supplement to 'IRE Standards on Receivers: Methods of Measurement of Interference Output of Television Receivers in the Range of 300 to 10,000 kc, 1954,' " vol. 46, pp. 1418–1420; July, 1958.

[11] "IRE Standards on Methods of Measurement of the Conducted Interference Output of Broadcast and Television Receivers in the Range of 300 Kc to 25 Mc, 1956," vol. 44, pp. 1040–1043; August, 1956.

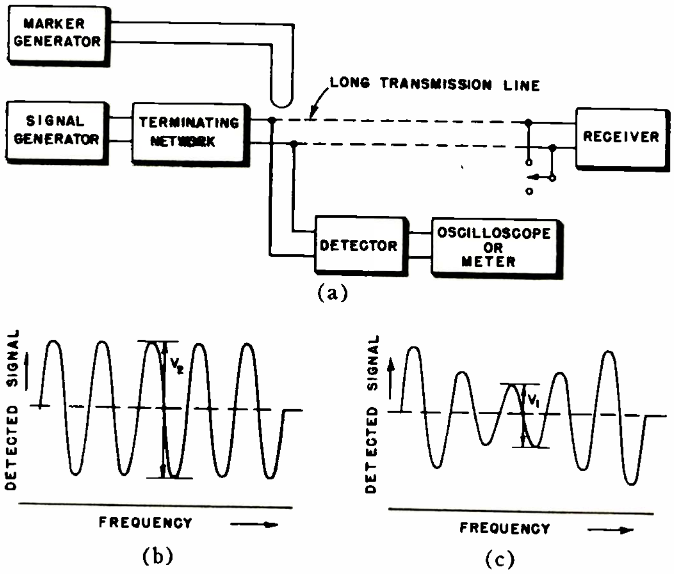



Fig. 12.1—(a) Circuit arrangement for measurement of voltage-standing-wave ratio. (b) Detected signal with receiver end of the transmission line short-circuited. (c) Detected signal with transmission line terminated with the receiver input terminals.

The transmission line must be long enough so that a sufficient number of undulations is recorded within a frequency range corresponding to the pass band of the receiver. The frequency separation between adjacent minima is

$$f = \frac{v}{2l},$$

where

$v$ = velocity of propagation of the transmission line' and

$l$ = length of the transmission line,

when the far end of the transmission line is short-circuited. The attenuation of the transmission line must be low enough so that the undulations are of sufficient amplitude when the far end of the transmission line is short-circuited.

By using a sweep signal generator the detected signal can be displayed on an oscilloscope. If the detector is not linear, a calibration of the indication is necessary. The applied signal should not be so large that the input portion of the receiver is overloaded. The tests should be repeated with the AGC voltage fixed at values corresponding to higher input levels.

*12.1.4 Presentation of Data.* The VSWR is stated for each channel and input level measured. When the VSWR varies across the channel, the stated value should be for frequencies in the region of the picture carrier.

*12.2 Change in Band-Pass by Antenna Mismatch*

*12.2.1 Definition.* The change in band-pass by antenna mismatch is defined as the change in selectivity produced by a 4-to-1 change in the dummy-antenna impedance from the matched value, when the transmission line between the dummy antenna and the receiver is varied in electrical length over a range of one-half wavelength, keeping the amplitude of the response at the picture carrier frequency constant. This measurement is designed to simulate results which are obtained with conventional antennas which cause mistuning and loading of the receiver input circuits.

*12.2.2 Method of Measurement.* The equipment is arranged to measure the selectivity as in Section 5.2.1, or a sweep oscillator and oscilloscope display may be used, with markers at the picture carrier frequency and at 3 mc higher. Provision is made to change the dummy-antenna impedance to either one-fourth or four times the standard value (300 ohms). The AGC voltage should be stabilized at the value corresponding to the signal level being used. Using the standard dummy antenna, the response at the picture carrier frequency is set to standard test output, and the response at other frequencies of interest measured. The standard dummy antenna is then replaced by the mismatched dummy antenna, and the signal input adjusted to give the same response at the picture carrier frequency. The response at the other frequencies is again measured. The transmission line between the dummy antenna and the receiver is replaced by one having an electrical length of one-eighth wavelength greater, and the process repeated. Several lengths of transmission line, up to one-half wavelength greater electrical length than the original, are substituted.

The tests should be repeated for applied signals of different levels.

*12.2.3 Presentation of Data.* The maximum change in response at each frequency of interest is given in decibels. The change in response at the frequency corresponding to 3-mc video modulation, and at the sound carrier frequency, should be included.

# Standards on Radio Interference: Methods of Measurement of Conducted Interference Output to the Power Line from FM and Television Broadcast Receivers in the Range of 300 kc to 25 Mc, 1961*

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* Approved by the IRE Standards Committee, February 9, 1961. Reprints of IRE Standard 61 IRE 27.S1 may be purchased while available from The Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N.Y., at $.60 per copy. A 20 per cent discount will be allowed for 100 or more copies mailed to one address.

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# STANDARDS ON RADIO INTERFERENCE: METHODS OF MEASUREMENT OF CONDUCTED INTERFERENCE OUTPUT TO THE POWER LINE FROM FM AND TELEVISION BROADCAST RECIEVERS IN THE RANGE OF 300 kc TO 25 Mc, 1961

## 1. Introduction

FM and television broadcast receivers are frequently potential sources of interference to other FM and television broadcast receivers as well as to receivers in other services. In the range of 300 kc to 25 Mc, this interference can arise from high-level receiver signals such as the IF and, in television receivers, the horizontal deflection system. This standard defines a method for obtaining a measure of the interference conducted by the power line from these various interference sources in the frequency range of 300 kc to 25 Mc. It supersedes and replaces the following three standards: "IRE Standards on Receivers: Methods of Measurement of Interference Output of Television Receivers in the Range of 300 to 10,000 kc, 1954" (54 IRE 17.S1), "IRE Standards on Methods of Measurement of the Conducted Interference Output of Broadcast and Television Receivers in the Range of 300 kc to 25 Mc, 1956" (56 IRE 27.S1), and "Supplement to IRE Standards on Receivers: Methods of Measurement of Interference Output of Television Receivers in the Range of 300 to 10,000 kc, 1954 (54 IRE 17. S1)" (58 IRE 27. S1).

This standard describes standard input signals, the equipment set-up and measurement techniques.

## 2. Equipment Required and Method of Installation

### 2.1 Equipment Required

To perform the measurements described in this standard, the following equipment is required: screen room (2.1.1), power line impedance network (2.1.2), source of RF signal (2.1.3), a tuned voltmeter (2.1.4), and, for television receivers only, a picture carrier IF signal source (2.1.5).

*2.1.1* A screen room large enough to meet the requirements of Section 2.2.1 with adequate shielding and filtering to eliminate external interference. A typical size is 7 feet high by 7 feet wide by 10 feet long.

*2.1.2* A power line impedance network. The purpose of this network is to present a standard value of power line impedance to the receiver under test regardless of the local power line conditions.

*2.1.2.1* The line impedance network is schematically illustrated in Fig. 1. The purpose of the one-ohm (non-reactive) resistor is to limit any possible resonance effects of the series circuit of the 5-$\mu$h inductor and the 1.0-$\mu$f capacitor. The purpose of the 1000-ohm resistors is to limit the line voltage that may appear at the coaxial connectors.

*2.1.2.2* The impedances of the line network measured from each side of the receiver receptacle to chassis must conform within $\pm 5$ per cent to the characteristic shown in Fig. 2. (For this requirement the power plug is open-circuited and both measurement outlets terminated in 50 ohms as shown in Fig. 3.)

*2.1.2.3* A suitable method of measuring the magnitudes of impedances is shown in Fig. 3. This measurement technique is a substitution method. The reference resistor is chosen so that the voltage drop across this resistor is equal to the voltage across the line-impedance network at each frequency of measurement. The value of the resistor is then taken as the absolute value of the impedance. Since the impedance of the line network is considerably less than that of the 470-ohm resistor, the generator impedance has a negligible effect on the measurements. The accuracy of the voltmeter is unimportant since it is only used to hold the voltage constant when the switch is changed. It is important to keep the lead lengths as short as possible.

*2.1.2.4* To minimize variations which might occur among different line impedance networks and to permit more uniformity in test facilities, detailed construction drawings of a suitable network, of which assembly drawings are shown in Fig. 4(a) and (b), have been pre-

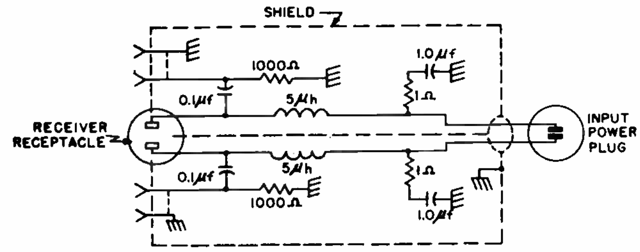



Fig. 1—Power-line impedance network schematic.

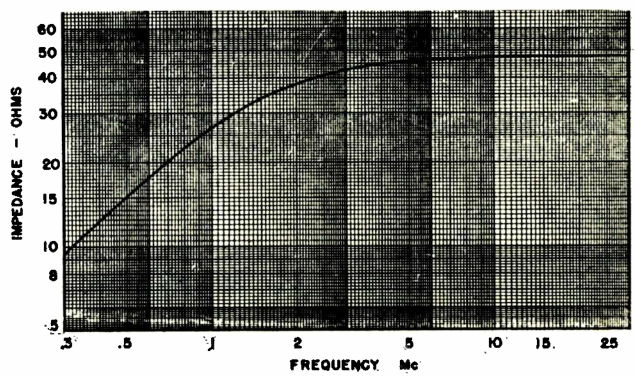



Fig. 2—Impedance magnitude characteristic of line measured from either side of the receiver receptacle to chassis.

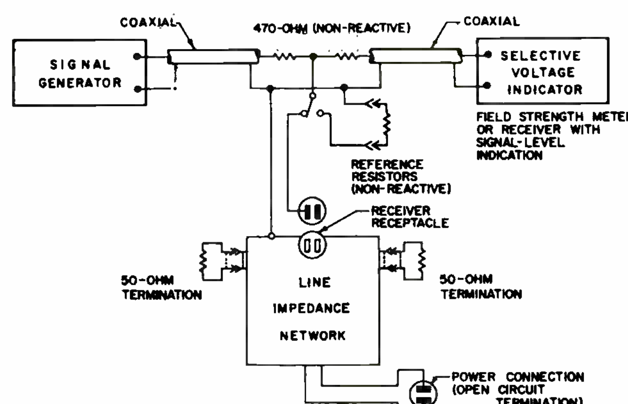
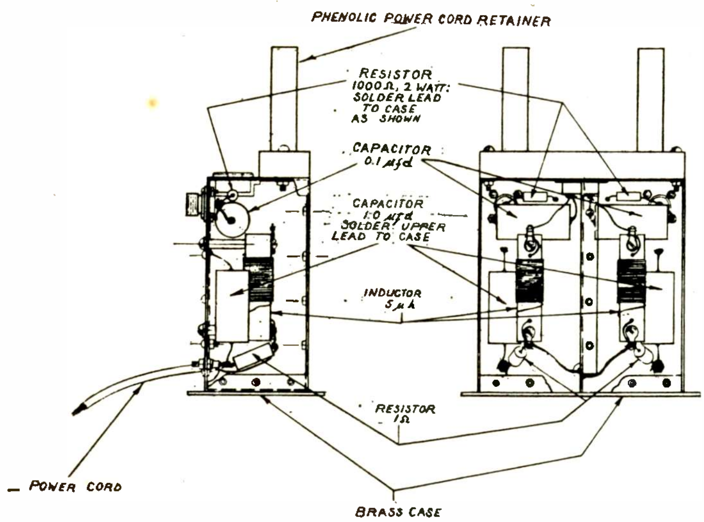
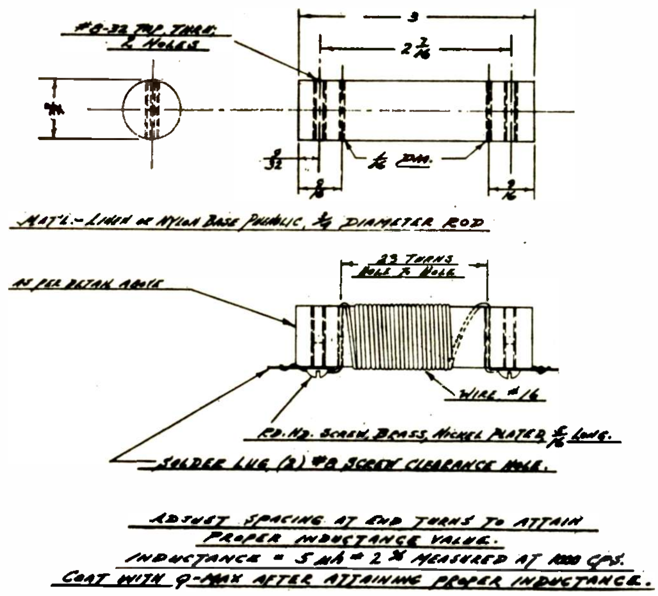



Fig. 3—Circuit for measurement of impedance.




(a)




(b)

Fig. 4—(a) Line impedance assembly. (b) Inductor 5 μh.

pared.[1] A network constructed according to these drawings should nevertheless be tested in order to insure that it meets the requirement of Section 2.1.2.2.

*2.1.3* A source of a standard RF input signal.

*2.1.3.1* The RF signal shall be supplied to the receiver under test through a 20-db 300-ohm antenna coupling pad. This network, details of which are shown in Fig. 5, is designed to have an impedance of 300 ohms balanced, and 300 ohms unbalanced (impedance between the two output terminals connected together and ground). If the signal generator is not located within the screen room, adequate filters should be installed at the signal input to the screen room to exclude undesired signals in the frequency band of interest.

If the receiver has a built-in antenna, it shall be disconnected from the antenna terminals during these tests. If the signal generator does not have a nominal 300-ohm center-tapped output impedance, a suitable matching network shall be provided between the signal generator and the pad.

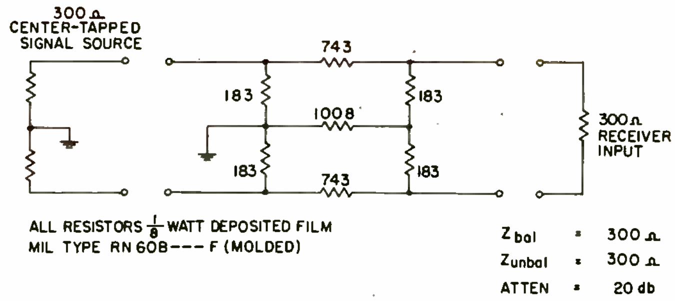
If the receiver is designed for use with an unbalanced shielded transmission line, a line having the characteristics recommended by the receiver manufacturer shall be used in place of the twin-lead in Figs. 5 and 7. The input terminals of the transmission line are connected to the output terminals of the pad. In addition, a resistor is connected in shunt with the output terminals of the pad so that the combination of pad and resistor matches the nominal input impedance of the receiver.

*2.1.3.2* For a television receiver, the input signal shall consist of simulated sound and picture signals on any standard television channel.

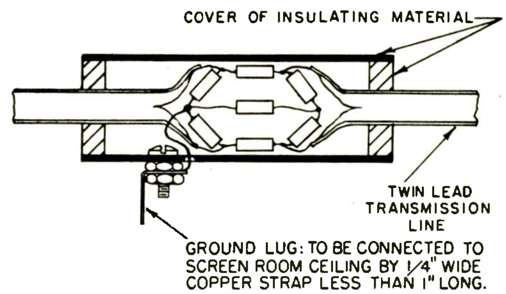
*2.1.3.2.1* The modulation of the picture signal shall consist of the mixture of the following signals as shown in Fig. 6 (observed on a double-sideband detector or equivalent, with a video frequency response that is uniform within ±0.5 db up through 3.58 Mc):

a) Pulses of 5 μs width at a repetition rate of 15,750 pulses per second to represent horizontal synchronizing pulses. The pulse amplitude shall be sufficient to modulate the picture carrier so that the level between pulses is 37.5 per cent of the peak level during the pulses.

b) A sine wave of 2.0 Mc to represent video modulation. The amplitude of this modulation shall be sufficient to produce 1 per cent peak-to-peak modulation during the time interval between the synchronizing pulses. This sine wave may be allowed to run through the synchronizing pulse period. (A method of obtaining 1 per cent modulation is to adjust the modulation level for 10 per cent to permit observation on an oscilloscope and then to reduce the modulating 2.0 Mc signal by 20 db.)




(a)




(b)

Fig. 5—Antenna coupling pad. (a) Schematic diagram. (b) Drawing of typical construction.

[1] These drawings may be purchased from The Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y., at a cost of $2.00 per copy. In ordering, refer to "61 IRE 27.S1-A, Construction Drawings of IRE Line Impedance Network."

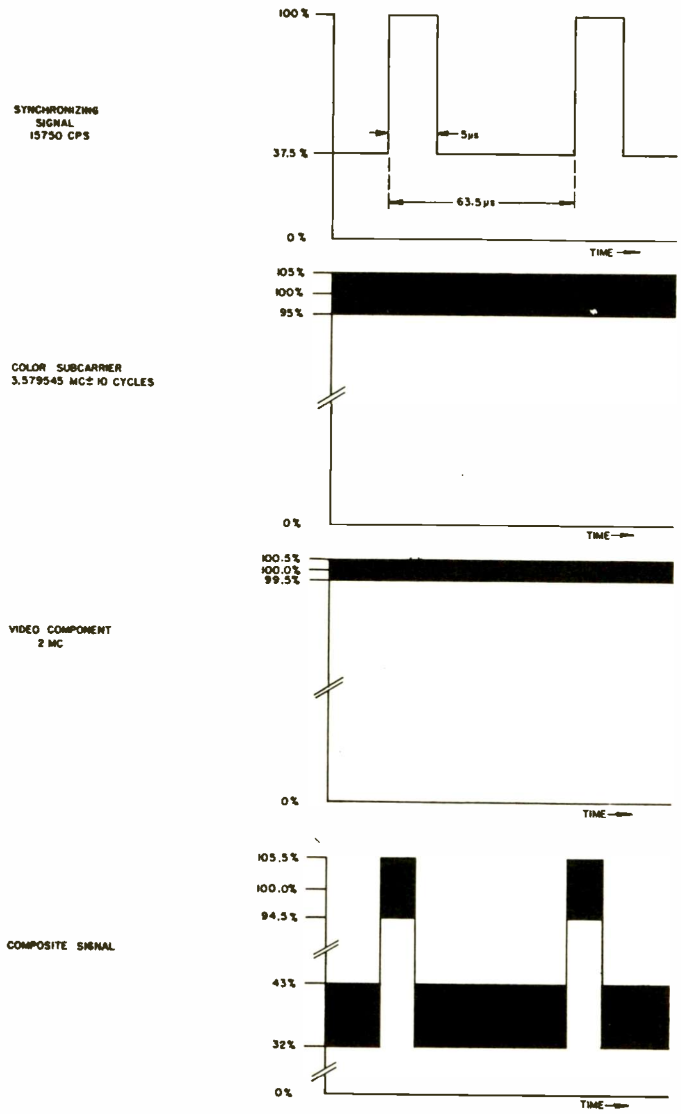



Fig. 6—Modulation of picture signal (see Section 2.1.3.2.1).

c) A sine wave of 3.58 Mc to represent color signal modulation. The amplitude of this modulation shall be sufficient to produce 10 per cent peak-to-peak modulation between the synchronizing pulses. This sine wave may be allowed to run through the synchronizing pulse period.

*2.1.3.2.2* No modulation of the sound signal is employed.

*2.1.3.2.3* The peak level of the picture carrier delivered at the output terminals of the 300-ohm antenna coupling pad shall be nominally 3200-$\mu$v rms open circuit. The open circuit sound carrier level shall be 3 db below the peak level of the modulated picture carrier.

*2.1.3.3* For an FM broadcast receiver, the input signal shall be delivered from the 300-ohm antenna coupling pad at a nominal open circuit level of 1000-$\mu$v rms at a frequency of 98 Mc. No modulation will be employed.

*2.1.4* A suitable tuned voltmeter (field strength meter.)

*2.1.4.1* The tuned voltmeter shall have a nominal 50-ohm input impedance and be tunable over at least the frequency range of interest. The nominal bandwidth of the voltmeter shall not exceed 10 kc. Means shall be provided for either internal or external calibration. The instrument shall be adequately shielded and the power leads filtered to prevent spurious pick-up.

*2.1.4.2* The tuned voltmeter shall indicate the rms carrier level of the signal to which it is tuned. This measurement position is normally designated as "field intensity" or "carrier."

*2.1.5* For television receivers, a reference picture IF signal source. This shall consist of a signal source at the nominal picture carrier intermediate frequency. The signal is injected into the television receiver as a reference to facilitate the proper tuning of the receiver as described in Section 3.1.1.

*2.1.6* A regulated source of primary input power. Unless otherwise specified, the line voltage at the receiver receptacle shall be maintained at 117 volts ± 2 volts. The harmonic content of this line voltage shall be less than 5 per cent.

### *2.2 Installation of Equipment*

*2.2.1* All portions of the receiver under test shall be at least 30 inches from the wall of the shielded enclosure. Floor model receivers shall be placed on a nonmetallic platform 18 inches above the metallic floor of the shielded enclosure, and table models placed on a nonmetallic platform 30 inches above the floor. If the receiver is equipped with remote cables, these should be connected to the receiver and terminated either with the normal equipment or with a dummy load. They should be coiled up and located on top of the receiver.

*2.2.2* The power-line impedance network shall be located on the floor of the screen room directly below the back of the cabinet of the receiver under test. The center line of the power line impedance unit shall be coincident with the center line of the receiver back. Similarly, the RF signal coupling pad shall be mounted at the ceiling of the screen room directly above the power line impedance network. The standard arrangement is shown in Fig. 7.

*2.2.3* The power-line impedance network shall be connected to the metallic floor by means of four solid copper straps as shown in Fig. 8. The width-to-length ratio of each strap shall be at least 1 to 5, and the thickness of the strap shall be at least 0.025 inch. In the unit shown in Fig. 8, four holes have been provided for this purpose. The connection from the power-line impedance network to the power source should be kept close to the walls or floor of the shielded room when inside the enclosure.

*2.2.4* A 50-ohm resistive load shall be connected to each of the two coaxial connectors of the line impedance network at all times. The voltages developed across these loads represent the conducted-interference output of the receiver. A 50-ohm nonreactive resistor, a 50-ohm input impedance field-strength meter, or any combination of field-strength meter and external resistor to equal 50 ohms can be used as the resistive load.