

International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

K.40

(11/2019)

SERIES K: PROTECTION AGAINST INTERFERENCE

**Protection against lightning electromagnetic
pulses in telecommunication centres**

Recommendation ITU-T K.40

ITU-T



Recommendation ITU-T K.40

Protection against lightning electromagnetic pulses in telecommunication centres

Summary

Recommendation ITU-T K.40 proposes guidelines for the design of an effective protective system for a telecommunication structure against lightning electromagnetic pulse (LEMP). The concept of lightning protection zones is introduced as a framework where specific protective measures are merged: earthing, bonding, cable routing, shielding, coordinated SPD system and isolating interfaces. Information about simulating the LEMP effects and a shopping list for the protective measures in existing and new buildings are also given.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T K.40	1996-10-18	5	11.1002/1000/3878
2.0	ITU-T K.40	2018-01-13	5	11.1002/1000/13444
3.0	ITU-T K.40	2019-11-13	5	11.1002/1000/14069

Keywords

Bonding, cable routing, earthing, isolating interfaces, lightning electromagnetic pulse (LEMP), shielding, surge protective device (SPD).

* To access the Recommendation, type the URL <http://handle.itu.int/> in the address field of your web browser, followed by the Recommendation's unique ID. For example, <http://handle.itu.int/11.1002/1000/11830-en>.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at <http://www.itu.int/ITU-T/ipr/>.

© ITU 2019

All rights reserved. No part of this publication may be reproduced, by any means whatsoever, without the prior written permission of ITU.

Table of Contents

	Page
1 Scope.....	1
2 References.....	1
3 Definitions	1
3.1 Terms defined elsewhere	1
3.2 Terms defined in this Recommendation.....	2
4 Abbreviations and acronyms	2
5 Conventions	2
6 Reference configuration.....	2
7 Need for protection	3
8 Protective measure.....	3
8.1 General principles: lightning protection zones (LPZs)	3
8.2 Earthing	5
8.3 Bonding: minimum CBN	6
8.4 Cabling routing.....	7
9 Additional protective measures	7
9.1 General	7
9.2 Shielding.....	7
9.3 Coordinated SPD system.....	8
9.4 Isolating interfaces.....	8
Appendix I – Simulation of LEMP effects – Test set-up.....	9
Appendix II – Protection management	13
II.1 New telecommunication centres.....	13
II.2 Existing telecommunication centres.....	13
Bibliography.....	15

Introduction

This Recommendation is aimed at setting out the installation and testing principles necessary to protect a telecommunication structure against lightning electromagnetic pulse (LEMP). It focuses on the design of an effective protective system for the telecommunication structure environment.

The installation engineering guidelines that this Recommendation lays down are based on the following standards, produced by IEC TC 81: "Protection against lightning – Part 1: General principles" [IEC 62305-1] and "Protection against lightning – Part 4: Electrical and electronic systems within structures" [IEC 62305-4].

The basic principles for protecting a structure against LEMP, earthing, shielding and bonding, can be found in [ITU-T K.27] and [ITU-T K.35]. If after applying these principles to a structure, the result of the risk assessment as stated in [ITU-T K.39] is that additional protective measures should be taken, this Recommendation gives advice on these special measures. A telecommunication site with antennas at the top or near a telecommunication site is more at risk of damage by a direct lightning strike; special attention is given to these structures.

Recommendation ITU-T K.40

Protection against lightning electromagnetic pulses in telecommunication centres

1 Scope

This Recommendation addresses new and existing structures, such as telecommunication centres, large installations at a subscriber's premises and remote sites, and gives advice on the design and installation of protective measures against lightning electromagnetic pulses (LEMPs), in order to reduce damages to the equipment and cabling inside these structures.

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.27] | Recommendation ITU-T K.27 (2015), <i>Bonding configurations and earthing inside a telecommunication building</i> . |
| [ITU-T K.35] | Recommendation ITU-T K.35 (1996), <i>Bonding configurations and earthing at remote electronic sites</i> . |
| [ITU-T K.39] | Recommendation ITU-T K.39 (1996), <i>Risk assessment of damages to telecommunication sites due to lightning discharges</i> . |
| [ITU-T Lightning Handbook] | ITU-T Lightning Handbook (1978), <i>The protection of telecommunication lines and equipment against lightning discharges</i> . |
| [IEC 60664-1] | IEC 60664-1:2007, <i>Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests</i> . |
| [IEC 61643-12] | IEC 61643-12:2008, <i>Low-voltage surge protective devices – Part 12: Surge protective devices connected to low-voltage power distribution systems – Selection and application principles</i> . |
| [IEC 61643-22] | IEC 61643-22:2015, <i>Low-voltage surge protective devices – Part 22: Surge protective devices connected to telecommunications and signalling networks – Selection and application principles</i> . |
| [IEC 62305-1] | IEC 62305-1:2010, <i>Protection against lightning – Part 1: General principles</i> . |
| [IEC 62305-4] | IEC 62305-4:2010, <i>Protection against lightning – Part 4: Electrical and electronic systems within structures</i> . |

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

All terms and definitions already defined in [IEC 62305-1] and [IEC 62305-4] are applicable for this Recommendation. These include:

3.1.1 LEMP protection measures, SPM [IEC 62305-4]: Measures taken to protect internal systems against the effects of LEMP.

NOTE – This is part of overall lightning protection.

3.1.2 surge protective device, SPD [IEC 62305-4]: Device intended to limit transient overvoltages and divert surge currents; contains at least one non-linear component.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 bonding: A measure to establish a direct or indirect (through an SPD) contact between metallic parts.

3.2.2 MCBN: The minimum common bonding network against LEMP configuration required for protection against LEMP at a telecommunication centre. Additional bonding may be installed to improve the behaviour against LEMP to reduce the risk of damage. As stated in various clauses of this Recommendation, the efficiency of these enhancements may be estimated with [ITU-T K.39].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

BN	Bonding Network
CBN	Common Bonding Network
LEMP	Lightning Electromagnetic Pulse
LPS	Lightning Protection System
LPZ	Lightning Protection Zone
MCBN	Minimum Common Bonding Network
MOM	Method of Moments
SPD	Surge Protective Device
SPM	LEMP Protection Measures

5 Conventions

None.

6 Reference configuration

As a reference configuration, that is, to what type of telecommunication environment should the guidelines suggested in this Recommendation be considered, structures with telecommunication towers on the roof or adjacent to the structure should be taken into account.

In this configuration a direct lightning strike to the telecommunication tower is the source of the LEMP phenomena. As the lightning current flows through the tower, it creates a strong electromagnetic field; this field couples with the internal and external cabling of the equipment inside the telecommunication structure, inducing overvoltages and overcurrents that can destroy electronic components of the equipment.

A resistive coupling mechanism takes place as well due to the earth potential rise; partial lightning current will flow in the cable screens resulting in voltages between the conductors and the screen.

The resistive coupling may cause also a firing of the surge protective devices (SPDs) installed at the telecommunication cables entrance, the LEMP disturbance is then propagated through the core of the telecommunication cable and may cause damage to the cable when the isolating breakdown voltage between shield and core is surpassed, not only in the telecommunication cables but to a large extent in the mains conductors, and may cause problems for mains-connected equipment if their resistibility is lower than the protective level given by the mains SPD. See Figure 1.

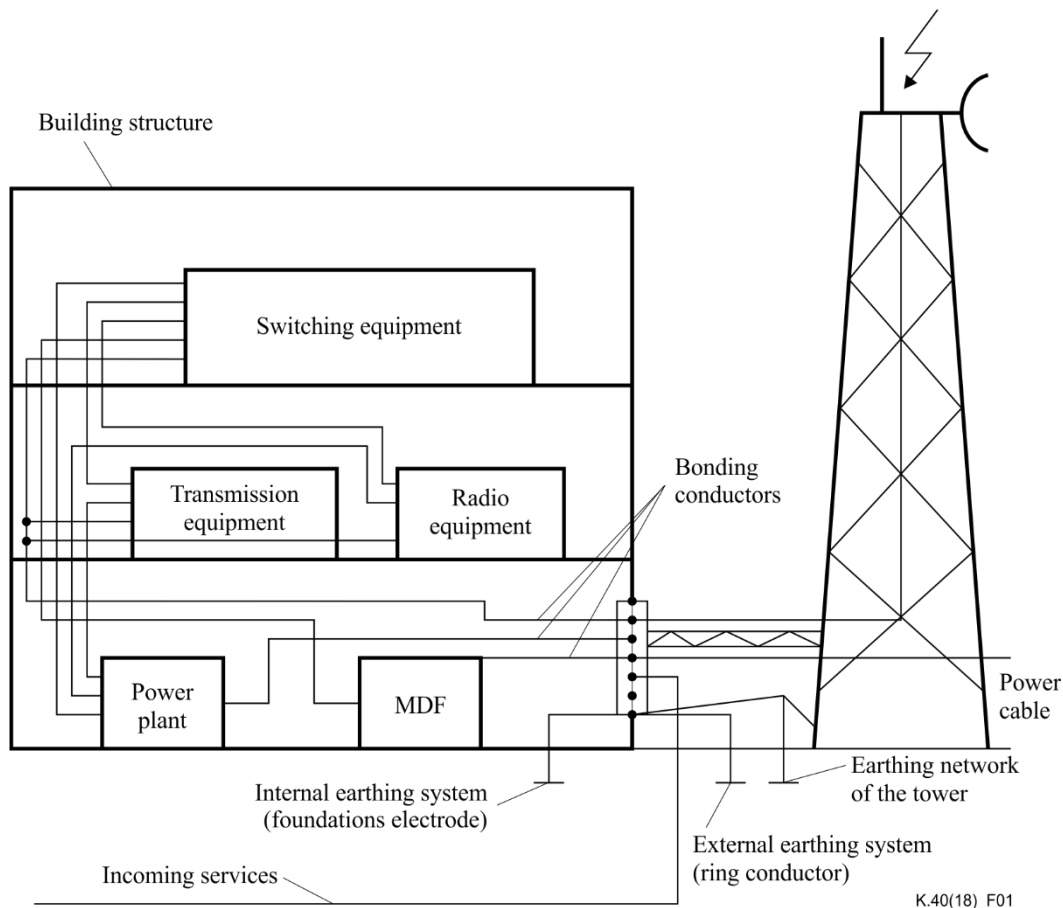


Figure 1 – Example of reference configuration

7 Need for protection

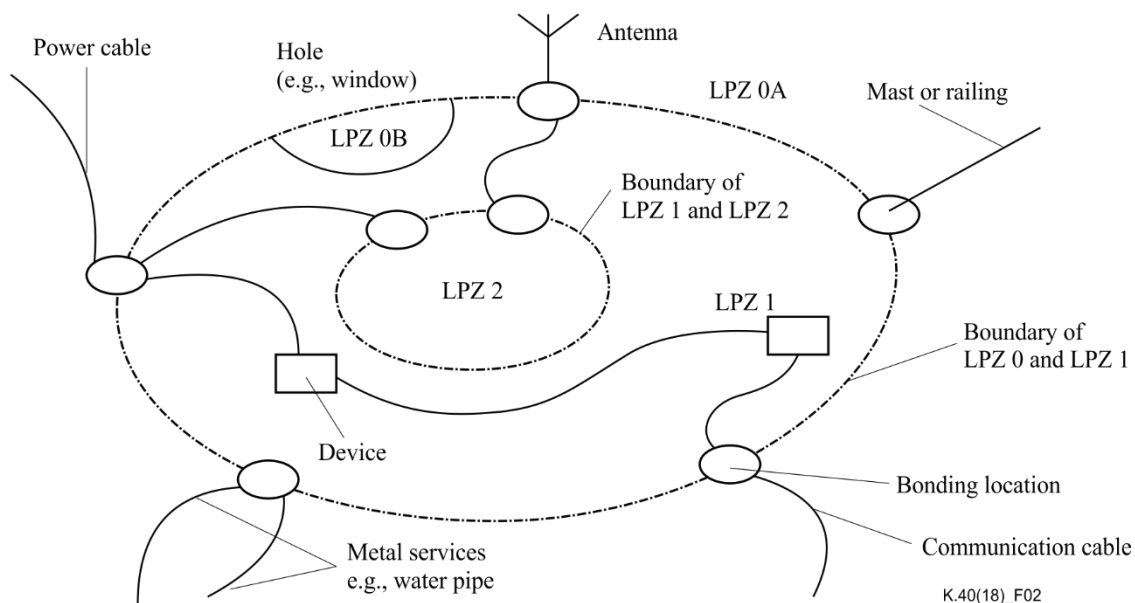
In order to estimate the need of protection of a given structure against LEMP, [ITU-T K.39] should be used to evaluate the risk due to a direct strike to the structure itself (R_d) and to an adjacent structure (R_a). If the result of the calculation shows that the risk R is higher than the acceptable risk level R_{accept} ($R > R_{\text{accept}}$), the protective measures suggested here should be considered to attain an acceptable risk level.

8 Protective measure

In the following subclauses, protective measures are proposed to achieve protection against LEMP considering the resistibility of equipment interfaces with internal cabling.

8.1 General principles: lightning protection zones (LPZs)

It is advantageous to divide the telecommunication site to be protected into lightning protection zones (LPZs) to define volumes of different LEMP severities and to designate locations for bonding points on the zone boundaries. See Figure 2.



- LPZ 0 : Items in this zone are exposed to unattenuated electromagnetic conditions caused by lightning. It is advantageous to split LPZ 0 into LPZ 0A and LPZ 0B.
- LPZ 0A : Items in this zone are subject to direct lightning strikes and therefore may have to carry the full lightning current. The unattenuated electromagnetic field occurs here.
- LPZ 0B : Items in this zone are not subject to direct lightning strikes but the unattenuated electromagnetic field occurs.
- LPZ 1 : Items in this zone are not subject to direct lightning strikes. The current on all conductive parts within this zone will be reduced compared with zone 0. In this zone the electromagnetic field might be attenuated depending on the screening measures. With regard to telecommunication buildings, shielded and unshielded installations can be found in practice.
- Subsequent zones (LPZ 2, etc.): Subsequent zones may be introduced if a reduction of conducted currents and/or electromagnetic field is required. The requirements for these zones should be selected according to the protection requirement of the system to be protected.

Figure 2 – Different LPZs of a structure to be protected

The boundaries of the zones are characterized by significant changes of the electromagnetic conditions.

At the boundary of the individual zones, bonding for all metal penetrations should be provided and screening measures should be installed. Bonding at the boundary between LPZ 0 and LPZ 1 is defined as equipotential bonding. It has to be noted that the electromagnetic fields inside a structure are influenced by openings such as windows, by currents on metal conductors (e.g., bonding bars, cable shields and tubes) and by cable routing.

Figure 3 shows an example of the several zones in which a telecommunication centre may be divided. Here all electric power and signal lines enter the protected volume (LPZ 1) at one point and are bonded to bonding bar 1 at the boundary of LPZ 0 and LPZ 1. In addition, the lines are bonded to the internal bonding bar at the boundary of LPZ 1 and LPZ 2. Furthermore, the outer shield 1 of the structure is bonded to bonding bar 1 and the inner shield to bonding bar 2. Where cables pass from one LPZ to another, the bonding must be executed at each boundary. LPZ 2 is constructed in such a way that partial lightning currents are not led to this volume and cannot pass through it.

With regard to the internal earthing system, it is common practice to provide a ring conductor (not shown in the figure) for making shorter bonding connections between the different LPZs within the building, in order to improve the performance at high frequencies. In most of the telecommunication centres it will not be necessary to build a room for shield 2, the boundary of LPZ 2 can be the structure of the equipment.

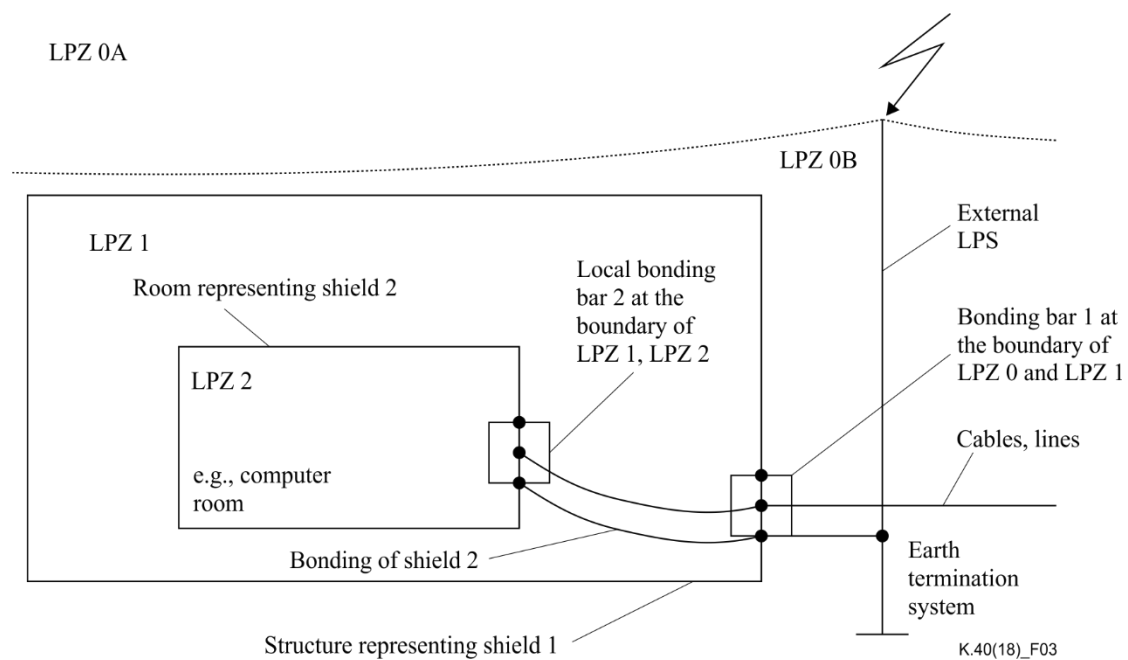


Figure 3 – Example of LPZs at a telecommunication centre

8.2 Earthing

The general ring earth electrode for the earthing of a telecommunication centre is given in [ITU-T K.27] and [ITU-T K.35].

If there are adjacent structures between which power and communication cables pass, the earthing systems must be interconnected and it is beneficial to have many parallel paths forming a meshed network in the soil to reduce the currents in the cables. Transmission and power supply cables should be well shielded or laid in metallic pipes that are bonded in both ends to the earthing network, in order to reduce the lightning current effects.

Figure 4 illustrates the above principles.

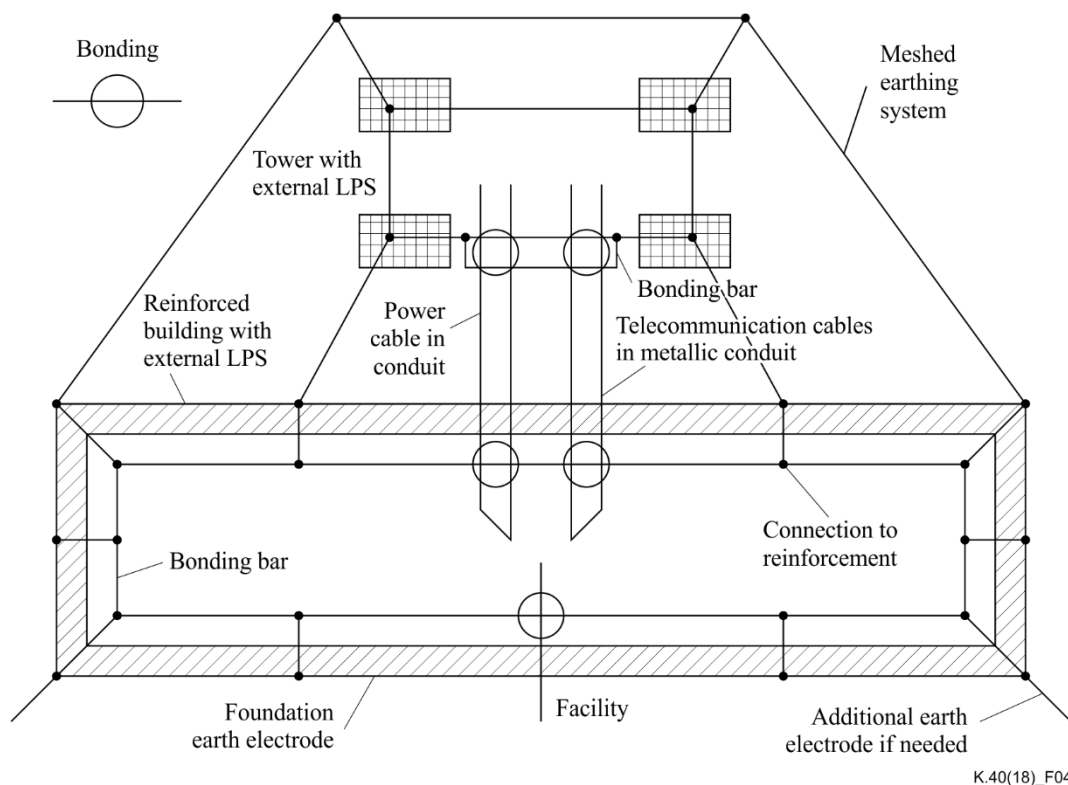


Figure 4 – Example of meshed earthing

8.3 Bonding: minimum CBN

The purpose of bonding is to reduce potential differences between metal parts and systems inside the volume to be protected during a lightning strike. For this purpose, a minimum common bonding network (MCBN) is required.

Bonding must be provided and installed at the boundaries of LPZs for the metal parts and systems crossing the boundaries as well as for metal parts and systems inside an LPZ. Bonding at bonding bars is performed by means of bonding conductors and clamps, and where necessary by SPDs.

The MCBN is defined as follows:

- at each floor of the telecommunication centre, a ring conductor along the inside perimeter of the building. Details for the recommended practice for the ring conductor may be found in [ITU-T K.27] and [ITU-T K.35].
- A connection between the ring conductor of each floor with vertical bonding conductors, approximating a Faraday cage; the distance between the vertical conductors should not be about 5 m or less.
- At the ground floor, it is a connection of the ring conductor to the ring earth electrode.

Figure 5 illustrates the MCBN.

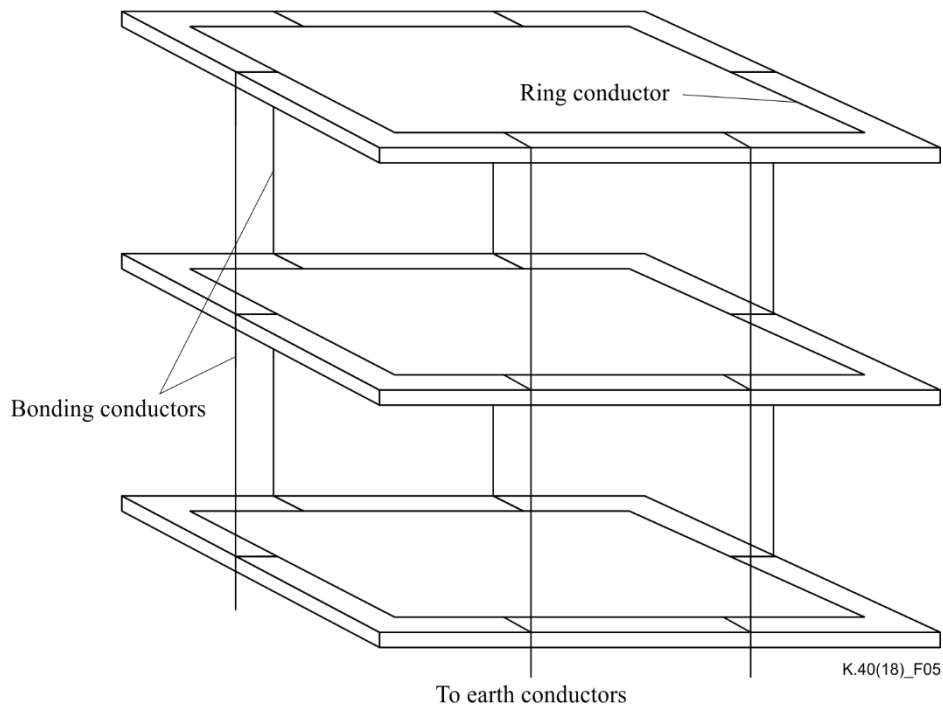


Figure 5 – Minimum common bonding network (MCBN)

8.4 Cabling routing

For the reduction of the overvoltages and overcurrents induced on cabling and bonding conductors, it is recommended to reduce the loop dimensions by a close routing of signal and power cabling and bonding conductors. Constraints due to the structure and equipment locations should be taken into account.

9 Additional protective measures

9.1 General

The following subclauses propose additional protective measures to those defined in clause 7, that are recommended when the resistibility of equipment interfaces are not defined.

9.2 Shielding

Shielding is the basic measure to reduce electromagnetic interference including magnetic field effects.

9.2.1 The structure

In order to improve the electromagnetic environment, all metal parts of significant dimension associated with the structure should be bonded together and to the lightning protection system (LPS), i.e., metal skin roofs and facades, metal reinforcement of the concrete and metal frames of doors and windows.

With regard to telecommunication buildings, shielded and unshielded structures can be found in practice.

- Unshielded buildings, e.g., made of wood or bricks, where an internal bonding system should then be installed to distribute equalizing currents among a greater number of conducting objects creating a reference plane for the entire communication installation.
- Shielded buildings, made of well-interconnected reinforced concrete or steel, that have excellent shielding qualities and where all the metallic parts shall be utilized as reference for the installation.

9.2.2 The cabling

It is recommended to use shielded cables within the volume to be protected. They should be bonded at least at both ends as well as at the LPZ boundaries.

Cabling shielding using a low impedance metallic duct connected in several points to the MCBN, provides a strong reduction (about one hundred times) of the induced voltages and currents to levels that the equipment can resist. The metallic duct should be divided in two parts by a metallic septum: on one side the signal conductors are placed, on the other the power cabling and bonding conductors. The metallic duct should be connected at each floor ring conductor in order to be merged in the MCBN.

9.3 Coordinated SPD system

The protection of internal systems against surges requires a systematic approach consisting of coordinated SPDs for both power and signal lines. The rules for the selection and installation of a coordinated SPD system are referred to [IEC 61643-12] and [IEC 61643-22].

In LEMP protection measures (SPM) using the lightning protection zones concept with more than one inner LPZ (LPZ 1, LPZ 2 and higher), an SPD(s) shall be located at the line entrance into each LPZ.

In SPM using LPZ 1 only, an SPD shall be located at the line entrance into LPZ 1 at least.

In both cases, additional SPDs may be required if the distance between the location of the SPD and the equipment being protected is long.

9.4 Isolating interfaces

Isolating interfaces may be used to reduce the effects of LEMP. Protection of such interfaces against overvoltages, where needed, may be achieved using SPDs. The withstand level of the isolating interface, and the voltage protection level of the SPD (U_p) shall be coordinated with the overvoltage categories of [IEC 60664-1].

Appendix I

Simulation of LEMP effects – Test set-up

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

For the purposes of analytical estimation of current distribution in the LPS and bonded installation, the lightning current source may be considered as a constant current generator injecting a lightning current, consisting of several strokes, into the conductor of the LPS and its bonded installation. This conducted current, as well as the current in the lightning channel causes electromagnetic interferences.

In order to measure the induced voltages due to the lightning strike in a telecommunication centre, a test surge current as defined in [IEC 62305-1], should be fed into the building. The surge generator is connected to a specific point of the building metallic structure, i.e., the centre pillars, so that the current could be distributed and directed to earth through the parallel paths provided by the metallic structure of the building. The lightning current returns to the generator via the grounding ring and return conductors joined to the ring.

Figures I.1 and I.2 show that the induced voltage in a measuring loop inside the building depends on the geometry of the current injection circuit. The distance of the return conductor is responsible for the current distribution in the building and therefore also responsible for the induced voltage (position a). In order to simulate approximately the real lightning current distribution, we need to install the return conductor so far that its position does no longer have a significant influence on the induced voltage (position b, c or d). From practical experience, reasonable conditions for flat buildings are: Figure I.2 d: $\beta \geq 45^\circ$ and $d \geq 2/3a$. For tower-like structures, a reasonable homogeneous current distribution can be obtained by spacing the return conductor from the structure in a distance of ≥ 3 times the diameter of the structure.

A single return conductor configuration is suitable to simulate a lightning strike into an edge or corner of a building, which is in reality the worst case. If several return conductors were used (a spider-like configuration), they shall be installed also in a distance from the roof which is at least 10 times larger than the spacing between the lightning interception wires on the roof (e.g., 2 m above a reinforced concrete sealing, when the reinforced bars are used for lightning current distribution). Otherwise the current distribution in the horizontal part of the building would be governed by these conductors, which would produce unrealistic results.

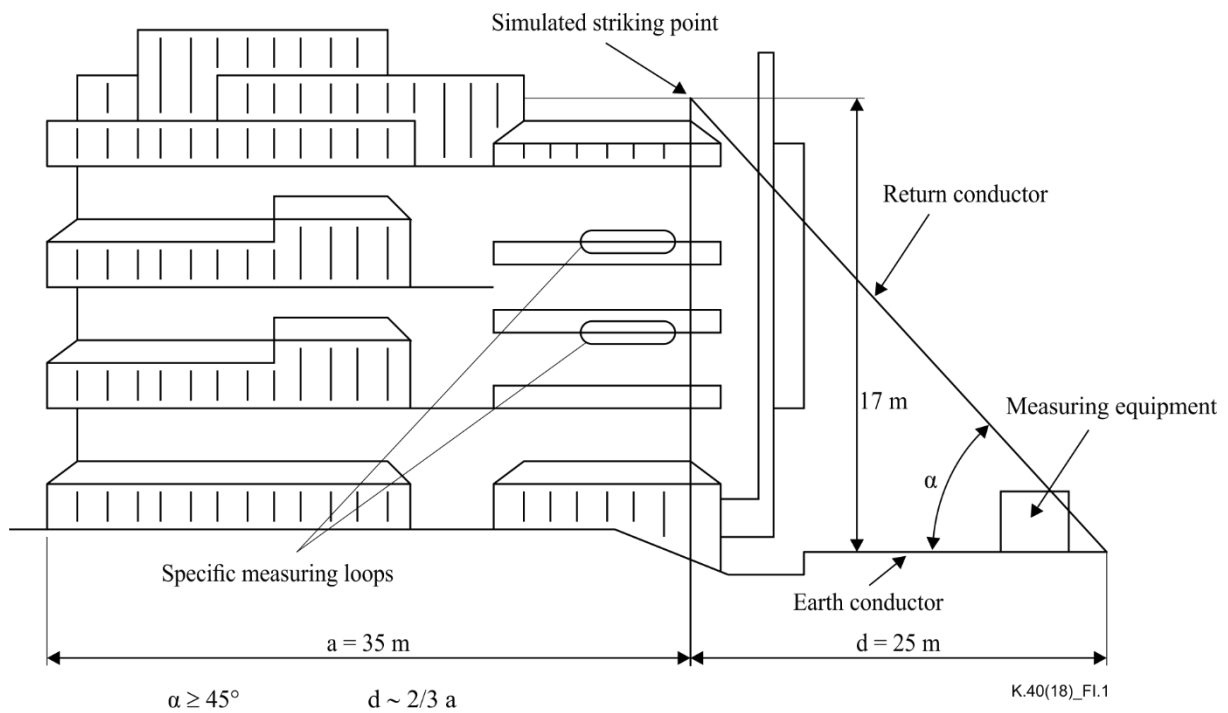


Figure I.1 – Test set-up

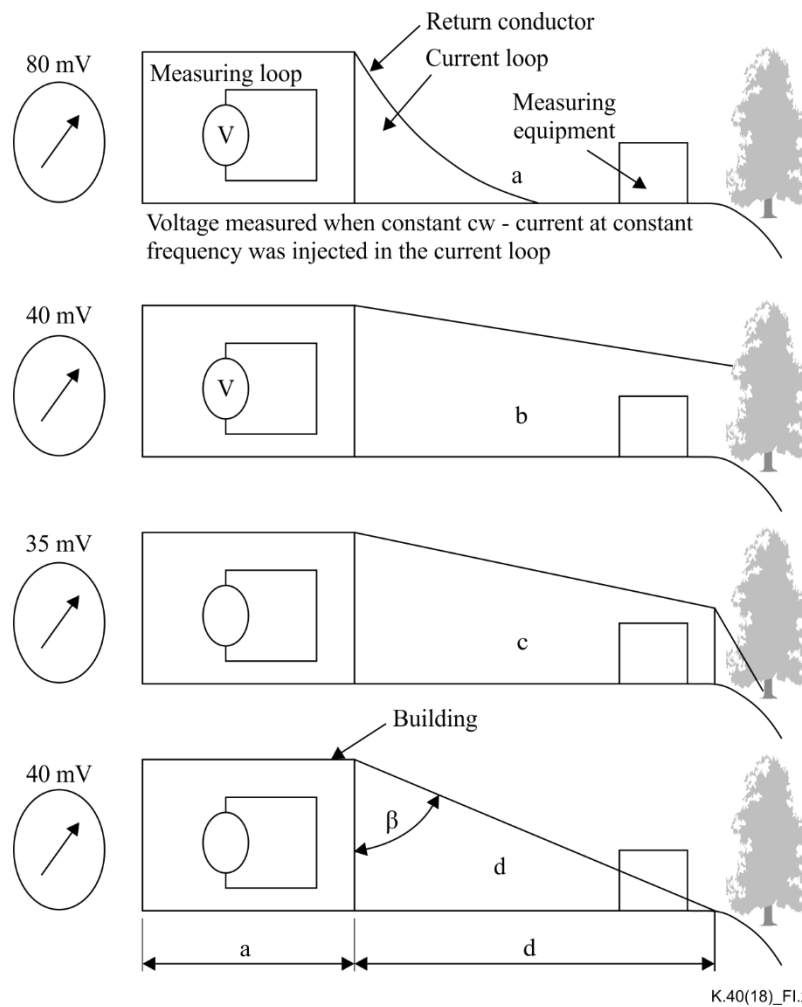


Figure I.2 – Influence of the position of the return conductor to the measured voltage

For the current injection, power generators for frequencies in the range from some kHz up to 250 kHz can be applied. The inductance L of the current loop needs normally to be compensated by series capacitors. The induced voltage can then be measured with very sensitive, selective voltmeters. The impedance against frequency can be measured. In most cases it is a straight line which gives a constant mutual inductance between the measuring loop and the lightning current.

The application of lightning pulse generators demand very high voltages for the generator because the steepness of the lightning current is:

$$\frac{di}{dt} = \frac{U}{L},$$

where:

U is the maximum of the pulse generator

L is the self-inductance of the current path (normally some 100 μH for the needed large loop).

For example, to get a di/dt of 50 kA/ μs , the maximum voltage of the pulse generator needs to be:

$$U = L \cdot \frac{di}{dt} = 100 \mu\text{H} \cdot 50 \text{kA} / \mu\text{s} = 5 \times 10^6 \text{V}$$

In some cases, especially in newly erected buildings before telecommunication equipment is installed, the law of reciprocity can be applied. The voltage measuring loop becomes the current injection loop and vice versa. This reduces the self-inductance of the new current loop to a few μH , which allows the application of pulse generators with some 10 kV charging voltage.

Surge currents in the pillars and walls of the building can be measured using a Rogowski coil and an E/O-O/E (electrical-optical, octocouplers) transmitter (bandwidth d.c.-10 MHz). Measured time domain data is converted to frequency domain data using Fourier transformation. Next the frequency domain data is revised using amplitude and phase data and is then reconverted again to time domain data.

Induced voltages may be measured using a high impedance probe and an E/O-O/E transmitter. The magnetic horizontal field can be measured using an inductive probe fixed at the height of, for example, 1 m from the floor.

For computer simulation of the lightning strike effect, the method of moments (MOMs) may be used. It is a general procedure for solving linear field problems, and also called a matrix method because it reduces the original functional equation to a matrix equation. The method is used for finding the voltages and current distributions in the LPS of the telecommunication centre, as well as the radiated field inside the building due to the lightning strike. The thin-wire approximation is widely used for the analysis of wire structures regarding its electromagnetic behaviour. Under certain assumptions the LPS may be considered as a thin-wire structure. The problem to consider is to solve the thin-wire electric-field integral equation for the LPS, and a method to solve these equations is the MOM. The target of the above analysis is to estimate the efficiency of the protection system installed in the telecommunication centre.

Numerical simulations and tests were conducted to study the behaviour of telecommunication centres when struck by LEMP; for analysis purposes the current may be defined as [IEC 62305-1]:

$$i = \frac{I}{\eta} \cdot \frac{(t / \tau_1)^{10}}{1 + (t / \tau_1)^{10}} \cdot e^{-\frac{t}{\tau_2}}$$

where:

I Peak current

η Correction factor for the peak current

t Time
 τ_1 Front time constant
 τ_2 Tail time constant

Appendix II

Protection management

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

II.1 New telecommunication centres

In order to set up and to maintain a well-designed LEMP protection system for a telecommunication centre, the steps shown in Table II.1 shall be followed.

II.2 Existing telecommunication centres

For existing installations, a checklist, see Table II.2, should help to address the specific points and to select the most economical measures for the hardening of the equipment against LEMP. This checklist should be used in conjunction with [ITU-T K.39].

Table II.1

Step	Aim	Executive
System planning	Elaboration of an integral protection concept with definition of: <ul style="list-style-type: none">– protection levels– LPZ and their boundaries– spatial shielding measures– bonding networks– bonding measures for services and lines at the LPZ boundaries– cable routing and shielding	Lightning protection expert in contact with: <ul style="list-style-type: none">– the owner– the architect– the planners of relevant installations– the subcontractors– equipment manufacturer
System design	<ul style="list-style-type: none">– General drawings and descriptions– Elaboration of lists for tenders– Detailed drawings and timetables for the erection	i.e., an engineering office in contact with: <ul style="list-style-type: none">– equipment manufacturer
System erection including supervision	<ul style="list-style-type: none">– Quality of installation– Documentation– Possibly, revision of detailed drawings	System installer and lightning protection expert or engineering office or supervising institution
Approval	Checking and documentation of the state of the system	Lightning protection expert or supervising institution
Recurrent inspection	Ensuring the adequacy of the system	Lightning protection expert or supervising institution

Table II.2

Structure characteristics and surroundings	Installation characteristics	Equipment characteristics
<ul style="list-style-type: none"> – Masonry, bricks, wood, reinforced concrete, steel frame structures? – One single integrated structure or interconnected blocks with expansion joints? – Flat and low or high-rise structures? – Are reinforced bars electrically connected throughout the structure? – Metal façades electrically connected or not? – Window sizes? – Frames of the windows electrically bonded or not? – Roof material metallic or not? – Structure equipped with an external LPS? – Type and quality of this LPS? – Nature of ground (rock, soil)? – Adjacent structures (height, distance) earth termination? 	<ul style="list-style-type: none"> – Incoming services (underground or overhead)? – Aerials (antennas or other external apparatus)? – Type of power supply (HV, LV, overhead or underground)? – Configuration TN, TT or IT? – Location of the electronics? – Cable routing (number and location of risers, ducts)? – Use of metal trays? – Are the electronics self-contained within the structure? – Metallic conductors to other structures? 	<ul style="list-style-type: none"> – Multiple interconnections of protective safety earth with signal earth of the electronics? – Type of information technology equipment links (screened or unshielded multicore cables, coax cable, analogue and/or digital, symmetrical and/or asymmetrical, fibre optic data lines)? – Are the immunity levels of the equipment specified?

Bibliography

- [b-CCITT/SG V TD 5] CCITT/SG V TD 5 (1989), *Report on IEC TC 81 activity on protection against LEMP*, May.
- [b-CCITT/SG V TD 25] CCITT/SG V TD 25 (1992), *Report on IEC TC 81 activity on protection against LEMP*, March.
- [b-CCITT/SG V COM-V-26] CCITT/SG V COM-V-26 (1986), *Simulation of overvoltages in telecommunication building caused by lightning*, January.
- [b-Arzur] Arzur, Blech, Zeddarn, Gabillet: *Protection for switching systems: lightning, power grid, EMC, LEMP and related phenomena*, *Intelec 93*, pp. 193-199.
- [b-Battini] Battini, Bessi Chiti, Pompon, *LEMP effects on equipment in telecommunication centres*.
- [b-COM 5-3] COM 5-3, *Protection against LEMP for equipment within existing structures*, Source: Switzerland, December 1993.
- [b-Computational Electromagnetics] Computational Electromagnetics; *Frequency-domain method of moments*, *IEEE Press*, 1992.
- [b-Kuramoto] Kuramoto, Sato, Ohta (1991), *Surge current and voltage distribution in a reinforced concrete building caused by direct lightning stroke*, *IEEE Symp. on EMC*, pp. 84-89.
- [b-Montandon1] Montandon (1995), *Lightning simulation technique on a building*, *Rapporteurs Group meeting WP 3/5*, September.
- [b-Montandon2] Montandon, Beyeler (1994), *Lightning induced voltages on electrical installations on a Swiss PTT instrumented tower in St. Chrischona*, Switzerland, *Proceedings 22nd ICLP*, Report R 4-11, Budapest.
- [b-Motorola] Motorola: *Grounding guideline for cellular Radio Installations*.
- [b-Söderlund] SÖDERLUND, *Earthing of telecommunications lines and installations in subscriber's networks as a protective measure against lightning damages*, *CENELEC BTTF 69-4*.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	Tariff and accounting principles and international telecommunication/ICT economic and policy issues
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Environment and ICTs, climate change, e-waste, energy efficiency; construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling, and associated measurements and tests
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities
Series Z	Languages and general software aspects for telecommunication systems