# Timing Offset Estimation in IEEE 802.15.4a Channel Model for UWB-IR Receivers

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**Abstract – This paper demonstrates timing synchronization in impulse radio UWB systems. An insight into various UWB modulation schemes is provided, and an overview of the state-of-the art synchronization techniques is discussed. Ultra wideband has significance for both high-data-rate (HDR) and low-data-rate (LDR) short range communications. In wireless communication UWB technology is a reliable transmission scheme for high data rates. In this paper data aided (DA) synchronization is used for UWB-IR receivers for single user in IEEE 802.15.4a channel. Random timing offset using Walsh codes is estimated before every transmitted sequence which further act as pilot sequence to achieve timing synchronization. In order to show the performance of pilot sequence, SNR Vs BER graph is plotted for different modulation schemes. Further in order to alleviate the negative effects of timing offset it can be helpful.**

**Index Terms – Ultra-wide band Impulse radio (UWB-IR), IEEE 802.15.4a channel model, Sliding correlation window, Walsh code, Error variance.**

## 1. INTRODUCTION

With the growing capacity in wireless communication a new type of method is required which does not interfere with current systems. UWB is the new technology that does not interfere with current system and in addition promises low power and high processing gain. Channel estimation and synchronization are important tasks for the performance of UWB systems. In this paper, the performance of the UWB system is presented in terms of bit error rate (BER). It is shown that in system uplink and downlink the techniques used for synchronization and channel estimation have good performance. Impulse radio UWB are baseband pulses of very short duration. Frequency up-conversion and down-conversion is not required in the transceiver due to carrier less nature of IR-UWB. Due to carrier less nature of IR-UWB complexity and power consumption of transceiver is reduced and is suitable for low-complexity and low power wireless sensor network applications. In short data transmission range it can be used possessing high bandwidth.

Pulses of UWB are of very short duration in order of nanoseconds. These pulses are called monopulses. The signal energy here is expanded consistently. The energy of these pulses are widened over a few gigahertzes, due to which the signal becomes ultra wideband. Power spectral density for these devices is -41.3 dBm/MHz, or 75 nW/MHz. In UWB short data pulses are transmitted. It is invulnerable from problems such as sensitivity, fading or multipath effects, due to extremely short duration of pulses which the existing systems now days suffer. The information here is encoded in baseband signal and does not require a continuous carrier frequency, due to which UWB does not suffer from problems including sensitivity to multipath propogation. These properties of UWB give rise to fine time resolution, rich multipath diversity, low probability of detection, enhanced penetration capability, high user-capacity, and potential spectrum compatibility with existing narrowband systems.

## 2. UWB SYSTEM

There are two common forms of UWB called multicarrier UWB (MC-UWB) and impulse radio UWB (IR-UWB). In this thesis, IR-UWB systems are considered, however, an overview of both systems is given briefly in the following subsections.

### ➢ MC-UWB System

The approach using multiple simultaneous carriers for transmission of UWB signals is called MC-UWB or frequency domain UWB. Orthogonal Frequency Domain Multiplexing (OFDM) is a special case of multicarrier transmission that permits subcarriers to overlap in frequency without mutual interference and hence spectral efficiency is increased. The multiband-OFDM UWB is one of the proposed physical layer standard for IEEE 802.15.3a WPANs.

### ➢ IR-UWB System

Impulse radio UWB communicates with baseband pulses of very short duration, typically on the order of a nanosecond, thereby spreading the energy of the radio signal very thinly from near dc to a few gigahertz (GHz). Typically, each symbol consists of multiple frames carrying one pulse per frame. Multiple pulses are associated with a single symbol to obtain sufficient energy per symbol while maintaining sufficiently low PSD. Due to baseband (carrier-less) nature of IR-UWB signals, frequency up conversion and down-conversion is not required in the transceiver. This reduces the complexity and power consumption of transceiver and thus makes IR-UWB

suitable for low-complexity and low power wireless sensor network applications. The pulse shapes, modulation and multiple access schemes of IR-UWB system are discussed in the following subsections.

### A. UWB Pulse Shape

Pulse shape is an important agenda for UWB, because it is a baseband technology, and its spectrum is determined by the pulse shape and pulse width. The pulses used for UWB communication can be any shape whose spectrum satisfies FCC spectral mask for UWB signals. A UWB pulse shape consists of two factors. First one is to spread the energy in frequency to minimize the power spectral density and the interference. Second one is to avoid a dc component to maintain the antenna radiation efficiency. Pulse shapes that are commonly used include the Laplacian pulse,Gaussian pulse, the Rayleigh pulse also known as Scholtz monocycle or Gaussian second derivative, the RZ Manchester and the Hermitian pulse . These pulses do not have dc component and consist of wide 3-dB bandwidths. They also have balanced positive and negative excursions. Gaussian first derivative pulse is the most popular pulse shape. Gaussian first derivative has one zero crossing. In time domain Gaussian monopulse can be expressed as

$$W(t) = A\pi f_c t e^{-2(\pi f_c (t-t_c))2}$$

Gaussian second derivative monopulse can be expressed as

$$W(t) = A\,(1-4\pi\,(f_c\,(t-t_c))^2)\,e^{-2\pi\,(f_c\,(t-t_c))^2}$$

Gaussian second derivative has two Zero crossing.

### B. Modulation techniques for UWB

In order to prevent system from interference modulation techniques are used. The most widely used modulation techniques are as follow:

- pulse position modulation (PPM)
- on-off keying (OOK)
- binary phase shift keying (BPSK)

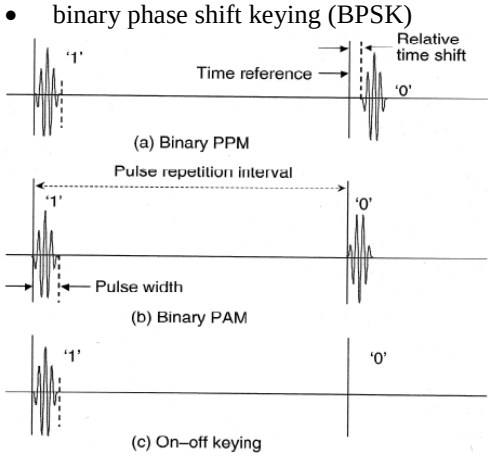


Figure1: Common IR UWB Modulation Schemes

All the modulation schemes used above are digital. In this paper modulation techniques such as PSK, BPSK and QPSK has been used and the graph of BER Vs SNR for all the three techniques is plotted. Adaptive modulation techniques such as QAM can also be used for UWB communication.

## 3. SYSTEM MODEL

### A. Transmitter Structure

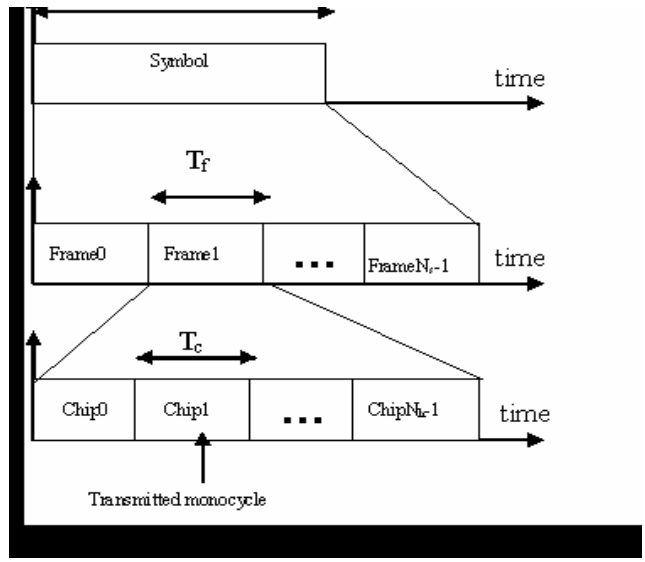


Fig2: Frame structure for timing hopping signal

Fig2 illustrates the frame structure of transmitted signal. The block diagram of Synchronization system is showm in fig(3)

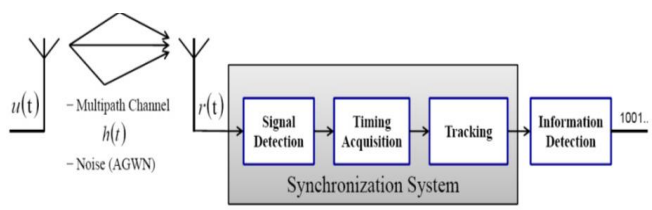


Fig.3: Synchronization block

From fig(3), the synchronization block is divided into three parts: signal detection, timing acquisition and tracking. The first part is Signal Detection, for deciding if the signal received is desired UWB signal or noise only. Timing Acquisition is the second block, which is also known as coarse synchronization. It is employed to find the approximate initial point of the each symbol being received and also used to reduce the timing error of UWB pulse duration. Tracking is the third step. It is used to maintain and lock the satisfactory synchronization in the presence of timing offset.

### A. Channel Model

For designing of transmitters and receivers channel model is used. For UWB system IEEE has standardised some model, out

of which IEEE 802.15.4a channel model is used for this work and to do the simulations. This model is very close to realistic channel and calculated with the latest measurements.

### B. Receiver Structure

The waveform at the output of the receiver antenna is:

$$r(t) = \sqrt{\varepsilon_s} \sum_{k=0}^{\infty} s[k] \sum_{j=0}^{N_f-1} \sum_{l=0}^{L-1} \alpha_l \, p(t - kT_s - jT_f - \tau_{l,0}) + w(t)$$

Denotes the aggregate receiver waveform of each symbol duration $T_s$.

## 4. TIMING SYNCHRONIZATION FOR UWB

Basically in UWB timing synchronization is the main issue. Timing synchronization includes Timing Offset Acquisition and Tracking.

### A. Acquisition

Timing acquisition is the difficult task in the UWB systems mainly due to following problems

- Low transmitted power
- High-resolution multipath

Due to Imperfect synchronization the performance of UWB-IR is affected. So to minimize this difficulty of synchronization, DA method is adopted, in which fixed length pilot bits are sent prior to each transmitted frame. This pilot sequence has good auto correlation property, which help in estimating the symbol boundary.

To analyze the performance of synchronization in IEEE 802.15.4a channel, Error variance of timing offset estimation is calculated. Error variance VS SNR and its BER performance for different modulation schemes are analyzed and discussed.

### B. Timing Offset Estimation

Timing offset estimation and tracking are further parts of timing synchronization. Here DA algorithm is performed in IEEE 802.15.4a Channel mode. In this algorithm a predefined preamble sequence is sent prior to each data sequence.

The diagram for transmitted frame structure is as given below in Fig.(4)

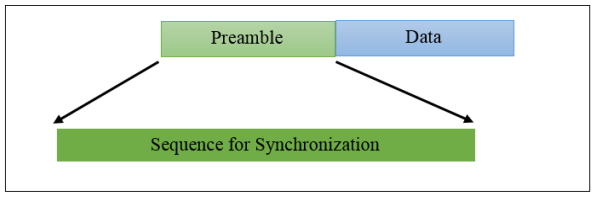


Fig.4: frame structure of each symbol

Fig(5). shows the the received bit stream that are correlated with sliding window. After this a peak value at an instant is obtained. This instant of peak is estimated as symbol boundary.

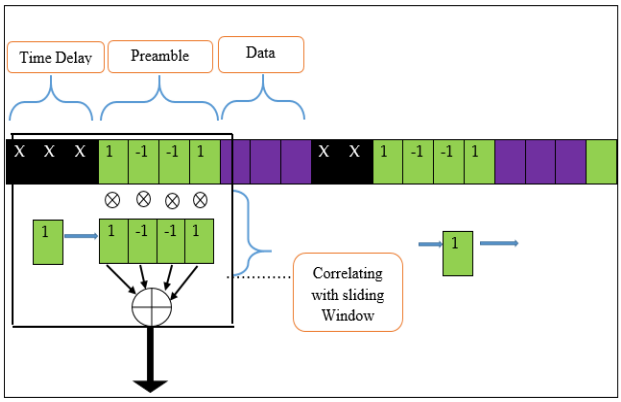


Fig.5: Diagram indicating Correlation of received bit stream with 4 bit Walsh code

### C. Tracking

After detecting UWB signals and estimating the timing offset, next target is the maintenance of synchronization between the receiver and the signals to be received. In order to alleviate the effects of timing offset variations due to transmitter receiver motion (Doppler effects) and to maintain the transmission quality, tracking unit is used. For tracking purpose, we will use Delay-Locked Loop (DLL) approach which is considered as structural tracking technique for spread-spectrum devices and UWB communication. For improving the tracking performance in UWB systems several DLL schemes have been proposed. It further enables timing offset variations in the received signals and also used to enhance the BER performance.

## 5. SIMULATION RESULTS

In fig (6),(7),(8) and (9) the graph for BER Vs SNR is plotted for different modulation schemes where there is decrease in BER with the increase in SNR values.

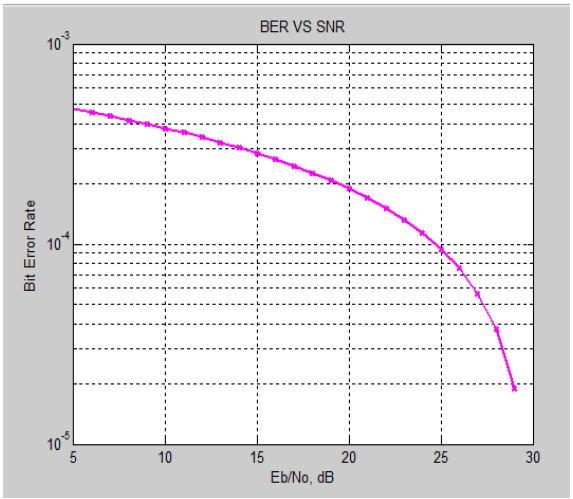


Fig6: BER Vs SNR for BPSK modulation

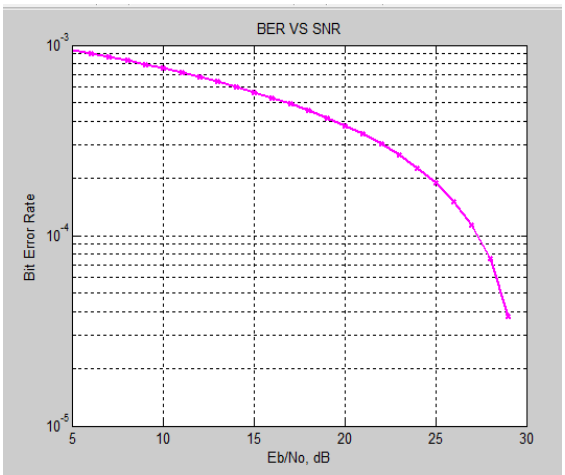


Fig7: BER Vs SNR for QPSK modulation

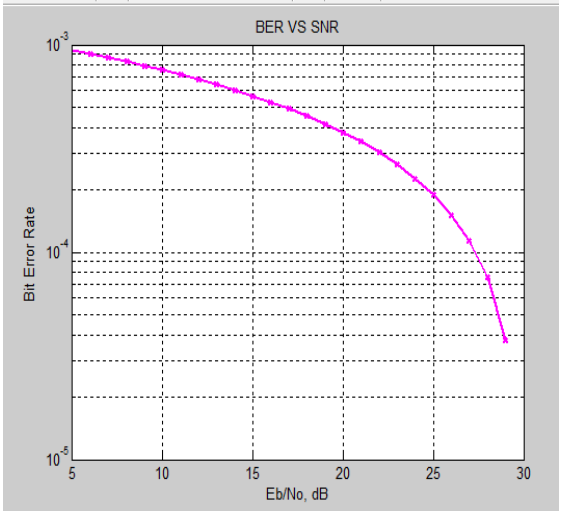


Fig8: BER Vs SNR for 16PSK modulation

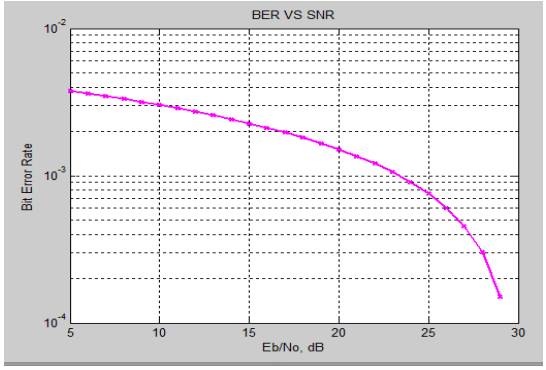


Fig9: BER Vs SNR for 256PSK modulation

The calculated total time and the difference in estimated offset for the SNR value 30 for different modulation schemes is as shown below in the table:

| For SNR 30 | BPSK | QPSK | 16PSk | 256PSK |
|---|---|---|---|---|
| Total time | 7.41s | 7.03s | 6.99s | 7.03s |
| Difference in estimated offset | 0.35 | 0.16 | 0.23 | 0.44 |

Table 1 Comparison table for calculated time and difference in estimated time offset

## 6. CONCLUSION

From the result obtained it can be observed that with the increasing SNR values the graph for BER is decreasing. It has been observed that by using DA algorithm, synchronization can be achieved easily in low SNR environment. Also the total time and difference in estimated offset for different modulation techniques has been calculated. Further by using adaptive modulation techniques higher throughputs and better spectral efficiency can also be achieved.

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