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Realization of Physical Layer Performance of IEEE 802.15.4

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ABSTRACT: Zigbee is a standard which aims at low cost, low data rate and low power consumption. It is used in wireless sensor networks for home/office automation, military and medical applications. It is used to communicate important and critical parameters to the base station. Zigbee nodes are deployed in different types of environment. It is essential to understand its behaviour so that we are able to analyze the effect of various communication channels and parameters such as bits per symbol. In this paper we focus on developing models in MATLAB to simulate and analyze the performance of Zigbee in the physical layer under different conditions and draw conclusions from the results obtained.

KEYWORDS: Additive White Gaussian Noise Channel(AWGN) , Bit Error Rate (BER), Packet Error Rate (PER), Rayleigh Channel, Ricean Channel, Signal to Noise ratio (SNR),Transceiver.

1. INTRODUCTION

In recent years the wireless communication technologies have been adopted in various monitoring and control applications as they provide significant reduction in cost due to elimination of wires and also increase variety of these applications [4]. The IEEE 802.15.4 PHY layer protocol defines operation using modulation schemes such as Binary Phase Shift Keying (BPSK) and orthogonal Quadrature Phase Shift Keying (OQPSK), in the 2450 MHz ISM band to provide a maximum data rate of 250Kbps.

The link reliability is an important metric to analyze a wireless technology [2]. It is measured as the packet success or error rate on the link. Hence we study the packet success / error rate under different channel models such as Additive White Gaussian Noise (AWGN), Rayleigh and Ricean channel. In AWGN channel the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density and a Gaussian distribution of amplitude. It does not account for fading. These effects are taken into account in Rayleigh and Ricean channel. Hence it is useful for gaining insight into the underlying behaviour of a Zigbee system before the other phenomena are considered. Hence we first observe the PER versus SNR performance of Zigbee in AWGN channel.

For terrestrial links the effects of multipath and terrain blocking should be considered. Hence we further observe the PER versus SNR performance of Zigbee in Rayleigh and Ricean channel. For experimenting under the Rayleigh and Ricean channel it is important to consider the background noise of the channel under study, in addition to multipath and terrain blocking effects. Hence for proper terrestrial path modelling, AWGN channel is used along with Rayleigh or Ricean channel. The effect of bits per symbol on the BER versus SNR performance is also experimented which gives us important insights.

Section II discusses the transceiver that was realized in MATLAB to study the above parameters, Section III discusses the Results obtained and Section IV gives the conclusion and future scope.

2. TRANSCEIVER

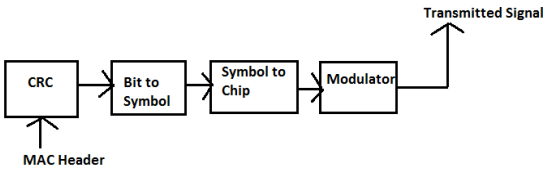

Fig 1: Block diagram of transmitter

The MAC header (MHR) is the MAC layer data which is the input to the PHY layer. Zigbee transmitter comprises of the cyclic redundancy check (used for error detection), bit –to –symbol block (used to map every four bits to symbol) symbol to chip block (each symbol is multiplied by a 32 chip PN sequence-DSSS) and modulator [3].This signal is transmitted through the channel. Fig.1 gives the block diagram of the transmitter.

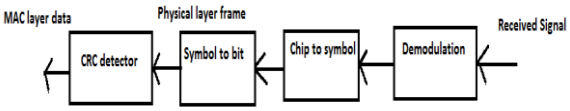

Fig 2: Block diagram of receiver

The signal is received demodulated and multiplied with PN sequence to extract the symbol (de-spreading). All the symbols are converted into bits which gives the complete PHY layer packet.CRC is performed to retrieve the MAC layer data. Now the bit and packet error rate are formed. Fig 2 gives the block diagram of the receiver.

3. RESULTS AND ANALYSIS

3.1. IMPACT OF BITS PER SYMBOL

We observed the performance for 1 bit per symbol, 4 bits per symbol and 8 bits per symbol. Our findings show that the bit error rate decreases as we increase the number of bits per symbol. Figs. 3, 4 and 5 show the response of BER to the SNR in AWGN , Rayleigh and Ricean Channels respectively.

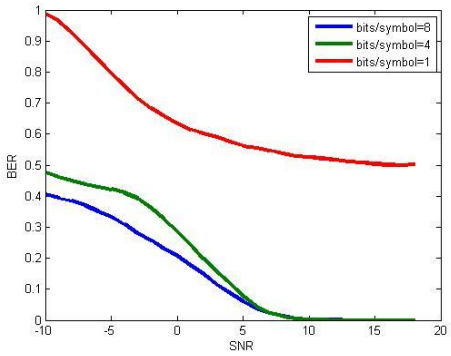

Fig 3: BER versus SNR for 1,4, and 8 bits per symbol for AWGN channel.

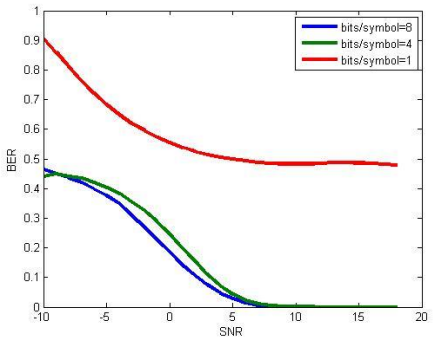

Fig 4: BER versus SNR for 1,4, and 8 bits per symbol for Rayleigh Channel.

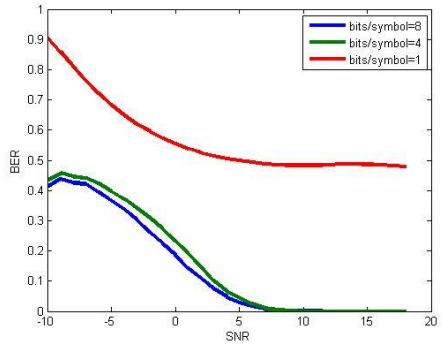

Fig 5: BER versus SNR for 1,4, and 8 bits per symbol for Ricean Channel.

TABLE I
Average decrease in BER for AWGN, Rayleigh and Ricean Channels.

	Maximum decrease in BER between 1 and 4 bits per symbol	Maximum decrease in BER between 4 and 8bits per symbol
AWGN Channel	0.5343	0.1233
Rayleigh Channel	0.4888	0.1087
Ricean Channel	0.4888	0.0942

3.2. AWGN CHANNEL

The packet error rate quickly deteriorates from 0 to 1 as SNR decreases beyond the threshold .We have calculated this threshold to be 7 dB to 0 dB. We hence conclude that the Packet error rate on IEEE 802.15.4 link shows a step like response (from 0 to 1) as SNR deteriorates beyond a threshold.

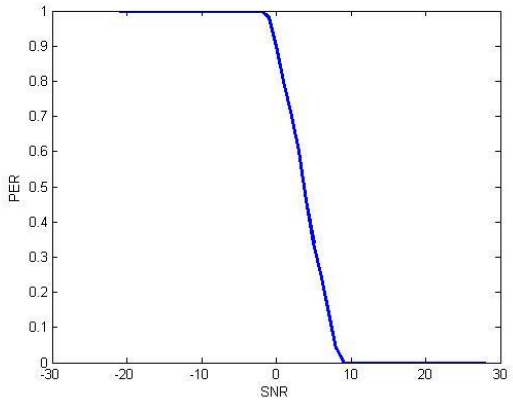

Fig 6. PER response for AWGN channel

3.3. RICEAN CHANNEL

Taking the multipath interference effects into consideration we experiment with the Ricean channel. In this channel there is line of sight path between transmitter and receiver. The threshold SNR is found to be 7 dB to 1 dB beyond which the Packet error rate rises to 1.

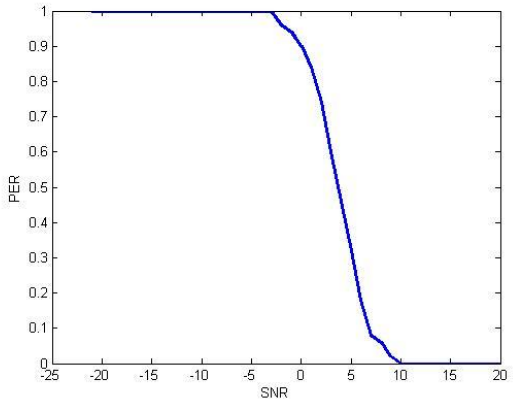

Fig. 7 PER response for Ricean channel

3.4. RAYLEIGH CHANNEL

Rayleigh channel is the special case of Ricean channel with no line of sight path. The packet error rate changes from 0 to 1 as SNR deteriorates beyond a particular threshold which is found to be 9dB to 2 dB. We observe a step like response.

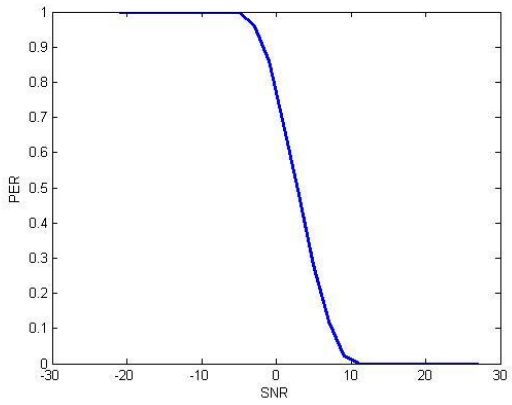

Fig.8 PER response for Rayleigh channel

4. Conclusion

Our conclusion is two fold:

1. The BER decreases as the number of bits per symbol is increased.
2. The PER shows a step like response to SNR deterioration .This response has been observed for all the three channels.

Application:

Wireless technologies which are used in various critical and commercial applications demand high link reliability which can be achieved through improving parameters such BER and PER.

This requires analysis of:

- dependency of technology on various factors.
- performance in different types of environments.

Future Scope:

The Physical Layer of IEEE 802.15.4 that we have implemented in MATLAB can be further converted into a Verilog/VHDL implementation. This will help to optimize the transceiver for minimum hardware realization on an FPGA.

The same platform we have implemented can be used to realize the performance of different wireless technologies like Wi-Fi and Bluetooth.

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