

INTERNATIONAL STANDARD



AMENDMENT 1

**Electromagnetic compatibility (EMC) –
Part 4-24: Testing and measurement techniques – Test methods for protective
devices for HEMP conducted disturbance**

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ELECTROMAGNETIC COMPATIBILITY (EMC) –

Part 4-24: Testing and measurement techniques – Test methods
for protective devices for HEMP conducted disturbance

AMENDMENT 1

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Amendment 1 to IEC 61000-4-24:2015 has been prepared by subcommittee 77C: High power transient phenomena, of IEC technical committee 77: Electromagnetic compatibility.

The text of this Amendment is based on the following documents:

Draft	Report on voting
77C/330/FDIS	77C/331/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Amendment is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications/.

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2 Normative references

Replace the reference with the following new reference:

IEC 61000-2-10:2021, *Electromagnetic compatibility (EMC) – Part 2-10: Environment – Description of HEMP environment – Conducted disturbance*

3 Terms, definitions and abbreviated terms

Replace the definition of 3.1.2 with the following new definition:

3.1.2 gas discharge tube GDT

device with two or three metal electrodes hermetically sealed so that gas mixture and pressure are under control and designed to protect apparatus or personnel from high transient voltages

Add, after Clause 5, the following new Clause 6:

6 Measurement method of HEMP protectors for RF antenna ports

6.1 General

For the early-time HEMP, the high-amplitude electric field couples efficiently to antennas which are used within the frequency spectrum of HEMP. The HEMP coupling into the antenna is called front-door coupling. The antenna coupling mechanism is extremely variable and dependent on the details of the antenna design. The near worst-case peak response of a vertical electric monopole to the HEMP early-time waveform is considered for the test level for RF antenna ports. The waveforms for the conducted environments at antenna ports are damped sinusoids with a frequency approximately equal to the designed dominant response frequency f_c of the antenna.

6.2 Test level and injection waveform specification

Table 7. – Pulsed current injection test level for RF antenna ports

Type of Injection	Dominant response frequency f_c , MHz	Peak current injection ^a test level, A	Injection waveform	Rise time ns	FWHM ns
Inner conductor to outer shield	≤ 30	1 200	^b Double exponential	Refer to Table 1	Refer to Table 1
	^c $30 < f_c \leq 1\,000$	$36\,000/f_c$, in MHz	Damped sinusoidal	3 ± 2	30 ± 20

^a The test level in the current is measured with the condition of short-circuit of the output of the generator.

^b Double exponential waveform of conducted early-time HEMP shown in Table 1.

^c Above 1 GHz, the HEMP requirement is under consideration.

The early-time HEMP double exponential waveform shall be used for antenna port testing at a dominant response frequency ≤ 30 MHz. The double exponential generator is used because most of the energy content of early time HEMP is below 30 MHz. The double exponential generator specified in Table 1 is needed to reach the peak test level.

A damped sinusoidal waveform shall be used for antenna port testing when its dominant response frequency is $30 \text{ MHz} \leq f \leq 1\,000 \text{ MHz}$. A recommended waveform is provided in IEC 61000-2-10:2021, Annex E. If the required current injection level exceeds the damped sinusoidal pulse generator capability, an early-time HEMP double exponential waveform shall be used.

If the output voltage of a damped sinusoidal pulse generator is measured instead of short-circuit current, the test level voltage shall be determined by multiplying the required current test level, specified in Table 7, with the antenna load impedance (usually $50 \text{ }\Omega$).

6.3 Verification of test level

The configuration for test level verification is shown in Figure 9.

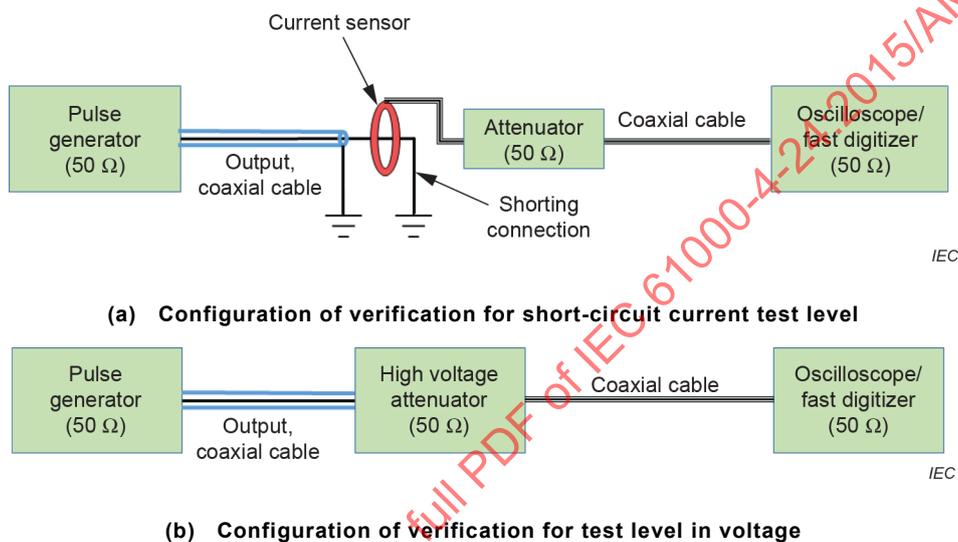


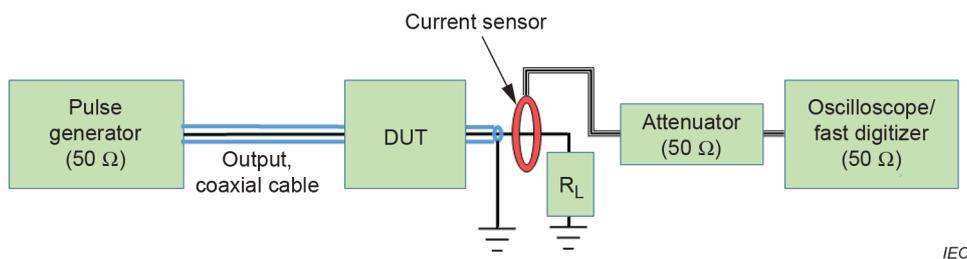
Figure 9 – Typical verification setup

Parasitic coupling between the pulse generator and the oscilloscope shall be avoided. It is recommended to use cables with multiple braided wire shields or solid shields. The cable and connectors shall be capable of withstanding the high voltage pulse without a breakdown. The shorting connection shall be as short as possible.

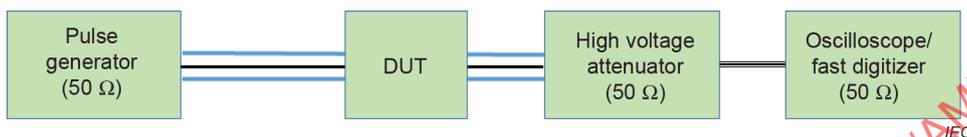
Perform the verification of the test level with 10 %, 25 %, 50 % and 100 % of the maximum test current and record the verified levels, the charging voltage and settings of the pulse generator required to achieve these test levels.

6.4 Measurement procedure

The measurement setup is shown in Figure 10.



(a) Setup for current measurement at DUT output with a 50 Ω resistive load (R_L)



(b) Setup for voltage measurement at DUT output

Figure 10 – Typical measurement setup

The measurement procedures shall be as follows:

- Set up the DUT and measurement instruments as shown in Figure 10.
- Inject a pulse three times into the DUT with the generator charging voltages verified in 6.3.
- Record the measurement results of the DUT output waveform. Either the current waveform or voltage waveform shall be measured.
- Compare the results to the performance criteria (see 6.5).

6.5 Evaluation of test results

The pass/fail results shall be classified in terms of the peak current or voltage at the output of a HEMP protector for an RF antenna. The required performance criteria are given in Table 8 for the early-time HEMP test.

Table 8 – Performance criteria of filters against early-time HEMP – RF antenna ports

RF antenna port mode	Peak residual norms	
	I_{Load} , A	U_{Load} , V
For receive only systems	< 0,5	$I_{Load} \times R_L$

The test shall be performed to ensure that the DUT is not damaged during the test. This shall be checked by ensuring that the DUT operates normally after the test.

In general, the manufacturer of the DUT shall specify the peak residual voltage and the residual energy into the nominal load. These values have to be compared with the immunity levels of the device to be protected (receiver, transmitter, antenna matching unit etc). Refer to Annex C.

6.6 Test report

For each step in the testing sequence, the following parameters should be included in the test report:

- a) waveform, peak current and source impedance of verified pulses;
- b) test mode;
- c) test load resistance;
- d) peak current or voltage of residual pulses;
- e) measured waveforms of residual pulses;
- f) comparison of results with immunity levels of equipment to be protected;
- g) performance of additional tests with equipment to be protected as a load to verify proper protection.

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Add the following new Annex C:

Annex C (informative)

Residual measurements for antenna port protectors

C.1 Evaluating the required protection for RF antenna ports

When evaluating the effectiveness of conducted HEMP protection for any type of point of entry or point of egress (POE) it is typically the case that some type of residual current or voltage is measured. This is done quite effectively for conducted signal or power lines, which can use an electric surge arrester (ESA) filter combination to reduce the residual currents or voltages into the device being protected. It is natural then to specify a similar method for evaluating the performance criteria of a HEMP protector for RF antenna ports against early-time HEMP. But there are a number of difficulties with this approach on RF antenna ports. This is especially the case for HF antennas where the early-time HEMP is in-band of both a transmitter and receiver RF port.

Most modern day HF antenna ports connect to equipment that uses the antenna as both a receiving antenna and a transmitter antenna.

This transmit/receive equipment is typically referred to as a transceiver and it is widely used in commercial and military applications.

Thus, the equipment antenna port has two functions; it serves as a receiver port and a transmitter port as shown in Figure C.1.

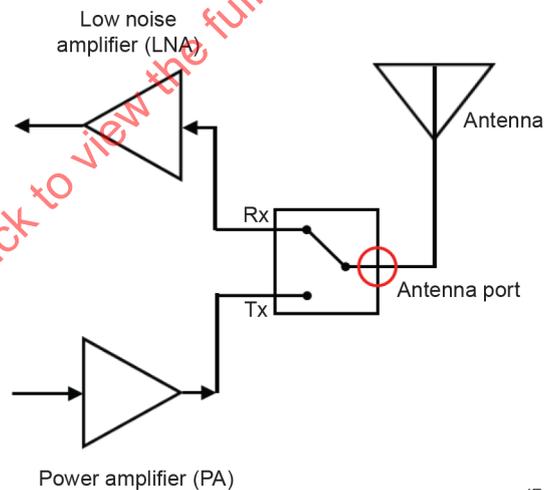


Figure C.1 – Transceiver with antenna port shown

While it can be fairly straightforward to select a protector with particular residuals for the transmitter side, on the receive mode the same protector could not work at protecting the receiver front end of the equipment.

The reason for this is that on transmit, much higher levels of current and voltage are present on the RF port than on the receive mode. Thus a protector external to the equipment's RF port for a transceiver would not protect the equipment when on receive mode operation.

Specifying residuals for an external RF port protector can only be made for the transmit mode of the transceiver and yet this would leave the receive mode vulnerable to breakdown during an early time pulse while on receive operation.

One solution would be to require transceiver manufacturers to add early-time protection internally to the transceiver on the signal path of the receive and transmit modes as shown in Figure C.2.

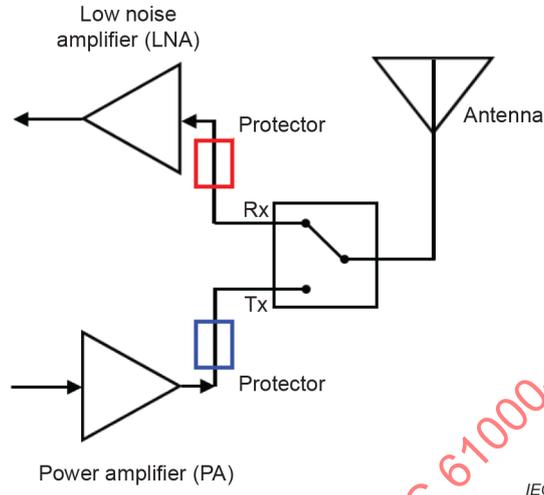


Figure C.2 – Protectors on RX and TX signal path internal to the transceiver after the RF port

This scheme, however, has the disadvantage that it leaves the RF port itself vulnerable to breakdown during an early-time pulse event.

Since the receive front end of the transceiver is the most vulnerable to high voltages and quite sensitive to small signals, it makes sense then that early-time protection should be added internally to the transceiver directly in front of the receiver front end.

In addition, in order to protect both the transmitter side of the transceiver and the antenna RF port itself, the protector for the antenna port may be placed by the equipment owner just outside the RF port as shown in Figure C.3.

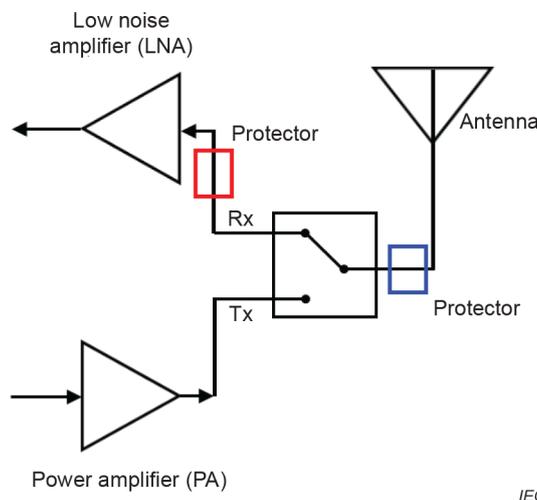


Figure C.3 – Protector internal to equipment for RX side protection and outside the equipment at the antenna port for transmit and port protection

Residuals for the protector of the RF port and transmit side can actually be simple to calculate if the maximum output power of the transmitter is known or the maximum power that the port can handle is known, whichever is lower.

For example, a typical N-type RF connector has a maximum operating RMS voltage of 707 V and a maximum operating power of 10 kW.

In this case, the residual for a protector can be measured in amperes and be limited to a peak current $I_{pk} = I_{RMS} \times \sqrt{2}$ of no more than 20 A, where $I_{RMS} = \sqrt{P/R}$ and R is the typical 50 Ω load of RF systems.

If, however, the transmitter has a maximum operating RF output of 1 000 W, then the residual for a protector should measure a peak of less than 6,3 A.

Allowing the residuals to be higher in this case might damage the transmitter front end even though it would not damage the RF port.

Figure C.4 shows a typical commercially available port protector. However, these devices have typically not been tested for an early-time pulse and let through residual currents are not readily available.



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Figure C.4 – N-type RF antenna port protector using GDTs

Computing safe residuals for a protective device on the receive side of the transceiver, as shown in Figure C.3, is a far more complicated problem. Since receivers are sensitive to very small levels of signal, in the order of microvolts, it is incumbent upon the manufacturer to know at what voltage the front end of the receiver will saturate, overload, or stop working.

With this information, protective devices may be added in the receive signal path that can react fast and clamp the early-time pulse peak voltage to a safe level. But because the characteristics of each receiver are different and the semiconductors used can vary in type, it is practically impossible to define a level at which protective devices can be tested in order to ensure survivability of the equipment during an early-time pulse event.

Because HF transceivers (3 MHz to 30 MHz) are in-band of an early-time pulse, transceivers, antennas, and antenna ports in these units are especially vulnerable to damage by a HEMP.

While the use of external port protectors at the antenna port can be useful in protecting against damaging the port or the transmitter sections of a transceiver, it does nothing for the protection of the receive side.

Manufacturers of both protective devices and transceivers may need to come together in this area and devise practical ways of protecting receiver front-ends in transceivers; standardization can then be attempted.