International Telecommunication Union

# ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

# K.47

(04/2008)

SERIES K: PROTECTION AGAINST INTERFERENCE

---

# Protection of telecommunication lines using metallic conductors against direct lightning discharges

Recommendation ITU-T K.47

## Recommendation ITU-T K.47

# Protection of telecommunication lines using metallic conductors against direct lightning discharges


### Summary

Recommendation ITU-T K.47 specifies a procedure for the protection of telecommunication lines using metallic conductors against direct lightning discharges to the line itself or to structures that the line enters. The protection procedure is related to the exposure of the line to direct lightning discharges and includes the selection of cable characteristics/installation, bonding/earthing of the cable shield, use of shield wires, lightning protective cable, steel tube, lightning protective cable duct, installation of surge protective devices (SPDs) and route redundancy.

Examples of application of this Recommendation are reported in Appendix III.



### Source

Recommendation ITU-T K.47 was approved on 13 April 2008 by ITU-T Study Group 5 (2005-2008) under Recommendation ITU-T A.8 procedure.



### Keywords

Direct lightning, failure current, protection, risk, risk assessment, sheath breakdown current, test current.

## 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/.

## CONTENTS

# Recommendation ITU-T K.47

## Protection of telecommunication lines using metallic conductors against direct lightning discharges

### 1 Scope

The scope of this Recommendation is the protection of telecommunication lines using metallic conductors against direct lightning discharges to the line itself or to the structures that the line enters. When applying this Recommendation, the user shall follow the risk management procedure, as described in [ITU-T K.72].

This Recommendation provides a procedure in order to evaluate the expected risk of damage ($R_d$) due to direct lightning discharges. If this value is higher than the tolerable risk of damages ($R_T$), then additional protection measures shall be applied in the telecommunication line in order to reduce $R_d$.

In accordance with the risk management procedure [ITU-T K.72], the difference between the tolerable risk and the expected risk of damage due to direct flashes ($R_T - R_d$) constitutes the tolerable risk for the expected risk of damage due to flashes near a telecommunication line. The latter is evaluated following the procedure reported in [ITU-T K.46]. Lines made from the following types of cables are covered by this Recommendation:

– symmetric cable: Cable with a metallic sheath and a core made of one or many metallic symmetric copper pairs, with or without a plastic covering and/or a supporting wire;

– coaxial cable: Cable with metallic inner and outer conductors separated by a dielectric, with or without a plastic covering and/or a supporting wire.

The protection need of line equipment (such as multiplexers, power amplifiers, optical network units) and line termination equipment is not considered by this Recommendation and it should be evaluated using the risk assessment applied to the structure where the equipment is located (i.e., exchange, customer's building or remote site). The protection procedures for lines made of optical fibre cables are given in [ITU-T K.25].

### 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.12] Recommendation ITU-T K.12 (2006), *Characteristics of gas discharge tubes for the protection of telecommunication installations*.

[ITU-T K.25] Recommendation ITU-T K.25 (2000), *Protection of optical fibre cables*.

[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.72] Recommendation ITU-T K.72 (2008), *Protection of telecommunication lines using metallic conductors against lightning – Risk Management*.

[IEC 62305-2] IEC 62305-2 (2006), *Protection against lightning – Part 2: Risk management*. <http://webstore.ch/webstore/webstore.nsF/artnum/035440>

## 3 Definitions

Definitions given in [ITU-T K.72] and [ITU-T K.46] apply.

This Recommendation defines the following terms:

**3.1 breakdown voltage ($U_b$)**: Impulse breakdown voltage between metallic components in the core and the metallic sheath of a telecommunication cable.

**3.2 damage correction factor ($K_d$)**: Factor which allows a conservative evaluation of the frequency of damage.

**3.3 expected loss per damage (L)**: Relative amount of expected service loss per damage caused by direct lightning discharge to a telecommunication line.

**3.4 expected risk of damages ($R_d$)**: Expected annual loss of service to the telecommunication line due to direct lightning discharges.

**3.5 failure current ($I_a$)**: Minimum peak value of the lightning current that causes damage in a telecommunication line.

**3.6 frequency of damage ($F_d$)**: Average annual number of service interruptions in a telecommunication line caused by direct lightning discharges.

**3.7 keraunic level ($T_d$)**: Number of days per year in which thunder is heard in a given location.

**3.8 lightning protective cable**: Special cable with increased dielectric strength, whose metallic sheath is in continuous contact with the soil either directly or by the use of conducting plastic covering.

**3.9 lightning protective cable duct**: Cable duct of low resistivity in contact with the soil (for example, concrete with interconnected structural steel reinforcements or a metallic duct).

**3.10 number of dangerous events due to flashes to a structure ($N_D$)**: Expected average annual number of dangerous events due to lightning flashes to a structure.

**3.11 number of dangerous events due to flashes to a telecommunication line ($N_L$)**: Expected average annual number of dangerous events due to lightning flashes to a service.

**3.12 protection factor ($K_p$)**: Factor taking into account the effect of protection procedures.

**3.13 sheath breakdown current ($I_s$)**: Minimum current flowing in the metallic sheath which causes breakdown voltages between metallic elements in the cable core and the metallic sheath, thus leading to damage.

**3.14 shielded cable**: Group of one or more pairs of twisted wires balanced with respect to earth, assembled together and covered by a continuous metallic sheath.

**3.15 shielding wire**: Metallic wire used to reduce physical damage due to lightning flashes to a service.

**3.16 striking distance (D)**: Distance from the line that, when multiplied by 2, by the line length (L) and the ground flash density ($N_g$) gives the number of lightning strokes per year that reaches the line.

**3.17 test current ($I_t$)**: Minimum current injected by arc in the cable sheath that causes a primary failure due to thermal or mechanical effects.

**3.18 tolerable risk of damages ($R_T$)**: Maximum level of risk of damages not requiring additional protective measures.

**3.19 unshielded cable**: Group of one or more pairs of twisted wires balanced with respect to earth and assembled together without a metallic sheath.

## 4 Reference configuration

In order to evaluate the risk of damage ($R_d$) for a line, it may have to be segmented in such a way that each section has the same characteristics regarding:

– type of cable installation (aerial, buried);

– keraunic level;

– average soil resistivity;

– type of cable;

– type of environment (urban, suburban, rural).

It is also important to identify the structures that the line or its branches enter. The value of $R_d$ has to be evaluated for each section, and the value for the line is the sum of section values, including the values corresponding to discharges to the structures that the line enters. Figure 1 shows an example of a line with different types of cable installation.

The risk of damage shall be evaluated for all transmission media of a cable (twisted pair or coaxial), regardless of whether they are being used for a service or kept as spare.

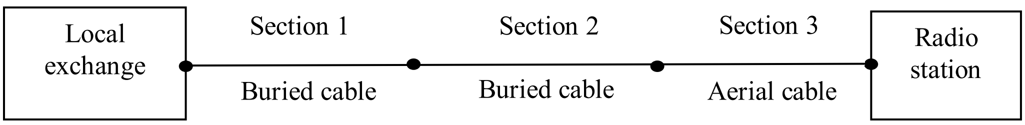


**Figure 1 – Reference configuration (example)**

## 5 Expected risk of damage

### 5.1 General

Each risk component, as described in [IEC 62305-2], may be calculated by the following general equation:

$$R_X = N_X \times P_X \times L_X \quad (1)$$

where:

$N_X$ is the number of dangerous events (ground flashes within the collection area);

$P_X$ is the probability of damage to a service, taking into account protection measures;

$L_X$ is the consequent loss.

The product between the number of dangerous events ($N_X$) and the probability of damage ($P_X$) is the frequency of damage ($F_X$). Then the risk can be also expressed by the following equation:

$$R_X = F_X \times L_X \quad (2)$$

The procedures for lightning protection of a telecommunication line depend on the expected risk of damages ($R_d$) and its tolerable risk of damages ($R_T$). The expected risk of damages ($R_d$) is given by the following equation:

$$R_d = R'_V + R'_B = F'_{Va} \times L_a + F'_{Vb} \times L_b + F'_B \times L_s \qquad (3)$$

where:

- $F'_{Va}$ is the frequency of damage due to direct lightning discharges to aerial cables;
- $F'_{Vb}$ is the frequency of damage due to direct lightning discharges to buried cables;
- $F'_B$ is the frequency of damage due to direct lightning discharges to structures that the cable enters;
- $L_a$ is the expected loss per damage due to direct lightning discharges to aerial cables;
- $L_b$ is the expected loss per damage due to direct lightning discharges to buried cables;
- $L_s$ is the expected loss per damage due to direct lightning discharges to structures that the cable enters.

The values of $L_a$, $L_b$ and $L_s$ shall be determined by the network operator or the owner of the installation. Some representative values are proposed in Appendix II.

It is the responsibility of the authority having jurisdiction to identify the value of tolerable risk. The maximum value of tolerable risk of damage ($R_T$) requested by this Recommendation is $R_T = 10^{-3}$(i.e., the representative value given in Table 1 of [ITU-T K.72]).

If the expected risk of damage is higher than the tolerable risk of damage ($R_d > R_T$), then additional protective measures are necessary in order to reduce $F_d$. A procedure for the evaluation of $F_d$ is presented in the following clauses.

### 5.2 Frequency of damage to cables

The frequency of damage for aerial and buried cables ($F'_{Va}$ and $F'_{Vb}$) can be calculated by the following equations:

$$F'_{Va} = 2N_g \times [L - 3(H_a + H_b)] \times D \times p(I_a) \times C_d \times 10^{-6} \text{ [damages/year]} \qquad (4)$$

$$F'_{Vb} = 2N_g \times [L - 3(H_a + H_b)] \times D \times p(I_a) \times C_d \times K_d \times 10^{-6} \text{ [damages/year]} \qquad (5)$$

where:

- $L$ is the line length [m];
- $H_a$ is the height of the structure connected at the end "a" of the line;
- $H_b$ is the height of the structure connected at the end "b" of the line;
- $p(I_a)$ is the current probability factor (see clause 5.4.2);
- $C_d$ is the location factor (see clause 5.4.4);
- $N_g$ is the lightning ground flash density [$km^{-2}.year^{-1}$] (see clause 5.4.1);
- $D$ is the striking distance [m] (see clause 5.4.3);
- $I_a$ is the failure current [kA] (see clause 6);
- $K_d = 2.5$ is the damage correction factor (see [ITU-T K.25]).

### 5.3 Frequency of damage to structures that the cable enters

The lightning current of a direct stroke to a structure flows into the grounding system of the structure and into the metallic services entering the structure. Therefore, a part of the lightning current enters the cable connection and the cable sheath of the telecommunication cable. This current can cause damage to the telecommunication cable. This frequency of damages ($F'_B$) can be estimated by using the following equation:

$$F_B^{'} = N_g \times A_d \times p(I_a) \times C_d \quad (6)$$

where:

$A_d$ is the collection area for direct lightning strikes to the structure.

For isolated structures on flat ground, the collection area $A_d$ is the area defined by the intersection between the ground surface and a straight line with 1/3 slope which passes from the upper parts of the structure (touching it there) and rotating around it. Determination of the value of $A_d$ may be performed graphically or mathematically.

For an isolated rectangular structure on flat ground, the collection area $A_d$ can be calculated by equation 7:

$$A_d = (a.b + 6h.a + 6h.b + 9\pi\ h^2)10^{-6}\ [km^2] \quad (7)$$

a = length [m]

b = width [m]

h = height [m]

### 5.4 Parameters for the evaluation of the frequency of damage

#### 5.4.1 Lightning ground flash density ($N_g$)

Lightning ground flash density ($N_g$) is the average number of lightning discharges to ground per square kilometre per year. In some countries, the $N_g$ is directly measured by means of lightning detection systems so that this information is available with relative accuracy. In a case where there are no data on $N_g$, it can be estimated by the following equation:

$$N_g = 0.04 \times T_d^{1.25}\ [\text{km}^{-2}.\text{year}^{-1}] \quad (8a)$$

or

$$N_g = 0.1 \times T_d\ \ [\text{km}^{-2}.\text{year}^{-1}] \quad (8b)$$

In equation 8, $T_d$ is the keraunic level. Values of $T_d$ are usually available in the form of isokeraunic maps.

#### 5.4.2 Current probability factor (p(i))

The current probability factor is the cumulative probability distribution of lightning (p(i)), as given approximately by equation 9:

$$p(i) = 10^{-2} e^{(a-bi)} \qquad \text{for } i \geq 0 \quad (9)$$

where:

i lightning peak current [kA]

a = 4.605 and b = 0.0117 for i ≤ 20 kA

a = 5.063 and b = 0.0346 for i > 20 kA

### 5.4.3 Effective striking distance (D)

a) **Buried cable**

The striking distance for buried cables is calculated as a function of earth resistivity, as follows:

$$D = 0.482(\rho)^{1/2} \qquad \text{for } \rho \leq 100\ \Omega.m \qquad (10)$$

$$D = 2.91 + 0.191(\rho)^{1/2} \qquad \text{for } 100\ \Omega.m < \rho < 1000\,\Omega.m$$

$$D = 0.283(\rho)^{1/2} \qquad \text{for } \rho \geq 1000\ \Omega.m$$

b) **Aerial cables**

For aerial cables, the striking distance is given by the following equation:

$$D = 3H\,[m] \qquad (11)$$

where:

H line height [m], which shall be between 4 m and 15 m.

### 5.4.4 Location factor

The following location factor values can be defined:

$C_d$ = 0.25 for an aerial line or structure surrounded by structures of greater height (power lines, trees, etc.);

$C_d$ = 0.50 for aerial line or structure surrounded by smaller or same height structures;

$C_d$ = 1 for isolated aerial line or structure (no other objects in the vicinity);

$C_d$ = 2.0 for a line or structure on a hilltop or a knoll.

## 6 Determination of failure current ($I_a$)

### 6.1 Lightning discharges to cables

For unshielded cables, the failure current is considered to be zero as long as every direct lightning discharge to the cable will produce damage. For shielded cables, the failure current ($I_a$) is the lower value among the following values:

– the test current ($I_t$);

– twice the sheath breakdown current ($I_s$), evaluated with the procedure given in Annex A.

For typical buried telecommunication cables with lead or aluminium sheath and steel armouring, the value of the test current is 40 kA, while for typical aerial telecommunication cables with aluminium sheath, this value is 20 kA. If there is any evidence that these values are not applicable for a given cable design, the tests described in Appendix I shall be used for the evaluation of the test current ($I_t$).

### 6.2 Lightning discharges to structures where the cable enters

The direct lightning current to the structure causing damage to the telecommunication line entering the structure, i.e. the failure current $I_a$, is evaluated under the following hypothesis:

– 50% of the lightning current flows into the earthing system of the structure;

– the remaining 50% of the current is shared between the *n* services entering the structure (telecommunications, electrical power, water);

– the whole current in the telecommunication line flows into the sheath of a shielded cable or is shared between the *m* conductors of the unshielded line.

For strikes to structures where the cable enters, the failure current ($I_a$) is given by:

a) Shielded cable

$$I_a = 2 \times n \times I_s \qquad (12)$$

b) Unshielded cable

$$I_a = 2 \times n \times m \times I_c \qquad (13)$$

where:

$I_s$ is the sheath breakdown current evaluated with the procedure given in Annex A;

$I_c$ is the current allowed to flow into each conductor:

– for unshielded cables without SPDs, $I_c = 0$;

– for unshielded cables with SPDs:

$$I_c = 8 \times S_c \quad \text{[kA]} \qquad (14)$$

where $S_c$ is the cross-section area of the conductor in square millimetres.

NOTE – The SPD shall withstand the lightning current flowing through it (see [ITU-T K.12]).

## 7 Protection procedures

### 7.1 General principle

The metallic elements of the telecommunication cable shall be continuous along the length of the line, which means that they shall be connected across all splices, regenerators, etc. The metallic elements shall be bonded (either directly or through an SPD) to the equipotential bonding bar at the ends of the cable.

While evaluating the frequency of damage ($F_d$), it is important to identify the line segments that are more representative of the value of $F_d$ and concentrate the protection efforts on them. The use of protective procedures reduces the frequency of damage by the protection factor ($K_p$), as follows:

$$F'_d = F_d \cdot K_p \qquad (15)$$

where:

$F'_d$ is the frequency of damage after the application of the protective procedure;

$F_d$ is the frequency of damage before the application of the protective procedure.

Many protective procedures will reduce the frequency of damage by increasing the failure current. In this case, the protection factor is given by:

$$K_p = \exp[b_1(I_a - I'_a)] \quad \text{for } I_a \text{ and } I'_a \le 20\,kA \qquad (16)$$

$$K_p = \exp[b_2(I_a - I'_a)] \quad \text{for } I_a \text{ and } I'_a > 20\,kA$$

$$K_p = \exp[(a_2 - a_1) + (b_1 I_a - b_2 I'_a)] \quad \text{for } I_a \le 20\,kA \text{ and } I'_a > 20\,kA$$

where:

$I'_a$ is the failure current after the application of the protective procedure;

$I_a$ is the failure current before the application of the protective procedure;

$a_1$ = 4.605;

$a_2$ = 5.063;

$b_1$ = 0.0117;

$b_2$ = 0.0346.

### 7.2 Protective measures against flashes to lines

a) For buried lines, the following protective measures may be considered:

1) Shield wire(s), generally consisting of a galvanized steel wire with a diameter of 8 mm. Other materials or diameters are also possible, for example, for corrosion protection problems.
2) Lightning protective cable.
3) Steel tube(s), generally consisting of galvanized steel. Interruptions at cable collars to be kept as short as possible; the interruptions should be bridged by a close metal jacket or at least three shield wires by a cage arrangement, each offset by 120°.
4) Lightning protection cable duct.

b) For aerial lines, the following protective measures may be considered:

1) Use of a supporting wire, as shielding wire (see clause 7.6.2).
2) Substitute all or part of the aerial cable with a buried one (see clause 7.4) and use the protective means indicated in a) above.

c) For both buried and aerial lines, the following protective measures may be considered:

1) Substitute the aerial or buried cable with a non-metallic transmission system, for example, metal-free optical cable or radio link (see clause 7.3.1).
2) Use of cable with high sheath breakdown current (see clause 7.3.2).
3) Use of cable with high sheath breakdown voltage (see clause 7.3.3).

### 7.3 Choice of the cable

#### 7.3.1 Dielectric optical fibre cable

A dielectric optical fibre cable is not directly struck by lightning. Therefore, its use provides a protection factor $K_p = 0$.

#### 7.3.2 Cable with high sheath breakdown current

If the failure current ($I_a$) is determined by the sheath breakdown current ($I_s$), it is possible to obtain a cable with a higher $I_s$ by:

– increasing the sheath breakdown voltage, for example, by selecting plastic insulation instead of paper or improving the insulation at the splices;

– reducing the sheath resistance, for example, by using a thicker metallic sheath.

For protection against direct lightning discharges to the telecommunication line, the sheath breakdown current shall not be increased above the test current.

The protection factor due to the increase in the failure current is given by equation 16.

### 7.3.3 Cable with high sheath breakdown voltage

If the failure current ($I_a$) is determined by the test current ($I_t$), it is possible to obtain a cable with a higher $I_t$ by:

– using a sheath with high mechanical strength (for example, iron);

– using a thicker metallic sheath.

For protection against direct lightning discharges to the telecommunication line, the test current shall not be increased above the sheath breakdown current.

The protection factor due to the increase in the failure current is given by equation 16.

## 7.4 Buried or aerial installation

Aerial cables are more exposed to lightning discharges than buried cables. For soil resistivity between 100 and 1000 Ω.m and a line height of 5-6 metres, an aerial line will receive between 3 and 1.7 times more lightning discharges than a buried one. However, the value of the failure current for a buried installation may be higher or lower than the value for an aerial installation, depending on the cable characteristics. It shall also be considered that damage to buried cables take more time to repair than in aerial cables, which means that the relative amount of loss per damage may offset a reduction in the expected frequency of damage due to burying the cable. Therefore, the decision to bury the cable in order to protect it against direct lightning discharges has to take into account the specific characteristics of the cable. This can be done by calculating and comparing the risk of damage ($R_d$) for aerial and buried installation, using the procedures of this Recommendation.

## 7.5 Use of surge protective devices (SPDs)

Surge protective devices (SPDs) can be installed at the point where the cable enters a structure exposed to direct lightning discharges in order to reduce the frequency of damage ($F'_B$). The SPD shall comply with [ITU-T K.12] and be connected between the conductors of the cable and the equipotential bonding bar (EBB) of the structure. If the cable is shielded, its shield shall be bonded to the EBB.

The installation of an SPD as described in this clause will increase the sheath breakdown current (see Annex A).

The protection factor due to the increase in $I_s$ is given by equations 13 and 16.

## 7.6 Shielding wire and lightning protective cable or metal conduit

### 7.6.1 Protection length

The length $L_p$ of the lightning protective cable, metal conduit, reinforced cable ducts or shielding wires connected to the equipotential bonding bar (EBB), shall be equal to or greater than the effective length of a horizontal earth electrode given by the following approximated equation:

$$L_p \geq 2.5 \times \sqrt{\rho} \qquad \text{[m]} \qquad (17)$$

where ρ is the soil resistivity, in ohm metres (Ω·m).

If the part of the network with enhanced protection $L_r$ is shorter, its protection factors value $K'_p$ can be evaluated with equation 18:

$$K'_p = K_p \times L_p / L_r \qquad (18)$$

In any case, the protective measure shall have a minimum length of 50% of the value calculated by equation 17.

### 7.6.2 Shield wire

In order to limit the current entering the cable sheath, it is possible to install shield wires in parallel with the cable so that the current is shared among the cable and the shield wires. The shield wires increase the value of the failure current ($I_a$) and, therefore, reduce the frequency of damage. The new value of failure current ($I'_a$) is given by:

$$I'_a = \frac{I_a}{\eta} \tag{19}$$

Where $\eta$ is the shielding factor. The protection factor ($K_p$) obtained by the use of shield wires is given by equations 19 and 16.

Values of shielding factors for different arrangements of shield wires are given in [ITU-T K.25] and summarized in Table 1.

**Table 1 – Typical values of shielding factors for shield wire**

| Number of shielding wires | Shielding factor (η) |
|---|---|
| 1 | 0.6 |
| 2 | 0.4 |
| 3 | 0.3 |

For properly installed shield wire(s) (see [b-ITU-T Lightning]), approximated values for the protection factor are reported in Table 2.

**Table 2 – Values of the factor $K_p$ as a function of the protection measures**

| Protection measure | $K_p$ |
|---|---|
| No protection measures | 1 |
| One shielding wire (Note) | 0.6 |
| Two shielding wires (Note) | 0.35 |
| Three shielding wires (Note) | 0.2 |
| Lightning protective cable duct | 0.1 |
| Lightning protective cable | 0.02 |
| Placing the cable inside a steel tube | 0.01 |
| NOTE – The shielding wire is installed about 30 cm above the cable; two shielding wires are located 30 cm above the cable symmetrically disposed in respect of the axis of the cable (see [b-ITU-T Lightning]). | |

Where the supporting wire of aerial cables is used as shield wire, it shall be connected:

– to ground approximately at every 200 m with an electrode whose minimum length is:
  - $l_1$ = 5 m for radial horizontal electrode; or
  - $l_1$ = 2.4 m for vertical (inclined) electrode;

– to the metallic shield of the cable at both ends of the shielded section.

NOTE – The tie-rods/stay wire of the supporting wire can be considered as a natural connecting conductor to earth of the supporting wire.

### 7.6.3 Lightning protective cable or metal conduit

The cross-section area, *S*, of the metallic shield (the lightning protective cable, the steel tube or the lightning protection cable duct) which is in contact with the soil shall be greater than that calculated by equation 20 (in agreement with Annex B of [IEC 62305-3]):

$$S_{\min} = \left(L_p \times \rho_c \times I_s\right) / U_b \qquad (20)$$

where:

- $S_{min}$ is in square millimetres ($mm^2$);
- $I_s$ is in kiloamperes (kA);
- $\rho_c$ is the resistivity, in ohm·square millimetres per metre ($\Omega \cdot mm^2/m$), of the shield material in contact with the soil of the protective measure;
- $U_b$ is the breakdown voltage, in kilovolts (kV), of the plastic covering of the cable;
- $L_p$ is the length, in metres (m), of the protective measure.

For bends (for example, entrances into buildings), the rigid steel conduit can be replaced by flexible metal conduits connected by welding or flanges.

Examples of protection measures for telecommunication line entering an exposed building are reported in Figure 2.

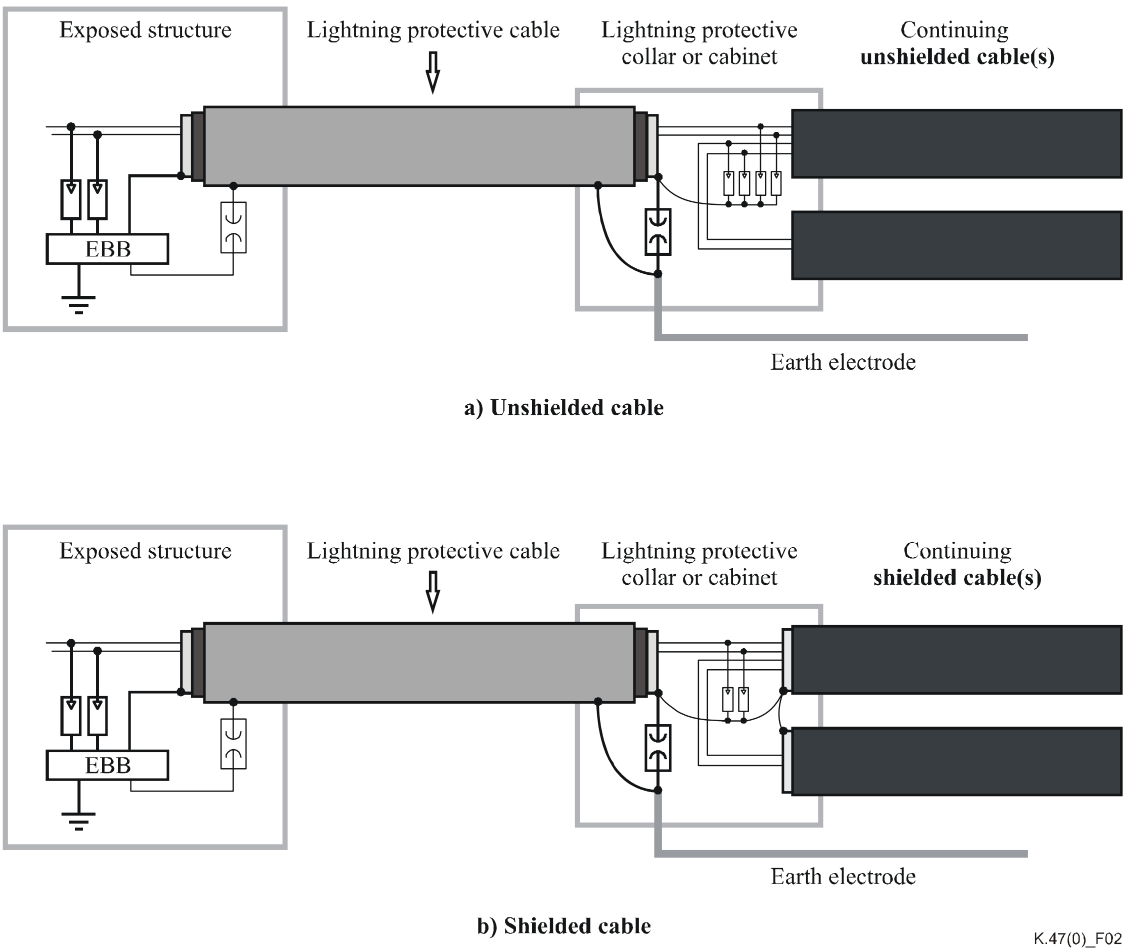


**Figure 2 – Examples of protection measures for telecommunication line entering an exposed building**

The values of the protection factor for the different protection measures are reported in Table 2.

### 7.7 Route redundancy

In order to improve system reliability, one possibility is to install two lines so that the probability of both being subjected to primary failures simultaneously is very small. By adequately selecting the separation between the lines, it is possible to prevent the same lightning discharge from damaging both lines. A minimum separation of 30 m and 50 m for soil resistivity 100 Ω.m and 1000 Ω.m, respectively, is sufficient for buried cables or aerial cables. If the lines are separated so that the probability of a given lightning discharge reaching both lines is negligible, it is still possible to have damage to both lines during a short time interval, so that the maintenance crew is not able to repair the first line that failed before the second fails. This situation may occur during the same thunderstorm and will determine the frequency of damage for the redundant routes.

# Annex A

## Evaluation of the sheath breakdown current

(This annex forms an integral part of this Recommendation)

The procedure of this annex applies to cables with one metallic sheath. For typical telecommunication cables, the following values of breakdown voltage are considered:

– cables with paper insulation: $U_b = 1.5$ kV;

– cables with plastic insulation: $U_b = 5$ kV.

If there is any evidence that these values are not applicable for a given cable design, the tests described in Appendix I shall be used for the evaluation of the breakdown voltage.

### A.1 Buried cable

The sheath breakdown current ($I_s$) of cable with a metallic sheath, with or without an insulating protective covering, may be estimated with the following equation:

$$I_s = \frac{U_b}{K \cdot R \cdot \rho^{1/2}} \qquad [kA] \tag{A.1}$$

where:

- K = 8 is the waveshape factor for lightning current $[(m/\Omega)^{0.5}]$);
- R is the sheath resistance per unit length [Ω/km] (for cable with sheath and armouring, R is given by the parallel between the sheath and the armouring resistance values per unit length);
- $U_b$ is the breakdown voltage of the cable [V];
- ρ is the soil resistivity [Ω.m].

### A.2 Aerial cable

The sheath breakdown current ($I_s$) is calculated using equation A.2:

$$I_s = \frac{U_b}{K \cdot R \cdot \rho_e^{1/2}} \tag{A.2}$$

$\rho_e$ is the effective earth resistivity in Ω.m, which is defined as:

$$\rho_e = \frac{\pi \cdot d \cdot R_g}{\ln\left(2 \cdot \frac{H}{a}\right)} \tag{A.3}$$

where:

- d is the spacing between earthing points, in metres (d is assumed to be short, so that reflections occur long before the crest voltage or current is reached);
- H is the height of the cable in metres;
- a is the radius of the cable in metres;
- $R_g$ is the resistance of the earthing points in Ω.

NOTE – In general $\rho_e$ value is high and $I_s$ value is around a few kA. Therefore, $p(I_a) = 1$ can be assumed for aerial cable. The presence of a metallic supporting wire can reduce this $p(I_a)$ value to 0.95.

### A.3 Buried or aerial cable with SPDs between conductors and the shield for direct flashes to the structure where the cable is entering

When SPDs are installed at the entrance of the cable into a structure, the failure current due to direct flashes to the structure should be evaluated with the following procedure:

– calculate the breakdown sheath current, $I_s$, using equation A.1 or A.2;

– calculate the total current, $I_f$, entering the shield and the *m* conductors:

$$I_f = I_s \times \frac{m \times R_s + R_c}{R_c} \tag{A.4}$$

– calculate the current entering the conductor, $I_c$, which causes damage to the cable, with equation 12;

– calculate the total current, $I'_f$, entering the shield and the m conductors:

$$I'_f = I_c \times \frac{m \times R_s + R_c}{R_c} \tag{A.5}$$

– if $I_f$ is lower than $I'_f$, using this $I_f$ value, the failure current, $I_a$, is estimated with the following equation:

$$I_a = 2 \times n \times I_f \tag{A.6}$$

– if $I'_f$ is lower than $I_f$, using this $I'_f$ value, the failure current, $I_a$, is estimated with the following equation:

$$I_a = 2 \times n \times I'_f \tag{A.7}$$

# Appendix I

## Tests for the evaluation of surge resistibility of cables

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

It shall be observed that these tests are intended to evaluate the lightning resistibility of metallic cables and are not applicable for the qualification of a cable design. Under the cable manufacturer's responsibility, the test results on one type of cable can be used for another cable with similar characteristics from the construction point of view.

The breakdown voltage test shall be performed with an impulse generator that produces an open circuit voltage with a double exponential 1.2/50 µs waveform. The current generator for the test for surge current resistibility of cables is under study. The following current waveforms, measured with the test sample in place, are suggested:

– double exponential waveform with a rise time of 10 µs and a time to half value of 350 µs;
– damped oscillatory waveform with a maximum time-to-peak value of 15 µs and a maximum frequency of 30 kHz; the time to half value of its waveform envelope shall be between 40 µs and 70 µs.

### I.1 Breakdown voltage ($U_b$)

A cable sample 5 metres in length shall be used for the test. The conducting components inside the cable core shall be electrically connected together to form one terminal. Another terminal is made by the metallic sheath isolated from the other conducting elements. The sheath termination shall be treated in order to reproduce, as closely as possible, the conditions of a real installation. A surge voltage generator shall be placed between the two terminals. The test voltage is measured during the test. Following the application of voltages in ascending amplitudes, the test identifies a threshold value of surge voltage ($U_b$) which causes a breakdown.

### I.2 Test current ($I_t$) for buried cable

A cable sample of 1 m in length shall be immersed in wet sand contained in a non-conducting rigid box having a minimum length of 0.75 m in all inside linear dimensions. The box shall have two holes in the bottom for water drainage, approximately 25 mm in diameter. The sand shall be 20-40 mesh silica sand, and shall be fully saturated for a maximum time interval of 8 hours and drained for at least five minutes before tests. The cable sample shall be placed in the test box and the wet sand tamped around it. The moisture content of the sand in the more critical sand volume shall be 15% by weight. A discharge electrode shall be located near the centre of the test box, at a distance of 26 ± 1 mm from the sample. All conducting components at the cable end shall be electrically connected together to form one terminal and a current generator shall be placed between this terminal and the discharge electrode. In order to let the test current flow through the sample, any insulation covering the outer metallic sheath shall be opened with a small slit or hole with a 1 mm diameter tool facing the discharge electrode. If the voltage of the test generator cannot break down the air-gap, a thin wire shall connect the discharge electrode with the metallic sheath. Following the application of discharge currents in ascending amplitudes, the sample is tested for continuity of the metallic elements and insulation resistance between them. The test identifies a threshold value of surge current which causes primary failure. This value is the test current ($I_t$).

### I.3 Test current ($I_t$) for aerial cable

A cable sample 1 metre in length shall be in tension according to the manufacturer's specifications. A discharge electrode shall be located near the sample at a distance of 26 ± 1 mm. All conducting components in the cable shall be electrically connected together to form one terminal and a current generator shall be placed between this terminal and the discharge electrode. In order to let the test current flow through the sample, any insulation covering the outer metallic sheath shall be opened with a small slit or hole with a 1 mm diameter tool facing the discharge electrode. If the voltage of the test generator cannot break down the air-gap, a thin wire shall connect the discharge electrode with the metallic sheath. Following the application of discharge currents in ascending amplitudes, the sample is tested for continuity of the metallic elements and insulation resistance between them. The test identifies a threshold value of surge current which causes damage. This value is the test current ($I_t$).

# Appendix II

## Expected loss per damage (*L*)

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

The damage caused by lightning to a telecommunication installation may produce unacceptable loss of service. In this case, the decision whether or not to provide protective measures should be taken by a comparison of the expected risk of damages ($R_d$) of the installation with the value of the tolerable risk of damages ($R_T$). The value of $R_d$ is calculated by equation 1, based on the relative amount of the expected loss per damage.

The values of the expected loss per damage *L* can be determined in terms of relative amount of possible loss from the approximate relationship:

$$L = \frac{n_p \times t}{n_t \times 8760} \qquad \text{(II.1)}$$

where:

$n_p$ is the mean number of users not served;

$n_t$ is the total number of users served;

$t$ is the annual period of loss of service (in hours).

The following values of expected loss per damage, for use when the determination of $n_p$, $n_t$ and t is uncertain or difficult, are proposed:

$L_a = 2\times10^{-3}$ (due to direct lightning to aerial lines)

$L_b = 3\times10^{-3}$ (due to direct lightning to buried lines)

$L_s = 2\times10^{-3}$ (due to direct lightning to structure)

# Appendix III

## Examples of application

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

### III.1 Telecommunication line with shielded and unshielded sections in suburban environment

Consider a subscriber line located in an old suburban area, where the land is occupied by houses.

The line is connected at one end to the exchange building where there are n = 10 entering services and at the other end at the customer's building where there are only n = 2 entering services. The buildings are surrounded by structures with the same height; the location factor, according to clause 5.4.4, is $C_d = 0.5$. Using equation 7, the collection area $A_d$ of each structure is calculated and shown in Table III.1 together with the building dimensions.

**Table III.1 – Building characteristics connected at both ends of the line**

| Building | L [m] | W [m] | H [m] | $C_d$ | n | $A_d$ [m$^2$] |
|---|---|---|---|---|---|---|
| Exchange | 20 | 30 | 10 | 0.5 | 10 | 6430 |
| Customer | 10 | 10 | 6 | 0.5 | 2 | 1840 |

The keraunic level of the region is 60 thunderstorm days per year ($T_d = 60$, $N_g = 6$ flashes/km$^2$×y) and the average earth resistivity is 500 Ωm. The line fits into the configuration E/PC/D/S (see Figure 1 of [ITU-T K.46]). The characteristics of the sections are tabulated in Table III.2.

**Table III.2 – Characteristics of the line**

| Section | Insulation | Sheath material | Sheath thickness | Number of pairs | Conductor diameter | Length [m] | Installation |
|---|---|---|---|---|---|---|---|
| E/PC | Paper | Lead | 2 mm | 1200 | 0.40 | 3200 | Buried |
| PC/D | Plastic | Aluminium | 0.2 mm | 100 | 0.40 | 500 | Aerial |
| D/S | Plastic | No sheath | – | 1 | 0.80 | 140 | Aerial |

The sheath resistance per unit length ($r$) can be obtained from Appendix II of [ITU-T K.46], based on the sheath material, thickness, conductor diameter and number of pairs. For the sections E/PC and PC/D, Appendix II of [ITU-T K.46] gives $r = 0.54$ Ω/km and $r = 2.0$ Ω/km, respectively. The buried cable is protected by an armouring (2 iron tapes: thickness 0.8 mm) with $r_a = 0.37$ Ω/km ($\rho_{fe} = 130$ Ωmm$^2$/km). The equivalent resistance of this buried cable is $r_e = 0.22$ Ω/km.

The next step is to assess the risk due to direct flashes as the sum of the risk components due to direct flashes to the structures and the risk components due to direct flashes to the telecommunication line. The calculated values are shown in Table III.3.

Assuming $R_T = 10^{-3}$, $R_d$ is less than $R_T$, then no protection measures against direct flashes are necessary.

The $R_d$ value shall be used by [ITU-T K.46] for determining the protection need against the risk of loss of service due to flashes near the telecommunication line.

**Table III.3 – Risk due to direct flashes $R_d$**

| Risk components ($10^{-3}$) | | | | | |
|---|---|---|---|---|---|
| | | **Section 1** | **Section 2** | **Section 3** | **Line** |
| Lightning direct to the structure (S1) | $N_{de}$ | 0.0193 | – | – | |
| | $N_{ds}$ | – | – | 0.0055 | |
| | $I_a$ [kA] | 760 | – | 0 | |
| | $p(I_a)$ | 0.001 | – | 1 | |
| | $\boldsymbol{R'_B}$ | 0.000039 | – | 0.011 | **0.01106** |
| Lightning direct to the line (S2) | $N'_L$ | 0.3447 | 0.0540 | 0.0151 | |
| | $I_a$ | 40.0 | 5 | 0.0 | |
| | $p(I_a)$ | 0.4 | 0.95 | 1 | |
| | $\boldsymbol{R'_V}$ | 0.41362 | 0.1026 | 0.0302 | **0.5464** |
| S1 + S2 | $\boldsymbol{R_d}$ | | | | **0.558** |

## III.2 Telecommunication line with only shielded sections in suburban environment

Consider a subscriber line located in a new suburban area, where about half of the land is occupied by houses. The line is connected at one end to a multiplex where there are n = 3 entering services and at the other end at the customer's building where there are only n = 2 entering services. The multiplex shelter and the customer's building are surrounded by structures with greater and same height, respectively; the location factors ($C_d$), according to clause 5.4.4, are 0.25 and 0.5, respectively. Using equation 7, the collection area $A_d$ of each structure is calculated and shown in Table III.4 together with the building dimensions.

**Table III.4 – Building characteristics connected at both ends of the line**

| Structure | L [m] | W [m] | H [m] | $C_d$ | n | $A_d$ [$m^2$] |
|---|---|---|---|---|---|---|
| Remote site | 1 | 1 | 2 | 0.25 | 3 | 140 |
| Customer's building | 10 | 20 | 10 | 0.5 | 2 | 4480 |

The keraunic level of the region is 50 thunderstorm days per year ($T_d = 50$, $N_g = 5$ flashes/$km^2 \times y$) and the average earth resistivity is 400 Ωm. The line fits into the configuration R/V/S (see Figure 1 of [ITU-T K.46]). The characteristics of the sections are tabulated in Table III.5.

**Table III.5 – Characteristics of the line**

| Section | Insulation | Sheath material | Sheath thickness | Number of pairs | Conductor diameter | Length [m] | Installation |
|---|---|---|---|---|---|---|---|
| R/V | Plastic | Aluminium | 0.2 mm | 100 | 0.40 | 2000 | Aerial |
| V/S | Plastic | Aluminium | 0.2 mm | 10 | 0.40 | 250 | Aerial |

The sheath resistance per unit length ($r$) can be obtained from Appendix II of [ITU-T K.46], based on the sheath material, thickness, conductor diameter and number of pairs. For the sections R/V and V/S, Appendix II of [ITU-T K.46] gives $r = 2.0$ Ω/km and $r = 5.2$ Ω/km, respectively.

The next step is to assess the risk due to direct flashes as the sum of the risk components due to direct flashes to the structures and the risk components due to direct flashes to the telecommunication line. The calculated values are shown in Table III.6.

**Table III.6 – Risk due to direct flashes $R_d$**

| Risk components ($10^{-3}$) | | | | |
|---|---|---|---|---|
| | | **Section 1** | **Section 3** | **Line** |
| Lightning direct to the structure (S1) | $N_{de}$ | 0.0002 | | |
| | $N_{ds}$ | | 0.0112 | |
| | $I_a$ [kA] | 104 | 12 | |
| | $p(I_a)$ | 0.05 | 0.9 | |
| | $R'_B$ | 0.000017 | 0.0201 | **0.0202** |
| Lightning direct to the line (S2) | $N'_L$ | 0.18 | 0.0225 | |
| | $I_a$ | 5 | 5 | |
| | $p(I_a)$ | 0.95 | 0.95 | |
| | $R'_V$ | 0.341 | 0.0427 | **0.384** |
| S1 + S2 | $R_d$ | | | **0.40** |

Assuming $R_T = 10^{-3}$, $R_d$ is less than $R_T$, then no protection measures against direct flashes are necessary.

The $R_d$ value shall be used by [ITU-T K.46] for determining the protection need against the risk of loss of service due to flashes near the telecommunication line.

### III.3 Telecommunication line with shielded and unshielded sections in rural environment

Consider a subscriber line located in a rural area. The line is connected at one end to the exchange building where there are n = 3 entering services and at the other end at the customer's building where there are only n = 2 entering services. The buildings are isolated; the location factor ($C_d$), according to 5.4.4, is 1. Using equation 7, the collection area $A_d$ of each structure is calculated and shown in Table III.7 together with the building dimensions.

**Table III.7 – Building characteristics connected at both ends of the line**

| Structure | L [m] | W [m] | H [m] | $C_d$ | n | $A_d$ [m$^2$] |
|---|---|---|---|---|---|---|
| Exchange building | 6 | 10 | 6 | 1 | 3 | 1650 |
| Customer's building | 10 | 15 | 6 | 1 | 2 | 2070 |

The keraunic level of the region is 50 thunderstorm days per year ($T_d = 50$, $N_g = 5$ flashes/km$^2$×y) and the average earth resistivity is 600 Ωm. The line fits into the configuration E/PC/D/S (see Figure 1 of [ITU-T K.46]). The characteristics of the sections are tabulated in Table III.8.

**Table III.8 – Characteristics of the line**

| Section | Insulation | Sheath material | Sheath thickness | Number of pairs | Conductor diameter | Length | Installation |
|---|---|---|---|---|---|---|---|
| E/P | Paper | Lead | 2 mm | 400 | 0.40 | 1500 m | Buried |
| P/CD | Plastic | Aluminium | 0.2 mm | 50 | 0.40 | 2400 m | Buried |
| CD/S | Plastic | No sheath | – | 2 | 0.80 | 400 m | Aerial |

The sheath resistance per unit length ($r$) can be obtained from Appendix II of [ITU-T K.46], based on the sheath material, thickness, conductor diameter and number of pairs. For the sections E/P and

P/CD, Appendix II of [ITU-T K.46] gives $r$ = 1.1 Ω/km and $r$ = 2.9 Ω/km respectively. The buried cable is protected by an armouring (2 iron tapes: thickness 0.5 mm) with $r_a$ = 1.7 Ω/km ($\rho_{fe}$ = 130 Ωmm$^2$/Km). The equivalent resistances of these buried cables are $r_e$ = 0.67 Ω/km and $r_e$ = 1.1 Ω/km respectively.

The next step is to assess the risk due to direct flashes as the sum of the risk components due to direct flashes to the structures and the risk components due to direct flashes to the telecommunication line. The calculated values are shown in Table III.9.

Assuming $R_T = 10^{-3}$, $R_d$ is greater than $R_T$, then protection measures against direct flashes are necessary.

Installing one shielding wire above both the buried cables (protection factor η = 0.6), $R_d$ is reduced below the tolerable risk, as shown in Table III.9.

This $R_d$ value shall be used by [ITU-T K.46] for determining the protection need against the risk of loss of service due to flashes near the telecommunication line.

**Table III.9 – Risk due to direct flashes $R_d$**

| **Risk components ($10^{-3}$)** | | | | | |
|---|---|---|---|---|---|
| | | **Section 1** | **Section 2** | **Section 3** | **Line** |
| Lightning direct to the structure (S1) | $N_{de}$ | 0.0083 | | | |
| | $N_{ds}$ | | | 0.0103 | |
| | $I_a$ [kA] | 114 | | 0 | |
| | $p(I_a)$ | 0.05 | | 1 | |
| | $R'_B$ | 0.00083 | | 0.0207 | **0.0215** |
| Lightning direct to the line (S2) | $N'_L$ | 0.2846 | 0.4553 | 0.072 | |
| | $I_a$ | 23 | 40 | 0.0 | |
| | $p(I_a)$ | 0.8 | 0.4 | 1 | |
| | $R'_V$ | 0.683 | 0.5464 | 0.1440 | **1.373** |
| S1 +S2 | $R_d$ | | | | **1.39** |
| **Protection measure** | | **1 shielding wire above buried cable sections** | | | |
| Lightning direct to the line (S2) | $I_a$ [kA] | 40 | 77 | 0 | |
| | $p(I_a)$ | 0.4 | 0.1 | 1 | |
| | $R'_V$ | 0.3415 | 0.1366 | 0.1440 | **0.6221** |
| | $R_d$ | | | | **0.6436** |

# Bibliography

[b-ITU-T Lightning] ITU-T Handbook (1995), *The Protection of Telecommunication Lines and Equipment Against Discharges*.

## SERIES OF ITU-T RECOMMENDATIONS

| | |
|---|---|
| Series A | Organization of the work of ITU-T |
| Series D | General tariff principles |
| 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 | 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 |
| 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 and next-generation networks |
| Series Z | Languages and general software aspects for telecommunication systems |

Printed in Switzerland
Geneva, 2009