IEEE Std C37.90.2-1995
(Revision of Trial-Use IEEE Std C37.90.2-1987)

IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers

Sponsor

Power System Relaying Committee
of the
IEEE Power Engineering Society

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IEEE Standards Board

Abstract: A design test to evaluate the susceptibility of protective relays to single-frequency electromagnetic fields in the radio frequency domain, such as those generated by portable or mobile radio transceivers is established.
Keywords: electromagnetic compatibility, protective relays, radiated electromagnetic interference, relays, relay systems, transceivers

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Introduction

(This introduction is not a part of IEEE Std C37.90.2-1995, IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers.)

The use of hand-held transceivers (walkie-talkies) has increased dramatically over the past few years. When operated in close proximity to a static protective relay, these transceivers will produce local, high field-strength electromagnetic radiation that may affect relay performance. The need for a standard on radiated interference withstand capability for static protective relays is, therefore, apparent.

In 1985, the Working Group on High-Frequency Radiation Effects on Static Control and Protection Devices of the Power System Relaying Committee produced a trial-use test standard to meet this need. The standard was published in 1987 as IEEE Std C37.90.2-1987. During the trial-use period, members of the Working Group and other users of the test provided comments and suggestions for its revision. These comments are incorporated into this new standard.

The principal changes made as a result of the trial-use experience are as follows:

a) The test field-strength level has been increased from 10–20 V/m to 35 V/m. The 35 V/m level is intended to roughly approximate the effect of a walkie-talkie operated at 15 cm (6 in) from the exposed surface of the relay and is the result of extensive testing by members of the Working Group.
b) The method of measuring and maintaining the specified test level has been left to the user rather than specified in the standard. Also, the use of discrete frequency steps has been made an alternative to a continuous sweep of the frequency. These changes are in recognition of the variety of modern equipment used to conduct these types of tests.
c) The requirement for shielded external wiring to the relay under test has been replaced with a requirement for non-shielded external wiring, unless the manufacturer specifies shielded wiring for the normal installation of the device.
d) The in-service conditions of the SWC test in IEEE Std C37.90.1-1989, have been adopted for the EMI test.
e) The Digital Equipment Modulation Test has been deleted, since it did not appear to yield any additional information. The Keying Test has been revised.
f) A caution has been added that successfully completing the standard test demonstrates a practical level of EMI withstand capability but does not guarantee that false relay operations cannot be caused by incautious use of walkie-talkies in close proximity to the relays.

We encourage comments in the form of technical papers that permit formal discussion and closure. Direct them to the IEEE Technical Activities Department, Special Services for PES.

The Working Group on High-Frequency Radiation Effects on Static Control and Protection Devices of the Relay Electrical Environment Subcommittee had the following membership at the time this standard was developed:

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IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers

1. Overview

1.1 Scope

This standard establishes a test method to evaluate the susceptibility of protective relays to single-frequency electromagnetic fields in the radio frequency domain, such as those generated by portable or mobile radio transceivers.

1.2 Purpose

The purpose of this standard is to establish a common reference and test procedure for evaluating the performance of static protective and control relays used in electric power facilities.

2. Reference

The following publication shall be used in conjunction with this standard.

IEEE Std 100-1992, IEEE Standard Dictionary of Electrical and Electronics Terms.[1]

3. Definition

Terms other than those defined here have standard definitions as listed in IEEE Std 100-1992.

3.1 transmitter (radio): A device or circuit that generates high-frequency electric energy, controlled or modulated, which can be radiated by an antenna.

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[1]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

4. Single-frequency test parameters

The most common source of single-frequency interference to static protective and control relays is provided by portable radio transmitters when they are used in close proximity to the relays.

The portable transceivers normally used in power system communications have output power less than 10 W measured at the base of the antenna. There are other factors, besides power level, that may affect the susceptibility of the relay equipment to these devices, such as the frequency and modulation level. In deciding on a meaningful test level, it is important to know what field strengths are produced by commercial portable transceivers, since these are the dominant interfering sources. Data by European researchers on the field strength produced by six portable VHF and UHF transceivers supports the following empirical equation for field strength, *E*. (See [B3].[2])

$$E = (1.6\sqrt{P})/d \qquad \text{(V/m)}$$

where

d is distance, in meters
P is manufacturer's advertised rating of the transceiver, in watts

For a 10 W rated transceiver, this equation gives a value for *E* of 5 V/m at a distance of 1 m and a value of 34 V/m at 15 cm. These data reveal the practical effects of transmitter and antenna efficiencies when compared to the theoretical equation for the field produced by a half-wave dipole radiator as follows:

$$E = (7.02\sqrt{P})/d \qquad \text{(V/m)}$$

For the same 10 W transceiver, the theoretical equation gives about 22 V/m at 1 m and 148 V/m at 15 cm. See [B3] for a discussion of antenna efficiency, which points out that, for antennas used with portable transceivers, efficiency is not likely to exceed 50% and may be much less. On this basis, it seems that a field strength of 35 V/m is a realistic value that represents the field that can reasonably be expected due to a portable transceiver operated 15 cm distant.

5. Test conditions

5.1 Selection and preparation of samples

5.1.1 Relay systems

Static protective or control relays, when supplied as an integrated relay system with an enclosure, shall be tested in the enclosure. All components should be mounted and interconnected. Where system components are unavailable at the time of the test, dummy modules may be used, and these modules shall, insofar as possible, duplicate the shielding to be realized from the actual components.

5.1.2 Individual relays

Individual relays shall be tested separately without regard to their ultimate relationship to other circuit components after the relays are finally installed in a system. The responsibility for testing a complete system that is assembled by the user shall rest with the user.

[2]The numbers in brackets correspond to those in the bibliography in annex B.

5.1.3 Selection of test sample

This test is a *design test* and shall, therefore, be applied to a randomly selected relay or relay system of each type. The test shall be repeated for each modification to the physical arrangement or selection of components contained in the relay or system, unless documentation is available to indicate tests are not needed.

5.2 External wiring

The equipment shall be tested in as close to installed conditions as possible. Wiring shall be consistent with the manufacturer's recommended procedures. If the use of shielded cable is not specified by the manufacturer for normal installation, unshielded wiring shall be used for the test. At least 1 m of the external wiring shall be run vertically to simulate rack wiring. All external connection terminals of the relay shall be connected to external wiring. To reduce the amount of wiring required, more than one terminal may be connected to a wire provided that such grouping does not interfere with the normal operation of the relay.

5.3 Grounding

All equipment used in the tests, such as relays, relay panels, relay enclosures, and cable shields, shall be properly grounded. Cable trays, conduit, or external cables shall also be grounded.

6. Test methods

6.1 General

The purpose of this clause is to establish a method of determining the susceptibility of static protective and control relays to single-frequency sources of radio frequency interference. A method of developing electromagnetic fields in the vicinity of a protective relay is described. To generate fields that are useful for simulation of field conditions may require significant antenna drive power to achieve high field-strength levels.

CAUTION

The requirements of the Federal Communications Commission Rules and Regulations or any other regulating agency must be considered before testing in accordance with this standard. Refer to [B2] for further information.

6.2 In-Service conditions

It is the intent of this test to duplicate as nearly as possible in-service conditions with the relay in its normal non-transitional state. Where appropriate, the relay shall be energized with rated voltage and current equal to 75% of the nominal current transformer (CT) rating. The relay settings should be chosen such that the relay is as close as possible to its transitional state, but not closer than the recommended margins for its application. Input voltage to the power supply circuit should be within the specified limits. The relay shall be tested in its case with the cover(s) and access doors, if any, in the closed position.

6.3 Environment

A shielded enclosure is recommended for testing. Dimensions for such an enclosure, along with the location of the radiating element and the test specimen, are shown in figure 1.

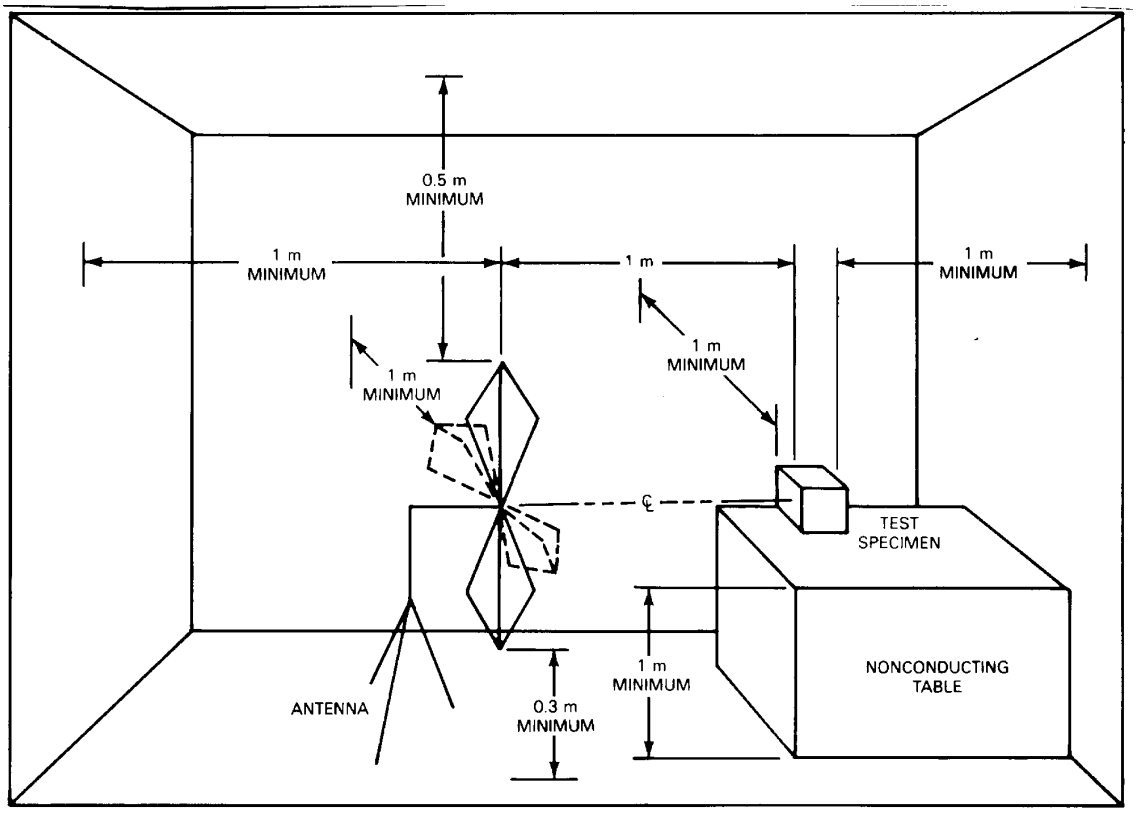

Figure 1—Test setup for radiation susceptibility

Use of an anechoic enclosure is recommended to minimize the effect of reflection within the enclosure. Temperature, atmospheric pressure, and relative humidity are not recognized as influential factors for this testing. When a means is required to support the test sample, it should be constructed of nonmetallic material.

6.4 Test equipment

The following test equipment is recommended. The use of other means of establishing and controlling the field is acceptable providing the following required conditions can be verified:

a) A shielded enclosure having a size adequate to maintain distances shown by figure 1
b) Signal generator(s) capable of covering frequency range with capability of amplitude modulation (if automatic sweep, sweep rate should be capable of achieving 0.005 octave/s)
c) A power amplifier to amplify signal and provide antenna drive if signal generator is inadequate
d) Antennas capable of covering the frequency range such as
    1) Biconical
    2) Conical logarithmic spiral

e) Field strength monitor antennas with EMI meter.

f) Associated equipment to monitor output of test sample to establish operating performance and signals for test sample during test.

CAUTION

It is important that test equipment used to generate relay voltages and currents not be affected by the radiated interference.

6.5 Test procedure

6.5.1 General

The test procedure assumes the use of biconical or conical logarithmic antennas and continuous automatic control of the test level. Other methods of establishing the fields are acceptable providing the proper fields can be generated.

6.5.2 Field-strength measurement point

The applied field shall be measured at a point 5 cm in front of the relay surface being radiated near the center of that surface.

6.5.3 Radiation susceptibility test

1) Set up the test sample and the transmitting antenna per the distance restrictions of figure 1. For the biconical transmitting antenna, adjust it so that the electromagnetic field is polarized vertically.
2) Sweep or step the test frequency through the range of 25 to 1000 MHz, maintaining a field strength of not less than 35 V/m. Document the response of the test sample.
   If the frequency is stepped through the range, the step size shall be not more than 1 MHz. The minimum duration at each frequency step shall not be less than 0.5 s. If the frequency is swept, the sweep rate shall be not more than 0.005 octave/s.
3) Step 2) shall be repeated three times to expose each of the four sides of the test sample (excluding top and bottom) to the maximum radiation.
4) When using the biconical antenna, change the electromagnetic wave polarization to horizontal and repeat step 2), exposing only the back and front of the sample.

6.5.4 Keying test

Some equipment is susceptible to repeated operation of a transmitter. This test shall be performed to evaluate the test specimen in this mode. Exposure need be to the front of the test specimen only.

If the frequency is swept, the signal source shall be 100% pulse or square-wave modulated. The modulating signal shall have on and off durations of not less than 0.5 s each. The pulse or square wave shall have a rise and fall time of no greater than 50 μs. There shall be at least three keying cycles per frequency octave.

Alternatively, if frequency steps are used, the test signal may be turned off between steps to produce the keying simulation. The on and off periods should not be less than 0.5 s. This may be done during the basic test (see 6.5.3) to eliminate the need for a separate keying test.

7. Acceptance criteria

A test is successful when no erroneous output is present, no component failure occurs, and there is no change in calibration exceeding normal tolerance. An erroneous output is one that presents false information, such as targets or trip outputs.

CAUTION

Successful completion of this test demonstrates that the relay has a practical level of withstand capability to electromagnetic interference. It does not guarantee that the relay is immune to false operation from incautious use of walkie-talkies in close proximity to the relay.

Annex A

(informative)

Transceiver field strength test data

During the development of this standard, two members of the Working Group contributed test data on the measured field strength of 5 W, 150 MHz and 450 MHz walkie-talkies at various distances from the measuring point. The maximum values reported are listed below for information.

Distance (cm)	Field strength (V/m)
7.5	100
10	60
15	35
22	20
100	5

Annex B

(informative)

Bibliography

[B1] Attwood, S. S., *Electric and Magnetic Fields,* New York: Dover, 1967.

[B2] FCC 47 CFR, Part 15, Radio Frequency Devices (1990).[3]

[B3] IEC Technical Committee No. 65: "Industrial-Process Measurement and Control, Electromagnetic Compatibility for Industrial-Process Measurement and Control Equipment, Part 3: Radiated Electromagnetic Field Requirements," *IEC Publication* 801-3, 1984.

[B4] IEC Technical Committee No. 95 (formerly SC41b): "Electrical Relays, Part 23: Electrical Disturbance Tests for Measuring Relays and Protection Equipment, Section Three—Radiated Electromagnetic Field Disturbance Tests," *IEC Publication* 255-22-3, 1989.

[B5] Jordan, E. C., *Electromagnetic Waves and Radiating Systems,* New York: Prentice Hall, 1955.

[B6] Kraus, J. D., *Antennas,* New York: McGraw-Hill, 1950.

[B7] Kraus, J. D., *Electromagnetics,* New York: McGraw-Hill, 1953.

[B8] Ramo, S. and Whinnery, J. R., *Fields and Waves in Modern Radio,* New York: Wiley, 1953.

[B9] Ryder, J. R., *Networks, Lines and Fields,* Englewood Cliffs, New Jersey: Prentice Hall, 1955.

[B10] Scientific Apparatus Makers Association (SAMA), "Electromagnetic Susceptibility of Process Control Instrumentation," Standard PMC 33.1, 1978.

[B11] Skilling, H. H., *Fundamentals of Electric Waves,* New York: Wiley, 1948.

[3]CFR publications are available from the Superintendent of Documents, US Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA.