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CISPR/I: ELECTROMAGNETIC COMPATIBILITY OF INFORMATION TECHNOLOGY EQUIPMENT, MULTIMEDIA EQUIPMENT AND RECEIVERS

Report on Mitigation Factors and Methods for Power Line Telecommunications

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The CISPR/I Project Team CISPR-22-PLT has been considering limits and method of measurement of broadband telecommunication equipment over power lines. In the course of this work, mitigation techniques that might be employed (in addition to limits and measurement techniques) to protect against interference to radio services have been brought to the attention of the Project Team.

The Project Team is in the process of releasing two documents, a CD (CISPR/I/257/CD) amendment to CISPR 22 containing limits and measurement techniques for PLT and this draft document that is a compilation of possible mitigation techniques that may be employed and is intended to become a Technical report.

Mitigation techniques are generally considered to be regulatory measures that are outside the scope of CISPR standards. One purpose of this document is to make CISPR work other than standards, such as this, available to entities that are not CISPR members. This document contains information that may be of particular interest to National Administrations.

This document is being circulated for comments to seek the opinion of the National Committees as to whether it is suitable for circulation as a Draft Technical Report (DTR).

The National Committees are invited to submit their comments and suggestions on the proposed project. The input, to be submitted through the IEC voting system, is requested by:

2008-05-09.

Subject: **Report on Mitigation Factors and Methods for Power Line Telecommunications**

There is increasing demand for and use of broadband access to the Internet throughout the world and power line telecommunications (PLT) systems may provide one means of such access. We call these applications ”PLT Access systems”.

Home networking is another application of PLT which has a great potential. PLT will enable to interconnect all digital consumer electronic devices within a single family house or an apartment, without a new installation of network wires and without the propagation problems that may exist with wireless solutions. We call these applications of “PLT In-house systems”.

Depending the particular application PLT system may use internal low voltage house wiring to carry communications signals, or outside (overhead or buried) low voltage (LV) wiring or outside medium voltage (MV) wiring, or a combination.

But such systems are unintentional emitters of RF radiation, and may cause interference to radio receivers.

In adopting regulations applicable to PLT, limits on emission levels may be employed to protect against interference, or a combination of emission limits and mitigation factors may be employed.

PLT system operators can incorporate capabilities to modify their systems’ operations and performance to mitigate or avoid potential harmful interference to radio services and to deactivate specific units found to actually cause harmful interference that cannot be remedied through modification of their operations. Yet, PLT equipment manufacturers and operators can still have flexibility to design and implement a broad range of products and system designs to meet particular service and operational needs while ensuring that systems have the capabilities to make operational changes to avoid any interference that may arise.

In addition to mitigation techniques, interference complaint procedures may be established. Parties who believe they are experiencing interference from a PLT device are first expected to bring the matter to the attention of the operator of the PLT device. If that action does not resolve the interference, the party may then seek intervention by an administration agency.

This report provides guidance on mitigation factors and interference complaint procedures that may be considered.

Attenuation of PLT Signals

PLT modems are symmetric signal sources that inject RF power into networks with a certain degree of asymmetry. A small part of the injected RF power is radiated into the environment and some of it may be picked up by antennas of shortwave receivers. This coupling mode called “radiated” is in most cases the dominant one, but there are other modes. Sometimes the PLT signals conducted via the low voltage network to the power supply of the broadcast receiver is the dominant cause of interference. The latter coupling mode called “conducted” is mainly of interest for small indoor receivers with integrated (asymmetric) stick antennas and operated in buildings in which PLT is operated.

Radiated signal strength is a strong function of distance from the emitter. Thus, interference to short wave receivers can be mitigated if such receivers are moved so that they are not operated close to PLT modems.

Conducted signals are strongly attenuated by the network and sometimes by electricity meters. Within an apartment or a small house we find typical attenuations of around 40 dB, to neighboring apartments we may have 60 dB or more. It may be beneficial to install blocking filters in the distribution panels of multi apartment houses. Common mode filters installed in the power supply cord of perturbed receivers are efficient means of mitigation. See, for example, “System, device, and method for isolating signaling environments in a power line communication system”, United States Patent No. 6,590,493, Rasimas, et al., July 8, 2003.

Protection of Critical Radio Services

Certain radio services may warrant special protection from PLT emissions. These services include national defense, maritime distress and safety, aeronautical navigation and communications, emergency response, radioastronomy, and others that provide important safety and research services. Their functions could be afforded additional protection against possible interference from PLT operations, by means of frequency band exclusions, geographical exclusion zones, or consultation area requirements.

Frequency Band Exclusions

PLT systems could be required to exclude ("place no carrier frequencies in") certain designated bands. This technique is sometimes called "static notching" or simply "notching".

For example, one administration has imposed such a requirement on some bands between 2 MHz and 22 MHz as well as 74.8-75.2 MHz (used for aircraft reception of marker beacons) to overhead outdoor MV wires, to outdoor MV and LV wires, or to underground wires (LV or MV). This protects bands allocated to aeronautical mobile [R] and radio-navigation services that are used to provide aeronautical safety of life services. In this case, the requirement was applied only to overhead outdoor MV wires, not to LV or underground MV wires. The excluded frequency bands account for less than 2.18% of the frequencies between 1.7 and 80 MHz.

Geographical Exclusion Zones

PLT operators could be prohibited from using certain frequency bands within specified distances of licensed radio stations in particular services. (See **Annex--Rationale for the Separation Distances.**)

For example, one administration has prohibited PLT use of Access systems in the frequency band 2.1735-2.1905 MHz (global maritime distress band) within 1 km of about 110 designated maritime radio stations. It also prohibited PLT operators from using 73.0-74.6 MHz (radio astronomy frequencies) within 65 km of one radio astronomy observatory (applicable only to overhead MV) or within 47 km of the RA observatory (applicable to underground MV and overhead LV lines).

Consultation Area Requirements for PLT Access systems

In order to make the detection and mitigation of interference more efficient, PLT Access system operators could be required to give advance notice of installations to certain radio service licensees.

For example, one administration has required PLT operators to give 30 days advance notice of installations in the following bands and locations:

- on 1.7-30 MHz, if within 4 km of certain specified administration monitoring stations and about 60 aeronautical and land HF radio stations;
- on 1.7-80 MHz, if within 4 km of about 16 radio astronomy sites;
- on 1.7-30 MHz, if within 37 km of three specified radar receive sites;
- on 1.7-80 MHz, if within 1 km of certain other specified sites;
- to frequency coordinators for police, fire and emergency medical agencies licensed to operate mobile radio services in the area.

For planned operations within the consultation areas defined above, PLT operators must supply the following information:

1) name of the PLT operator
2) frequencies of the PLT operation
3) postal codes served by the PLT operation
4) the manufacturer of and type of PLT equipment being deployed
5) point of contact information (both telephone and e-mail address) and
6) the proposed or actual date of initiation of PLT operation.

Dynamic Mitigation Techniques for PLT Access Systems

Access PLT operators could be required to employ equipment with interference mitigation techniques under the control of the operator. This would permit PLT operators to notch or decrease signal strength to mitigate interference at particular locations in particular bands when it is reported. Notches could be required to reduce emissions by a fixed amount below applicable emission limits.

One administration, based on field experience, determined that below 30 MHz, notching of 20 dB below the applicable emission limit for Short Range Devices is adequate to resolve interference occurrences that might result to mobile reception from PLT operations. This was based on the low signal levels allowed for Short Range Devices and the fact that a mobile transceiver can readily be re-positioned to provide some separation from the PLT operation. The interference potential from emissions at this low level would be limited to a very short range from a PLT device or a power line on which PLT transmissions are carried. It also determined that notching at this level with some distance separation will generally avoid interference to fixed operations, including those that use more sensitive receivers. (Under this requirement, PLT systems would have to be able to limit their emissions in bands selected notching to 50 dBµV/m at frequencies from 1.705 to 30 MHz and 30 dBuV/m at frequencies above 30 MHz. These values apply for measurements at 3 meters.)

Above 30 MHz, it determined that a notching capability of at least 10 dB is sufficient to provide the same level of protection, given the more Short Range Devices emission limits that apply to PLT transmissions above 30 MHz and the increased attenuation of emissions that occurs from propagation losses as the frequency of operation increases. (For example, the free space propagation loss between two isotropic antennas separated by 100 meters is approximately 18.5 dB at 2 MHz, 32 dB at 10 MHz, 38 dB at 20 MHz, 42 dB at 30 MHz, and 50 dB at 80 MHz.)

Access PLT operators could also be required to employ equipment with a “last resort” remote controllable PLT transmission shut-down feature for the deactivation of any unit found to cause harmful interference.

This capability allows system operators to deactivate limited portions of their plant so that localized interference problems can be addressed without affecting service to all of their subscribers. As a secondary benefit, the shut-down feature will allow system operators to rapidly diagnose whether their operations are causing reported interference. The shut-down feature in individual devices could be remote-controllable from the central system operations facility or other appropriate location. This will allow rapid response to resolve interference in any emergency or other urgent situation that might arise.

Adaptive Notching for PLT In-house Systems

Adaptive Notching is a new technique in an advanced state of development in industry and in ETSI. It aims to protect in-house short wave broadcast reception and avoids static notching of all broadcast bands at all times, which would result in substantial permanent performance loss. Laboratory and field tests jointly with the EBU have successfully demonstrated this technique. Adaptive Notching is a powerful mitigation technique for PLT devices.

Adaptive notching operates autonomously. The modems sense the radio frequency spectrum, detect the broadcast channels received with usable quality at the site and at the time and notch out these channels in the transmitted signal. The loss of throughput of a PLT system due to adaptive notching is very low. Only the few broadcast channels which offer useful indoor reception at a given time are notched.

PLT Operator Database for PLT Access Systems

Access PLT system operators could be required to establish a publicly accessible database of PLT operations to make interference mitigation more efficient. Such a database could be managed by an industry trade association, by a government agency, or by an independent third party. The database could contain the following information, for example:

1) name of the PLT operator
2) frequencies of the PLT operation
3) postal codes served by the PLT operation
4) the manufacturer of and type of PLT equipment being deployed
5) point of contact information (both telephone and e-mail address) and
6) the proposed or actual date of initiation of PLT operation.

The database manager need have no role in any interference complaint or investigation, but information in the database could be used in such investigations.

Interference Complaint Procedures

Procedures should exist for submission of and response to PLT interference complaints.

For example, the complainant should first take reasonable steps to confirm that interference exists, and is caused by a PLT system. In case the interference is caused by his own PLT In-house system he should seek advice and if necessary assistance from his supplier of the PLT equipment.
In case the interference is likely to be caused by a PLT Access system, the complainant should notify the operator. The PLT operator should investigate within a time that is reasonable for the service suffering interference. For example, the PLT operator might be allowed 24 hours to investigate and mitigate complaints from public safety licensees, but longer to investigate interference to HF broadcast services. If the interference cannot be mitigated in this manner, the licensee could then file a complaint with the appropriate administration agency, which would then assign its technical and legal resources to mitigating the interference.

Annex--Rationale for the Separation Distances

Scientists from one administration analyzed the PLT emissions from a Medium Voltage power line model with Numerical Electromagnetic Code (NEC) simulations to determine the minimum dimensions of exclusion zones and coordination areas needed to prevent significant increases in the receiver noise floor.[1]

Assumptions for Radio Receivers
The analysis assumed that the PLT signal sources will operate at the emission limits for Short Range Devices below 30 MHz, and at Class A device emission limits above 30 MHz.

Commercial deployments are likely to result in PLT devices separated by ½ to 1 km. To account for aggregation of multiple co-channel emission sources seen at an elevated, ground-based antenna, this analysis assumes that the radio receiver antenna receives the equivalent of two equal-power PLT signals.

The NEC power line model used in this analysis is representative of a long, 3-phase Medium Voltage distribution line. The model parameters are:

- 340 meter power line lengths;
- 3 horizontally-oriented power lines spaced 0.6 meters apart;
- no neutral wire;
- conductors were modeled with conductivity characteristics of copper wire and AWG 4/0 diameter;
- the power lines are 8.5 meters above ground having average electrical parameter values;
- one outer power conductor was center-fed using a voltage source and series resistor to simulate a PLT coupler;

The exclusion zones and coordination areas are intended to substantially reduce the risk of harmful interference to weak signal reception at these protected receiver sites. Their radii are determined by noting the distance from the power line model where the noise floor is raised by a certain amount. The radii were chosen to be the distance at which the probability that a receiver experiences an increase in noise floor level (I+N/N) of 1 dB.

The PLT interfering signal power was determined by the NEC simulations. The noise power was assumed to be the lowest predicted median noise level for a quiet rural noise environment. The assumption of a quiet rural noise environment is reasonable, as most receiver sites dealing with weak signal reception were selected because they exhibit very low background noise levels. In addition, personnel at these sites (where manned) actively work with local utilities to prevent increases in ambient noise due to power line noise sources.

Quiet Rural Noise levels used in this analysis:

In 2.8 kHz BW:	
4 MHz	-135.3 dBW
10 MHz	-136.7 dBW
15 MHz	-144.7 dBW
20 MHz	-147.9 dBW
25 MHz	-150.2 dBW
In 16 kHz BW:	
30 MHz	-144.6 dBW
40 MHz	-147.5 dBW

Assumptions for Radio Astronomy at 73.0 – 74.6 MHz and Radar Receivers
The same power line structure described above was used for analyses of impact on radio astronomy and radar receivers. These analyses employed four PLT sources operating at the Short Range Device emissions limit (the Class A limit was used above 30 MHz). The protection requirement for both Very Long Baseline Array (VLBA) radio astronomy receivers in the 73.0 – 74.6 MHz frequency band and for radar receivers in the 1/7 – 30 MHz band is to limit the power flux density to a level less than -258 dBW/m2-Hz.

Results for Radio Receivers

[1] This annex is extracted from Chapter 3 of the NTIA Phase 2 Report, Potential Interference From Broadband Over Power Line (BPL) Systems To Federal Government Radiocommunication Systems at 1.7 - 80 MHz, *Phase 2 Study,* http://www.ntia.doc.gov/osmhome/reports/2007/NTIA_BPL_Phase2_VolumeI_3.pdf

Some results were displayed as figures showing the percentage of points along a PLT power line where the noise floor increase due to PLT emissions from 4 to 40 MHz exceeds 1 dB, in a receiver having antenna gain of 0 dBi towards the power line.

Other results were displayed as figures showing the results at 4, 15 and 25 MHz for a 14 dBi gain receiver site antenna having up to 5 dBi gain towards the power line.

One figure summarizes the minimum radii needed to limit the increase in noise floor level to 1 dB or less. It shows that distances beyond which a 1 dB increase in noise are predicted to be possible (i.e., distances where the curves meet the X axis) increase slowly as frequency increases from 1.7 MHz to over 10 MHz, mainly as a result of decreasing median noise power levels.

Between 15 MHz and 30 MHz, the radiation efficiency of the PLT power line significantly increases the distances where the noise floor can increase by 1 dB or more. The gain of the modeled high- gain antenna in the direction of the PLT power line is greatest between 15 MHz and 30 MHz as well.

Thus, distance results for 4 MHz were applied to establish the proposed 1 km exclusion zone dimension for the 2,173.5-2,190.5 kHz band used by marine and aeronautical coast stations. Upward rounding of the 4 MHz distance of 895 meters to 1 km and application of that distance from the boundary of the coast station facility accommodate receiver antenna location flexibility, error tolerance in the reported antenna coordinates, and the possibility that other PLT power line configurations not evaluated in this study may generate higher field strength.

Among the frequencies considered, the largest distance within which a 1 dB increase in noise is predicted occurs at 25 MHz (distance of about 3.9 km). Upward rounding of this distance to 4 km would accommodate error tolerance in the reported antenna coordinates and the possibility that other PLT power line configurations and PLT signal aggregation not evaluated in this study may generate higher field strength.

Results for Radar Receivers

The analysis calculated the PFD at a radar receiving antenna due to four equal-power co-frequency overhead PLT sources, positioned at a height of 8.5 meters above the ground and radiating at the Short Range Device limit in the direction of the receiving antenna at various horizontal distances. The modeled overhead power line radiates most effectively at 25 MHz, and therefore, this frequency was chosen for evaluation in the radar receiver analysis. The maximum PFD levels begin to exceed the assumed threshold of -258 dBW/m2-Hz at horizontal distances of 36 km or less from the power line.

Results for Radioastronomy Receivers

This analysis assumed that there were four equal-power co-frequency PLT sources radiating at the Short Range Device limit in the direction of the receiving antenna. For the overhead PLT power line case, the PLT sources were assumed to be positioned at a height of 8.5 meters off of the ground.

Analysis showed that for the PFD levels expected at a radioastronomy antenna located at various horizontal distances from overhead and underground PLT sources, the PFD falls below the -258 dBW/m2-Hz threshold interference level at distances greater than 29 km from the overhead PLT sources. (An exclusion distance of 65 km was based on a separation distance of 29 km plus an antenna array radius of 36 km.)

For the underground PLT case, the power flux density falls below the threshold interference level at distances beyond 11 km from the underground MV power lines. From experience conducting field measurements on underground PLT systems, emissions levels are typically well below the Short Range Device limits, and in many cases, the radiated PLT signal was not measurable.