PLC-Workshop
Brussels, 16 October 2003

Source: Deutsche Telekom AG, radio and DSL-operator

Subject: Compatibility of PLC-technology and radio services; "mitigated PLC" to obtain some coexistence with radio services

Management summary

- Due to physical reasons current PLT-systems are not compatible with the operation of radio services
- The interference potential of PLC (Last-Mile-PLC as well as Inhouse-PLC) has to be reduced dramatically by
  - not using ("notching") critical frequency bands being received in a home environment (e.g. not using broadcasting frequencies)
  - restricting unwanted radiation in the other bands to NB30-level to prevent accumulation effects

1. Introduction

Deutsche Telekom is operating radio services in the frequency range below 30 MHz (the long-, medium and short wave bands), is one of the promoters of DRM (digitalisation of broadcasting in those bands) and thus has a strong interest in the protection of radio services.
Deutsche Telekom is also operating 4 million DSL-systems. The ADSL-systems in use as well as the VDSL-systems in evaluation are being designed according to well established EMC-principles and will protect radio services.
In this context the NB30-radiation limits are supported by Deutsche Telekom to be incorporated in the European "EMC-Standard for Networks".

Due to physical reasons the possible deployment of PLC-systems (Access/Last Mile PLC as well as Inhouse PLC) is a great threat to the future operation and development of radio services in the frequency range up to 30 MHz.
Taking into account developments in the US, where BPL (Broadband over Powerline) demands to use spectrum up to 80 MHz, the threat might be even more "broadband".

The **Annex** quotes ECC-Report 24 (PLT, DSL, CABLE COMMUNICATIONS (INCLUDING CABLE TV), LANS AND THEIR EFFECT ON RADIO SERVICES), chapter 2.5, which describes in detail, why the risk of PLC-systems to interfere with radio services is much greater compared to DSL-systems.

2. EMC- Principles

EMC means "Electromagnetic Compatibility". Compatibility is given when both wireless and wire bound equipment, networks and services can be operated without causing interference to each other. The EMC-Directive requires that electronic equipment must be constructed in

such a way as to ensure that radio services and radio receivers can still be “operated as intended”.
As a consequence systems like PLC must not interfere with the reception of radio signals.

3. Basic facts concerning physics of radiation and radio reception

Applying a high frequency signal (or a high bitrate stream of data) to a piece of unshielded copper wire which is equivalent or longer than a quarter of the wavelength of the frequency or frequencies used will result in a remarkable radiation from that cable. Even small levels of injected power will result in high field strengths of unwanted radiated energy. The higher the frequencies used the shorter the lengths of cable may be to make a good radiator.

A radio communication receiver needs a receiving signal exceeding the required minimum field strength for the radio service concerned. Any unwanted signal (also being received on the same frequency at the antenna of this receiver) has to be at least 20 dB below the wanted receiving signal. These approx. 20 dB are called the protection margin which varies according to radio service and mode of operation.

As a consequence at the receivers location any unwanted (potentially disturbing) signal must be smaller than $1/10^{th}$ of the wanted signal (meaning 20 dB attenuated compared to the wanted signal) as not to obstruct reception.
Any unwanted signal (e.g. caused by cable networks) being stronger than this “field strength of the receiving signal minus the protection margin” will interfere with the radio receiver and prevent this receiver “to operate as intended”.

4. No compatibility of current PLT-systems with radio reception

A very good radiating network is the mains power supply network, which consists of unshielded cables of low symmetry with many resonant stubs (unterminated random lengths of wire producing “standing waves”).
According to the basics quoted above unharmed radio reception needs a signal which is at least 20 dB (10 times stronger) than an interfering signal on the same frequency.
Measurements have shown that in the case of a short wave broadcasting receiver being operated in a real PLT-network the PLT-(unwanted) radiation at the antenna of the receiver is either in the order of magnitude of the wanted receiving signal or in many cases even stronger.

To achieve compatibility between broadcast reception in this case and PLT-operation an attenuation of the unwanted PLT-radiation of at least 20 dB would be required.

These 20 dB of attenuation of the unwanted radiation could either be obtained by injecting less power into the mains network (meaning reduction of the injected PLT power level to 1/10) or by increasing the distance between the radio receiver and the power supply cabling.
The first alternative would reduce the PLT-systems range and would make operation unreliable. Increasing the distance between the network and the victim receiver is also hardly possible because the latter is being operated “within the antenna structure” of the PLT-network. In addition it should be remembered that most receivers are fed by the mains power supply network. Therefore an increase of distances between unwanted PLC-radiator and victim receiver is not feasible.
Even the reception of very strong broadcasting signals is interfered in a PLC-environment.
The reception of weak broadcasting signals or low-signal-services like the Amateur Service is interfered in a wide area around any PLC-network (Last-Mile-PLC or inhouse-PLC).

Due to simple physical facts described above there is no compatibility between “unmitigated PLT-systems” and radio services.

5. Mitigation measures to obtain coexistence with radio services

The Spectrum Management community uses the term “mitigation” to describe technical and/or operational measures to improve the coexistence of services or technologies. By implementing mitigation the risk of PLC to create interference to radio receivers can be reduced dramatically.

The most endangered radio users are those operating their receivers and antennas in a home environment “within the antenna structure of PLC”.
Thus the most probable victims of PLC-technology are the listeners of the short wave broadcasting service and the radio amateurs. Both potential victims have no chance to reduce the impact of PLC-radiation e.g. by increasing the distance to the radiating network. Even by applying the moderate NB30-radiation limits the interference to the receivers of these radio services will become a problem.

The risk of interference to other radio services is much smaller because their operating locations, antennas and receivers are geographically separated from PLC-operated networks. In their case the far field effect (e.g. problem of “accumulation”, the aggregated increase in background noise) may become a medium to long term problem, if PLC-radiation limits are set to high or are not met. The studies conducted by the CEPT-Project Team SE35 and the ECC Report 24 indicate that radiation limits higher than NB30 may result in long distance interference to radio services due to accumulation. Due to the very good propagation conditions in the short wave band an increase of the noise floor could have a negative worldwide effect.

Therefore the **following mitigation measures** are proposed for Access/Last mile-PLC and inhouse-PLC-equipment, which will reduce the risk of interference to radio receivers dramatically:

- Not to use broadcasting frequency bands (“notching” of at least the most popular broadcasting bands)
- Not to use amateur frequency bands
- In addition to prevent negative long term effects of a broad deployment of PLC-systems (inhouse and access-PLC) a limitation of radiation on other frequency bands to NB30-level is necessary

Whether the protection of security radio services can be ensured by setting and respecting the NB30-limits or if an additional attenuation of those frequency subbands is also required has to be discussed.

6. Conclusions

- The EMC principles laid down in the EMC-Directive of the European Commission have to be respected by all electronic appliances and networks including PLC. Any operation of electrical appliances or networks has to ensure that “radio services can still be operated as intended”.

- Due to physical reasons there is no compatibility between radio services and “unmitigated PLC” using very broad frequency ranges without “notches”.

- Compatibility requires to “notch” (not to use) frequency bands used by receivers being operated in a home environment, where PLC may be put into operation.

Annex

The physical and technical reasons, why PLC is such a great risk to radio services is described in detail in the ECC-Report 24 (PLT, DSL, CABLE COMMUNICATIONS (INCLUDING CABLE TV), LANS AND THEIR EFFECT ON RADIO SERVICES; Chapter 2.5.:

Comparison of the various cable technologies

Data transmissions over wired media have a range of different characteristics. These are determined by the degree of screening or balance inherent in the transmission cable, the nature of the transmission itself, and the transmission power employed, the frequencies involved and the ability to take mitigation measures in cases of interference.

A comparison between three types of wideband transmission highlights the fundamental differences in aspects of the systems:

Nature	Coaxial Cable	DSL	PLT
Suitability of the transmission medium to carry wideband data	Very Good	Medium	**Poor**
Features of the cable system	Screened	Balanced	Unscreened and unbalanced
Available bandwidth and potential for expansion	Very Good	Fair	Poor
Practicality of applying mitigating measures	Good	Medium	Very poor

Table 2.5-1: Comparison of the cable technologies

The discussion of coexistence should not be restricted to radiation limits to be imposed on cable systems to protect radio services. The risk of interference is not only a matter of the limit itself but also a question how systems are deployed and used in an environment shared by radio services and wire systems. The difference becomes obvious, when comparing PLT and DSL, which are using frequencies below 30 MHz.

The following critical factors must be compared when evaluating the risk of interference to radio services caused by these two systems:

- The total bandwidth necessary to operate a cable system directly influences the number of services and frequencies potentially affected by a cable usage.
- The upper frequency limit of a cable system is decisive concerning the potential for unwanted radiation. This potential depends on “wavelengths of the frequencies used” related to the average “length of (unshielded) cable” to be found within the network. The higher this frequency limit is the more energy is likely to be radiated especially when using unshielded cable with bad symmetry.
  Example: A PLT-system may use spectrum up to 10 MHz (λ = 30 m); pieces of cable as short as 7,5 m (λ/4) are resonant and thus are very good radiators at this frequency. In contrast to this the ADSL-system mentioned in the table below is using a frequency range up to 1,1 MHz (λ = 270 m) only; therefore an unshielded piece of cable needs to be about 68 m long to radiate energy with the same “efficiency” than in the first case. The probability to find wires of efficiently radiating lengths is decreasing with increasing wavelengths of frequencies used within the cable system.
  The radiating efficiency of unshielded cables with resonant lengths of λ/4 or multiples of this is at least 20 dB higher than for dimensions $l < \lambda/4$. In this context the upper frequency limit of a cable system in relation to the cable dimensions found within the network is the decisive parameter.
- The potential of unwanted radiation is also depending on the structure of the cable network. A symmetrical telephone line properly matched and without resonant stubs radiates far less energy than a local mains distribution network. (Stubs are pieces of cable of random length without proper termination as to be found in great numbers in the mains power supply). In addition to supply only one PLT-customer a whole local power supply network has to be taken into operation and is radiating thus

creating interference potential for a much bigger area than is necessary to bring service to a single DSL-customer.

- **Another point is the probability for decoupling by distance between a random victim receiver and the radiating cable network. This is the case especially for broadcasting and amateur receivers being operated in the vicinity of PLT- or DSL-networks. The probability for a receiver location interfered by radiation being distributed by the mains power supply is much greater than the risk of interference caused by the telephone line. This is due to the fact that the power supply infrastructure is more widely distributed especially in private homes compared to the telephone infrastructure. In addition most radio communication receivers are connected directly to the mains power supply, increasing the risk of interference even more.**

In Table 2.5-2 below these critical factors are compared between a DSL- and a PLT-system. The second generation of an ADSL-systems rolled out in Germany is taken as an example for the DSL-system.

Critical factors concerning coexistence with radio services	**ADSL** (example: 2. ADSL-generation to be deployed in Germany; 1,5 MBit/s to each customer)	**Access-/Last-Mile-PLT** (approx. 2 MBit/s shared by all users in the local network)
Frequency spectrum to be used by the cable system (resulting in unwanted radiation in this frequency range)	**100 kHz – 1,1 MHz**	**1 – 10 MHz**
Bandwidth **necessary to operate the cable system** **Radio services potentially affected** by operation of the cable system due to bandwidth	1 MHz Long- and Medium wave services	9 MHz Medium and short wave services
Quality of transmission line **used by the cable system** Attenuation of unwanted radiation **due to** **Symmetry of cables used** **Shielding of cables used** **(shielded/unshielded cables)**	medium 30 – 50 dB 40 dB / 0 dB **(partially shielded)**	poor less than 30 dB 0 dB **(not shielded)**
Potential for unwanted radiation **due to relation l / l** **(wavelength of frequencies used / cable lengths involved)**	low	high **(at 10 MHz at least 20 dB higher than at 1 MHz compared to the ADSL-system)**
Structure of unwanted radiator	**Matched single line radiator** (supplying an individual customer), few stubs, very few resonant stubs	**Large area radiator** (independent from number of customers), many resonant stubs, no proper termination of stubs
Probability of decoupling by distance **between interfering source (cable) and random receiver location (in case of broadcasting or amateur receivers)**	**medium**	**small**
Conclusion: **Resulting risk of interference to radio services**	**moderate**	**high**

Table 2.5-2: Comparison of critical factors between ADSL- and PLT-systems concerning the coexistence with radio services

Notes:

- The first generation of ADSL currently deployed in high numbers in Germany is providing 768 kBit/s downstream/128 kBit/s upstream. More than 2,2 million customers are using this service at present (June 2002). No cases of interference observed. **(Remark: 4 million DSL-customers as of September 2003)**
- The second generation of this ADSL-system will provide 1,5 MBit/s downstream, service starting in autumn 2002
- The third generation will provide up to 5 MBit/s downstream

The upper frequency limit of all these ADSL-systems is or will be 1,1 MHz.

Conclusion

Due to the accumulation of critical factors the risk of interference to radio services caused by PLT-systems is considerably higher than with DSL-technology.

Even on the condition that the two different systems will meet the same radiation limits, the number of cases of interference caused by PLT-systems is expected to be higher than with DSL-technology because in DSL, the HF signal is only fed on the lines of the customer of the system, whereas in PLT, all the electrical infrastructure around the local transformer will be fed with the HF signal.