AMERICAN NATIONAL STANDARD

ANSI/IEEE Std 185-1975
(Revision of IEEE Std 185-1947)

IEEE/IHF Standard Methods of Testing Frequency Modulation Broadcast Receivers

IHF-T-200, 1975
Supersedes IHFM-T-100, 1958

INSTITUTE OF HIGH FIDELITY

ANSI/IEEE Std 185-1975

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Foreword

(This foreword is not a part of IEEE Std 185-1975, IHF-T-200, 1975, Standard Methods of Testing Frequency Modulation Broadcast Receivers.)

This standard is the result of an industry-wide effort including active participation of the Electronics Industries Association and the Institute of High Fidelity to promote standardization in the field of frequency modulation receiver performance measurements. Particularly noteworthy is the removal of the 6dB ambiguity in receiver sensitivity which has stemmed from the widespread usage of "terminated microvolts" to express the input signal to a receiver, as opposed to the long-established IRE-IEEE usage of "open-circuit microvolts". This ambiguity was resolved by expressing sensitivity in terms of available power, this being consistent with both IEEE and IEC standardization. Input signal levels are standardized in terms of dBf, with one femtowatt (10^{-15} W) as the reference level. At a 300 Ω impedance level, 1 dBf corresponds to 1.1 μV open circuit, while 120 dBf corresponds to 1.1 V, leading to a convenient scale.

This standard was initiated by the Subcommittee on Frequency Modulation Receivers of the IEEE Broadcast and Television Receivers Group*. The 1968-1970 membership of this subcommittee was:

D. R. von Recklinghausen, *Chairman*

J. J. Bubbers
H. N. Frihart
H. Heisrath
A. L. Limberg
F. L. Mergner
R. Snelling

The 1971-1974 membership of this subcommittee which included active representation from EIA and IHF was:

H. N. Frihart, *Chairman*
E. M. Tingley, *Secretary*

M. Alexander
O. E. Beckman
D. French
J. Hirsch
L. Feldman
L. Pearson

This standard was approved by the Standards Committee of the IEEE Consumer Electronics Group. Membership of this committee was:

J. Avins, *Chairman*

D. Sillman
H. O. Wood

*Currently known as the IEEE Consumer Electronics Group.

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IEEE/IHF Standard Methods of Testing Frequency Modulation Broadcast Receivers

1. Introduction

1.1 Scope. This standard defines conditions and methods of measurement for determining performance characteristics of monophonic and stereophonic FM (frequency modulation) broadcast receivers so that the results may be compared to measurements of other receivers or by other observers. It contains material not previously available in a single standard and replaces withdrawn IEEE Std 185-1947, Methods of Testing Frequency Modulation Broadcast Receivers and its supplement, Tests for Effects of Mistuning and Downward Modulation. See Refs [1]–[5] for further information.

Measurements are described for equipment designed to receive 88 to 108 MHz band FM broadcasts made in accordance with the present rules of the FCC (Federal Communications Commission). The tests apply to receivers powered by ac lines, by batteries, and by automobile generator and storage battery systems. The methods may be used for frequency modulation receivers for other services by applying the proper system requirements.

Techniques herein enable evaluation of complete receiver performance, with no provision for testing individual circuits or components. The standard methods described do not involve injection or extraction of signals at other than the normal input and output terminals, nor are internal modifications specified to inhibit normal receiver operation, although this may be desirable for diagnostic purposes. Because receiver designs vary too much for convenient use of a single test procedure, supplementary and alternative tests are included.

To facilitate interpretation of the test results, each test is designed to determine a single characteristic with as little interference as possible from other parameters, such as the audio-amplifier performance. Acoustic measurements are not included. Refs [6] –[11] should be consulted for acoustic tests and complete amplifier measurement methods.

This standard applies to receivers with internal amplifiers for driving loudspeakers, and to tuners designed for connection to external amplifiers. The term *receiver* is used to include tuners where no distinction is required. If a receiver has audio input terminals, the audio-frequency section will be tested before measuring the radio reception characteristics. If a receiver has output terminals for connection to a tape recorder or external amplifier, the performance as a tuner may be measured as well as overall receiver performance.

Measurements of radiation and conducted interference are not within the scope of this standard. The allowable limits for such radiation and the measurement methods are described in the FCC *Rules and Regulations* [12]. Measurement methods are also described in Refs [13]–[17].

Limiting values of the various quantities for acceptable performance are not specified. Some tutorial material is included to help in evaluation of the measurement results.

2. Definitions

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

maximum system deviation. The greatest deviation specified in the operation of the system.

NOTE: Maximum system deviation is expressed in kilohertz. In the case of FCC authorized frequency modulation broadcast systems in the range from 88 to 108 MHz, the maximum system deviation is ± 75 kHz.

monophonic. Audio information carried by a single channel.

NOTE: A monophonic receiver responds only to main channel signals, lacking the capability of detecting subcarrier information. The main channel signals may be either monophonic or the left-plus-right (L+R) information from the left and right channels of a composite stereophonic signal. Monophonic receivers have no output from L = −R stereophonic signals. Stereophonic receivers may be manually or automatically switched to the monophonic mode, responding only to monophonic or main channel L+R signals.

SCA subcarrier modulation. The FCC permits broadcasters to transmit privileged information and control signals on subcarriers as specified under the SCA (Subsidiary Communications Authorization), but only when transmitted in conjunction with broadcast programming.

With monophonic broadcasting, the SCA service may use from 20 to 75 kHz with no restriction on the number of subcarriers, but the total SCA modulation of the RF (radio frequency) carrier must not exceed 30 percent and the crosstalk into the main channel must be at least 60 dB down.

With stereophonic broadcasting, the SCA service is limited to 53 — 75 kHz, 10 percent modulation of the carrier, and must still comply with the 60 dB crosstalk ratio. A 67 kHz subcarrier with ±6 kHz modulation is often used.

separation. The process of deriving individual channel signals (for example, for stereophonic systems) from a composite transmitted signal.

NOTE: Separation describes the ability of a receiver to produce left and right stereophonic channel signals at its output terminals and is a measured parameter for stereo receivers only. Left-channel signal separation is defined as the ratio in dB of the output voltage of the left output of the receiver to that of the right output when an "L"-only signal is received. Right-channel separation is similarly defined.

standard de-emphasis characteristic. A falling response with modulation frequency, complementary to the standard pre-emphasis characteristic and equivalent to an RC circuit with a time constant of 75 μs.

NOTE: The de-emphasis characteristic is usually incorporated in the audio circuits of the receiver.

stereophonic. Audio information carried by a plurality of channels arranged to afford the listener a sense of the spatial distribution of the sound sources.

NOTE: A stereophonic receiver responds to both the L+R main channel and the L−R subcarrier channel of a composite stereophonic signal, so that one output contains substantially only L information, and the other only R. In addition to the main channel, stereophonic program modulation requires transmission of a 19 kHz pilot signal and the sidebands of a suppressed 38 kHz subcarrier carrying L−R information. This combination is called the composite signal, and it may be used alone or with other subcarrier (SCA) signals to frequency modulate the RF carrier.

After pre-emphasis, the left and right channels are added for main channel information. The right-channel program material is subtracted from the left to derive a difference signal that then amplitude modulates a 38 kHz subcarrier. The subcarrier is suppressed, divided by two, and transmitted as a 19 kHz pilot signal to facilitate demodulation of the suppressed carrier information at the receiver.

3. Test Equipment Requirements

All measuring instruments used should be at least five times more accurate than the test result to be recorded so that no more than 20 percent uncertainty will be introduced. If this is not possible, then the accuracy will be stated as a part of the test data.

3.1 RF Generator. This generates an adjustable-frequency RF carrier, with controlled attenuation, provision for frequency and amplitude modulation, meter monitoring of the carrier output, and meter indication of the deviation and modulation depth. An internal fixed-frequency audio generator is usually included to serve as a modulating signal source. Two generators are required for several tests described in Section 6, but only one need be modulated.

3.1.1 *Frequency Range.* While a range of 88 to 108 MHz is adequate for most FM broadcast receiver tests, continuous coverage from the IF (intermediate frequency) of 10.7 MHz to at least 216 MHz is needed for spurious response tests. If a generator with FM modulation capability covers 67 kHz as a carrier frequency, it can be used as an SCA generator (Section 3.4).

Since frequency stability is important, sufficient time should be allowed for warm-up and stabilization. Generator frequencies should be read with a frequency counter except for the tests that do not require exact frequencies.

3.1.2 *Spurious Output.* The carrier output purity is important, particularly in the spurious response measurements. RF output filters may be used if the impedance match and attenuator calibration are not affected. Field-strength meters and spectrum analyzers are convenient instruments for verifying signal purity. The method of frequency generation and the potential spurious output frequencies should be known, so that the receiver responses may be correctly identified. Generators may have fundamental oscillators, oscillator–multiplier combinations, multiple-oscillator mixers, or full synthesis systems. Any response below the tuned frequency of the receiver should be particularly checked, as these are often due to generator harmonics.

3.1.3 *Output Range.* The generators should be capable of providing the standard input levels (Section 5.1), with allowance for dummy antenna attenuation (Section 3.6). Few precision generators are capable of the higher levels, and wide-band or tuned RF amplifiers may be needed to increase the output range. The amplifier output should be checked for harmonic content that could affect some measurements. A suitable meter should be used to calibrate the output and attenuators. Accurate calibration of low signal inputs requires low leakage or other unwanted signal conduction into the receiver.

3.1.4 *Frequency Modulation.* Linear frequency-modulation capability is necessary from 30 to at least 15 000 Hz for monophonic tests, and to 75 kHz for complete stereophonic measurements. Linear deviation to ± 150 kHz is also necessary, with up to ± 300 kHz convenient for measuring many receivers. For linear modulation, the RF bandwidth of the generator must be sufficient to pass the FM signal sidebands without distortion. A straightforward method of checking the modulation capability is based on a wide-band monitor receiver that has a calibrated linear discriminator. Response and linearity of the generator are measured with distortion or harmonic analyzers at the output of the discriminator. The audio generator used for a modulation source must have low distortion.

The generator and modulation source distortion must total no more than 20 percent of the distortion result from the receiver tests. Random FM from hum and noise should be held to a similar portion of the test results. The frequency response of the modulator should be verified.

Deviation can be measured with a frequency counter if access to the direct-coupled portion of the generator modulation circuits is available. The linearity and sensitivity of the modulator are determined by relating the direct modulating potential or current to the modulated output frequency.

The deviation meter may not be accurate for stereo modulation. It usually has an average-rectifying characteristic, but is calibrated for peak deviation of sine-wave modulation. It is likely to have a 6 dB error for left- or right-only signals, and a 10 dB error for L – R. To check the reading, record the peak-to-peak oscilloscope indication for sine-wave modulation giving ± 75 kHz deviation. Convert this value to ± volts per kilohertz deviation. Oscilloscope measurement of any modulating signal with more than one frequency component can then be converted to peak-to-peak deviation in kilohertz.

3.1.5 *Amplitude Modulation (AM).* For the AM suppression tests described in Section 6.17, the generator must be capable of at least 30 percent amplitude modulation of its output signal simultaneously with the frequency modulation.

Many generators produce incidental phase and frequency modulation when they are amplitude modulated. The amount is usually specified by the manufacturer, but it should be verified by the monitor receiver described in Section 3.1.4, or by an equivalent method. The error introduced by the incidental modulation may be large enough to invalidate the measurement of AM suppression.

An external amplitude modulator may be used to reduce incidental phase modulation. If a bridge modulator with low-capacity diodes is used, the RF level should be maintained constant by using an external attenuator. Care must be taken to avoid incidental phase modulation from standing waves in the modulator, attenuator, dummy antenna, and cable connections.

Simulated airplane flutter and similar tests require deeper modulation at a very low frequency, but some incidental FM or phase modulation may be tolerated.

3.2 AF Generator. Most RF generators have internal AF (audio-frequency) generators for modulation sources, but usually with only one or two frequencies, and often with too much distortion for the precision readings needed on some receiver designs. The modulation source usually has external terminals that may be used to measure its distortion, or the overall distortion may be measured as described in Section 3.1.4.

An external modulation source is needed for other audio frequencies, and two simultaneous frequencies are needed for several measurements. The external generator must have a range of 30 to 15 000 Hz for response tests and preferably to over 75 kHz for high-frequency filtering tests. The output must be uniform from 30 to 15 000 Hz, though the output may be monitored with an audio voltmeter if necessary. The frequency calibration may be verified with a counter, but the dial indication is usually adequate for all but a few critical tests. The distortion should be verified regularly. A variable electronic filter may be used at the audio generator output for precise measurements.

A function generator with sine-wave output, electronic sweep, and analog drive for an X–Y recorder is convenient for frequency-response measurements, particularly if pre-emphasis is used. Some such generators have a voltage-controlled oscillator that can be modulated with audio frequencies, so that it can also serve as an SCA generator (Sections 3.4 and 7.10).

3.3 Composite Stereo Generator. A composite stereophonic signal generator produces the modulation components described in Section 2 and should have provision for adding a simulated SCA subcarrier. Pre-emphasis networks and self-contained audio generators are desirable, and some commercial generators include a fixed-frequency RF generator with output attenuators. Usually the composite signal is used to modulate an RF generator as described in Section 3.1. Among the required features are: four modulation modes, L only, R only, L = R, and L = −R; pilot signal terminals for external use, pilot switchable on–off and controllable from 0 to 15 percent or more. A "set-modulation" switch is convenient.

The generator may use matrix modulation or time multiplexing, but the main channel-to-subcarrier level differences that may occur with time multiplexing are easier to detect than the phase differences that are common with matrix modulation. The composite generator combines L and R signals from internal or external sources with a pilot signal and generates main and subcarrier components. This is a complex process and careful verification of the modulating signal is important.

Each of the signal characteristics should be verified. A spectrum analyzer can do most of this, and a harmonic analyzer can do fairly well, but other tests can help too. An oscilloscope may be used to verify the subcarrier suppression when L = R = 0. This must not exceed 1 percent deviation and should be nulled if possible. The subcarrier must be the second harmonic of the pilot, which may be verified by a double-trace scope, and the pilot must be within 2 Hz, which can be checked by a counter.

3.4 SCA Generator. The SCA rejection tests of Section 7.10 require a generator with a center frequency from 53 to 75 kHz and FM modulation capability. A 67 kHz center frequency with a ± 6 kHz deviation at 2.5 kHz is satisfactory. Some function generators used for Section 3.2 may serve here too. The center frequency should be verified with a counter, and the remainder of the characteristics checked as in Section 3.1.

3.5 Frequency Counter. A digital counter capable of measuring audio, ultrasonic, and RF frequencies to 216 MHz is required for accurate frequency measurements, particularly generator frequency calibration and verification. Care must be taken that switching transients do not interfere with the receiver measurements.

A low-capacity pickup or insulated FET (field-effect transistor) probe with a wide-band amplifier may be used with a counter to monitor the local oscillator frequency as needed for some of the measurements. Care must be taken that the pickup does not detune the oscillator or introduce coupling errors into other measurements. If the counter sensitivity is high, a tuned loop may be used. If access to the inside of the receiver is necessary to read the oscillator frequency, care must be taken so that the receiver operates normally.

3.6 Dummy Antenna. A dummy antenna is a transformer or network that presents the specified source impedance to the receiver and reflects the specified load impedance to the signal generator. The dummy antennas described below are for connection of one or two generators with 50 Ω internal impedances to receivers designed for 300 Ω balanced, 300 Ω unbalanced, and 75 Ω unbalanced inputs.

Receivers designed for monopole or whip antennas should be measured with a suitable dummy stating the dummy used as part of the test results. The receiver should not be grounded for these tests, and the generator connection to the chassis must be carefully located to correctly simulate the antenna.

The ideal dummy would give loss-free impedance transformation so the generator could be direct reading in available power, but most transformers do not have constant output over the required frequency range. If resistive pads are used, the loss in available power must be subtracted from the generator reading to find the power available to the receiver. This loss is shown for each of the various configurations.

For each dummy antenna shown,

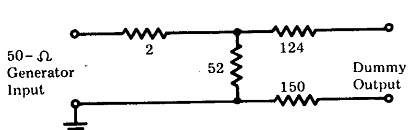
E_G Generator terminated output voltage as usually indicated on the output attenuator, half of the generator open-circuit voltage

E_O Open-circuit voltage at the receiver terminals in terms of E_G

P_L Dummy-antenna power loss in dB

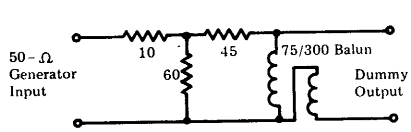
P_A Power available to the receiver in terms of E_G

(1) 300 Ω balanced input, resistive pad, one generator:

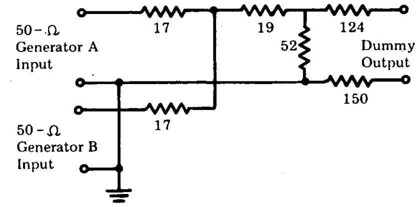


$E_O = E_G$
$P_L = 13.8$ dB
$P_A = \frac{(E_G)^2}{1200}$

(2) 300 Ω balanced input, pad plus balun, one generator:

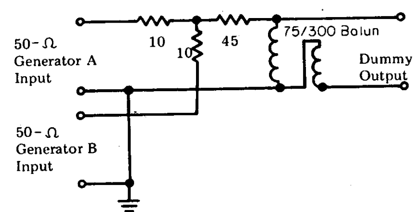


$E_O = 2\,E_G$
$P_L = 7.8$ dB
$P_A = \frac{(E_G)^2}{300}$



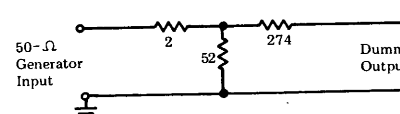
$E_O = .5\,E_G$
$P_L = 19.8$ dB
$P_A = \frac{(E_G)^2}{4800}$
(for each frequency)

(3) 300 Ω balanced input, resistive pad, two generators:



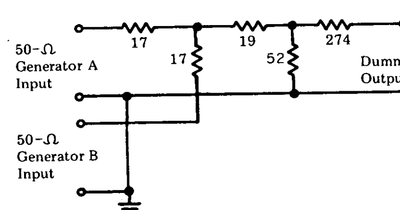
$E_O = 2\,E_G$
$P_L = 7.8$ dB
$P_A = \frac{(E_G)^2}{300}$
(for each frequency)

(4) 300 Ω balanced input, pad plus balun, two generators:



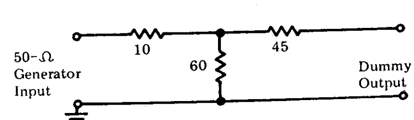
$E_O = E_G$
$P_L = 13.8$ dB
$P_A = \frac{(E_G)^2}{1200}$

(5) 300 Ω unbalanced input, resistive pad, one generator:



$E_O = 0.5\,E_G$
$P_L = 19.8$ dB
$P_A = \frac{(E_G)^2}{4800}$
(for each frequency)

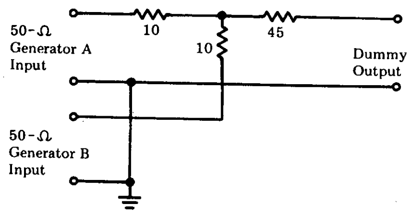
(6) 300 Ω unbalanced input, resistive pad, two generators:



$E_O = E_G$
$P_L = 7.8$ dB
$P_A = \frac{(E_G)^2}{300}$

(7) 75 Ω unbalanced input, resistive pad, one generator:

(8) 75 Ω unbalanced input, resistive pad, two generators:



$E_O = E_G$
$P_L = 7.8$ dB
$P_A = \frac{(E_G)^2}{300}$
(for each frequency)

3.7 Output Load. Each receiver terminal pair designed to supply signal power to a loudspeaker will be terminated with a resistive load having less than 10 percent reactive component at any frequency below 75 kHz. The resistor shall have a value that remains within 1 percent of the load specified by the manufacturer while dissipating the full output of the receiver. If not otherwise specified, an 8 Ω load will be used.

Receiver terminals intended to supply signal voltage to the input of a subsequent amplifier will be terminated with a 100 kΩ ± 5 percent resistor shunted by a 1000 pF ± 5 percent capacitor, unless the manufacturer of the receiver specifies otherwise.

The loading of the receiver output caused by other test equipment will be considered part of the load.

3.8 Output Filters. Except for measurements of the receiver's hum, ultrasonic output, and frequency response, a 200 to 15 000 Hz bandpass filter will be interposed between the output terminals of the receiver and the measuring instruments. The attenuation will not exceed 3 dB at 200 and 15 000 Hz, with a slope on each side of the passband of at least 18 dB per octave, and at least 30 dB attenuation at 19 kHz and above (see Section 7.2). This filter is modified to a 200 Hz high-pass filter for certain tests and to a 15 000 Hz low-pass filter for other specified tests. It becomes a 200 to 1500 Hz bandpass filter for standard AM suppression tests. A variable electronic filter may be used for complete AM suppression tests, or the components due to the addition of AM may be determined with a wave analyzer or spectrum analyzer.

Distortion, hum, and noise introduced by the filter must be included in the maximum allowable 20 percent inaccuracy, and the filter input impedance must be considered part of the output load.

3.9 Output Meter. The audio voltmeter used for output measurements will have average rectifying characteristics and be calibrated to read the rms (root mean square) voltage of a sine wave. It should be accurate to ± 2 percent of full-scale indication from 20 Hz to 200 kHz. The voltmeter's input impedance will be considered part of the receiver load.

The wide-band mode of the distortion meter (Section 3.11) may be used, with the advantage of using the same meter for distortion measurements, thus reducing the potential inaccuracies.

As specified for some audio measurements, rms true characteristic voltmeters may be used, but the measurement will not correlate with subjective response.

A logarithmic converter and $X-Y$ recorder in combination with a suitable sweep generator is useful in plotting frequency response.

3.10 Oscilloscope. An oscilloscope is necessary for the stereophonic FM measurements and useful for monitoring the output during other tests. It should have a frequency response from dc to at least 200 kHz to permit the calibration of ac waveforms against dc offsets. The linear time-base sweep should allow external triggering, and the scope should permit $X-Y$ displays for viewing Lissajous figures. Dual-trace capability is helpful for equipment verification and many of the measurements.

3.11 Distortion Analyzer. The distortion meter should have average rectifying characteristics and be capable of measuring the total residual hum, noise, and distortion components through subcarrier frequencies to an accuracy of at least ± 5 percent of full-scale indication. The reading of this meter is defined in this standard as distortion. The input impedance will be considered part of the receiver load. A spectrum analyzer is useful for quick evaluation of distortion components.

A narrow-band voltmeter or harmonic analyzer with a range of 50 Hz to 53 kHz and a bandwidth of 1/10 octave or less is useful, particularly for many stereophonic measurements. This may be more informative than total distortion readings. The total distortion is then expressed as

$$K = \frac{\sqrt{A_2^2 + A_3^2 + \ldots + A_n^2}}{\sqrt{A_1^2 + A_2^2 + \ldots + A_n^2}}$$

where A_1 is the fundamental amplitude, A_2 is the second harmonic, etc. K may be expressed in percent or decibels.

Harmonic distortion may also be expressed as the ratio of individual harmonic amplitudes to the amplitude of the fundamental, again in percent or decibels, for each of the significant harmonics.

4. Operating Conditions

Standard test conditions are described in this section. If standard conditions are not possible, then deviations should be stated as part of the test results.

4.1 Precautions. If the receiver uses a line-connected chassis, an isolation transformer should be used. Care should be taken that it does not influence the measurements.

4.2 Shields and Covers. All shields, covers, cases, and bottom plates will be fastened in their normal operating position.

4.3 Accessories. All specified accessory equipment or equivalent substitutes will be connected during tests if the loads or coupling affect the stability or the parameters to be measured. If more than one accessory case or cabinet is available for the receiver, it should be tested in the enclosure causing the highest operating temperature.

4.4 Preconditioning. All units will be preconditioned by operating in their normal position at one-tenth of their rated output for 1 hour or until stable operation is achieved. An exception is prior to the warm-up drift measurements given in Section 6.18.

4.5 Ground Connections. Accurate measurement of many receivers is not possible if a common ground connection causes abnormal coupling or instability. The equipment connected to the input must then be isolated from that connected to the output and from the ac supply to the receiver. Isolation transformers or battery-powered equipment may be necessary. If an isolation transformer is used for the receiver, a secondary-to-ground capacitor may be an adequate substitute for the normally grounded line.

Many portable receivers should not be grounded during measurements.

4.6 Normal Environment. All normal preconditioning and tests will be made in an ambient temperature of 25 °C ± 3 °C, in less than 90 percent relative humidity, and in a screened room with adequate attenuation of extraneous signals.

4.7 Extreme Environment. FM receivers obtaining power from the ac lines are normally used indoors, with a maximum expected ambient temperature range of 15 to 45 °C. The preconditioning and measurements will be repeated at these extremes within ± 3 °C when ac operated receivers are to be tested for full temperature range operation.

Portable and automobile receivers are subjected to lower temperatures and may be measured in an ambient temperature of 5 °C ± 3 °C, with no preconditioning. They may be checked for functional operation below 5 °C and above 45 °C.

4.8 AC Supply. The ac supply will be at 120 V ± 1 percent at 60 Hz ± 2 Hz, and with less than 2 percent total distortion. Line-voltage range tests will be from 105 to 130 V or as marked on the receiver. An ac wattmeter will be used to measure the power drain, usually at minimum volume and at the fraction of reference output required for safety listing.

4.9 Battery Supply. The receiver may be powered by new batteries of the type specified, or a power supply may be substituted that simulates the battery characteristics and is within 3 percent of the nominal voltage for the type specified. Supply currents will be measured for each mode of operation and for various power output levels. Receivers designed for use with both ac and battery supplies will be tested on both for all measurements that are affected by the type of supply.

All tests of the receiver significantly affected by changes in the supply voltages should be repeated using the maximum voltage for the particular type of battery as specified in Table 1. This may be done with actual batteries, if the necessary voltage can be achieved, or by simulation using a low-resistance power supply. The values given in the table assume battery charging circuits to be used in automobile applications, but not in other applications. If charging circuits are used elsewhere, appropriate maximum values should be determined.

Table 1
Battery Supply Voltages

Type of Cell and Receiver	Nominal Voltage	Normal Voltage	Maximum Voltage	Minimum Voltage
Dry cells	1.5			
Transistor radios		1.5	1.6*	0.75
End-of-life tests				0.90
Lead acid storage cells	2.0			
In automobiles		2.4	2.6	1.8
Other receiver types		2.0	2.2	1.8
Nickel-cadmium storage cells with gas vent	1.2			
Automobile receivers			1.6	1.1
Other receiver types		1.2	1.4	1.1
Nickel-cadmium storage cells gas tight	1.2			
Automobile receivers			1.4	1.1
Other receiver types		1.2	1.35	1.1

*The maximum voltage of a dry cell may be as high as 1.7 V, depending upon variables of manufacturing. Where tests are to be carried out at the maximum battery voltage, this should be ascertained from the battery manufacturer and quoted with the test results.

All tests of the receiver significantly affected by changes in the supply voltages should be repeated using the minimum voltage for a particular type of battery, as specified in Table 1. This minimum voltage is developed by the series combination of a low-resistance power supply as used above and a dropping resistor to simulate the increased internal resistance of the supply battery while the receiver current drain is maximized. Should the receiver fail to operate at the recognized minimum supply voltage, the usable range of operation should be noted. In the instance of transistor receivers with very low current drain, it may be desirable to test at the minimum supply voltage that will sustain receiver operation, reducing the supply voltage by increasing the resistance of the series dropping resistor.

5. General Test Procedures

5.1 Input Signal Levels. Input signal levels are expressed in terms of available power, the power delivered by the signal generator and dummy antenna to a matched load, the specified source impedance for which the receiver was designed. The available power is equal to $E^2/4R$, where E is the equivalent open-circuit voltage from the generator or dummy antenna, and R is the internal impedance.

In addition to resolving the 6 dB ambiguity between open-circuit and terminated microvolts, the expression of input levels as available power has been an accepted method for many years and for receivers in many services. It is particularly advantageous when comparing measurements of receivers designed for different source impedances.

Many signal generators are calibrated in terms of power available to a matched load and can be made direct reading by use of a matching balun or transformer that has a flat response over the required frequency range.

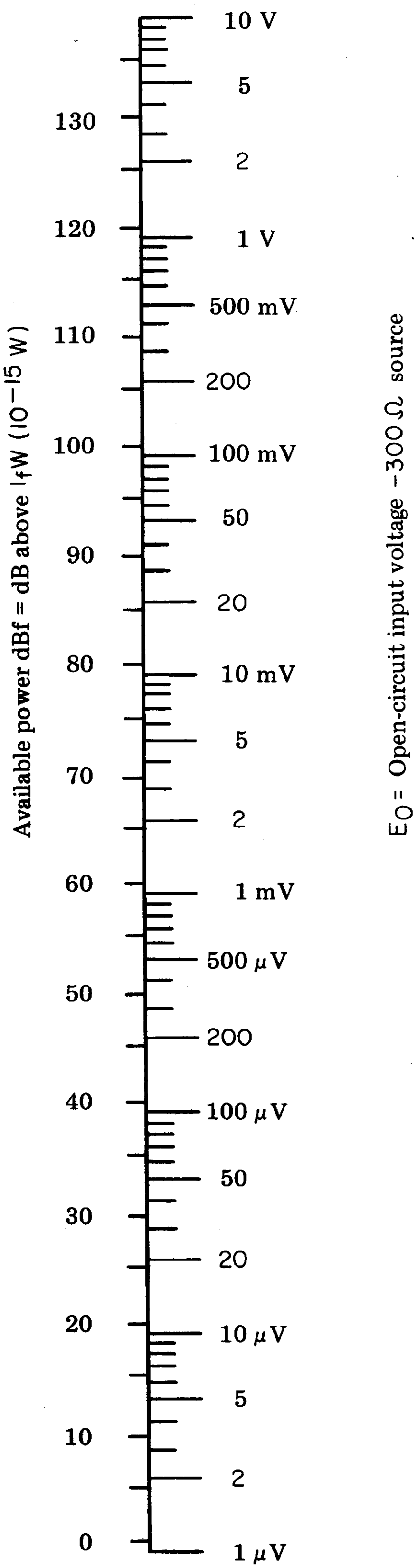
5.1.1 ***Available Power.*** For convenient expression of input levels in terms of available power, the reference level chosen is 1 fW (10^{-15} W), stated as 0 dBf.

5.1.2 ***Equivalent Microvolts.*** The reference level of 0 dBf corresponds to an open-circuit voltage of 1.1 μV, and 120 dBf corresponds to an open-circuit voltage of 1.1 V, both at a 300 Ω impedance level. For example, if the sensitivity of a receiver is 10 dBf, the equivalent open-circuit voltage at 300 Ω is 3.5 μV.

Fig 1 shows the relationship between available power, open-circuit microvolts, and terminated microvolts for 300 and 75 Ω impedances.

5.1.3 ***Mean Signal Input.*** Mean signal input is chosen as 65 dBf, which corresponds to an open-circuit input voltage of 1950 μV at 300 Ω.

Fig 1
Available Power versus Equivalent Microvolts



Available Power From Dummy Antennas (Section 3.6) in Terms of Terminated 50 Ω Generator Output E_G

Impedance Dummy	300 Ω (2),(4)	300 Ω (1),(5)	300 Ω (3),(6)
Impedance Dummy	75 Ω (7),(8)		
dBf			
0	0.55 μV	1.1 μV	2.2 μV
5	0.97 μV	1.9 μV	3.9 μV
10	1.7 μV	3.5 μV	6.9 μV
15	3.1 μV	6.2 μV	12 μV
20	5.5 μV	11 μV	22 μV
25	9.7 μV	19 μV	39 μV
30	17 μV	35 μV	69 μV
35	31 μV	62 μV	120 μV
40	55 μV	110 μV	220 μV
45	97 μV	190 μV	390 μV
50	170 μV	350 μV	690 μV
55	310 μV	620 μV	1.2 mV
60	550 μV	1.1 mV	2.2 mV
65	970 μV	1.9 mV	3.9 mV
70	1.7 mV	3.5 mV	6.9 mV
75	3.1 mV	6.2 mV	12 mV
80	5.5 mV	11 mV	22 mV
85	9.7 mV	19 mV	39 mV
90	17 mV	35 mV	69 mV
95	31 mV	62 mV	0.12 V
100	55 mV	0.11 V	0.22 V
105	97 mV	0.19 V	0.39 V
110	0.17 V	0.35 V	0.69 V
115	0.31 V	0.62 V	1.2 V
120	0.55 V	1.1 V	2.2 V

E_0 = open-circuit voltage

$= \sqrt{4 \times 10^{-15} R \times 10^{dBf/10}}$

R = impedance level

dBf = available power for a 1 fW reference level

$= 10 \log (E_0^2 / 4R \times 10^{-15})$

5.2 Standard Test Frequencies. The standard mean carrier frequency for use when measurements are to be made at a single frequency is 98 MHz. The standard group of three carrier frequencies is 90, 98, and 106 MHz. When measuring receivers with preset or fixed channel selection, these principal test frequencies become 90.1, 98.1, and 106.1 MHz.

5.3 Standard Modulation

5.3.1 ***Monophonic Modulation.*** Standard monophonic test modulation refers to a signal that is frequency modulated at 1000 Hz with 100 percent of maximum system deviation (± 75 kHz).

5.3.2 ***Stereophonic Modulation.*** The standard test modulation for stereophonic measurements consists of the components described in Section 2, with a 1 kHz sine wave as the encoded audio information for all of the standard modes:

(1) L = −R, subcarrier (L−R) only, main channel (L+R) = 0

(2) L = R, main channel (L+R) only, subcarrier (L−R) = 0

(3) L only, R = 0

(4) R only, L = 0

Except where otherwise indicated, the L = −R mode will be used.

The 19 kHz ± 2 Hz pilot signal frequency modulates the RF carrier 9 percent (± 6.75 kHz). The peaks of the modulating signal, including the pilot as specified above in (1), (2), (3), and (4) shall in each case modulate the carrier 100 percent (± 75 kHz).

5.4 Standard Tuning. A receiver is tuned accurately to a desired signal by first tuning it approximately and then adjusting the controls so the distortion of the audio frequency output is at a minimum. This point may be readily located by using a signal with the deviation temporarily increased to a value that the receiver will not accept without significant distortion. Correct tuning will then tend to show equal clipping on positive and negative half-cycles as observed on the output monitoring oscilloscope. In practice, the fine-tuning adjustment is accomplished by varying the generator since the vernier and incremental tuning controls allow more precise tuning. When input levels are small, and the noise becomes a significant part of the output, minimum distortion is interpreted as minimum noise content.

At higher input levels some receivers will give ambiguous results in tuning for minimum distortion due to complementary matching of the modulation and detection transfer characteristics, or to the normal reaction of some detector circuits. Zero-center-tuning meters may be used for tuning such receivers if the indication coincides with minimum distortion at lower inputs.

When the receiver has been tuned for minimum distortion or correct meter indication as described above, the tuning should not be readjusted to favor the particular parameter under measurement. When the input signal level is changed, tuning is readjusted as necessary.

5.5 Standard Test Output. The standard output for receivers with amplifiers for driving loudspeakers is chosen about 10 dB below rated output or clipping, for a convenient meter reading such as a zero or integral dB calibration on the audio voltmeter scale. This level is selected so that the audio distortion from the amplifier has minimum effect on the measurements.

A standard output level for tuners with level controls is chosen similarly, about 10 dB below maximum output level with 100 percent modulation and sufficient input for full limiting action. Alternatively, full output may be used.

5.6 Control Settings. Unless otherwise called for in the measurement procedures, the controls will be set as described below.

Tuning: The receiver is set to 98 MHz according to the dial calibration, the generator is adjusted to the receiver (Section 5.4) with standard monophonic modulation, and the input to the receiver is as stated in the test description. If two generators are used, this setting is made using generator *A*, with zero output from generator *B*.

Volume: Volume may be marked "Loudness." Set for standard output when the receiver is tuned as above.

Tone: Set for flattest measured electrical response on a pre-emphasized signal at the volume setting above. This applies to all controls that affect the frequency response, including those marked bass, treble, timbre, or tone.

Filters: Set in off or inactive position if this is the one giving nearest flat response. This applies to those marked high, low, scratch, rumble, etc.

Voice/Music: Set controls to music position, or that giving flattest response, before tone controls are adjusted as above.

Loudness Countour: Set in off or inactive position.

Balance: Set for equal measured output from each channel at the volume setting above.

AFC (Automatic Frequency Control): Set in off, inactive, or minimum position for AFC. Some measurements will be repeated with AFC turned on.

Mode: Set in monophonic or stereophonic position, as required for the particular test.

Mute: The muting control may be marked "squelch." Set in off, defeated, or minimum effect position.

Sensitivity: The sensitivity control may be marked "local/distant." Set in most sensitive or distant position.

Separation: Set for greatest separation at all audio frequencies. Separation may be marked "blend" or "stereo noise filter."

Selectivity: Set in broadest or least selective position.

Monitor: Set in off or "source" position.

Speakers: Set in the position directing the output to the terminals used for testing.

Any controls for special functions or automatic circuits not listed above should be in the off or not-effective position, but without internal receiver modification.

For all stereophonic measurements, the mode switch should be in the stereo position and the automatic stereo switching should be monitored to be sure it is in the stereo position. This may be checked by using L = −R modulation, which gives no output if the mode is set for monophonic reception.

Any exception to these settings should be entered as part of the test results.

6. Monophonic Performance Tests

The monophonic performance of a receiver is determined by measurement of the individual characteristics described in the following sections. The foregoing sections specify the setup of the measuring apparatus and the receiver under test.

6.1 Tuning Range and Calibration. The tuning control is set for the respective minimum and maximum carrier frequencies in each tuning range that the receiver 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, preferably using a frequency counter, as described in Section 3.5. This procedure may be extended to obtain a frequency calibration of the dial. If an error in frequency calibration is found, the maximum error in megahertz shall be stated.

6.2 Monophonic Usable Sensitivity. This test is performed at the three standard test frequencies. With a standard matching dummy antenna, standard monophonic test modulation, standard tuning, standard control settings, and standard output, the signal input level is reduced to the least value that will produce a 30 dB drop in indicated output when the output is measured through a 1000 Hz null filter. This is the monophonic usable sensitivity. This serves to indicate the relative freedom of the tuner from objectionable internal receiver noise during pauses in modulation when receiver noise is not masked by the modulation. The test also serves to indicate the relative freedom of the tuner from objectionable distortion during periods of maximum modulation.

The input signal levels are expressed in available power. The rated monophonic usable sensitivity is defined in Section 6.3.

6.3 Volume Sensitivity. This test is performed at 98 MHz with standard monophonic operating conditions. The output is noted as the input signal level is reduced below 100 dBf. The input signal level at which the output falls by 20 dB below the output for an input of 100 dBf is the volume sensitivity. The rated monophonic usable sensitivity shall be equal to the usable sensitivity or the volume sensitivity, whichever is poorer, and is expressed in dBf.

6.4 Monophonic 50 dB Quieting Sensitivity. This test is performed at 98 MHz, using a similar procedure to that in Section 6.2, but omitting the 1000 Hz null filter. The input signal level is reduced until there is a 50 dB increase in output when the standard test modulation is turned on. This test is a measure of how high an input signal level is required to attain a signal-to-noise ratio of 50 dB.

The rated monophonic 50 dB quieting sensitivity shall be the input signal level determined in this test, expressed in available power (dBf).

6.5 Monophonic Signal-to-Noise Ratio at 65 dBf. This test is performed at 98 MHz with an input signal level of 65 dBf under standard conditions with standard monophonic test modulation. The output obtained with the test modulation removed is measured, and the resultant signal-to-noise ratio is expressed in dB. This test is a measure of the signal-to-noise ratio attained for relatively strong input signals. The rated monophonic signal-to-noise ratio, termed the monophonic signal-to-noise ratio at 65 dBf, shall be the ratio obtained in this test, expressed in dB.

6.6 Hum and Noise at 65 dBf. This test is similar to that in Section 6.5 except that the output filter is changed from the 200 to 15 000 Hz bandpass filter to a 15 000 Hz low-pass filter to include power supply components (hum). The resultant signal-to-(hum and noise) ratio is expressed in dB.

6.7 Minimum Volume Hum and Noise. This test measures the total residual output under the same conditions as given in Section 6.6, except that the volume control is set at minimum and the measurement is made with no modulation. The minimum-volume output, including hum and noise, is referred to the standard test output and expressed as a signal-to-(minimum volume output) ratio in dB. The absolute output in microwatts should also be noted for speaker output terminations.

6.8 Muting Threshold. Many tuners and receivers are equipped with muting or squelch circuits designed to reduce output noise normally heard when tuning between FM station signals. These tests are designed to measure the signal intensity required to overcome these muting circuits. For receivers with abruptly applied muting, apply an input signal of mean carrier frequency at a level of 65 dBf and with standard monophonic test modulation. Gradually decrease the input until muting is observed. Record this input in dBf, and the output decrease with muting as the "muting ratio." Gradually increase the input until the muting action is overcome and record this input level in dBf. The difference of the signal levels for switching muting in and out is called the muting hysteresis. Reduce the input signal to zero with full muting action, recording the residual output in dB below standard output as the muting attenuation.

Rated muting threshold is the mean of the two levels of signal input (in dBf) observed above and is stated in dBf.

For receivers with gradually applied muting, gradually decrease the input to a level causing a 3 dB reduction in output when the muting is turned on. Record this input in dBf and further reduce the input until a 30 dB reduction is observed. This input is also recorded, and the difference in the two inputs, expressed in decibels, is called the differential muting sensitivity.

Rated muting threshold in this case is the mean of the two readings observed and is expressed in dBf.

For receivers having an external control capable of varying the muting threshold, measurements described above shall be made at each extreme position of this control and both results, stated in dBf, shall be the rated muting threshold range.

6.9 Frequency Response. The frequency response test shows the manner in which the audio output depends upon the modulating frequency. It takes into account all the characteristics of the receiver. The receiver is tuned to a signal at standard mean carrier frequency and a signal level of 65 dBf, frequency modulated with standard monophonic test modulation. Output is measured with all controls set to the standard control settings. The output variation is observed while the modulation frequency is varied continuously from 30 to 15 000 Hz. The results are compared to the response of the standard de-emphasis curve unless pre-emphasis was used (Section 3.2) and are expressed in dB with reference to the 1000 Hz output.

If the frequency response of the receiver varies with the volume-control setting because of fixed loudness compensation, then the curve should be repeated at 10 dB steps in the control setting. The modulation percentage may be reduced if necessary for measurements of higher volume settings.

The response should be repeated with tone controls at maximum and minimum settings in addition to the standard setting for flattest response. If overloading is observed, the curve may be plotted at a lower output level. The overload condition should be recorded with the data. Additional curves should be plotted with all other controls that affect response in their active position, particularly filters. If the receiver is equipped with any automatic controls that affect the response other than those above, the effects should be determined by additional tests. Rated frequency response shall be stated as: From 30 Hz to 15 000 Hz $\pm X$ dB.

6.10 Distortion. Harmonic distortion tests evaluate the spurious AF harmonics in the audio output of the receiver under various operating conditions. The THD (total harmonic distortion) is the rms value of the harmonics expressed as a percentage of the total electrical output. The maximum modulation frequency at which harmonic distortion can be detected by the ear in the output is 7.5 kHz.

For measurement of intermodulation distortion from simultaneous modulation, two tones separated by several hundred hertz (typically 1000 Hz) are used, and the nonlinear distortion is evaluated in terms of the spurious 1000 Hz difference output (Section 6.12).

6.10.1 *Distortion at 50 dB Quieting.* The test is performed at 98 MHz with an input signal level equal to the 50 dB monophonic quieting sensitivity. Under standard conditions with standard monophonic test modulation, the total harmonic distortion is measured.

The measurement is repeated with the modulation frequency at 100 Hz and 6000 Hz.

The rated values of THD at the 50 dB quieting sensitivity level shall be the total harmonic distortion as measured with 1000 Hz, 100 Hz, and 6000 Hz modulation, expressed in percent.

6.10.2 *Distortion at 65 dBf.* The procedure for this test is identical with that described in Section 6.10.1, except that the input signal level is increased to 65 dBf, corresponding to 1950 μV, open circuit, at 300 Ω.

The rated distortion at 65 dBf is the total harmonic distortion (rms) measured with an input signal level of 65 dBf at the three modulation frequencies used in Section 6.10.1, expressed in percent.

6.11 Distortion versus Operating Parameters. The following series of tests shows the effect of the operating parameters on distortion. Unless otherwise stated, standard monophonic operating and test conditions are assumed, and distortion is expressed in percent.

6.11.1 *Variation of Output.* With an input signal level of 65 dBf at 98 MHz, the THD is noted as the output is varied by means of the volume control.

This test is repeated for several modulation frequencies between 30 and 7500 Hz.

6.11.2 *Variation of Modulation.* With the input signal level for 50 dB quieting (Section 6.4) at 98 MHz, the distortion is noted as the modulation is varied from 30 percent to 120 percent ($\pm$ 90 kHz) of maximum system deviation. The volume is readjusted as necessary to maintain standard test output. This test evaluates the effects of modulation including overmodulation on infrequent peaks as allowed by the FCC.

The test may be repeated for other modulation frequencies between 30 and 7500 Hz, and at other input levels between usable sensitivity and 65 dBf.

6.11.3 *Variation of Modulation Frequency.* With an input signal level of 65 dBf at 98 MHz, the distortion is noted as the frequency is varied from 30 to 7500 Hz, maintaining standard test output with the volume control, or as near standard output as de-emphasis and system gain will allow.

6.11.4 *Variation of Input Signal Level.* The THD is noted as the 98 MHz input signal level is varied over the operating range in 20 dB steps, starting with the 50 dB quieting sensitivity level.

6.11.5 *Variation of Tuning.* With the input signal level for 50 dB quieting at 98 MHz, the distortion is noted as the generator frequency is varied in small increments in each direction from standard tuning until the distortion rises sharply. This test evaluates the effects of drift (Section 6.18) and the correction needed by AFC (Section 6.19). The distortion in percent may be plotted versus the frequency deviation from standard tuning in kilohertz.

6.12 Intermodulation Distortion. Rated intermodulation distortion is measured at 98 MHz with an input signal level of 65 dBf. Test modulation consists of two signals of equal amplitude at 14 000 Hz and 15 000 Hz, with an instantaneous peak deviation of 100 percent (± 75 kHz). The 1000 Hz intermodulation component is measured using a 200 to 1500 Hz bandpass filter and expressed as a percentage of the output that would be obtained when 1000 Hz modulation with a deviation of ± 75 kHz is used.

6.13 Capture Ratio. Capture ratio describes the capability to receive a stronger signal in the presence of a weaker interfering signal having the same carrier frequency.

Two signal generators are required only one of which need be capable of frequency modulation. Both generators are connected to the receiver through a (dual) dummy antenna (Section 3.6) and are set accurately to the same frequency (nominally 98 MHz) by zero beating or by counter measurement.

The output of the unmodulated interfering signal generator *B* is initially set at zero output. With standard monophonic test modulation on the desired signal generator *A* and an input signal level corresponding to the 50 dB quieting sensitivity, the controls are adjusted for standard test conditions. The output level of generator *B* is now advanced until its interfering signal causes the receiver output to drop by 1 dB as the interfering signal begins to capture the channel; this output level of generator *B* is noted in dB. The output level of generator *B* is further advanced until the receiver output falls by a total of 30 dB, indicating that the interfering signal has substantially captured the channel; this output level of generator *B* is again noted in dB. The difference in the two dB readings of generator *B* divided by two is defined as the capture ratio. During the above procedure, the receiver tuning should be readjusted slightly as necessary for maximum reduction in output. Monitoring the output with an oscilloscope is helpful since correct tuning is indicated by equal notching of the positive and negative peaks of the output waveform.

The smaller the spread between the output levels of generator *B* which causes the 1 dB and 30 dB drop in receiver output, the less vulnerable the receiver is to cochannel interference. The capture ratio is normally small enough so that the two generators can be assumed to have equal output at a point (geometrically) midway between the 1 dB and 30 dB levels, so that the capture ratio indicates the ratio of desired to undesired signal required for approximately 30 dB suppression of the undesired signal.

The measurement is repeated at input signal levels of 45 dBf, 65 dBf, 80 dBf, and 100 dBf.

The rated capture ratio is the greater (poorer) of the two capture ratios measured at the 45 dBf and 65 dBf input signal levels.

6.14 Adjacent and Alternate Channel Selectivity. This measurement describes a receiver's capability to receive a signal without interference in the presence of an interfering signal which is relatively close to the desired signal.

Test conditions are similar to those for the measurement of capture ratio, except that the interfering signal generator *B* is separated from the desired signal by one or more standard channel separations. With generator *B* at zero output, standard monophonic modulation is applied to generator *A* and the input level adjusted initially to 45 dBf with all controls adjusted for standard test conditions. The modulation is removed from generator *A*, applied to generator *B*, and the output of generator *B* is increased until the interference produced is 30 dB below the standard test output. The ratio of the generator outputs is noted in dB. The procedure is repeated with generator *B* offset a like amount on the opposite side of the desired signal. The average of the two ratios in dB is the selectivity ratio. A 1 kHz bandpass filter is used at the output to reduce errors from noise.

The ratio corresponding to a separation of one channel (200 kHz) is called the adjacent channel selectivity ratio. The ratio corresponding to a separation of two channels (400 kHz) is called the alternate channel selectivity ratio. The rated values of these two ratios are the values for a desired input level of 45 dBf.

The procedure is repeated for other values of the desired signal, starting with the usable sensitivity level, and continuing at levels of 65 and 80 dBf.

Table 2 is useful in tabulating the data.

Table 2
Adjacent and Alternate Channel Selectivity

Input (dBf)	Channels from Desired Signal −2 (dB)	−1 (dB)	+1 (dB)	+2 (dB)
15	69	−6	8	71
25	75	−4	1	61
35	58	−3	−1	57
45	48	−3	0	47
55	38	−3	0	37
65	28	−3	−1	27

When measuring receivers with preset or fixed channel selection, the generators are set to the exact channel frequencies within ± 2 kHz.

Complete selectivity measurements may require signal levels beyond the capability of generator *B*. An amplifier may be used as described in Section 3.1.3.

6.15 Spurious Responses

6.15.1 *Spurious Response Ratio.* With the receiver tuned to the desired frequency, the signal generator frequency should be continuously varied over a wide range to determine whether the receiver is responsive at frequencies other than the frequency to which it is tuned. Because the generation of these spurious responses may involve a multiplication in the observed signal deviation, the spurious response sensitivity is measured with an unmodulated signal, the signal input being increased for each spurious response noted until the noise output of the receiver is reduced to the same level as that used when the monophonic usable sensitivity is measured, as described in Section 6.2. The spurious response ratio is the ratio, expressed in dB, of the input signal level at the interfering frequency to the monophonic usable sensitivity input level at the desired frequency (to which the receiver is tuned), both giving this same (reduced) noise output.

The harmonic output of the signal generator must be attenuated sufficiently so that it does not affect the spurious responses.

The rated spurious response ratio is the poorest of those measured, as described in Sections 6.15.4 and 6.16, or found by scanning the frequencies, as described in this section.

6.15.2 *Image Response Ratio.* Using the procedure described in Section 6.2, the monophonic usable sensitivity is measured at 98 MHz and the noise output noted with the modulation off. Without altering test conditions, the generator frequency is changed to the image response frequency (98 MHz + 2 × 10.7 MHz) and the input level increased until the same noise level is obtained. The ratio of this input to the monophonic usable sensitivity input, in dB, is the rated image response ratio. The measurement may be repeated at 90 and 106 MHz.

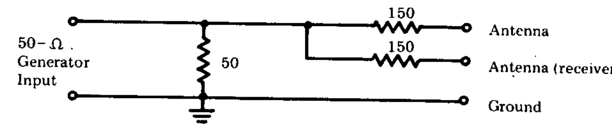


Fig 2
Dummy Antenna for Unbalanced IF Response Measurement

6.15.3 *IF Response Ratio.* The balanced IF response ratio is measured as described in Sections 6.15.1 and 6.15.2, but with the generator frequency changed from 98 MHz to 10.7 MHz.

To measure the unbalanced IF response ratio, the usable sensitivity is first measured and expressed in terms of the open-circuit input voltage (Fig 1). The standard dummy antenna is then changed to the dummy shown in Fig 2 and the increased generator open-circuit input required to produce the reference noise input is measured. The ratio of the two generator levels in dB is the unbalanced IF response ratio.

6.15.4 *Characteristic Frequency Tests.* In addition to the image and IF responses, superheterodyne receivers are susceptible to spurious responses at characteristic frequencies involving harmonics of the local oscillator and signal frequency. Particular frequencies of interest are $f_s + (f_i/2)$, $f_s + (2f_i/3)$, $2f_s + f_i$, where f_i is the IF frequency. The measurement procedure is the same as for image response and the figures of merit are expressed in the same way. The rated value for this test is the $f_s + (f_i/2)$ spurious response ratio measured at 103.35 MHz, with $f_s = 98$ MHz.

6.16 RF Intermodulation. Intermodulation spurious responses are generated in a receiver when two or more undesired signals are mixed in a nonlinear portion of the receiver. Interference results when the generated spurious response is of sufficient amplitude and on or near the desired frequency to which the receiver is tuned.

An important response due to two interfering signals f_1 and f_2 occurs when these frequencies are related by the equation $f_S = 2f_1 - f_2$ where f_S is the desired frequency to which the receiver is tuned. This relationship is satisfied, for example, when f_2 = 99.6 MHz and f_1 = 98.8 MHz, and the interfering signals are separated by 800 kHz from the desired frequency, corresponding to possible channel assignments in a given locality.

To measure this spurious response, both generators are connected to the receiver through a dual dummy antenna. The monophonic usable sensitivity is first measured at 98 MHz with generator *A* and the noise output noted with the modulation off. Generator *B* is unmodulated throughout. Generators *A* and *B*, both unmodulated, are next adjusted to 99.6 and 98.8 MHz, respectively. Keeping their outputs equal, their common output level is increased until the (usable sensitivity input) reference noise level is obtained. Generator *A* frequency may be varied slightly for maximum reduction of noise. The ratio of this output level to the usable monophonic sensitivity level at 98 MHz is the spurious response ratio.

The rated two-signal spurious response ratio is the ratio defined above when the two interfering frequencies are at 98.8 and 99.6 MHz and the desired signal frequency is 98 MHz.

Other spurious responses will occur with sufficiently strong interfering signals when sum and difference combinations of harmonics of the signals and harmonics of the local oscillator are equal to the tuned signal frequency, its image frequency, or the IF frequency.

6.17 AM Suppression. The AM suppression ratio is a measure of the receiver's ability to suppress response to amplitude modulation components in the signal. The AM may result from fading, multipath effects, airplane flutter, incidental transmitter AM, or a relatively narrow or misaligned receiver passband. Note that any oscillator shift due to signal level change results in FM at the detector which will not be removed. Also, multipath effects may result in external phase modulation which cannot be eliminated. In this case, the distortion increases with modulation frequency which can seriously degrade stereo reception.

The AM suppression ratio is defined in terms of the relative disturbance caused by amplitude modulation when the carrier is simultaneously amplitude and frequency modulated.

The AM suppression ratio = FM caused output (100 percent modulation, 1 kHz)/AM caused output (30 percent modulation, 400 Hz), expressed in dB.

6.17.1 *Measurements.* With a 45 dBf input signal at 98 MHz, simultaneously modulate the generator as defined by the AM suppression ratio: 100 percent FM at 1 kHz and 30 percent AM at 400 Hz.

Refer to Section 3.1.5 for precautions to avoid incidental phase modulation. Do not change the volume control setting. A nulled notch filter is used to remove the 1 kHz output. A 200 to 1500 Hz bandpass filter should be used to reject harmonic distortion and hum components. The remaining AM output, principally at 400 Hz, 600 Hz, and 1400 Hz, is recorded in dB below standard output. Normalize the reading if de-emphasis is other than −0.7 dB from 400 Hz to 1 kHz. Repeat the test at each standard signal level, since the suppression varies widely with input. To verify that the reading is due to AM modulation, it is useful to remove the 400 Hz modulation, checking for the drop in output.

6.17.2 *Supplementary Measurements.* For more complete analysis, AM suppression should be measured at AM frequencies from 3 Hz to 50 kHz, but particularly at the lower frequencies where receiver time constants may be a factor. The electronic filter described in Section 3.8 may be used. A wave analyzer or spectrum analyzer is convenient for distinguishing between AM intermodulation components and harmonic distortion components.

Some receivers have a multipath indicator that may be monitored during the above tests to check its response characteristics. As an additional test, the AM depth may be increased, even though this may add some incidental FM or phase modulation. A useful test is to simultaneously AM and FM modulate with approximately (but not exactly) the same modulation frequency, with standard FM, and the AM varied in modulation depth.

6.17.3 *Presentation.* The AM suppression ratio should be measured versus input level for at least the standard test. The ratio at 45 dBf input is the rated AM suppression ratio. The supplementary test data may be tabulated or curves may be drawn for each frequency.

6.18 Frequency Drift. This test is intended to show the variation of the tuned frequency of the receiver. The tests are normally performed with the receiver tuned to the standard mean carrier frequency and the controls set to their normal settings. The AFC is first turned off or set to minimum. The variation of frequency is observed by adjusting the frequency of the signal generator so that the receiver remains correctly tuned and the frequency is measured by a frequency counter. The local-oscillator frequency is also monitored (Section 3.5) for exact measurements.

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

(1) The frequency varies with time during the warm-up period of the receiver. A curve of frequency drift with time is plotted with time in minutes as the abscissa on a logarithmic scale and frequency drift in kilohertz as the ordinate on a linear scale. Time is measured from switching the tuner "on," with observations started immediately. The warm-up drift in kilohertz shall be stated as the maximum drift observed during a 2 hour period. If the receiver is intended for different types of installations, these tests should be repeated for the corresponding thermal environmental conditions.

(2) The frequency varies with ambient temperature. The receiver is tested in an environmental test chamber over the range which it is expected to operate. The drift is recorded for each temperature setting, starting with standard ambient as the reference. Sufficient time must be allowed for the receiver to reach thermal equilibrium.

(3) The frequency may vary with power supply voltage. The line voltage shall be varied from 105 to 130 and the resultant frequency drift shall be observed 1 minute after the voltage change has occurred. The amount of frequency drift for a line voltage change from 105 to 130 V is noted.

(4) If the receiver has AGC (automatic gain control), the variation of signal input may affect the oscillator frequency indirectly by way of the control circuit. The frequency drift with variation of signal input voltage should be observed after the receiver has been in operation a sufficient length of time to reach temperature stability. The maximum frequency drift when the input signal level is changed from the monophonic usable sensitivity level to 100 dBf is observed.

The rated frequency drift is the maximum frequency drift value obtained at the standard mean carrier frequency in any of the tests described above. The setting of the AFC must be stated.

6.19 Automatic Frequency Control. Many FM receivers employ AFC, using dc voltage or current from the output of the frequency-sensitive FM detector to regulate the frequency of the local oscillator. This negative feedback improves the centering of the heterodyned signal within the passband of the IF amplifier and FM detector. AFC reduces the care required in tuning and compensates for local-oscillator drift.

6.19.1 *AFC Characteristic.* The local oscillator frequency is monitored for AFC measurements. The receiver is set to 98 MHz with the volume control at minimum, 45 dBf input signal, and the signal unmodulated. The other controls are set for standard test conditions.

To plot the AFC characteristic, the generator is tuned to 99 MHz and slowly returned toward 98 MHz in small increments, recording the generator and local-oscillator frequencies at each step. The generator change is continued until 97 MHz is reached, then reversed toward 98 MHz again and continued until 99 MHz is reached, recording the two frequencies at each step.

The tuning error (generator frequency − oscillator frequency) is plotted against the generator detuning as shown in Fig 11. Note that the arrows show the tuning direction, and some readings at those frequencies may have to be repeated since the action is abrupt. The "AFC pull-in range" and the "AFC hold-in range" are shown. The various ratings are determined at an input of 45 dBf and should be correlated with other tuning characteristics (Section 6.11.5).

6.19.2 *AFC Correction Factor.* With the AFC off, the receiver is detuned by ± 75 kHz. The AFC is switched on and the tuning error is noted. The AFC correction factor is the ratio of the tuning error with AFC off to the tuning error with AFC on.

The rated AFC correction factor is measured at 98 MHz with a 45 dBf input signal.

6.19.3 *AFC Offset Error.* If the AFC can be switched off, the receiver is tuned for minimum distortion with the AFC off, and the local oscillator frequency is noted. The AFC is then switched on and the change in oscillator frequency is recorded as the AFC offset error.

The rated AFC offset error is measured at 98 MHz with a 45 dBf input signal.

6.19.4 *Repetition of Tests with AFC On.* AFC markedly affects many characteristics of the radio receiver. Earlier tests have been made with AFC off. Some of these measurements should be repeated with AFC active to determine if the AFC action affects the results.

6.20 Antenna Input Impedance. The specified source impedance for which a receiver has been designed is not to be confused with the actual input impedance of the receiver as measured at the antenna terminals. Receiver input impedance is measured using a VHF (very high frequency) impedance bridge or a vector impedance meter. The receiver is connected to the measuring instrument which may obtain the test signal from an FM generator. A 65 dBf input at 98 MHz is normally used, with the receiver tuned as given in Section 5.4. The impedance varies with both frequency and signal level so the test should be repeated to derive a family of curves, or at least repeated at 90 and 106 MHz and at several input levels, including usable sensitivity level. The results of the above tests may be converted into VSWR (voltage standing wave ratio), or a VSWR measuring system may be used.

6.21 Antenna Unbalance Ratio. Many receivers are provided with a balanced input circuit to reduce interference entering in an unbalanced or asymmetrical mode. The efficiency of the balanced input is determined by the unbalance ratio, usually expressed in dB and defined as the ratio between balanced and unbalanced input signals that produce the same output, with the receiver operating in a linear mode (below limiting). A large ratio indicates good balance.

The effect of reversing the antenna terminal connections will indicate unbalance by a change in the output, but a lack of change does not necessarily indicate a balanced system. The unbalance ratio may be measured using first a balanced dummy antenna (Section 3.6(1)) and then an unbalanced dummy antenna (Fig 2), with inputs well below the limiting action of the receiver and a 1 kHz bandpass filter to allow a more accurate indication by reducing the noise output.

6.22 Regeneration. Regeneration occurs when a signal generated within a receiver is coupled back to the input terminals in an amount sufficient to affect the receiver performance. If the reciprocal of the coupling exceeds the loop gain, oscillation is maintained. A desired carrier and the ninth or tenth harmonic of the IF may give two slightly different intermediate frequencies, beating to give an audio-frequency output, called tweet.

Regeneration may occur at certain frequencies, with different control settings, with or without an RF input signal, without an antenna, or with a particular antenna configuration. Such regeneration may be detected as increased distortion or modified signal-to-noise ratio.

Most receiver designs have enough gain to detect regeneration with no input signal. The set is tested in a well-shielded room with an audio voltmeter and a monitor speaker connected to the output. The dial is scanned slowly, watching for a change in the noise character or amount, particularly around 96.3 and 107 MHz. Local transmitters may cause a change in noise even if the room attenuation prevents usable reception. The receiver should be tested with various combinations of control settings, with a terminating resistor across the antenna terminals, with open terminals, with an unbalanced pick up (open wire lead), and with its built-in antenna. If regeneration is detected, a loosely coupled input signal may help in determining the exact frequency and in locating the feedback path. Plotting the noise level versus tuning frequency may help locate gradual changes.

6.23 Radiation and Power Line Conduction. Radiation of the oscillator and power line conduction shall be measured in accordance with the IEEE Std 187-1951, Open Field Method of Measurement of Spurious Radiation from Frequency Modulation and Television Broadcast Receivers, and IEEE Std 213-1961, Methods of Measurement of Radio Interference: Conducted Interference Output to the Power Line from FM and Television Broadcast Receivers in the Range of 300 kHz to 25 MHz.

6.24 Acoustic Feedback. Acoustic feedback occurs when the acoustic and mechanical vibrations produced by the receiver's loudspeaker system cause variation in the response of the receiver and consequently in the audio output. The receiver, plus any separate speakers, is placed in normal operating position. The receiver is tuned to at least an 80 dBf signal modulated 10 percent at 1 kHz. The volume control is adjusted to rated output or maximum setting. The modulation is removed and the output is examined for possible howl, ringing, and other outputs not associated with the input signal.

7. Stereophonic Performance Tests

Because of the nature of the stereophonic composite signal and the additional circuitry incorporated in a stereophonic receiver (generally referred to as the multiplex circuitry), a number of the measurements described in Section 6 must be repeated using stereophonic modulation, as described below. Many of the same parameters are measured and stereophonic ratings are determined. In addition, certain measurements specifically relating to stereophonic performance must be made in order to adequately describe the performance of a receiver capable of receiving both stereophonic and monophonic broadcasts.

Note that the filter described in Section 3.8 is to be connected between the receiver output and the audio voltmeter in all stereophonic measurements and tests unless otherwise specified.

7.1 Stereophonic Usable Sensitivity. Signal-to-noise ratios measured in the receiver when it is operating in the stereo mode will differ from those measured with the receiver in the monophonic mode. Stereophonic usable sensitivity is measured in the same manner as monophonic usable sensitivity (Section 6.2), except that standard stereophonic test modulation (L = −R mode) is used and a 19 kHz ± 2 Hz pilot-signal frequency modulates the RF carrier 9 percent (±6.75 kHz). The peaks of the modulating signal, including pilot, modulate the carrier 100 percent (±75 kHz). Signal output of the generator is reduced to the least value which will produce a 30 dB drop in indicated output when the output is measured through a 1000 Hz null filter.

The result, expressed in dBf, is the rated stereophonic usable sensitivity.

If the receiver under test is equipped with automatic switching facilities for altering the mode of operation from monophonic to stereophonic, and if those facilities are non-defeatable by the user, the stereophonic usable sensitivity shall be equal to the stereo threshold rating (Section 7.4), providing that stereo threshold rating, expressed in dBf results in at least a 30 dB drop in indicated output when measured through the 1000 Hz null filter, as previously discussed. Any stereo threshold range control available for external adjustment by the user shall be placed in its most sensitive setting (least input required to effect monophonic to stereophonic switching) for this test.

7.2 Stereophonic 50 dB Quieting Sensitivity. This test is performed at 98 MHz, using a procedure similar to the monophonic measurement (Section 6.4), except that standard stereophonic test modulation is used, the receiver is operated in the stereophonic mode, and the generator is modulated by the pilot only when the tone modulation (L = −R) is removed. The signal input is reduced until the output with standard modulation is 50 dB above the output with pilot modulation only. The result, expressed in dBf, is the rated stereophonic 50 dB quieting sensitivity.

In the event that the filter inserted between the receiver output and the audio voltmeter is insufficiently sharp to eliminate residual pilot products (19 kHz) from the resultant reading, the distortion analyzer (Section 3.11) may be inserted between the receiver output and the output meter and tuned for a null at 19 kHz for this test as well as for the tests of Sections 7.3, 7.6, and 7.7. The smaller number of dB observed for left or right output shall be used in these ratings.

7.3 Stereophonic Signal-to-Noise Ratio at 65 dBf. This test is performed at 98 MHz with an input signal level of 65 dBf under standard conditions, with standard stereophonic modulation and the receiver in the stereophonic mode. The output obtained with pilot modulation only is measured and the resulting rated signal-to-noise ratio is expressed in dB. This test is a measure of the signal-to-noise ratio attained for relatively strong input signals.

Alternatively, a graph may be presented, in which signal input intensity in dBf is plotted along the horizontal axis, and output with pilot only, measured in dB, is plotted along the vertical axis. Increasing signal shall be plotted from left to right and increasing signal-to-noise ratios shall be plotted from top to bottom. Such a presentation shall include signal inputs from 0 dBf (or from stereo threshold level described in Section 7.4) to at least 65 dBf.

7.4 Muting-Stereo Threshold. In most stereophonic receivers, the subcarrier detection may be defeated during monophonic reception with a manual override switch, thus reducing noise and potential crosstalk from subcarriers. In some receivers, the subcarrier detection is defeated automatically under poor stereo reception conditions. In such receivers setting the selector switch to stereo may not insure stereo operation unless the automatic switch is also activated by sensing a 19 kHz pilot signal. The input signal level and the pilot level usually determine the automatic switching action so that the subcarrier channel is made inoperative under poor stereo reception conditions.

With the receiver tuned to mean carrier frequency, input signal level at 65 dBf, and with its mode switch set to stereo (or automatic stereo), apply standard stereophonic test modulation (L = −R mode) at 100 percent deviation. The signal input is decreased until the output drops sharply and this signal value is recorded in dBf. The signal input is then increased until the output is restored and this level, in dBf, is also recorded. The two input levels are a measure of the stereo switching sensitivity and the hysteresis of each. The rated stereo threshold is the mean of the two signal levels observed above and is stated in dBf. If the receiver is equipped with a variable stereo threshold control, the tests should be repeated for each extreme setting of the control and the minimum and maximum stereo threshold values shall be stated in dBf.

The automatic stereo switch response to pilot level changes is measured by maintaining 65 dBf signal input and reducing the pilot level until the output drops sharply. Record the pilot modulation at this point in percent. This determines switch performance in the presence of some types of multipath effects.

The automatic stereo switch vulnerability to harmonics of the modulation frequency is determined by maintaining 65 dBf signal input with standard (L = −R) modulation at 100 percent with no pilot signal. The modulation frequency is varied around 6333 and 9500 Hz. Any increases indicate switch operation. The threshold may be determined by finding the minimum signal deviation for switch operation at the most effective modulation frequency.

7.5 Stereophonic Frequency Response. The stereophonic frequency response tests are performed in a manner similar to those described in Section 6.9 except that the generator is modulated with standard stereophonic test modulation and with L-only and R-only signals at modulation frequencies from 30 to 15 000 Hz. Outputs are recorded from each channel and compared to the response of the standard de-emphasis network (unless pre-emphasis is used, Section 3.2). Results are expressed in dB with reference to a 1000 Hz output obtained with standard stereophonic test modulation in L-only or R-only mode. The rated frequency response shall be stated as: From 30 to 15 000 Hz ± X dB.

7.6 Distortion

7.6.1 *Distortion at 50 dB Quieting Sensitivity.* The rated distortion at stereophonic 50 dB quieting sensitivity is the percentage of distortion measured with the signal generator modulated 100 percent in the L = −R mode at 100 Hz, 1 kHz, and 6 kHz. The receiver is tuned to standard mean carrier frequency and the input is set at 50 dB quieting sensitivity level (Section 7.2). The greater percentage observed from either the right or left output shall be used in this rating.

7.6.2 *Distortion at 65 dBf.* The rated stereophonic distortion at 65 dBf input is the percentage of distortion measured with the signal generator modulated 100 percent in the L = −R mode at 100 Hz, 1 kHz, and 6 kHz. The receiver is tuned to standard mean carrier frequency and the input is set at 65 dBf. The greater percentage observed from either the right or left channel output shall be the rated distortion at 65 dBf.

7.6.3 *Intermodulation Distortion.* Stereophonic intermodulation distortion is measured at 98 MHz with an input signal level of 65 dBf and standard (L = −R) stereophonic modulation. The 1 kHz product from intermodulation of the 19 kHz pilot with the second harmonic of 9 or 10 kHz modulation at 100 percent is measured using a 200 to 1500 Hz bandpass filter. It is expressed as a percentage of the output from 100 percent modulation at 1 kHz. Products from other modulation frequencies at subharmonics of 18 kHz may also be determined.

7.7 Stereo Separation. Separation measurements are often affected by other parameters, so it is suggested that the RF and audio tests be completed first, for better evaluation of separation test results.

A 65 dBf signal, at mean carrier frequency is applied to the receiver. Standard stereophonic test modulation (L-only or R-only mode) is used at 100 percent total modulation. An L-only signal is applied at a frequency of 1000 Hz and the L-output level is recorded as a reference. Next, the output from the right-channel is recorded and the difference between the two readings is recorded. This value, expressed in dB is the left separation at 1 kHz.

This procedure is repeated, this time with R-only modulation applied, and the difference between the R output and the L output is recorded in dB. The smaller of the two readings obtained is the rated separation at 1 kHz.

Tests are repeated at other modulating frequencies from 30 Hz to 15 kHz and the results may be plotted with audio frequency plotted logarithmically along the abscissa and dB plotted linearly along the ordinate. If a complete graphic plot is not presented, published separation ratings must include separation values at least at audio frequencies of 100 Hz, 1000 Hz, and 10 000 Hz.

For more complete measurements, separation should be measured as a function of pilot level.

Some receivers are equipped with cross-blending circuits that reduce residual noise in the stereophonic listening mode when activated. Such circuits tend to reduce separation at mid and high frequencies as well. Whenever mention is made of such a feature in a published specification, that mention shall include a statement as to realizable separation at 1 kHz and 5 kHz when the switch is activated.

7.8 Identicality. The term *identicality* is used as a measure of symmetry in the two channels. It is expressed in dB as the ratio of the mean scalar output voltage of the two channels to one-half the vector sum of the output voltage of the two channels, when L = −R modulation is applied. For identical channels, the scalar output voltage = |L| = |R| and the vector output voltage L + R = 0.

Identicality factor is defined in this way for stereo receivers to make it consistent with usage for stereo amplifiers. However, the unbalance is referred to the mean scalar output voltage, rather than to the voltage at the junction of the two equal resistors when L = R modulation is applied, so that the identicality factor will reflect any abnormal behavior of the subcarrier channel in the receiver.

7.8.1 *Measurements.* Two equal resistors are connected in series across the two channel outputs, and the voltmeter is connected to the junction of the resistors so that it reads one-half the vector sum of the output from each of the two channels. When measuring normal loudspeaker outputs, 1000 Ω resistors are used, and 1 MΩ resistors are used when measuring tuner outputs.

With a 65 dBf input and L = −R modulation, the controls are adjusted for normal reception and standard output. The balance control is set for minimum output indication. The control settings are not changed while the modulation frequency is varied from 300 to 10 000 Hz in suitable increments. For each frequency, the output of each channel is measured and the average noted as the (|L| + |R|)/2. The vector unbalance (L + R)/2 at the junction of the two equal resistors is also noted. The corresponding identicality factor is the ratio of $\frac{1}{2}(|L| + |R|)/\frac{1}{2}(L + R)$, expressed in dB. Note that the voltage measured at the junction of the two resistors is one-half the vector sum so that no additional factor need be applied.

The factor may be measured at various control settings to check on the tracking, or a quick evaluation may be made by listening while varying each control at several frequencies.

If noise or hum affect the readings, a bandpass filter may be used at each frequency.

7.8.2 *Presentation.* The identicality factor in dB is plotted linearly versus modulating frequency as a logarithmic abscissa. The control tracking is plotted in dB error versus dB change from normal settings or maximum settings.

7.9 Subcarrier Product Rejection. With the signal generator connected as usual and tuned to mean standard carrier frequency, standard stereophonic test modulation (L = −R) is applied at 100 percent system modulation. Output level is recorded, using either the left or the right channel output connection. The filter (Section 3.8) is changed to a 200 Hz highpass filter. Next, all modulation except the 19 kHz pilot signal is removed and the output level is once more recorded. The rated subcarrier product rejection is the difference between the two output readings taken above, expressed in dB.

7.10 SCA Rejection. SCA interference is caused by intermodulation with the effectively reinserted 38 kHz subcarrier which is always present. SCA interference is most objectionable during quiet parts of a program, and it is desirable to test for SCA interference with a composite signal with pilot only.

A study of possible subcarrier spectra and the receiver's de-emphasis characteristics indicates that an SCA subcarrier modulated by a 2.5 kHz sine wave will generate more interference than any other possible modulation. Accordingly, a 67 kHz subcarrier with a ± 6 kHz deviation at 2.5 kHz is used (Section 3.4). The SCA generator should be filtered to meet FCC specifications for out-of-band energy.

The signal generator, tuned to mean standard carrier frequency and at an output level of 65 dBf is connected under standard test conditions. Modulation is stereophonic, with only the 19 kHz pilot applied to provide 9 percent modulation. The SCA generator is adjusted to add a 67 kHz subcarrier with ± 6 kHz modulation at 2.5 kHz, and its output level is adjusted for 10 percent modulation of the main carrier. SCA interference is measured in the left and right channel outputs using the standard output filter (Section 3.8). Results are expressed in dB below the output obtained with standard stereophonic test modulation (L = −R mode) adjusted for 90 percent of maximum total deviation. Rated SCA rejection shall be the smaller reading obtained from either the left or the right channel outputs in the above tests.

8. Performance Evaluation

To facilitate the evaluation of receiver performance, specifications should include the rated characteristics given in Table 3.

9. Standard Data Format

In addition to the performance ratings listed in Section 8, receiver test records often require curves and tables for analysis of several parameters. This section covers standard forms for this presentation, the necessary test steps, and some secondary function tests needed for the records. The relationship to the rating tests is indicated by section references.

The test report headings should include a description of the receiver sample, the output load used, the standard test output chosen, and any variation from standard procedure.

9.1 Monophonic Measurements

9.1.1 *Sensitivity Curves.* See Fig 3. Curves are obtained by making the following measurements:

(1) S + D + N: Signal plus distortion plus noise output with standard modulation

(2) D + N: Distortion plus noise measured with distortion meter, with standard modulation

(3) N: Noise output without modulation

(4) Muting (dashed curves): With muting active

Table 3
Receiver Performance Evaluation

Specification Ratings		Monophonic	Stereophonic
Usable sensitivity	dBf	(Section 6.2)	(Section 7.1)
50 dB quieting sensitivity	dBf	(Section 6.4)	(Section 7.2)
Signal-to-noise ratio at 65 dBf	dB	(Section 6.5)	(Section 7.3)
Hum and noise at 65 dBf	dB	(Section 6.6)	—
Minimum volume hum and noise	dB	(Section 6.7)	—
Muting threshold	dBf	(Section 6.8)	(Section 7.4)
Frequency response 30 Hz to 15 kHz	±dB	(Section 6.9)	(Section 7.5)
Distortion at 50 dB quieting	percent	(Section 6.10.1)	(Section 7.6.1)
Distortion at 65 dBf	percent	(Section 6.10.2)	(Section 7.6.2)
Intermodulation distortion	percent	(Section 6.12)	(Section 7.6.3)
Capture ratio	dB	(Section 6.13)	—
Adjacent channel selectivity	dB	(Section 6.14)	—
Alternate channel selectivity	dB	(Section 6.14)	—
Spurious response ratio	dB	(Section 6.15.1)	—
Image response ratio	dB	(Section 6.15.2)	—
IF response ratio (balanced)	dB	(Section 6.15.3)	—
IF response ratio (unbalanced)	dB	(Section 6.15.3)	—
RF intermodulation	dB	(Section 6.16)	—
AM suppression ratio	dB	(Section 6.17.3)	—
Frequency drift	kHz	(Section 6.18)	—
AFC correction factor	—	(Section 6.19.2)	—
AFC offset error	±kHz	(Section 6.19.3)	—
Stereo separation	dB	—	(Section 7.7)
Subcarrier product ratio	dB	—	(Section 7.9)
SCA rejection ratio	dB	—	(Section 7.10)

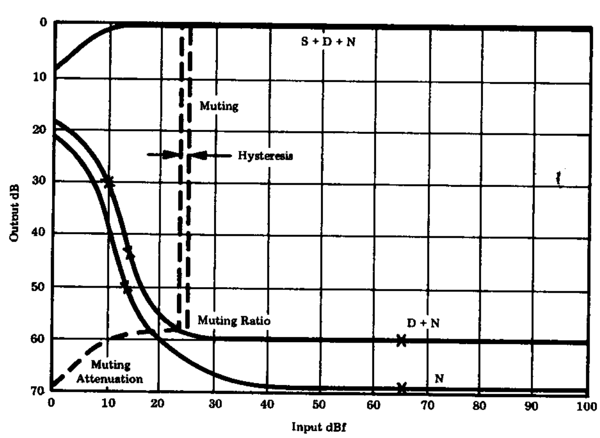


Fig 3
Monophonic Sensitivity Curves

Significant points obtained from the curves are:

(1) Usable sensitivity (measured at 90, 98, and 108 MHz): Input where (S + D + N) − (D + N) = 30 dB (Section 6.2)

(2) Volume sensitivity: Input where (S + D + N) = −20 dB (Section 6.3)

(3) 50 dB quieting sensitivity: Input where (S + D + N) − (N) = 50 dB (Section 6.4)

(4) Distortion at 50 dB quieting: (S + D + N) − (D + N) at above input (Section 6.10.1)

(5) Distortion at 65 dBf: (S + D + N) − (D + N) at 65 dBf input (Section 6.10.2)

(6) Signal-to-noise ratio at 65 dBf: (S + D + N) − (N) at 65 dBf input (Section 6.5)

(7) Hum and noise at 65 dBf: Signal-to-noise ratio with low-pass filter instead of bandpass filter (Section 6.6)

(8) Minimum volume hum and noise: Measurement at 65 dBf with volume control at minimum (Section 6.7)

(9) Muting ratio: Reduction in (S + D + N) at muting, stated in dB (Section 6.8)

(10) Muting threshold: Mean of two input levels for hysteresis as shown on curve, stated in dBf. (Section 6.8)

(11) Muting hysteresis: Difference in input levels for switching hysteresis as shown on curve, stated in dBf (Section 6.8)

(12) Muting attenuation: Reduction in (S + D + N) at zero input, stated in dB (Section 6.8)

(13) For reference in the test report, other curve points may be identified as "20 dB quieting," "1 dB limiting," etc

Supplementary tests that can be made are:

(1) Tuning meter threshold, minimum in-

Table 4
Input Level Table

Input Level (dBf)	Capture Ratio (dB)	AM Suppression (dB)	Selectivity in dB Channels from Desired Signal −2	−1	+1	+2
Usable sensitivity	3.8	22	78	−6	−5	78
50 dB quieting sensitivity	3.3	28	72	−5	−4	72
25	2.2	41	75	−4	1	61
35	2.0	43	58	−3	−1	57
45	1.7*	43*	48*	−3*	0*	47*
55	1.6	43	38	−3	0	37
65	1.6*	43	28	−3	−1	27
80	1.6	42	—	—	—	—
100	1.7	37	—	—	—	—

*Values used for ratings.
NOTE: The AM suppression at 20 Hz AM should also be recorded at 45 dBf input.

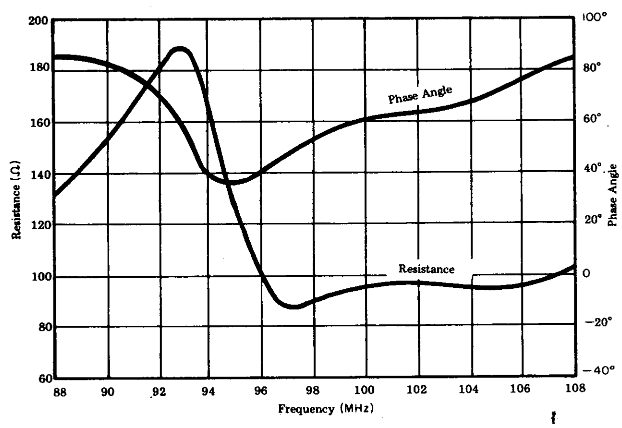


Fig 4
Input Impedance

put in dBf for useful indication, may be different inputs for peak and zero center types

(2) Gain reserve: At 65 dBf input, advance volume to maximum setting, reducing modulation to maintain standard output; record modulation reduction in dB as the gain reserve.

9.1.2 *Input Impedance and Unbalance (Sections 6.20 and 6.21).* See Fig 4. Alternatively, the impedance may be stated in ohms at the three principal frequencies (Section 6.20). The unbalance is stated in dB (Section 6.21).

9.1.3 *Input Level Table.* The capture ratio (Section 6.13), AM suppression (Section 6.17.3), and selectivity (Section 6.14) may be tabulated versus input on a single form, as shown in Table 4.

9.1.4 *Spurious Responses (Section 6.15).* Spurious responses should be tabulated, including those listed and any others found:

IF, unbalanced	10.7 MHz	Section 6.15.3
IF, balanced	10.7 MHz	Section 6.15.3
Signal + (1/2) IF	103.35 MHz	Section 6.15.4
Signal + (2/3) IF	105.13 MHz	Section 6.15.4
Image	119.4 MHz	Section 6.15.2
2 × signal + IF	206.7 MHz	Section 6.15.4

The rated spurious response ratio is the poorest of those measured under Sections 6.15.4 and 6.16 or found by scanning the frequencies listed in Section 6.15.1.

9.1.5 *RF Intermodulation (Section 6.16).* The first response listed is used for rating, the others are for more complete tests:

$2f_1 - f_2$ = signal, 2 × 98.8 − 99.6 = 98.0 MHz
$f_2 - f_1$ = signal, 198 − 100 = 98.0 MHz
$f_1 + f_2$ = signal, 0.8 + 97.2 = 98.0 MHz
$f_2 - f_1$ = IF, 110.7 − 100 = 10.7 MHz
$f_1 + f_2$ = image, 59 + 60.4 = 119.4 MHz

9.1.6 *Frequency Response (Section 6.9).* See Fig 5. Measurements for curves *A* through *E* are made as follows:

(1) For curve *A* measurements are made at full volume with reduced modulation for standard output

(2) For curve *D* measurements are made with the same modulation and volume control lowered to reduce 1 kHz 30 dB

(3) For curve *C* measurements are made with loudness compensation turned on

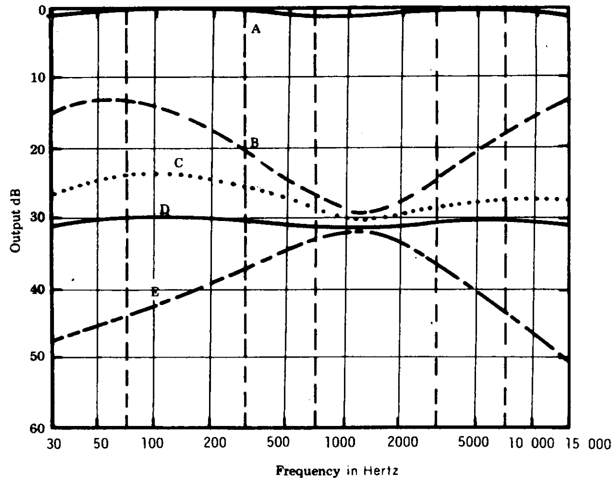


Fig 5
Monophonic Frequency Response

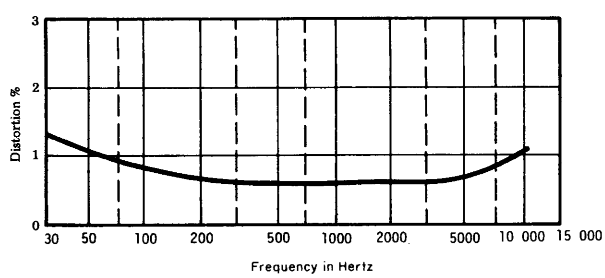


Fig 6
Distortion versus Modulation Frequency

(4) For curve *B* measurements are made with bass and treble controls turned fully on

(5) For curve *E* measurements are made with bass and treble controls at minimum

Significant points from the curves are:

(1) Response from 30 to 15 000 Hz ± *X* dB

(2) Loudness compensation at 50 Hz and at 10 kHz

(3) Bass control range at 50 Hz, + *X* dB to − *X* dB

(4) Treble control range at 10 kHz, + *X* dB to − *X* dB

9.1.7 ***Distortion versus Frequency.*** See Fig 6. Curves are obtained by making the measurements given in Section 6.11.3:

(1) Record change in distortion at 50 Hz with AFC on (Section 6.19.4)

(2) Record intermodulation distortion product from 14 kHz and 15 kHz (Section 6.12)

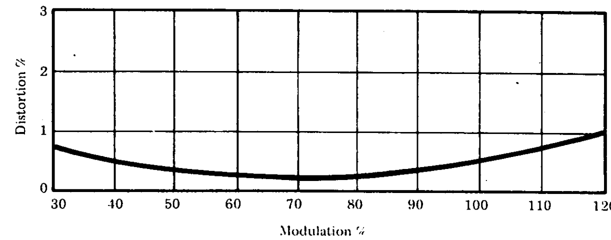


Fig 7
Distortion versus Modulation

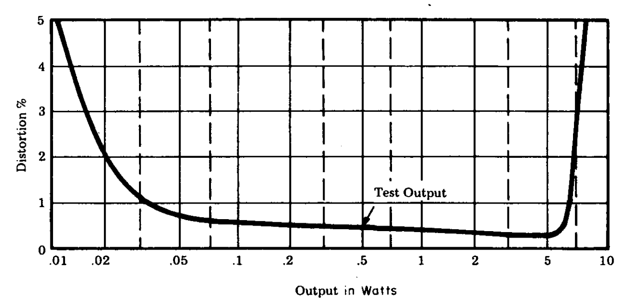


Fig 8
Distortion versus Output

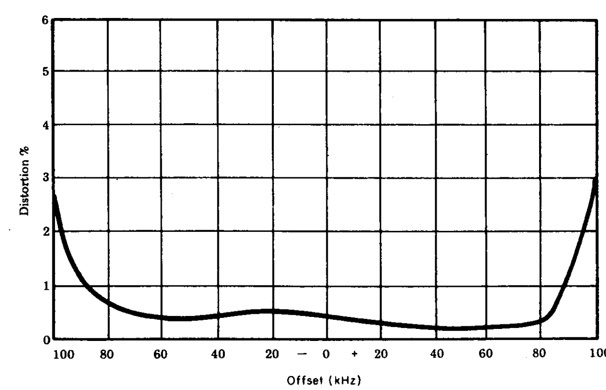


Fig 9
Distortion versus Tuning

9.1.8 ***Distortion versus Modulation.*** See Fig 7. Curves are obtained by making the measurements given in Section 6.11.2.

9.1.9 ***Distortion versus Output.*** See Fig 8. Curves are obtained by making the measurements given in Section 6.11.1. The curve may be repeated for the other output channel and for other frequencies.

9.1.10 ***Distortion versus Tuning.*** See Fig 9. Measurements for curve per Section 6.11.5. Curve may be repeated at other input levels.

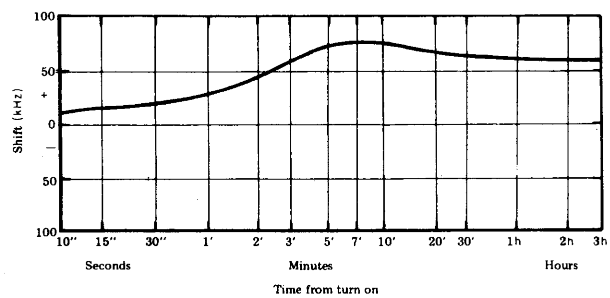


Fig 10
Frequency Drift versus Time from Turn On

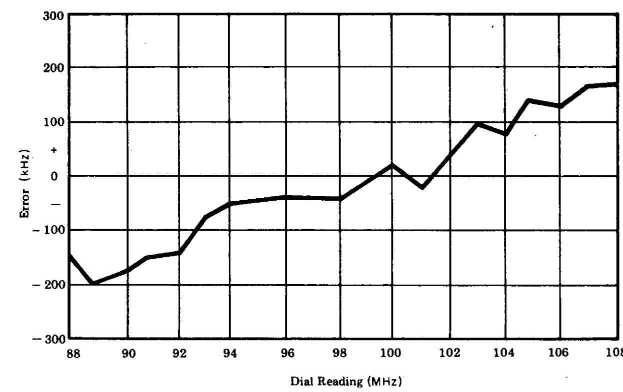


Fig 12
Dial Calibration Error

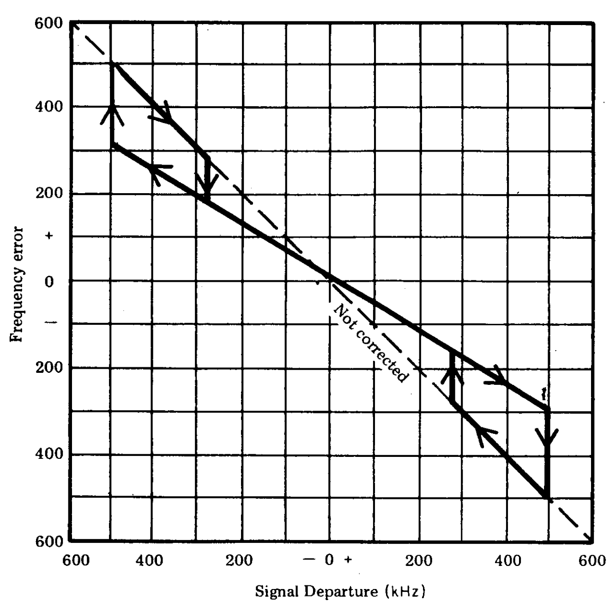


Fig 11
AFC Characteristic

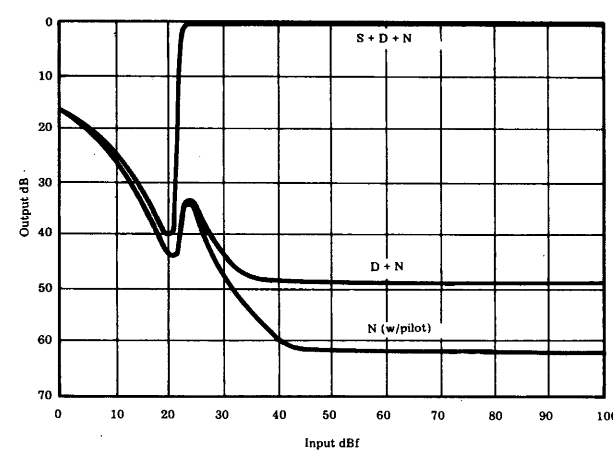


Fig 13
Stereophonic Sensitivity Curves

9.1.11 *Frequency Drift (Section 6.18).* See Fig 10. Curve is obtained by making the measurements given on Section 6.18(1). Record also the change in oscillator frequency for line voltage from 105 to 130 V as described in Section 6.18(3), and for input signal change from usable sensitivity to 100 dBf, as described in Section 6.18(4).

9.1.12 *AFC Performance.* See Fig 11. Curves are obtained by making the measurements given in Section 6.19.1. Record also the AFC correction factor described in Section 6.19.2 and the AFC offset error described in Section 6.19.3. Another useful figure of merit is the ratio of the hold-in range to the pull-in range.

9.1.13 *Tuning Range and Calibration.* See Fig 12. Curves are obtained by making the measurements given in Section 6.1. Record the tuning range, also measured according to Section 6.1.

9.2 Stereophonic Measurements

9.2.1 *Sensitivity Curves.* See Fig 13. The measurements for these curves are like those for Fig 3, except for the use of stereophonic

Table 5
Separation versus Pilot Signal Level

Pilot Level (percent)	Separation (dB)
15	44
12	44
10	44
7.5	30
5.0	25
2.0	20
0.5	10

NOTE: See Section 7.7.

modulation instead of monophonic, and N is measured without tone modulation, but with the pilot on. The stereo switch action is indicated by the sudden drop in output (S + D + N). The test references for the rating points are:

(1) Usable sensitivity, Section 7.1
(2) Muting threshold, Section 7.4
(3) Stereo switch versus pilot, Section 7.4
(4) Stereo switch versus modulation harmonics, Section 7.4
(5) 50 dB quieting sensitivity, Section 7.2
(6) Distortion at 50 dB quieting, Section 7.6.1
(7) Distortion at 65 dBf, Section 7.6.2
(8) Signal-to-noise ratio at 65 dBf, Section 7.3

A supplementary test is the stereo indicator threshold, that is, the minimum input for useful indication of stereo reception.

9.2.2 ***Frequency Response and Separation.*** See Fig 14. Frequency curves are obtained by making the measurements given in Section 7.5. Record variation from 1 kHz output as 30 to 15 000 Hz ± X dB. Use the measurements for separation versus frequency curves described in Section 7.7. Record minimum separation at 1 kHz, 100 Hz, and 10 kHz. Record also the effect on separation when the stereo noise filter is turned on. See Table 5.

9.2.3 ***Distortion versus Modulation Frequency (Section 7.6.3).*** See Fig 15. Curves are obtained by making the measurements given in Section 7.6.3. Record the IM resulting from modulation frequencies at subharmonics of 18 kHz and 20 kHz.

9.2.4 ***Ultrasonic Interference.*** To obtain values for ultrasonic interference:

(1) Record the subcarrier products rejection as described in Section 7.9

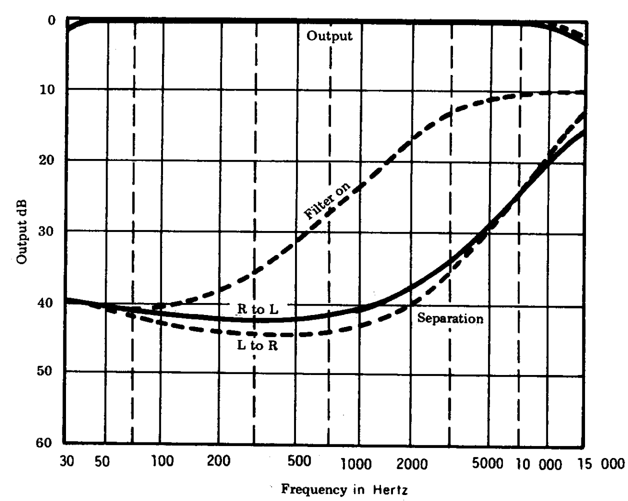


Fig 14
Frequency Response and Separation versus Frequency

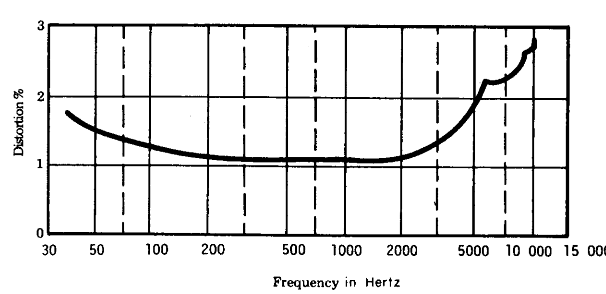


Fig 15
Distortion versus Modulation Frequency

(2) Record the SCA rejection as described in Section 7.10.

9.2.5 ***Identicality.*** See Figs 16 and 17. Curves are obtained by making the measurements given in Section 7.8.

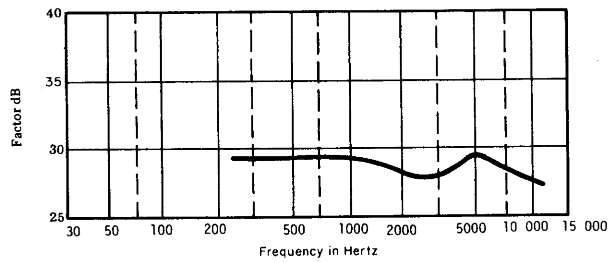


Fig 16
Identicality Factor versus Modulation Frequency

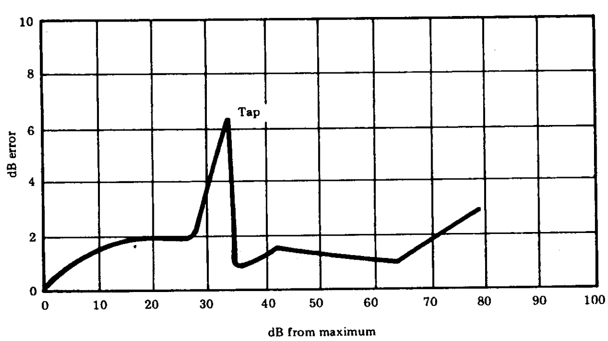


Fig 17
Control Tracking Error

10. References[1]

10.1 General

[1] Federal Communications Commission, *Rules and Regulations,* vol III, pt 73, Radio Broadcast Services, Subpart B, FM Broadcast Stations

[2] IEC Publication 91 (1968), Recommended Methods of Measurement of Receivers for Frequency Modulation Broadcast Transmissions

[3] IEC Publication 315, Methods of Measurement on Radio Receivers for Various Classes of Emission: Part 1 — General Conditions for Measurements and Measuring Methods Applying to Several Types of Receivers, (1970); Part 4 — Radio Frequency Measurements on Frequency Modulation Receivers, in preparation; Part 5 — Specialized Radio-Frequency Measurements. Measurements on Frequency Modulated Receivers of the Response to Impulsive Interference, (1971)

[4] IEEE Std 190-1960 (ANSI C16.13-1961), Methods of Testing Monochrome Television Broadcast Receivers

[5] IHF Std IHFM-T-100 (1958) and Addendum 1 (1959), Standard Methods of Measurement for Tuners

10.2 Acoustic and Audio Amplifier Measurements

[6] EIA Std RS-234-C (1971), Standard Methods of Measurement for Audio Amplifiers Used in Home Equipment

[7] IEC Publication 315, Methods of Measurement on Radio Receivers for Various Classes of Emission: Part 2 — Measurements Particularly Related to the Audio-Frequency Part of a Receiver, 1971

[8] IEC Publication 268-5 (1972) (ANSI S1.5-1971), Sound System Equipment: Part 5 — Loudspeakers

[9] IHF Std IHFM-A-201, (1966), Standard Methods of Measurement for Audio Amplifiers

[10] IEEE Std 219-1961, Recommended Practice for Loudspeaker Measurements

[11] Federal Trade Commission, *Trade Regulation Rule,* Power Output Claims for Amplifiers Utilized in Home Entertainment Products, effective November 4, 1974

10.3 Radiation and Power Line Conducted Measurements

[12] Federal Communications Commission, *Rules and Regulations,* vol II, pt 15, Radio Frequency Devices, Subpart C, Radio Receivers, particularly Sections 15.61, 15.63, 15.69 through 15.72, 15.75, and 15.82

[13] IEC Publication 106 (1959) and 106A (1962), Methods of Measuring Radiation

[14] IEEE Std 187-1951, Open Field Method of Measurement of Spurious Radiation

[1]IEC standards are available from The American National Standards Institute, 1430 Broadway, New York, NY 10018. IHF standards are available from the Institute of High Fidelity, 516 Fifth Avenue, New York, NY. EIA standards are available from The Electronic Industries Association, 2001 Eye Street NW, Washington, DC, 20006.

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[15] IEEE Std 213-1961, Methods of Measurement of Radio Interference: Conducted Interference Output to the Power Line from FM and Television Broadcast Receivers in the Range of 300 kHz to 25 MHz

[16] EIA Publication RS-378 (1970), Measurement of Spurious Radiation from FM and TV Broadcast receivers in the Frequency Range of 100 to 1000 MHz, Using the EIA-Laurel Broad-Band Antenna

[17] EIA Consumer Products Bulletin Number 4 (1971), Standard Form for Reporting Measurements of TV and FM Broadcast Radio Receivers in Compliance with FCC Part 15-Rules