Abstract: This paper is focusing on development of ZigBee transceiver at physical layer using IEEE 802.15.4. ZigBee technology was developed for a wireless personal area networks (PAN), aimed at control and military applications with low data rate and low power consumption. ZigBee is a low-cost, low-power, wireless mesh networking standard. First, the low cost allows the technology to be widely deployed in wireless control and monitoring applications. Second, the low power-usage allows longer life with smaller batteries. Third, the mesh networking provides high reliability and more extensive range. Here, Minimum Shift Keying (MSK) modulation technique is described, an analysis of which shows that the theoretical maximum bandwidth efficiency of MSK is 2 bits/s/Hz which is same as for Quadrature Phase Shift Keying (QPSK) and Offset Quadrature Phase Shift Keying (Offset QPSK). The implementation clearly confirms the viability of theoretical approach. Results show that OQPSK modulation with half sine pulse shaping is perfectly employed ZigBee technology.

Keywords: ZigBee, Quadrature Phase Shift Keying, Personal Area Networks, Minimum Shift Keying.

I. INTRODUCTION

Wireless personal area network (WPAN) and wireless local area network (WLAN) technologies are growing fast with the new emerging standards being developed. For some time, Bluetooth was most widely used for short range communications. Now, ZigBee is becoming an alternative to Bluetooth for devices with low power consumption and for low data rate applications.
ZigBee Standard reduced the implementation cost by simplifying the communication protocols and reducing the data rate. The minimum requirements to meet ZigBee and IEEE 802.15.4 specifications are relatively relaxed compared to other standards such as IEEE 802.11, which reduces the complexity and cost of implementing ZigBee compliant transceivers.

II. HISTORY OF ZIGBEE

The ZigBee technology is designed to provide a simple and low-cost wireless communication and networking solution for low-data rate and low power consumption applications, such as home monitoring and automation, environmental monitoring, industry controls, and emerging low-rate wireless sensor applications. It was conceived around 1998, when many application engineers realized that both Wi-Fi and Bluetooth were going to be unsuitable for many applications. In particular, many engineers saw a need for self-organizing ad-hoc digital radio networks [4].

The ZigBee specifications were ratified on 14 December 2004, and its Alliance membership had more than doubled in 2004, growing to more than 100 member companies, in 22 countries.

By April 2005 membership had grown to more than 150 companies, and by December 2005 membership had passed 200 companies. Alliance announces the completion and immediate member availability of the enhanced version of the ZigBee Standard in September 2006, known as ZigBee 2006 Specification. During the last quarter of 2007, ZigBee PRO, the enhanced ZigBee specification was finalized. The name of the brand was “ZigBee”, originated with reference to the behaviour of honey bees after their return to the bee hive [5].

A. Relationship Between Zigbee and IEEE 802.15.4 Standard

ZigBee wireless networking protocols are shown in Figure 2.1. ZigBee protocol layers are based on the Open System Interconnect (OSI) basic reference model. As shown in Figure 1, the bottom two networking layers are defined by IEEE 802.15.4 standard. This standard is developed by IEEE 802 standards committee and was initially released in 2003. IEEE 802.15.4 defines the specifications for PHY and MAC layers of wireless networking, but it does not specify any requirements for higher networking layers [6]. The ZigBee standard defines only the networking, applications and security layers of the protocol and adopts IEEE 802.15.4 PHY and MAC layers as a part of the ZigBee networking protocol. Therefore, ZigBee-compliant device conforms to IEEE 802.15.4 as well.
III. DESIGN OF ZIGBEE

A. Design of ZigBee Transmitter

The design of ZigBee transmitter using OQPSK modulation with half sine pulse shaping is shown in the Figure 2 below. Here the input bit stream is having a data rate of 250Kbps.

![Figure 2: Block Diagram of Zigbee Transmitter](7]

Now we are mapping 4 input data bits to a symbol having a symbol rate of 62.5Kilo symbols per second. The symbol is then used to select one of 16 nearly orthogonal 32-chip PN sequences to be transmitted and results in a chip rate of two mega chips per second. After that, resultant chip sequence is send to the serial to parallel converter [8]. It is used here to separate the even indexed chips and odd indexed chips. Following this half sine pulse shaping is performed and signal modulated with a 2.4 GHz carrier on the I and Q data stream and add it to get the required transmitter output signal. Step by step procedure to implement ZigBee transmitter using simulink is presented below.

1. Bit To Symbol and Symbol to Chip Mapping
   i. Generating binary data stream: By using Random integer generator block in the communication tool box, we can generate binary data stream of 250Kbps. By adjusting the parameters like M- ary number, initial seed, sample time and output data type, we can achieve the fixed binary stream. In a real time scenario, this data stream is supplied by application that will generate information to be transmitted.

   ii. Generating PN sequence: By using PN sequence generator block in the communication tool box, we can generate 32 bit- PN sequence of 2Mbps data rate. By adjusting the parameters like generator polynomial, initial states, sample time and output data type, we can achieve 32 bit Pseudo Noise code.

   iii. Generating DSSS signal: After generating the input bit stream and PN sequence, the code generated is converted to NRZ format and multiplied to get a direct spread spectrum signal.

2. Serial to Parallel Converter Implementation

By using flip-flops in Simulink extras tool box, we can get the parallel data from the serial data. The necessary instruments are one clock, one JK flip flop and two D flipflops. The initial conditions of the flip-flops using is zero and the period of the clock was decided by the input data stream. By this way we can easily generate the parallel data technically called as inphase and Quadrature data. Here necessary one bit offset delay is provided by the D flip flop itself.

3. Performing Half Sine Pulse Shaping

By the multiplication of NRZ form of inphase data with sine wave generator, we can get a smoothened version of baseband waveform. But we must take care while designing this because edge of inphase data must be in synchronize with phase of the half sine wave.

4. Performing Modulation

After obtaining the inphase and Quadrature signals after half sine pulse shaping, we need to do modulation for the transmission of the signal. Generally we do this with the help of high frequency(2.4GHz) sinusoidal carrier. By using sine wave block in Signal Processing Tool Box, sine wave can be generated by adjusting the parameters like amplitude, frequency, sample time, phase and sine type. Now the inphase signal after half sine pulse shaping is multiplied by a
sine wave and Quadrature signal after half sine pulse shaping is multiplied by its orthogonal carrier i.e., cosine signal which is nothing but 900 phase shift of original sinusoidal carrier.

5. Output of the ZigBee Transmitter
Addition of both inphase and Quadrature signals after modulation, generates the required transmitter output. The required output signal is generated by using sum block in commonly used blocks. There will be no phase transitions in the output, which is an advantageous property.

B. Design of ZigBee Receiver
There are two type detection schemes available for the detection of original baseband data. They are coherent detection and non-coherent detection. In coherent detection, the phase of carrier that we used in the transmitter and phase of recovered carrier must be same. So proper carrier synchronization is necessary in the coherent demodulation. In case of non-coherent demodulation, there is no need of carrier synchronization. Coherent detection is costlier to implement, that is, the receiver must be equipped with a carrier recovery circuitry, which in turn increases system complexity, and can increase size and power consumption. Additionally, there is no ideal carrier recovery circuit. So, no practical digital communication system works under perfect phase coherence. While Non coherent detection uses previous bit information for extracting the original data and there is no need of using the carrier recovery circuit. Non-coherent detection is simpler, but it suffers from performance degradation as compared to coherent detection, but this difference can be small in practice for some modulation schemes due to the specifics of the modulation and also due to the penalty caused by imperfections in the carrier recovering process [9].

This section describes the implementation of ZigBee receiver system. Here we are concentrating on the MSK coherent detection technique for recovering original data in receiver. The block diagram of the ZigBee Receiver is shown in Figure 3 below. The step by step procedure to implement ZigBee receiver using Simulink is presented below.

![Figure 3: Design of ZigBee Receiver [9]](image)

In the receiver configuration of ZigBee, we are using a MSK demodulator and a multiplier for despreading. This multiplier is supplied by a PN sequence data that is an exact replica that used in the transmitter. The data coming from the MSK demodulator (i.e. at the parallel to serial converter) is having a data rate of 2Mbps. From this data, the original data is extracted by multiplying with the PN sequence data. But the 2Mbps data obtained at the output of parallel to serial converter contains some offset delay. This offset delay must introduced in the PN sequence data while multiplying with 2Mbps data. So that output contains original bit stream without any errors.

The receiver design is explained below. The incoming received signal is applied to two synchronous demodulators, consisting of a multiplier followed by a lowpass filter. Here one multiplier is supplied with a signal, which is the multiplied signal of carrier cosw0t and
IV. SIMULATION RESULTS

There are two types of modulations used in the ZigBee transmitter. They are direct spread spectrum modulation and modulation with high frequency carrier. Similarly, at the receiver end, demodulation and dispreading operations have to be performed.

A. At The Transmitter End

The simulation results at each step are shown below. The following figures demonstrate simulation results for ZigBee transmission system. The results are displayed in the form of snapshots of scope signals. These figures demonstrate we can know easily what happens exactly inside a ZigBee transmitter. The input stream is generated from a random integer generator. This is presented in Figure 4. It has a data rate of 250Kbps. i.e., it generates a bit for every 4μs as shown in the time axis. Each division for the time axis is taken as 10μs.

Clearly, the results show that there is no phase transition in the output by using OQPSK with half sine pulse shaping. By taking this as advantage, an efficient power amplifier design is possible in the realization of hardware.

B. At the Receiver End

The transmitted signal is passed through an AWGN channel. The noisy version of the transmitted signal at the input of receiver is shown in Figure 8. The output bit stream shown in Figure 9 and the input bit stream shown in Figure 5 are same except a small amount of delay (1.5μs).
CONCLUSION
The work presented here helps to implement a transceiver for ZigBee wireless communication system. A model for MSK has been presented, an analysis of which shows that the theoretical maximum bandwidth efficiency of MSK is 2 bits/s/Hz, the same as for QPSK and Offset QPSK. Here, we indirectly implemented Minimum Shift Keying modulation and demodulation (OQPSK with half sine pulse shaping). Use of direct spread spectrum technique, reduces the interference effects, while the use of direct conversion receiver fulfills the requirement of ZigBee i.e., low cost and low power consumption.

References

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