Simulink Based Verification Model for ZigBee Transceiver

Dipak V. Vaniya[#1], Sima K. Gonsai[*2]

 # P.G. student, Electronics & Communication Department, L. D. College of Engineering, Gujarat Technological University
[1]`dipak.vaniya30@gmail.com`

*Asst. Professor, Electronics & Communication Department, L. D. College of Engineering, Gujarat Technological University
[2]`simagonsai@gmail.com`

Abstract— **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 implementation requires understanding of its architecture and the operation of its layers relative to specific application. Mesh network is possible for ZigBee which is meet the requirement for high reliability, security, low power, low cost. This paper is mainly focusing on development of Simulink model for ZigBee transceiver at physical layer using IEEE 802.15.4.**

Keywords— **ZigBee, IEEE 802.15.4, Physical layer, MAC layer, bit-to-chip.**

I. INTRODUCTION

ZigBee is an established set of specifications for wireless personal area networking (WPAN), i.e. digital radio connections between computers and related devices. WPAN Low Rate or ZigBee provides specifications for devices that have low data rates, consume very low power and characterized by long battery life. ZigBee makes possible completely networked homes where all devices are able to communicate and be controlled by a single unit. The ZigBee Alliance, the standards body which defines ZigBee. The current application of ZigBee are:

- Home Automation
- ZigBee smart Energy
- Telecommunication Application
- Personal Home

ZigBee is one of the global standards of communication protocol formulated by the relevant task force under the IEEE 802.15 working group. ZigBee is at the fourth place of IEEE series which gives the specification for low data rate and consumes low power which increase the battery life. Other standards like Bluetooth and IrDA address high data rate applications such as voice, video and LAN communications. ZigBee devices are actively limited to a through-rate of 250Kbps, compared to Bluetooth's much larger pipeline of 1Mbps, operating on the 2.4 GHz ISM band, which is available throughout most of the world. In the consumer market ZigBee is being explored for everything from linking low-power household devices such as smoke alarms to a central housing control unit, to centralized light controls. The specified maximum range of operation for ZigBee devices is 250 feet (76m), substantially further than that used by Bluetooth capable devices, although security concerns raised over "sniping" Bluetooth devices remotely, may prove to hold true for ZigBee devices as well. Due to its low power output, ZigBee devices can sustain themselves on a small battery for many months, or even years, making them ideal for install-and-forget purposes, such as most small household system [1].

The ZigBee networks layer supports star, tree and mesh networks. ZigBee network parameter and maintenance is carried out by the network coordinator so it must that every ZigBee network have one coordinator. As shown in figure 1. In star networks, the most coordinator must be the central node. Both tree and mesh network allow extend communication by ZigBee router at network layer.
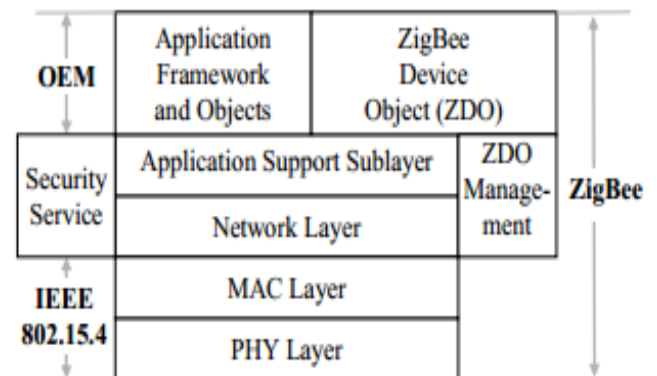

Fig. 1 : ZigBee network protocol stacks [1].

II. NEED FOR ZIGBEE

1) There are a multitude of standards that address mid to high data rates for voice, PC LANs, video, etc. Up till now there is no standard which meets the unique needed of sensors and control device. Sensors and controls don't need high bandwidth but they do need low latency and very low energy consumption for long battery lives and for large device arrays [2][3].

2) There are a multitude of proprietary wireless systems manufactured today to solve a multitude of problems that also don't require high data rates but do require low cost and very low current drain.

3) These proprietary systems were designed because there were no standards that met their requirements. These legacy systems are creating significant interoperability problems with each other and with newer technologies.

III. ZigBee Characteristics

The focus of network applications under the IEEE 802.15.4 /ZigBee standard include the features of low power consumption, needed for only two major modes (Tx/Rx or Sleep), high density of nodes per network, low costs and simple implementation. These features are enabled by the following characteristics.

1) 2.4GHz and 868/915 MHz dual PHY modes. This represents three license-free bands: 2.4-2.4835 GHz, 868-870 MHz and 902-928 MHz The number of channels allotted to each frequency band is fixed at sixteen (numbered 11-26), one (numbered 0) and ten (numbered 1-10) respectively. The higher frequency band is applicable worldwide, and the lower band in the areas of North America, Europe, Australia and New Zealand .

2) Low power consumption, with battery life ranging from months to years. Considering the number of devices with remotes in use at present, it is easy to see that more numbers of batteries need to be provisioned every so often, entailing regular (as well as timely), recurring expenditure. In the ZigBee standard, longer battery life is achievable by either of two means: continuous network connection and slow but sure battery drain, or intermittent connection and even slower battery drain.

3) Maximum data rates allowed for each of these frequency bands are fixed as 250 kbps @2.4 GHz, 40 kbps @ 915 MHz, and 20 kbps @868 MHz

4) High throughput and low latency for low duty-cycle applications (<0.1%)

5) Channel access using Carrier Sense Multiple Access with Collision Avoidance (CSMA - CA)

6) Addressing space of up to 64 bit IEEE address devices, 65,535 networks.

7) Transfer reliability is achieved by fully hand-shacked protocol. Range is 50m typical (5-500m based on environment)

IV. Overview of ZigBee Layers

The ZigBee protocol IEEE 802.15.4 WPAN standard is considered to be newly introduced which was approved and published in 2003 [6]. It defines the physical layer and the MAC layer characteristics. In this part has a double A brief description of these two layers is presented.

A. The IEEE 802.15.4 Physical Layer

Like any wireless technology on the other hand, the main function of the prevalence of physical layer transmission, signal modulation and demodulation. Physical layer, ZigBee ISM band operates in three different frequency bands. There is only one channel between 868.0 and 868.6MHz, channel 0, 902.0 and 928.0 MHz, 10 channels, Ch 1-10, and 16 channels between 2.4 and 2.4835 GHz, channel 11 -26. ZigBee uses DSSS as a spreading technique. DSSS is used to increase the frequency of the signal to increase power and reduce the influence of noise from neighbouring systems. The 2.4 GHz band Orthogonal Quadrature Phase Shift Keying (OQPSK) modulation technique using the chip. Every chip is mapped into 4-bit symbol PN sequence 32. as shown in Fig. 2. A symbol for a single bit in the 915 MHz and 868 MHz PN Code 15 is set in correspondence with the sequence, and binary phase shift modulation (BPSK) modulation technology ZigBee standard receiver sensibility -92 dbm in 868/915 MHz band and 2.4 GHz band is -85 dbm receiver sensibility specified. Frequency band as the general frame structure uses the physical layer, as shown in Fig. 3. After a number of channels available in different frequency bands within the spectrum makes it possible to move.

B. The IEEE 802.15.4 MAC Layer

MAC layer control the access to communication channels. It provides flow control on acknowledgments and retransmissions. This data Validation, and is responsible for the delivery of services to the upper layer. Two Type of ZigBee standard equipment, the full function of the defeated (FFD) and a reduced function (RFD). The FFD can operate in three different modes: a personal area network (PAN) coordinator, a coordinator, or a device. Simple application does not require the transfer of the RFD that broadly amounts of data and is designed to require minimal resources A WPAN is formed when at least two devices communicate with a device that actuates a one FFD assume the role of a coordinator. Depending on application requirements, ZigBee overcame either a star topology or a point to point topology.
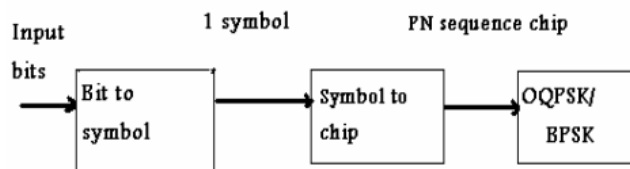

Fig. 2: Example of a ZigBee spreading technique at the physical layer [7]

Fig. 3: The ZigBee physical layer frame structure [7]

There are three types of data transfer mechanisms between ZigBee devices: from a coordinator to a device, from a device to a coordinator and between two peer devices. Data transfer system that supports or not depend on the transmission network beacons. Suppose that in a non-beacon enabled network device transmits data frames coordinator just use slotted CSMA-CA. However, a beacon enabled network, the device listens beacon network, and at the right time transmits the data frame, using slotted CSMA-CA to the coordinator.

In a peer-to-peer network, any device can communicate with any other device within its transmission radius using one of two options: by constantly listening to the channel and transmitting its data using un-slotted CSMA-CA or by synchronizing with other nodes in order to save power. . Beacon enabled network, the super-frame structure used. Coordinator on-frame structure is defined the super-frame [7].The super-frame, surrounded by two beacons and the time between these two beacons divided into 16 time slot. It has an active and an inactive portion. In inactive side, coordinator enters a low power mode and will not interact with your PAN. The active portion is divided into two periods: a contention access period (CAP), and a contention free period (CFP). In CAP, the device with other devices using the slotted CSMA-CA mechanism must compete. In the CFP, PAN coordinator is a single device, which forms the CFP with guaranteed time slot (GTS).

V. ZIGBEE TRANSCEIVER ARCHITECTURE

Fig. 4 shows the block diagram of the proposed ZigBee transceiver. The RF signal is down-converted to baseband by the RF receiver (Rx) and quantized by the analog-to-digital converters (ADC). These digital signals are sent to the MAC after the digital demodulation performed by the proposed Rx.The PSDU from MAC is modulated by the proposed transmitter (Tx), and the resultant PPDU packet is transmitted by the RF Tx. The details of each block are described in the following text.
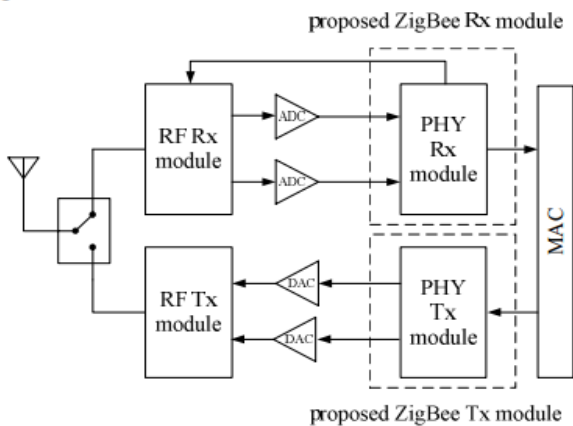

Fig. 4: Block diagram of the ZigBee transceiver for 2.45 GHz band [8]

A. Design of ZigBee Tx

Design of ZigBee Tx in Fig. 5 is based on [9]. The PPDU (physical layer protocol data unit) packet is composed of the PSDU from MAC and the header added by the header insertion stage. Every 4 bits are mapped into one data symbol. The symbol-to-chip stage performs the direct-sequence spread spectrum (DSSS), where each symbol is mapped into a 32-chip pseudo-random noise (PN) sequence. Notably, the O-QPSK modulation is adopted in 2.45 GHz mode. The fundamental O-QPSK method is to sum the in-phase signal with quadrature phase signal delayed by half a cycle in order to avoid the sudden phase shift change. Then, the modulated

O-QPSK signal goes along with the pulse shaping stage to reduce the inter-symbol interference (ISI). Each baseband chip is represented as a half-sine pulse shape. The resultant signal is transmitted by the RF transmitter
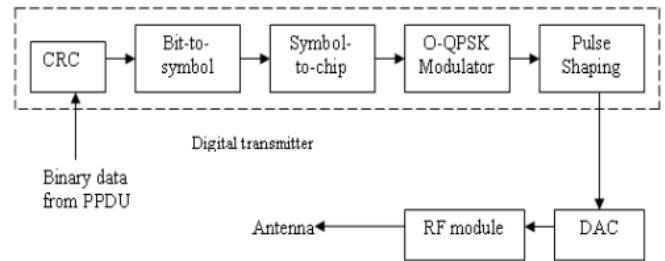

Fig. 5: Detailed block diagram of Zigbee transmitter

B. Design of ZigBee Rx

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 [10]. This section describes the implementation of ZigBee receiver system which is describe as given in below figure 6.
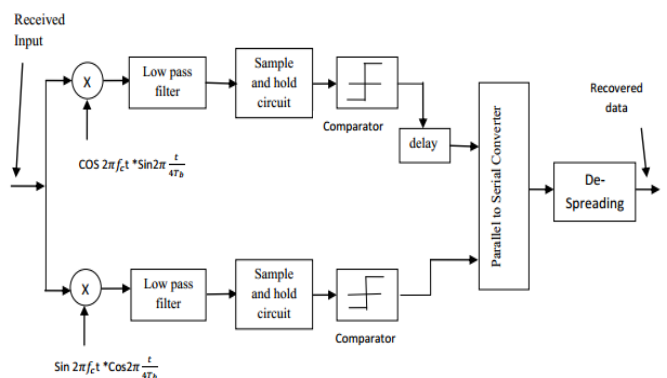

Fig. 6: Detailed block diagram of Zigbee receiver

In the receiver configuration of ZigBee, we are using a MSK demodulator and a multiplier for dispreading. 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.

VI. Simulation Using Simulink

This section describes the implementation of ZIGBEE transceiver system. The implementation was built on Matlab/Simulink using fundamental components in Simulink to demonstrate how reliably complex modulation schemes can be built, cost effectively and efficiently. The design of ZigBee transmitter using OQPSK modulation with half sine pulse shaping is shown in the Figure 7. given below.
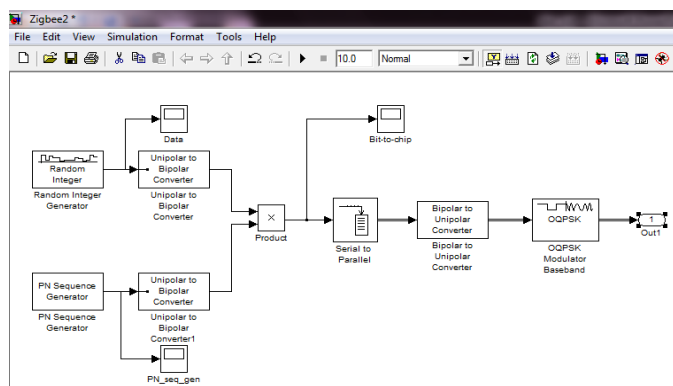

Fig. 7: ZigBee transmitter in Simulink work space.

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 8 below. The step by step procedure to implement ZigBee receiver using Simulink is presented below.
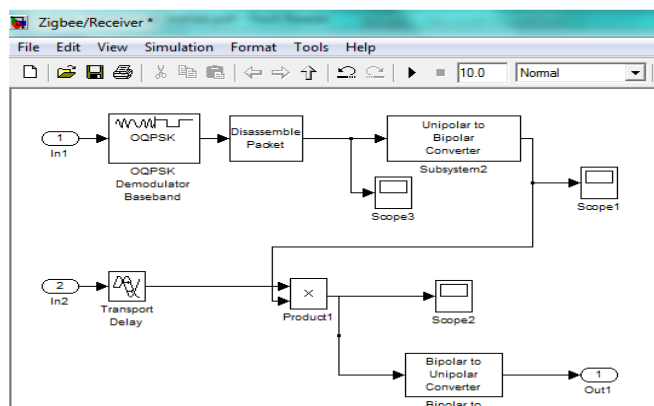

Fig. 8: ZigBee transmitter in Simulink work space

The implementation of ZigBee transceiver system combining ZigBee transmitter and receiver. The AWGN

channel adds noise to the transmitted signal when it is passed through it. The noisy version of the transmitted signal at the input of receiver. The Simulink implementation of transceiver is presented below in figure 9.
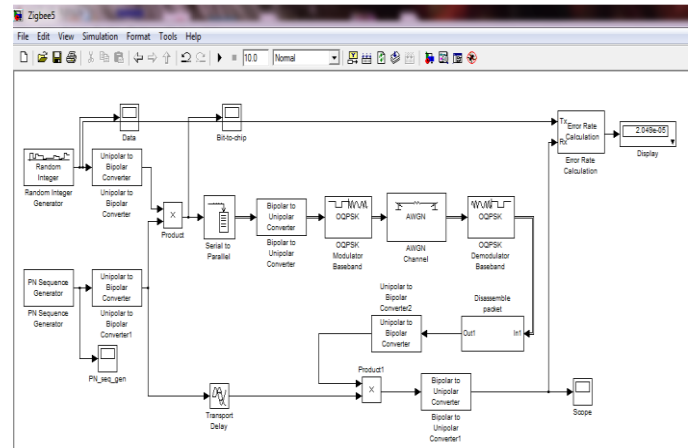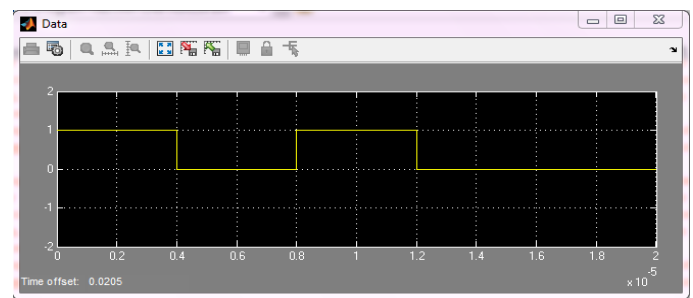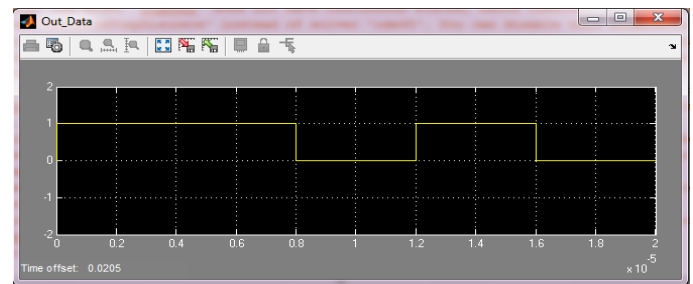

Fig. 9: ZigBee transceiver in Simulink work space

After simulate this transceiver model we get the output which is exact as the input except a small amount of delay .This is shown in figure 10 given below.

(a)

(b)

Fig. 10: Simulation result of ZigBee transceiver (a) input data (b) output data

VII. CONCLUSIONS

ZigBee is the reliable wireless network technology which is used for sensor network at low cost and low power. So it is used for wide range , home automation and also for military application. This paper describes the development of the bit-to-chip block as a part of the digital transmitter for 2.4 GHz band ZigBee Standard on Simulink. This block is used to improve the performance of receivers in a multipath environment. For future development this whole work is

transmitted into physical world using hardware description language like VHDL and verifies the performance of this ZigBee transceiver.

REFERENCES

[1]   S.S.Riaz Ahamed, "The role of Zigbee technology in future data communication system" Journal of Theoretical and Applied Information Technology, pp.129-135, 2009 .

[2]   P.Rohitha,P. Ranjeet Kumar "Wireless Networking Through ZigBee Technology ", International Journal of Advanced Research in Computer Science and Software Engineering Volume 2, Issue 7, pp.49-53, July 2012.

[3]   William Stalling,"Wireless Communication and Networks," Fourth Edition, Pearson Publication Limited, 2004, Pp 39-118.

[4]   ZigBee Alliance, Network Layer Specification 1.0, Dec. 2004. http://www.zigbee.org.

[5]   C. E. Perkins and E. M. Royer, "Ad hoc On-Demand Distance Vector Routing," in Proc. of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, pp. 90-100, 1999.

[6]   IEEE P802.15.4/ D18, "Low Rate Wireless Personal Area Networks" draft std, February 2003.

[7]   Khaled Shuaib, Maryam Alnuaimi, Mohamed Boulmalf, Imad Jawhar, Farag Sallabi and Abderrahmane Lakas, "Performance Evaluation of IEEE 802.15.4: Experimental and Simulation Results", Journal of Communications, Vol. 2, No. 4, pp 29-37 June 2007.

[8]   Chua-Chin Wang, Jian-Ming Huang, Lung-Hsuan Lee, Sen-Hung Wang, Chih-Peng Li, "A Low-Power 2.45 GHz ZigBee Transceiver for Wearable Personal Medical Devices in WPAN", IEEE, 2007.

[9]   IEEE Std 802.15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) specifications for Low Rate Wireless Personal Area Networks (LR-WPANs), 2003.

[10] Dayan Adionel Guimarˇaes, Digital Transmission: A Simulation-Aided Introduction with VisSim/Comm. NewYork, USA: Springer, 2009.
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