

International Telecommunication Union

**ITU-T**

TELECOMMUNICATION  
STANDARDIZATION SECTOR  
OF ITU

**K.78**

(06/2009)

SERIES K: PROTECTION AGAINST INTERFERENCE

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## **High altitude electromagnetic pulse immunity guide for telecommunication centres**

Recommendation ITU-T K.78





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### **High altitude electromagnetic pulse immunity guide for telecommunication centres**

#### **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. Immunity levels can be improved by applying a protection concept of surge protective devices (SPDs) for surge mitigation and electromagnetic screening to the building and equipment enclosures.

#### **Source**

Recommendation ITU-T K.78 was approved on 29 June 2009 by ITU-T Study Group 5 (2009-2012) under Recommendation ITU-T A.8 procedures.

#### **Keywords**

High altitude electromagnetic pulse (HEMP), immunity, security, telecommunication equipment.

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## Recommendation ITU-T K.78

### High altitude electromagnetic pulse immunity guide for telecommunication centres

#### 1 Scope

This Recommendation gives guidance on the protection of telecommunication centre equipment, such as switching, transmission, radio, and power, 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 equipment enclosures. This Recommendation discusses immunity contribution of each item and defines an immunity test approach and testing levels.

#### 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.20] Recommendation ITU-T K.20 (2008), *Resistibility of telecommunication equipment installed in a telecommunications centre to overvoltages and overcurrents*.
- [ITU-T K.46] Recommendation ITU-T K.46 (2008), *Protection of telecommunication lines using metallic symmetric conductors against lightning-induced surges*.
- [ITU-T K.47] Recommendation ITU-T K.47 (2008), *Protection of telecommunication lines using metallic conductors against direct lightning discharges*.
- [ITU-T K.48] Recommendation ITU-T K.48 (2006), *EMC requirements for telecommunication equipment – Product family Recommendation*.
- [IEC 61000-2-9] IEC 61000-2-9 (1996), *Electromagnetic compatibility (EMC) – Part 2-9: Environment – Description of HEMP environment – Radiated disturbance*.
- [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 (2004), *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*.

- [IEC 61000-4-5] IEC 61000-4-5 (2005), *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*.
- [IEC 61000-4-11] IEC 61000-4-11 (2004), *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*.
- [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 (2000), *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/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*.
- [IEC 61000-5-3] IEC 61000-5-3 (1999), *Electromagnetic compatibility (EMC) – Part 5-3: Installation and mitigation guidelines – HEMP protection concepts*.
- [IEC 61000-6-6] IEC 61000-6-6 (2003), *Electromagnetic compatibility (EMC) – Part 6-6: Generic standards – HEMP immunity for indoor equipment*.

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

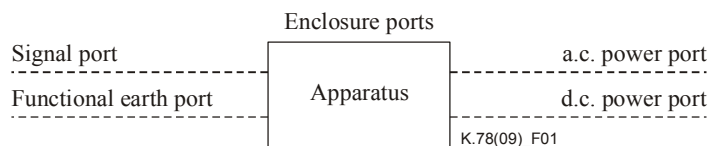
**3.1.1 antenna port** [IEC 61000-6-6]: A port that is connected to an antenna, either directly or by a cable. The antenna may be external or internal to the building.

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 [IEC 61000-6-6].

**3.1.3 electrical fast transient/burst (EFT/B)** [IEC 61000-4-4]: The 5/50 ns pulse defined in [IEC 61000-4-4].

**3.1.4 enclosure port** [IEC 61000-6-6]: A physical boundary of the apparatus which electromagnetic fields may radiate through or impinge upon. The equipment case is normally considered the enclosure port (see Figure 1).



**Figure 1 – Example of ports**

**3.1.5 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).

**3.1.6 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.

**3.1.7 immunity (to a disturbance)** [b-IEC 60050-161]: The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

**3.1.8 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  $1\text{ m} \times 1\text{ m} \times 1\text{ m}$ .

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

**3.1.10 medium voltage (MV)** [b-IEC 60050-601]: 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.

**3.1.11 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).

**3.1.12 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 1).

**3.1.13 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  $1\text{ m} \times 1\text{ m} \times 1\text{ m}$ .

**3.1.14 surge protection device (SPD)** [b-IEC 61643-21]: A device to suppress line conducted overvoltages and currents, such as surge suppressors defined in [b-IEC 61643-21].

## **3.2 Terms defined in this Recommendation**

This Recommendation defines the following terms:

**3.2.1 HEMP immunity test:** The HEMP immunity test is made up of four types of tests. The radiated test is defined in clause 5 of [IEC 61000-4-25], and is used with a large HEMP simulator and a small radiated test facility. The other three types are the conducted tests along the HEMP waveforms; early-, intermediate- and late-HEMP. These are also defined in clause 5 of [IEC 61000-4-25].

**3.2.2 minimum immunity requirement against HEMP:** When the building concept level is 5 or 6, the equipment immunity level is at the minimum level. The levels are defined in clause 8 and Annex A, and a comparison of immunity levels is tabulated in Appendix I.

## **4 Abbreviations and acronyms**

This Recommendation uses the following abbreviations and acronyms:

|       |                                                                      |
|-------|----------------------------------------------------------------------|
| E1    | Early time high altitude electromagnetic pulse electric field        |
| E2    | Intermediate time high altitude electromagnetic pulse electric field |
| E3    | Late time high altitude electromagnetic pulse electric field         |
| 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                      |
| PoE  | Point of Entry                      |
| RF   | Radio Frequency                     |
| SE   | Shielding Effectiveness             |
| TEM  | Transverse Electromagnetic          |

## **5 Equipment test requirements**

This clause describes the three types of conducted HEMP test.

### **5.1 Early time HEMP (E1)**

The waveform rise time and time-to-half value 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 enclosed equipment to a radiated immunity test, as specified in clause 8.4.1;
- subject all cable ports of all enclosed equipment to a conducted immunity test, as specified in clause 8.4.2.

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.

### **5.2 Intermediate time HEMP (E2)**

The waveform rise time and time-to-half value, and the peak value are medium. The waveform of intermediate time HEMPs is similar to a lightning surge. This type of disturbance travels over relatively long lines, such as outdoor telecommunication and power lines. Standard 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 SPDs that comply with [ITU-T K.11] to all external telecommunication cables;
- 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 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 [ITU-T K.46] and [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 important to note that this SPD is only intended to protect the power consumption meter. It is necessary to fit additional SPDs such that the total protection applied to the power cables matches with that applied to the telecommunication cables.

### 5.3 Late time HEMP (E3)

The conducted late time HEMP disturbance is characterized as a quasi-d.c., unidirectional current waveshape with a 1/50-s shape. This disturbance occurs only in long conducting lines that are connected to the earth at both ends. 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 transformer from a primary distribution circuit to a low-voltage outlet will be nearly zero.

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.

Radiation of HEMP disturbs electric or electronic systems by the radiated and/or conducted electromagnetic interferences. To ensure the protection of communication systems against HEMP disturbances, the test specifies the immunity requirements for radiated and conducted electromagnetic pulses.

## 6 Test methods

### 6.1 Radiated tests

The test levels and test methods are described in clause 8.4.1.

The test level applied during the radiated test is affected by the shielding effectiveness (SE) of a telecom centre building. This means:

- The SE of the telecom centre building should be determined as per the procedure presented in Annex A.

### 6.2 Conducted tests

#### 6.2.1 Telecom equipment

The test levels and methods are described in clause 8.4.2.

The test number applied for telecom equipment is listed in Table 1.

**Table 1 – HEMP test list for telecom equipment**

| HEMP phenomena | Test number                                                     |
|----------------|-----------------------------------------------------------------|
| E1             | 2.1, 3.1, 3.2, 4.1, 4.2, 5.1, 5.2, 5.3, 6.1, 6.2, 6.3, 7.1, 7.2 |
| E2             | –                                                               |
| E3             | 6.4, 6.5                                                        |

### 6.2.2 Power equipment

The test levels and methods are described in clause 8.4.2.

The test number applied for power equipment is listed in Table 2.

**Table 2 – HEMP test list for power equipment**

| HEMP phenomena | Test number                                  |
|----------------|----------------------------------------------|
| E1             | 2.1, 5.1, 5.2, 5.3, 6.1, 6.2, 6.3, 7.1, 7.2. |
| E2             | –                                            |
| E3             | 6.4, 6.5                                     |

## 7 Protection concepts for buildings and enclosures

### 7.1 Protection concepts for buildings

Building protection concepts are considered for both radiated and conducted environments. These concepts are summarized in Table 3.

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.

Any additional shielding increases the attenuation. It is up to the operator to determine if the equipment to be protected inside the building needs additional building shielding. The owner of the facility can use the test methods described in [IEC 61000-4-23] to determine the shielding effectiveness of the building. The owner of the equipment can use [IEC 61000-2-11] to classify the environments inside the building, and the test methods described in [IEC 61000-4-25] to evaluate the immunity of the equipment inside (see clause 8).

**Table 3 – Building protection concept**

| Radiated attenuation<br>[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 2B includes an overvoltage protection but not additional filtering. |     |                      |             |
| NOTE 2 – Lightning overvoltage protection and filtering.                                                                       |     |                      |             |

## 7.2 Protection concepts for shielded enclosures

Shielded enclosure protection concepts are summarized in Table 4. These shielded cages can be installed inside or outside the buildings, depending on the equipment to be protected.

**Table 4 – Protection concepts for shielded enclosures**

| Radiated attenuation<br>[dB]                           |           | Conducted protection |
|--------------------------------------------------------|-----------|----------------------|
|                                                        |           | Protected            |
| 1 MHz to 200 MHz                                       | $\geq 20$ | 3 (Note)             |
|                                                        | $\geq 40$ | 4 (Note)             |
|                                                        | $\geq 60$ | 5 (Note)             |
|                                                        | $\geq 80$ | 6 (Note)             |
| NOTE – Lightning overvoltage protection and filtering. |           |                      |

The same concepts for building protection have been adopted, i.e., both the radiated and conducted environments are considered.

The attenuation figures provided in Table 4 refer to electric field, high-frequency magnetic field and plane wave attenuations ( $\sim 1$  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  $\omega B$ , 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  $\omega$ .

## 8 HEMP immunity tests and levels

### 8.1 Immunity test

HEMP immunity tests consist of two major types: radiated immunity and conducted immunity. Most telecommunication equipment is relatively small – in the order of  $1\text{ m} \times 1\text{ m} \times 1\text{ m}$  or smaller. It is expected that most of the tests on such small equipment will be performed in laboratories using current injection simulators and TEM cells. For radiated immunity tests, size can be an important factor since very large systems may be difficult to test, especially using radiated fields. In general, radiated field tests on systems and large equipment with dimensions greater than 1 m will require a large HEMP simulator [IEC TR 61000-4-32]. One aspect of HEMP testing that is different from other kinds of EMC testing is that there are several large ( $\sim 10$  m high) early time ( $t < 1\text{ }\mu\text{s}$ ) HEMP simulators throughout the world. It is possible to expose some systems and large equipment to the early time HEMP threat by reproducing pulsed electric and magnetic fields. These simulators are also useful in verifying that equipment designed and tested for HEMP survival at the equipment level will work properly when integrated into a complete system.

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

### 8.2 Performance criteria

A functional description and a definition of performance criteria, during or as a consequence of the HEMP immunity testing, should be provided by the manufacturer and noted 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.

For performance criteria refer to [ITU-T K.48].

### 8.3 HEMP immunity requirements for equipment

This clause sets HEMP immunity requirements for electrical and electronic equipment intended for use indoors. The indoor HEMP environment depends on the electromagnetic shielding quality of a facility and the level of protection against the conducted environment. This Recommendation is intended for telecommunication centres. This Recommendation includes indoor equipment for connection to a low voltage (1 kV or less) power network, to the telecom network, and/or to external antennas. The levels and test methods are based on [IEC 61000-6-6].

Immunity test values are based on the 90% severity levels in [IEC 61000-4-25]. All telecom lines are assumed to have gas discharge tube protectors 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.

For the purpose of this clause, the nuclear high altitude electromagnetic pulse environment consists of two major parts: a radiated environment and a conducted environment. The standard 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].

### 8.4 HEMP immunity tests levels

This Recommendation defines electromagnetic disturbances that represent those that could result at the equipment ports due to a high altitude nuclear event. These electromagnetic disturbances are the result of the radiated and conducted HEMP environments, as modified by any protection elements. The test methods are defined in [IEC 61000-4-25] and the requirement levels are based on [IEC 61000-6-6].

#### 8.4.1 Radiated immunity

The radiated immunity tests are for early time HEMPs.

The radiated immunity tests and levels are listed in Table 5. 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 5 – Immunity tests – Enclosure port**

| Test | Radiated disturbance and ESD    | 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 |

#### 8.4.2 Conducted immunity

The conducted immunity test is for early time HEMP and late time HEMP phenomena. 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, 7.2 are for early time HEMP, and 6.4, 6.5 are for late time HEMP.

The conducted immunity test is applied to the port types defined in clause 3. The test levels are shown in Tables 6 to 11.

Table 6 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 6 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, the basic standard for test 2.1 is [IEC 61000-4-25]. A bulk cable test should be performed with plus and minus polarity using a capacitive clamp with an EFT/B repetition rate of 2.5 kHz for 10 ms. Test 2.1 is a common-mode test.

**Table 6 – Immunity tests – Signal 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 |
| 2.2  | Electrostatic discharge | [IEC 61000-4-2]                                          | B         | 0.5 kV                          | 0.5 kV | 0.5 kV | 0.5 kV | 0.5 kV | 0.5 kV |

Table 7 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 [IEC 61000-6-6] Annex A 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 basic standard is [IEC 61000-4-25], and tests with plus and minus polarity should be performed with an EFT/B repetition rate of 2.5 kHz for 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 7 – 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<br>320 A                  | 16 kV<br>320 A | 4 kV<br>40 A | 4 kV<br>40 A | 4 kV<br>40 A | 0.5 kV<br>5 A | Not required |

Table 8 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 for 10 ms. For protection concepts 3 through 6, the basic standard for test 4.2 is the [IEC 61000-4-4] EFT/B test, and if a gas-tube protector is not used at the building entry for protection concepts 1 and 2, the 16 kV EC9 of [IEC 61000-4-25] is used.

**Table 8 – 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 $\mu$ s 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 9 applies to interior d.c. power cables. Severity test levels are based on interior cable lengths of 20 m. For longer cables, increase the current level proportionally with cable length up to a maximum of 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 for 10 ms. For protection concepts 1A and 1B, the basic standard is [IEC 61000-4-25]. In test 5.3, both line-to-earth and line-to-line tests should be performed.

**Table 9 – 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 $\mu$ s 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 10 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 those of the line-to-earth test levels shown in this table. In test 6.2, the EFT/B repetition rate is 2.5 kHz for 10 ms. In test 6.3, both line-to-earth and line-to-line tests should be performed.

**Table 10 – 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<br>25 kV<br>(Note 1)      | 16 kV | 20 kV<br>25 kV<br>(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<br>>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 EUT has a back-up power source, the C performance criterion may be changed to A or B.                                                                                                                   |                                |                  |           |                                 |       |                            |       |        |        |      |

Table 11 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 for 10 ms.

**Table 11 – 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 | – | – | –   |

## Annex A

### Guide for application of protection approach

(This annex forms an integral part of this Recommendation)

#### A.1 Introduction

The protection of systems in telecommunication centres is achieved by the combination of shielding of the building, surge protection measures of power and telecommunication lines, and resistibility and immunity of equipment of the system.

#### A.2 Protection approaches

There are two approaches for applying protection measures:

- Case 1: 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.
- Case 2: When the system has not yet been installed, we apply an equipment requirement, which works in the given shielding and surge protection measures of the building. In this case, the requirement depends on the protection concept of the building.

#### A.3 Protection concepts

A protection concept describes the fundamental ideas that guide the operator to obtain HEMP-resistant equipment, systems and/or buildings. As this Recommendation aims at telecommunication centre applications, the HEMP-hardened system consists of telecommunication equipment that is sometimes housed in special enclosures.

The protection concepts deal mainly with housing and interconnections in a building. The required immunity level of equipment is set by the concept level of the building and/or enclosure where the equipment is installed.

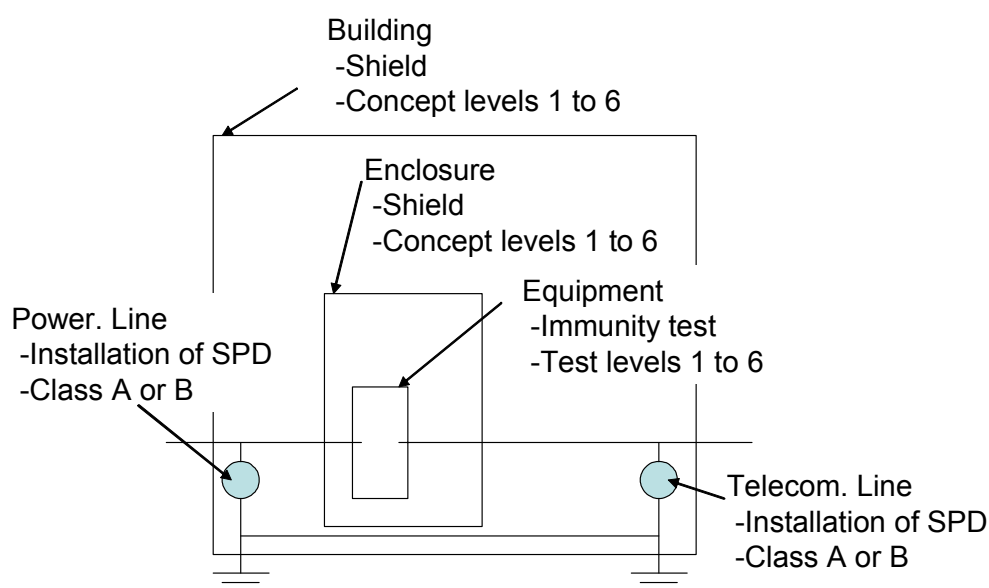


Figure A.1 – Concept and immunity test levels

For the purposes of this HEMP environment classification, six major protection concepts are defined below (see [IEC 61000-5-3] for additional details). The external environments and protection concepts result in internal environment levels, which are appropriate for equipment or subsystems that are placed within these protection zones. The concepts are described as:

**Concept 1:** Above-ground wooden, brick or concrete building or structure with large windows and doors without rebar or other explicit shielding. Lack or presence of conducted lightning protection (overvoltage protection without filtering) defines subconcepts 1A and 1B, respectively.

**Concept 2:** Above-ground concrete building or structure with rebar or buried brick or concrete. Lack or presence of conducted lightning protection (overvoltage protection without filtering) defines subconcepts 2A and 2B, respectively.

**Concept 3:** Shielded enclosure with minimal RF shielding effectiveness such as a typical equipment box with small apertures and nominal lightning overvoltage and EMI conducted penetration protection (filtering).

**Concept 4:** Shielded enclosure with modest RF shielding effectiveness, good bonding at all points of entry (PoEs) and nominal lightning overvoltage and EMI conducted penetration protection (filtering).

**Concept 5:** Shielded enclosure with good RF shielding effectiveness and PoE protection (overvoltage and filtering).

**Concept 6:** Shielded enclosure with high-quality RF shielding and PoE protection (overvoltage and filtering).

The EM field attenuation levels described below in Table A.1 are to be evaluated at frequencies between 100 kHz and 30 MHz for concepts 1 and 2, and at frequencies between 1 MHz and 200 MHz for concepts 3 to 6, using the methods described in [IEC 61000-4-23].

**Table A.1 – Minimum required attenuation of peak time domain external environments for six principal protection concepts**

| Concept level                                                                                                                               | Minimum attenuation dB |                |                   |
|---------------------------------------------------------------------------------------------------------------------------------------------|------------------------|----------------|-------------------|
|                                                                                                                                             | Electric field         | Magnetic field | Conducted current |
| 1A                                                                                                                                          | 0                      | 0              | 0                 |
| 1B                                                                                                                                          | 0                      | 0              | 20                |
| 2A                                                                                                                                          | 20                     | 20             | 0                 |
| 2B                                                                                                                                          | 20                     | 20             | 20                |
| 3                                                                                                                                           | 20                     | 20             | 40                |
| 4                                                                                                                                           | 40                     | 40             | 40                |
| 5                                                                                                                                           | 60                     | 60             | 60                |
| 6                                                                                                                                           | 80                     | 80             | 80                |
| NOTE – Frequency evaluation ranges for E and H fields are 100 kHz to 30 MHz for concepts 1 and 2, and 1 MHz to 200 MHz for concepts 3 to 6. |                        |                |                   |

When the telecommunication centre is protected from HEMP phenomena, the surge protectors should be installed on all lines such as a.c. mains, telecommunication lines and antenna feeds.

## **A.4 Topological considerations**

From a topological point of view, two possible approaches can be considered: global protection and distributed protection.

If global protection is chosen, the whole installation, which consists of several interconnected pieces of equipment, will be in a protected environment.

If distributed protection is chosen:

- each piece of equipment should be sometimes hardened with a shielding cabinet;
- the connection cables between the equipment should be hardened.

To select the concept and immunity test levels, the following flows should be used.

### **A.4.1 Design procedure**

#### **A.4.1.1 General considerations**

When an operator or a manufacturer chooses a protection concept, the first question to answer should be whether or not to provide installation or equipment protection against HEMP.

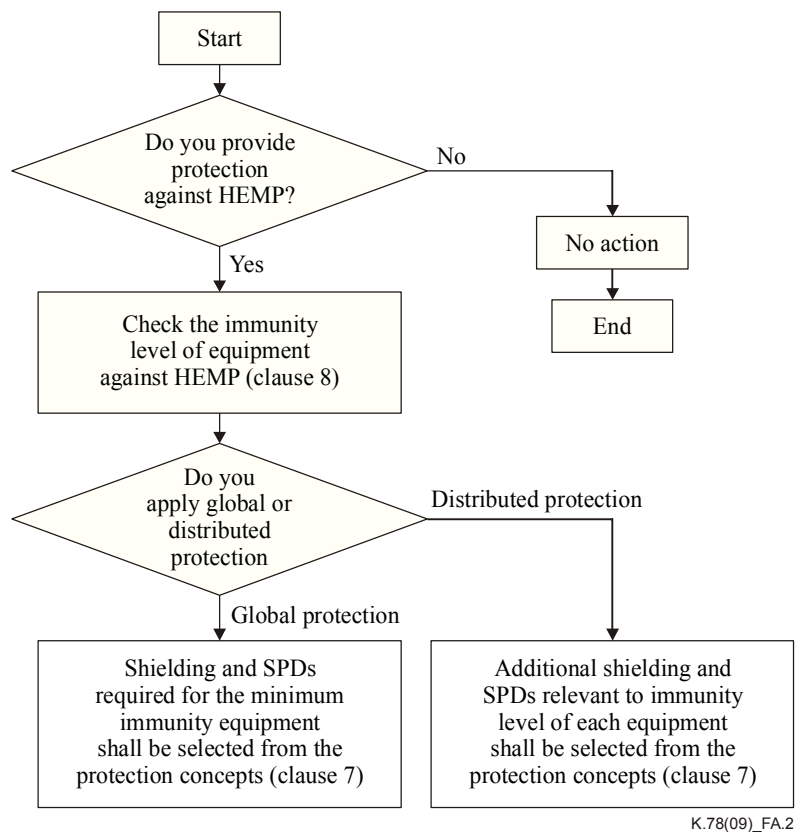
The answer to this question will depend on:

- the importance for the installation or equipment to survive HEMP. It should be noted that, in some cases, only a portion of the installation need survive;
- considerations on whether interruptions of a certain time duration are permitted.

Once the protection concept has been decided upon, the immunity test level is determined by the degree of the protection concept applied to the portion where the equipment is installed. The performance criteria are set by the acceptable degree of degradation determined by the operator.

#### **A.4.1.2 Design flow chart for case 1**

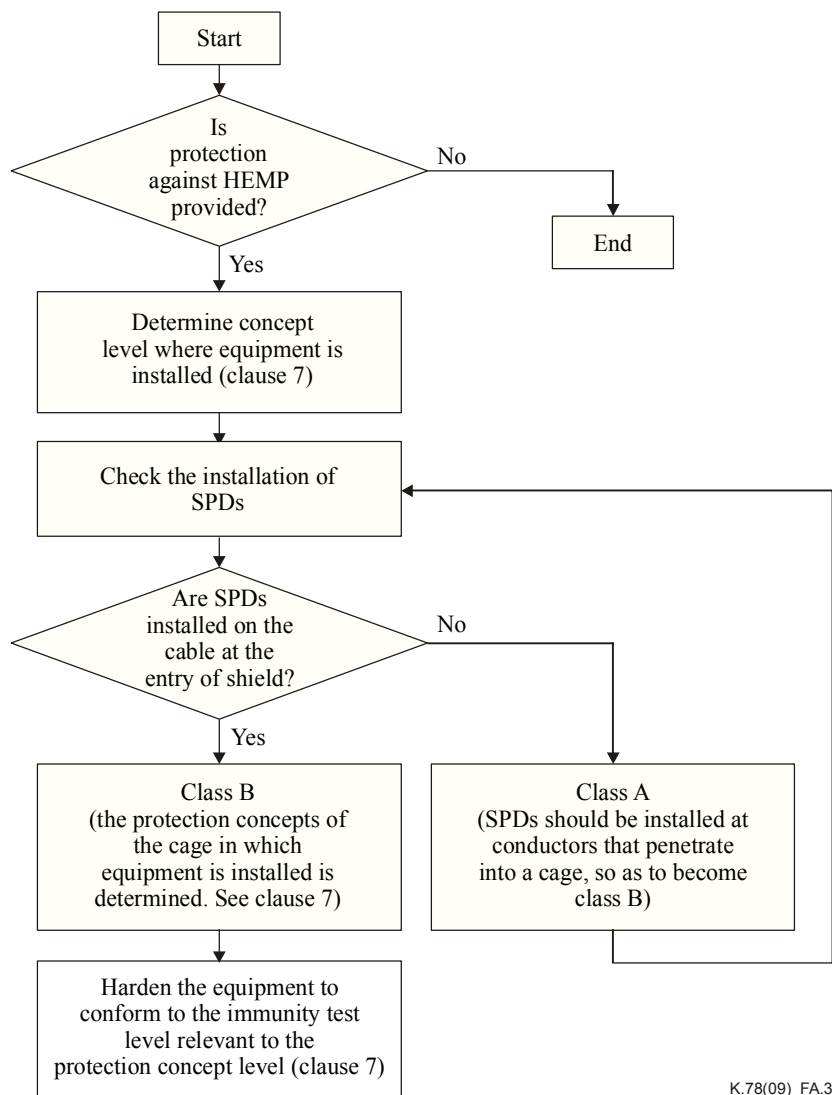
When we apply a protection concept to a telecommunication centre building, in which a system has already been installed, only additional shielding and surge protection measures can be applied. The design flow chart is shown in Figure A.2. In this case, the system equipment must conform to the immunity requirement against HEMP. If the equipment is HEMP immune (see clause 8), an additional shielding level can be selected as a building concept level (see clause 7). If the equipment has the minimum HEMP immunity level (see Appendix I), the additional shielding level is concept level 5 or 6 with additional SPDs and filters on telecommunication and power lines.



**Figure A.2 – Design flow chart for case 1**

#### **A.4.1.3 Design flow chart for case 2**

When the building has no system installed yet, we can require that the equipment will work in the given shielding a surge protection measures of the building. In this case, the requirement depends on the protection concept of the building. The design flow chart is shown as Figure A.3. For example, when the building concept level is determined as level 4 (shield 40 dB, see clause 7), the installation of SPDs on the cable should first be confirmed, and the equipment, which should have a HEMP immunity level of 4 (see clause 8), should be installed in the telecommunication centre.



**Figure A.3 – Design flow chart for case 2**

## 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 [ITU-T K.48] and [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 comparison 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                             |
| 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 |
| [ITU-T K.48]    | Radio frequency electromagnetic field | [ITU-T K.48]     | B         | 3 V/m<br>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         |
| [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 |
| [ITU-T K.48]    | Fast transients field   | [ITU-T K.48]    | B         | 0.5 kV<br>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 |
| [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<br>320A                   | 16 kV<br>320A | 4 kV<br>40A | 4 kV<br>40A | 4 kV<br>40A | 0.5 kV<br>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 |
| [ITU-T K.48]    | Surge<br>1.2/50 us    | [ITU-T K.48]    | B         | 0.5 kV (line-to-line)<br>1 kV (line-to-ground) |      |      |      |      |      |      |
| [ITU-T K.20]    | Surge<br>10/700       | [ITU-T K.20]    |           | Basic: 1 kV<br>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 |
| [ITU-T K.48]    | Fast transient        | [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 |
| [ITU-T K.48]    | Surge<br>1.2/50                           | [ITU-T K.48]     | B         | 0.5 kV (line-to-line)<br>1 kV (line-to-ground) |       |      |      |        |        |        |
| [ITU-T K.20]    | Surge<br>1.2/50                           | [ITU-T K.20]     |           | Basic: 1 kV<br>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   |
| [ITU-T K.48]    | Fast transient                            | [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 |  |
| [ITU-T K.48]    | Surge<br>1.2/50                           | [ITU-T K.48]     | B         | 0.5 kV (line-to-line)<br>1 kV (line-to-ground) |       |       |       |      |      |      |  |
| [ITU-T K.20]    | Surge<br>1.2/50                           | [ITU-T K.20]     |           | Basic: 1 kV<br>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 |  |
| [ITU-T K.48]    | Fast transient                            | [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<br>>95% 5 s                            |       |       |       |      |      |      |  |
| [ITU-T K.48]    | Voltage dips                              | [ITU-T K.48]     | B<br>C    | >95% 0.5 s<br>30% 25 s                         |       |       |       |      |      |      |  |
| [IEC 61000-6-6] | Power frequency harmonics                 | [IEC 61000-4-13] | B         | Class 3                                        |       |       |       |      |      |      |  |
| [ITU-T K.48]    | Fast transient                            | [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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