Experimental Study of UWB Transmission Over Powerline Channel

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1. Introduction

This paper presents the experimental study undertaken in order to characterize wired UWB transmission over conventional household powerline. Powerline cables have long been used for low data rate (in the order of few hundred Kbits/s) narrow-band transmission for control and supervision services. High data rate broadband communications would enable effortless in-home networking given the availability of power cables in homes. Although research has been done for frequencies up to 30MHz, the increasing requirements on high transmission data-rates for in-home networking such as high definition video streaming make the utilization of higher frequency ranges necessary [1].

UWB technology maps information in very short bursts of pulses, which are followed by a guard time to cope with channel dispersion. This results in a very high data rate over the available bandwidth. Wired UWB is a viable approach to resolve the limited transmission rates of powerlines. Encouraging results on UWB pulse transmission has been shown below 100MHz frequency range [2]. However, limited work has been done in higher frequency ranges, i.e. up to gigahertz range. Therefore, this paper presents the study of indoor powerline channel characteristics in frequencies up to 1 GHz.

2. Measurement set-up

2.1 Powerline cable

The most commonly used type of cable for indoor power distribution in the UK is the 2.5mm flat twin earth cable (figure 1). It can be several decades of metres long, depending on the size of the home, and is laid within the walls of buildings connecting power outlets and the isolation transformer of the power network. This type of cable consists of three conductors, each one made up of a single copper wire. These conductors are the 'live' (red), 'neutral' (blue) and 'ground' (no plastic sheath).

2.2 RF Coupler

An RF coupler for powerline communication should not introduce a high loss to the system. Ideally, it would have a transmission loss of less than 3dB. As it will operate simultaneously with the AC power on, the 220V AC power should be filtered for safety reasons. The coupling system comprises of filters and transformers (Fig. 1) [3]. The filter is realized by capacitors that block the low-frequency power signal. The transformer provides galvanic isolation between the power circuitry and communication circuitry, and couples the signal to the powerline system differentially.

The design of a broadband coupler is extremely challenging and up to now a band-width of 30MHz was available. For this study, a novel coupler was developed with a-6dB band-width of 0.8MHz. The surface mount ADT1.5-122+ transformer was built on FR4 PCB with a pair of 100pF safety capacitors, which filter the DC and 50Hz AC power. In order to allow for maximum energy transfer through the coupler, no resistor was used (0 Ω). The performance of the coupler was initially investigated without the presence of powerline. This was done by connecting the couplers back-to-back and measuring the S-parameters with a VNA. It can be observed from Fig. 2 that the 10dB bandwidth of the return loss (S11) is very wide and extends in the range of 80-930MHz. The insertion loss has a flat profile and is approximately 4dB throughout the 80-930MHz frequency range.

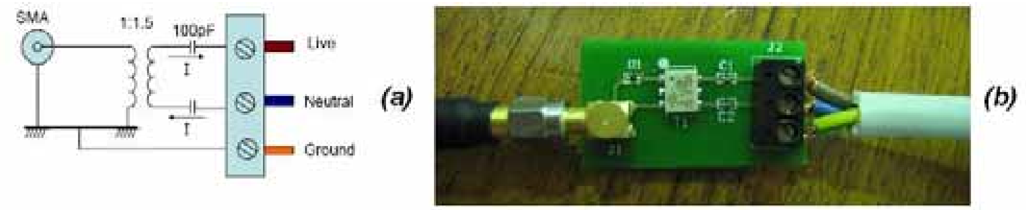


Figure 1: RF coupler coaxially connected to the powerline cable (a) circuit outline (b) photograph (R1=0 **Ω**).

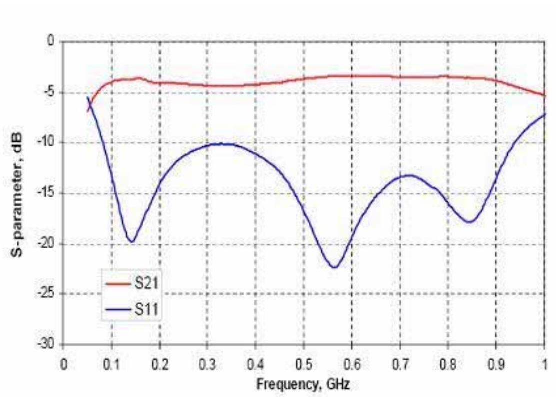
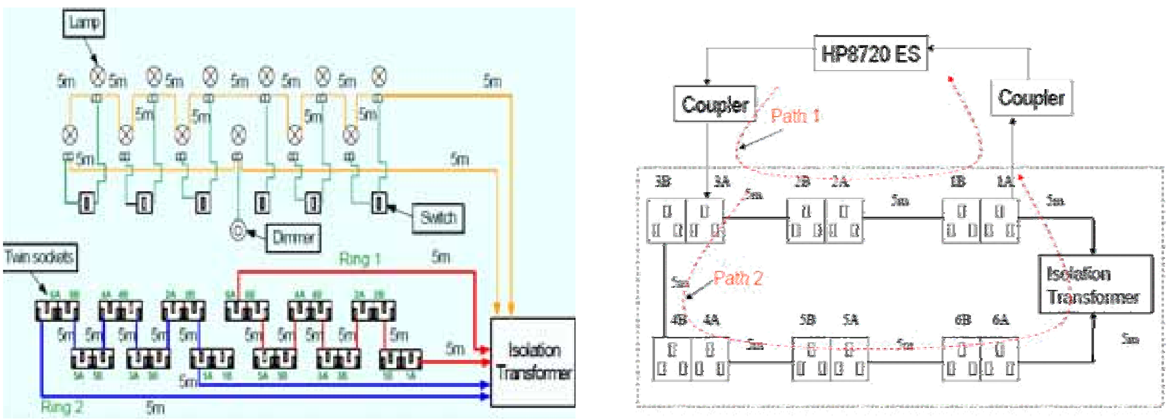


Figure 2: S-parameters of two RF couplers connected back-to-back.

2.3 Powerline network test-bed

A test bed was built to simulate the wiring of a home environment in the lab. UK electrical power circuits are based on a ring-circuit topology. In ring-circuits, power is transmitted from point-to-point by a single length of cable linking each point to the next. The test bed wiring is shown in Fig. 3 (a). It consists of 3 circuit rings each connected to the isolation transformer. The isolation transformer plays two roles, namely to decouple the circuit rings from each other and to act as a 1:1 power transformer as a safety measure. There are three circuit rings, two for wall outlets and one for lighting.

It can be seen from Fig. 3 (b) that within a circuit loop, there exist two transmission paths. If we transmit from outlet 3A and receive at 1A, the signal will not only travel through path 1, but also via path 2, at 25 meters. As a result, multi-path transmission can occur in this set-up.



(a) (b)

Figure 3: (a) Schematic diagram of powerline test bed wiring (b) Multi-path transmission on a circuit ring (ring 1) between outlet 3A and 1A

3. Measurement: time and frequency domain results

3.1 Frequency domain results

The frequency response of the coupler has been measured in 50MHz to 1GHz. 1601 sample points were collected at a sweep rate of 3.204 seconds. Fig. 4 illustrates the transfer function (S21) from outlet 3A to other outlets in the same circuit ring (Fig. 3 (b)).

The indoor powerline channel exhibits low pass properties and the transmission performance degrades with frequency and transmission distance. The measured frequency domain performance can be divided into two sub-bands according to the loss profiles; the low band and the high band. In the low band, channel attenuation increases with frequency. Furthermore, its bandwidth decreases with transmission distance. In the high band however, channel loss fluctuates between 40 to 70dB and more transmission nulls exist. Table 1 compares the average attenuation in the 50 – 550MHz and 0.5 – 1GHz ranges. It can be seen from table 1 that the low band yields a 10dB lower attenuation level.

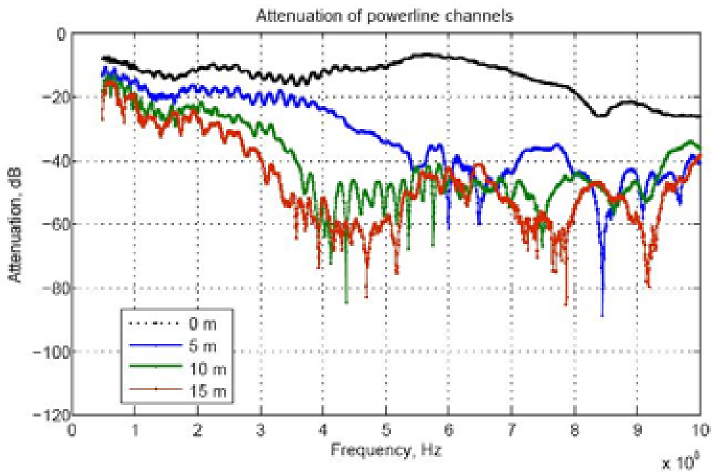


Figure 4: Frequency Domain results. Signal attenuation versus frequency for cable lengths between 0-15m.

Table 1: Comparison of average attenuation between frequency band 50 – 500MHz and 0.5 – 1GHz

	Average attenuation in dB			
	0 m	5 m	10 m	15 m
50 - 550MHz	11.459	23.745	35.323	42.184
500 - 1000 MHz	15.751	38.082	49.716	53.956

3.2 Time domain results

In the time-domain measurements, a 1ns square pulse was transmitted at 1V amplitude that had a broad power spectrum up to 1GHz. The transmitted signal was received by a digital oscilloscope with a sample rate of 40Gsamples/s, which yields 0.025ns/sample.

The received signal was distorted and had a differential tail, which is caused by the RF coupler that filters the DC and low frequency components. The signal attenuates as the transmission distance increases. The fact that time delay increases with distance also proves that the signal is being propagated through the powerline channel and not being received from radiation. A secondary signal exists due to multi-path effects.

The power spectral density (PSD) of the received signal needs to be also examined. Figure 6 shows the received (normalised) signal PSD transmitted from socket 3A and received at 5A at a transmission distance of 10 meters. The PSD of the transmitted signal has similar profile to the measured S21 curve; signal power decreases with frequency in 0 - 600MHz range, and then fluctuates around -40dBm/Hz range, showing the signal has been severely attenuated above 600MHz.

Therefore, experimental results show that a broad spectrum of 500MHz (50 – 550MHz) can be used for UWB communication over the powerline.

4. Conclusions

This work presented novel study of UWB transmission over indoor powerline channel in a very wide spectrum in the range 0 – 1GHz. A broadband RF coupler has been developed for this study. Measurement results and analysis have shown that the powerline provides a promising channel in the 50 – 550 MHz frequency range. Additionally, the time domain results have shown that UWB signals can propagate through the wire in very high frequency range. In summary, experimental results have proven that UWB transmission over powerline is feasible.

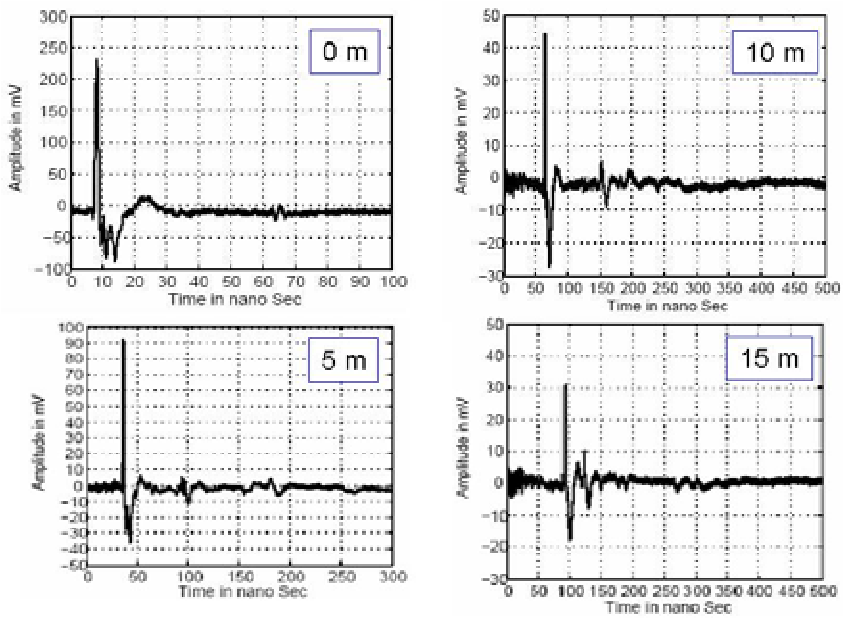


Figure 5: Time Domain results-Amplitude of received signal versus time for cable lengths between 0-15m.

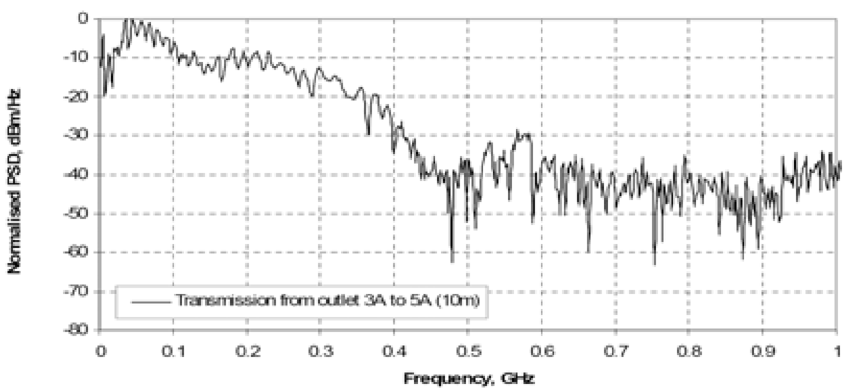


Figure 6: PSD of the received signal transmitted from 3A and received at 5A.

References

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