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Design of Analog and Digital Beamformer for 60GHz MIMO Frequency Selective Channel through Second Order Cone Programming

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Abstract: *In this work Analog and Digital Beamformer system is considered in Frequency Selective Channel. Analog beamforming vector will be designed using SOCP; while digital beamforming will be performed using precoding and postcoding techniques. A novel method of designing analog beamforming considering the practical frequency selective fading channel parameter is proposed. The proposed method is optimal in a sense that for a given number of RF chains, the weighted sum of the squared distances between the combined analog and digital beamforming vectors derived by the proposed method and the ideal beamforming vectors is minimized, where the weights are the singular values corresponding to the singular vectors. The proposed architecture uses antenna element spacing derived from the principles of diffraction limited optics to establish multiple parallel data channels. Operation at millimeter wave carrier frequencies reduces the antenna array size to reasonable dimensions. The simulations will be performed in MATLAB using CVX tool.*
Keywords: *Analog and Digital Beamformer, Frequency Selective Channel, Second Order Cone Programming.*

I. Introduction

Millimeter wave Communication is a most recent technology in wireless communication to increase the effective range of radio without exceeding the power output limits that exist in unlicensed bands throughout the world. It is used in mobile data services and available in higher bandwidth. The antenna array has played a vital role in reduce the size and power consumption of the communication devices. The gain offered by the millimeter wave required MIMO signal processing which leverages higher aperture.

The MIMO system provides generally two types of gain known as spatial multiplexing and diversity gain. The multiplexing gain transmits independent data signals from different antennas to increase the throughput. The diversity gain will provide the receiver with multiple identical copies of a given signal to combat fading. The faster bit error rate will decrease the function of the signal SNR. The ISI can also be reduced by using smart antenna techniques. Higher cost only due to the deployment on multiple antennas.

In the non-blocked line-of-sight path between a transmitter (TX) and a receiver (RX) and we are only concerned with a single spatial stream (without spatial multiplexing), the optimal beamforming vector is nearly frequency flat over a range of few GHZ bandwidth. Otherwise, on the other hand the optimal beamforming vector (for a single spatial stream) or matrix for (multiple spatial streams) may be frequency selective.

The combined analog and digital beamformer could be adapted to frequency. The performance of such activity is expected to depend on the number of RF chains. However the allowable number of RF chains is limited due to the implementation complexity .The RF chains have devices are power amplifier, combiner, baseband receiver unit, alarm extension, transceiver, control function.

II. Beamforming

The multiple antennas at the transmitter and receiver can be used to obtain diversity gain instead of capacity gain. The same symbol weighted by a complex scale factor, is sent over each transmit antenna, so that the input covariance matrix has unit rank The diversity gain will depends on whether or not the channel is known at the transmitter. The beamforming technique is used in smart antenna to improve the wireless system performance. Generally there are two types of beamforming.

(A) Analog Beamformer
(B) Digital Beamformer

(A) Analog Beamformer

The analog beamformer is a simpler method where the individual signal received from array of antennas are cophased and summed to maximize the signal reception. The cophase is achieved through data independent weight which is predefined as per direction of arrival. It have the centralized receiver channel the received signals from each element of the phased array antenna, are combined at the RF carrier frequency level.

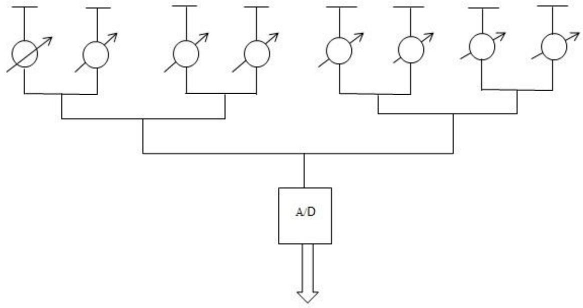

Figure 1.1 Analog Beamformer

(B) Digital Beamformer

It has one receiver at each of the radiating elements of the antenna from which easy to decorrelate the noise and signal distortion. The down-converting to IF-Frequency and digitizing the signal is realized at each individual antenna element. It is based on the conversion of RF signal at each antenna element into two streams of binary baseband signal representation of the sine and cosine channel. These two streams of binary baseband signal used to recover both amplitude and phase of the signal received at each element of the array. The process of the Digital Beamformer implies weighting by a complex weighting function and then adding together to form desired output. The key technology is accurate translation of analog signal into digital regime. Multiple independent beams steered in all directions can be formed in the digital beamforming processor. The benefits of digital beamformers are:

- Improved dynamic range.
- Controlling of multiple beam.
- Better and faster control of amplitude and phase.
- Low sampling rate.

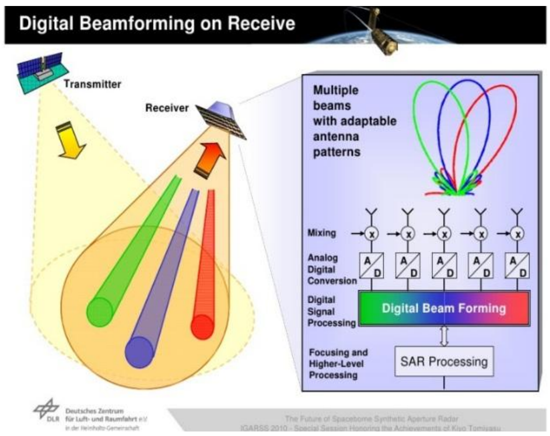

Figure 2.1 Digital Beamformer

The digital beamforming have two techniques one is precoding and postcoding. The precoding is a generalization of beamforming to support multistream transmission in multi-antenna wireless communications. In point-to-point systems, precoding means that multiple data streams are emitted from the transmit antennas with independent and appropriate weightings such that the link throughput is maximized at the receiver output.

III. Frequency Selective Channel

The frequency selective channel is best at selecting frequency and also one of the frequency dependent channels; it can be described with large small scale effect and time is invariant shows frequency dependent response. It is also said to be time flat channel. Between the transmitter and receiver this channel allow the multipath to reach the destination and it also have ground reflection path; from which the power to be reduced in the channel when compared to Signal to Noise Ratio (SNR). The important advantage in the channel it has less interference.

IV. Convex Optimization

Many situations arise in machine learning where we would like to optimize the value of some function. That is, given a function f: R^nR, we want to find X€R^n that minimize or maximize f(x). In the general case find the global optimum of a function can be very difficult task. However for a special class of optimization problems we can efficiently find the global solution in many cases. Here the efficiency has both practical and theoretical connotation it means we can solve many real world problems in a reasonable amount of time and it means that theoretically we can solve a problem in time that depends only polynomial on the problem size.

CVX is an open source MATLAB based modeling tool. The optimization problem has to be a convex optimization problem. For example linear programs, quadratic programs, maximization, entropy. CVX is not for large scale problems. CVX will converts the problem into a format accepted by those solvers and call them to solve the problem .Disciplined Convex Programming (DCP) is a methodology for constructing convex optimization problems in a suitable format for CVX. DCP imposes a set of rules. Problems have to be written such that those rules are satisfied. Otherwise problem will be rejected, even when the problem is convex.

What CVX does?

- Transform problem into Linear Programming.
- Calls solver SDPT3.
- Overwrites (Object) x with (numeric) optimal value.
- Assign problem optimal value to CVX optimal value.
- Assign problem status to CVX status.

(a)Second Order Cone Programming

It is a generalization of linear and quadratic programming that allows for affine combination of variables to be constrained inside second order cones. The SOCP model includes as special cases problem with convex quadratic objective and constrains. SOCP models are particularly useful in geometry problems as well as in linear programs where the data is imprecisely known. SOCP can be solved with great efficiency by interior point's method. It is not a polyhedral. Feasible region of SOCP is not polyhedral. IT is fast algorithm for finding global optimum values. Application of SOCP is finite horizon optimal control and antenna array weight design. SOCP-able programs have Sum of norms and Maximum of norms. The advantage of SOCP is used to get minimum power in the system.

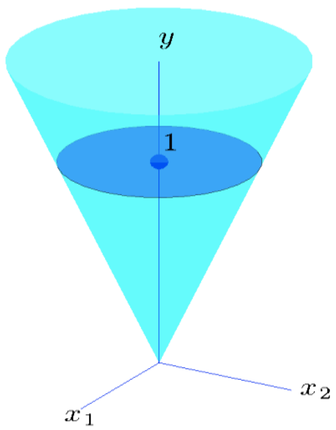

Figure 3.1 Second Order Cone Programming

V. Proposed System

In this proposed system to design analog beamforming by using Second Order Cone Programming technique, to design digital beamforming by using precoding and postcoding technique. To perform simulation considering the practical channel model based on the 60GHz conference room STA-STA model.

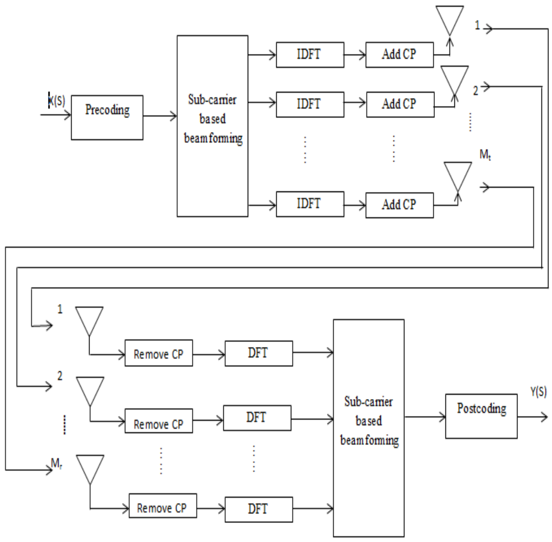

Figure 4.1 Structure of MIMO System

In this system the digital input signal is given to the precoding is precoded only the digital input. And also it support multi-layer transmission in the multi antenna wireless communication. The main advantage of precoding is maximum throughput to be obtained in the receiver. The digital input is not able to transmit so we use transmit analog beamforming.

The frequency selective channel is used to send the analog input to next chain, the channel is time independent. In the next chain the receiver analog beamforming to receive the analog input signal here some noise are added with that signal after we can done postcoding technique to get digital output signal.

VI. Simulation Result

1.Analog Beamformer

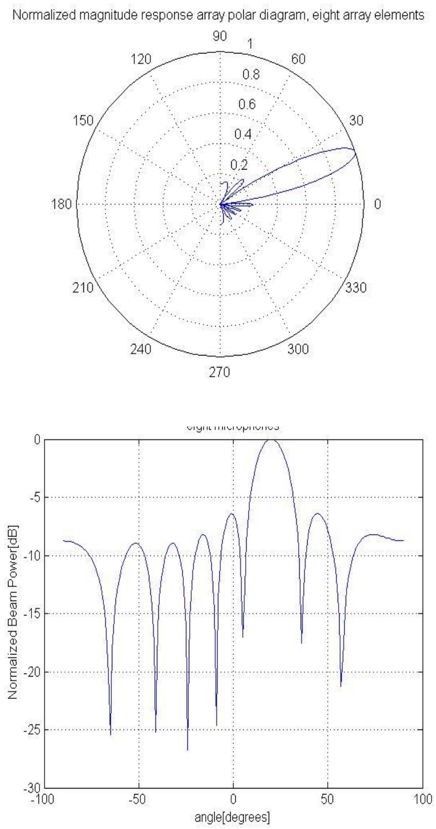

Fig 5.1: Beamforming plot to detect angle of the target.

Inference:

When a target is placed at a certain angel with the help of beamforming the angle is found out by forming a virtual beam towards the particular direction.

2. Beamformer output:

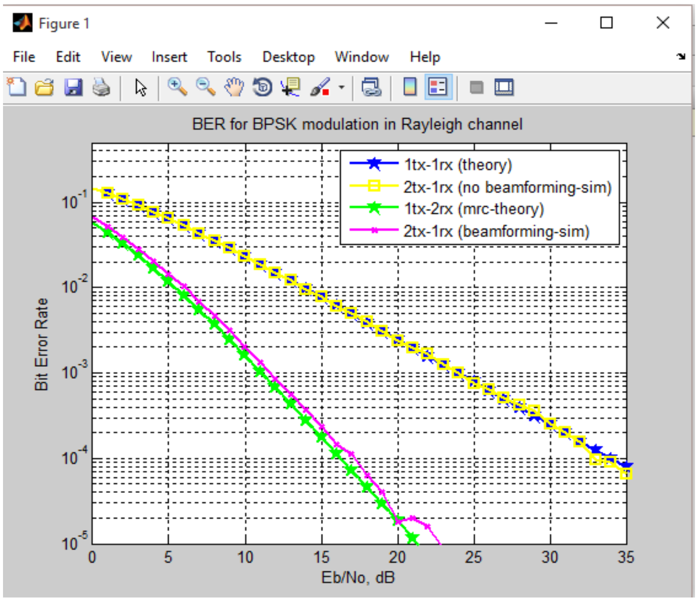

Figure 6.1: MRC equalization technique for beamforming

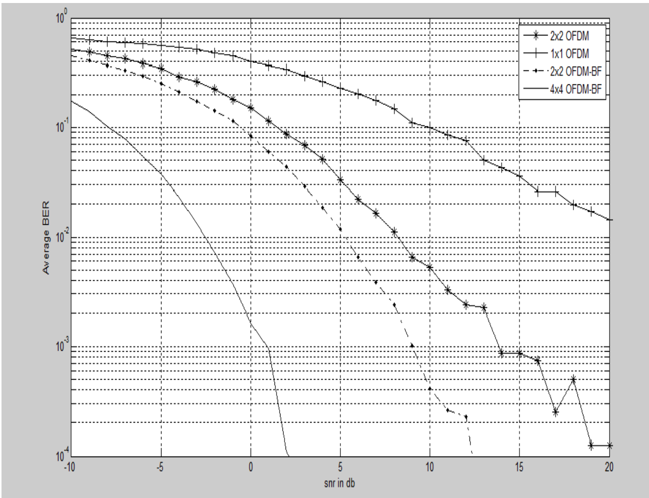

Figure 7:1 OFDM Beamforming

Inference:

It is evident that an increasing the number of antennas improve the system performance which can be further improved by incorporating Beamforming technique

3.Finding the Optimized Value:

Using the convex optimization technique, the optimized value for weight vectors and total transmit power is found. Two cases are considered

Case 1: Orthogonal Channels,

Case 2: Correlated Channels.

Case 1: Two orthogonal channelsResults Obtained

S.NO	PARAMETERS	VALUES	
1	Optimal Value (cvx_optval)	+2.82805	
2	SINR	**Link 1**	**Link2**
		1.9985	1.9985
3	Weight Vectors	**Link 1**	**Link 2**
		0.7068	0.7068
		0.7068	-0.7068
4	Total transmit power	2.8280	

Table 1: Optimal values obtained for Case 1

Inferemce:

The optimal values for weight vectors for the two orthogonal channels are found to be 0.7068 using CVX. The optimal value of transmit power is 2.28280.

Case 2: Two highly correlated channelsResults Obtained

Optimal value (cvx_optval): +Inf

SINR of link 1&2:

SINR = NaNNaN

Weight vectors:

W = NaNNaN

NaNNaN

Total transmit Power:

x = NaN

Inference:

Since the two channels are considered highly correlated the problem becomes infeasible. Hence there are no results obtained.

Case 3: Summary of MIMO OFDM system incorporating beamforming

	SNR	Average BER
1x1 OFDM	-10	0.6
	20	0.003
2X2OFDM	-10	0.5
	20	0.0002
2X2 OFDM with Beamforming	-10	0.4
	13	0.0001
4x4 OFDM with Beamforming	-10	0.2
	2	0.0001

Table 2: MIMO OFDM system incorporating beamforming

From above table it is made clear by comparing the result of 2*2 OFDM with 2*2 OFDM Beamforming that MIMO-OFDM system along with beamforming provides better performance .By making a comparative study of 2x2 OFDM –beamforming and 4x4 OFDM-beamforming it is inferred that increasing number of antennas obviously enhances the performance.

VII. Conclusion

In this paper we studied about the analog and digital beamformer for proposed frequency selective channel. The proposed system is an attractive alternative to traditional designs methods. The equalization techniques are play a vital role in the proposed system, mainly maximum ratio combining technique are used to get the difference in with and without beamformer.This evident that an increasing the number of antennas improve the system performance which can be further improved by incorporating Beamforming technique Due to maximum ratio combining low signal to noise ratio to be obtained, from which it will improve the channel performance.

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