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High altitude electromagnetic pulse immunity guide for telecommunication centres

Recommendation ITU-T K.78

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Summary

Recommendation ITU-T K.78 specifies the radiated and conducted immunity requirements against a high altitude electromagnetic pulse (HEMP) for equipment installed in telecommunication centres for functions such as switching, transmission, radiocommunication, and power distribution. The requirements consist of immunity test methods and levels for telecommunication equipment in each installation condition. The telecommunication system can be more robust by applying surge protective devices (SPDs) for surge mitigation and electromagnetic screening to the building and/or equipment enclosures.

History

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Keywords

Electromagnetic security, high altitude electromagnetic pulse, HEMP, intentional electromagnetic interference, IEMI, immunity.

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High altitude electromagnetic pulse immunity guide for telecommunication centres

1 Scope

This Recommendation provides principles on the protection of telecommunication centre equipment, such as routing, switching, transmission, access, server, storage, radio, power, air conditioning and supervisory equipment, from damage and disruption due to a high altitude electromagnetic pulse (HEMP).

The overall radiated and conducted immunity is a combination of the inherent equipment immunity, SPD surge mitigation and the electromagnetic screening of building and additional shielding enclosures. This Recommendation discusses the contribution of each element of installation to mitigate the stress on equipment and defines an immunity test level relevant for each condition.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.11] Recommendation ITU-T K.11 (2009), *Principles of protection against overvoltages and overcurrents*.

[ITU-T K.21] Recommendation ITU-T K.21 (2009), *Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents*.

[ITU-T K.27] Recommendation ITU-T K.27 (2015), *Bonding configurations and earthing inside a telecommunication building*.

[ITU-T K.34] Recommendation ITU-T K.34 (2020), *Classification of electromagnetic environmental conditions for telecommunication equipment – Basic EMC Recommendation*.

[ITU-T K.136] Recommendation ITU-T K.136 (2018), *Electromagnetic compatibility requirements for radio telecommunication equipment*.

[ITU-T K.137] Recommendation ITU-T K.137 (2018), *Electromagnetic compatibility requirements and measurement methods for wire-line telecommunication network equipment*.

[IEC 61000-2-9] IEC 61000-2-9:1996, *Electromagnetic compatibility (EMC) – Part 2 Environment – Section 9: Description of HEMP environment – Radiated disturbance. Basic EMC publication.*

[IEC 61000-2-10] IEC 61000-2-10:1998, *Electromagnetic compatibility (EMC) – Part 2-10: Environment – Description of HEMP environment – Conducted disturbance*.

[IEC 61000-2-11] IEC 61000-2-11:1999, *Electromagnetic compatibility (EMC) – Part 2-11: Environment – Classification of HEMP environments*.

[IEC 61000-4-2] IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*.

[IEC 61000-4-4] IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*.

[IEC 61000-4-5] IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*.

[IEC 61000-4-11] IEC 61000-4-11:2020, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase*.

[IEC 61000-4-13] IEC 61000-4-13:2002, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low frequency immunity tests*.

[IEC 61000-4-23] IEC 61000-4-23:2016, *Electromagnetic compatibility (EMC) – Part 4-23: Testing and measurement techniques – Test methods for protective devices for HEMP and other radiated disturbances*.

[IEC 61000-4-25] IEC 61000-4-25:2001, *Electromagnetic compatibility (EMC) – Part 4-25: Testing and measurement techniques – HEMP immunity test methods for equipment and systems*.

[IEC 61000-5-3] IEC TR 61000-5-3:1999, *Electromagnetic compatibility (EMC) – Part 5-3: Installation and mitigation guidelines – HEMP protection concepts*.

[IEC 61000-6-6] IEC 61000-6-62003, *Electromagnetic compatibility (EMC) – Part 6-6: Generic standards – HEMP immunity for indoor equipment*.

[IEC TR 61000-4-32] IEC TR 61000-4-32:2002, *Electromagnetic compatibility (EMC) – Part 4-32: Testing and measurement techniques – High-altitude electromagnetic pulse (HEMP) simulator compendium*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 antenna port [IEC 61000-6-6]: A port that is connected to an antenna, either directly or by a cable. The antenna may be external or internal to the building.

NOTE – Antenna ports connected to antennas internal to the building are covered by signal ports.

3.1.2 cable port [IEC 61000-6-6]: A port at which a conductor or cable is connected to the apparatus.

3.1.3 enclosure port [b-IEC 60050]: A physical boundary of the apparatus which electromagnetic fields may radiate through or impinge. (see Figure 1 of [IEC 61000-6-6]).

3.1.4 functional earth port [IEC 61000-6-6]: A cable port other than a signal, control or power port, intended for connection to earth for purposes other than safety (see Figure 1 of [IEC 61000-6-6]).

3.1.5 high voltage (HV) transmission line [IEC 61000-4-25]: Power line with a nominal a.c. system voltage equal to or greater than 100 kV.

3.1.6 immunity (to a disturbance) [b-IEC 60050]: The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

3.1.7 large HEMP simulator [IEC 61000-6-6] [IEC 61000-4-25]: Transient electromagnetic pulse test facility with a test volume sufficiently large to test objects with cubical dimensions equal to or greater than 1 m × 1 m × 1 m.

3.1.8 low voltage (LV) power circuit [IEC 61000-6-6]: Power circuit with a nominal a.c. voltage equal to or less than 1 kV.

NOTE – The standard voltages in this voltage range are presented in [b-IEC 60038].

3.1.9 medium voltage (MV) [b-IEC 60050]: Any set of voltage levels lying between low and high voltage.

NOTE – The boundaries between medium and high voltage levels overlap and depend on local circumstances and history or common usage. Nevertheless, the band 30 kV to 100 kV frequently contains the accepted boundary.

3.1.10 power port [IEC 61000-6-6]: Point at which a conductor or cable carrying the electrical power needed for operation of the equipment is connected to the apparatus (see Figure 1 of [IEC 61000-6-6]).

3.1.11 signal port [IEC 61000-6-6]: A cable port at which there is a cable carrying information for transferring data to or from the apparatus. Examples are input/output (I/O) data ports and telecom ports, etc. (see Figure 1of [IEC 61000-6-6]).

3.1.12 small radiated test facility [IEC 61000-6-6] [IEC 61000-4-25]: Laboratory transient electromagnetic pulse test facility such as a transverse electromagnetic (TEM) cell with a test volume sufficiently large to test objects with cubical dimensions of less than 1 m × 1 m × 1 m.

3.1.13 surge protective device (SPD) [b-IEC 60050]: Device that is intended to protect the electrical apparatus from transient overvoltages and to divert surge currents.

NOTE – A surge protective device contains at least one non-linear component.

3.1.14 operator [b-ITU-T L.1410]: Organization operating networks and services.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 shielded enclosure: An electromagnetic shielding barrier inside or outside of a building to protect equipment inside.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC Alternating Current

DC Direct Current

EFT/B Electrical Fast Transient/Burst

EM Electromagnetic

EMC Electromagnetic Compatibility

EMI Electromagnetic Interference

EMP Electromagnetic Pulse

ESD Electrostatic Discharge

EUT Equipment Under Test

HEMP High altitude Electromagnetic Pulse

HV High Voltage

I/O Input/Output

LV Low Voltage

MV Medium Voltage

RF Radio Frequency

SE Shielding Effectiveness

SPD Surge Protective Device

TEM Transverse Electromagnetic

5 Conventions

None.

6 Overview of HEMP

HEMP occurs when nuclear explosion occurs at high altitude above 30 km. The detail of the phenomena and the electromagnetic (EM) environment are described in [IEC 61000-2-9] and [IEC 61000-2-10].

HEMP consists of early, intermediate and late time HEMP, indicated as E1, E2 and E3 respectively. The characteristics of these three types of phenomena are outlined in clauses 6.1 to 6.3.

6.1 Early time HEMP (E1)

The rise time and time-to-half of EM field waveform are very short, and the peak value is very high. The EM field affects equipment not only through power and telecommunication lines, but also directly through the enclosure port. Accumulation through the length of the cable is not considerable, because the wavelength is in the range of tens of cm to about 100 m.

This disturbance is similar to the electrical fast transient/burst (EFT/B)

To protect telecommunication centres from this phenomenon, it is necessary to:

- subject all installed equipment to a radiated immunity test, as specified in clause 8.2.1;
- subject all cable ports of all installed equipment to a conducted immunity test, as specified in clause 8.2.2.

NOTE – A result of the very short duration of the E1 pulse in the time domain is that the pulse contains components in the frequency domain that can efficiently couple to metallic cables with lengths in the 0.1-100 m range. This includes all metallic cables within the telecommunication centre and all externally attached metallic telecommunication and power cables.

6.2 Intermediate time HEMP (E2)

The rise time and time-to-half value, and the peak value of EM field waveform are medium. The waveform of intermediate time HEMP is similar to that of a lightning surge. Accumulation of induced voltage on a cable is considerable since induced disturbance travels over relatively long lines, such as outdoor telecommunication and power lines. General lightning surge tests can be applied for the immunity test of equipment against this type of HEMP. Standard lightning protection will provide adequate protection against this conducted disturbance.

To protect telecommunication centres from this phenomenon, it is necessary to:

- fit surge protective devices (SPDs) that comply with [ITU-T K.11] to all external telecommunication cables; and
- fit additional SPDs to external power cabling.

NOTE 1 – A result of the comparatively longer duration of the E2 pulse in the time domain is that the pulse contains components in the frequency domain that efficiently couple to metallic cables with long lengths. This will generally exclude metallic cables within the telecommunication centre and makes the main threat the external metallic cables that are connected to the telecommunication centre.

NOTE 2 – SPDs are typically fitted to external metallic telecommunication cables as a result of a risk assessment specified in [b-ITU-T K.46] and [b-ITU-T K.47]. This risk-based principle can be applied here for E2 protection.

NOTE 3 – SPDs are normally applied to external power cabling as it enters the telecommunication centre. It is necessary to specify SPDs such that the total protection applied to the power cables matches with the resistibility of telecommunication equipment.

6.3 Late time HEMP (E3)

EM field waveform of late time HEMP has long rise time and time-to-half value, i.e., up to 1 second and 100 seconds respectively, but peak value is low, i.e., up to 10 mV. The conducted late time HEMP disturbance is characterized as a quasi-d.c., unidirectional current waveshape, e.g., with a 1/50-s surge waveshape. This disturbance occurs only in long conducting lines such as HV power transmission lines. The open-circuit voltage for a 100 km line is estimated to be about 4000 V.

The direct effects of this late time HEMP disturbance will not likely affect equipment connected to low-voltage secondary power circuits, since the amount of the quasi-d.c. current passing through the distribution transformer from MV to LV mains is negligibly small.

For a 10-km telecommunication line, the open circuit voltage is estimated to be 400 V, and this is less severe than induction voltage from power lines onto telecommunication lines.

7 Protection concepts for buildings and enclosures

According to the protection principle in [IEC 61000-5-3], protection concept for buildings and enclosures are as defined in clause 7.1.

7.1 Protection concepts for buildings

Building protection concepts are considered for both radiated and conducted environments. These concepts are specified in [IEC 61000-5-3] and they are summarized in Table 1.

The building shielding effectiveness class is based on the building materials used:

– class 1 (1A and 1B) is related to materials that provide no attenuation of the electromagnetic field;

– class 2 (2A and 2B) is related to materials that provide significant attenuation of the electromagnetic field. This attenuation should be at least 20 dB, a level of ordinary concrete material with rebar and no other special shielding measures.

The operator may specify the immunity test requirement described in clause 8.2 to ensure that the equipment can operate appropriately in the HEMP environment relevant to the protection concept of the building.

The operator controlling facility can use the test methods described in [IEC 61000-4-23] to measure the shielding effectiveness of the building to determine the protection concept. The protection concept can be obtained according to [IEC 61000-2-11].

Table 1 – Building protection concept

Radiated attenuation [dB]		Conducted protection	
		Not protected	Protected
100 kHz to 30 MHz	0	1A	1B (Note 1)
	>20	2A	2B (Note 1)
1 MHz to 200 MHz	≥20		3 (Note 2)
	≥40		4 (Note 2)
	≥60		5 (Note 2)
	≥80		6 (Note 2)
NOTE 1 – Lightning overvoltage protection. This means that 1B and 2B includes an overvoltage protection but not additional filtering. NOTE 2 – Lightning overvoltage protection and filtering.			

7.2 Protection concepts for shielded enclosures

Any additional shielding can increase the attenuation. It is up to the operator to determine if the equipment to be protected inside the building needs additional building shielding.

Shielded enclosure protection concepts are summarized in Table 2. These shielded enclosures can be installed inside or outside the buildings, depending on the equipment to be protected.

Table 2 – Protection concepts for shielded enclosures

Radiated attenuation [dB]		Conducted protection
		Protected
1 MHz to 200 MHz	≥20	3 (Note)
	≥40	4 (Note)
	≥60	5 (Note)
	≥80	6 (Note)
NOTE – Lightning overvoltage protection and filtering.		

The concepts for buildings protection have been adopted for shielded enclosures, i.e., both the radiated and conducted environments are considered.

The attenuation figures provided in Table 2 refer to electric field, high-frequency magnetic field and plane wave attenuations (~1 MHz to 200 MHz). At low frequencies, the magnetic field attenuation is much lower. However, the forcing term due to the magnetic field component appears in the coupling equation as ωB, where $\omega = 2\pi f$, with f being the frequency and B the magnetic flux-density component perpendicular to the plane containing the circuit to be protected.

This means that, at low frequencies, its contribution to the induced voltages and currents will not be as important due to the low value of ω.

8 HEMP immunity tests and levels

8.1 Immunity test types

HEMP environment consists of two major parts: a radiated environment and a conducted environment. The HEMP radiated environment is defined in [IEC 61000-2-9] and the conducted

environment is defined in [IEC 61000-2-10]. Both types of environments are classified in [IEC 61000-2-11].

Considering the environment elements, HEMP immunity tests are classified as two types: radiated immunity and conducted immunity tests.

8.1.1 Radiated immunity test

Radiated immunity test is conducted against E1 only among three HEMP phenomena, because the electromagnetic waves of E2 and E3 are less likely to be directly induced on a device and cause a failure.

The radiated field generator shall be selected according to the size of telecommunication equipment. For telecommunication equipment smaller than 1 m × 1 m × 1 m, small radiated field test facility that meets the specification in clause 5.4.3 of [IEC 61000-4-25] shall be used. Tests for such small equipment may be performed in laboratories using current injection simulators and transverse electromagnetic (TEM) cells.

For telecommunication equipment with dimensions greater than 1 m on a side, a large HEMP simulator that meets the specification in clause 5.4.4 of [IEC 61000-4-25] shall be used. In general, radiated field tests on systems and large equipment will require a large HEMP simulator as described in [IEC TR 61000-4-32].

The details of test methods are defined in [IEC 61000-4-25].

8.1.2 Conducted immunity test

Conducted immunity test is applied to cable ports to account for HEMP propagation through the cable into the equipment. The cable ports to be tested are signal port which include an external antenna port, telecommunication port, DC and AC power supply port, and functional earth port; these ports are defined in clause 3.

Conducted immunity test for E1 is substituted by EFT/B test in [IEC 61000-4-4] and damped oscillatory wave test in [IEC 61000-4-25]. Detailed test methods are described in each standard.

The EFT/B test should be performed with positive and negative polarities at a repetition rate of 2.5 kHz and a burst duration of 10 ms. In [IEC 61000-4-4], test level is specified up to ±4 kV. If a test level larger than ±4 kV is required, the test method should be based on [IEC 61000-4-25].

The conducted immunity test for E2 is substituted by the lightning surge test in [IEC 61000-4-5].

The conducted immunity test for E3 is replaced by voltage dips and interruptions test [IEC 61000-4-11], and power frequency harmonics test [IEC 61000-4-13]. Detailed test methods are described in each specification.

8.2 HEMP immunity requirements for equipment

The indoor HEMP environment depends on the electromagnetic shielding performance of a facility corresponding to the protection level. The test methods are defined in [IEC 61000-4-25] and the requirement levels are based on [IEC 61000-6-6].

All telecom lines are assumed to have surge protective devices at the point where they enter the building and the insulation flashover voltage on low-voltage lines is assumed to be three times that of lightning level. For signal ports connected to internal cables, severity test levels are based on cables that have a length of 10 m and a procedure is provided for longer cables.

Most of the test consists of three test levels: the levels shown in Tables 3 to 9, represent 50%, and 25% of the level. Two exposures shall be performed at each test level. Some tests require exposures at both negative and positive polarities.

8.2.1 Radiated immunity

The radiated immunity tests and levels are listed in Table 3. Test 1.1 is an electromagnetic pulse test.

In test 1.1, each test should consist of the following six pulses applied to each side of the equipment enclosure:

- two at 25% of the test level;
- two at 50% of the test level;
- two at 100% of the test level.

Table 3 – Immunity tests – Enclosure port

Test	Radiated disturbance	Basic standard	Criterion	Protection concept of telecommunication centre building					
				1A	1B	2	3	4	5-6
1.1	2.5/25 ns electromagnetic pulse	[IEC 61000-4-25]	B	50 kV/m	50 kV/m	5 kV/m	5 kV/m	Optional 500 V/m	Not required

8.2.2 Conducted immunity

The conducted immunity test specific for medium time HEMP is not required in this Recommendation since it is assumed that equipment in telecommunication centre conforms to the resistibility requirement in [ITU-T K.21].

Therefore, conducted immunity test for early time HEMP and late time HEMP phenomena are specified. The test levels are shown in Tables 4 to 9. The test numbers, 2.1, 3.1, 3.2, 4.1, 4.2, 5.1, 5.2, 5.3, 6.1, 6.2, 6.3, 7.1 and 7.2 in Tables 4 to 9 are related to early time HEMP, and test numbers 6.4 and 6.5 are related to late time HEMP.

Table 4 applies to signal ports other than telecom and exterior antenna ports. All conductors require a conducted immunity test, so these other ports are covered by the Table 4 tests.

Severity test levels are based on interior cable lengths of 10 m. For longer cables, the current should be increased proportionally with cable length up to a maximum of 100 m. Interior antennas are included in this table.

Each test consists of six exposures: two at 25% of the test level, two at 50% of the test level, and two at 100% of the test level. For protection concepts 1A and 1B, test method should refer to the basic standard [IEC 61000-4-25]. A bulk cable test should be applied with plus and minus polarity using a capacitive clamp with an EFT/B repetition rate of 2.5 kHz and burst length of 10 ms.

Table 4 – Immunity tests – Signal ports (other than telecom and exterior antenna ports)

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building					
				1A	1B	2	3	4	5-6
2.1	5/50 ns EFT/B	[IEC 61000-4-4] (or [IEC 61000-4-25] for 1A and 1B only)	B	8 kV	8 kV	1 kV	0.5 kV	0.5 kV	0.5 kV

Table 5 applies to antennas designed for frequencies within the range of 25 MHz to 450 MHz. For protection concepts 1A and 2A, if an antenna with a centre frequency lower than 115 MHz is used, see Table A.1 in [IEC 61000-6-6] for conducted disturbance exterior antennas.

Each test consists of six exposures: two at 25% of the test level, two at 50% of the test level, and two at 100% of the test level.

In test 3.1, for protection concepts 1A and 2A, the test method in [IEC 61000-4-25] should be applied, and tests with plus and minus polarity should be performed with an EFT/B repetition rate of 2.5 kHz and burst length of 10 ms. Test 3.1 is a common-mode cable shield current test, and the levels are based on a 40-m antenna cable.

Table 5 – Immunity tests – Signal ports (exterior antennas)

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building						
				1A	1B	2A	2B	3	4	5-6
3.1	5/50 ns EFT/B	[IEC 61000-4-4] (or [IEC 61000-4-25] for 1A and 1B only)	B	16 kV	4 kV	16 kV	4 kV	0.5 kV	0.5 kV	0.5 kV
3.2	Damped oscillatory wave	[IEC 61000-4-25]	B	16 kV 320 A	16 kV 320 A	4 kV 40 A	4 kV 40 A	4 kV 40 A	0.5 kV 5 A	Not required

Table 6 applies to telecommunication cables. Each test consists of six exposures: two at 25% of the test level, two at 50% of the test level, and two at 100% of the test level.

In test 4.1, a line-to-earth test with plus and minus polarity should be performed. In test 4.2, both line-to-earth and line-to-line tests with plus and minus polarity should be performed with an EFT/B repetition rate of 2.5 kHz and burst length of 10 ms. For protection concepts 3 through 6, the basic standard for test 4.2 is the [IEC 61000-4-4] EFT/B test. If SPD is not used at the entry of a building of protection concepts 1A to 2B, immunity level of 16 kV that is EC9 of [IEC 61000-4-25] should be applied.

Table 6 – Immunity tests – Signal ports (telecommunication)

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building						
				1A	1B	2A	2B	3	4	5-6
4.1	1.2/50 µs surge	[IEC 61000-4-5]	B	4 kV	2 kV	4 kV	2 kV	1 kV	1 kV	1 kV
4.2	5/50 ns EFT/B	[IEC 61000-4-4] (or [IEC 61000-4-25] for 1 and 2 only)	B	8 kV	8 kV	8 kV	8 kV	1 kV	1 kV	1 kV

Table 7 applies to indoor d.c. power cables. Severity test levels are based on indoor cable lengths of 20 m. For longer cables, test current level increases in proportional to the cable length up to 100 m.

Each test consists of six exposures: two at 25% of the test level, two at 50% of the test level, and two at 100% of the test level.

In tests 5.1 and 5.2, line-to-earth and line-to-line tests with plus and minus polarity should be performed. In test 5.2, the EFT/B repetition rate is 2.5 kHz and burst length of 10 ms. For protection concepts 1A and 1B, the basic standard [IEC 61000-4-25] apply. In test 5.3, both line-to-earth and line-to-line tests should be performed.

Table 7 – Immunity tests – Input and output d.c. power ports

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building						
				1A	1B	2A	2B	3	4	5-6
5.1	1.2/50 µs surge	[IEC 61000-4-5]	B	4 kV	4 kV	4 kV	1 kV	0.5 kV	0.5 kV	0.5 kV
5.2	5/50 ns EFT/B	[IEC 61000-4-4] (or [IEC 61000-4-25] for 1A and 1B only)	B	16 kV	16 kV	4 kV	2 kV	0.5 kV	0.5 kV	0.5 kV
5.3	Damped oscillatory wave	[IEC 61000-4-25]	B	4 kV	4 kV	4 kV	4 kV	2 kV	1 kV	1 kV

Table 8 applies to a.c. power ports.

Tests 6.1, 6.2 and 6.3 consist of six exposures: two at 25% of the test level, two at 50% of the test level, and two at 100% of the test level. In tests 6.2 and 6.3, both line-to-earth and line-to-line tests with plus and minus polarity should be performed, but the line-to-line test levels are half of the line-to-earth test levels shown in this table. In test 6.2, the EFT/B repetition rate is 2.5 kHz and burst length of 10 ms.

In test 6.3, both line-to-earth and line-to-line tests should be performed.

Table 8 – Immunity tests – Input and output a.c. power ports

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building						
				1A	1B	2A	2B	3	4	5-6
6.1	1.2/50 µs surge	[IEC 61000-4-5]	B	4 kV	2 kV	4 kV	2 kV	1 kV	1 kV	1 kV
6.2	5/50 ns EFT/B	[IEC 61000-4-4]	B	20 kV 25 kV (Note 1)	16 kV	20 kV 25 kV (Note 1)	16 kV	1.6 kV	1.6 kV	1 kV
6.3	Damped oscillatory wave	[IEC 61000-4-25]	B	4 kV	4 kV	4 kV	4 kV	1 kV	1 kV	1 kV
6.4	Voltage dips and interruptions	[IEC 61000-4-11]	C	60% 1 s >95% 5 s (Note 2)						
6.5	Power frequency harmonics	[IEC 61000-4-13]	B	Class 3						

NOTE 1 – For test 6.2 with protection concepts 1A and 2A, [IEC 61000-4-25] is used as the basic standard. Use 20 kV, a sublevel of EC11, for above ground lines and 25 kV (EC10) for underground power lines. An insulation breakdown of over 25 kV has been assumed for the slower rising 25 kV EC10 pulse and over 20 kV for the faster rising 20 kV EC11 pulse. These tests are conducted with single pulses as described in [IEC 61000-4-25].

NOTE 2 – For the voltage-dip test, the voltage dip must be a 60% reduction for 1 s. For the voltage interruption test, the amplitude reduction must be greater than 95% for 5 s. This test is not applicable to a.c. output ports. If the equipment under test (EUT) has a back-up power source, the C performance criterion may be changed to A or B.

Table 9 applies to functional earth ports. Each test consists of six exposures: two at 25% of the test level, two at 50% of the test level, and two at 100% of the test level.

In test 7.1, both plus and minus polarity should be performed with an EFT/B repetition rate of 2.5 kHz and burst length of 10 ms.

Table 9 – Immunity tests – Functional earth port

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building						
				1A	1B	2A	2B	3	4	5-6
7.1	5/50 ns EFT/B	[IEC 61000-4-4]	B	4 kV	4 kV	2 kV	2 kV	–	–	–
7.2	Damped oscillatory wave	[IEC 61000-4-25]	B	4 kV	4 kV	2 kV	2 kV	–	–	–

8.3 Conditions during test

8.3.1 General

The equipment shall be tested under normal test conditions according to relevant product and basic standards or to the information provided with the equipment.

Tests shall be performed within range of humidity, temperature and supply voltage specified by manufacture or operator.

In cases where the equipment under test (EUT) require the use of external protection devices according to the EUT specification, the tests shall be performed with the external protection devices or measures in place.

EUT configuration and mode of operation shall represent the intended use and the most susceptible operating mode consistent with normal applications should be included if possible.

The test conditions, EUT configuration and mode of operation shall be recorded in the test report.

8.3.2 Test configuration

Equipment may provide different functions, all available functions of the EUT should be tested, i.e., switching or router network equipment may provide electrical and optical transmission functions.

For equipment supporting multi-type line cards and supporting several combinations of these line cards to achieve different marketing configurations, for example the gigabit Ethernet (GE) card, 10 GE card, of optical or electrical interface, for uplink or downlink, then each type of the functional line card should be selected for the test configuration. In principle, every type of line card should be assessed.

Where there are multiple line cards of the same type, the manufacturer should determine whether to load these additional cards, considering:

– a representative configuration;

– reproducibility.

This process may also be applied to establishing the number of similar elements (e.g., plugin modules, internal memory) within the EUT.

Where the EUT has more than one analogue/digital data port, ports should be included in the measurement arrangement for conducted immunity as follows:

– if there are multiple same ports on the same card or module type, then it is acceptable to assess one typical port;

– where there are ports of the same type on different card or module types, then it is acceptable to assess one typical port on each card or module types.

The test report should identify the ports assessed.

The tested ports should be configured for connection to another port at the other port's nominal impedance. Auxiliary equipment may be used to simulate the functional termination of the ports. Ports which are not connected to cables during normal operation (e.g., service connectors, programming connectors, temporary connectors) shall not be connected to any cables for the purpose

of EMC testing. Where cables have to be connected to these ports, or interconnecting cables have to be extended in length in order to exercise the EUT, precautions shall be taken to ensure that the evaluation of the EUT is not affected by the addition or extension of these cables. Test configurations for several specific equipment are described in clause 7 of [ITU-T K.136] and Annexes D through H of [ITU-T K.137].

8.3.3 Operational condition

The measurement should be made at the nominal voltage of the EUT, if an EUT supports a wide range of supply voltage, then the typical operating voltage, for example 110 V and 230 V, is recommended for the measurement. Equipment with a DC power port powered by a dedicated AC/DC power converter is considered to be an AC mains powered equipment and should be measured with a power converter. Where the power converter is provided by the manufacturer, the converter provided should be used.

The environmental parameters (temperature, humidity and atmospheric pressure) should be limited to the installation conditions of the EUT, and it is not necessary to repeat measurements at more than one set of these environmental parameters.

The loading status of the power supply and/or the bit rate of the interface should be representative of the typical use of the EUT. One or more measurements may be repeated to adequately assess the immunity of the EUT. For digital interfaces, it is acceptable to measure at the highest bit rate.

All ports should be exercised in a manner which is representative of a system in as normal an operation as possible. For example, the ports are high speed driven as is specified, and the line attenuation is simulated as close to the actual length as possible.

The exercising signal should be selected to simulate the intended function and the correct operation of the equipment, for example, the data rate, packet length.

Special exercising equipment and/or software may be used with the object of reducing test time and simulating traffic conditions, and the actual situation of the test should be recorded in the test report.

For the telecommunication centre, typical facilities inside and characteristics of the environment are as follows:

– the internal electrical power distribution is a 48 V DC or high voltage DC source, e.g., 240 V/380 V nominal and a 220 V/230 V/400 V, or 127 V/220 V or 100 V AC nominal 50 Hz or 60 Hz;
– it is assumed that switching of loads on the DC supply seldom occurs and, therefore, has not been taken into account;
– battery backup is available at 48 V DC port;
– it is assumed that there is no separation between DC power cables and signal cables, while internal AC power cables are kept separate at some distance to DC power cables and signal cables in order to reduce mutual coupling. Normal practice is to use grounded, metallic cable supports;
– a dedicated earthing and bonding network is implemented according to [ITU-T K.27]. Also, the AC power distribution inside the building is in accordance with the requirements of [ITU-T K.34].

Some electrostatic discharge (ESD) preventive measures are either incorporated in the building installation (e.g., charge dissipating floors or control of the relative humidity) or through guidelines for handling and operation of the equipment (e.g., use of wrist-straps, charge dissipating shoes).

Some distance to high power broadcast or mobile communication transmitters is assumed. In cases where radio communication transmitters are present at the premises, it is assumed that special precautions are taken to prevent exposure of the emitted field. The use of mobile radio equipment

such as cell phone, indoor radio distribution system, access point and others are assumed in telecommunication centres. The telecommunication operator or other business entities cannot control the external radio-frequency environment.

9 Performance criteria

The generic performance criteria specified in [ITU-T K.137] apply. Specific performance criteria for telecommunication network equipment is specified in [ITU-T K.136] and [ITU-T K.137].

The requirements given in specific product family recommendations may supersede the requirements given in this Recommendation. The desired performance criterion for each immunity test is described in clause 8.2.

If these criteria are not adequate for a particular equipment, then specific criteria may be derived by agreements between an operator and an equipment manufacturer.

The manufacturer should provide a functional description and a definition of performance criteria during or as a consequence of the HEMP immunity test. Test implementers should note them in the test report. If, as a result of the application of the tests defined in this Recommendation, the apparatus becomes dangerous or unsafe, the equipment should be deemed to have failed the test.

Appendix I

Immunity level comparison between Recommendations ITU-T K.48/ ITU-T K.20 and [IEC 61000-6-6]

(This appendix does not form an integral part of this Recommendation.)

When we apply protection measures to a telecommunication centre building, in which a system has already been installed, the only options are additional shielding and surge protection. In this case, the system equipment must conform to the minimum requirement against HEMP. However, there is a difference between the minimum requirements for HEMP and the ITU-T K.48 immunity, ITU-T K.20 resistibility requirements. Hence, even if the equipment was tested conforming to [b-ITU-T K.48] and [b-ITU-T K.20], additional testing may be required to confirm the ports meet the minimum HEMP requirements given in Tables I.1 or I.2.

The comparisons of the immunity levels are listed in Tables I.3 through I.9 for different port types.

A filter is included in the building concept.

Table I.1 – Minimum requirement against HEMP for building concept levels 5 and 6

Test port	Test	Basic standard	Criterion	Minimum requirement against HEMP
Signal ports	5/50-ns EFT/B	[IEC 61000-4-4]	B	1 kV
Signal ports (exterior antenna)	5/50-ns EFT/B	[IEC 61000-4-4]	B	1 kV
Input and output d.c. power ports	5/50 ns EFT/B	[IEC 61000-4-4]	B	2 kV
	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	1 kV
Input and output a.c. power ports	1.2/50-us surge	[IEC 61000-4-5]	B	2 kV
	5/50-ns EFT/B	[IEC 61000-4-4]	B	2 kV
	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	1 kV
Functional earth port	5/50-ns EFT/B	[IEC 61000-4-4]	B	1 kV
	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	0.5 kV

Table I.2 – Immunity requirement against HEMP for building concept level 4

Test port	Test item	Basic standard	Criterion	Minimum requirement against HEMP
Signal ports	5/50-ns EFT/B	[IEC 61000-4-4]	B	1 kV
Signal ports (exterior antenna)	5/50-ns EFT/B	[IEC 61000-4-4]	B	1 kV
	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	0.5 kV
Input and output d.c. power ports	5/50-ns EFT/B	[IEC 61000-4-4]	B	2 kV
	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	1 kV

Table I.2 – Immunity requirement against HEMP for building concept level 4

Test port	Test item	Basic standard	Criterion	Minimum requirement against HEMP
Input and output a.c. power ports	1.2/50-us surge	[IEC 61000-4-5]	B	2 kV
	5/50-ns EFT/B	[IEC 61000-4-4]	B	2 kV
	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	1 kV
Functional earth port	5/50-ns EFT/B	[IEC 61000-4-4]	B	1 kV
	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	0.5 kV

Table I.3 – Immunity tests – Enclosure port

Test	Radiated disturbance and ESD	Basic standard	Criterion	Protection concepts of building					
				1A	1B	2	3	4	5-6
[IEC 61000-6-6]	2.5/25-ns electromagnetic pulse	[IEC 61000-4-25]	B	50 kV/m	50 kV/m	5 kV/m	5 kV/m	Optional 500 V/m	Not required
[b-ITU-T K.48]	Radio frequency electromagnetic field	[b-ITU-T K.48]	B	3 V/m 10 V/m (800 MHz-1.5 GHz)					
[IEC 61000-6-6]	Electrostatic discharge	[IEC 61000-4-2]	B	8 kV	8 kV	8 kV	8 kV	8 kV	8 kV
[b-ITU-T K.48]	Electrostatic discharge		B	4 kV					

Table I.4 – Immunity tests – Signal ports

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building					
				1A	1B	2	3	4	5-6
[IEC 61000-6-6]	5/50-ns EFT/B	[IEC 61000-4-4]	B	8 kV	8 kV	1 kV	1 kV	1 kV	1 kV
[b-ITU-T K.48]	Fast transients field	[b-ITU-T K.48]	B	0.5 kV line-to-line and line-to-earth					
[IEC 61000-6-6]	Electrostatic discharge	[IEC 61000-4-2]	B	8 kV	8 kV	8 kV	8 kV	8 kV	8 kV
[b-ITU-T K.48]	Electrostatic discharge		B	0.5 kV					

Table I.5 – Immunity tests – Signal ports (exterior antennas)

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building						
				1A	1B	2A	2B	3	4	5-6
[IEC 61000-6-6]	5/50-ns EFT/B	[IEC 61000-4-4]	B	16 kV	4 kV	16 kV	4 kV	1 kV	1 kV	1 kV
[IEC 61000-6-6]	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	16 kV 320A	16 kV 320A	4 kV 40A	4 kV 40A	4 kV 40A	0.5 kV 5A	Not required

Table I.6 – Immunity tests – Signal ports (telecommunication)

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building						
				1A	1B	2A	2B	3	4	5-6
[IEC 61000-6-6]	1.2/50-us surge	[IEC 61000-4-5]	B	4 kV	2 kV	4 kV	2 kV	1 kV	1 kV	1 kV
[b-ITU-T K.48]	Surge 1.2/50 us	[b-ITU-T K.48]	B	0.5 kV (line-to-line) 1 kV (line-to-ground)						
[b-ITU-T K.20]	Surge 10/700	[b-ITU-T K.20]		Basic: 1 kV Enhanced: 1.5 kV						
[IEC 61000-6-6]	5/50-ns EFT/B	[IEC 61000-4-4]	B	8 kV	8 kV	8 kV	8 kV	1 kV	1 kV	1 kV
[b-ITU-T K.48]	Fast transient	[b-ITU-T K.48]	B	1 kV						

Table I.7 – Immunity tests – Input and output d.c. power ports

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building						
				1A	1B	2A	2B	3	4	5-6
[IEC 61000-6-6]	1.2/50-us surge	[IEC 61000-4-5]	B	4 kV	4 kV	4 kV	1 kV	0.5 kV	0.5 kV	0.5 kV
[b-ITU-T K.48]	Surge 1.2/50	[b-ITU-T K.48]	B	0.5 kV (line-to-line) 1 kV (line-to-ground)						
[b-ITU-T K.20]	Surge 1.2/50	[b-ITU-T K.20]		Basic: 1 kV Enhanced: 1.5 kV						
[IEC 61000-6-6]	5/50-ns EFT/B	[IEC 61000-4-4]	B	16 kV	16 kV	4 kV	2 kV	2 kV	2 kV	2 kV
[IEC 61000-6-6]	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	4 kV	4 kV	4 kV	4 kV	2 kV	1 kV	1 kV
[b-ITU-T K.48]	Fast transient	[b-ITU-T K.48]	B	0.5 kV						

Table I.8 – Immunity tests – Input and output a.c. power ports

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building						
				1A	1B	2A	2B	3	4	5-6
[IEC 61000-6-6]	1.2/50-us surge	[IEC 61000-4-5]	B	4 kV	2 kV	4 kV	2 kV	2 kV	2 kV	2 kV
[b-ITU-T K.48]	Surge 1.2/50	[b-ITU-T K.48]	B	0.5 kV (line-to-line) 1 kV (line-to-ground)						
[b-ITU-T K.20]	Surge 1.2/50	[b-ITU-T K.20]		Basic: 1 kV Enhanced: 1.5 kV						
[IEC 61000-6-6]	5/50-ns EFT/B	[IEC 61000-4-4]	B	20 kV	16 kV	20 kV	16 kV	2 kV	2 kV	2 kV
[b-ITU-T K.48]	Fast transient	[b-ITU-T K.48]	B	1 kV						
[IEC 61000-6-6]	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	4 kV	4 kV	4 kV	4 kV	2 kV	2 kV	1 kV
[IEC 61000-6-6]	Voltage dips and interruptions	[IEC 61000-4-11]	C	60% 1 s >95% 5 s						
[b-ITU-T K.48]	Voltage dips	[b-ITU-T K.48]	B C	>95% 0.5 s 30% 25 s						
[IEC 61000-6-6]	Power frequency harmonics	[IEC 61000-4-13]	B	Class 3						
[b-ITU-T K.48]	Fast transient	[b-ITU-T K.48]	B	1 kV						

Table I.9 – Immunity tests – Functional earth port

Test	Conducted disturbance	Basic standard	Criterion	Protection concepts of building						
				1A	1B	2A	2B	3	4	5-6
[IEC 61000-6-6]	5/50-ns EFT/B	[IEC 61000-4-4]	B	4 kV	4 kV	2 kV	2 kV	1 kV	1 kV	1 kV
[IEC 61000-6-6]	Damped oscillatory wave cable shield test	[IEC 61000-4-25]	B	4 kV	4 kV	2 kV	2 kV	1 kV	1 kV	0.5 kV

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