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Quadrature Phase Shift Keying and Offset Quadrature Phase Shift Keying BER Performance Comparison

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Abstract: Modulation plays an important role in transmission of signals from transmitter to receiver in all communication systems and the performance of digital modulation systems is of the most important key factors to achieve the best results of the communication process . This paper presents a comparative study of some performance parameters or performance metrics of a digital communication system with the aid of a Simulink model between Quadrature Phase Shift Keying (QPSK) and Offset Quadrature Phase Shift Keying (OQPSK) modulations in simple steps in terms of description of inputs and outputs in simulations, complex signal representations ,computations of bit error rate (BER) simulated and theoretical results for (QPSK) , (OQPSK) and Comparison of the symbol error rate performance using MATLAB program .

KeyWords : *QPSK ,OQPSK,, Modulator, performance ,Bit Error Rati , Simulator(Matlab),*

I. Introduction

In wireless, satellite, and space communication systems, reducing error is critical. Wireless medium is quite different from the counterpart using wires and provides several advantages, for example; mobility, better productivity, low cost, easy installation facility and scalability. On the other hand, there are some restrictions and disadvantages of various transmission channels in wireless medium between receiver and transmitter where transmitted signals arrive at receiver with different power and time delay due to the reflection, diffraction and scattering effects. Besides the BER (Bit Error Rate) value of the wireless medium is relatively high. These drawbacks sometimes introduce destructive effects on the wireless data transmission performance. As a result, error control is necessary in these applications. During digital data transmission and storage operations, performance criterion is commonly determined by BER which is simply: Number of error bits / Number of total bits. Noise in transmission medium disturbs the signal and causes data corruptions. Relation between signal and noise is described with SNR (signal-to-noise ratio). Generally, SNR is defined as signal power / noise power and is inversely proportional with BER. It means, the less the BER the higher is the SNR and the better is the communication quality . A comparative study of QPSK and OQPSK using Root Raised Cosine and Raised Cosine Pulse-shaping Filters in terms of EVM, Magnitude Error, Phase Error, Bandwidth efficiency and BER showed that EVM is better for QOPSK with RRC filter (α=0.35), OQPSK and QPSK with RRC (α=0.35) have similar performance for magnitude and phase error, OQPSK with RC filter (α=0.22) has better bandwidth efficiency and in terms of BER QPSK with RRC filter (α=0.7) showed better performance [1].

II. *QPSK Modulation*.

Quadrature Phase Shift Keying (QPSK) is a form of Phase Shift Keying in which two bits are modulated at once, selecting one of four possible carrier phase shifts (0, 90, 180, or 270 degrees). QPSK allows the signal to carry twice as much information as an ordinary PSK using the same bandwidth. QPSK is used for satellite transmission of MPEG2 video, cable modems, Videoconferencing, cellular phone systems, and other forms of digital communication over an RF carrier.

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QPSK (Quadrature Phase Shift Keying) is one of the modulation schemes used in wireless communication system due to its ability to transmit twice the data rate for a given bandwidth. The mathematical analysis shows that QPSK can be used either to double the data rate compared with a BPSK system while maintaining the same bandwidth of the signal, or to maintain the data-rate of BPSK but halving the bandwidth needed. In this latter case, the BER of QPSK is exactly the same as the BER of BPSK [2].The QPSK modulator is illustrated in fig 1.The binary sequence is separated by the serial-to-parallel converter into odd-bit-sequence for I channel and even bit- sequence for Q channel.[3]

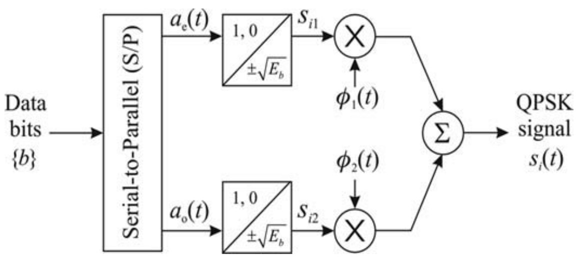

Fig. 1. QPSK modulator

$a_e(t)$ and $a_o(t)$ can be detect and estimated independently the streams by means of two BPSK demodulators in parallel. This is illustrated in the coherent QPSK demodulator shown in Fig. 2. Note that after the estimates of the bit streams $a_e(t)$ and $a_o(t)$ are performed, a parallel-to-serial converter produces the estimate of the transmitted data bit stream

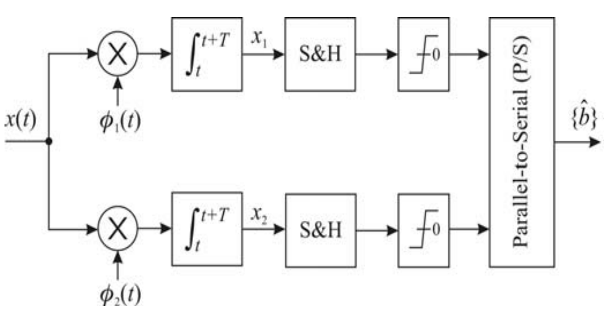

Fig. 2 Coherent QPSK demodulator

III. *Offset QPSK Modulation.*

The idea behind the offset QPSK (OQPSK) or staggered QPSK (SQPSK) modulation is very simple, though very interesting. A QPSK signal can be formed by adding two independent BPSK signals, one carrying even data bits and the other carrying odd data bits. Observing the waveforms shown in Fig. 3 ,it can be noticed that whenever the in-phase *or* the Quadrature component of the BPSK signal exhibits a phase transition, the corresponding QPSK phase transition is $\pm\pi/2$.[3]

Now consider the block diagram shown in Fig. 4, in which the insertion of a delay in the even data stream is the only difference between a conventional QPSK modulator and the resulting OQPSK modulator.

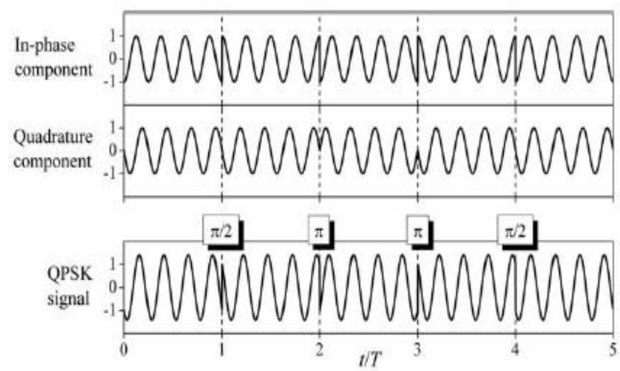

Fig. 3 . In-phase, quadrature and composite phase transitions of a QPSK signal

This delay guarantees that phase transitions in the in-phase and quadrature component BPSK signals never occur Simultaneously , avoiding the occurrence of phase transitions of $\pm\pi$ in the resultant OQPSK signal. As a consequence, a filtered OQPSK signal will exhibit lower envelope fluctuations, becoming a more attractive choice as compared to the conventional QPSK modulation when nonlinear distortion is present in the signal path.

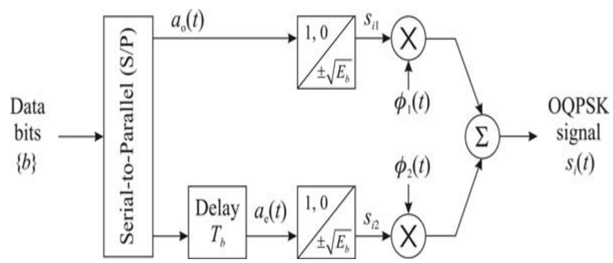

Fig. 4 OQPSK modulator

Offset quadrature phase-shift keying OQPSK is a variant of Phase Shift Keying modulation using 4 different values of the phase to transmit. It is sometimes called Staggered quadrature phase shift keying SQPSK . OQPSK limits the phase-jumps that occur at symbol boundaries to no more than 90° and reduces the effects on the amplitude of the signal due to any low-pass filtering. [6]

The implementation shown in Fig. 5 still corresponds to the multiplexing of two independent data streams through orthogonal carriers, as in the case of the conventional QPSK modulation. Then, the OQPSK demodulator is very similar to the QPSK demodulator, the only difference being the fact that the two BPSK detectors operate T_b seconds delayed from one another. Then, before parallel-to-serial conversion, the estimated data streams must be aligned in time by using a delay block placed in the arm opposite to the one where the delay was inserted at the modulator. [1]

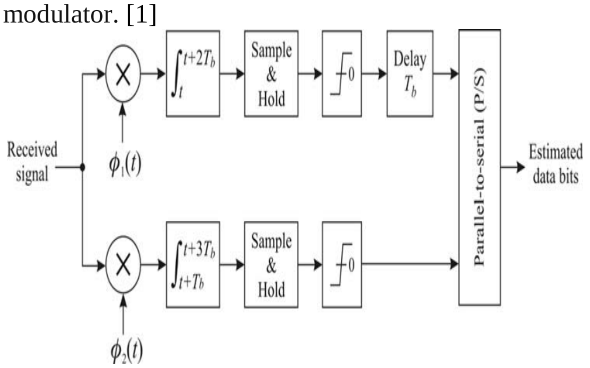

Fig. 5. Coherent OQPSK demodulator

Due to obvious reasons, the power spectral density and error probability for the OQPSK modulation are the same as those derived for the conventional QPSK modulation.[5]

IV. Bit error probability of digital modulation schemes

The bit error probability of QPSK is identical to BPSK, but twice as much data can be sent in the same bandwidth. Thus when compared to BPSK, QPSK provides twice the spectral efficiency with exactly the same energy efficiency. Similar to BPSK, QPSK can also be differentially encoded to allow non-coherent detection. Phase modulation with Quadrature offset is referred to as OQPSK.

Table 1 The Input Parameters

Parameter	QPSK Value	OQPSK Value
M-ary number	4	4
Phase offset(rad):	pi/4	0
Constellation	Gray coding	Gray coding
Input type	Integer	Integer
Symbol period	1 s	1s
Sample time	1 s	1s
Random integer seed	37	37
Average signal power	0.1 W	0.1 W
computation delay	0 s	0s

OQPSK has the same spectral properties as QPSK for linear amplification, but it has higher spectral efficiency under nonlinear amplification [1]. The maximum phase transition of the signal is 90°, corresponding to the maximum phase transition in either the in phase or Quadrature branch but not both simultaneously. This Quadrature offset makes the signals less sensitive to distortion during symbol transitions. Comparing the equation of QPSK and OQPSK, the offset QPSK has exactly same probability of symbol error in an AWGN channel as QPSK except the delay in the basis function. The equivalence in noise performance between these phase shift keying schemes assumes the use of coherent detection. The reason for the equivalence is that statistical independence of the In phase and Quadrature components applies to both QPSK and OQPSK. The error probability P_b in the In phase and Quadrature components applies to both QPSK and offset QPSK. Therefore the P_b of OQPSK is

$$P_b = Q\sqrt{\frac{2E_b}{N_o}} \qquad (1)$$

E_b is the energy in one bit and N_o is the noise power while the odd (or even) bits are used to modulate the quadrature-phase component of the carrier. BPSK is used on both carriers and they can be independently demodulated. As a result, the probability of bit-error for QPSK is the same as for BPSK: However, in order to achieve the same bit-error probability as BPSK, QPSK uses twice the power (since two bits are transmitted simultaneously). The symbol error rate is given by:

$$P_s = 1-(1-P_b)^2 \qquad (2)$$

$$.= 2Q\left(\sqrt{\frac{E_s}{N_o}}\right) - \left[Q\left(\sqrt{\frac{E_s}{N_o}}\right)\right]^2 \qquad (3)$$

If the signal to noise ratio is high (as is necessary for practical QPSK systems) the probability of symbol error may be approximated:

$$P_S = 2Q\left(\sqrt{\frac{E_s}{N_o}}\right) \qquad (4)$$

V. Simulation and Results

A Matlab Simulink is used to implement the block diagram shown in figure 6 which consists of a random integer generator source and QPSK modulator and demodulator connected through AWGN channel as well as OQPSK modulator and demodulator connected through AWGN channel in order to estimate BER for both QPSK and OQPSK to evaluate performance under various values of E_b/N_o. Table 1 shows the input parameters of model.

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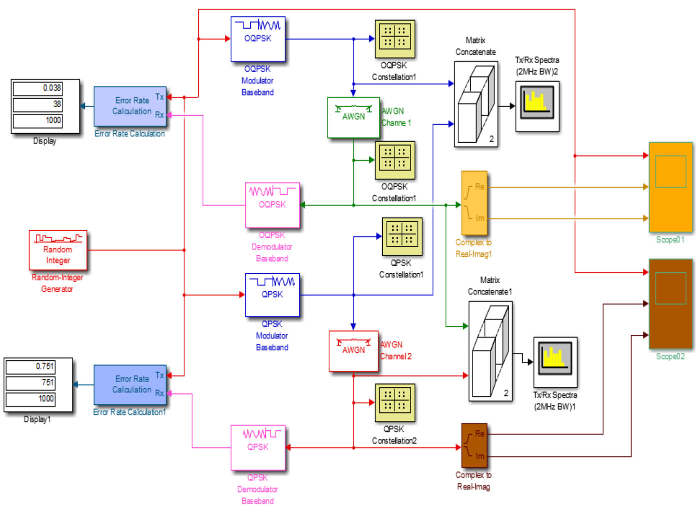
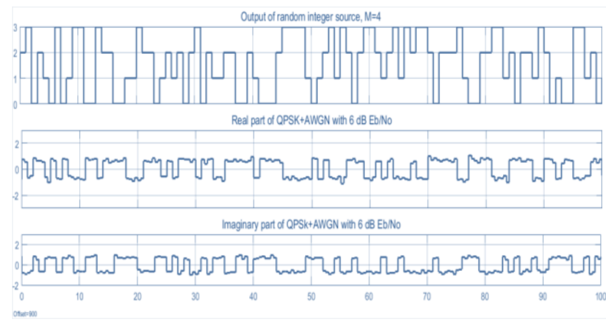
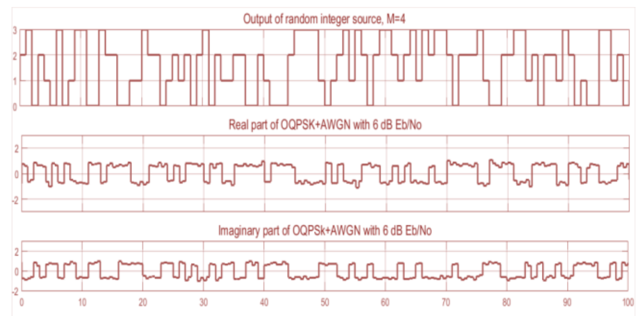


Fig.6. (QPSK & OQPSK) systems simulation model



(a)



(b)

Fig 7 signal display of scopes 1 & 2 at 6dB E_b/N_o

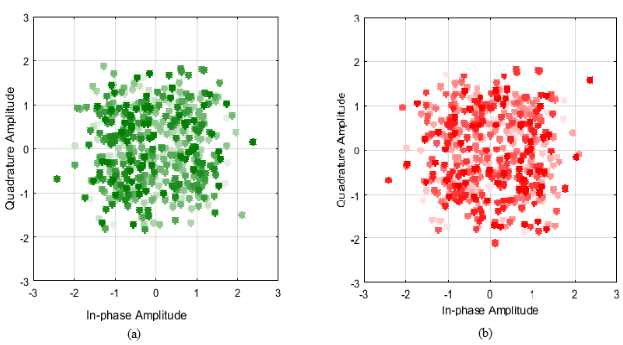
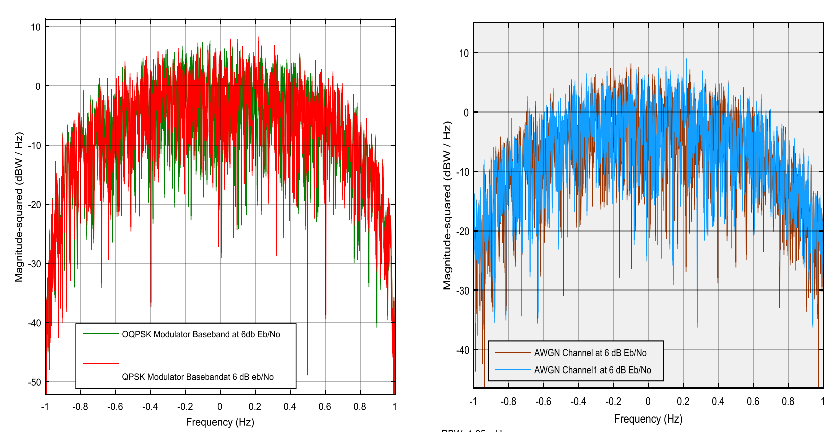


Fig 8 Constellation diagram at the input of demodulators

(a) OQPSK, (b) QPSK



(a) QPSK (b) OQPSK

Fig 9 Tx/Rx spectra (a) OQPSK & QPSK Modulators
(b) AWGN Channels

The simulation was run several times by varying the E_b/N_o value for both AWGN channels 1 & 2 using the model in fig 6.The range for E_b/N_o at which the BER values are calculated is -6 to 6 dB for both QPSK and OQPSK, From simulation several results were obtained which are illustrated in the show figures. Fig 7 shows the display of scopes 1 & 2 for the real part and imaginary part of the input digital signal at AWGN Eb/No of 6 dB for both OQPSK and QPSK. Fig 8 show the constellation diagram for both OQPSK and QPSK at the input of the demodulators. Fig 9 shows the TX/Rx spectra for the OQPSK and QPSK baseband modulators and the AWGN channels 1 & 2.From the obtained results a comparison chart was generated for the BER for OQPSK and QPSK shown in fig 10. From the figure it can be seen that OQPSK performs better over the test range of E_b/N_o. Fig 10 shows the resultant plot of BER for OQPSK and QPSK and from the figure it can be seen that the OQPSK performs better than the QPSK for the selected E_b/N_o range and hence OQPSK has a better bandwidth efficiency and has a channel frequency error of 1.6779 mHz which is better than QPSK frequency error of -2.1887 mHz.

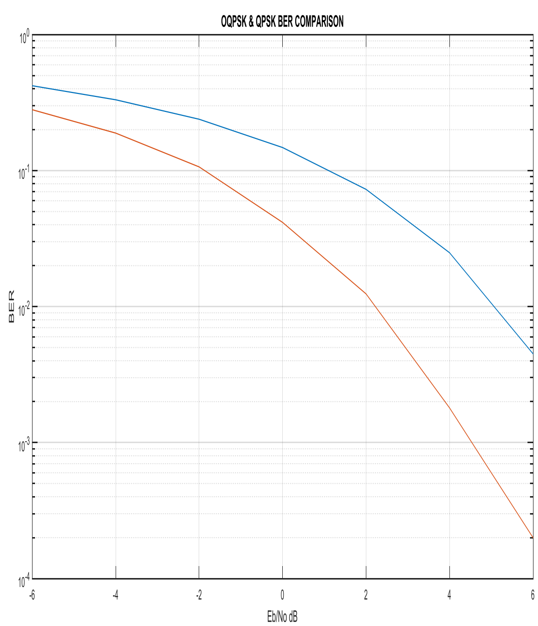


Fig.10 Bit Error Rate for the QPSK & OQPSK

VI. Conclusions

From the obtained results it can be concluded that OQPSK performs better than QPSK modulation in terms of BER, which indicates that OQPSK has a better bandwidth efficiency and hence it can be used for systems with less power since it has a better channel frequency error.

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