Impact of devices connected to powerline on selected BPL topologies

Michal Mahút[1] and Petr Musil[1]

[1]Department of Telecommunications, Brno University of Technology, Brno, Czech Republic

E-mail: xmahut00@vutbr.cz, xmusil56@vutbr.cz

Abstract—The following article deals with the impact of device originated noise on BPL (Broadband over powerline) communication for different topologies of BPL modems. In household scenario, every device connected to power line has an impact on transmission spectrum and limits throughput. Different topologies and two types of devices were tested and evaluated. The aim of this article is to determine the appropriate connection of BPL modems into the powerline with the lowest possible decrease of data throughput.

Keywords— BPL modem, PLC, noise level analysis, powerline, throughput, topology

1. INTRODUCTION

BPL is technology which operates in the 1.8 – 500 MHz and reaches data rates at the physical layer from Mbps to Gbps [1, 2]. Several standards for broadband over power lines as HomePlug AV, HD-PLC, ITU-G.hn were developed [3]. BPL communication is promising technology to transmit information in cases, where we cannot use other technologies such as optical or wireless approach. Nowadays it is possible to transmit information via BPL with high throughput up to 800 Mbps according to [4]. Communication over powerline is affected by noise that is produced by devices connected into powerline. The main objective is to find a capable topology for connecting BPL modem to keep the impact of devices on communication as low as possible. Devices which fed and running are main source of noise in the frequencies where BPL operate. In addition to noise, communication is also affected by impedance of device and its power cord. This measurement focuses on the real conditions, therefore typical office devices were connected into the powerline cord in close proximity to the BPL modem. The nosiest device is a desktop PC according to [5] which has power spectral density up to -110 dBV/Hz in the frequency range below 4 MHz. Such noise might have time-variant characteristic with period equal to the mains period, which might have effect on throughput fluctuations. As [6] describes situations, when vendors state that their products fulfill Electromagnetic Compatibility requirements EMC - that means that it conforms to noise emission standards, led to (50 % drop) of data throughput of BPL modems. According to [7] the maximum PSD (power spectral density) of BPL is below 30 MHz. Due to this fact we need to ensure interference minimization for optimal transmission conditions.

2. MEASUREMENT

For these measurements 2 BPL modems were chosen, prototype modem (D1) and commercial modem (D2). Both devices utilize G.hn protocol and operate on similar bandwidth, D2 works on bandwidth, which is 6 MHz higher than bandwidth used for D1. Modems support MIMO communication, which enables higher throughput in network. An overview of the used devices is displayed in Table I. Modem D1 was used as a tool for acquisition of noise levels in the operating frequency range.

Table I: BPL modems.

Label	BPL Modem	Standard	Bandwidth	PHY throughput MIMO
			[MHz]	[Mbps]
D1	Prototype	G.hn	2 – 80	1200
D2	Commercial	G.hn	2 – 86	2000

50 m long extension cord connects the measured topology with the plug. Isolation transformer is used for minimizing the impact of power line interference. The 5 m long extension cord with first BPL modem is connected to isolation transformer. This described part of the layout is similar for all measurements to ensure the most efficient measurement conditions. All measured values come from position BPL02 (second).

The first measured topology is shown in the Figure 1. Two 2 m extension cords are connected to the 5 m one. The second BPL02 modem is at first connected in parallel extension cord (brown), which is in this case used for measuring BPL data throughput. The second extension cord is used for powering PC, monitor, mobile phone and laptop charger. These interfere with communication and simulate noise on powerline in household scenario. Starting condition (0 in throughput Figure 5) was measured when all devices were unplugged from second extension cord.

Second extension cord (magenta) was used for measurement of the noise and throughput on BPL modem, when second-BPL02 was connected in different positions: 1-green, 2-blue (Phone charger was moved to position 1), 3-orange (Laptop charger was moved to position 2), 0-purple (all devices were unplugged). The yellow and magenta cables represent the throughput measurements in Figure 5 and Table II for different positions. The coloured numbers and sockets represent position of BPL modem for Figure 3, when the noise level was measured.

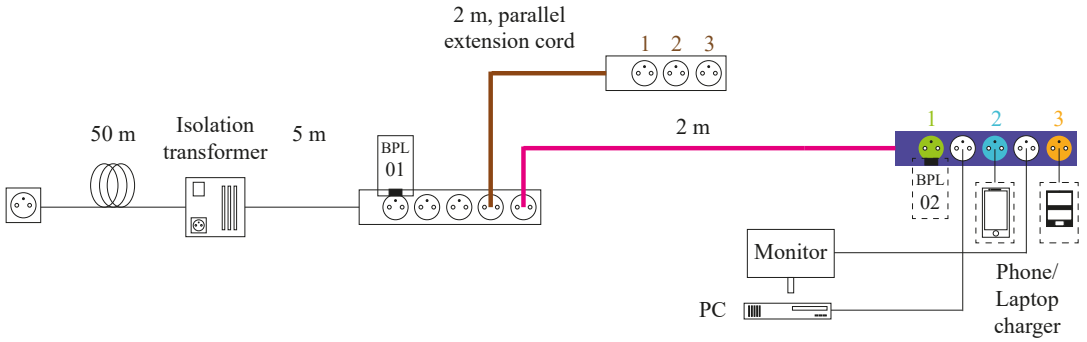

Figure 1: Topology with 2 m extension cord.

The second topology uses the connection with isolation transformer described above. Topology contains 2 m, 50 m and 2 m extension cords, to which devices with their interference and second BPL modem are connected. The measurement method used on the last extension cord and colour description are identical to the method used on the first topology, results of the noise impact are displayed in Figure 4. Cyan and dark blue cables were used for the throughput measurements in Figure 5 and Table II for different positions.

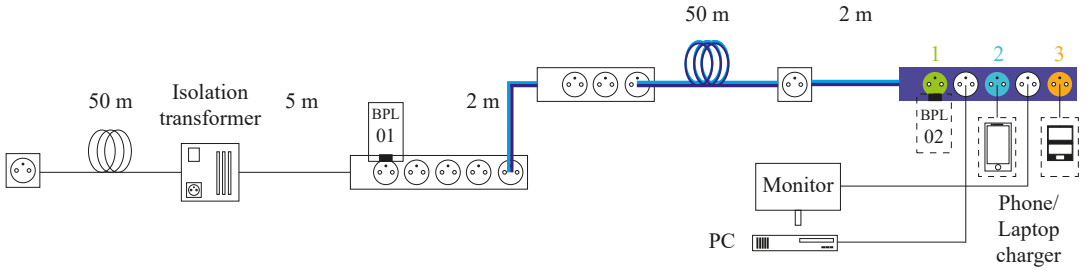

Figure 2: Topology with 54 m extension cord.

3. RESULTS AND DISCUSSION

Graph captured in Figure 3 shows noise level dependence on frequency from first topology measurement, when results are measured on second extension cord. 0-purple curve represents measurement when BPL modem was in position 1 and devices were unplugged. 1, 2, 3 curves represent change of position of the devices and BPL in extension cord as shown in 1. In Figure 3 we can see that after the devices are connected, noise is increased by 10 – 15 dB. Green curve represents position 1 in cord with noise level lower than other two positions.

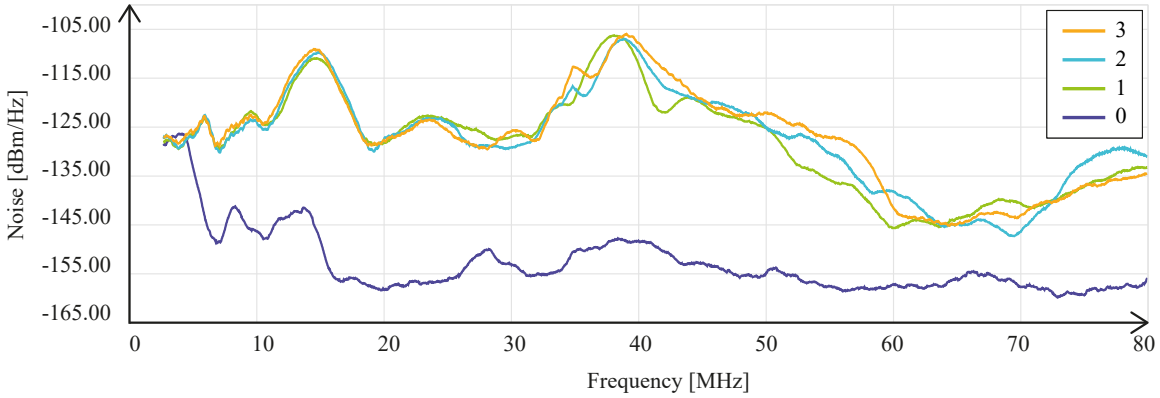

Figure 3: Graph of the noise level for topology with 2 m extension cord.

Noise levels shown in Figure 4 represents measurement of the second topology. Curve 0 has flatter characteristic then in previous measurement (Figure 3), because 50 m cord might have filtered out more noise coming from the powerline. Noise level in the frequency band above 45 MHz is higher than in previous measurements. This is due to the lower BPL power on these frequencies. As in the previous measurement, the lowest noise level can be seen in position 1.

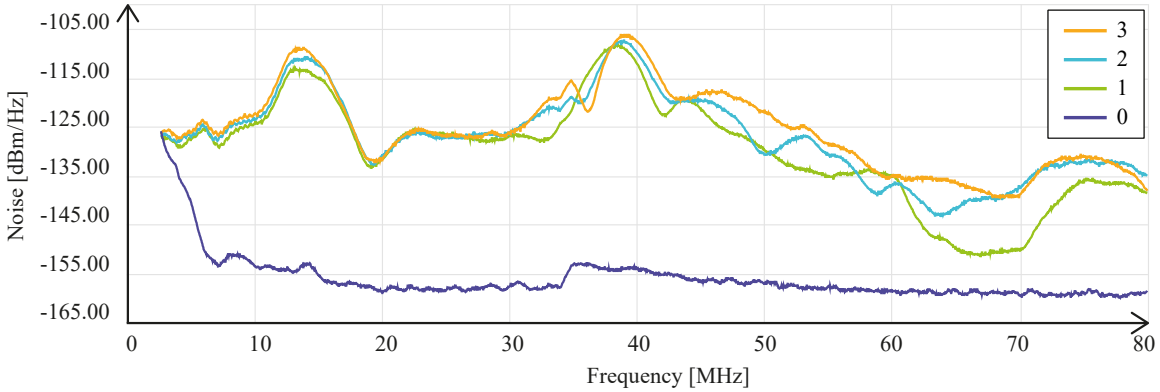

Figure 4: Graph of the noise level for topology with 54 m extension cord.

Figure 5 shows comparison of throughput according to position of BPL modem and devices in extension cord for first and second topology. Measured values can be found in the Table II. Brown and magenta curves are for D1 in first topology. Cyan and dark blue for D1, D2 devices and second topology. Layout 0 represents cord without connected devices with only BPL modem. 1, 2, 3 are positions in the cord.

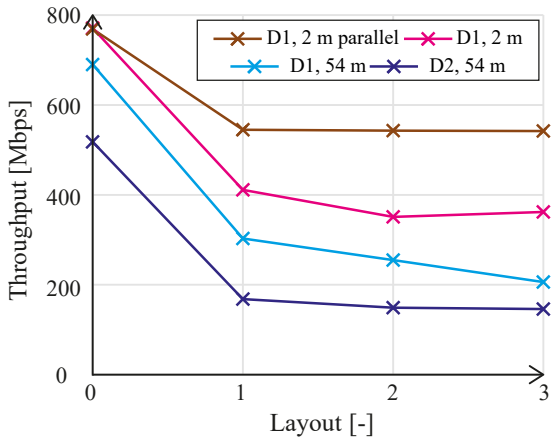

Figure 5: Throughput – position in cord.

Table II: Throughput for different layouts and devices.

	BPL Modem	D1	D1	D1	D2
	PL length [m]	2	2, parallel	54	54
		Throughput [Mbps]			
Layout	without devices (0)	771	769	690	518
	1	411	545	303	168
	2	351	543	255	149
	3	362	542	206	146

4. CONCLUSION

As described before two topologies were measured. From result of the measurement with 2 m extension cord (1), it can be concluded that use of parallel extension cord with BPL modem connected and second extension cord for devices is better. Parallel connection has 29 % throughput drop. In case of BPL modem connected in the second cord beside the working devices is the throughput drop much higher at 47 %. Significant discovery is when the usage of the parallel cord is not possible. In this case position 1 in the second cord shows the best results, others positions show throughput drop of at least 15 %. An overview of the throughput change is displayed in the Table II. The reason for decrease in throughput position 2 and 3 is increase of noise level, which can be visible in Figure 3.

Second measurement (2) contains comparison of real use cases with two BPL modems D1, D2 at 54 m powerline with impact of connected devices. From Table II and Figure 5 is visible the large decrease in throughput influenced by connected active devices. In position 1 the decrease in throughput is 56 % on D1 and 68 % for BPL D2 compared to the case, when no devices are connected. From the results it is visible, that the position 1 has noticeably lower throughput drop compared to other two measured positions. Throughput drop is 16 % for D1 and 11 % for D2.

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