HIPERLAN/2 AND IEEE 802.11A FOR THE WIRELESS LOCAL LOOP

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ABSTRACT

This paper investigates the application of the ETSI HIPERLAN/2 and IEEE 802.11a physical layer standards to the wireless local loop. Simulation results are presented. A simulation model of the 5.5 GHz wireless local loop channel has been parameterised using the results of real channel measurements. This model is combined with models of the transmitter, receiver and various impairments to allow the performance of the physical layer to be studied. In addition to basic performance results, the effects of cochannel interference, adjacent channel interference and one practical channel estimation technique are considered.

1. INTRODUCTION

In the Wireless Local Loop (WLL) [1, 2], access to core telecommunications networks may be provided using radio as the transmission medium. The rapid expansion in the delivery of broadband services to the business and to the home has heralded a plethora of new access methods attempting to compete with the existing fixed infrastructure [3, 4]. Wireless as an access method started off purely as a narrow band mobile service but rapidly expanded into the areas of long and medium range narrow band WLL, and short range wide band Local Area Network (LAN) connections. Wireless point-to-point links are also extensively used in core networks for applications such as feeder links to mobile base stations.

Currently there are many commercial WLL products but terminal equipment prices are high. While costs may drop with volume production, there is a problem of supply and demand to start the process. One approach is to use a local area technology in order to take advantage of the much greater device volumes from LAN and cordless products. This approach has been taken with Digital European Cordless Telephony (DECT) [5, 6]. Wireless LAN systems are usually intended for indoor operation, whereas WLL operates in an outdoor environment. There are a number of emerging 'next generation' wireless LAN standards and systems [7]. The ETSI HIPERLAN/2 and IEEE 802.11a standards are two examples of these, featuring compatible physical layers. The suitability of the HIPERLAN/2 and IEEE 802.11a physical layer for WLL access applications has not before been investigated.

2. SIMULATION MODEL

Figure 1 shows a diagram of the simulation model used in this work. The circular symbols represent gain blocks, included to preserve unit mean burst power throughout the system. The following subsections discuss the model in more detail.

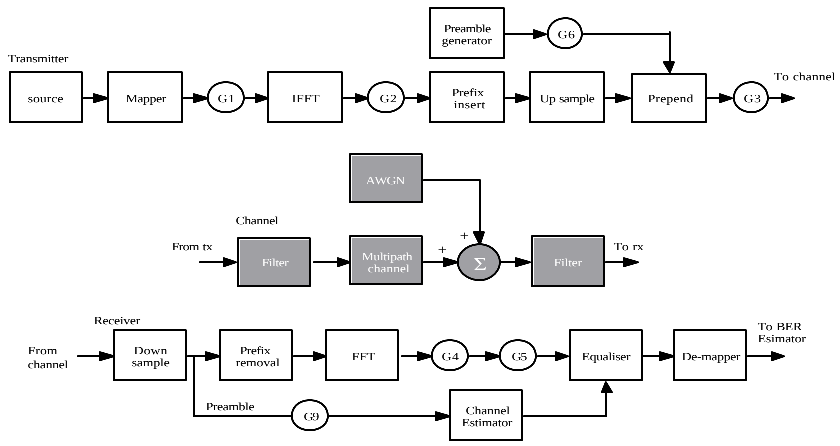

Figure 1: Simulation Block Diagram. Shaded Sections are Simulated in the Low-Pass Equivalent Domain

2.1. TRANSMITTER AND RECEIVER

The simulation models of the transmitter and receiver are direct implementations of the relevant parts of the standards. Square Root Raised Cosine (SRRC) filters are used before and after the channel. Complex baseband representation [8] is used for the RF sections to avoid the need for high simulation sampling rates or multirate sampling techniques. The models assume ideal synchronisation. Equaliser coefficient calculation is by means of idealised (noiseless) channel estimation via the preambles defined in the standards.

2.2. CHANNEL

A tapped delay line channel model was parameterised using results from measurements of real channels. A channel sounder capable of the wideband characterisation of the 5.5 GHz WLL channel in terms of delay spread and absolute path loss has been developed [9]. The channel sounder measures the delay spread magnitude only, without phase information. A large number of measurements have been taken in central Cambridge. Such measurements were necessary since there are no full channel models (as opposed to models of absolutes path loss or data on propagation characteristics such as average delay) in the open literature.

The measured delay spread data is averaged into time bins. The magnitude distribution for each time bin is then classified (by means of curve fitting) in terms of an appropriate Probability Distribution Function (PDF) [10]. Each time bin corresponds to a channel model tap. Hence, each tap has a magnitude PDF representing a generalisation of the real measured data.

In order to create an instance of the channel model, a magnitude value drawn from the PDF for each bin is combined with a phase value drawn from a uniform distribution on {-p, p} to form the complex gain for each tap. Hence, the lack of phase information from the channel sounder is unimportant. These values are used to parameterise a standard tapped delay line model. Due to the uniform random phase of the tap gains, the model assumes uncorrelated scattering. There are 60 uniformly spaced taps and the maximum delay represented by the channel model is 2.5 µs. The channel is assumed stationary during each transmission burst, this being the final part of the commonly used Wide-Sense Stationary Uncorrelated Scattering (WSSUS) assumptions.

3. RESULTS

The results of simulations using the models described ion the last section are presented here, in terms of Bit Error Rate (BER) against the ratio of energy per bit to noise power per unit frequency (E_b/N_o). Firstly, the effect of the four subcarrier modulation schemes defined in the standard is described. The effects of adjacent channel and cochannel interference from other HIPERLAN/2 and IEEE 802.11a systems are then considered. Finally, the effect of one practical channel estimation technique, the least-squares scheme, is considered.

3.1. PERFORMANCE WITH VARIOUS SUBCARRIER MODULATION SCHEMES

Figure 2 shows the results of the simulations for the four subcarrier modulation schemes defined in the standards. These are Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK) and 16 / 64 state Quadrature Amplitude Modulation (16QAM / 64QAM). Figure 3 shows the BPSK and 64QAM results of figure 2 with error bars indicating ±1 standard deviation around the mean value. Such error bars have been omitted from the other graphs for reasons of clarity.

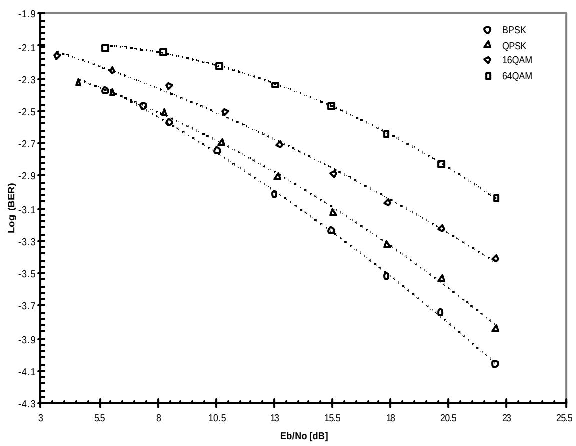

Figure 2: Performance with Various Subcarrier Modulation Schemes

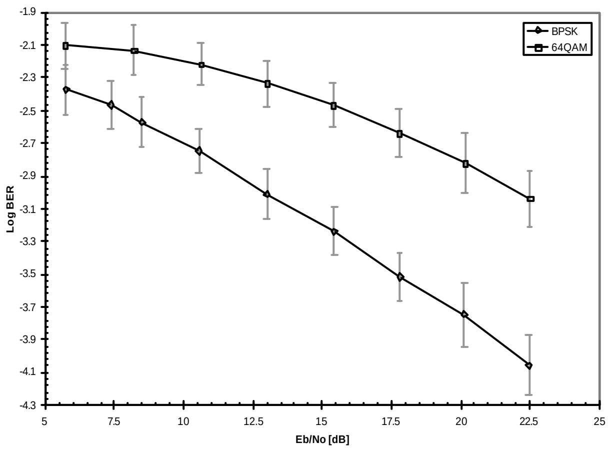

Figure 3: BPSK and 64QAM Results of Figure 2 With Error Bars Showing ±1 Standard Deviation

3.2. EFFECT OF ADJACENT CHANNEL AND COCHANNEL INTERFERENCE

Figure 4 shows the simulation results for BPSK and 16QAM modulations with adjacent channel interference at various power levels. The power leakage into adjacent channels is entirely dependent on the attenuation and roll-off rate of the filters employed in the transmitters. In order to quantify the affect of adjacent channel interference, the simulations were parameterised in terms of the power ratio between the sidelobes of the adjacent channel signal at the band edge and the peak of the spectrum of the system under study.

Figure 5 shows the results of simulations with cochannel interference of various levels. The relative power in this case is measured at +5 MHz Baseband Equivalent Frequency (BEF), as the subcarrier at 0 Hz BEF (DC) is not used for data transmission.

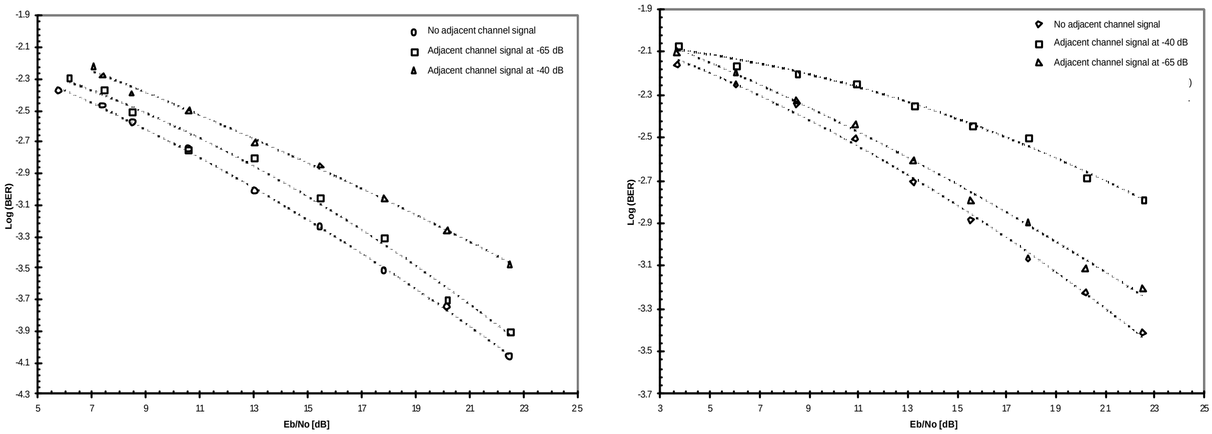

Figure 4: Effect of Adjacent Channel Interference: BPSK (left), 16QAM (right)

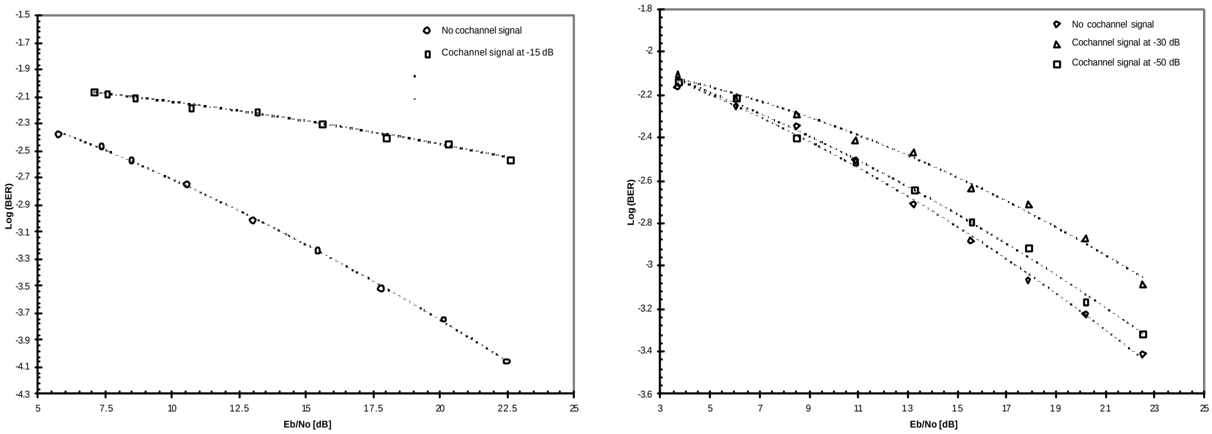

Figure 5: Effect of Cochannel Interference: BPSK (left), 16QAM (right)

3.4. DIRECT TRAINING SYMBOL (PREAMBLE) BASED CHANNEL ESTIMATION

Known training symbols are sent in the preamble section of the transmission burst Two training symbols are commonly averaged to reduce the effect of noise on the channel estimate. The resulting averaged training symbol can then be used in a number of ways to estimate the transfer function of the channel, as outlined in the following sections. The receiver has a permanently stored copy of the training symbols (preamble). Hence, the transmitted training symbols are known at the receiver. Having obtained *H'(n,k)*, an estimate of the channel, the received signal is equalised by [11]:

$$z(n,k) = \frac{x(n,k)}{H'(n,k)} \qquad (1)$$

where *z(n,k)* is the OFDM signal after equalisation, *x(n,k)* is the OFDM signal before equalisation, *n* is the symbol number and *k* is the sub-carrier number.

3.4.1. LEAST SQUARES SCHEME

The least squares scheme directly uses the received training symbol and the stored preamble signal. [11-13]. The two received training symbols $y_1(n,k)$ and $y_2(n,k)$ are divided by the transmitted symbol *x(n,k)* to give the channel estimate *H'(n,k),* where *n* is the symbol number and *k* is the sub-carrier number:

$$H'(n,k) = \frac{y_1(n,k) + y_2(n,k)}{2x(n,k)} \qquad (2)$$

Figure 6 shows the results of simulations with least-squares channel estimation, for BPSK and 16QAM subcarrier modulations.

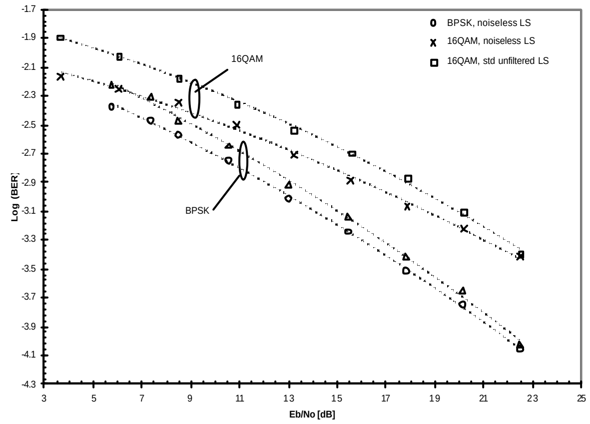

Figure 6: Effect of Least-Squares Channel Estimation with BPSK and 16QAM Subcarrier Modulations

4. CONCLUSIONS

This paper has presented the initial results of research investigating the application of the ETSI HIPERLAN/2 and IEEE 802.11a physical layer standards to the wireless local loop. Simulation results were presented for the system assuming ideal synchronisation and channel estimation. The effects of cochannel interference, adjacent channel interference and least-squares channel estimation were then considered.

Ongoing work aims to investigate the performance of the system with various other real channel estimation techniques, and with nonlinear RF power amplifiers. The effect of the forward error correction codeing and interleaving schemes defined in the standards will also be investigated. Further channel measurements are also being conducted, leading to channel models representing central London and Cambridge Science Park, areas having a greater and lesser density respectively of buildings compared to the central Cambridge area used to parameterise the channel model employed for the simulations described in this paper.

ACKNOWLEDGEMENTS

This work was financially supported by an Engineering and Physical Sciences Research Council (EPSRC) CASE award in association with Cambridge Consultants Ltd (CCL). The contribution of Mr Edward Ball at CCL towards the design and realisation of the channel sounder is also acknowledged.

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