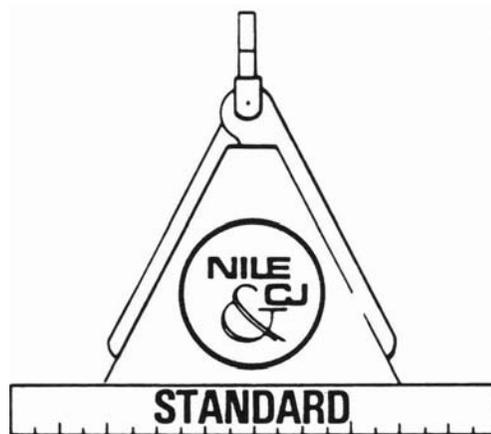


NILECJ-STD-0213.00
NOVEMBER 1977

LAW ENFORCEMENT STANDARDS PROGRAM

FM REPEATER SYSTEMS



U.S. DEPARTMENT OF JUSTICE
Law Enforcement Assistance Administration
National Institute of Law Enforcement and Criminal Justice

LAW ENFORCEMENT STANDARDS PROGRAM

**NILECJ STANDARD
FOR
FM
REPEATER SYSTEMS**

**A Voluntary National Standard Promulgated by the
National Institute of Law Enforcement and Criminal Justice.**

NOVEMBER 1977

**U.S. DEPARTMENT OF JUSTICE
Law Enforcement Assistance Administration
National Institute of Law Enforcement and Criminal Justice**

**NATIONAL INSTITUTE OF LAW ENFORCEMENT
AND CRIMINAL JUSTICE**

Blair G. Ewing, Acting Director

**LAW ENFORCEMENT ASSISTANCE
ADMINISTRATION**

James M. H. Gregg, Acting Administrator

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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 Jacob J. Diamond, Chief of LESL. NBS Electromagnetics Division staff members responsible for the preparation of the standard were Harold E. Taggart, project manager, Robert M. Jickling, and John F. Shafer. Acknowledgment is given to previous work in this field by the Associated Public-Safety Communications Officers, Inc.; The Institute of Electrical and Electronics Engineers, Inc.; and the Electronics Industries Association.

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NILECJ STANDARD FOR FM REPEATER SYSTEMS

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FOREWORD

Following a Congressional mandate¹ to develop new and improved techniques, systems, and equipment to strengthen law enforcement and criminal justice, the National Institute of Law Enforcement and Criminal Justice (NILECJ) has established the Law Enforcement Standards Laboratory (LESL) at the National Bureau of Standards. LESL's function is to conduct research that will assist law enforcement and criminal justice agencies in the selection and procurement of quality equipment.

In response to priorities established by NILECJ, LESL is (1) subjecting existing equipment to laboratory testing and evaluation and (2) conducting research leading to the development of several series of documents, including national voluntary equipment standards, user guidelines, state-of-the-art surveys and other reports.

This document, NILECJ-STD-0213.00, FM Repeater Systems, is a law enforcement equipment standard developed by LESL and approved and issued by NILECJ. Additional standards as well as other documents are being issued under the LESL program in the areas of protective equipment, communications equipment, security systems, weapons, emergency equipment, investigative aids, vehicles and clothing.

This equipment standard is a technical document consisting of performance and other requirements together with a description of test methods. Equipment which can meet these requirements is of superior quality and is suited to the needs of law enforcement agencies. Purchasing agents can use the test methods described in this standard to determine firsthand whether a particular equipment item meets the requirements of the standard, or they may have the tests conducted on their behalf by a qualified testing laboratory. Law enforcement personnel may also reference this standard in purchase documents and require that any equipment offered for purchase meet its requirements and that this compliance be either guaranteed by the vendor or attested to by an independent testing laboratory.

The necessarily technical nature of this NILECJ standard, and its special focus as a procurement aid, make it of limited use to those who seek general guidance concerning FM repeater systems. The NILECJ Guideline Series is designed to fill that need. We plan to issue guidelines to this as well as other law enforcement equipment as soon as possible, within the constraints of available funding and the overall NILECJ program.

The guideline documents being issued are highly readable and tutorial in nature in contrast to the standards, which are highly technical and intended for laboratory use by technical personnel. The guidelines provide, in non-technical language, information for purchasing agents and other interested persons concerning the capabilities of equipment currently available. They may then select equipment appropriate to the performance required by their agency. Recommendations for the development of particular guidelines should be sent to us.

NILECJ standards are subjected to continuing review. Technical comments and recommended revisions are invited from all interested parties. Suggestions should be addressed to the Program Manager for Standards, National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, U.S. Department of Justice, Washington, D.C. 20531.

Lester D. Shubin
Program Manager for Standards
National Institute of Law
Enforcement and Criminal Justice

¹Section 402(b) of the Omnibus Crime Control and Safe Streets Act of 1968, as amended.

NILECJ STANDARD for FM REPEATER SYSTEMS

1. PURPOSE AND SCOPE

The purpose of this document is to establish performance requirements and test methods for frequency modulated repeater systems used by law enforcement agencies. For fixed repeaters, these requirements complement those established by the NILECJ fixed and base station transmitter and receiver standards [17, 21]. Likewise, for mobile repeaters, these requirements complement those established by the NILECJ mobile transmitter and receiver standards [18, 22]. This standard applies to repeater systems which either do not have special subsystems such as tone coding or selective signaling, or in which such subsystems are bypassed or disabled during testing for compliance with this standard.

2. CLASSIFICATION

For the purposes of this standard, FM repeaters are classified by the band and number of operating frequencies.

2.1 Frequency Band

2.1.1 Type I

Repeaters which operate in the 400–512 MHz band.

2.1.2 Type II

Repeaters which operate in the 150–174 MHz band.

2.1.3 Type III

Repeaters which operate in the 25–50 MHz band.

2.2 Number of Operating Frequencies

2.2.1 Type A

Repeaters which receive and retransmit on the same frequency (F_1/F_1).

2.2.2 Type B

Repeaters which receive on one frequency and retransmit on a different frequency (F_1/F_2).

2.3 Repeater Mobility

2.3.1 Fixed Repeater

See paragraph 3.2.

2.3.2 Mobile Repeater

See paragraph 3.3.

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 (Radio Antennas, Transmitters and Receivers) [9]."

3.1 Duplexer

A device that permits a single antenna system to be used simultaneously for both receiving and transmitting.

3.2 Fixed Repeater (Mobile Relay Station)

A base station that automatically retransmits mobile service communications that originate on the transmitting frequency of the mobile stations and are retransmitted on the receiving frequency of the mobile stations.

3.3 Mobile Repeater (Mobile Repeater Station)

A mobile station that automatically retransmits on a mobile service frequency those communications originated by handcarried mobile units or by other mobile or base stations directed to such hand-carried units.

3.4 Repeater

A combination of apparatus for receiving RF communication signals and automatically retransmitting corresponding signals on the same or a different frequency.

3.5 Repeater Audiofrequency Harmonic Distortion

Nonlinear distortion of a repeater system characterized by the appearance in the output of harmonics, in addition to the fundamental component, when the input wave is sinusoidal.

3.6 Repeater Sensitivity

The minimum cw signal level at the receiving frequency that, applied to the input port, will cause the repeater transmitter to energize and remain energized.

3.7 Selective Signaling

A means of obtaining the attention of a specific receiver by a transmitter using coded modulation.

4. REQUIREMENTS

4.1 Minimum Performance Requirements

The performance of the transmitter and receiver components of a fixed repeater shall meet or exceed the requirements of NILECJ-STD-0201.00, Fixed and Base Station FM Transmitters [13], and NILECJ-STD-0206.00 Fixed and Base Station FM Receivers [17]. The performance of the transmitter and receiver components of a mobile repeater shall meet or exceed the requirements of NILECJ-STD-0202.00, Mobile FM Transmitters [14], and NILECJ-STD-0207.00, Mobile FM Receivers [18]. In addition, the performance of the repeater system shall meet or exceed the requirements of this standard; these are summarized in table 1. All performance requirements are in agreement with the Rules and Regulations of the Federal Communications Commission. In addition, all applicable licensing and operating requirements of the FCC shall apply [22, 23].

4.2 User Information

The repeater manufacturer or distributor shall supply all the information specified for the transmitter and receiver (see paragraph 4.2 of each appropriate standard listed above) as well as nominal values for the characteristics in table 1.

4.3 Test Sequence

First, the repeater system shall be subjected to the environmental tests specified in paragraph 4.4. Laboratory testing shall then be performed on the repeater system as specified in paragraph 4.5. Next, the transmitter and receiver components shall be tested in accordance with the appropriate NILECJ standard except that the tests for receiver sensitivity, carrier output power variance, frequency deviation, modulation limiting, and audiofrequency harmonic distortion may be omitted.

4.4 Environmental Characteristics

The ability of the repeater system to operate in environmental extremes shall be determined using the test methods described in paragraph 5.3.

4.4.1 Temperature Stability

When the repeater system is operated at ambient temperatures of -30°C (-22°F) and 60°C (140°F), its sensitivity shall be $1.4\ \mu\text{V}$ or less and its carrier output power shall not vary more than $-3, +0.5\ \text{dB}$ from the nominal value (paragraph 4.2).

4.4.2 Humidity Stability

After the repeater system has been maintained at 50°C (122°F) ambient and at least 90 percent relative humidity for eight hours or more, its sensitivity shall be $1.4\ \mu\text{V}$ or less and its carrier output power shall not vary more than $-3, +0.5\ \text{dB}$ from the nominal value.

4.4.3 Vibration Stability (mobile repeaters only)

No fixed part of the mobile repeater system shall loosen, nor movable part be shifted in position or adjustment, as a result of this test.

4.4.4 Shock Stability (mobile repeaters only)

No fixed part of the mobile repeater system shall loosen, nor movable part be shifted in position or adjustment, as a result of this test.

4.5 Repeater Characteristics

The repeater system characteristics of sensitivity, carrier output power, frequency deviation, modulation limiting and audiofrequency harmonic distortion shall be measured in accordance with paragraph 5.4.

4.5.1 Sensitivity

The repeater transmitter shall be energized and remain energized when a cw signal of $0.7\ \mu\text{V}$ or less is applied to the repeater input.

4.5.2 Carrier Output Power

When the repeater transmitter is energized, the measured carrier output power delivered to a standard output load shall be within $-0.2, +0.4\ \text{dB}$ of the nominal value except for the initial two seconds after applying power.

4.5.3 Frequency Deviation

When an rf signal with standard test modulation is applied to the repeater input, the measured frequency deviation from the repeater transmitter output shall be within 5 percent of $\pm 3\ \text{kHz}$.

4.5.4 Modulation Limiting

When an rf signal modulated with a 1 kHz audio signal and a frequency deviation of $\pm 6\ \text{kHz}$ is applied to the repeater input, the measured frequency deviation from the repeater transmitter output shall be within 5 percent of $\pm 4.5\ \text{kHz}$.

4.5.5 Audiofrequency Harmonic Distortion

When an rf signal with standard test modulation is applied to the repeater input, the measured distortion at the output of the repeater transmitter shall not exceed 10 percent.

Table 1. Minimum Performance Requirements for FM Repeater Systems

Characteristic	Requirements
	Frequency Band (MHz) 25-50; 150-174; 400-512
A. Repeater Sensitivity	$0.7\ \mu\text{V}$
B. Carrier Output Power Variance	$-0.2, +0.4\ \text{dB}$
C. Frequency Deviation	5%
D. Modulation Limiting	5%
E. Audiofrequency Harmonic Distortion	10%
Temperature and Humidity Characteristics	
F. Repeater Sensitivity	$1.4\ \mu\text{V}$
G. Carrier Output Power Variance	$-3, +0.5\ \text{dB}$

5. TEST METHODS

5.1 Standard Test Conditions

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

5.1.1 Standard Temperature

Standard ambient temperature shall be between 20° C (68° F) and 30° C (86° F).

5.1.2 Standard Relative Humidity

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

5.1.3 Standard Power Supply Voltage

The standard supply voltage for fixed repeater systems shall be 120 volts unless otherwise specified by the manufacturer. For mobile repeaters, 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. During testing, the standard supply voltage shall be adjusted to within one percent of the voltage required.

5.1.4 Standard Test Frequencies

The standard test frequency of the repeater transmitter shall be the specified operating frequency of the repeater transmitter (f_{TX}). The standard test frequency of the repeater receiver shall be the specified operating frequency of the repeater receiver (f_{RX}).

5.1.5 Standard Test Modulation

Standard test modulation shall be a 1 kHz sinusoidal signal (from a source with distortion less than one percent) at a level required to produce a ± 3 kHz frequency deviation.

5.1.6 Standard Duty Cycle

The standard duty cycle shall be continuous operation.

5.2 Test Equipment

This section is limited to the equipment that is most critical in making the measurements discussed in this standard. All other test equipment shall be of comparable quality. It does not include all of the test equipment discussed in references [13,14,17,18].

5.2.1 Test Receiver

The test receiver used to determine the audiofrequency distortion shall include a standard audio output load whose resistance is equal to the load into which the receiver normally operates and shall have an audiofrequency distortion of less than one percent at standard modulation.

5.2.2 Power Meter

The power meter shall measure forward power in a 50-ohm system to an uncertainty of 5 percent or less. It may be a through-line directional wattmeter, or directional couplers with power meters on the side arms.

5.2.3 Standard Output Load

The standard rf output load shall be a 50-ohm resistive termination having a standing wave ratio (SWR) of 1.1 or less at the frequencies being tested. If coaxial connectors and cable are used with the standard output load, the combined SWR shall be 1.1 or less.

5.2.4 Audio Distortion Analyzer

The distortion analyzer shall be capable of measuring total audio distortion at frequencies from 0.2 to 4.0 kHz with a measurement uncertainty of 0.5 percent or less. The input impedance in both the distortion mode and the voltmeter mode shall be 1 megohm or greater. As a minimum, the voltmeter range shall be from 0.3 to 30 volts.

5.2.5 Environmental Chamber

The environmental chamber shall produce air temperatures of -30 and 60° C (-22 and 140° F) and relative humidities in excess of 90 percent at 50° C (122° F) while shielding the test specimen from heating or cooling air currents blowing directly on it. The temperature of the item being tested 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.

5.2.6 Deviation Meter

The deviation meter shall be capable of measuring the peak deviation of a modulating waveform within an uncertainty of five percent of the deviation being measured.

5.2.7 FM Signal Generator

The FM signal generator shall have a 50-ohm output level accurate to ± 2 dB. 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 five percent. If an integral frequency counter is not included, a separate frequency counter having the required accuracy shall be provided.

5.3 Environmental Tests

5.3.1 Temperature Test

Place the repeater system in an environmental chamber and adjust the temperature to $-30 \pm 2^\circ \text{C}$ ($-22 \pm 3.6^\circ \text{F}$). Allow the repeater system to reach temperature equilibrium and maintain it at this temperature for 30 minutes. With the repeater system still in this environment, perform the measurements described in paragraphs 5.4.1 and 5.4.2 without adjusting the repeater system. Repeat the above procedure at $60 \pm 2^\circ \text{C}$ ($140 \pm 3.6^\circ \text{F}$).

5.3.2 Humidity Test

Place the repeater system in an environmental chamber, adjust the relative humidity to at least 90 percent at $50 \pm 2^\circ \text{C}$ ($122 \pm 3.6^\circ \text{F}$), and maintain it in this environment for at least 8 hours. With the repeater system still in this environment, perform the tests described in paragraphs 5.4.1 and 5.4.2 without adjusting the repeater system.

5.3.3 Vibration Test (mobile repeaters only)

Perform a two-part test for a total of 30 minutes in each of three directions, namely the directions parallel to both axes of the base and perpendicular to the plane of the base.

First, subject the repeater system to three five-minute 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 two and one-half minutes, then decreased at a uniform rate to 10 Hz in two and one-half minutes.

Then, subject the repeater system to three five-minute cycles of simple harmonic motion having an amplitude of 0.19 mm (0.0075 in) [total excursion 0.38 mm (0.015 in)] applied initially at a frequency of 30 Hz and increased at a uniform rate to 60 Hz in two and one-half minutes, then decreased at a uniform rate to 30 Hz in two and one-half minutes.

Repeat for each of the other two directions.

5.3.4 Shock Test (mobile repeaters only)

Subject the repeater system to a series of ten impacts in each of three mutually perpendicular directions (paragraph 5.3.3), each impact to consist of a half sine wave acceleration of 20 g_m peak amplitude and 11 milliseconds duration. Apply the impacts to the repeater mounting.

5.4 Repeater Tests

Connect the equipment as shown in figure 1 if the repeater system has two ports; one for the transmitter output, and one for the receiver input. Connect the equipment as shown in figure 2 if the repeater system has only one port for both input and output.

5.4.1 Sensitivity

Connect the test equipment to the repeater system in accordance with paragraph 5.4. Tune the FM signal generator to the receive frequency with no modulation. Starting with zero output from the generator, slowly increase the output until the transmitter is energized and remains energized. Record the signal generator output. If the setup in figure 2 is used, correct the generator output for the losses of the attenuator and directional coupler. The value obtained is the repeater sensitivity.

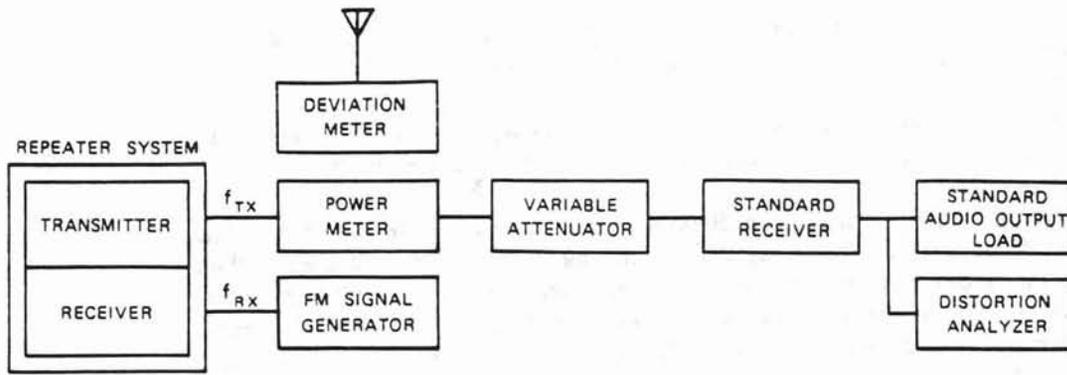


Figure 1. Two-Port Measurement Setup.

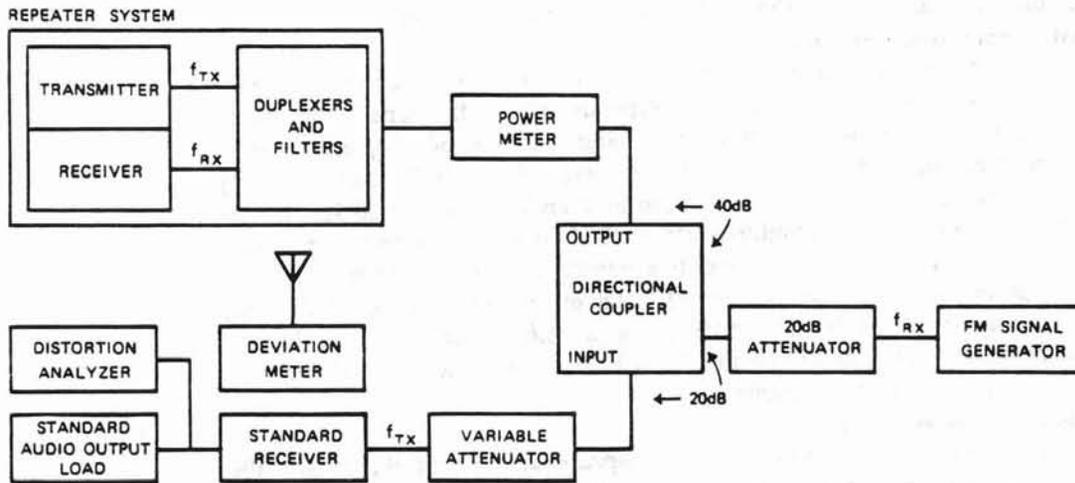


Figure 2. Single Port Measurement Setup.

5.4.2 Carrier Output Power

Connect the test equipment to the repeater system in accordance with paragraph 5.4. Energize the transmitter with no modulation, either manually or by use of the receiver, and record the output power indicated on the power meter.

5.4.3 Frequency Deviation

Connect the test equipment to the repeater system in accordance with paragraph 5.4. Set the FM signal generator to the receive frequency and adjust it for standard test modulation. Adjust the generator output so that 1 millivolt is applied to the receiver input port and the transmitter is energized. Measure the frequency deviation from the transmitter.

5.4.4 Modulation Limiting

Connect the test equipment to the repeater system in accordance with paragraph 5.4. Set the FM signal generator to the receive frequency and adjust it for standard test modulation. Adjust the generator rf output so that one millivolt is applied to the receiver input port and the transmitter is energized. Adjust the frequency deviation of the FM signal generator to 6 kHz and measure the frequency deviation of the repeater.

5.4.5 Audiofrequency Harmonic Distortion

Connect the test equipment to the repeater system in accordance with paragraph 5.4. Set the FM signal generator to the receive frequency and adjust the generator for standard test modulation using a 1 kHz modulating signal with a total distortion of 0.5 percent or less. Adjust the rf output of the signal generator so that 1 millivolt is applied to the receiver input port and the transmitter is energized. The standard receiver is sampling the output of the transmitter. Measure the distortion at the output of the test receiver using the distortion analyzer.

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0310.00	A Simple Test for Evaluating the Spectral Responsivity of Monochrome TV Cameras, February 1977	027-000-00445-8
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**NATIONAL INSTITUTE OF LAW ENFORCEMENT
AND CRIMINAL JUSTICE GUIDES (NILECJ-GUIDE)**

NILECJ-GUIDE	TITLE	GPO STOCK NO.
0301.00	Selection and Application Guide to Fixed Surveillance Cameras	027-000-00281-1
0101.00	Selection Guide to Hearing Protectors for Use on Firing Ranges. April 1976	027-000-00427-0