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Performance of (2x2) MIMO Communication Systems for Various PSK Modulation Schemes

Ms. Harsha Gurdasani,[1] Dr. A G Ananth,[2] Dr. T C Manjunath[3]
[1]*Research Scholar, Faculty of Electronics Engg JAIN University, Bengaluru.*
[2]*Professor, E& C Department, NMAMIT, Nitte, Mangalore*
[3]*Professor & Head, ECE DSCE, Bengaluru*

Abstract— *As the demand of bandwidth is escalating along with intolerance for errors and latency, data-communication engineers are looking for new ways to utilize the available bandwidth to the maximum and improve the quality of transmission. Some probable solutions could be Modulation, Multiplexing, and employment of efficient Error Correction techniques. Forward error correction (FEC), has been used for years to enable efficient, high-quality data communication over noisy channels, such as those found in satellite and digital cellular-communications applications. To achieve an excellent quality of service, the third generation partnership project (3GPP) long term evolution (LTE) employs multiple-input multiple-output (MIMO) systems along with special error-correcting codes. This paper discusses MIMO in Wireless Communication by using Spatial Multiplexing for the calculation of the Bit Error Rate (BER) for various modulation techniques for AWGN channel.*

Keywords- *MIMO, BERvs SNR, BPSK, QPSK, QAM*

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I. Introduction

The ever-growing demands for high-speed data and multimedia services are the driving forces behind the requirements for future wireless communication systems. The next generation of mobile communication, often referred to as 4G and 5G networks are comprehensive IP solutions that deliver voice, data, and multimedia content to mobile users anytime and almost anywhere. Wireless communication is inherently limited by the available spectrum and impaired by path loss, interference and multi-path propagation. Hence, to meet the capacity needs for future wireless systems without increasing the required spectrum, accomplishment of implementation of advanced communication techniques is necessary.

The intent of 4G technology is to converge high speed data application requirements and compete with other technologies. Different techniques i.e relaying, carrier aggregation, multiple input multiple output, and heterogeneous networks provide higher throughputs, low latency and enable LTE to become a Standard for Wireless broadband. In this paper, Spatial multiplexing technique has been used to increase the channel capacity significantly. BPSK, QPSK, 16 QAM & 64 QAM are the modulation techniques in the AWGN channel using simulation tool MATLAB. A comparative study of various modulation schemes for MIMOs and results are shown in the next sections. BER is calculated and analyzed for comparison.

II. MIMO

Multiple Input Multiple Output (MIMO) Communication System is a new and emerging technology and is expected to play a very important role in 4G and 5G wireless systems. MIMO technology makes use of multiple antennas both at the transmitter section and at the receiver section to make excellent utilization of the available bandwidth and to reduce the effects of fading and signal loss. This technique also helps to increase the number of bits transmitted i.e. bitrate. Most

recently MIMO systems are also used in wired power line communications for 3-wire installations. Figure 1 shows a typical MIMO link model.

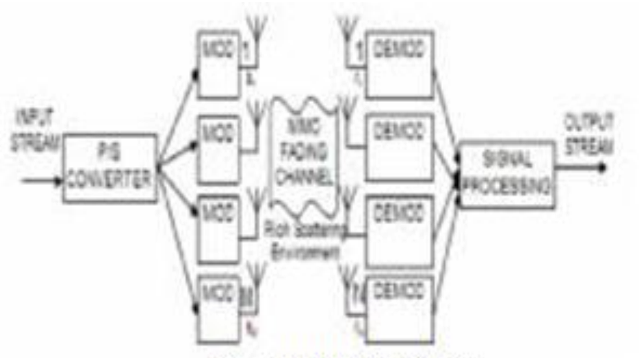

Fig 1: MIMO Link Model

AWGN Channel: Additive White Gaussian Noise channel is a commonly used channel model for analyzing modulation schemes. In AWGN channel a white Gaussian noise is added to the signal that passes through it. Fading does not exist for this channel. The mathematical expression of received signal is:

r(t) = s(t) + n(t)

Where s(t) is transmitted signal and n(t) is additive white Gaussian noise .

III. Forward Error Correction

This design technology has been used extensively for years to enable efficient, high-quality data communication over noisy channels, such as those found in satellite and digital cellular-communications applications. Recently, there have been significant advances in FEC technology that allow today's systems to approach the Shannon limit. Theoretically, this is the maximum level of information content for any given channel. These advances are being used successfully to reduce cost and increase performance in a variety of wireless communications systems including satellites, wireless LANs, and fiber communications. In addition, high-speed silicon ASICs for FEC applications have been developed, promising

to further revolutionize communication systems design. The big attraction of FEC technology is how it adds redundant information to a data stream. This enables a receiver to identify and correct errors without the need for retransmission. As the capabilities of FEC increase, the number of errors that can be corrected also increases. The advantage is obvious. Noisy channels create a relatively large number of errors. The ability to correct these errors means that the noisy channel can be used reliably. This enhancement can be parlayed into several system improvements, including bandwidth efficiency, extended range, higher data rate, and greater power efficiency, as well as increased data reliability.

IV. Digital Modulation Schemes

A. Binary Phase Shift Keying (BPSK)

It is the Simplest form of PSK and is also known as Phase reversal keying or 2-PSK. Phases are separated by 180°. The maximum rate of modulation is 1 bit/ symbol. Figure 2 shows the block diagram for a BPSK Transmitter and Receiver.

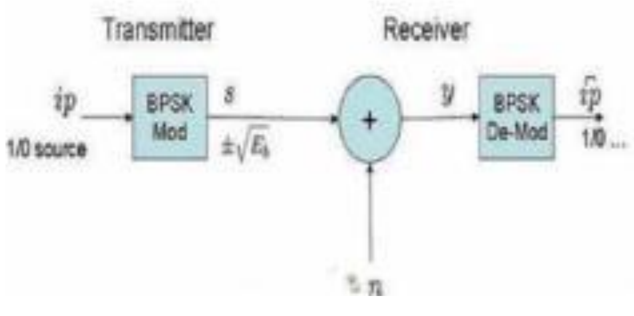

Fig 2: BPSK Transmitter and Receiver

Figure 3 shows the generated BPSK output for a random sequence

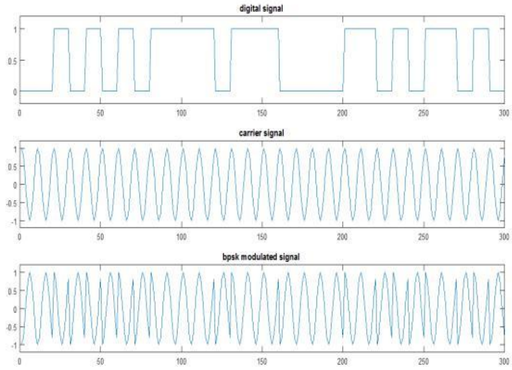

Fig 3: BPSK output for a Random Sequence

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B. Quadrature Phase Shift Keying (QPSK)

QPSK is a form of phase modulation technique, in which two information bits (combined as one symbol) are modulated at once, selecting one of the four possible carrier phase shift states. The main advantage of a QPSK system is its very good noise immunity. For the same bit error rate, the bandwidth required by QPSK is reduced to half as compared to BPSK because of which the information transmission rate of QPSK is higher. Also, Baud rate is half the bit rate therefore more effective utilization of the available bandwidth of the transmission channel. Due to these advantages the QPSK is used for very high bit rate data transmission.

Figure 4 shows the block diagram for a QPSK Transmitter and Receiver.

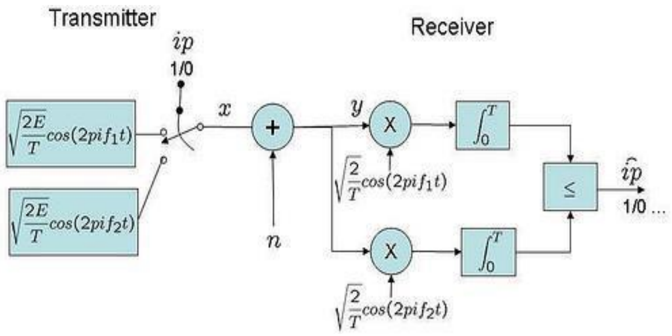

Fig 4: QPSK Transmitter and Receiver

Figure 5 shows the In-phase component and Quadrature component and the QPSK output for a random sequence.

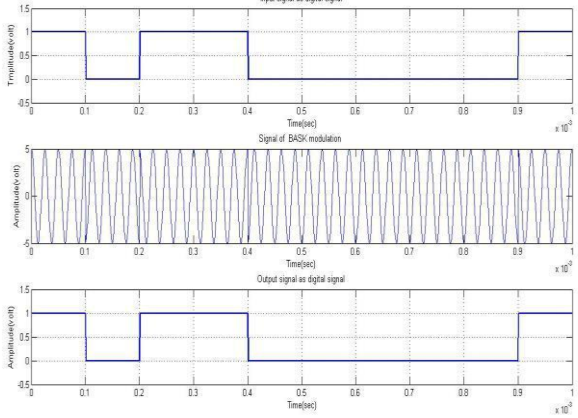

Fig 5: QPSK output for a Random Sequence

C. Quadrature Amplitude Modulation (QAM)

QAM is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. The two carrier waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components, hence the name of the scheme. The modulated waves are summed, and the resulting waveform is a combination of both phase-shift keying (PSK) and amplitude-shift keying (ASK) or (in the analog case) of phase modulation (PM) and amplitude modulation. In the digital QAM case, a finite number of at least two phases and at least two amplitudes are used. Arbitrarily high spectral efficiencies can be achieved with QAM by setting a suitable constellation size, limited only by the noise level and linearity of the communications channel.

Figure 6 shows the block diagram for a QAM Transmitter and Receiver.

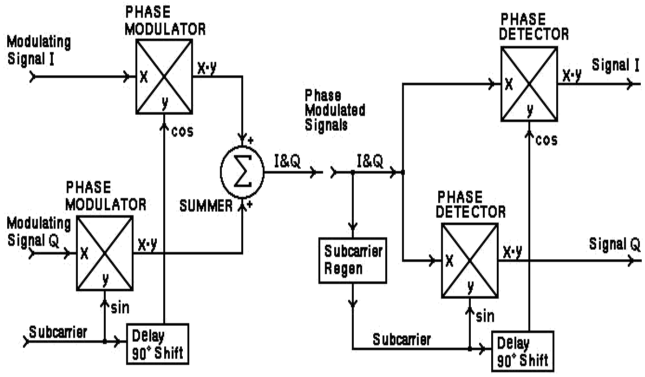

Fig 6 : Block diagram for a QAM Transmitter and Receiver.

Figure 7 shows the generated 16 bit QAM output for a random sequence

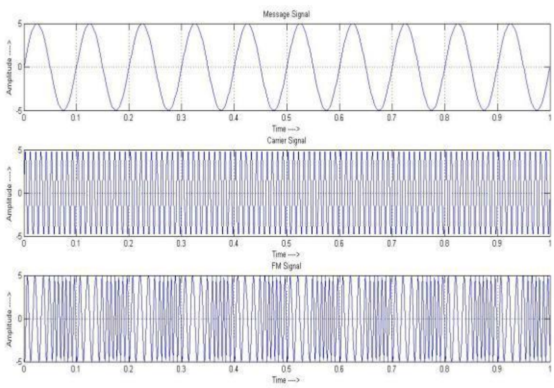

Fig 7: 16 bit QAM output for a random sequence

V. Results

A. SNR vs BER curve for BPSK Modulation Scheme

Figure 8 compares the theoretical results with simulation results for SNR vs BER curve for a BPSK modulation scheme.

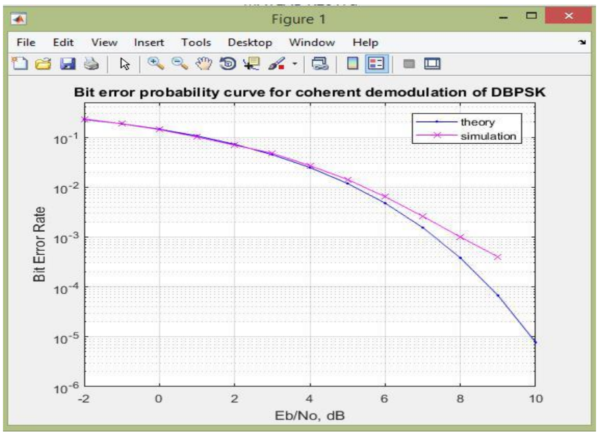

Fig 8: SNR vs BER curve for BPSK Modulation Scheme

From the above graph we can deduce that for BPSK Modulation Scheme, the BER falls as the SNR increases. That is for SNR = 15 DB , BER <10^{-5}

B. SNR vs BER curve for QPSK Modulation Scheme

Figure 9 compares the theoretical results with simulation results for SNR vs BER curve for a QPSK modulation scheme.

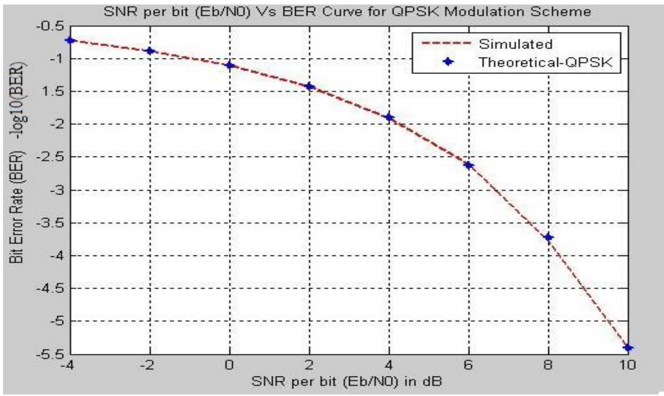

Fig 9: SNR vs BER curve for QPSK Modulation Scheme

From the above graph we can deduce that, for QPSK Modulation scheme, the BER falls as the SNR increases. That is for SNR = 10 dB , BER <10^{-5}

C. SNR vs BER curve for 16 bit QAM Modulation Scheme

Figure 10 compares the theoretical results with simulation results for SNR vs BER curve for a 16 bit QAM modulation scheme.

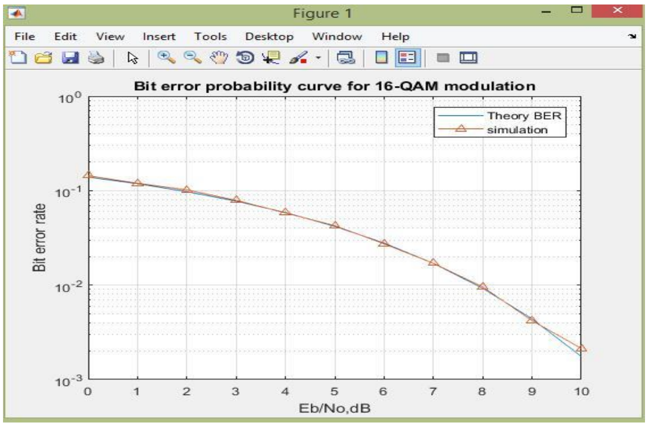

Fig 10: SNR vs BER curve for 16 bit QAM

From the above graph we can deduce that for QAM Modulation scheme, the BER falls as the SNR increases. That is for SNR = 15 DB , BER $<10^{-3}$

VI. Comprehensive Results & Conclusion

Figures 11 exhibits the comparative study of SNR vs BER curves for various Modulation Schemes done in one of the research papers whereas the practically experimented results for a sample size of 10000 are shown in Figure 12.
Also, results of the comparative study in terms of BER vs SNR for various modulation schemes are tabulated in Table 1. We can deduce from the table that 64 Bit QAM yiels the best BER vs SNR tradeoff.

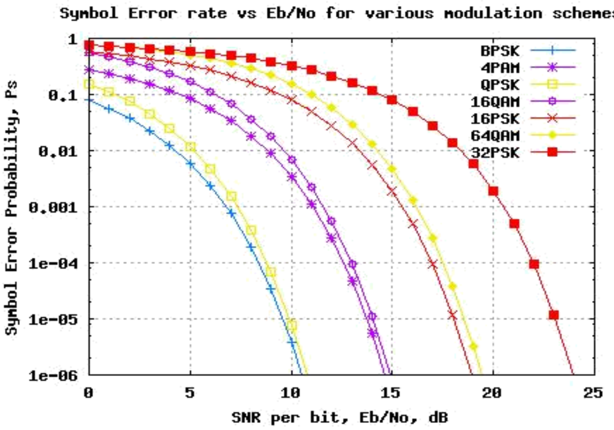

Fig 11: Theortical SNR vs BER curves for various Modulation Schemes

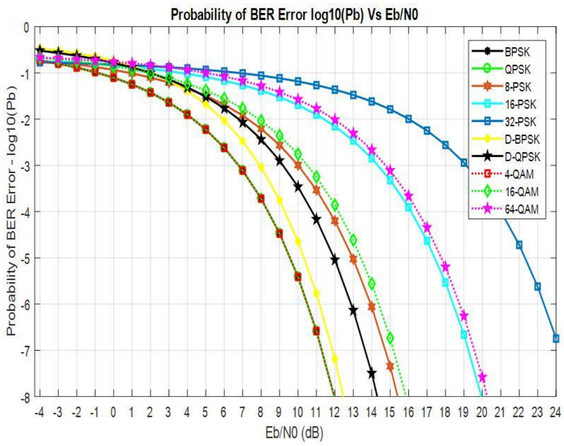

Fig 12: Practical results achieved after simulation

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Table1: Tabulated Results from the above graphs

SNR Eb/No(dB)	BER (10 $\log_{10}$Pb)				
	BPSK/QPSK/4-QAM	D-BPSK	D-QPSK	16QAM	64 QAM
0	-1.1	-0.7	-0.78	-0.8	-0.7
2	-1.9	-1.31	-1	-1	-0.9
4	-2.6	-2.01	-1.3	-1.25	-1.1
6	-3.7	-3.02	-1.7	-1.6	-1.3
8	-4.5	-4.63	-2.4	-2.1	-1.6
10	-5.5	-7.25	-5.1	-2.8	-1.6
12				-3.8	-2.
14				-5.5	-2.7

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