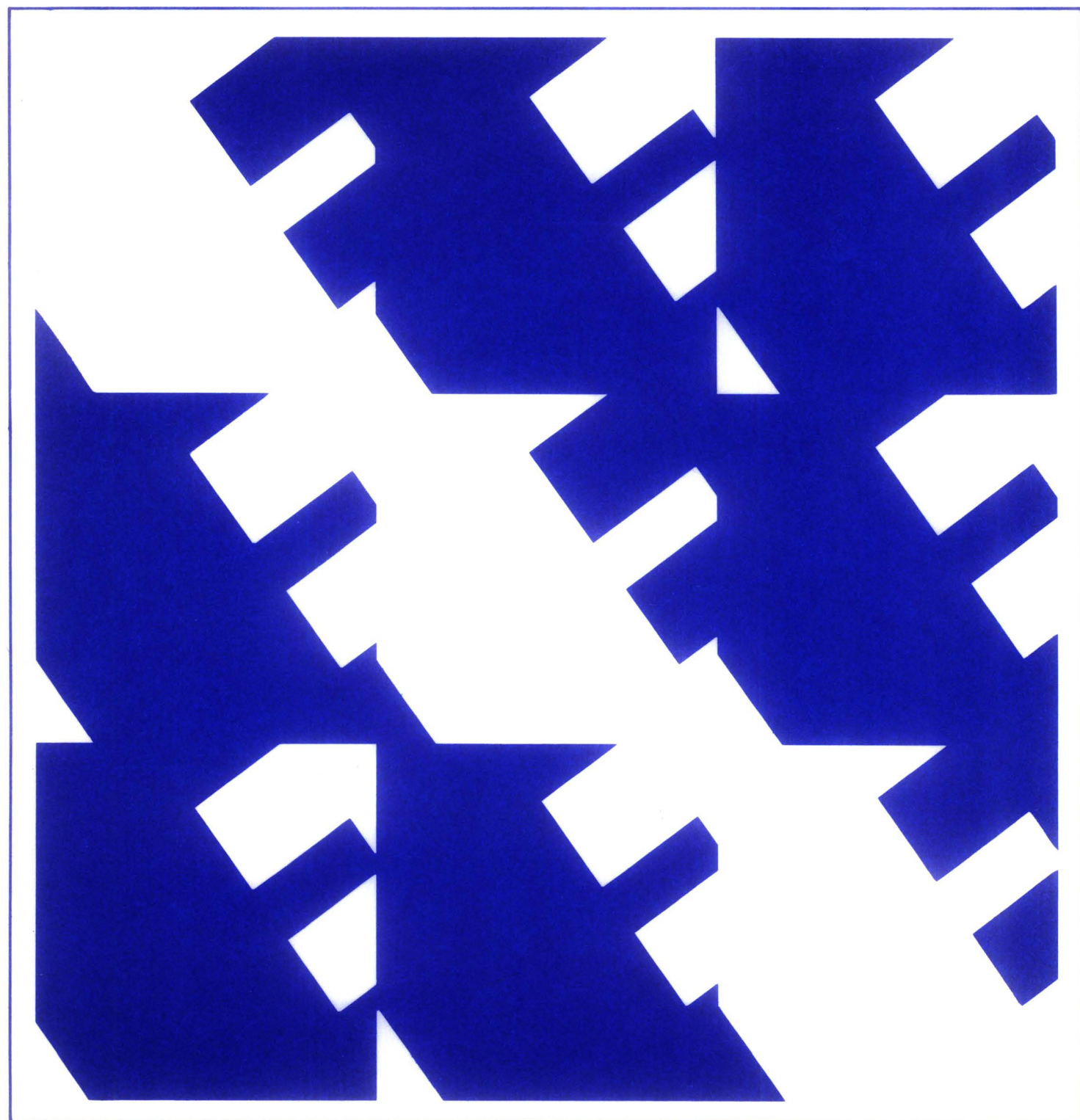


IEEE/IHF Standard Methods of Testing Frequency Modulation Broadcast Receivers

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Supersedes IHFM-T-100, 1958



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Frequency Modulation Broadcast Receivers

Sponsors

Electronics Industries Association, Inc
IEEE Consumer Electronics Group
Institute of High Fidelity, Inc

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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 $300\ \Omega$ impedance level, 1 dBf corresponds to $1.1\ \mu\text{V}$ 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
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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.

Contents

SECTION	PAGE
1. Introduction	7
1.1 Scope	7
2. Definitions	7
3. Test Equipment Requirements	8
3.1 RF Generator	8
3.2 AF Generator	9
3.3 Composite Stereo Generator	10
3.4 SCA Generator	10
3.5 Frequency Counter	10
3.6 Dummy Antenna	10
3.7 Output Load	12
3.8 Output Filters	12
3.9 Output Meter	12
3.10 Oscilloscope	12
3.11 Distortion Analyzer	12
4. Operating Conditions	13
4.1 Precautions	13
4.2 Shields and Covers	13
4.3 Accessories	13
4.4 Preconditioning	13
4.5 Ground Connections	13
4.6 Normal Environment	13
4.7 Extreme Environment	13
4.8 AC Supply	13
4.9 Battery Supply	13
5. General Test Procedures	14
5.1 Input Signal Levels	14
5.2 Standard Test Frequencies	16
5.3 Standard Modulation	16
5.4 Standard Tuning	16
5.5 Standard Test Output	16
5.6 Control Settings	16
6. Monophonic Performance Tests	17
6.1 Tuning Range and Calibration	17
6.2 Monophonic Usable Sensitivity	17
6.3 Volume Sensitivity	17
6.4 Monophonic 50 dB Quieting Sensitivity	17
6.5 Monophonic Signal-to-Noise Ratio at 65 dBf	18
6.6 Hum and Noise at 65 dBf	18
6.7 Minimum Volume Hum and Noise	18
6.8 Muting Threshold	18
6.9 Frequency Response	18
6.10 Distortion	19
6.11 Distortion versus Operating Parameters	19
6.12 Intermodulation Distortion	20
6.13 Capture Ratio	20
6.14 Adjacent and Alternate Channel Selectivity	20
6.15 Spurious Responses	21

6.16	RF Intermodulation	21
6.17	AM Suppression	22
6.18	Frequency Drift	23
6.19	Automatic Frequency Control	23
6.20	Antenna Input Impedance	24
6.21	Antenna Unbalance Ratio	24
6.22	Regeneration	24
6.23	Radiation and Power Line Conduction	24
6.24	Acoustic Feedback	25
7.	Stereophonic Performance Tests	25
7.1	Stereophonic Usable Sensitivity	25
7.2	Stereophonic 50 dB Quieting Sensitivity	25
7.3	Stereophonic Signal-to-Noise Ratio at 65 dBf	26
7.4	Muting-Stereo Threshold	26
7.5	Stereophonic Frequency Response	26
7.6	Distortion	26
7.7	Stereo Separation	27
7.8	Identicality	27
7.9	Subcarrier Product Rejection	28
7.10	SCA Rejection	28
8.	Performance Evaluation	28
9.	Standard Data Format	28
9.1	Monophonic Measurements	28
9.2	Stereophonic Measurements	32
10.	References	34
TABLES		
Table 1	Battery Supply Voltages	14
Table 2	Adjacent and Alternate Channel Selectivity	21
Table 3	Receiver Performance Evaluation	29
Table 4	Input Level Table	30
Table 5	Separation versus Pilot Signal Level	33
FIGURES		
Fig 1	Available Power versus Equivalent Microvolts	15
Fig 2	Dummy Antenna for Unbalanced IF Response Measurement	21
Fig 3	Monophonic Sensitivity Curves	29
Fig 4	Input Impedance	30
Fig 5	Monophonic Frequency Response	31
Fig 6	Distortion versus Modulation Frequency	31
Fig 7	Distortion versus Modulation	31
Fig 8	Distortion versus Output	31
Fig 9	Distortion versus Tuning	31
Fig 10	Frequency Drift versus Time from Turn On	32
Fig 11	AFC Characteristic	32
Fig 12	Dial Calibration Error	32
Fig 13	Stereophonic Sensitivity Curves	32
Fig 14	Frequency Response and Separation versus Frequency	33
Fig 15	Distortion versus Modulation Frequency	33
Fig 16	Identicality Factor versus Modulation Frequency	34
Fig 17	Control Tracking Error	34

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 mea-

surements 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 μ s.

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 con-

tains 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 $\pm$ 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,

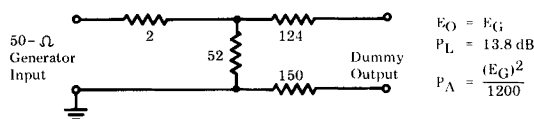
E_G Generator terminated output voltage as usually indicated on the output attenuator, half of the generator open-circuit voltage

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

P_L Dummy-antenna power loss in dB

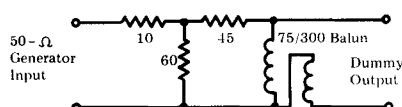
P_A Power available to the receiver in terms of E_G

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

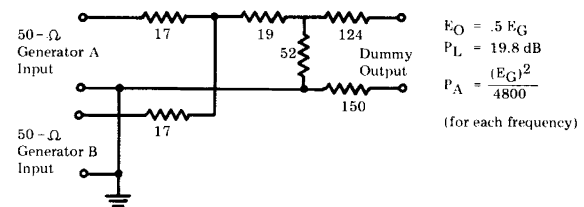


$$\begin{aligned} E_O &= E_G \\ P_L &= 13.8 \text{ dB} \\ P_A &= \frac{(E_G)^2}{1200} \end{aligned}$$

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



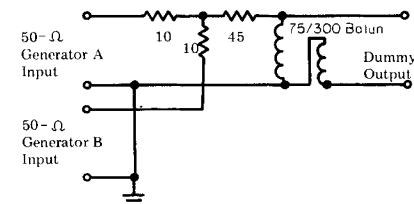
$$\begin{aligned} E_O &= 2 E_G \\ P_L &= 7.8 \text{ dB} \\ P_A &= \frac{(E_G)^2}{300} \end{aligned}$$



$$\begin{aligned} E_O &= .5 E_G \\ P_L &= 19.8 \text{ dB} \\ P_A &= \frac{(E_G)^2}{4800} \end{aligned}$$

(for each frequency)

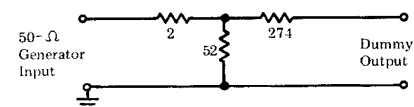
(3) 300 Ω balanced input, resistive pad, two generators:



$$\begin{aligned} E_O &= 2 E_G \\ P_L &= 7.8 \text{ dB} \\ P_A &= \frac{(E_G)^2}{300} \end{aligned}$$

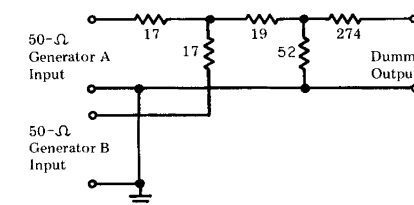
(for each frequency)

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



$$\begin{aligned} E_O &= E_G \\ P_L &= 13.8 \text{ dB} \\ P_A &= \frac{(E_G)^2}{1200} \end{aligned}$$

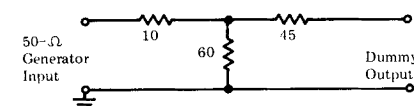
(5) 300 Ω unbalanced input, resistive pad, one generator:



$$\begin{aligned} E_O &= 0.5 E_G \\ P_L &= 19.8 \text{ dB} \\ P_A &= \frac{(E_G)^2}{4800} \end{aligned}$$

(for each frequency)

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



$$\begin{aligned} E_O &= E_G \\ P_L &= 7.8 \text{ dB} \\ P_A &= \frac{(E_G)^2}{300} \end{aligned}$$

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