Performance Analysis of Multiuser DS-UWB system with Orthogonal and Non-orthogonal code under synchronous and Asynchronous transmission with UWB channel models

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***Abstract*—In this paper we have considered the downlink multimedia transmission with Direct Sequence-Ultra wideband (DS-UWB) [1] communication system. We have evaluated performance of DS-UWB system under multiuser scenario. We have investigated performance of the system under synchronous and asynchronous transmission. We have discussed the effect of orthogonal and non-orthogonal code selection with effect of different UWB pulse selection. Also the performance of DS-UWB with non-orthogonal code is compared with TH-PAM UWB [2]. We have considered AWGN and UWB channel model for simulation.**

***Keywords*-UWB; Synchronous-Asynchronous transmission; UWB channel model.**

I. Introduction

Ultra wideband (UWB) was known as Impulse radio [3], [4] as in principle, it uses the extremely short pulses for high speed data transmission. UWB promises to provide effective high speed data transmission in wireless personal area networks (WPAN) [5], [6]. In future WPAN networks (IEEE 802.15.3a, IEEE 802.15.4a), UWB will be the candidate at physical layer for enabling several Mbps data rate, which is quite higher than Bluetooth's data rate.

FCC assigned unlicensed spectrum of 3.1 GHz -10.6 GHz for UWB communication [7]. Signal with the fractional bandwidth (B_f) of more than 20 % at -10 dB emission points is considered as a UWB signal. Where fractional bandwidth is defined as a ratio of signal bandwidth to its centre frequency. New industrial definition for UWB signal is the signal which occupies bandwidth of more than 500 MHz in assigned frequency range, is considered as UWB signal [7]. For multiple access in UWB literatures [3], [8] suggest method based on Time Hopping (TH) technique. This access technique can be used with Pulse Position Modulation (PPM) or Pulse Amplitude Modulation (PAM) technique. Depending upon modulation scheme TH UWB signal is known as TH-PPM UWB [9], [10] or TH-PAM UWB [2]. Also Direct Sequence UWB (DS-UWB) approach proposed in [1] is same as TH-PAM UWB except minor difference. In all TH-UWB method single bit duration (T_b) is divided into number of frames (N_f) each with equal duration of (T_f). Further each frame duration (T_f) is divided into number of chips (N_c) of duration (T_c). During each chip period (T_c) UWB radio signal, which is Gaussian pulse or its derivative is transmitted depending upon unique TH code. UWB signal comprised of sub-nano second duration pulses. A sequence of pulses (N_f) are used to encode a transmitted symbol. In TH-PPM, UWB pulse will take additional delay of δ at the beginning of chip duration when data bit $'1'$ is transmitted. In TH-PAM instead of using shift of δ, antipodal signal is used for data bit $'1'$ and $'0'$.

In this paper, we have considered DS-UWB [1] method as a multiple access technique for multimedia transmission. We have considered downlink communication under multiuser environment. In this situation each user signal is identified with unique Pseudo random (PN) code. Here we investigated the performance of multiuser UWB system with DS-UWB under synchronous and asynchronous transmission. Also the effect of selection of orthogonal and non-orthogonal code is discussed with both the transmission schemes. Effect of selection of UWB pulse shape is discussed. Finally we have compared performance of DS-UWB multiuser system with TH-PAM UWB multiuser system with non-orthogonal codes.

Paper is organized as follows, In Section II, we have discuss the general scenario for downlink communication with multimedia transmission under multiuser environment. In section III the system model for DS-UWB is discussed. In section IV we have described the system model for TH-PAM UWB. Section V discusses different UWB channel model. In section VI we showed simulation results with AWGN and UWB channel for synchronous and asynchronous transmission. Also effect of selection of code is discussed in detail. Performance comparison with TH-PAM UWB has been discussed in section VI. Finally in Section VII, we conclude our work and discuss future scope in Section VIII. This work is an extension of our previously published paper [11].

II. Multimedia transmission scenario for UWB Communication

Figure 1 shows multimedia transmission scenario with UWB for multiuser environment. where different users (or Multimedia devices) data is transmitted by UWB device. Here, we have considered that this UWB device transmits data by, DS-UWB [1] or by other TH access technique [2], [9], [10]. We considered that this UWB device transmits data under two cases as synchronous and asynchronous transmission. This UWB device adds all users signal and transmits information together over downlink channel. Hence UWB device itself adds multiuser interference (MUI) in system.

To make uniformity throughout discussion we have considered all multimedia devices data as different users data and performance is discussed by considering multiuser environment for multimedia transmission.

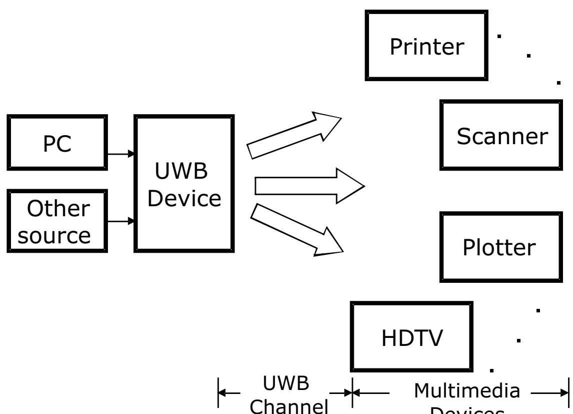

Figure 1. Multimedia Transmission scenario for UWB communication.

III. DS-UWB system

A. System Model DS-UWB

For Ultra wideband transmission, DS-UWB multiple access scheme is proposed in [1]. In DS-UWB one bit duration (T_b) is divided into number of frames (N_f) each with equal duration (T_f) such that T_b=N_f T_f. During each frame UWB pulse is transmitted which is Gaussian monocycle or Scholtz Monocycle. This pulse is a subnano second pulse. In Multiuser environment DS-UWB signal is represented as

$$s^{(k)}(t) = \sum_{i=-\infty}^{\infty} \sum_{j=0}^{N_f-1} d_{(i)}^{(k)} w(t - jT_f)$$

$s^{(k)}(.)$ is k^{th} user signal, $d_i^{(k)}$ is k^{th} user bipolar spreaded data, which is defined as $d_i^{(k)} = b_i^{(k)} c_i^{(k)}$. Where $b_i^{(k)}$ is k^{th} user raw data and $c_i^{(k)}$ is k^{th} user code. N_f is number of frames per bit, $w(.)$ is UWB pulse. Before transmission UWB device combines the entire users signal.

B. Receiver Configuration for DS-UWB

Received signal is contaminated by multipath fading and AWGN which is given as

$$r(t) = \int_0^{\infty} h(\tau, t) s(t - \tau)\, d\tau + n(t)$$

Where $h(\tau, t)$ is channel response, $n(t)$ is AWGN and $s(t)$ is

$$s(t) = \sum_{k=1}^{N} \sum_{i=-\infty}^{\infty} \sum_{j=0}^{N_f-1} d_i^{(k)} w(t - jT_f)$$

N is total number of users in the system. For synchronous transmission τ is zero. Here receiver is correlation based receiver as described in [1]. In which locally template $p(t)$ is generated and data is recovered by correlation receiver. Template $p(t)$ is defined as $p(t) = \sum\limits_{j=0}^{N_f-1} w(t - jT_f)$. Correlation receiver output Z which is defined as $z = \int\limits_0^{Tb} r(t)p(t)dt$. Using z decision is made in favour of transmitted data bit. After this particular user data is demodulated by code $c^{(k)}(.)$.

IV. TH-PAM UWB system

A. System Model for TH-PAM UWB system

In literature [2] TH-PAM UWB system is considered for Ultra wideband communication. In TH-PAM UWB single bit duration (T_b) is divided into N_f number of frames each with equal duration T_f, so $T_b = N_f T_f$. Further each frame is divided into N_c chips with chip duration of T_c such that $N_c T_c \le T_f$. During each frame UWB pulse is transmitted which is either Gaussian monocycle or Scholtz Monocycle. UWB pulse occupy one chip slot depending on time hopping code c_j which can take value such that $0 \le c_j \le N_c - 1$. During each bit duration N_f UWB pulses are transmitted by TH-PAM transmitter. For modulation antipodal pulses are used. TH-PAM UWB signal is represented as

$$s^{(k)}(t) = \sum_{i=-\infty}^{\infty} \sum_{j=0}^{N_f-1} d_{(i)}^{(k)} w(t - jT_f - c_j^{(k)} T_c)$$

Where $S^{(k)}(.)$ is k^{th} user signal, $d_{(i)}^{(k)}$ is k^{th} user bipolar data, N_f is number of frames per bit and $w(.)$ is UWB pulse.

B. Receiver Configuration for TH-PAM UWB system

Received signal is contaminated by multipath fading and AWGN which is given as

$$r(t) = \int_0^{\infty} h(\tau, t) s(t - \tau)\, d\tau + n(t)$$

Where $h(\tau, t)$ is channel response, $n(t)$ is AWGN and $s(t)$ is

$$s(t) = \sum_{k=1}^{N} \sum_{i=-\infty}^{\infty} \sum_{j=0}^{N_f-1} d_{(i)}^{(k)} w(t - jT_f - c_j^{(k)} T_c)$$

N is total number of users in the system. Here receiver is correlation based receiver. In which locally template $p(t)$ is generated and data is recovered by correlation receiver. Correlation template $p(t)$ for k^{th} user is defined as,

$$p(t) = \sum_{j=0}^{N_f-1} w(t - jT_f - c_j^{(k)} T_c)$$

Correlation receiver generate output Z, which is given as $z = \int_0^{Tb} r(t)p(t)dt$. Using z decision is made in favour of transmitted data bit.

In DS-UWB and TH-PAM UWB, we have considered AWGN channel so for equiprobable binary symbols correlation receiver gives optimum results.

V. UWB CHANNEL MODEL

In wireless channel multipath fading [12] will take place due to scattering, reflection and refraction. This fading can be slow fading or fast fading, which will change parameter of received signal envelope and phase. This fading problem is more critical in indoor channel due to presence of many scatterers. So perfect channel modelling is required for improving performance of receiver.

By considering the assumption of static scatter the Channel impulse response(CIR) for time-invariant channel is given as,

$$h(t) = \sum_{n=0}^{N} \alpha_n \delta(t - \tau_n) \quad (1)$$

Here N is number of multipath components, α_n is attenuation for n^{th} path and τ_n is delay for n^{th} path. In UWB the channel model is based on Saleh-Valenzuela model [13].

A. UWB channel model recommendation by IEEE 802.15.3a working group

IEEE 802.15.3a working group has suggested channel model for indoor UWB communication. This model should be used for evaluating the performance of different physical layer proposal. This proposed model is based of input given by [13]–[21]. UWB channel model is cluster based model. In this model(SV model) the same pulses multipath components are grouped in to cluster. This cluster arrival is modelled as a Possion process with arrival rate of λ as,

$$P(T_n|T_{n-1}) = \lambda e^{-\lambda(T_n - T_{n-1})} \quad (2)$$

Here, T_n is time of arrival for n^{th} cluster and T_{n-1} is time arrival of $(n-1)^{th}$ cluster. In each cluster the multipath components of same pulse is also model as a Possion process with arrival rate of Δ as,

$$P(\tau_{ni}|\tau_{(n-1)i}) = \Delta e^{-\Delta(\tau_{ni} - \tau_{(n-1)i})} \quad (3)$$

Here,τ_{ni} is time of arrival of the n^{th} pulse in the i^{th} cluster and $\tau_{(n-1)i}$ is time of arrival of the $(n-1)^{th}$ pulse in the i^{th} cluster. The gain of the n^{th} pulse in i^{th} cluster is complex random variable as

$$A_{ni} \angle \Theta_{ni} \quad (4)$$

with,

$$p(A_{ni}) = \frac{2A_{ni}}{E\left[|A_{ni}|^2\right]} e^{-\frac{A_{ni}^2}{E\left[|A_{ni}|^2\right]}} \quad (5)$$

and

$$p(\Theta_{ni}) = \frac{1}{2\pi} with 0 \leq \Theta_{ni} \leq 2\pi \quad (6)$$

Here,

$$E\left[|A_{ni}|^2\right] = E\left[|A_{00}|^2\right] e^{-\frac{Tn}{\Gamma}} e^{-\frac{\tau ni}{\gamma}} \quad (7)$$

A_{00} is the energy of the first path of the first cluster, Γ and γ power decay profile for cluster and components within cluster respectively. IEEE working group has suggested some variation in this SV model to make it more realistic channel model for UWB as, multipath gain amplitudes are considers as log-normal distributed. The UWB channel model is described as,

$$h(t) = X \sum_{n=1}^{N} \sum_{k=1}^{K(n)} \alpha_{nk} \delta(t - T_n - \tau_{nk}) \quad (8)$$

X is log-normal distributed which represent the gain of channel.N is number of clusters, $K(n)$ is the number of multipath components of same UWB pulse within the N^{th} cluster. α_{nk} is magnitude of component in N^{th} cluster. τ_{nk} is delay of component in N^{th} cluster. The channel coefficient $\alpha_{nk} = \pm(1)_{nk}\beta_{nk}$, whereβ_{nk} is the log-normal distributed channel coefficient of multi-path components k for cluster n. β_{nk} is defined as $\beta_{nk} = 10^{\frac{x_{nk}}{20}}$ Where x_{nk} is assumed to be a Gaussian random variable with μ_{nk} mean and σ_{nk}^2 variance. The random variable x_{nk} is further decomposed as,

$$x_{nk} = \mu_{nk} + \xi_n + \zeta_{nk} \quad (9)$$

Where ξ_n andζ_{nk} are two Gaussian random variables which represent the variation of the channel coefficient on each cluster and in each path within cluster respectively.

Finally channel model of UWB channel is described by,

$$h(t) = X \sum_{n=1}^{N} \sum_{k=1}^{K(n)} \alpha_{nk} \delta(t - T_n - \tau_{nk}) \quad (10)$$

With following parameters,

The cluster arrival rate of λ

UWB pulse arrival rate with in cluster is Δ

Power decay profile of cluster and pulse with cluster is Γ and γ

The variance of σ_ξ^2 and σ_ζ^2 for variation of fluctuations of channel coefficient for cluster and pulse within cluster respectively.

This parameters are defined for different four cases of UWB communication as mentioned in table I below,

Table I
PARAMETERS FOR UBW CHANNEL MODEL

Case	Λ	λ	Γ	γ	σ_ξ	σ_ζ
Case A	0.0233	2.5	7.1	4.3	3.3941	3.3941
Case B	0.4	0.5	5.5	6.7	3.3941	3.3941
Case C	0.0667	2.1	14	7.9	3.3941	3.3941
Case D	0.0667	2.1	24	12	3.3941	3.3941

Here Case A is Line of sight(LOS) communication between transmitter and receiver with maximum separation between them is 2 meter, Case B is Non line of sight(NLOS) communication between transmitter and receiver with maximum separation between them is 2 meter, Case C is NLOS with 8 meter of maximum TR separation. Case D is Extreme NLOS multipath channel with maximum TR separation of 8 meter. Based on IEEE 802.15.3a channel model recommendation, figure 2, 3, 4, 5 illustrate the four typical power delay profile (PDP) of UWB channel model. From this PDP it is clear that in channel model case A the first received component has highest energy compared to subsequent component. So in this case if we use partial RAKE with lower fingers then we can expect good result. From figure 3 it can be seen that near to several strongest peak smaller peaks are surrounded. This indicates that channel response is combinations of the several overlapping clusters. Also the strongest peak is not first one but is can occur at any position in sequence due to reflections from scatterer. So here partial RAKE will not give expected result but we have to select the strongest component in cluster hence SRAKE is required to use. From channel model C figure 4, it can be seen that here channel is more time dispersive. Components are available up to around 70 nsec, while in case A and B it is available up to around 40 nsec. This indicate that here we have to use selective RAKE to achieve desired result. From figure 5 it can be seen that channel in this case is more time dispersive and components are available till 150nsec. So here the effective data rate goes down to achieve the ISI free communication. In this case more fingers required to consider for achieving good SNR at receiver.

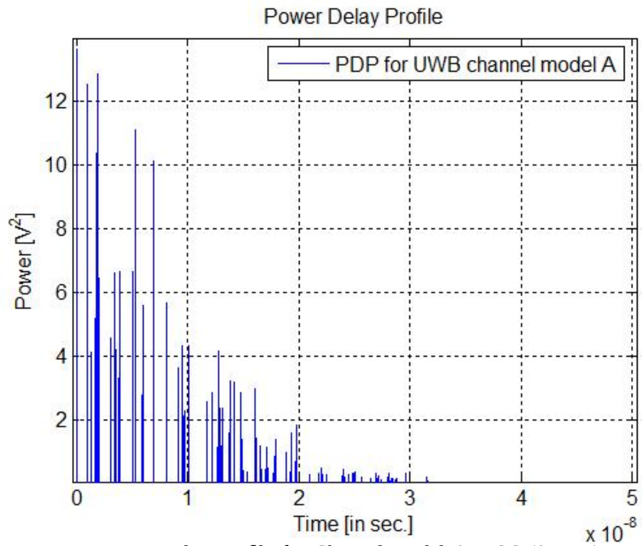

Figure 2. Power Delay Profile for Channel model A, LOS (0-4 mt).

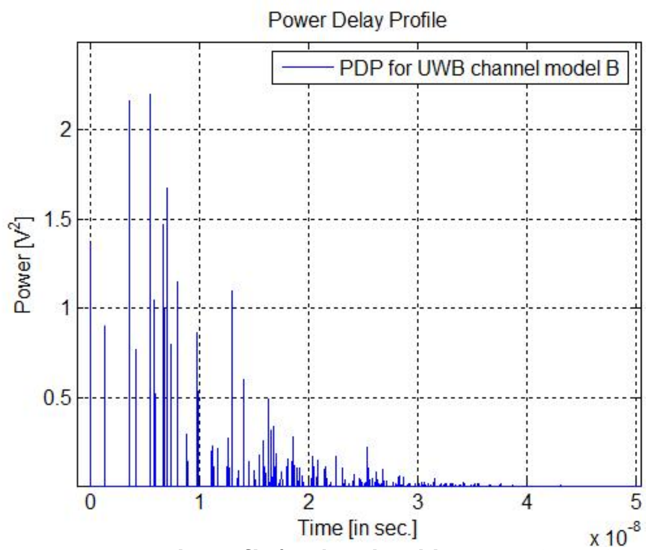

Figure 3. Power Delay Profile for Channel model B, NLOS (0-4, mt).

VI. SIMULATION RESULTS

Here we have investigated performance of DS-UWB system under synchronous and asynchronous transmission with orthogonal and non-orthogonal code. We investigated performance under AWGN channel. Bit error rate is used as performance comparison criterion. Also performance of DS-UWB is compared with TH-PAM UWB [2] with non-orthogonal code. For DS-UWB simulation parameters are shown in Table 1. For TH-PAM UWB simulation parameters are shown in Table 2. In both the cases performance is evaluated with Gaussian pulse shape and Scholtz monocycle as a UWB pulse.

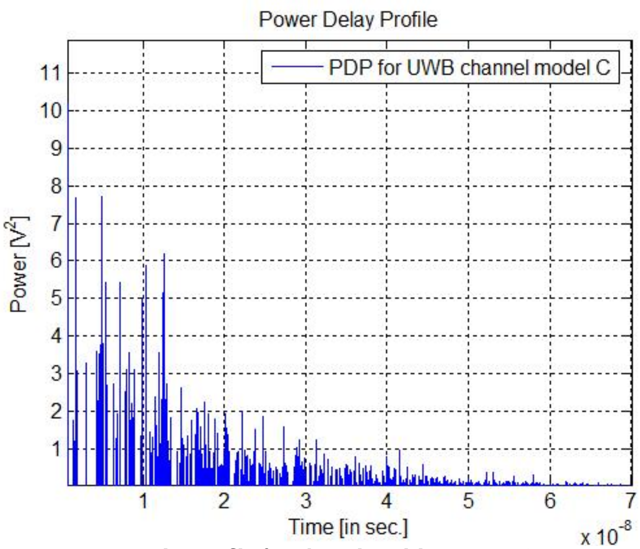

Figure 4. Power Delay Profile for Channel model C, NLOS (4 to 8mt).

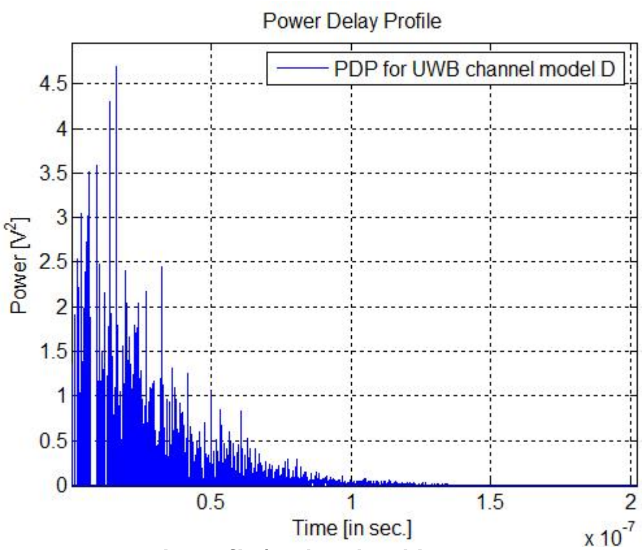

Figure 5. Power Delay Profile for Channel model D, extreme NLOS (up to 8 mt).

Figure 6 shows performance of DS-UWB with orthogonal code under synchronous transmission. Here it can be seen that with compared to two user case almost 1 dB more power is required when number of users are eight in system with Gaussian pulse as a UWB signal. When Scholtz monocycle is considered as a UWB pulse almost same behaviour is observed. When Gaussian pulse shape is selected, under both the cases of two and eight users performance is better compared to Scholtz monocycle. This improvement factor is around 1 dB. Figure 7 shows the performance of DS-UWB with orthogonal code under asynchronous transmission. Here almost same performance is achieved with two and eight users under selection of Gaussian UWB pulse and Scholtz UWB pulse. From figure

Table II
SIMULATION PARAMETERS FOR DS-UWB SYSTEM

DS-UWB Parameters	
Number of users	2 and 8
Data rate	62.5 Mbps
Number of frames (N_f)	8
Frame duration (T_f)	$2nsec$
UWB pulse duration (T_p)	$0.5nsec$
Pulse shape factor(τ)	$0.25nsec$
Async. transmission Delay	$< 2nsec$

Table III
SIMULATION PARAMETERS FOR TH-PAM UWB SYSTEM

TH-PAM UWB Parameters	
Number of users	2 and 8
Data rate	62.5 Mbps
Number of frames (N_f)	8
Frame duration (T_f)	$2nsec$
Number of chips (N_c)	3
Chip duration (T_c)	$0.67nsec$
UWB pulse duration (T_p)	$0.5nsec$
Pulse shape factor(τ)	$0.25nsec$
Async. transmission Delay	$< 2nsec$

6 and 7 we can see that almost same performance is achieved in DS-UWB with orthogonal code under synchronous and asynchronous transmission. If numbers of users are more than eight then system performance degrade as code would lose its orthogonality property as number of frames (N_f) are eight in DS-UWB. Under asynchronous transmission if the asynchronous transmission delay (τ) will more than frame duration (Here $2nsec$) then performance also degrade.

Figure 8 and 9 shows performance of DS-UWB with non-orthogonal code under synchronous and asynchronous transmission respectively. From figure 8 it can be seen that system performance degrades by large amount under synchronous transmission. From figure 8 it is clear that non-orthogonal code should not be selected under synchronous transmission. Also it can be seen that with Gaussian UWB pulse shape improvement factor is almost 1 dB compared to Scholtz monocycle as UWB pulse. In figure 9 performance under asynchronous transmission is shown with non-orthogonal code. Here almost 2dB improvement is achieved with two users compared to eight users case with both, Gaussian and Scholtz UWB signal. From figure 7 and 9 it can be seen that DS-UWB system performs better with orthogonal code under asynchronous transmission.

Also we have compared performance of DS-UWB with TH-PAM UWB [2] with non-orthogonal code. Here Gaussian pulse shape is considered as UWB pulse for comparison in both the cases. Here we evaluated the performance for non-orthogonal code. To accommodate large number of user under orthogonal code we need to select more chips/frames which actually puts limitation on effective data rate. In TH-PAM UWB number of chips (N_c) are three and to accommodate eight users with orthogonal code require eight

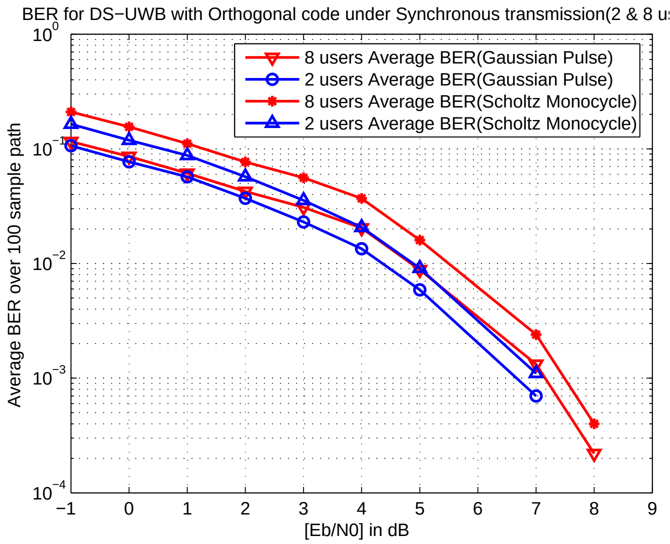

Figure 6. Avg. BER with orthogonal code and Synchronous transmission.

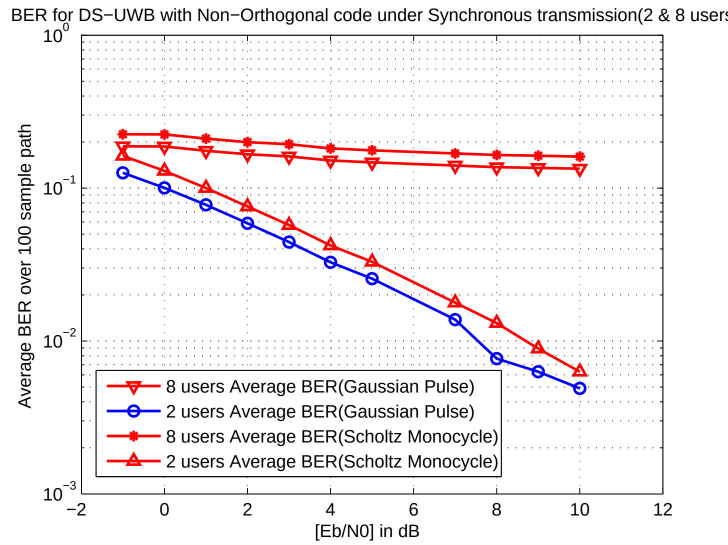

Figure 8. Avg. BER with Non-orthogonal code and Synchronous transmission.

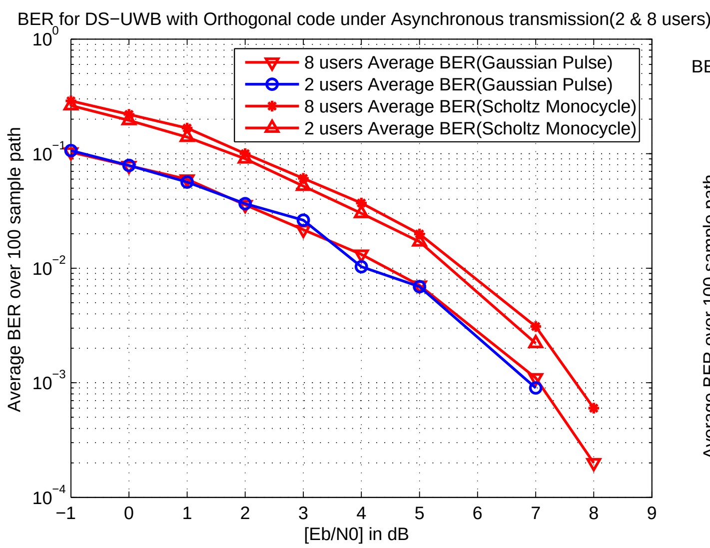

Figure 7. Avg. BER with orthogonal code and Asynchronous transmission.

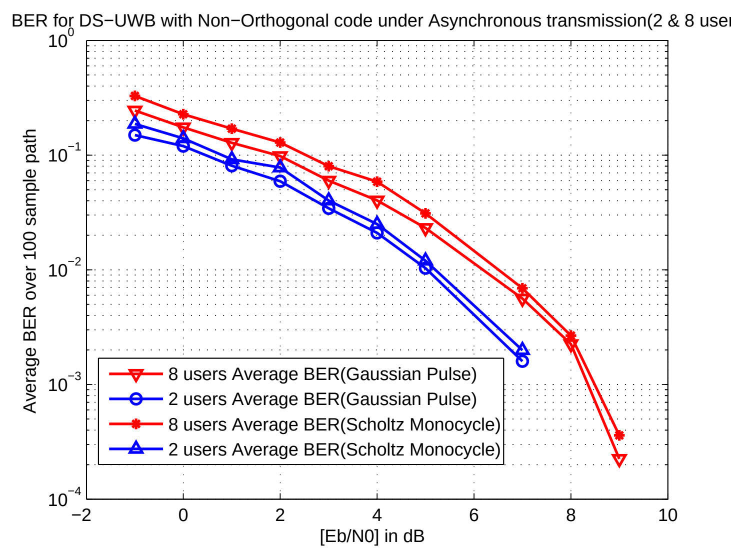

Figure 9. Avg. BER with Non-orthogonal code and Asynchronous transmission.

chips (N_c) which is not possible for the case which we have considered here in simulation. In TH-PAM UWB, selection of orthogonal code is possible if we select eight chips (N_c) by reducing data rate in system (parameter in Table 2). From figure 10 we can see that DS-UWB performs better compared to TH-PAM UWB under synchronous and asynchronous transmission. Under asynchronous transmission this improvement factor is of 1dB with eight users. For less interfering signals this improvement factor will be more. Figure 11 shows performance of DS-UWB under different users condition with orthogonal and non-orthogonal code with synchronous and asynchronous transmission.

Figure 12,13, 14 and 15 shown performance of DS-UWB with Different UWB channel model. Here in simulation we have consider perfect equalization of UWB channel. Figure 12 and 13 shows the performance of DS-UWB with UWB channel model A and B. Figure 12 shows the performance of UWB system with two and eight users under asynchronous transmission with non orthogonal code as a signature waveform. Except the synchronous transmission all parameters for simulation is same in Figure 13 as 12. From Figure 13 it is seen that under synchronous transmission for better performance orthogonal codes are required.

Figure 14 and 15 shows the performance of DS-UWB system with UWB channel model C and D. Same observation as channel model A and B is seen here.

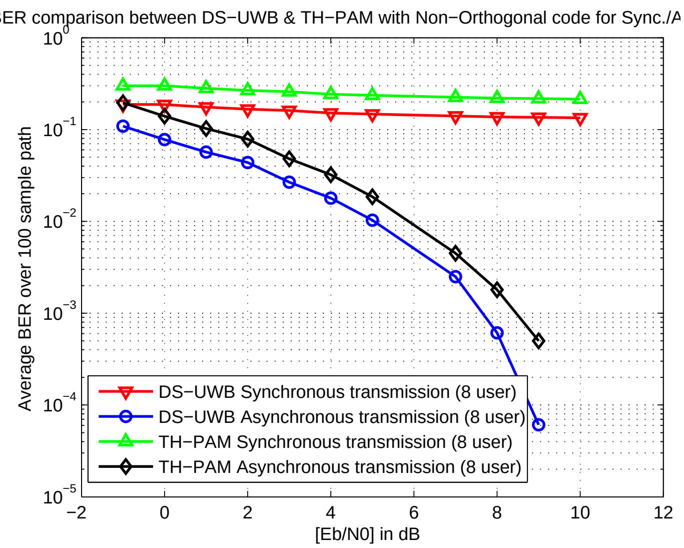

Figure 10. Avg. BER comparison with TH-PAM and DS-UWB with sync. and Async. transmission(8 users).

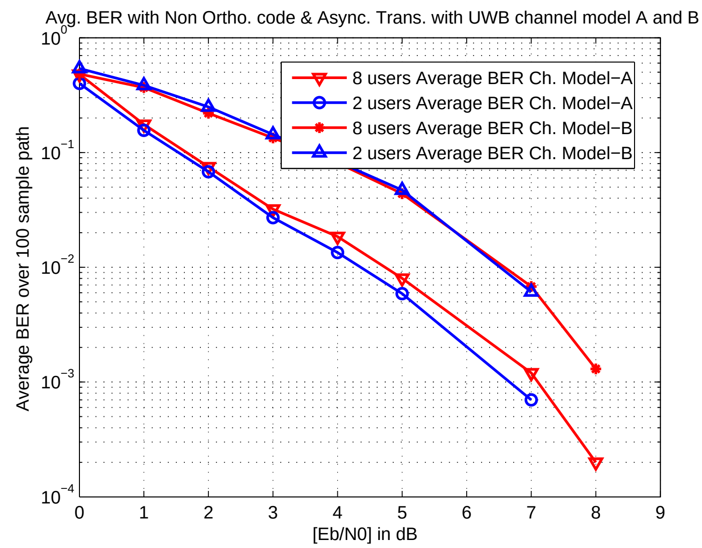

Figure 12. BER Performance with different users under Non Ortho. code with Async. Transmission (UWB ch. Model A B).

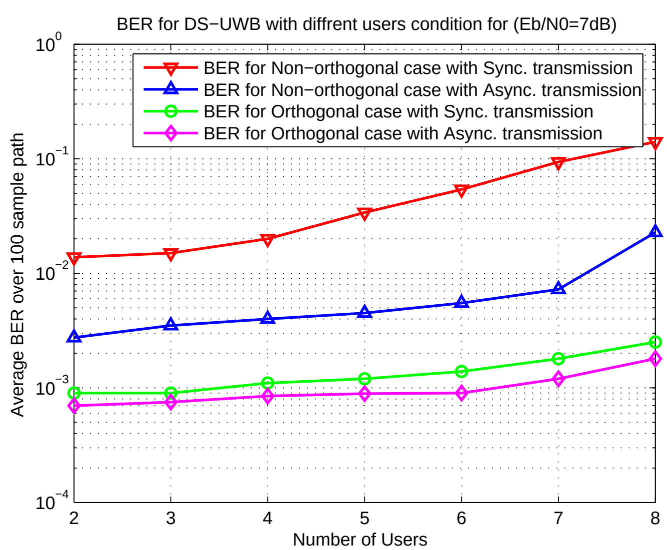

Figure 11. BER Performance with different users under different code with Sync and Async. transmission.

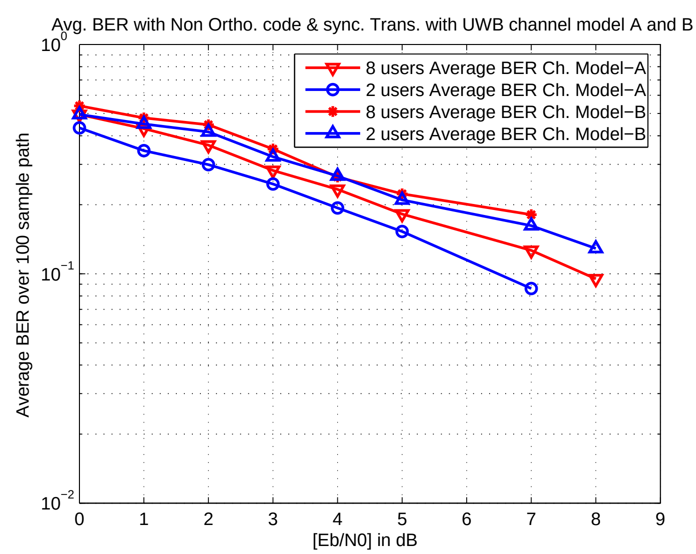

Figure 13. BER Performance with different users under Non Ortho. code with Sync. Transmission (UWB ch. Model A B).

VII. Conclusion

Here we have investigated performance of multiuser DS-UWB system with orthogonal and non-orthogonal code under synchronous and asynchronous transmission. BER is evaluated for each case with AWGN channel. Here it is seen that DS-UWB system performs equally with orthogonal code under synchronous and asynchronous transmission. When asynchronous transmission is considered in DS-UWB with non-orthogonal code, almost 2dB improvement is achieved with two users compared to eight users case. System performance degrade drastically when non-orthogonal codes are used under synchronous transmission. Under same situation system performs little better with asynchronous transmission. Also DS-UWB system perform better compared to TH-PAM UWB in multiuser environment. Non-orthogonal code with higher spreading factor can be selected in multiuser DS-UWB system when all users transmit data under asynchronous transmission. In multiuser environment asynchronous transmission is the more general case so in multiuser DS-UWB system non-orthogonal code can be chosen for increasing the capacity. Gaussian pulse shape gives better performance compared to Scholtz mono cycle as UWB pulse. For synchronous transmission orthogonal code

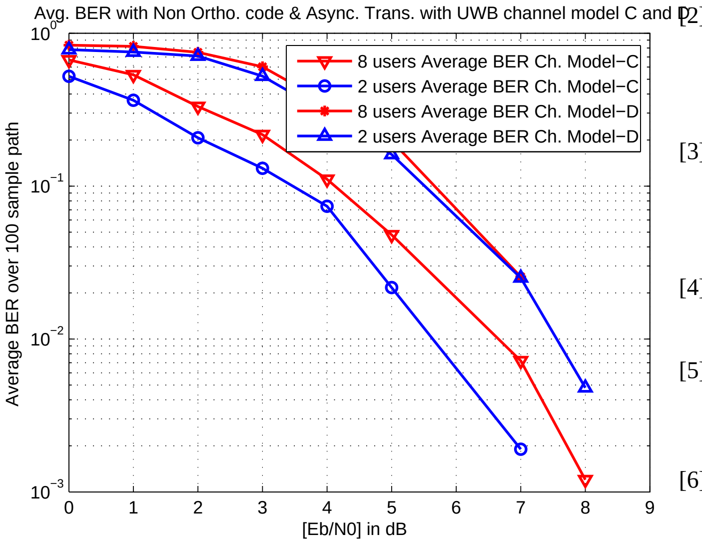

Figure 14. BER Performance with different users under Non Ortho. code with Aync. Transmission (UWB ch. Model C D).

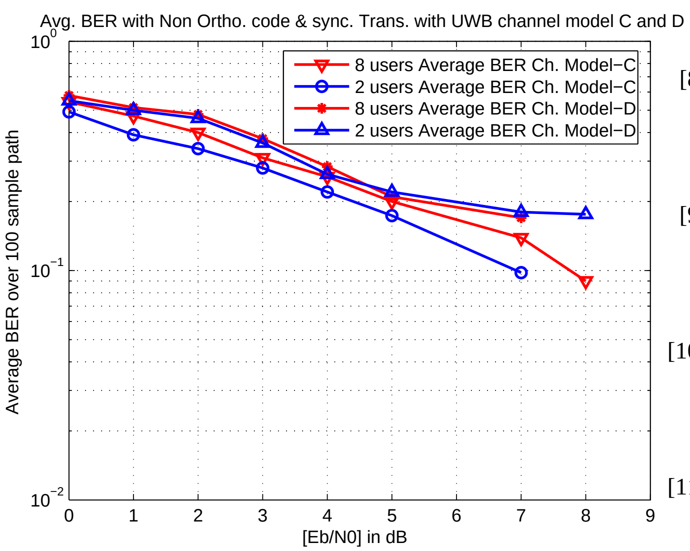

Figure 15. BER Performance with different users under Non Ortho. code with Sync. Transmission (UWB ch. Model C D).

is required with multiuser DS-UWB system.

VIII. Future Work

In this paper the system performance is evaluated with correlation based receiver. We will extend our work and ensure the performance of DS-UWB and other types of UWB system under multiuser environment with adaptive multiuser detection techniques [22].

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