

U.S. Department of Justice  
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154253 **NIJ**

**National Institute  
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***Technology Assessment  
Program***

# **Personal FM Transceivers**

**NIJ Standard 0209.01**

**NCJRS**

**MAY 19 1995**

**ACQUISITIONS**

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James K. Stewart, Director  
National Institute of Justice

## *Technology Assessment Program*

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**James K. Stewart, Director**

**ACKNOWLEDGMENTS**

This standard was formulated by the Law Enforcement Standards Laboratory of the National Bureau of Standards under the direction of Marshall J. Treado, Program Manager for Communications Systems, and Lawrence K. Eliason, Chief of LESL. NBS Electromagnetic Fields Division staff members responsible for the preparation of this standard were Ramon Jesch, Bill Bensema and Art Wainright. Acknowledgment is given to previous work in this field by the Associated Public-Safety Communications Officers, Inc. and the Electronic Industries Association. This standard has been reviewed and approved by the Technology Assessment Program Advisory Council and adopted by the International Association of Chiefs of Police (IACP) as an IACP Standard.

## FOREWORD

This document, NIJ Standard-0209.01, Personal FM Transceivers, is an equipment standard developed by the Law Enforcement Standards Laboratory of the National Bureau of Standards. It is produced as part of the Technology Assessment Program of the National Institute of Justice. A brief description of the program appears on the inside front cover.

This standard is a technical document that specifies performance and other requirements equipment should meet to satisfy the needs of criminal justice agencies for high quality service. Purchasers can use the test methods described in this standard to determine whether a particular piece of equipment meets the essential requirements, or they may have the tests conducted on their behalf by a qualified testing laboratory. Procurement officials may also refer to this standard in their purchasing documents and require that equipment offered for purchase meet the requirements. Compliance with the requirements of the standard may be attested to by an independent laboratory or guaranteed by the vendor.

Because this NIJ standard is designed as a procurement aid, it is necessarily highly technical. For those who seek general guidance concerning the selection and application of law enforcement equipment, user guides have also been published. The guides explain in nontechnical language how to select equipment capable of the performance required by an agency.

NIJ standards are subjected to continuing review. Technical comments and recommended revisions are welcome. Please send suggestions to the Program Manager for Standards, National Institute of Justice, U.S. Department of Justice, Washington, DC 20531.

Before citing this or any other NIJ standard in a contract document, users should verify that the most recent edition of the standard is used. Write to: Chief, Law Enforcement Standards Laboratory, National Bureau of Standards, Gaithersburg, MD 20899.

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# NIJ STANDARD FOR PERSONAL FM TRANSCEIVERS

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# NIJ STANDARD FOR PERSONAL FM TRANSCEIVERS

## 1. PURPOSE AND SCOPE

The purpose of this document is to establish performance requirements and methods of test for nontrunked frequency modulated (FM) personal transceivers and their associated antennas and power sources. This standard applies to transceivers which either do not have special subsystems such as selective signaling or voice privacy, or in which such subsystems are bypassed or disabled during testing for compliance with this standard. This standard supersedes NILECJ-STD-0209.00 Personal FM Transceivers.

## 2. CLASSIFICATION

For the purpose of this standard, personal FM transceivers are classified by their operating frequencies.

### 2.1 Type I

Transceivers which operate in the 25-50 MHz band with a receiver channel spacing of 20 kHz.

### 2.2 Type II

Transceivers which operate in the 150-174 MHz band with a receiver channel spacing of 30 kHz.

### 2.3 Type III

Transceivers which operate in the 400-512 MHz band with a receiver channel spacing of 25 kHz.

### 2.4 Type IV

Transceivers which operate in the 806-866 MHz band with a receiver channel spacing of 25 kHz.

## 3. DEFINITIONS

The principal terms used in this document are defined in this section. Additional definitions relating to law enforcement communications are given in LESP-RPT-0203.00, Technical Terms and Definitions Used with Law Enforcement Communications Equipment [1]<sup>1</sup>.

### 3.1 Adjacent-Channel Selectivity and Desensitization

The ability of a receiver to discriminate against a signal at the frequency of an adjacent channel.

### 3.2 AM Hum and Noise

The residual amplitude modulation present on an unmodulated carrier.

### 3.3 Audio Harmonic Distortion

Nonlinear distortion characterized by the appearance in the output of integral multiples of an audio-frequency input signal.

<sup>1</sup>Numbers in brackets refer to references in appendix A.

### **3.4 Audio Hum and Noise Power**

The average audiofrequency power dissipated in a load across the output terminals of a receiver having an unmodulated radio frequency (rf) signal input.

### **3.5 Audio Noise Output Power**

The average audiofrequency power dissipated in a load across the output terminals of an unmodulated receiver having no rf signal input.

### **3.6 Audio Output Power**

The audiofrequency power dissipated in a load across the receiver output terminals of an unmodulated receiver having a modulated rf signal input.

### **3.7 Audio Response of a Receiver**

The variation in the output of a receiver as a function of audiofrequency within a specified bandwidth.

### **3.8 Audio Response of a Transmitter**

The degree of precision with which the frequency deviation of a transmitter responds to a designated audiofrequency signal level.

### **3.9 Authorized Bandwidth**

The maximum width of the band of frequencies specified by the Federal Communications Commission (FCC) to be occupied by an emission, i.e., 20 kHz for public-safety agencies[2].

### **3.10 Carrier Attack Time**

The time required for a transmitter to produce 50 percent of the rated carrier output power after the carrier control switch is activated.

### **3.11 Carrier Output Power**

For a transmitter, the rf power available at the antenna terminal when no modulating signal is present.

### **3.12 FM Hum and Noise**

The frequency modulation present on an unmodulated carrier.

### **3.13 Frequency Deviation**

In frequency modulation, the difference between the instantaneous frequency of the modulated carrier and the unmodulated carrier frequency.

### **3.14 Frequency Stability**

The maximum permissible departure by the center frequency of the frequency band occupied by an emission from the assigned frequency.

### **3.15 Intermodulation Attenuation**

The ratio, expressed in decibels, of (1) the level of specified signals that produces an intermodulation response under specified conditions to (2) the receiver's SINAD sensitivity.

### **3.16 Intermodulation Response**

The response resulting from the mixing of two or more frequencies, in the nonlinear elements of a receiver, in which a resultant frequency is generated that falls within the range of frequencies passed by the receiver.



### **3.17 Minimum Usable Bandwidth**

The frequency displacement from the unmodulated carrier frequency, +3 kHz, of an input test signal which is 6 dB above the 12-dB SINAD sensitivity voltage and which produces a 12-dB SINAD ratio.

### **3.18 Modulation Limiting**

That action, performed by an FM transmitter, which intentionally restricts the signal to the required spectral limits by restricting the total deviation of the emission.

### **3.19 Noise Quieting**

The reduction of receiver audio noise output caused by the presence of an incoming rf signal.

### **3.20 Nominal Value**

The numerical value of a device characteristic as specified by the manufacturer.

### **3.21 Occupied Bandwidth**

The width of the frequency band containing those frequencies at which a total of 99 percent of the radiated power appears, extended to include any discrete frequency at which the power is at least 0.25 percent of the total radiated power.

### **3.22 Radiation Efficiency**

The ratio of (1) the maximum effective radiated power in the horizontal plane of a transmitter-antenna system to (2) the transmitter output power into a 50- $\Omega$  load.

### **3.23 Rated Capacity, Battery**

A designation by the battery manufacturer which indicates the approximate capacity, in ampere-hours or milliampere-hours, at typical discharge rates.

### **3.24 Rated System Deviation**

The maximum carrier frequency deviation permitted by the FCC. For law enforcement communications systems, it is  $\pm 5$  kHz.

### **3.25 Receiver Attack Time**

The time required to produce a designated audio output power level upon application of a specified rf input signal, when the squelch control is in the threshold squelch position.

### **3.26 Receiver Closing Time**

The time required to reduce a specified audio output power to a designated level upon removal of the rf input signal, when the squelch control is in the threshold squelch position.

### **3.27 Sampler**

A series device which couples energy over a broad frequency range from a transmission line into a third port. The attenuated output signal from the third port has the same waveform as the original signal.

### **3.28 Selectivity**

The extent to which a receiver is capable of differentiating between the desired signal and signals at other frequencies, some of which may differ only slightly from the desired signal.

### **3.29 Service Life**

The length of time that a primary cell (or battery) or a fully charged secondary cell (or battery) will provide satisfactory service for a transceiver under specified conditions.

### **3.30 Sideband Spectrum**

The emissions generated by a modulated transmitter that are within 250 percent of the authorized bandwidth, i.e.,  $\pm 25$  kHz.

### **3.31 SINAD Ratio**

The ratio, expressed in decibels, of (1) signal plus noise plus distortion to (2) noise plus distortion produced at the output of a receiver; from *Signal Noise And Distortion Ratio*.

### **3.32 SINAD Sensitivity**

The minimum modulated rf signal input level required to produce a specified SINAD ratio at a specified audio output power level.

### **3.33 Spurious Emission**

Any part of the rf output that is not a component of the theoretical output or exceeds the authorized bandwidth.

### **3.34 Spurious and Harmonic Response**

The output of a receiver caused by a signal at a frequency other than that to which the receiver is tuned.

### **3.35 Squelch**

A circuit function for preventing a receiver from producing audio output power in the absence of an rf input signal.

### **3.36 Squelch Block**

A squelched condition resulting from excessive frequency deviation due to a specified rf modulated input signal.

### **3.37 Standby Mode**

The condition of a transceiver when it is energized but not receiving or transmitting.

### **3.38 Standing Wave Ratio (SWR)**

The ratio of the maximum to the minimum amplitudes of the voltage or current appearing along a transmission line.

### **3.39 Threshold Squelch Position**

The adjustment of the squelch control, starting from the maximum unsquelched position, that first reduces the audio noise output power by a specified amount.

### **3.40 Threshold Squelch Sensitivity**

The minimum standard modulated rf signal input level required to unsquelch a receiver when the squelch control is in the threshold squelch position.

### **3.41 Tight Squelch Sensitivity**

The minimum standard modulated rf signal input level required to unsquelch a receiver when the squelch control is in the maximum squelch position.

### **3.42 Transceiver**

The combination of radio transmitting and receiving equipment in a common housing, usually for portable or mobile use.

## 4. REQUIREMENTS

### 4.1 Minimum Performance

The transceiver performance shall meet or exceed the requirement for each characteristic as given below and in tables 1 through 4. The performance requirements listed in tables 1 and 2 meet or exceed those given in the Rules and Regulations published by the FCC [2].

TABLE 1. Minimum performance requirements for receivers used in personal FM transceivers

Receiver characteristic	Minimum requirement Frequency band (MHz)			
	25-50	150-174	400-512	806-866
<b>Sensitivity Characteristics</b>				
A. SINAD Sensitivity	0.4 $\mu$ V	0.4 $\mu$ V	0.4 $\mu$ V	0.4 $\mu$ V
B. SINAD Sensitivity Variance (Supply Voltage Varied +10% and -20%)	0.7 $\mu$ V	0.7 $\mu$ V	0.7 $\mu$ V	0.7 $\mu$ V
<b>Selectivity Characteristics</b>				
C. Minimum Usable Bandwidth	5 kHz	5 kHz	5 kHz	5 kHz
D. Adjacent-Channel Selectivity and Desensitization	60 dB	70 dB	60 dB	70 dB
E. Spurious and Harmonic Response Attenuation	70 dB	60 dB	60 dB	60 dB
F. Intermodulation Attenuation	65 dB	60 dB	60 dB	60 dB
<b>Squelch Characteristics</b>				
G. Threshold Squelch Sensitivity	0.3 $\mu$ V	0.3 $\mu$ V	0.3 $\mu$ V	0.3 $\mu$ V
H. Tight Squelch Sensitivity	2.5 $\mu$ V	2.5 $\mu$ V	2.5 $\mu$ V	2.5 $\mu$ V
I. Threshold Squelch Sensitivity Variance (Supply Voltage Varied +10% and -20%)	0.45 $\mu$ V	0.6 $\mu$ V	0.6 $\mu$ V	0.6 $\mu$ V
J. Squelch Block	$\pm 5$ kHz	$\pm 5$ kHz	$\pm 5$ kHz	$\pm 5$ kHz
K. Receiver Attack Time	150 ms	150 ms	150 ms	150 ms
L. Receiver Closing Time	250 ms	250 ms	250 ms	250 ms
<b>Audio Characteristics</b>				
M. Audio Output Power (Loudspeaker)	500 mW	500 mW	500 mW	500 mW
N. Audio Output Power (Earphones)	3-12 mW	3-12 mW	3-12 mW	3-12 mW
O. Audio Output Power Variance (Supply Voltage Varied +10% and -20%)	3 dB	3 dB	3 dB	3 dB
P. Audio Distortion	10%	10%	10%	10%
Q. Audio Response (Loudspeaker)	-10,+2 dB	-10,+2 dB	-10,+2 dB	-10,+2 dB
R. Audio Response (Earphones)	-10,+2 dB	-10,+2 dB	-10,+2 dB	-10,+2 dB
S. Audio Hum and Noise (Unsquelled)	40 dB	40 dB	40 dB	40 dB
T. Audio Hum and Noise (Squelled)	50 dB	50 dB	50 dB	50 dB
<b>Temperature Stability</b>				
U. SINAD Sensitivity	6 dB	6 dB	6 dB	6 dB
V. Minimum Usable Bandwidth	20%	20%	20%	20%
W. Adjacent-Channel Selectivity and Desensitization	12 dB	12 dB	12 dB	12 dB
X. Tight Squelch Sensitivity	6 dB	6 dB	6 dB	6 dB
Y. Threshold Squelch Sensitivity	6 dB	6 dB	6 dB	6 dB
Z. Audio Output Power	6 dB	6 dB	6 dB	6 dB

TABLE 1. Minimum performance requirements for receivers used in personal FM transceivers—Continued

Receiver characteristic	Minimum requirement Frequency band (MHz)			
	25-50	150-174	400-512	806-866
AA. Audio Hum and Noise	10 dB	10 dB	10 dB	10 dB
AB. Audio Distortion	18%	18%	18%	18%
Humidity Stability				
AC. SINAD Sensitivity	10 dB	10 dB	10 dB	10 dB
AD. Minimum Usable Bandwidth	20%	20%	20%	20%
AE. Adjacent-Channel Selectivity and Desensitization	12 dB	12 dB	12 dB	12 dB
AF. Tight Squelch Sensitivity	10 dB	10 dB	10 dB	10 dB
AG. Threshold Squelch Sensitivity	10 dB	10 dB	10 dB	10 dB
AH. Audio Output Power	3 dB	3 dB	3 dB	3 dB
AI. Audio Hum and Noise	10 dB	10 dB	10 dB	10 dB
AJ. Audio Distortion	18%	18%	18%	18%

TABLE 2. Minimum performance requirements for transmitters used in personal FM transceivers

Transmitter characteristic	Minimum requirement Frequency band (MHz)			
	25-50	150-174	400-512	806-866
Radio Frequency Carrier Characteristics				
BA. Carrier Output Power Variance	-0.3 dB	-0.3 dB	-0.3 dB	-0.3 dB
BB. Output Power Variance (Supply Voltage Varied $\pm 10\%$ )	-3 dB	-3 dB	-3 dB	-3 dB
BC. Output Power Variance (Supply Voltage Varied $-20\%$ )	-6 dB	-6 dB	-6 dB	-6 dB
BD. Carrier Frequency Tolerance	0.002%	0.0005%	0.0005%	0.00025%
BE. Frequency Stability (Supply Voltage Varied $\pm 15\%$ )	0.002%	0.0005%	0.0005%	0.00025%
BF. AM Hum and Noise Level	34 dB	34 dB	34 dB	34 dB
BG. Carrier Attack Time	100 ms	100 ms	100 ms	100 ms
Audio Modulation Characteristics				
BH. Audio Harmonic Distortion	5%	5%	5%	5%
BI. FM Hum and Noise Level	40 dB	40 dB	40 dB	40 dB
BJ. Audio Response	+1, -3 dB	+1, -3 dB	+1, -3 dB	+1, -3 dB
BK. Frequency Deviation	5%	5%	5%	5%
BL. Modulation Limiting	$\pm 5$ kHz	$\pm 5$ kHz	$\pm 5$ kHz	$\pm 5$ kHz
Electromagnetic Compatibility Characteristics				
BM. Radiated Spurious Emissions	43 dB	43 dB	43 dB	43 dB
BN. Sideband Spectrum ( $\pm 10$ kHz Frequency Separation)	25 dB	30 dB	30 dB	30 dB
BO. Sideband Spectrum ( $\pm 20$ kHz Frequency Separation)	50 dB	60 dB	60 dB	60 dB

TABLE 2. Minimum performance requirements for transmitters used in personal FM transceivers—Continued

Transmitter characteristic	Minimum requirement Frequency band (MHz)			
	25-50	150-174	400-512	806-866
Temperature Stability				
BP. Output Power	-3 dB	-3 dB	-3 dB	-3 dB
BQ. FM Hum and Noise Level	34 dB	34 dB	34 dB	34 dB
BR. Carrier Frequency Tolerance	0.002%	0.0005%	0.0005%	0.00025%
BS. Audio Harmonic Distortion	9%	9%	9%	9%
Humidity Stability				
BT. Output Power	-3 dB	-3 dB	-3 dB	-3 dB
BU. FM Hum and Noise Level	34 dB	34 dB	34 dB	34 dB
BV. Carrier Frequency Tolerance	0.002%	0.0005%	0.0005%	0.00025%
Vibration Stability				
BW. FM Hum and Noise Level	25 dB	25 dB	25 dB	25 dB
BX. Carrier Frequency Tolerance	0.002%	0.0005%	0.0005%	0.00025%

TABLE 3. Minimum performance requirements for personal transceiver antennas

Antenna characteristic	Minimum requirement Frequency band (MHz)			
	25-50	150-174	400-512	806-866
CA. Radiation Efficiency	NA	20%	50%	60%

TABLE 4. Minimum performance requirements for personal transceiver batteries

	Minimum requirement			
	Ni-Cad	Mercury	Alkaline	Carbon-Zinc
DA. Service Life: 20 to 30 °C	8 h	40 h	20 h	4 h
DB. Service Life: -30 °C	2 h	NA	NA	NA
DC. Service Life: +60 °C	7 h	40 h	24 h	5 h

## 4.2 User Information

A nominal value for each of the characteristics listed in tables 1 through 4 shall be included in the information supplied to the purchaser by the manufacturer or distributor. In addition, the manufacturer shall provide the range of temperatures within which the transceiver is designed to be operated, the transmitter and receiver operating frequencies, and nominal values for the transmitter carrier output power, the receiver audio output impedance, the standard supply voltage and the current drains in the transmit, receive and standby modes. The manufacturer shall also indicate the magnitude of the audio input signal necessary for rated system deviation and provide sufficient audio input impedance information to enable test personnel to design an impedance matching network for use between the audio generator and transmitter audio input circuits. The manufacturer or distributor shall label each battery with the nominal voltage, battery type and model, rated capacity, indication of polarity, and month and year of manufacture.

## 4.3 Performance at Environmental Extremes

The ability of the transceiver to operate in environmental extremes shall be determined using the test methods described in section 5.3. These tests shall be performed before the transceiver is tested for compliance with the requirements of sections 4.4 through 4.7.

### 4.3.1 Temperature Stability

Low temperature tests shall be conducted at  $-30^{\circ}\text{C}$  ( $-22^{\circ}\text{F}$ ) or the lowest temperature at which the manufacturer states (sec. 4.2) that the unit will operate properly, whichever is lower, and high temperature tests shall be conducted at  $60^{\circ}\text{C}$  ( $140^{\circ}\text{F}$ ) or the highest temperature at which the manufacturer states that the unit will operate properly, whichever is higher.

When the transceiver is operated at low and high temperatures, as defined above, its performance shall not vary, with respect to the appropriate values in table 1 (items A through T), more than items U through AA, for the characteristics listed. In addition, the receiver audio distortion at an audio output power of 500 mW (item M, table 1) shall be less than 18 percent (item AB) for an rf signal with standard modulation. The transmitter rf output power shall be within 3 dB (item BP, table 2) of the nominal value, its FM hum and noise level shall be attenuated a minimum of 34 dB (item BQ), the carrier frequency shall be within (item BR) of the assigned value and the audio harmonic distortion shall be a maximum of 9 percent (item BS).

The transceiver primary or fully charged secondary batteries shall operate the transceiver for (item DB or DC, table 4, as appropriate) before the nominal transceiver output power decreases 3 dB.

### 4.3.2 Humidity Stability

After the transceiver has been maintained at  $40^{\circ}\text{C}$  ( $104^{\circ}\text{F}$ ) and 90 percent relative humidity or greater for at least 4 h, its performance shall not vary, with respect to the appropriate values in table 1 (items A through T), more than items AC through AI, for the characteristics listed. In addition, the receiver audio distortion at an audio output power of 500 mW (item M) shall be less than 18 percent (item AJ) for an rf signal with standard modulation. The transceiver rf output power shall be within 3 dB (item BT) of the nominal value, its FM hum and noise level shall be attenuated a minimum of 34 dB (item BU), and the carrier frequency shall be within (item BV) of the assigned value.

### 4.3.3 Vibration Stability

No fixed part of the transceiver shall come loose, nor movable part be shifted in position or adjustment, as a result of this test. During the test, the FM hum and noise level shall be attenuated a minimum of 25 dB (item BW) and the carrier frequency shall be within (item BX) of the assigned value.

### 4.3.4 Shock Stability

The transceiver shall suffer no more than superficial damage as a result of this test. No fixed part shall come loose, nor movable part be shifted in position.

## 4.4 Receiver Performance

### 4.4.1 SINAD Sensitivity

When measured in accordance with section 5.4.1, the SINAD sensitivity of the receiver shall be  $0.4 \mu\text{V}$  (item A) or less at a SINAD ratio of 12 dB and an audio output power of at least 50 percent of 500 mW, i.e., 250 mW. When the standard power supply voltage is varied +10 percent and -20 percent, the SINAD sensitivity shall be  $0.7 \mu\text{V}$  (item B) or less.

### 4.4.2 Selectivity Characteristics

The selectivity characteristics of minimum usable bandwidth, adjacent-channel selectivity and desensitization, spurious and harmonic response attenuation, and intermodulation attenuation shall be measured in accordance with section 5.4.2.

#### 4.4.2.1 Minimum Usable Bandwidth

The minimum usable bandwidth of the receiver shall be no less than 5 kHz (item C) for an applied rf signal 6 dB above the measured 12-dB SINAD sensitivity value.

#### 4.4.2.2 Adjacent-Channel Selectivity and Desensitization

The adjacent-channel selectivity and desensitization of the receiver shall be (item D) or more for a degradation of an on-channel signal from 12-dB SINAD ratio to 6-dB SINAD ratio caused by an adjacent-channel signal.

#### 4.4.2.3 Spurious and Harmonic Response Attenuation

The spurious and harmonic response attenuation of the receiver shall be (item E) or more as compared to the on-channel 20 dB noise-quieting signal voltage for responses of the receiver between the lowest intermediate frequency of the receiver and at least twice the receiver operating frequency, or 1000 MHz, whichever is higher.

#### 4.4.2.4 Intermodulation Attenuation

The intermodulation attenuation of the receiver shall be (item F) or more for a degradation of an on-channel signal from 12-dB SINAD ratio to 6-dB SINAD ratio by two relatively strong signals located at one- and two-channel spacings, respectively, from the receiver frequency, both signals being at frequencies either above or below the on-channel signal.

### 4.4.3 Squelch Characteristics

The squelch characteristics of sensitivity, block, receiver attack time, and receiver closing time shall be measured in accordance with section 5.4.3.

#### 4.4.3.1 Squelch Sensitivity

The threshold squelch sensitivity of the receiver shall be  $0.3 \mu\text{V}$  (item G) or less. The tight squelch sensitivity shall be  $2.5 \mu\text{V}$  (item H) or less. When the standard power supply voltage is varied +10 percent and -20 percent, the threshold squelch sensitivity shall be (item I) or less.

#### 4.4.3.2 Squelch Block

The receiver shall not squelch for modulation frequencies of 0.3 to 3 kHz when the squelch control is adjusted to the maximum squelch position and the frequency deviation of the input signal is  $\pm 5$  kHz (item J) or less.

#### 4.4.3.3 Receiver Attack Time

The time for the receiver to produce an audio output power of 90 percent of 500 mW, i.e., 450 mW, shall be 150 ms (item K) or less.

#### 4.4.3.4 Receiver Closing Time

The time for the audio output power of the receiver to decrease to 10 percent of 500 mW, i.e., 50 mW, shall be 250 ms (item L) or less.

#### **4.4.4 Audio Characteristics**

The audio characteristics of output power, distortion, response, and hum and noise shall be measured in accordance with section 5.4.4.

##### **4.4.4.1 Audio Output Power**

The audio output power of the receiver shall be at least 500 mW (item M) if a loudspeaker is used at the receiver output and at least 3 mW but not greater than 12 mW (item N) if earphones are used. When the standard supply voltage is varied +10 percent and -20 percent, the audio output power shall not be reduced more than 3 dB (item O) below 500 mW.

##### **4.4.4.2 Audio Distortion**

Audio distortion at audio output powers of 500 mW (loudspeaker) and 3-12 mW (earphones) shall be less than 10 percent (item P) for an rf input signal with standard modulation.

##### **4.4.4.3 Audio Response**

The audio response of the receiver, when used with a loudspeaker, shall be within -10, +2 dB (item Q) of an ideal 6 dB per octave de-emphasis curve with constant frequency deviation at frequencies between 0.3 and 3 kHz, with the exception that a 6 dB per octave roll-off from 600 to 300 Hz may be present. When used with earphones, the audio response of the receiver shall also be within -10, +2 dB (item R) of the same curve at frequencies between 0.3 and 3 kHz, with the exception that a 6 dB per octave roll-off from 600 to 300 Hz may be present.

##### **4.4.4.4 Audio Hum and Noise**

The audio hum and noise output power from the receiver in the unsquelched condition shall be 40 dB (item S) or more, and in the maximum squelched condition, shall be 50 dB (item T) or more below an audio output power of 500 mW.

#### **4.5 Transmitter Performance**

##### **4.5.1 Radio Frequency Characteristics**

The radio frequency carrier characteristics of output power, frequency stability, AM hum and noise level, and carrier attack time shall be measured in accordance with section 5.5.1.

###### **4.5.1.1 Output Power**

Transmitter output power is specified by the FCC [2]. When the transceiver is in the transmit mode, the carrier output power delivered to a standard output load shall not decrease more than 0.3 dB (item BA) from the nominal value at any time during the standard test duty cycle, except for the initial second after the transceiver has been switched from the standby mode to the transmit mode. When the standard supply voltage is varied  $\pm 10$  percent, the output power shall not decrease by more than 3 dB (item BB). When the standard supply voltage is reduced by 20 percent, the output power shall not decrease by more than 6 dB (item BC).

###### **4.5.1.2 Frequency Stability**

The carrier frequency shall be within (item BD) of the assigned value at all times during the transceiver test duty cycle that the transceiver is in the transmit mode, except for the initial second after the transceiver has been switched from the standby mode to the transmit mode. When the standard supply voltage is varied  $\pm 15$  percent, the carrier frequency shall be maintained within (item BE) of the assigned value.

###### **4.5.1.3 AM Hum and Noise Level**

The AM hum and noise level shall be attenuated a minimum of 34 dB (item BF) below the unmodulated nominal carrier output power level.

###### **4.5.1.4 Carrier Attack Time**

The carrier output power shall increase to 50 percent of its nominal value in less than 100 ms (item BG).



#### 4.5.2 Audio Modulation Characteristics

The audio modulation characteristics of harmonic distortion, FM hum and noise level, response, frequency deviation, and modulation limiting shall be measured in accordance with section 5.5.2.

##### 4.5.2.1 Audio Harmonic Distortion

The audio harmonic distortion shall be a maximum of 5 percent (item BH).

##### 4.5.2.2 FM Hum and Noise Level

The FM hum and noise level shall be attenuated a minimum of 40 dB (item BI).

##### 4.5.2.3 Audio Response

The audio response of the transmitter shall not vary more than +1, -3 dB from a true 6 dB per octave pre-emphasis characteristic from 0.3 to 3 kHz as referred to the 1-kHz level, as shown in figure 1, with the exception that a 6 dB per octave roll-off from 600 to 300 Hz and from 2.5 to 3 kHz may be present.

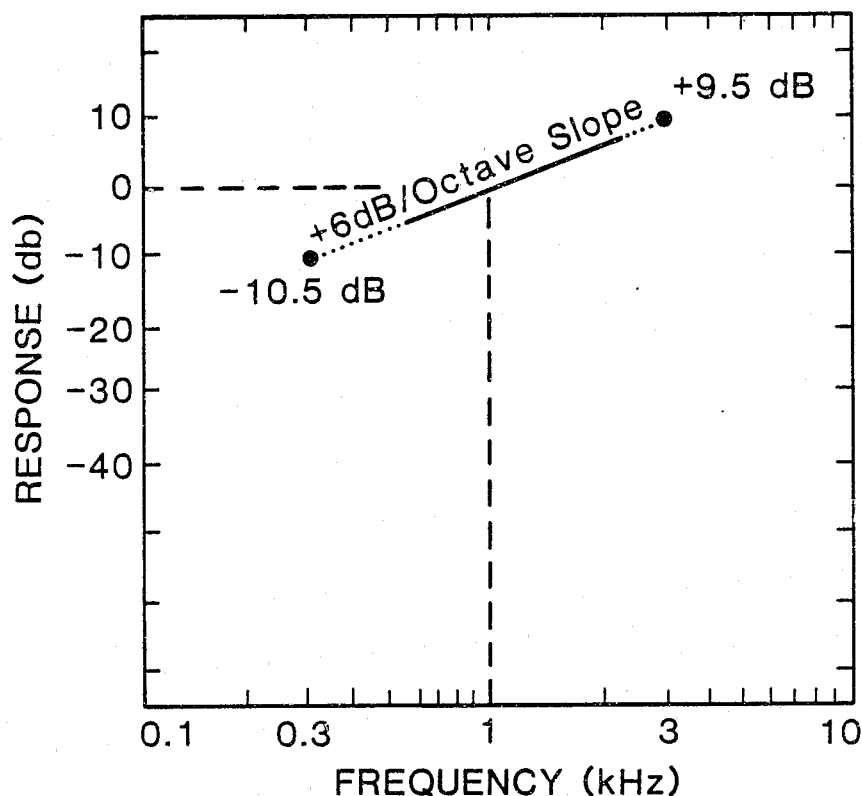


FIGURE 1. Audio response characteristic of personal FM transmitters.

##### 4.5.2.4 Frequency Deviation

The maximum frequency deviation shall be within 5 percent (item BK) of  $\pm 4.75$  kHz.

##### 4.5.2.5 Modulation Limiting

The instantaneous peak and the steady state frequency deviation shall not exceed the maximum value of rated system deviation of  $\pm 5$  kHz (item BL) with a 20 dB increase in audio above the nominal input level.

#### 4.5.3 Electromagnetic Compatibility Characteristics

The electromagnetic compatibility characteristics of radiated spurious emissions and sideband spectrum shall be measured in accordance with section 5.5.3.

#### **4.5.3.1 Radiated Spurious Emissions**

Each radiated spurious emission shall be attenuated a minimum of  $[43 \text{ (item BM)} + 10 \log_{10} (\text{output power in watts})]$  dB below the nominal field strength of the carrier, i.e., each radiated spurious emission shall be less than  $50 \mu\text{W}$ .

#### **4.5.3.2 Sideband Spectrum**

Each spurious sideband emission shall be attenuated greater than (item BN) when the frequency is separated from the assigned carrier by  $\pm 10 \text{ kHz}$ , and shall be attenuated greater than (item BO) when the frequency is separated from the assigned carrier by  $\pm 20 \text{ kHz}$ .

### **4.6 Antenna Performance**

#### **4.6.1 Radiation Efficiency**

When measured in accordance with section 5.6.1, the radiation efficiency shall be (item CA, table 3) or greater.

#### **4.7 Battery Service Life**

When tested in accordance with section 5.7, each primary or fully-charged secondary battery shall operate the transceiver for (item DA) before the nominal transmitter output power decreases 3 dB. See also the high and low temperature service life requirements given in section 4.3.1.1.

## **5. TEST METHODS**

### **5.1 Standard Test Conditions**

Allow all measurement equipment to warm up until the system has achieved sufficient stability to perform the measurement. Unless otherwise specified, perform all measurements under standard test conditions.

#### **5.1.1 Standard Temperature**

Standard ambient temperature shall be between  $20$  and  $30^\circ\text{C}$  ( $68$  and  $86^\circ\text{F}$ ).

#### **5.1.2 Standard Relative Humidity**

Standard ambient relative humidity shall be between 10 and 85 percent.

#### **5.1.3 Standard Supply Voltage**

The standard supply voltage shall be the nominal battery voltage as specified by the manufacturer in accordance with section 4.2. Tests shall be performed using either a battery of the same type as normally used in the equipment or a well-filtered electronic dc supply. In the latter case, it shall be adjusted to within one percent of the voltage required.

#### **5.1.4 Standard Test Frequencies**

The standard test frequencies shall be the transmitter and the receiver operating frequencies.

#### **5.1.5 Standard Test Modulation**

##### **5.1.5.1 Audio Test Modulation**

Audio test modulation shall be a 1-kHz signal (from a source with distortion less than 1%) at the level required to produce 60 percent of rated system deviation (i.e.,  $\pm 3 \text{ kHz}$ ).

##### **5.1.5.2 Electromagnetic Compatibility Test Modulation**

Electromagnetic compatibility test modulation shall be a 2.5 kHz sine wave at an input level 16 dB greater than that required to produce 50 percent of rated system deviation at 1 kHz.

#### **5.1.6 Rated System Deviation**

Rated system deviation shall be  $\pm 5 \text{ kHz}$ .

### **5.1.7 Standard Squelch Adjustment**

The squelch control shall be adjusted to the maximum unsquelch position for all receiver measurements except where otherwise specified.

### **5.1.8 Standard Duty Cycles**

#### **5.1.8.1 Transceiver Test Duty Cycle**

The transceiver test duty cycle shall be 2 min in the transmit mode followed by 3 min in the standby mode.

#### **5.1.8.2 Battery Test Duty Cycle**

The battery test duty cycle will be 6 s in the transmit mode, 6 s in the receive mode, and 48 s in the standby mode.

### **5.1.9 Standard Radiation Test Site**

#### **5.1.9.1 Type I and II Transceivers**

The standard radiation test site shall be located on level ground which has uniform electrical characteristics (i.e., ground constants). Reflecting objects (especially large metal objects), trees, buildings, and other objects which would perturb the electromagnetic fields to be measured should not be located closer than 90 m (295 ft) from any test equipment or equipment under test. All utility lines and any control circuits between test positions should be buried underground. The ambient electrical noise level shall be as low as possible and shall be carefully monitored to ensure that it does not interfere with the test being performed.

#### **5.1.9.2 Type III and IV Transceivers**

In addition to the requirements described in 5.1.9.1, the standard radiation test site shall have microwave absorbing material placed on the ground between the transceiver and the receiving antenna to restrict standing waves, produced by reflections from the ground, to no larger than  $\pm 1$  dB. If available, an anechoic chamber may be used instead (sec. 5.2.18).

### **5.1.10 Standard Charge**

Prior to testing, each secondary battery shall be discharged to a voltage of 1 V per cell at a current of C or less, where C is numerically equal to the battery rated capacity in ampere-hours or milliampere-hours. Slow-charge batteries shall then be recharged at a rate of 0.1 C for 14 to 16 h. Fast-charge batteries shall be fully recharged in accordance with the manufacturer's instructions.

## **5.2 Test Equipment**

The test equipment discussed in this section is limited to that equipment which is the most critical in making the measurements discussed in this standard. All other test equipment shall be of comparable quality.

### **5.2.1 Environmental Chamber(s)**

The environmental chamber(s) shall produce air temperatures from  $-30$  to  $60^{\circ}\text{C}$  ( $-22$  to  $140^{\circ}\text{F}$ ) and relative humidities in the range of 90 to 95 percent. The test item shall be shielded from air currents blowing directly from heating or cooling elements in the chamber. The temperature of the test item shall be measured with a thermometer separate from the sensor used to control the chamber air temperature. Likewise, humidity shall be measured with a hygrometer separate from the sensor used to control humidity.

### **5.2.2 Vibration Tester**

The vibration tester shall be adjustable in frequency from 10 to 60 Hz, in a linear-sweep mode, and it shall be servo-controlled, with a reference signal derived from a suitable calibrated accelerometer or other calibrated sensor. It shall also provide an adjustable simple harmonic motion in at least one plane for a total excursion of 0.04 in (1 mm).

### 5.2.3 FM Signal Generator

The FM signal generator shall have a 50- $\Omega$  output impedance, a maximum SWR of 1.2 and a calibrated variable output level accurate to  $\pm 2$  dB when terminated in a 50- $\Omega$  load. It shall also have a single sideband 1-Hz bandwidth phase noise less than  $-135$  dB below the carrier at 25 kHz separation for carrier frequencies of 500 MHz and lower ( $-130$  dB at 900 MHz). The generator should include a digital frequency counter having an uncertainty no greater than one part in  $10^6$ , and a deviation monitor or calibrated control for determining the peak frequency deviation with an uncertainty no greater than 5 percent. If an integral frequency counter is not included, a separate frequency counter having the required accuracy shall be provided. Three of these are required.

### 5.2.4 CW Sweep Signal Generator

The CW sweep signal generator shall have the same characteristics as the FM signal generator except that the FM capability and the low phase noise capability are not required. The sweep generator should have some means of slowly, automatically sweeping the frequency band, especially for the higher frequencies.

### 5.2.5 Distortion Analyzer

The distortion analyzer shall have a required input level of between 1 and 5 V rms, an input impedance of at least 50,000  $\Omega$  shunted by less than 100 pF, and an accuracy of at least  $\pm 1$  dB. It shall have the capability to measure both audio distortion and the rms voltage of audio signals to within  $\pm 3$  percent. The analyzer shall incorporate a 1000-Hz band elimination filter for the audio distortion measurements.

### 5.2.6 Isolation Transformer

The isolation transformer shall have a turns ratio of 1 to 1, an impedance of 600  $\Omega$ , a frequency response within  $\pm 0.1$  dB from at least 300 to 3000 Hz, and a power handling capability of 20 dBm. The isolation transformer is needed when the receiver audio output does not have an isolating circuit such as an output transformer or capacitor and the following measuring instrument (e.g., distortion analyzer) has a single ended input.

### 5.2.7 Standard Audio Output Load (Receiver)

The standard audio output load shall be either the actual speaker or an impedance equivalent to the nominal impedance of the transceiver speaker with a power rating equal to or exceeding the nominal audio output power of the transceiver receiver. A filter network shall not be used between the audio output terminals and the audio output load. If an external monitor speaker is used, a matching network to maintain the standard output load impedance at the audio output terminals shall be provided.

### 5.2.8 Standard RF Input Load (Receiver)

The standard rf input load shall consist of a shielded 50- $\Omega$  resistor whose SWR is less than 1.05.

### 5.2.9 Signal Combiner

A signal combiner shall be used when two or more signal generators are connected to the receiver under test. Its amplitude imbalance shall be no greater than 0.2 dB, its SWR shall be no greater than 1.3 and the isolation between input terminals shall be a minimum of 30 dB. A variety of multiport devices may be used as signal combiners including power dividers, directional couplers, and hybrid junctions.

### 5.2.10 Audio Voltmeter

The audio voltmeter shall measure rms voltage to an uncertainty of 1 percent or less.

### 5.2.11 Chart Recorder

The chart recorder shall have sufficient speed of response to record spurious receiver responses when the signal generator is swept slowly.

### 5.2.12 Standard RF Output Load (Transmitter)

The standard rf output load shall be a 50- $\Omega$  resistive termination having an SWR of 1.1 or less at the standard test frequencies. If connectors and cables are used to attach the standard output load to the transmitter, the combined SWR, including the load, shall be 1.1 or less.

### **5.2.13 Standard Audio Input Load (Transmitter)**

The standard audio input load shall consist of a low-noise load whose impedance is equal to the specified input impedance of the transceiver transmitter.

### **5.2.14 Test Receiver**

The test receiver shall include a standard audio output load as specified by the manufacturer of the test receiver (sec. 5.2.14.6) and shall have the characteristics specified in the following sections.

#### **5.2.14.1 Audio Response**

The audio response characteristics shall not vary more than 1 dB from a 750- $\mu$ s de-emphasis characteristic when the system deviation is held constant and the modulation frequency is varied between 0.05 and 3 kHz.

#### **5.2.14.2 Harmonic Distortion**

The audio harmonic distortion shall be less than 1 percent at standard audio test modulation. The harmonic distortion at 1 kHz (for larger than rated system deviation) shall be less than 3 percent. The harmonic distortion shall be measured when the test receiver is tuned to a nominal 1-mV rf source which is modulated by a sine wave at a level which produces a system deviation 50 percent greater than rated system deviation (i.e.,  $\pm 7.5$  kHz).

#### **5.2.14.3 Audio Hum and Noise Level**

The unswitched audio hum and noise level shall be at least 55 dB below the audio output power when measured with a 1-mV input signal.

#### **5.2.14.4 Adjacent-Channel Interference**

The test receiver shall differentiate by 85 dB or more between a desired modulated signal and a modulated adjacent-channel signal 30 kHz on either side, when the adjacent-channel interference degrades the desired signal from 12-dB SINAD to 6-dB SINAD.

#### **5.2.14.5 Selectivity**

The test receiver shall have a bandwidth of 24 to 30 kHz at the -80 dB points.

#### **5.2.14.6 Standard Audio Output Load**

The standard audio output load shall provide an impedance equal to the load impedance into which the test receiver normally operates.

### **5.2.15 Deviation Meter**

The deviation meter shall be capable of measuring the peak deviation of a modulating waveform with an uncertainty no greater than 5 percent of the deviation being monitored.

### **5.2.16 Field Strength Meter**

The field strength meter, consisting of an antenna and a well-shielded calibrated receiver which operate at the standard test frequencies, shall have a resolution of at least 0.2 dB. The receiver should be located near the receiving antenna to keep the length of the cable between them as short as possible.

### **5.2.17 Microwave Absorber**

The microwave absorber shall attenuate the reflected energy at least 25 dB at 400 MHz at an incidence angle of 40°.

### **5.2.18 Anechoic Chamber**

The anechoic chamber shall be a room covered on the inside surfaces with microwave absorber such that standing waves produced by imperfect absorption are no larger than  $\pm 1$  dB.

### 5.3 Transceiver Environmental Tests

Conduct these tests on the complete transceiver including the antenna and battery. Where indicated, operate the transceiver using the transceiver standard duty cycle.

#### 5.3.1 Temperature Test

Place the transceiver, with the power turned off and all covers in place, in the environmental chamber. Adjust the chamber to the required low temperature  $\pm 2^{\circ}\text{C}$  ( $\pm 3.6^{\circ}\text{F}$ ). Allow the transceiver to reach temperature equilibrium and maintain it at this temperature for 30 min. With the transceiver still in this environment, connect it to the standard supply voltage and operate it at the transceiver standard duty cycle. Fifteen minutes after turn-on, test the transceiver to determine whether it meets the requirements of section 4.3.1. Repeat the above procedure at the required high temperature  $\pm 2^{\circ}\text{C}$  ( $\pm 3.6^{\circ}\text{F}$ ).

#### 5.3.2 Humidity Test

Place the transceiver, with power turned off and all covers in place, in the environmental chamber. Adjust the relative humidity to a minimum of 90 percent at  $40^{\circ}\text{C}$  ( $104^{\circ}\text{F}$ ) or more and maintain the transceiver at these conditions for at least 4 h. With the transceiver still in this environment, connect it to the standard supply voltage and operate it at the transceiver standard duty cycle. Fifteen minutes after turn-on, test the transceiver to determine whether it meets the requirements of section 4.3.2.

#### 5.3.3 Vibration Test

Fasten the transceiver to the vibration tester using a rigid mounting fixture. Perform a two-part test for a total of 30 min in each of three mutually perpendicular directions, one of which is the vertical.

First subject the transceiver to three 5-min cycles of simple harmonic motion having an amplitude of 0.38 mm (0.015 in) [total excursion of 0.76 mm (0.03 in)] applied initially at a frequency of 10 Hz and increased at a uniform rate to 30 Hz in 2-1/2 min, then decreased at a uniform rate to 10 Hz in 2-1/2 min.

Then subject the transceiver to three 5-min cycles of simple harmonic motion having an amplitude of 0.19 mm (0.0075 in) [total excursion of 0.38 mm (0.015)] applied initially at a frequency of 30 Hz and increased at a uniform rate to 60 Hz in 2-1/2 min, then decreased at a uniform rate to 30 Hz in 2-1/2 min.

Repeat for each of the other two directions.

#### 5.3.4 Shock Test

Drop the transceiver once on each of four or more sides (all sides not having a protrusion or antenna connection), from a height of 1 m (3.28 ft) onto a smooth concrete floor. Turn off the transceiver power during the test, and use guides to ensure contact with the floor by the correct equipment surface.

### 5.4 Receiver Tests

#### 5.4.1 SINAD Sensitivity Test

Connect the transceiver receiver and test equipment as shown in figure 2 for those transceivers with a balanced receiver audio output. For those transceivers with an unbalanced receiver audio output, the isolation transformer is not required. Set the squelch control to the standard squelch adjustment. Adjust the FM signal generator to the standard test frequency with standard audio test modulation. Set the generator for 1-mV output and the receiver volume control for an audio output power of 500 mW. Do not readjust the volume control for the remainder of the measurement. Decrease the output level of the generator until the SINAD ratio of the receiver is 12 dB, as determined with the distortion analyzer. Measure the audio output power to make certain it is at least 250 mW and record the generator output voltage for convenience in resetting to a 12-dB SINAD ratio, as required by some of the following tests. Repeat for changes in standard supply voltage of +10 percent and -20 percent.

#### 5.4.2 Selectivity Tests

##### 5.4.2.1 Minimum Usable Bandwidth Test

Connect the transceiver receiver and test equipment as shown in figure 2, with or without the isolation transformer, as necessary. Adjust the receiver and FM signal generator in accordance with section 5.4.1 until a 12-dB SINAD ratio is reached. With the generator still set for standard audio test modulation, increase the



FIGURE 2. Block diagram for SINAD sensitivity, minimum usable bandwidth, squelch sensitivity, squelch block, and audio distortion measurements.

generator rf output by 6 dB. Adjust the frequency of the generator above the test frequency until the 12-dB SINAD signal ratio is obtained again. Record the generator frequency. Repeat this measurement by adjusting the generator frequency below the test frequency and record the generator frequency. The smaller displacement from the test frequency  $\pm 3$  kHz (standard test modulation deviation) is the receiver bandwidth.

#### 5.4.2.2 Adjacent-Channel Selectivity and Desensitization Test

Connect the transceiver receiver and test equipment as shown in figure 3. With the output of FM signal generator No. 2 set to zero, adjust the receiver and signal generator No. 1 in accordance with section 5.4.1 until a 12-dB SINAD ratio is reached. Adjust signal generator No. 2 for 3-kHz frequency deviation at 400 Hz, and set it to a frequency corresponding to the center of the next higher adjacent channel. Then adjust the output of signal generator No. 2 to produce a 6-dB SINAD ratio with both signals present. The ratio, expressed in decibels, of the output voltage of signal generator No. 2 to that of signal generator No. 1 is the adjacent channel selectivity for the upper channel. Repeat the above procedure for the next lower adjacent channel. The smaller of the two ratios is the required measurement.

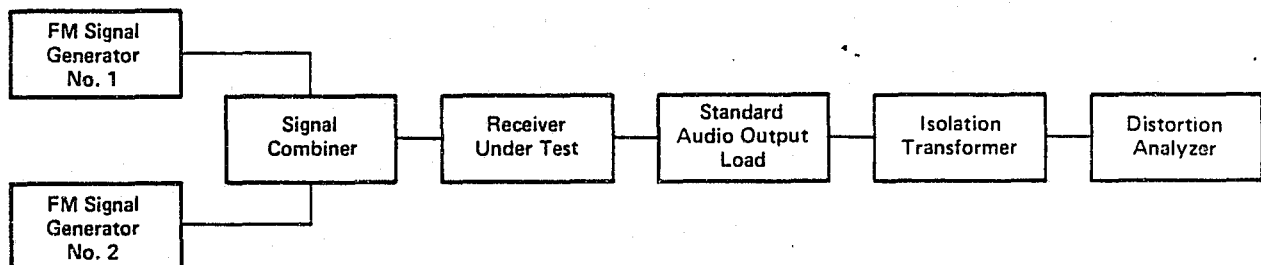


FIGURE 3. Block diagram for adjacent-channel selectivity and desensitization measurement.

#### 5.4.2.3 Spurious and Harmonic Response Attenuation Test

Connect the transceiver receiver and test equipment as shown in figure 4. Adjust the CW sweep signal generator to the standard test frequency. With the generator adjusted for zero output, adjust the receiver volume control to produce 125 mW. The output power is entirely noise power. Do not readjust the volume control for the remainder of the measurement. Increase the output of the generator until the audio noise output power of the receiver is decreased by 20 dB, i.e., 20 dB of noise quieting. Note the generator output in decibels above one microvolt ( $\text{dB}\mu\text{V}$ ) at this frequency. Then increase the output of the generator to approximately 0.1 V, and slowly vary the generator frequency continuously from just below the lowest intermediate frequency of the receiver to at least twice the receiver operating frequency or 1000 MHz, whichever is higher. Synthesized receivers preclude easy prediction of spurious response frequencies. Note each frequency that produces a receiver response as indicated by noise quieting in the receiver's audio output. Ignore harmonic frequencies of the generator that fall within the channel to which the receiver is tuned. For large frequency bandwidths covered, use a signal generator that can be swept automatically, and a chart recorder or similar automatic means of recording frequencies of receiver response, as this sweep may take many hours. Then go back and measure the response at each frequency recorded. For each response, adjust the generator output to produce 20 dB of noise quieting. Record the generator output in  $\text{dB}\mu\text{V}$ . The generator output at the spurious response frequency minus the generator output at the standard test frequency is the spurious response attenuation. Repeat for all spurious responses. The smallest attenuation is the value sought.

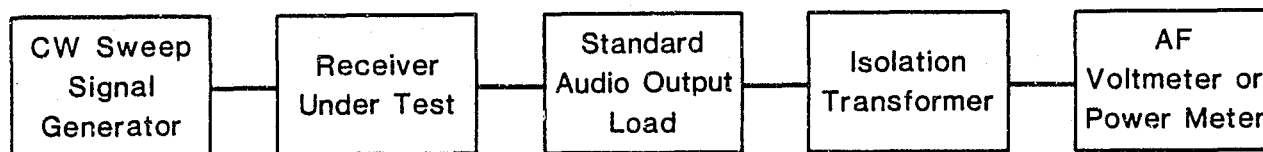


FIGURE 4. Block diagram for spurious and harmonic response attenuation measurement.

#### 5.4.2.4 Intermodulation Attenuation Test

Connect the transceiver receiver and test equipment as shown in figure 5. With the output levels of FM signal generator Nos. 2 and 3 set to zero, adjust the receiver and FM signal generator No. 1 in accordance with section 5.4.1 until a 12-dB SINAD ratio is reached. Adjust unmodulated generator No. 2 to the center frequency of the next higher adjacent channel. Adjust generator No. 3 for 3-kHz frequency deviation at 400 Hz, and set it to the center frequency of the second higher adjacent channel, i.e., two channels above the standard test frequency. Then adjust the output levels of generator Nos. 2 and 3 to produce a 6-dB SINAD ratio with all three signals present. Maintain generator Nos. 2 and 3 at equal output voltages throughout the measurement. Adjust slightly the frequency of generator No. 3 to obtain the 6-dB SINAD ratio with the minimum signal levels from generator Nos. 2 and 3. The ratio, in decibels, of the output voltage of generator No. 2 (or 3) to that of generator No. 1 is the intermodulation attenuation for the upper channels. Repeat the above procedure for the lower two adjacent channels, with generator No. 3 set to the lowest channel. The smaller of the two ratios is the value sought.

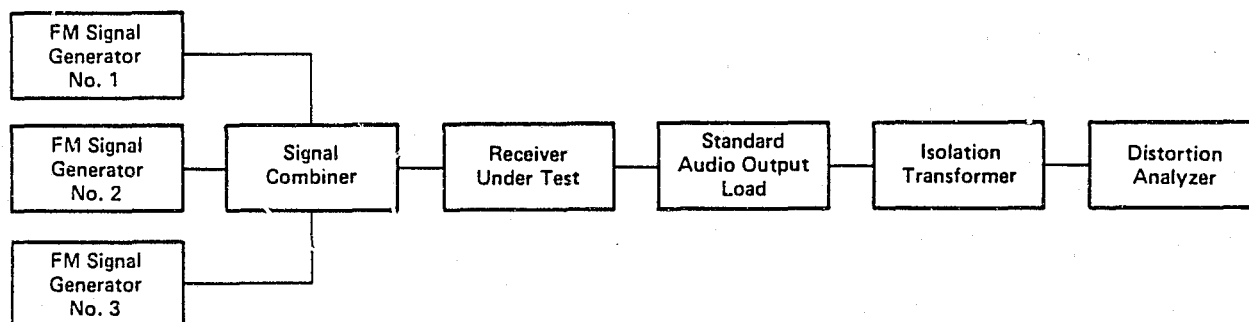


FIGURE 5. Block diagram for intermodulation attenuation measurement.

### 5.4.3 Squelch Tests

#### 5.4.3.1 Squelch Sensitivity Tests

Connect the transceiver receiver and test equipment as shown in figure 2, with or without the isolation transformer, as necessary. Adjust the receiver and FM signal generator in accordance with section 5.4.1 until a 12-dB SINAD ratio is reached. Set the output level of the generator to zero, and measure the audio noise output power. Slowly adjust the squelch control until the audio noise output power drops abruptly (40 dB or more). Do not adjust the squelch control any further. This is the threshold squelch position. Increase the output level of the signal generator until the measured audio output power is within 10 dB of 500 mW. The signal generator output voltage is the value for the threshold squelch sensitivity. Repeat for changes in standard supply voltage of +10 percent and -20 percent.

Repeat the above procedure with the squelch control in the maximum squelch position. The resultant signal generator output voltage is the value for tight squelch sensitivity.



#### 5.4.3.2 Squelch Block Test

Connect the transceiver receiver and test equipment as shown in figure 2, with or without the isolation transformer, as necessary. Adjust the receiver and FM signal generator in accordance with section 5.4.1 to give 500 mW of audio output power. Set the output level of the signal generator to zero, and measure the audio noise output power. Then set the squelch control to the maximum squelch position. Adjust the output level of the generator to 12 dB above the measured value of the receiver's tight squelch sensitivity voltage. Then increase the frequency deviation of the generator until the audio output power drops abruptly (40 dB or more). Repeat the above procedure with modulation frequencies of 0.3, 0.5, 2.5, and 3 kHz. The frequency deviations of the signal generator modulation are the values for squelch block.

#### 5.4.3.3 Receiver Attack Time Test

Connect the equipment as shown in figure 6a. Open and close the SPST switch to trigger the oscilloscope trace. Connect the dc output of the coaxial diode detector to the vertical input of the oscilloscope and adjust the horizontal centering controls so that the start of the detector output begins at the left graticule of the oscilloscope screen. Do not adjust the oscilloscope trigger or centering controls any further.

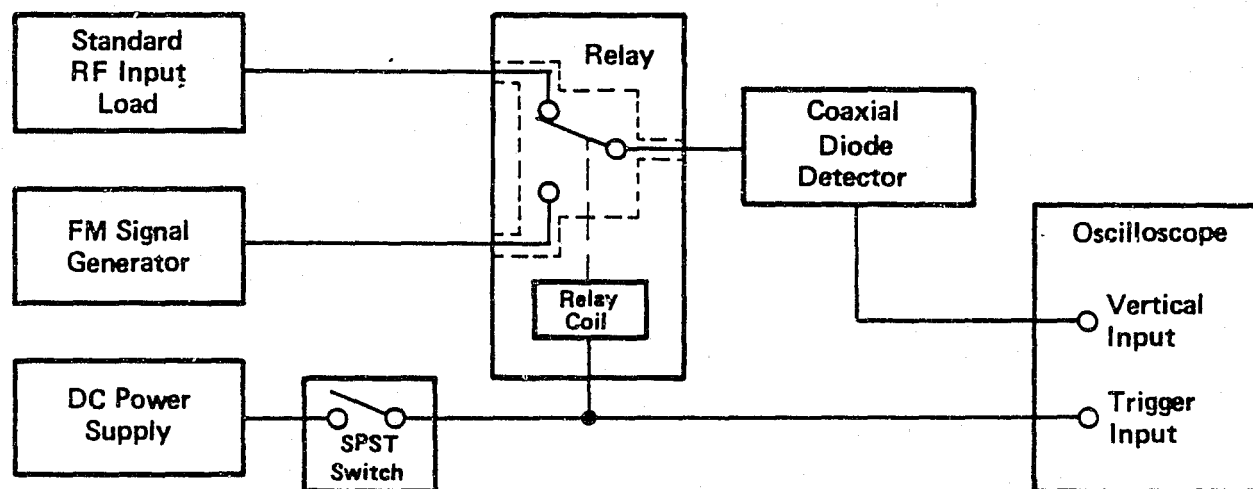


FIGURE 6a. Block diagram for setting oscilloscope trigger.

Connect the transceiver receiver and test equipment as shown in figure 6b. With the SPST switch closed, adjust the FM signal generator in accordance with section 5.4.1 until a 12-dB SINAD ratio is reached. Set the signal generator to zero, and measure the audio noise output power. Slowly adjust the squelch control until the audio output power drops abruptly (40 dB or more). Do not adjust the squelch any further. Adjust the generator output level to 12 dB above the measured value of the receiver threshold squelch sensitivity voltage. With the oscilloscope on recurrent sweep, adjust the oscilloscope vertical controls for full-scale deflection. Do not adjust the trigger. Return the oscilloscope to external trigger and open and then close the SPST switch and photograph the trace. The time required for the sweep to travel from the left side of the oscilloscope graticule until the audio output power level reaches 450 mW is the value of receiver attack time.

#### 5.4.3.4 Receiver Closing Time Test

Connect the equipment as shown in figure 6a. Adjust oscilloscope so the output from the coaxial diode detector stops at the left graticule of the oscilloscope when the SPST switch is opened. Connect the receiver and test equipment as shown in figure 6b. Adjust all equipment as in section 5.4.3.3. Open the SPST switch and photograph the display. The time required for the sweep to travel from the left graticule of the oscilloscope until the audio output power level falls to 50 mW is the value of receiver closing time.

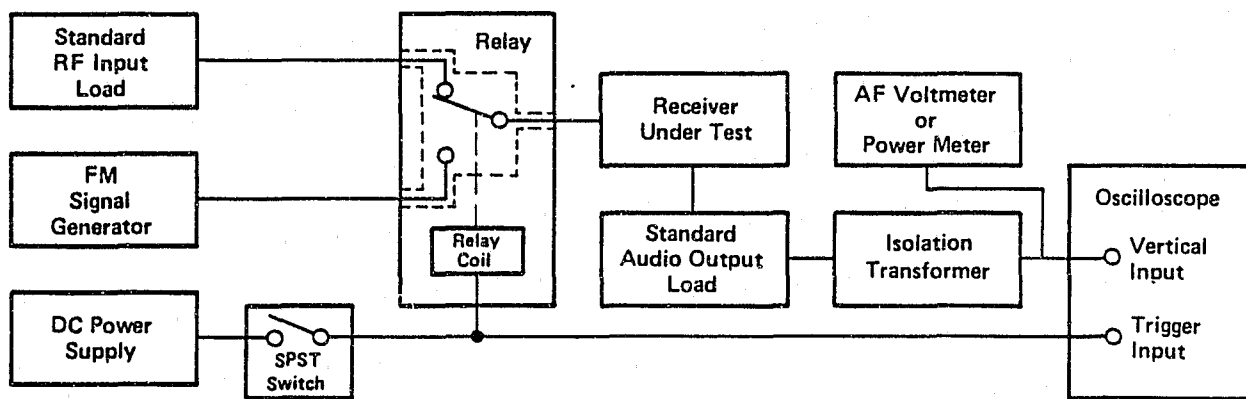


FIGURE 6b. Block diagram for receiver attack time and receiver closing time measurements.

## 5.4.4 Audio Tests

### 5.4.4.1 Audio Output Power Test

Connect the transceiver receiver and test equipment as shown in figure 7. Modulate the FM signal generator with standard audio test modulation and set it to the standard test frequency. With the signal generator adjusted for 1-mV output, set the receiver volume control to the maximum position and measure the audio output power. Repeat for changes in standard supply voltage of +10 percent and -20 percent.



FIGURE 7. Block diagram for audio output power, audio response, and audio hum and noise measurements.

### 5.4.4.2 Audio Distortion Test

Connect the transceiver receiver and test equipment as shown in figure 2, with or without the isolation transformer, as necessary. Modulate the FM signal generator with standard audio test modulation and set it to the standard test frequency. With the signal generator adjusted for 1-mV output, adjust the receiver volume control for an audio output power of 500 mW and measure the audio distortion. Repeat at an audio output power of 3-12 mW for those transceivers used with earphones.

### 5.4.4.3 Audio Response Test

Connect the transceiver receiver and test equipment as shown in figure 7. Modulate the FM signal generator with standard audio test modulation and set it to the standard test frequency. With the signal generator adjusted for 1-mV output, adjust the receiver volume control for an audio output power of 500 mW. Do not readjust the volume control for the remainder of the measurement. Reduce the generator frequency deviation to 1 kHz, and measure the audio output power. Repeat for modulating frequencies of 0.3, 0.5, 2, and 3 kHz. Compute the ratio, in decibels, of each of these latter power levels relative to the output power at 1-kHz modulation. Repeat at an output power of 3-12 mW for those transceivers used with earphones.

### 5.4.4.4 Audio Hum and Noise Tests

Connect the transceiver receiver and test equipment as shown in figure 7. Modulate the FM signal generator with standard audio test modulation and set it to the standard test frequency. With the signal generator adjusted for 1-mV output, adjust the receiver volume control for an audio output power of 500 mW.

Do not readjust the volume control for the remainder of the measurement. Remove the modulation from the signal generator and measure the audio hum and noise output power. Compute the ratio, in decibels, of the audio output power to the audio hum and noise output power. This is the value for audio hum and noise (unsquelched).

Set the squelch control to its maximum squelch position. Set the output level of the generator to zero and measure the audio hum and noise output power. Calculate the ratio in decibels of the audio output power to the audio hum and noise output power. This is the value for audio hum and noise (squelched).

## 5.5 Transmitter Tests

### 5.5.1 Radio Frequency Carrier Tests

#### 5.5.1.1 Output Power Test

Operate the transceiver transmitter without modulation. Measure the output power as shown in figure 8, using standard supply voltage and a power meter accurate to 5 percent. Change the standard supply voltage +10 percent, allow it to stabilize at least 5 s, and determine the output power. Repeat for changes in standard supply voltage of -10 percent and -20 percent.

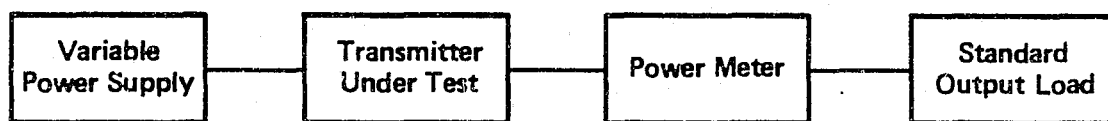


FIGURE 8. Block diagram for output power measurement.

#### 5.5.1.2 Frequency Stability Test

Operate the transceiver transmitter without modulation. Measure the frequency as shown in figure 9, using standard supply voltage. Change the standard supply voltage +15 percent, allow it to stabilize for 5 s, and determine the change in frequency. Repeat for a change in standard supply voltage of -15 percent.

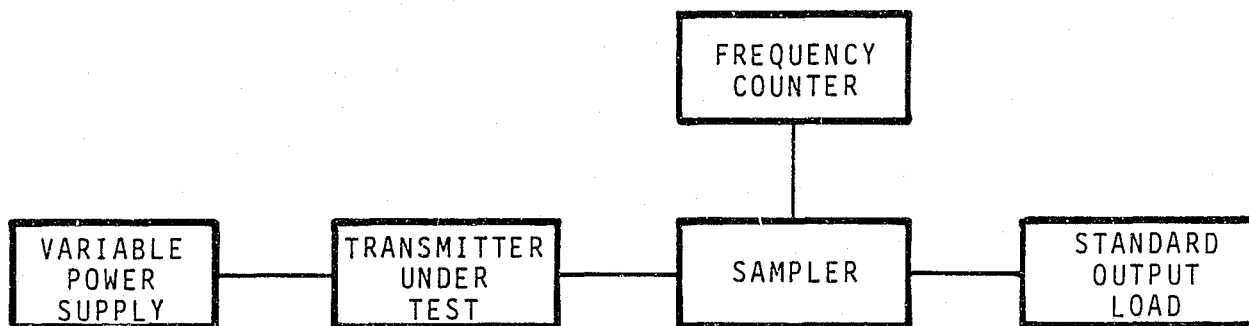


FIGURE 9. Block diagram for frequency stability measurement.

#### 5.5.1.3 AM Hum and Noise Level Test

Connect the transceiver transmitter and test equipment as shown in figure 10. Use a linear peak-carrier responsive AM detector to detect the sampled output of the transmitter. With the transmitter operating at nominal output power with no modulation, measure the dc voltage across the detector load resistor with the

high impedance dc voltmeter. Without adjusting the transmitter, measure the peak ac voltage with the oscilloscope. Calculate the AM hum and noise level as  $20 \log_{10} (V_p/V_{dc})$ , where  $V_p$  is the peak ac voltage and  $V_{dc}$  is the dc voltage.

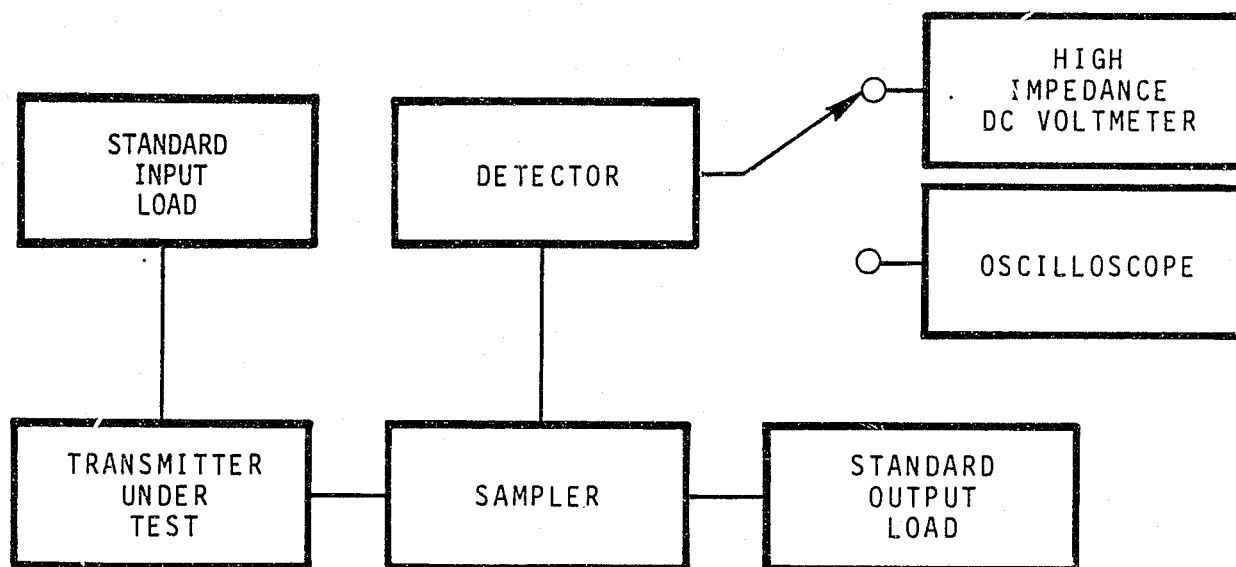


FIGURE 10. Block diagram for AM hum and noise measurement.

#### 5.5.1.4 Carrier Attack Time Test

Although carrier attack time is defined in terms of rated carrier output power, the test method described herein uses a voltage measurement technique to determine the value of this characteristic. Make the measurement using a calibrated oscilloscope and peak detector connected as shown in figure 11. The peak detector should have a short time constant ( $< 10$  ms) and provide a linear response with amplitude. Close the trigger circuit of the oscilloscope through the transmitter control switch to start the time interval. The peak detector, sampling the rf carrier, provides a voltage to the oscilloscope vertical input. Measure the time required for the trace to reach 71 percent of the peak detector maximum output.

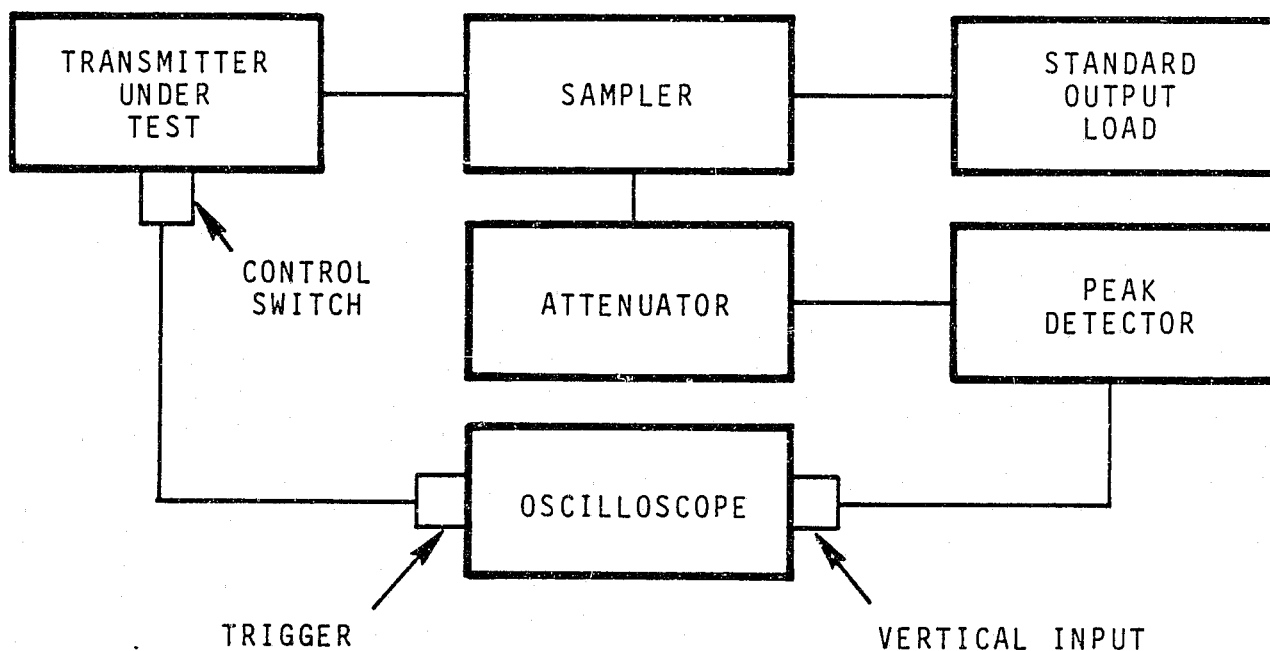


FIGURE 11. Block diagram for carrier attack time measurement.

## 5.5.2 Audio Modulation Tests

### 5.5.2.1 Harmonic Distortion Test

Connect the transceiver transmitter and test equipment as shown in figure 12. Operate the transmitter at nominal carrier output power and adjust the audio input for standard audio test modulation. Ensure that the 1-kHz modulating signal has a total distortion of 0.5 percent or less. Process the sampled transmitter output using the test receiver. Connect the distortion analyzer across the standard audio output load to remove the 1-kHz tone and measure the remaining signal, which is a combination of all the noise and harmonic components.

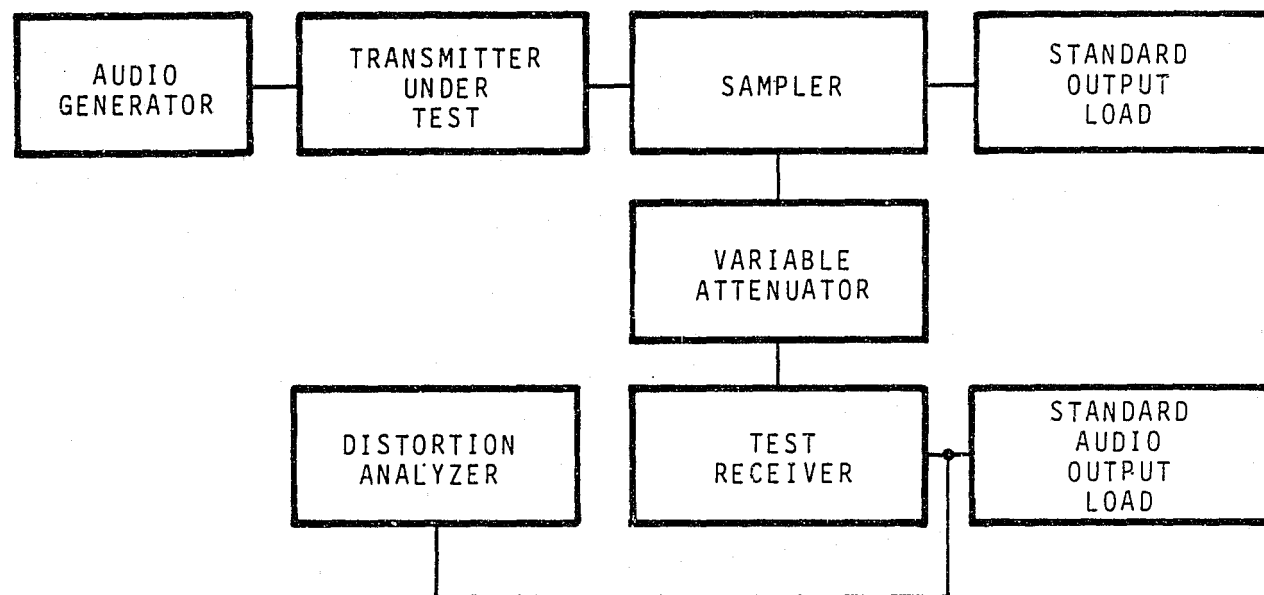


FIGURE 12. Block diagram for harmonic distortion and FM hum and noise measurements.

### 5.5.2.2 FM Hum and Noise Level Test

Connect the transceiver transmitter and test equipment as shown in figure 12. Operate the transmitter at nominal carrier output power and adjust the audio input for standard audio test modulation. Measure the audio output voltage,  $V_1$ , of the test receiver using the distortion analyzer as a voltmeter. Remove the modulation by disconnecting the audio generator and replacing it with the standard audio input load. Measure the resulting audio voltage,  $V_2$ , at the distortion analyzer. Calculate the FM hum and noise level as  $20 \log_{10} (V_1/V_2)$ . The method provides reliable measurements up to 50 dB.

### 5.5.2.3 Audio Response Test

Connect the transceiver transmitter and test equipment as shown in figure 13, using a broadband matching network (sec. 4.2) to match the audio generator output impedance to the transmitter audio input impedance.

Apply selected audio frequencies from 0.3 to 3 kHz to the transmitter, and maintain the audio input level at a constant 30 percent of rated system deviation (i.e., 1.5 kHz) as observed with the deviation meter. Determine the audio voltmeter reading in decibels relative to the voltmeter reading at 1 kHz for each test frequency, and draw a graph similar to that shown in figure 1.

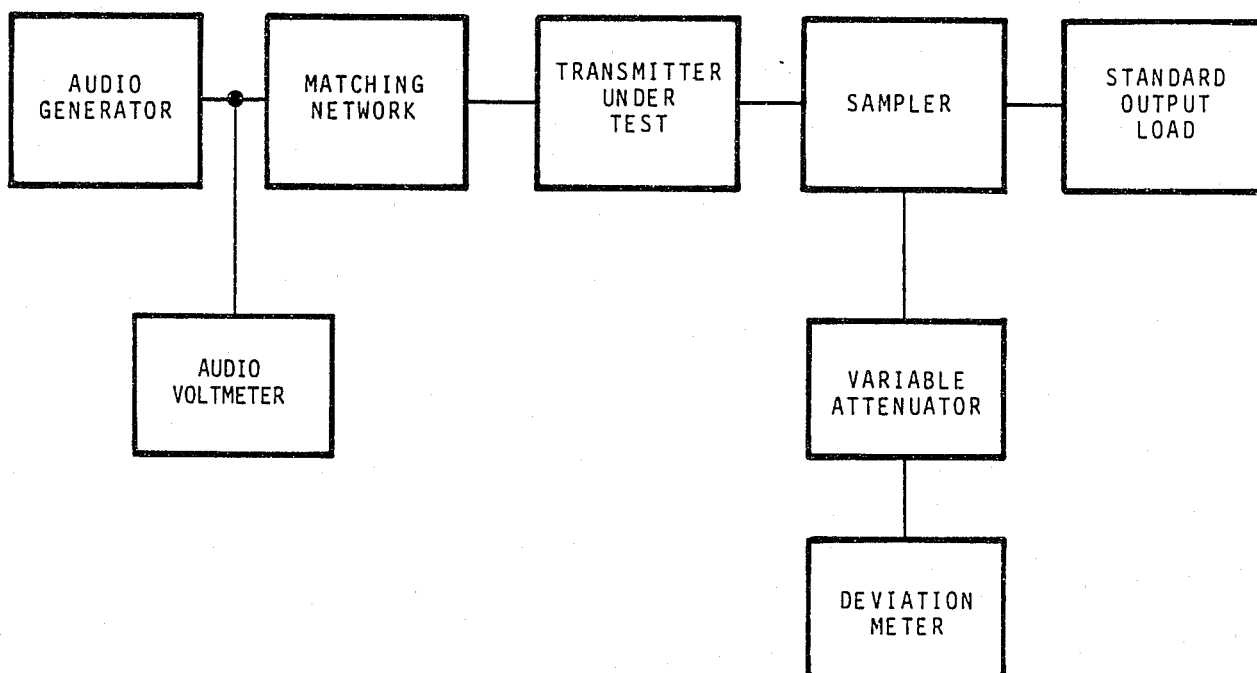


FIGURE 13. Block diagram for audio response measurement.

#### 5.5.2.4 Frequency Deviation Test

Connect the transceiver transmitter and test equipment as shown in figure 14 and adjust the transmitter controls for normal operation. Adjust the audio input for standard audio test modulation, and increase the audio input level until maximum frequency deviation is observed. Measure the frequency deviation with the deviation meter.

#### 5.5.2.5 Modulation Limiting Test

Connect the transceiver transmitter and test equipment as shown in figure 14 and adjust the transmitter controls for normal operation. Adjust the audio input for standard audio test modulation and increase the audio input level 20 dB. Hold the audio input level constant, vary the frequency from 0.3 to 3 kHz and measure the frequency deviation with the deviation meter.

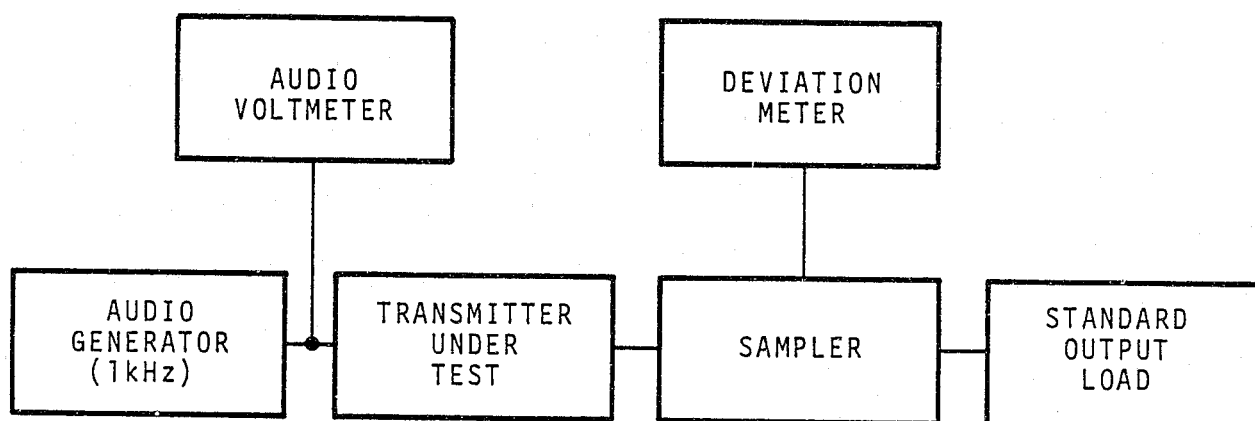


FIGURE 14. Block diagram for frequency deviation and modulation limiting measurements.

### 5.5.3 Electromagnetic Compatibility Tests

#### 5.5.3.1 Radiated Spurious Emissions Test (Type I and II Transceivers)

Set up the test as shown in figure 15, at a site that meets the requirements of section 5.1.9.1. Have a person stand facing the receiving dipole antenna holding the transceiver with the antenna attached 15 cm (6 in) from the body, with the base of the antenna 1.7 m (68 in) above the earth. Place the vertical receiving dipole antenna 30 m (98.4 ft) from the transceiver and 3.0 m (9.8 ft) above the earth. Turn on the transmitter and measure the field strength of the unmodulated carrier frequency in decibels above 1 microvolt per meter ( $\text{dB}\mu\text{V}/\text{m}$ ) using the technique described in the following paragraph. Then measure the field strength in  $\text{dB}\mu\text{V}/\text{m}$  of any radiated spurious emissions, from the lowest radio frequency generated in the transmitter to the tenth harmonic of the carrier, or to 1000 MHz, whichever is lower. Calibrate the receiving antenna for each frequency measured.

For the carrier and each spurious frequency, position the horizontally-polarized receiving antenna a quarter wavelength in any direction to obtain a maximum reading on the field strength meter. Rotate the transmitter to further increase this maximum reading. Repeat this procedure of raising and lowering the receiving antenna and rotating the transmitter until the largest signal has been obtained and recorded. Then orient the receiving antenna for vertical polarization and repeat the procedure for each spurious signal.

The attenuation of each radiated spurious emission is the field strength in  $\text{dB}\mu\text{V}/\text{m}$  of the carrier frequency minus the maximum field strength in  $\text{dB}\mu\text{V}/\text{m}$  of the radiated spurious emission.

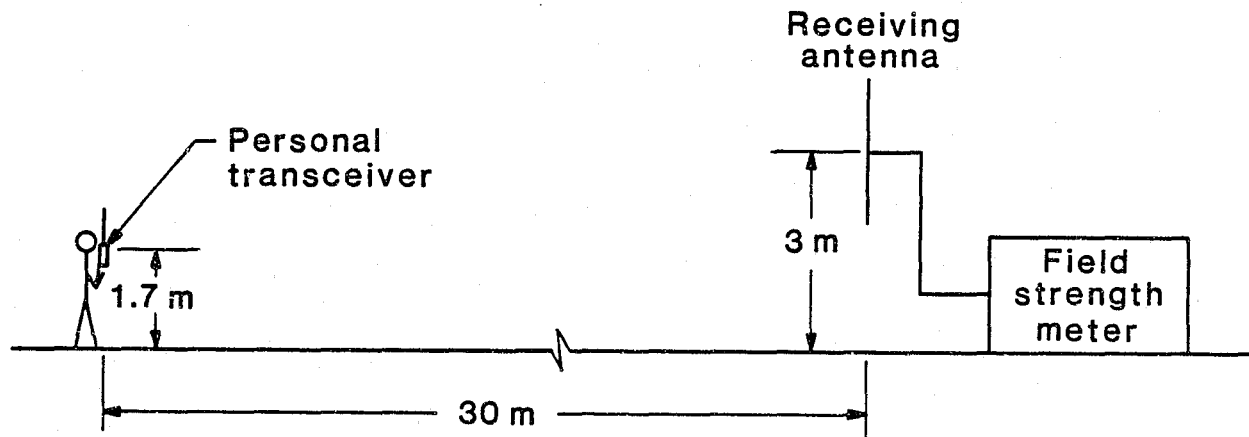


FIGURE 15. Block diagram for radiated spurious emission and radiation efficiency measurements for type I and II transceivers.

#### 5.5.3.2 Radiated Spurious Emissions Test (Type III and IV Transceivers)

Set up the test as shown in figure 16, at a site that meets the requirements of section 5.1.9.2. Place the microwave absorber, at least 1.8 m (6 ft) wide, on the ground between the mobile transceiver and the receiving antenna, as shown. A horn antenna may be used as the receiving antenna, and this test may be performed in an anechoic chamber (sec. 5.2.18). Have a person stand facing the receiving antenna holding the transceiver with the antenna attached 15 cm (6 in) from the body, with the base of the antenna 1.7 m (68 in) above the earth. Place the vertical receiving antenna 3 m (9.8 ft) from the transceiver and 1.7 m (68 in) above the earth. Turn on the transmitter and measure the field strength of the unmodulated carrier frequency in  $\text{dB}\mu\text{V}/\text{m}$  using the technique described in the following paragraph. Then measure the field strength in  $\text{dB}\mu\text{V}/\text{m}$  of any radiated spurious emissions, from the lowest radio frequency generated in the transmitter to 3 GHz. Calibrate the receiving antenna for each frequency measured.

For the carrier and each spurious frequency, rotate the transmitter with the receiving antenna horizontally polarized to obtain a maximum reading on the field strength meter. Record this reading. Then orient the receiving antenna for vertical polarization and repeat the procedure for each spurious signal.

The attenuation of each radiated spurious emission is the field strength in  $\text{dB}\mu\text{V}/\text{m}$  of the carrier frequency minus the maximum field strength in  $\text{dB}\mu\text{V}/\text{m}$  of the radiated spurious emission.

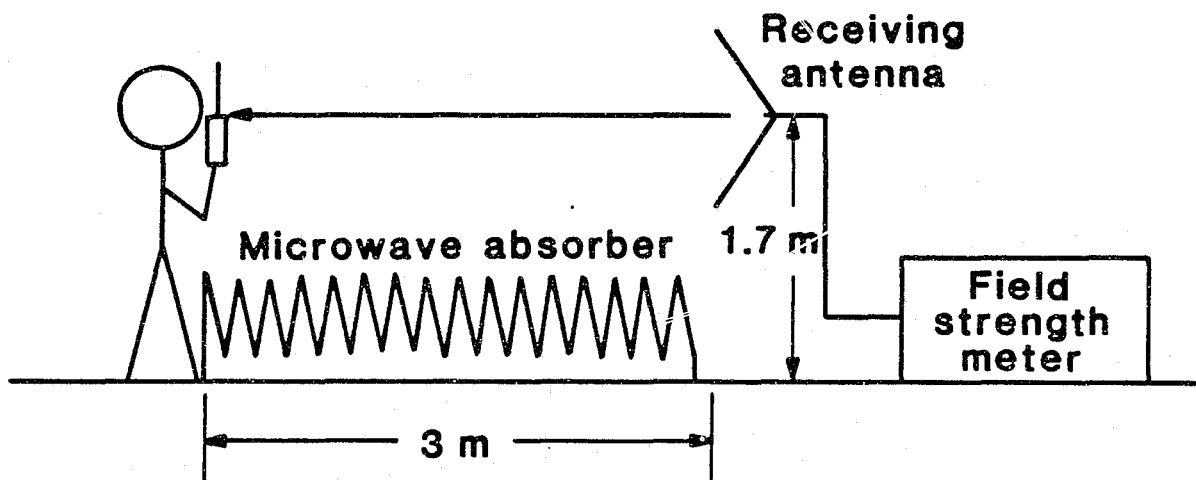


FIGURE 16. Block diagram for radiated spurious emission and radiation efficiency measurements for type III and IV transceivers.

### 5.5.3.3 Sideband Spectrum Test

Connect the transceiver transmitter and test equipment as shown in figure 17. Using the variable attenuator, adjust the unmodulated carrier signal for a full-scale signal at least 60 dB above the noise displayed on the spectrum analyzer. Apply electromagnetic compatibility test modulation and measure the average envelope of the resulting spectrum at both  $\pm 10$  kHz and  $\pm 20$  kHz from the center frequency. Adjust the spectrum analyzer controls so that approximately 50 kHz of transmitter spectrum is centered on the display. The image on the cathode ray tube of the spectrum analyzer should be similar to that shown in figure 18.

Record the sideband spectrum attenuations as the differences between the center frequency amplitude and the amplitudes of the sidebands located at  $\pm 10$  kHz and  $\pm 20$  kHz from the center frequency.

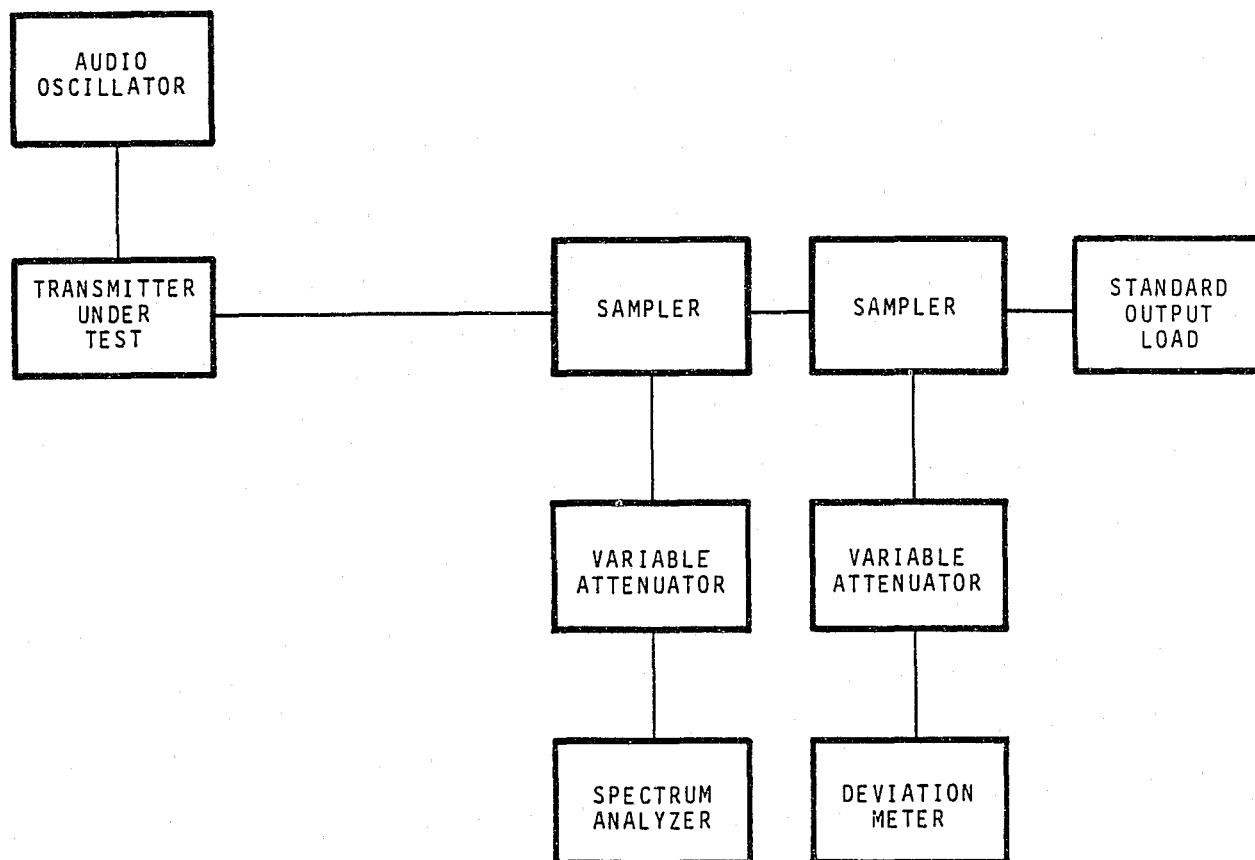


FIGURE 17. Block diagram for sideband spectrum measurement.



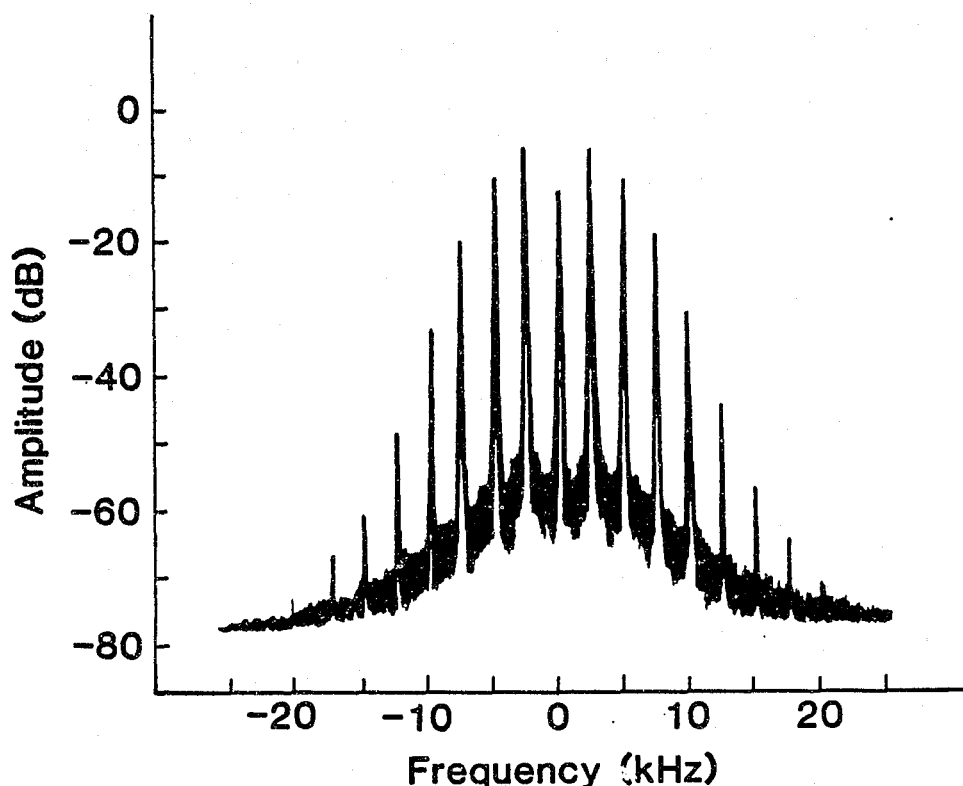


FIGURE 18. Typical sideband spectrum of a transmitter using a 2.5 kHz tone 16 dB greater than that required to produce  $\pm 2.5$  kHz deviation at 1.0 kHz.

## 5.6 Antenna Tests

### 5.6.1 Radiation Efficiency Test (Type I and II Transceivers)

Set up the test as shown in figure 15, at a site that meets the requirements of section 5.1.9.1. Have a person stand facing the receiving dipole antenna holding the transceiver, with the antenna attached, 15 cm (6 in) from the body, with the base of antenna 1.7 m (68 in) above the earth. Place the vertical receiving dipole antenna 30 m (98.4 ft) from the transceiver and 3.0 m (9.8 ft) above the earth. Turn on the transmitter and move the horizontally-polarized receiving antenna a quarter wavelength in any direction to obtain a maximum reading on the field strength meter. Rotate the transceiver to further increase this maximum reading. Repeat this procedure of raising and lowering the antenna and rotating the transceiver until the largest signal has been obtained and recorded. Measure the field strength of the unmodulated carrier frequency. Calculate the radiation efficiency using the equation  $E^2 d^2 / 30P$  where  $E$  is the measured field strength in volts per meter,  $d$  is the separation distance in meters, and  $P$  is the measured transmitter output power in watts (sec. 5.5.1.1) when terminated in a 50- $\Omega$  load.

### 5.6.2 Radiation Efficiency Test (Type III and IV Transceivers)

Set up the test as shown in figure 16, at a site that meets the requirements of section 5.1.9.2. Place the microwave absorber, at least 1.8 m (6 ft) wide, on the ground between the mobile transceiver and the receiving antenna, as shown. A horn antenna may be used as the receiving antenna, and this test may be performed in an anechoic chamber. Have a person stand facing the receiving antenna holding the transceiver, with the antenna attached, 15 cm (6 in) from the body, with the base of the antenna 1.7 m (68 in) above the earth. Place the vertical receiving antenna 3 m (9.8 ft) from the transceiver and 1.7 m (68 in) above the earth. Turn on the transmitter. Rotate the transceiver to obtain a maximum reading on the field strength meter. Record this reading. Measure the field strength of the unmodulated carrier frequency in volts per meter. Calculate the radiation efficiency as in section 5.6.1.

## 5.7 Battery Service Life Test

Connect the transceiver and test equipment as shown in figure 19. Adjust the transceiver for 500-mW audio output power. Use the signal generator to provide a 1-mV signal to the transceiver receiver. Start the test, and use an interval timer to operate the transceiver in accordance with the battery test duty cycle (5.1.8). Measure the time required for the transmitter output power to decrease by 3 dB.

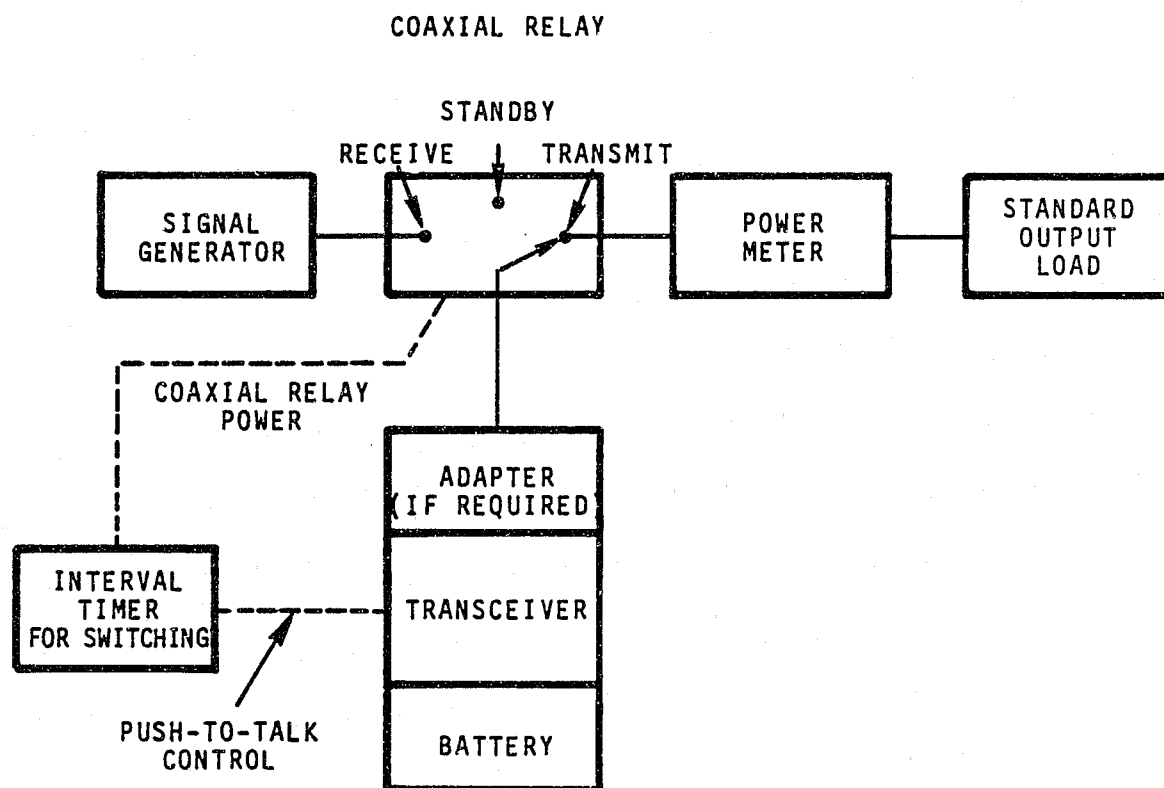


FIGURE 19. Block diagram for battery service life measurement.

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