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Improvement of MFSK -BER Performance Using MIMO Technology on Multipath Non LOS Wireless Channels

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ABSTRACT
Digital communications has evolved rapidly with a lot of success. The new trend seems to be the reinvention of already existing and even discredited or discarded theories or in this case, channels. Extensive research into optimizing or enhancing already existing schemes is still gaining momentum with practical results for all to experience and utilize. This paper describes the design and BER performance of an M-ary frequency shift keyed (FSK) signaling and demodulation scheme improved by MIMO antenna technology for wireless communications. MFSK and MIMO systems were briefly reviewed including AWGN, Non LOS fading and an important factor employed to estimate the performance of digital transmission. The research was performed using MATLAB for simulation and evaluation of the BER.

Keywords: *MIMO, MFSK, Modulation, BER, AWGN, Fading channels*

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I. INTRODUCTION

Multiple-input multiple-output(MIMO) is a radio frequency technology or wireless communications technology that is trending in its application to other modern telecommunication technologies, such as wireless routers, WiMax and Long Term Evolution (LTE). It is even more interesting that, what were earlier rejected as interference paths are now used by MIMO technology to provide better spectral efficiency, increased link capacity and improved link reliability.

Frequency shift keying (FSK) is a modulation process in which a frequency keyed transmitter has its frequency shifted by the message. Thus the information is mapped to the changes in frequency of the carrier signal.It is used in communication systems like teleprinters, armature radios and emergency broadcasts. FSK has the advantage of high power efficiencies over other modulation techniques but has low bandwidth (BW) efficiencies (Sklar, 2001).Multiple Frequency Shift Keying (MFSK) which also known as M-ary Frequency Shift Keying is a variant of FSK which uses more than two frequencies to transmit digital information. This delivers an improvement of error rate reduction as the quantity of tones is increased though with a drawback of more bandwidth utilization and the need to ensure good transceiver stability.

MFSK Bit Error Rate (BER) performance can be further improved and the overall transceiver stability guaranteed by the integration of MIMO antenna technology into the MFSK system design. This paper presents a comparative BER performance of MFSK and MFSK-MIMO systems on a multipath fading channel theoretically modeled and analyzed to confirm the one with the best performance (Omijeh and Agoye, 2015).

II. THEORETICAL REVIEWS

MFSK is an M-ary signaling system and as such, tones (M in number) are established with the transmitter selecting one tone at a time from the total signal for transmission. It is orthogonal (each tone can be separately detected without being influenced by another tone) and generally uses non coherent detection. Each tone for transmission can be represented as $log_2 M$ data bits. M could be a power of 2, 4, 8, 16 etc. Without the need for multi symbol coherent detection, the tolerable E_b/N_0 ratio for a given probability of error will decrease as M increases within the Shannon limit. Practically M is usually with the range of 2 to 64.

MFSK is technique for digital data transmission which extends the radio teletype (RTTY) two-tone technique to multiple tones usually one tone at a time. It makes use of relatively narrow tone spacing, so interesting data rates are achievable for a given bandwidth.

Multiple Inputs Multiple Outputs, (MIMO) uses the space dimension to enhance wireless systems capacity, range and dependability. It uses multiple antennas located in different positions at the transmitter and receiver to

enable a variety of signal paths to carry the data, thus taking benefit of different radio paths that exist in a typical terrestrial environment which previously only served to introduce fading and interference. Fading may affect a channel, negatively impacting the signal to noise ratio and for a digital data transmission, the error rate. MIMO simply, is a diversity system. On one hand, **spatial diversity** provides the receiver with multiple versions of the same signal, which helps to stabilize a link, improves performance and reduce error rate. On the other hand, **spatial multiple xing** provides extra data capacity by making use of the different paths available to carry extra traffic, which helps to increase the data throughput capability. These are the two main MIMO formats(Gerard et al, 1996). Separate channels, where M is the number of transmit antennas and N is the number of receive antennas. Therefore capacity scales linearly with min(M,N) while still obeying Shannon's law.
The maximum rate at which error free data can be transmitted over a given bandwidth in the presence of noise is defined by Shannon's law . It is usually expressed in the form:

$C = W \log_2(1 + S/N)$--------------(1)

Where C is the channel capacity in bits per second, W is the bandwidth in Hertz, and S/N is the SNR (Signal to Noise Ratio).
Clearly, with a given bandwidth, there is an ultimate limit on the capacity of a channel. However, the capacity is also limited by the signal to noise ratio of the received signal even before this point is reached.
Based on these limits, a balance exists between the allowable error rate and the data rate, signal to noise ratio and power that can be transmitted. Though improvements can be made using higher order modulation schemes to increase channel capacity while struggling to improve signal to noise ratio, these may be difficult and rather expensive. MIMO is a novel way data throughput for individual channels can be improved.
Bit Error Rate (BER) is th number of bit errors that occur for a given number of bits transmitted. It is related to the error probality because it is the ratio of bit errors to bits transmitted. The energy per bit is the amount of power in a digital bit for a given amount of time (Proakis, 2000; Jeffery and Gary, 2008; Vinay and Sanjeet, 2012). The expression is shown below:

$$BER = \frac{\text{Number of bits with errors}}{Total\ number\ of\ bits\ sent}$$ ----------- (2)

The presence of Additive White Gaussian Noise (AWGN) in a channel distorts the quality of the received signal. The deviation of the received symbols with respect to the constellation set increases with respect to higher variance of the noise .And this leads to higher probability, demodulating a wrong symbol to make errors(Molisch,2005:Saiful et al, 2015).
The major effect of multipath propagation can be described in terms of fading and delay spread (Sklar, 1997). These delay spread and phase fluctuations in turn cause fluctuations in the received signal amplitude with time resulting in a phenomenon called small scale fading or multipath fading.
The probability density function (pdf) of Rayleigh fading which is also called Small-scale fading (Goldsmith, 2005) is given by:

fRayleigh(r) = $(0 \le r \le)$ (3)

III. DESIGN APPROACH

Scientific computer simulation software, MATLAB is the tool used for this study and simulation (Omijeh, 2016). Two models were setup. First, MFSK system was modeled using a Random integer generator to allow various parameters to be varied and tested with a multipath fading channel attached. The design models used in this work are shown in Figure1 and Figure2 below:

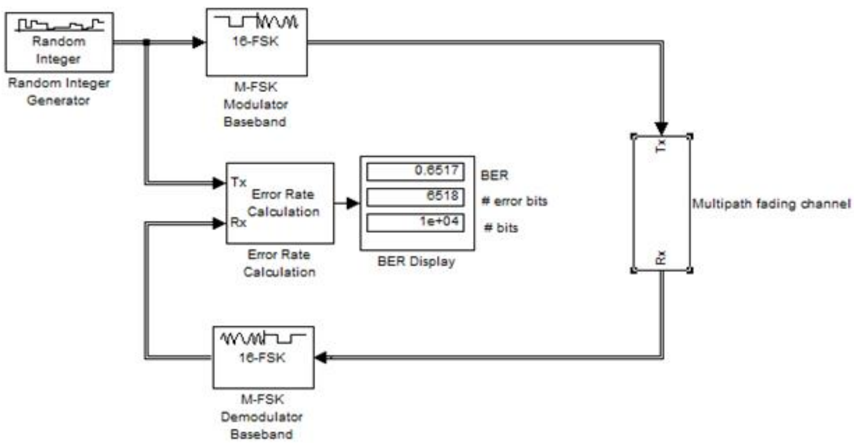

Figure 1: Basic MFSK transmitter and receiver system over a multipath channel (MFSK model)

Secondly, another identical MFSK system was designed with an adaptive orthogonal space-time block code (OSTBC) transceiver system over a MIMO channel system attached. This uses variable numbers of receive and transmit antennas. Here 3 transmit antennas and 2 receive antennas were used. For both models, error rate calculation and BER display blocks were installed.

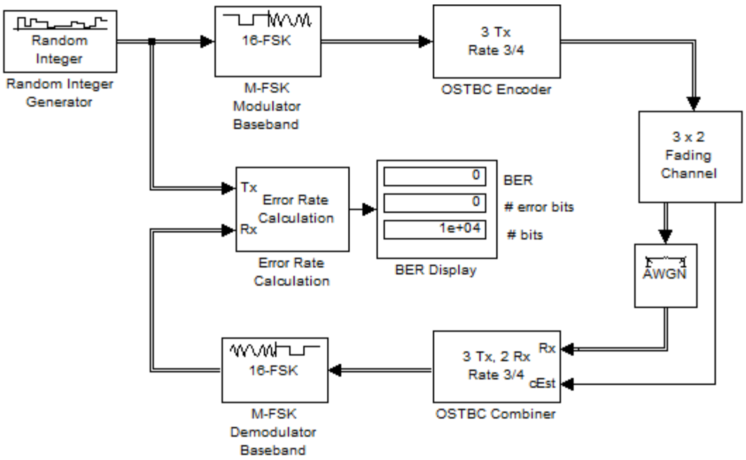

Figure 2: Basic MFSK transmitter and receiver system over a multipath MIMO channel (MFSK-MIMO model)

IV. SIMULATION RESULTS AND RESULTS

Simulation time was set to 10 MATLAB seconds. Tables1 &2 below show results obtained:

Table1: MFSK model results

MFSK			
4FSK			
Eb/N0	BER	#error bits	#bits
5	0.4442	4443	1.00E+04
10	0.383	3831	1.00E+04
15	0.3246	3247	1.00E+04
20	0.2661	2662	1.00E+04
8FSK			
Eb/N0	BER	#error bits	#bits
5	0.5702	5703	1.00E+04
10	0.4648	4649	1.00E+04
15	0.3636	3637	1.00E+04
20	0.2699	2700	1.00E+04
16FSK			
Eb/N0	BER	#error bits	#bits
5	0.6517	6518	1.00E+04
10	0.5032	5033	1.00E+04
15	0.354	3541	1.00E+04
20	0.2328	2328	1.00E+04

Table2: MFSK-MIMO model results

MFSK-MIMO			
4FSK			
Eb/N0	BER	#error bits	#bits
5	0.03739	374	1.00E+04
10	0.0139	139	1.00E+04
15	0.00399	40	1.00E+04
20	0.0013	13	1.00E+04
8FSK			
Eb/N0	BER	#error bits	#bits
5	0.02859	286	1.00E+04
10	0.00479	48	1.00E+04
15	0.00059	6	1.00E+04
20	0.00005	1	1.00E+04
16FSK			
Eb/N0	BER	#error bits	#bits
5	0.02739	274	1.00E+04
10	0.0025	25	1.00E+04
15	0.00009	1	1.00E+04
20	0	0	1.00E+04

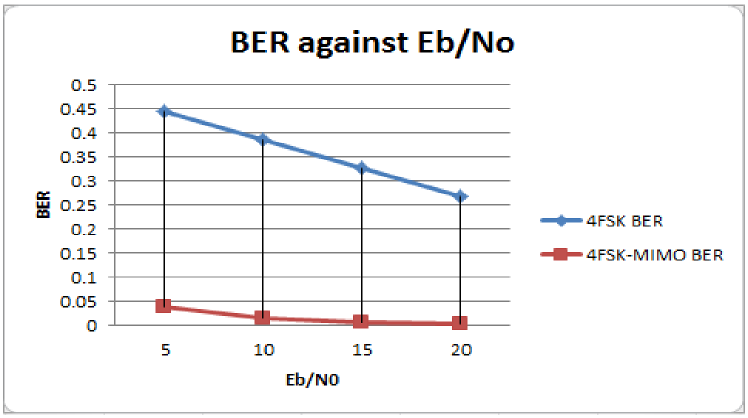

Figure 3: BER comparison for 4FSK

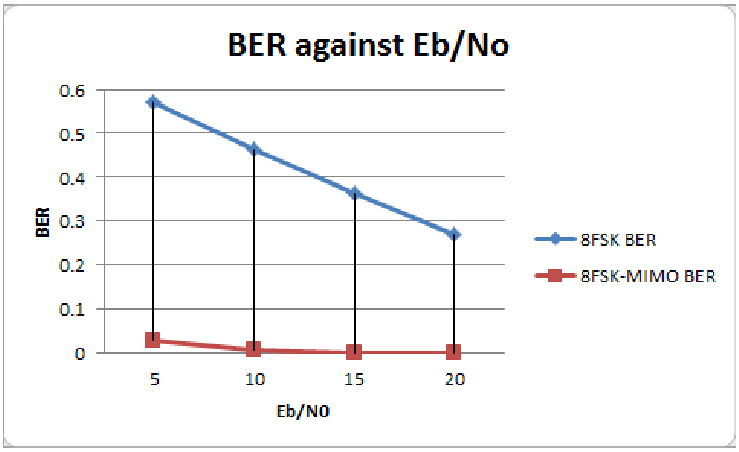

Figure 4: BER comparison for 8FSK

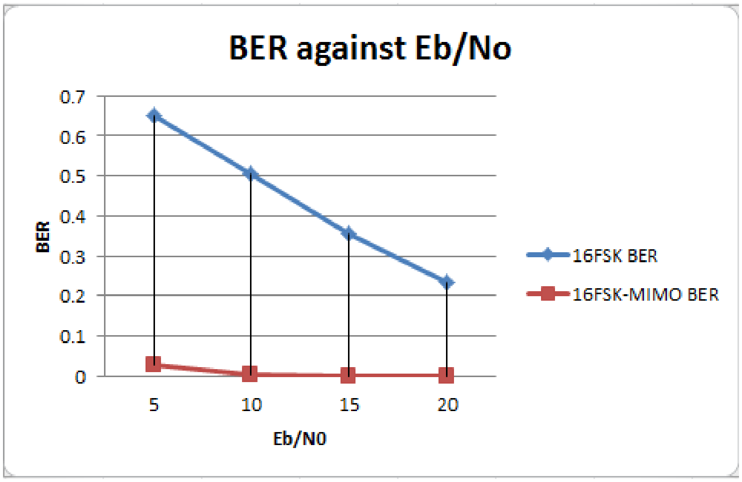

Figure 5: BER comparison for 16MFSK

It is observed from Table1 and Table 2 that for the same number of bits sent, the bit error rate reduced as the M-ary number increased. However, from Table 2 it's different. It was observed that again, for the same number of bits sent, the bit error rate for Table 2 due to the integration of the MIMO system, decreased drastically and returned no errors when the M-ary number got to 16. Figure 3, 4 & 5 illustrates the difference in the BER when Tables 1 & 2 BER values were plotted againstE_b/N_0. This shows that the addition and integration of the MIMO system model into the MFSK model produced a drastic improvement in the BER of the simulated communication system.

V. CONCLUSION

In this paper, an M-ary frequency shift keyed (FSK) signaling and demodulation scheme improved by MIMO antenna technology for wireless communications was modeled and simulated then BER performance was tested. The BER performance of the basic MFSK model was also capture. The designed system has a high level of reliability thanks to the MATLAB software. The MIMO system successfully improved the MFSK BER. As spectral bandwidth is now an ever more valuable commodity for radio communications systems, techniques such as implemented here are needed to manage the available bandwidth more effectively.

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