Compatibility Between VDSL & PLT Systems And Radio Services that Operate in the Range 1.6 MHz to 30 MHz

Sections 3.2 and 7.2 for the final report of the technical working group

3.2 Power Line Telecommunications (PLT)

PLT is a system for voice and data transmission that makes use of power lines as pipes for traffic within and on the way to the home. A modem, the ONELINE™ Box, allows to set up data networks from the medium-voltage power network via the low-voltage distributed network to the customer's in-house electrical power distribution system.

3.2.1 PLT Access Technology

PLT Access Technology uses the local loop, i.e. a utilities' low voltage power network, to provide public telecom services to homes and small offices. Additionally, the ONELINE™ access technology can establish point-to-point links where the telecom signal is injected into a point in the medium or high voltage power distribution network and received at another point.

The ONELINE™ Boxes, installed in the same low voltage segment, form a network by interacting with each other. Incoming and outgoing voice and data signals are carried over the electric network from one customer connection to the next until they reach a backbone connection point.

The distance from the customer's home to the backbone connection is split up into a number of short transmission links. This enables the transmission of data and voice using low signal strengths according to the distance these signals must cover enabling services to be provided to households that are far away from the backbone connection. This allows the construction of flexible topologies tailored to suit the existing network structure.

In order to satisfy radiated emissions regulations and to avoid the need of an increased power to cover large distances from the transformer to the home, ONELINE has pioneered a signal repeating mechanism that allows for "hopping" from home to home. Because the distance between homes is generally shorter than the distance from the transformer to any given home, this system is able to use very low injected energy, hence meeting all current regulations for radio-frequency radiation.

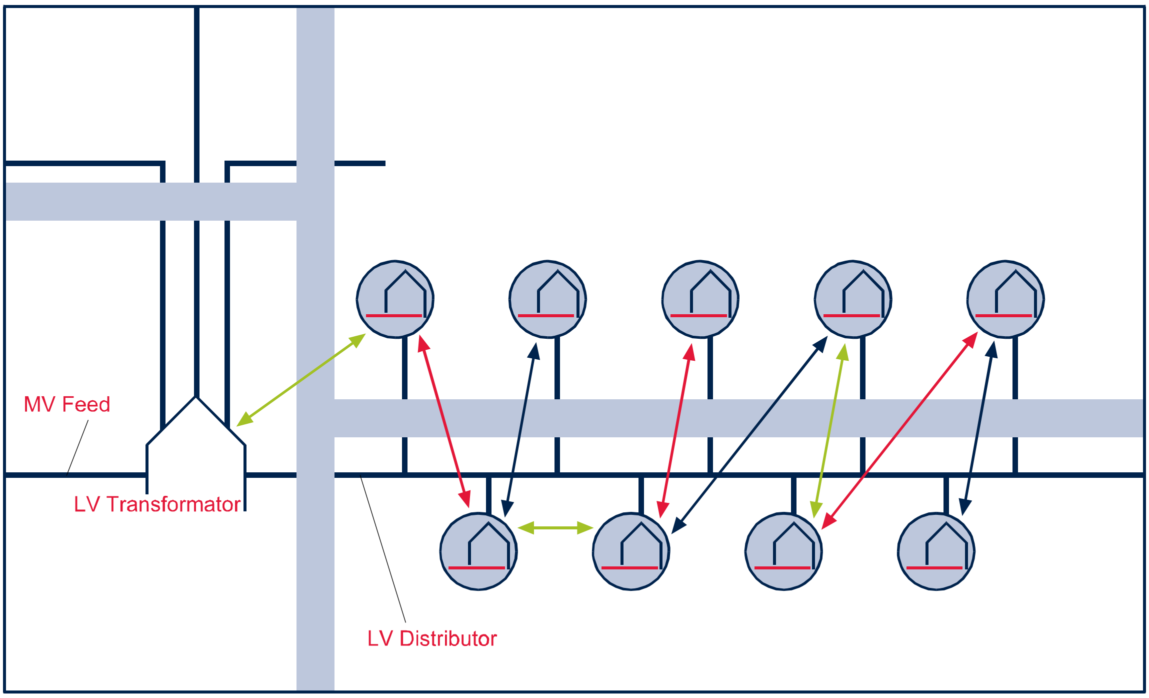

Figure 1: Signal Repeating Mechanism

The ONELINE™ Box uses a OFDM (Orthogonal Frequency Division Multiplexing) method and ONELINE™ Technology generally is compatible with third-party transmission technologies and systems thanks to a complement of standard interfaces. The ONELINE™ Box incorporates the following standard interfaces: Ethernet 10BaseT, A/B, S0, E1/DSS1, RS232. Embedded asynchronous transfer mode (ATM) and voice algorithm software gives the modem Quality of Service (QoS) parameters necessary for real-time bi-directional service offerings such as voice telephony.

ONELINE™ Technology is SNMP (Simple Network Management Protocol) compliant, which enables end-to-end management of the communication infrastructure including the power lines. This allows connectivity to and high integration with existing infrastructures, and substantially reduces costs.

The ONELINE™ Box - unlike many other broadband systems - also integrates WAN (wide area network) access technology with in-home LAN (local area network) technology. ONELINE's system architecture includes an in-home networking component effectively extending the broadband access connection to multiple devices within the home.

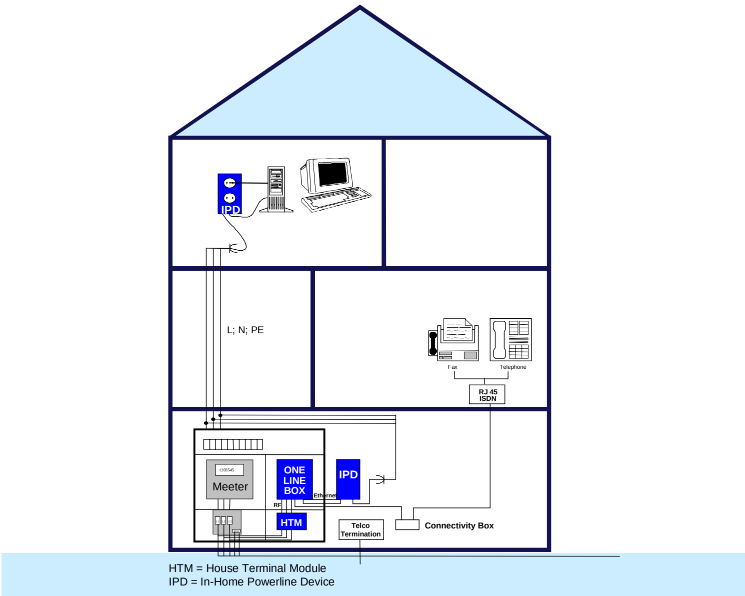

Figure 2: Example for a PLC installation using ONELINE's Technology

To achieve end-to-end connectivity, ONELINE integrates its PLC access technology (the ONELINE™ Box) with an in-home powerline device (IPD). Figure shows how these components – together with the coupling unit (house terminal module - HTM) – are installed in a typical household.

ONELINE's powerline technology is embodied in the ONELINE™ Box and has the technical characteristics as shown in Table **Error! Unknown switch argument.**:

Frequency band	1.5-30MHz
Maximum transmission level	0 dBm
Minimum transmission level	-36 dBm
Typical transmission level	-10 dBm
Minimum receiving level	-70 dBm
Transmission power	ca. 1 mW, dynamically regulated
Large signal resistance	20 dBm
Efficiency of modulation	5 bits per Hz
Access modem bandwidth	2,3 Mbps
Scalability of the voice interface	N x 64 Kbps
Processing kernel	Power PC architecture
Radio interference	Compliant with NB 30
Modulation method	Modified OFDM (orthogonal frequency division multiplexing)
Error correction	FEC (interleaved)
Hamming distance	25
Management	SNMP
Data encryption mode	Blowfish, Rijndael

Table Error! Unknown switch argument.**: ONELINE™ Box technical data and characteristics**

3.2.1.1 Frequency Plan

The operational frequency range of the ONELINE™ *access* Technology is from 1,5 to 15 MHz. and uses a low signal transmission strength (in the milliwatt range), to keep emissions below the tight limits required by Regulation Authorities.

By the flexible management of frequencies in the range from 2 to 30 MHz (for both access and in-home technology), ONELINE can ensure the co-existence of PLC access and PLC in-home systems. There is no need to preserve certain frequency spectrums for either in-home or access applications and the whole frequency spectrum can be used and no bandwidth is wasted. Similarly, the bandwidth provided to customers is dynamically managed ensuring an optimum allocation of available transmission capacity and a standard quality of service at all times.

3.2.1.2 Deployment Options

Functioning as the communications centre at the customer's home, the ONELINE™ Box provides the technical basis for providing phone, Internet up to 2,3 Mbits, smart home and value-added energy services over the power grid.

- Phone Services : Local and Long Distance Services

The ONELINE™ Technology can support both analogue and ISDN devices with a capacity of up to 30 telephone channels per modem. Consumers can continue to use their existing telephone equipment, including telephones, fax machines and answering machines, as well as next generation ethernet and voice over internet protocol (VoIP) based phones.

- Internet Access at speeds of up to 2,3 Mbps

The ONELINE™ Technology allows broadband internet access at speeds of up to 2,3 Mbps per household. This "always on" connection enables the customer to browse the internet at broadband speeds and talk on the phone at the same time. The ability to offer bundled voice and high speed internet services provides a distinct advantage over data-only broadband solutions.

- Smart Home Services

Smart Home Services are mainly security and convenience services. The ONELINE ™ Technology provides end-consumers with a software interface and interoperability platform to control and automate functions in the home. The control and automation platform acts as the "control-centre" for appliances, consumer electronic devices, security systems, and lights within the home.

Security services provide ordinary alarm equipment with remote access. Alarm equipment such as fire and burglary alarm devices can be coupled to the powerline system. Convenience services provide household appliances, lights, heating and other electric/electronic equipment with remote access.

- Value-Added Energy Services

Value–Added Energy Services help utilities to increase their operational efficiency and to save costs. These services are mainly Demand-Side Management (DSM), Intelligent Load Shedding (ILS) and Automated Meter Reading (AMR).

DSM enables utilities to shed loads instantaneously from individual homes on their grid. Since each home is a virtual node on the PLC access network, utilities can target specific homes and demand full shedding or shedding on a percentage basis. The DSM interface is web-based and leverages bi-directional messaging so utilities can accurately monitor and control usage statistics of individual homes in real-time.

ILS allows the detection of patterns in common energy usage and uses this information to adjust the peak load of homes automatically. AMR gathers data to establish real time pricing systems that allow an electric utility to charge its consumers according to their energy consumption during different times of the day.

3.2.1.3 Network Characterization

The network characterization is used to demonstrate the technical feasibility of PLT deployment. The physical, electro-technical and electro-mechanical parameters of the network are carefully examined in order to determine what technical adaptations are necessary to the powerline technology to satisfy particular network, regulatory and environmental requirements.

The network characterization includes three main analyses: an electrical and telecommunication network topology analysis, a high frequency evaluation and a powerline evaluation.

- Electrical and Telecommunications Network Topology Analysis

The electrical and telecommunication network topology analysis is an evaluation of typical network topologies, typical installations and operating scenarios, as well as customer access installations and the materials used. Customer and backbone access requirements for telecommunications are also considered.

Some of the points to evaluate in a network topology include:

- the relationship between high voltage (HV) and medium voltage (MV) infrastructure compared to the low voltage (LV) distribution (distances from HV/MV to LV sites, connection of LV transformers to the HV/MV grid, distances between LV sites, size, number and cable types of the communication lines “pilot wires”, use of optical fibre deep into the network, etc.),

- the transformer size (typical residential LV transformer sizes of 100 KVA, 200 KVA, 400 KVA, 630 KVA and 1 MVA, LV transformer size in non-residential areas),

- the transformer housing used for the LV transformers and associated equipment (brick or concrete building protected from the environment with heating / air conditioning, how is the equipment pad mounted (base plate), space available for telecommunications equipment, equipment expected to be installed in its own outdoor cabinet, min/max temperature, humidity shock and vibration, etc.),

- the transformer bus bars and fuses (positions, where it is permitted to make connections to the bus bars for communications purposes, use of back feeding to increase the service availability in case of a LV power break down in parts of the residential area, metal enclosures or covers used in the area of the bus bars or fuses, etc.)

- the low voltage distribution cable/line type (cable and overhead lines, cable types, etc.)

- the distribution cable practice (outer casing used as a neutral, existence of a copper foil wrap around the neutral, etc.)

- the distribution network distances (distance from LV transformer to homes), distribution to the service cable (number of houses per connection point, number of homes per mini-pillar, connection of street lights, drop into the home with a coaxial neutral, wires twisted, etc)

- the distribution network voltages and its standards.

• High Frequency Evaluation

The high frequency evaluation is carried out in low voltage segments. Basic physical parameters of the network are evaluated to identify appropriate network parameters and the prediction of the behavior of the networks. Typical powerline-relevant parameters are attenuation, based on the network and frequency involved, time and network dependency of noise and impedance, and the impedance and frequency dependent radiation characteristics of the network.

• Powerline Evaluation

The aim of the powerline evaluation is to obtain relevant data concerning achievable data quality and performance. It consist of three phases:

First, an evaluation system is installed. The evaluation system consists of a point-to-point connection in the low voltage segment without actual customer and backbone access. It uses internal measurement procedures in order to carry out long-term bit error rate (BER) tests, error analysis and performance observations.

Second, a powerline trial is carried out. This trial consist on a connection of x (x= less than five) households. The purpose of the trial is to test the quality and performance of services delivered via powerline technology over a period of time. The trial tests also demonstrate the basic technical feasibility of the powerline system and interoperability of its interfaces. Access to the traditional telecommunication service provider is not interrupted during the trial.

Third, a powerline pilot system is installed connecting 20 households. This demonstrates the system interoperability, manageability and performance in a larger and near fully operational context. Access to the traditional telecommunication service provider is not interrumpted during the pilot.

3.2.1.4 EMC Mitigation

The ONELINE™ Access Technology has passed the EMC Mitigation Tests in Germany. The purpose of the EMC Mitigation Test was to prove the ability of the ONELINE™ Box to work satisfactorily in its intended surroundings without interference to its function from external sources or interference to adjacent equipment, appliances or persons.

The functionality of the ONELINE™ Box was tested in different scenarios with the aim, first, to evaluate the electrical integrity, i.e., if the ONELINE™ Box is unaffected by the normal environment conditions that usually appear in the intended surroundings and secondly, whether the ONELINE™ Box emits undesirable signals, i.e., whether the ONELINE™ Box disturbs other appliances in the surrounding area.

The systematic EMC Mitigation tests carried out with the ONELINE access technology were:

First, an evaluation of the system integrity against fast transient electric signals (Burst-Test). The Burst-Test was executed according to DIN EN 6100-4-4 without grounding of the casing in the following situations:

- Spike frequency power supply 5 kHz
- 1000 V energy supply / PE
- 500 V data management / interfaces
- Burstlenght of 15 m
- Period 300 ms

The tests on the power supply between L, N were successfully executed with positive and negative polarity of the impulses.

Secondly, an evaluation of the system inegrity against high-tension impulses. The examination of the system integrity through management-tied impulse-disturbances was executed according to EN DIN 6100-4-5. The impulse-disturbances were directly connected into the corresponding conductor L + N with the following qualities:

- Umax = 1000V
- Rise time = 1,2 µs
- Half period = 50 µs
- 5 Impulses with positive and negative polarity
- 1 Impulse per second

3.2.2 PLT Home Networks

PLT Home Networks (ONELINE™ InHome Technology) uses in-building power cabling to set up private local area networks. The telecom signal is transmitted on the domestic power cable via the residential gateway. PLT Home Networks can be used as either a broadband data transmission medium to connect a PC and its peripherials or as a narrow band data transmission medium to monitor and control electrical appliances i.e. lights, heating systems, household appliances, and stereos.

Once the customer's house is fitted with the ONELINE™ Box, a broadband internet connection exists. To extend the connection to the PC in the living space, an in-home powerline device (IPD) is required.

The IPD allows the transmission of voice and data signals through existing power-lines within the home to and from any power socket. The IPD is a power-line-to-ethernet transceiver embedded in a wall module. This wall module plugs into any electrical socket and offers the customer an ethernet jack and phone jacks to connect PCs. The main purpose of the IPD is to extend the ethernet and phone interfaces on the ONELINE™ Box to any socket where the customer wishes to send and receive data and/or voice.

For ONELINE™ InHome Technology's support to Smart Home Services (the automation and control of electrical appliances), a CEbus is used as the core technology. CEbus provides a standardized and proven technology for narrowband control and automation applications. Many manufacturers of white-goods appliances and consumer electronics devices are specifying CEbus into designs of their devices. CEbus is a well-respected emerging standard for devices that will be automated in the future.

For narrowband control and automation applications, smart-house software has to be pre-installed in the IPD. The software allows for control and automation of electrical appliances. By connecting household appliances to the software, they become sufficiently "intelligent" to receive automation commands and operate according to pre-determined or controllable rules.

Because PLT's is available throughout a home, it serves as a perfect medium for attaching wireless transceivers. The power-line inside the home serves as the "backbone network" and wireless modules can be plugged into the power socket to provide each room with wireless connectivity without regard for walls and structures that might normally impede the wireless signal. ONELINE™ InHome Technology coupled with wireless provides a total networking solution where "plugged in" devices are served by the powerline connection, and the powerline connects multiple wireless modules in different rooms to the broadband access connection (modem) providing total connectivity throughout the entire home.

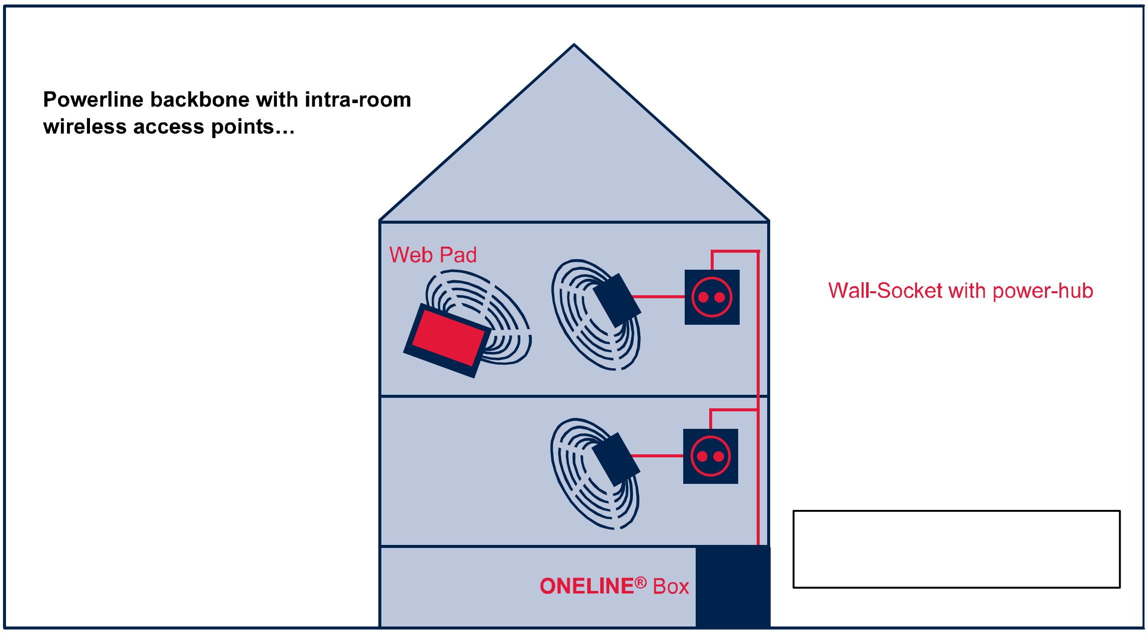

Figure Error! Unknown switch argument.**: Integration of PLC and wireless technologies**

3.2.2.2 EMC Mitigation

The ONELINE™ InHome Technology has passed the same EMC Mitigation tests as the ONELINE™ Access Technology. First, the system integrity was evaluated against fast transient electric signals (Burst-Test) and second against high-tension impulses.

7.2 PLT Field Measurements

The PLT field measurements conducted by ONELINE AG included an Access Data Transfer Rate, and an Access Radiated Emissions Test for the ONELINE™ Access Technology and, for the ONELINE™ InHome Technology, an In-Home Data Transfer Rate, an In-Home Radiated Emissions Test, a Test of the Privacy Between Homes, a Dynamic Range and a VDE Mark Test.

Field measurements were made in small offices and at homes in the German region of Sachsen-Anhalt, at maximum transmit power, i.e. data rates of 1-4 Mbps between sockets.

The measurements in small offices were conducted in offices of 12m x 42m, on average, and in different floors of three story structures.

The measurements in homes were conducted in 4-level households (basement, two floors, and a loft), where the power meter was located in the basement. There are, on average, three meters in the basement; a main meter and two secondary meters. The secondary meters allow the houses to be split into two apartments. The breaker panels associated with each secondary meter are located on the first and second floors. The size of the basements on each floor (excluding lofts) were on average 10m x 12m.

7.2.1 PLT Access Technology

- Access Data Transfer Rate

Access data transfer rates between a power substation and a house were measured. Two 20 ohm source impedance units were modified to transmit and receive signals through the SMA test connector. These units were connected to the low voltage power lines at the substation and house through the ONELINE™ coupling circuits. The units were configured to transmit maximum power.

- Access Radiated Emissions Test

Field strength measurements were taken three metres from the exterior wall nearest the injection point for the signal at both the power substation and houses.

7.2.2 PLT Home Networks

- In-Home Data Transfer Rate Measurements

In-Home Data Transfer Rate Measurements were conducted in small offices and in households.

In-Home data transfer rate measurements in small offices were collected for three configurations of the units. First, a 20 ohm source impedance, second, a 100 ohm source impedance and finally, a 20 ohm source impedance with transmitted power reduced 15 dB.

At homes, data transfer rate measurements were collected for three configurations of the units. First, 20 ohm source impedance. Second, a 100 ohm source impedance and finally, a 20 ohm source impedance with transmitted power reduced 11 dB. In addition to varying the configuration of the units, two positions for the receiving unit were used in the houses. One position was located next to the power meter in the basements. The second position was located on the first floors.

- In-Home Radiated Emissions Test

In-Home Radiated Emissions Tests were carried out in households. The prescan spectrum was captured with and without the units transmitting. The prescan spectrum was used to select frequencies for measurement. The measurements frequencies were selected from the 16 carrier centre frequencies of the units. The NB30 field strength limits identified in the following sections were calculated with the following equation:

Limit = 40 – 8.8*log10 (frequency); where frequency units are MHz

- Test of the Privacy Between Homes

Privacy Tests were conducted between two houses. A single house always separated the test houses. The units were configured for maximum transmit power.

- Dynamic Range Test

The receiver dynamic range was demonstrated. For the demonstrations, two 20 ohm source impedance units were modified to transmit and receive signals through the SMA test conductor. Normally, these units were configured to transmit and receive signals through the AC power entry module. The units were cabled together with various attenuator values.

- VDE Mark Test

VDE Mark Tests were conducted. The VDE Mark indicates conformity with the VDE standards of European or internationally harmonized standards and confirms compliance with protective requirements of the applicable EC Directive(s).

The VDE Marks Licence Certificate confirms compliance with standards and the requirements of the Appliance Safety Law (GSG). It also forms the basis for the EC Declaration of Conformity and CE marking by the manufacturer or his authorized representative. Finally, the VDE Marks Licence Certificte confirms compliance with the standards of the EC Low-voltage Directive 73/23/EEC and its Amendments.

Testing was based on the Harmonization Documents (HD) listed in the HAR Agreement. Products (harmonized power cables) tested and found in compliance with the requirements of the mentioned standards may be marked with the VDE HARmonization Marking.