MIMO Configuration Scheme With Spatial Multiplexing And QPSK Modulation

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Abstract—
Wireless communication has shown tremendous increase in capacity due to the easy handling and portability. Multiple Inputs Multiple Output (MIMO) systems have recently emerged as a key technology in wireless communication systems for increasing both data rates and system performance. There are many schemes that can be applied to MIMO systems such as space time block codes, space time trellis codes, and the Vertical Bell Labs Space-Time Architecture (V-BLAST) and Spatial Multiplexing technique. This paper proposes a signal detector scheme called MIMO detectors to enhance the performance in MIMO channels. We study the general MIMO system, the Spatial Multiplexing with Maximum Likelihood (ML), and Minimum Mean- Square Error (MMSE) detectors and simulate this structure in Rayleigh fading channel and with AWGN. Also compares the performance of MIMO system with QPSK modulation technique in considered fading channels. The simulations shown that Spatial Multiplexing performs in the same way as V-BLAST algorithm and provides optimal ordering to improve the performance with lower complexity. Although ML receiver appears to have the best BER performance, Spatial Multiplexing achieves Bit error rates close to the ML scheme while retaining the low-complexity.

Index Terms: **MIMO, Spatial Multiplexing, ML, MMSE and ZF.**

1. Introduction

Wireless communication networks need to support extremely high data rates in order to meet the rapidly growing demand for broadband applications such as high quality audio and video. Existing wireless communication technologies cannot efficiently support broadband data rates, due to their sensitivity to fading. Recent research on wireless communication systems has shown that using MIMO at both transmitter and receiver offers the possibility of wireless communication at higher data rates, enormous increase in performance and spectral efficiency compared to single antenna systems. The information-theoretic capacity of MIMO channels was shown to grow linearly with the smaller of the numbers of transmit and receiver antennas in rich scattering environments, and at sufficiently high signal-to-noise (SNR) ratios [1].

MIMO wireless systems are motivated by two ultimate goal of wireless communications: high-data-rate and high-performance [2], [3]. During recent years, various space-time (ST) coding schemes have been proposed to collect spatial diversity and/or achieve high rates. Among them, V-BLAST (Vertical Bell Labs Layered Space-Time) transmission has been widely adopted for its high spectral Efficiency and low implementation complexity [4].When maximum-likelihood (ML) detector employed; V-BLAST systems also enjoy receives diversity, but the decoding complexity is exponentially increased by the number of transmit- antennas. Although some (near-) ML schemes (e.g., sphere- decoding (SD), semi-definite programming (SDP)) can be used to reduce the decoding complexity, at low signal to- noise ratio (SNR) or when a large number of transmit antennas and/or high signal constellations are employed, the complexity of near-ML schemes is still high. Some suboptimal detectors have been developed, e.g., successive interference cancellations (SIC), decision feedback equalizer (DFE), which are unable to collect receive diversity [5]. To further reduce the complexity, one may apply linear detectors such as zero-forcing (ZF) and minimum mean- square error (MMSE) equalizers. It is well known that linear detectors have inferior performance relative to that of ML detector. However, unlike ML detector, the expected performance (e.g., diversity order) of linear equalizers has not been quantified directly. The mutual information of ZF equalizer has been studied in [6] with channel state information at the transmitter.

We propose to use Spatial Multiplexing scheme to perform in a better way as compared to the V-BLAST algorithm. And to produce correctness in channel convergence and corrections in power consumption.

2. Considered Channels in Proposed model

2.1. Additive White Gaussian Channel

In telecommunication, inter symbol interference (ISI) is a form of distortion of a signal in which one Symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable. ISI usually caused by multipath propagation or the inherent non-linear frequency response of a channel causing successive symbols to "blur" together. The presence of ISI in the system introduces errors in the decision device at the receiver output. Therefore, in the design of the transmitting and receiving filters, the objective is to minimize the effects of ISI, and thereby deliver the digital data to its destination with the smallest error rate possible. Ways to fight inter symbol interference include adaptive equalization and error correcting codes.

2.2. Rayleigh Fading Channel

Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium will vary randomly, or fade, according to a Rayleigh distribution the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well modeled as a Gaussian process irrespective of the distribution of the individual components.

If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed. Calling this random variable R, it will have a probability density function:

$$P_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, \quad r \geq 0,$$

Where $\Omega = E(R^2)$.

Often, the gain and phase elements of a channel's distortion are conveniently represented as a complex number. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modeled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes.

3.Equalizers

3.1. Optimum Equalizer

For an optimized detector for digital signals the priority is not to reconstruct the transmitter signal, but it should do a best estimation of the transmitted data with the least possible number of errors. The receiver emulates the distorted channel. All possible transmitted data streams are fed into this distorted channel model. The receiver compares the time response with the actual received signal and determines the most likely signal. In cases that are most computationally straight forward, root mean square deviation can be used as the decision criterion [1] for the lowest error probability. Suppose that there is an underlying signal $\{x(t)\}$, of which an observed signal $\{r(t)\}$ is available. The observed signal r is related to x via a transformation that may be nonlinear and may involve attenuation, and would usually involve the incorporation of random noise. The statistical parameters of this transformation are assumed known. The problem to be solved is to use the observations $\{r(t)\}$ to create a good estimate of $\{x(t)\}$. Maximum likelihood sequence estimation is formally the application of maximum likelihood to this problem. That is, the estimate of $\{x(t)\}$ is defined to be sequence of values which maximize the functional

$$L(x) = p(r \mid x),$$

Where $p(r|x)$ denotes the conditional joint probability density function of the observed series $\{r(t)\}$

. Bays' theorem implies that

$$P(x) = p(x \mid r), = \frac{p(r \mid x)p(x)}{p(r)}$$

In cases where the contribution of random noise is additive and has a multivariate normal distribution, the problem of maximum likelihood sequence estimation can be reduced to that of a least squares minimization.

3.2. MMSE Equalizer

In statistics and signal processing, a minimum mean square error (MMSE) estimator describes the approach, which minimizes the mean square error (MSE), which is a common measure of estimator quality. The term MMSE specifically refers to estimation in a Bayesian setting, since in the alternative frequents setting there does not exist a single estimator having minimal MSE. A somewhat similar concept can be obtained within the frequents point of view if one requires unbiasedness, since an estimator may exist that minimizes the variance (and hence the MSE) among unbiased estimators. Let X be an unknown random variable, and let Y be a known random variable (the measurement).

An estimator $\hat{X}(y)$ is any function of the measurement Y, and its MSE is given by

$$MSE = E\{\,(\hat{X} - X)^2\}$$

Where the expectation is taken over both X and Y.

The MMSE estimator is then defined as the estimator achieving minimal MSE. In many cases, it is not possible to determine a closed form for the MMSE estimator. In these cases, one possibility is to seek the technique minimizing the MSE within a particular class, such as the class of linear estimators. The linear MMSE estimator is the estimator achieving minimum MSE among all estimators of the form AY + b. If the measurement Y is a random vector, A is a matrix and b is a vector. (Such an estimator would more correctly be termed an affine MMSE estimator, but the term linear estimator is widely used.)

3.3. Zero forcing Equalizer

Zero Forcing Equalizer refers to a form of linear equalization algorithm used in communication systems, which inverts the frequency response of the channel. This form of equalizer was first proposed by Robert Lucky. The Zero-Forcing Equalizer applies the inverse of the channel to the received signal, to restore the signal before the channel. It has many useful applications. For example, it is studied heavily for IEEE 802.11n (MIMO) where knowing the channel allows recovery of the two or more streams which will be received on top of each other on each antenna. The name Zero Forcing corresponds to bringing down the inter symbol interference (ISI) to zero in a noise free case. This will be useful when ISI is significant compared to noise. For a channel with frequency response $F(f)$ the zero forcing equalizer $C(f)$ is constructed by $C(f) = 1 / F(f)$. Thus the combination of channel and equalizer gives a flat frequency response and linear phase

$F(f)C(f) = 1$.

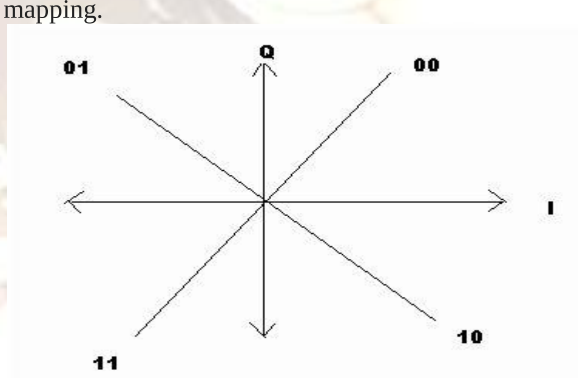
In reality, zero-forcing equalization does not work in most applications, for the following reasons:

Even though the channel impulse response has finite length, the impulse response of the equalizer needs to be infinitely long

At some frequencies, the received signal may be weak. To compensate, the magnitude of the zero-forcing filter ("gain") grows very large. Consequently, any noise added after the channel gets boosted by a large factor and destroys the overall signal-to-noise ratio. Furthermore, the channel may have zeroes in its frequency response that cannot be inverted at all. (Gain * 0 still equals 0).

Modulation Technique: Quadrature Phase Shift Keying (QPSK)

Quadrature Phase Shift Keying (QPSK) is the digital modulation technique. 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, Π/2, Π, and 3Π/2). QPSK perform by changing the phase of the In-phase (I) carrier from 0° to 180° and the Quadrature-phase (Q) carrier between 90° and 270°. This is used to indicate the four states of a 2-bit binary code. Each state of these carriers is referred to as a Symbol. Quadrature Phase-shift Keying (QPSK) is a widely used method of transferring digital data by changing or modulating the phase of a carrier signal. In QPSK digital data is represented by 4 points around a circle which correspond to 4 phases of the carrier signal. These points are called symbols. Fig given below shows this mapping.



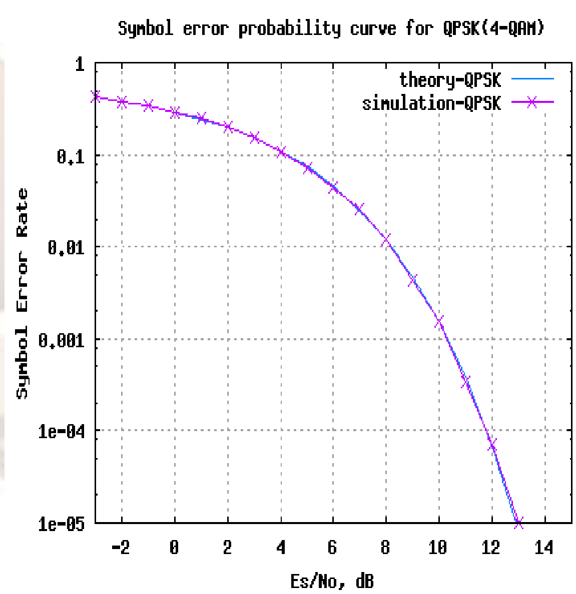


Figure: QPSK diagram
Figure: QPSK SER Curve

Simulation and Result Discussion

From the simulation model of the QPSK, we find that the response of the QPSK is same as the theoretical results. Therefore it is clear that the considered modulation scheme will provide us the best results in wireless communication. Please consider the above figure to justify our statement for the same.

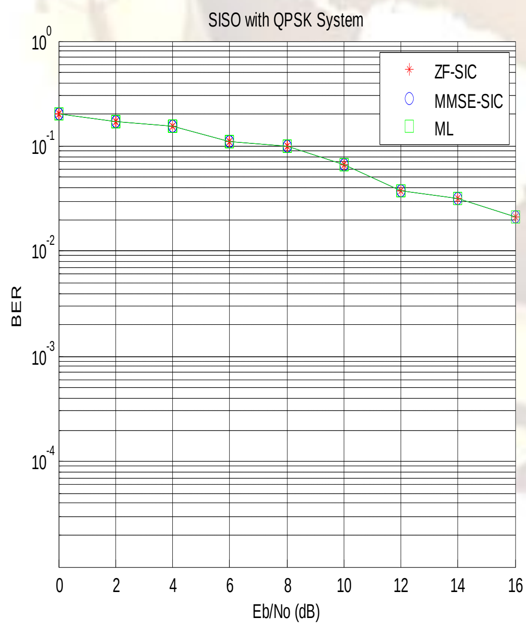
Concept of MIMO Capacity

Let us look at the capacity of the Multiple input and Multiple output antennas considered in transmitters and receivers. If we increase the size of MIMO like 2x2, 3x3, 4x4 etc than the capacity of the MIMO is increased with the size. This results in increased performance but at the cast of high simulation time. Therefore we always prefer such combinations that can result in high BER performance and with less complexity and with less simulation time and with less power consumptions. Based on the above simulation result now we select the suitable combination to recover and equalizer our data.

SISO with QPSK and considered Equalizers

Let us now investigate the performance of the single input single output antenna scheme with the MLSE equalizer and with the MMSE equalizer and with ZF, we find that all equalizers perform in a same way therefore the resources of the receiver are completely utilized or consumed by all the cast of high power and with high complexity. Please see the following figure for comparison:

Figure: SISO with MLSE, MMSE, ZF with QPSK



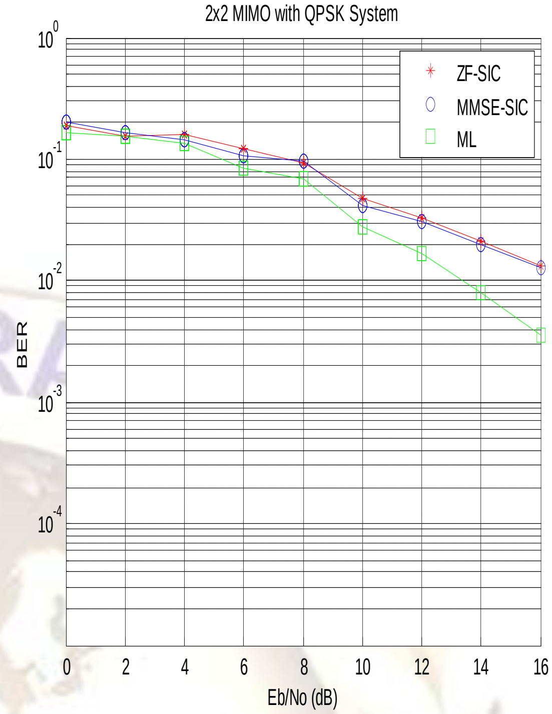


Figure: MIMO with MLSE, MMSE, ZF with QPSK

MIMO with QPSK and considered Equalizers

An improvement can be obtained if we consider the 2x2 MIMO scheme with QPSK. Here MLSE performs better in comparison with the other considered approaches. See the above figure:

CONCLUSION

In this paper we analyzed the performance of linear detectors for MIMO Spatial Multiplexing systems in Rayleigh fading channel and AWGN channel for QPSK modulation, which exhibited the best trade-off between performance and complexity among Spatial Multiplexing techniques. We show that conventional linear equalizers can only collect diversity Nr–- Nt +1 for MIMO systems though they have very low complexity. By investigating and simulating each receiver concepts, it Spatial Multiplexing implements a detection technique, i.e. MMSE receiver and optimal ordering to improve the performance, although ML receiver appears to have the best BER performance. In this paper, the MIMO principle is based on a Rayeigh multipath environment. So finally we proposed that ML detector for MIMO-Spatial fading model with QPSK modulation is the ultimate optimization technique in the next generation broadband communication system.

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