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SERIES K: PROTECTION AGAINST INTERFERENCE

Conducted and radiated electromagnetic environment in home networking

Recommendation ITU-T K.92

Recommendation ITU-T K.92

Conducted and radiated electromagnetic environment in home networking

Summary

Recommendation ITU-T K.92 describes the home networking electromagnetic environment. It gives the typical conducted and radiated phenomena in the home networking environment, the attributes of the home networking environment and the specification of disturbance characteristics and levels. This Recommendation also provides guidance on how to evaluate the electromagnetic (EM) environment in home networking.

This Recommendation also provides several case studies about the home networking environment and information on how to evaluate the electromagnetic (EM) environment in home networking.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T K.92	2012-05-29	5

Keywords

Electromagnetic environment, home networking.

FOREWORD

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Recommendation ITU-T K.92

Conducted and radiated electromagnetic environment in home networking

1 Scope

This Recommendation defines the electromagnetic environmental conditions in home environments where home networking devices are installed. This Recommendation applies to telecommunication equipment installed in home networking.

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

[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.74] Recommendation ITU-T K.74 (2008), *EMC, resistibility and safety requirements for home network devices*.

[CISPR 11] CISRP 11 (2009), *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*. <http://webstore.iec.ch/webstore/webstore.nsf/Artnum_PK/43918>

[IEC 60050-161] IEC 60050-161-Amd. 2 (1999), *International Electrotechnical Vocabulary. Chapter 161: Electromagnetic compatibility*. <http://webstore.iec.ch/webstore/webstore.nsf/ArtNum_PK/22945?OpenDocument>

[IEC 61000-2-5] IEC/TR 61000-2-5 (2011), *Electromagnetic compatibility (EMC) – Part 2-5: Environment – Description and classification of electromagnetic environments*. <http://webstore.iec.ch/webstore/webstore.nsf/ArtNum_PK/45165?OpenDocument>

3 Definitions

3.1 Term defined elsewhere

This Recommendation uses the following term defined elsewhere:

3.1.1 electromagnetic environment [IEC 60050-161]: Totality of electromagnetic phenomena existing at a given location.

NOTE – In general, this totality is time-dependent and its description might need a statistical approach.

3.2 Term defined in this Recommendation

This Recommendation defines the following term:

3.2.1 EM source: The object that may be at the origin of electromagnetic waves.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC	Alternating Current
ASDL	Asymmetric Digital Subscriber Line
ATM	Automatic Teller Machine
CATV	Cable Television
CB	Citizen Band
DC	Direct Current
DVD	Digital Video Disc
EFT/B	Electrical Fast Transients/Bursts
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
FFT	Fast Fourier Transformation
FM	Frequency Modulation
IP	Internet Protocol
ISDN	Integrated Services Digital Networks
ISM	Industrial, Scientific and Medical
ITE	Information Technology Equipment
LAN	Local Access Network
ONU	Optical Network Unit
PC	Personal Computer
PLT	Power Line Telecommunication
PSTN	Public Switched Telephone Network
RADAR	Radio Detection And Ranging
REIN	Repetitive Electrical Impulsive Noise
STB	Set-Top Box
TE	Transverse Electric
TM	Transverse Magnetic
VCR	Video Cassette Recorder
VDSL	Very high speed Digital Subscriber Line
VDU	Visual Display Unit
Wi-Fi	Wireless Fidelity
xDSL	X-type Digital Subscriber Line

5 Home networking environment

5.1 Description of home networking environment

With the recent advances in telecommunication technologies, high-speed access networks, by which users can easily access networks, have been introduced in home environments. As a result, many users can now enjoy many network-based services, and many electronic devices are connected to the network so that home networks can be easily constructed.

On the other hand, there are many wired and wireless technologies that have appeared on the market, and these kinds of technologies could be introduced in a home network environment. In these network configurations, several kinds of network-related equipment are introduced in the home and are set in close proximity to each other.

The home networking environment refers to customer premises (residential location) environments. In accordance with Figure 1, the residential location exists in an area of land designated for the construction of domestic dwellings. The function of a domestic dwelling is to provide a place for one or more people to live in.

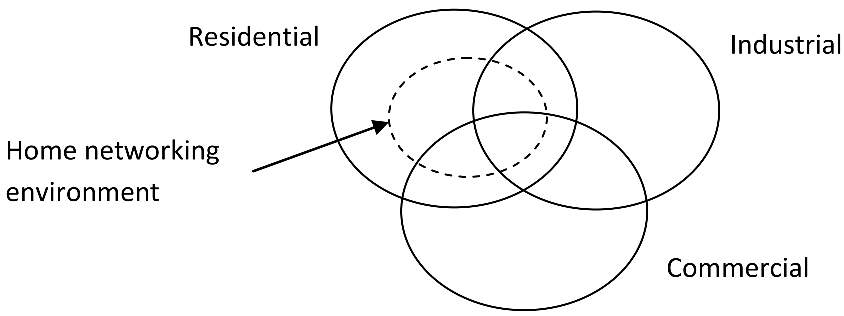

Figure 1 – Concept of location classes

5.2 Equipment installed in the home networking environment

Any equipment within the home networking environment is connected to the telecommunication networks (e.g., public switched telephone networks (PSTNs), integrated services digital networks (ISDN), x-type digital subscriber lines (xDSL), etc.), local area networks (e.g., Ethernet, token ring, etc.) and similar networks.

The home networking environment is characterized by the ad hoc location of telecom, electrical and electronic equipment used by the residents. Equipment items can therefore be placed in very high density. The typical locations include:

- the home office desk, with PC located on/below the desk; VDU, speakers, printer, wireless keyboard and wireless mouse located on the desktop; laptops, portable telephone handset and/or cellular telephone handset located on the desktop, near to or in physical contact with one of the items;
- the 'adolescent's bedroom', which may contain the above described home office desk in addition to a TV set with DVD/VCR and games console. High-density locations typically access the internal low voltage power supply network via a single outlet socket that is fitted with a distribution board/power strip.

A non-exhaustive list of the types of equipment present and operated within the home networking environment is presented below.

1) Home network devices [ITU-T K.74]:
   a) telecommunication devices, such as ONUs, routers, or broadband modems;
   b) controlling devices with telecommunication ports, such as STBs;
   c) information technology equipment (ITE), such as PCs, with telecommunication ports.
2) Multimedia equipment, household equipment and ITE devices operate with home networking devices.

At the boundary of the home networking environment, there is the following wireline infrastructure:

- extension wiring of telecom network;
- coaxial distribution network;
- low-voltage power supply distribution network.

6 Typical phenomena in home networking environment

The typical phenomena in home networking environment are:

a) Conducted low-frequency phenomena:
   – harmonics of the fundamental power frequency;
   – power supply network voltage amplitude and frequency changes;
   – power supply network common-mode voltages;
   – signalling voltages in power supply networks (0.1-3 kHz);
   – induced low-frequency voltages;
   – DC voltage in AC networks;
   – lighting.
b) Radiated low-frequency phenomena:
   – magnetic fields (DC, railway, power system, power system harmonics, etc.);
   – electric fields (DC lines, railway (16 2/3 Hz), power system (50-60Hz)).
c) Conducted high-frequency phenomena:
   – direct-conducted continuous wave;
   – induced continuous wave;
   – transients.
d) Radiated high frequency phenomena:
   – radiated (continuous wave) oscillatory disturbances;
   – radiated (modulated) signal disturbances;
   – radiated (transient) pulsed disturbances.
e) Electrostatic discharge (ESD) phenomena
   – conducted;
   – radiated.

Some of these phenomena may be generated by home networking, such as induced continuous wave. Some of these phenomena are generated by others but may interface with the home networking, such as ESD. The details of these phenomena are described in the basic EMC Recommendation, [ITU-T K.34] and in [IEC 61000-2-5]. In the context of the Recommendation and in accordance with the IEC EMC approach, the term "low frequency" applies to frequencies up to and including 9 kHz; the term "high frequency" applies to frequencies above 9 kHz.

The case studies of the phenomena occurring in home networking environments are collected in Appendix I.

7 Disturbance characteristics and levels

7.1 Attributes of home networking environment

The attributes of the home networking environment are:

Enclosure

– amateur radio further than 100 m;
– citizen band (CB) radio further than 20 m;
– broadcast transmitter operating below 1.6 MHz further than 5km;
– FM and TV transmitters further than 1 km;
– radiated signal from cellular communications systems and portable communication systems (e.g., base stations, hand-held transceivers, mobile phones, wireless phones, Bluetooth, Wi-Fi, etc.);
– paging systems, base stations, further than 1 km;
– aviation RADAR further than 5 km;
– high concentration of multimedia and household equipment;
– presence of microwave oven up to 1.5 kW;
– presence of medical equipment (Group 2 according to [CISPR 11]) further than 20 m;
– proximity to MV/LV substations further than 20 m;
– proximity to arc welders (mobile) further than 20 m;
– proximity to HV sub-stations further than 100 m;
– possible proximity to low power ISM;
– possible presence of audio/hearing aid systems.

AC power

– feeding MV- or HV-line further than 20 m;
– LV AC cabling;
– high concentration of switched mode power supplies;
– existence of PLT equipment;
– lighting.

Signal/control

– telecommunication cables or lines;
– cable TV;
– lines <30 m (this includes: Ethernet, security systems);
– lightning exposure;
– close coupling between signal systems and switched power systems.

Reference

– abundant metallic structures which may or may not be bonded or earthed;
– frequent interfaces of power and telecom (including local) systems;
– local earth can be absent, or present high impedance;
– multiple local earths might not be coordinated.

Additional notes

– interfaces with customer systems;
– HV lines may be routed over buildings.

The attributes from home networking are:

– high concentration of home network devices and many ITE devices, which may be connected into networks (such as LAN);
– high-speed, high-performance and continuously operating home network devices and other devices;
– several telecommunication cables connected with home network devices and other devices;
– switched mode power adapters of home network devices.

7.2 Specification of disturbance characteristics and levels

The disturbance characteristics and levels of the environment of customer premises are described in [ITU-T K.34] and clauses 8.3 and A.1 of [IEC 61000-2-5].

As examples, the characteristics of two phenomena are listed in the following table:

Table 1 – Examples of characteristics of phenomena

Phenomena	Coupling path	Environmental parameter
Electrostatic discharges (ESD)	Enclosure	8 kV In higher humidity environments, lower levels of ESD may occur; [IEC 61000-2-5] specifies 4 kV.
Electrical fast transients/bursts (EFT/B)	Signal line entering the building	Common mode Amplitude 1000 V (peak) Several events/week Rise time 5 µs, impedance 50 Ω
	Signal lines remaining within the building	Common mode Amplitude 1000 V (peak) Several events/week Rise time 5 µs, impedance 50 Ω
	AC power mains	Common mode Amplitude 2000 V (peak) Several events/week Rise time 5 µs
NOTE – The characteristics of the other phenomena are described in [ITU-T K.34] and clauses 8.3 and A.1 of [IEC 61000-2-5].		

8 Guidance on how to evaluate EM characteristics in the home networking environment

8.1 Preparation for the evaluation

8.1.1 Basic records

The basic records could include the following elements:

1) date, time, ambient temperature, humidity and actual positions on which the measurement will be made;
2) the types of home networking devices and their working mode and operation status;
3) the information on the location, e.g., building walls and rooms in the house, the surrounding structures like fencing, trees, radio base stations, electric and electrical installations;
4) the measuring instruments to determine EM levels, e.g., the kind of antenna, current/voltage probes, oscilloscope and spectrum analyser, etc.

8.1.2 Checking before measurement

Before the measurement, the following points could be checked:

(a) Frequency bandwidth for measurement

Measuring instruments and probes have their own frequency bandwidths for measurements, so each one should be selected in accordance with the target EM sources.

(b) Separation of power supply for measuring instruments

Without batteries, some measuring instruments require a commercial power supply, so power supply lines should be separated to avoid EM interferences. One way is to insert an insulation transformer with EMI filters to prevent EMI noise flowing into measuring systems. In addition, some problems like electric shocks caused by the earthing of measuring instruments should be avoided.

(c) Warming-up of measuring instruments

To perform precise and re-producible measurements, measuring instruments should be warmed up. Taking at least 30 minutes to warm up measuring instruments for stable measurements is important.

(d) Site verification and calibration of measuring instruments

It is recommended to perform auto calibrations after the warming-up period, if the measuring instruments have an auto calibration function. To perform precise and re-producible measurements, verifying the measuring instruments at the test site is important and required.

8.1.3 Finding EM sources

The home networking devices, ITE devices, household devices, ISM devices and other electric/electronic devices are EM sources. Before measurement it is important to find the location, check the set-up, cable connection and typical working modes of these EM sources. If there are sources of EM interference in the home networking environment, the procedure described in Appendix II should be used.

8.2 Measurement

8.2.1 Conducted measurement

(1) Measurement on telecommunication cables

When measuring the EM level on telecommunication cables (lines), a noise-cut filter (insulating transformer) should be connected to the power line of the measuring instrument. The EM level on telecommunication lines is generally related to the common-mode (longitudinal mode), in which the noise propagated along the cable is compared to the earth (reference point). If the earthing cannot be set, conductive lines such as water pipes and steel frames of a house can be used. In this case, however, the earthing point should not be changed while measuring.

Here, the EM level measured by current probes corresponds to the common-mode type. When using voltage probes (e.g., high-impedance probe), the common-mode noise on the telecommunication line should be separately measured, such as at L1- and L2-earthing points.

To measure the normal-mode (differential mode/transverse mode) noise in telecommunication cables, the difference between two lines (L1 and L2) is calculated by subtracting measured voltages for L1 and L2. Some oscilloscopes have a differential mode, by which measured results at two channels can be subtracted from each other. To avoid electric shocks and malfunctions of telecommunication systems, normal-mode measurements should not be performed by using only one voltage probe.

(2) Measurement on AC power cable

As in the case for telecommunication lines, a noise-cut filter (the insulating transformer) should be connected to the measuring instrument. In addition, the target signal needs to be measured on the basis of a reference earthing point, and normal-mode noise on AC power lines should not be directly measured by a probe. Common mode noise on power cables can be effectively measured by current probes, but voltage probes can be effective for detecting detailed waveform information. Here, voltage probes should not be directly inserted into electric sockets to avoid electric shocks and short circuits (e.g., the common mode AC power voltage can be effectively measured via the power distribution transformer). It is necessary to check carefully which terminal voltage corresponds to the earthing and then select sensitivity of voltage probes such as 10:1 or 100:1. If there are EMI problems in the power systems, distortion waveforms are observed in common-mode noise measured at power cables.

8.2.2 Radiated measurement

A noise-cut filter should be set to the measuring instruments. For radiated measurement, the measuring instruments and sensors (EMI antenna, or EM-field sensor) should be selected according to the type of EM sources and their frequency range. In addition, the set-up points, heights, and distances from the noise sources to EMI antennas should also be checked.

Because many EMI sensors for measuring radiated fields have directional patterns, the direction and the mode of electromagnetic waves (transverse magnetic, TM, or transverse electric, TE, wave modes) for measurement should be checked. It is recommended to measure vertical and horizontal components of radiated fields and then to check the compound value derived from two components to perform accurate evaluations.

8.3 Monitoring of the EM environment

8.3.1 Monitoring of power frequency electromagnetic fields

To monitor the strength of power frequency electromagnetic fields, the power frequency field strength meter could be used. With those strength meters, the electric field as well as the magnetic field can be measured. The distribution of monitoring sites should be set on the direction of electric or magnetic field. People conducting the measurements should be more than 2 m away from the EM sources to avoid electromagnetic field distortion.

8.3.2 Monitoring of radio frequency electromagnetic fields

The radio frequency field generally refers to the electromagnetic field above 9 kHz. When monitoring RF fields, the following points should be taken into consideration.

(1) Select the appropriate measuring instruments

To obtain a strict assessment of the EM environment, it is recommended to use the broadband field probes and the frequency-selective field probes simultaneously. The broadband probe provides an independent measurement of the frequency, which integrates all of the emissions in a desired frequency band. A broadband probe that covers the band of interest should be used. This probe should be isotropic and the isotropic deviation should be less than 2.5 dB for frequencies up to 3 GHz, and less than 3.5 dB for frequencies up to 6 GHz. Each one of the three field components should be measured at the same time in order to have a correct total field result. Besides, the probe should have a dynamic range adapted to the measurement levels.

The purpose of using the frequency-selective field probes is to identify the contribution of each EM source and the impact of each EM source on the EM environment.

(2) Calibrate monitoring instruments in time

Measuring probes and instruments without calibration cannot be used to monitor the EM environment.

(3) Select the probe or antenna correctly according to the frequency band of the EM sources

The selection of broadband measuring probe is required to be in accordance with the frequency band. The frequency range of the measuring instruments should be sufficient to cover the frequencies of the EM field sources to be measured. To obtain an accurate measurement result, the monitoring frequency band of EM sources should be placed in the middle band portion of the probe.

For the frequency-selective measurement, the choice of the antenna becomes very important. Generally, in the range from 150 kHz to 30 MHz the electric fields are measured, using an active rod antenna. In the range from 30 MHz to 300 MHz, the electric field is also measured, but using the half-wave element antenna or log-periodic antenna, with the length of the element appropriately adjusted to make it equal to half-wavelength of the measured electromagnetic waves. In the range from 300 MHz to 1 GHz, generally a log-periodic antenna is used. Above 1 GHz a double ridge waveguide horn antenna is recommended.

(4) Pay attention to the polarization of electromagnetic fields during monitoring

Generally, the transmission of television signals use horizontal polarization; the transmission of radio broadcasting communications signals use vertical polarization; and the radar and satellite earth stations use circular polarization or elliptical polarization. The measuring antenna should be placed with the same polarization. For circular or elliptical polarization measurement of the vertical and horizontal components is needed, and sometimes measurement at different angles.

(5) Calibration of measuring instruments and probes

In general, new instruments can automatically be adjusted to zero but some old instruments need to be adjusted to zero manually before the measurement.

When the measurement is completed, the antenna calibration curve or calibration data, and all kinds of loss should be corrected.

(6) Distribution of test sites

When monitoring the omnidirectional radiation sources, select the sites on the direction and distance where large differences on the measurement environment existed; when monitoring the directional sources, select a number of points in the direction of maximum radiation. The measurement distances depend on the requirement of the monitoring standards. But in exceptional circumstances, measurement distances should be adjusted according to the local conditions.

(7) Selection of the monitoring time

Radio and television facilities are basically transmitting on the same power frequency. So the monitoring time can be selected in the morning, in the afternoon and in the evening for television facilities. For radio communication facilities, the monitoring time should be selected at the peak time of the communication.

(8) Environmental conditions should meet the provisions of the standard

If the environmental conditions cannot meet the provisions of the standard, it should be recorded on the report, along with a full estimate of the impact of environmental conditions.

(9) Distance and height should be confirmed

The relative distance and height from monitoring points to the target EM sources are two very important factors.

8.4 Analysis and mitigation

8.4.1 Analysis of measured signal

When performing time-domain measurements, the obtained signals provide effective information for discriminating EM sources and their effects on electrical equipment. Namely, by checking the amplitude, energy and duration of the obtained signal, the EM level and kinds of EM sources could be determined. The time-frequency transformation, such as FFT, gives qualitative information for discriminating the kinds of EM sources. However, it should be noted that original waveforms are often distorted, especially when the target EM signals are transient- or pulse-type; e.g., oscillations may be generated when the EMI noise is induced in the cables. Distortions due to EMI sensors may be observed.

When performing frequency-domain measurements, the obtained signals also provide effective information for discriminating the kinds of EM sources and their effects on electrical equipment. Namely, by checking the amplitude, energy and resonance frequency, the EM level and kinds of EM sources could be effectively determined. Wireless-related signals generally generate higher harmonic components, so the maximum level of several resonance frequencies should be checked when identifying the kinds of EM sources.

8.4.2 Evaluating the EM environment and clarifying EMI sources

Evaluating measurement results is an important part of solving EMI. The following points should be taken into account in order to distinguish EMI sources.

1) The level and frequency of the conducted and radiated emissions should be checked. Comparison between measured data and other related information is useful to find the trouble source. Items to be compared with the data are:
   - immunity level with which the equipment complies;
   - specifications of suspected equipment, such as clock or switching frequencies, and transmission rate.
2) The relationship between the trouble and the disturbances should be checked. The timing of the occurrences of disturbances and trouble is an important factor in distinguishing trouble sources. Items to be considered are:
   - occurrence time, such as hour, duration and day of week;
   - synchronization between disturbance and trouble;
   - other information, such as the installation of new equipment, new construction, and power failures.

8.4.3 Mitigation techniques

For detailed mitigation techniques, see [ITU-T K.37].

8.5 Evaluation report

The evaluation report should include all test conditions and results together with the methods of measurement used. Included items in the report should be:

a) information from basic records;
b) frequency bandwidth for measurement;
c) instruments used;
d) site verification results;
e) EM sources position and cable layout;
f) measurement results of frequency and level;
g) analysis of measured signal;
h) evaluation results and conclusions;
i) mitigation information.

Appendix I

Case studies in home networking environments

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

I.1 Checklist of case studies

The case studies in this appendix are listed in Table I.1.

Table I.1 – Checklist of case studies

Title of study case	Victim	Phenomena	Disturbing source	Detail table number
CATV interfered with by land mobile radio services	CATV	Radiated emission	Radio service on a taxi	Table I.4
VDSL interfered with by a defective water feed pump	VDSL	Impulsive noise	Defective water feed pump	Table I.5
Network trouble of wide area Ethernet caused by impulsive noise	Media converter of ATM online system	Impulsive noise	Elevator, room light	Table I.6
xDSL disturbances in telecommunication networks caused by electrical equipment	xDSL devices	Crosstalk noise	Satellite receivers, AC-DC-adapter	Table I.7

Table I.2 shows the case studies related to impulsive noise described in [ITU-T K.74].

Table I.2 – Case studies from [ITU-T K.74]

Title of study case	Victim	Phenomena	Disturbing source	Notes
Example of a problem in home networks – trouble for IPTV broadcasting service over DSL	TV over DSL	Impulsive noise	–	Appendix I of [ITU-T K.74]
Example of a problem in home networks – degradation of performance of ADSL service caused by REIN	ADSL	Repetitive electrical impulsive noise (REIN)	Switch power supply	Appendix II of [ITU-T K.74] During the EMC test, downlink performance of ADSL can be degraded when the cable carrying ADSL service is moved towards the switch power unit

Table I.2 – Case studies from [ITU-T K.74]

Title of study case	Victim	Phenomena	Disturbing source	Notes
Example of a problem in home networks – trouble in a wide area Ethernet network caused by impulsive noise	Media converter of ATM online system	Impulsive noise	Elevator, room light	Appendix III of [ITU-T K.74] As the AC power line of the room light was running in parallel with the communication line, the impulsive noise was inducted onto the communication line and came into the media converter. This room is an ATM booth in a shopping mall, and the network equipment could not be bonded to the earth conductor

I.2 Template for case studies

The following template may be used for collecting information of case studies in the home networking environment.

Table I.3 – Template of the information table for case studies

Title					
Sort of trouble		Acoustic noise, malfunction, disturbance, other ( )			
		More detail:			
Environment	Type	1. Co-location 2. User building (used by one user/used by multiple users) 3. Detached house 4. Semi-detached house			
	Use	1. Telecom centre 2. Data centre 3. Office 4. Residence 5. Others ( )			
Situation, configuration, measured data, etc. (Please add figures, if necessary.)					
Source of EM interference					
Type of the interference		Characteristics of the interferences			
		Type	Frequency (band)	Level	Others
Conducted	Voltage or current	Continuous	Hz	[ ]	
		Impulsive	Hz	[ ]	
Radiated	Electromagnetic wave (field)	Continuous	Hz	[ ]	
		Impulsive	Hz	[ ]	

I.3 Case studies

I.3.1 CATV interfered with by land mobile radio services

The information of this case study is collected in the Table I.4.

Table I.4 – CATV interfered with by land mobile radio services

<table>
<tr><td colspan="2">Title</td><td colspan="4">CATV interfered by land mobile radio services</td></tr>
<tr><td colspan="2" rowspan="2">Sort of trouble</td><td colspan="4">Disturbance</td></tr>
<tr><td colspan="4">More detail: radiated</td></tr>
<tr><td rowspan="2">Environment</td><td>Type</td><td colspan="4">Co-location</td></tr>
<tr><td>Use</td><td colspan="4">Residence</td></tr>
<tr><td colspan="6">Situation, configuration, measured data, etc. (Please add figures, if necessary.)</td></tr>
<tr><td colspan="6">Situation: RF leakages from CATV splitters cause interference with land mobile radio services. This has occurred when a taxi has been stopping nearby a tension pole on which a CATV splitter is mounted.
Configuration:
RF leakage from CATV: 447.246 MHz (–115 dB)
Taxi: 447.250 MHz (–117 dB)
Measurement set-up:
Distance = 10 m
Half-wave dipole antenna: V/H polarization
Receiver: detector = QP; resolution BW = 1 kHz</td></tr>
<tr><td colspan="2">Source of EM interference</td><td colspan="4">Land mobile radio service on the taxi</td></tr>
<tr><td colspan="2" rowspan="2">Type of the interference</td><td colspan="4">Characteristics of the interferences</td></tr>
<tr><td>Type</td><td>Frequency (band)</td><td>Level</td><td>Others</td></tr>
<tr><td rowspan="2">Conducted</td><td rowspan="2">Voltage or current</td><td>Continuous</td><td>447.246 MHz</td><td>–115 dB</td><td></td></tr>
<tr><td>Impulsive</td><td>Hz</td><td>[ ]</td><td></td></tr>
<tr><td rowspan="2">Radiated</td><td rowspan="2">Electromagnetic wave (field)</td><td>Continuous</td><td>447.250 MHz</td><td>–117 dB</td><td></td></tr>
<tr><td>Impulsive</td><td>Hz</td><td>[ ]</td><td></td></tr>
</table>

I.3.2 VDSL interfered with by a defective water feed pump

The information of this case study is collected in Table I.5.

Table I.5 – VDSL interfered with by a defective water feed pump

<table>
<tr><td colspan="2">Title</td><td>VDSL interfered by the defective water feed pump</td></tr>
<tr><td colspan="2" rowspan="2">Sort of trouble</td><td>Malfunction</td></tr>
<tr><td>More detail: EMC problem occurred only when the defective feed pump was started or stopped</td></tr>
<tr><td rowspan="2">Environment</td><td>Type</td><td>User building (used by multiple users)</td></tr>
<tr><td>Use</td><td>Residence</td></tr>
<tr><td colspan="3">Situation, configuration, measured data, etc. (Please add figures, if necessary.)</td></tr>
<tr><td colspan="3">Figure I.1 shows the set-up of the VDSL system in the case of some cluster housing. The EMC problem was that the link between the VTU-O and the VTU-R was occasionally disconnected by a broadband impulsive conducted disturbance caused by the defective water feed pump.</td></tr>
</table>

Table I.5 – VDSL interfered with by a defective water feed pump

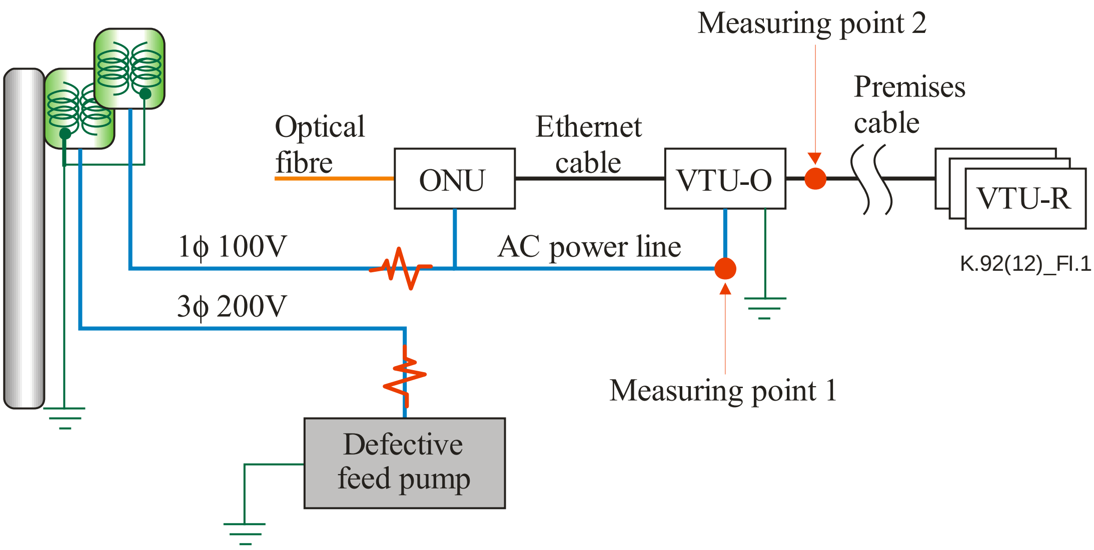

Figure I.1 – The set-up of a VDSL system in cluster housing

Source of EM interference		The defective water feed pump			
Type of the interference		Characteristics of the interferences			
		Type	Frequency (band)	Level	Others
Conducted	Voltage or current	Continuous	Hz	[ ]	
		Impulsive	Below and over 1 MHz	33 Vp-p	
Radiated	Electromagnetic wave (field)	Continuous	Hz	[ ]	
		Impulsive	Hz	[ ]	

As this EMC problem occurred only when the defective feed pump was started or stopped, the common-mode voltages of the electromagnetic disturbance were measured at two measuring points. The first measuring point was the AC power port of the VTU-O and second measuring point was the telecommunication port of the VTU-O. The broadband impulsive conducted disturbance at both the AC power and telecommunication ports of the VTU-O (measuring points 1 and 2) was seen to be coincident with the operation of the defective feed pump, as shown in Figure I.2.

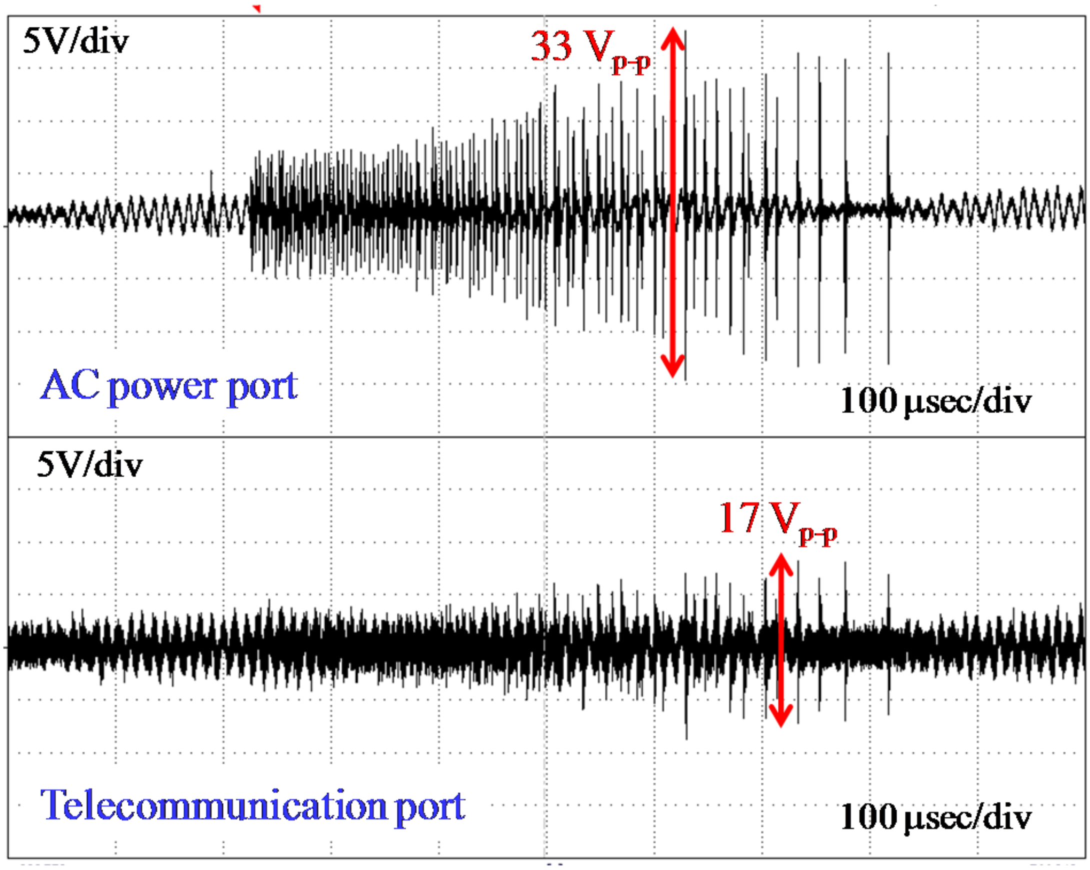

Figure I.2 – A broadband impulsive conducted disturbance at the AC power and telecommunication ports

Figure I.3 shows the FFT analysis result for the measured broadband impulsive conducted disturbance and the VDSL transmission signal at the telecommunication port of the VTU-O (measuring point 2). The measured broadband impulsive conducted disturbance has high-frequency components over 1 MHz, as with the VDSL transmission signal.

Although most of the broadband impulsive conducted disturbances which can affect the performance of broadband telecommunication equipment may be electromagnetic disturbances caused by the defective electrical devices, these may have a wider bandwidth than the DSL transmission signal. Moreover, as it is difficult to identify the source of a disturbance and the responsibility of the EMC trouble caused by it may not be understood by costumers, the performance of DSL equipment against broadband impulsive conducted disturbances should be evaluated using electromagnetic disturbances that have a wider bandwidth than the DSL transmission bandwidth.

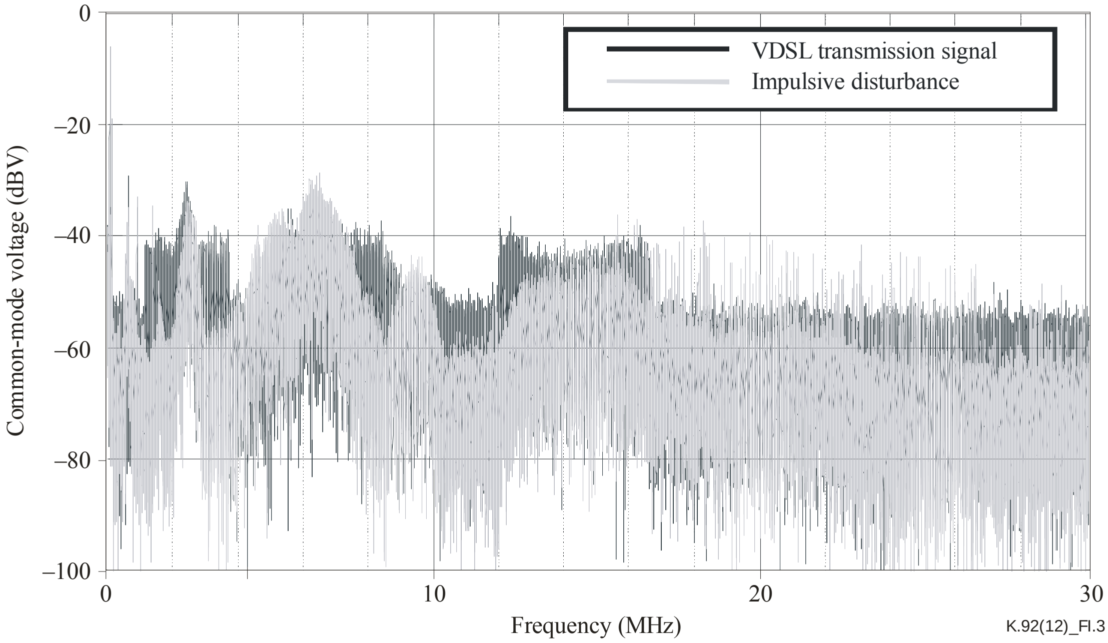

Figure I.3 – FFT analysis result for the measured broadband impulsive conducted disturbance and the VDSL transmission signal at the telecommunication port of the VTU-O

I.3.3 Network trouble of wide area Ethernet caused by impulsive noise

The information of this case study is collected in Table I.6.

Table I.6 – Network trouble of wide area Ethernet caused by impulsive noise

Title		Network trouble of wide area Ethernet caused by impulsive noise
Sort of trouble		Disturbance
		More detail: impulsive noise
Environment	Type	Co-location
	Use	Office, shopping mall
Situation, configuration, measured data, etc. (Please add figures, if necessary.)		
Figure I.4 shows the configuration of an ATM online system. The network has a redundancy configuration, and consisted of a wide area Ethernet (main) and an integrated service digital network (ISDN). The trouble was that the wide area Ethernet could not hold the link in the data transfer state and the main line was changed to the ISDN line. The trouble occurred when the media converter had a malfunction caused by the impulsive noise conducted through the AC power line.		

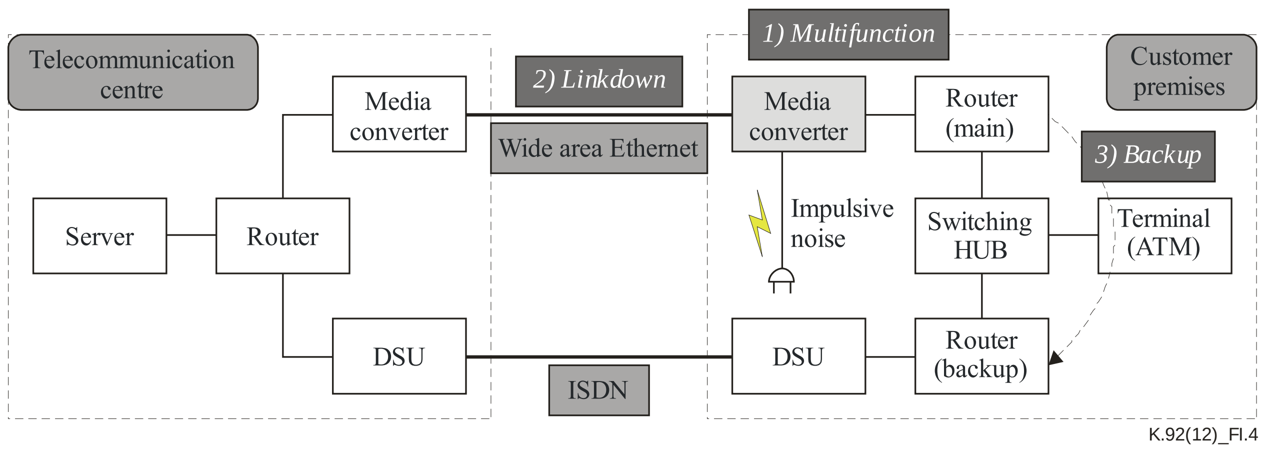

Table I.6 – Network trouble of wide area Ethernet caused by impulsive noise

<table>
<tr><th colspan="6">Figure I.4 – The configuration of the ATM online system when network trouble occurred</th></tr>
<tr><td colspan="2">Source of EM interference</td><td colspan="4">Elevator and room light</td></tr>
<tr><td colspan="2" rowspan="2">Type of the interference</td><td colspan="4">Characteristics of the interferences</td></tr>
<tr><td>Type</td><td>Frequency (band)</td><td>Level</td><td>Others</td></tr>
<tr><td rowspan="2">Conducted</td><td rowspan="2">Voltage or current</td><td>Continuous</td><td>Hz</td><td>[ ]</td><td></td></tr>
<tr><td>Impulsive</td><td>1-10 kHz</td><td>12 mA (Figure I.5)
2.8 KVp-p (Figure I.6)</td><td></td></tr>
</table>

Figure I.5 shows the impulsive noise measured by an oscilloscope at the AC power line of the media converter. The noise was generated in sync with the operation of an elevator.

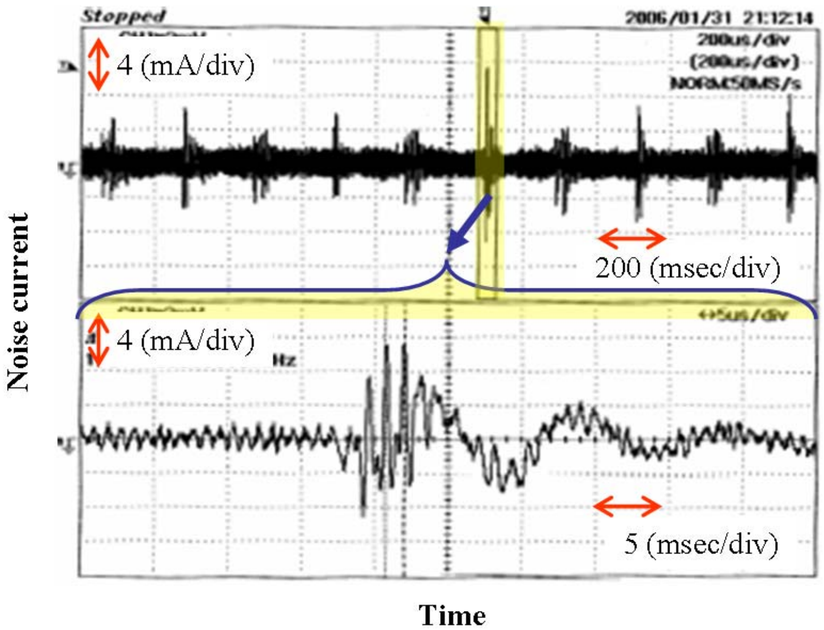

Figure I.5 – Noise current measured during elevator operation

Figure I.6 shows the impulsive noise measured at the AC power line of a room light when turned on/off. As the AC power line of the room light was in parallel with the communication line, the impulsive noise was induced in the communication line and came into the media converter. This room is an ATM booth in a shopping mall, and the network equipment could not be bonded to the earth conductor.

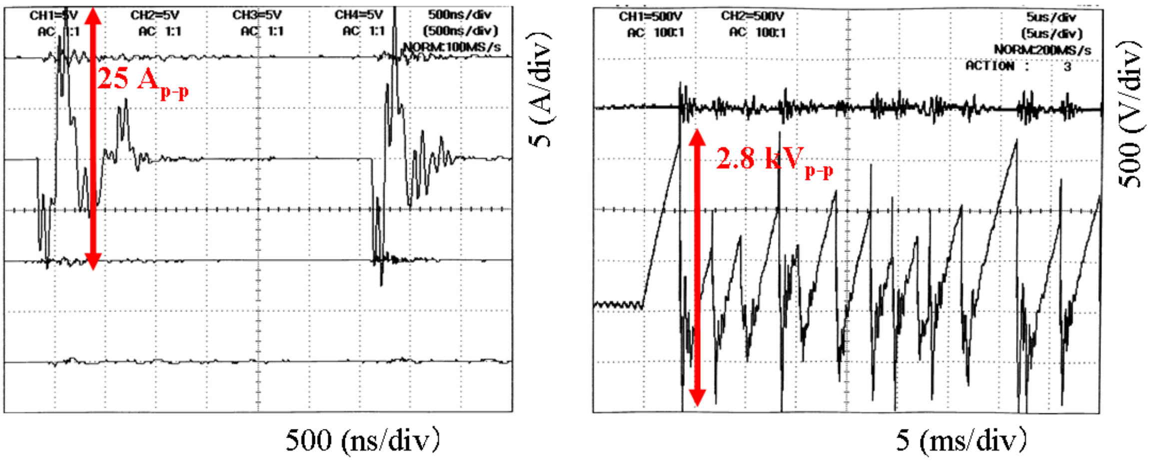

Figure I.6 – Noise current and voltage measured when room light turned on/off

I.3.4 xDSL disturbances in telecommunication networks caused by electrical equipment

The information of this case study is collected in Table I.7.

Table I.7 – xDSL disturbed by electrical equipment

Title		xDSL disturbances in telecommunication networks caused by electrical equipment
Sort of trouble		Disturbance
		More detail: common mode disturbances on the AC mains network to the telecommunication wiring
Environment	Type	User building
	Use	Residence
Situation, configuration, measured data, etc. (Please add figures, if necessary.)		
Typical for DSL problems due to extremely high emissions from household appliances are: significant reduction of the DSL performance or complete loss of connection for several subscribers in the vicinity of the interfering source; interference to radio services in the medium- and short-wave frequency range. **Disturbing sources** The service personal mostly identifies defective switching power supplies as cause of the described DSL problems. These power supplies apparently work as intended but emit permanently a broadband noise spectrum on the AC power line (comparable to REIN). Figure I.7 provides an example of the measurement result of the conducted emission (frequency domain) of such an interfering device that vastly exceeds the limits of [b-CISPR 22] for the AC ports.		

Table I.7 – xDSL disturbed by electrical equipment

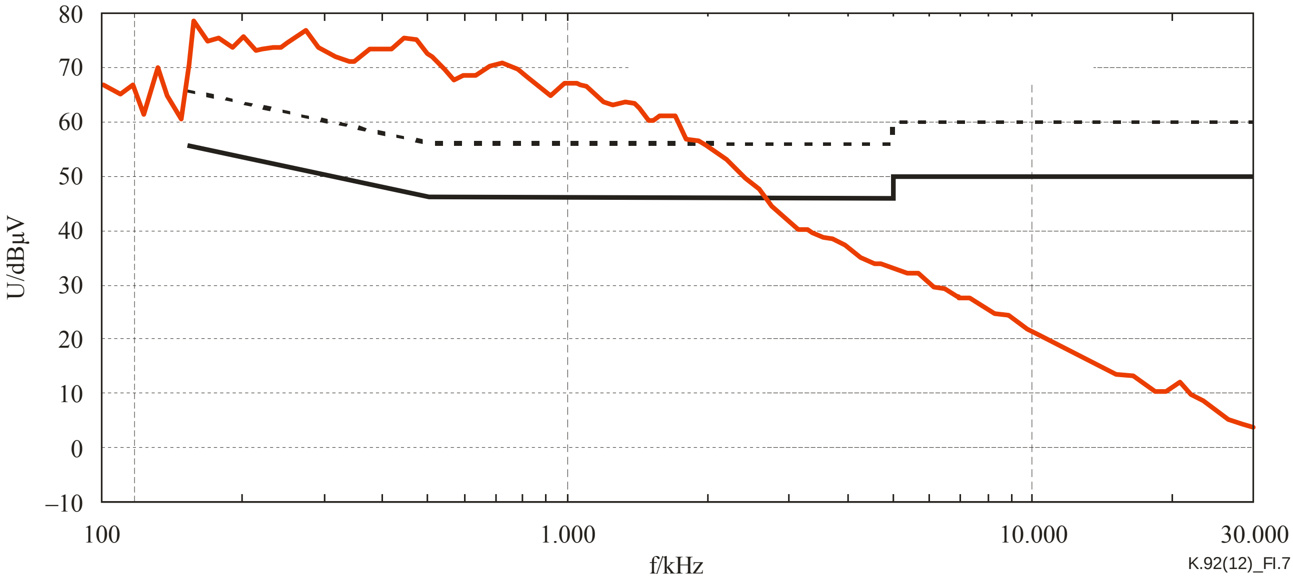

Figure I.7 – Example of the conducted emission measured on the AC port of an interfering device (average detector, class B limits)

Source of EM interference		Satellite receivers, followed by AC-DC adapter			
Type of the interference		Characteristics of the interferences			
		Type	Frequency (band)	Level	Others
Conducted	Voltage or current	Continuous	Below 5 MHz	70 dBµV	
		Impulsive	Hz	[ ]	

Coupling paths to the telecommunication network and propagation

Several paths for the coupling of the common mode disturbances on the AC mains network to the telecommunication wiring inside a building can exist. Two possible paths are shown in Figure I.8 schematically: (left) the common mode field coupling in a cable section where AC and telecommunication lines are close to each other (e.g., in cable ducts), and (right) the coupling within telecom devices (via stray capacitances and inductances, etc.).

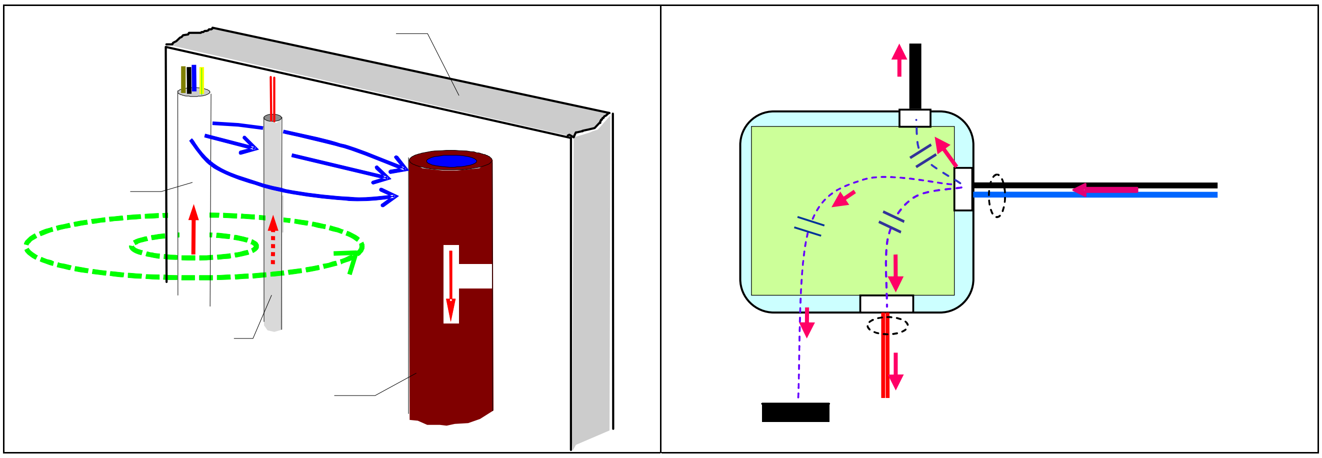

Figure I.8 – Coupling of common mode voltages and currents on the mains lines to the telecommunication wiring in buildings: field coupling (left) and coupling via telecom device

The coupled common mode signal on the telecommunication cable is converted into differential mode due to the limited balance of the wire-pairs inside the cable (mode conversion). These differential mode signals on the wire-pairs propagate and interfere with DSL signals if they cover the same frequency range.

Appendix II

Evaluation of the EM environment in home networking

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

It is important to evaluate the EM environment to solve the problem of interference. Methodologies for measuring the EM environment are described in clause 8 of this Recommendation. Involved parties should measure the EM environment in the place where the problem occurred. Both conducted and radiated electromagnetic environments should be taken into account. Also, in some cases, an EM disturbance may come from outside the place where the problem occurred. Hence, measurement should be performed not only in the place where the problem has occurred, but also in the vicinity of that place.

When problems of telecom equipment occur, many causes could be considered. EMI is one of the possible causes, but other possible causes should be checked; for example, a hardware malfunction, protocol problems and software glitches. After other possible causes have been ruled out, and EMI is suspected as a cause of the problem, compliance with the EMC requirements of both suspected and affected equipment should be checked.

II.1 Methods for finding EM sources in actual environments

When the cause of EMI problems cannot be clarified by an on-site investigation, one effective way to find EMI sources is to set EMI devices and sensors near the EMI-affected equipment.

If the EMI-affected equipment can emit alarm signals for indicating operating problems, the time of those signals should be simultaneously recorded. Because the alarm signal is emitted after some time, it is not recommended to use the alarm signal as a trigger signal for measuring noise. Here, if the target EMI source is wireless generated, it may continue for more than several seconds, so the alarm signal may be used as a trigger signal for the measuring instruments. On the other hand, the alarm signal can be used as a trigger signal for judging the log of EMI noise that is detected before the output of it.

When setting EMI-measuring systems, the following needs to be selected: sensing method (time- or frequency-domain), the range of frequency, the trigger level of target signal, etc. If the cause of EMI problems is estimated due to transient noise, time-domain measurement using oscilloscopes is recommended. If the cause of EMI problems seems to be due to wireless-related stationary or quasi-stationary sources, frequency-domain-based measurement using spectrum analysers, which generally have wideband and wide-dynamic ranges, is recommended. Some spectrum analysers allow the setting of a trigger line in the frequency domain, and the alarm signal from electrical equipment can be a trigger to start measurement.

One difficulty in using a measuring system in actual environments is the setting of the measurement conditions. Namely, it is often difficult to estimate the level, frequency range, and duration of EMI noises beforehand. The receiving input range, trigger level, sampling time, buffer-length, etc., can be used as selective parameters for an oscilloscope, and the receiving input range, trigger level, frequency range, etc., can be used as selective parameters for a spectrum analyser. Here, the dead time for measuring systems tends to increase, if the buffer length of oscilloscopes, or the sweep times of spectrum analysers is increased.

In storing detected data, time information (detection time) should also be stored to investigate the cause of EMI problems. Data transmission via networks can also be effective for checking the environment without having to go to the location.

When setting up an EMI measuring system in a real environment, the electric power level should be checked to avoid unexpected power problems. In addition, E/O or O/E converters can be used when the cable connecting sensors and measuring instruments become too long (e.g., the measurements for lightning surges in real environments).

II.2 Flow chart for solving EMI problems of home networking equipment

A flow chart for solving EMI problems of home networking equipment is shown in Figure II.1.

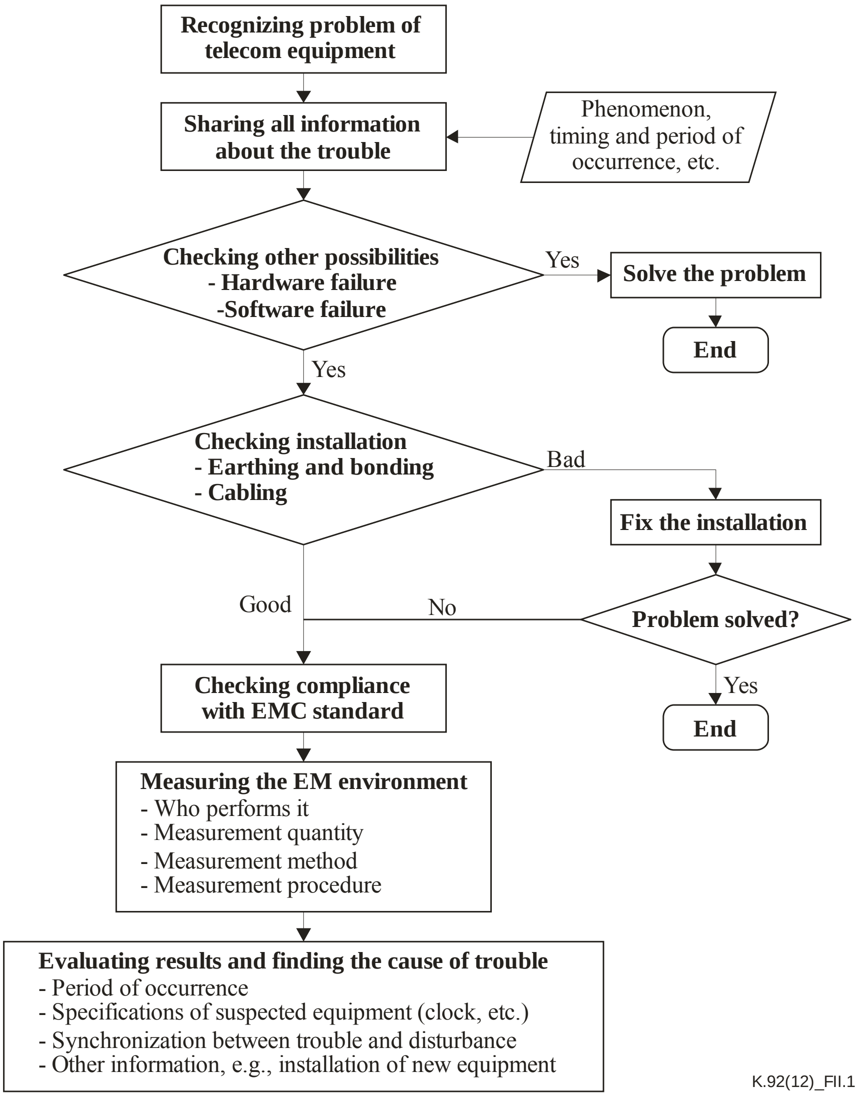

Figure II.1 – Flow chart for solving EMI problems of home networking equipment

Bibliography

[b-CISPR 22] CISPR 22:2008, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*.

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