The Bit Error Rate analysis of Direct Sequence Ultra Wide Band System in Mine Channel

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Abstract

The necessity for wireless communications in underground mines is well understood. Some companies have started to deploy modern wireless networks in mine galleries with the objective of increasing safety and productivity. This paper presents the Bit Error Rate (BER) analysis of Direct Sequence Pulse Amplitude Modulation (PAM) Ultra Wide Band (UWB) system for underground mine environment. Discrete time channel impulse response is used to build up revised channel model for underground mine which is based on the UWB channel model proposed by IEEE802.15.3a.With the revised channel model, we compare the performance of IEEE channel and mine channel by considering Mean Excess Delay, Root Mean Square (RMS) delay and Number of significant Paths with in 10 dB of peak (NP_{10dB}) and observe the significant increase in the parameter. We evaluated the BER performance using RAKE receiver employing maximal ratio combining (MRC) for different data rate, repeat bit and number of RAKE figure in underground mine channel. Simulation results shows that DS-PAM-UWB system can sustain in the dense multipath environment of underground mine and provide acceptable BER.

Keywords: *Ultra Wide Band (UWB),DS-PAM UWB, UWB channel Model, Underground mine channel. RAKE receiver*

1. Introduction

Short-range wireless connectivity has become an essential part of everyday life thanks to the enormous growth in the deployment of wireless local area networks (WLAN) and wireless personal area networks (WPAN). However, toda do not meet the requirements of upcoming wireless services that demand high-data rates to operate. This issue has motivated the resurgence of ultra-wideband (UWB) technology, certainly the oldest form of radio communication ever created, whose origins date back to the late 19th century. Ultra-wideband technology is based on the emission of extremely-short pulses with a spectral occupancy on the order of several GHz. This is in contrast with traditional narrowband and wideband communication systems, whose transmitted bandwidth is on the order of some kHz and some MHz, respectively. As a result of this huge spectral occupancy, UWB technology can provide unique and attractive features. For instance, this accounts for ultra-high-speed data rates, ultra-fine time resolution for precise positioning and ranging, multipath immunity and low probability of interception due to the low power spectral density. Because of this great potential, UWB technology is being considered for the physical layer of next generation short-range wireless communications, radar, ad-hoc networking, sounding and positioning systems. The complex natural environment and operating conditions in coal mine restrict the development of mine wireless communication seriously. Ultra-Wide band (UWB) Wireless Communication with a high transfer rate, low power consumption, anti-interference is conducive to resolve the issue of radio communication under the complex environment in underground mines. The remainder of the paper is organized as follows. In the next section we present UWB transmission scheme for mine channel. Section 3 deals with IEEE UWB Channel Modeling, section 4 deals with Underground Mine UWB channel modeling and performance comparison of channels. In the section 5 paper deals with UWB Signal Receiver Structure. The paper ends with simulation results and conclusion.

2. UWB Transmission Scheme for Mine Channel

To evaluate the BER performance in IEEE channel and in underground mine channel we are using the DS-PAM-UWB system model. In DS-UWB combine with binary PAM, the UWB signal can be schematized to be generated as shown in figure (1).

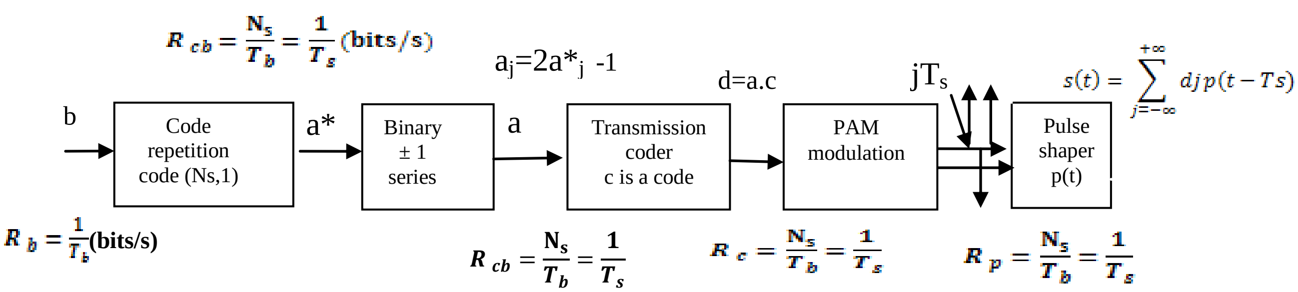

Figure 1. Transmission scheme of DS-PAM-UWB system

Given binary sequence to be transmitted *b=(é ,b_0,b_1, é ,b_K,b_{K+1}, é)*, generated at the rate of $R_b=1/T_b$ bits/s, a first system repeats each bit N_s times and generates a binary sequence *(é .,b_0,b_0, é ,b_0,b_1,b_1, é ,b_1, é ,b_K, b_K, é ,b_K,b_{K+1}, b_{K+1}, é ,b_{K+1}, é) = a** at a rate of $R_{cb}=N_s/T_b=1/T_s$ bits/s. A second system Transforms the a* sequence into a positive and negative valued sequence *a=(é ,a_0,a_1,..,a_j,a_{j+1}, é)*.The transmission coder applies a binary code *c=(é ,c_0,c_1, é ,c_j,c_{j+1}, é)* composed of ±1 N_p to the sequence *a=(é ,a_0,a_1,..,a_j,a_{j+1}, é)* ,and generates a new sequence *d=a.c* composed of element $d_j=a_jc_j$. N_p is commonly assumed to be equal to N_s.A more general assumption to set N_p as a multiple of N_s. Note that *d* is a ±1 's se is generated at a rate $R_c=N_s/T_b=1/T_s$ bits/s. Sequence *d* enters a third system,the PAM modulator, which generates a sequence of unit pulses at a rate of $R_p=N_s/T_b=1/T_s$ pulses/s. These pulses are located at times jT_s. The output of the modulator enters the pulse shaper filter with impulse response p(t),where *s(t)* representing the transmitted signal. $s(t) = \sum_{j=-\infty}^{\infty} d_j\, p(t - T_s)$

3. IEEE UWB Channel Modeling

In July 2003, the Channel-Modeling sub-commettee of study group IEEE 802.15.SGa published the final report regarding the UWB indoor multi-path channel model (IEEE 802.15.SG3a, 2003). IEEE channel-Modeling sub-commettee finally converged to a model, based on the cluster approch proposed by Saleh and Valenzuela in 1987 [2].The S-V model is based on the observation that usually multipath contributions generated by the same pulse arrive at the receiver grouped into cluster. The time of arrival of cluster is modeled as a poission arival process with rate Λ .

$$p(T_n|T_{n-1}) = \Lambda e^{-\Lambda(T_n - T_{n\ 1})} \tag{1}$$

where T_n and T_{n-1} are the time of arrival of the *n-th* and *(n-1)-th* cluster respectively. Within each cluster, subsequent multipath contributions a

$$p(\tau_n|\tau_{(n-1)k}) = \lambda e^{-\lambda(\tau_n - \tau_{n\ 1})} \tag{2}$$

The channel impulse response of the IEEE model can be express as

$$h(t) = X \sum_{n=1}^{N} \sum_{k=1}^{K(n)} \alpha_{nk}\, \delta(t - T_n - \tau_{nk}) \tag{3}$$

where X is a lognormal distributed random variable representing the magnitude of channel gain.

$$X = 10^{\frac{g}{20}} \tag{4}$$

where g is Gaussian random variable with mean g_0 and variance ů$_g^2$, N is the observed number of clusters, $K(n)$ is the received number of multipath in the n^{th} cluster, Ǔ$_{nk}$ is coefficients of the k^{th} path in the n^{th} cluster. T_n is the arrival time of the n^{th} cluster, Ű$_{nk}$ is the k^{th} path delay in the n^{th} cluster. The channel coefficient Ǔ$_{nk}$ can be define as follows:

$$\alpha_{nk} = p_{nk}\beta_{nk} \tag{5}$$

where p_{nk} is a discrete random variable assuming ±1 with equal probability and ɓ$_{nk}$ is the log-normal distributed channel coefficient of multipath contribution, k belonging to cluster n. the ɓ$_{nk}$ term can thus be express as follows:

$$\beta_{nk} = 10^{\frac{x_{nk}}{20}} \tag{6}$$

where x_{nk} is assume to be Gaussian random variable with mean ε_{nk} and standard deviation ů$_{nk}$. Variable x_{nk} in particular, can be further decomposed as follows:

$$x_{nk} = \mu_{nk} + \xi_{nk} + \zeta_{nk} \tag{7}$$

where ɜ$_{nk}$ and ɛ$_{nk}$ are two Gaussian random variable the represents the fluctuation of the channel coefficient on each cluster and so on each contribution, respectively. We indicate the variance of ɜ$_{nk}$ and ɛ$_{nk}$ by $_\xi^2$ and $_\zeta^2$ .The ε_{nk} value is determined to reproduce the exponential power decay for the amplitude of the cluster and for the amplitude of multi-path contribution within each cluster. One can thus write.

$$\left\langle \left|\beta_{nk}\right|^2 \right\rangle = \left\langle \left| 10^{\frac{\mu_{nk}+\xi_n+\zeta_{nk}}{20}} \right|^2 \right\rangle \stackrel{\wedge}{=} \left\langle \left|\beta_{00}\right|^2 \right\rangle e^{\frac{T_n}{\Gamma}} e^{-\frac{\tau_k}{\gamma}} \Rightarrow \mu_{nk} = \frac{10\log_e\left(\left\langle \left|\beta_{nk}\right|^2 \right\rangle\right) - 10\frac{T_n}{\Gamma} - 10\frac{\tau_{nk}}{\gamma}}{\log_e 10} - \frac{\left(\alpha_\xi^{\ 2} + \alpha_\zeta^{\ 2}\right)\log_e 10}{20} \tag{8}$$

where β00 represents the average energy of t
the power decay coefficient for clusters and multipath respectively. According to (8) the average PDP (Power Delay Profile) is characterized by exponential decay of the amplitude of the cluster, and a different exponential decay for the amplitude of the received pulse within each cluster is shown in the Figure. 2.

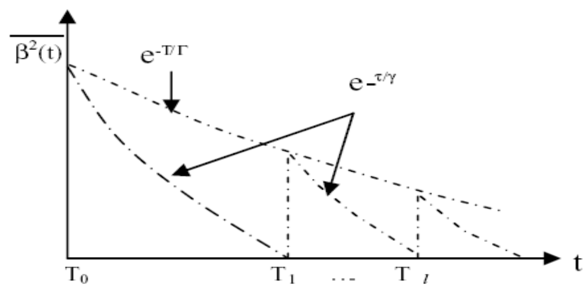

Figure 2.Schematic representation of UWB channel Model

According to the above definitions the channel model represented by the impulse response of (3) is fully characterized when the following parameter are defined [2]:

- The cluster average arrival rate Λ.
- The pulse average arrival rate λ.
- power delay factor Γ for cluster.
- The power delay factor γ for pulse within a
- The standar ξ of the fluctuation of the channel coefficient for the clusters.
- The standar ζ of the fluctuation of the channel coefficient for pulse within each cluster.
- The standard de g of the channel amplitude gain.

The IEEE suggested an initial set of values for the above parameters. These values where tuned to fit some of the measurement data submitted to IEEE. The value of parameters for LOS scenario is given in Table 1.

4. Underground Mine UWB Channel Modeling

A significant number of theoretical analyses and experiments have been conducted on radio channel characteristics in underground Mines. Wang Yanfen [5] proposed a LOS UWB semi-deterministic model with double cluster statistical model, which is depend on the testing environments of references A.Chehri et.al [4] ,[3] and IEEE 802.15.3a indoor multipath model [6], some of the parameters are determined by the propagation environments, others can be obtained from measured data. Reference [10], gives a coal mine multipath channel characteristics and corresponding model parameters. According to the model parameters, they use MATLAB to simulate the channel model. The clustering of the multipath arrivals is observed and validates the multi paths arriving in clusters of UWB channel and observed that before 200ns the amplitude fading lentamente, here the model is able to best fit the channel propagation law, but after 200ns the amplitude fading prick up and almost near zero. Yanjing Sun [11] use the IEEE802.15.3a cluster-based channel model as a basis to improve the channel model for underground mine. In order to determine the values of parameters, they obtain statistic parameters of these characteristics. After that, they use the fitting method to get the concrete parameters. Table 1 shows the parameter required for the setting of IEEE UWB Channel and parameter for environmental characteristics of underground mine [11].

Table 1: Channel parameter

Parameter	IEEE Channel	Underground Mine [11]
Λ (1 / n	0.0233	0.0667
λ (1 /	2.5	2.1
Γ	7.1	36
γ	4.3	24
σ_{ξ}(dB)	3.3941	3.3941
σ_{ζ}(dB)	3.3941	3.3941
σ_{g}(dB)	3	3

4.1 Comparison of channels

We use MATLAB to simulate the channel model using the above parameter, the clustering of the multipath arrivals is evidence observed in figure (3), and this validates the multi-paths arriving in clusters of UWB channel measurement data. It is the typical result in the multipath attenuation channel, any more the amplitude fading statistics of the channel impulse response are exponential. It can be seen that before 300ns the amplitude fading lentamente, here the model is able to best fit the channel propagation law, but after 300ns, the amplitude fading prick up and almost near zero.

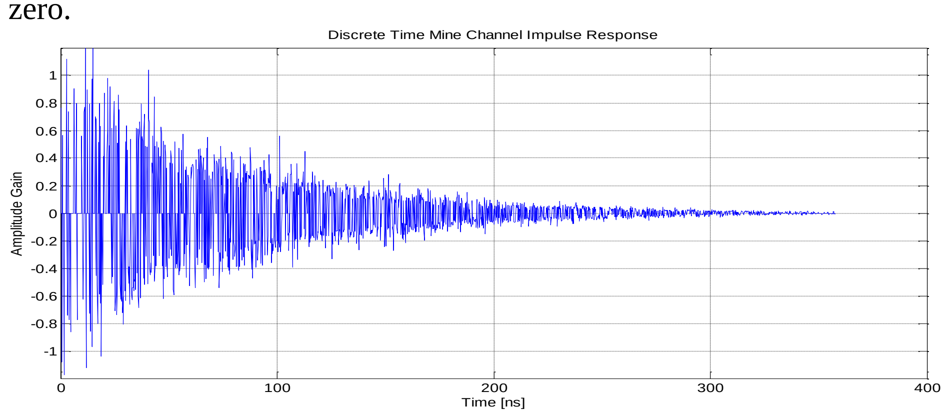

Figure 3 Discrete time impulse response of Underground Mine Channel

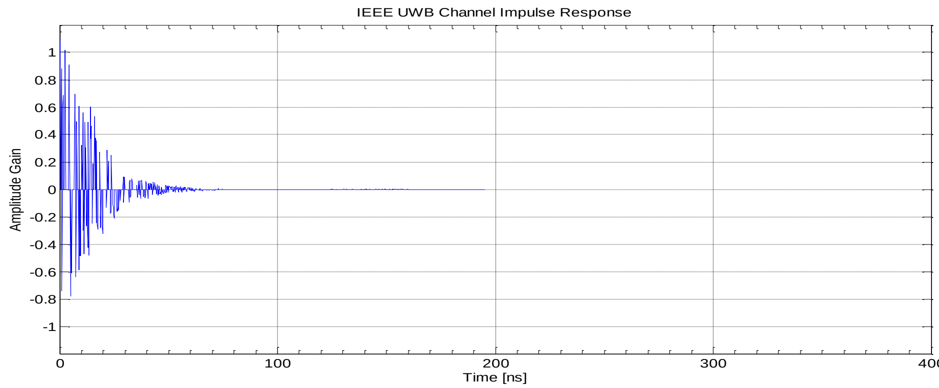

Figure 4 Discrete time impulse response of IEEE UWB channel

We compare the performance of both the channel by considering Mean Excess Delay, RMS (Root Mean Square delay) and Number of significant Paths with in 10 dB of peak (NP $_{10dB}$) and observe a large increase in RMS delay and significant paths in underground mine channel. Table 2 shows the mean value of RMS delay and NP $_{10dB.}$ Figure 6 compare the variation of RMS delay and figure 5 Mean Excess Delay of IEEE channel and underground mine channel. Figure 7 compare the NP $_{10dB}$ in both the channel. We consider the 100 number of simulation for the analysis of parameter.

Table 2: Simulated value of parameter

Parameter	IEEE Channel	Mine Channel
Mean Excess Delay (nS)	5.0482	51.0854
Mean RMS Delay (nS)	5.4440	42.0112
Mean NP_{10dB}	12.5100	68.0400

Figure 5. Excess delay of Underground Mine Channel

In order to compare different multipath channels and to develop some general design guidelines for wireless systems, parameters which grossly quantify the multipath channel are used. The mean excess delay, rms delay spread, and excess delay spread (X dB) are multipath channel parameters that can be determined from a power delay profile. The time dispersive properties of wide band multipath channels are most commonly quantified by their mean excess delay $\bar{\tau}$ and rms delay spread σ_τ. The mean excess delay is the first moment of the power delay profile and is defined to be[12]

$$\bar{\tau} = \frac{\sum_{\kappa} a_k^2 \tau_\kappa}{\sum_{k} a_k^2} = \frac{\sum_{\kappa} P(\tau_k)\,\tau_k}{\sum_{k} P(\tau_k)} \qquad (9)$$

The rms delay spread is the square root of the second central moment of the power delay profile and is defined to be

$$\sigma_\tau = \sqrt{\overline{\tau^2} - (\bar{\tau})^2} \qquad (10)$$

$$\overline{\tau^2} = \frac{\sum_{\kappa} a_k^2 \tau_\kappa^2}{\sum_{k} a_k^2} = \frac{\sum_{\kappa} P(\tau_k)\,\tau_\kappa^2}{\sum_{k} P(\tau_k)} \qquad (11)$$

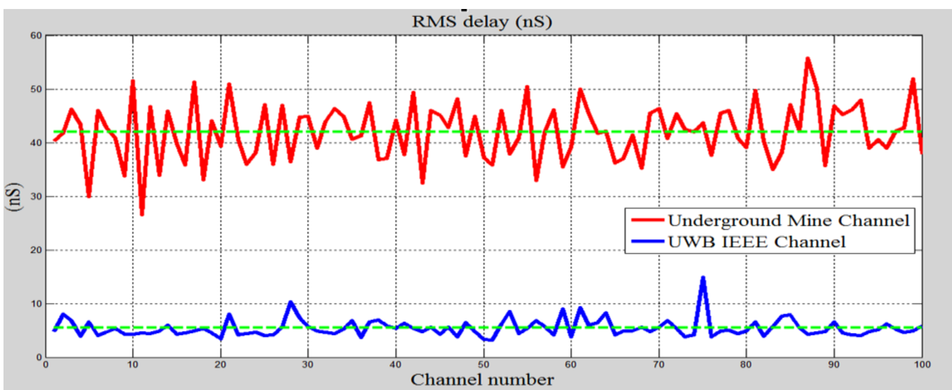

Figure 6. Root Mean Square delay of Channels

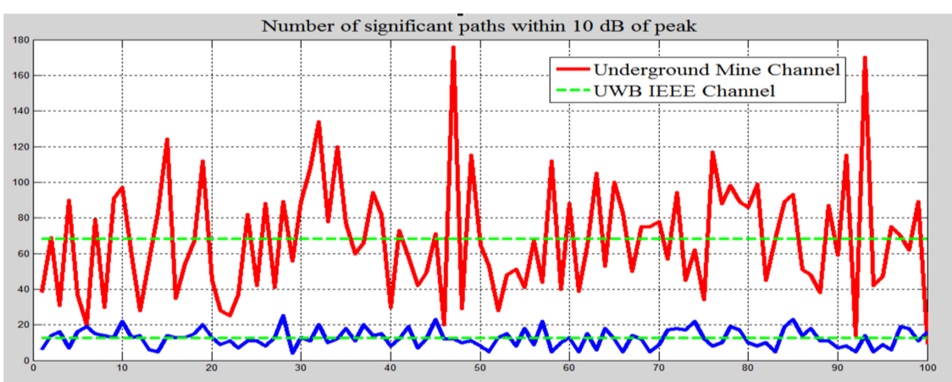

Figure 7. Comparison of Number of Significant paths with in 10 dB of peak

5. UWB Signal Receiver Structure

The propagation of UWB signal in underground mine will bring glomerate multipath as well as time dispersion. Accordingly, the UWB system has the specialty of resisting multipath attenuation and the system capability can improved effectively via adopt Rake configuration. However, owing to the time width of the UWB impulse signal is nanosecond level, multipath propagation made a serious dispersion of the signal energy. There for, it demands a large number of Rake fingers. To design the UWB receiver, it should be compromised from Rake fingers and system capability by dint of exact multipath channel model[16] . Arake (All rake) receiver combines all the separable multipath signal, the combine mode divided into Maximum Ratio Combine (MRC) and Equal Gain Combine

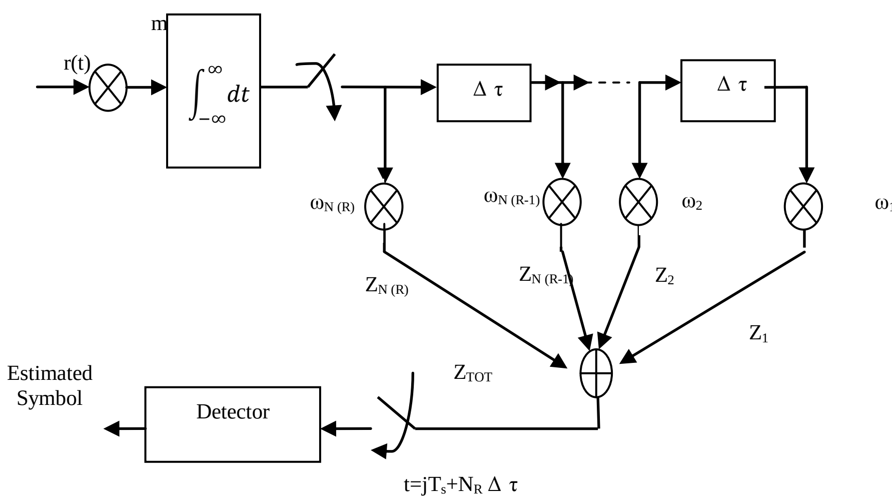

Figure 8. RAKE Receiver

(EGC).MRC excelled EGC, here we adopt the MRC Rake receiver[10]. In the proposed receiver shown in the figure (8) the output of the combiner can be express as

$$Z_{TOT} = \sum_{j=1}^{N_R} \omega_j \int_{T_L} r(t) m_j(t)\, dt$$

$$= \sum_{j=1}^{N_R} \omega_j \int_{T_L} r(t) m_j(t-\tau_j)\, dt \qquad (12)$$

Where T_L is the observation interval,N_R is the number of branches of j the weighting factor of j^{th} component ,m(t) is the correlation mask for the transmitted symbol and τ_j is the delayof the multipath component,which is processeed on the j^{th} branch.

$$r(t) = \sum a_j \, s_m(t - \tau_j) + n(t) \tag{13}$$

where $n(t)$ is AWGN at the receiver input. Equation (12) can be rewritten for IR transmission on the basis of statistical channel model discussed equation(3)

$$r(t) = X\sqrt{E_{TX}} \sum_j \sum_{n=1}^{N} \sum_{k}^{k(n)} a_{nk}\, a_j p_0\left(t - jT_s - \varphi_j - \tau_{nk}\right) + n(t) \tag{14}$$

Where E_{TX} Transmitted energy per pulse ,a_j amplitude of j^{th} transmitted pulse T_s is average pulse repetition time, φ_j is time dithering.

6. Simulation Results

We evaluated the BER performance using RAKE receiver employing maximal ratio combining (MRC) for repeat bit, number of RAKE figure in underground mine channel and different data rate, Figure 9 is the curve of BER with signal noise ratio (SNR) of the above system for IEEE UWB Channel and Modified Underground Mine channel environment with repeat bits of 30,40,50. Figure 10 shows the BER performance of Mine channel environment for number of RAKE figures 6,8,10 and BER for different data rates of 50Mb/s,100Mb/s and 200Mb/s is shown in figure 11.

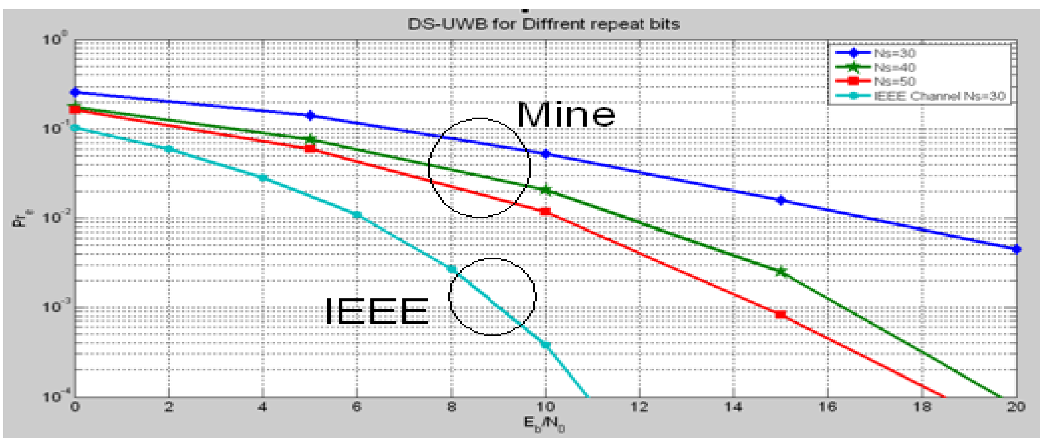

Figure (9) BER performance IEEE UWB and Mine channel environment with repeat bits

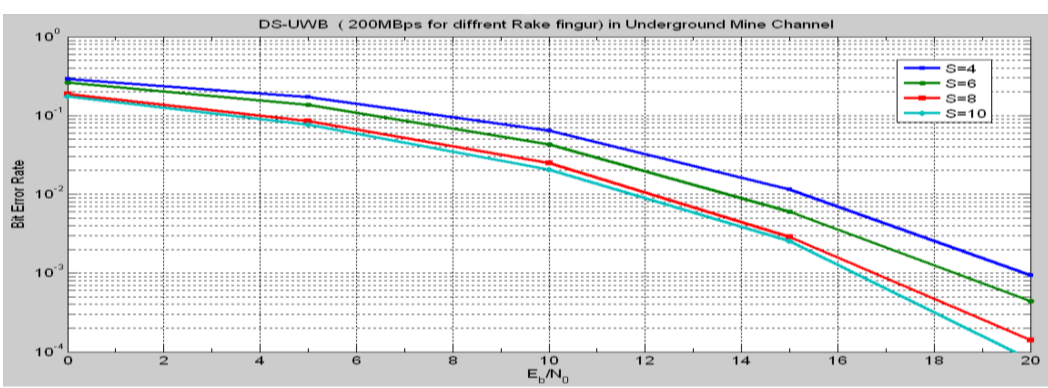

Figure (10) BER performance of Mine channel environment with number of RAKE figures

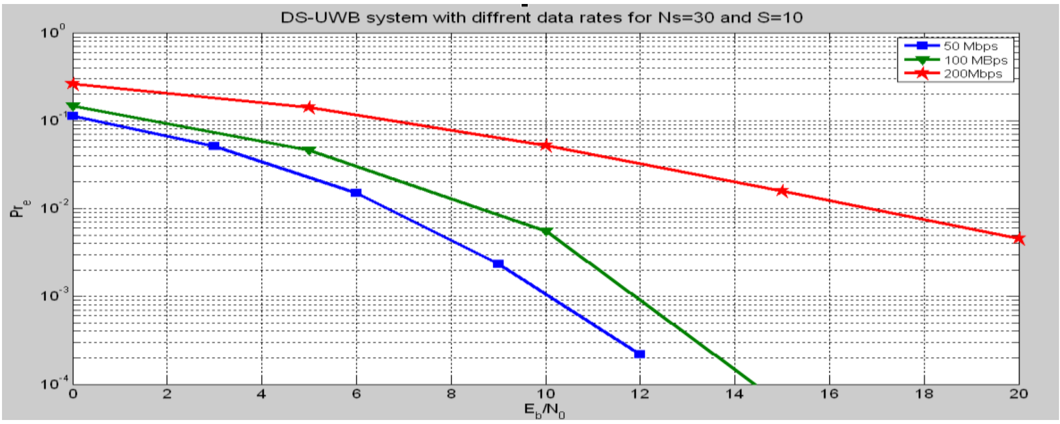

Figure (11) BER performance of Mine channel environment with different data rates

7. Conclusion

The BER performance of a RAKE receiver for DS-PAM-UWB system was analyzed in Underground Mine channel model and IEEE UWB channel based on an extensive set of indoor channel measurements. Simulation results and analysis show that the underground wireless communication system of UWB based on DS-PAM can effectively with-stand multipath fading and can sustain in the dense multipath environment of underground mine with acceptable BER. BER curve of DS-PAM-UWB system degrades it performance by 13dB in mine channel compare to IEEE channel hence further research is required for developing effective RAKE architectures to combine large numbers of multipath components with low complexity.

References

[1] W. Pam Siriwongpairat, K. J. Ray Liu, "Ultra-Wideband Communications Systems Multiband OFDM Approach" IEEE Press 2007 A

[2] M.-G. Di Benedetto, G. Gianloca, "Understandi
Pearson Education LPE 2008 ISBN 978-81-317-2279-4

[3] Abdellah Chehri, Paul Fortier, Pierre-Martin Tardif, "Frequency d
channel propagation in underground mines" IEEE 1-4244-0063-5/06 ©2006

[4] Abdellah Chehri, Paul Fortier, Pierre-Martin Tardif "Measurements
of-Sight UWB channel in underground mines" IEEE GLOBECOM 2006 proceedings

[5] Wang Yanfen Zhang Chuan "Modeling Underground Mining Multipath C
UWB LOS Environments" Conference 978-1-4244-3693-4/09/©2009

[6] Jeff Foerster, "Channel Modeling Sub-committee Report" Final IEEE P802.1
Group February 2003

[7] Mathieu Boutin, Ahmed Benzakour, Charles L. Despins, "Radio Wave Charact
and Modeling in Under-ground Mine Tunnels" IEEE Trans
Propagation, Vol. 56, No. 2, February 2008 Pp.540-549

[8] Abdellah Chehri, Paul Fortier, Pierre Martin Tardif "Characteriz
Wideband Channel in Confined Environments" ©
Springer 2010 Wireless Pers Commun DOI 10.1007/s11277-010-0097-2 pp.

[9] Abdellah Chehri, Paul Forti Pierre -Scale Fading and Time Dispersion Parameters of UWB Ch in U Hindawi Publishing Corporation International Journal of Antennas and Propagation Volume 2008, Article ID 806326, 10 pages doi:10.1155/2008/806326

[10] SUN Yanjing, PENG Li, LIU Xue ,“ Wireless Channel Model of U Tunnels in Coal Mine” ©IEEE Conference 978-1-4244-3693-4/09 2009

[11] Yanjing Sun, Beibei Zhang, “System Model of OFDM” Int. J. Communications, Network and System Sciences, 2011, 4, pp.59-64

[12] Theodore S. Rappaport,” Wireless communicat India ISBN -81-203-2381-5.

[13] A Saleh, R Valenzuela., “A Statistical Mod JSAC, 1987, vol.5, pp. 128-137.

[14] Abdellah Chehri, Paul Fortier, Pierre-Martin Tardif, “An Investi -Based Wireless Networks in Industrial Automation” Science and Network Security, VOL.8 No.2, February 2008

[15] Yanjing SUN, Li PENG , Tl UWB Modified S-V Channel and Model ” is of -1-4244-3693-4/09 ©2009 IEEE

[16] Rajeswaran A, Somayazulu V S, Foerster J R, system in a realistic UWB indoor channel,” I 2883

[17] Athar Ravish Khan, Sanjay M. Gulhane,” Perform System in Underground Mine Channel” International Journal of Electronics and Communication Engineering. ISSN 0974-2166 Volume 4, Number 5 (2011), pp. 543-553

[18] Ph. Mariage, M. Lienard, and P. Degauque, “Theoretical and the Propagation of High Frequency Waves i IEEE Transactions On Antennas And Propagation, Vol. 42, No. 1 , January 1994.

[19] R. Liu and J. Elmirghani, *ñPerformance of impulse radio direct sequence ultra-wide band system with variable-length spreading sequencesò* IET Commun., 2007, 1, (4), pp. 597–603.

[20] Jeng-Kuang Hwang · Yu Lun Chiu · Rih-Lung Chung “Near Optimum an Deci-sion Feedback Receivers for Direct Sequence Ultra-Wideband Radio” © Springer Wireless Pers Commun (2007) 43:pp.1653–1665.

[21] Liang Zhaohui, Jiang Ting, Zhou Zheng“ A New Synchronization Sch Punctured Binary Sequence Pairs In DS-UWB System” JOURNAL OF ELECTRONICS (CHINA) Vol.23 No.2 March 2006 pp 231-235.

[22] Liang Zhonghua Zhu Shihua Wang Shaopeng“ A Three-Input Efficient Adaptive Transmit-Receive Scheme For Indoor DS-UWB Systems” Vol.25 No.1 JOURN ELECTRONICS(CHINA) January 2008 pp.39-46.