POWER ALLOCATION ANALYSIS OF MIMO-OFDM SYSTEM USING SVD AND WATER FILLING ALGORITHM

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ABSTRACT:-

In this paper, MIMO is paired up with OFDM improve the performance of wireless transmission systems. Multiple antennas are employed both at the transmitting as well as receiving ends. The performance of an OFDM system is measured, considering multipath delay spread, channel noise, Rayleigh fading channel and distortion. In this paper, bits are generated and then mapped with modulation schemes such as QPSK, 8PSK, and QAM. Then, the mapped data is divided into blocks of 120 modulated data where a training sequence of the data is inserted both at the beginning and ending parts of the block. The equalization is used to determine the variation to the rest of data. The singular value decomposition (SVD) and water filling algorithm have been employed to measure the performance of the MIMO-OFDM integrated systems. Therefore, the capacity is increased by transmitting different streams of data through different antennas at a same carrier frequency. Any inter symbol interference (ISI) produced after the transmission is recovered by using spatial sampling integrated with the signal processing algorithm. Furthermore, the performance remains the same with different combinations of transmitting and receiving antennas.

KEYWORDS: MIMO; OFDM; ISI; SVD; Water filling algorithm

INTRODUCTION:-

In older multi-channel systems using FDM, the total available bandwidth is divided into N *non-overlapping* frequency sub-channels. Each sub-channel is modulated with a separate symbol stream and the N sub-channels are frequency multiplexed. OFDM is a multi-channel modulation system employing Frequency Division Multiplexing (FDM) of orthogonal sub-carriers, each modulating a low bit-rate digital stream. In FDM, the prevention of spectral overlapping of sub-carriers reduces Inter channel Interference,

but leads to an inefficient use of spectrum. The guard bands on either side of each sub-channel are a waste of precious bandwidth. To overcome this problem, OFDM uses N overlapping (but orthogonal) sub carriers, each carrying a baud rate of 1/T and spaced 1/T apart. Because of the frequency spacing selected, the sub-carriers are all mathematically orthogonal to each other. This permits the proper demodulation of the symbol streams without the requirement of non overlapping spectra.

Another way of specifying the sub-carrier Orthogonality condition is to require that each sub-carrier have exactly integer number of cycles in the interval T. It can be shown that the modulation of these orthogonal sub-carriers can be represented as an Inverse Fourier Transform. Alternatively, one may use a DFT operation followed by low-pass filtering to generate the OFDM signal. It must be noted that OFDM can be used either as a modulation or a multiplexing technique.

Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL broadband internet access, wireless networks, and 4G mobile communications.

OFDM is essentially identical to coded OFDM (COFDM) and discrete multi-tone modulation (DMT), and is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. On several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional *single-carrier* modulation schemes in the same bandwidth.

Principles of OFDM

OFDM is a block transmission technique. In the baseband, complex-valued data symbols modulate a large number of tightly grouped carrier waveforms. The transmitted OFDM signal multiplexes several low-rate data streams — each data stream is associated with a given subcarrier. This property is often measured via the signal's peak-to-average power ratio. To be able to transmit and receive these peaks without clipping the signal, the A/D and D/A need to be designed with high demands on range and precision.
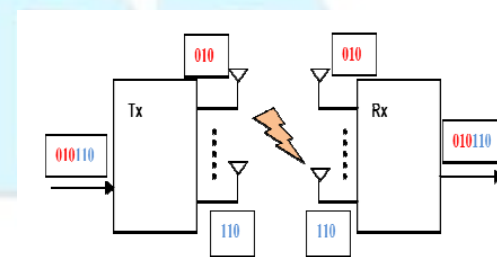

Fig:1 A basic MIMO-OFDM system

The main advantage of this concept in a radio environment is that each of the data streams experiences an almost flat fading

channel. In slowly fading channels, the inter symbol interference (ISI) and inter carrier interference (ICI) within an OFDM symbol can be avoided with a small loss of transmission energy using the concept of a cyclic prefix.

Signal generation

An ideal OFDM signal, which could be generated by a bank of oscillators. Such an implementation could, however, become prohibitively complex as the number of subcarriers becomes large. Similar to the demodulation of the data samples with the DFT, the baseband signal can be generated digitally by means of an IDFT OFDM transmitter. This has paved the way for practical use of OFDM. Consider the signal

$$\tilde{s}(t) = \sum_{n=0}^{lN-1} s_n g\left(t - \frac{nT}{l}\right), \qquad \text{for all } t,$$

Where

$$s_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} x_k e^{j2\pi \frac{kn}{lN}}, \qquad n = 0, \ldots, lN - 1,$$

Is the oversampled IDFT of the constellation symbols X_k, the integer L>1 and $g_{(t)}$ is an interpolating filter. The output signal from the D/A, $s_{(t)}$, can be made very close to the ideal signal $s_{(t)}$ as defined. The quality of the approximation depends on, for example, the characteristics of the D/A including the interpolation filter and the IDFT

A spectrum of an OFDM signal is shown. The spectrum decays with 1/f and

spectral leakage into neighbouring bands is sometimes too large to meet regulation requirements. Several approaches have been taken to combat this out-of-band emission. The most straightforward is perhaps to use a large number of subcarriers to narrow the spectra, however at the cost of increased complexity, increased sensitivity to Doppler effects, and higher demands on the accuracy of frequency synchronization.

Another approach is to use pulse shaping of the OFDM symbol to change the spectral occupancy. Pulse shaping can be done either by applying a time OFDM symbol or by passing the OFDM signal through a filter, typically combined with the interpolation filter above. Pulse shaping has to be applied with care since orthogonality between the subcarriers is rarely maintained.

In an N subcarriers MIMO-OFDM system, the data streams are first passed through an OFDM modulator. Then, the resulting OFDM symbols are launched simultaneously through the transmit antennas. In the receiver side, the individual received signals are passed through OFDM demodulator. The outputs of the OFDM demodulator are decoded and rearranged to get the desired output. Fig. shows the schematic diagram of a basic MIMO-OFDM system.

IFFT PROCESS:-

This method involves computing the quantile function of the distribution — in other words, computing the cumulative distribution function (CDF) of the

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distribution (which maps a number in the domain to a probability between 0 and 1) and then inverting that function. This is the source of the term "inverse" or "inversion" in most of the names for this method. Note that for a discrete distribution, computing the CDF is not in general too difficult: We simply add up the individual probabilities for the various points of the distribution. For a continuous distribution, however, we need to integrate the probability density function (PDF) of the distribution, which is impossible to do analytically for most distributions (including the normal distribution).
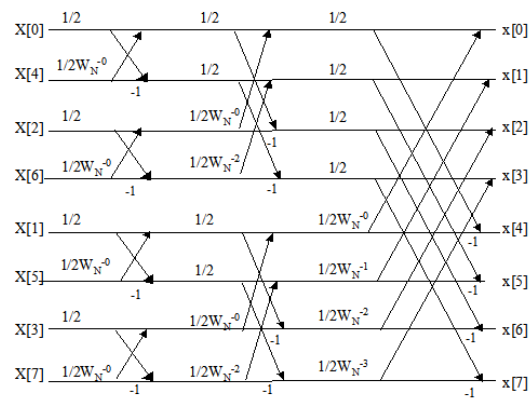

Fig: 2 FFT TO IFFT PROCESS

As a result, this method may be computationally inefficient for many distributions and other methods are preferred; however, it is a useful method for building more generally applicable samplers such as those based on rejection sampling.

$$X[k] = \sum_{n=0}^{N-1} x[n] W_N^{kn} \qquad 0 \le k \le N-1$$

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X[k] W_N^{-kn} \qquad 0 \le n \le N-1$$

Fig: 3 OFDM model used for simulations: (a) OFDM transmitter and (b) OFDM receiver
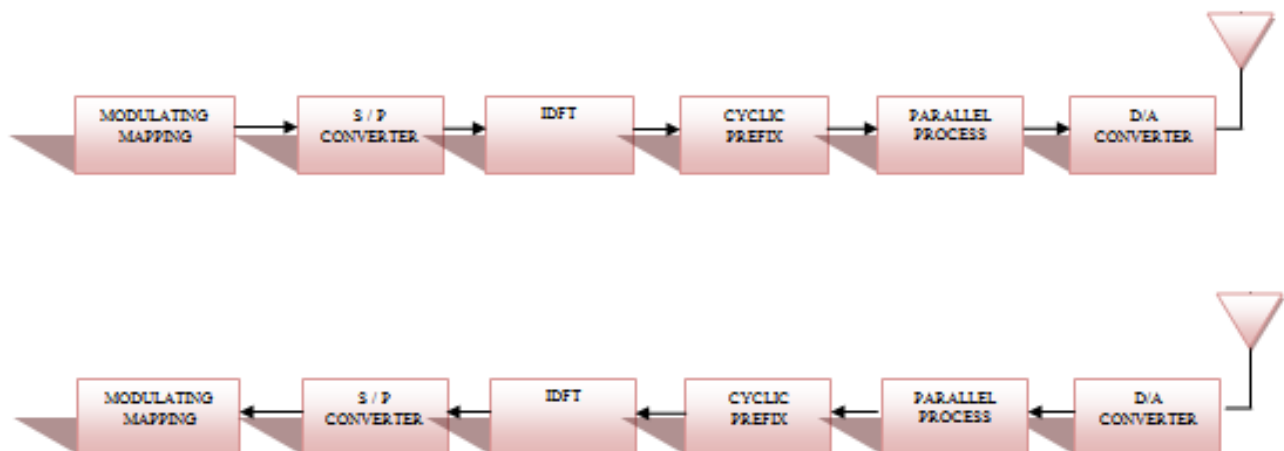
For the normal distribution, the lack of an analytical expression for the corresponding quantile function means that other methods (e.g. the Box–Muller transform) may be preferred computationally. It is often the case that, even for simple distributions, the inverse transform sampling method can be improved on. See, for example, the ziggurat algorithm and rejection sampling. On the other hand, it is possible to approximate the quantile function of the normal distribution.

extremely accurately using moderate-degree polynomials, and in fact the method of doing this is fast enough that inversion sampling is now the default method for sampling from a normal distribution in the statistical package R

Spatial Multiplexing

The transmission of multiple data streams over more than one antenna is called spatial multiplexing Spatial Diversity Spatial diversity improves the signal quality and achieves a higher signal to noise ratio at the receiver side. The principle of diversity relies on the transmission of structured redundancy. This redundancy can be transmitted at any time, from any antenna, over any frequency or at any polarization. Two kinds of spatial diversity need to be considered:

Tx where a signal copy is transmitted through more than one antenna,

Rx-Diversity, where the received signal is multiple evaluated.

MIMO CHANNEL MATRIX:-

The MIMO system has multiple links and operates on the same frequency whereas the non-MIMO system is linked over multiple channels by several frequencies. The challenge of this technology is the separation and the equalization of the signal in all paths. The channel model includes the channel matrix H with the direct and the indirect channel components.

Consider an OFDM symbol of N sub-symbols and cyclic prefix, P, the length of which is less than the last significant tap delay. The sent signal is 'x' and the received signal is 'y'. A time and narrowband channel is assumed. The output y can be expressed in a matrix format as follows;

$$_s\ y = H\ x\ \eta$$

Where y is the received vector, x is the transmitted vector and η is complex AWGN vector.

Capacity:-

Equation for the theoretical channel capacity:

$$c_{SISO} = f_g \log_2(1 + S/N)$$

.

It includes the transmission bandwidth fig and the signal noise ratio. Most channel capacity improvements are based on bandwidth extensions or modulations. The Shannon capacity of MIMO Systems additionally depends on the number of antennas. For MIMO the capacity is given by the following equation:

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$$c_{MIMO} = Mf_g \log_2(1 + S/N)$$

Where M is the minimum of MT (number of transmitting antennas) or MR (number of receiving antennas) and represents the number of spatial streams. For example, a 2 x 3 system can only support two spatial streams, which is also true for a 2 x 4 system. Asymmetrical antennas constellations are referred to receive or transmit diversity.

$$c_{Tx/Rx} = f_g \log_2\left(1 + M\left(\frac{S}{N}\right)\right)$$

SNR Threshold:-

In the proposed transmission control scheme, the threshold value identifies whether multiple transmit antennas should be used or not. Therefore, it is obvious that selecting the right threshold value has significant effect on the performance of the MIMO system. A small threshold increases the complexity without achieving high multiplexing gain.

Water Filling

Water filling refers to a technique whereby the power for the spatial channels are adjusted based on the channels gain.
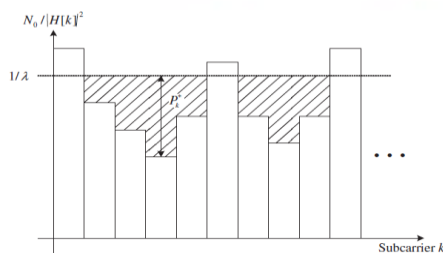

Fig: 4 WATERFILLING ALGORITHM PROCESS

The channel with high gain and sign given more power. More power maximizes the sum of data rates in all sub channels. The data rate in each sub channel is related to the power allocation by Shannon's G formula C = B log (1 + SNR). However, because of t is a logarithmic function of power, the data rate is usually insensitive to the exact power allocation. This motivates the search for simpler power allocation schemes that can perform close to the optimal.

Singular Value Decomposition

The SVD technique decouples the channel matrix in spatial domain in a way similar to the DFT decoupling the channel in the frequency domain. The channel matrix H is the T x R channel matrix. If H has independent rows and columns, SVD yields:

$$H = U \sum V^h$$

Where U and V are unitary matrices and Vh is the hermit an of V. U has dimension of R x R and V has dimension of T x T. $\sum$ is a T x R matrix. If T = R, then $\sum$ become a diagonal matrix. If T > R, it is made of R x R diagonal matrix followed by T − R zero columns. If T < R, it is made of T x T diagonal matrix followed by R − T zero rows. This operation is called the singular value decomposition.

In case, where T ≠ R, the number of spatial channels become restricted to the minimum of T and R. If the

number of transmit antennas is greater than the receive antennas (T > R), U will be an R x R matrix, V will be a T x T matrix and ∑ will be made of a square matrix of order R followed by T-R zero columns.

OFDM SYSTEM PARAMETERS USED FOR SIMULATION

PARAMETER	VALUE
CARRIER MODULATION	QPSK
FFT SIZE	128
NO OF CARRIERS	120
GUARD TIME	32 SAMPLES (40 deg)
GUARD PERIOD TYPE	FULL CYCLE CALCULATION

SIMULATION RESULT ANALYSIS

In this simulation, a highly scattered environment is considered. The capacity of a MIMO channel is analyzed with the antenna configuration as shown in Table.
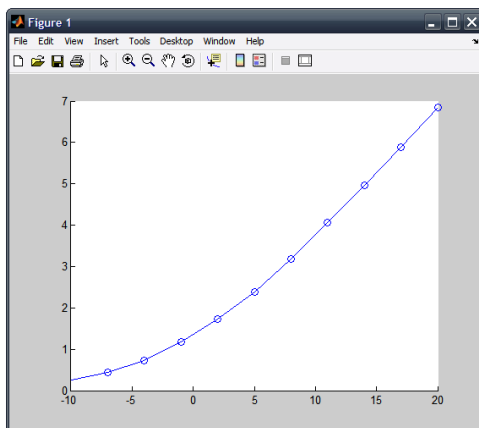
Fig 5 (a): 1Tx-1RX Operation

Each channel is considered as a parallel flat fading channel. The power in a parallel channel (after decomposition) is distributed as water filling algorithm. Channel matrix H is measured using Rayleigh distribution

function. This simulation computes channel capacity and PDF (probability density function) of elements in SVD of matrix H, by varying the SNR from -10 dB to 20 dB, where 104 iterations are performed.
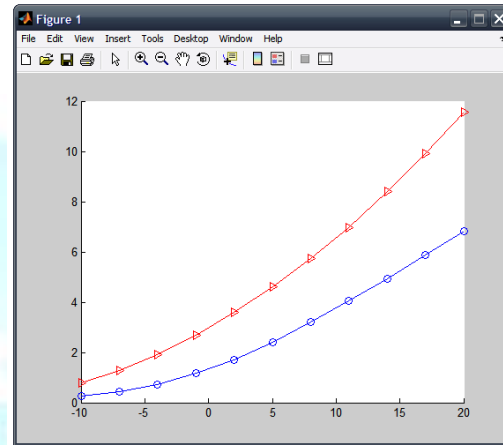

Fig 5 (b): 2Tx-2RX Operation

TRANSMITTING AND RECEIVING ANTENNA COMBINATION

COMBINATION	No of TX	No of RX
1	1	1
2	2	2
3	2	3
4	3	2
5	4	4

MIMO-OFDM Simulation Results:-

The CHANNEL CAPACITY VS SNR curve of different MIMO systems is shown in Fig.5. Fig.6 represents the power spectral density (PDF) VS SNR. These graphs depict that the 4 x 4 MIMO systems provides better channel capacity and PDF than other combinations. This indicates that a higher order MIMO system increases the system performance.

This motivates the search for simpler power allocation schemes that can perform close to the optimal. The water filling algorithm is based on iterative procedure
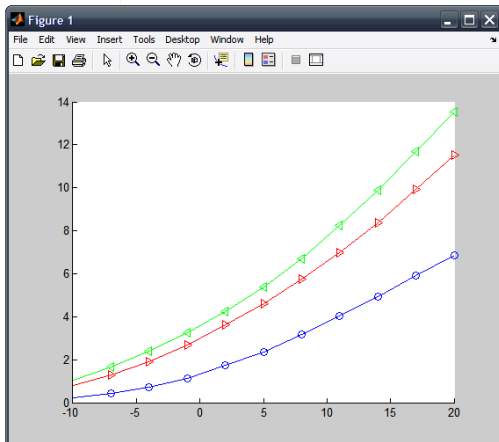

Fig 5 (c): 2Tx-3RX Operation

In case, where T ≠ R, the number of spatial channels become restricted to the minimum of T and R. If the number of transmit antennas is greater than the receive antennas (T > R), U will be an R x R matrix, V will be a T x T matrix and ∑ will be made of a square matrix of order R followed by T-R zero columns

Fig 5 (d) (i): 3Tx-2RX Operation

It is interesting to note that the system performance remains almost the same when the number of transmitter and receiver antennas is altered (2x3 MIMO and 3x2 MIMO systems).
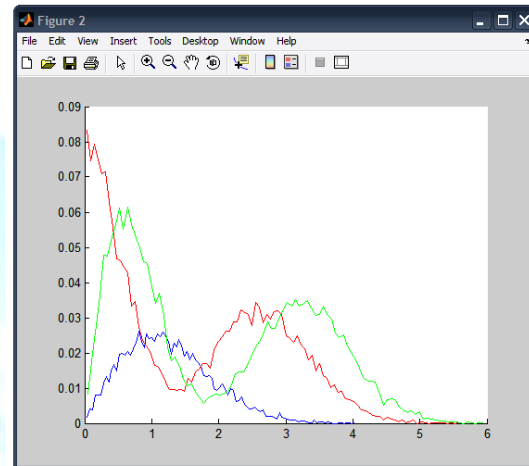

Fig 5 (d) (ii) Comparison of PDF of different MIMO system.

Bandwidth is the difference between the upper and lower frequencies in a continuous set of frequencies. It is typically measured in hertz, and may sometimes refer to pass band bandwidth, sometimes to baseband bandwidth, depending on context. Pass band bandwidth is the difference between the upper and lower cut off frequencies of, for example, a band pass filter, a communication channel, or a signal spectrum. In case of a low-pass filter or baseband signal, the bandwidth is equal to its upper cut off frequency. Bandwidth in hertz is a central concept in many fields, including ECE, IT, DCE RD DSP and Spectroscopy..
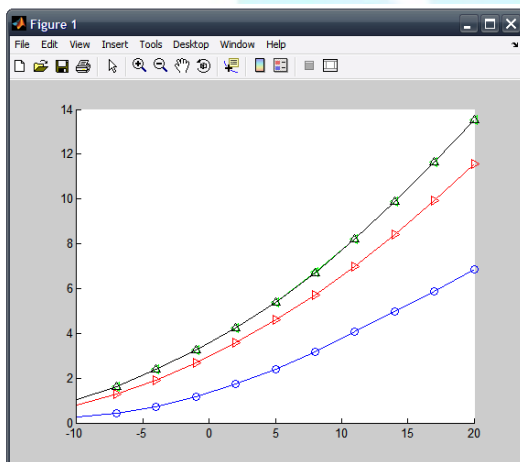
Multiple-input and multiple-output, or **MIMO**, is the use of multiple antennas at both the transmitter and receiver to improve

communication performance. It is one of several forms of smart antenna technology. Note that the terms input and output refer to the radio channel carrying the signal, not to the devices having antennas
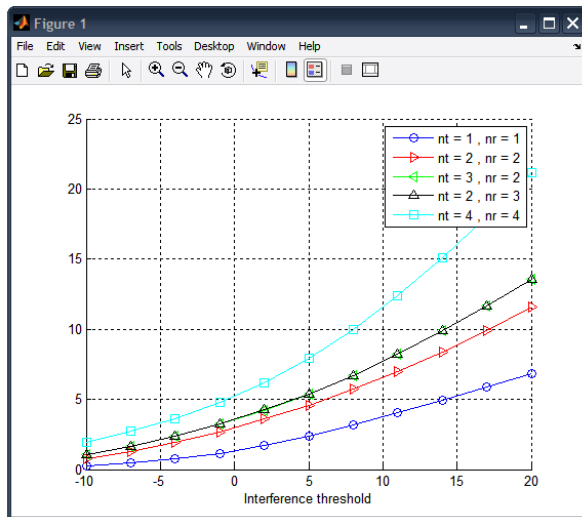

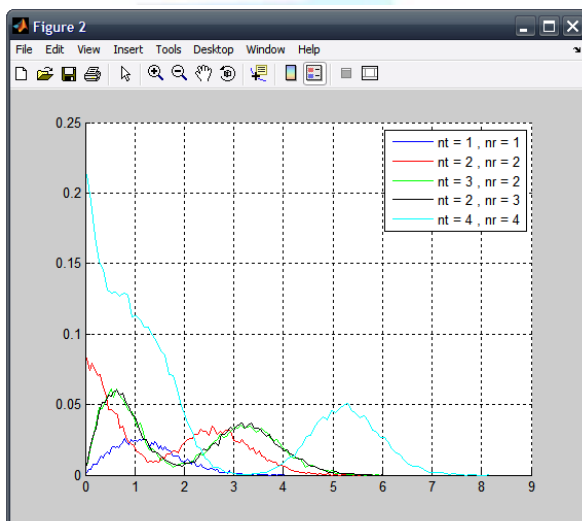**Fig 6 (a) Comparison of channel capacity of different MIMO system.**

Fig 6 (b) Comparison of PDF of different MIMO systems.

CONCLUSION

An OFDM link was demonstrated through computer simulations and practical tests performed on a low bandwidth base-band signal. Four main performance criteria were tested, which include OFDM's tolerance to multipath delay spread, channel noise, peak power clipping and start time error. Several other important factors affecting the performance of OFDM have only been partly measured. In the past, there were a lot of problems with multiple wave propagation which led to creation of ISI. The MIMO has helped to reduce the ISI problem. With the implementation of MIMO-OFDM, the probability that the transmission arrives at the receiver with little or no error is greatly increased compared to the rest of the transmission techniques. In this system, the capacity is increased significantly by transmitting the different streams of data through different antennas at a same carrier frequency.

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