An Innovative Method for UWB Channel Estimation Using Time Hopped Modulation

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Abstract—Channel knowledge is the important information required for good UWB communications. So many methods are available for UWB channel estimation. However, it is critical to find the multi-path clustered model of UWB transmission. In this paper, we present a new Innovative method with very simple and less complex channel estimation technique. We derived channel estimation equation for the Time Hopped Pulse Position Modulation (TH-PPM), and Time Hopped Pulse Amplitude Modulation (TH-PAM) based on the method of Maximum likelihood channel estimation. The simulations have been done for single user and multi user with varying number of Rake fingers. The simulation results show that TH-PAM with Gold Code System Model capable of determining the accurate channel parameters with very less computational complexity. These are characteristics does not exist in the available channel estimation methods.

Keyword- UWB, Channel Estimation, Time-Hopped Pulse Position Modulation, Time-Hopped Pulse Amplitude Modulation.

I. INTRODUCTION

The UWB systems have numerous applications due to following advantages of unlicensed usage of an extremely wide-band spectrum and usage of a spectrum greatly increases spectral efficiency and opens new doors for wireless applications. UWB (both impulse radio and multi-carrier) is also offers great flexibility of spectrum usage. This system is characterized, by a variety of parameters that can enable the design of adaptive transceivers, and that can be used for optimizing system performance as a function of the required data rate(on the order of 1 Gbps), range, power, quality of- service, and user preference. Excellent time resolution is the key benefit of UWB signals for ranging applications. Due to the extremely short duration of transmitted pulses, sub decimeter ranging is possible. In IR-UWB systems, no up/down-conversion is required at the transceivers, with the potential benefit of reducing the cost and size of the devices. Other benefits of UWB include low power transmission and robustness against eavesdropping (since UWB signals look like noise).

Ultra Wide Band (UWB) technology consists of transmitting radio signals over frequency bandwidth from 500 MHz to several GHz Recent communication requires higher data rate than ever, and the UWB communication system has drawn a lot of interest as a promising scheme to realize this requirement. UWB signaling is being considered for high data rate wireless multimedia applications for the home entertainment and personal computer industry, low data rate sensor networks with low power devices. It is also considered a potential candidate for alternate physical layer protocols for the high-rate IEEE 802.15.3 and the low-rate IEEE 802.15.4 wireless personal area network (WPAN) standards. The application of UWB system requires knowledge of the Propagation channel where the system is to be implemented. Characterization of the channel has been done by estimating path delays and attenuation of the signals. The main motivation of this work is to introduce a system with low complexity and exact extraction of channel parameters. Most of the methods mentioned before have high complexity.

Ultra Wide-band Communication is divided into two groups of Single band, Multiband. Time-hopping spread-spectrum impulse radio (TH-UWB) and direct-sequence spread- spectrum impulse radio (DS-UWB) are the techniques for single band impulse systems. A multi-band radio system could use hybrid frequency-hopping / multi-carrier spread-spectrum (MC-SS) are Multiband carrier impulse radio Systems. This paper is discussed about single-band impulse radio systems where narrow pulses (< 1 ns) are transmitted. We analyze the performance of the two spread sequences. They are applied in DA channel estimation and NDA channel estimation.

Multiple-Access (MA) can be implemented using the techniques such as Time-Hopping Pulse-Position-Modulation (TH-PPM) or Time-Hopping Pulse-Amplitude-Modulation (TH-PAM) or Direct-Sequence (DS) spread-spectrum [4], [5]. Due to large bandwidth, UWB systems produce high resolution different path with delays of a nanosecond. To capture the signal energy spread over a multi-path environment, RAKE receiver consisting of correlators are used [6], [7]. Channel knowledge is the very essential factor affect the performance for RAKE receiver. So channel estimation is an important task of the receiver. In UWB systems, Channel parameters can be estimated by the optimum and sub-optimum method. The Maximum Likelihood (ML) method is the accurate method with high complexity. Since UWB channels exhibit clusters [8], a cluster-based channel estimation method is proposed in [10]. Different methods such as ML method subspace approach and first-order cycle-stationary-based method [11] are proposed for blind channel.

The rest of the paper is organized as follows. Section II, System Description, introduces IEEE UWB channel model and TH-PPM signaling. The proposed method is explained in Section III. Finally, the simulation results are presented in Section IV and conclusions are drawn in Section V.

II. SYSTEM DESCRIPTION

A. An IEEE UWB Channel Model

IEEE UWB standard channel model [6] is used in this paper. In this model, multi-paths arrive in clusters. The mathematical form of the channel impulse response is as follows.

The IEEE UWB channel model is based on the Saleh– Valenzuela model where multi-path components arrive in clusters [2] this multi-path channel can be expressed as.

$$h(t) = X \sum_{k=1}^{K} \sum_{l=0}^{L} \alpha_{k,l}\, \delta\left(t - T_l - \tau_{k,l}\right) \qquad (1)$$

Where the real-valued multi-path gain is defined by $\alpha_{k,l}$, for cluster l and ray k. The l^{th} cluster arrives at T_l and its K^{th} ray arrives at $\tau_{k,l}$ which is relative to the first path in cluster (i.e.) $\tau_{0,l}$. The inter arrival time between two clusters $T_{l+1} - T_l$ or two rays within one $\tau_{k+1,l} - \tau_{k,l}$ is exponentially distributed. Clearly, the inter arrival time between any two rays is not an integer multiple of the pulse duration.

Log-normal shadowing is modeled with $X=10^{n/20}$ where n has a normal distribution with mean μ equal to 0 dB and standard deviation σ equal to 3 dB. There are four models, CM1, CM2, CM3 and CM4,[4] with different channel characteristics. NP_{10} dB is the number of paths within 10 dB of the strongest path and NP 85% gives the number of paths containing 85 percent of the energy. The above models assume that the channel impulse response is constant during transmission of one packet if it is shorter than 200 µs. Moreover, channel realizations are assumed to be independent between packets. Transmission of the information symbols is performed by repeating a short pulse p(t) called monocycle. The repetition is over NT_f frames, each of T_f duration. It is assumed that a monocycle p(t) has the shape of the second derivative of a Gaussian function with duration Tg. The pulse shape used is a typical monocycle g(t) is used [2]

$$p(t) = \left[1 - 8\pi\left(\frac{t - T_g}{T_g}\right)^2\right] exp\left[-4\pi\left(\frac{t - T_g}{T_g}\right)^2\right] \qquad (2)$$

III.SIGNAL MODEL

UWB systems have a bandwidth exceeding 2GHz and can resolve multi-path components with differential delays of a fraction of a nanosecond [8]. Two popular techniques in UWB systems are TH-SS (time hopped spread spectrum) and DS-SS (direct sequence spread spectrum).The transmitted binary baseband pulse amplitude modulated information signal (t) can be presented as $x(t)=a_i.\ g(t)$ where g(t) Second derivative of Gaussian pulse.

$$a_i = \begin{Bmatrix} -1, & i = 0 \\ 1, & i = 1 \end{Bmatrix} \qquad (3)$$

In TH-SS, a PN sequence is used to ‘pseudo-randomly’ shift the position of a periodic pulse train from its nominal position using the low duty cycle of the pulse trains, while DS-SS UWB uses high duty cycles. The signal transmitted by the desired user is modeled as [3]

$$S(t) = \sum_{i=1}^{n} m\left(t - iNT_f - a_i\Delta\right) \qquad (4)$$

Where

$$m(t) = \sum_{j=0}^{N-1} p\left(t - jT_f - c_jT_c\right) \qquad (5)$$

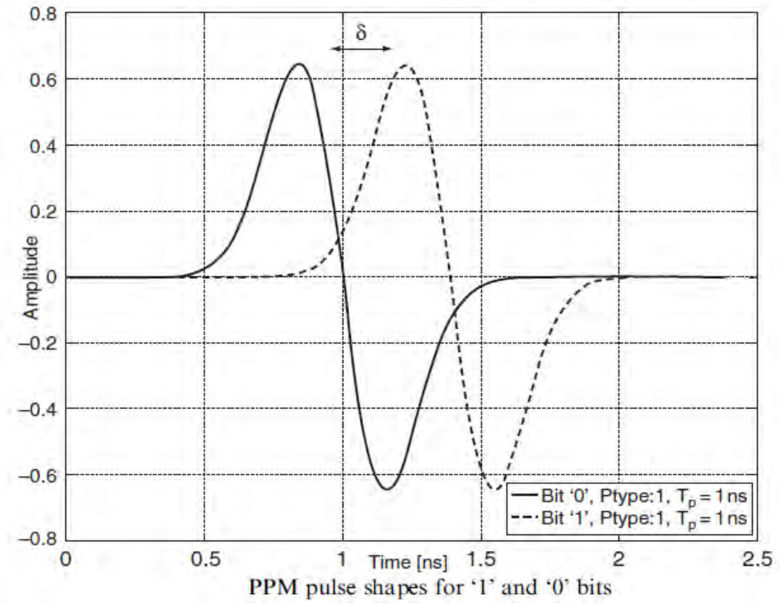

Fig.1 PPM Pulse Shapes

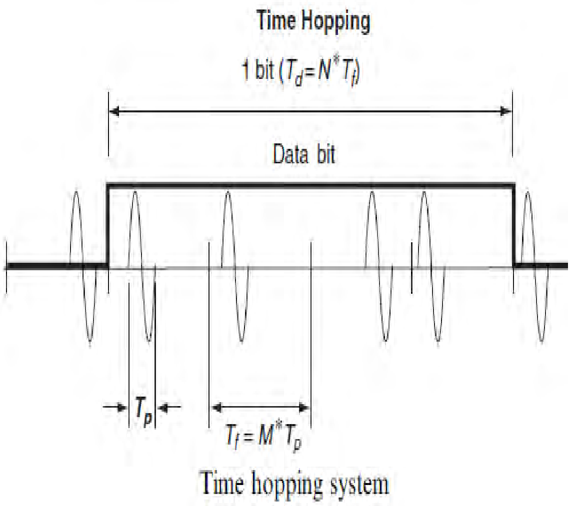

Fig.2 Time hopping frame

In the above equation, p(t) is the basic pulse used to convey information (Referred as a Gaussian monocycle) and T_f is the frame time, i.e., the separation between adjacent mono cycles when the symbols Cj are identically zero. The sequence { Cj} is the user's time-hopping code, and its elements are integers taking values in the range $0 \leq C_j \leq N_h - 1$.The choice of Δ affects the detection process, It is easily seen that they may be partially overlapped, depending on the values of T_f, Δ, Tc and $\{C_j\}$. Overlapping is not desirable.

However, as it generates inter-symbol interference (ISI) and complicates the detection process. The minimum distance (d_{min}) between the last monocycle in a block and the first in the next block is greater than twice the monocycle duration Tg.

This guarantees that no ISI occurs at the output of a filter matched to b(t) and, in consequence, optimum data detection can be performed in a symbol-by-symbol fashion.

The received signal is

$$r(t) = \sum_{l=1}^{L_c} \gamma_l S(t - \tau_l) + w(t) + m(t) \qquad (6)$$

In this equation, S(t) is the desired user's signal, γ_l and τ_l are the attenuation and the delay of the l^{th} path, w(t) is thermal noise and m(t) represents the MAI caused by the other users. Both noise affect more on signal. Based on the central limit theorem all the users share equal powers then a dominant path conveys the more information.

$$r(t) = \sum_{l=1}^{L_c} \gamma_l \, S(t - \tau_l) + w_t(t) \qquad (7)$$

The min probability of error can be achieved by computing the correlation between r(t) and v(t) where $v(t) = b(t) - b(t - \Delta)$

So

$$Y_k^{(1)} = \int_{KNT_f}^{(K+1)NT_f} r(t)\, v\big(t - KNT_f - \tau_1\big) dt \qquad (8)$$

and deciding $a_i = 1 \; iff \; Y_k^{(1)} \geq 0$ and $a_i = 0 \; iff \; Y_k^{(1)} < 0$ This leads to a Rake receiver with L fingers (Rake), This decision and correlation process is done in Rake receiver with more number of fingers. The final data decision is done with maximal ratio complaining of all the rake fingers output [6]

$$Z_K = \sum_{l=1}^{L} \gamma_l \int_{KNT_f}^{(K+1)NT_f} r(t)\, v\big(t - KNT_f - \tau_1\big) dt \qquad (9)$$

The channel parameters of attenuations and delays are unknown. To perform better response with rake receiver channel estimation is done.

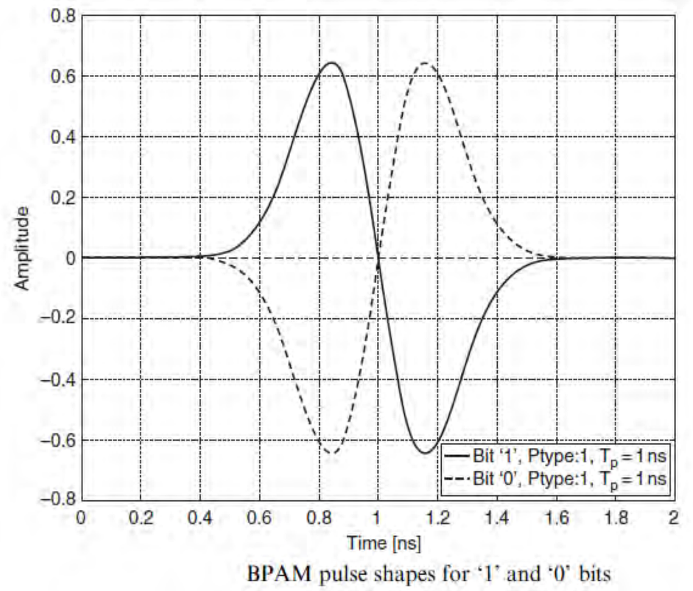

Fig. 3 Binary Pulse Amplitude Shapes

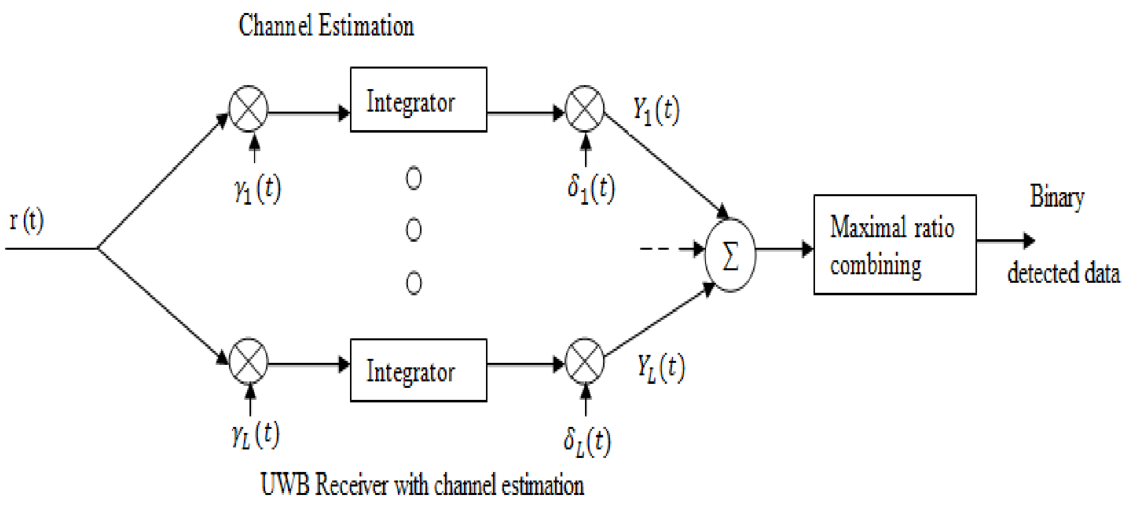

Fig.4 Rake Receiver

In order to capture energy from different paths, RAKE receiver is used because this structure is optimum for single user scenario in a multi-path environment. This receiver correlates the received signal with delayed version of the template signal and combines the weighted correlators outputs. These weights and delays correspond to channel paths delays and attenuations. Unfortunately, the number of paths in UWB propagation environments is very large, so, in order that the receiver to be implementable, a limited number of paths must be chosen. In selective RAKE with L correlators (SL-RAKE), the L strongest channel paths are exploited.

IV. RAKE RECEIVER

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V. CHANNEL ESTIMATION

In this section, we present two channel estimation methods using time hopped PAM system: DA estimation and NDA estimation. These two methods are based on the following assumption [8]

a) The channel is quasi-static.

b) No Inter symbol interference

c) Perfect synchronization

The overall noise W tot (t) has a spectral density No/2. The parameters $\gamma = [\gamma_1, \gamma_2, \gamma_3, \ldots \gamma_L]$ and $\tau = [\tau_1, \tau_2, \tau_3, \ldots \tau_L]$, are viewed as unknown deterministic quantities and, for the time being, the number of paths L is taken as a known quantity in the interval, $0 \leq T \leq T_0$ with MTf. We use a notation of the type Î to indicate a trial value of a variable and we define the possible realization of the signal is

$$\tilde{S}\,(t) = \sum_{l=1}^{L} \tilde{\gamma_l}\, S(t - \tilde{\tau}_l) \qquad (10)$$

Then, the log-likelihood function of the pair (γ,τ) takes the form

$$log[\Lambda(\tilde{\gamma}, \tau)] = 2\int_0^{T_0} r(t)\tilde{S}\,(t)dt - \int_0^{T_0} \tilde{S}^2\,(t)dt \qquad (11)$$

Neglecting the correlation between signal echoes,

Data aided estimation, Likelihood function becomes

$$\log[\Lambda(\tilde{\gamma}, \tilde{\tau})] = 2\sum_{l=1}^{Lc} \tilde{\gamma}_l \sum_{k=0}^{M-1} Z_k(\tilde{\tau}, a_k) - ME_b \sum_{l=1}^{Lc} \tilde{\gamma}_l{}^2 \qquad (12)$$

For Non data aided estimation the Likelihood estimation function becomes

$$\log[\Lambda(\tilde{\gamma}, \tilde{\tau})] = 2\sum_{l=1}^{Lc} \tilde{\gamma}_l \sum_{k=0}^{M-1} \left(\frac{Z_k(\tilde{\tau}, 0) + Z_k(\tilde{\tau}, 1)}{2}\right) - ME_b \sum_{l=1}^{Lc} \tilde{\gamma}_l{}^2 \qquad (13)$$

Where Eb is the energy of the frame

$$Z_k(\tilde{\gamma}, a_k) = [r(t) \otimes m(-t)]_{t=kNT_f + \Delta a_k + \tilde{\tau}_l} \qquad (14)$$

The above equation is sufficient to compute the ML estimates of channel parameters.

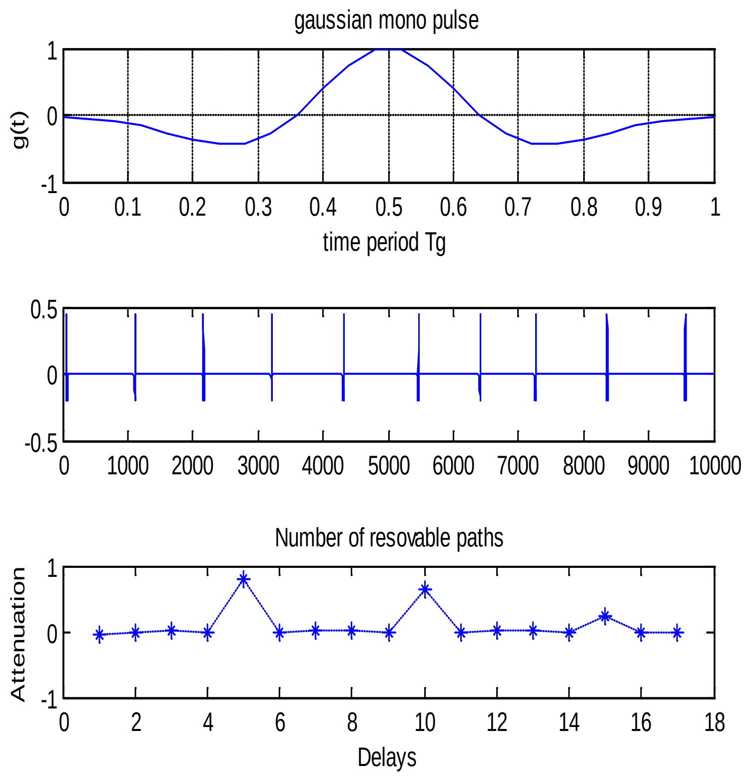

Fig.5 a.Gaussian Mono pulse b.Frame structure. C.delay

In order to maximize likelihood estimation, the expression is varying in attenuation while keeping delay is constant. After finding maximum attenuation then replace the attenuation expression in the likelihood expression with this estimated attenuation and look for maximum value of delays .

$$\gamma_l = \frac{1}{ME_b} J(\tau_l) \qquad (15)$$

$$0 \le l \le Lc$$

With

$$J(\tilde{\tau}) = \sum_{k=0}^{M-1} Z_k(\tau, a_k) \quad (16)$$

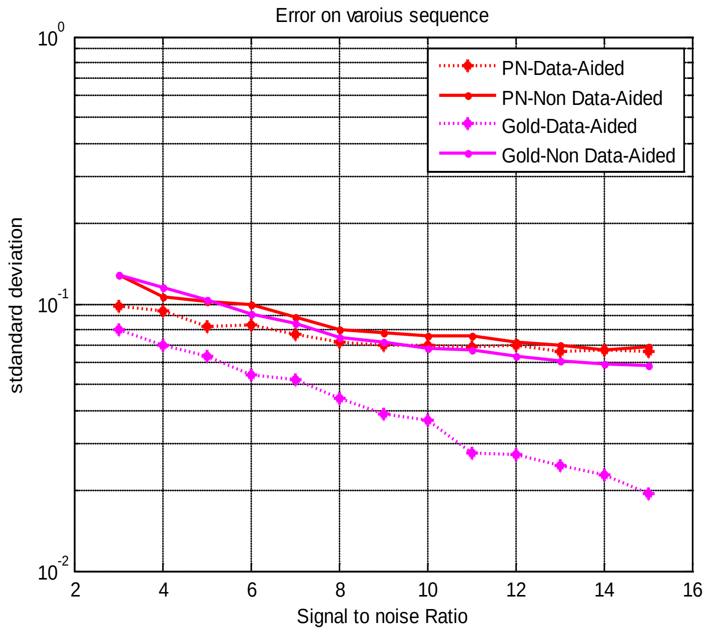

Fig.6 performance of DA and NDA Estimation

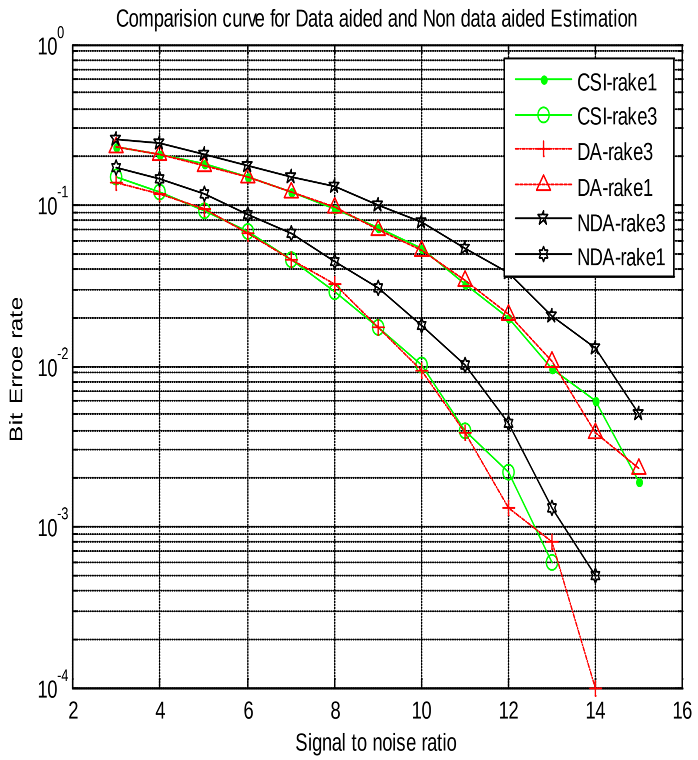

Fig.7 BER curves of variation in Fingers for CSI,DA and NDA

VI. RESULTS AND DISCUSSION

In the simulations, the pulse shape used is a typical monocycle p(t) is used [5]

$$p(t) = \left[1 - 8\pi \left(\frac{t - \frac{T_g}{2}}{T_g}\right)^2\right] exp\left[-4\pi \left(\frac{t - \frac{T_g}{2}}{T_g}\right)^2\right] \qquad (17)$$

Tg - monocycle duration=Δ, Tf=40Tg and Tc==Tf/20,(small duty cycle) ,Nh-Time hopping codes are PN sequence and gold codes. Ts=0.04Tg (may change), from Fig ,Fig.2. The estimation accuracy of the DA and NDA algorithms is done by considering three-path channels. An observation interval of a hundred symbols is chosen (M=100) and the channel parameters are τ_l =l* 5Tg (l=1, 2, 3) and γ_1 =0.85 , γ_2 =0.65 , γ_3 =0.25. It is seen that the three major positive peaks correspond to the signal echoes while the other gains vary from run to run with the Rayleigh distribution mentioned above attenuation. Hence gain and timing errors are closely equal to the assumed channel gain and delays and DA is superior to NDA. From Fig.3 the effect of imperfect channel estimation on the BER performance of an UWB PAM system with a SBR (single bit receiver) .The number of sequential rake fingers are three. The degradation in BER performance due to channel estimation errors is clearly visible[15]. This figure also shows the effect of varying the number of pilot pulses per symbol, N, on channel estimation performance. Performance for imperfect channel estimation is around 1dB worse compared to that with perfect channel estimation, which in turn is 2 dB worse than the performance of an ideal rake receiver.

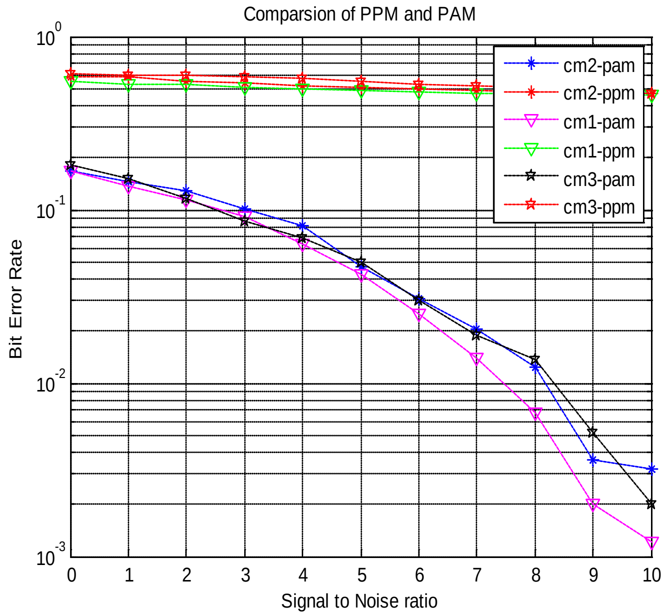

Fig.8 Performance comparison PAM and PPM

In this, paper presented a new novel approach with very simple and less complex channel estimation technique. We derived channel estimation equation for the Time Hopped Pulse Position Modulation (TH-PPM), and Time Hopped Pulse Amplitude Modulation (TH-PAM) based on the method of Maximum likelihood Data – aided channel estimation. The simulations have been done for single user and multi user with varying number of Rake fingers. The simulation results show that this method capable of finding the exact value channel parameters of delays and attenuations with very less computational complexity by selecting proper spreading sequence. These are characteristics does exist in the available channel estimation methods. We develop a data-aided estimation of the channel parameters from the received signal in UWB systems, employing TH-PPM. This method can be used in TH-PAM systems. Simulation results show that this method in single-user and multi-user scenarios performs as good as the ML method but with low complexity. In addition, we can extract the exact parameters of the impulse response of the channel by ML method.

Also, perfect power control and an estimation window of 100 symbols have been generally assumed. In these conditions, we have found that up to 10 users can be accommodated with limited BER degradations provided that DA estimation is used. The result shows that PAM performs better than PPM and gold code gives better results than Pseudo random sequence. The bit error rate is small for the UWB channel model. This shows that if number of parameters increased the estimation error also increases.

VII.CONCULSION

In this paper, we present a new Innovative method with very simple and less complex channel estimation technique. We derived channel estimation equation for the Time Hopped Pulse Position Modulation (TH-PPM), and Time Hopped Pulse Amplitude Modulation (TH-PAM) based on the method of Maximum likelihood channel estimation. The simulations have been done for single user and multi user with varying number of Rake fingers. The simulation results show that TH-PAM with Gold Code System Model capable of determining the accurate channel parameters with very less computational complexity. But this method is less complex for 10 number users. This can extend for different code with more number of users.

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