Indian Journal of Science and Technology, *Vol 9(48), DOI: 10.17485/ijst/2016/v9i48/92672, December 2016* *ISSN (Print) : 0974-6846* *ISSN (Online) : 0974-5645*

Performance Analysis of IEEE 802.15.4 RF Zigbee Transceiver in an Indoor and Outdoor Environment

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Abstract

Objective: This paper focuses on the Bit Error Rate (BER) performance of IEEE 802.15.4 RF Zigbee transceiver compliant WSN in an interference environment. This includes 1. Studying of effect of various building materials and partitions in an indoor environment and 2. Effect of interference that coexist in an outdoor environment. **Methods/Statistical Analysis**: In an indoor environment, building materials such as hard board, concrete wall and the partitions of two floors are considered for the analysis. Path loss due to those materials in an indoor environment is calculated by log-distance model. Improved Gaussian Approximation (IGA) technique is used to derive the closed form expression for BER considering less number of interferers in a Rayleigh fading outdoor environment. BER are analysed by varying the IEEE 802.15.4 standard specific physical layer parameters, such as number of bits in a Zigbee symbol, number of modulation levels used in an OQPSK modulator and spreading length of PN sequence. **Findings:** The analysis in an indoor environment points out that, path-loss provided by hard board and concrete wall to the signal is equal. In case of floors, path-loss value get increased as number of floors increases between transmitter and receiver. In outdoor environment, it is analysed that BER performance of Zigbee transceiver shows better performance when lower number of bits in a Zigbee symbol and lower level of modulation scheme in OQPSK modulator. **Application/Improvements:** The performance can be improved by using chaotic sequence for spreading in place of PN sequence and can be implemented for IoT based applications.

Keywords: Bit Error Rate, IEEE 802.15.4, Improved Gaussian Approximation, Rayleigh, Signal to Noise Ratio, Wireless Sensor Network, Zigbee

1. Introduction

Wireless communication has nowadays become the most essential in modern telecommunication. Any wireless network must have proper design and deployed through the better analysis of radio signals. The environment and frequency of transmission are the factors that decide upon the Radio wave propagation. In an indoor environment propagation of signal get attenuated by building material, passage of human (shadowing) and any obstacles present on its propagation path. The requirement of number of transmitters and receivers and the best possible place to locate them are very difficult in a wireless system design. This is greatly influenced in the indoor environment by the nature of the building and the location of walls etc. Small sized sensor nodes operated with limited battery supply that are capable of handling various operations are used in large number to form a WSN. This energy resource must be utilized effectively to satisfy increased lifetime of particular application[1]. Reliable communication is required for the application to satisfy its purpose. It is well known that the wireless medium through which sensor information is transmitted is prone to error because of the interference introduced by the users of same

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frequency, multipath transmission etc. Bit Error Rate (BER) is the measure used to analyze the reliability of the wireless channel. In this work, the BER performance of IEEE 802.15.4 Zigbee transceiver is analysed by calculating path-loss in an Indoor environment and expression for BER of WSN under AWGN and Rayleigh fading channels is derived and analysed.

The research done by other researchers related to this work is deliberated below. Firstly, Path loss measurement of 2.4 GHz propagation models for indoor wireless communications within building is proposed in[2] and provides attenuation factor values for hard board, concrete wall and floors. BER evaluation of IEEE 802.15.4 compliant Wireless Sensor Networks under various fading channels has been derived in[3]. The researcher presented BER analysis of IEEE 802.15.4 Compliant WSN. Expression for BER of an IEEE 802.15.4 transceiver is obtained for WSNs from[3]. In[3] the entire analysis is done by considering large number of interference, hence Gaussian approximation technique is considered.

The coverage analysis of Wi-Fi signals in an indoor environment has been studied in[4]. The authors have compared the Wi–Fi measurements between ITU propagation model and the practical measurements made by considering the effect of building structure and different locations of access points. In[5] the design of wireless communication systems based on the EM wave propagation through construction materials is studied. The delay involved in penetration of EM signal through the construction material is also calculated in[5].

Indoor channel prediction model of WSN has been developed in[6] and discusses about several factors that affects propagation of radio signals. In this research through the linear regression analysis of the measured values the prediction of channel model for a given environment was developed. Basic fundamentals of Wireless Sensor Network and Zigbee understand from[7–11].

In[12] the researcher designed Wireless Sensor Network in space. The performance in Wireless Sensor Network by considering BER, energy level and error control codes is analyzed in[13–15]. The authors[16,17] showed the experimental results and theoretical models related to Rayleigh fading channel. In[18] one of the applications and implementation of Zigbee module in mining industry is discussed. Mathematical relation, integrals, series and products discussed in[19].

The main work involved in this paper is: 1. Analysis of BER performance of an IEEE 802.15.4 RF transceiver under 2.4 GHz frequency band in an indoor environment considering hard board, concrete wall and partition of floors. 2. Deriving and analyzing the BER performance of IEEE 802.15.4 RF transceiver over AWGN and Rayleigh fading channel under less interference environment.

The paper is organized as follows: Analytical results of IEEE 802.15.4 RF Zigbee transceiver in an indoor and outdoor environment is discussed in Section 2. Section 3 describes the numerical results and graphs for the analysis of IEEE 802.15.4 RF Zigbee transceiver in an indoor and outdoor environment. Finally, Section 4 presents the conclusions.

2. IEEE 802.15.4 Zigbee Transceiver in Indoor and Outdoor Environment

The Wireless Sensor Network comprised of IEEE 802.15.4 compliant sensor nodes operated with 2.4 GHz frequency band is considered for study. Zigbee has adopted the standard IEEE 802.15.4 for WSN technology. The three unlicensed frequency band in which physical layer of the IEEE 802.15.4 standard can be operated are 858 MHz, 915 MHz and 2.4 GHz. The IEEE 802.15.4 standard with frequency band 2.4 GHz is an internationally used licence free ISM frequency band is used in this work for analysis purpose.

2.1 IEEE 802.15.4 Zigbee Transceiver

The data rate of Zigbee transceiver with 2.4 GHz is 250 Kbps and Direct Sequence Spread Spectrum using Offset Quadrature Phase Shift Keying (DSSS-OQPSK) is the underlying modulation scheme here. Figure 1 shows the block diagram of an IEEE 802.15.4 Zigbee transceiver system. Firstly, the Zigbee symbol is formed by grouping 4 input bits. One of the 16 orthogonal PN sequences to be transmitted is selected based on the 4 bits symbol. The mapping of symbols to chips is achieved through 32-chip PN sequences shown in Table 1.

Through cyclic shifts PN sequences are correlated with each other and the PN sequences are sent to the OQPSK modulator one after the other. This modulated signal transmitted through the channel and the noise gets added to the transmitted signal. The Euclidean distance is used to make the decision about transmitted and received signal. At the receiver, the transmitted symbols are estimated.

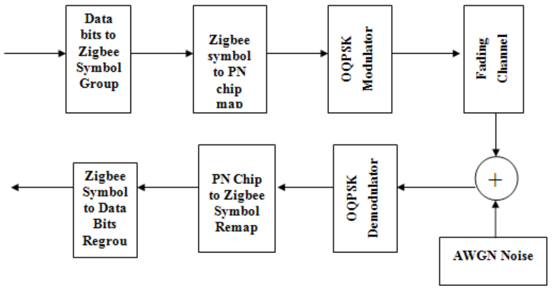

Figure 1. Block diagram of Zigbee IEEE 802.15.4 transceiver.

Table 1. Zigbee symbol to chip mapping.

Zigbee Symbol	Chip Values $(c_0c_1....c_{30}c_{31})$
0000	11011001110000110101001000101110
1000	11101101100111000011010100100010
0100	00101110110110011100000110101010
1100	00100010111011011001110000110101
0010	01010010001011101101100111000011
1010	00110101001000101110110110011100
0110	11000011010100100010111011011001
1110	10011100001101010010001011101101
. . .	. . .
0111	10010110000001110111101110001100
1111	11001001011000000111011110111000

The OQPSK modulation provides a good performance when the channel has components with non-linearity. Two chips has been comprised by each OQPSK signal element at the input of the modulator and hence OQPSK symbol energy can be represented as E = 2EC. In general OQPSK symbol energy can be rewritten as:

$$E = E_c \log_2 M \tag{1}$$

Where M denotes M-ary signalling and in this work we consider M = 4. In OQPSK modulation, the signal energy at the input of the modulator is E and the bit energy at modulator input is

$$E_s = kE_{b.} \tag{2}$$

Also, each Zigbee symbol is represented using L_c = 32 chips. Therefore symbol energy can be represented in Spreading gain as $E_s = E_c L_c$, where $L_c = T_b/T_c$ and here T_b is the bit duration; T_c is the chip duration. Therefore from (2), the bit energy can be represented in terms of chip energy as,

$$E_b = \frac{E_c L_c}{K} \tag{3}$$

2.2 Performance Analysis of IEEE 802.15.4 Zigbee Transceiver in an Indoor Environment

Propagation of signal in indoor environment takes place by the mechanisms like reflection, diffraction and scattering. However, conditions are much more variable. For example, signal levels vary depending on whether interior doors are open or closed inside a building. Propagation model is considered for analysing the performance of IEEE 802.15.4 Zigbee transceiver in an indoor environment. Propagation models available are log-distance model, ITU model and attenuation factor model. Here in our work we consider log-distance model, log-distance model is a radio communication model that predicts the path loss of a signal encounters inside a building and log-distance model is the propagation model that most commonly used in an indoor environment for analysis purpose.

2.2.1 Calculation of Path Loss

Log-distance model is considered in our work for calculating path loss created by the materials like concrete wall, hardboard and floors. Attenuation factor is required to calculate the path loss of signal. This is the reciprocal of transmission factor.

The distance between transmitter antenna and receiver antenna is ‘d’ and wavelength ‘ë’ is speed of light (c) divided by frequency of the signal. As the signal propagates through building, attenuation occurs at two interfaces i.e. free space and walls and other obstruction inside building. Path loss attenuation factor for concrete wall and hard board is calculated by the Equation,

$$PL = PL_{\text{free space}}(d) + AF \tag{4}$$

Where path loss free space is given as:

$$PL_{freespace} = 20\log_{10}(4\pi d/\lambda) \quad (4)$$

The Equation (4) is referred from Rappaport [4.93] on page 161.

In the case of floors, mean path loss exponent 'n' is required for calculating path loss made by the floor.

Number of floors between transmitter and receiver severely influence the path loss, mean path loss exponent 'n' is a variable which get varies with number of floors. In multi-floored environment the path loss is predicted from mean path loss exponent that is function of number of floors between transmitter and receiver.

$$PL = PL(d_0) + 10n_{\text{multi floor}} \log_{10} d/d_0 \quad (5)$$

Where 'd' denotes the distance between transmitter and receiver and 'd_o' represents initial distance between transmitter and receiver. Equation (5) referred from Rappaport (4.95) on page 163.

The losses between floors of a building are determined by the external dimensions and materials of the building as well as the type of construction used to create the floors and the external surroundings. Even number of windows in a building and the presence of tinting can impact the losses between floors. The floor attenuation factor is a function of number of floors and building type. The Equation for calculating path loss by considering FAF is given as:

$$PL = PL(d_0) + 10n_{\text{same floor}} \log_{10}(d/d_0) + FAF \quad (6)$$

Analysis of Bit Error Rate (BER) expression of Zigbee RF Transceiver under an AWGN channel.

The BER of an IEEE 802.15.4 Zigbee RF transceiver as:

$$BER(\gamma) = \frac{1}{2} erfc\left(\sqrt{\gamma \log_2 M}\,\sin(\pi/M)\right) - \frac{1}{8} erfc^2\left(\sqrt{\gamma \log_2 M}\,\sin(\pi/M)\right) \quad (7)$$

Where the received instantaneous SNR is' γ', erfc is complimentary error function and M represented as M-ary signalling. For analysing BER, we fix a range of SNR values by varying transmit power of antenna (P_t). We obtain range of SNR from the Equation:

$$SNR, \tilde{a} = \frac{P_t}{PLFkT_0B} \quad (8)$$

$$PL_{AF}(d) = PL_{freespace}(d) + AF$$

$$PL_{AF}(d) = PL_{freespace}(d) + AF$$

Where F is the noise figure, k is Boltzmann constant (1.023 x 10^{-23}); B is noise band width and T_0 is the room temperature.

The above relation obtained between SNR and transmit antenna gain in Equation (8) is from:

$$Systemgain, As = \frac{P_t}{SNRFkBT_0}$$

We know that system gain is equal to reciprocal of path loss. By that relation we calculated SNR value by varying transmit power respectively. From the Equation (4), (5) and (6) we calculated path loss value for concrete wall, hard board and partition of floors respectively. By these path loss values we obtained range of SNR for plotting graph between BER and SNR and hence analysed the performance of Zigbee in an indoor environment.

2.3 Performance Analysis of IEEE 802.15.4 in an Outdoor Environment

Radio transmission in a wireless communication system often takes over irregular terrain. For estimating path loss terrain profile of a particular area needs to be taken into account. Outdoor environment where less devices operating under frequency band of 2.4 GHz is considered for analyzing the performance of RF Zigbee transceiver. For less number of interference a deep in analysis is applied by Improved Gaussian approximation technique. In this technique 'ψ', variance of the multiple access interference is involved as compared to Gaussian approximation technique.

2.3.1 BER Derivation for IEEE 802.15.4 Zigbee RF Transceiver under an AWGN Channel

IGA technique is for evaluating less interference outdoor environment with perfect power control and in addition to this IGA technique is to treat the power levels of k-1 interfeing users as independent and identically distributed random variables.

Assume less number of users exists in an environment and only one user is the allowed user in that specific band of system. Then, rest k-1 users are interfering users operates under same frequency band, but coexists along with Zigbee in the environment.

Referring to (E.98) on page 643 of Rappaport, the bit error probability of an IEEE 802.15.4 Zigbee transceiver under noise significant condition is given as:

$$\text{Ñ}_e = \frac{2}{3}Q\left(\sqrt{\frac{\text{Ñ}_{\text{Ï}}\,\text{Ô}_b{}^2}{2\left(\text{ì}_{\text{ø}} + \frac{\text{Í}_{\text{Ï}}\,\text{Ô}_b}{4}\right)}}\right) + \frac{1}{6}Q\left(\sqrt{\frac{\text{Ñ}_{\text{Ï}}\,\text{Ô}_b{}^2}{2\left(\text{ì}_{\text{ø}} + \sqrt{3}\text{ó}_{\text{ø}} + \frac{\text{Í}_{\text{Ï}}\,\text{Ô}_b}{4}\right)}}\right) + \frac{1}{6}Q\left(\sqrt{\frac{\text{Ñ}_{\text{Ï}}\,\text{Ô}_b{}^2}{2\left(\text{ì}_{\text{ø}} - \sqrt{3}\text{ó}_{\text{ø}} + \frac{\text{Í}_{\text{Ï}}\,\text{Ô}_b}{4}\right)}}\right) \tag{9}$$

Where the P_0 is the desired power of a user in a system, T_b is the bit period, N_o is the zero mean Gaussian noise and μ_ψ is the mean of the variance of the multiple access interference, ψ and $\sigma_\psi{}^2$ s the variance of ψ. The μ_ψ and σ_ψ are given as follows:

$$\text{ì}_{\text{ø}} = \frac{\text{Í}}{3}\left(\text{Ê} - 1\right) \tag{10}$$

$$\text{ó}_{\text{ø}}{}^2 = \left(\text{Ê} - 1\right)\left[\frac{3\,\text{Í}^2}{360} + \text{Í}\left(\frac{1}{2} + \frac{K-2}{6}\right) - \frac{1}{2} - \frac{\text{Ê}-2}{6}\right] \tag{11}$$

Where N represents ratio of number of chips to number of bits, K represents number of users in a system. Here all the users are under power control and hence all users have identical power levels. μ_ψ represents mean of variance of multiple access interference and $\sigma_\psi{}^2$ is the variance of ψ.

Equation (9), (10) and (11) referred from Rappaport E(98) on page 643.

The expression can be further simplified for analysis purpose as follows:

$$P_e = \frac{2}{3}Q\left[\sqrt{\frac{1}{\frac{2N_{\text{Ï}}}{E_b\text{Ô}_b}\left(\frac{\text{ì}_{\text{ø}}}{\text{Í}_{\text{Ï}}} + \frac{\text{Ô}_b}{4}\right)}}\right] + \frac{1}{6}Q\left[\sqrt{\frac{1}{\frac{2\text{Í}_{\text{Ï}}}{E_b\text{Ô}_b}\left(\frac{\text{ì}_{\text{ø}}}{\text{Í}_{\text{Ï}}} + \frac{\sqrt{3}\text{ó}_{\text{ø}}}{\text{Í}_{\text{Ï}}} + \frac{\text{Ô}_b}{4}\right)}}\right] + \frac{1}{6}Q\left[\sqrt{\frac{1}{\frac{2\text{Í}_{\text{Ï}}}{E_b\text{Ô}_b}\left(\frac{\text{ì}_{\text{ø}}}{\text{Í}_{\text{Ï}}} - \frac{\sqrt{3}\text{ó}_{\text{ø}}}{\text{Í}_{\text{Ï}}} + \frac{\text{Ô}_b}{4}\right)}}\right] \tag{12}$$

Expression can be further simplified by substituting $P_0T_b = E_b$, after substituting this expression in to Equation (12).

$$\frac{E_b}{N_0} = \gamma \log_2 M \sin^2 \frac{\pi}{M}$$

We rewrite expression by this relation. .Now by grouping the constants in the denominator of both the terms in the obtained expression as:

$D = (T_b \log_2 M \sin^2 (\pi/M))/4$,

$D' = \mu_\psi / N_O + T_b/4$ and

$D'' = \sqrt{3}\sigma_\psi / N_O$.

The expression changed to

$$\text{Ñ}_{e\ \text{AWGN}} = \frac{1}{3}\text{erfc}\left(\sqrt{\frac{2D}{D'}}\right) + \frac{1}{2}\text{erfc}\left(\sqrt{\frac{2D}{D'+D''}}\right) + \frac{1}{2}\text{erfc}\left(\sqrt{\frac{2D}{D'-D''}}\right) \tag{13}$$

BER derivation for IEEE 802.15.4 Zigbee RF Transceiver under a Rayleigh Fading Channel.

The average probability of error for Rayleigh fading channel is obtained by integrating over a fading distribution. The BER obtained by averaging the BER of Zigbee n AWGN channel with respect to instantaneous SNR a follows:

$$\text{BER}_{\text{Rayleigh}} = \int_0^\infty P_{e,\ \text{AWGN}}(\gamma) f_{\text{Rayleigh}}(\gamma)\, d\gamma \tag{14}$$

Where Probability density function,.

$$f_{\text{Rayleigh}}(\gamma) = \frac{1}{\gamma_O} e^{\frac{-\gamma}{\gamma_O}}$$

Here γ depends on squared value of 'α', Rayleigh distributed. γ_0 is the mean value of the received SNR defined as $\gamma_o = (E_b/N_o)\ (\alpha^2)$. Where (α^2) is the mean square value of the Rayleigh distributed random variable α. Substituting in Equation (12) and get:

$$\text{BER}_{\text{Zig, Ray}} = \frac{1}{2} - \frac{1}{3}\left(1 - \frac{\frac{\text{ì}_{\text{ø}}}{\text{Í}_{\text{Ï}}} + \frac{\text{Ô}_b}{4}}{\text{ã}_{\text{Ï}}\frac{T_b}{4}\log_2 \text{Ì}\sin^2\left(\frac{\text{ð}}{\text{Ì}}\right)}\right)^{\frac{-1}{2}} - \frac{1}{2}\left(1 - \frac{\frac{\text{ì}_{\text{ø}}}{\text{Í}_{\text{Ï}}} + \frac{\text{Ô}_b}{4} + \frac{\sqrt{3}\text{ó}_{\text{ø}}}{\text{Í}_{\text{Ï}}}}{\text{ã}_{\text{Ï}}\frac{T_b}{4}\log_2 \text{Ì}\sin^2\left(\frac{\text{ð}}{\text{Ì}}\right)}\right)^{\frac{-1}{2}} - \frac{1}{2}\left(1 - \frac{\frac{\text{ì}_{\text{ø}}}{\text{Í}_{\text{Ï}}} + \frac{\text{Ô}_b}{4} - \frac{\sqrt{3}\text{ó}_{\text{ø}}}{\text{Í}_{\text{Ï}}}}{\text{ã}_{\text{Ï}}\frac{T_b}{4}\log_2 \text{Ì}\sin^2\left(\frac{\text{ð}}{\text{Ì}}\right)}\right)^{\frac{-1}{2}}$$

3. Numerical Results and Discussions

IEEE 802.15.4 Zigbee transceiver performance is analyzed by calculating path loss of hard boar, concrete wall, partition of floors and partition of floors with floor attenuation factor in Indoor environment. BER equation for Zigbee in AWGN and Rayleigh fading channel is derived by Improved Gaussian Approximation technique in less interference Outdoor environment. The BER analysis of Zigbee transceiver is performed using MATLAB for both indoor and outdoor environment.

Performance analysis of Zigbee transceiver in Indoor environment.

In indoor environment the attenuation factor of the material referred and the path loss calculated by log-distance model. Using path loss value and by varying transmit power of antenna, we obtained SNR values respectively and plotted graph between BER and SNR for each materials.

Analysis and inferences of Zigbee transceiver performance related to selected materials discussed below.

Analysis of Zigbee performance related to hard board and concrete wall.

Hard board is a building material taken here in account. Hard board means High-Density Fibreboard (HDF), is a type of fibreboard, which is an engineered wood product. It is similar to particle board and medium-density fibreboard, but is denser and much stronger and harder because it is made out of exploded wood fibres that have been highly compressed. The density of hard board is 31 lbs[4]. Concrete wall is an eclectic category; it's similar to brick wall but concrete wall being used in indoor environment.

The attenuation factor of hard board[1] = 2.45 dB and concrete wall[2] = 4.86 dB. By substituting attenuation factor value in to Equation (4), we get path loss for hard board and concrete wall.

P_L (dB) for hard board = 60.04 dB.

P_L (dB) for concrete wall = 60.043 dB.

By varying the transmit power of IEEE802.15.4 transceiver, a range of SNR values is been obtained from Equation (8). This SNR values are used in simulation for analysing BER of Zigbee transceiver.

The graph between Bit Error Rate and Signal Noise Ratio is plotted in MATLAB software using Equation (7). The obtained graph is shown below:

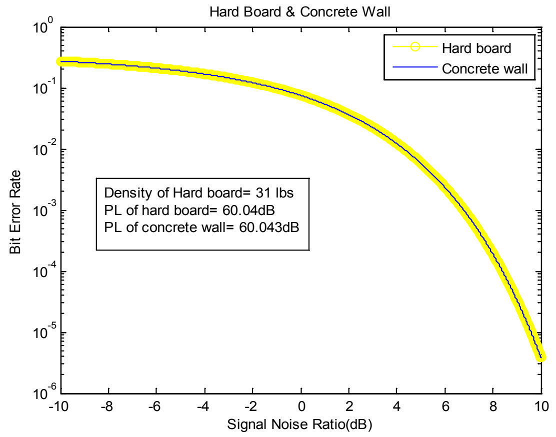

Figure 2. IEEE 802.15.4 performance analysis on hard board and concrete wall.

The graph infers that, as transmit power of antenna increase, SNR of the system increases by that BER of the Zigbee transceiver decreases. Both hard board and concrete wall attenuation factors are 2.45 dB and 4.86 dB respectively but path loss made by these materials are same. Analysis shows that both materials BER are same for different values of SNR. Thus we analyse the performance of Zigbee transceiver in hard board and concrete wall and concluded that both materials affects performance of Zigbee transceiver in Indoor environment equally.

Analysis of Zigbee performance related to two floors above by considering floor attenuation factor

The building dimensions, materials used in the construction of a building, type of construction, number of windows and tinting determines the losses between floors. The FAF through two floors above is 16.9 dB and path loss exponent of same floor is 2.9069 dB. By substituting these values in to Equation (6) gives path loss value of same floor as 93.85 dB.

Thus graph obtained between SNR and BER in case of two floors above with FAF is Figure 4.

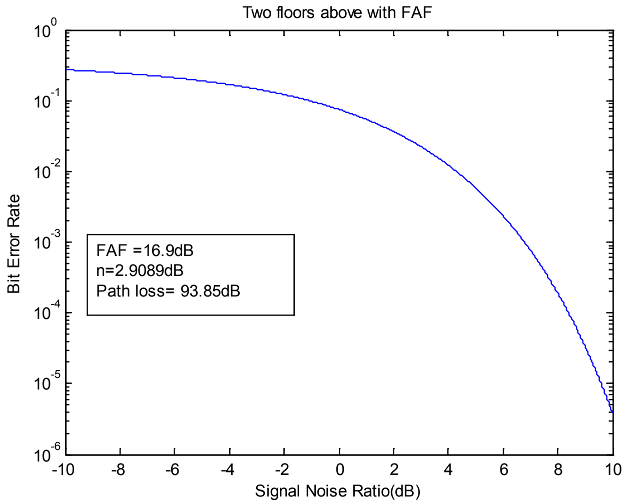

Figure 3. IEEE 802.15.4 performance analysis on two floors above.

The above graph represents the performance analysis of IEEE 802.15.4 on two floors above by considering Floor Attenuation Factor (FAF). The graph infers that by considering Floor Attenuation Factor along with the path loss of same floor then more attenuation occurs due to higher path loss made to the performance of Zigbee transceiver in a building. Hence more transmit power to be given to overcome the BER as compared to the case without considering FAF.

3.1 Performance analysis of Zigbee Transceiver in an Outdoor Environment

The IEEE 802.15.4 RF Zigbee transceiver in AWGN and Rayleigh fading channel are analyzed by varying the number of input bits in a symbol, 'k' and number of modulation level used in OQPSK of Zigbee transceiver, 'M'. The number of interferers present in the environment that operates under same frequency band as IEEE 802.15.4 is chosen as '10'.

Figure 5 shows the variation of the BER as a function of SNR for different values of bits per symbol over an AWGN channel. For analysis purpose number of bits in a Zigbee symbol took as 2, 4, 6 and 8. By plotting graph between BER and SNR it is found that for higher value of k, such as 6 and 8 there is degradation in BER performance. As k value increases the orthogonality between the PN sequence decreases and which makes receiver to take erroneous decisions on the received chip sequence resulting in increased BER.

It is also found that as SNR from -10 dB to 0 dB (noisy environment) as well as SNR values from 0 dB to 10 dB the BER value is decreasing for all value of 'k' in less interference case. But in case of large interference case in noisy SNR range from -10 dB to 0 dB the value of BER for all value of k is high.

Similarly for Rayleigh fading channel also analysis undergone by considering same conditions and mean SNR took as 2. It is found that BER of Rayleigh fading channel is not very high considered to AWGN channel in case of less interference environment. In case of large interference the BER values of Rayleigh fading channel is very high as compared to AWGN channel.

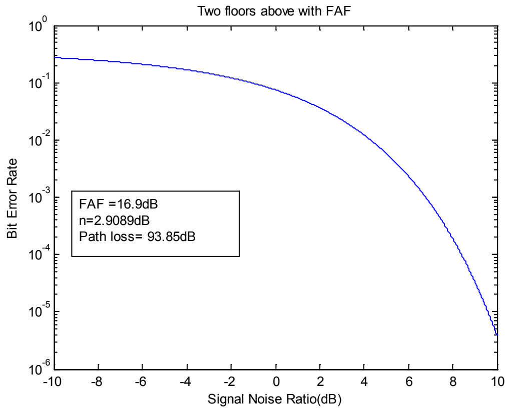

Figure 4. BER of IEEE802.15.4 Zigbee transceiver for various values of bits/symbol in the presence of interferers in AWGN channel environment.

In AWGN channel and Rayleigh fading channel as by increasing number of bits in a Zigbee symbol has no effects on BER improvement. However, the less number of bits in a Zigbee symbol reduce the error rate in less interference environment.

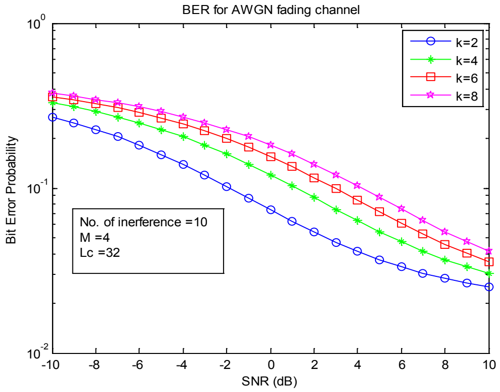

Figure 5. BER for IEEE 802.15.4 Zigbee transceiver over Rayleigh fading channel for different values of bits/symbol in the presence of interferers.

The BER performance is also studied by varying Modulation levels in Zigbee transceiver under AWGN and Rayleigh fading channels. Figures 7 and 8 represent the graph between BER and SNR with different modulation level schemes 4, 8, 16 and 32. It is observed that as modulation level increases of Zigbee transceiver then BER performance degraded. This is due to the fact that as modulation level scheme increases then transmitted signal elements are closely located in their signal space constellations and this create difficulty to decision device to estimate the transmitted signal, and that leads to erroneous decision.

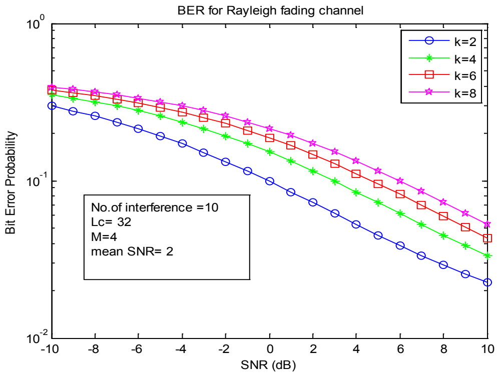

Figure 6. BER for IEEE 802.15.4 Zigbee transceiver over AWGN channel for various M-ary modulation schemes.

In AWGN channel BER curve for modulation scheme for M = 16 and M = 32 almost constant throughout the SNR. In case of Rayleigh fading channel the BER curve varies when modulation scheme is M = 32 and M = 16. But the BER value is high at high value of modulation

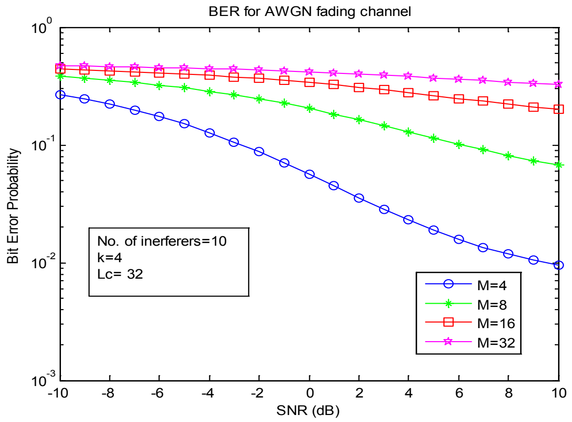

Figure 7. BER for IEEE 802.15.4 Zigbee transceiver over Rayleigh fading channel for various M-ary modulation schemes in presence of less interference

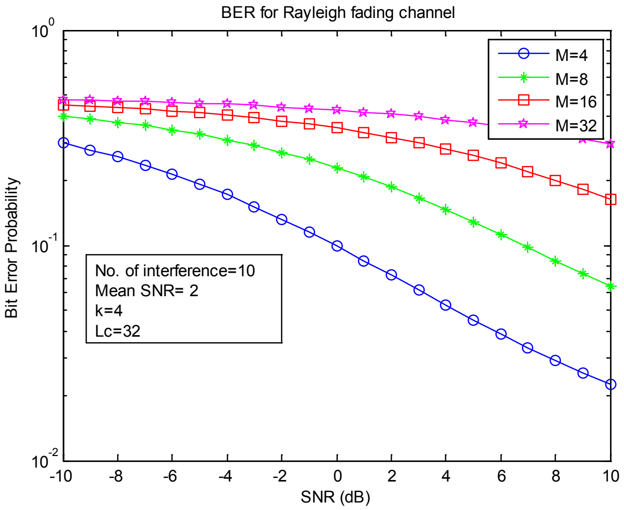

Figure 8. BER for Raleigh fading channel.

Hence by increasing modulation level schemes more than 4 in both AWG and Rayleigh fading channel no improvement in BER performance is able to observe.

4. Conclusion

BER performance of IEEE 802.15.4 RF Zigbee transceiver in an indoor environment is analyzed. In an indoor environment, specifically hard board, concrete wall and partition of floors are considered. Here, after analysis it came to observe that both concrete wall and Hardboard provide equal path-loss value even though attenuation factor differs. In case of floors, error performance analysis of RF Zigbee transceiver has been done by considering FAF.

BER performance of IEEE 802.15.4 RF Zigbee transceiver in an outdoor environment is analysed in presence of less interference. Improved Gaussian approximation technique has been considered for analysing purpose. BER expressions have been derived for Zigbee RF transceiver in AWGN and Rayleigh fading channel. Moreover, BER performance analyzed by varying IEEE 802.15.4 standard specific layer parameters and observed that as lower the number of bits in Zigbee symbol and lower level of modulation scheme in OQPSK modulator increase the error performance of RF Zigbee transceiver.

As the performance of Zigbee are studied in an indoor environment by considering hardboard, concrete wall and floors in this paper, this work can be extended for other building materials.

This paper also deals with the analysis of BER performance of Zigbee transceiver under AWGN and Rayleigh fading channel. Other multipath channel models like Weibull, Lognormal and Chi-square distributions can also be analysed in presence of less interference environment as future work of study.

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