Wideband Characterization of Low Voltage outdoor Powerline Communication Channels in India

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ABSTRACT

We present results and discussions based on measurements in a campus underground powerline network in India. Most results on powerline channels presented in the literature thus far do not deal with the link between the distribution transformer and various sites served by it. This link is relevant to the use of power line as an access (last mile) medium for Internet and telephony applications. This technology could potentially be of interest to countries with very low telephone densities, especially in rural areas. Results presented here based on both frequency and time-domain measurements indicate the possibility of using this segment of the powerline network for providing telephony and low-data-rate internet access.

Introduction

Powerline communications is a promising means to deliver telephony and related services in a country like India where telephone lines are not widely available as in developed countries. The power network in India reaches well over 75% of the population and in many regions there is 100 % penetration representing an infrastructure already in place. Our motivation is to investigate the characteristics of the powerline network in India since it's construction and maintenance might not be the same as in developed countries where most such measurements have been conducted and reported.

The main goal is to investigate the low voltage outdoor network, viz from the distribution transformer (DT) to the entry points for electricity at the various buildings served by it. We consider here a typical campus network, though we have planned for further studies in other environments. The lengths of the cable involved in the measurement, the quality of the cable, and the maintenance are typical of Indian conditions. The measurement methods used here have been typically used by other groups [1-4] to present the quality of the powerline channel for indoor applications, and we have extended the same to the outdoor case. We first outline some details of the study site as well as the measurement setup. Measurements made in the frequency domain are discussed followed by discussions on time-domain results. We conclude with a summary of significant points about the measurements.

Measurement Details

All outdoor measurements were carried out on a campus underground network and Fig. 1 shows the various buildings involved and the approximate distances. The maximum distance involved in the investigation is a little over 200 meters. The distribution transformer (DT) serving this segment of the campus is expected to serve as a location for basestation for telephony and internet access using the powerline. The power hut (PH) is an intermediary node which does not have any significant loads in the vicinity while all the other buildings have computers and other electronic and electrical equipment connected to the power network. The DT feeds another load through a 125KVA Voltage Stabilizer which is located near it (not shown in figure). The measurement point in all buildings was at the entry point for electricity. Some indoor measurements were also conducted in a recently constructed building having fully stabilized power supply.

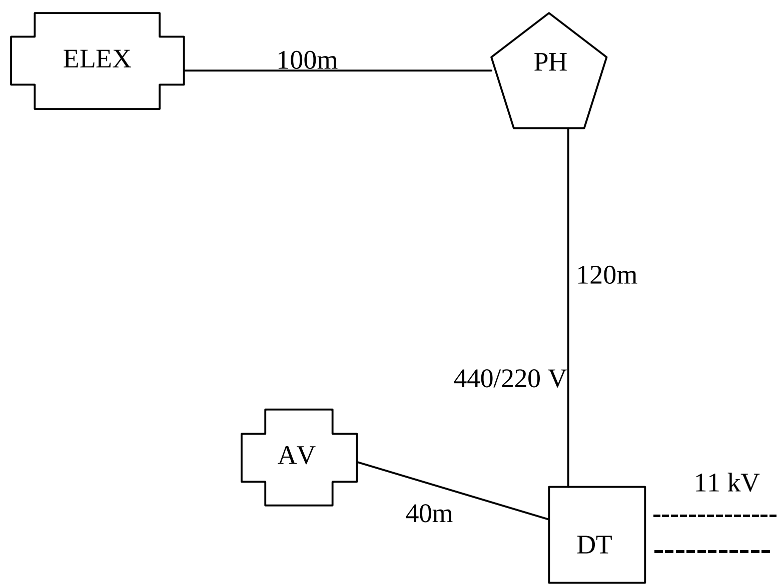


Fig. 1: **Measurement Site**

A signal generator (Agilent 33250A) capable of generating sinusoids upto a frequency of 80 MHz and pulses with a width of 8 ns was used as the transmitter and the output impedance was set to 50 ohms. A coupler was used to inject and capture signals onto the powerline and also to isolate the 50 Hz 220 Volts signal using a 1:1 isolation transformer. The coupler was designed as a highpass filter with a cutoff frequency of 500 kHz and results indicate that it has a flat response atleast upto 50 MHz. Experiments were performed with other values of the turns ratio but results indicate that a turns ratio of one gives the best performance in our environment. At the receive end, the output from the coupler is fed to instruments for both time-domain and frequency-domain measurements. A digital storage oscilloscope (Agilent 54622D) is used to measure time-domain output and it has an input impedance of 1 Mohm while the spectrum analyzer (HP 8590L) is used to measure results in frequency domain with an input impedance of 50 ohms and a resolution bandwidth of 10 kHz. In all measurements with the DSO, the output was measured across a 50 ohms resistor.

Frequency Domain Measurements

Measurements were conducted by transmitting a sinusoid whose frequency was swept from 500 kHz in steps of 50 kHz. Measurements were carried out at three buildings at different distances from the DT, which was the injection point for the signal. The signal level at the corresponding frequency was measured using a spectrum analyzer and the average value over 100 sweeps is presented in dBm in Fig. 2 Also shown is a typical noise spectrum measured at the entrance to the building. It is seen that the range of

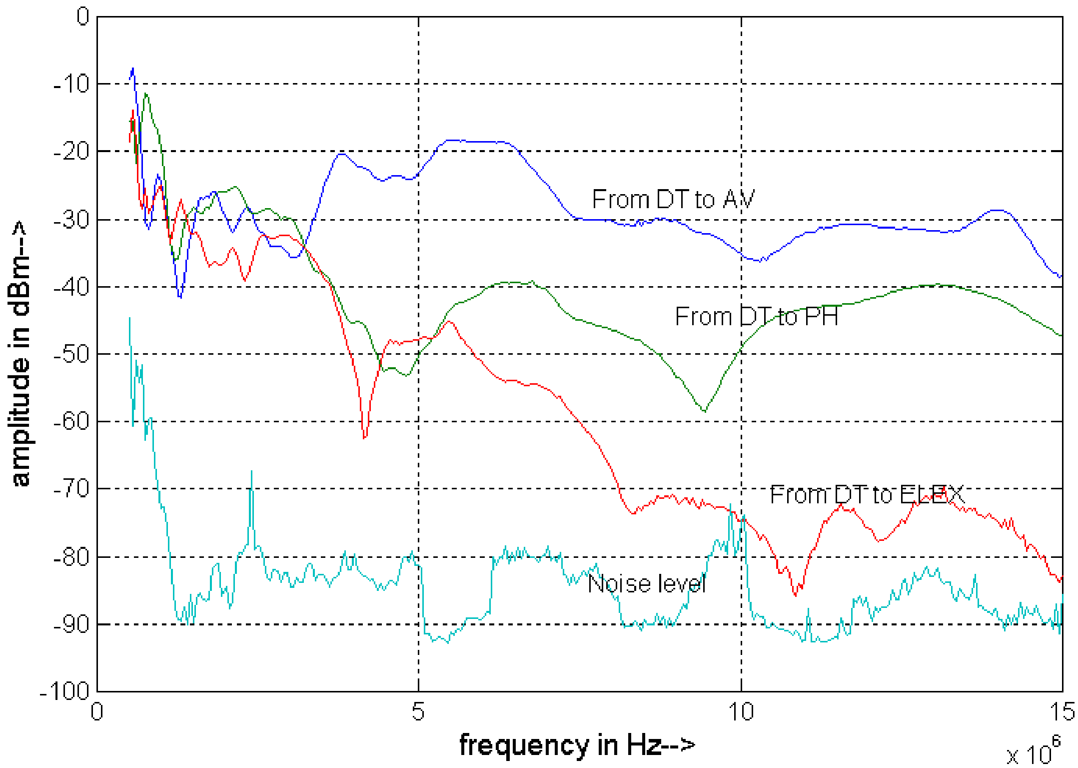
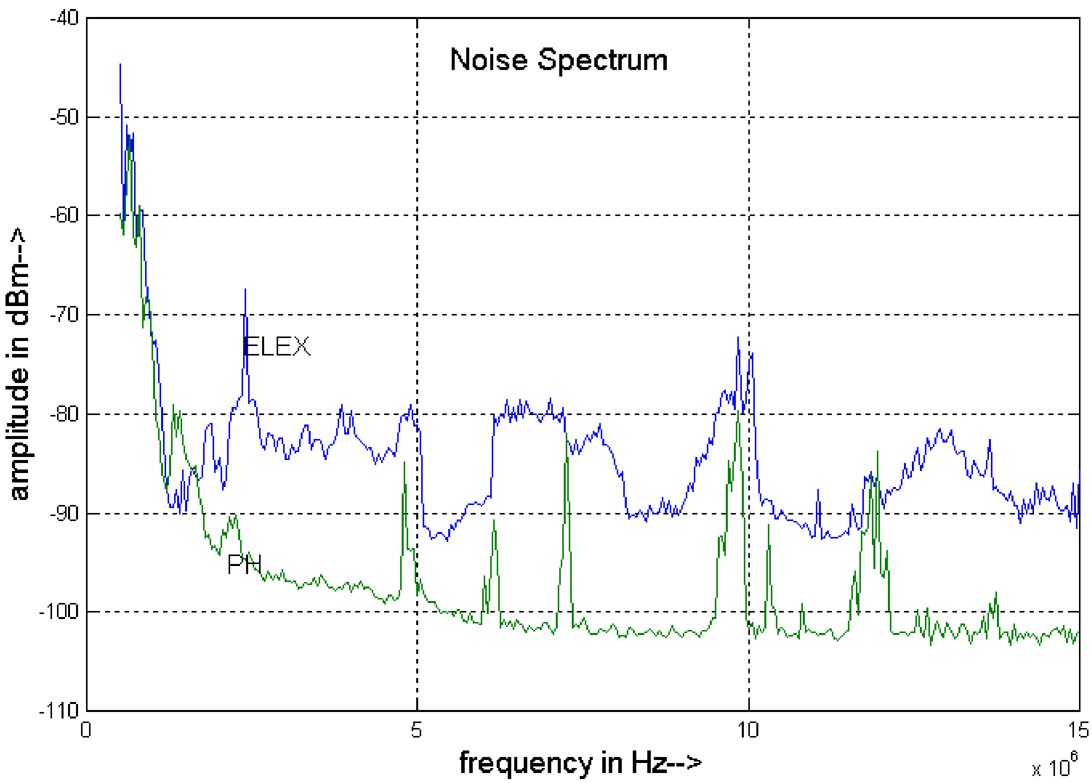


Fig. 2 : **Signal spectrum and noise spectrum of various channels**

frequencies over which the signal level can be measured clearly over the noise level decreases as distance increases from 45 MHz at AV to 35MHz at PH to 15 MHz at ELEX. These results suggest that a communication system which can potentially use different frequency bands for the different buildings could be a suitable strategy in this context to maximize capacity while sharing the same physical communications resource among different users in a campus.

Noise measurements were also conducted by connecting the coupler to the outlets in the different buildings and the power level in dBm was measured using the spectrum analyzer at the same frequency points as in the previous experiment (see Fig. 3). Results were averaged over 100 sweeps and it was noticed that the noise peaks shifted in frequency at different times. The mean noise power was found to decrease as frequency was increased as in other studies [4-6] and noise peaks due to various sources were also seen. The influence of the effects of loads in the vicinity of the measurement point can be gauged by comparing the noise measurements at the ELEX and the PH buildings. It can be seen that the average noise levels at the PH is about 10 dB lower than at the ELEX, and this correlates well with the fact that the former site has little electrical loads in its vicinity as compared with the latter building. Such effects are also mentioned in the study presented in [4]. This feature of the link can be taken into account while designing the communications system since the SNR levels expected in the different directions of the link will be different.

Fig. 3: **Noise Spectrum at ELEX and PH**



Time Domain Measurements

A short duration pulse was used to measure the impulse response characteristics of the channel over a certain bandwidth. The frequency-domain measurements enable us to gauge the usable frequency range in a link. Based on this, we have decided on pulse widths such that the pulse response can be measured. For instance, a pulse of 50 ns duration enables us to characterize the system with a bandwidth of about 20 MHz. The repetition period of the pulse is 10 μs which was chosen based on multipath delay spread values reported in [7] from wherein we can conclude that all significant multipath components can be expected to arrive well within this time. At the receiving end, the DSO was set to capture many periods of the pulse response, which were suitably time-aligned and averaged over 100 periods to remove noise and get a clear impulse response. To conclude about the number of significant paths in a link, a threshold was applied and the peaks above this threshold were assumed to be the discrete multipath components. The threshold operation on the measured impulse response is illustrated in Fig 4. where the power of the impulse response component is shown in dB, and the threshold is fixed 3 dB above the noise peak. The peaks above the threshold are taken as the discrete multipath components and the relative delay between the paths are also noted. Various measurement parameters based on this are calculated and are shown in Table 1 for different links.

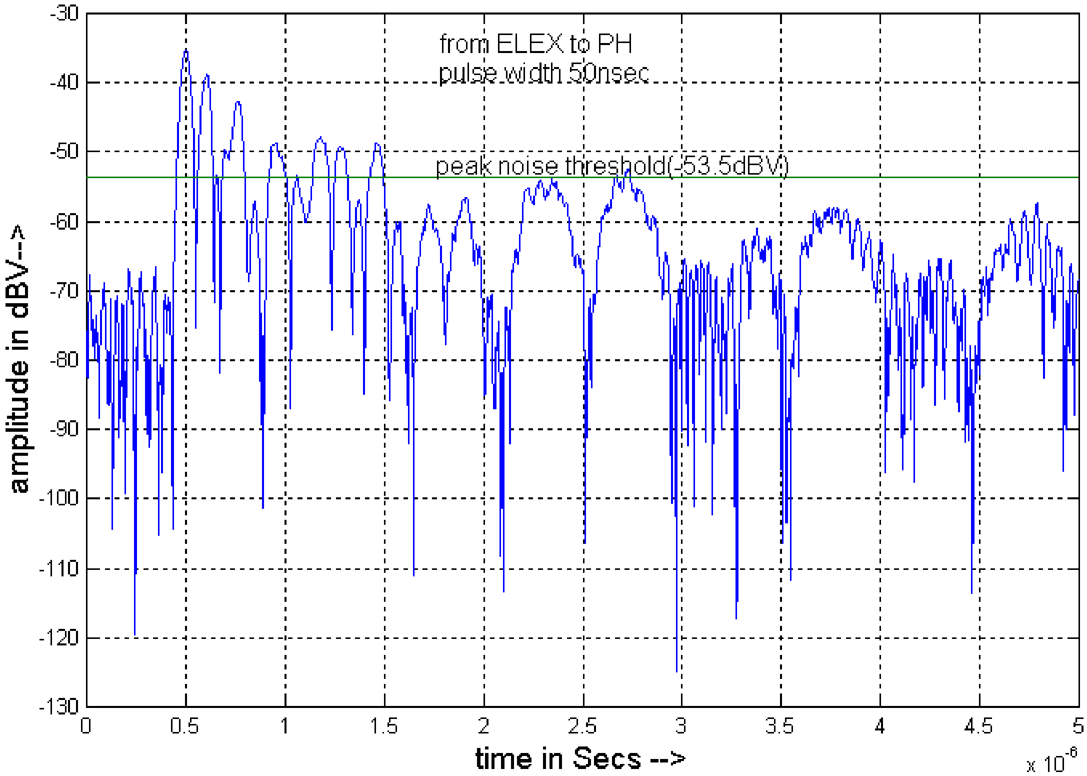


Fig. 4 : **Average Power Delay profile**

Table- 1: **Time dispersion and frequency correlation parameters of the outdoor powerline channel**

Tx-Rx Location	Maximum excess delay (µ sec)	Mean delay Spread (µ sec)	rms delay spread (µ sec)	Coherence Band width (kHz)
ELEX –PH	0.965	0.13	0.228	87.5
ELEX –DT	2.85	0.64	0.796	25.13
DT – PH	0.563	0.21	0.272	73.5
DT – AV	0.488	0.09	0.145	138

The rms delay spread and the coherence bandwidth are important channel parameters, which are used in the design of communications system operating over this channel. For instance, it can be seen that the maximum rms delay spread observed is 796 ns which results in a data rate of 0.63 Mbps without complex modulation/equalization techniques. Using the minimum rms delay spread value we can achieve a data rate of 3.45 Mbps over 15 MHz bandwidth. Using the averaged impulse response measurements, frequency response data was obtained which was then used to obtain the 90% coherence bandwidth. This rms delay spread was also used to calculate the coherence bandwidth using standard formulae [8], and it was found that the 2 methods yielded close results. The lowest coherence bandwidth of 25 kHz was observed with the longest connection (220m) with loads close to both transmitter and receiver ends.

Conclusions

Measurement results over a campus network in India are presented. These measurements are relevant to the design of a communication system for telephony and internet access over powerlines, where the DT point serves as the base station. Frequency-domain results presented indicate the effect of frequency and distance on the signal level as well as the noisiness of the channel . Combined with the time-domain measurements these results indicate that a flexible communications strategy can be used taking into account the varying distances and asymmetries involved in this network and using available communications techniques. We are planning to demonstrate a communication system working in this environment in the near future.

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