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Measurement of background noise levels conducted over low voltage power lines in urban and rural areas

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Abstract

This paper presents results of study focused on the measurement of background noise conducted over low voltage power lines in the 0.15 MHz - 30 MHz frequency range in urban and rural areas. The paper also describes relationships, which can be used to assess background noise levels on power lines located in urban and rural areas. A block diagram of a background noise voltage measuring system with supporting components is provided too.

1. Introduction

We have observed increased interest in technologies, which use low voltage power lines to transmit data within buildings. These data transmission systems are referred to as Power Line Communications (PLC) solutions. Low voltage circuits are convenient data transmission pathways for indoor premises within a building. To make use of these circuits, one needs to install dedicated powerline modems, which need to be plugged directly into a electrical wall socket. Energy suppliers use power lines for a similar purpose, i.e. to collect metering information from compatible energy meters. Therefore, background noise levels on low voltage power lines are an important concern to anyone deploying Power Line Communications technologies. Measurements of background noise levels conducted over voltage power lines within frequency ranges up to 500 kHz can be found in available literature [2, 3, 4, 5]. To assess whether a given power line circuit is able to support PLC with broadband speeds (up to several Mbit/s), information on background noise levels in a wider frequency range, up to 30 MHz, is required. However, information provided in current literature [1] on background noise measurement in that frequency range is outdated. The last paper on this subject was published in 1999, and focuses solely on urban areas. This paper presents original results of a study focused on the measurement of background noise conducted over low voltage power lines in the 0.15 MHz - 30 MHz frequency range. Background noise levels conducted over low voltage power lines in rural and urbanized areas, measured over a 24-hour period, are presented herein. Parameters for these circuit filters is specified as well.

A detailed method of measurement along with an example schematic of the measurement system were presented in an earlier issue of this magazine.

2. Measurement system

This section of the paper describes the measurement system used to measure the conducted noise levels $U_{n,b}$ in low voltage power lines for each location, as well as the measurement procedure.

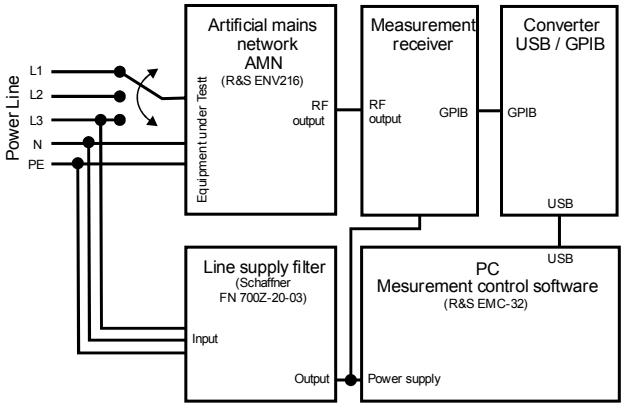


Figure 1. Block diagram of a measurement system designed to measure conducted background noise voltage levels $U_{n,b}$ for a frequency range of 150 kHz - 30 MHz

Figure 2. Illustration of a measurement system designed to measure conducted noise levels

See Fig. 1 for a block diagram of the measurement system, which was used to measure the conducted noise levels $U_{n,b}$ in low voltage power lines. The measurement system consists of:

- a Rohde&Schwarz ESIB26 test receiver operating in a range of 9 kHz – 22 GHz.
- Rohde&Schwarz ENV216 V-network Artificial Means Network operating in a range of 150 kHz-30 MHz.
- A Schaffner FN 700Z 20 3 AC 230V 50Hz powerline filter, which minimizes disturbance conducted by the components of the measurement system (the test receiver and the personal computer). This is achieved by filtering conducted interference signals generated by these components out from the measurement of conducted background noise $U_{n,b}$ in low voltage power lines.
- A personal computer with EMC 32 measurement control software, set up with a remote control system via USB and GPIB interfaces,
- Agilent 82357A USB/GPIB remote control interface adapter.

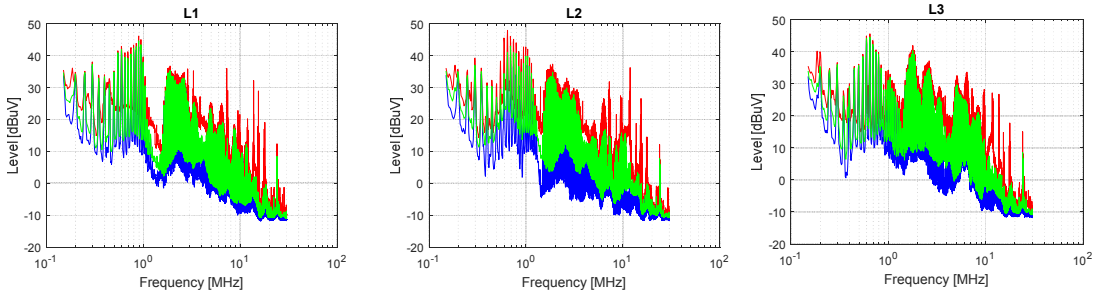


Figure 3. Maximum (red), minimum (blue) and average (green) values for the conducted background noise level $U_{n,b}$ measured in the 150 kHz – 30 MHz frequency range on each low voltage power line: L_1, L_2 and L_3 in an urban area

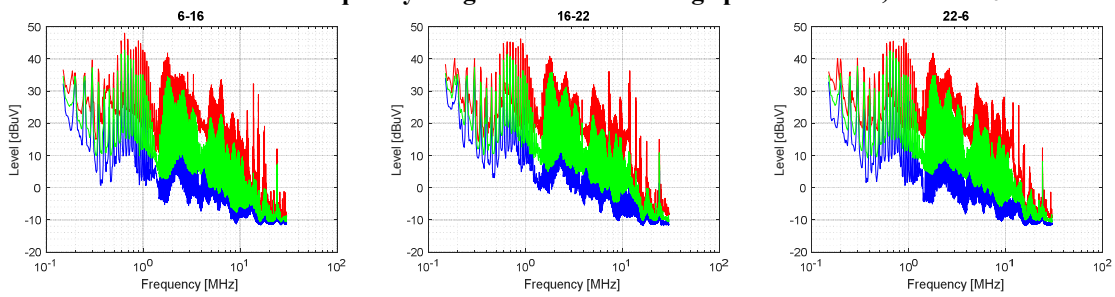


Figure 4. Maximum (red), minimum (blue) and average (green) values for the conducted background noise level $U_{n,b}$ measured in the 150 kHz – 30 MHz frequency range on all low voltage power lines: L_1, L_2, L_3 and N for an urban area measured during the day (from 6 AM to 4 PM), the evening (from 4 PM to 10 PM) and during the night (from 10 PM to 6 AM)

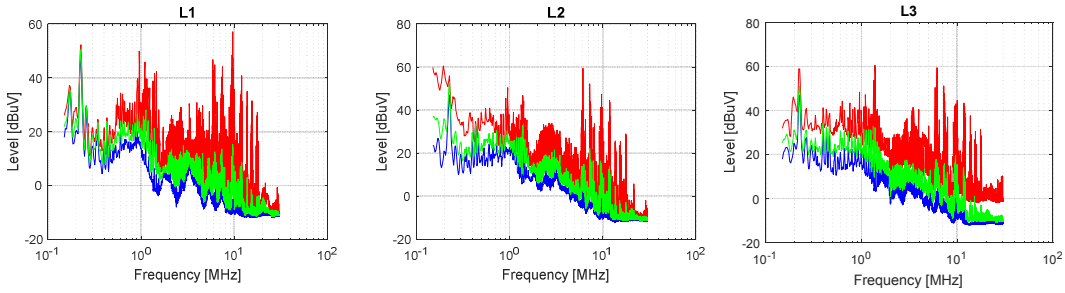


Figure 5 Maximum (red), minimum (blue) and average (green) values for the conducted background noise level $U_{n,b}$ measured in the 150 kHz – 30 MHz frequency range on each low voltage power line: L_1, L_2 and L_3 in a rural area

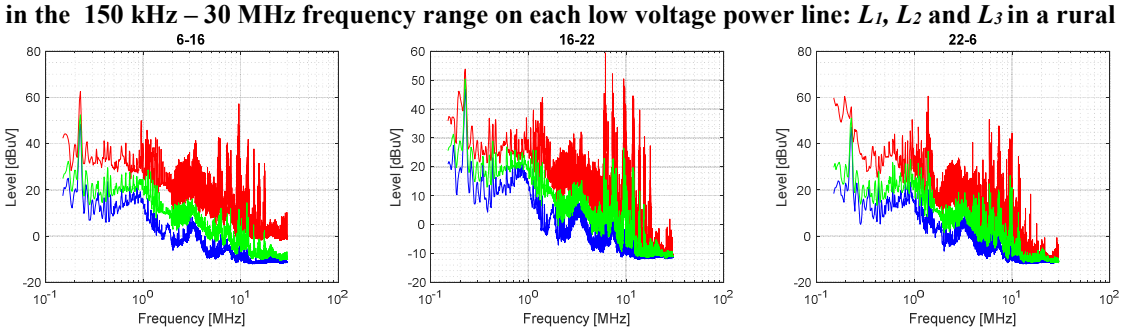
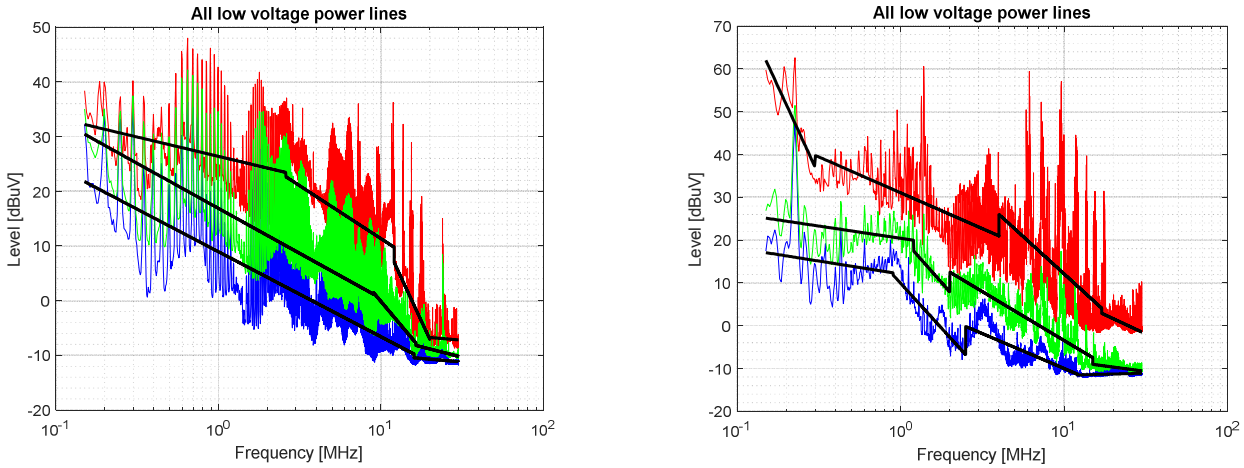


Figure 6 Maximum (red), minimum (blue) and average (green) values for the conducted background noise level $U_{n,b}$ measured in the 150 kHz – 30 MHz frequency range on all low voltage power lines: L_1, L_2, L_3 and N for a rural area measured during the day (from 6 AM to 4 PM), the evening (from 4 PM to 10 PM) and during the night (from 10 PM to 6 AM)



a) b)

Figure 7 Maximum (red), minimum (blue) and average (green) values along with approximation functions for the conducted background noise level $U_{n,b}$ measured in the 150 kHz – 30 MHz frequency range on all low voltage power lines: L_1, L_2, L_3 and N in: a) an urban area over a 24-hour period, b)a rural area over a 24-hour period

3. Measurement results

Measurement results of conducted environmental noise levels $U_{n,b}$ on low voltage power lines in urban and rural areas were presented on Figs. 3, 4 and 7a and Figs. 5, 6 and 7b, respectively:

The collected measurement results of average values of the conducted background noise level $U_{n,b}$ measured in the 150 kHz – 30 MHz frequency range on all low voltage power lines are as follows: L_1, L_2, L_3 and N for urban and rural areas allow for the following conclusions:

- the results exhibit a significant variance of 20 dB in noise levels between minimum and maximum noise values,
- the highest level of noise conducted in the power line circuit was measured in the frequency range of 150 kHz – 20 MHz,
- the level of conducted noise in the power line circuit is much lower in the frequency range of 20 kHz-30 MHz,
- conducted environment noise levels in rural areas are much lower than those measures in the urban area,
- there is significant variance in conducted environment noise levels recorded during the day (6 AM – 4 PM), during the evening (4 PM – 10 PM) and during the night (10 PM – 6 AM); the lowest values were recorded during the evening and during the night, whereas the highest values were recorded during the day.

Maximum, minimum and average values along with approximation functions for the conducted background noise level $U_{n,b}$ measured in the 150 kHz – 30 MHz frequency range on all low voltage power lines: values of L_1, L_2, L_3 and N were presented over a 24-hour period on Fig. 7a and Fig. 7b for the urban and rural areas respectively. In these figures, black straight lines were used to represent the approximate minimum, maximum and average values for the voltage levels of background noise conducted in each frequency subrange from 150 kHz to 30 MHz. The analytical form for the approximating functions is described using the relationship (1):

$$U_{n,9kHz} = a_1 \cdot \log f + a_2 \qquad (1)$$

where:

$U_{n,9kHz}$ – environment noise voltage levels conducted in the 9 kHz band, expressed in [dBµV],

f - signal frequency [Hz],

a_1, a_2 - factors take the values provided in Table 1 depending on the frequency subrange and the type of area where the noise is measured.

Table 1. Values of factors a_1 and a_2 of the approximating function (1) for the measured values of voltage levels for conducted environment noise $U_{n,9kHz}$ for various frequency bands and measurement locations

Item no.	Area type	Minimum values			Average values			Maximum values		
		a_1	a_2	Frequency range [MHz]	a_1	a_2	Frequency range [MHz]	a_1	a_2	Frequency range [MHz]
1.	Urban area	-15.5430	8.9395	0.15÷16	-16.445	16.8655	0.15÷9	-7.0807	26.3740	0.15÷2.6
2.		-2.5936	-7.3331	16÷30	-35.355	35.2130	9÷16.4	-19.3349	30.6736	2.6÷12
3.		-	-	-	-7.5997	1.0450	16.4÷30	-63.9932	76.1967	12÷20
4.		-	-	-	-	-	-	-2.4555	-3.5482	20÷30
5.	Rural area	-6.0536	12.0833	0.15÷0.90	-5.7144	20.4281	0.15÷1.2	-82.8007	-6.2268	0.15÷0.30
6.		-41.9102	9.9109	0.90÷2.5	-43.202	20.9092	1.2÷2	-16.7360	31.0566	0.30÷4
7.		-16.3007	6.3122	2.5÷12	-22.8477	19.3892	2÷15	-34.8787	46.9863	4÷17
8.		0.9883	-12.5714	12÷30	-5.0641	-3.0787	15÷30	-17.8377	24.8452	17÷30

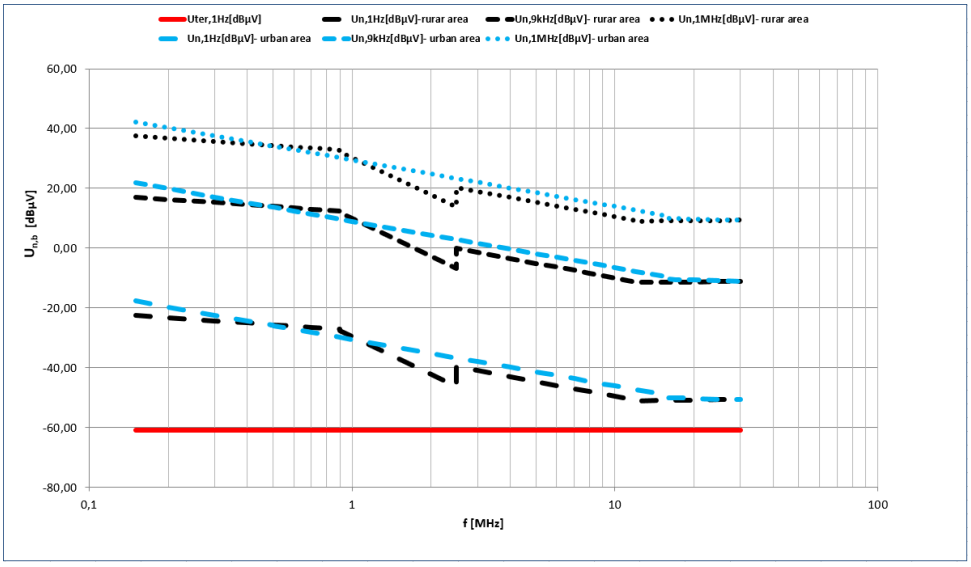


Figure 8. Functions approximating minimum voltage levels for conducted environment noise in low voltage power lines, in a frequency range of 150 kHz – 30 MHz for band *b*=1 Hz, 9 kHz and 1 MHz, for various frequency ranges and for each type of measurement location.

4. Summary

In order to acquire usable data required to assess background noise levels $U_{n,b}$, conducted on low voltage power lines, over the summer of 2016, measurements of conducted noise levels were performed in two locations:

- urbanized area – residential premises in an apartment block in Poland, Warsaw, Ursynów district.
- rural area – a residential home in the Cendrowice village near the town of Góra Kalwaria, Poland.

Three phase circuits and a neutral line (L_1, L_2, L_3, N) were measured for a period of 24 hours.

Approximating functions (1) for measured minimum voltage values for conducted environment noise $U_{n,9kHz}$, various frequency bands and measurement locations, presented in Table 1, may be used to specify minimum values for the voltage levels of conducted background noise in low voltage power lines, in a frequency range of 150 kHz – 30 MHz for any band *b*. The measured minimum levels of conducted background noise levels $U_{n,1Hz}$ in low voltage power lines in the frequency range (0,15 - 30) MHz take values, which are respectively 40 dB to 10 dB higher than the thermal noise value $U_{ter,1Hz}$ for a given filter band of the 1 Hz monitoring receiver. See Fig 8 for the values of $U_{ter,1Hz}$ in the frequency function, which are plotted as a red line. See Fig. 8 for example minimum values of $U_{n,b}$ for filters with bandwidths of *b*=1 Hz, *b*=9 kHz and *b*=1 MHz.

In practice, filters with parameters coherent with the relationship (1) and factor values a_1 and a_2 (Table 1) for specified frequency ranges and terrain types can be used to separate devices connected to the internal circuit from any disturbances present in power distribution networks. These filters separate individual network components in various locations. This enables operation of multiple home networks using the PLC standard at once, and the use of the PLC for smart metering systems by energy providers.

5. References

1. Liu D., Flint E., Gaucher B., Kwark Y., "Wide Band AC Power Line Characterization", IEEE Transactions on Consumer Electronics, Vol. 45, No. 4, November 1999, pp. 1087– 1097.

2. O'Neal J. B., "The residential power circuit as a communication medium, IEEE Transactions on Consumer Electronics, pp. 5670576", August, 1986.

3. Chan M. H. L. and Donaldson R. W., "Amplitude, width, and interarrival distributions for noise impulses on intra building power line communication networks", IEEE Transactions on Electromagnetic Compatibility, pp. 320-323, August, 1989.

4. Vines R. M., Trussel H. J., Gale L. J., O'Neal J. B., "Noise on residential power distribution circuits", IEEE Transactions on Electromagnetic Compatibility, pp. 161-168, November, 1984.

5. O'Neal J. B., "Substation noise at distribution-line communication frequencies, IEEE Transactions on Electromagnetic Compatibility", pp. 71-77, February, 1988.

6. EN 55022:2010, Information technology equipment-Radio disturbance characteristics - Limits and methods of measurement