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SERIES K: PROTECTION AGAINST INTERFERENCE

**Resistibility of subscriber's terminal to
overvoltages and overcurrents**

ITU-T Recommendation K.21

(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.21 was revised by ITU-T Study Group 5 (1993-1996) and was approved by the WTSC (Geneva, 9-18 October, 1996).

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 follows:
 - an *annexe* to a Recommendation forms an integral part of the Recommendation;
 - an *appendice* to a Recommendation does not form part of the Recommendation and only complementary explanation or information specific to that Recommendation.

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SUMMARY

This Recommendation seeks to establish fundamental testing methods and criteria for the resistibility of telecommunication equipment connected to local subscribers' lines to overvoltages and overcurrents.

This Recommendation describes tests that should be applied to equipment which is metallically connected directly to balanced pairs.

This Recommendation concentrates on a series of tests made principally at the telecommunication line and mains input terminals.

Aspects of overvoltages or overcurrents covered by this Recommendation include surges due to lightning on or near the line plant, short-term induction of alternating voltages from adjacent power lines or railway systems, direct contacts between telecommunication lines and power lines and electrostatic discharges.

INTRODUCTION

This Recommendation has been produced by Study Group 5 to meet the requirements of Administrations and manufacturers who are using or designing subscriber's equipment. The attention of the reader is drawn to the following further subjects:

- bonding configurations and earthing; rise of earth potential, see Recommendation K.31;
- electrostatic discharges, see Recommendation K.32;
- electrical fast transients and radio frequency phenomena, see Recommendation K.34.

Recommendation K.21

RESISTIBILITY OF SUBSCRIBER'S TERMINAL TO OVERVOLTAGES AND OVERCURRENTS

(Melbourne, 1988; revised in 1995, 1996)

1 Purpose of this Recommendation

When modern telecommunications equipment is connected to local subscribers' lines, the equipment may be damaged as a result of overvoltages or overcurrents which occur on these lines under occasional conditions. The probability and magnitude of these conditions vary due to many factors, e.g. geography, climate, construction methods, shielding effects. Overvoltage or overcurrent surges arising from electrostatic discharges or transient surges which occur on mains-voltage power supplies may also damage equipment or cause its misoperation. This Recommendation seeks to establish fundamental testing methods which may be varied in detail to suit particular local circumstances and which help to predict the likelihood of survival when the equipment is exposed to these overvoltages or overcurrents.

In its present form, this Recommendation describes tests that should be applied to equipment which is metallicity connected directly to balanced pairs. Further studies relating to equipment connected to coaxial and optical fibre cables are being made.

This Recommendation assumes that Surge Protective Devices (SPD) are fitted externally to the equipment in exposed areas. Operators individually will decide their policies for protection. The guidance of Recommendations K.11 and K.39 should be followed when making this judgement and should take account of the routing of lines to the equipment, in addition to its location.

This Recommendation assumes that earthing and bonding configurations fulfil Recommendation K.31.

2 Scope

This Recommendation deals principally with desk-borne equipment. Recommendation K.20 deals with switching equipment powered by central-battery. For the more complex subscriber equipment, operators should use either Recommendation K.20 or K.21 as appropriate.

This Recommendation relates to type tests only. Recognizing the difficulty in testing a complex item of subscribers' equipment, this Recommendation concentrates on a series of tests made principally at the telecommunication line and mains input terminals. The tests should be applied at any chosen stage during the normal use of the equipment.

As the equipment may be used in either an exposed or unexposed environment, tests are made with and without line protectors fitted.

The tests for lightning surges assume that an electrical connection between the power system earth terminal and the telecommunications equipment earth can be effected.

The tests for power induction and power contact apply to longitudinal and transversal effects.

This Recommendation deals primarily with resistibility of equipment and although it may provide some level of safety, it is not sufficient by itself to fully protect the user. National standards for electrical safety should be followed in each country where the equipment is used.

3 Overvoltage and overcurrent conditions

Aspects of overvoltage or overcurrent by this Recommendation are:

- surges due to direct or indirect lightning strokes on or near the line plant;
- short-term induction from adjacent power lines or railway systems, usually when these lines or systems develop faults;

- direct contacts between telecommunication lines and power lines, usually of a low voltage nature;
- electrostatic discharges generated by users touching the equipment or adjacent plant;
- transient surges on mains-voltage power supplies to the equipment.

It is recognized that lightning surges generally influence all conductors of a subscriber line. Overvoltages or overcurrents may occur simultaneously on all the input pairs of the subscribers' terminal and produce large currents in common wiring or components. Such conditions are covered by the simultaneous lightning surge test under Table 1, No. 1c). This test is only applied to small private branch exchanges with analogue lines from the switching exchange.

4 Equipment boundary

Variations in equipment make it necessary for each unit to be seen as a "black box" having three or more terminals, A, B, etc. and E (earth). Some protective devices may have already been provided within the equipment, e.g. distributed on cards, or connected to internal terminals.

For the purposes of these tests, manufacturers are expected to define the boundaries of the "black box" and any protective device which is thereby included must be considered as an immutable part of the equipment. Where any auxiliary telecommunications wire is provided, e.g. to an extension, or as a signalling earth, these wires should be seen to extend the number of terminals to be tested, e.g. A, B, C, D, etc. and E (earth).

5 Test conditions

The following general conditions apply to all the tests specified in clauses 8, 9 and 10 except where otherwise stated.

5.1 All tests are type tests.

5.2 The input terminals at which tests on the equipment are to be applied should be identified by the manufacturer and labelled A, B, C, D, etc. and earth.

5.3 For the tests specified in clauses 8 and 10 only, the equipment should be enclosed in a foil shroud over those parts likely to have a human contact during use, and the foil connected to the E terminal.

5.4 The equipment should be tested in each operating mode of significant duration.

5.5 The equipment should be capable of passing the tests in clauses 8 and 10 within the ranges of temperature, relative humidity and air pressure of its intended use.

5.6 In all cases where a maximum voltage is specified, tests should also be made at lower voltages if this is necessary to confirm that the equipment will resist any voltage up to the maximum value specified.

5.7 Each test should be applied the number of times indicated in Table 1. The time interval between applications should be one minute and, in the case of pulse tests, the polarity should be reversed between consecutive pulses.

5.8 Power induction tests should be made at the frequency of the a.c. mains and electrified railway systems used in the country of application.

6 Coordination with primary protection

6.1 General

Some of the tests in Table 1 require the addition of primary protection. It is current practice to protect exposed subscribers' lines with some SPD such as gas discharge tubes. The best place for the insertion of the primary protection is the border of the building. The characteristics of the external SPD shall comply with the requirements of Recommendations K.12 and K.28 respectively. The same type should be used for the operation and for the test of the equipment.

A new set of protectors may be used after the completion of each test sequence.

6.2 Lightning surge simulation

The operation of the primary protection has two effects:

- It limits the maximum voltage applied to the equipment and hence, depending on the internal impedance of the equipment, the maximum current which the equipment must withstand.
- It produces a very rapid change in U and I which, by inductive or capacitive effects, can reach sensitive parts of the subscribers' equipment not apparently exposed to line voltages.

The coordination is achieved when the primary SPD is activated carrying out tests with U_c below 4 kV and the equipment complies with criterion A of this Recommendation when tested following the test procedure in 5.6.

If the primary protection is not activated, attention should be paid to the value of the currents that can flow in the cabling network. Large currents in the internal cabling network may disturb other equipment. Recommendation K.31 describes earthing and bonding inside a subscriber's building and treats coordination with electrical protection devices.

6.3 Power induction and power contact

The impedance to ground of both a and b inputs of subscribers' equipment is normally high. The input impedance between the a and b wires however can be low.

The voltage across the impedance to ground during the power induction test can activate the primary protection. As mentioned in Recommendation K.11, the SPD on the two wires of a pair may not operate simultaneously and so a transverse pulse may be produced. Under certain conditions, particularly if the equipment to be protected has a low impedance, operation of one SPD may prevent the operation of the other one and a transverse voltage may remain as long as the longitudinal voltages are on the line.

The input impedance of subscriber equipment can be low under several conditions:

- When the subscribers' equipment is in the off-hook state.
- When the secondary overvoltage protection between the a and b input of the subscribers' equipment is activated.

Therefore a transversal test for power induction and power contact is performed on subscribers' equipment.

7 Permitted malfunction or damage

Two levels of malfunction or damage are recognized:

- Criterion A – Equipment shall withstand the test without damage or other disturbance, e.g. corruption of software or misoperation of fault-protection facilities and shall operate properly within the specified limits after the test. It is not required to operate correctly during the test.
- Criterion B – A fire hazard should not arise in the equipment as a result of the tests. Any damage or permanent malfunction occurring should be confined to a small number of external line interface circuits.

8 Tests related to lightning surges, power induction and power contact

The test circuits used for the three overvoltage or overcurrent conditions are as follows:

- Figures 1 and 2: lightning surges;
- Figure 3: power induction;
- Figure 4: power contact.

The equipment should be tested according to Table 1.

Figure 1 shows the test circuit for lightning surges on a single port. Its open circuit voltage has a 10/700 μ s waveform.

Figure 2 shows the test circuit for the simultaneous surge test on all input pairs.

Decoupling elements (e.g. diodes) are necessary between surge generator and equipment under test to prevent a short-circuit of the input terminals of the equipment.

NOTE – The decoupling elements used in the tests shall be selected in such a way as to have a minimum influence on the waveform from the generator regarding the waveshape, voltage and current profiles.

The power induction test shall be carried out without and with primary protection.

The following test conditions are to be applied in the tests without primary protection (according to Figure 3 and Table 1, No. 2):

$$U_{a.c.(max)r.m.s.} = 600 \text{ V}, t = 200 \text{ ms}, R = 600 \Omega$$

The test conditions with primary protection cover in normal cases according to Figure 3 and Table 1, No. 2 the following values:

$$U_{a.c.(max)r.m.s.} = 600 \text{ V}, t = 1000 \text{ ms}, R = 600 \Omega$$

The normal test conditions with primary protection may be adapted to the local conditions by variation of the test parameters within the following limits, so that $I^2t = 1 \text{ A}^2\text{s}$ is fulfilled:

$$U \quad 300 \text{ V} \leq U_{a.c.(max)r.m.s.} \leq 600 \text{ V}$$

$$t \quad \leq 1000 \text{ ms}$$

R is to be adjusted after calculation I^2t (for the purpose of this calculation, the input resistance of the equipment under test is taken as 0)

I is the current flowing through each output terminal of the generator.

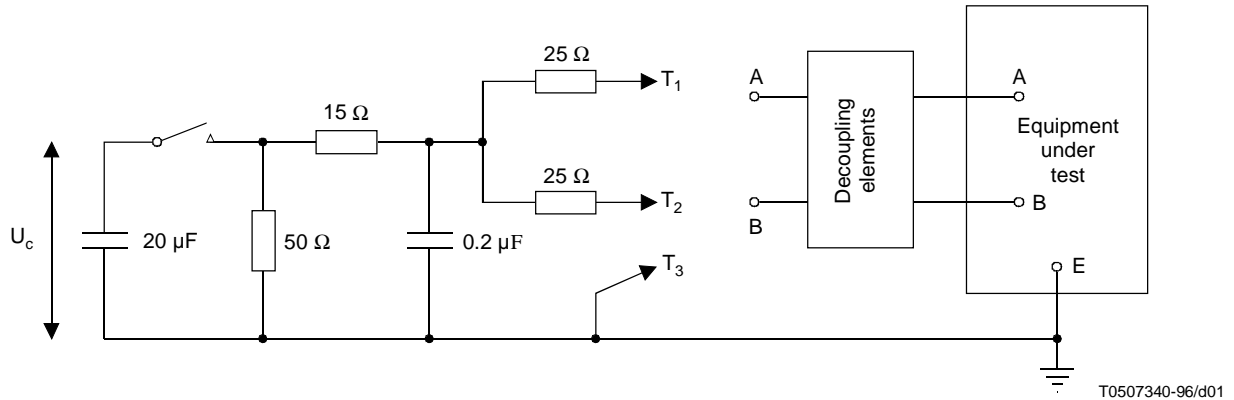


Figure 1/K.21 – Test circuit for lightning surges on a single input

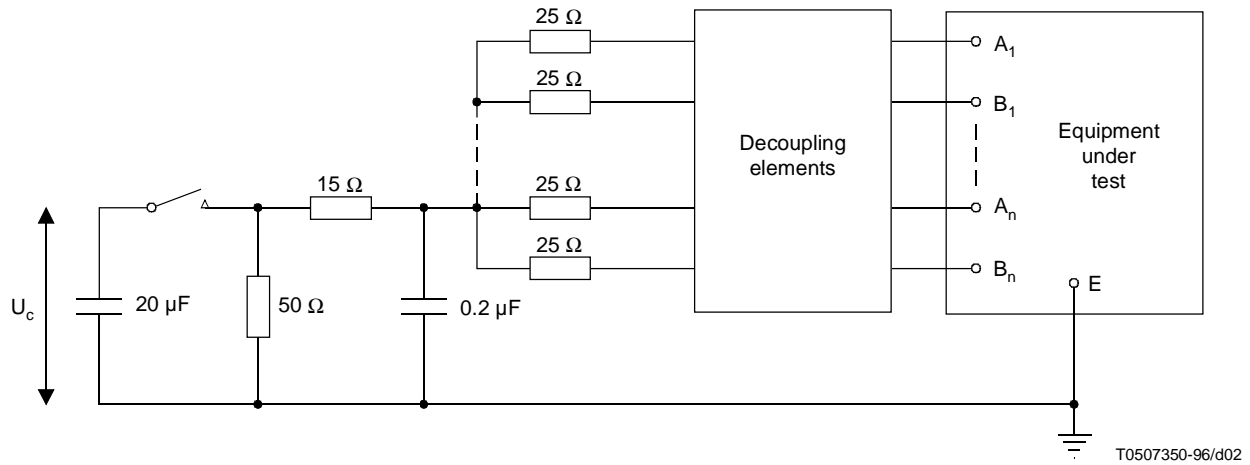


Figure 2/K.21 – Test circuit for simultaneous lightning surges on all inputs

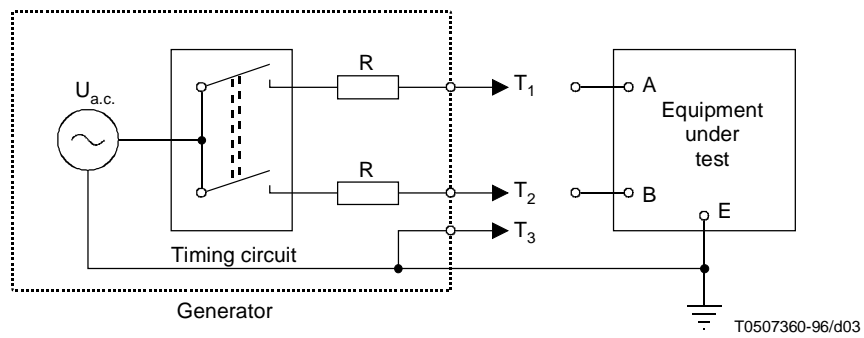


Figure 3/K.21 – Test circuit for power induction

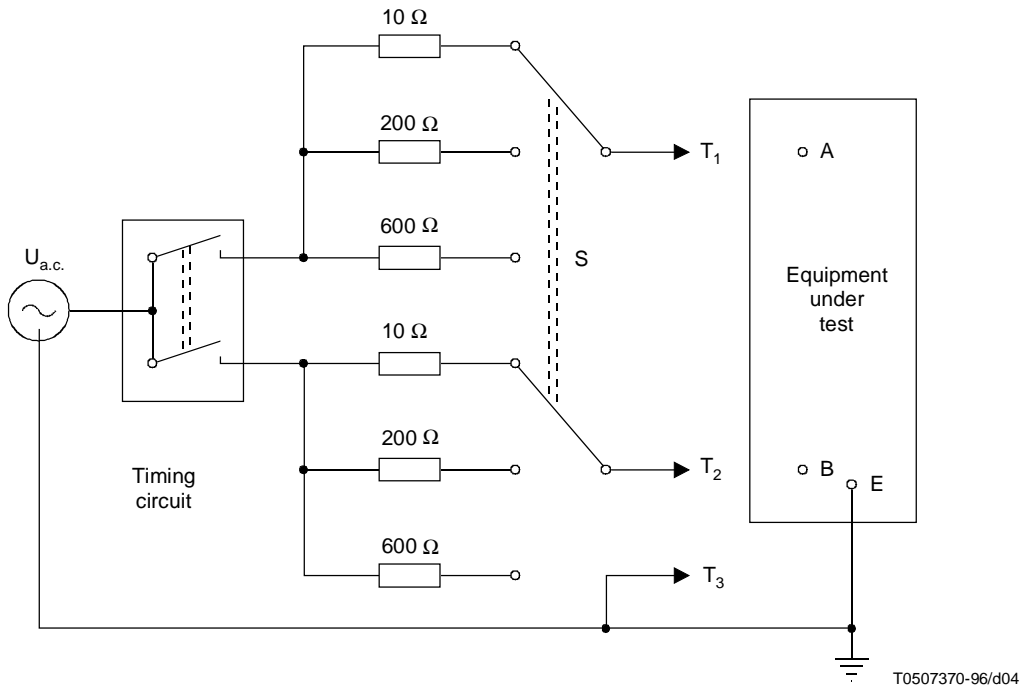


Figure 4/K.21 – Test circuit for power contact

Table 1/K.21 – Test conditions

No.	Test	Terminal connections	Test circuit	Maximum test voltage and duration	Number of tests	Added primary protection	Acceptance criterion
1a)	Lightning surge simulation	T1 and A	Figure 1	$U_{c(max)} = 1.5 \text{ kV}$	10	None	A
		T2 and B		$U_{c(max)} = 4 \text{ kV}$	10	Yes	A
1b)	Lightning surge simulation	T1 and A, B, etc. in turn, T3 and all other terminals (Note 1)	Figure 1	$U_{c(max)} = 1.0 \text{ kV}$	10	None	A
				$U_{c(max)} = 4 \text{ kV}$	10	Yes	A
1c)	Simultaneous lightning surge simulation	$n \times (A + B)$ and E	Figure 2	$U_{c(max)} = 1.5 \text{ kV}$	10	None	A
2a)	Power induction	T1 and A T2 and B	Figure 3	$U_{a.c.(max)r.m.s.} = 600 \text{ V}$ 0.2 s	5	None	A
			Figure 3	$U_{a.c.(max)r.m.s.} = 600 \text{ V}$ 1 s (Notes 2 and 6)	5	Yes	A
2b)	Power induction	T1 and A, B, etc. in turn, T3 and all other terminals (Note 1)	Figure 3	$U_{a.c.(max)r.m.s.} = 600 \text{ V}$ 0.2 s	5	None	A
			Figure 3	$U_{a.c.(max)r.m.s.} = 600 \text{ V}$ 1 s (Notes 2 and 6)	5	Yes	A

Table 1/K.21 – Test conditions (concluded)

No.	Test	Terminal connections	Test circuit	Maximum test voltage and duration	Number of tests	Added primary protection	Acceptance criterion
3a)	Power contact	T1 and A T2 and B	Figure 4 Tests made with S in each position (Notes 3 and 4)	$U_{a.c.(max)r.m.s.} = 230 \text{ V}$ 15 min (Note 5)	1 For each position of S	None	B
3b)		T1 and A, B, etc. in turn, T3 and all other terminals (Note 1)	Figure 4 Tests made with S in each position (Notes 3 and 4)	$U_{a.c.(max)r.m.s.} = 230 \text{ V}$ 15 min (Note 5)	1 For each position of S	None	B

NOTE 1 – An earthed connection may prevent the establishment of normal conditions when the test is made. In these cases, alternative testing procedures should be followed to meet the requirements of this test (e.g. a low voltage spark-gap or other variation in the earth connection should be used).

NOTE 2 – The rationale for the test voltage and duration values is given in A.2/K.20.

NOTE 3 – Fuses, fuse cables, etc. may be left in circuit during these tests.

NOTE 4 – If the switch S is in the position “10 Ω”, the current may be limited to lower values according to national regulations.

NOTE 5 – The value of $U_{a.c.(max)}$ shall be varied according to the local mains voltage.

NOTE 6 – See the possible variation of test conditions in clause 8.

9 Tests related to electrostatic discharges

The requirements of Recommendation K.32 and IEC publication 1000-4-2 [1] should be followed. The equipment shall meet criterion A of this Recommendation when tested to severity level 4 of IEC 1000-4-2 (8 kV contact discharge, 15 kV air discharge).

10 Tests related to mains-powered equipment

The following tests are made on mains-powered equipment to ensure that the equipment can adequately resist high voltage surges which may arise on power conductors from lightning or other causes, such as load switching.

The equipment under test should be tested with normal operating power applied and with the telecommunication line access at the equipment terminated in such a manner as to simulate the conditions in each state of operation of significant duration.

Equipment not complying with a) below should meet criterion A of this Recommendation when tested with surge tests applied between phase, neutral and protective earth terminals of the equipment in accordance with b) below.

a) *Insulation coordination*

IEC publication 664-1 [2] describes overvoltage categories for mains-powered equipment, including telecommunication equipment, in respect of overvoltage arising in the supply network. Most subscribers' equipment is expected to be installed in overvoltage category II in which the maximum surge voltage arriving at its mains terminals is 2.5 kV peak. Given this and certain other assumptions about atmospheric pollution (e.g. dust) and the quality of insulation, IEC 664-1 gives guidance to IEC standards committees on coordinated creepage distances and clearances that can be expected to give adequate performance during the lifetime of the equipment.

The guidance in IEC 664-1 has been adopted in IEC publication 950 [3]. Subject to cases mentioned in c) below, telecommunication equipment that employs insulation spacings that are dimensioned and tested in accordance with IEC 950 need not be subjected to further tests under this Recommendation.

b) *No insulation coordination*

Where reliance is not placed on insulation coordination, the equipment shall be subjected to tests along the lines indicated in references [3] and [4]. For pluggable equipment type A, the requirements of 6.3 of the IEC publication 950 must be observed.

c) *Exceptional overvoltages*

In cases where electrical disturbances may be of exceptional amplitude or simply greater than the values adopted for the tests, it is recommended that additional protective measures be used, e.g.:

- power transformers with high dielectric strength (or the order of 10 kV) in relation to the mains leads;
- overvoltages limiting devices such as lightning arrestors, air gaps, non-linear resistances, etc.;
- combinations of the above.

NOTE 1 – For situation a), the experience has shown that a lightning surge generator according to Figure 1 may be substituted, i.e. with waveshape 10/700 μ s and an internal impedance of 40 ohms. A test voltage of $U_{c(max)} = 2.5$ kV assured a satisfactory performance of equipment operated at a load level interface of low-voltage distribution systems with a nominal voltage of 230/400 V.

NOTE 2 – Attention is drawn to matters of safety which relate to electrical barriers between the mains power and telecommunication line terminals. These are normally subject to national regulations which have to be followed in each country.

References

- [1] IEC 1000-4-2:1995, *Electromagnetic compatibility (EMC), Part 4: Testing and measurement techniques – Section 2: Electrostatic discharge immunity test – Basic EMC Publication.*
- [2] IEC 664-1:1992, *Insulation coordination for equipment within low-voltage systems, Part 1: Principles, requirements and tests.*
- [3] IEC 950:1991, *Safety of information technology equipment, including electrical business equipment,* and IEC 950 A 1, 1992.
- [4] CENELEC EN 41003, *Particular safety requirements for equipment to be connected to telecommunication networks,* Brussels, 1993.

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