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SERIES K: PROTECTION AGAINST INTERFERENCE

EMC, resistibility and safety requirements and guidance for determining responsibility under co-located telecommunication installations

Recommendation ITU-T K.58

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Summary

With the liberalization of telecommunications, many services are provided by several operators on the same cable. Equipment owned by different operators is installed in the same telecommunication facilities and, in many cases, is interconnected. Therefore, problems related to electromagnetic compatibility (EMC), resistibility and safety can occur.

Recommendation ITU-T K.58 describes the necessary steps to ensure safe and problem-free operation in co-located telecommunication installations from EMC, resistibility and safety points of view.

This Recommendation also gives guidance for determining responsibility of EMC problems under co-located telecommunication installations.

Source

Recommendation ITU-T K.58 was approved on 13 April 2008 by ITU-T Study Group 5 (2005-2008) under Recommendation ITU-T A.8 procedure.

FOREWORD

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Recommendation ITU-T K.58

EMC, resistibility and safety requirements and guidance for determining responsibility under co-located telecommunication installations

1 Scope

The purpose of this Recommendation is to provide guidance aimed at ensuring safe and problem-free operation in a co-located telecommunications installation from the viewpoint of electromagnetic compatibility (EMC), resistibility and safety.

This Recommendation deals with the following environments where equipment owned by several operators can be installed:

– telecommunication centres;
– remote electronic sites;
– in some instances, the customer premises when the equipment owned by operators is installed in that environment.

Minimum requirements are given in this Recommendation in order to ensure safe and problem-free operation and to reduce EMC, resistibility and safety problems. The main aspects are: safety for humans, and equipment; electromagnetic emission and immunity; resistibility against overvoltage and overcurrent; and earthing. The procedures and countermeasures that are used in case of problems are also described in this Recommendation.

Also, this Recommendation provides guidance on determining responsibility when an EMC problem occurs. If national regulations or agreements for co-location between operators exists, then this Recommendation supports the items that these documents do not cover.

Requirements that are not related to EMC, resistibility and safety are outside the scope of this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.11] Recommendation ITU-T K.11 (1993), *Principles of protection against overvoltages and overcurrents.*

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

[ITU-T K.20] Recommendation ITU-T K.20 (2008), *Resistibility of telecommunication equipment installed in a telecommunications centre to overvoltages and overcurrents*.

[ITU-T K.21] Recommendation ITU-T K.21 (2008), *Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents*.

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

[ITU-T K.28] Recommendation ITU-T K.28 (1993), *Characteristics of semi-conductor arrester assemblies for the protection of telecommunications installations*.

[ITU-T K.34] Recommendation ITU-T K.34 (2003), *Classification of electromagnetic environmental conditions for telecommunication equipment – Basic EMC Recommendation*.

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

[ITU-T K.37] Recommendation ITU-T K.37 (1999), *Low and high frequency EMC mitigation techniques for telecommunication installations and systems – Basic EMC Recommendation*.

[ITU-T K.43] Recommendation ITU-T K.43 (2003), *Immunity requirements for telecommunication equipment*.

[ITU-T K.44] Recommendation ITU-T K.44 (2008), *Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation*.

[ITU-T K.45] Recommendation ITU-T K.45 (2008), *Resistibility of telecommunication equipment installed in the access and trunk networks to overvoltages and overcurrents*.

[ITU-T K.48] Recommendation ITU-T K.48 (2006), *EMC requirements for telecommunication equipment – Product family Recommendation*.

[ITU-T K.50] Recommendation ITU-T K.50 (2000), *Safe limits of operating voltages and currents for telecommunication systems powered over the network*.

[ITU-T K.54] Recommendation ITU-T K.54 (2000), *Conducted immunity test method and level at fundamental power frequencies*.

[ITU-T K.66] Recommendation ITU-T K.66 (2004), *Protection of customer premises from overvoltages*.

[ITU-T K.76] Recommendation ITU-T K.76 (2008), *EMC requirements for telecommunication network equipment (9 kHz-150 kHz)*.

[IEC 60950-1] IEC 60950-1 (2005), *Information technology equipment – Safety – Part 1: General requirements*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/035320>

[IEC 60950-21] IEC 60950-21 (2002), *Information technology equipment – Safety – Part 21: Remote power feeding*. <http://webstore.iec.ch/webstore/webstore.nsf/artnum/029602>

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

3 Definitions

This Recommendation defines the following term:

3.1 co-located telecommunications installation: An installation containing equipment from more than one operator, being located within distinct and separated sections of the equipment room and sharing common infrastructure (i.e., earthing and bonding arrangement, power supply, etc.).

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC Alternative Current

DC Direct Current

DSL Digital Subscriber Line

EM ElectroMagnetic

EMC ElectroMagnetic Compatibility

EMI ElectroMagnetic Interference

ESD ElectroStatic Discharge

LPS Lightning Protection System

MDF Main Distribution Frame

POTS Plain Old Telephone Service

POI Point Of Interference

SE Source Equipment

SEO Source Equipment Owner

SPD Surge Protective Device

VE Victim Equipment

VEO Victim Equipment Owner

5 Configuration and problems in a co-located telecommunications installation

An example of a co-located telecommunications installation is illustrated in Figure 1. In a telecommunication centre, telecommunication equipment owned by different operators could be installed in the same floor or room, and may connect to each other. Moreover, in some cases, telecommunication devices owned by different operators could be installed in the same customer premises because users may simultaneously use several kinds of telecommunication services provided by each of them.

In some cases, equipment belonging to several operators may be installed close to each other. Furthermore, the different operators may share common installation infrastructure, such as the earthing system, the AC power supply, the DC power supply and the MDF connected with a primary protector. One operator may maintain the whole telecommunication installation, or each operator may maintain its own, separate infrastructure.

The reliability and safety of equipment may be ensured by unifying equipment specifications or testing equipment installed in a telecommunication facility when the equipment is owned by one operator. However, in a co-location environment, reliability and safety are sometimes difficult to ensure because different operators may employ different equipment specifications and/or working practices. Therefore, minimum common requirements for equipment or systems related to EMC, resistibility and safety should be established to avoid malfunction or damage arising from electromagnetic interference, and to ensure the safety of service personnel and customers. Moreover, ensuring problem-free operation requires the definition of earthing and bonding methods, working procedures and protection measures.

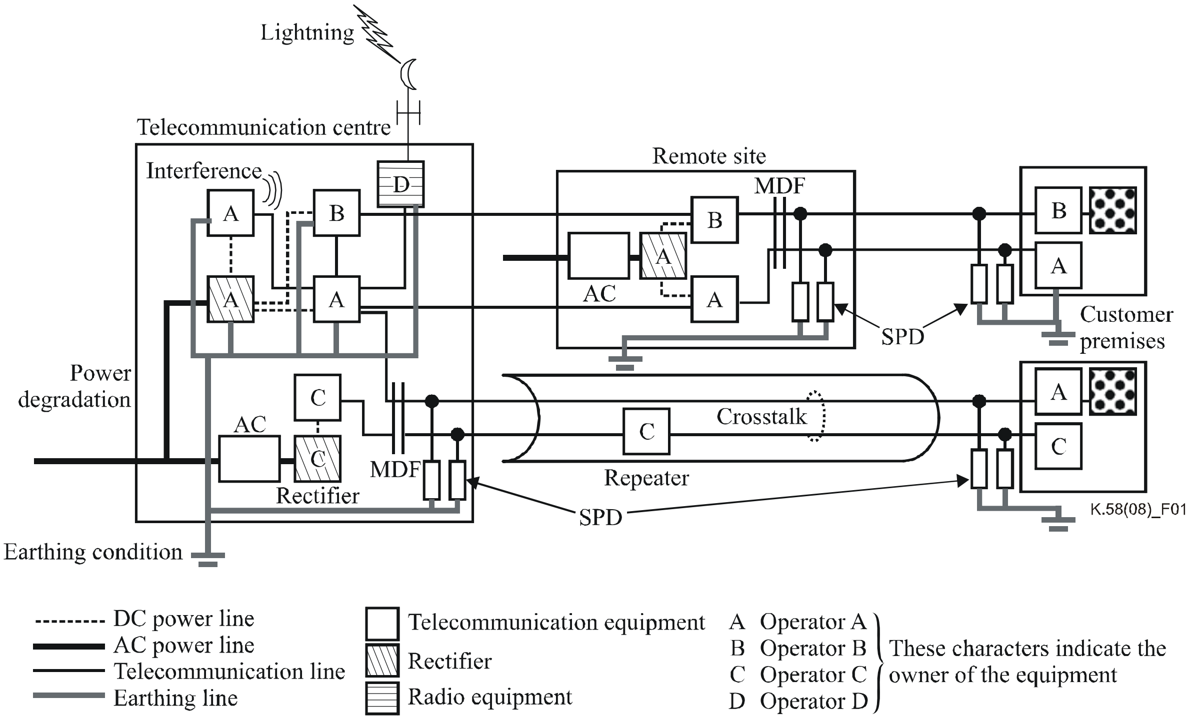


Figure 1 – An example of a co-located telecommunications installation

6 Issues to be considered

1) Electromagnetic interference

Interference by both radiated and conducted emissions should be taken into account because telecommunication equipment may be installed close to radio equipment and its power-feeding cable and telecommunication cable are interconnected between equipment owned by different operators.

2) Quality and stability of the power supply

Fluctuations in operating voltage can occur when another piece of equipment connected to the same power supply is switched on.

Unintentional oscillations in the power feeding system can occur for specific conditions of output impedance of the power system, load impedance and inductance of the power line cable. If this happens, in the worst case, equipment connected to the system would shut down or break down.

3) Lightning

In the case of a direct lightning strike to a telecommunication building, lightning current flows from the radio tower or lightning rods to earth through the building structure or LPS down-conductors. In this case, a surge voltage is induced on cables connected to the equipment, or the lightning surge directly invades from the antenna feeder into the equipment through the interface cable, or from the power supply cable. The influence of these surges depends on the earthing and bonding configuration inside the telecommunication facilities, on the cable shield, and the characteristics of the primary protector. These characteristics are important factors to limit a lightning surge at the equipment interface coming through a power-feeding or telecommunication cable.

4) Electrostatic discharge (ESD)

An ESD problem may arise when measures for reducing ESD do not meet the immunity level of the equipment. Moreover, ESD caused by service personnel of one operator may cause a malfunction in another operator's equipment.

5) Emission beyond the telecommunication facilities

When radio interference caused by emission from equipment in co-located telecommunication facilities occurs, operators should collaborate to investigate the EMC problems and apply mitigation measures.

7 Guiding principle

Labelling or showing information about a contact point or a person for each operator is necessary in each co-located place. Common technical requirements should be taken into account between the operators. It is also necessary to adopt common safety requirements for people in a co-located telecommunications installation.

8 Typical EM environment in co-location

The typical electromagnetic environment in a telecommunication centre is presented in [ITU-T K.34]. In general, [ITU-T K.34] applies also to co-located telecommunication installations, even though a more severe EM environment could exist in some specific installations. When an EMC problem occurs, it is necessary to evaluate the EM environment by using the measurement techniques described in [b-ITU-T Mitigation].

9 Requirements

Essential requirements to ensure a safe and problem-free operation in co-located installations are described in the following clauses.

To avoid duplication, existing ITU-T Recommendations are referred to.

Where existing Recommendations cannot be applied, the requirements of this Recommendation are applicable.

If additional or enhanced requirements are needed by national or other local regulations, the involved operators should define how to comply with these requirements; in this situation, special measures may need to be agreed upon between operators.

9.1 General conditions

Equipment and cables installed in a co-located environment shall comply with requirements for signals, interfaces and for intended operation.

9.2 Safety

9.2.1 Equipment requirements

Equipment shall comply with [IEC 60950-1] and [IEC 60950-21].

9.2.2 Requirement for working practices

Working practices on telecommunication networks shall comply with [ITU-T K.50] that defines general and special (such as labelling or marking) working practices.

9.3 EMC requirements

9.3.1 General EMC requirements

Equipment shall comply with the general EMC requirements described in [ITU-T K.43] and [ITU-T K.48].

In general, the performance criteria shall comply with [ITU-T K.43].

The performance criteria for telecommunication equipment shall comply with [ITU-T K.48].

When interconnected equipment does not satisfy these requirements, the operator may need to take appropriate measures, such as those described in [ITU-T K.37].

9.3.2 Immunity requirements against induced voltage from power or railway lines

The immunity level at fundamental power frequencies (16⅔, 50 and 60 Hz) shall comply with [ITU-T K.54].

Induction caused by harmonics of the fundamental power frequency is an issue that can affect the function of telecommunications equipment.

9.4 Resistibility

9.4.1 Basic requirements

Equipment shall comply with the resistibility requirements given in [ITU-T K.11], [ITU-T K.20], [ITU-T K.21], [ITU-T K.44] and [ITU-T K.45].

The application of these Recommendations allows the verification of the equipment's resistibility and the coordination between primary protectors (SPDs) and the inherent equipment protection. This coordination is particularly important in a co-located environment in order to avoid dangerous overvoltages for the equipment owned by different operators due to different protection levels of the installed SPDs.

When high resistibility is required, operators may choose the enhanced level of these Recommendations. Guidance on choosing the enhanced level is given in clause 5 of [ITU-T K.44].

If a requirement in [ITU-T K.20], [ITU-T K.21] and [ITU-T K.45] is not satisfied or does not meet the protection required by national regulations, operators involved should define appropriate protection measures.

9.4.2 Primary protection

Guidance on installing primary protectors is given in [ITU-T K.11].

The need to install primary protectors as the telecommunication and power cables enter a telecommunication facility can be evaluated through use of the risk assessment method presented in [IEC 62305-2].

9.5 Earthing and bonding

Earthing and bonding characteristics are important for achieving EMC, resistibility and safety requirements. For example, earthing and bonding can control emissions and immunity, especially in the low-frequency range, in a telecommunication facility.

Basic concepts of earthing and bonding in a telecommunication facility are described in [ITU-T K.27], [ITU-T K.35] and [ITU-T K.66]. The installation shall comply with the requirements of these Recommendations.

9.6 Interface and port condition

This clause presents some important aspects that should be taken into account in a co-located environment. Some of these aspects are not clearly covered by existing ITU-T Recommendations or other international standards.

9.6.1 Interface condition between telecommunication ports

If EMC, resistibility and safety problems can occur as a result of interconnection of a telecommunication cable between telecommunication equipment, appropriate protection measures should be taken, such as described in [ITU-T K.37] or [b-ITU-T Mitigation].

9.6.2 Interface condition for power-feeding system

The following aspects could be taken into consideration because results may cause EMC problems in a co-located environment.

9.6.2.1 Quality of DC power

In a co-located environment, a set of power supply equipment may be dedicated to a single operator or may be shared by several operators. In the latter case, the quality of the DC power supply is important in order to avoid malfunctions caused by the power system and to ensure steady operation. Interference below 150 kHz should be studied as a measure of DC power quality. EMC requirements below 150 kHz are given in [ITU-T K.76].

9.6.2.2 Transition current, voltage fluctuation

In the case of power supply equipment being shared between operators, the existing power equipment may be affected by voltage fluctuation caused by the inrush current when newly installed equipment is switched on. Malfunction can be mitigated by limiting the inrush current by adding measures in the equipment or reducing the voltage dip by adding a capacitor at the DC power supply.

Equipment shall comply with the immunity test for DC voltage perturbations in [ITU-T K.48].

9.6.2.3 Equipment impedance as a load for power supply

DC power system oscillation might occur for a specific impedance of connected equipment, for a specific impedance of connected cables, or because of the power equipment condition. This phenomenon should be taken into account when new equipment is either connected to or disconnected from the DC power-feeding system. In this case, inserting a capacitor at the output port of the DC power supply and/or using a short feeder length can solve the oscillation of the DC power system.

10 Procedure for countermeasures

The procedure for solving a problem or taking measures against it is described in [b-ITU-T Mitigation].

Measures for EMC, resistibility and safety are described in ITU-T Recommendations and Handbooks, such as [ITU-T K.11], [ITU-T K.37], [ITU-T K.50], [b-ITU-T Mitigation] and [b-ITU-T Earthing].

The following clauses provide guidance on the procedure to solve problems. Collaboration between operators is necessary in order to proceed with taking countermeasures against problems.

10.1 Safety

10.1.1 Procedure for solving problems

When safety problems occur, the causes of the problems should be identified in accordance with the following procedure:

1) Equipment that causes safety problems should be identified by measuring normal-mode or common-mode voltage or current in steady-state condition.
2) The reason why measured voltage or current has occurred (by malfunction or by normal operation) should be specified.
3) In case of a problem caused by induction from the power line, the cause of the problem should be estimated using the fault record of the power line and the condition of telecommunication installation and equipment.

10.1.2 Countermeasures

To ensure safety of operating personnel, precautions, such as labelling or marking, could be necessary according to [ITU-T K.50] or to national regulations.

10.2 EMC

10.2.1 Procedure for solving problem

When an emission or immunity problem occurs, the following procedure should be used to identify the cause(s) of the problem:

1) The electromagnetic environment around the equipment should be measured. Disturbance sources that cause the emission or immunity problem can be identified by analysing these measured results. Frequencies of interference that may cause malfunction and the location of the problem are important information to identify the cause of the problem.
2) By clarifying the relationship between the disturbance and the problem or between the signal and noise, the type of malfunction can be established.

10.2.2 Countermeasures

Countermeasures against EMC problems are described in [ITU-T K.37].

10.3 Resistibility

10.3.1 Procedure for solving problems

When a resistibility problem occurs, the following procedure could be used to identify the causes of the problem:

1) The invading route of overvoltage and overcurrent can be determined by investigating the installation damage and checking the system configuration.
2) Protection measures for each operator should be checked. Protection coordination between operators should also be checked.
3) An appropriate protection measure, such as adding an SPD or lightning-protection transformer, should be installed if the cause of the problem is determined.

10.3.2 Countermeasures

Installing primary protection outside the equipment or inserting a lightning protection transformer are both countermeasures against overvoltage and overcurrent.

Characteristics of primary protectors are given in [ITU-T K.12] and [ITU-T K.28]. Information on protection transformers can be found in [ITU-T K.37].

10.4 Aspects to be considered

If a problem occurs in an existing installation, the following aspects should be taken into account:

1) It takes a long time to change existing equipment and it is difficult to add countermeasures to existing equipment. Countermeasures should mainly be done for newly-installed equipment.

2) To define adequate countermeasures against EM noise, it is useful to investigate the earthing and bonding characteristics, search out the interference source, and identify the route of the noise. This requires the operators' collaboration.

3) In the case of a failure caused by overvoltages and overcurrents, such as due to a lightning EM field or induction from power or railway lines, it is necessary to verify the compliance of the earthing and bonding characteristics, the equipment resistibility, and the primary protectors characteristics to relevant Recommendations. This requires the operators' collaboration.

11 Guidance for distinguishing responsibility

This clause describes how to determine the cause of EM problems and the concept of responsibility for taking measures against EMC problems in co-location environments.

11.1 Determining the cause of the problem

When EMC problems occur in co-location environments, the first step is to clarify the cause of the emissions from the EM sources. The procedure for solving a problem or taking measures against it is in clauses 9 and 10 of [b-ITU-T Mitigation].

The owners of equipment or locations should check the cause of EMC problems by measuring and evaluating the EM environment.

To clarify the cause of EMC problems, the following procedures should be undertaken.

1) Identification of EM disturbance

   By checking the type of EMC problems and measuring EM environments, it is possible to identify the types of disturbance that cause EMC problems and evaluate their properties.

2) Determination of EMC causes

   In order to clarify the cause of EMC problems, suppliers of co-locations and owners of equipment should cooperate to measure the EM environment in which EMC problems have occurred. If there are inter-connection systems, engineers should investigate the cause of problems and measure EM disturbance within their POI. When the cause of the problems is difficult to be determined, the parties involved should evaluate the relationship between the cause and effect by studying the properties of EM disturbances and equipment specifications. To clarify the cause of EM problems, inter-connections may be temporarily cut and equipment should be turned off if necessary.

Flow charts of the suggested procedure for evaluating the EM environment and finding the problem cause are shown in Figure 2 to Figure 4.

11.2 Responsibility

After the investigation of the cause of the problem, involved parties should consider the responsibility for solving the problem and taking countermeasures. Table 1 shows the identification of the responsibility for countermeasures.

Table 1 – Example of responsibility for countermeasures

Cause of the problem		Responsibility for countermeasures	
		SEO	VEO
Installation fault is in SE		√	–
Installation fault is in VE		–	√
Source of the problem is SE	Exceeds emission limit	√	–
	Does not exceed the limit	–	Check immunity level
Poor immunity level		–	√
Coupling path of the problem	Owned by SEO	√	–
	Owned by VEO	–	√

11.2.1 Known source of the problem

If the sources of the disturbances are determined, the cause of the problem should be identified. In general, there are two possible causes of the problem; one is installation failure and the other is an emission from the source equipment or the immunity of the victim equipment.

If the source equipment has installation failure, the owner of the source equipment has to fix the failure. In the other case, i.e., the victim equipment has the failure, the owner of the victim equipment has to fix their failure.

Equipment in telecommunication centre buildings should comply with the emission and immunity level required by [ITU-T K.48]. Both the emission level of the source equipment and the immunity level of the victim equipment should be checked. If the emission level of the SE exceeds the limits, then the owner of the SE should take countermeasures. On the other hand, if the level does not exceed the limits, then the immunity level of the VE should be checked. If the SE does not exceed emission limits and the VE has poor immunity characteristics, then the immunity level of the VE needs to be improved.

When the source of the problem is identified, the flow chart for the procedure for distinguishing responsibility, shown in Figure 3, should be followed.

11.2.2 Unknown source of the problem

In this case, to solve the problem and distinguish responsibility, the characteristics of the disturbance needs to be measured, then the coupling path of the disturbance should be determined. If the coupling path is confirmed and the victim equipment clearly has no relation with the disturbance, then the owner of the floor or building should take countermeasures.

If the characteristics or the coupling paths of the disturbance are unknown, then involved parties should share all information about the problem and carry out an investigation to estimate the possible cause with the highest probability.

A flow chart for the procedure for distinguishing responsibility in the case of an unknown source of the problem is shown in Figure 4.

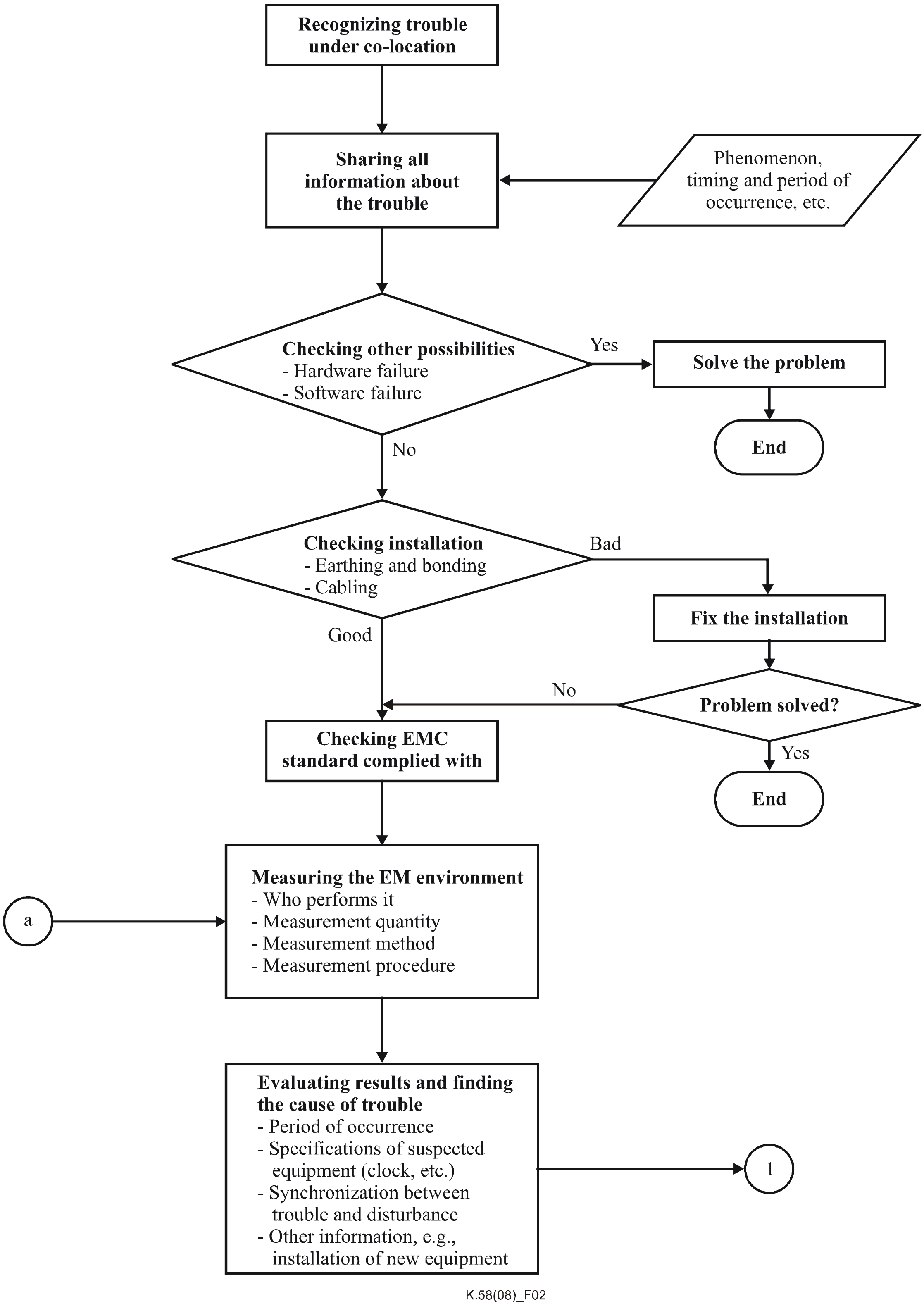


Figure 2 – Procedure to evaluate EM environment

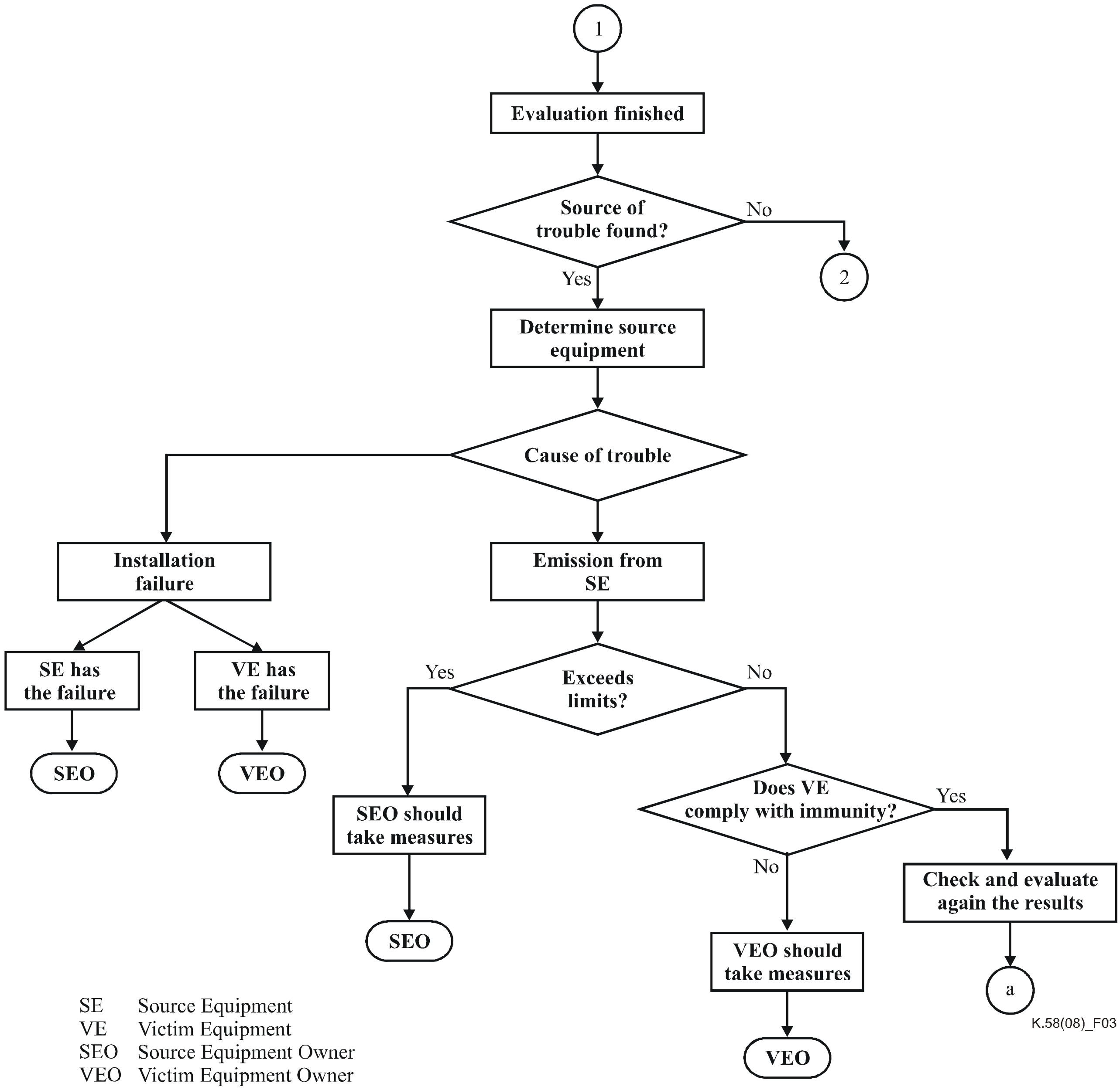


Figure 3 – Procedure for distinguishing responsibility when the source of the problem is determined

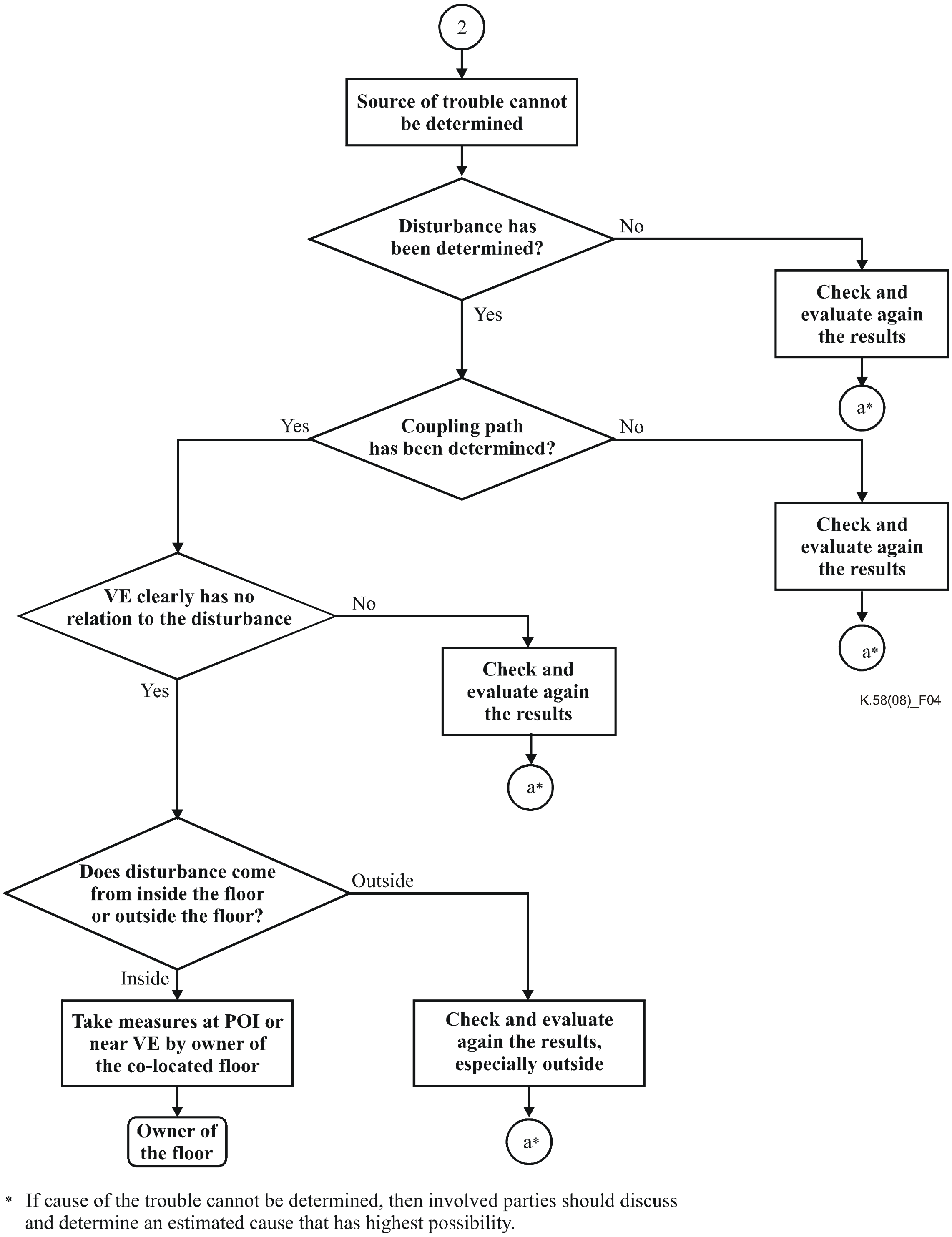


Figure 4 – Procedure for distinguishing responsibility when the source of the problem is not determined

Appendix I

Example of EMI problem in co-located environment

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

I.1 Introduction

This appendix presents an example of a real EMI problem in a co-located environment.

The purpose of this appendix is to help the user's understanding of this Recommendation.

The case indicated in this appendix happened in a real co-located environment where the two operators exist in the same floor.

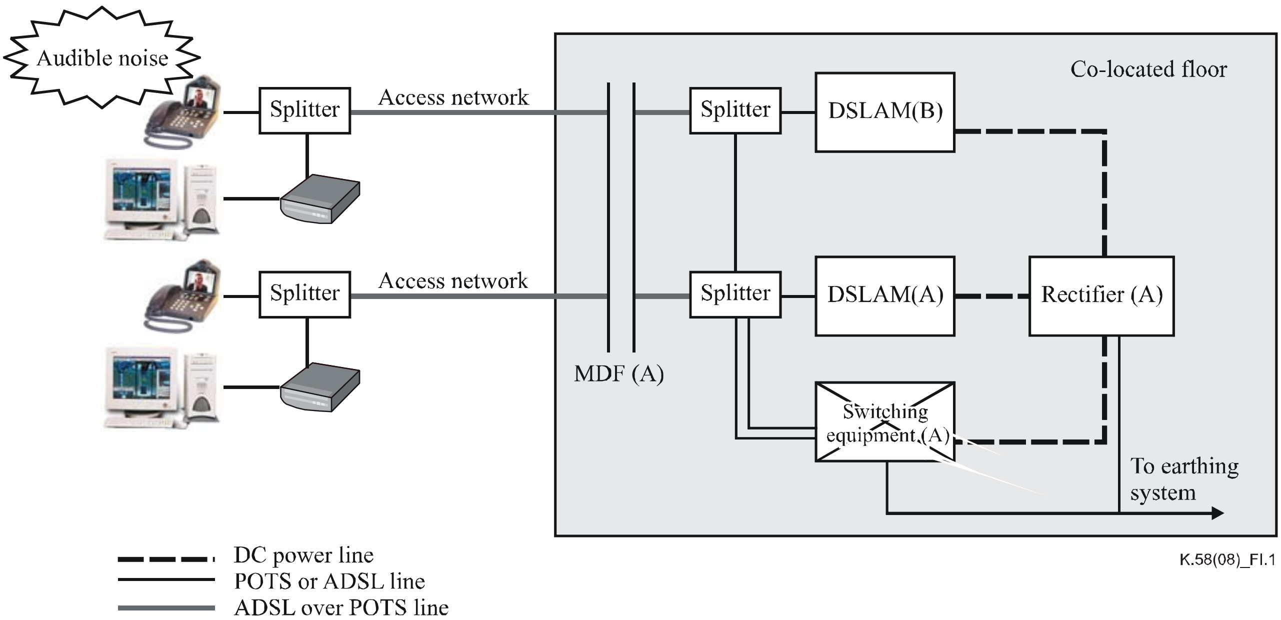
I.2 Example of the procedure for how to solve an EMI problem in co-located environment

I.2.1 Situation of the problem

The situation of the EMI problem in the field is as follows:

1) A customer of the DSL over POTS system provided by operator B claimed that audible noise was present in the POTS system.
2) Telecommunication equipment for the DSL system was set under the co-located space provided by operator A.
3) A POTS system was provided by Operator A. On the other hand, the DSL system was provided by operator B's equipment. The equipment was installed in the same floor in operator A's telecommunication building.
4) The same rectifier, owned by operator A, fed dedicated DC power to all concerned equipment.
5) The sound of the noise was like "zee zee zee zee".

Configuration of the installation is shown in Figure I.1.



NOTE – Inside the brackets indicates owner of the equipment.

Figure I.1 – Situation of the problem and configuration of the installations

I.2.2 Survey of the EMI problem

First, the involved parties, i.e., operators A and B, confirmed the problem occurred in the field. They also shared all information on the problem.

The following steps were carried out by the operators.

I.2.2.1 Checking possible causes of the problem

The possible cause of the problem was checked by the operators.

In this case, operator B changed all possible equipment, such as the modem, splitter, line card, and so on. Operator A also changed access network lines and internal cabling in the floor. As a result, the function of this equipment was normal and it worked normally, but the audible noise still existed. Therefore, the two operators confirmed that the possible cause of interference may be EMI.

I.2.2.2 Checking compliance with standards

All equipment installed in the floor complied with relevant EMC, resistibility and safety requirements, such as [ITU-T K.48], [b-IEC CISPR 22] and [b-IEC CISPR 24], IEC 60950-series, [ITU-T K.20], [ITU-T K.21], and so on.

I.2.2.3 Determining the area where the cause of the problem exists

Next step was to determine the area where a problem source existed.

The area was divided into two parts: inside and outside of the building.

In this case, the simple method shown in Figure I.2 was applied. First, access lines were disconnected at the MDF, and splitters and telephones were set. Then, audible noise was checked by both operators. Acoustic noise was identified although the access network was disconnected. Therefore, operators concluded that the source of the disturbance was inside the building in the co-located floor.

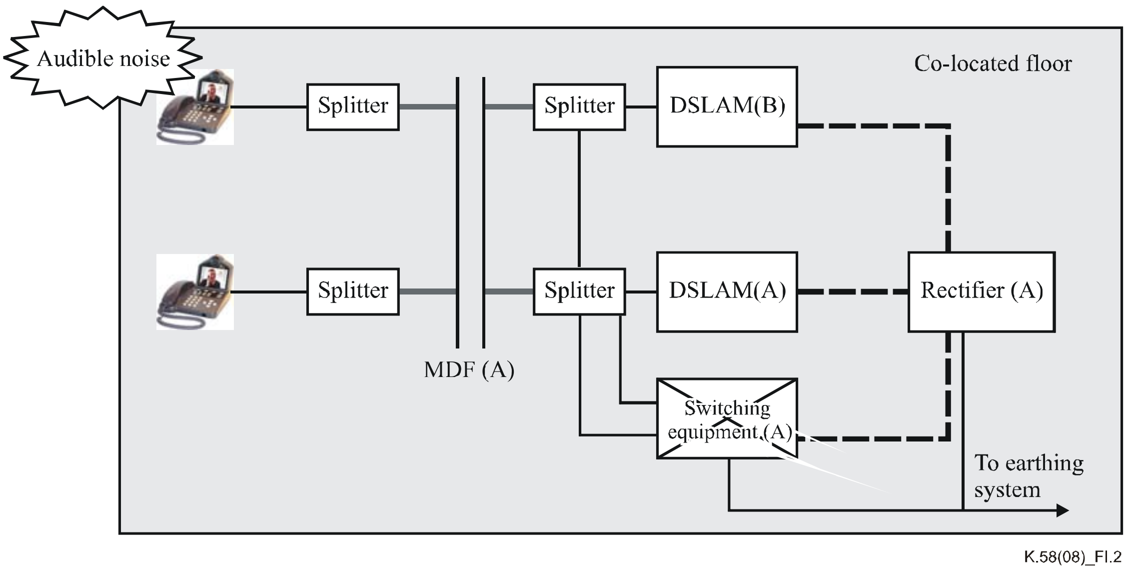


Figure I.2 – Installation only inside the building in the co-located floor

I.2.2.4 Measuring EM environment

The next step was the measurement of the EM environment in the floor.

First, the operators discussed the investigation procedure and who had to perform the investigation. They have also decided the date and time of the investigation, and the necessary steps to solve the problem.

In this case, operator B did not have any capability to evaluate the EM environment. Therefore, operator A carried out the measurements in collaboration with operator B. They decided the date and time of the investigation. Operator A proposed the procedure of the investigation which was shared between the operators. Furthermore, during the investigation, it was sometimes necessary to disconnect a line. Therefore, operator B informed his customer about the investigation.

I.2.2.4.1 Determining the measurement quantities, tools and procedure

In this case, measurements were mainly carried out using current probes, because they simply clamp around the cable and, therefore, can measure the disturbing current under normal operating conditions. A voltage probe was also used to measure the common mode voltage on the telecommunication line connected to operator B's equipment. A digital oscilloscope was used to measure the disturbance.

Characteristics of the tools are as follows:

a) Current probe — It has flat sensitivity in the frequency range from 10 kHz to 150 MHz. The attenuation ratio of the probe in this range is 1.

b) Voltage probe — It has flat sensitivity in the frequency range from DC to 10 MHz. The attenuation ratio is 0.1.

c) Digital oscilloscope — The maximum sampling rate is 100 MHz and the record length is 10 kilobytes. The measurable frequency range is from DC to 200 MHz.

Measurement points of the EM environment in the co-located floor are shown in Figure I.3. Conducted disturbance current on the cable was measured by the current probe at all measurement points. Common mode voltages on the telecommunication lines were also measured by the voltage probe. Figure I.4 shows the measured results of the common mode voltages on the telecommunication line. From these results, the main frequency components of the noise were about 50 kHz and 250 kHz.

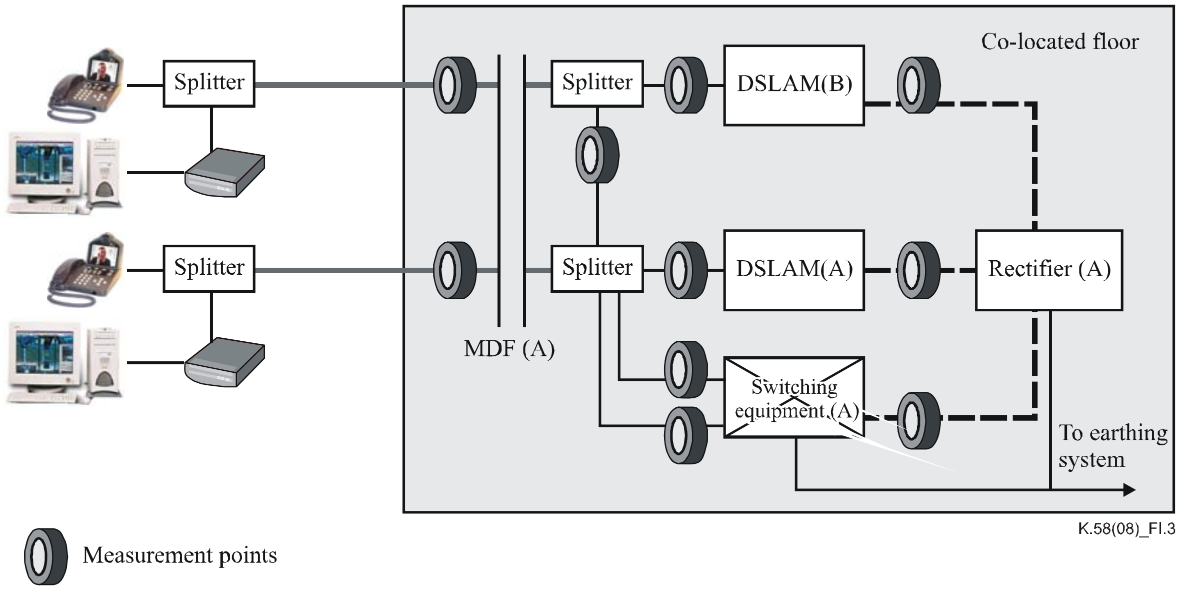


Figure I.3 – Measurement points

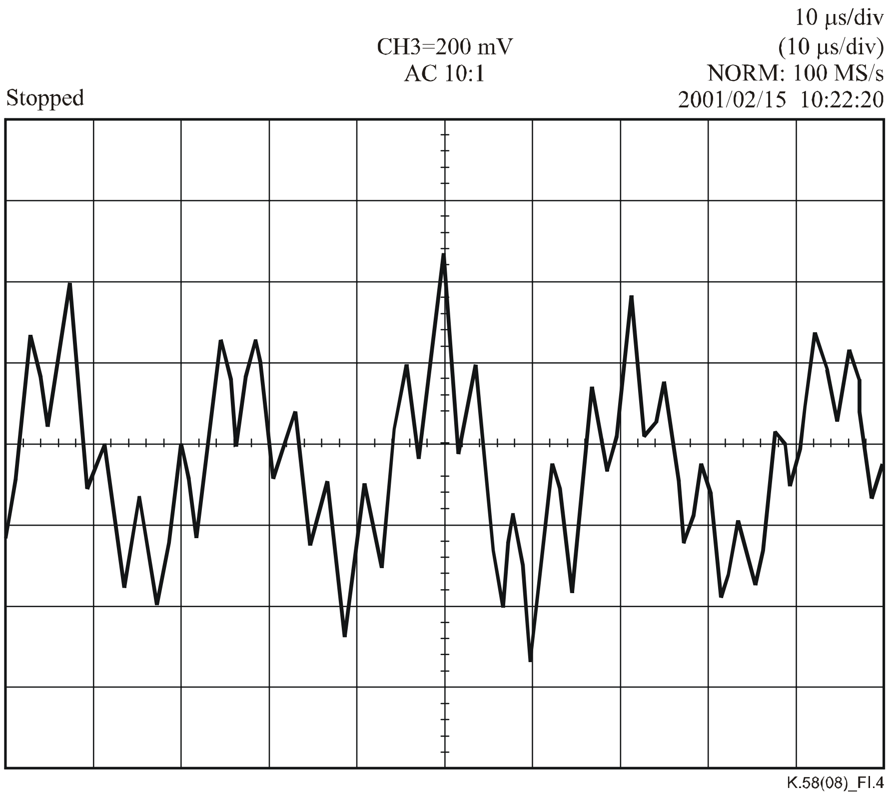


Figure I.4 – Example of the measurement result

I.2.2.5 Evaluating EM environment

In this case, the common mode disturbance produced by the rectifier propagated into DSLAM(B) via the DC power feeding cable, then it propagated toward switching equipment (A) via the telecommunication line through the splitter.

The common mode disturbance became normal mode noise by the imbalance of equipment (A). By detecting the envelope of the disturbance, this disturbance was converted to audible noise at the line card in equipment (A), then it propagated to the customer's equipment, recognizable as audible noise.

The investigated situation of the problem is shown in Figure I.5.

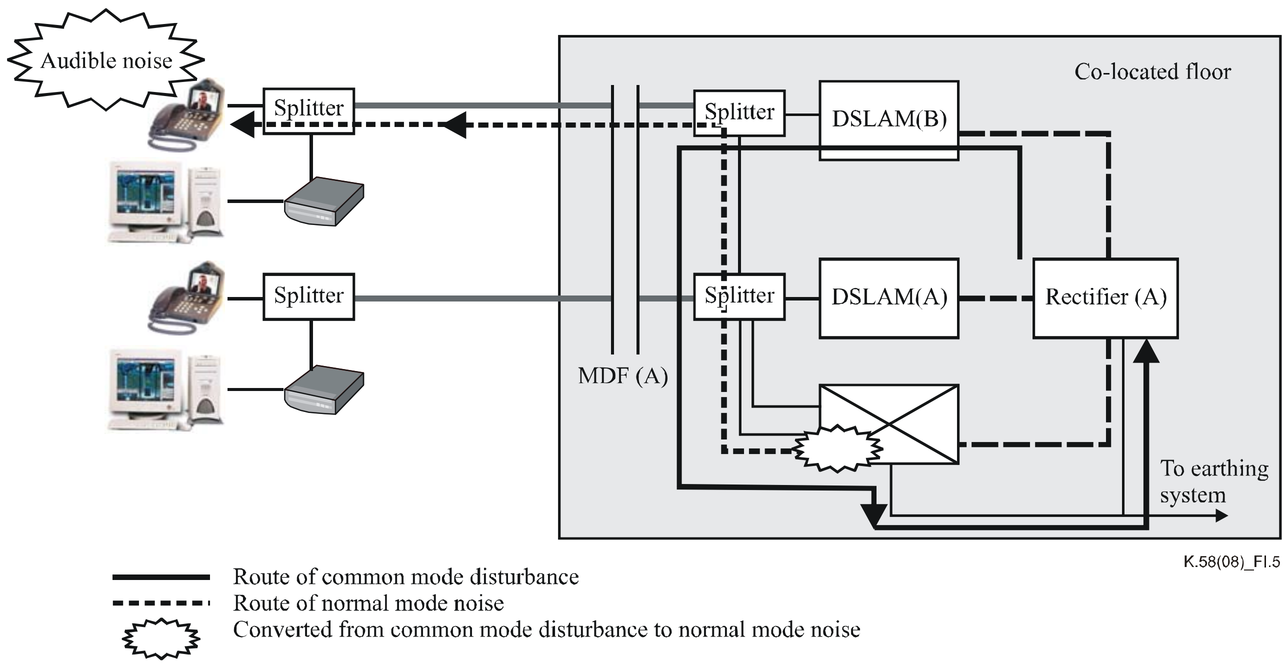


Figure I.5 – Investigated situation of the conducted disturbances

I.2.3 Considering the responsibility

In this case, the problem was produced by the rectifier owned by operator A. Therefore, operator A had a responsibility to take mitigation measures for this problem.

The best solution was to take countermeasures at the rectifier level. Mitigation measures for solving this problem were as follows:

1) Inserting a common mode choke coil at the output port of the rectifier.

2) Inserting a common mode choke coil into the telecommunication line.

I.2.4 Mitigation measures for solving the problems

In this problem, at first, it was difficult to apply countermeasure 2 to the rectifier owned by operator A. Therefore, operators agreed to take countermeasure 1 to solve the problem. Operator A prepared the appropriate common mode choke coil and installed it at the MDF into the telecommunication line connected to the customer, solving the noise problem.

Finally, operator A applied countermeasure 2 and the audible noise disappeared.

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