

# UWB Technology for Wireless Body Area Network

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**ABSTRACT:** Nowadays the use of wireless sensor networks has increased and the size of electrical devices is miniaturised which allow the evolution of Wireless Body Area Network (WBAN). It is a small size, low-power sensor which are connected or inserted into a human body to monitor body status. The sensors of WBAN are used to measure body temperature, Electro Cardio Graphy (ECG) and Electro Encephalo Gram (EEG) etc. WBAN application uses a UWB wireless technology because of its small form factor, low power consumption, and scalable data rates ranging from Kbps to Mbps.

**KEYWORDS:** WBAN, UWB, Gaussian pulse, AWGN channel

## I. INTRODUCTION

Due to increase in elder population and limited financial resource current health care system faces a many challenges. One of the solutions is the timely identification of health condition and gives immediate alert to concerned people. This can be done using a real time update of patient's vital parameter through internet. Since the patients are unable to remain in the hospital for a very long time, it is necessary to enable the patient with sensors and wireless technology to communicate with the hospital. To overcome these problems wireless technology is employed which is known as Wireless Body Area Network (WBAN).

WBAN is a network formed by intelligent, small size, low-power sensor which are attached or implanted into a human body [1]. This monitors the body functions and changes in surrounding environment and gives a real time feedback to doctor or patients, and obtained information are stored in a database. This type of technology use Wireless Medical Telemetry System and Medical Implant Communication System to provide efficient healthcare facility and to reduce the load at hospitals. It is a difficult task to connect all the devices and sensors through wires, as it causes complication. In order to avoid that, WBAN technology has been used. WBAN provides easier, low cost and real time response.

The IEEE wireless body area network standard (IEEE 804.15.6 TG6) [4] had been formed in order to develop and standardize the Physical Layer (PHY) and Medium Access Control (MAC) protocols for short range, low power and highly reliable wireless communication schemes to operate in, on and around the human body [7]. Due to new improvement in sensor technology, sensed signal by the sensors increased drastically. Hence to transmit large amount of data a WBAN require a high capacity wireless link that should support data rates from a few bps to several Mbps. To achieve high capacity wireless link WBAN use a UWB technology.

For the transmission of large amount of digital data with low power over a wide spectrum of frequency band for a short distance a new wireless technology is implemented which is known as Ultra Wide Band (also known as UWB or as digital pulse wireless). One among the three technologies (narrow band, ultra wide band, human body communication) is UWB. In that most suitable technology is UWB. Different modulation schemes are used to modulate UWB communication system and transmitted through a channel. Different channels are used to transmit the signal they are Nakagami, lognormal, AWGN and so on. At the receiver side, the transmitted signal is demodulated. To determine the system performance in physical layer, bit error rate (BER) is calculated. BER is the number of error bits divide by the total number of bits transmitted.

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In this paper, Section II deals with related work carried out. Section III and IV deals with the UWB technology and different modulation techniques used in UWB. Section V discuss about AWGN channel and Section VI deals with experimental setup used in transmitting signal. Results and Conclusion are discussed in Section VII and VIII.

## II. LITERATURE SURVEY

Bluetooth Network standard technology (IEEE 802.15.1) with master slave architecture is designed for short range wireless communication such as Wireless Personal Area Network (WPAN). It uses a frequency hopping spread spectrum to access physical medium and it operates in 2.4 GHz ISM band [2]. Piconet network topology is used to communicate one device to the other and common clock is used to synchronize the devices used in same piconet. Many wireless techniques operates in 2.4 GHz ISM band and hence it creates interference with each other. Due to less number of channels, it lacks the scalability in terms of data rate. The recent technology in Bluetooth is Bluetooth Low Energy (BLE) which is designed to reduce the power consumption and cost [2]. BLE use less number of channels hence synchronization can be done in few milliseconds and hence it can provide data rate upto 1Mbps. But this technology also operates in 2.4 GHz ISM band, hence it creates interference.

Currently the Body Area Network uses IEEE 802.15.4 standard, under this technology we have ZigBee which is used in WPAN, which is designed to support low power consumption and cost effective technology [5]. It supports three types of topologies such as star, cluster tree and mesh. Cluster, tree topology and mesh topology provides multi-hop routing. This is one of the advantages of ZigBee Technology. ZigBee has a several drawbacks for health care applications. It operates in 2.4 GHz ISM band along with Bluetooth, hence it create interference and also suffers from variable path loss near human body. Maximum data rate supported by ZigBee is 250 kbps which is inadequate to support real time, large scale BANs. The power consumption is considerably high for a ZigBee based sensor node.

IEEE 802.15.6 is a recent wireless technology proposed for WBAN, this technology is designed for low power devices. For transmission it, uses a different frequency band i.e. narrow band and Ultra Wide Band. Narrow band include 400, 800, 900 MHz and 2.3 and 2.4 GHz and Ultra Wide Band uses frequency band 3.1-10.6 GHz. UWB has a low power spectral density emission. Hence it is suitable for short range indoor environments.

## III. UWB TECHNOLOGY

### UWB PULSE GENERATION

For the transmission of large amount of digital data with low power over a wide spectrum of frequency band for a short distance a new wireless technology is implemented which is known as Ultra wideband [6]. A pulsed UWB transceiver is used in wireless communication due to its low cost and low power. UWB technique must satisfy FCC definition that is, either the absolute bandwidth must be equal to or greater than 500 MHz or the fraction bandwidth equal to or greater than 0.20. In an UWB system, the representation of the filters, selection of receiver bandwidth, bit error rate and the performance in multipath propagation environments will depend on the pulse shape of the signal. The most common pulse shape used in UWB transmission is a Gaussian pulse and its derivatives. The standard Gaussian pulse waveform is given by:

$$x(t) = -\frac{A}{\sqrt{2\pi}\sigma^2} e^{-\left(\frac{t^2}{2\sigma^2}\right)} \quad (1)$$

where  $-\infty < t < \infty$ , A is constant amplitude and  $\sigma$  is the Gaussian standard deviation. The Gaussian monocycle is the first derivative of the Gaussian pulse and it is given by equation (1). Gaussian monocycle has a single zero crossing and further derivatives will have additional zero crossing, one additional zero crossing for each additional derivative. equatin (2) shows the second derivative of equation (3) known as Gaussian doublet.

$$x^{(1)}(t) = -\frac{A}{\sigma^3\sqrt{2\pi}} e^{-\left(\frac{t^2}{2\sigma^2}\right)} \quad (2)$$

$$x^{(2)}(t) = -\frac{A}{\sigma^3\sqrt{2\pi}} \left(1 - \frac{t^2}{\sigma^2}\right) e^{-\left(\frac{t^2}{2\sigma^2}\right)} \quad (3)$$

In this paper, Gaussian doublet waveform as a UWB pulse shape. These pulses are easily generated and have zero DC components. Although these pulses have a zero DC component, their spectra still goes down to very low frequencies, which are well below the minimum 3.1 GHz of the UWB spectra. Depending on the width of pulse; the spectra of

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doublet is decided whether it is in the UWB spectral range or not. The shorter pulse duration can cover a wider frequency range, but it requires a filter to remove the lower frequency component. Hence the higher order Gaussian pulse is more effective, as they are able to satisfy the FCC mask without filtering requirement.

## IV. UWB MODULATION TECHNIQUES

Modulation is a process in which the amplitude, phase or frequency of a high frequency carrier is varied in accordance with the amplitude of the message signal. In information theory, discrete digital data can be encoded in two distinct states. In the presence of noise and interference the modulation state of a UWB signal must be distinguished and recognized correctly. Different modulation schemes are used to modulate data in the UWB communication systems. The modulation methods are categorized into two basic types as time-based techniques and shape-based techniques. PPM (Pulse Position Modulation) is time based modulation technique and pulse amplitude modulation (PAM), On/Off keying (OOK), bipolar signalling (BPSK) are shape based modulation technique.

### Amplitude Shift Keying (ASK)

In this modulation, a carrier wave is used to modulate the amplitude of the signal. A UWB carrier wave is a Gaussian pulse. The transmitted binary information signal  $(t)$  is modulated and that can be represented

$$y(t) = d_i \cdot u_{tr}(t) \quad (4)$$

where  $u_{tr}(t)$  represents the UWB pulse waveform,  $i$  represents the bit transmitted (0 or 1) and

$$d_i = \begin{cases} 0, & i = 0 \\ 1, & i = 1 \end{cases} \quad (5)$$

ASK modulation for UWB system, in which UWB pulse will be transmitted for signal value 1 and no signal will be transmitted for signal value 0 for a bit duration of  $T$  seconds.

### Binary Phase Shift Keying (BPSK)

BPSK is also known as bi-phase modulation (BPM). In BPSK, sequences of binary symbols  $b_j$  are used to denote the bit stream and it takes the values +1 or -1.  $N_c$  is used to represent the single bit, where  $N_c$  refers to the length of the PN code  $C_i$ . In BPSK, the signal is modulated with respect to polarity of pulses. The transmitted signal  $S_{BPSK}(t)$  is represented below for BPSK modulation in which each frame has duration  $T_f$ . The duration of each bit is given by  $N_c T_f$ . Here  $A$  denote the amplitude of each pulse  $p(t)$ .

$$S_{BPSK}(t) = A \sum_{j=-\infty}^{\infty} \sum_{i=0}^{N_c-1} b_j C_i p(t - jN_c T_f - iT_f) \quad (6)$$

The difference between two pulses levels is twice the pulse amplitude hence it is less susceptible toward distortion is the main advantage of BPM. Change of polarity of pulses produces a zero mean and also removes the PSD spectral lines. BPSK supports binary communication.

## V. UWB THROUGH AWGN CHANNEL

To mimic the effect of many random processes that occur in nature information theory use a basic noise model this is known as AWGN channel. It is used in communication as a channel model for a linear addition of wideband or white noise with a constant spectral density and Gaussian distribution of amplitude. An AWGN with zero mean and two sided spectral density equal to  $N_0/2$  is used to transmit the modulated binary signal [3]. The signal to noise ratio (SNR) is defined as

$$SNR = 10 \log_{10} \frac{E_b}{N_0} \quad (7)$$

where  $E_b$  stands for the data bit energy and  $N_0$  is the two-sided noise density power spectrum.

The transmitted signal is given by the following Equation

$$S(t) = \sum_{i=1}^N (2S_i - 1)(m \times P) \quad (8)$$

where,  $S$  is the Symbol to be sent,  $m$  is the Pulse waveform and  $N$  refers to the number of transmitted data.

$$P(t) = \begin{cases} 1, & \text{for } -T < t < T \\ 0, & \text{otherwise} \end{cases}$$

The signal transmitted through the AWGN channel is received at the receiver and the received signal is given by,

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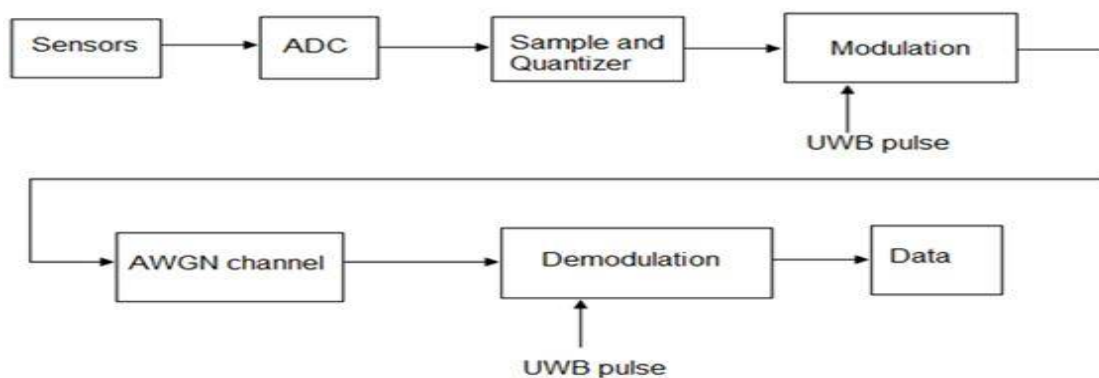
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$$R(t) = S(t) * h(t) + n(t) \tag{9}$$

where  $n(t)$  is the noise.

At the receiver site, the received signal is correlated with the pulse reference comparable to a pulse shape which is used in transmitter site. The pulse shape that is used in transmitter site is Gaussian waveform.

## VI. EXPERIMENTAL SETUP



**Figure 1: Practical Implementation of UWB Technology**

The practical implementation of UWB technology is shown in Figure 1. The sensors are used to sense the parameters such as ECG, EEG, blood pressure etc., from a human body. To convert the analog signal sensed by sensors to digital form, ADC is used. The two process involved in ADC, that is sampling and quantization. In sampler, the voltage signal is converted into discrete time signal. This discrete time signal directly cannot be stored and processed by numerical methods. In order to store and process this discrete time signal, each signal is replaced with appropriate set of discrete values and this can be done using quantization method. A Gaussian pulse as a carrier signal for modulation is generated. The digital data generated by a sampling and quantization process is modulated using a UWB signal for the transmission through a AWGN channel. Modulation is a process used in communication to prevent the system from interference. The modulated signal is passed through AWGN channel where noise is added. Then the output of this is given to a demodulator to recover the transmitted binary data.

### FLOWCHART FOR COMMUNICATION USING UWB TECHNOLOGY

Figure 2 shows a flow chart for transmitting a digital data. The random binary data is used, instead of using a sensed signal and converting them into a digital data. The random binary data are generated using MATLAB 2013a. The binary data are the message signals that need to be transmitted using function, UWB Gaussian pulse as carrier signal. Different modulation technologies are used to modulate the transmitted signal, but in this ASK and BPSK modulation are used. In ASK modulation, if the transmitted signal is 1 then it transmits a UWB signal. If it is 0 then no signal will be transmitted. In BPSK modulation, if the transmitted signal is 1, then it transmits a UWB signal. If it is 0, then the UWB signal will be phase shifted by 180. Modulated signal will pass through a different channel model such as Rayleigh channel, AWGN channel, Nakagami etc., But in this part of the project, the modulated signal is passed through an AWGN channel.

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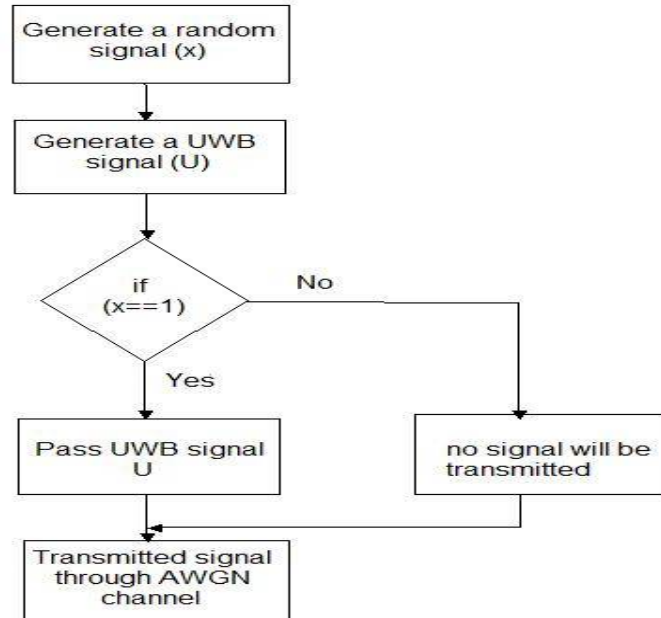


Figure 2: Flowchart for transmitting signal

The flow chart for a recovery of digital data is shown in Figure 3. The received signal from a AWGN channel is passed through a demodulator, where it compares the received signal with UWB pulse. If the received pulse is greater than 0 then it generate a binary data 1, else it generates a 0. Hence the transmitted signal will be recovered.

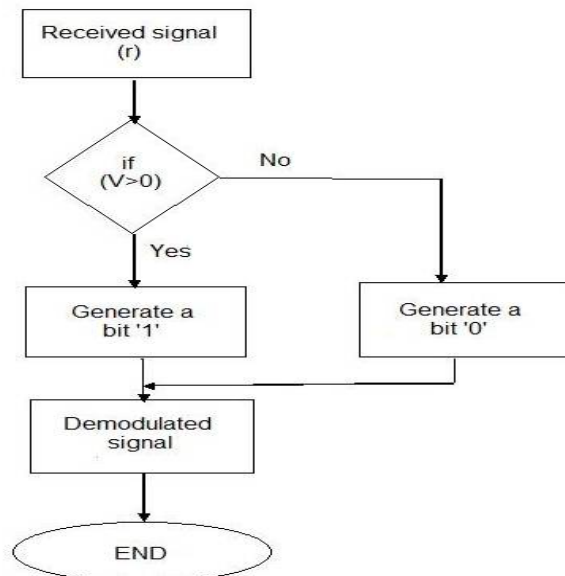


Figure 3: Flowchart for receiving signal

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## VII. RESULTS

In this paper, Gaussian derivatives are used for transmitting information as a UWB transmitted signal. They have a wide bandwidth with no DC component and no side lobes in their frequency spectrums. Filtering of the DC component and shifting the center frequency is needed for Gaussian pulses to meet the FCC mask, whereas shifting of center frequency and shape filtering is required for Gaussian derivatives. The Gaussian pulse and its derivatives are obtained using (1), (2), and (3) and generated using MATLAB 2013a. Figure 4 shows a Gaussian pulse generated and its derivative pulses with pulse width of 10 ps, and the values are varied from -5 to 5 with duration of 0.1 ps.

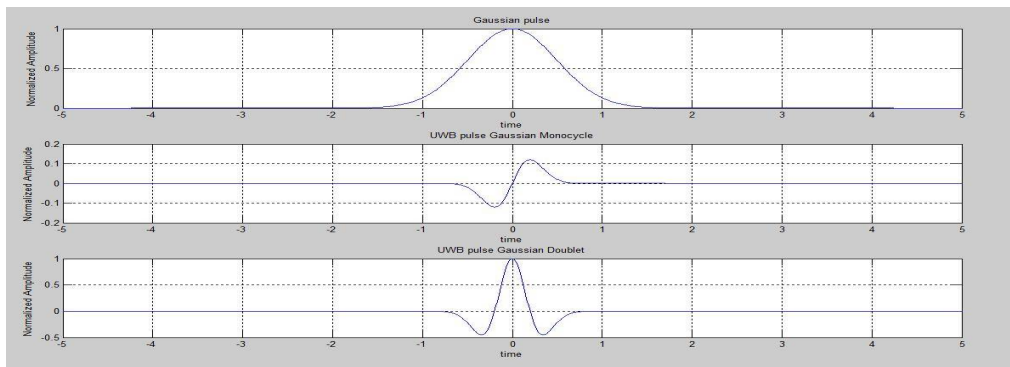


Figure 4 Generation of (a) Gaussian pulse (b) UWB Gaussian monocycle pulse (c) UWB Gaussian doublet pulse

The binary data are the message signals that need to be transmitted using function is shown in Figure 5 (a). UWB Gaussian pulse as carrier signal is generated which is shown in Figure 5 (b).

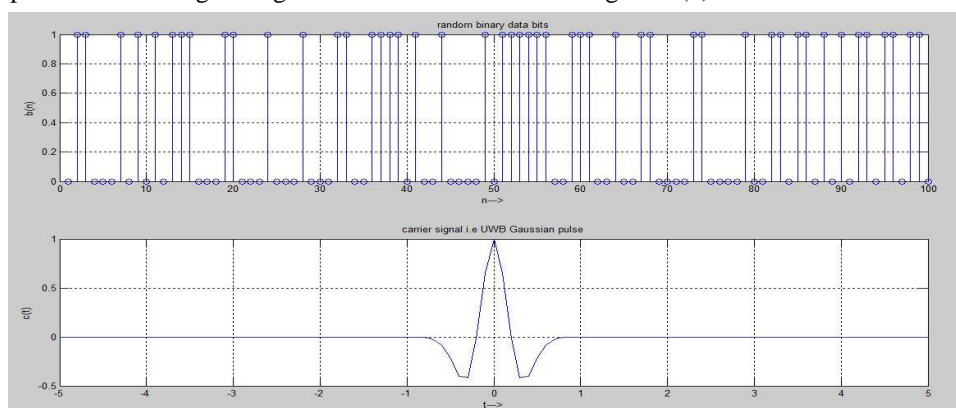


Figure 5 (a) Generated random binary data bits (b) UWB Gaussian pulse as carrier signal

The message signal which is to be transmitted is shown in Figure 6 (a). Thus an Ultra Wide Band signal is generated and utilized in the process of modulation of the binary data. Modulation of the signal is shown in Figure 6 (b) and Figure 6 (c).



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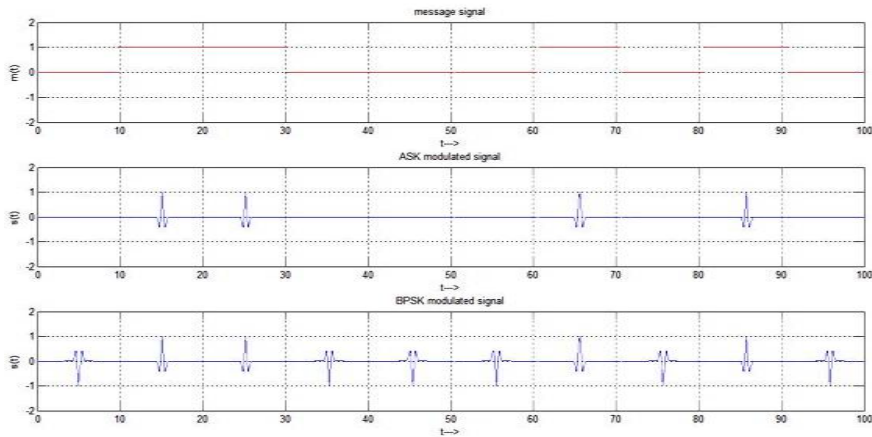


Figure 6 (a) Message signal (b) ASK modulated signal (c) BPSK modulated signal

The signal then is transmitted through AWGN channel. Hence the transmitted signal will be recovered as shown in Figure 7(a) and Figure 7(b).

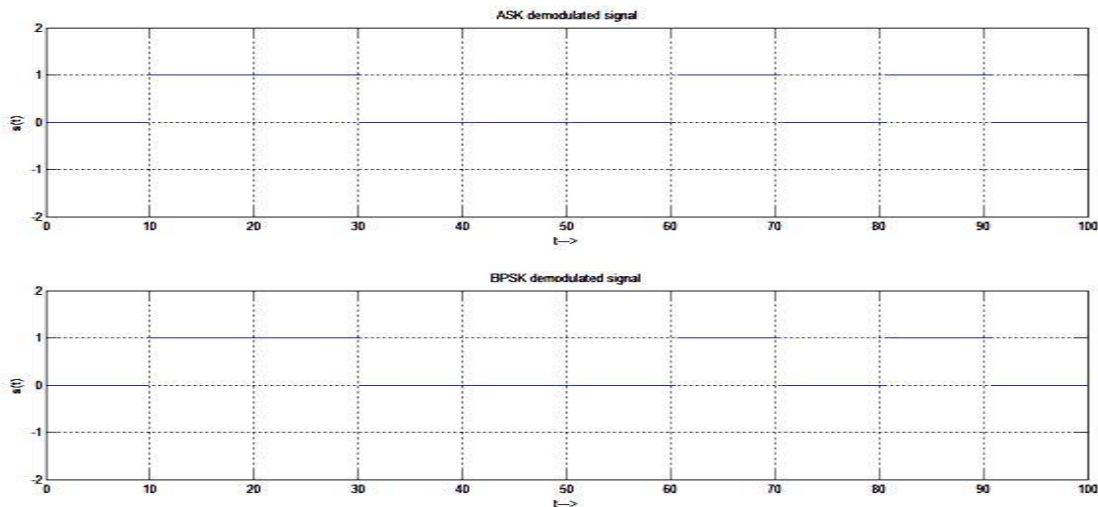


Figure 7 (a) ASK demodulated signal (b) BPSK demodulated signal

In a digital transmission, when data is transmitted over a data link, there is a possibility of errors being introduced into the system. Hence to determine the performance of the system, BER is calculated. From the Table 1 we can concluded that BPSK modulation has better performance compared to ASK.

Table 1: Comparison of modulation techniques

Modulation Technique	Theoretical BER	Practical BER
ASK	0.1131	0.0037
BPSK	0.0163	0.0013

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## VIII. CONCLUSION

UWB communication is one of the standards devised for Wireless Body sensor Networks by IEEE 802.15.4(TG6) which is known as IEEE 802.15.6 standard. This standard has become the WBAN standard now. One among the three technologies (Narrow band, Ultra Wide Band and Human Body Communication) UWB is found to be one of the most suitable technology. Hence UWB pulse and random data are generated in various forms. The binary data has been transmitted over AWGN channel using ASK and BPSK modulation schemes. Also the signals are recovered using suitable demodulation techniques. Simulation and BER for the system is has been carried out with MATLAB. Depending upon the BER the BPSK modulation is most effective modulation scheme in practical communication system.

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