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***Technology Assessment
Program***

Personal/Mobile FM Transceivers

NIJ Standard-0224.00

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U.S. Department of Justice
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National Institute of Justice**

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FOREWORD

This document, NIJ Standard-0224.00, Personal/Mobile 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.

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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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FOR
PERSONAL/MOBILE FM TRANSCEIVERS
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COMMONLY USED SYMBOLS AND ABBREVIATIONS

A	ampere	H	henry	nm	nanometer
ac	alternating current	h	hour	No.	number
AM	amplitude modulation	hf	high frequency	o.d.	outside diameter
cd	candela	Hz	hertz (c/s)	Ω	ohm
cm	centimeter	i.d.	inside diameter	p.	page
CP	chemically pure	in	inch	Pa	pascal
c/s	cycle per second	ir	infrared	pe	probable error
d	day	J	joule	pp.	pages
dB	decibel	L	lambert	ppm	part per million
dc	direct current	L	liter	qt	quart
°C	degree Celsius	lb	pound	rad	radian
°F	degree Fahrenheit	lbf	pound-force	rf	radio frequency
diam	diameter	lbf-in	pound-force inch	rh	relative humidity
emf	electromotive force	lm	lumen	s	second
eq	equation	ln	logarithm (natural)	SD	standard deviation
F	farad	log	logarithm (common)	sec.	section
fc	footcandle	M	molar	SWR	standing wave ratio
fig.	figure	m	meter	uhf	ultrahigh frequency
FM	frequency modulation	min	minute	uv	ultraviolet
ft	foot	mm	millimeter	V	volt
ft/s	foot per second	mph	mile per hour	vhf	very high frequency
g	acceleration	m/s	meter per second	W	watt
g	gram	N	newton	λ	wavelength
gr	grain	N-m	newton meter	wt	weight

area = unit² (e.g., ft², in², etc.); volume = unit³ (e.g., ft³, m³, etc.)

PREFIXES

d	deci (10 ⁻¹)	da	deka (10)
c	centi (10 ⁻²)	h	hecto (10 ²)
m	milli (10 ⁻³)	k	kilo (10 ³)
μ	micro (10 ⁻⁶)	M	mega (10 ⁶)
n	nano (10 ⁻⁹)	G	giga (10 ⁹)
p	pico (10 ⁻¹²)	T	tera (10 ¹²)

COMMON CONVERSIONS

(See ASTM E380)

ft/s × 0.3048000 = m/s
 ft × 0.3048 = m
 ft-lbf × 1.355818 = J
 gr × 0.06479891 = g
 in × 2.54 = cm
 kWh × 3 600 000 = J

lb × 0.4535924 = kg
 lbf × 4.448222 = N
 lbf/ft × 14.59390 = N/m
 lbf-in × 0.1129848 = N-m
 lbf/in² × 6894.757 = Pa
 mph × 1.609344 = km/h
 qt × 0.9463529 = L

Temperature: $(T_F - 32) \times 5/9 = T_C$

Temperature: $(T_C \times 9/5) + 32 = T_F$

NIJ STANDARD FOR PERSONAL/MOBILE FM TRANSCEIVERS

1. PURPOSE AND SCOPE

The purpose of this document is to establish performance requirements and methods of test for non-trunked, frequency modulated (FM) personal/mobile transceivers. This standard applies to personal transceivers with rechargeable batteries and personal/mobile transceivers which use a charger/mobile unit, with or without an rf power amplifier, and 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. The individual personal FM transceivers are expected to meet the minimum performance requirements as established in NIJ Standard-0209.01 for Personal FM Transceivers [1]¹ prior to being tested for the requirements of this standard. Due to the lack of use of personal/mobile transceivers in the 25–50 MHz and 806–866 MHz frequency bands, requirements for these transceivers are not included in this standard.

2. CLASSIFICATION

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

2.1 Type I

Personal/mobile transceivers which operate in the 25–50 MHz band with a receiver channel spacing of 20 kHz.

2.2 Type II

Personal/mobile transceivers which operate in the 150–174 MHz band with a receiver channel spacing of 30 kHz.

2.3 Type III

Personal/mobile transceivers which operate in the 400–512 MHz band with a receiver channel spacing of 25 kHz.

2.4 Type IV

Personal/mobile 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 [2].

3.1 AM Hum and Noise

The residual amplitude modulation present on an unmodulated carrier.

¹ Numbers in brackets refer to the references in appendix A.

3.2 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.

3.3 Audio Noise Output Power

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

3.4 Audio Output Power

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

3.5 Audio Response of a Receiver

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

3.6 Audio Response of a Transmitter

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

3.7 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 [3].

3.8 Carrier Output Power

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

3.9 Charger/Mobile Unit

A vehicle-mounted unit that automatically connects the mobile antenna, mobile microphone, external speaker, and charging circuit to a personal FM transceiver and converts it into a mobile FM transceiver when the personal FM transceiver is inserted into the unit.

3.10 Dead Battery Effects

The effects attributed to a dead battery in a personal FM transceiver which, when inserted in a charger/mobile unit, could reduce the operating performance of a personal/mobile FM transceiver to a level below the minimum performance requirements of this standard.

3.11 FM Hum and Noise

The frequency modulation present on an unmodulated carrier.

3.12 Insertion Power Loss

The output power loss incurred by insertion of the personal FM transceiver into the charger/mobile unit. The ratio, expressed in decibels, of (1) the output power of the personal FM transceiver before insertion to (2) the output power of the charger/mobile unit after insertion of the personal FM transceiver.

3.13 Nominal Value

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

3.14 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.

3.15 Personal/Mobile FM Transceiver

A personal FM transceiver that converts to a vehicular mobile FM transceiver system when inserted into a charger/mobile unit.

3.16 Rated System Deviation

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

3.17 RF Power Amplifier

An rf amplifier that is used in conjunction with the charger/mobile unit to increase the transmit power of the personal/mobile FM transceiver.

3.18 Sampler

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

3.19 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*.

3.20 SINAD Sensitivity

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

3.21 Spurious Emission

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

3.22 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.

3.23 Squelch

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

3.24 Standby Mode

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

3.25 Standing Wave Ratio (SWR)

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

3.26 Transceiver

The combination of radio transmitting and receiving equipment in a common housing.

4. REQUIREMENTS

4.1 Minimum Performance

The personal/mobile FM transceiver performance shall meet or exceed the requirement for each characteristic as given below and in table 1. The performance requirements listed in table 1 meet or exceed those given in the Rules and Regulations published by the Federal Communications Commission [3].

TABLE 1. Minimum performance requirements for personal/mobile FM transceivers.

	Minimum requirement	
	Frequency band (MHz)	
	150-174	400-512
<i>Receiver Characteristic</i>		
Sensitivity Characteristics		
A. SINAD Sensitivity	0.4 μ V	0.4 μ V
B. SINAD Sensitivity Variance (Supply Voltage Varied $\pm 10\%$)	0.7 μ V	0.7 μ V
Audio Characteristics		
C. Audio Output Power (Loudspeaker)	0.5-5 W	0.5-5 W
D. Audio Output Power Variance (Supply Voltage Varied +10% and -20%)	2 dB	2 dB
E. Audio Distortion	5%	5%
F. Audio Response (Loudspeaker)	-10, +2 dB	-10, +2 dB
G. Audio Hum and Noise (Unsquelled)	45 dB	45 dB
H. Audio Hum and Noise (Squelched)	60 dB	60 dB
<i>Transmitter Characteristic</i>		
Radio Frequency Carrier Characteristics		
I. Carrier Output Power Variance	-0.3 dB	-0.3 dB
J. Output Power Variance (Supply Voltage Varied $\pm 10\%$)	-3 dB	-3 dB
K. Output Power Variance (Supply Voltage Varied -20%)	-6 dB	-6 dB
L. Insertion Power Loss	1 dB	1 dB
M. AM Hum and Noise Level	34 dB	34 dB
Audio Modulation Characteristic		
N. Audio Response	+1, -3 dB	+1, -3 dB
Electromagnetic Compatibility Characteristics		
O. Conducted Spurious Emissions	55 dB	55 dB
P. Radiated Spurious Emissions	1.65 mV/m	16.5 mV/m
Vibration Stability		
Q. FM Hum and Noise Level	25 dB	25 dB
R. Carrier Frequency Tolerance	0.0005%	0.0005%
<i>Transceiver Characteristic</i>		
S. Insertion/Withdrawal Life	5000	5000

4.2 User Information

A nominal value for each of the characteristics listed in table 1 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 personal/mobile FM 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 personal FM transceiver standard supply voltage, and the battery current drain in the transmit mode. 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.

4.3 Performance at Environmental Extremes

The ability of the personal FM transceiver to operate in temperature and humidity extremes should already have been determined by testing it in accordance with NIJ Standard-0209.01, Personal FM Transceivers [1]. It is suggested that the vibration and shock stability tests in this standard be performed before the personal/mobile transceiver is tested for compliance with the requirements of sections 4.4 through 4.7.

4.3.1 Vibration Stability

When tested in accordance with section 5.3.1, no fixed part of the transceiver shall come loose, nor movable part be shifted in position. During the test, the FM hum and noise level shall be attenuated a minimum of 25 dB and the carrier frequency shall be within 0.0005 percent of the assigned value.

4.3.2 Shock Stability

When tested in accordance with section 5.3.2, the transceiver shall suffer no more than superficial damage. 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 $0.4 \mu\text{V}$ or less at a SINAD ratio of 12 dB and an audio output power at least 50 percent of the nominal audio output power (sec. 4.2). When the standard power supply voltage is varied +10 percent and -10 percent, the SINAD sensitivity shall be $0.7 \mu\text{V}$ or less.

4.4.2 Audio Characteristics

The audio characteristics of output power, distortion, response, and hum and noise shall be measured in accordance with section 5.4.2.

4.4.2.1 Audio Output Power

The audio output power of the receiver shall be between 0.5 and 5 W if a loudspeaker is used at the receiver output. When the standard supply voltage is varied +10 percent and -20 percent, the audio output power shall not be reduced more than 2 dB below the nominal value.

4.4.2.2 Audio Distortion

Audio distortion at the nominal audio output power shall be less than 5 percent for an rf input signal with standard modulation.

4.4.2.3 Audio Response

The audio response of the receiver, when used with a loudspeaker, shall be within -10, +2 dB 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.

4.4.2.4 Audio Hum and Noise

The audio hum and noise output power from the receiver in the unsquelched condition shall be 45 dB or more and, in the maximum squelched condition, shall be 60 dB or more below the value of nominal audio output power.

4.5 Transmitter Performance

4.5.1 Radio Frequency Characteristics

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

4.5.1.1 Output Power

Transmitter output power is specified by the FCC [3]. When the personal/mobile FM transceiver is in the transmit mode, the carrier output power delivered to a standard output load shall not decrease more than 0.3 dB from the nominal value at any time during the transmitter test duty cycle, except for the initial second after the personal/mobile FM transceiver has been switched from the standby mode to the transmit mode. When the standard supply voltage is varied ± 10 percent, the output power shall not decrease by more than 3 dB. When the standard supply voltage is reduced by 20 percent, the output power shall not decrease by more than 6 dB.

4.5.1.2 Insertion Power Loss

The insertion power loss incurred when the personal/mobile FM transceiver is inserted into the charger/mobile unit shall not exceed 1 dB.

4.5.1.3 AM Hum and Noise Level

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

4.5.2 Audio Modulation Characteristic

When measured in accordance with section 5.5.2, 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.

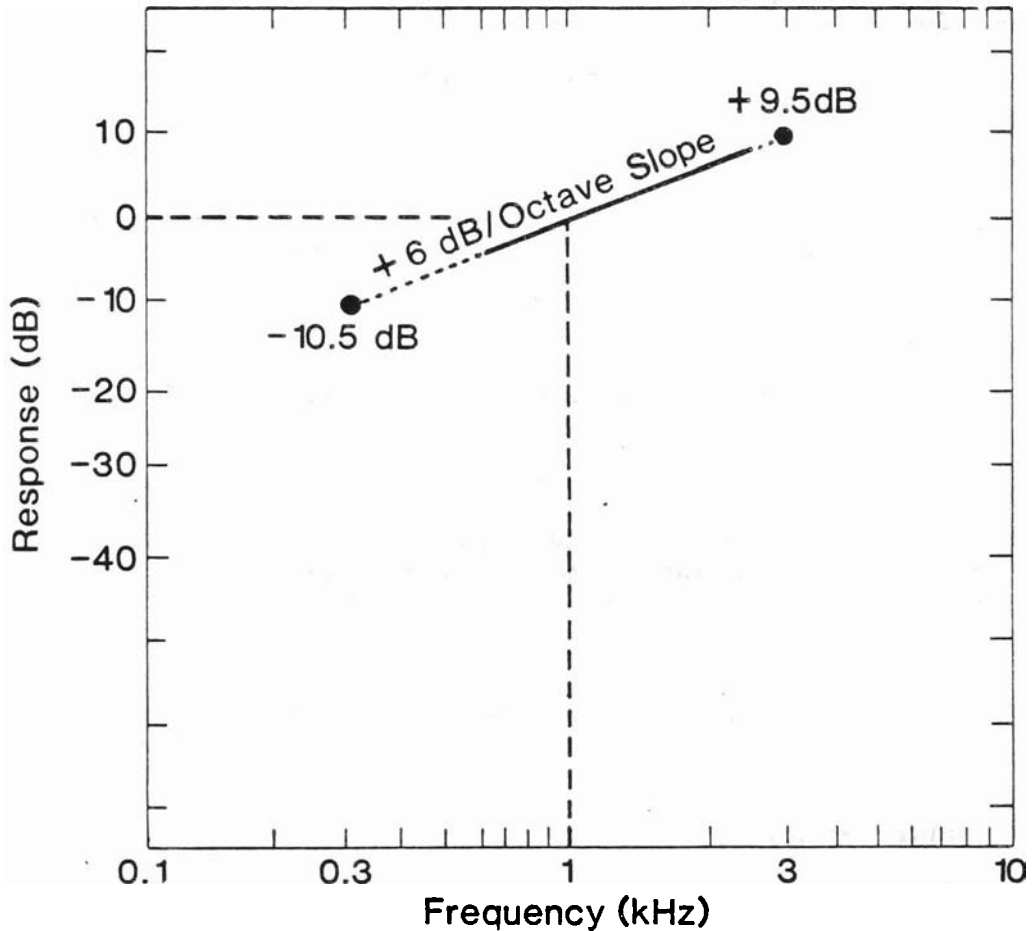


FIGURE 1. Audio response characteristic of personal/mobile FM transmitters.

4.5.3 Electromagnetic Compatibility Characteristics

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

4.5.3.1 Conducted Spurious Emissions

Each conducted spurious emission shall be attenuated a minimum of $[55 + 10 \log_{10}(\text{output power in watts})]$ dB below the level of the transmitter output power.

4.5.3.2 Radiated Spurious Emissions

Each radiated spurious emission shall be no larger than 1.65 mV/m at 30 m for type II transceivers or 16.5 mV/m at 3 m for type III transceivers, i.e., each radiated spurious emission shall be less than $50 \mu\text{W}$.

4.6 Dead Battery Effects

When measured in accordance with section 5.6, the transmitter and receiver minimum performance requirements shall meet or exceed the values given in table 1.

4.7 Insertion/Withdrawal Life

When tested in accordance with section 5.7, the transmitter and receiver minimum performance requirements shall meet or exceed the values given in table 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 °C (68 and 86 °F).

5.1.2 Standard Relative Humidity

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

5.1.3 Standard Supply Voltage

A nominal 12-V system shall be used when testing the personal/mobile FM transceiver. The standard supply voltage shall be determined from the equation $V = 13.8 - (0.02)I$ where I is the current (in amperes) delivered to the mobile unit. For example, if the current while transmitting is 12 A, the standard supply voltage should be approximately 13.6 V. When testing the personal FM transceiver separately, 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 1 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., ± 3 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 ± 5 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 Radiation Test Site

5.1.8.1 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. Preferably, the test site should be equipped with a turntable located at ground level.

5.1.8.2 Type III and IV Transceivers

In addition to the requirements described in section 5.1.8.1, the standard radiation test site shall have microwave absorbing material placed on the ground to restrict standing waves, produced by reflections from the ground, to no larger than ± 1 dB. If available, an anechoic chamber may be used instead (sec. 5.2.12). Preferably the test site should be equipped with a turntable located 1 m above ground level and supported by nonreflective material.

5.1.9 Standard Duty Cycles

5.1.9.1 Receiver Test Duty Cycle

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

5.1.9.2 Transmitter Test Duty Cycle

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

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 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).

5.2.2 Isolation Transformer

The isolation transformer shall have a turns ratio of 1 to 1, an impedance of 600 Ω , a frequency response within ± 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.

5.2.3 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 shunted by less than 100 pF, and an accuracy of at least ± 1 dB. It shall have the capability to measure both audio distortion and the rms voltage of audio signals to within ± 3 percent. The analyzer shall incorporate a 1000-Hz band elimination filter for the audio distortion measurements.

5.2.4 FM Signal Generator

The FM signal generator shall have a 50- Ω output impedance, a maximum SWR of 1.2, and a calibrated variable output level accurate to ± 2 dB when terminated in a 50- Ω 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.

5.2.5 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 personal/mobile FM transceiver speaker and a power rating equal to or exceeding the nominal audio output power of the personal/mobile FM 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.

5.2.6 Audio Voltmeter

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

5.2.7 Standard Output Load (Transmitter)

The standard output load shall be a nonradiating 50- Ω 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.

5.2.8 Standard Input Load (Transmitter)

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

5.2.9 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.

5.2.10 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 measurement uncertainty of ± 2 dB or less. It shall be calibrated

to accurately measure field strengths from approximately 0.1 to 1 mV/m over the frequency range of interest. When testing type III transceivers, field strength measurements are required at frequencies up to 2 GHz. The receiver should be located near the receiving antenna to keep the length of the cable between them as short as possible.

5.2.11 Microwave Absorber

The microwave absorber shall attenuate the reflected energy at least 20 dB at 400 MHz at an incidence angle of 56°.

5.2.12 Anechoic Chamber

An 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 ± 1 dB.

5.3 Transceiver Environmental Tests

Perform the environmental tests using the standard supply voltage and measurement techniques described in sections 5.4 and 5.5.

5.3.1 Vibration Test

Fasten the personal/mobile 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 personal/mobile FM 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 personal/mobile FM 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 (0.15)] 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.

5.3.2 Shock Test

Fasten the personal/mobile FM transceiver to a test bench using a rigid mounting fixture and subject the transceiver to a series of 10 impacts in each of three mutually-perpendicular directions (sec. 5.3.1). Each impact shall consist of a half sinewave acceleration of 20-g peak amplitude and 11-ms duration applied horizontally to the transceiver mounting facilities and measured with an accelerometer. The transceiver shall be in the transmit mode during one-half the impacts in each direction and in the standby mode during the other half.

5.4 Receiver Tests

5.4.1 SINAD Sensitivity Test

Connect the personal/mobile FM 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 nominal audio output power (0.5–5 W). Do not readjust the volume control for the remainder of the measurement. Decrease the output level of the generator



FIGURE 2. Block diagram for SINAD sensitivity and audio distortion measurements.

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 50 percent of the original value 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 power supply voltage of +10 percent and -10 percent.

5.4.2 Audio Tests

5.4.2.1 Audio Output Power Test

Connect the personal/mobile FM transceiver receiver and test equipment as shown in figure 3. 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 power supply voltage of +10 percent and -10 percent.



FIGURE 3. Block diagram for audio output power, audio response, and audio hum and noise measurements.

5.4.2.2 Audio Distortion Test

Connect the personal/mobile FM 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 nominal audio output power and measure the audio distortion.

5.4.2.3 Audio Response Test

Connect the personal/mobile FM transceiver receiver and test equipment as shown in figure 3. 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 nominal audio output power. 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.

5.4.2.4 Audio Hum and Noise Tests

Connect the personal/mobile FM transceiver receiver and test equipment as shown in figure 3. 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 nominal audio output power. 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 (unscelched).

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

Connect the personal/mobile FM transceiver and the test equipment as shown in figure 4. Operate the transceiver transmitter without modulation and measure the output power 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 this for changes in standard supply voltage of -10 percent and -20 percent.



FIGURE 4. Block diagram for output power and insertion power loss measurements.

5.5.1.2 Insertion Power Loss Test

Connect the personal FM transceiver and the test equipment as shown in figure 4. Operate the transceiver transmitter without modulation and measure the output power using standard supply voltage. Insert the personal FM transceiver in the charger/mobile unit and measure the output power, without amplification, using the same standard supply voltage. The insertion loss is calculated as $10 \log_{10} (A/B)$, where A is the output power of the personal FM transceiver and B is the output power of the charger/mobile unit with the personal FM transceiver inserted.

5.5.1.3 AM Hum and Noise Level Test

Connect the personal/mobile FM transceiver transmitter and test equipment as shown in figure 5. Use a linear peak-carrier responsive AM detector to detect the sampled output of the transmitter. With the transmitter operating at rated 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.

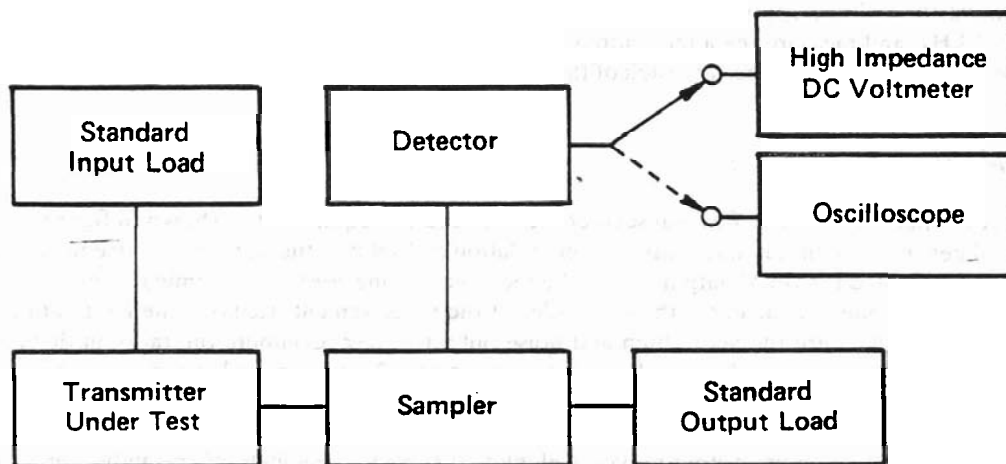


FIGURE 5. Block diagram for AM hum and noise measurement.

5.5.2 Audio Response Test

Connect the personal/mobile FM transceiver transmitter and test equipment as shown in figure 6, using a broadband matching network (sec. 4.2) to match the audio generator output impedance to the transmitter audio input load.

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.

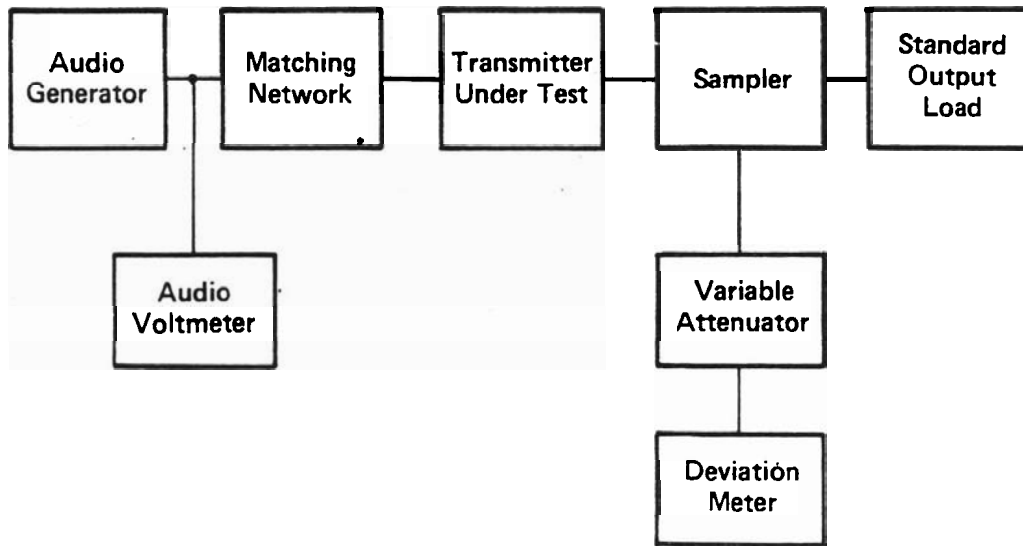


FIGURE 6. Block diagram for audio response measurement.

5.5.3 Electromagnetic Compatibility Tests

5.5.3.1 Conducted Spurious Emissions Test

Connect the personal/mobile FM transceiver transmitter as shown in step 1, figure 7. The selective rf voltmeter or spectrum analyzer shall be capable of measuring signals at least 80 dB below the carrier level. Modulate the transmitter with electromagnetic compatibility test modulation, and measure the transmitter output power in decibels above 1 mW (dBm). Record the spurious emissions from the transmitter using the selective voltmeter or spectrum analyzer.

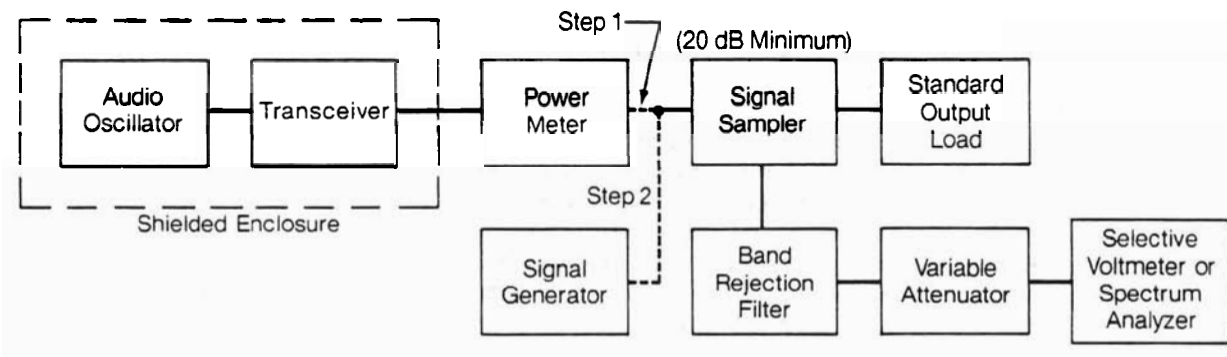


FIGURE 7. Block diagram for conducted spurious emission measurement.

Disconnect the power meter, transmitter, and audio oscillator from the circuit and connect the signal generator as shown in step 2. Use a signal generator with a calibrated output. Adjust the signal generator to obtain the same frequencies and magnitudes of spurious signals as were recorded above, and record the corresponding outputs of the signal generator in dBm. The transmitter output power in dBm minus the signal generator output in dBm is the value sought.

Measure all frequencies from the lowest frequency generated within the transmitter to the 10th harmonic of the carrier, or 3 GHz, whichever is lower.

5.5.3.2 Radiated Spurious Emissions Test (Type I and II Transceivers)

Set up the personal/mobile FM transceiver and the test equipment as shown in figure 8 at a site that meets the requirements of section 5.1.8.1. Connect the transmitter to the standard output load and adjust it to produce nominal output power. Measure the spurious emissions with the receiving antenna 30 m (98.4 ft) from the transmitter and 3 m (9.8 ft) above the earth. Tune the field strength meter from the lowest radio frequency generated in the personal/mobile transmission equipment up to the 10th harmonic of the carrier or 1000 MHz, whichever is lower. Note each spurious emission.

For each spurious frequency noted, raise and lower the receiving antenna with a horizontal polarization to obtain a maximum reading on the field strength receiver. Rotate the transmitter to further maximize the reading. Repeat this procedure of raising and lowering the antenna and rotating the transmitter until the largest signal has been obtained and recorded. Then orient the antenna for vertical polarization and repeat the procedure for each spurious signal. Record the maximum field strength of the spurious frequencies.

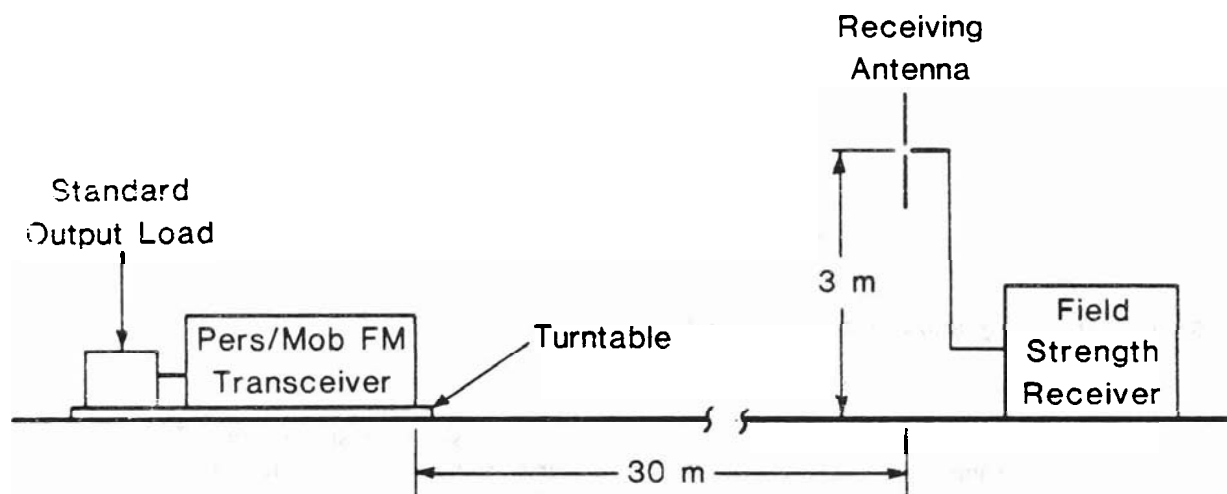


FIGURE 8 Diagram for radiated spurious emission measurement for type I and II personal/mobile FM transceivers.

5.5.3.3 Radiated Spurious Emissions Test (Type III and IV Transceivers)

Set up the personal/mobile FM transceiver and the test equipment as shown in figure 9 at a site that meets the requirements of section 5.1.8.2. Place the microwave absorber, at least 1.8 m (6 ft) wide, on the ground between the personal/mobile FM transceiver and the receiving antenna, as shown. Connect the transmitter to the standard output load and adjust it to produce nominal output power. Measure the spurious emissions with both the receiving antenna and the transmitter 1 m (3.3 ft) above the earth and the receiving antenna 3 m (9.8 ft) from the personal/mobile transmitter. Tune the field strength meter from the lowest radio frequency generated by the transmitter up to 3 GHz. Note each spurious emission.

For each spurious emission frequency noted, raise and lower the receiving antenna with a horizontal polarization to obtain a maximum reading on the field strength receiver. Rotate the personal/mobile transmitter to further maximize the reading. Repeat this procedure of raising and lowering the antenna and rotating the transmitter until the largest signal has been obtained and recorded. Then orient the antenna for vertical polarization and repeat the procedure for each spurious signal. Record the maximum field strength of the spurious frequencies.

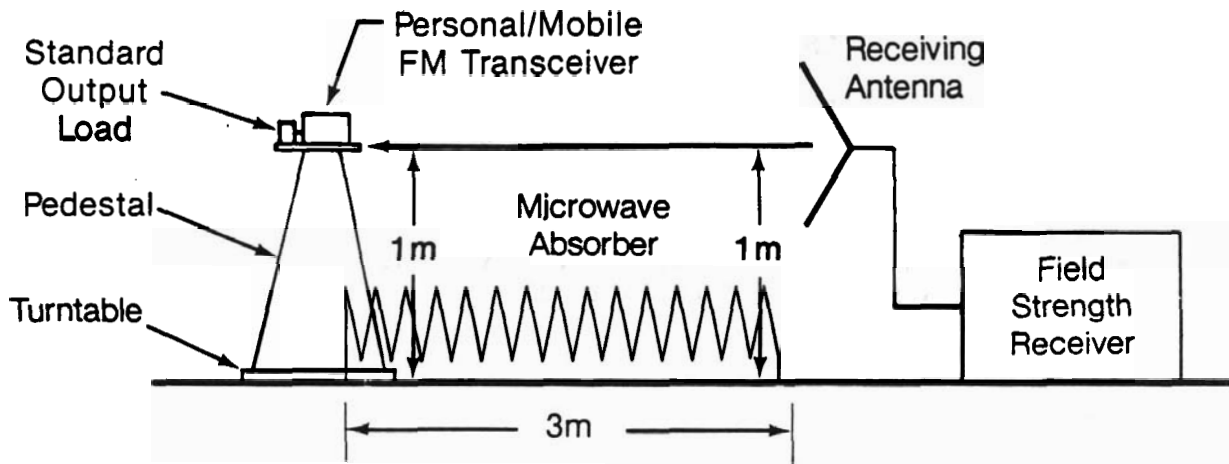


FIGURE 9. Block diagram for radiated spurious emission measurement for type III and IV personal/mobile FM transceivers.

5.6 Dead Battery Effects Test

Remove the personal FM transceiver from the charger/mobile unit and discharge the batteries in the transceiver to a voltage of 1 V per cell. Once this condition is reached, insert the personal FM transceiver into the charger/mobile unit and repeat the receiver and transmitter tests given in sections 5.4 and 5.5.

5.7 Insertion/Withdrawal Life Test

Withdraw and reinsert the personal FM transceiver, either automatically or manually, into the charger/mobile unit 5000 times. Nonabrasive cleaning of the connectors on both the personal FM transceiver and charger/mobile unit is permitted after each 10 complete insertion/withdrawal operations. Upon completion, insert the personal FM transceiver into the charger/mobile unit and repeat the receiver and transmitter tests given in sections 5.4, 5.5.1, and 5.5.2.

APPENDIX A—REFERENCES

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