Performance Evaluation of Detection Schemes for MIMO-OFDM System in Extended Vehicular Environment

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ABSTRACT
In the present paper performance analysis for Multiple-Input Multiple-Output (MIMO)-Orthogonal Frequency Division Modulation (OFDM) system with various detection schemes is reported. The performance of two detection techniques i.e Zero Forcing (ZF) and Minimum Mean Square Error (MMSE) is measured for various modulation schemes viz 4-QAM,16-QAM,64-QAM and 256-QAM. Extended vehicular environment with Low Correlation is assumed for simulation. The investigations reported in this paper helps in estimating the optimal MIMO detector.

Keywords
MIMO-OFDM, QAM, SNR, BER, MMSE, ZF

1. INTRODUCTION
Multiple Input Multiple Output (MIMO)is an indispensable key air-interface technology for implementing high data-rate wireless communications with limited frequency resources. The enriched capacity of the mimo spatial multiplexing (MIMO-SM) systems is simply a consequence of the fact that different signals sharing the same frequency, transmit from plural antennas at the same time slot. However, since these transmitted signals are linearly superimposed as they travel through the wireless channel, the receiver must properly unravel the mixture of the signals. Such an operation is called demultiplexing, signal detection, or estimation. It almost determines achievable performance in terms of error probability, and therefore it has been one of the major issues in a multi-antenna system design.

1.1 Spatial Multiplexing
Spatial Multiplexing (SM) has been utilized in MIMO systems to provide higher transmission rate without allocating additional bandwidth or increasing the transmit power[1]. Spatial multiplexing deploy multiple antennas at both transmitter and receiver ends. The input data streams can be divided into different independent sub streams and then transmitted simultaneously via sufficiently-separated antennas. This results in a linear increase in the channel capacity proportional to the minimum number of transmit and receive antennas. Some special detection techniques have been proposed in the paper in order to exploit the high spectral capacity offered by MIMO systems.[2]

1.2 OFDM
Orthogonal frequency division modulation method is known for its capability to attenuate multipath. OFDM converts the high speed data stream into Nsc narrowband data streams where Nsc corresponding to the subcarriers or sub channels i.e. one OFDM symbol consists of N symbols modulated by QAM or PSK [2]. As a result the symbol duration is N times longer than in a single carrier system with the same symbol rate. Further the symbol duration is made longer by adding a cyclic prefix (CP) to each symbol. As long as the cyclic prefix is longer than the channel delay spread OFDM offers inter-symbol interference (ISI) free transmission. Another important advantage of OFDM is that it dramatically reduces equalization complexity by enabling equalization in the frequency domain. OFDM is implemented with IFFT at the transmitter and FFT at the receiver which converts the wideband signal, affected by frequency selective fading, into N narrowband flat fading signals.

OFDM is used to efficiently combat inter-symbol interference (ISI), inherent in broadband transmissions, while MIMO is used for improving the channel spectral efficiency and/or suppress interference.[3]

1.3 MIMO-OFDM
Considering the two vital goals: high-data-rate and high Performance, this combination of MIMO and OFDM i.e MIMO-OFDM is a very promising feature. OFDM is able to sustain more of antennas since it simplify equalization in MIMO systems. In OFDM, fading is considered as a problem in wireless network. On the other hand a MIMO channel uses fading to increase the capacity of the entire communication network. MIMO is a frequency-selective technique and OFDM can be used to convert such a frequency-selective channel into a set of parallel frequency-flat sub channels [4].

2. DETECTION SCHEMES
MIMO detector is one of the most complex blocks of the MIMO receiver. The basic purpose behind MIMO detection is to decouple the transmitted streams at the receiver, after passing through a MIMO channel. The present paper employs two Linear Detection schemes viz. ZF and MMSE.

2.1 Zero Forcing (ZF) Detection
This is a linear detection algorithm used in communication systems, which inverts the frequency response of the channel at the receiver to restore the signal before the channel.
The equalization matrix 'g' for ZF detection method is given by the pseudo inverse of H [5]:

$$G = H^{\#} = (H^H H)^{-1} H^H$$

Thus the result of ZF equation is

$$Y_{zf} = H^{\#} = (H^H H)^{-1} H^H Y = S + \tilde{n}$$

Which is the transmitted data vector s corrupted by the transformed noise $\tilde{n}$=$H^{\#}$n.this means that the interference caused by the channel is completely removed or "forced to zero". However the transformed noise $\tilde{n}$=$H^{\#}$n is larger than n i.e noice enhancement.[5]

We can see from above equation that the complexity of zero forcing detector is linear.

2.2 Minimum Mean Square Error (MMSE) Detection
A MMSE detector is a method in which it minimizes the mean square error (MSE), which is a universal measure of estimator quality [4]. The most important characteristic

of MMSE equalizer is that it does not usually eliminate ISI totally but instead of minimizes the total power of the noise and ISI components in the output [6].

The equalization matrix 'G' for MMSE is given by [5]:

$$G = (H^H H + \sigma_w^2 I)^{-1} H^H$$

Where σ_w^2 is the noice variance.

Here G is minimizing the mean square error. Thus the result is

$$Y_{mmse} = (H^H H + \sigma_w^2 I)^{-1} y$$

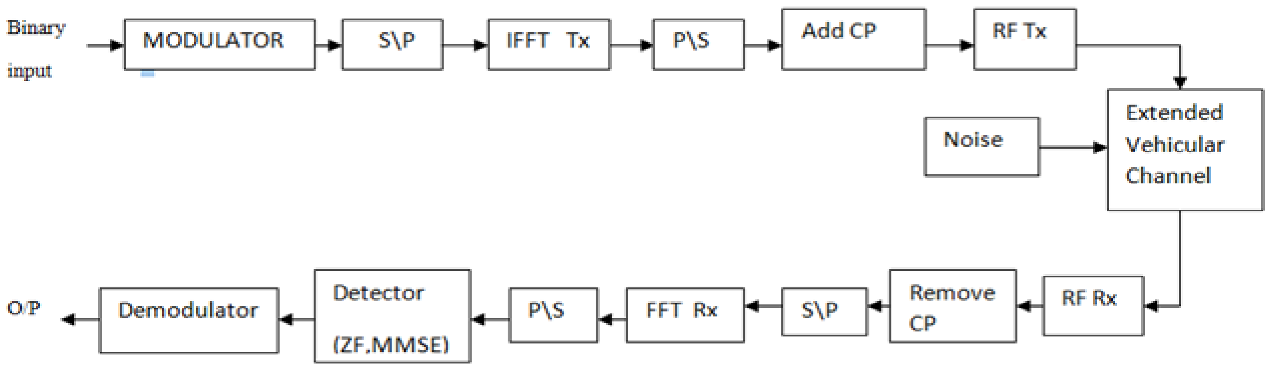

Fig 1: System model of MIMO-OFDM

3. SYSTEM MODEL

A simplified block diagram using MIMO-OFDM is shown in Figure 1. The parameters assumed for simulation are tabulated below in Table 1.In the above block diagram the input signal is binary data which is to be transmitted. Then the signal is modulated using various modulators (4/16/64/256 QAM).64 QAM and 256 QAM are studied as they will be used in the upcoming future technologies like 5G etc. and 16\64 QAM are being used in present scenario.The modulated signal is converted from serial to parallel (S\P) by the converter. There are subcarriers which are provided to inverse fast fourier transform (IFFT) block.The role of IFFT is that it eliminates the need for separate sinusoidal converters.FFT block is used as its dual at the receiver side. Then again the signal is reshaped into serial order by sending it to parallal to serial converter block (P\S).

Cyclic prefix (CP) is added to make the OFDMsignal robust to radio channel frequency selectivity.

As this is a MIMO model there are two transmit antennas at transmitter section and two receive antennas at the receiver section. This signal is then transmitted through these antennas. The channel taken under consideration is extended vehicular environment with low correlation.

Reason for considering extended vehicular environment is that mobile coverage is high in urban areas and next task is to provide coverage at on intercity or interstate highways. This environment is characterized by large cells, high transmit power and fast moving terminals [8].

The noise considered is AWGN .The signal is received at receiver antennas followed by removal of cyclic prefix. Then the signal is send to a fast fourier transform (FFT) block.

The next block depicts the detection method undertaken i. e ZF or MMSE and its output is demodulated to obtain the final bits.

Table 1. Parameters of simulation

Parameters	Values
Size of signal	1024
No. of transmitters	2
No. of receivers	2
IFFT/FFT Size	16
Number of Carriers	16
No. of Cyclic Prefix	16
Modulation Scheme	4/16/64/256 QAM
Channel model	Extended Vehicular
Detectors	ZF, MMSE
Signal to Noise Ratio (dB)	1 to 25

4. RESULTS AND DISCUSSIONS

The simulation results are plotted for BER performance of ZF and MMSE detectors using various modulation techniques.

All results have been simulated on MATLAB software.

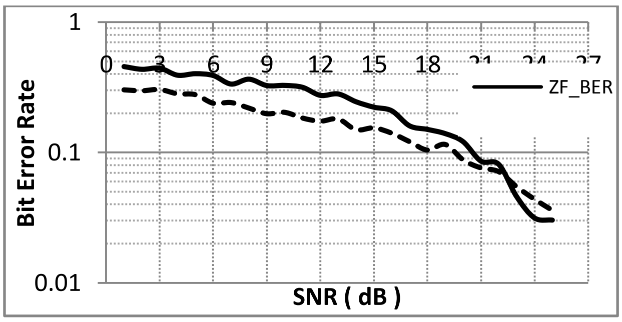

Fig 2. BER vs SNR with 4_QAM modulation

Fig 2 depicts a slight change at lower SNR between ZF and MMSE techniques in 4 QAM modulation and it is practically of no use. The acceptable BER (1%) for ZF and MMSE is not achieved even at high SNR i.e upto 24 dB.

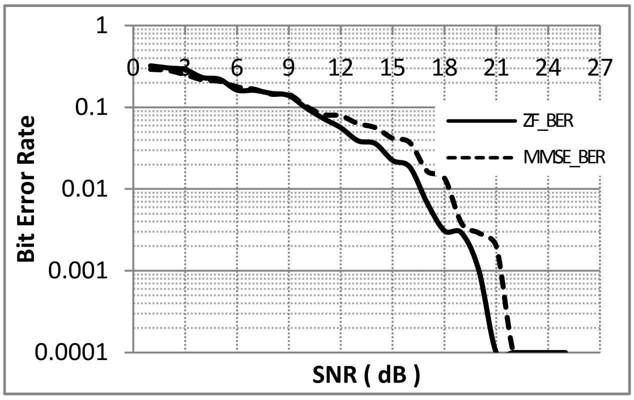

Fig 3. BER vs SNR with 16_QAM modulation

Fig 3 employs 16 QAM modulation scheme. It is observed that for lower SNR range the error rates are high for both ZF and MMSE. In this the tolerable limit of BER (1%) is reached at approximately 16 dB and 18 dB for ZF and MMSE respectively. Therefore we can say that Zf performs better as it achieves 2 dB gain over MMSE at 1% BER.

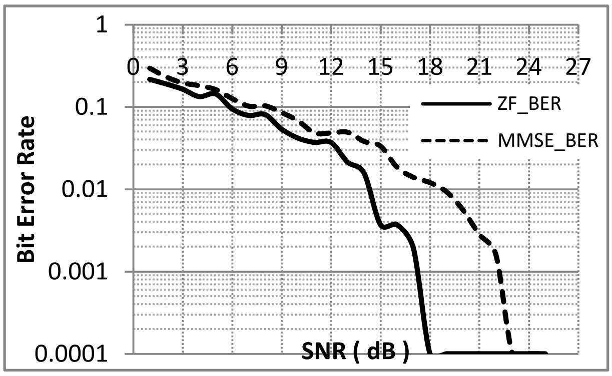

Fig 4. BER vs SNR with 64_QAM modulation

In Fig 4.at a reference value of 1%BER, ZF achieves 4 dB gain over MMSE. There is a sudden decrease in BER for ZF as the SNR value increases. In above Fig the acceptable BER(1%) for ZF is 14 dB and for MMSE is 18 dB.

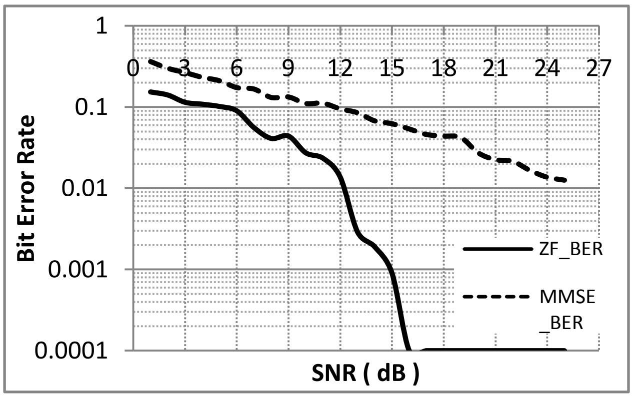

Fig 5 BER vs SNR with 256_QAM modulation

From Fig 5. An alluring observation can be made for 256 QAM modulation above 12 dB SNR, ZF has a fast decay or roll off compared to MMSE.As compared to all other above plots the tolerable BER (1%) is achieved at a lower SNR for ZF i.e. at 12 dB and it goes beyond 25 dB for MMSE.

5. CONCLUSION

This paper is entitled to show a comparison between ZF and MMSE in MIMO-OFDM spatially multiplexed system in extended vehicular environment employing various modulation schemes viz 4\16\64\256 QAM. The paper concludes that at high SNR values, the BER is substantially low and keeps on decreasing for both ZF and MMSE. However ZF has shown a better performance over MMSE for all the modulation techniques. The difference is more clear as we increase the modulation order.

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