

Performance Evaluation of 802.15.3a UWB Channel Model with Antipodal, Orthogonal and DPSK Modulation Scheme

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Abstract—In this paper for performance evaluation of IEEE 802.15.3a channel model the parameter which was selected is average bit error rate (ABER). We find out the BER performance of UWB system over the 802.15.3a indoor channel model for all channels profile CM1, CM2, CM3 and CM4 with different modulation scheme. In this paper all modulation scheme used in UWB are included in different main categories. The major categories are synchronous and asynchronous. In synchronous we again divided different modulation scheme e.g. BPSK, PPM, PAM etc into antipodal and orthogonal schemes. In the asynchronous category we have studied about DPSK. These all modulation categories are comparing on the common platform and finally we got antipodal modulation scheme category is good for UWB in term of ABER.

Keywords- Log normal fading, Wilkinson's Method, 802.15.3a channel model, Antipodal signalling, and orthogonal signalling.

I. INTRODUCTION

A widely accepted UWB (Ultra Wide Band) indoor communication channel model 802.15.3a developed by channel modeling subcommittee and it is define in [1, 2].

According to [2] the 802.15.3a channel model UWB system exhibits high frequency selective fading and can be modeled as a discrete linear filter whose impulse response is expressed as,

$$h(t) = \sum_{l=0}^{L_{\max}-1} \beta_l \alpha_l \delta(t - \tau_l) \quad (1)$$

The L_{\max} is the maximum number of resolvable multipath components (MPCs) and it is decided by the number of fingers of rake receiver or sampling resolution of receiver.

The α_l is the channel fading coefficient for the l^{th} path and its modeled as lognormal random variable, whose parameter depends on the arrival time τ_l . The τ_l is arrival time of l^{th} path relative to 1st path ($l=0$ & $\tau_0 = 0$ assumed) and $\delta(t)$ is Dirac delta function.

The channel gain α_l is modeled as $\alpha_l = p_l \beta_l$, where $p_l = +1/-1$ with equal probability it models the random pulse inversion that can occur due to reflections it is define in [2]. The second term β_l is a magnitude of l^{th} MPC and it is log normally distributed for indoor channels. The parameters of

lognormal random variable are mean and standard deviation. The standard deviation of fading amplitude is in the range of 3-5dB given in [2] and mean value depends on the parameters of channel profile CM1, CM2, CM3, CM4 such as cluster arrival rate, ray arrival rate, cluster decay factor, ray decay factor etc given by [1, 2].

These channel profile parameters such as distribution of path arrival time sequence τ_l and power delay profile (PDP) of the channel are chosen to follow the modified Saleh-Valenzuela (S-V) model suggested in [3].

Effect of different modulation scheme on 802.15.3a channel model is also studied by so many researchers but in that research some of them not studied all modulation categories just like [4]. In this paper the modeled UWB channel model very well but they only study about hybrid combination of pulse amplitude and pulse position modulation not about the other better options. In [5] they studied about antipodal and orthogonal signaling but there analytical method is not accurate because they not modeled UWB channel accurately. So there frame work cannot be achieved desire accuracy. In this paper we proposed a analytical method that cover all modulation scheme which is used in UWB and we also modeled UWB channel model accurately with the help of Wilkinson's method.

II. PROBLEM FORMATION

As in [6] they present the instantaneous signal to noise ratio (SNR) model by considering one of the channel impairments i.e. intra pulse interference (IPI) according to [6] for a realistic UWB system having a finite temporal resolution T_p i.e. often limited by the receiver sampling frequency or the width of UWB pulse. The instantaneous signal to noise ratio (SNR) per bit can be written as

$$\begin{aligned} \gamma_i &= \frac{E_s}{N_0} \sum_{l=0}^{\lfloor \frac{T_i}{T_p} \rfloor - 1} \gamma_l^2 \\ &= \frac{E_s}{N_0} \sum_{l=0}^{\lfloor \frac{T_i}{T_p} \rfloor - 1} [\sum_{i \in I_l} (\beta_i \alpha_i)]^2 \end{aligned} \quad (2)$$

In this model second summation is taken for accounting the intra pulse interference i.e. occurs between MPCs. where

I_l is set given by: $I_l = \{ i \mid lT_p \leq \tau_i < (l + 1)T_p \}$ denotes the collection of multipath components (MPCs) arriving in the interval $[lT_p, (l + 1)T_p]$, i.e. the number of MPCs in a single finite temporal resolution but right now in this paper the impairments that we want to model is shadowing not the intra pulse interference so width of pulse is adjusted such that $T_p \ll 1$. In this case $\gamma_l \rightarrow \beta_l \alpha_l$ and equation (2) from the [6] can be written as

$$\gamma_i = \frac{E_s}{N_0} \sum_{l=0}^{L_{\max}-1} \alpha_l^2 \quad (3)$$

III. PERFORMANCE ANALYSIS

The major parameters that researchers generally use to figure out the performance of UWB channel are outage probability and average bit error rate (ABER). In this paper we are using the ABER.

The process of finding the ABER given in [7], the average bit error rate can be calculated by averaging the conditional BER which is $P(\gamma_i)$ over the probability density function (PDF) of instantaneous SNR i.e. $f(\gamma_i)$ as

$$P_e = \int_0^\infty P(\gamma_i) f(\gamma_i) d\gamma_i \quad (4)$$

The conditional BER for fixed set of β_l for different modulation scheme are given in table 1.

A number of modulation schemes may be used with UWB systems. The potential modulation schemes include both orthogonal and antipodal schemes

A. Antipodal Sceme (BPSK, PAM)

The antipodal signal scheme in which multiplication of two transmitted symbol is -1. The classic binary pulse amplitude modulation (PAM) can be presented using e.g. two antipodal Gaussian pulses as shown in Figure 1 from [8].

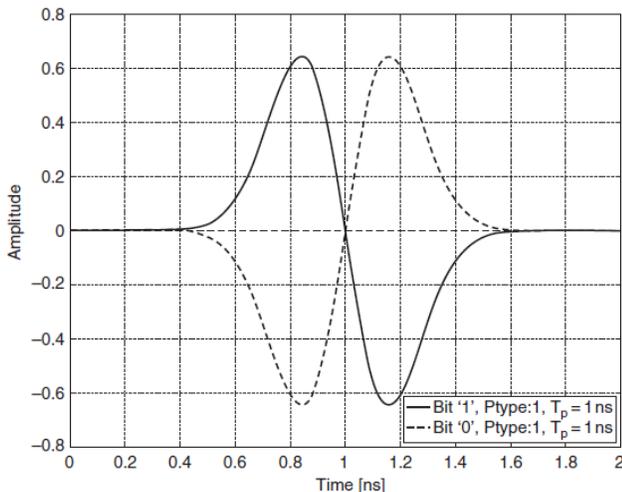


Figure 1. BPAM pulse shapes for '1' and '0' bits

The transmitted binary baseband pulse amplitude modulated information signal (t) can be presented as

$$X(t) = d_j * P(t)$$

Where $P(t)$ represents the UBW pulse waveform, j represents the bit transmitted ('0' or '1') and

$$d_j = \begin{cases} -1, & j = 0 \\ 1, & j = 1 \end{cases}$$

B. Orthogonal Scheme (OOK, PPM)

The orthogonal signaling scheme in which multiplication of two transmitted symbol is 0. The example of orthogonal modulation scheme is binary on-off keying (OOK). Using the above definitions of orthogonal modulation scheme with a single Gaussian pulse shown in figure 2, from [8].

$$IV. \quad d_j = \begin{cases} 0, & j = 0 \\ 1, & j = 1 \end{cases}$$

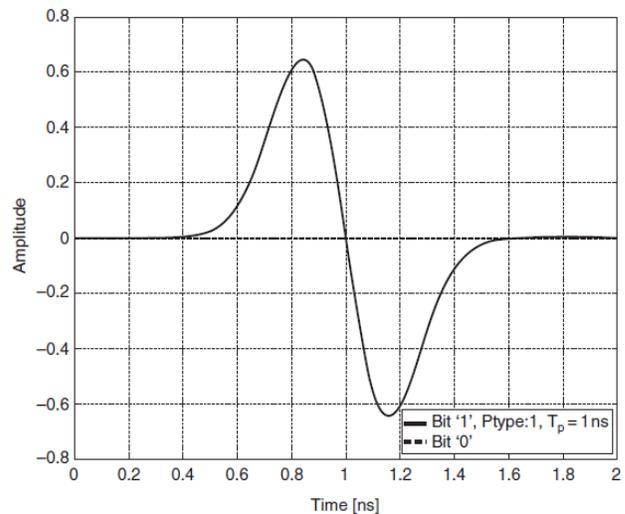
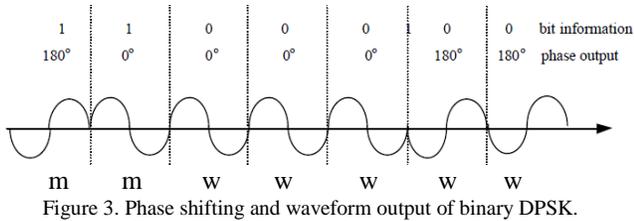


Figure 2. OOK pulse shapes for '1' and '0' bits

C. Asynchronous Modulation Scheme (DPSK)

To solve the problem of synchronous receiver we can use differential detection technique. For binary phase shift keying this technique is called differential phase shift keying (DPSK). This problem can be solves by using encoding technique.

In figure 3 taken from [9], high state is represented by an M in modulated signal and low state is represented by W in modulated signal DPSK encodes two distinct signals of same frequency with 180 degree phase difference between the two.



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IV. AWGN EFFECT ON ALL MODULATION SCHEME PERFORMANCE AND PDF CALCULATION

The conditional BER for all modulation schemes are given in table 1, by [8]. In each case conditional BER is a function of SNR.

TABLE I. BINARY DATA MAPPING FORMATS AND BER PERFORMANCE

Modulation Scheme Performance	
<i>Modulation Scheme</i>	$P(\gamma_i) = \text{Conditional BER}$
BPSK (Antipodal)	$Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q(\sqrt{2SNR})$
PPM (Orthogonal)	$Q\left(\sqrt{\frac{E_b}{N_0}}\right) = Q(\sqrt{SNR})$
OOK (Orthogonal)	$Q\left(\sqrt{\frac{E_b}{N_0}}\right) = Q(\sqrt{SNR})$
DPSK (Asynchronous)	$\frac{1}{2} \exp\left(-\frac{E_b}{N_0}\right) = \frac{1}{2} \exp(-SNR)$

For calculating the ABER we require the PDF of instantaneous SNR $f(\gamma_i)$. There are many methods for calculating the PDF of instantaneous SNR. A major section of research in the field of UWB has been done for finding the accurate PDF of their instantaneous SNR model. In [6] they have suggested three methods for approximating the PDF of instantaneous SNR model according to severances of fading. The distributions used in [6] to approximate the PDF of γ_i are coxian, Lognormal, Gamma and parameters of these approximation are find out using least square error criteria by minimizing the mean square error. Our process for finding the PDF of instantaneous SNR is little bit different and it is best according to our model. In this paper we have computed the PDF of term $\left(\frac{E_s}{N_0}\right) \sum_{l=0}^{L_{\max}-1} \alpha_l^2$. This term is simply the square of sum of lognormal random variables and estimation of distributions can be given by [9]. They have suggested three methods for the estimation of distribution. The method which we are using in this paper is Wilkinson's method.

Let assume that

$$\gamma_i = \left(\frac{E_s}{N_0}\right) \sum_{l=0}^{L_{\max}-1} \alpha_l^2 = \sum_{l=0}^{L_{\max}-1} g_l$$

Where $g_l = \left(\frac{E_s}{N_0}\right) \beta_l^2$ and $\alpha_l = p_l \beta_l$. According to UWB channel committee report β_l is a lognormal random variable so $g_l = \left(\frac{E_s}{N_0}\right) \beta_l^2$ is also lognormal RV. Thus γ_1 is a sum of L independent lognormal RVs.

Let a lognormal RV $\beta_l = e^{m_l}$ where m_l is a normal RV, i.e. $m_l \sim N(\mu_{m_l}, \sigma_{m_l}^2)$.

Then $g_l = e^{a_0 + 2m_l}$, where $a_0 = \ln\left(\frac{E_s}{N_0}\right)$.

The Jth moment of β_l is given as

$$E\{\beta_l^j\} = e^{\frac{j\mu_{m_l} + j^2\sigma_{m_l}^2}{2}}$$

The PDF of sum of lognormal R.V. suggested by [9]. This procedure is based on the assumption that a sum of independent lognormal RV's is again a lognormal RV.

Let $\gamma_i = e^z$, where $z \sim N(\mu_z, \sigma_z^2)$, is a normal RV. In Wilkinson's method, the two parameter μ_z and σ_z are obtained by matching the first two moments of γ_1 with the first two moments of $\sum_{l=0}^{L_{\max}-1} g_l$. These two parameters given as

$$\mu_z = \ln\left(\frac{W_{L1}^2}{W_{L2}}\right), \sigma_z = \ln\left(\frac{W_{L2}}{W_{L1}^2}\right)$$

Where W_{L1} and W_{L2} are related to μ_{y_1} and $\sigma_{y_1}^2$ as

$$W_{L1} = \sum_{l=0}^{L-1} e^{(c_0 + 2\mu_{m_l} + 2\sigma_{m_l}^2)} \quad (5)$$

$$W_{L2} = \sum_{l=0}^{L-1} e^{2(c_0 + 2\mu_{m_l} + 4\sigma_{m_l}^2)} + 2 \sum e^{2(c_0 + 2\mu_{y_m} + \mu_{y_n} + \sigma_{y_m}^2 + \sigma_{y_n}^2)} \quad (6)$$

Where the 2nd sum in (6) is extended to all combinations of (m, n), $m < n = 0 \dots L-1$.

The approximated PDF of γ_i is given as

$$f(\gamma_i) = \frac{1}{\gamma_i \sqrt{2\pi\sigma_z^2}} \exp\left[-\frac{(\ln(\gamma_i) - \mu_z)^2}{2\sigma_z^2}\right] \quad (7)$$

V. NUMERICAL RESULTS: FRAMEWORK VALIDATION

In these result we compare three different category of modulation schemes i.e. antipodal, orthogonal and one of asynchronous category i.e. DPSK on same platform. To obtain these results the number of fingers taken for rake receiver is ten and range of SNR $\left(\frac{E_s}{N_0}\right)$ is 1 to 10dB.

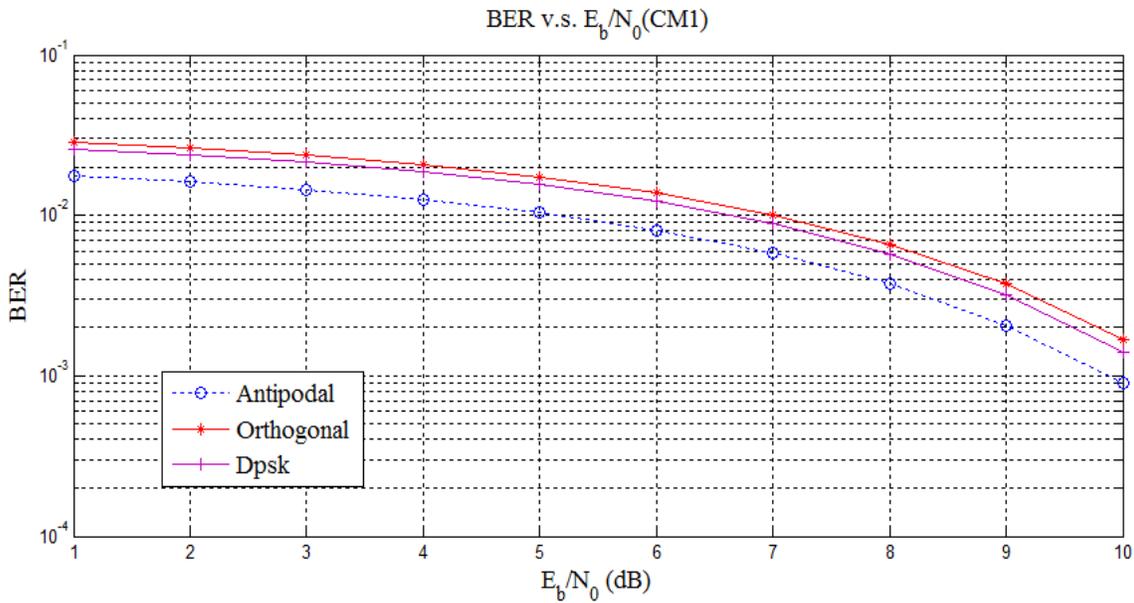


Figure 4. BER Performance of the IEEE 802.15.3a UWB channel for CM1 with different modulation scheme.

The above result is obtained for channel model 1. This channel model is of a line of sight (LOS) case with the transmitter and the receiver antenna being separated by a distance in the range (0-4 m). The parameters used for these result are given in [3].

From the figure 4 it is clear that the average bit error rate (ABER) for all modulation schemes in case of CM1 is near about 10^{-3} at SNR value of 10dB.

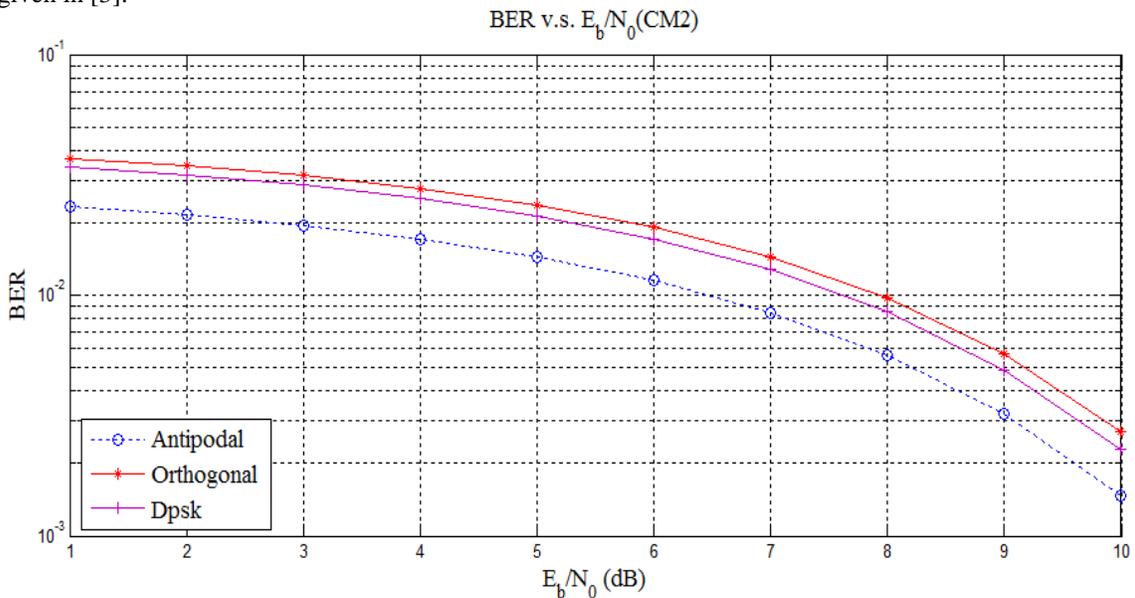


Figure 5. BER Performance of the IEEE 802.15.3a UWB channel for CM2 with different modulation scheme.

The above result is obtained for channel model 2. This channel is a model for a non line of sight (NLOS) case with antenna separation being in the range (0-4 m). The parameters used for these result are given in [3].

From the figure 5 it is clear that the average bit error rate (ABER) for all modulation schemes in case of CM2 is above of 10^{-3} at SNR value of 10dB.

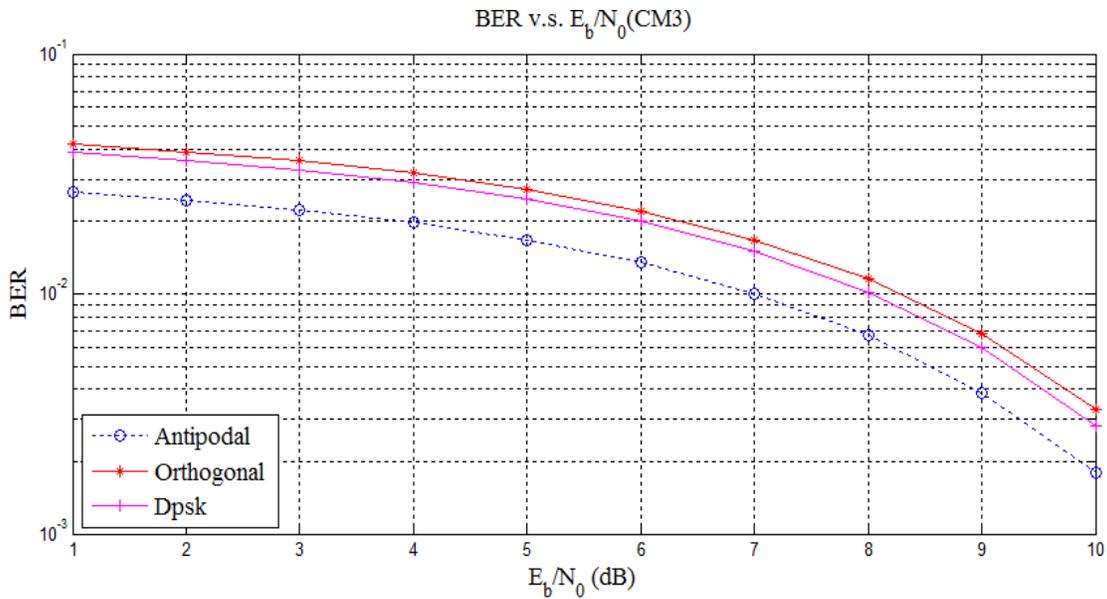


Figure 6. BER Performance of the IEEE 802.15.3a UWB channel for CM3 with different modulation scheme.

The above result is obtained for channel model3. This channel is a model for a non line of sight (NLOS) case with antenna separation being in the range (4-10 m).The parameters used for these result are given in [3].

From the figure 6 it is clear that the average bit error rate (ABER) for all modulation schemes in case of CM3 is in the mid of 10^{-2} and 10^{-3} at SNR value of 10dB.

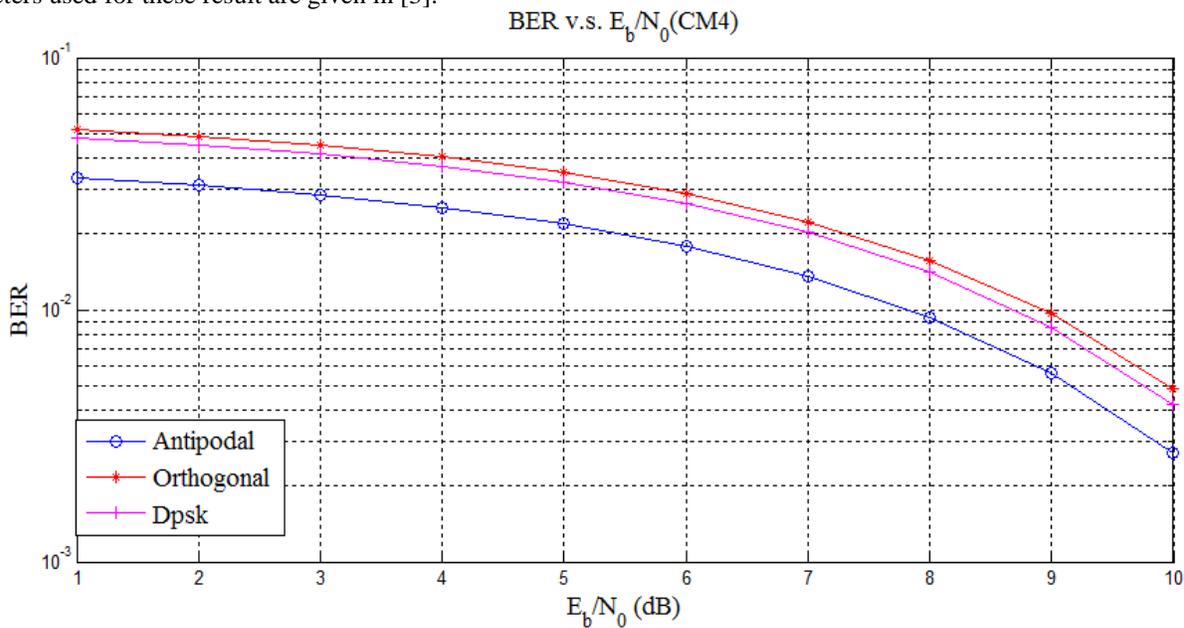


Figure 7. BER Performance of the IEEE 802.15.3a UWB channel for CM4 with different modulation scheme.

The above result is obtained for channel model 4. This channel is a model for a extreme NLOS multipath channel to fit a 25 ns RMS delay spread. The parameters used for

these result are given in [3]. From the figure 7 it is clear that the average bit error rate (ABER) for all modulation schemes in case of CM4 is

closer to 10^{-2} at SNR value of 10dB.

In all channel models minimum ABER is obtained for antipodal modulation scheme and maximum ABER is obtained for DPSK modulation scheme.

In the below results we compare all channel profile on same platform with best modulation scheme which comes from previous result i.e. antipodal category (BPSK).

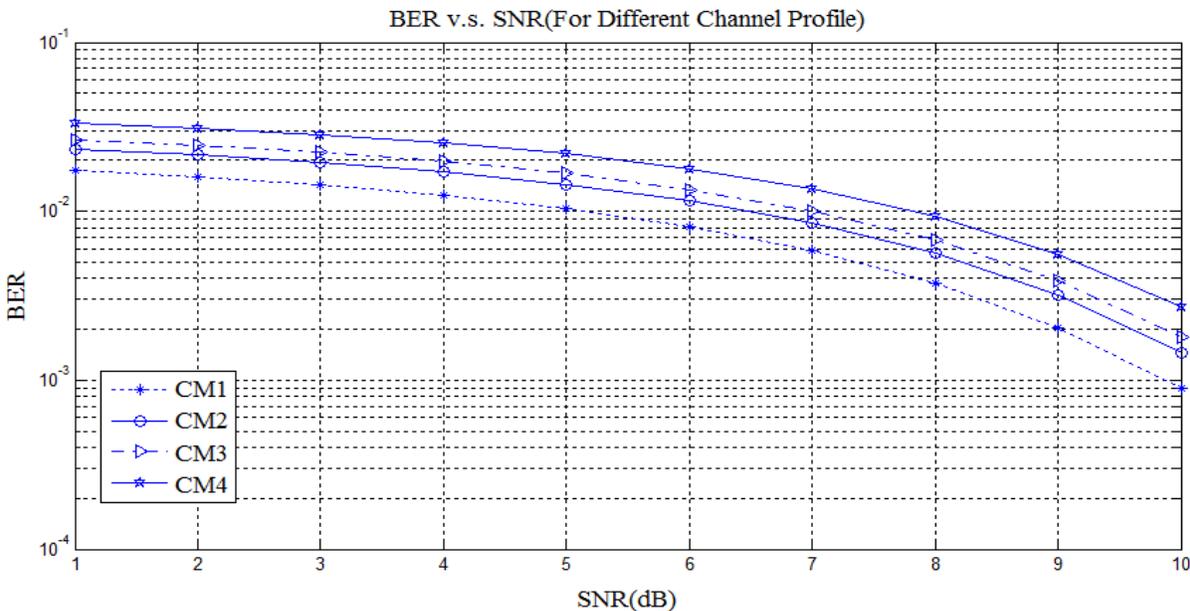


Figure 8. BER Performance of the IEEE 802.15.3a UWB channel CM1, CM2, CM3, CM4 with best modulation (BPSK) Scheme.

VI. CONCLUSION

Performance results showed that the best modulation schemes in terms of ABER belongs to antipodal category. The antipodal modulation scheme is generally belongs to synchronous modulation scheme category and there is a disadvantage with synchronous modulation scheme. The receiver must use a carrier recovery to make synchronization with the transmitter. To solve this problem we can use differential detection technique. For binary phase shift keying this technique is called differential phase shift keying (DPSK). With the use of DPSK we can solve the problem of synchronous detection but this is achieved at the cost of increasing ABER. So at the last all modulation schemes are application dependent. But the major applications in the field of UWB are related to higher data transmission rate near about 300 to 500Mbps up to distance of 10ft. In such a higher data rate increment in the BER will not be better choice. So best modulation scheme in favor of UWB belongs to antipodal (BPSK) category.

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