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Analyzing Pulse Position Modulation Time Hopping UWB in IEEE UWB Channel

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***Abstract**: Ultra-wideband (UWB) employs very narrow band pulses of nano-seconds duration to provide high data rate communications. Pulses spread the energy over a wide frequency because of that it is called ultra-wideband. Ultra wideband (UWB) technology, useful for both communication and sensing applications, uses the radio spectrum differently than the vast majority of radio communication technologies. In this paper, we will discuss the UWB pulse position multiple access modulation schemes using rake configurations with help of MATLAB simulations.*

***Keywords**: UWB, PPM, PPM-TH, ISI.*

I. Introduction

UWB transmission is a signal, that occupies a bandwidth of more than 25% of a center frequency, or more than 1.5GHz greater The basic element in UWB radio technology is the use of Gaussian monocycle as shown in figure 1. in both time and frequency. [3][4].

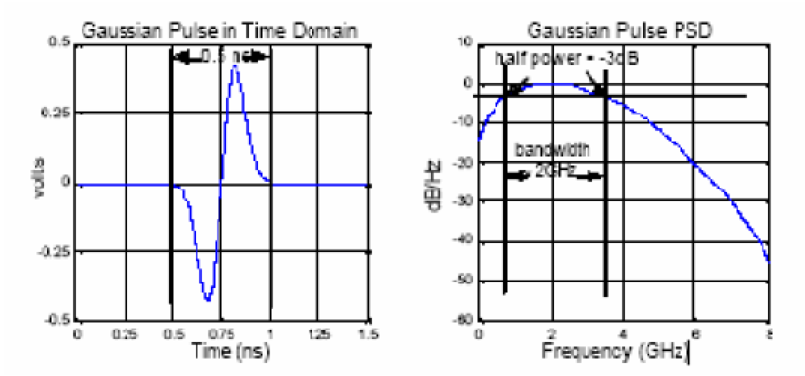

Fig.1.UWB bandwidth in time & frequency domain

II. PPM Modulation

In PPM modulation, each pulse is delayed or sent in advance of a regular time scale. A binary communication system can be established with a forward or backward shift of the pulse in time. The data is encoded by adding an extra time shift ‘‘δshift’’ to the impulse as shown in Fig. The binary PPM signal is given by

$$s(t) = \sum_{k=-\infty}^{\infty} a_k \; p\left(t - kT_f \; \pm \delta_{shift}\right) \quad (1)$$

where the data modulation is done by small shifts in the pulse position δshift, p(t) is the UWB pulse and Tf is the frame duration.

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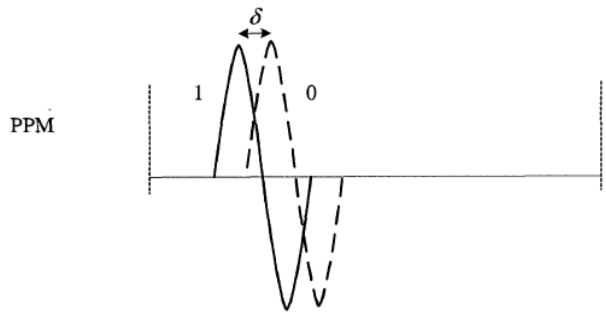

Fig.2. PPM Modulation

III. PPM-TH-UWB Transmitter

In this paper we will consider the design considerations of UWB transmitter using Pulse Position Modulation Time Hopping (PPM-TH) multiple access modulation scheme. The digital information contained in the bits needs to be mapped to the analog pulses which are transmitted and this is done via the help of modulation. The most common modulation technique for UWB is the pulse position modulation (PPM). In PPM each pulse is delayed or sent in advance of the regular time scale. So depending on the data bits, the pulse can be delayed accordingly. PPM is advantageous because of its ease of controlling the delay and simplicity. The spectral peaks with PPM along with Gaussian pulse can cause interference with other RF systems and hence the signal must be time shifted with the help of PN codes

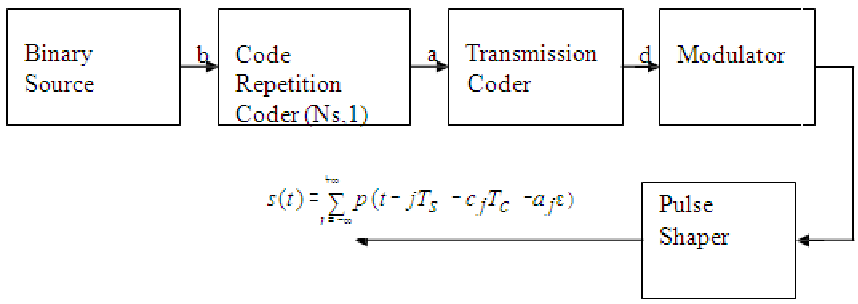

Fig.3. PPM-TH-UWB Transmitter

The binary source generates the bits to be transmitted at rate $R_b = 1/T_b$ .given to code repetition coder which introduces redundancy and acts as channel coder. It repeats the bits generated by the binary source Ns times so the bits are now generated at the rate $R_{cb} = N_s/T_b$ .The transmission coder generates a PN (pseudo random code) with a period N_p and applies this code to the repeated bits generating a new sequence of bits

$$d_j = c_jT_c + a_j\varepsilon, \qquad (2)$$

where, T_C is the chip time, c_j is the pseudo random code, the shift generated by PPM the modulator is $a_j\varepsilon$.

The pulse shaper generates a pulse with impulse response p(t) such that the output of the pulse shaper filter is non-overlapping pulses . The Gaussian derivative pulses is used for this purpose.

The signal at the output of the PPM-TH-UWB transmitter is represented as

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$$s(t) = \sum_{j=-\infty}^{+\infty} p(t - jT_s - c_j T_c - a_j \varepsilon) \quad (3)$$

where, $c_j T_c$ = time dither introduced by the TH code, $a_j \varepsilon$ = time shift introduced by the PPM modulator, one bit duration is $T_b = T_S N_S$. This signal s (t) is transmitted by the UWB transmitter over the channel and received at the receiver end.

The above described model is created using MATLAB software and the transmitted signal is generated using PPM-TH multiple access modulation scheme using the following parameters Pow=30, fc=50e9, numbits=3, Ts=3e9, Ns=5, Tc=1e-9 and dPPM=0.5e-9.

where Pow = Average transmitted power (dBm), fc = sampling frequency , numbits = number of bits generated by the source, Ts = frame time, pulserepetition period, Ns = number of pulses per bit, dPPM= time shift introduced .

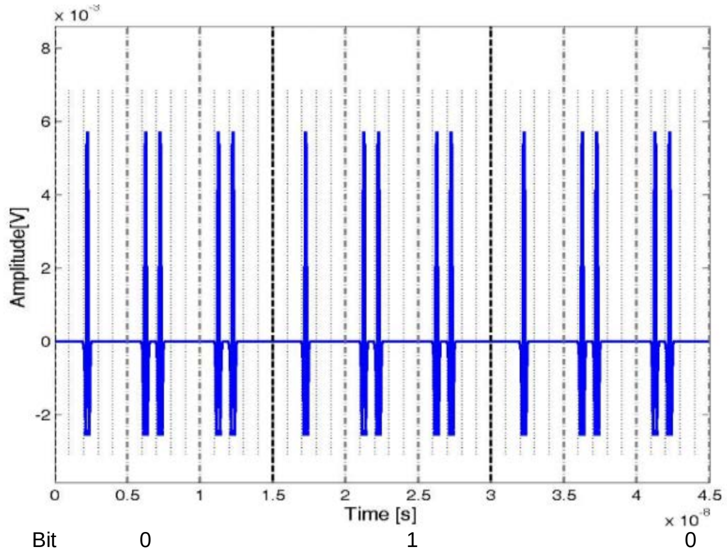

Fig.8. Transmitted PPM-TH-UWB before modulation

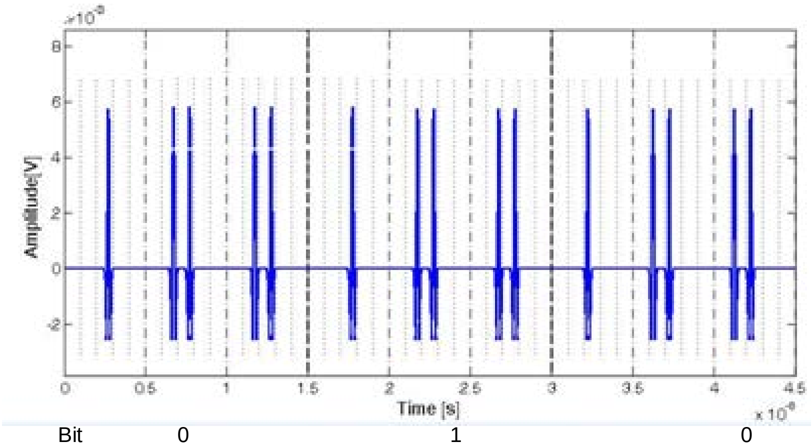

Fig.9.Transmitted PPM-TH-UWB after modulation

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IV. IEEE UWB Channel Model

The signal transmitted by the transmitter reaches the receiver via the channel. The channel affects the signal by attenuating it, delaying it and distorting it. The UWB signals have a very large bandwidth in the order of 500MHz and the signals constitute of pulses. The traditional channel models do not work for the UWB signals as they assume the attenuation due to materials and other propagation effects to be constant over the bandwidth.

AS UWB signals have a very large bandwidth the effects are not constant over the entire band. In UWB signals, each pulse may go through distortion in addition to the distortion in the total received signal.

Also it has the presence of multiple paths between transmitter and receiver which introduces complexity at both channel model and receiver structure**.** The channel exhibits time-varying properties that must be taken into account into the channel model. Distortion is also present for indoor transmissions where propagation is perturbed by a number of interfering objects.

IEEE 802.15.3a proposed a UWB multipath channel model in July 2003 The multipath components arrive at the receiver in groups, called clusters, with Poisson distribution. The path (ray) within each cluster also arrives with Poisson distribution.[6] The channel impulse response is given by:

$$h(t) = X \sum_{l-1}^{L} \sum_{n-1}^{M} \alpha_{nl} \ \delta(t - T_l - \tau_{kl}) \tag{4}$$

Where L is number of clusters, M is number of paths within a cluster, α_{nl} is the multipath gain of the nth path corresponding to l th cluster. T_l *is* delay of l th cluster and τ_{kl} is the time delay of nth ray of the lth cluster. The amplitude fading is defined as $\alpha_{nl} = P_{nl} \cdot \varepsilon_l \beta_{nl}$, where P_{nl} is the sign of the coefficient and takes l with equal probability and accounts for signal inversions due to reflections. ε_l is the fading associated with the lth cluster. β_{nl}, is the fading associated with the nth ray of the lth cluster. Using this model IEEE came up with initial set of values for different environmental scenarios. The list is as shown in the table below.

Scenario	$\Lambda(1/ns)$	$\lambda(1/ns)$	Γ	Υ	σ_{ξ} (dB)	σ_{ζ} (dB)	σ_g (dB)
Case A LOS (0-4m)	0.0233	2.5	7.1	4.3	3.3941	3.3941	3
Case B NLOS (0-4m)	0.4	0.5	5.5	6.7	3.3941	3.3941	3
Case C NLOS (4-10m)	0.0667	2.1	14	7.9	3.3941	3.3941	3
Case D Extreme NLOS Multipath channel	0.0667	2.1	24	12	3.3941	3.3941	3

Table1. IEEE UWB Channel model parameters

V. UWB Receiver

The primary task of a receiver is to collect the received signal which is an attenuated, distorted and delayed version of the transmitted signal, and decode the useful signal from it. The

ISSN 1512-1232

UWB signal is composed of non-overlapping pulses with each pulse having a specific pulse duration within a given time interval. However, the channel can affect the transmitted signal introducing varying delays and thus causing inter-symbol interference. The multi-paths will also result in delayed replicas of the signal causing ISI. Moreover, when we consider the case of multiple users transmitting at the same time, the signal of one user can be interference to that of other user [3].

The multi-path delayed and attenuated versions of the transmitted signals can be efficiently separated at the receiver and then combined in order to improve the signal-to-noise ratio with the help of a RAKE receiver which collects the delayed versions of the original signal by providing a separate correlation receiver for each of multi-path signals.

The RAKE receiver consists of a correlator, which converts the received signal into set of decision variables, $\{Z\}$ and detector makes a decision on which signal is transmitted based on the decision variable $\{Z\}$. The transmitter sends M different waveforms $Sm(t)$ with m=0,1…,M-1.The received signal is cross-correlated with the M possible transmitted waveforms and the maximum over the M resulting values is selected as the transmitted signal.

The received signal can be represented as

$$r(t) = r_u(t) + n(t) \quad , \tag{5}$$

where, $r_u(t)$ is the useful signal at the receiver and $n(t)$ is additive noise assumed to be Gaussian process with PSD $N_0/2$

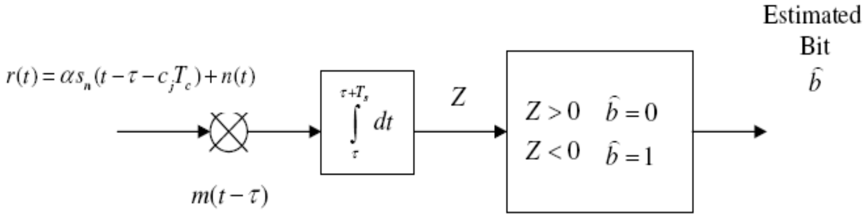

Fig.4. Single correlator scheme for 2PPM-TH-UWB Receiver

VI. Receiver Configurations

The different replicas of the transmitted pulse are combined using the Maximum Ratio Combining (MRC) in which weighting factors are applied to the different contributions to maximize the SNR.

The typical RAKE receiver configurations considered in this section are the Ideal or All RAKE, Selective RAKE and Partial RAKE. All RAKE (ARAKE) collect the energy of signal from all the resolvable multi-path contributions, the Selective RAKE (SRAKE) combines the best L_c paths out of L paths and PRAKE on the other hand combines the first L_c arriving paths without making any selection decisions on the incoming multi-path contributions using Maximal Ratio Combining (MRC).

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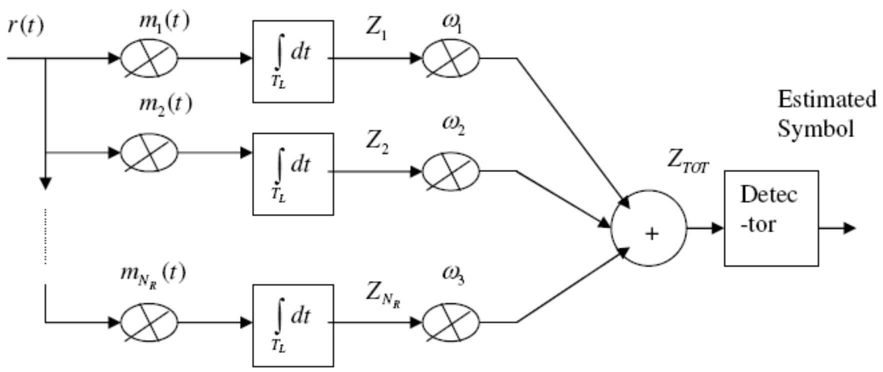

Fig.4. RAKE Receiver with parallel correlators

The transmitter, channel model and the receiver are simulated using MATLAB. The modulation scheme used is binary pulse position modulationwith time shift introduced by PPM is 0.5×10^{-9} s and the results achieved for code repetition of 3 with 2 branches for the Ideal, Selective and the Partial RAKE receivers.

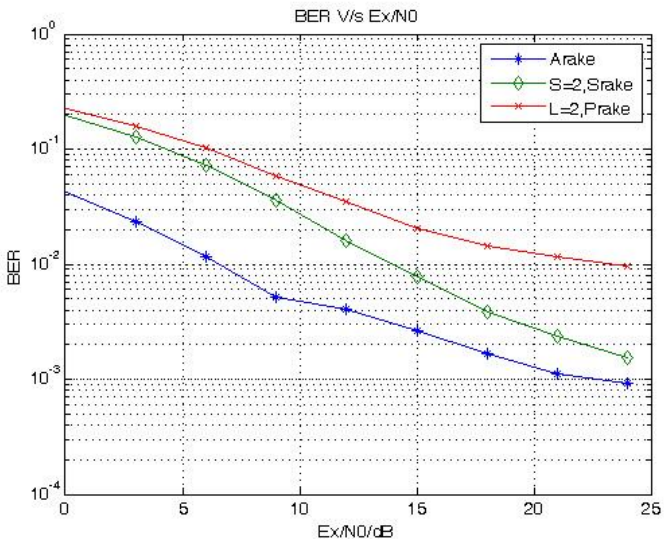

Fig.5. Analysis of 2PPM-TH-UWB for Ns = 3 with 2 branches

VII.Conclusion

In this paper all the basics of UWB modulation transmission and reception are explained in the presence of IEEE UWB channel model .We have generated the 2PPM-UWB transmitter modulation pulses and the 2PPM-UWB receiver using rake receiver configurations . All the simulations are carried out using MATLAB software. The results obtained for the rake receiver configurations shows that The Ideal RAKE Receiver gives the best results since it processes all the multi-path contributions resolved at the receiver but difficult to be implemented practically. While PRAKE is easy to implement but shows lower performance as compared to SRAKE and Ideal one. So depending upon the requirement and taking into account the cost of implementation the rake configuration can be chosen.

ISSN 1512-1232

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