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ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

K.40

(10/96)

SERIES K: PROTECTION AGAINST INTERFERENCE

Protection against LEMP in telecommunications centres

ITU-T Recommendation K.40

(Previously CCITT Recommendation)

ITU-T K-SERIES RECOMMENDATIONS

PROTECTION AGAINST INTERFERENCE

For further details, please refer to ITU-T List of Recommendations.

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The 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 Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation K.40 was prepared by ITU-T Study Group 5 (1993-1996) and was approved by the WTSC (Geneva, 9-18 October 1996).

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NOTES

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

2. The status of annexes and appendices attached to the Series K Recommendations should be interpreted as follows:

- an *annex* to a Recommendation forms an integral part of the Recommendation;
- an *appendix* to a Recommendation does not form part of the Recommendation and only provides some complementary explanation or information specific to that Recommendation.

CONTENTS

SUMMARY

Guidelines for the design of an effective protective system for a telecom structure against LEMP are proposed. The concept of lightning protection zones is introduced as a framework where the specific protective measures are merged: earthing, bonding, cable routing and shielding. Information about simulating the LEMP effects and a shopping-list for the protective measures in existing and new buildings are also given.

PROTECTION AGAINST LEMP IN TELECOMMUNICATIONS CENTRES

(Geneva, 1996)

1 Introduction

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

The installation engineering guidelines that this Recommendation lays down are based on the following standards, produced by IEC TC 81: "Protection of structures against lightning, Part 1 – General principles" (IEC 1024-1) and "Protection against lightning electromagnetic impulse, Part 1 – General principles" (IEC 1312-1).

The basic principles for protecting a structure against LEMP: earthing, shielding and bonding can be found in Recommendations K.27 and K.35. If after applying those principles to a structure, the result of the risk assessment as stated in Recommendation K.39 is that additional protective measures should be taken, this Recommendation gives advice on these special measures. A telecom site with antennas at the top or nearby a telecom site having more risk of damage by a direct lightning stroke, special attention has been paid herewith to these structures.

2 Scope and purpose

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

3 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; all 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.

[1] IEC 1024-1-1:1993, *Protection of structures against lightning, Part 1: General principles – Section 1: Guide A – Selection of protection levels for lightning protection systems.*

[2] IEC 1312-1:1995, *Protection against lightning electromagnetic impulse, Part 1: General principles.*

[3] IEC 1312-4:1995, *Application guide for protection against LEMP.*

[4] ITU-T Recommendation K.27 (1996), *Bonding configurations and earthing inside a telecommunication building.*

[5] ITU-T Recommendation K.35 (1996), *Bonding configurations and earthing at remote electronic sites.*

[6] ITU-T Recommendation K.39 (1996), *Risk assessment of damages to telecommunication sites due to lightning discharges.*

[7] ITU-T Lightning Handbook (1978), *The protection of telecommunication lines and equipment against lightning discharges.*

4 Definitions

All terms and definitions already defined in the standard IEC 1024-1 are applicable also for this Recommendation. The following additional terms and definitions apply as well.

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

4.2 **CBN**: The Common Bonding Network is the principal means for effecting bonding and earthing inside a telecommunications building. It is the set of metallic components that are intentionally or incidentally interconnected to form the principal BN (Bonding Network) in a building. These components include: structural steel or reinforcing rods, metallic plumbing, a.c. power conduit, PE (protective conductor), cable racks and bonding conductors. The CBN always has a mesh topology and is connected to the earthing network (for further information, refer to Recommendation K.27).

4.3 **MCBN**: The Minimum Common Bonding Network against LEMP configuration required for protection against LEMP at a telecom 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 Recommendation K.39.

4.4 **LPS**: Lightning Protection System.

4.5 **LPZ**: Lightning Protection Zone.

4.6 **surge protection device (SPD)**: A device that is intended to limit transient overvoltages and divert surge currents. It contains at least one non-linear component.

5 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 stroke 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 SPDs installed at the telecom cables entrance, the LEMP disturbance is then propagated through the core of the telecom cable and may cause damages to the cable when the isolating breakdown voltage between shield and core is surpassed, not only in the telecom cables but in 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.

6 Need for protection

In order to estimate the need of protection of a given structure against LEMP, Recommendation K.39 should be used to evaluate the risk due to direct stroke 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} ($R > R_{accept}$), the protective measures suggested herewith should be considered to attain an acceptable risk level.

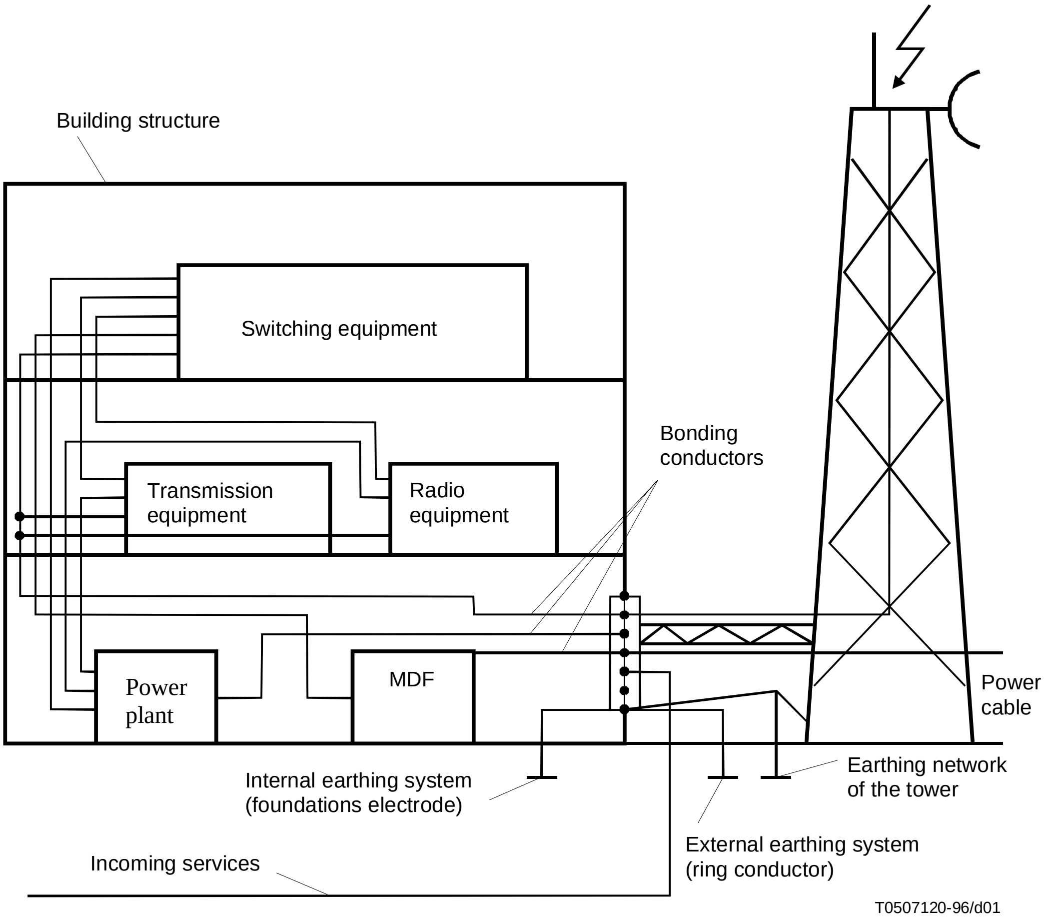


Figure 1/K.40 – Example of reference configuration

7 Protective measure

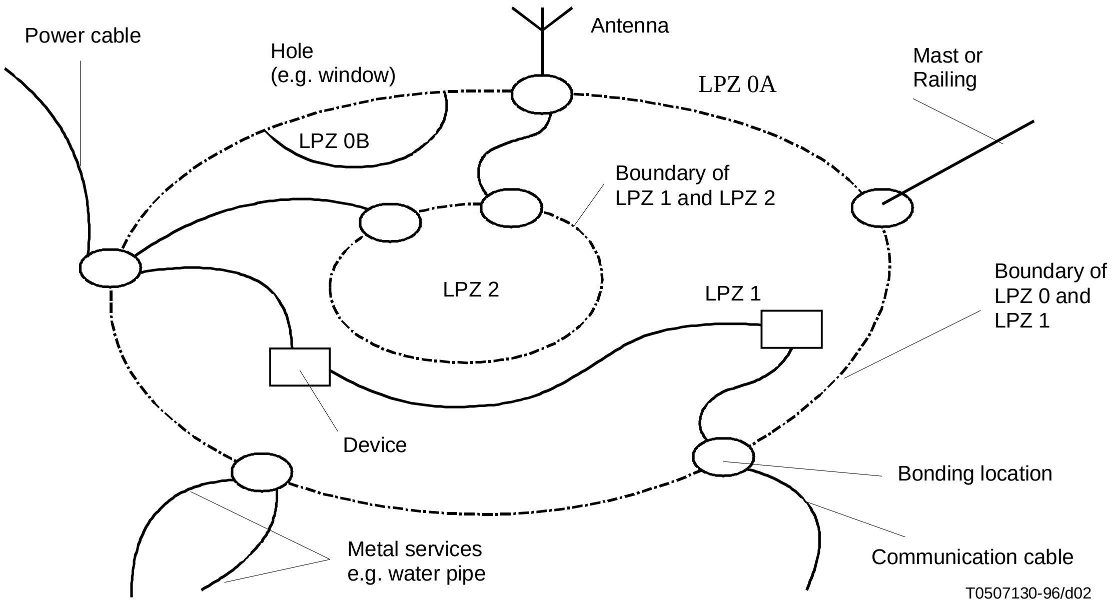
In the following subclauses, protective measures are proposed to achieve protection against LEMP considering the resistibility of equipment interfaces with internal cabling.

7.1 General principles: Lightning Protection Zones (LPZs)

It is advantageous to divide the telecom 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.

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 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.



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 telecom 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 requirement for those zones should be selected according to the protection requirement of the system to be protected.

Figure 2/K.40 – Different LPZs of a structure to be protected

Figure 3 shows an example of the several zones in which a telecom 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.

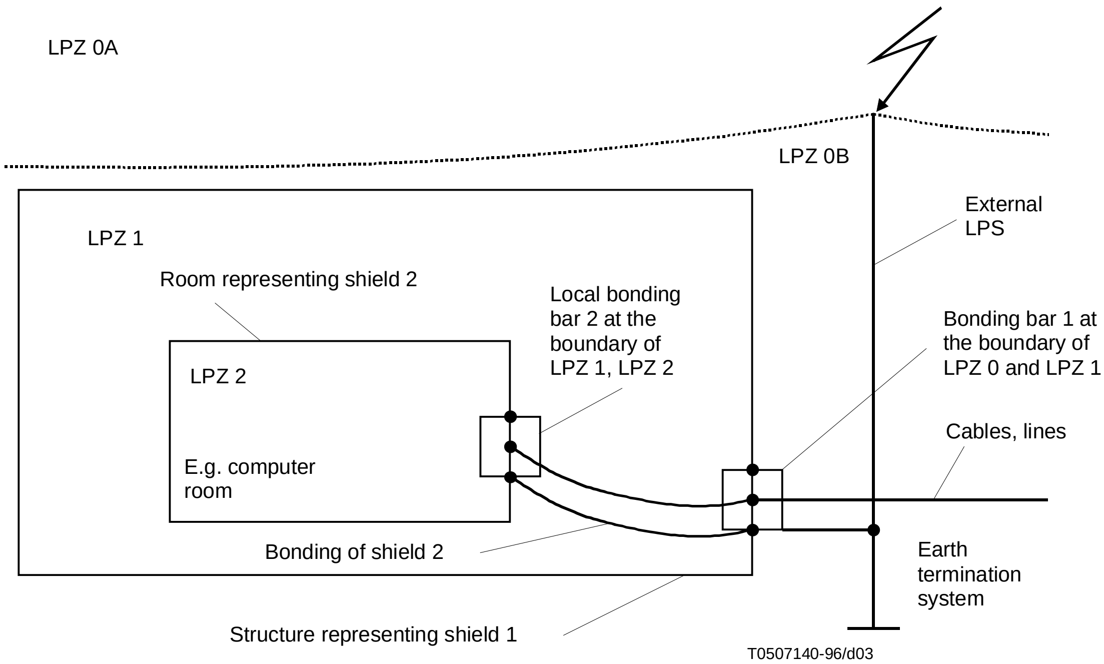


Figure 3/K.40 – Example of LPZs at a telecom centre

7.2 Earthing

The general ring earth electrode for the earthing of a telecom centre is given in Recommendations K.27 and 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.

7.3 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 stroke. 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 LPZ. Bonding at bonding bars is performed by means of bonding conductors and clamps, and where necessary by Surge Protection Devices (SPDs).

The MCBN is defined as follows:

– at each floor of the telecom centre, a ring conductor along the inside perimeter of the building. Details for the recommended practice for the ring conductor may be found in Recommendations K.27 and K.35;

– 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, connection of the ring conductor to the ring earth electrode.

Figure 5 illustrates the MCBN.

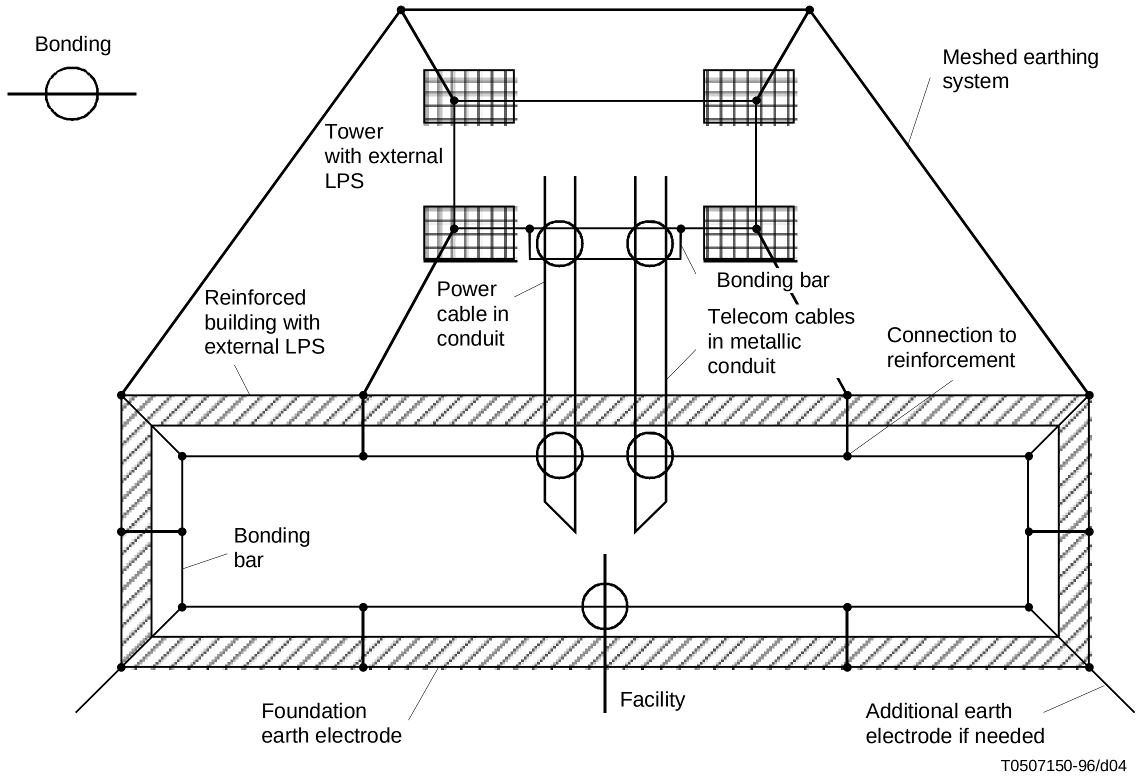


Figure 4/K.40 – Example of meshed earthing

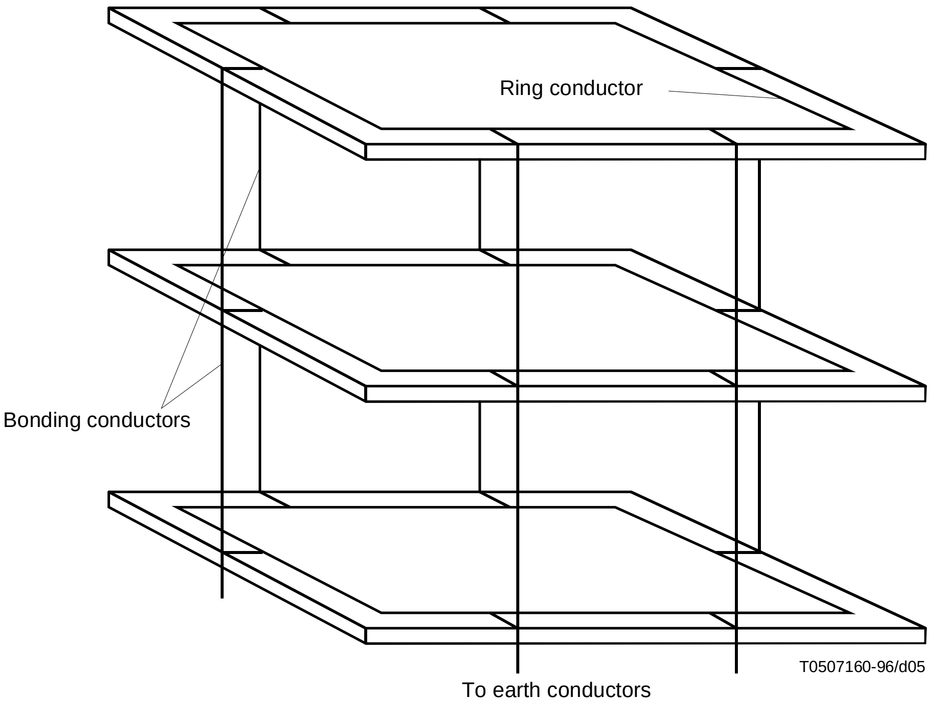


Figure 5/K.40 – Minimum common bonding network MCBN

7.4 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.

8 Additional protective measures

8.1 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.

8.2 Shielding

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

8.2.1 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 LPS, i.e. metal skin roofs and facades, metal reinforcement of the concrete and metal frames of doors and windows.

With regard to telecom 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 of steel that have excellent shielding qualities and where all the metallic parts shall be utilized as reference for the installation.

8.2.2 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: in one side the signal conductors are placed, in 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.

Appendix I

Simulation of LEMP effects – Test setup

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 stroke in a telecom centre, a test surge current as defined in IEC 1024-2, 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: $\beta \geq 45°$ 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.

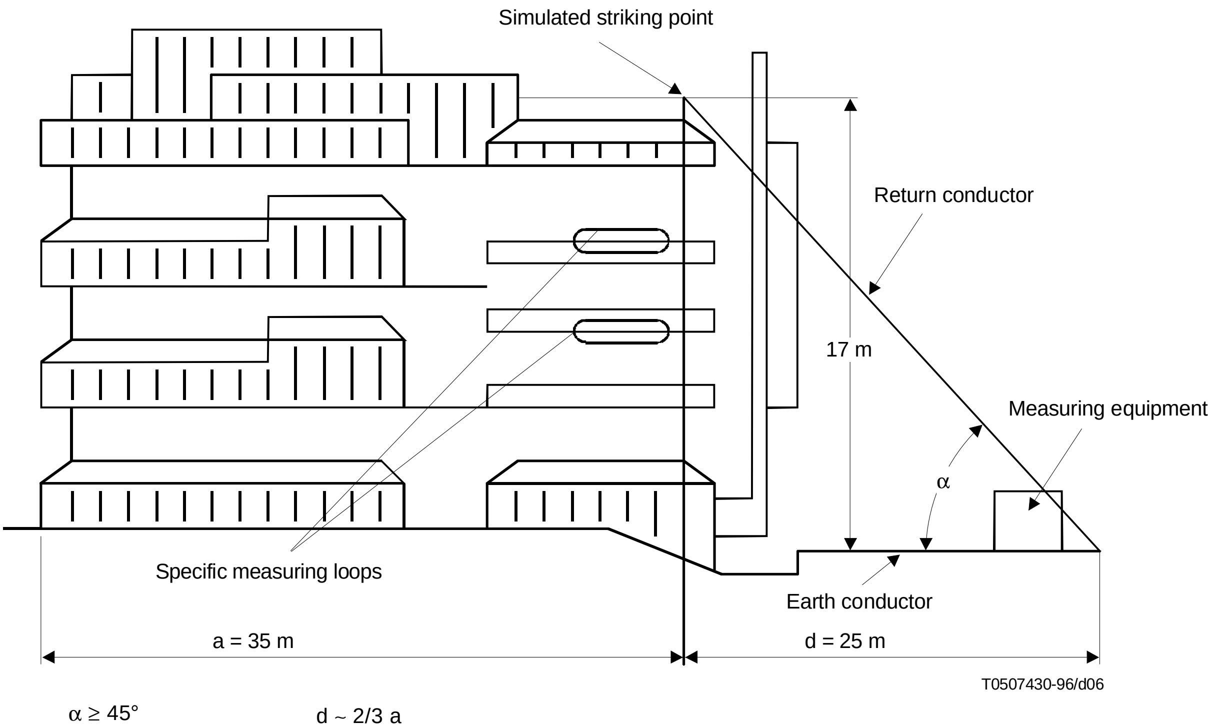


Figure I.1/K.40 – Test setup

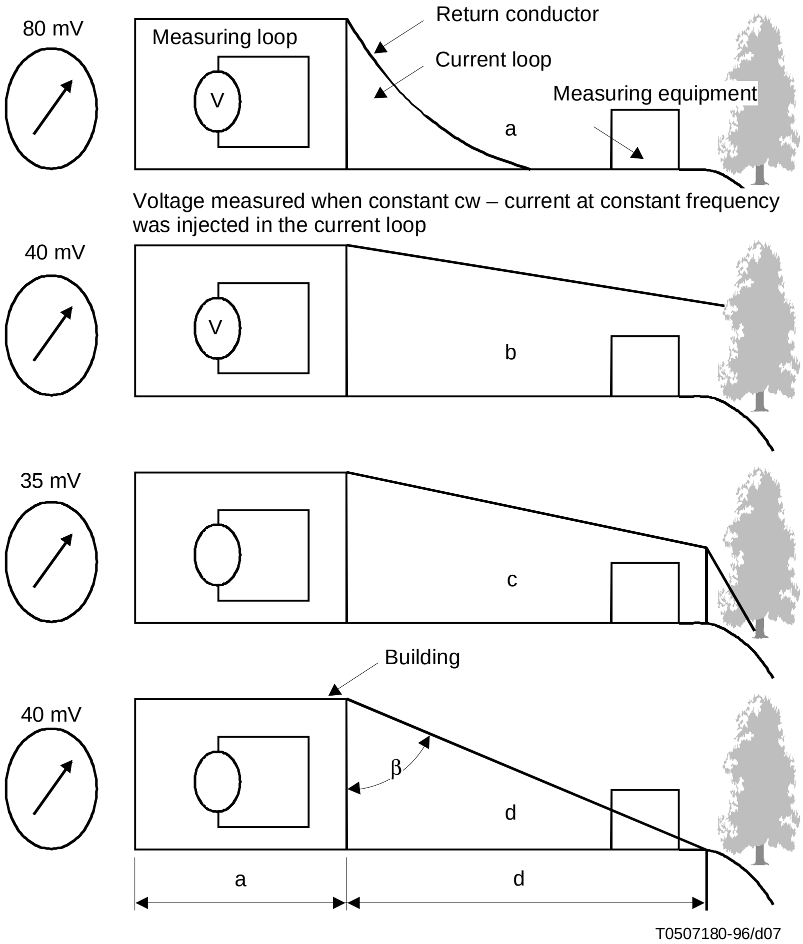


Figure I.2/K.40 – Influence of the position of the return conductor to the measured voltage

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 and 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:

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

In some cases, especially in newly erected buildings before telecom equipments are 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 to apply 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. 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 stroke effect, the Method of Moments (MOMs) may be used. It is basically 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 telecom centre, as well as the radiated field inside the building due to the lightning stroke. 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 telecom centre.

Numerical simulations and tests were conducted to study the behaviour of telecom centres when struck by LEMP; for analysis purposes the current may be defined as (IEC 1024-2):

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

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

II.1 New telecommunications centres

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

II.2 Existing telecommunications 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 Recommendation K.39 “Risk assessment of damages to telecommunication sites due to lightning discharges”.

Table II.1/K.40

Step	Aim	Executive
System planning	Elaboration of an integral protection concept with definition of: – 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: – the owner – the architect – the planners of relevant installations – the subcontractors – equipment manufacturer
System design	– General drawings and descriptions – Elaboration of lists for tenders – Detailed drawings and timetables for the erection	i.e. an engineering office in contact with: – equipment manufacturer
System erection including supervision	– 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/K.40

Structures characteristics and surroundings	Installation characteristics	Equipment characteristics
– 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?	– 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?	– Multiple interconnections of protective safety earth with signal earth of the electronics? – Type of information technology equipment links (screened or unscreened multicore cables, coax cable, analogue and/or digital, symmetrical and/or asymmetrical, fibre optic data lines)? – Are the immunity levels of the equipment specified?

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