IEEE Std 475-2000
(Revision of
IEEE Std 475-1983)

IEEE Standard Measurement Procedure for Field Disturbance Sensors 300 MHz to 40 GHz

Sponsor

Standards Development Committee
of the
IEEE Electromagnetic Compatibility Society

Approved 30 March 2000

IEEE-SA Standards Board

Abstract: Test procedures for microwave field disturbance sensors to measure radio frequency (RF) radiated field strength of the fundamental frequency, harmonic frequencies, near field power flux density, and nonharmonic spurious emissions of sensors operating within the frequency range of 300 MHz to 40 GHz are defined.
Keywords: field disturbance sensors, field strength measurements, measurement instrumentation, spurious emissions, test sites, test reports

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Introduction

(This introduction is not part of IEEE Std 475-2000, IEEE Standard Measurement Procedure for Field Disturbance Sensors 300 MHz to 40 GHz.)

This standard describes a test procedure for measurement of radio frequency (RF) emissions from microwave field disturbance sensors to assist manufacturers, standard laboratories, and test engineers in determining compliance with established technical specifications.

The IEEE Standards Association (IEEE-SA) Standards Board authorized the IEEE Electromagnetic Compatibility Society Standards Committee to update IEEE Std 475-1983 for consistency with other standards and regulatory requirements.

This revision was prepared by an appointed subcommittee of the Standards Development Committee of the Electromagnetic Compatibility Society. The members of this subcommittee were:

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IEEE Standard Measurement Procedure for Field Disturbance Sensors 300 MHz to 40 GHz

1. Overview

1.1 Scope

This standard defines test procedures for microwave field disturbance sensors to measure radio frequency (RF) radiated field strength of the fundamental frequency, harmonic frequencies, near field power flux density, and nonharmonic spurious emissions of sensors operating within the frequency range of 300 MHz to 40 GHz.

Field disturbance perimeter protection systems that employ a balanced transmission line around the property being protected are not covered by this standard.

1.2 Applications

Specific types of field disturbance sensors to which this standard applies are as follows:

a) RF intrusion detector
b) Production line counter detector
c) Anti-shoplifting detector
d) Level sensor

1.3 Description

1.3.1 Field disturbance sensor

A field disturbance sensor is a device that employs a highly localized source of RF energy to detect the motion or presence of an object in the vicinity of the source, and in which the emitter and receiver (or detector) are essentially at the same point, that is, a space-protected system.

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1.3.2 Characteristics

A typical single channel microwave field disturbance sensor operates at a nominal radiated center frequency of 0.915 GHz, 2.450 GHz, 5.800 GHz, 10.525 GHz, or 24.125 GHz. It commonly employs a Gunn-type diode as a microwave oscillator, which is mounted in a waveguide cavity and coupled to a horn antenna or other directional radiator. It establishes an RF field which, when perturbed by the motion of an intruder or reflecting object in this field, causes a change (doppler shift) in the frequency of the microwave signal. The sensor's receiver accepts a signal coupled directly from the internal oscillator and the external signals reflected from the illuminated area. If the microwave frequency of the reflected signal differs from that of the internal oscillator, this small difference in frequency is detected, amplified, and used to activate an alarm or indicator.

Since area coverage requirements vary in different installations, some field disturbance sensors are provided with optional antennas offering a selection of different radiation beam widths. Some sensors emit a signal without intentional modulation, while others employ frequency, amplitude, or pulse modulation. Field disturbance sensors that contain digital processing circuitry may be classed as unintentional radiating or computing devices by the regulatory authority.

2. References

This standard shall be used in conjunction with the following publications.

ANSI C63.2-1987, American National Standard for Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz—Specifications.[1]

ANSI C63.4-1992, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronics Equipment in the Range of 9 kHz to 40 GHz.

ANSI C63.14-1992, American National Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD).

ANSI/NCSL Z540.1-1994, American National Standard for Calibration—Calibration Laboratories in Measuring Test Equipment—General Requirements.

ANSI/NCSL Z540.2-1997, American Nation Standard for Expressing Uncertainty—US Guide to the Expression of Uncertainty in Measurement.

CISPR 22:1993, Limits and Methods of Measurement of Radio Disturbance Characteristics of Information Technology Equipment, Second edition.[2]

IEEE Std 149-1979 (Reaff 1990), IEEE Standard Test Procedures for Antennas.[3]

IEEE Std 474-1973, IEEE Standard Specifications and Test Methods for Fixed and Variable Attenuators, DC to 40 GHz.[4]

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[1]ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[2]CISPR documents are available from the International Electrotechnical Commission, 3, rue de Varembé, Case Postale 131, CH 1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). They are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[4]IEEE Std 474-1973 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (http://global.ihs.com/).

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IEEE Std C95.1-1991, 1999 Edition, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

IEEE Std C95.3-1991, IEEE Recommended Practice for the Measurement of Potentially Hazardous Electromagnetic Fields—RF and Microwave.

3. Definitions

For definitions of terms used, see ANSI C63.14-1992 and The IEEE Standard Dictionary of Electrical and Electronic Terms [B5].

4. Measurement instrumentation

4.1 General

Use of proper measurement instrumentation is critical to obtaining accurate, reproducible results.

4.1.1 Measuring instruments

The measurement instrument chosen for each required measurement shall satisfy the minimum specifications herein.

4.1.1.1 Power flux density

The instrument used to measure power flux density shall comply with IEEE Std C95.3-1991.

4.1.1.2 Frequency

The fundamental transmitter frequency (f_o) shall be measured. A spectrum analyzer, receiver, microwave frequency counter, or commercial frequency meter may be used, provided the frequency of the measurement instrument is accurate enough to ensure that the device is operating within the specified frequency band.

4.1.1.3 Field strength

The field strength shall be measured using a calibrated receiver or spectrum analyzer with an expanded amplitude uncertainty of ±2 dB and a minimum dynamic range of 50 dB coupled to a suitable antenna (see 4.1.2).

4.1.1.3.1 Detector function

The detector function shall conform to the requirements of ANSI C63.2-1987. Unless otherwise specified by the procuring authority or regulatory authority, the detector function for frequencies at or below 1 GHz shall be quasi-peak, and for frequencies above 1 GHz, shall be average. When the field disturbance sensor employs pulse modulation techniques, measurements shall also be made using a peak detector.

4.1.1.3.2 Bandwidth

At frequencies of 1 GHz and below, the 6 dB measurement bandwidth shall be 120 kHz. Above 1 GHz the 6 dB bandwidth shall be 1 MHz ±20%. When using a peak detector, the 6 dB bandwidth shall be not less than $1/t$ where t equals the minimum pulse width being measured.

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4.1.2 Antennas

Calibrated linearly polarized log periodic or horn antennas shall be used. Horns include double ridge guide horns, rectangular waveguide horns, pyramidal horns, optimum gain horns, and standard gain horns. Table 1 lists the maximum limit on horn antenna size for a 3 m measurement distance such that the far field criteria ($2d^2/\lambda$), is satisfied, (d is the separation distance between the antenna and the object under test, and λ is the wavelength at the indicated frequency).

Table 1—Maximum antenna aperture vs. frequency

Frequency (GHz)	Wavelength (λ) (m)	Maximum aperture size (d) (m)
0.3	1	1.22
1.0	0.3	1.67
1.5	0.2	0.55
10.0	0.03	0.21
16.6	0.018	0.16
40	0.0075	0.11

4.2 Receiver monitoring

All emissions shall be monitored using instrumentation with a headset, in combination with an oscilloscope or spectrum analyzer.

4.3 Calibration of measuring equipment

Instrumentation used for these measurements shall be calibrated on a periodic basis in accordance with ANSI/NCSL Z540.1-1994.

4.3.1 Antenna calibration

All antennas shall be individually calibrated at a minimum of 1 y intervals to show traceability to a standards developing organization. Calibration shall be performed at a measurement distance of 3 m and a height of 1 m above the ground using one of the methods specified in IEEE Std 149-1979 or ANSI C63.4-1992. An antenna calibrated at a distance $2d^2/\lambda$ may be used to make the measurements at any distance greater than $2d^2/\lambda$.

4.3.2 Cable and waveguide calibration

Cables and waveguides used for connection of the antenna to the measuring instrument shall be calibrated for loss using the procedures of IEEE Std 474-1973. Checks shall be made frequently for deterioration caused by exposure to the environment and physical wear.

4.3.3 Measuring instrument calibration

The measuring instruments used to measure field strength, frequency, and power flux density shall be calibrated periodically to verify conformance to the manufacturer's specifications and requirements of this standard.

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4.4 Measurement uncertainty

Measurement uncertainty reflects the quality and accuracy of a measured result as compared to the true value. Such statements are generally required when reporting results of measurements so that it is clear to the user of these measurement results that the results may differ due to the measurement uncertainty of the investigator's instrumentation, measurement techniques, and even in the standard used to set up the test itself.

Most uncertainties are calculated using the tolerances of the instrumentation used in the measurement, the measurement setup variability, and the technique of the tester in performing the test. Typically, the overall uncertainty is calculated, in part, by identifying uncertainties in the instrumentation chain used. Each will need to be evaluated as to their individual uncertainties. Measurement uncertainty shall be calculated in accordance with the procedures of ANSI/NCSL Z540.2-1997 and reported with the measurement results.

5. Test facilities

5.1 General requirements

Radiated measurements shall be made in an environment that assures valid, repeatable measurement results.

5.1.1 Power source

The field disturbance sensor shall be powered by a device the same as, or similar to, that used for a typical installation.

5.1.2 Ambient radio noise and signals

Radiated ambient radio noise and signal levels measured at the test site with the field disturbance sensor de-energized should be at least 6 dB below the allowable limit of the applicable specification or standard. If the ambient field exceeds the applicable limit(s), the alternatives listed in ANSI C63.4-1992 shall be used. In the event that the measured levels of ambient plus field disturbance sensor emissions are not above the applicable limit, the field disturbance sensor shall be considered to be in accordance with the limit.

5.2 Test-site requirements

Field strength measurements shall be made on a test site meeting the requirements of ANSI C63.4-1992. These include open-area test sites, semi-anechoic chambers, and all-weather covered sites.

6. General equipment configuration and operating conditions

6.1 Field disturbance sensor operating condition

Prior to performing the measurements defined in this standard, the field disturbance sensor shall be checked for conformance to the manufacture's performance specification. The operating controls and cabling shall be representative of that used for a typical installation. Shielded interconnect wiring shall not be used unless specified by the manufacturer's installation instructions.

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6.2 Grounding

The field disturbance sensor shall be isolated from the ground unless specifically required by the manufacturer or regulatory authority.

6.3 Shock and vibration isolators

When used in normal installations, shock and vibration isolators shall be included as part of the test setup.

6.4 Temperature

The ambient temperature of the testing location shall be between 10 °C and 40 °C. Temperatures outside this range are acceptable, provided the field disturbance sensor is designed to operate at that test temperature. Prior to making any measurements, the field disturbance sensor shall be allowed to stabilize to such temperatures.

6.5 Humidity

Measurements shall be made with the relative humidity between 10% and 90% at the ambient temperature of test, unless it is normal to operate under conditions of moisture condensation, in which case special testing procedures compensating for these conditions shall be documented and followed.

7. Radiated emission testing

7.1 Measurement requirements

Radiated emission measurements, unless otherwise specified by the procuring authority or regulatory authority, shall be made over the 300 MHz to 40 GHz frequency range. The measurements encompass near-field power flux density, fundamental frequency, fundamental and harmonic emissions, and spurious emissions.

7.2 Measurement procedure

7.2.1 Power flux density

The near-field power flux density produced by the field disturbance sensor, while operating in the *on with alarm disabled* mode shall be measured to verify that the maximum level does not exceed that specified in IEEE Std C95.1-1991 at a distance of 5 cm from the field disturbance sensor.

Position the power flux density meter on bore site at a distance of 5 cm from the plane of the aperture of the field disturbance sensor.

NOTE—If it can be determined by engineering analysis that a field disturbance sensor is incapable of establishing a power flux density greater than 1 mW/cm^2, this information can be reported as a substitute for measurement data. For example, the power flux density, S (mW/cm^2), of the sensor is equal to the dc input power, P (mW), divided by the physical area, A (cm^2), of the radiating aperture. If a field disturbance sensor operating from 20 Vdc, draws 250 μA of current and has a 7.5 cm × 8.3 cm horn aperture, it will have a power input of 5 mW, an aperture area of 62.25 cm^2, and a maximum power flux density at the aperture of 0.08 mW/cm^2. Since the calculated power flux density is well below 1 mW/cm^2, actual measurements need not be made.

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7.2.2 Fundamental frequency

Set up the field disturbance sensor and microwave measurement antenna in a temperature test chamber lined with RF anechoic material. Connect the measurement antenna to the frequency measurement device located outside the temperature chamber. After allowing the field disturbance sensor to stabilize at the low test temperature, turn on the power and measure the frequency every 5 min for a period of 1 h. Repeat this procedure for the high test temperature. Field disturbance sensors designed for indoor use shall be tested at 10 °C and 40 °C. Outdoor devices shall be tested at the manufacturer's minimum and maximum specified operating temperatures. In addition, a third measurement shall be made at the median temperature.

7.2.3 Field strength

The field strength of the field disturbance sensor fundamental, harmonics, and spurious emissions shall be measured from the lowest intentional frequency generated or 300 MHz, whichever is higher, up to 40 GHz.

7.2.3.1 Open-area test site configuration

The field disturbance sensor shall be mounted 0.8 m above the ground on a nonconducting support such that the field disturbance sensor antenna's main beam bore site is parallel to the ground. The support device shall allow the field disturbance sensor to be rotated in azimuth. The measurement antenna shall be positioned at a distance of 3 m from the field disturbance sensor's radiating aperture.

7.2.3.2 Measurement procedure

Measure the field strength of the fundamental frequency, harmonics, and spurious emissions using a measuring instrument conforming to the requirements of paragraph 4.1.1.3. Radiated emissions produced by the field disturbance sensor shall be measured using the procedures in ANSI C63.4-1992.

Measurements of field strength shall be made for both horizontal and vertical polarization. The larger of the two readings shall be compared to the emission level requirements.

The frequency range from 300 MHz to 40 GHz shall be scanned and measurements made of field strength.

8. Conducted emissions

8.1 Applicability

Power line conducted emission measurements are only required when the field disturbance sensor or its associated power supply is attached to the ac mains.

8.2 Measurement procedure

Power line conducted emissions on ac mains produced by the field disturbance sensor shall be measured using the procedures in ANSI C63.4-1992, CISPR 22:1993, or as specified by the procuring or regulatory authority.

9. Test report

The report shall include the information specified as follows or as required by the procuring authority or regulatory authority.

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9.1 Field disturbance sensor description

a) Manufacturer
b) Model number
c) Serial number
d) Month and year of manufacture
e) Operating frequency
f) Number of channels
g) Effective isotropic radiated power
h) Input power
i) Operating line voltage
j) Other pertinent performance parameters

9.2 Measuring equipment

a) Manufacturer
b) Nomenclature
c) Model number
d) Serial number
e) Accuracy
f) Calibration due date
g) Periodicity of calibration
h) Measurement use

9.3 Test-site parameters

a) Test date
b) Test-site description
c) Location
d) Temperature
e) Relative humidity

9.4 Test procedure description

a) Test setup illustration or photograph
b) Test plan
c) Measurement test setup diagrams

9.5 Test data summary

a) Power flux density
b) Frequency
c) Field strength, fundamental
d) Field strength, harmonics
e) Field strength, spurious
f) Power line conducted emissions

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9.6 Test data

a) Data sheets
b) Power flux density calculations
c) Sample field strength calculations
d) Antenna factors
e) Cable insertion loss
f) Line impedance stabilization network (LISN) impedance

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Annex A

(informative)

Bibliography

[B1] ANSI C63.5-1998, American National Standard For Calibration of Antennas Used for Radiated Emission Measurements in Electromagnetic Interference (EMI) Control.

[B2] ANSI C63.7-1992, American National Standard Guide for Construction of Open Area Test Sites for Performing Radiated Emission Measurements.

[B3] CISPR 16-1:1993, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1. Radio Disturbance and Immunity Measuring Apparatus, First edition.

[B4] CISPR 16-2:1996, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 2. Methods of Measurement of Disturbances and Immunity, First edition.

[B5] IEEE Standard Dictionary of Electrical and Electronic Terms, Sixth edition.

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