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Performance Evaluation of Time Hopping UWB System in Underground Mine Channel

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Abstract

In order to effectively overcome the path loss, multi-path delay and different channels power attenuation of underground mines, wireless communication Ultra Wide Band system, based on Time Hopping Pulse Position Modulation for coal mine is presented. 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 observation that usually multi-path contributions generated by the same pulse arrive at the receiver grouped into cluster. With the revised channel model, we compare the performance of the system in IEEE channel and mine channel and evaluate the performance of a RAKE receiver employing maximal ratio combining (MRC).The log-normal fading statistics of multipath fading channel is considered with different RAKE finger and repetition code. Mean excess delay and RMS delay spread are calculated to characterize the temporal dispersive properties of the multipath channel. The model of the system was simulated in the complex environment of mine, simulation results and analysis show that the underground wireless communication system of UWB based on TH-PPM can effectively with-stand multipath fading and has the advantages of low bit-error rate.

Keywords: TH-PPM Ultra-Wideband (UWB) system, IEEE802.15.3a UWB Channel, Modified Mine Channel

Introduction

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. Ultra-Wideband (UWB) technology has gained much interest for its applications in wireless communications. 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. Ultra wide band (UWB) wireless communication system has became the principal scheme of short distance high speed digital transmission, resisting on multipath interference as well as its low power consumption. The analysis and design of a UWB communication system requires, an accurate channel model to determine the maximum achievable data rate, efficient modulation schemes, and associated signal processing algorithms [1]. This paper evaluate a performance of an Ultra-Wideband (UWB) system in an underground mine channel. The remainder of the paper is organized as follows. In the next section we present modulate technique and Choice of UWB wave in coal mine. Section 3 deals with channel modeling and receiver structure in Underground Mine and in Section. 4 the paper ends with simulation results and conclusion.

Choice of UWB Wave and Modulate Technique in Underground Mine

Choice of Modulate Technique and channel coder

In TH-UWB combine with binary PPM (2PPM-TH-UWB), the UWB signal can be schematized to be generated as shown in Figure(1).Given the binary sequence to be transmitted **b**= $(..,b_0,b_1,\dots b_k,b_{k+1},\dots)$,generate at rate of $R_b=1/T_b$ bits/sec, a first system repeats each bit N_s times and generates a binary sequence$(.,b_0,b_0,\dots b_0,b_1,b_1,..,b_{k+1},b_{k+1}\dots b_{k+1},.)=(..a_0,a_1\dots.a_j,a_{j+1})$ = **a** at the rate of $R_{cb}=N_s/T_b=1/T_s$ bits/s. This system introduce the redundancy and is a$(N_s,1)$ block coder indicated as a code repetition coder in classical terminology this is channel coder. A second block called a transmission coder applies an integer-valued code **c**=$(..c_0,c_{1,}\dots c_j,c_{j+1},\dots)$ to the binary sequence **a**=$(..a_0$, a1…..a_j, aj$_{+1})$ and generate a new sequence **d**. The generic element of the sequence d is express as

$$d_j=c_jT_c+a_j\ \varepsilon \tag{1}$$

where T_c and ε are constant terms that satisfy the condition $c_jT_c+\varepsilon < T_s$ for all c_j One also has, in general, $\varepsilon< T_c$, **d** is a real-valued sequence as opposed to **a**, which is binary and to **c**, which is integer-valued, assume that **c** is a pseudorandom code, its generic element c_j being an integer verifying $0 \le c_j \le N_h - 1$. The code **c** might be periodic, and in that case, its period is indicated by N_p. Two particular cases are worth discussing. The first corresponds to the absence of periodicity in the code, that is, N_p tends to ∞ and the second to $N_p = N_s$. In the second case, which is the most commonly adopted, the periodicity of the code coincides with the length of the repetition code [7]. The coded real-valued sequence **d** enters a third system, the PPM modulator, which generates a sequence of unit pulses (Dirac pulses $\delta(t)$) at a rate of $R_p = N_s / T_b = 1/T_s$ pulses/s. These pulses are located at times jT_s+d_j, and are therefore shifted in time from nominal positions jT_s by d_j. Pulses occur at times $(jT_s+c_jT_c+a_j\,\varepsilon)$. Note that code **c** introduces a TH shift on the generated signal, and it is for this reason that it is indicated as TH code. Note that the shift introduced by the PPM modulator, $a_j\varepsilon$, is usually much smaller than the shift introduced by the TH code, c_jT_c, that is, $a_j\varepsilon < c_jT_c$, except for $c_j = 0$. T_c is called chip time refer figure(2). The last system is the pulse shaper filter with impulse response p(t). The impulse response p(t) must be such that the signal at the output of the pulse shaper filter is a sequence of strictly non-overlapping pulses. The most commonly adopted pulse shapes is second derivative of a Gaussian function.

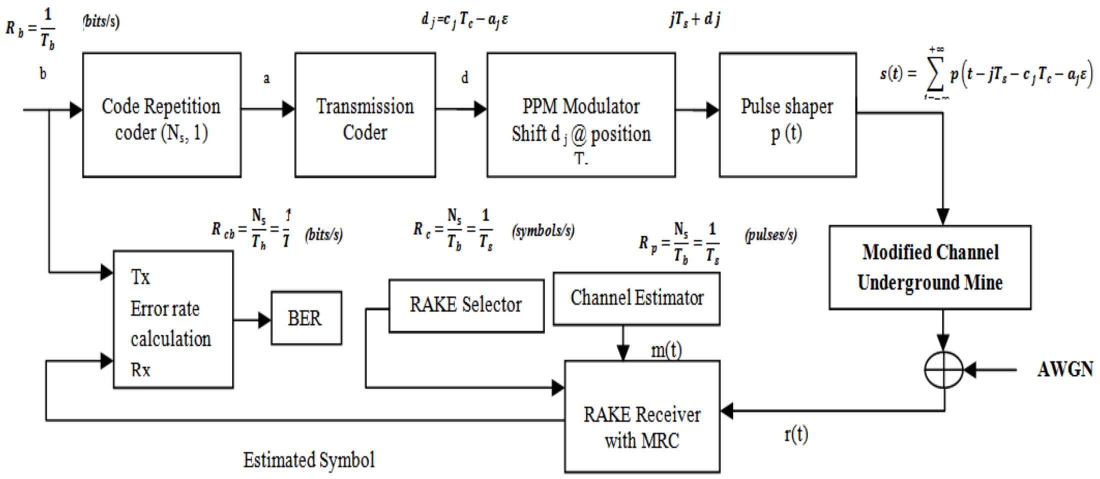

Figure 1: Proposed 2PPM-TH-UWB System model for Underground Mine

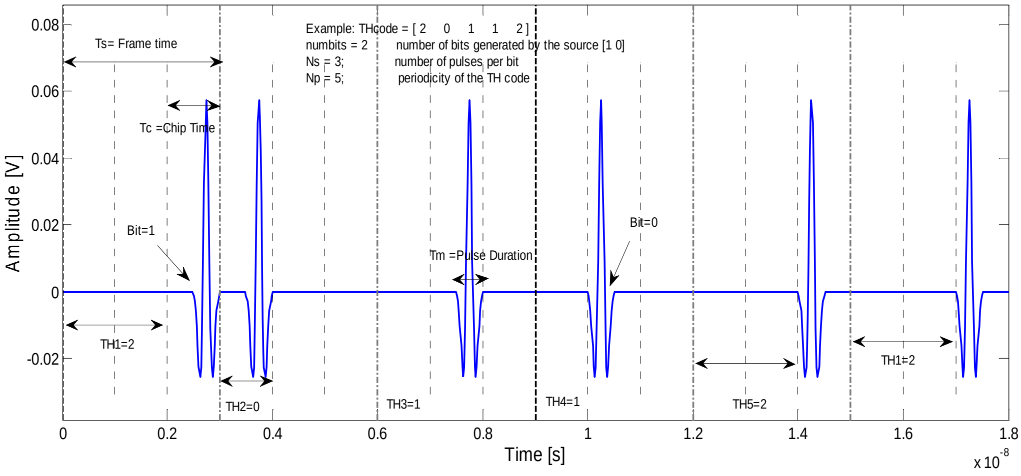

Figure 2: 2PPM-TH with Pulse Shape.

Narrow impulse wave

Narrow impulse wave has great infection in UWB communication system, so it is very important to choose the narrow impulse. The narrow impulse signal waves in common used now include the Guass wave, Cosine wave, multi-period impulse wave and so on. The Gauss wave applied most commonly of these [1]. In the non-carrier wave impulse UWB communications, we usually modeling the transmitting and receiving antenna to a differential operation. The Gauss impulse signal can be expressed as

$$p(t) = \pm\frac{1}{\sqrt{2\pi\sigma^2}}\,e^{-\left(\frac{t^2}{2\sigma^2}\right)} = \pm\frac{\sqrt{2}}{\alpha}\,e^{-\left(\frac{2\pi t^2}{\alpha^2}\right)} \tag{2}$$

Where $\alpha^2=4\pi\sigma^2$ is shape factor and σ^2 is variance ,to be radiate in efficient way Gaussian derivatives are suitable [7] the most currently adopted pulse shape is modeled as the second derivative of a Gaussian function described by

$$\frac{d^2\,p(t)}{dt^2} = \left(1 - 4\pi\frac{t^2}{\alpha^2}\right) e^{-\left(\frac{2\pi t^2}{\alpha^2}\right)} \tag{3}$$

Ideally, a second derivative Gaussian pulse can be obtained at transmitting antenna if the antenna is fed with a current pulse shaped as the first derivative of Gaussian waveform ,the radiating pulse being proportional to the derivative of the drive current in an ideal antenna(Immoreev and Sinyavin 2002) [7]. The signal s(t) at the output of the cascade of the systems shown in Figure(1) can be expressed as follows:

$$s(t) = \sum_{j=-\infty}^{+\infty} p\left(t - jT_s - c_j\,T_c - a_j\varepsilon\right) \tag{4}$$

Note that the bit interval, or bit duration, that is, the time used to transmit one bit T_b is: $T_b = N_sT_s$. Also note that in Eq. (4), the term c_jT_c defines pulse randomization or dithering with respect to the nominal instances of time occurring at multiples of T_s. If we represent the time shift introduced by the TH code c_jT_c by a random TH dither η_j, which can be assumed to be distributed between 0 and $T_\eta < Ts$, we obtain:

$$s(t) = \sum_{j=-\infty}^{+\infty} p\left(t - jT_s - \eta_j - a_j\varepsilon\right) \tag{5}$$

As noticed above, η_j is usually much larger than ε. The global effect of these two terms is to introduce a random time shift, distributed between 0 and $T_\eta + \varepsilon < Ts$, which will be indicated by θ_j leading to the following expression for the transmitted signal

$$s(t) = \sum_{j=-\infty}^{+\infty} p\left(t - jT_s - \theta_j\right) \tag{6}$$

Receiver Structure and Channel Modeling in Underground Mine

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).This model should be used for evaluating the performance of different physical layers as submitted to the IEEE 802.15.3 task group. IEEE channel-Modeling sub-commettee finally converged an a model based on the cluster approch proposed by Turin and others in 1972(Turin et.al.1972)and further formalized by Saleh and Valenzuela in 1987(Saleh and Valenzuela,1987)[7]in the seminal work on statistical modeling for indoor multi-path propagation .The S-V model is based on the observation that usually multi-path contributions generated by the same pulse arrive at the receiver grouped into cluster. In this model the gain of the n^{th} ray of k^{th} cluster is a complex random variable.

To better fit the data resulting from UWB measurement campaign, the IEEE group proposed a few modifications to S-V model. In particular, a log-normal distribution was suggested for characterizing the multi-path gain amplitude, and an additional log-normal variable was introduced for representing the fluctuations of the total multipath gain. Finally, the channel coefficient was assumed to be real variables rather than complex variables. The channel impulse response of the IEEE model can be express as

$$h(t) = X \sum_{n=1}^{N} \sum_{k=1}^{k(n)} \alpha_{nk} \, \delta(t - T_n - \tau_{nk}) \tag{7}$$

Where X is a lognormal distributed random variable representing the magnitude of channel gain. N is the observed number of clusters. K(n) is the received number of multipath in the n^{th} cluster. α_{nk} is coefficients of the k^{th} path in the n^{th} cluster. T_n is the arrival time of the nth cluster. τ_{nk} is the k^{th} path delay in the n^{th} cluster. Table 1 shows the parameter required for the setting of IEEE UWB Channel and Table 2 Shows Parameter for environmental characteristics of Underground Mine [6].

Table 1: Parameter required for the setting of IEEE UWB Channel.

IEEE UWB Channel	Λ (1/ns)	λ (1/ns)	Γ	γ
	0.0233	2.5	7.1	4.3
	σ_ξ(dB)	σ_ζ(dB)	σ_g(dB)	Type
	3.3941	3.3941	3	LOS

Where Λ is the cluster average arrival rate, λ in pulse average arrival rate ,Γ is power delay factor for cluster, γ is power delay factor for pulse within a cluster, σ_ξ is standard deviation of the fluctuation of the channel coefficient for the clusters, σ_ζ is standard deviation of the fluctuation of the channel coefficient for pulse within a the clusters, σ_g , is standard deviation of the channel amplitude gain.

Table 2 Parameter for environmental characteristics of Underground Mine

Modified UWB Channel for Underground Mine	Λ (1/ns)	λ (1/ns)	Γ	γ
	0.0667	2.1	36	24
	σ_ξ(dB)	σ_ζ(dB)	σ_g(dB)	Type
	3.3941	3.3941	3	LOS

The mean excess delay and RMS delay spread are two important parameters use to characterize the temporal dispersive properties of the multipath channel. The RMS delay spread parameter determines the frequency selectively of the channel which degrades the performance of digital communication systems. The RMS delay spread limits the maximum data transmission rate that can be reliably supported by the channel figure (5) shows the RMS delay of Underground Mine Channel and figure (6) shows the Excess delay of Underground Mine Channel, simulated for 100 number of channel. The clustering of the multipath arrivals is evidence observed in figure (3), 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.

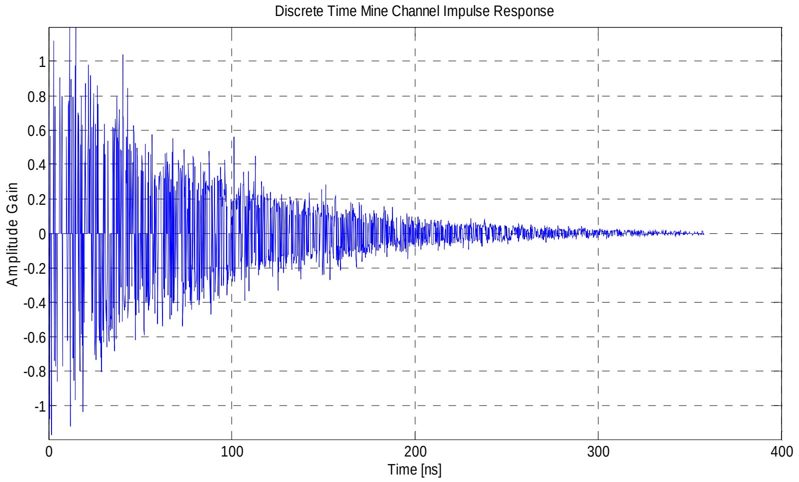

Figure 3 Discrete time impulse response of Underground Mine Channel.

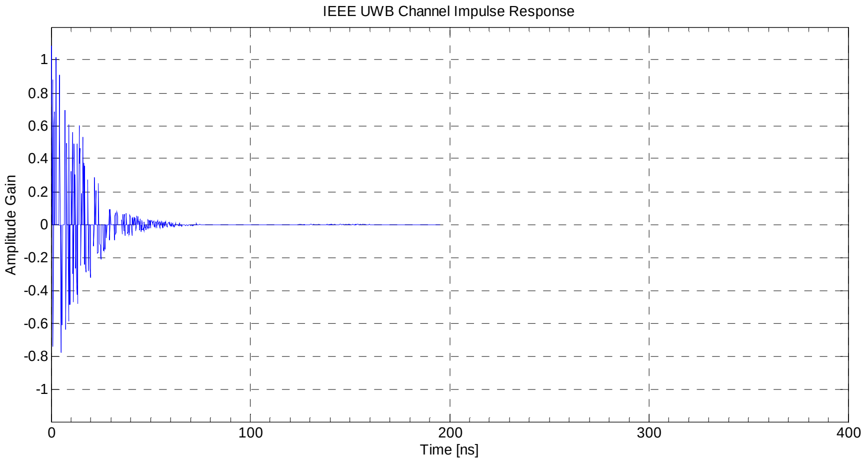

Figure 4 Discrete time impulse response of IEEE UWB channel

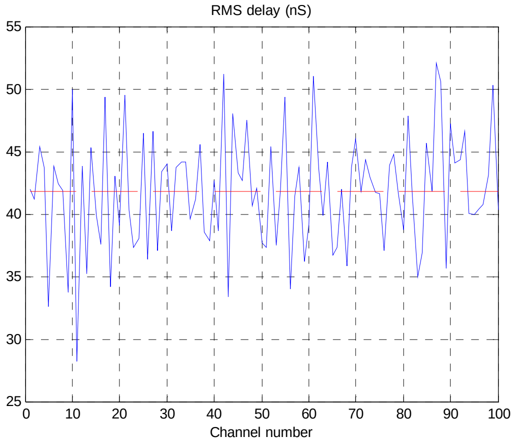

Figure 5 Root Mean Square delay of Underground Mine Channel.

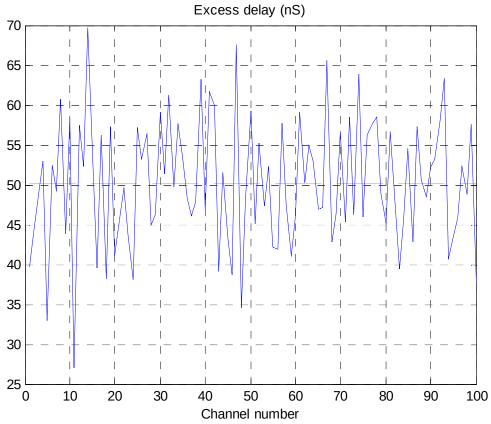

Figure 6 Excess delay of Underground Mine Channel.

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[4] . Arake (All rake) receiver combines all the separable multipath signal, the combine mode divided into Maximum Ratio Combine (MRC) and Equal Gain Combine

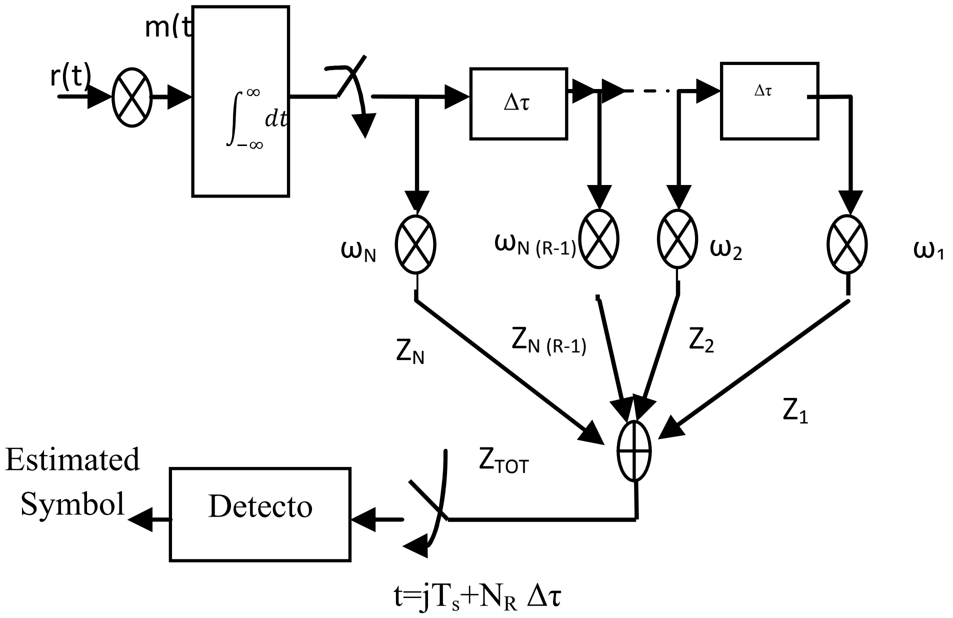

Figure 7. RAKE Receiver

(EGC).MRC excelled EGC, here we adopt the MRC Rake receiver[1]. In the proposed receiver shown in the figure (3) the output of the combiner can be express as

$$Z_{TOT} = \sum_{j=1}^{N_R} \omega_j \int_{T_L} r(t)\, m_j(t)\, dt = \sum_{j=1}^{N_R} \omega_j \int_{T_L} r(t)\, m_j(t-\tau_j)\, dt \tag{8}$$

Where T_L is the observation interval,N_R is the number of branches of the RAKE receiver, $\omega_j$is 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.

$$r(t) = \sum a_j\, s_m(t-\tau_j) + n(t) \tag{9}$$

where n(t) is AWGN at the receiver input. Equation (8) can be rewritten for IR transmission on the basis of statistical channel model discussed equation(7)

$$r(t) = X\sqrt{E_{TX}} \sum_j \sum_{n=1}^{N} \sum_{k}^{k(n)} a_{nk}\, a_j p_0(t - jT_s - \varphi_j - \tau_{nk}) + n(t) \tag{10}$$

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

Simulation Results

Figure 8 is the curve of bit error rate (BER) with signal noise ratio (SNR) of the above system for IEEE UWB Channel and Modified Underground Mine channel environment.

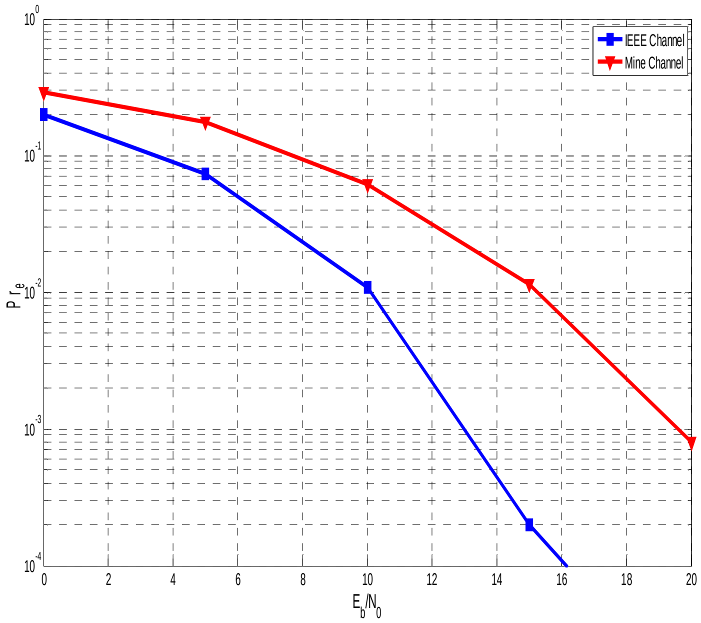

Figure 8 BER performance in IEEE channel Vs Underground Mine Channel

Figure 9 and figure 10 is the curve of bit error rate (BER) with signal noise ratio (SNR) which evaluate the performance of RAKE receiver for different RAKE finger and different value of repeat bits in the transmission coder respectively for modified Underground Mine channel environment.

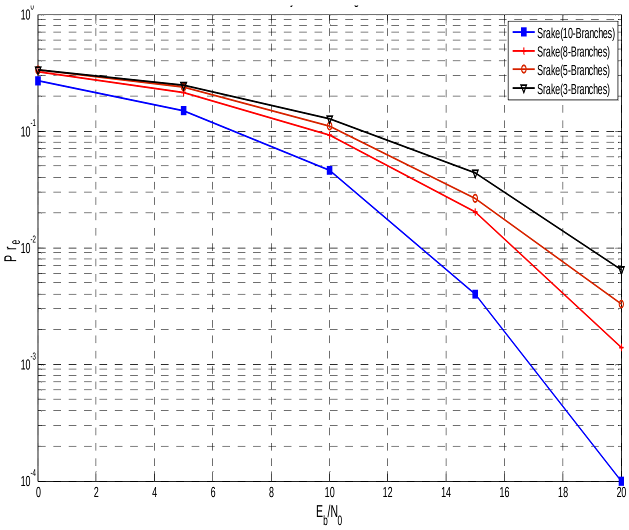

Figure 9: BER performance in Underground Mine Channel for different RAKE finger

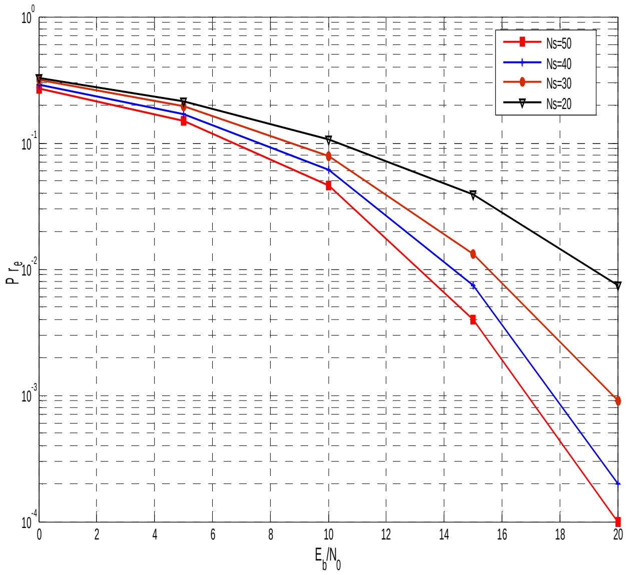

Figure 10: BER performance in Underground Mine Channel for different repetition coder

Conclusion

In this paper, the propagation of the UWB signal in Underground Mine is analyzed. The performance of a RAKE receiver for 2PPM-TH- 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 TH-PPM can effectively with-stand multipath fading and has the advantages of low bit-error rate. Research is continuing into developing effective RAKE architectures to combine large numbers of multipath components with low complexity.

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