International Telecommunication Union

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Radiocommunication Sector of ITU

Report ITU-R SM.2157

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MEASUREMENT METHODS FOR POWER LINE HIGH DATA RATE TELECOMMUNICATION SYSTEMS

SM Series

Spectrum management

International Telecommunication Union

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REPORT ITU-R SM.2157

Measurement methods for power line high data rate telecommunication systems

(Question ITU-R 218/1)

(2009)

Summary

There is an increasing demand for and use of broadband access to the Internet throughout the world. Power line telecommunication systems may provide one means of such access. Such systems are unintentional emitters of RF radiation, and such unintentional emission may cause interference to radiocommunication receivers. The interference coupling path to victim receivers may be by means of radiated emissions, or may be by means of conducted emissions.

Some administrations have already adopted or are developing methods or procedures for measuring either the radiated emissions or the conducted emissions from power line telecommunication systems, or both. This report is a compilation of those methods and procedures. See Annexes 1 to 6.

Other administrations are in the process of evaluating such measurement methods. Those administrations may wish to consider the methods described in the annexes to this Report.

In addition, the International Special Committee on Radio Interference (CISPR), which develops limits and methods of measurement for radio frequency disturbances originating from various types of sources, also has work underway on measurement methods for conducted emissions from power line telecommunication systems.

1 Unintentional emissions from PLT systems

PLT modems are designed to communicate with each other by transmitting and receiving signals through power lines. Therefore, in general, the signal power is concentrated in the vicinity of two wires of the power line. However, if the two wires are not well-balanced, the signal power may leak from the power line in the form of radiated emission. Imbalance of the power lines is caused by various loads connected to the lines, such as electrical or electronic devices, and many branch lines connected in parallel with backbone power lines, such as circuits of lamps with their switches. In addition, branch lines may cause resonance at certain frequencies, resulting in unbalanced signal currents in the lines. Thus, radiated emission from power lines may be caused by imbalance of the signal currents flowing in the PLT system, including factors such as the PLT modems, layout of the power lines, and varying loads. The imbalance currents in a PLT system may vary with time and frequency. Accordingly, radiated emission levels from a PLT system depend primarily on the signal power of PLT modems, but may change extensively with time, frequency and location (and possibly other factors such as reflective objects that are nearby to the power lines).

2 Measurements on the PLT emissions

There are two different categories of measurements of PLT emissions: radiated emission measurement and conducted emission measurement.

2.1 Radiated emission measurement

Electromagnetic fields radiated from a PLT system are usually measured along the power lines or outside the house equipped with PLT systems. In general, field-strength measurement results strongly depend on the measurement distance and direction from radiating sources, and the polarization and height of an antenna being used. In the HF band, either a loop antenna or a monopole antenna is used for measuring the magnetic field or electric field, respectively.

However, it is difficult to mutually convert the measurement data between the magnetic field strength and the electric field strength, especially at a distance less than about $\lambda/2\pi$, because a conversion factor of 377 Ω may not be applicable.

Radiated emission measurements are usually conducted *in situ* where interference to radio services may occur. However, as described in the previous section, it should be noted that the results may vary with time, frequency, and location.

To minimize the likelihood that PLT systems will cause interference, radiated emission measurements are required by regulations and standards as shown in Annexes 1 (ITU-T), 2 (United States of America), and 3 (Germany). Annex 4 describes work underway (in Brazil) to correlate radiated measurements that are made with different antenna types. Key factors for the radiated emission measurement are the characteristics of a measuring receiver and the antenna being used (as discussed in Annexes 3 and 4). In addition, the measurement distance, antenna height, and influence of reflecting objects that may be nearby to measurement positions are also important. Annex 6 contains the methods used by the Communications Research Centre to carry out measurements of both radiated and conducted RF emissions from PLT devices operating in a residential environment. The results of these measurements can be found in Report ITU-R SM.2158.

2.2 Conducted emission measurement

In contrast to the radiated emission measurement, the conducted emission measurement may be employed in the equipment authorization test.

As described in § 2.1, unintentional radiation from a PLT system originates from the imbalance (common mode) currents that are transformed from the balanced (differential mode) signal currents due to imbalance and resonance of the PLT system. Therefore, measurements are made on the balance and imbalance components of the signal voltage or current conducted on the power line. In actual situations, however, measurement data may be spread in an extremely wide range, because imbalance in PLT modems, power lines, and connected equipment greatly varies with time and frequency as well as layouts and nearby objects to the power lines. Accordingly, in compliance tests of the PLT modem, a network called an "impedance stabilization network (ISN)," is usually used to simulate representative characteristics of actual power line conditions.

To control interference potential of other kinds of electrical/electronic equipment, such as personal computers and household appliances, conducted emission measurements are always requested to show compliance with relevant limits by various standards such as CISPR standards, especially in the frequency range below 30 MHz. In the same way, conducted emission measurements can be applied to PLT modems for equipment authorization tests. Annex 5 (Japan) requests measurements of the common mode signal currents flowing out of a modem under test when it is connected to an ISN. Since the ISN characteristics are strictly specified as a fixed load to the modem, the differential mode signal currents are also restricted by the limits for the common mode currents. Key factors to the conducted emission measurement are the characteristics of a measuring receiver and an ISN being used.

Protection requirements for radiocommunication services have to take account of the level of RF energy radiated from PLT systems into free space as well as conducted emissions from PLT systems sharing common electrical power circuits with receiving equipment. However, there is not a well-defined correspondence between the RF energy radiated by PLT systems and the values of conducted current measured at the outlets of PLT systems, or the power delivered to power lines by

PLT modems. This Report includes a method for measuring conducted emissions, but does not consider whether conducted emissions or radiated emissions should be used for regulating PLT.

2.3 Other relevant ITU-R texts

Recommendation ITU-R SM.1753 – Method for measurements of radio noise.

Recommendation ITU-R P.372-9 – Radio Noise.

Report ITU-R SM.2055 – Radio noise measurements.

Report ITU-R SM.2155 – Man-made noise measurements in the HF range.

Annex 1

Disturbance emission measurements from ITU-T Recommendation K.60[1]

A1.1 General

In order to get the highest readings of disturbance emissions, it should be ensured that the part of the telecommunication network being assessed operates at the maximum signal levels for this site and in the mode previously identified as resulting in maximum RF disturbance field strength. If the system is interactive, it will be important to check for the presence of the reverse path (upstream) signals if these are in the same frequency range as reported in the complaint(s).

Indoor measurements are particularly subjected to uncertainties due to reflections or unknown cable routes for example. It is important to carefully search for the maximum emission and take into account possible influence factors.

Although the measurement of the radiated field has the drawbacks of a relatively high measurement uncertainty and positioning difficulties, this method is applicable both indoor and outdoor. In addition, when performing indoor measurement, a particular attention to reflections has to be drawn. In certain cases, the field intensity may be double that of the calculated value.

A1.2 Normalization of measurement results to the standard measurement distance

Local restrictions in space (appearing e.g. during indoor measurements) can require a reduction of the measuring distance to less than the standard measurement distance. The measurement distance chosen will be as large as possible, but not closer than 1 m. In case of outdoor measurements, it may also be necessary to use a measurement distance which is larger than the standard distance.

If a measurement distance greater or smaller than the standard measurement distance needs to be used, then three different and accessible measuring points located along the measuring axis will be chosen. The distance between these points should be as large as possible. At each point, the level of the disturbing field strength has to be measured. The local conditions and measurability of the disturbance field strength will be the determining factors.

[1] The purpose of this Recommendation is to guide administrations when considering complaints of interference between telecommunication systems and is not intended to set compliance requirements or recommendations for protecting the radio spectrum.

The measurement results will then be plotted in a diagram showing the field strength level (dB(µV/m)) versus the logarithm of the measurement distance. The line interconnecting the measurement results represents the slope in field strength along the measuring axis. If this slope cannot be determined, then additional measuring points have to be chosen. The field strength level at the standard measurement distance can be read from the diagram using the straight prolongation of the interconnecting line.

Normalization of measurement results is not permitted if, at the measurement location, the true distance to the telecommunication network cable is not known.

A1.3 Disturbance emission measurements in the frequency range 9 kHz to 30 MHz

A1.3.1 Introduction

In the frequency range 9 kHz to 30 MHz, the magnetic component of the radiated disturbance emission has to be measured and assessed.

A calibrated measuring system, in accordance with CISPR 16-1-1, consisting of a radio disturbance measuring receiver (or a suitable spectrum analyser), in conjunction with an associated loop antenna for the measurement of magnetic field components, and a tripod are required.

Other specialized equipment such as resonant loop antennas can also be used, if necessary.

In order to speed up the measurement, a peak detector has first to be used. If the background noise makes this simple measurement unusable, a quasi-peak detector will be used and the quasi-peak level applied.

It is recommended that both the measuring receiver and the loop antenna have an independent power source with no ground connection (e.g. battery power), particularly in case of indoor measurements, in order to minimize the possibility of current loops via earth that could affect the measurement.

A1.3.2 Measurement procedure

The loop antenna will be mounted on a tripod at a height of 1 m (at the lower edge of the loop) and allocated at the measurement location previously identified as having the maximum disturbance field strength so that it is at the standard measurement distance.

Set the measuring receiver to the frequency carrying the disturbance and type of detector required, and position the loop antenna so that the maximum reading is obtained.

The measurement of magnetic fields radiated from telecommunication networks in the frequency range up to 30 MHz may become complicated due to the presence of a variety of high-level wanted RF emissions from radio services. In view of this, it may be necessary to identify some frequencies (hereafter described as “quiet frequencies”) allocated close to the frequency of the radio service being affected, with low field strengths such that the background noise and any ambient signals are below the applicable limit. Where possible, this margin should be greater than 6 dB. This should be done without altering the antenna position, and ideally with the telecommunication network switched off.

If the network cannot be switched off, then the following alternative may be used:

– Orientate the loop antenna for minimum coupling to the network emission and check that the background noise and any ambient signals are below the applicable limit: where possible, this margin should be greater than 6 dB.

– Orientate the loop antenna for maximum coupling and then increase the measurement distance and check that there is a reduction in the measured field strength in accordance with § 7.2 of ITU-T Recommendation K.60.

The quiet frequencies, or frequency ranges, identified will be used to measure the disturbance emission. The operator of the measuring receiver should assess the background noise levels subjectively, on each of these frequencies. Using the measuring bandwidth and detector specified, the highest disturbance field strength level (dB(μV/m)) observed over a period of 15 s has to be recorded. Any short duration isolated peaks should be ignored.

A1.4 Disturbance emission measurements in the frequency range 30 MHz to 3 000 MHz

A1.4.1 Introduction

The electric component of the radiated disturbance emission has to be measured and assessed.

Usually the electric component will be measured as electric field strength (in dB(μV/m)) at the standard measurement distance.

A1.4.2 Measuring equipment

A calibrated measuring system in accordance with CISPR 16-1-1, consisting of a radio disturbance measuring receiver (or a suitable spectrum analyser) in conjunction with an associated broadband dipole, a biconical, a logarithmic-periodical antenna, or a horn antenna, or similar linearly polarized antenna, each suitable for measurement of electric components of the electromagnetic field, and an antenna mast are required.

In order to speed up the measurement, a peak detector has first to be used. If the background noise makes this simple measurement unusable, a quasi-peak detector will be used and the quasi-peak level applied. Above 1 GHz, no quasi-peak detector exists and only the peak detector has to be used.

A1.4.3 Measurement of the electric disturbance field strength

The measuring antenna will be mounted at the mast and position of the measurement location previously identified as having the maximum disturbance field strength, so that it is at the standard measurement distance.

Local restrictions in space (appearing e.g. during indoor measurements) can require a reduction of the measuring distance. In this case, the measurement distance chosen has to be greater or equal to 1 m. For the measurement, the antenna will be oriented such that maximum coupling is obtained to the disturbing source, without any height scan.

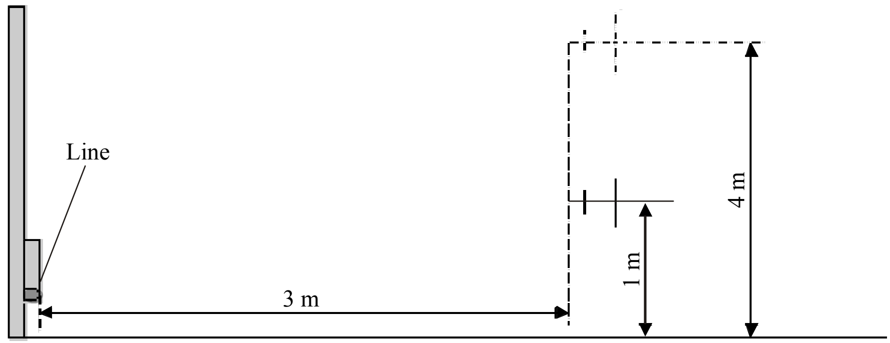
Set the measuring receiver or spectrum analyser to the frequency carrying the disturbance and type of detector required, and perform the measurements. At the specified measurement location and measuring point(s), the direction, height, and polarization (horizontal and vertical) of the measuring antenna will be varied in order to determine the maximum RF disturbance field strength. The electrical component of the disturbance field strength is to be determined by observing the indication of the measuring receiver over a period of approximately 15 s, and subsequently recording its maximum indication. Isolated peaks occurring casually should be disregarded.

If the antenna and the telecommunication network are located at the same level, then the antenna height will vary between 1 m and 4 m (or the maximum determined by the ceiling) in order to determine the maximum field strength. In varying the antenna height, the antenna should not be positioned closer than 0.5 m to reflecting objects (e.g. walls, ceilings, metallic structures, etc.). The antenna height variation may be restricted owing to local conditions (see Fig. 1).

In the case of an outdoor measurement, the antenna height will be varied from 1 m to 4 m.

FIGURE 1

Antenna height variation



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Annex 2

Measurement methods applicable to radiated emissions from power line telecommunication systems in the United States of America

A2.1 Definitions

Carrier current system: A system, or part of a system, that transmits radio frequency energy by conduction over the electric power lines. A carrier current system can be designed such that the signals are received by conduction directly from connection to the electric power lines (unintentional radiator) or the signals are received over-the-air due to radiation of the radio frequency signals from the electric power lines (intentional radiator).

Access PLT: A carrier current system operating as an unintentional radiator using frequencies between 1705 KHz and 80 MHz on medium voltage (MV) or low voltage (LV) lines to provide broadband communications and located on the supply side of the utility service's points of interconnection with customer premises.

MV wires carry between 1 000 and 40 000 V from a substation and may be overhead or underground; LV wires carry low voltage, e.g. 240/120 V from a distribution transformer to a customer premise.

In Home PLT: A carrier current system operating as an unintentional radiator using frequencies between 1705 KHz and 80 MHz on LV lines that are not owned, operated or controlled by an electric service provider. This includes closed networks within a customer premise and includes customer premise networks forming connections with access BPL systems.

A2.2 General measurement principles for access PLT and in-house PLT

1 Testing shall be performed with the power settings of the equipment under test (EUT) set at the maximum level.

2 Testing shall be performed using the maximum RF injection duty factor (burst rate). Test modes or test software may be used for uplink and downlink transmissions.

3 Measurements should be made at a test site where the ambient signal level is 6 dB below the applicable limit. (See CISPR 16-1-4 – Specification for radio disturbance and immunity measuring apparatus and methods, Ed. 1.1, 2004-05, § 5 and 8.)

4 If the data communications burst rate is at least 20 burst/s, quasi-peak measurements shall be employed. If the data communications burst rate is 20 bursts/s or less, measurements shall be made using a peak detector.

5 For frequencies above 30 MHz, an electric field sensing antenna, such as a biconical antenna is used. The signal shall be maximized for antenna heights from 1 to 4 m, for both horizontal and vertical polarizations, in accordance to CISPR 16-1-4 – Specification for radio disturbance and immunity measuring apparatus and methods, Ed. 1.1, 2004-05, § 4 procedures. For access PLT measurements only, as an alternative to varying antenna height from 1 to 4 m, these measurements may be made at a height of 1 m provided that the measured field strength values are increased by a factor of 5 dB to account for height effects.

6 For frequencies below 30 MHz, an active or passive magnetic loop is used. The magnetic loop antenna should be at 1 m height with its plane oriented vertically and the emission maximized by rotating the antenna 180 degrees about its vertical axis. When using active magnetic loops, care should be taken to prevent ambient signals from overloading the spectrum analyser or antenna pre-amplifier.

7 The six highest radiated emissions relative to the limit and independent of antenna polarization shall be reported as stated in CISPR 22 – Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement, Ed. 5, 2004-05, § 8.

8 All operational modes should be tested including all frequency bands of operation.

A2.3 Access PLT measurement principles

a) Test environment

1 The equipment under test (EUT) includes all PLT electronic devices *e.g.* couplers, injectors, extractors, repeaters, boosters, concentrators, and electric utility overhead or underground medium voltage lines.

2 *In situ* testing shall be performed on three typical installations for overhead line(s) and three typical installations for underground line(s).

b) Radiated emissions measurement principles for overhead line installations

1 Measurements should normally be performed at a horizontal separation distance of 10 m from the overhead line. If necessary, due to ambient emissions, measurements may be performed a distance of 3 m. Distance corrections are to be made using an extrapolation factor of 20 dB/decade for frequencies at or above 30 MHz to the specified distance; and an extrapolation factor of 40 dB/decade for frequencies below 30 MHz to the specified distance.

2 Testing shall be performed at distances of 0, 1/4, 1/2, 3/4, and 1 wavelength down the line from the PLT injection point on the power line. Wavelength spacing is based on the mid-band frequency used by the EUT. In addition, if the mid-band frequency exceeds the lowest frequency injected onto the power line by more than a factor of two, testing shall be extended in steps of 1/2 wavelength of the mid-band frequency until the distance equals or exceeds 1/2 wavelength of the lowest frequency injected. (For example, if the device injects frequencies from 3 to 27 MHz, the wavelength corresponding to the mid-band frequency of 15 MHz is 20 m, and wavelength corresponding to the lowest injected frequency is 100 m.

Measurements are to be performed at 0, 5, 10, 15, and 20 m down line – corresponding to zero to one wavelength at the mid-band frequency. Because the mid-band frequency exceeds the minimum frequency by more than a factor of two, additional measurements are required at 10-m intervals until the distance down-line from the injection point equals or exceeds 1/2 of 100 m. Thus, additional measurement points are required at 30, 40, and 50 m down line from the injection point.)

3 Testing shall be repeated for each access PLT component (injector, extractor, repeater, booster, concentrator, etc.).

4 The distance correction for the overhead-line measurements shall be based on the slant range distance, which is the line-of-sight distance from the measurement antenna to the overhead line. Slant range distance corrections are to be made using an extrapolation factor of 20 dB/decade for frequencies at or above 30 MHz to the specified distance; and an extrapolation factor of 40 dB/decade for frequencies below 30 MHz to the specified distance. (For example, if the measurement is made at a horizontal distance of 10 m with an antenna height of 1 m and the height of the PLT-driven power line is 11 m, the slant range distance is 14.1 m (10 m vertical distance and 10 m horizontal distance. At frequencies below 30 MHz, the measurements are extrapolated to the required 30-m reference distance by subtracting 40 log (30/14.1), or 13.1 dB from the measured values. For frequencies above 30 MHz, the correction uses a 20 log factor.)

NOTE 1 – In cases where access PLT devices are coupled to low-voltage power lines (i.e., home-plug or modem boosters), apply the overhead-line procedures as stated above along the LV lines.

c) Radiated emissions measurement principles for underground line installations

Underground line installations are those in which the PLT device is mounted in, or attached to, a pad-mounted transformer housing or a ground-mounted junction box and couples directly only to underground cables.

1 Measurements should normally be performed at a separation distance of 10 m from the in-ground power transformer that contains the PLT device(s). If necessary, due to ambient emissions, measurements may be performed a distance of 3 m. Distance corrections are to be made using an extrapolation factor of 20 dB/decade for frequencies at or above 30 MHz to the specified distance; and an extrapolation factor of 40 dB/decade for frequencies below 30 MHz to the specified distance.

2 Measurements shall be made at positions around the perimeter of the in-ground power transformer where the maximum emissions occur. Measurements shall be made at a minimum of 16 radial angles surrounding the EUT (or In-ground transformer that contains the PLT device(s)). If directional radiation patterns are suspected, additional azimuth angles shall be examined.

A2.4 In-house PLT measurement principles

1 *In situ* testing is required for testing of the In-house PLT device.

2 If applicable, the device shall also be tested in a laboratory environment, as a computer peripheral, for both radiated and conducted emissions tests per the measurement procedures in CISPR 22 – Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement, Ed. 5, 2004-05, § 8.

a) Test environment and radiated emissions measurement principles for *in situ* testing

1 The EUT includes In-house PLT modems used to transmit and receive PLT signals on low-voltage lines, associated computer interface devices, building wiring, and overhead or underground lines that connect to the electric utilities.

2 *In situ* testing shall be performed with the EUT installed in a building on an outside wall on the ground floor or first floor. Testing shall be performed on three typical installations. The three installations shall include a combination of buildings with overhead-line(s) and underground line(s). The buildings shall not have aluminium or other metal siding, or shielded wiring (e.g. wiring installed through conduit, or BX electric cable).

3 Measurements shall be made at positions around the building perimeter where the maximum emissions occur.

4 Measurements should normally be performed at a separation distance of 10 m from the building perimeter. If necessary, due to ambient emissions, measurements may be performed a distance of 3 m. Distance corrections are to be made using an extrapolation factor of 20 dB/decade for frequencies at or above 30 MHz to the specified distance; and an extrapolation factor of 40 dB/decade for frequencies below 30 MHz to the specified distance.

b) Additional measurement principles for *in situ* testing with overhead lines

1 In addition to testing radials around the building, testing shall be performed at three positions along the overhead line connecting to the building (i.e. the service wire). It is recommended that these measurements be performed starting at a distance 10 m down the line from the connection to the building. If this test cannot be performed due to insufficient length of the service wire, a statement explaining the situation and test configuration shall be included in the technical report.

2 Measurements should normally be performed at a horizontal separation distance of 10 m from the overhead line connecting to the building. If necessary, due to ambient emissions, measurements may be performed a distance of 3 m. Distance corrections are to be made using an extrapolation factor of 20 dB/decade for frequencies at or above 30 MHz to the specified distance; and an extrapolation factor of 40 dB/decade for frequencies below 30 MHz to the specified distance.

3 The distance correction for the overhead-line measurements shall be based on the slant range distance, which is the line-of-sight distance from the measurement antenna to the overhead line. Slant range distance corrections are to be made using an extrapolation factor of 20 dB/decade for frequencies at or above 30 MHz to the specified distance; and an extrapolation factor of 40 dB/decade for frequencies below 30 MHz to the specified distance.

c) Measurement principles for testing as a computer peripheral

1 The data rate shall be set at the maximum rate used by the EUT. Test modes or test software may be used to simulate data traffic.

2 Conducted emissions measurements shall be performed in accordance with CISPR 22 – Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement, Ed. 5, 2004-05, § 5.

3 For In-house PLT devices operating as unintentional radiators either below 30 MHz or above 30 MHz, the radiated emissions from the computer peripheral shall be measured at an Open Area Test Site (OATS) in accordance with the measurement procedures in CISPR 16-1-4 – Specification for radio disturbance and immunity measuring apparatus and methods, Ed. 1.1, 2004-05, § 5.

Annex 3

Specification for the measurement of disturbance fields from telecommunication systems and networks in the frequency range 9 kHz to 3 GHz in Germany

A3.1 General introduction

A3.1.1 Scope

The present text provides procedures for *in situ* measurements of unwanted disturbance emissions caused by telecommunication installations and networks. Subject of measurements are unwanted disturbance emissions within the radio frequency (RF) spectrum that are caused by use of frequencies for transmission of information in and along conductors. In case of broadband signals the use of an auxiliary carrier might be necessary. In case additional descriptions of the measurement procedure is required.

The networks in question include WAN, LAN, and CATV networks as well as the recently developed technologies in the telecommunications access area utilizing electric power distribution (PLT) and telephone networks (xDSL).

The present document does not provide procedures for the measurement of emissions from electronic equipment for conformity testing purposes in accordance with the German electromagnetic compatibility act (EMVG).

Radio applications that may be affected by unwanted RF disturbance emissions include, but are not restricted to, standard frequency and standard time signal receivers, receivers for mobile radio services, sound and TV broadcasting radio services, and fixed services, cordless telephones and radio equipment for amateur radio services.

Protection from unwanted RF disturbance emissions radiated by telecommunication networks is specifically called for in RR No.15.12 and provided for in Article 4 (2) of Council Directive 2004/108/EG of 15 December 2004 (EMC Directive).

This specification does not cover any provision for measurement of emissions from electrical or electronic apparatus in the framework of product conformity tests according to the German EMVG or FTEG.

A3.1.2 Frequency range

The present text is applicable in the frequency range 9 kHz to 3 GHz.

A3.1.3 Measurement procedures

The present text sets out methods of measurement for unwanted RF disturbance emissions accompanying wire-bound wanted signals and emanating from telecommunication installations and networks.

A3.1.4 Limits

Limits for unwanted disturbance emissions from telecommunication installations and networks, listed in Appendix 1 to Annex 3 of the present text.

A3.2 Definitions and abbreviations

For the purposes of the present text the following definitions apply:

Antenna reference point: The geometric centre of the antenna or the reference point referred to in the antenna calibration procedure.

Detector weighting factor: The difference of indication obtained from a quasi-peak detector to the peak detector, for a specific signal.

Disturbance field strength: Field strength produced at a given location by an electromagnetic disturbance, measured under specified conditions. (IEC – IEV 161-04-02)

NOTE – For the purposes of the present text, only those components of the wire-bound wanted signals are considered that may cause unwanted disturbance emissions in form of fields.

Electromagnetic disturbance: Any electromagnetic phenomenon that may degrade the performance of a device, equipment or system. (IEC – IEV 161-01-05)

Emission: The phenomenon by which electromagnetic energy emanates from a source. (IEC – IEV 161-01-08)

Minimum coverage: For the purposes of this specification, minimum coverage is normally given if the minimum field strength necessary for the relevant radio service or application can be verified at the location of measurement.

Radio (frequency) disturbance: Electromagnetic disturbance having components within the radio frequency range. (IEC – IEV 161-01-13)

Telecommunication network: Entirety of technical equipment (transmission lines, switching equipment and any other equipment) that are indispensable to ensure normal intended operation of the telecommunication network), to which telecommunication terminal equipment is connected to by appropriate termination.

Telecommunication installation: Any technical equipment or systems capable of sending, transmitting, switching, receiving, steering or controlling as messages identifiable electromagnetic or optical signals.

NOTE – If referred to telecommunication networks only hereafter, then related information is also applicable to telecommunication installations.

Unwanted disturbance emission: Components of wanted signals caused by wire-bound currents or voltages that unintentionally emanate from the conductor and may interfere with radio communications through inductive or capacitive coupling (near field) or electromagnetic wave propagation (far field).

Unwanted emission: A signal that may impair the reception of a wanted signal. (IEC – IEV 161-01-03)

Wanted signal: The wanted signal comprises the frequency spectrum required for the communication in and along conductors.

A3.3 Principles for preparation and performance of measurements

A3.3.1 General

It will be essential to gather all technical information necessary for a complete understanding of the operating parameters and layout of the telecommunication network requiring measurement. For example, the telecommunication network operator should provide EMC related specifications and parameters of the cables and connecting hardware. In all cases the information obtained should be verified by the preliminary investigation as detailed below in order to rule out measuring unwanted emissions from the telecommunication network that are regulated by other than that being assessed.

A3.3.2 Performance characteristics of telecommunication networks

The basic performance characteristics needed are: spectral amplitude distribution and frequency characteristics of the wire-bound wanted signals and the operating mode(s) that cause maximum RF disturbance emission levels at all, or any particular, frequencies of interest.

It may also be necessary to discover whether spectral amplitude variations can result from dynamic power control and whether frequency spectrum characteristics can vary, depending on the given data transfer rate.

These parameters can best be determined at a high $(S + N)/N$ ratio by means of a current clamp and automated scanning measuring receiver with panoramic display monitoring the conducted current at the feeding (or terminating) interface of the telecommunications line. Cooperation with the telecommunications operator will probably be needed to exercise the system as necessary.

During a preliminary investigation stage, it is also necessary to clarify whether the observed unwanted emissions are unwanted disturbance emissions as defined in § A3.2, or other unwanted emissions from electronic equipment connected to the network, which do not belong to the wire-bound wanted signal. Observed unwanted disturbance emissions within the frequency band of the wire-bound wanted signal shall meet the provisions of NB 30, if not having been identified as other unwanted emissions.

A3.3.3 Selection of measuring points

The selection of measuring points will depend on the reason for the measurements. The reason for the measurements may be investigation of interference complaints or verification of compliance with the limits.

A3.3.3.1 Investigation of complaints on radio interferences

For the investigation of interference, the initial measuring point (indoor or outdoor) should be at that part of the transmission line closest to the interfered-with radio receiver and/or antenna of the victim of interference.

A3.3.3.2 Verification of telecommunication installations and networks on compliance

For compliance testing, the topology of the telecommunication installation or network will dictate where initial measurements should be made. This point (these points) should be located there, where experience shows the highest disturbance emissions to be expected. For most interactive systems these points will be, for example, at each end of the transmission line, at any intermediate amplifiers that may be deployed, or at points of impedance discontinuity or leakage in the transmission line.

In either case (i.e. in case of § A3.3.3.1 and § A3.3.3.2) it will be necessary to use a portable receiver with a signal level indicator, or other convenient tracing technique, to identify and record the exact locations where radiated disturbance emission levels are the highest.

It will be necessary to measure the wanted signal with an appropriate $(S + N)/N$ ratio in order to determine the waveform. Such a "fingerprint" of the signal can be taken by measuring the conducted current at an accessible point of the transmission line (see § A3.3.2).

A3.3.4 Measurement distance

A3.3.4.1 Verification of telecommunication installations and networks on compliance

For indoor and outdoor measurements, the standard measurement distance d is 3 m. This distance is the spacing between the reference point of the measuring antenna and the nearest part of the telecommunication network.

A3.3.4.1.1 Drawing the measurement distance for indoor measurements

If the part of the telecommunication network subject to investigation is inaccessible, located within or behind a wall, duct or similar structure, then the measurement distance *d* shall be taken rectangular from the front edge of the wall or duct.

If, for indoor measurements in the frequency range up to 30 MHz, free spacing of 3 m between the telecommunication network and measuring antenna is not available, then the measurement distance mentioned above can be reduced down to 1 m. In this case the provisions of § A3.4.2.2 and A3.5.2.3 apply.

A3.3.4.1.2 Drawing the measurement distance for outdoor measurements

For measurements made outside a building or other structure carrying telecommunication network equipment or cabling, the measurement distance *d* shall be taken rectangular from the external wall of the building or relevant structure.

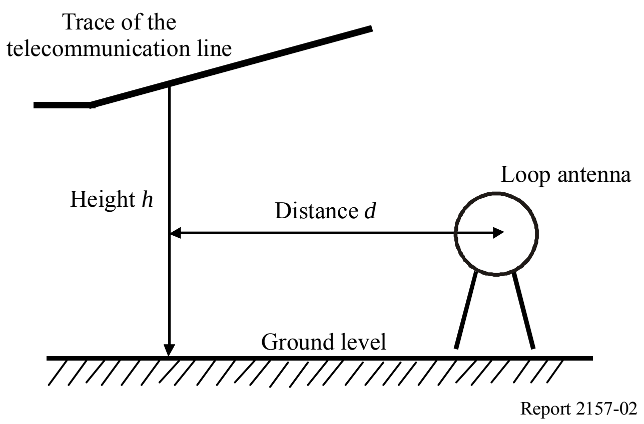
If the part of the telecommunication network to be measured is below ground, then the measurement distance *d* shall be taken rectangular from the line representing the vertical projection of the telecommunication network on to the surface of the ground.

If the part of the telecommunication network to be measured is above the measuring antenna, then the measurement distance *d* shall be taken rectangular from the line representing the vertical projection of the telecommunication network on to the surface of the ground.

The principle is shown in Fig. 2.

FIGURE 2

Drawing the measuring distance *d* from the vertical projection of the trace of the telecommunication line to ground level



If, for outdoor measurements, location of the measuring antenna at 3 m distance is not possible due to local conditions, then the method of measurement specified in Section A3.4.2.3 shall apply for measurements in the frequency range up to 30 MHz.

If the telecommunication cable tract to be measured is significantly above the height of the available antenna mast (e.g. in more than 10 m height above ground), then the method of measurement specified in § A3.4.2.3 shall apply for measurements in the frequency range up to 30 MHz, and the radiated RF disturbance power level shall be measured in accordance to § A3.7 of this specification, in the frequency range above 30 MHz.

A3.3.4.2 Investigation of complaints on radio interferences

No specific measurement distances are defined for identification of the source of interference. If the source of interference is identified, then the relevant part of the telecommunication installation or network is measured following the principles set out in § A3.3.4.1. Due to specific reasons, deviations from these principles are permitted, if necessary.

A3.3.5 Limits for permissible disturbing emissions from telecommunication installations and networks

The limits (together with necessary corrections) are shown in Appendix 1 to Annex 3 of the present text.

Please note that the field strength limits shown in Appendix 1 to Annex 3 are peak limits. Though, in order to minimize the uncertainty arising from the use of the peak detector, a quasi-peak detector is used for the measurements.

To enable direct comparison between measured quasi-peak levels and the peak limits, it will be necessary to use a quasi-peak detector weighting factor that shall be added to the quasi-peak level readings. This weighting factor will depend on the measuring bandwidth and signal architecture of the telecommunication network being investigated.

Unless the quasi-peak weighting factor is already known and has been agreed with the telecommunication network operator, it shall be established during the preliminary investigation stage. This is most easily and accurately achieved by using a current clamp to measure the telecommunication network at a point providing a clean wanted signal with at least 20 dB $(S + N)/N$ ratio.

In the frequency range 30 MHz to 1 000 MHz the quasi-peak weighting factor can also be determined by positioning the antenna in direct vicinity of the source of radiation.

In the frequency range 1 000 MHz to 3 000 MHz the measurement results do not need to be corrected because the peak detector is used in any case.

A3.4 Disturbance emission measurements in the frequency range 9 kHz to 30 MHz

A3.4.1 Measuring equipment

The following measuring equipment, as specified in CISPR Publication 16-1, is required:

– a calibrated measuring system, consisting of a radio disturbance measuring receiver and associated loop antenna for the measurement of magnetic field components, with tripod, and

– a calibrated measuring system, consisting of a radio disturbance measuring receiver and associated current clamp for the measurement of high frequency currents at conductors,

respectively.

In the frequency range 9 kHz to 150 kHz, a measuring bandwidth of 200 Hz and the quasi-peak detector shall be used.

In the frequency range 150 kHz to 30 MHz a measuring bandwidth of 9 kHz and the quasi-peak detector shall be used.

If necessary, other specialized equipment such as resonant loop antennas or antennas for the electric field may also be used. For any measurements of the electric field strength that may become necessary an active dipole as described in Appendix 5 to Annex 3 or a similar dipole is to be used.

To minimize the possibility of earth loops affecting the measurement, it is recommended that both the measuring receiver and loop antenna have an independent power source with no ground connection (e.g. battery power), particularly in case of indoor measurements.

A3.4.2 Method of measurement

A3.4.2.1 General

As specified in Appendix 1 to Annex 3, the measured magnetic field strength is converted with an intrinsic impedance of 377 Ω into the electric field strength.

This conversion may be done automatically already in various measuring equipment.

It shall be taken into account that the telecommunications system operates with its normal maximum signal levels and in the mode, if any, previously identified as resulting in maximum disturbance field levels. If the system is interactive, it will be particularly important to check for the presence of the reverse path (upstream) signals if these are in the same frequency range as that of any interference complaint.

If measurements are to be made at a single frequency or in a narrow frequency band only (e.g. in cases of interference), then the antenna should be adjusted so as to obtain maximum coupling to the telecommunication network under investigation.

If measurements are to be made at a large number of frequencies or over a swept frequency range, separate measurement runs should be made with the antenna adjusted in each of three orthogonal directions, X, Y and Z. The data for each measurement run should be stored and for each frequency, the effective field strength (E_{eff}) shall be calculated using equation (A3-1).

$$\frac{E_{eff}}{V/m} = \sqrt{\frac{{E_X}^2}{(V/m)^2} + \frac{{E_Y}^2}{(V/m)^2} + \frac{{E_Z}^2}{(V/m)^2}} \qquad \text{(A3-1)}$$

This task is most easily accomplished by reading the data for each measurement run into a spreadsheet and subsequent automated calculation of E_{eff}.

To reduce measurement time, it is recommended to start with a pre-scan over the frequency range concerned using the peak detector, followed by another measurement of the found maximum disturbance field-strength values using the quasi-peak detector.

For the loop antenna, the measurement distance *d* is the spacing between its geometrical centre and the telecommunication network, and for the active dipole the measurement distance *d* is the spacing between the reference point of the dipole and the telecommunication network.

Mount the loop antenna on a tripod at a height of 1 m (at lower edge of the loop), at the location previously identified as having the maximum disturbance field strength, so that it is at the prescribed measurement distance from the telecommunication network.

Set the measuring receiver to the frequency and detector required and rotate the loop antenna for maximum telecommunication network signal indication, or in the orthogonal directions X, Y and Z, and subsequently calculate the effective field strength.

The measurement of magnetic fields radiated from telecommunication networks in the frequency range up to 30 MHz may become complicated due to the presence of a variety of high-level wanted RF emissions from radio services. In view of this it can be necessary to identify some frequency ranges with low field strengths in the gaps between radio transmissions such that the background noise and any ambient signals are below the applicable limit specified in Appendix 1 to Annex 3. This should be done without altering the antenna position and ideally with the telecommunication network switched off.

If the network cannot be switched off, then the following alternatives may be used:

– Orientate the loop for minimum coupling to the network emission and check that the background noise and any ambient signals are below the applicable limit in Appendix 1 to Annex 3.

– Orientate the loop for maximum coupling and then increase the measurement distance and check that there is a corresponding reduction in the measured field strength.

The number of quiet frequencies or frequency ranges required would depend on whether overall compliance measurements are intended or whether a smaller scale interference complaint is to be investigated. For overall compliance testing, the largest possible number of quiet frequency ranges is preferred. These should be spaced as evenly as possible over the full wanted signal spectrum of the investigated telecommunication service. A frequency plot for the whole frequency range being measured will aid rapid identification of those quiet frequencies that may be suitable for subsequent analysis. Sweeps over the frequency range observed can be made with a peak detector in subsequent steps of half the measuring bandwidth.

For investigation of interference complaints a few quiet frequencies around the frequency of complaint should be sufficient. These can be identified and measured using manual tuning.

In both cases the quiet frequencies or frequency range identified will be used to measure the unwanted disturbance emission. The operator of the measuring receiver should assess the background noise levels subjectively, on each of these frequencies. Using the measuring bandwidth and detector specified, the highest disturbance field strength level (dB(μV/m)) observed over a 15 s period shall be recorded. Any short duration isolated peaks should be ignored.

With the telecommunication network operating, the measurements shall be repeated on all previously identified quiet frequencies using the same procedure specified above. The results shall be recorded and the difference calculated between the levels measured with the telecommunication network operating normally and with it switched off.

If the ambient noise level is still higher than the limit, a current clamp can be used to verify the calculated difference. (This test method is still subject to further consideration.)

A3.4.2.2 Measurement at a distance smaller than 3 m

In case of measurements at a smaller distance than 3 m the measurement distance is to be taken as the straight rectangular line from the telecommunications cable tract (or its projection to ground level) to the outer boundary of the loop antenna.

If adherence to the standard measuring distance of 3 m is not possible, e.g. due to local conditions within a building, then measurements can be made at smaller spacing not falling short of 1 m.

In this case the same method of measurement as for measurements at 3 m distance applies and the measurement result shall be corrected using the conversion factor given in equation (A3-2):

$$E_{dist} = E_{meas} + 20 \log \frac{d_{meas}}{d_{stand}} \qquad \text{(A3-2)}$$

where:

E_{meas}: measurement result (dB(μV/m))

E_{dist} : corrected measurement result (dB(μV/m))

d_{meas}: measurement distance (m)

d_{stand}: standard measurement distance (3 m).

A3.4.2.3 Measurement at a distance greater than 3 m

If, owing to local conditions, a measurement distance of more than 3 m is to be chosen, then two measuring points located at the measuring axis rectangular to the telecommunication cable tract are to be determined. As a guide, the distance between the two points should be as large as possible. The level of the disturbing field strength shall be measured as described in § A3.4.2.1. Eventually decisive are the local conditions and measurability of the disturbance field strength.

The measurement results (dB(µV/m)) are to be plotted in a diagram over the logarithm of the distance. The straight line interconnecting the measurement results represents the decrease in field strength at the axis measured. If the decrease in the field strength level cannot be determined, then additional measuring points shall be chosen. The field strength level at standard measurement distance of 3 m is to be read from the diagram using the interconnecting line.

A3.4.3 Measurement of the electric field strength

The electric field strength is measured in cases of interference only where the disturbance emission is assumed to be a predominantly electric field. This could be the case if the limit for the magnetic field strength was not exceeded but nonetheless interference to radio receiving equipment utilizing an electric field antenna did occur.

The measurement procedure is the same as that for the magnetic disturbance field strength. The antenna required is described in Appendix 5 to Annex 3.

A3.5 Disturbance emission measurements in the frequency range 30 MHz to 3 000 MHz

A3.5.1 Measuring equipment

The following measuring equipment (in accordance to CISPR 16-1) is necessary:

– calibrated measuring system consisting of a radio disturbance measuring receiver in conjunction with an associated broadband dipole, or an associated logarithmic-periodical antenna, each suitable for measurement of the electric component of the field, and an antenna mast.

NOTE 1 – Measurement results obtained by means of the calibrated measuring system described above do not need any subsequent correction, even if possibly measured under near field conditions.

Requirements for radio disturbance measuring receivers and antennas are described in CISPR Publication 16-1.

For the frequency range from 30 MHz to 1 000 MHz, a measuring bandwidth of 120 kHz and a quasi-peak detector shall be used.

For the frequency range from 1 000 MHz to 3 000 MHz, a measuring bandwidth of 1 MHz and a peak detector shall be used.

A3.5.2 Methods of measurement

A3.5.2.1 General

It shall be taken into account that the telecommunications system operates at its normal maximum signal levels and in that mode (if more than one mode of operation exists) previously identified as resulting in maximum RF disturbance field levels. If the system is interactive, it will be particularly important to check for the presence of the reverse path (upstream) signals if these are in the same frequency range as reported in the interference complaint(s).

In order to reduce duration of measurements it is recommended at first to perform the sweep over the frequency range to be examined using a peak-detector, and subsequently to measure with a quasi-peak detector at frequencies only where maximum indications of RF disturbance field-strength levels have been recorded before.

The measurement distance *d* is the distance between the part of the telecommunication network to be examined and the balun, in case of a broadband dipole, or the reference point of the antenna, in case of a logarithmic-periodical antenna.

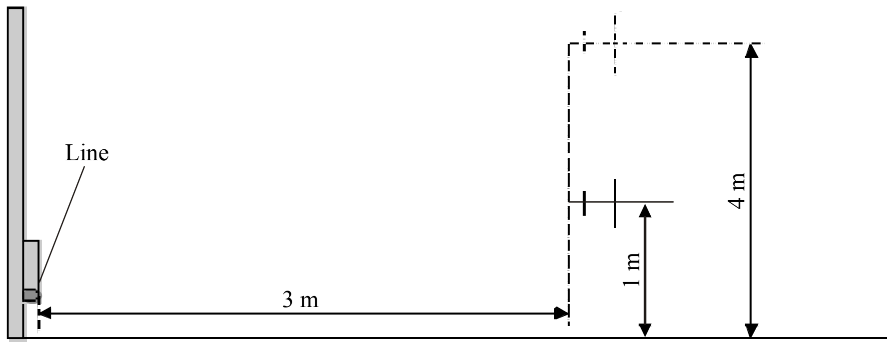
A3.5.2.2 Measurement at 3 m distance (standard distance)

The measurement distance is 3 m. At the specified measuring point, the direction, height, and polarization (horizontal and vertical) of the measuring antenna shall be varied in order to measure the maximum RF disturbance field strength.

If the antenna and the telecommunication network are located at the same ground plane level, then the antenna height shall be varied between 1 m and 4 m in order to determine the maximum field strength. In varying the antenna height, the antenna shall not be positioned closer than 0.5 m to reflecting objects (e.g. walls, ceilings, metallic structures, etc.). The antenna height variation may be restricted owing to local conditions (see Fig. 3).

FIGURE 3

Antenna height variation



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If, e.g. in case of an outdoor measurement, the antenna support is not at the same ground plane level as the telecommunication line or tract, then the antenna shall be varied in height resulting in a variation range comparable to that in the foregoing paragraph.

A3.5.2.3 Measurement at a distance smaller than 3 m

Measurements for verification of compliance on telecommunication installations and networks in the frequency range above 30 MHz are performed outdoors only. Here, the measurement distance can be chosen such that either it is 3 m (standard distance) or greater than 3 m.

If, during investigation of complaints on radio interferences, indoor measurements were necessary for identification of disturbing sources, and a spacing of 3 m could not be made due to local conditions, then measurements can be made at smaller spacing not falling short of 1 m. The measuring distance is that between the conductor and the reference point of the antenna. For the measurement, the antenna shall be oriented such that maximum coupling is obtained to the disturbing source, without any height scan. In this case, the measurement result shall be corrected using the conversion factor given in equation (A3-3):

$$E_{dist} = E_{meas} + 20 \log \frac{d_{meas}}{d_{stand}} \qquad \text{(A3-3)}$$

where:

E_{meas}: measurement result (dB(μV/m))

E_{dist}: corrected measurement result (dB(μV/m))

d_{meas}: measurement distance (m)

d_{stand}: standard measurement distance (3 m).

NOTE 1 – Measurement results obtained by means of the calibrated measuring system (see § A3.5.1) do not need any subsequent correction, even if possibly measured under near field conditions.

A3.5.2.4 Measurement at a distance greater than 3 m

If local conditions call for a measurement distance of more than 3 m, then the radiated RF disturbance power shall be measured in accordance with the substitution method specified in § A3.6.

A3.5.3 Determination of the electric field strength

The electrical component of the disturbance field strength is to be determined by observing the indication of the measuring receiver over a period of approximately 15 s and subsequent recording of its maximum indication. Isolated peaks occurring casually should be disregarded.

If the method of measurement provides measurement results given in terms of RF voltage levels only, then the level of the disturbance field strength can be calculated from the RF voltage level measured at the antenna port of the measuring receiver by means of equation (A3-4):

$$E_{dist} = V_{rec} + a_c + AF \qquad \text{(A3-4)}$$

where:

E_{dist}: calculated disturbance field strength level (dB(μV/m))

V_{rec}: measured RF voltage level (dB(μV)) at the antenna input port of the measuring receiver (at 50 Ω)

a_c: attenuation of the measuring cable (dB)

AF: antenna factor[2] of the measuring antenna (dB).

NOTE 1 – For calculation of disturbance field-strength levels, the antenna factor belonging to the measuring antenna (free space, according the manufacturer's declaration or calibration report) shall be used in any case, independently from the actually used measurement distance.

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[2] Antenna factor according to the manufacturer's declaration, or calibration report (for the standard distance, if available).

A3.6 Measurement of radiated RF disturbance power from 30 MHz to 3 000 MHz

A3.6.1 Measuring equipment

The requirements for radio disturbance measuring receivers, the measuring bandwidths, detectors and antennas used for the measurement of the radiated RF disturbance power are described in CISPR Publication 16-1.

A3.6.2 Measurement distance

The measurement of electric components of the electromagnetic field bears inherent uncertainties due to reflections on dielectric or conductive junctions and due to parasitic elements within the surrounding of the measuring location. Measurements performed in near field conditions can result in further uncertainties. Some of these uncertainties can be ruled out by determining the radiated RF disturbance power of the source of interference in the same ambient conditions using a substitution antenna.

The radiated RF disturbance power shall be measured at a distance providing far field conditions with respect to the source of the radiated disturbance. For dipole-like radiators, the far field condition is fully met where the appropriate measurement distance is calculated and used in accordance with equation (A3-5):

$$d \geq 4\lambda \tag{A3-5}$$

or where the measurement distance d is equal to or greater than 30 m. (In most practical cases, fulfilment of the condition, $d \geq \lambda$, is already sufficient.)

A3.6.3 Location of the measuring antenna

The measurement of the radiated disturbance power shall be made only in the far field as described in § A3.6.2. Subject to this condition, the measuring point for unwanted radiated emissions from the telecommunication network (and the equivalent radiated disturbance power subsequently simulated by the substitution antenna) will be the location of the maximum disturbance field strength identified as described in § A3.3.3.

A3.6.4 Location of the substitution antenna

Initially, the substitution antenna should be located 1 m from the front face of the building accommodating the telecommunication network.

The location should be chosen such as to ensure that an imagined line between the substitution antenna and the measuring antenna is perpendicular to the direction of the telecommunication network cable or face of the building accommodating the telecommunication network.

A3.6.5 Method of measurement

A3.6.5.1 Measurement of radiated RF disturbance emissions

At the measuring point chosen in accordance with § A3.6.3, direction, height, and polarization of the measuring antenna shall be varied in order to identify maximum unwanted radiated emission levels from the telecommunication network. The measuring antenna shall be left in this position once the maximum disturbance field strength level has been determined and recorded.

NOTE 1 – A substitution measurement is not necessary if the disturbance field strength measured in accordance with § A3.5 under far field conditions, after its conversion into the field strength level at the standard 3 m distance using equation (A3-2), exceeds the related limit (Appendix 1 to Annex 3) by more than 20 dB.

A3.6.5.2 Substitution measurement

During operation of the substitution antenna, its operation frequency shall not already been occupied by other terrestrial radio services or applications.

When performing compliance tests on telecommunication installations and networks, adequate frequencies in the ISM frequency bands or such frequencies dedicated for this purpose shall be used.

When investigating reported cases of complaints on radio interference, after identification of the disturbing source, the relevant part of the telecommunication network should be switched off, or at least the telecommunications service causing the disturbance should be taken temporarily out of operation, and the frequency of the wanted radio service or application affected by interference should not be occupied. If this is not possible, then the operation frequency of the substitution antenna should be changed by the smallest possible amount in order to fade out the unwanted emission(s) from the telecommunication network, and/or to avoid emissions at frequencies already occupied by terrestrial radio services or applications.

The substitution antenna shall be placed at its specified location (see § A3.6.4) and fed by an unmodulated RF signal generator.

NOTE 1 – For the frequency range below 150 MHz, a broadband dipole antenna is used as substitution antenna. For higher frequencies a tuned half-wave dipole or a logarithmic-periodical antenna is used. To facilitate optimum matching, an attenuator of 10 dB shall be connected to the feeding point of the substitution antenna. To inhibit radiation via the antenna cable, grouped sets of 3 ferrite cores shall be clamped along the entire antenna cable every 30 to 50 cm.

The substitution antenna shall be fed by the RF signal generator with a constant RF power level. The antenna height (1 to 4 m), its distance to the building, and its polarization plane orientation shall now be varied in order to obtain the maximum reading on the measuring receiver. Subsequently, the RF level of the signal generator shall be adjusted to give the same reading on the measuring receiver as previously recorded for the unwanted radiated emission from the telecommunication network (see § A3.6.5.1).

A3.6.5.3 Calculation of radiated RF disturbance power

The level of the effective radiated RF disturbance power is calculated using equation (A3-6).

$$p_U = u_S - a_S - a_c - c_r + G_D + 4 \qquad \text{dB} \qquad \text{(A3-6)}$$

where:

- p_U: calculated radiated RF disturbance power level (dB(pW))
- u_S: voltage level at the RF signal generator output (dB(μV)) at 50 Ω
- a_S: insertion loss of the attenuator at the antenna feeding point (dB)
- a_c: insertion loss of the antenna cable connecting the signal generator and substitution antenna (dB)
- c_r: conversion factor for converting the RF power level at the feeding point of a tuned half-wave dipole (the substitution antenna) into the power corresponding to the effective radiated RF disturbance power:

$$c_r = 10 \log Z_{Fp} \text{ dB}(\Omega) \qquad \text{(A3-7)}$$

  for a feeding point impedance of Z_{Fp} = 50 Ω, the resulting conversion factor is c_r = 17 dB. The insertion loss of the balun is regarded as negligible
- G_D: gain of the substitution antenna relative to a tuned half-wave dipole

4 dB: correction factor accounting for reflections from the wall in front of which the measurement is made.

A3.7 Processing of obtained measuring results and comparison with specified limits

A3.7.1 Correction of measurement results obtained with a quasi-peak detector

Measurement results obtained with a quasi-peak detector shall always be corrected by adding the quasi-peak weighting factor.

If the $(S + N)/N$ ratio is greater than 20 dB, then no further correction of the obtained measurement results is required. If the ratio $(S + N)/N$ is smaller than 20 dB, and N is dominated by noise, then the measurement result can possibly be corrected further by ΔU as shown in Appendix 2 to Annex 3.

NOTE 1 – For any reasonable correction of the measurement results, the ratio $(S + N)/N$ shall be greater than 2 dB.)

If the ratio $(S + N)/N$ is smaller than 20 dB and the measurement result was not corrected, then the higher measurement uncertainty specified in Appendix 3 to Annex 3, Table 3 applies.

A3.7.2 Correction of measurement results obtained with a peak detector

If the $(S + N)/N$ ratio is greater than 20 dB, then further correction of the obtained measurement results is not necessary. If the ratio $(S + N)/N$ is lower than 20 dB, and N is dominated by noise, then the measurement result can be corrected in accordance with the method described in Appendix 4 to Annex 3.

A3.7.3 Treatment of measurement uncertainty

For compliance testing, the provisions for the measurement uncertainty apply in favour of the telecommunication network and to the disadvantage of the radio communications service. Half of the relevant measurement uncertainty is to be subtracted from the measurement result and this value shall be compared with the specified limit.

For investigation of reported cases of complaints on radio interference, the measurement uncertainty is not accounted for in the measurement result.

The measurement uncertainty shall be recorded in the test report.

A3.7.4 Comparison of measurement results with specified limits

The results of the measurements, possibly corrected in accordance with the provisions of § A3.7.1 or A3.7.2, shall eventually be compared with the related specified limits for permissible unwanted radiated emissions found in Appendix 1 to Annex 3.

Appendix 1
to Annex 3

Examples of limits for unwanted radiated emissions from telecommunication installations and networks in the frequency ranges containing safety frequencies

TABLE 1

Examples of limits for unwanted radiated emissions

Frequency range (MHz)	Disturbance field strength limit (peak values (dB(μV/m))	Measurement distance (m)	Measuring bandwidth
0.009-0.15	40 to 20*log (*f*/MHz)	3	200 Hz
0.15-1	40 to 20*log (*f*/MHz)	3	9 kHz
1-30	40 to 8.8*log (*f*/MHz)	3	9 kHz
30-1 000	27(1)	3	120 kHz
1 000-3 000	40(2)	3	1 MHz

(1) This corresponds to an equivalent effective radiated RF power of 20 dB(pW).

(2) This corresponds to an equivalent effective radiated RF power of 33 dB(pW).

Agreed arrangements

In the frequency range 30-3 000 MHz, the limits for the disturbance field strength and their corresponding radiated RF disturbance power represent the same disturbance potential only if the radiated RF disturbance is generated by a single point radiator at a distance of 3 m.

The limits are specified in terms of electric field strength. In the frequency range below 30 MHz these limits also apply, formally converted by means of the free space wave propagation impedance of 377 Ω, to the magnetic field strength measured in accordance with § A3.4.

For outdoor measurements at a distance of 3 m, the measurement result shall be corrected by the relevant factor *C* set out in Table 2.

For indoor measurements, the measurement result shall always be corrected by the relevant factor *C* set out in Table 2.

TABLE 2

Correction factor *C* accounting for differences in free-space and free-field electromagnetic wave propagation

Frequency range (MHz)	Correction factor for		
	Outdoor measurements at 3 m distance		Indoor measurements
	C (dB), vertical polarization	*C* (dB), horizontal polarization	*C* (dB)
30-40	−3	+2	−3
> 40-50	−3	±0	−3
> 50-80	−3	−2	−3
> 80-3 000	−3	−3	−3

These correction factors *C* account for the difference between free-space and free-field field strength[3].

For comparison of measuring results with the limits specified in Table 1 the following equation applies:

$$E_{corr} = E_{dist} + C \qquad \text{(A1)}$$

where:

E_{dist}: measured disturbance field strength level (dB(μV/m)), and

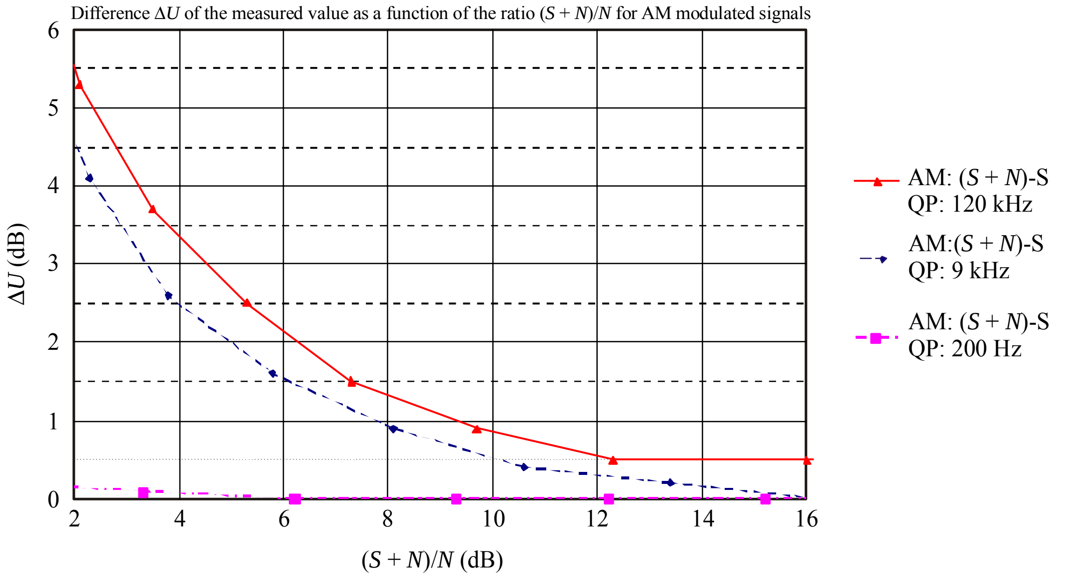
E_{corr}: corrected disturbance field strength level (dB(μV/m)) intended for comparison with the specified limits.

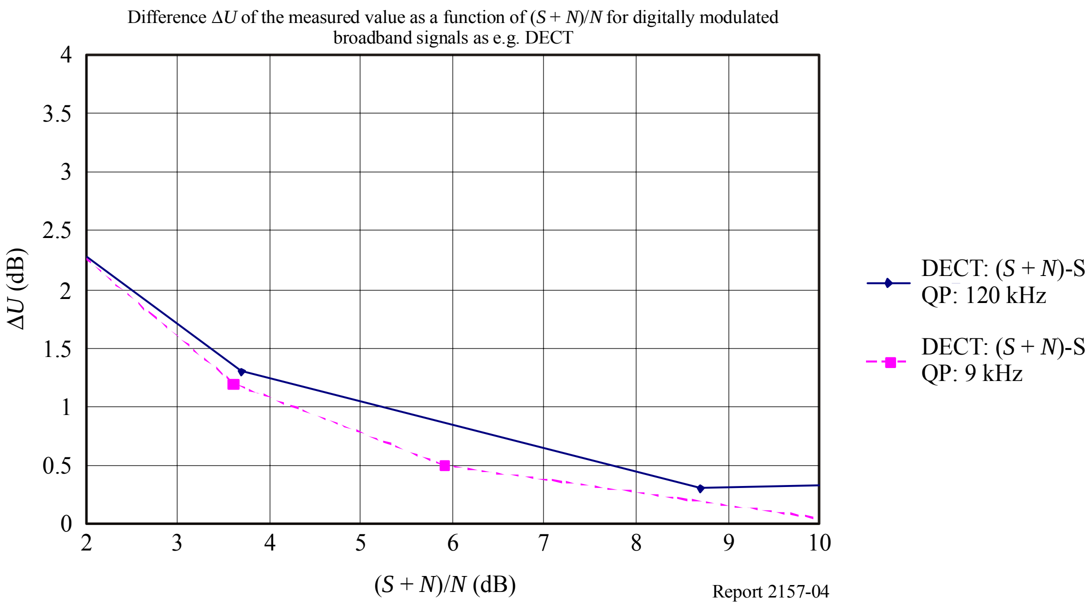
3 Measurement on a test site with an ideal conducting ground plane.

Appendix 2
to Annex 3

FIGURE 4

Correction of readings obtained with quasi-peak detectors in case of small $(S + N)/N$ ratios





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Legend:

$(S + N) – N$:	signal-plus-noise to noise ratio (dB)
$(S + N) – S$:	signal-plus-noise to signal ratio (dB)
U:	increase in signal level owing to signal superposition (dB)

Correction to be applied:

$U_{meas.} = \quad U_{indication} - \Delta U$

Appendix 3
to Annex 3

Determination of measurement uncertainty

A3.A3.1 Measurement uncertainty occurring during field-strength measurements

Contributions of individual components of the measuring system to the total measurement uncertainty are shown in Table 3. They were derived in accordance with the principles described in CISPR/A.

TABLE 3

Contributions of individual components of the measuring system to the measurement uncertainty during field-strength measurements in the frequency range up to 1 000 MHz (Frequency range up to 3 GHz under consideration.)

	Measurement of			
	Magnetic field strength	Electric field strength		
Frequency range	**< 30 MHz**	**< 30 MHz**	**30-300 MHz**	**300-1 000 MHz**
Component of the measuring system	**Contribution (dB)**			
Receiver reading	0.1	0.1	0.1	0.1
Attenuation: antenna – receiver	0.1	0.1	0.2	0.2
Antenna factor	1.0	1.0	2.0	2.0
Receiver				
Sine wave voltage	1.0	1.0	1.0	1.0
Pulse amplitude response	1.5	1.5	1.5	1.5
Pulse repetition rate	1.5	1.5	1.5	1.5
Mismatch between antenna and receiver	-	-	0.7	0.7
Antenna				
Antenna factor frequency interpolation	-	-	0.5	0.3
Antenna height deviations	-	-	1.0	0.3
Directivity difference	-	-	0	1.0
Phase centre location	-	-	0	1.0
Cross polarization/ balance	-	-	0.9	0.9
Site				
Repeatability at site	2.0	2.0	3.0	3.0
Separation distance	0.3	0.3	0.3	0.3
Environment	3.0	3.0	5.0	5.0
Total (dB)	**5.1**	**5.1**	**7.7**	**7.8**

The obtained measurement results bear a total inherent measurement uncertainty as shown in Table 3.

A3.A3.2 Measurement uncertainty in case of a small (*S* + *N*)/*N* ratio

If, during measurements, the (*S* + *N*)/*N* ratio is small only, then a measurement uncertainty of about 3 dB, which is bound to the quasi-peak detector, becomes significant resulting in the following:

TABLE 4

Contribution of the quasi-peak detector at small (*S* + *N*)/*N* ratios

	Measurement of			
	Magnetic field strength	**Electric field strength**		
Frequency range	**< 30 MHz**	**< 30 MHz**	**30-300 MHz**	**300-1 000 MHz**
Component of the measuring system	**Contribution (dB)**			
Quasi-peak detector	3	3	3	3
Total (dB)	**6.2**	**6.2**	**8.4**	**8.5**

The obtained measurement results bear a total inherent measurement uncertainty as shown in Table 4.

A3.A3.3 Measurement uncertainty occurring during radiated RF disturbance power measurements

If, during the measurements, the (*S* + *N*)/*N* ratio is greater than or equal to 20 dB, then the obtained results bear a total inherent measurement uncertainty of 8 dB.

If, during the measurements, the (*S* + *N*)/*N* ratio is greater than 6 dB and smaller than 20 dB, then the obtained results bear a total inherent measurement uncertainty of 9 dB.

Appendix 4 to Annex 3

Correction of readings obtained with peak or average detectors in case of small (*S* + *N*)/*N* ratios

(According to principles set out in CISPR/A)

A3.A4.1 Explanation of the problem

During measurements of telecommunication installations and networks performed under *in situ* conditions, the ambient field-strength conditions often are not in line with the recommendations of CISPR Publication 16-1 for open area test sites.

The unwanted disturbing emission is often located within frequency ranges already occupied by other ambient field strengths and cannot be measured and assessed with the CISPR measurement receiver, due to insufficient margin between the frequency of the disturbance itself and another ambient field strength, or due to superposition of both field strengths. In such cases, the measuring receiver is not able to discriminate between unwanted radiated emissions from the telecommunication network and other ambient field strengths.

In the following a modified method of measurement is described that makes it possible to distinguish between unwanted radiated emissions from telecommunication networks and other present ambient field strengths.

A3.A4.2 Method of measurement

A3.A4.2.1 Overview

The following combinations of unwanted radiated disturbing emissions and ambient field strengths can occur in practice:

TABLE 5

Combinations of radiated disturbing emissions and ambient field strengths

Type of disturbing emission emanating from the installation/network under test	Type of ambient field strength found under in situ conditions
Narrow-band	Narrow-band
	Broadband
Broadband	Narrow-band
	Broadband

During the measurement of unwanted radiated disturbing emissions two problems have to be solved:

– firstly, the disturbing emissions emanating from the telecommunication installation or network have to be discriminated from other ambient field strengths; and

– secondly, distinction shall be made between narrow-band and broadband emissions.

For this purpose, modern measuring receivers and spectrum analysers offer several measurement bandwidths and types of detectors. These features and facilities can be used for analysis of the frequency spectrum of the received summation signal, for discrimination between frequency spectra caused by disturbing emissions and ambient field strengths, narrow-band and broadband emissions, and for measurement (or at least estimation) of the disturbing emission.

A3.A4.2.2 Method of measurement for disturbing emissions considering the presence of narrow-band ambient field strengths

Dependent on the type of disturbing emission emanating the installation or network the measurement is based on:

– analysis of the summation signal spectrum with a bandwidth narrower than that specified in CISPR Publication 16-1 for the measuring receiver;

– specification of a suitable bandwidth for identification of a narrow-band disturbance emission close to other ambient field strengths;

– use of the peak detector, if the disturbing emission appears to be amplitude modulated, or use of the average detector;
– increase of the signal to noise ratio by reduction of the measuring bandwidth, in case of a narrow-band disturbing emission appearing within another broadband-type ambient field strength; and
– consideration of the superposition of disturbing emission and ambient field strength, if separation of both is not possible.

A3.A4.2.3 Method of measurement for disturbing emissions considering the presence of broadband ambient field strengths

In this case the measurement is based on:

– analysis of the summation signal spectrum with a bandwidth for the measuring receiver according to CISPR Publication 16-1;
– measurement with a narrow bandwidth (in case of narrow-band-type disturbing emissions reduction of the receiver's bandwidth causes an increase of the signal to noise ratio);
– use of the average detector, in case of narrow-band-type disturbing emissions;
– consideration of the superposition of disturbing emission and ambient field strength, if separation of both is not possible.

A3.A4.3 Correction of measurement results in case of superposition

If a disturbing emission and another signal present at the location of measurement appear in the same frequency range, then this causes a superposition of these signals in the RF receiving tract of the radio disturbance measuring receiver, subsequently leading to an increased reading of the measuring result. The increase can be analysed as follows:

– the level of the ambient field strength E_a (dB(µV)) shall be measured with the disturbing source switched off;
– the level of the resulting field strength E_r (dB(µV) shall be measured with the disturbing source switched on;
– the amplitude ratio d between the measured levels shall then be calculated:

$$d = E_r - E_a \tag{A4-1}$$

The amplitude ratio d represents the increase of the reading caused by superposition of the signals.

The increased reading is corrected by subtraction of correction factor I from the reading E_r:

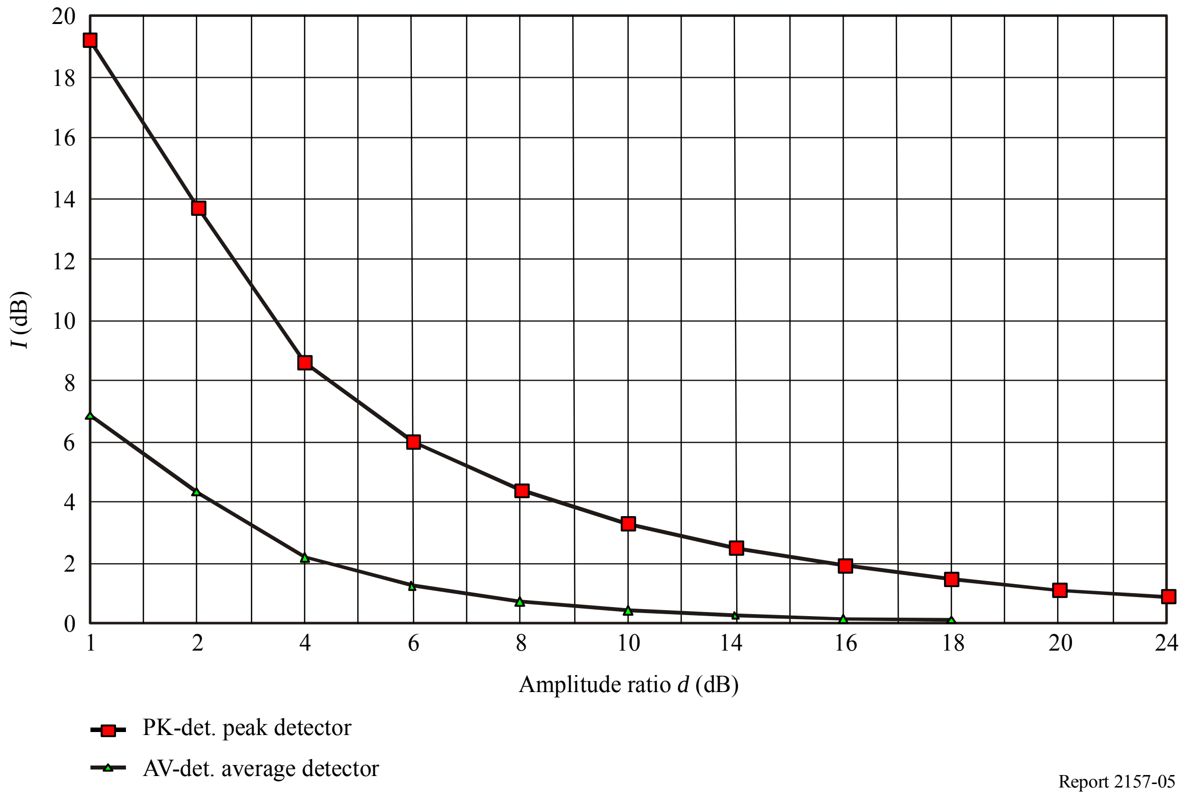
$$E_i = E_r - I \tag{A4-2}$$

The obtained corrected level of the reading E_i, representing the measurement result, shall be recorded in the test report.

Correction factor *I* can graphically be derived from the diagram shown in Fig. 5.

FIGURE 5

Determination of the disturbing signal amplitude by means of amplitude ratio *d* and correction factor *i*



Appendix 5 to Annex 3

Measurement of electric field-strength components in the frequency range up to 30 MHz; requirements for an active dipole

An active dipole suitable for measurements of electric field strengths in the frequency range from 9 kHz to 30 MHz should have the following features and parameters:

– total length of dipole: < 0,50 m

– balance of the dipole: ≤ 1 dB

– antenna factor: ≤ 20 dB/m

– output impedance: 50 Ω

Annex 4

Correlation of mobile monitoring station monopole antenna with loop antenna in Brazil

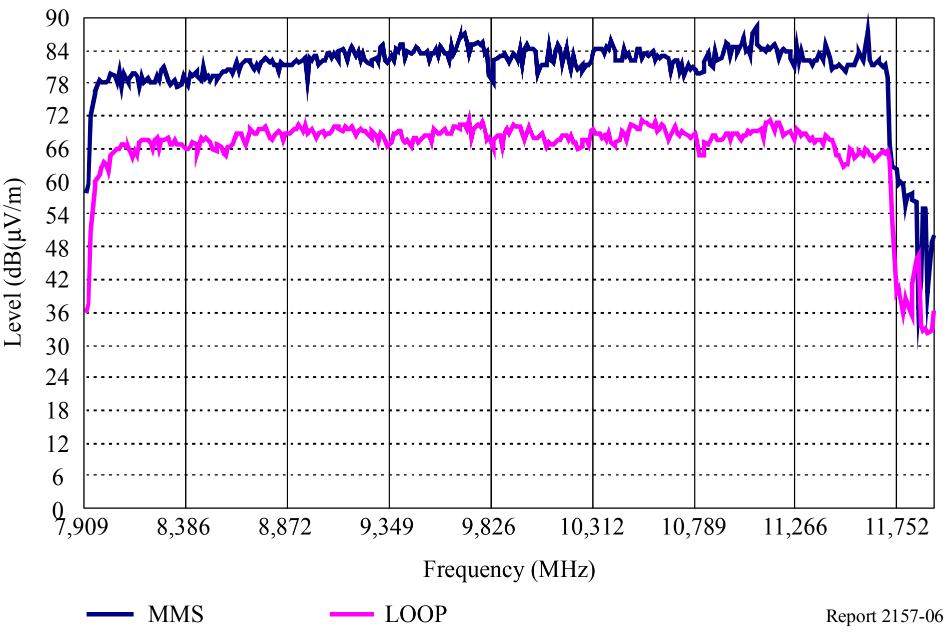
Power line telecommunication (PLT) systems are unintentional emitters of RF radiation and may cause harmful interference to radio receivers. This document describes the Brazilian studies on measuring interference from power line high data rate telecommunication systems (PLT) based on an alternative method using a monopole antenna installed on a mobile monitoring station. The results should be traceable to methods and results established on ITU-T Recommendation K.60 and FCC-04-245 documents. These References were used in this work.

The tests were conducted considering the 7-12 MHz band. This band has several telecommunications services. The advantage of this investigative method is to use the automated functions of a mobile monitoring station to perform the measurements.

This alternative method was compared with the traditional method, which uses a loop antenna connected to a spectrum analyser to perform the measurements. Results showed that systematic error occurs. Preliminary tests showed that cross polarization rejection has significant influence over mobile monitoring station measurement system. However, if a correction factor were established the error could be minimized.

Figure 6 compares the measurements obtained using both methods. Approximately a 12 dB difference can be observed.

FIGURE 6



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Currently, the method using the mobile monitoring station can be used for a qualitative evaluation, being adequate for regular spectrum monitoring operation, or a first order approximation for a quantitative evaluation. The analysis of uncertainties and error statistics will be subject of further studies.

Annex 5

Measurement methods for the compliance test in Japan

A5.1 Artificial mains network (AMN)

AMN shall have the characteristics specified in CISPR 16-1-2.

A5.2 Impedance stabilization network

A5.2.1 ISN1

ISN1 shall have the following characteristics in the frequency range from 150 kHz to 30 MHz:

a) It shall have the ports for a PLT EUT, a power supplying mains source, and a metallic reference ground plane. The power source is also connected to associated equipment (AE) for performing communication with the EUT.

b) The common-mode impedance seen from the EUT port shall be 25 ± 3 Ω with a phase 0±20º.

c) The differential-mode impedance seen from the EUT port shall be 100 ± 10 Ω with a phase 0±25º.

d) The LCL measured at the EUT port shall be 16 ± 3 dB.

e) To prevent the AE signal current from disturbing the measurement results, the AE differential-mode currents shall be attenuated by at least 20 dB.

f) To prevent the AE common-mode current from disturbing the measurements, it shall be attenuated by at least 35 dB.

A5.2.2 ISN2

ISN2 shall have the characteristics of the impedance stabilization network (ISN) for the telecommunication port specified in CISPR 22.

A5.3 Current probe

The current probe for measuring the PLT common-mode current shall meet the requirements specified in CISPR 16-1-2.

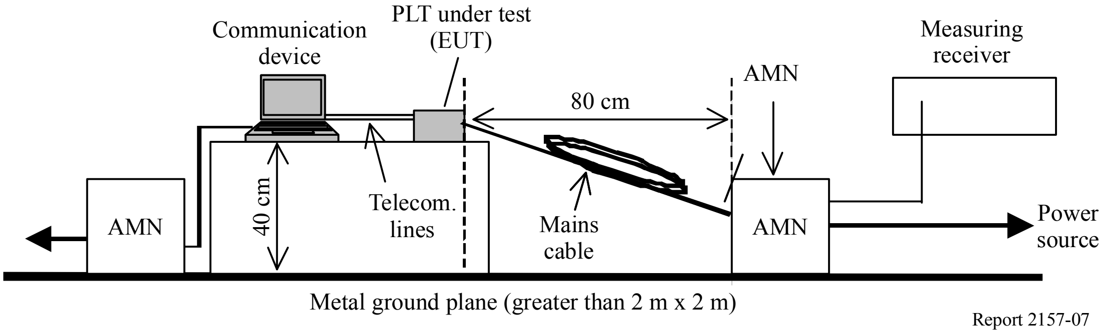
A5.4 Measurement arrangements for the compliance tests

A5.4.1 Measurement of the mains terminal voltage at the mains port in the PLT idle mode

See Fig. 7.

FIGURE 7

Measurement of the mains terminal voltage at the mains port in the PLT idle mode



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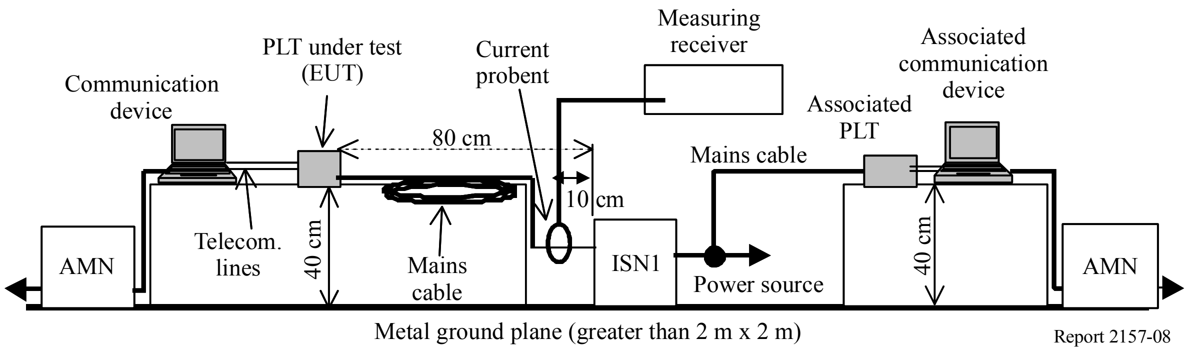
A5.4.2 Measurement of the common-mode current at the mains port in the PLT communication mode

See Fig. 8.

FIGURE 8

Measurement of the common-mode current at the mains port in the PLT communication mode



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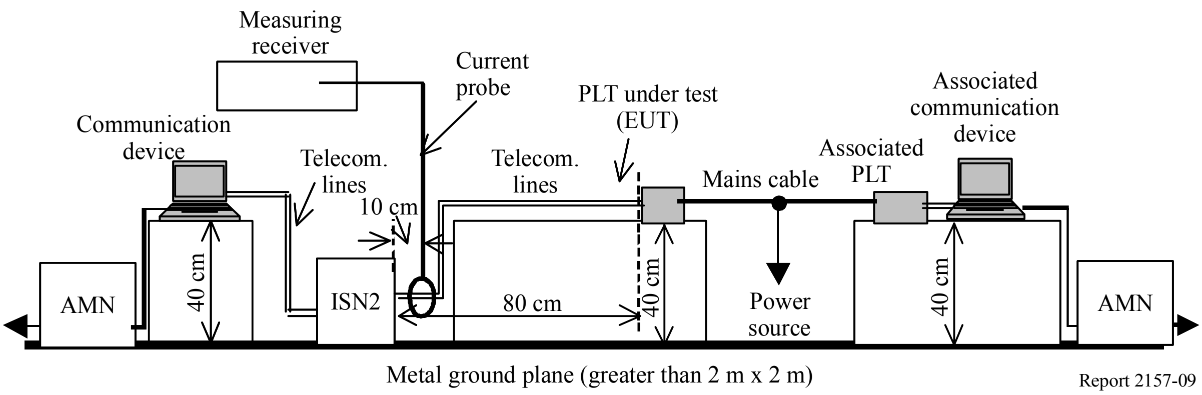
A5.4.3 Measurement of the common-mode current at the telecom. Port in the PLT communication mode

See Fig. 9.

FIGURE 9

Measurement of the common-mode current at the telecom port in the PLT communication mode



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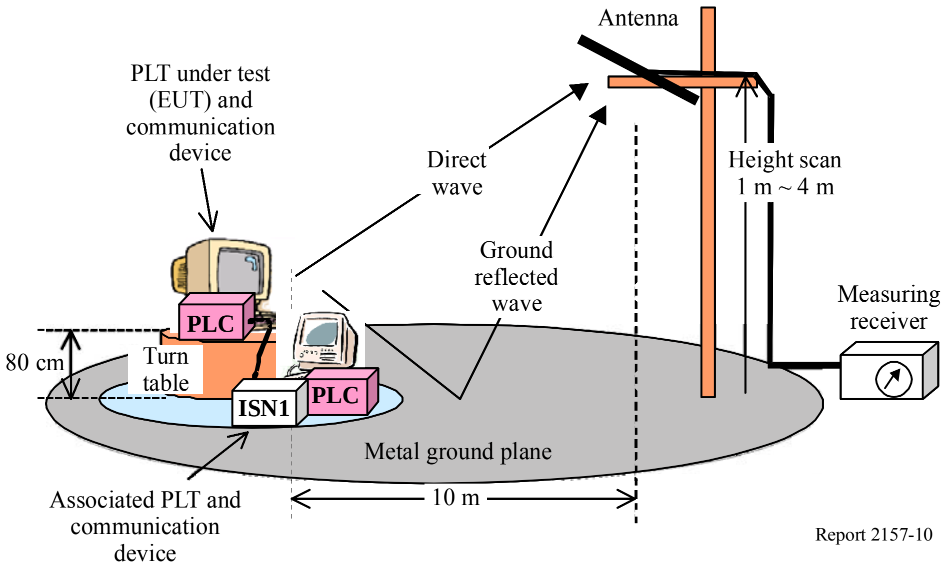
A5.4.4 Measurement of the radiated emission in the PLT communication mode

See Fig. 10.

FIGURE 10

Radiated emission measurement



Annex 6

Communications Research Centre (Canada) test methodology for the determination of RF emissions from PLT devices

The North American Broadcasters Association (NABA) contracted the Canadian Communications Research Centre (CRC) to carry out Measurements of RF emissions from Power Line Telecommunication (PLT) devices operating in a residential environment. Annex 6 describes the test procedure for the measurement of RF emissions to determine the extent of potential interference from PLT devices to broadcast services operating in a residential environment. The tests were carried out by CRC from November 2008 to January 2009.

A laboratory evaluation of PLT devices is presented in § A6.1, which aims at characterizing conducted emissions of these devices as a reference point for EM radiation measurements. § A6.2 contains the field trial methodology.

A6.1 Laboratory evaluation

The PLT devices are evaluated in the laboratory prior to field trial. The primary objective of these tests is to characterize and compare all PLT devices on the following criteria:

– Operating frequency range;

– Conducted power within the operating frequency range as specified by the manufacturer;

– Conducted power up to 110 MHz;

– General spectrum shape;
– Quantify the radiated emission differences between data transfer mode and idle mode;
– Quantify the difference between measurements using a peak detector and a quasi-peak detector.

Moreover, the laboratory evaluation allowed an understanding of the operation of these devices, more specifically:

– Practice measurement procedure and how the devices operate;
– Study PLT devices data transfer mode and idle mode of operation;
– Quantify PLT devices output power level.

The laboratory characterization is done in two parts. The first part of the laboratory evaluation is to assess the use of a quasi-peak detector for field trial. Quasi-peak detection is usually used for EM radiated emissions measurements in the frequency of operation of PLT devices. However, early work with a quasi-peak detector showed that this type of detector is meant to measure narrow band signals and will be inadequate to measure the wide band signals of PLT devices. This first part of this section explains this issue and will determine the relationship between measurements using peak and quasi-peak detectors.

The second part of the laboratory evaluation characterizes and compares the PLT devices using conducted power measurements.

A6.1.1 Laboratory tests setup

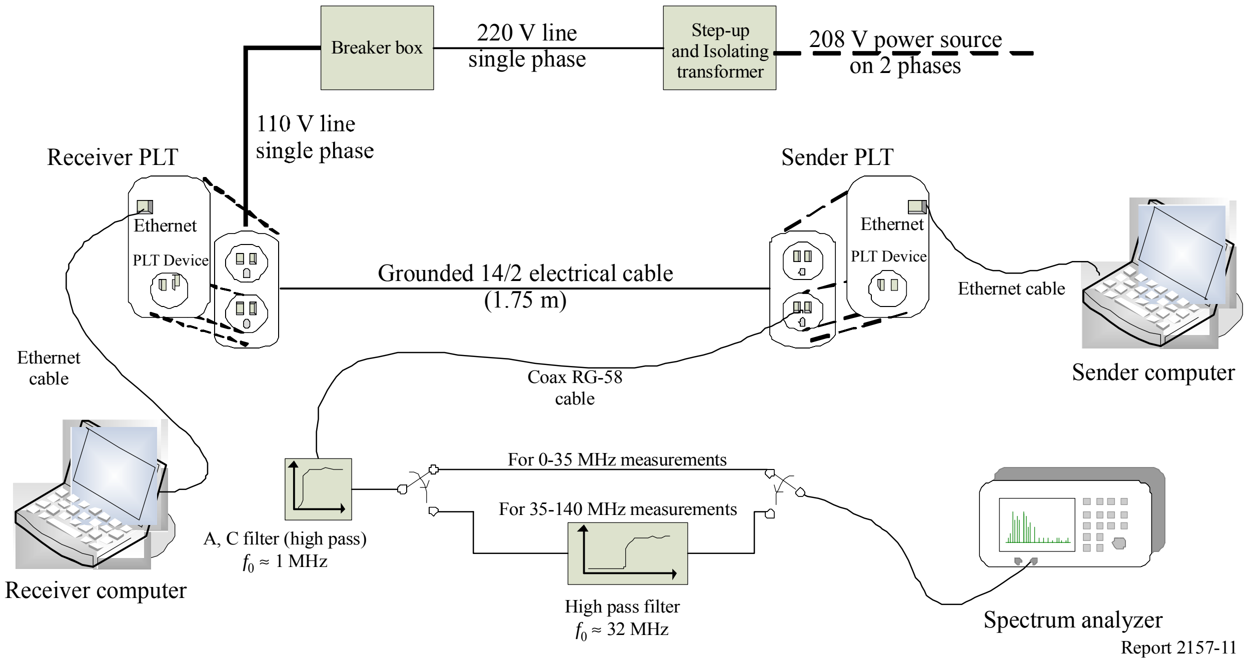
The laboratory setup for the conducted power measurement is presented in Fig. 11. The a.c electrical source is a 208Va.c/2 phase main power through a step up transformer and a breaker box to isolate and convert the a.c to 110-120 single phase voltage. Two outlets, used to plug in the PLT device pairs, are linked with a grounded 14/2 electrical cable of 1.75 m. A computer is assigned to each PLT device for the transfer of data. One computer sends a large file to a receiving computer.

The power measurement is performed using a spectrum analyser, set with a resolution bandwidth of 9 kHz and using peak detector. In order to measure the conducted signal from the PLT devices with the spectrum analyser, an ac filter is required to remove the a.c 110-120 V component. The a.c filter consists of a custom-made second-order LC filter with a cut-off frequency of 1 MHz.

In order to measure low signal levels of the PLT devices above 30 MHz with better precision, a high-pass filter is used to attenuate the main PLT signal carriers present in the operating frequency range. This is necessary in order to measure the emissions up to 110 MHz without overloading the spectrum analyser. As shown in Fig. 11, two laboratory setups are used; one without and one with the high-pass filter. The high-pass filter has a –3 dB cut-off frequency of 32 MHz. Only measurements above 35 MHz are made and recorded using this high-pass filter. The resolution bandwidth for these measurements is 120 kHz.

FIGURE 11

PLT devices conducted power measurements test bed



A6.1.2 Peak vs. quasi-peak detector measurements in the context of PLT emissions

Electro-magnetic compatibility measurements in the frequency of operation of PLT devices are normally done using a quasi-peak detector. A quasi-peak detector consists of a peak detector followed by a lossy integrator that has a longer falling time than rising time. This type of detector is meant to measure the annoyance factor of impulse signals to other devices. Due to the complexity of its implementation, the quasi-peak detector available for the spectrum analyser has an extremely slow response time. Measuring signals in the 1-108 MHz range could take up to two hours for a measurement that would take a few seconds using a regular peak detector. Therefore, peak detection is selected for the field trial measurements. Laboratory tests are carried out to find the relationship between peak and quasi-peak detectors.

A6.1.2.1 Test methodology

Conducted power measurements are performed to compare peak versus quasi-peak detectors. The measurements are made over a small 100 kHz bandwidth at a 15 MHz centre frequency. An average power measurement is performed in this 100 kHz band for each of the PLT device pairs, and for each of the two detectors. The difference in average power is considered to be the difference between peak and quasi-peak detection. It is shown in the laboratory that this small 100 kHz bandwidth is wide enough so that results will be repeatable with other centre frequencies. This test is made for each PLT device chosen for field trial, and the measurements are made while the PLT devices are sending data.

A6.1.3 Conducted power measurements

The conducted power measurements are made for the frequency range of 0 to 110 MHz using two modes of operation: data transfer mode and idle mode. The goal of the tests is to determine the output level injected into electrical lines up to 110 MHz in both modes and the bandwidth and spectral shape of the PLT devices.

A6.1.3.1 Test methodology

The test setup for these measurements is presented in Fig. 11. In order to obtain good precision, the measurements are made from 0 to 110 MHz in consecutive frequency spans of 10 MHz wide with the spectrum analyser set to a resolution bandwidth of 9 kHz and using peak detection. In general, the reference level of the spectrum analyser is adjusted as low as possible without creating spectral overload. As explained in § A6.1.1, a high-pass filter is used to obtain a more precise measurement at frequencies above 35 MHz. Because of this, a discontinuity in the noise floor can be observed in the results at 35 MHz.

A first measurement is made to evaluate the ambient noise level of the system. In this instance, no PLT devices are connected to the test bed. Following this, the output level of each PLT device is measured from 0 to 110 MHz while the devices are transferring data at full data rate (data transfer mode). Finally, a third set of measurements is made while the devices are not actively transferring data (idle mode). The PLT output power level during the tests is the factory pre-set power, which may not be adjustable.

A6.2 EMI field tests

The RF field-strength measurements are made using one and two-story residential houses. The houses are connected to a electricity distribution grid through underground or overhead a.c lines. The front and the back of the houses should have enough clearance to make field-strength measurements at three and ten metres from the outer walls, thus these two distances are selected for RF field-strength measurements.

A6.2.1 Field tests methodology

Multiple houses are selected for the measurement of RF field strength, representing various layouts and construction materials. A summary of the test sites is recorded with a full description of each test site, including the type of house, the material of the outer walls and the type of electrical line used to connect the house to the electricity grid of the neighbourhood (underground or overhead lines), pictures of the house and a diagram of each house. The PLT devices are tested in pairs of the same model, connected to a.c outlets inside the houses. The pairs of PLT devices are selected as per the laboratory tests discussed in § A6.1.1 above. During field tests, the devices are positioned inside the house to be far apart from each other, representing a realistic home network. The devices are positioned as to have one device from a PLT pair in a room near the front of the house and the other device near the back of the house. In the case of two-story homes, one PLT device is on the first floor and one is on the second floor. The PLT output power level during the tests is the factory pre-set level, which may not be adjustable.

Each PLT device is connected to a personal computer. Two modes of PLT operation are tested: Data Transfer mode for all the houses and Idle mode for a few selected houses. For the data transfer mode, measurements are made while a large file is transferred between the two computers. Reference measurements of the ambient noise are also performed at each measurement location.

The RF field strength is measured using a calibrated loop antenna for the frequency range of 0 to 30 MHz and a calibrated dipole antenna for the frequencies of 30 to 108 MHz (see § A6.2.2 for antenna specifications). The antenna factor of these antennas is precisely calibrated to yield RF field-strength measurements (dB(μV/m)). The antennas are positioned at 2 m above ground level. The measurements are made at 3 m and 10 m from the front and back outer walls of the houses.

The measurements in idle mode and in the frequency range of 30 to 108 MHz (dipole antenna) are made to confirm the conclusions reached in the laboratory evaluation.

There are four measurement locations at each of the houses:

– Front of the house, 3 m distance
– Front of the house, 10 m distance
– Back of the house, 3 m distance
– Back of the house, 10 m distance.

The following measurements are made at each location:

– Ambient noise level between 0 to 30 MHz (loop antenna)
– RF field strength between 0 to 30 MHz in data transfer mode for each of the PLT device pairs.

To confirm the conclusions reached during the laboratory test, the following measurements are made only for a few selected houses:

– RF field strength between 0 to 30 MHz in idle mode
– RF field strength between 30 to 108 MHz in idle and file transfer modes.

Also, additional tests are carried out to measure the RF field strength under overhead electrical lines.

A6.2.2 Field tests setup

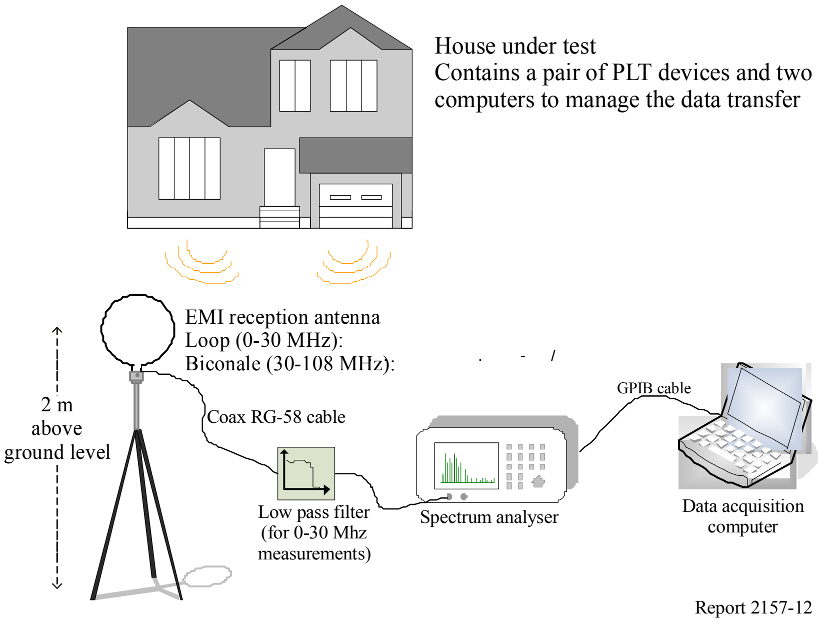
The measurement of the RF field strength required calibrated components and measuring equipment for the frequency range of 0-108 MHz. The following lists the equipment that is used for the field tests:

– Spectrum analyser
– Loop antenna (passive)
  – Operating Range: 10 kHz-30 MHz
– Dipole antenna (passive)
  – Operating range: 20 MHz-330 MHz
– Low-pass RF filter
  – −1 dB cut-off frequency: 31 MHz
  – −40 dB cut-off frequency: 35 MHz
– PLT device pairs
– Two computers used to transfer data over the PLT network
– One computer used to store the field-strength measurements

Figure 12 shows the test setup for RF field-strength measurements. As discussed previously, there are four antenna locations at each house where the field strength is measured (front and back, 3 m and 10 m). The antenna is positioned at 2 metres above ground level. A low pass filter connected between the antenna and the spectrum analyser is used to remove high-powered VHF signals (FM and TV stations) when measuring below 30 MHz, so as not to overload the spectrum analyser. A laptop computer is used to control the spectrum analyser and store the measurements.

FIGURE 12

RF field-strength measurements test setup



The following procedure is used at each house and for each measurement location. A first measurement is performed to record ambient noise level. Then, a pair of PLT devices is connected and a file transfer is initiated to carry out the RF field-strength measurement. The same process is repeated for the two other PLT device pairs. The antenna is then moved to another location and another set of measurements is carried out.

Additional tests for idle mode, dipole antenna (30-108 MHz) and overhead electrical lines are made for a few selected houses.

The spectrum analyser measurements are made using peak detection instead of quasi-peak, as explained in § A6.1.2. The low-pass filter, cable and antennas are calibrated to measure the EMI (dB(μV/m)). The following settings are used on the spectrum analyser for the measurements:

For frequencies 0 to 30 MHz (using loop antenna):

– Resolution bandwidth = 9 kHz

– Peak detector

– Max hold trace (10 s)

– One trace point every 50 kHz (601 points total)

For frequencies 30 to 108 MHz (using dipole antenna):

– Resolution bandwidth = 120 kHz

– Peak detector

– Max hold trace (10 s)

– One trace point every 50 kHz (1561 points total).

A6.2.3 Analysis methodology

For the purpose of analysing the measured RF field strength, all measurements done on the various houses were grouped by their respective devices and distance from the houses. Sites are not included in this statistical analysis if interference is detected from PLT devices in neighbouring houses. The statistical analysis includes the maximum RF field strength measured for each device.

Furthermore, the measurements from all the houses are used to calculate a confidence interval that should represent the expected maximum field strength from PLT devices radiated from typical houses. A 95% confidence interval of the RF field strength is calculated from the standard deviation of the houses sampled, given a normal distribution. The calculations in this statistical analysis are made with linear values. As explained above, the contribution of interference from sources other than PLT devices is not negligible and cannot be removed from the statistical analysis.

A6.3 CMI and DMI field test

Common mode current (CMI) and differential mode current (DMI) measurements are made in the residential dwellings. The purpose of measuring CMI and DMI is to determine if there is a relationship between these two measurements and EMI caused by PLT devices.

A6.3.1 CMI and DMI field test setup

The measurements are made at four electrical outlets in each house. Two of these outlets are the same outlets that are used to connect the PLT devices during EMI field tests. The CMI and DMI are measured at these two outlets by inserting a short extension cable between the PLT device and the outlet. Two additional outlets are tested, one on each floor of the houses. An open ended extension cable is used to measure the CMI and DMI at these outlets. Consequently, there are two different test setup used for these measurements, as is described below.

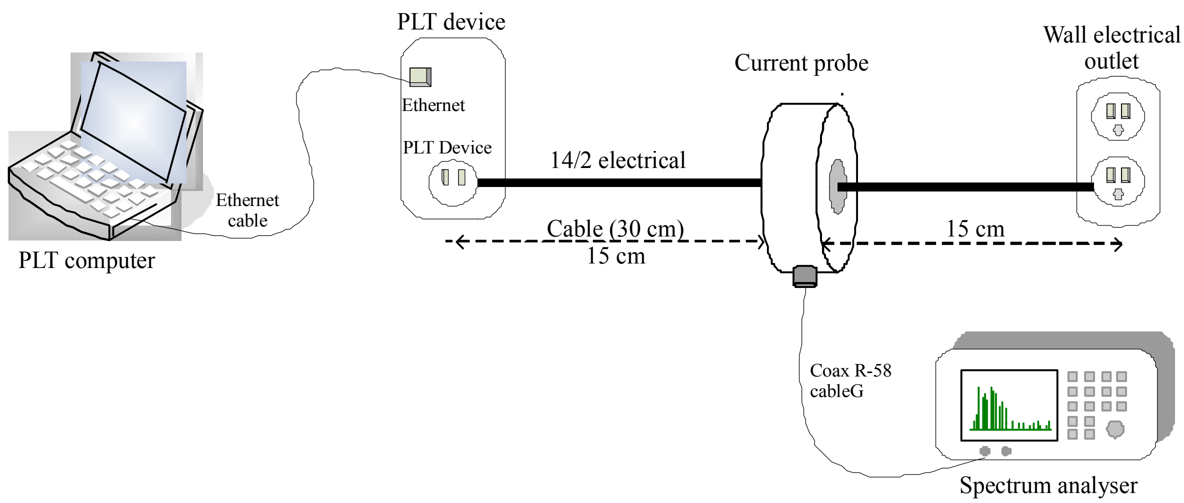
CMI and DMI measurements required the following equipment:

- Spectrum analyser
- Current probe
  - Operating range: 20 kHz to 100 MHz
- 2 × 14/2 grounded electrical cable (30 cm and 3 m cables)
- PLT device pairs
- Two computers used to transfer data over the PLT network.

Figures 13 and 14 show the configuration for the test setups and the equipment used. Figure 13 shows the test setup when testing on an outlet that had a PLT device connected, while Fig. 14 is the setup that is used to test at other outlets in the houses (no PLT device connected).

FIGURE 13

CMI and DMI test setup at PLT outlet



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As shown in Fig. 13, an electrical cable extension of 30 cm is inserted between the PLT device and its respective outlet. A current probe is placed halfway on the extension cable to measure the current with the spectrum analyser. Measurements are made while the pair of PLT devices present on the electrical network is in data transfer mode.

During CMI measurements, the current probe encircles all the wires in the electrical cable (Live, Neutral and Ground). For DMI measurements, the electrical cable sheath is removed and only the Live wire is placed in the current probe, while the Neutral and Ground are looped outside the probe.

FIGURE 14

CMI and DMI test setup at other outlet

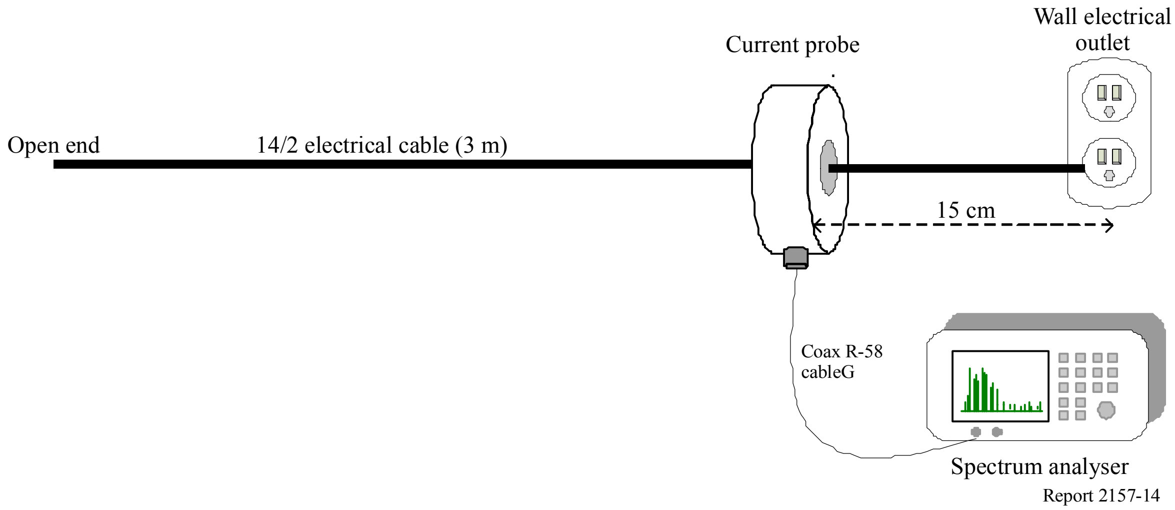

Figure 14 shows the test setup when testing on outlets that had no PLT devices connected. As can be seen in the figure, an open ended extension cable of 3 m is used to place the current probe. The pair of PLT devices is still connected to their original outlets in the house, and the data transfer is initiated.

The measurements are made over the frequency range of 0 to 30 MHz for configurations. The following settings are used for the spectrum analyser:

– Resolution bandwidth = 10 kHz
– Average detector
– Max hold trace (10 s)
– One trace point every 50 kHz (601 points total).

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