Characteristics of Low-Voltage Installations as Transport Medium in Office Buildings

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Abstract – **Data transfer through powerline network in typical office building is measured and tested. Achieved results are presented within this paper, and conclusion is made based on presented results that powerline network could be new transmission media in the access network.**

Keywords – **Low-voltage network, Ethernet, Data transfer**

I. INTRODUCTION

During last few years, the strong development of powerline communication technologies could be seen in the world. PLC became a competitive technology for access and home network.

Constant follow up with latest achievement within powerline communication industry resulted in our consideration that the most interesting area for deployment of powerline communication will be home network. Main reason for that consideration is the fact that is possible to establish a new home network without installation of new network infrastructure. Instead, PLC use existing indoor low-voltage (220V AC) network, thus power cables becomes also the network infrastructure.

Based on above mentioned, we focused our work on measurement of characteristics related to attenuation and data transfer through home low-voltage electrical installation.

Measurements, presented in this paper, are result of continuous work on PLC network. Results from the first phase of our measurements are published at Telfor 2007 [3]

II. EQUIPMENT – TECHNICAL DESCRIPTION

Used PLC network is an ISO-OSI layer 2 system. This system operates by transporting Ethernet frames to/from non-PLC systems. PLC devices implement an IEEE 802.1D compliant bridge functionality to achieve interworking with external non-PLC world. The system operates at layer-2 for end-user traffic, but each individual device still runs complete implementation of TCP/IP protocol stack and application protocols on top of TCP/IP.

Used equipment operates in a frequency range between 2 and 34MHz, but each device could be configured to use a pre- or user-defined subset of above mentioned frequency range, which is used in frequency dependence of line characteristics measurement. Equipment work on an OFDM based physical layer, which is highly optimized to deliver a data-rate of 205Mbps.

OFDM is particularly suitable for harsh communication environments and is the de-facto transmission technology of choice for PLC networks.

Used equipment comprises two devices, with same hardware functionalities, but configured to be a master and repeater device in the PLC network.

Used API-2000-GW, developed by Current Technologies, is a specially designed low-cost, high performance infrastructure device for low-voltage powerline networks. API-2000-GW has a transmission speed of up to 205 Mbps and the capability of handling up to 32 parallel PLC connections.

III. CHANNEL ATTENUATION MEASUREMENT RESULTS

Propagation of telecommunication signals over powerline introduces an attenuation, which depends on the line length and the frequency. According to [4], the transfer function in the frequency domain can be presented as:

$$H(f) = \sum_{i=1}^{N} g_i A(f, l_i) \cdot e^{-j2\pi f \tau_i}$$

where is

g_i – weighting factor, depend of reflection and transmission

τ_i – variable, represents delay by the path and

l_i – path length

So, first phase of experiment comprises dependence of channel attenuation upon distance between end user device and master device. Master device was stationary and connected to one power outlet within building electrical installation while end user device position has being changed increasing distance from master device. Results of feasible data flow is given in table 1 (Downstream is feasible date flow from master to end user DB and Upstream is feasible data flow from end user DB to master), whilst figures 1-5 gives graphs for receiver level upon frequency dependence for four particular distances.

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Value attained for distance of 2m is referent value, because there is no influence of the power load in the home electrical network. Distance of 2m is obtained through one power cable which is not connected to building electrical installation.

TABLE 1
FEASIBLE BANDWIDTH UPON DISTANCE DEPENDENCE

Distance [m]	Downstream (Physical layer)	Upstream (Physical layer)
2	153 Mbps	150 Mbps
10	133 Mbps	115 Mbps
12	129 Mbps	83 Mbps
16	125 Mbps	82 Mbps
20	102 Mbps	78 Mbps
25	88 Mbps	88 Mbps
30	73 Mbps	86 Mbps

From the table above, it can be seen that feasible data flow is decreased with distance. Also, that 30m distance (through electrical installation) could be exceeded with powerline master device and feasible data stream on physical layer is above 70Mbps.

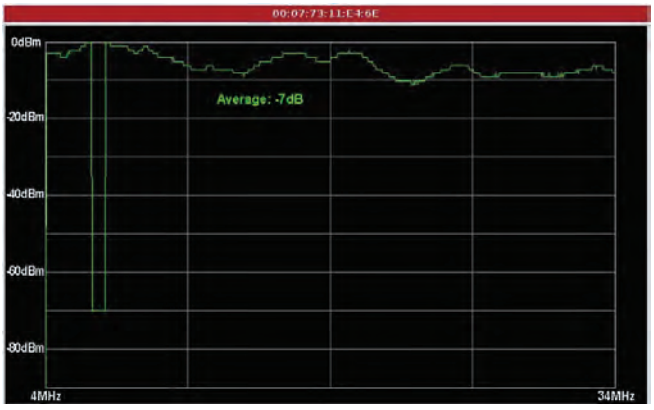

Fig. 1. – Receiver level for 2m distance

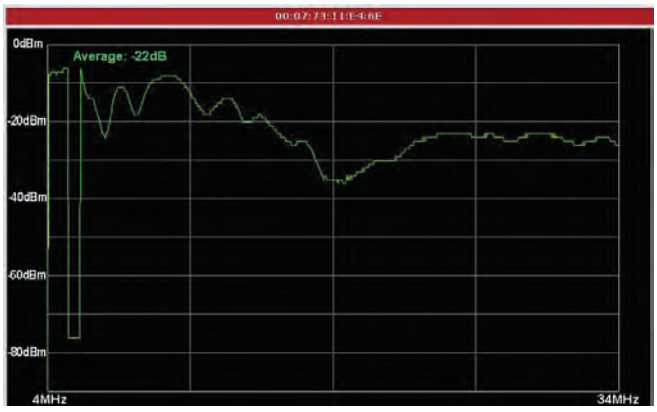

Fig. 2. – Receiver level for 10m distance

Values shown in the above table are feasible data flow on the physical layer and downstream values are higher than upstream on lower distances. With increase of distance, these two values became alike.

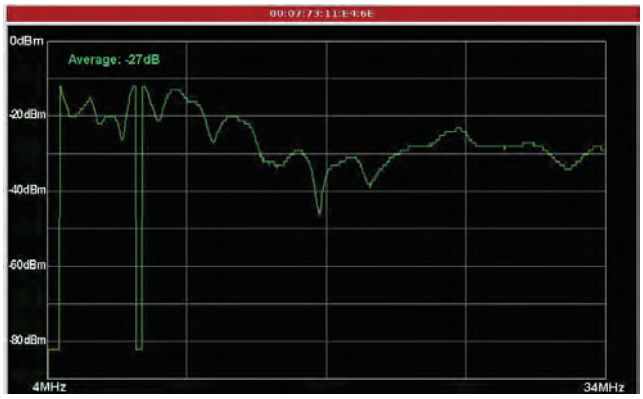

Figure 3. – Receiver level for 16m distance

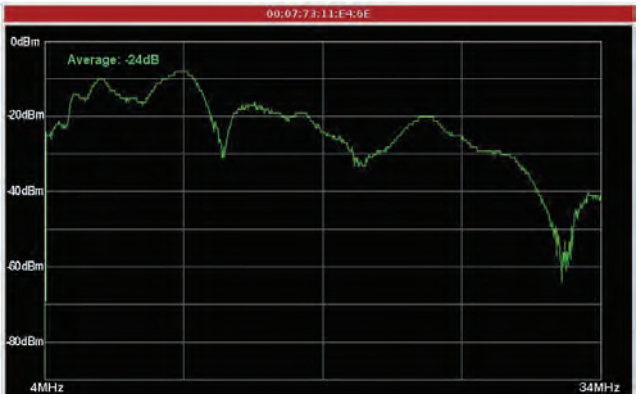

Fig. 4. – Receiver level for 25m distance

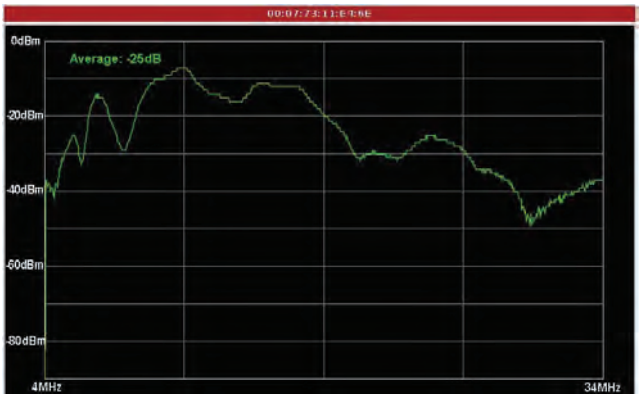

Fig. 5. – Receiver level for 30m distance

Forehead figures show that receiver level is decreased with distance. Also special attention shall be paid on figures 2 and 3, which show average level of -22dB and -27dB. But there is a hole in receiver level value below 10MHz, which descend average receiver level.

Our next phase target will be to determine maximum possible distance in order to have data transfer through powerline with stated quality of service.

IV. CHANNEL CHARACTERISTICS DEPENDANCE ON FREQUENCY

PLC uses bandwidth from 2-34MHz for data transfer. In this experiment phase this bandwidth will be changed. Channel characteristics will be measured in three custom bandwidths on the same distance of 20m between master and end user device to identify dependence of receiver level from frequency.

Measurement was conducted in following bandwidths:

Band number	Frequency [MHz]
1	2-12
2	2-22
3	13-33

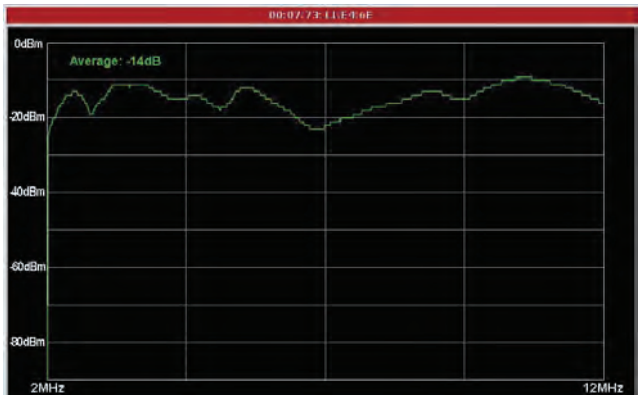

Fig. 6. – Receiver level between 2-12MHz

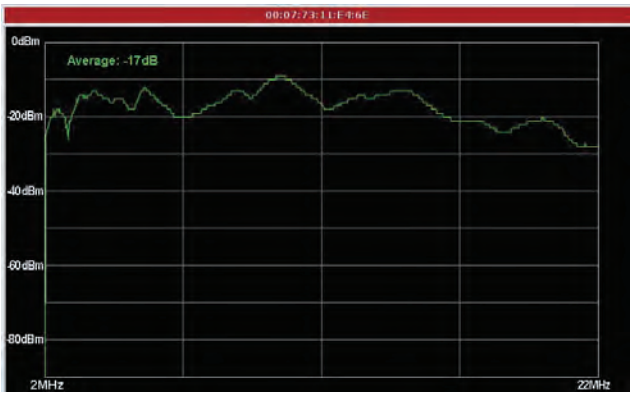

Fig. 7. – Receiver level between 2-22MHz

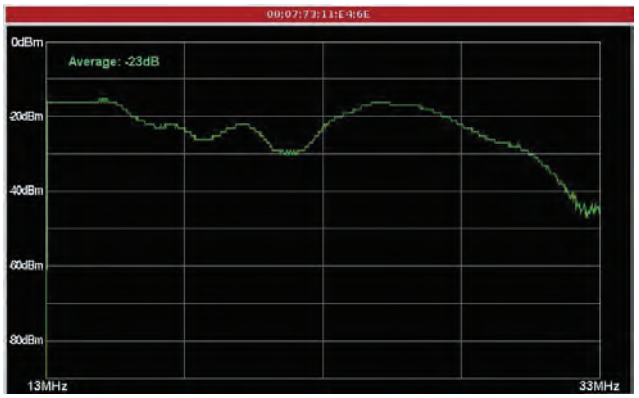

Fig. 8. – Receiver level between 13-33MHz

Figures 6, 7 and 8 presents measured results. From the attained results, it can be concluded that receiver level is highest at the beginning of frequency band. Difference between the receiver level on frequency band 1 and frequency band, which is twice wider, is 3dB. Also, receiver level is above attained values for distance of 25m and 30m and presented in previous chapter.

Values presented on figures 2 and 3 are lower than attained for distance of 20m, and that is result of holes in frequency band below 10MHz.

Presented results imply that data transfer is possible with powerline as transmission medium. In the following chapter comparison of data flow within UTP and PLC based LAN will be shown.

V. COMPARISON OF UTP AND PLC

Last step of conducted experiment was to compare PLC and UTP as physical layers in the computer network. One 40MB data file was transferred between two computers, and current data flow between these two computers was measured within 100s. Attained results are shown with figures 9 and 10.

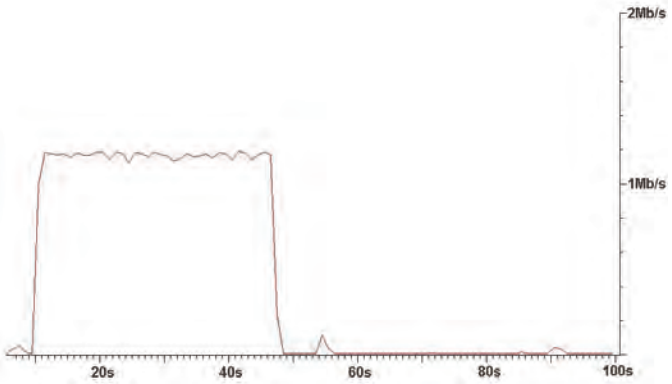

Fig. 9. – Data flow between computers through UTP based LAN

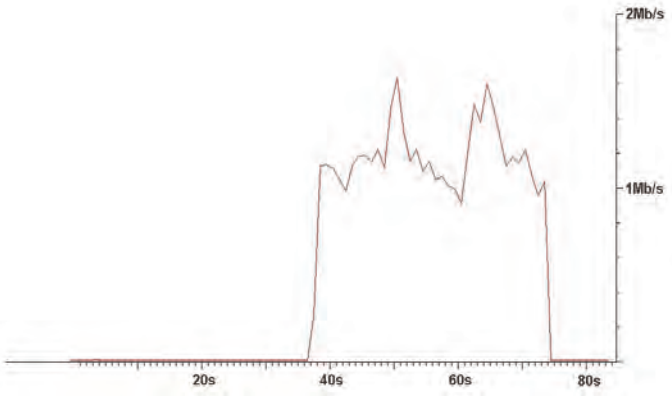

Fig. 10. – Data flow between computers through PLC based LAN

These results show that data flow is nearly the same through UTP and PLC network (around 1Mbps, y axis on the

attached figure), which is great discover for further development of PLC networks in Serbia. Big advantage of PLC networks is that this technology use existing cable infrastructure (electrical installation) and that initial expenses for network establishment are lower than for other network technologies.

PLC technology use OFDM as modulation technique. From the figure 10 it can be seen that data flow is not stationary. Data flow varies within time, because particular sub-carriers are not used due to noise on the subject frequency. At the one moment, data flow is higher, because all sub-carriers are used and after, the data flow is lower, because particular sub-carriers are not used.

VI. Following Measurements

It is clear, from the conducted measurements, that PLC could be competitive technology to other home network technologies. Plan for following measurements is to establish PLC network with protection earth and neutral conductor and to measure channel characteristics within those conditions. According to theoretical results additional power load shall have smaller influence, when protection earth and neutral conductor is used, than that of phase and neutral conductor.

Additionally, same network topology could be installed with phase and neutral or protective earth and neutral conductor, so influence from additional power load could be measured.

VII. Conclusion

Conducted measurements show that data transfer through PLC network is possible and that PLC is valuable technology which uses electrical installation for access and home network.

In comparison with UTP based LAN, data transfer in local network was nearly without difference. So with improved standardization on global level, which is certainly the problem and with further development of user equipment, PLC technology could be deployed and tested within one of local Power Distributions for the purpose of establishing of smart electrical grid.

Smart electrical grid and smart home will be established in near future and PLC, as common medium, should be considered for that.

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[6] www.currenttechnologies.com

Abbreviations

PLC	Power Line Communication
MAC	Media Access Control
HTTP	HyperText Transfer Protocol
UTP	Unshielded Twisted Pair