A Channel State Information Feedback System using Massive MIMO-OFDM

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Abstract - Multiple input multiple output (MIMO) communication systems can offer significant channel capacity (high data transfer rate and maximum array gain with feedback receive processing. The maximum gains are perceived in relation to array gain and diversity. However it may requires perfect channel knowledge in the term of Channel State Information at the transmitter end. If the estimation of channel is not possible or non-availability of CSI at receiving end, receiver quantized the channel information and sent back to the transmitter. In the case of narrowband channels, considerable work has been done in reducing the feedback information while maintaining bit-error-rate performance close to the case of perfect channel knowledge. In this paper, Orthogonal Frequency Division Multiplexing (OFDM) is considered with complexity implementation of MIMO over frequency quantizing channel information. Various methods have been discussed with regards to that. We develop special emphasis on Time domain of Vector quantization in MIMO-OFDM with and without feedback CSI.

Keyword: MIMO, SVD, ML, CSI.

I. INTRODUCTION

We used single user communication model and consider a point-to-point link where the transmitter is equipped with n_T*no of* antennas and the receiver employs n_R*no of* antennas. In the *single* user assumption in the depiction as point-to-point link, we suppose that no inter-symbol interference (ISI) occurs. This implies that the bandwidth of the transmitted signal is very small and can be assumed frequency-flat (coherent bandwidth), such that each signal path can be represented by a complex-valued gain factor. For practical purposes, it is common to model the channel as frequency-flat whenever the bandwidth of the system is smaller than the inverse of the delay spread of the channel; hence a wideband system operating where the delay spread is fairly small.

Now let $x_{i,j}$ be the complex-valued path gain from transmit antenna jto receive antenna i(the fading coefficient).If at a certain time instant the complex-valued signals { s1……….. s_{nT} }are transmitted via the nT antennas, respectively, the received signal at antenna i can be expressed a s

$$y_i = \sum_{j=1}^{nr} x_{i,j} \ \ s_j + n_i \qquad (1)$$

wheren_i represents additive noise this linear relation can be easily written in a matrix framework. Thus, let s be a vector of size n_T containing the transmitted values, and y be a vector of size n_R containing the received values, respectively. We have $s \ \in C^{nT}$ $, y \in C^{nR}$. [3]

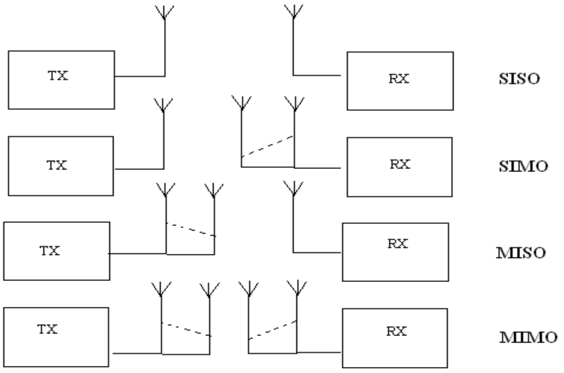

Figure 1: MIMO channel model

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

OFDM is encouraging user for achieving high data rate transmission in wireless environment. The application of OFDM to high data rate mobile communication system is being investigated by many researchers.

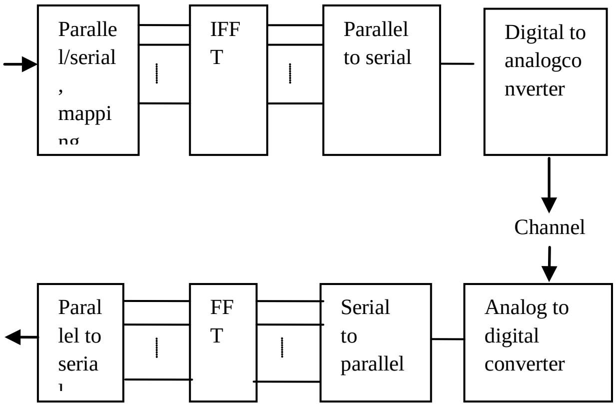

Figure: 2 Basic OFDM Transmission System

In the OFDM the transmitter, the signal is defined in the frequency domain. It is a sampled signal, and it is defined such that the discrete Fourier spectrum exists only at distinct frequencies. Each OFDM carriers corresponds to one element of this discrete Fourier spectrum.

The amplitudes and phases of the carriers depend on the data to be transmitted. The data transitions are synchronized at the carriers, and can be processed together, symbol by symbol as shown in diagram be figure 2.

Data coming from the input are arranged into vectors with number of components equal to the number $\widetilde{N}$ of carriers. Each component is composed by a number of bits depending on the alphabet of the modulation scheme used on the next stage. For example, if we use a 1536 carriers system with BPSK, we'll have vectors of 1536 component each one composed by 1 bit (BPSK is 2-ary).Each component (group of bits) is mapped into a complex symbol depending on the alphabet of the modulation scheme used. For example, with BPSK the alphabet is{ -1 ; +1 }.In order to obtain real samples after IFFT, a 2*Number of carrier points IFFT is done with :

The Inverse Fast Fourier Transform algorithm (IFFT) is applied to the vector giving a real samples vector. The guard interval is added at the beginning of the vector by repeating the components of the end. Vectors are concatenated to form a time signal (parallel/serial conversion) Windowing the signal is necessary to limit the bandwidth. Most used window is the raised cosine. The signal is then passed through the channel. Channel is modeled by a linear system with frequency response c(t) together with a source of additive Gaussian noise. At the reception, signal is rearranged again into vectors (serial/parallel conversion) and guard interval is dropped.

Fast Fourier Transform (FFT) is computed in order to get back the complex vector of symbols.

Mapping of digital signal is performed by the DFT in OFDM in to complex signal and reverse mapping is performed by IDFT.

Let consider K be the size of IDFT and extended cyclically to include a cyclic prefix (CP) of lengthNcp

$$x[n] = \sum_{k \in SA} s[k] e^{\frac{i2\pi\, nk}{K}}, n = -Ncp, \ldots\ldots, K-1.$$

Sets of all inputs of IDFT is

$$S \in \{-\frac{K}{2}, \ldots\ldots, \frac{K}{2} - 1\}$$

III. QUANTIZATION SCHEME DESIGN

To design optimum quantization design for OFDM – MIMO with noiseless as well low no. of bits we have to satisfy following expression:

$$P\ \{\ |N_{cp}|\ > d_{min}/2\ \} \rightarrow 0$$

where d_{min} is the minimum distance between the constellation symbols X_k. The Probability density function (PDF) of N_k only depends upon the quantization step. The optimum quantization results are obtained only if the equation is satisfied. That means we can detect X_k correctly.

If we apply error correcting codes (e.g. LDPC codes) to mitigate the quantization effect, we can design the error correcting codes according to the channel limit which is dependent on the signal-to-quantization-noise ratio (SQR). The required SQR determines the variance of quantization noise, which corresponds to the quantization step.

The optimum quantization step is to be designed which makes the number of quantization level N_{cp} as small as possible. The peak-to-average ratio is large and moreover peaks occur not often. So it is advantageous to allow some clipping and hence lower the consumption of the Analog to Digital converters. Here, the optimum quantization scheme is designed for two scenarios: one without clipping and the other with clipping

Without clipping:

In without clipping that means there is limited range of real and imaginary part of X_k . It means realand imaginary parts of Xkare bounded with unity modules.

And X_n can be expressed with the cosine and sine term as

$$X_n = \frac{1}{\sqrt{N}} \sum_k [(real\ (X_k) \cos(\frac{2\,\pi\, nk}{K}) - img\ (X_k) \sin\ (\frac{2\,\pi\, nk}{K})) + j\ real(X_k) \sin(\frac{2\,\pi\, nk}{K}) - img\ (X_k) \cos\ (\frac{2\,\pi\, nk}{K})\ )]$$

X_n is the range bounded with modulus of $\sqrt{2N}$

Once the quantization step size is decided, variance can be easily calculated, then quantizationlevel is derived without clipping as

$$N_p = 2[\sqrt{2N}] / \text{step size}.$$

With clipping:

In this system number of sub carrier N decide the range of X_n as well finds the quantization level.

With clipping system if the real part of $X_n$is large at the certain value the probability density function approaches to zero.

$$P\{\ \text{real}\ X_n \leq \text{Certain value}\ \} \rightarrow 1$$

When clipping is allowed the number of quantization levels can be reduced to:

$N_q = 2[c/\text{ step size}]$.

The clipping technique employs clipping or nonlinear saturation around the peaks to reduce the PAPR (Peak-to-Average Power Ratio). It is simple to implement, but it may cause in-band and out-of-band interferences while destroying the orthogonality among the subcarriers. This particular approach includes block-scaling technique, clipping and filtering technique, peak windowing technique, peak cancellation technique, Fourier projection technique, and decision-aided reconstruction technique.

The clipping approach is the simplest PAPR reduction scheme, which limits the maximum of transmit signal to a pre-specified level. However, it has the following drawbacks: Clipping causes in-band signal distortion, resulting in BER performance degradation. Clipping also causes out-of-band radiation, which imposes out-of-band interference signal to adjacent channels. Although the out-of-band signals caused by clipping can be reduced by filtering, it may affect high-frequency components of in-band signal (aliasing) when the clipping is performed with the Nyquist sampling rate in the discrete-time domain. However, if clipping is performed for the sufficiently-oversampled OFDM signals (e.g. $L < 4$) in the discrete-time domain before a low-pass filter (LPF) and the signal passes through a band-pass filter (BPF), the BER performance will be less degraded. Filtering the clipped signal can reduce out-of-band radiation at the cost of peak regrowth. The signal after filtering operation may exceed the clipping level specified for the clipping operation.

IV. CONCLUSION

At the reception itisvery important to distinguish the starting point of FFT to avoid wrong demodulation. And sosynchronization has to be precise. It explains the use of special symbols (pilot) for synchronization in transmission.

Hardware design of transmitter and receiveris important because of highpeak to average ratio which cause distorsions if dynamic range of amplifiers and convertersis not highenough.

OFDM is very sensitive to carrier frequency offsets. Such offsets are mainly the cause of receiver local oscillators instability and doppler effect, when mobile is moving.

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