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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This TOP describes the engineering Test Method and Techniques for evaluating Sensitivity performance of non-pulsed receivers and other devices. The Test Methods provide empirical determinations of Sensitivity, gain and noise limi 12 dB SINAD, Quieting and Squelch sensitivity. The evaluation is related to teria expressed in the ROC and MN requirements. These procedures were devel from NBSIR 73-333 modified for receivers up to 400 MHz.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-105 11 July 1980
Test Operations Procedure 6-2-544
AD NO. A088149

RADIO RECEIVER SENSITIVITY (NON-PULSED)

1.0 SCOPE

The objective of this test operations procedure is to standardize methods for determining the sensitivity of analog radio frequency receiving equipment, and similar devices.

2.0 FACILITIES AND INSTRUMENTATION

2.1 Facilities - A shielded enclosure or room is required which provides 100 dB attenuation of all (RF) radiated fields and 100 dB attenuation of conducted interference on the power lines in the test frequency range. Refer to MIL-STD-449* for details, and appendix C for test conditions. (If desired, field measurements may be conducted in areas free from the interference which could affect results.)

CHARACTERISTIC	TOLERANCE
RF shielding, room	95-100 dB or greater
RF Line Filtering	95-100 dB or greater
Powerline, Volts/Freq	$\pm$5 percent

*MIL-STD-449D Radio Frequency Spectrum Characteristics, Measurement of, 23 Feb 1973 and Notice 1.

2.2 Instrumentation

ITEM/CHARACTERISTICS	TOLERANCE
Frequency Counter	±1 ppm (parts per million)
Time Domain Reflectometer	0.001 sensitivity
RF Signal Generator with Amplitude Modulation	
Frequency	±2 ppm
Amplitude (power)	±2.0 dB of setting
Audio Oscillator	
Frequency	±2 percent
Distortion	Less than ±2 percent
True rms Voltmeter	Less than ±1 percent in range from 50 Hz to 1 GHz
Frequency Selective Voltmeter (Field Intensity Meter)	±2.0 dB
AF Power Meter	±2 percent
Impedance Matching Network	±3 percent
Distortion Analyzer:	
Input Impedance	>100 K ohms
Harmonic Measurement	±3 percent full scale
Frequency	±5 percent
Narrowband rejection filter precision type insertion loss	±0.5 dB
Dummy load or terminating resistor output impedance	±5 percent resistance
Oscilloscope,*	
Horizontal Deflection	±3 percent
Vertical Deflection	±2 percent

*The quoted accuracy is the tolerance for the instrument and does not reflect the accuracy of the measured signal. (Equivalent to HP 180 series with TDR plug-in HP-1818A.)

3. PREPARATION FOR TEST

3.1 Facilities - Assure facilities conform to minimum requirements. Inspect carefully for defects and possible damage.

3.2 Equipment - No specialized equipment required. However, a spectrum analyzer may be useful in resolving problems.

3.3 Instrumentation - Set up all instrumentation to be used. Using the manuals make careful check of the controls, meters and voltage/power levels.

3.4 Data Required - Record the following:

3.4.1 Test Item: Type, serial number and nomenclature, and characteristics as suggested in MIL-STD-449D, Method CS101.

3.4.2 Instrumentation: Type, model, serial number, manufacturer and calibration date.

3.4.3 Personnel Data: Technicians' names and MOS/Series, if applicable.

4. TEST CONTROLS

4.1 All measuring instrumentation and the test item will be set up in the screen room to minimize the effects of interfering signals, or in a field area having low interference levels as determined by measurement.

4.2 The output impedance of the rf signal generator must match the input impedance of the test item to permit maximum power transfer. A 6 dB matching pad is used if required at the output of the generator.

4.3 The rf network impedance will be checked using time domain reflectometer *(TDR) techniques to determine the existence of any discontinuities, and to confirm the match.

4.4 The test item output will be terminated by its designed impedance to enable proper simulation of loading. The effect of measuring instrumentation input impedance will be included in the determination of the dummy load to be used.

4.5 The standard test frequencies will be the 10, 50 and 90 percent points in each frequency band as a minimum as specified in MIL-STD-449D.

4.6 Turn all instruments and test item on and allow them to attain thermal equilibium.

4.7 The open circuit output voltage of the rf signal generator will be recorded.

*HP 180 Oscilloscope with TDR plug-in HP-1818A, or equivalent.

4.8 The bandwidth of the narrow band rejection filter will be much less than the audio bandwidth of the test item. Its center frequency will be f_1 as defined in 4.9 below.

4.9 The audio output frequency, f_1, will be 1000 Hz, unless otherwise specified. Therefore, the modulating signal for AM and FM receivers shall be a tone of constant frequency, f_1 and the modulating signal for SSB and BFO equipped receivers shall be a CW waveform of frequency $f_o \pm f_1$ where f_o is a standard test frequency.

5. PERFORMANCE TESTS

5.1 Sensitivity General Ref. NBSIR 7.3-333* et al

The sensitivity of a receiver is a measure of its ability to receive weak signals. To express this ability in quantitative terms, sensitivity is broadly defined as the smallest R.F. input signal necessary to produce an acceptable demodulated output signal. Several types of sensitivity are defined to provide for different types of receivers and different receiving requirements. Of these, the following types are described, and measurement methods are given:

Sensitivity (Gain-Limited AM receivers)

6 dB SN/N sensitivity (AM receivers). Noise limited (NL)

12 dB SINAD sensitivity (AM and FM receivers), NL (para 5.4)

Quieting sensitivity (FM receivers)

Squelch sensitivity (AM and FM receivers)

(Noise Factor in AM and FM receivers, is treated in footnote reference.*)

5.2 SENSITIVITY OF A GAIN-LIMITED AM RECEIVER

5.2.1 Definitions

a. The sensitivity of a gain-limited AM receiver is the open circuit output voltage, in microvolts, from a signal generator amplitude modulated 30 percent with a 1000 Hz sinusoid, that will produce 50% rated audio output power at the receiver output terminals.

b. A gain-limited receiver is a receiver whose gain and internal noise are such that, when its input termination has a noise temperature of 290 K, rated audio output power cannot be produced by amplification of system noise alone. Therefore, 50% of the rated audio output power is used as reference.

*NBSIR 73-333 Test Procedures Handbook, M.G. Arthur 11/73. EM Div., NBS, Boulder, Colorado.

5.2.2 Purpose

The purpose of this measurement method is to measure the sensitivity of gain-limited AM receivers. For such receivers, sensitivity is essentially a measure of the total receiver gain. The method ignores the effects of distortion; therefore, for non-linear receivers it does not yield accurate results.

5.2.3 Method

The method uses an amplitude modulated signal generator and a voltmeter or power meter as shown in figure 1. The signal generator supplies a known voltage to the receiver at the measurement frequency. The voltmeter or power meter indicates the receiver output signal level.

5.2.4 Results

Measurement uncertainties as small as 3 percent are possible under the best conditions and range from about 5 percent to 20 percent, typically. Obviously, this is due to the inherent characteristics of gain-limited AM receivers.

5.2.5 Procedure, Gain Limited AM Recevier Figure 1, Section 5.2 or 5.2'.

a. Connect the input port of the receiver to the output port of the SIGNAL GENERATOR through an IMPEDANCE MATCHING NETWORK that provides the specified source impedance, Z_s, to the receiver at the measurement frequency, f_o. If the signal generator output impedance equals Z_s, no matching network is required.

b. Connect the TERMINATION RESISTOR having a resistance equal to the specified load resistance, R_ℓ, and a power rating in excess of the receiver's rated audio output power level P_o, to the audio output port of the receiver. Connect the ac VOLTMETER ACROSS THIS RESISTOR, CALCULATE, $P_o = E_o^2/R_\ell$. Adjust the Signal Generator to give E_o output.

c. Alternately, connect a Power Meter of the proper impedance, R_ℓ, to the audio output of the receiver, set P_o directly.

d. Set the power meter on a range to indicate the reference output power, P_o. Set receiver controls as given in table I.

5.2.5.1 Tune the signal generator and the receiver to the measurement frequency, f_o. Adjust the amplitude modulation in the signal generator to 30 percent at 1000 Hz. Adjust the output level of the signal generator to give reference audio power output, P_o, from the receiver.

5.2.5.2 Determine the open circuit signal voltage, E_1, in microvolts, at the OUTPUT TERMINALS of the matching network, if used; otherwise, at the output terminals of the generator. This is the SENSITIVITY of the receiver at frequency f_o.

TABLE I. AM RECEIVER, GAIN-LIMITED
(Except as Noted)
Initial Control Settings

Control	Setting
1. Band Switch	1. As desired
2. Frequency Tuning	2. As desired
3. Antenna Trimmer	3. Peak
4. RF Gain	4. Maximum[1]
5. IF Gain	5. Maximum[2]
6. AF Gain	6. Maximum rated P_o[3]
7. Line Gain	7. Optional
8. Detector Mode	8. AM
9. Beat Frequency Oscillator	9. OFF
10. BFO Frequency	10. N.A.
11. IF Bandwidth	11. As desired
12. AF Bandwidth	12. As desired
13. Noise Limiter	13. OFF
14. Squelch Level	14. OFF
15. AGC/MGC Mode Switch	15. MGC[4]
16. Meter Switch	16. Optional

[1] For Noise-limited receiver, 6 dB SN/N use highest setting of either IF or RF gain that does not produce clipping.

[2] Adjust as in Sec 5.4.4d Note, for 6 dB SN/N Noise limited receiver.

[3] Adjust the AF gain control per Sec 5.4.4.2 for 12 dB SINAD and 5.4.4.3 for 6 dB SINAD.

[4] Set, "As Desired" for 12 dB SINAD.

5.2.6 Data Required

a. Record the measurement frequency, f_o, in kilohertz or megahertz.

b. Record the value of source impedance, Z_s, in ohms, connected to receiver input port.

c. Record the value of termination resistance, R_ℓ, in ohms, connected to receiver audio output terminals. Record the output voltage, E_o, in volts

OR, alternately: Record the reference output power, P_o, in watts.

d. Record the open circuit signal voltage, E_i, in microvolts, at the output terminals of the matching network, if used; otherwise, at the output terminals of the generator. E_i is the sensitivity of the receiver.

5.2.7 Measurement Errors

The principal sources of the measurement error are the following:

a. Uncertainty, ΔE_i in the measured value of E_i.

b. Uncertainty, ΔE_i in the measured value of E_o. OR, Uncertainty, P_o, in the measured value of P_o.

c. The total relative uncertainty, ΔE_i (%), in the receiver sensitivity, E_i, expressed as a percent, is given by the equations:

$$\Delta E_i' (\%) = \left(\frac{\Delta E_i}{E_i} \times 100\% + \frac{\Delta E_o}{E_o} \times 100\%\right)$$

OR

$$\Delta E_i' (\%) = \left(\frac{\Delta E_i}{E_i} \times 100\% + \frac{1}{2}\frac{\Delta P_o}{P_o} \times 100\%\right). *$$

The uncertainty, ΔE_i, is obtained from the manufacturer's specifications on the output level indication of the signal generator. Uncertainties ΔE_o and/or ΔP_o are obtained from the manufacturers's specifications on the voltmeter and/or power meter, respectively.

5.3 6 dB SN/N SENSITIVITY OF A NOISE-LIMITED AM RECEIVER

5.3.1 Definitions and Purpose

a. The 6 dB SN/N sensitivity of a noise-limited AM receiver is the open circuit output voltage, in microvolts, from a signal generator amplitude

*NBSIR 73-333 Test Procedures Handbook, M. G. Arthur Oct 73 EM Div, IBS, NBS Boulder, Colorado 80302.

modulated 30 percent with a 1000 Hz sinusoid, that will produce a signal-plus-noise-to-noise ratio (SN/N) of 4 (6 dB) at the reference audio output power level from the receiver output terminals.

b. A noise-limited receiver is a receiver whose gain and internal noise are such that, when its input termination has a noise temperature of 290 K, reference audio output power can be produced in its output termination by amplification of system noise alone.

c. Purpose

The purpose of this measurement method is to measure the 6 dB SN/N sensitivity of noise-limited AM receivers. For such receivers, 6 dB SN/N sensitivity is essentially a measure of the smallest signal that has a usable strength. The method ignores the effects of distortion; therefore, for non-linear receivers it does not yield accurate results.

5.3.2 Method

a. The method uses an amplitude modulated signal generator and a power meter or true rms voltmeter as shown in figure 1. The signal generator supplies a known voltage to the receiver at the measurement frequency. The voltmeter or power meter indicates the receiver output signal level.

b. The generator level is adjusted to the open circuit output voltage that will produce a 6 dB signal-plus-noise-to-noise ratio at reference audio output power from the receiver. This voltage is the 6 dB SN/N sensitivity of the receiver.

5.3.3 Procedures, 6 dB SN/N Figure 1, Section 5.3 or 5.3'.

a. Connect the receiver and signal generator etc as indicated in Section 5.2.5a and 5.2.5b.

b. Connect the Termination Resistor R_ℓ as in section 5.2.5b.

c. Set the RMS Voltmeter, connected across R_ℓ, to a range to read E_o, given by $E_o = \sqrt{P_o R}$. P_o is referenced power output.

OR, Connect the Power Meter with impedance R_ℓ, to audio output terminals. Set the Power Meter to a scale to read P_o.

d. Set the Receiver controls as indicated on table I. (Observe Notes)

5.3.4 Adjustments

5.3.4.1 Tune the signal generator and the receiver to the measurement frequency f_o. Set the modulation frequency (AM) to 30 percent at 1000 Hz.

5.3.4.2 With the signal generator connected and its output level set to zero, adjust the receiver AF gain control to produce 25 percent of reference audio output power, P_o. This will be noise power only.

a. Adjust the output level of the signal generator to give reference audio output power, P_o. This will be approximately 25 percent noise power and 75 percent audio signal power (1000 Hz), and corresponds to a 6 dB signal-plus-noise-to-noise ratio (SN/N) sensitivity.

b. Determine the open circuit signal voltage, E_i, in microvolts, at the OUTPUT TERMINALS of the matching network, if used; otherwise, at the output terminals of the generator. This is the 6 dB SN/N SENSITIVITY of the receiver at the frequency f_o.

5.3.5 Data Required

a. f_o in kHz or MHz.

b. Source Impedance Z_s in ohms at receiver input port.

c. Terminal resistance R_ℓ at receiver audio output.

d. Receiver output voltage E_o, RMS volts or, if a power meter was used.

e. Receiver output power, P_o in watts.

f. Record the open circuit signal voltage E_i, in microvolts, at the output terminal of the network if used; otherwise at the output terminals of the generator. E_i is the 6 dB SN/N SENSITIVITY of the receiver.

5.3.6 Measurement Errors. Same calculations as in section 5.2.7.

5.4 SENSITIVITY, 12 dB SINAD

Noise-limited AM Receiver or an FM receiver, as noted.

5.4.1 General

a. SINAD is an acronym for "Signal plus Noise plus Distortion to Noise plus Distortion Ratio."

$$\text{SINAD} = \frac{S + N + D}{N + D} = \frac{P(s + n + d)}{P(n + d)}.$$

b. The 12 dB SINAD sensitivity of a noise-limited AM receiver is the open-circuit output voltage, in microvolts, from a signal generator amplitude modulated 30 percent with a 1000 Hz sinusoid, that will produce a SINAD of 16 (12 dB) at no less than 50 percent of the reference audio output power from the receiver output terminals.

c. A noise-limited receiver is a receiver whose gain and internal noise are such that, when its input termination has a noise temperature of 290 K, reference audio output power can be produced in its output termination by amplification of system noise alone.

d. The purpose of this measurement method is to measure the 12 dB SINAD sensitivity of noise-limited AM receivers. For such receivers, SINAD sensitivity is a measure of the smallest typical signal that has usable strength and that produces an audio output signal of acceptable quality. The method takes into account the effects of distortion within the receiver; therefore, it can be a more meaningful measure of sensitivity than 6 dB SN/N sensitivity for real-world receivers.

5.4.2 Method and Uncertainties

a. The method uses an amplitude modulated signal generator and an audio distortion analyzer as shown in figure 1. The signal generator supplies a known voltage to the receiver at the measurement frequency. The distortion analyzer measures the power in the audio output from the receiver under two conditions; viz., (a) with the 1000 Hz modulating signal present, and (b) with the 1000 Hz modulating signal filtered from the audio output power. The generator level is adjusted to the open circuit output voltage that causes the ratio of (a) to (b), above, expressed in decibels, to be 12 dB. This voltage is the 12 dB SINAD sensitivity of the receiver.

b. Measurement uncertainties as small as 5 percent are possible under best conditions, and range from approximately 8 percent to 30 percent typically. This method uses commonly available test equipment of moderate sophistication.

5.4.3 Test Equipment Required

Signal generator capable of amplitude modulation.

Input impedance matching network.

Termination resistor for receiver audio output port.

Audio distortion analyzer.

5.4.4 Procedure, 12 dB SINAD Sensitivity Figure 1, Section 5.4.

a. Connect the input port of the receiver to the output port of the SIGNAL GENERATOR through an IMPEDANCE MATCHING NETWORK that provides the specififed source impedance, Z_s, to the receiver at the measurement frequency, f_o. If the signal generator output impedance equals Z_s, no matching network is required.

b. Connect the TERMINATION RESISTOR having a resistance equal to the specified load resistance, R_ℓ, and a power rating in excess of the receiver's rated audio output power level, to the audio output port of the receiver. Connect the audio DISTORTION ANALYZER across this resistor.

c. Set the distortion analyzer on a range to indicate the reference output power, P_o.

d. Set receiver controls as given in table I.

Note: Check to make sure the maximum gain setting does not produce signal clipping or compression in the latter IF amplifier stages. If clipping or compression occurs, reduce RF or IF gain. Also Notes in table I.

5.4.4.1 Tune the signal generator and the receiver to the measurement frequency, f_o. Adjust the amplitude modulation in the signal generator to 30 percent at 1000 Hz. Set the signal generator output level to 1000 microvolts. For an FM Receiver set the frequency modulation to 60 percent at 1000 Hz.

5.4.4.2 Adjust the receiver AF gain control to produce reference audio output power, P_o. This is $P_{(s+n+d)}$.

a. Adjust the distortion analyzer so that the 1000 Hz rejection filter tunes out the 1000 Hz modulation from the signal generator. Measure the noise plus distortion output power, $P_{(n+d)}$.

b. Calculate SINAD ratio, in decibels, from the equation

$$\text{SINAD (dB)} = 10 \log \frac{P_o}{P_{(n+d)}}$$

5.4.4.3 If SINAD calculated in Step 5.4.4.2b is greater (or less) than 12 dB, decrease (or increase) the signal generator output by 3 dB or smaller and repeat all steps in 5.4.4.2. Continue this procedure until 12 dB SINAD is obtained.

Note: If 12 dB SINAD cannot be reached by INCREASING the signal generator output, the receiver is probably distortion-limited. In this case, and alternate reference SINAD such as 6 dB may be used.

5.4.4.4 Determine the open circuit signal voltage, E_i, in microvolts, at the OUTPUT TERMINALS of the matching network, if used; otherwise, at the output terminals of the generator. This is the 12 dB SINAD SENSITIVITY of the receiver at frequency f_o. (IF a 6 dB SINAD was necessary enter this change.)

5.4.5 Data Required

a. Record the measurement frequency, f_o, in kHz of MHz.

b. Record the value of source impedance, Z_s, in ohms, connected to receiver input port.

c. Record the value of termination resistance, R_ℓ, in ohms, connected to receiver audio output terminals.

d. Record the reference output power, P_o, in watts, $P_{(s+n+d)}$.

e. Record the noise plus distortion power in watts, $P_{(n+d)}$.

f. Record the SINAD ratio in decibels.

g. Record the open circuit signal voltage, E_i, in microvolts, at the output terminals of the matching network, if used; otherwise, at the output terminals of the generator. E_i is the 12 dB SINAD sensitivity of the receiver. (If a 6 dB SINAD, so note.)

5.4.6 Measurement Errors

The principal sources of measurement error are the following:

a. Uncertainty, ΔE_i, in the measured value of E_i.

b. Uncertainty, ΔP_o, in the measured value of P_o.

c. Uncertainty, ΔP_{n+d}, in the measured value of P_{n+d}.

The total relative uncertainty, ΔE_i (%), in the 12 dB SINAD sensitivity, E_i, expressed as a percent, is given by the equation:

$$\Delta E_i\ (\%) = \left(\frac{\Delta E_i}{E_i} \times 100\% + \frac{1}{2}\ \frac{\Delta P_o}{P_o} \times 100\% + \frac{1}{2}\ \frac{\Delta P_{n+d}}{P_{n+d}} \times 100\%\right).*$$

The uncertainty, E_i, is obtained from the manufacturer's specifications on the output level indication of the signal generator. Uncertainties ΔP_o and ΔP_{n+d} are obtained from the manufacturer's specifications on the distortion analyzer.

5.5 QUIETING SENSITIVITY OF AN FM RECEIVER WITH ONE OR MORE LIMITERS

5.5.1 General

a. The quieting sensitivity of a receiver is the minimum amount of signal from an unmodulated standard input signal source that is required to produce 20 decibels of noise quieting measured at the receiver audio output. EIA RS-204-72.*

*NBSIR 73-333 Test Procedures Handbook, M.G. Arthur, Oct 73, NBS

b. Noise quieting is the reduction of audio noise output power caused by the presence of an input signal to the receiver.

c. Purpose

The purpose of this measurement method is to measure the quieting sensitivity of FM receivers containing one or more amplitude limiter stages preceding the FM demodulator circuit. For such receivers, quieting sensitivity is a measure of the degree to which its limiters suppress amplitude fluctuations such as external and internal noise signals. The method ignores the effects of non-linearity in the audio stages; therefore, it may yield slightly inaccurate results.

5.5.2 Method

a. The method uses an unmodulated signal generator and a true rms voltmeter or power meter as shown in figure 1. The signal generator supplies a known voltage to the receiver at the measurement frequency. The voltmeter or power meter indicates the receiver output noise power level.

b. The generator level is adjusted to the open circuit output voltage that produces 20 dB of noise quieting as measured with the voltmeter or power meter. This voltage is the quieting sensitivity of the receiver.

c. Measurement uncertainties as small as 3 percent are possible under best conditions, and range from approximately 5 percent to 20 percent under typical conditions. This method uses rudimentary and commonly available test equipment.

5.5.3 Test Equipment Required

CW signal generator

Input impedance matching network

Termination resistor for receiver audio output port

AF power meter OR,

True rms voltmeter

5.5.4 Procedure Figure 1, Section 5.5 or 5.5'

a. Connect the input port of the receiver to the output port of the SIGNAL GENERATOR through an IMPEDANCE MATCHING NETWORK that provides the specified source impedance, Z_s, to the receiver at the measurement frequency, f_o. If the signal generator output impedance equals Z_s, no matching network is required.

*Reference EIA RS-204-72, Minimum Standards for Land mobile FM and PM Receivers 25-470 MHz.

b. Connect the TERMINATION RESISTOR having a resistance equal to the specified load resistance, R_ℓ, and a power rating in excess of the receiver's rated audio output power level, to the audio output port of the receiver. Connect the TRUE RMS VOLTMETER across this resistor; OR, connect the POWER METER, having an input impedance equal to the specified load resistance, R_ℓ, to the audio output port of the receiver.

c. Set the voltmeter on a range to indicate 25 percent of the rated output power, P_o. The voltage to be measured is given by the equation:

$$E_o = 0.5 \sqrt{P_o R_\ell} = \sqrt{\frac{1}{4} P_o R_\ell}$$

OR, Set the power meter on a range to indicate 25 percent of the rated output power, P_o. The power to be measured by the equation:

$$P_o = E_o^2/R_\ell$$

d. Set receiver controls as given in table II.

e. Tune the signal generator and the receiver to the measurement frequency, f_o.

f. Adjust the signal generator so that the signal is unmodulated.

g. With the signal generator connected and its output set to zero, adjust the receiver AF gain control to produce 25 percent of rated audio output power, P_o. This will be noise power only, equal to 0.25 P_o.

h. Increase the output level of the signal generator until the audio output noise power level is reduced to 0.25 percent of P_o (0.0025 P_o).

This is a reduction to 20 dB below the level indicated in Step g above.

Note: If the output noise power level cannot be reduced to 0.25 percent of P_o, select some other target value such as 2.5 percent of P_o (reduction of 10 dB). This would be 10 dB quieting.

i. Determine the open circuit signal voltage E_i, in microvolts, at the OUTPUT TERMINALS of the matching network, if used; otherwise, at the output terminals of the generator. This is the 20 dB QUIETING SENSITIVITY of the receiver at the frequency f_o (or 10 dB).

5.5.5 Data Required

a. Record the measurement frequency, f_o, in kilohertz of megahertz.

b. Record the value of source impedance, Z_s, in ohms, connected to receiver input port.

c. Record the value of termination resistance, R_ℓ, in ohms, connected to receiver audio output terminals.

TABLE II. QUIETING SENSITIVITY INITIAL CONTROL SETTINGS

Control	Setting
1. Band Switch	1. As desired
2. Frequency Tuning	2. As desired
3. Antenna Trimmer	3. Peak
4. RF Gain	4. Maximum
5. IF Gain	5. Maximum
6. AF Gain	6. As required
7. Line Gain	7. Optional
8. Detector Mode	8. FM
9. Beat Frequency Oscillator	9. OFF
10. BFO Frequency	10. N.A.
11. IF Bandwidth	11. As desired
12. AF Bandwidth	12. As desired
13. Noise Limiter	13. OFF
14. Squelch Level	14. OFF
15. AGC/MGC Mode Switch	15. As desired
16. Meter Switch	16. Optional

d. Record the measured output voltage, 0.1 E_o, in volts, or the measured output power, 0.0025 P_o, in watts, from Step h above. (If the 10 dB, or other, level of quieting sensitivity is measured, record the measured values of output voltage or power for this criterion.)

e. Record the open circuit signal voltage, E_i in microvolts, at the output terminals of the matching network, if used; otherwise, at the output terminals of the generator. E_i is the quieting sensitivity of the receiver.

5.5.6 Measurement Errors

The principal sources of measurement error are the following:

a. Uncertainty, ΔE_i, in the measured value of E_i.

b. Uncertainty, ΔE_o, in the measured value of E_o.

c. Uncertainty, ΔP_o, in the measured value of P_o.

The total relative uncertainty, E_i (%), in the receiver sensitivity, E_i, expressed as a percent, is given by the equations:

$$\Delta E_i\ (\%) = \left(\frac{\Delta E_i}{E_i} \times 100\% + \sqrt{2}\,\frac{\Delta E_o}{E_o} \times 100\%\right). *$$

or

$$\Delta E_i\ (\%) = \left(\frac{\Delta E_i}{E_i} \times 100\% + \frac{\sqrt{2}}{2}\,\frac{\Delta P_o}{P_o} \times 100\%\right). *$$

The uncertainty, ΔE_i, is obtained from the manufacturer's specifications on the output level indication of the signal generator. Uncertainties ΔE_o and/or ΔP_o are obtained from the manufacturer's specifications on the voltmeter and/or power meter, respectively.

5.6 SQUELCH SENSITIVITY

5.6.1 General

a. Definition

The audio squelch sensitivity of a receiver is the minimum value of the standard test input signal source, which, when modulated at standard test modulation, will open the receiver squelch. (EIA RS-204)

b. The purpose of this measurement method is to measure the squelch sensitivity of AM or FM receivers. This parameter is a measure of receiver's ability to break squelch on a weak signal.

c. The method uses an amplitude or frequency modulated signal generator and an audio distortion analyzer as shown in figure 1. The signal generator supplies a known input voltage to the receiver at the measurement frequency. The distortion analyzer measures the power in the audio output from the receiver. With the generator output level set to zero, the squelch control is adjusted to reduce the audio noise output power to at least 40 dB below the unsquelched value. Then the generator level is adjusted to the voltage that causes a continuous audio output level that is no less than 10 dB below reference output power. This voltage is the squelch sensitivity of the receiver.

*NBS 73-333 Test Procedures Handbook, M.G. Arthur, Oct 73, NBS.

TABLE III. SQUELCH SENSITIVITY
INITIAL CONTROL SETTINGS

Control	Setting
1. Band Switch	1. As desired
2. Frequency Tuning	2. As desired
3. Antenna Trimmer	3. Peak
4. RF Gain	4. Maximum
5. IF Gain	5. Maximum
6. AF Gain	6. As required
7. Line Gain	7. Optional
8. Detector Mode	8. AM, FM, as desired
9. Beat Frequency Oscillator	9. OFF
10. BFO Frequency	10. N.A.
11. IF Bandwidth	11. As desired
12. AF Bandwidth	12. As desired
13. Noise Limiter	13. OFF
14. Squelch Level	14. As required
15. AGC/MGC Mode Switch	15. As desired
16. Meter Switch	16. Optional

k. Adjust the squelch control to reduce the audio output power to at least 0.0001 P_n (40 dB below P_n), or lower if the squelch is a triggered system.

l. Increase the generator output to the first (lowest) level that just produces a continuous audio output power level that is no less than 10 dB below reference output power, P_o.

m. Determine the open circuit signal voltage, E_s, in microvolts, at the OUTPUT TERMINALS of the matching network, if used; otherwise at the output terminals of the generator. This is the SQUELCH SENSITIVITY of the receiver at frequency f_o.

5.6.4 Data Required

a. Record the measurement frequency, f_o, in kilohertz or megahertz.

b. Record the value of source impedance, Z_s, in ohms, connected to receiver input port.

c. Record the value or termination resistance, R_ℓ, in ohms, connected to receiver audio output terminals.

d. Record the reference output power, P_o, in watts.

e. Record the 12 dB SINAD sensitivity, E_i, in microvolts.

f. Record the output noise power, P_n, in milliwatts.

g. Record the squelch sensitivity, E_s, in microvolts.

5.6.5 Measurement Errors

The principal sources of measurement error are the following:

a. Uncertainty, ΔE_s, in the measured value of E_s.

b. Uncertainty, ΔP_o, in the measured value of P_o.

c. Uncertainty, ΔP_{n+d}, in the measured value of P_{n+d}.

The total relative uncertainty, ΔE_s (%), in the squelch sensitivity, E_s, expressed as a percent, is given by the equation:

$$\Delta E_s'(\%) = \left(\frac{\Delta E_s}{E_s} \times 100\% + \frac{1}{2}\frac{\Delta P_o}{P_o} \times 100\% + \frac{1}{2}\frac{\Delta P_{n+d}}{P_{n+d}} \times 100\%\right).$$

The uncertainty, ΔE_s , is obtained from the manufacturer's specifications on the output level indication of the signal generator. Uncertainties ΔP_o and ΔP_{n+d} are obtained from the manufacturer's specifications on the distortion analyzer.

6. DATA REDUCTION AND PRESENTATION

Refer to appendix C, page C-4, Sections 11 through 15.

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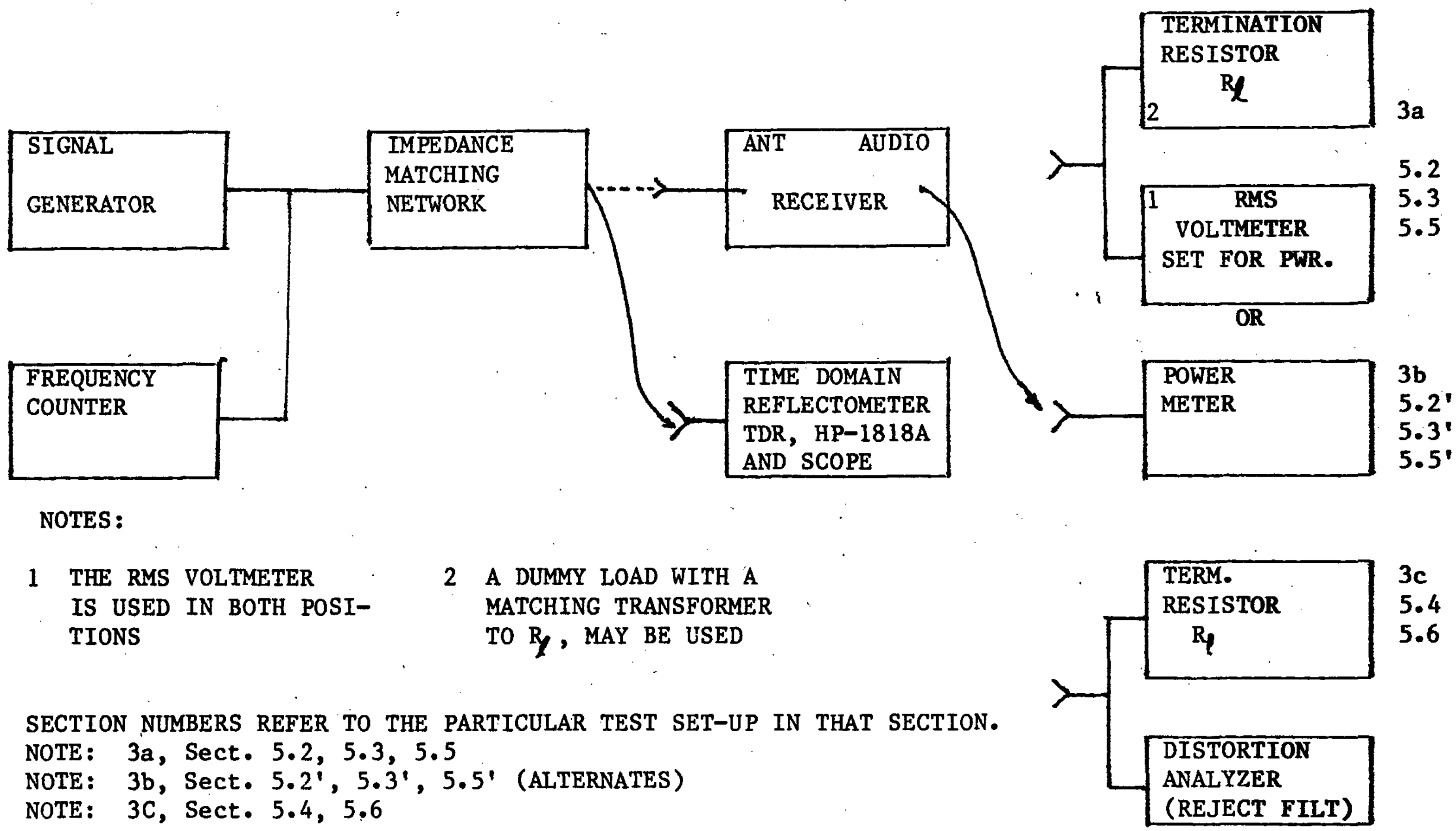

Figure 1. Sensitivity test configurations.

APPENDIX A.

CHECKLIST

RADIO RECEIVER SENSITIVITY (NON-PULSED)

1. Facility. The enclosure is checked for damage reducing its effectiveness. ____________

2. Power Line. Conducted interference is attenuated at least 100 dB and no evident damage to the filters. ____________

3. Instrumentation. Calibration due date will allow completion of the testing or, with recalibration, the test completion date can be met. ____________

4. Record instrumentation data and characteristics. ____________

5. Safety and security measures instituted. ____________

6. Determine that all instruments are in operating condition. ____________

7. Test item turned-on, warm-up time elapsed and all controls functioning; it operates satisfactorily. ____________

8. Test item measurements and data recorded. ____________

9. Personnel taking data, recorded, dated and signed Data Sheets.

APPENDIX B.

DATA RECORD, SENSITIVITY

1. GENERAL

   a. Sample Size (Number of Test Items): ____________

   b. Test Frequencies: ____________

   c. Number of Runs Planned: ____________

   d. Uncertainties of Measurements:

Sections 5.2, 5.3, 5.5	Best Case, Possible 3% Typical, 5 to 20%
Sections 5.4, 5.6	Best Case, Possible 5% Typical, 8 to 30%

2. TEST ITEMS

	Description	Type	Nomenclature	SN
a.				
b.				
c.				
d.				
e.				
f.				

3. INSTRUMENTATION

	Description	Mfg	Model No.	SN	Cal Due	Uncertain
a.						
b.						
c.						
d.						
e.						
f.						

ABBREVIATIONS

f_o	Test Frequency, use primes to designate (f_o', f_o'')
Z_s	Source Impedance, ohms, signal generator or impedance matching network connected to receiver INPUT PORT
R	Termination Impedance, ohms, audio/video
P_o	Reference Output Power, watts, Mfg'r rated power. Also 0.25 P_o, 25% of P_o and 0.0025 P_o, 0.25% of P_o, QUIETING
E_o	Output Voltage, rms from $E_o = \sqrt{P_o R_\ell}$
S_r	SINAD Ratio in dB
E_i	SINAD and all SENSITIVITY in microvolts except SQUELCH. This is an OPEN CIRCUIT signal voltage from the source
E_s	Squelch Sensitivity in microvolts. This is the OPEN CIRCUIT signal voltage of the source.
P_n	Output Noise Power, watts, SQUELCH (Sig gen connected, zero sig out)
$P_{(n+d)}$	Noise + Distortion Output Power watts, SINAD, s+n+d, with signal removed by 1000 Hz rejection filter
$P_{(s+n+d)}$	SINAD Rated Audio Output, P_o. Adjust AF gain to get $P_o = P_{(s+n+d)}$

$$\text{SINAD (dB)} = 10 \log \frac{P_o}{P_{(n+d)}}$$

4. TEST ITEM DESCRIPTION

Type (FM, AM, SSB, etc.) ____________________
Mfg'r ____________________ Model No. ____________________
Modulation Type ____________________ Frequency ____________________

5. DATA

Run No.	1	2	3	4
f_o				
Z_s				
R				
P_o				
E_o				
E_i				
E_s				
P_n				
P_{n+d}				
P_{s+n+d}				
SINAD(dB) = S_r				

6. COMMENTS on test item general performance, problems:

7. PERSONNEL

Data taken by ____________________ Grade ________ MOS ________
Other ____________________
Date ____________________

APPENDIX C.

STANDARD TEST CONDITIONS

1. GENERAL

a. Certain test conditions apply to the majority of these procedures and therefore can be "standardized." Deviations from these standard conditions occur in specific instances, and these are made clear in the appropriate section.

b. These standard test conditions are recommendations only, and may be modified according to the needs of a particular measurement situation. When this is done, the prevailing test conditions should be recorded with the test data so that proper account can be taken thereof, in the interpretation of the measurement results.

2. AMBIENT CONDITIONS

2.1 STANDARD TEMPERATURE

Standard temperature shall be +20°C to +35°C.

2.2 STANDARD RELATIVE HUMIDITY

Standard relative humidity shall be as follows:

a. Zero to 90 percent at 20°C to 30°C.

b. Zero to 79 percent at 30°C to 35°C.

2.3 STANDARD ATMOSPHERIC PRESSURE

Standard atmospheric pressure shall be the ambient atmospheric pressure at the time of the test.

3. PRIMARY INPUT POWER SUPPLY VOLTAGE

Standard input power supply voltage shall be within ±5 percent of the mean of the rated operating voltage range of the receiver, as given in the manufacturer's specifications.

4. ELECTROMAGNETIC COMPATIBILITY CONDITIONS

These tests shall be conducted, as far as practicable, in areas that are sufficiently free from electromagnetic interference fields to allow the measurements to be made without significant adverse effect on the results. Primary input power sources shall be sufficiently filtered to accomplish the same end. Test instrumentation shall be properly shielded, filtered, and grounded so as to minimize erroneous results caused by extraneous signals from these or other sources.

5. RECEIVER PREPARATION

5.1 OPERATING CONDITIONS

When important to the test results, the receiver should be situated so that it closely approximates the physical and electrical conditions in which it is intended to operate. All accessories that may affect test results shall be installed and put into operation.

5.2 RECEIVER CONDITION

Before any measurements are performed, the receiver shall be in proper operating conditon as stated in the receiver manual.

5.3 WARM-UP TIME

Sufficient warm-up time, e.g., from one-half to two hours, shall be provided before any measurements are performed to insure adequate stabilization of the receiver parameters.

6. TEST INSTRUMENTATION PREPARATION

6.1 OPERATING CONDITIONS

Test instruments shall be operated according to the manufacturer's instructions. Check for proper grounding, proper connections of cables and probes, and proper shielding, filtering, and isolation as required. Sufficient warm-up time shall be provided to insure stable operation.

6.2 CALIBRATION

All test equipment must meet the manufacturer's specifications on accuracy and other performance parameters. Information on accuracy, frequency response, spectral purity, etc., must be verified and at hand in order to obtain meaningful results from these tests.

7. TERMINATIONS

All terminations to receiver terminals (ports) shall be of the proper impedance and power rating, as specified by the receiver manufacturer. They shall be adequately shielded to prevent interference to, or from, other parts of the measurement system.

8. TEST FREQUENCIES

No standard test frequencies are stated in this TOP. As written, the discussion covers only one test frequency, however the Test Plan will define the number of tests to be run; each shall be treated as described and completed dated recorded. Generally high, middle, and low frequencies in the receiver band are desirable.

9. SIGNAL LEVELS

9.1 INPUT SIGNAL VOLTAGE

a. No standard input signal level is specified in this handbook. When a specific level is required for a particular test, it is so stated in that test procedure.

b. R.F. input signal levels are expressed in terms of the open circuit voltage across the output terminals of the source of the input signal. If an impedance matching, filter, or attenuating network is used between the signal generator output terminals and the receiver input terminals, the input signal level is the open circuit voltage used, the input signal is the open circuit voltage across the output terminals of the generator.

10. AUDIO OUTPUT POWER

Reference audio output power shall be established for the receiver as one of the following power levels:

a. 50 percent of manufacturer's rated audio output power.

b. Maximum audio output power having a 12 dB SINAD ratio (6.3 percent noise and distortion).

c. Manufacturer's rated audio output power.

d. If other levels are used, state the basis for the output power in the report.

11. DATA REDUCTION

A measurement error is the difference between the true value and the measured value of a quantity.

11.1 Types of Errors

Measurement errors are of two types: systematic and random. A systematic error is the difference between the true value and the limiting mean of a set of measured values of a quantity. A random error is the error caused by a random process, as contrasted with a systematic or deterministic process.

11.2 Origins of Errors

Measurement errors result primarily from uncertainties in the data. They can also result from procedural mistakes; but this source of error can be removed by using care, repeating measurements, cross-checking, and a variety of other procedural methods. Uncertainties in the data come from such sources as (a) uncertainties in the true value of an meter or dial reading, (b) uncertainties in the calibration of an instrument, (c) imprecision in the indicated meter reading due to random fluctuations or poor resolution, (d) variations in the parameter being measured during the measurement interval, and (e) variations caused by human frailties in performing the measurement.

12. ERROR EQUATION

See each section "Measurement Errors". The total measurement error is obtained by means of an error equation. The error equation comes from an error analysis of the measurement process, and contains terms which represent the individual sources of error.

A thorough error analysis of each measurement procedure is beyond the scope of this document. Further, the desired level of precision for these tests does not warrant a highly exhaustive treatment. Therefore, only the principal sources of error have been accounted for in the error equations provided here.

The total error of a measurement normally consist of both systematic and random errors. In general, the error equation applies separately to both types of errors. Thus, the error equation is used twice, once for systematic errors and once for random errors. The total error is then expressed in two parts, viz., a systematic part and a random part. In some cases, one type may predominate over the other, in which case the total error may be substantially systematic or random.

The error equations given in Section 4.0 are primarily for use with systematic uncertainties, although they can also be used with random uncertainties. For proper use of these equations, refer to Section 3.3.5. below.

13. REDUNDANCY

Measurements should be made more than once for the following reasons:

13.1 Gross errors and mistakes may be revealed.

13.2 The average result usually has a smaller error than each individual result.

13.3 The spread of the individual results provides an estimate of the measurement error.

13.4 Repeating the measurement may times can reduce the random error, but it will not reduce the systematic error. Systematic error is reduced by using test equipment having greater inherent accuracy.

13.4.1 Random error is expressed in terms of the standard deviation, s, of the measurement data. It is common practice to take 3s (three standard deviations) as the random error of the measured value of the parameter.

13.4.2 Standard deviation decreases with the square root of n, the number of measurement results. Significant improvements accrue as n increases from one to two to three, but note that the improvement decreases with increasing n. Seldom is it worthwhile to repeat measurements of the type given here more than ten times.

13.5 POOLING ERRORS

a. Independent systematic errors are combined algebraically. That is, if one erro is positive (+) and the other negative (-), the total of these two errors is their algebraic sum. If a systematic error can be either positive or negative ($\pm$) then judgement must be exercised when combining it with other errors. Unless knowledge about an error directs otherwise, the worst-case combination should be used. This normally means that the errors are pooled by adding their absolute values, thus disregarding their algebraic signs. If there is some interdependence (correlation) between individual errors, it may be taken into account to obtain a pooled error that is smaller than their worst-case sum.

b. Random errors are combined on a root-mean-square basis. That is, the two errors, a and b, produce a total error, c, given by the equation:

$$c = ((a)^2 + (b)^2)^{1/2}.$$

When there is a question as to whether an error is systematic or random, usual practice is to pool it with other errors on a worst-case basis.

14. TOTAL RELATIVE UNCERTAINTIES

Refer to sections on "Measurement Errors" to determine the total relative uncertainty.

15. PRESENTATION OF DATA

For each test item and each type of sensitivity test plot all measurements at each frequency within the test item bandwidth on semilog coordinate paper.

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