

Influence of LED Tubes on the Throughput of an Indoor Broadband PLC Channel

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Abstract— This paper shows how Light Emitting Diode (LED) Tubes negatively influence the data rate throughput of an indoor broadband Power Line Communications (PLC) channel. This negative influence on the data rate is due to noise being generated by the lamps. Differential Mode measurements were done with two PLC modems communicating and then introducing LED lamps that add noise to the channel. Drops in data throughput rates were measured and compared to a clean (no noise) channel. A significant decrease (up to 50%) in throughput was observed which can have important implications for applications of PLC in the presence of LED Tubes.

Index Terms— EMC; Interference; LED Tubes; Light Emitting Diode; Low Voltage Network; Noise; PLC.

I. INTRODUCTION

In future, PLC will be an enabling technology for the *Internet of Things* [1] and the *Smart Grid* [2] as it will enable systems and devices to communicate via the connections made by the power systems. There are, however, technical limits to the implementation of PLC on any network. This includes, most notably, the channel bandwidth and amount of noise present. This paper deals with one such a noise source - LED tubes.

LED's are grouped together to form lamps or tubes. These tubes use less power than fluorescent tube lighting and are considered energy saving. Even though they use less power for the same output of lumens they do have a negative property. Due to the power conversion in the LED tubes, electrical noise is produced. This is observed with numerous modern lighting technologies where power conversion takes place [3][4][5]. This noise negatively affects the data rate or throughput on a PLC channel which is measured in this paper. The throughput in the presence of noise for a given signal strength, bandwidth and noise is given in its theoretical limit by the Shannon-Hartley theorem [6] or:

$$C = B \log_2 \left(1 + \frac{S}{N} \right) \quad (1)$$

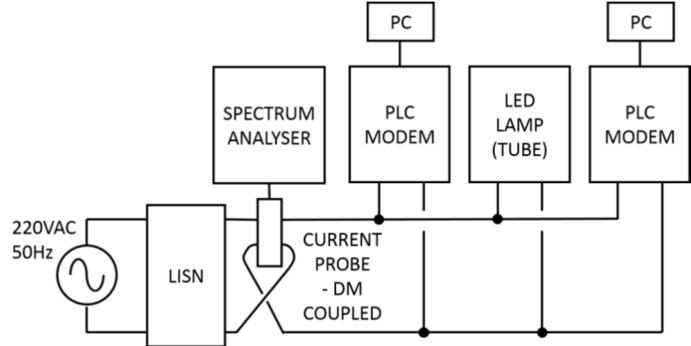


Fig. 1 -Measurement set-up. Modems in close proximity

where C is the channel capacity in bits per second through an analog channel; B the bandwidth of the channel in hertz; S the average received signal power over the bandwidth in watts and N the average noise power and interference over the bandwidth in watts.

In this paper data rates (throughput) are measured between two PLC modems in the presence and absence of noise from LED tubes. Two sets of measurements are done. One with the modems in close proximity – a reference case and one with the modems communicating over a 30m power line. The latter is a more realistic or practical case.

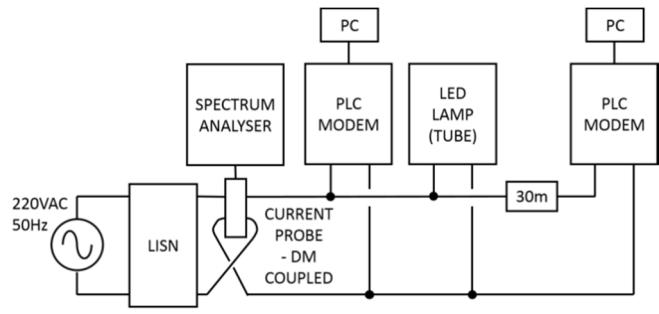


Fig. 2 -Measurement set-up. Modems at 30m

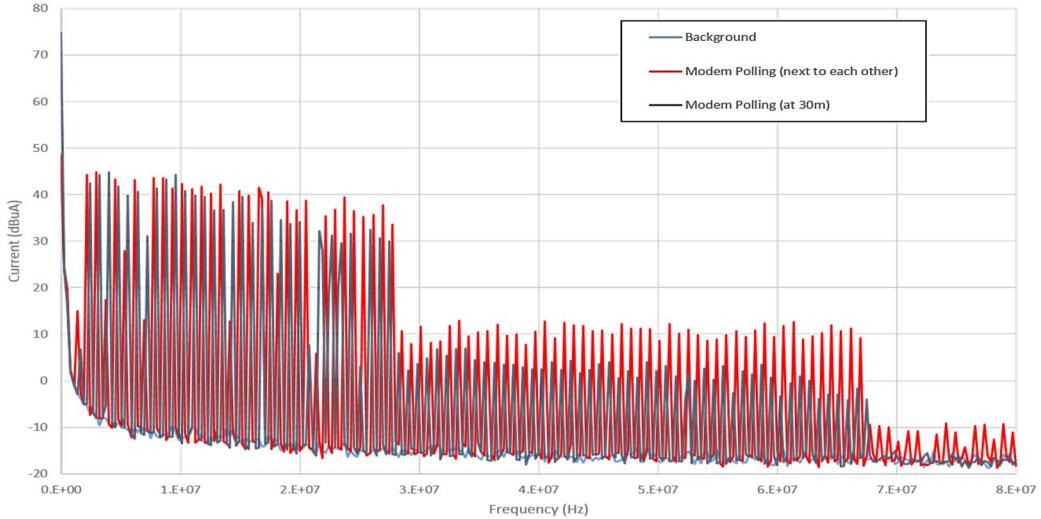


Fig. 3 –Spectrum of modems polling. Modem in close proximity and at 30m.

A significant decrease (up to 50%) in throughput is observed due to the presence of noise from the LED tubes. This was measured for three different manufacturers of lamps. This result can have implications for designers wanting to use PLC near energy saving LED tubes.

In this paper, results are given in the third section while the second section deals with the measurement set-up. A conclusion and references round up the paper.

II. MEASUREMENT SET-UP

The measurement set-up consists of two PLC (Homeplug AV2) modems communicating on an energized power network. Two PC's were used to communicate via the PLC network. 220VAC (50Hz) were supplied through a Line Impedance Stabilization Network (LISN). The LISN ensures that power from the mains is clean and it supplies a standardized impedance (50Ω to chassis above 1MHz) to the network from the modem's side. A RF current probe connected to a spectrum analyzer measures high frequency currents (typically above 1MHz). Since these currents flow through the impedance of the LISN and is a direct indication of the modems' transmission voltage and signal strength. The current probe is connected so that common mode current is cancelled and so that only Differential Mode (DM) current is measured. An LED lamp (tube) is connected between the modems and injects noise into the network. Measurements were taken with three different LED tubes energized.

Two physical measurement set-ups were used. These are shown in Fig. 1 and 2. The only difference in the two set-ups is the distance between modems. In Fig. 1, the modems are next to each other (close proximity), while in Fig. 2 they are connected by 30m of power cable.

Measured throughput results were taken by transferring a 100MB file from one PC to another (both download and upload) and measuring the time it took. Throughput is then calculated in Mbps. This is done with software that is routinely

used to determine upload and download speeds to servers. This was repeated five times to determine a spread of throughputs.

III. RESULTS

Figure 3 shows a spectrum of the modems polling. One trace is of a modem in close proximity (set-up as in Fig. 1) and another of the modem at 30m (set-up as in Fig. 2). The Orthogonal Frequency-Division Multiplexing (OFDM) carriers can clearly be seen. Only the carriers are present as the modems are polling and no data is being exchanged. Exclusion bands in the Short Wave (SW) band can also be seen. Up to 27MHz the transmission voltages of the modems are high and are limited from 27MHz to around 68MHz. The signal from the modem at 30m measures lower as the 30m power cable has an attenuating effect on the voltage (and therefore current) being produced. Depending on the frequency, the attenuation of the 30m power cable is around 5dB to 10dB.

Figure 4 shows the different noise spectra of three different LED tubes in the absence of any communication signal. The LED tubes are clearly different in their noise signatures. Brand A has the highest noise signature followed by brand C in the lower frequencies and then brand B. Brand A's noise level is at least 10dB to 20dB higher than the ambient.

Fig. 5 is the spectra of signals of modems communicating (that are in close proximity) while in the presence of noise from the LED tubes. This is different from the measurement of Fig. 3 as no OFDM carriers can be seen. Instead the spectrum is continuous over the bandwidths where data is being communicated. The Homeplug AV2 standard determines the maximum transmission signal strength and is higher from typically 2MHz to 27MHz than in the rest of the band up to about 68MHz.

Figure 5 also represents the conditions under which the throughput measurements were made for the reference condition of the two modems in close proximity (Fig. 1 and 6). Results of the throughput measurements with the modems in close proximity are given graphically in Fig.6.

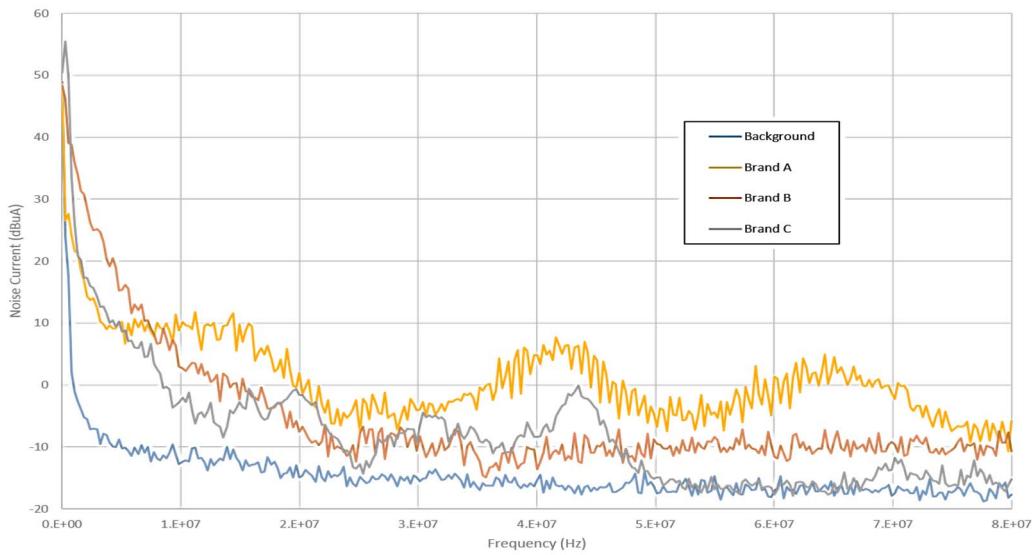


Fig. 4 – Noise spectra of different LED tubes.

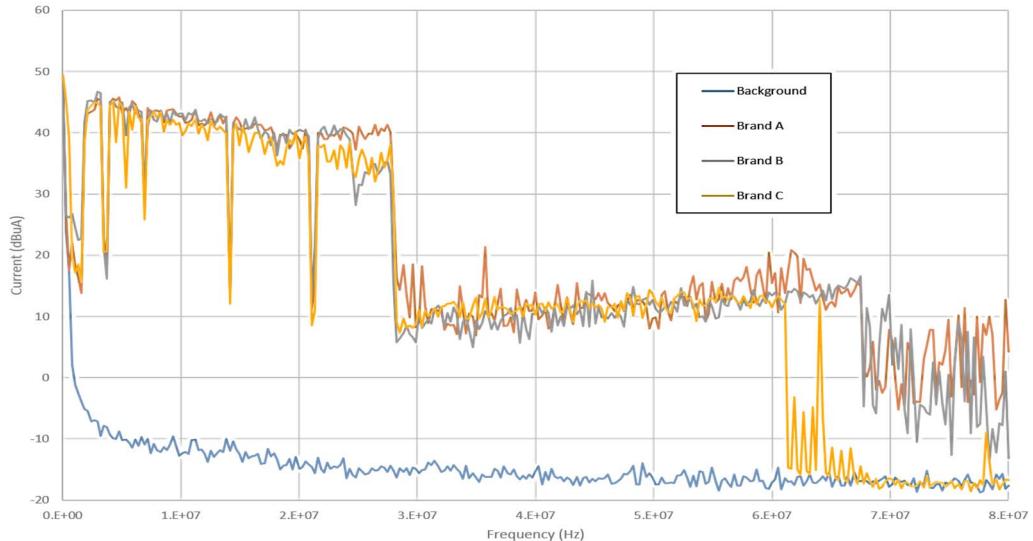


Fig. 5 – Spectrum of modems communicating in close proximity and in the presence of noise from the LED tubes.

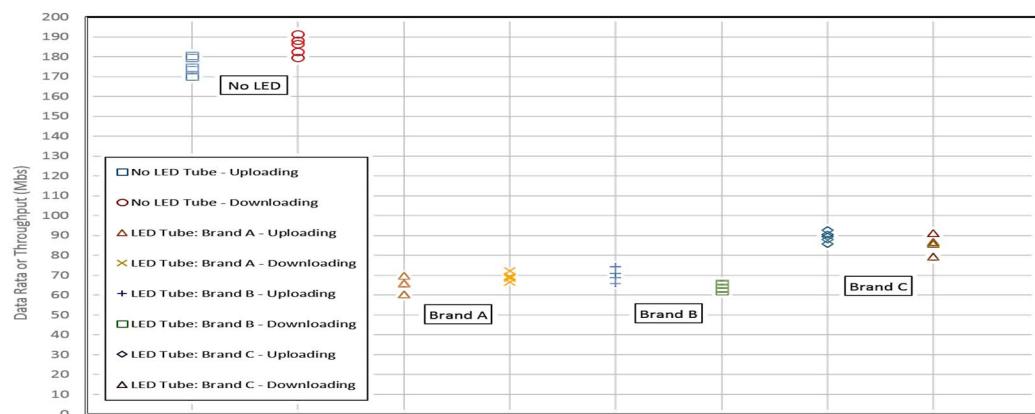


Fig. 6 – Throughput measurement results for modems in close proximity, with three kind of LED tubes and without.

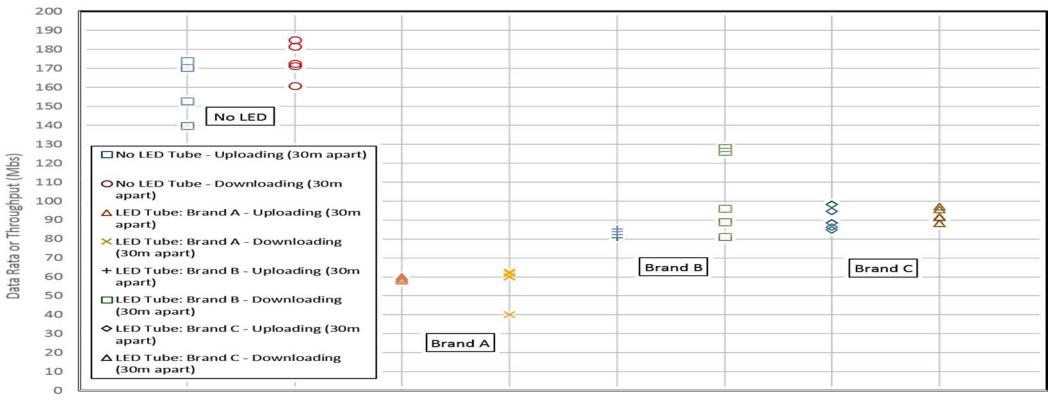


Fig. 7 – Throughput measurement results for modems at 30m, with three kind of LED tubes and without.

With the two modems in close proximity (next to each other on the power line) the system typically achieves data throughput rates of 170Mbps to 190Mbps. This is done as reference as two modems next to one another is not used in practice but will achieve maximum throughput. With the addition of noise from the LED tubes the data rates fall dramatically. For Brand A the throughput falls to 60Mbps to 70Mbps. For Brand B, 60Mbps to 75Mbps and for Brand C, around 80Mbps to 90Mbps. From a throughput and data speed point of view, performance is highest in the presence of Brand C. Brand C has a noise signature that is very close to ambient from around 50MHz with a virtual noise free band up to 70MHz. This most probably explains why the configuration with the Brand C LED tube has the best throughput under noisy conditions. It is important to note that with the inclusion of lamps directly next to the modems, the throughput data rate drops to at least 50%.

With the two modems at 30m and the noise source at the one modem, the system typically achieves data throughput rates of 140Mbps to 185Mbps (Fig. 2 and Fig. 7).

With the addition of noise from the LED tubes the data rates also fall dramatically with 30m of power cable. For Brand A the throughput falls to 40Mbps to 65Mbps. For Brand B, 80Mbps to 130Mbps and for Brand C, around 85Mbps to 100Mbps. From a throughput and data speed point of view, performance is highest in the presence of Brand C, but paradoxically higher than the two modems in close proximity. The reason for this is not clear although it is important to note that with the inclusion of lamps and the modems 30m apart, the throughput data rate drops to at least 50% and in some cases even further.

Further experimental measurements were performed to other types of LEDs and brands of modern lighting sources. By comparing the obtained results from other lighting sources with the results from LED tubes, lack of proper filtering leads to noise being visible and present on the power line channel and current harmonics do exist in most cases.

The main reason behind the LED tubes degradation in performance is the active power converters and bridge rectifiers that make part of LEDs and produce current harmonics and interference on the power line communications channel. This is caused as designers and manufacturers of lamps do not take in consideration implementing better quality of the internal circuits in the LED tubes. All LED's that have converters and

rectifiers produce noise, but not all are filtered as this adds more cost, and space is needed for the extra filter components. Low frequency noise (50Hz components) is generated due to the rectifier action where higher frequency noise at the DC-DC converter, switching frequency harmonics are also seen.

IV. CONCLUSION

In this paper data rates (throughput) are measured between two PLC modems in the presence and absence of noise from LED tubes (lamps). Two sets of measurements were conducted. One with the modems in close proximity – a reference case and one with the modems communicating over a 30m power line. The latter is a more realistic or practical case. In both cases (due to the noise caused by the LED tube power conversion) the throughput data rate dropped to at least 50% when LED tubes are included on the network. Although all three the LED tubes had Electromagnetic Compatibility (EMC) markings on them (and it is therefore assumed that they conform to noise emission standards) it influenced the data transmission rates of a PLC system on the same network. This has important consequences for system designers wanting to use PLC in the vicinity of LED tubes.

V. REFERENCES

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