Design & Implementation of IEEE 802.15.4 ZigBee System by MSK Modulation

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Abstract: ZigBee/ IEEE 802.15.4 was evolved for replacement of Bluetooth & Wi-Fi technologies, since they were not capable to transmit low data rate information in comparatively large area (10-100 m) [1]. Use of ZigBee transceiver system instead of other technologies were made for special wireless networks where distance & battery life was needs to be improved. In this paper we have implemented ZigBee system by MSK modulation technique, which is implemented using OQPSK, as defined in ZigBee specifications. Bit Error Rate by using OQPSK modulation is implemented & compared with MSK modulation. Results shows BER for MSK is better than OQPSK. All the simulations were performed using MATLAB.

Keywords- ZigBee, IEEE 802.15.4, MSK, OQPSK, BER, MATLAB.

I. INTRODUCTION

ZigBee is a home-area network designed specifically to replace the proliferation of individual remote controls. ZigBee was created to satisfy the market need for a cost-efficient, standards-based wireless network that supports low data rates, low power consumption, security, and reliability. To address this need, the ZigBee Alliance, an industry working group is developing standardized application software on top of the IEEE 802.15.4 wireless standard. Zigbee standard is basically design for low cost, low power consuming & low data rate required system. Zigbee standard is placed in Physical and Medium Access Layer (MAC). As Zigbee is an standard of Zigbee Alliance. Higher layer specified in the Zigbee standard is for industry alliance.

The application of Zigbee Technology can be seen in home monitoring system, climate sensors communication, collection of data in small area in research field & industrial control etc. The major application of Zigbee transceiver is shown in wireless sensor networking and automatic control system such as home controlling, biotelemetry, personal caring (for senior citizens) etc. Home, industry and other organization automation is the major application of Zigbee transmission. Light (Power) control, Light machinery control, SCADA networking etc are some more.

The IEEE 802.15.4 wireless standard for low power, low data-rate sensor networks operate in the 2.4GHz industrial, scientific and medical (ISM) band. The ZigBee standard provides network, security, and application support services operating on top of the IEEE 802.15.4 Medium Access Control (MAC) and Physical Layer (PHY) wireless standard. It employs a suite of technologies to enable scalable, self-organizing, self-healing networks that can manage various data traffic patterns. Here we are try to reduce packet error rate and bit error rate the packet error rate (PER). PER is obtained from the bit error rate (BER) and the collision time. The BER is obtained from signal to noise and interference ratio using OQPSK modulation. By using a platform MATLAB/SIMULINK.

Here a comparatively analysis of Zigbee, Bluetooth and Wi-Fi technology is also present that will help us that how Zigbee is different than other wireless networking technologies [3]:

System	ZigBee	Bluetooth	Wi-Fi
Application	Monitoring & Control	Cable Replacement	Internet
System Resources	4-32 KB	250 KB	1 MB+
Battery Life (Days	100s-1000	1-7	Hours
Nodes in Network	255/65K	7	32
Baseband (kb/s)	20-250	720	11 Mbps
Distance	1-100m	1-10m	100m
Key Characteristics	Stability low Consumption low cost	Price, Easy use, High Data Rate	Very High Speed Large Network

Table 1: comparison of ZigBee with other protocols

II. A. ZIGBEE AND IEEE802.11.4 SPECIFICATIONS

Zigbee Alliance was established in August, 2001,The ZigBee specification, officially named ZigBee 2007.It offers full wireless mesh networking capable of supporting more than 64,000 devices on a single network. It’s designed to connect the widest range of devices, in any industry, into a single control network. The ZigBee specification has two implementation options or Feature Sets: ZigBee and ZigBee PRO. The ZigBee Feature Set is designed to support smaller networks with hundreds of devices in a single network. The ZigBee PRO Feature Set is the most popular choice of developers and the specification used for most Alliance developed ZigBee Feature Set, plus facilitates ease-of-use and advanced support for larger networks comprised of thousands of devices. Both Feature Sets are designed to interoperate with each other, ensuring long-term use and stability. The ZigBee specification enhances the IEEE 802.15.4 standard by adding network and security layers and an application framework. From this foundation, Alliance developed standards, technically referred to as public application profiles, can be used to create a multi-vendor interoperable solutions. For custom application where interoperability is not required, manufacturers can create their own manufacturer specific profiles.

Some of the characteristics of ZigBee include:

 Global operation in the 2.4GHz frequency band according to IEEE 802.15.4

 Regional operation in the 915Mhz (Americas) and 868Mhz (Europe).

 Frequency agile solution operating over 16 channels in the 2.4GHz frequency

 Incorporates power saving mechanisms for all device classes

 Discovery mechanism with full application confirmation

 Pairing mechanism with full application confirmation

 Multiple star topology and inter-personal area network (PAN) communication

 Various transmission options including broadcast

 Security key generation mechanism

 Utilizes the industry standard AES-128 security scheme

 Supports Alliance standards (public application profiles) or manufacturer specific profiles.

II. B. ZIGBEE STANDARD DEVICE TYPES

ZigBee devices are the combination of application (such as light sensor, lighting control etc), ZigBee logical(coordinator, router, end device), and ZigBee physical device types (Full Function Device and Reduced Function Device)[1].

Figure 1: ZigBee Network

II. C. ZIGBEE LOGICAL DEVICE TYPES

There are three categories of nodes in a ZigBee system. They are Coordinator, Router and End devices.

1) Coordinator: Forms the root of the network tree and might bridge to other networks. There is exactly one coordinator in each network. It is responsible for initiating the network and selecting the network parameters such as radio frequency channel, unique network identifier and setting other operational parameters. It can also store the information about network, security keys.

2) Router: Router acts as intermediate nodes, relaying data from other devices. Router can connect to an already existent network, also able to accept connections from other devices and be some kind of re-transmitters to the network. Network may be extended through the use of ZigBee routers.

3) End Devices: End Device can be low-power /battery-powered devices. They can collect various information from sensors and switches. They have sufficient functionality to talk to their parents (either the coordinator or a router) and cannot relay data from other devices. This reduced functionality allows for the potential to reduce their cost. They support better low power models. These devices do not have to stay awake the whole time, while the devices belonging to the other two categories have to. Each end device can have up to 240 end nodes which are separate applications sharing the same radio.

These are end devices such as sensors actuators which only doing limited tasks like recording temperature data, monitoring lighting condition or controlling external devices. The current ZigBee standard requires FFDs to be always on, which in practice means that FFDs must be constantly powered. Battery-powered FFDs have a lifetime on the order of a few days.

II. D. ZIGBEE PHYSICAL DEVICE TYPES

Based on data processing capabilities, two types of physical devices are provided in IEEE 802.15.4: Full Function Devices (FFD) and Reduced Function Devices (RFD). Full Function Devices can perform all available operations within the standard, including routing mechanism, coordination tasks and sensing task. The FFD plays role of coordinator or router or end devices (It can be either FFD or RFD depends on its intended application). A typical FFD in a ZigBee network will be powered from an AC-fed mains supply, as it must always be active and listening to the network. Reduced Function Devices, on the other hand, implements a limited version of the IEEE 802.15.4 protocol. The RFDs do not route packets and must be associated with an FFD.

II. E. ZIGBEE / IEEE 802.15.4 PROTOCOL ARCHITECTURE

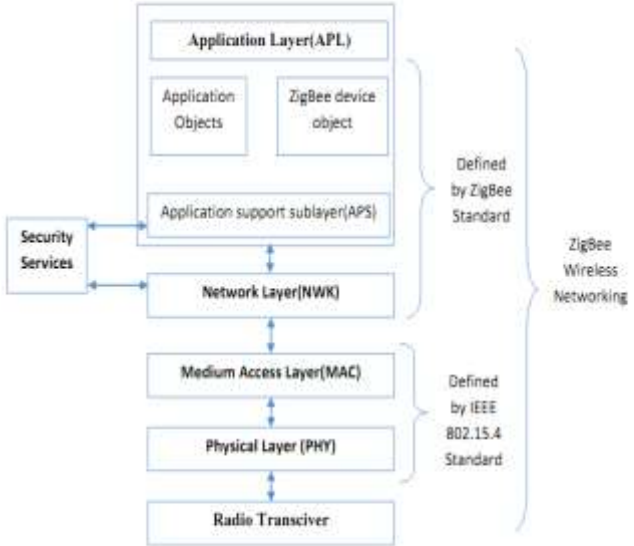

Figure 2: ZigBee/IEEE 802.15.4 Architecture

II. F. FREQUENCY BANDS AND DATA RATES

The standard specifies two PHYs:

1) 868 MHz/915 MHz direct sequence spread spectrum (DSSS) PHY (11channels) 1 channel (20Kb/s) in European 868MHz band 10 channels (40Kb/s) in 915 (902-928) MHz ISM band.

2) 2450 MHz direct sequence spread spectrum (DSSS) PHY (16 channels) 16 channels (250Kb/s) in 2.4GHz band.

III. PROPOSED METHODOLOGY

The main objective of this work is to simulate and physical level simulation of IEEE 802.15.4 ZigBee protocol. For this we have simulated the ZigBee system for IEEE 802.15.4. In this process first we have implemented the ZigBee system with existing OQPSK modulation, than the system is being implemented using MSK using OQPSK by using platform MATLAB.

PHY (MHz)	Frequency band (MHz)	Spreading parameters		Data parameters		
		Chip rate (k-chip/s)	Modulation	Bit rate (kb/s)	Symbol rate (k-symbol/s)	Symbols
868/915	868-868.6	300	BPSK	20	20	Binary
	902-928	600	BPSK	40	40	Binary
2450	2400-2483.5	2000	O-QPSK	250	62.5	16-ary Orthogonal

Table 2: Frequency Bands & Data Rates of ZigBee

Proposed Algorithm

1. Take the input signal bit stream.
2. Convert Bit sequence into symbols, i.e. generation of symbols for MSK 1 & 0 for MSK & 0 to 15 OQPSK.
3. Perform DSSS Mapping Replacing Symbols with the appropriate PN (Pseudo Noise) Sequence.
4. Perform Serial to Parallel Conversion.
5. Now perform Raised Cosine Pulse Shaping & or Root Raised Cosine shaping for half-half parts.
6. Then MSK modulation through OQPSK is performed separately for both the halves.
7. After modulation both the half portions are add-up, the combined signal is ZigBee compatible signal, which can be transmitted over wireless communication channel.
8. When signals are communicated through a wireless channel, it is contaminated by noise. In this work we have taken AWGN noise model.
9. At the reception the obtained signal from wireless channel is required some pre-processing first. The signal is filtered by a filter with Channel Impulse Response (CIR), but it also inserts some attenuation.
10. For detection of original the signal from received combined signal Matched Filter is used, which performs Root Raised Cosine filtering or Square Root Raised Cosine filtering.
11. MSK through OQPSK, demodulation is performed for demodulation of the signal.
12. This demodulated signal requires Header Correlation, which is required because of Filter Delay, hence it is Compensation.
13. To get the original bit sequence DSSS Demapping with logical operation like XOR/ XNOR, reverse is applied to extract original bit stream of symbol.
14. Finally, after extraction of original bit stream, BER calculation & plotting of BER vs SNR is performed.

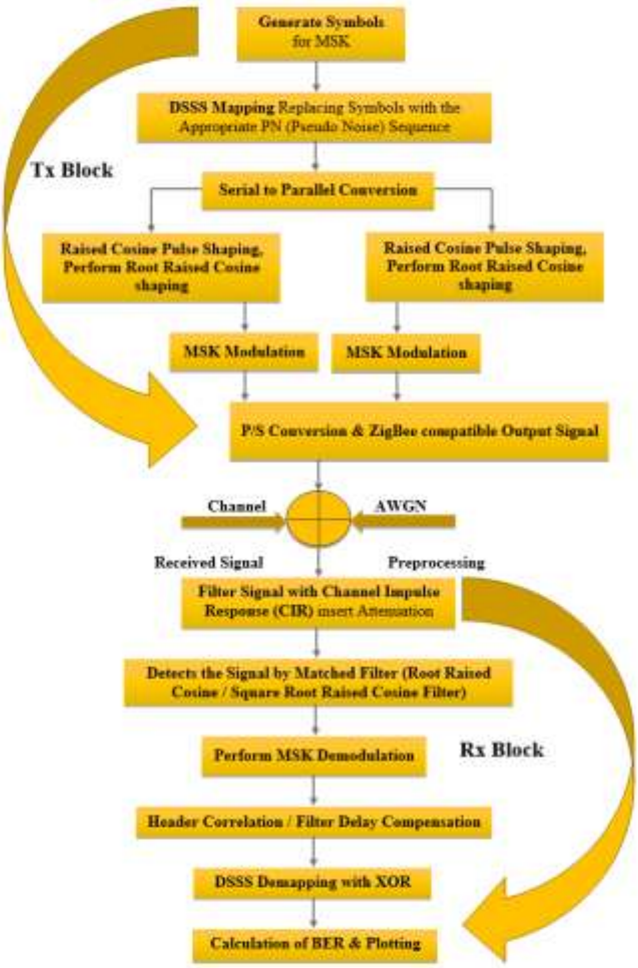

Figure 3: IEEE 802.15.4 / ZigBee Generic MATLAB Simulation Block Model

IV. SIMULATION RESULTS

In this work physical layer MSK modulation implementation of IEEE 802.15.4 ZigBee has been done. First with the help of existing OQPSK modulation technique the IEEE 802.15.4 ZigBee protocol, system was implemented, then using MSK through OQPSK modulation the system was implemented again. Several MATLAB/Simulink simulations were done to evaluate the performance of Zigbee/IEEE 802.15.4 physical layer. The simulation results show how the BER versus the SNR values were affected when varying communication parameters such the input data rate, the level of the AWGN power and number of bits per symbol.

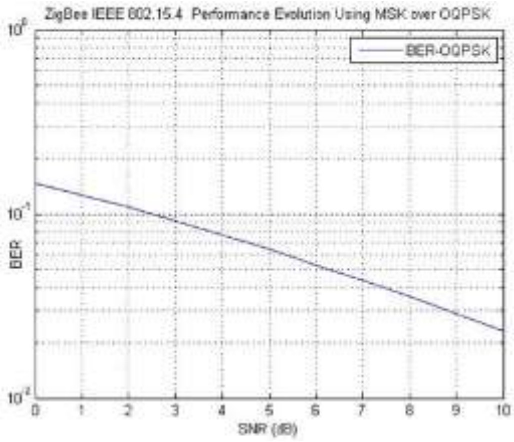

Figure 4: BER for ZigBee with Conventional OQPSK

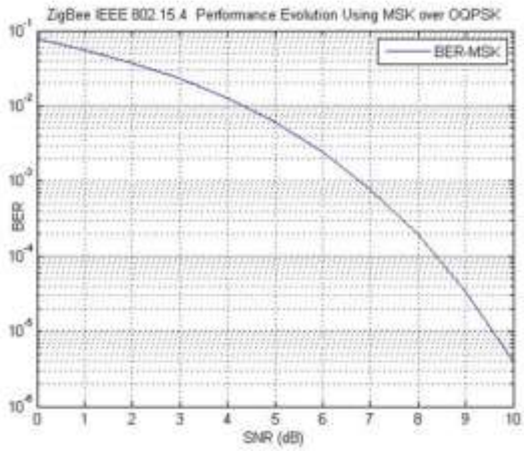

Figure 5: BER for ZigBee with MSK Using OQPSK

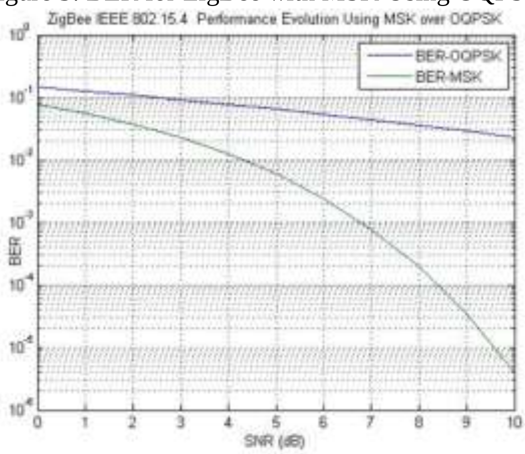

Figure 6: BER Performance of ZigBee for OQPSK & MSK

E_b/N_o	BER (Bit Error Rate Probability) OQPSK	MSK(Proposed)	% Improvement compared to OQPSK
0	0.1922500	0.0785980	59.10%
1	0.1708750	0.0560500	67.20%
2	0.1536250	0.0371180	77.33%
3	0.1320625	0.0228120	83.33%
4	0.1123750	0.0124060	88.70%
5	0.0896250	0.0059480	93.41%
6	0.0737500	0.0023800	96.87%
7	0.0548750	0.0007180	98.68%
8	0.0360000	0.0001520	99.58%
9	0.0223125	0.0000260	99.82%
10	0.0136250	0.0000002	99.98%
Overall Average Percentage Improvement			84.14%

Table 3: Simulation Results Comparison

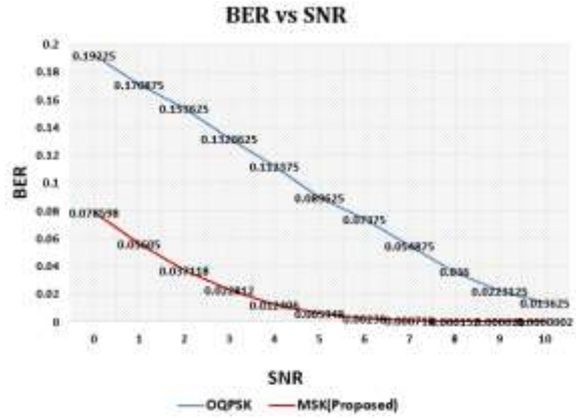

Figure 7: BER vs SNR for OQPSK & Proposed Schemes

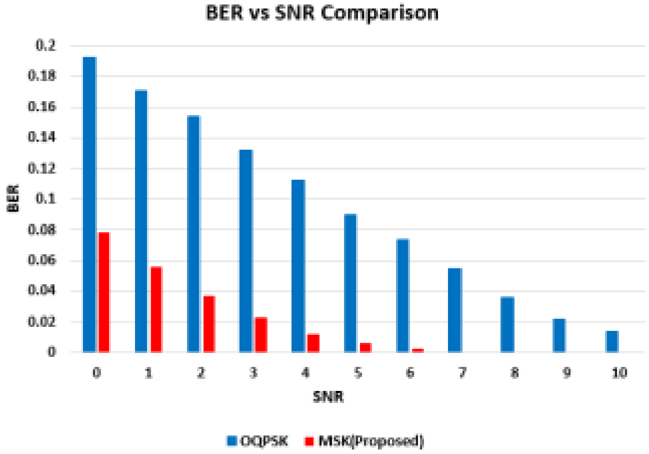

Figure 8: Graph for BER vs SNR Comparison

VI. CONCLUSION

In this work physical layer modulation level implementation of IEEE 802.15.4 / ZigBee protocol has been done. First the simulation of the system with existing OQPSK modulation has been done. Then, the system was implemented with the MSK modulation using OQPSK, was simulated. The simulation's BER plots and Table show that the MSK modulation has better bit error rates performance than the OQPSK modulation. The OQPSK system offers twice the data rate of the MSK system, but the OQPSK system requires more memory and compute cycles. Based on the results of this work, one would choose the 868 MHz or 968 MHz MSK Physical Layer to optimize the hardware cost and implement the 2.4 GHz Physical Layer to maximize data rate. But, overall we can conclude that due to minimum variations in MSK, the BER probability is less in MSK systems.

REFERENCES

[1] Pere Pala et al, "Superregenerative Reception of Narrowband FSK Modulations", IEEE Transactions on Circuits & Systems-I: Regular Papers, Vol. 62, No. 3, March 2015.
[2] Varshney et al., "Comparative Analysis of OQPSK and MSK Based ZigBee Transceiver Using MATLAB", International Journal of Advanced Research in Computer Science and Software Engineering 3(6), Pp. 948-956, June - 2013.
[3] Irfan Ali et al , "Bit-Error-Rate (BER) Simulation Using MATLAB", International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 ,Vol. 3, Issue 1, Pp.706-711, February 2013.

[4] Kapil Dev Jha et al, “Design & Simulation of ZigBee Transceiver System Based on MSK and QPSK Using Matlab”,International Journal of New Trends in Electronics and Communication (IJNTEC) ,Vol.1, Issue. 4, Nov. 2013.

[5] WeiYuan et al, “CoexistencePerformance of IEEE 802.15.4 Wireless Sensor Networks Under IEEE 802.11b/g Interference”, International Journal Distributed Sensor Networks volume , Article ID581081,Pp -6,2010.

[6] G.M.Tamilselvan and Dr.A.Shanmugam, “Probability Analysis of channel collision between IEEE 802.15.4 and IEEE 802.11b using Qualnet Simulation for various Topologies” International Journal of Computer Theory and Engineering, Vol. 1, No. 1, April 2009.

[7] Nazif CihanTas et-al,“IEEE 802.15.4 Throughput Analysis under IEEE 802.11 Interference” International Symposium on Innovations and Real Time Applications of Distributed Sensor Networks, 2007

[8] Yuan, W., Linnartz, J. P. M. G., & Niemegeers, “Adaptive CCA for IEEE 802.15.4 wireless sensor networks to mitigate interference” IEEE wireless communications and networking conference Sydney, pp.1–5,2010.

[9] Z. Alliance, “ZigBee Alliance,” WPAN industry group, the industry group responsible for the ZigBee standard and certification, 2010.

[10] C. V. Berta, D. P. A. Rodolfo, R. Susan, and P. Dirk, “Experimental evaluation of beacon scheduling mechanisms for multihop IEEE 802.15.4 wireless sensor networks,” in Proceedings of the 4th International Conference on Sensor Technologies and Applications (Sensor Comm '10), pp. 226–231, July 2010

[11] S. Ahmed, “The Role of ZigBee Technology in Future Data Communication System,”Journal of Applied Information Technology, vol. 5, no. 2, pp. 129 – 135, 2009.

[12] IEEE Standard for Local and Metropolitan Area Networks-Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs), IEEE Computer Society Std. IEEE 802.11b: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-Speed Physical Layer Extension in the 2.4GHz Band, 1999.

[13] K. Shuaib and I. Jawhar M. Alnuaimi, "Performance Evaluation of IEEE 802.15.4 Physical Layer Using Matlab/Simulink" in Innovations in information technology, Pp. 1-5 November 2006.

[14] MaryamAlnuaimi, Mohamed Boulmalf, FaragSallabi and AbderrahmaneLakas Khaled Shuaid, "Performance Evaluation of IEEE 802.15.4: Experimental and simulation Results," Journal of Communications, vol. 2, pp. 29-37, June 2007.

[15] IEEE Std.802-15.4, “IEEE Standard for Wireless Medium Access Control(MAC) and Physical Layer(PHY) Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs),” 2003.

[16] Ramanathan.P, Pradip Manjrekar, “Wireless Sensor Network For Monitoring Accidents Continuously Using Zigbee” in International Journal of New Trends in Electronics and Communication (IJNTEC) Vol.1, Issue. 4, Nov. 2013.

[17] Sohraby, K Jana, R. Chonggang Wang, Lusheng Ji, and M. Daneshmand, "Voice communications over ZigBee networks," IEEE communications magazine, vol. 46, pp. 121 -127, January 2008.

[18] Rumiana Krasteva, Ani Boneva, Vesselin Georchev, Ivilin Stoianov, “Application of Wireless Protocols Bluetooth and ZigBee in Telemetry System Development” in Problems of Engineering Cybernetics And Robotics, 55, Sofia, 2005.

[19] Chi-Chun Huang, Jian-Ming Huang, Chih-Yi Chang and Chih-Peng Li Chua-Chin Wang, "ZigBee 868/915-MHz Modulator/Demodulator for Wireless Personal Area Network," IEEE transactions on Very Large Scale Integration(VLSI) systems, vol. 46, pp. 936-939, July 2008.

[20] L. Skrzypczak, D. Grimaldi, R. Rak, “Basic Characteristics of Zigbee And Simplicity Modules to Use In Measurement Systems” XIX IMEKO World Congress Fundamental and Applied Metrology September 6!11, 2009, Lisbon, Portugal.

[21] Khaled Shuaib, Maryam Alnuaimi, Mohamed Boulmalf, Imad Jawhar, Farag Sallabi and Abderrahmane Lakas, “Performance Evaluation of IEEE 802.15.4: Experimental and Simulation Results” in Journal Of Communications, Vol. 2, No. 4, June 2007.

[22] K. Shuaib and I. Jawhar M. Alnuaimi, "Performance Evaluation of IEEE 802.15.4 Physical Layer Using Matlab/Simulink," in Innovations in information technology, Nov 2006, Pp. 1 -5.

[23] Nam-Jin Oh and Sang-Gug Lee, "Building a 2.4-GHZ radio transceiver using IEEE 802.15.4," Circuits and Devices Magazine, IEEE, vol. 21, no. 6, pp. 43-51, Jan - Feb 2006.

[24] Dayan Adionel Guimar˜aes, Digital Transmission: A Simulation-Aided Introduction with VisSim/Comm. NewYork, USA: Springer, 2009.

[25] Nisha Ashok Somani, Yask Patel, “Zigbee: A Low Power Wireless Technology For Industrial Applications” in International Journal of Control Theory and Computer Modelling (IJCTCM) Vol.2, No.3, May 2012.

[26] Yang Yong chang, Zong Peng and Wei Zhi yong, “The Influence of Space Environments on Radio Propagation”Spacecraft Environment Engineering, vol .26 No.(1), 2009,pp.26-31.

[27] Shahin Farahani, “Zigbee Wireless Sensors and Transceivers”1 st Edition, Kiesvier Publication, ISBN: 978-0-7506-8393-7.

[28] Simon Haykin, Communication Systems, 4th ed. NewYork, USA: John wiley, 2001.

[29] Fleisher S.M. and Qu S, "Multifrequency minimum shift keying," IEEE journal on selected areas of communications, vol. 10, no. 8, pp. 1243-1253, october 1992.

[30] Scolari N and Enz C.C., "Digital receiver architectures for the IEEE 802.15.4 standard," in ISCAS '04. Proceedings of the 2004 International Symposium on Circuits and Systems, vol. 4, 2004, pp. 345-348.

[31].Challoo, A. Oladeinde, N. Yilmazer, S. Ozcelik, L. Challoo,”An Overview and Assessment of Wireless Technologies and Coexistence of ZigBee, Bluetooth and Wi-Fi Devices” Procedia Computer science 12(2012)386-391.

[32] Sourangsu Banerji, Rahul Singha Chowdhury,” Wi-Fi & WiMAX: A Comparative Study “Indian Journal of Engineering, Vol.2, Issue. 5, 2013.

