Abstract—OQPSK modulation technique is used for designing Zigbee transceiver worldwide since several years of invention of ZigBee technology. It provides good battery life, better range and various other advantages for which Zigbee technology is known. But here we are discussing about the transceiver performance over the noisy channel. In noisy channel, we are proposing MSK based Zigbee technology and comparing it with OQPSK based Zigbee technology in terms of the effects of signal to noise ratio (SNR) of transmitted signal in both the modulation techniques.

Keywords—MSK, Noisy Channel, OQPSK, SNR, Zigbee.

I. INTRODUCTION

Zigbee is the standard which provides low cost, low power consumable & wireless mesh networking system. Low cost of transceiver allows the technology to be widely used in different applications. As it is required to maximize used of small size batteries. Low power consumption helps to use battery in long duration. And the small area networking (Mesh Network) provides high reliability and more extensive networking. Data rate achieved in Zigbee standard is low this we can be use this standard where low data rate communication required. Wireless devices which are based on Zigbee standard operate in 868MHz, 915MHz and 2.4GHz frequency bands. [1-3]. The main target application of Zigbee standard is the WPAN where low data rate, low cost & long battery life required. Like space craft sent to mars has its own WPAN to transmit low rate data as atmospheric temperature, pressure, longitude, latitude etc, to main server. Here we need long battery life because one space craft is placed in the space for several years. So, Zigbee technology may help to achieve these goals [4-7].

II. OFFSET QUADRATURE PHASE SHIFT KEYING (OQPSK)

Offset QPSK is essentially the same as QPSK except that the In-Phase and Quadrature-Phase channel pulse trains are staggered. The modulator and the demodulator of OQPSK using MATLAB are shown in Fig.1, which show the difference with the QPSK only by an extra delay of T/2 seconds in Q-channel. Based on the modulator, the OQPSK signal can be written as

\[ s(t) = \frac{1}{\sqrt{2}} d_r(t) \cos \left(2\pi f_d t + \frac{\pi}{4}\right) + \frac{1}{\sqrt{2}} d_q(t) \sin \left(2\pi f_d t + \frac{\pi}{4}\right) \]

Fig. 1: Zigbee Transmitter Using OQPSK Modulation Technique
Since OQPSK differs from QPSK only by a delay in the Q-channel signal, its power spectral density is the same as that of QPSK, and its error performance is also the same as that of QPSK. But here the maximum phase change in the waveform is \( \pi/2 \). So, OQPSK is more power-efficient than QPSK technique. Non-linear power amplification can be used without too much distortion in bandwidth [9-11]. Input signal given into the transmitter is 250 kbps pulse which is shown in Fig. 2.

![Fig. 2: Input bit stream generated by Bernoulli random generator](image)

After adding input signal with PN sequence using modulo-2 adder we get the spreaded signal. The advantage of spreaded signal is that it needs low signal power to transmit over the channel. The spreaded input signal is shown in Fig. 3.

![Fig. 3: Spreaded Input Data](image)

The In-phase data and Quadrature-Phase data after serial to parallel conversion will be of 1 Mbps because the odd and even bits will be held for half duration. To have In-Phase and Quadrature-Phase clock pulse, we used the J-K flip-flop. We may use here T flip-flop instead of J-K. The in-phase and quadrature-phase digital signal after passing through the D flip-flop which is operated by In-Phase and Quadrature-Phase clock are shown in Fig. 4.

![Fig. 4: In-phase and Quadrature-Phase data stream](image)

After multiplying sine wave with in-phase and quadrature-phase digital signal we got the half sine pulse shaped signal. As the sine pulse duration as twice of bit duration, the half pulse we result after multiplication. The resulted signals are shown in Fig. 5(a) & Fig. 5(b).

![Fig. 5(a): Half Sine Pulse shaping of In-Phase signal](image)
After adding both signals, we will get the final transmitted signal as shown in Fig. 6. For understanding the phase changes the zoomed view of signal is also presented here.

Here we can see that the maximum phase change is not more than 90°. By taking this advantage, an efficient power amplifier can be designed in the realization of hardware. After transmission of signal, we assume that it passes through the Additive White Gaussian Noise channel so some external noise will be added to it. So, transmitted signal with White Gaussian Noise will be received by the signal. The Zigbee receiver system using OQPSK modulation technique is shown in Fig. 7.

The signal shown below (Fig. 8) is the received signal that comes through AWGN channel. In this channel White Gaussian noise is added to the transmitted signal. Here we choose AWGN channel because the average noise power in all channel is zero.
Here we can’t see the variation in phase of signal, so zoomed signal of Fig. 8 is shown in Fig. 9.

![Zoomed view of received signal at receiver](image)

Fig. 9: Zoomed view of received signal at receiver

Now received signal is multiplied with the carrier and then with half sine wave. The carrier and half sine pulse carrier are generated as previous type. It generated the in-phase and quadrature-phase signal with high frequency components. The resultant signals containing both the high frequency harmonics and baseband signal components. It separates the baseband signal components form high frequency harmonics by passing through a low pass filter. These signals are passed through a 3rd order Butterworth low pass filter having cutoff frequency of 500 KHz for extracting only baseband data. As we will see the signal is just like the input signal of modulator at half sine pulse shaping, but some noise is added due to the AWGN channel which is shown in fig. 10 & 11.

![In-phase received signal after low pass filtering](image)

Fig. 10: In-phase received signal after low pass filtering

![Quadrature-phase received signal after low pass filtering](image)

Fig. 11: Quadrature-phase received signal after low pass filtering

Now a comparator is added to compare the signal with a threshold value. If signal is below ‘0’ volt then it is treated as ‘0’ otherwise it is taken as ‘1’. We can also use maximum likelihood detection technique. The compared in-phase & quadrature-phase signals are shown in fig. 12(a) & 12(b).

![In-Phase Data after Comparision](image)

Fig. 12(a): In-Phase Data after Comparision

![Quadrature-Phase Data after Comparision](image)

Fig. 12(b): Quadrature-Phase Data after Comparision
Here we recovered the original data after use of parallel to serial converter i.e. a switch & shifted version of PN sequence at the receiver end as shown in Fig. 13.

![Fig. 13: Delayed Baseband Digital Signal at Receiver](image)

As we found that the transmitted signal and received signal are similar but a small time delay is exists. This time delayed can be synchronized at receiver by clock synchronization techniques.

### III. Minimum Shift Keying (MSK)

In the replacement of QPSK and OQPSK we choose MSK modulation techniques because, in MSK, the baseband waveform, that multiplies the Quadrature carrier, is much smoother than the abrupt rectangular waveform of QPSK. While the spectrum of MSK has a main centre lobe which is 1.5 times as wide as the main lobe of QPSK, the side lobes in MSK are relatively much smaller in comparison to the main lobe, making filtering much easier. Minimum shift keying (MSK) is a special type of continuous phase-frequency shift keying (CPFSK) with $h=0.5$. A modulation index of 0.5 corresponds to the minimum frequency spacing that allows two FSK signals to be coherently orthogonal, and the name minimum shift keying implies the minimum frequency separation (i.e. bandwidth) that allows orthogonal detection [12-14]. MSK has one of two possible frequencies over any symbol interval:

$$s(t) = a_I(t)\cos\left(\frac{\pi}{27}\right) \cos 2\pi f_c t + a_Q(t)\sin\left(\frac{\pi}{27}\right) \sin 2\pi f_c t$$

A Simulink model of Zigbee transmitter using MSK modulation is shown in Fig. 14.

![Fig. 14: Zigbee Transmitter Using MSK Modulation Technique](image)

The results of MSK transmitter are shown below [16]. First the input signal applied to transmitter system is generated by bernaully generator which is shown in fig. 15.

![Fig. 15: Input bit stream generated by Bernoulli random generator](image)

In-Phase & Quadrature-Phase signals are same as OQPSK signals. Then 2.4GHz MSK wave form is constructed which is shown in Fig. 16.
Fig. 16: In-Phase & Quadrature-Phase MSK Modulated Signal

Addition of both data will generated the final MSK modulated Zigbee transmitter signal i.e. Shown in Fig. 17.

Fig. 17: Transmitted Signal with its zoomed view

Simulink model for Zigbee Transmitter system using OQPSK modulation is given. Here the signal coming through AWGN channel is converted into In-Phase and Quadrature-Phase via multiplication of In-Phase and Quadrature-Phase carrier. Then In-Phase and Quadrature-Phase signal passes through integrator which results the resulted original signal with noise. Then a comparator is used which compare the signal at 2 Mbps which give the result that incoming signal is 0 or 1. Then a delay is provided to In-Phase signal using D flip-flop and switch is used to convert this parallel signal into serial signal. The designed model is shown in Fig. 18.
For clarity zoomed view of Fig. 19 is presented in Fig. 20.

![Fig. 19: Received Signal at Receiver](image1)

**Fig. 19: Received Signal at Receiver**

**Fig. 20: Zoomed View of Received Signal**

To recover signal carrier signal of center frequency 2.4GHz is multiplied with received signal which create in-phase and quadrature-phase signal as shown in Fig. 21.

![Fig. 21: In-Phase and Quadrature-Phase Data after Carrier Multiplication](image2)

**Fig. 21: In-Phase and Quadrature-Phase Data after Carrier Multiplication**

The resulting signal passes through the integrator with time limit of $-T_b$ to $T_b$ for in-phase signal and 0 to $2T_b$ for Quadrature-Phase signal then it go to the sample and hold circuit. Sample & hold circuit & comparator provide us the original inphase & quadrature phase data. Then after providing one bit delay in quadrature phase data & find out the parallel to serial data. In-Phase & Quadrature-Phase data signal are shown in Fig. 22.

![Fig. 22: In-Phase & Quadrature-Phase Data after Comparison](image3)

**Fig. 22: In-Phase & Quadrature-Phase Data after Comparison**
Now signal can be serially received after using parallel to serial converter that’s a switch. This switch is operated with a clock of 250 Kbps & then we recovered the original data after use of shifted version of PN sequence at the receiver end. The received signal will be same as the input signal provided to the transmitter but a small time delay will achieve as shown in Fig. 23.

![Fig. 23: Delayed Baseband Digital Signal at Receiver](image)

Here we can compare both transceivers using Bit Error Rate and power consumption. Firstly the bit error rate is analysed according to various signals to noise ratio. The signal to noise ratio can be modulated by setting the parameter of AWGN channel. The amount of noise added in the channel is varying discretely. According this we calculated the Bit error rate for each SNR.

![Fig. 24: Bit error rate for OQPSK and MSK based Zigbee Transceiver](image)

From this graphs it can be seen that the performance in terms of values of irreducible BER is lower while using MSK modulation instead of OQPSK modulation in Zigbee transceiver system when signal to noise ratio is low. As the bandwidth required in both technology is same so, it is clear that we can use the MSK modulation technique in poor channel for low power consumption which is the most important feature of Zigbee technology.

**IV. CONCLUSION**

Here we have implemented the Zigbee transceiver on Simulink using OQPSK & MSK modulation technique. It provided a comparative analysis in both the technologies. After analysis we found that MSK produce constant envelope carrier signals, which have no amplitude & phase variations. This is a desirable characteristic for improving the power efficiency of transmitters. Amplitude variations can exercise nonlinearities in an amplifier’s amplitude-transfer function, generating spectral regrowth, a component of adjacent channel power. Therefore, more efficient amplifiers (which tend to be less linear) can be used with constant-envelope signals, reducing power consumption. After seeing scope graph of BER as shown in Fig. 24 we found that the error rate in MSK is lesser in comparison of OQPSK based Zigbee transceiver thus this may be the better option for designing new wireless sensor network using Zigbee technology and also it will be a more power saving methodology in comparison of other one. In another terms it can be concluded that for noisier channel, MSK modulation technique will be more efficient than OQPSK modulation technique.

**REFERENCES**

Varshney et al., International Journal of Advanced Research in Computer Science and Software Engineering 3(6), June - 2013, pp. 948-956


Authors Profile

Yash Vardhan Varshney has completed his bachelor degree from UPTU, Lucknow in 2009. He is currently doing his M Tech thesis work at the Deptt. of ECE, Institute of Engineering & Technology, Alwar affiliated to Rajasthan Technical University, Kota. His research area is Digital communication.

Dr. Anil Kumar Sharma (MIEEE) received his M.E. degree in Electronics & Communication Engineering (ECE) from Birla Institute of Technology, Deemed University, Mesra, Ranchi, India, in 2007 with CGPA of 8.45 and Ph. D in ECE in 2011. He has an experience of 20 years on various RADARs and Communication Equipments. He is currently a Professor in the Department of ECE and Vice Principal, Institute of Engineering and Technology, Alwar- 301030, Rajasthan, India. He has published 18 papers in International Journals and over 40 papers in Conferences. His research/teaching interest includes WSN, VLSI Design, RADARs and Soft Computing.