Realization of 2x2 MIMO Architecture using FPGA

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Abstract- **Multiple-Input Multiple-Output (MIMO) technology is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time. This paper describes MIMO system employing link adaptation of spatial multiplexing and spatial diversity. In this work, spectral efficiency is measured for single carrier QAM MIMO using spatial diversity and spatial multiplexing. The main scope of this proposed work is to improve the spectral efficiency that spatial multiplexing should enhance. 2x2 MIMO schemes are dynamically adapted to the changing channel conditions for enhancing the spectral efficiency. 2x2 MIMO signal processing is implemented in a spartan-6 FPGA hardware.**

Index Terms—MIMO, Channel Matrix, Eigen values, FPGA.

I. INTRODUCTION

Multiple Input Multiple Output (MIMO) uses multiple antennas at the transmitter and the receiver. MIMO transmits and receives two or more data streams through a single radio channel. Thereby the system can deliver two or more times the data rate per channel without additional bandwidth or transmit power. The addition of multiple antennas at the transmitter combined with advanced digital signal processing based algorithms and the receiver yields significant advantage in terms of capacity and diversity [1][2]. MIMO systems have achieved attention as it promises to increase capacity and performance with acceptable BER proportionally with the number of antennas[3][4]. The MIMO system comprises of transmitter and receiver sections. The transmitter comprises blocks such as bit generation, QAM modulation, adaptive SD/SM, ADC. The encoded data modulated using BPSK/ QPSK/QAM modulation [5][6][7]. The operation of receiver blocks is opposite to that of transmitter to receive the actual signal.

The paper is organized in the order mentioned as follows: Section 2 describes the system model. Section 3 discusses 2 x 2 MIMO architecture system. The experimental results has been discussed in Section 4. Section 5 concludes the paper with the summary of the carried out work.

II. SYSTEM MODEL

Let us consider 2X2 MIMO system with *M* transmitting antennas and *N* receiving antennas. The input data *X* is multiplexed into *M* parallel transmit data streams x_j ($j = 1,...,M$). Each new data streams are used to modulate the data. When transmitting two signals by modulating with QAM, the transmitted signal will be of the form

$$x(t) = I(t)\cos(2\pi f_c t) - Q(t)\sin(2\pi f_c t) \quad (1)$$

where *I*(t) and *Q*(t) are the modulating signals, f_c is the carrier frequency. As all data streams are transmitted at the same time, the received signal is a linear combination of all X_j. Its discrete time baseband MIMO channel model can be represented as

$$y = Hx + n \quad (2)$$

where **n** is the sum of thermal noise with zero mean and a variance σ^2, and the noise power spectral density is N_0. It is assumed that N_t data symbols $X_1, X_2, \dots, X_{N_t}$ are chosen randomly, equally-likely and independently to form an input data vector $x = [x_1, x_2,...,x_{N_t}]^T \in A^M$ where ***A*** is a given modulation constellation. Each Tx transmits independent symbols of the same power: $\langle \mathbf{xx}^* \rangle = Pt/Nt.\ \mathbf{I}$, where *Pt* is the total Tx power, **I** is the identity matrix, <> and * denote expectation and Hermitian conjugation respectively. The received signal vector is denoted by $y = [y_1, y_2, ..., y_{N_r}]^T$. Notation **H** denotes an $N_t \times N_r$ channel matrix, in which *hnm* is the non-negative and real coefficient between the *m*th transmitter antenna and the *n*th receiver antenna.

In order to de-multiplex the signals and retrieve the transmitted data, the MIMO system has first to estimate the channel estimation coefficients between a pair of Tx and Rx. To achieve this, training sequences of binary phase shift keying signals are periodically inserted in front of the data streams to obtain the matrix for channel estimation. Channel estimation should consider four different channels. Each row of the 2D array contains two training sequences, one from each transmitter.

$$t = \begin{bmatrix} ts_1 & 0 \\ 0 & ts_2 \end{bmatrix} \quad (3)$$

Thus, perform the channel estimation on each training sequence in each row then determine the four channel estimates. On receiving all pilot signals $\mathbf{y_t}$, an **H** matrix detailing channel estimation is logged. It is only then that the T_x can proceed with the simultaneous transmission of data on all channels

$$H = \frac{y_t}{t} = \begin{bmatrix} \frac{y_{11}}{t_{s1}} & \frac{y_{12}}{t_{s2}} \\ \frac{y_{21}}{t_{s1}} & \frac{y_{22}}{t_{s2}} \end{bmatrix} \quad (4)$$

The simplest method to estimate the transmitted data would be to invert **H** and multiply it with the received vector known as the Zero-forcing ZF.

$$w * y = X_{est} + n \quad (5)$$

where ***W*** is the beam former **H**-1. However, if the values of **H** are low, the noise vector **n** increases leading to noise amplification. If **H** is rank deficient, then matrix inversion cannot be performed. In such cases, the pseudo inverse of **H** can be used given by

$$H^* = (H * H)^{-1} H^* \quad (6)$$

where **H*** is the conjugated transpose of **H**. An estimate of **x** can then be made by using this pseudo inverse Zero-forcing, the de-multiplexing and post-equalization can be simultaneously realized.

Assuming that the channel matrix is perfectly known to the receiver via a training sequence and that the signals are independent then the spectral efficiency of the MIMO channels is given by

$$s = log_2\left[det\left(I_N + \frac{P_t}{N_t\sigma_t^2}HH^*\right)\right] \quad (7)$$

$$= \sum_{i=1}^{N_m} log_2\left(1 + \frac{p_t}{N_t\sigma_t^2}\lambda_i^2\right) \quad (8)$$

$$S = \leq log_2\left(1 + \frac{P_t}{N_t\sigma_0^2}\|H\|^2\right) \quad (9)$$

Where $N_m = \min(N_r, N_t)$, λ is Eigen value vector of HH^*.

III. 2X2 MIMO ARCHITECTURE

Fig 2 presents a block diagram and experimental setup of this 2X2 MIMO transmitter system. The random binary data is generated in scrambler and would be first split into two parallel streams, one for each transmitter (TX) channel. In this work develop adaptive MIMO modes control modules, which can adjust the optimal modulation formats and MIMO schemes to maximize the spectral efficiency and error performance according to the real-time MIMO channel conditions. There are two types of MIMO schemes for selection: Spatial Diversity(SD) MIMO and Spatial Multiplexing(SM) MIMO [8]. In each channel, the bit stream is mapped into *M*-array quadrature amplitude modulation (*M*-QAM) and there are four types of modulation formats: 8-QAM,16-QAM,64-QAM and 256-QAM.Thus, there are eight adaptive MIMO modes available for link adaptation (SM-8, SM-16, SM-64, SM-256, SD-4,SD-16, SD-64, SD-256). Initially, also choose the default mode oSM-64 (spatial multiplexing 8-QAM). Then channel training sequences inserted into the symbol streams. After adding cyclic prefix (CP) and up-sampling, pulse shaping by a raised cosine filter is employed.

After digital to analog conversion (DAC), the complex QAM streams are up-converted to RF frequency and generate the real analogue RF signals. The up-conversion used here provide flexible frequency allocation and offer RF frequency for I/Q modulation.

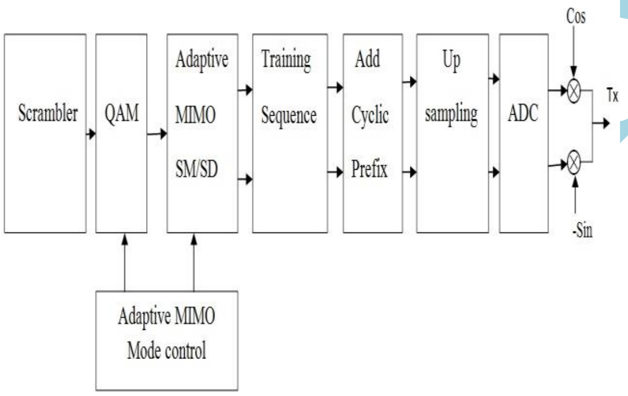

Fig. 2. 2x2 MIMO transmitter.

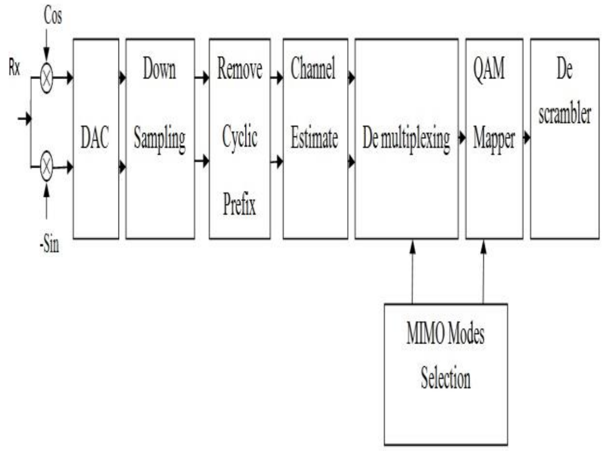

Fig. 3. 2x2 MIMO Receiver.

Fig. 3 shows that the block diagram of 2x2 MIMO receiver, Digital to analog conversion (DAC) the complex QAM streams are up converted into filtering the signal. At the transmitter , output signal was amplified, After down converting to baseband and down sampling by a matched filter, the sequences are acquired for synchronization and channel estimation, After removing CP, the received data streams are processed in MIMO demultiplexer. The final streams are passed through the QAM then passed through the QAM modulator to recover the original binary stream .Based on the channel estimation conditions, the adaptive MIMO modes selection module will calculate and select the corresponding optimum modes including modulation formats and MIMO schemes. Select the corresponding optimum modes including modulation formats and MIMO schemes.

IV. RESULTS AND DISCUSSION

The modelsim tool using analyze the performance of scrambler and QAM using spatial multiplexing and spatial diversity.

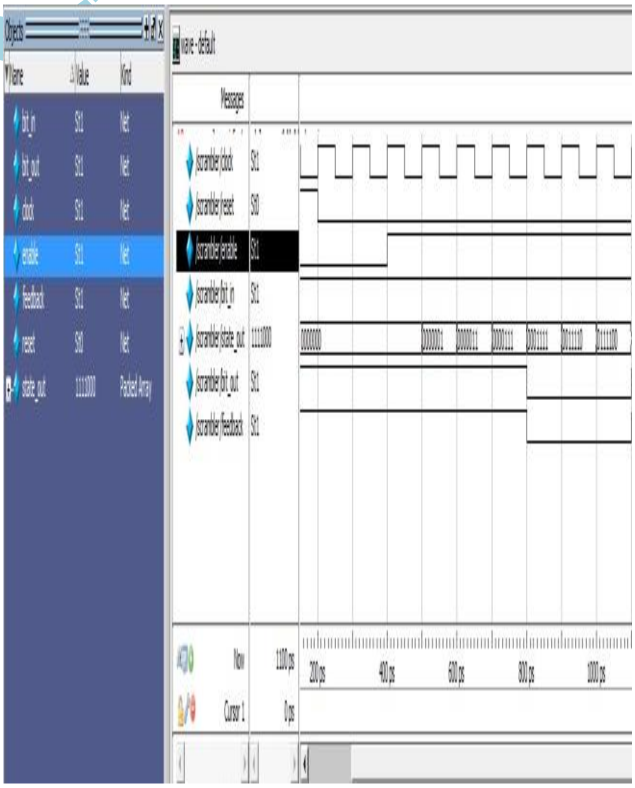

Fig. 4. Scrambler Output.

The above Fig. 4. shows the performance of scrambler. Here input signal is bit in, it is a one bit data and bit out represent output signal. If clock, enable and reset signal is high the input signal is fed through scrambler and for each clock signal, the input signal is given as feedback to the scrambler. Once the clock signal is completed, bit out becomes high.

The below Table 1 shows the area occupation of scrambler. Here 2 slices occupied 2% of utilization of area and 9 bonded Input Output Buffer (IOB's) occupied 4% of area utilization.

Table 1. Area Utilization of Scrambler

Area Utilization	Scrambler
Number of Slices	2
Utilization of Slices	2%
Number of Bonded IOB's	9
Utilization of Bonded IOB's	4%

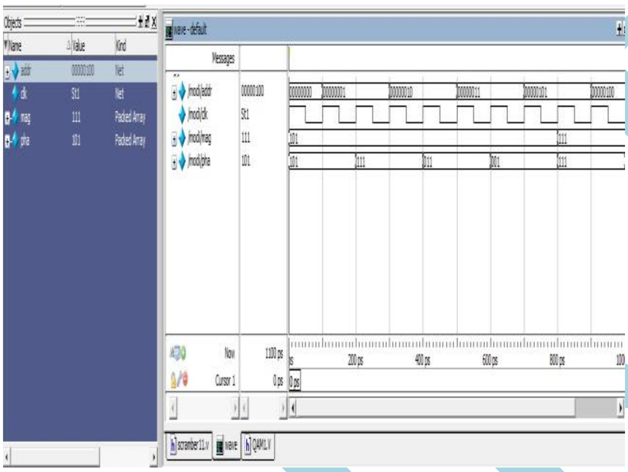

Fig. 5. QAM Modulation Output.

The above Fig. 5 shows the QAM Modulation. Here input signal is 8 bit address data and clock signal. Output signal is represented as 3 bit magnitude and phase. If 8 bit input address data is zero phase and magnitude value is five else magnitude and phase value is five and seven. So alternative signal is selected.

V. CONCLUSION

In this method 2x2 MIMO signal processing system employing link adaptation of spatial multiplexing and spatial diversity. This type of MIMO System can be used for 5G technique. The results obtained in terms of adaptive MIMO solution both the modulation schemas are dynamically adapted to the changing channel conditions for enhancing the spectral efficiency of this design.

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