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Specification on coexistence of VDSL2 and PLT modems in customer premises;
Spectral management of PLT and VDSL2 transceivers

Reference

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Powerline Telecommunications (PLT).

The present document is a deliverable covering the coexistence of Powerline Telecommunication transceivers with Very high speed Digital Subscriber Line transceivers in customer premises.

The present document on coexistence of VDSL2 and PLT is aligned on Recommendation ITU-T G.9979 Amendement 1 [i.5].

Executive summary

The overlapping of frequency bands between DSL and PLT is causing mutual interferences raising the issue of EMC.

The present document specifies reference models and functionality of a mechanism to mitigate interference caused by in-home powerline devices to xDSL (implementing access Recommendations like Recommendation ITU-T G.993.2 [2] and Recommendation ITU-T G.9701 [i.4]) and vice versa. It is defined as a pointer document to the Recommendation ITU-T G.9977 (2016) [1].

Addressing the coexistence problems of PLT and DSL operating in customer environments, the present document describes a coordination of both the xDSL access and in-home powerline transmission by an arbitration function (AF) which allows optimizing the performance of each part of the system in order to meet the throughput requirements to the end customer across both in-home and xDSL access networks by appropriately configuring parameters of xDSL and/or PLC devices based on a coordination policy whenever this policy is available.

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Over the past decades, broadband technologies for access networks and home networking have seen an increasing level of improvements to meet consumers expectations in speed and services.

The demand for higher bit rate data services from customer side is promoted by high-speed Internet access and many forthcoming innovative services as UHD video streaming. This demand become possible with the deployment of DSL technology as well as the extension to DSL vectoring and bonding.

Recent advances in power line communications (PLT) have made it popular for in-home networking. This makes PLT a source of interference for digital subscriber line (DSL) networks within the home environment.

The present document proposes interference mitigation solutions that allow the coexistence of in-home PLT and DSL networks.

In addition, the present document proposes two interference mitigation solutions that enhance the coexistence of in-home PLT and DSL networks.

The interactions between a Digital Subscriber Line (DSL) access network and Home Networks based on Powerline Telecommunication (PLT) have been reported during past years as PLT modems are widely used for IPTV distribution in a home.

PLT networks and DSL networks use some of the same frequencies in the unlicensed band from 2 - 88 MHz. PLT devices and DSL devices may often be placed in relative proximity to each other and there are concerns that this could present interference.

1 Scope

The present document defines a method to improve the coexistence by mitigating the interference between the DSL transceiver and PLT transceiver operating in overlapping frequency band but on different cables.

In-home PLT networks operate over the same spectrum as DSL networks. This increases the likelihood of crosstalk between PLT and DSL communications systems. For instance, two home networks that operate at the same frequency range, one over copper twisted-pairs (138 kHz - 30 MHz) and the other over power lines (1,8 MHz - 30 MHz), would interfere with each other.(ETSI TR 102 930 [i.1]).

The DSL and PLT interference environment is discussed in more detail. Communication standards for PLT, have been developed with mechanisms that prevent any interference between various systems within the home environment.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] Recommendation ITU-T G.9977 (02-2016): "Mitigation of Interference between DSL and PLC".

[2] Recommendation ITU-T G.993.2 (01-2015): "Very high speed digital subscriber line transceivers 2 (VDSL2)".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 102 930 (V1.1.1): "PowerLine Telecommunications (PLT); Study on signal processing improving the coexistence of VDSL2 and PLT".

[i.2] ETSI-PLUGTEST (May 25-29, 2009): "DSL and in-door PLT coexistence Tests Report" from LANPARK.

[i.3] BroadBand ForumTR-069: "CPE WAN Management Protocol".

NOTE: Available at http://www.broadband-forum.org/cwmp.php.

[i.4] Recommendation ITU-T G.9701: "Fast access to subscriber terminals (G.fast) - Physical layer specification".

[i.5] Recommendation ITU-T G.9979 (2014) Amendment 1 (02-2016): "Implementation of the generic mechanism in the IEEE 1905.1a - 2014 Standard to include applicable ITU-T Recommendations".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Arbitration Function (AF): entity that facilitates coordination between the DSL and PLC systems in order to reduce interference on the basis of coordination policy by appropriately configuring parameters of the DSL and PLC devices

NOTE: The coordination policy is expected to be determined and provided by the operator. In case such policy is not determined or provided by the operator, the AF works according to a predefined default policy.

Customer Premises Equipment (CPE): customer premises equipment implementing xDSL functionality that is compliant with at least one of the Recommendation ITU-Ts of G.99x and G.970x series

Centralized Control Mode (CCM): mode of a PLC network in which devices do not exchange information directly with the AF but via the PLC-NC

Distributed Control Mode (DCM): mode of a PLC network in which PLC devices exchange information directly with the Arbitration Function

PLC Network Controller (PLC-NC): in CCM, one of the PLC devices in the PLC network that is assigned to control all other devices in the network

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AF	Arbitraty Function
CPE	Customer Premises Equipment
DMT	Discrete MultiTone
DSL	Digital Subscriber Line
DSM	Dynamic Spectrum Management
EMC	ElectroMagnetic Compatibility
FDD	Frequency Division Duplexing
IPTV	Internet Protocol TeleVision
ITU-T	International Telecommunication Union - Telecommunication
LAN	Local Area Network
MAC	Medium Access Controler (Layer 2)
MIMO	Multiple Input Multiple Output
NMS	Network Management System
NT	NeTwork
OFDM	Orthogonal Frequency Division Multiplexing (multi-carrier transmission)
OPCODE	OPeration CODE
PHY	PHYsical layer /transmission (Layer 1)
PLC	PowerLine Communication
PLT	PowerLine Telecommunication
RGW	Residential GateWay
TV	TeleVision
UHD	Ultra High Definition (4K video)
VDSL2	Second generation of Very high speed Digital Subscriber Line

4 Configuration of VDSL2 gateway and PLT network in customer premise

4.1 Introduction

DSL and PLT technologies are based on OFDM transmission and both PLT and DSL modems operate in the frequency range from 2 MHz to 30 MHz, although on different cables.

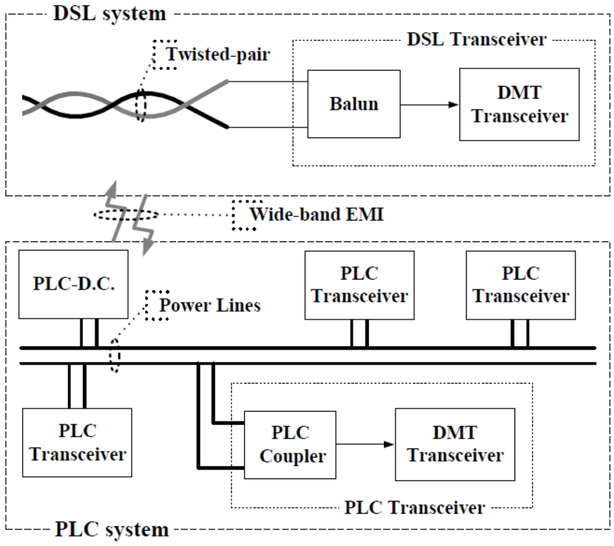

Figure 1: Interaction between DSL and PLT

The cross-channel coupling depends on the type of cables (twisted or untwisted) used for DSL transmission as well as on the following parameters (length, space/distance, type):

- Length of co-localized cables: 1 m, 5 m, 20 m.
- Space between cables: Contact, 1 cm, 6 cm, 20 cm.
- DSL cables: untwisted, CAT3, CAT5.
- Power cables: 3G2.5.

The cross-channel coupling occurs when cables are co-localized (telephone and electrical), this configuration includes customer premise equipments as residential broadband gateway, set-top-box and connected TV.

Under real life tests [i.2] with several PLT technologies allowed the following conclusions: the confirmation of DSL and PLT signals in-door coupling, depending on the quality (twisted or not twisted) of cables, the distance between the telephone and electrical cables.

4.2 DSL and PLT Channel Coupling Model

The DSL and PLT channels are usually modelled separately, for our purpose of coexistence of these two transceivers, a MIMO channel model of dimension using matrix H (2 x 2) was introduced to take into account the channel coupling and this is illustrated in figure 2).

In this MIMO model, coefficient h1,1 represents the DSL channel model, and coefficient h2,2 the PLT channel model.

This MIMO model exhibit also channel coupling coefficients as coefficient h2,1 from PLT to DSL and coefficient h1,2 vice-versa (i.e. from DSL to PLT).

The complete model also include additive noises (n1,n2) on each channel as depicted in figure 2.

In figure 2, the input signals are: X1 for DSL and X2 for PLT and output signals (the ones actually received by the modems) are Y1 for DSL modem and Y2 for PLT modem.

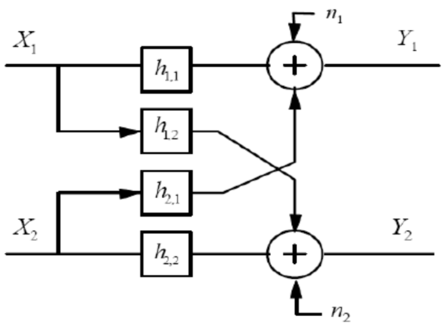

Figure 2: DSL and PLT channel coupling MIMO model

The coexistence between these two transceivers could be solved at different layers levels: Both PLT and VDSL2 modems operate in the frequency range from 2 MHz to 30 MHz, although on different cables.

The coupling factor is increasing as a function of frequency; this observation is correlated to the coupling factor between DSL lines in a same cable. H(f) is the transfer function, based on the PLT and DSL channel coupling model expressed as a matrix.

In the following, a MIMO transfer function is defined as H(f) based on the PLT and DSL channel coupling model as a matrix H where X1 represent DSL signal and X2 the PLT signal with additive Gaussian noises (n1, n2) as given by the equation (1):

$$
\begin{aligned}
Y_1 &= h_{11} X_1 + h_{12} X_2 + n_1 \\
Y_2 &= h_{21} X_1 + h_{22} X_2 + n_2
\end{aligned} \quad (1)
$$

It has been validated by real measurements [i.2] that interferences from a PLT modem to a DSL modem can reach -90 dBm/Hz, this crosstalk interference from PLT is affecting more the downstream of DSL received at the customer premises than the upstream. Under such conditions impacted DMT carriers may not be able to carry any data.

To solve the coexistence of PLT with DSL, the following MIMO [i.1] channel model was used in description of the coupling of telephone wires channels and electrical wires channels.

The PLUGTEST report [i.2] on PLT-DSL coexistence confirms the risk of potential interferences when the cables are very close to each other:

1) The dominating part of the interference above certain frequency is due to electromagnetic emission (radiation).

2) The interference (or the coupling) will increase with frequency up to a certain cut-off frequency.

3) The conducted field interference is not so strong as would generally be perceived.

In real customer premise, many wiring rules are adopted for electrical networks and telephone in home networks, the resulting coupling between the two wiring is unknown.

Depending on this coupling, the interferences from PLT signal on DSL signal is strong when the two wires are close.

4.3 Analysis of the PHY layers of PLT and DSL

The physical layer of PLT modem (PHY) is based on windowed OFDM as the basic modulation technique. The physical layer of VDSL2/ modem (PHY) is also based on windowed OFDM.

The separation of upstream and downstream transmissions by FDD is defined by the band plans [2].

The VDSL2 signal can potentially use the frequency range up to 35 MHz, although the maximum frequency used by a modem to transmit data depends on the selected band plan and the conditions of telephone line.

The VDSL2 transceiver may select one or more sub-carriers to use for timing recovery, called Pilot Tones. Pilot tones are selected separately for initialization and showtime. For VDSL2, two sub-carrier spacing are available: 4,3125 kHz and 8,625 kHz.