A 2x2 FPGA based WRAP Tested for Colored Image Transmission in MIMO Systems

Shreya Kaushal, Surbhi Sharma

Abstract- The paper deals with the utilization of MATLAB for simulation and analysis of the colored image transmission over multiple input multiple outputs (MIMO). In the proposed algorithm, we applied source coding scheme with convolution channel coding as well as space-time block coding techniques, associated with QAM modulation method, to improve colored image transmission performance. The data obtained from the colored image is encoded using STBC based on Alamouti transmitter diversity scheme in which we have used two transmitter antennas and two receiving antenna and two transmitter and one receiver also. The transmission is done with the help of Rayleigh fading and AWGN channel. With the availability of high data rates by MIMO channel. Images can be transmitted with high reliability. Simulation results show the the quality of the reconstructed image can be significantly improved over only using space time coding. The comparison has been done on the basis of quality of reproduced image by measuring image PSNR based on SNR and BER value for different system model is realized over Xilinx Virtex-4 XC4VFX100FFG1517-11C FPGA based WRAP board.

Keywords- Bit error rate (BER), FPGA, Peak to signal noise ratio (PSNR), Multiple input multiple output (MIMO), WRAP board, Joint source channel coding, Space time block coding (STBC).

I. INTRODUCTION

Modern radio communication systems have to provide higher and higher data rates. The growing demand for broadband wireless data communications has motivated many research efforts in the last decades. Spectral efficiency, robustness and implementation complexity are the most important issues that should be taken into account for the design of new physical layer technologies. As conventional methods like using more bandwidth or higher order modulation types are limited, new methods of using the transmission channel have to be used. Multiple input, multiple output –MIMO i.e Multiple antenna systems gives a significant enhancement to data rate and channel capacity [1]. The technology figures prominently on the list of recent technical advances with a chance of resolving the bottleneck of traffic capacity in future internet intensive wireless networks. MIMO exploits the fact that radio frequency signals usually are reflected by the objects found in their way generating the phenomenon called multiple path. MIMO uses a technique calls spatial multiplexing that transmit multiple data streams at the same frequency, but through different spatial channels.

MIMO take transmission over multiple channels and converts from a short falling benefit. MIMO make a channel more effective because a spatial multiplexing increases the speed ratio baud/hertz. “ multiple input” component of MIMO means that a MIMO WLAN equipment sends two or more radio signals to multiple antennas, and “ multiple output” means that two or more radio signals coming from multiple antennas and reach the radio equipment.

There has recently been strong research activity and interest in the area of test beds for evaluating and developing MIMO wireless systems. Depending on the research requirements, MIMO testbeds can generally be characterized into three types, software defined, high performance real time based, and FPGA or digital signal processor based[2]. However, when the intended testbed use includes developing hardware algorithm implementations, then inclusion of high performance FPGA or DSP cores is required to facilitate real time processing. FPGA design and implementation of MIMO test bed has received a significant attention in recent years. The use of two antennas improves the probability that at least one antenna will be visible at the receiver. However when both are visible at the receiver the two transmitted signals interfere with each other and the interference can cause dropouts in the telemetry data[2]. A solution to this problem is to use the Alamouti STBC to control that interference so that the receiver can recover the modulating bits[14]. This situation is a somewhat unique application of space-time coding. Usually STBCs are used on channels that experience Rayleigh fading, and so the performance of STBC systems over fading channels is of primary interest.

II. PRINCIPLE USED FOR COLORED IMAGE TRANSMISSION

A colored image in the form of a binary data stream is fed to a simplified transmitting block encompassing the functions of error control coding to complex modulation symbols. The latter produces several separate symbol streams which range from independent to partially redundant to fully redundant. Each is then mapped onto one of the multiple TX antennas. After upward frequency conversion, filtering and amplification, the signals are launched into the wireless channel. At the receiver, the signals are captured by possibly multiple antennas and demodulation operations are performed to recover the message.

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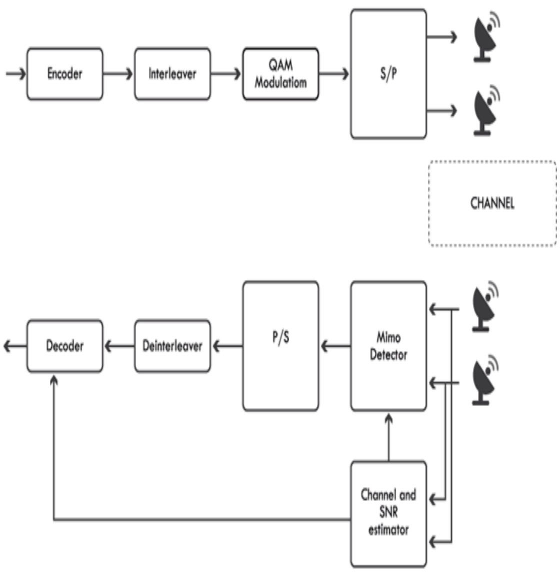

Fig.1 Structure of a basic MIMO system showing transmission and reception path

III. MIMO CAPABLE WRAP TEST BOARDS

Wireless open research platform (WRAP) is a programmable wireless research tool with is both scalable and extensible. The custom design of the WRAP physical (PHY) layer is tailored to the needs of high-performance wireless communications. The main objective of WRAP is to provide the community with such a flexible wireless research tool[3].

A. Development Tools

The Xilinx "Platform Studio" tool is an integrated programming environment that is used to control both the physical layer and MAC layer implementations. For physical layer design, Xilinx "system Generator", integrated in MATLAB simulink , provides abstractions for building and debugging high performance DSP systems in MATLAB using Xilinx block set. Moreover, the WRAP board supports Simulink "hardware co-simulation" that exploits the simulation and debugging steps[4].

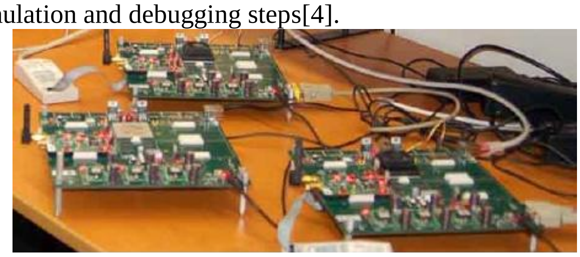

Fig.2 MIMO test bed

(i) Xilinx virtex-2 pro FPGA board- The FPGA includes a large number of embedded programmable logic blocks for real time DSP applications as well as two Power PC 405 cores. The C implementations of MAC protocols interact with the PHY processing units and supporting peripherals in the FPGA fabric. WRAP FPGA board has 4 general purpose daughter card slots.

(ii) MIMO-capable radios- The custom designed WARP radio boards are capable of targeting both the 2.4 GHz and 5GHz ISM bands. The dual-time radio transceiver is intended for wide band applications with a bandwidth up to 4) Mhz. Up to four radios can be mounted on a single WARP board to enable 2x2 MIMO systems.

(iii) 10/100 Ethernet port- Serves as the interface between the board and the wired internet.

(iv) Physical Layer description- The physical layer is a simplification version of the IEEE 802.11n PHY standard with two transmitting antennas and two receiving antennas. 802.11n PHY technique supports 20Mhz and 40Mhz bandwidth mode.

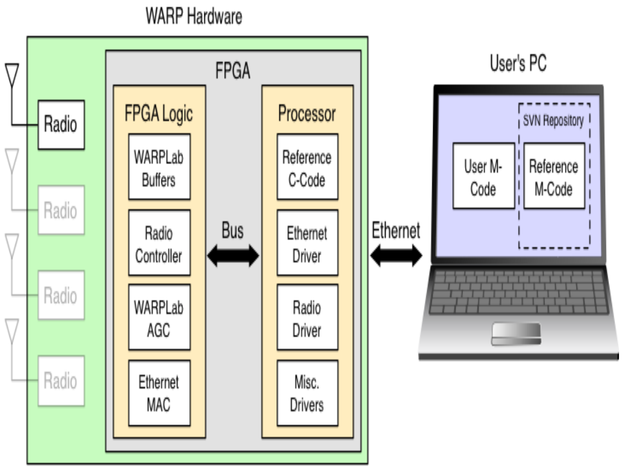

Fig.3 Interfacing between WARP hardware and PC

WARPlab is a framework which brings together WARP and MATLAB. With WRAP nodes directly from the MATLAB workspace. The WARPlab design includes transmit and receive buffers that takes samples from the Ethernet and transmits them over the air. The signals generated in MATLAB can be transmitted in real time over-the-air using WARP nodes[5].

B. Design flow for a PHY layer

The user creates in MATLAB the samples to be transmitted as part of the custom PHY. The samples to be transmitted are downloaded to buffers in the nodes assigned as transmitters. The user sends a trigger to transmitter and receiver nodes. Upon reception of this trigger, samples are transmitted over-the-air and captured in real time. The user reads captured samples from the receiver nodes to the MATLAB workspace. Received samples are Processed offline in MATLAB.

IV. SYSTEM MODEL

The theoretical system model considered has, in the general case, M transmit and N receive antennas, with $N \geq M$, denoted as MxN. The transmitted symbols are taken independently from a Quadrature Amplitude Modulation constellation of P points. Assuming symbol-synchronous receiver sampling and ideal timing, the received N- vector, using matrix notation is given by

$$r = Hs + n \qquad (1)$$

where $s = (s1, s2 \ldots s_M)t$ denotes the vector of transmitted symbols with $E[|si|2] = 1/M$, $n = (n1, n2, \ldots n_N)t$ is the vector of independent and identically distributed complex Gaussian noise samples with variance $\sigma 2 = N0$ and $r = (r1, r2 \ldots r_N)t$ is the vector of received symbols. H denotes the N×M channel matrix where hij is the complex transfer function from transmitter j to receiver i. The entries of H are modeled as i.i.d Rayleigh fading with $E[|hi\ j|2]=1$ and are perfectly estimated at the receiver[6].

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A. System Configuration

We are interested in joint source-channel coding with modulation scheme design under the channel capacity constraint consideration in a MIMO system. We have applied the transmission system design method for digital transmission of image over noisy channel. To transmit a given image bit stream efficiently, we propose a joint source-channel coding system. In this system, the image is undergone through convolution channel coding to protect the bit stream by the error correction encoder. The image is in BMP format. There are 456x455 pixels in the given picture. In order to reduce the complexity of decoding, we use convolution code and STBC in channel coding. The interleaver is effected resisting burst error in wireless channel. 16 QAM has been used for modulating the bitstream.

B. system configuration using WAPR Boards

It is assumed that the amplitudes of fading from each transmit antenna to each receiver antenna are mutually uncorrelated Rayleigh distributed and that the average signal power at each receiver antenna from each transmitter antenna is the same. Futhermore, we assume that the receiver has perfect knowledge of the channel. In the Fig.6 given below the simulation result of the conventional transmitter antennas and two receiver antennas (2TX,2RX) STBC coded system shows the best performance at higher SNR values over wireless Rayleigh fading channel, while the low performance goes to the (2TX,1RX)STBC coded system. Fig.7 Depicts the average power comparison map of 16-QAM modulation schemes used for the SNR-based rate in WARP PHY. The proposed coding system with (2 TX, 1RX) can improve the system performance especially in lower SNR(<6dB) situation, and with close performance as the (2TX,2RX) STBC coded system in SNR>8dB environment. In Fig.8 The similar result can be noticed that with changeable channel coding rates and the numbers of receiver antenna is outperformed the conventional STBC systems: (2TX,2RX) and (2TX,2RX) STBC scheme. We assume the channel coefficients unknown. Since the channel coefficients unknown, the channel coding rate is assumed to be fixed at 2/5.

V. EVALUATION PARAMETERS

In image processing, the most commonly used measurements for estimating the difference between two images are mean squared error (MSE) and peak signal-to-noise ratio(PSNR). PSNR, is a term for ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a wide dynamic range PSNR is usually expressed in terms of logarithmic decibel scale[8]. The PSNR is most commonly used as a measure of quality of reconstruction of lossy image. The signal in his case is the original data. For color images with three RGB values per pixel, the definition of PSNR is the same except the MSE is the sum over all squared value differences divided by image size and by three.

When the two images are identical, the MSE will be zero. For this value the PSNR is undefined[9].The comparison among these two system configuration is also done by calculating the BER. It is most easily defined via the mean squared error(MSE) which for two monochrome images and G where one of the images is considered a noisy approximation of the other is defined as[10]:

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}[F(i,j)-G(i,j)]\,^\wedge 2 \qquad (2)$$

The PSNR is defined as:

PSNR (dB)=10*log10([(maximum value)^2]/MSE) (3)

Or

PSNR(dB)=20*log10([MaximumValue/Sqrt(MSE)]) (4)

Pseudo code for PSNR:

```
For (each pixel)
{
Difference  = Pixel from Image A – Pixel from Image B
 Summed Error = Summed Error + Difference * Difference
}
Mean Squared Error = Summed Error / Number of Pixels
RMSE =sqrtt (Mean Squared Error)
PSNR = 20*log10 (255 / RMSE)
```
(5)

VI. RESULTS

This paper shows the bit error ratio (BER) performance as a function of the signal to noise ratio (SNR) per bit of the different versions of the system. The PHY protocol maps the received signal strength and decides the appropriate transmission rate. The simulation results of the PSNR and various SNR for proposed method on the different system models such as (2TX, 2RX) and (2TX, 2RX) antenna systems using 16QAM are plotted. With small change of the SNR at the low SNR, the performance improved dramatically. The bit correction processing can improve the performance especially on the low SNR and high BER. Average power for the system has been calculated for both system configuration. A 2x2 MIMO physical layer transceiver, i.e two daughtercard radio boards for each WARP node, has been designed and implemented on the WARP hardware. The data streams are spatially multiplexed on both the antennas. In order to up-convert the baseband signals to the RF band, two daughtercard radio boards are used in each WARP node. This design has been implemented in FPGAs and verified over real wireless channels at 2.4GHz.

Fig.4 Original image

Fig.5 Reconstructed image

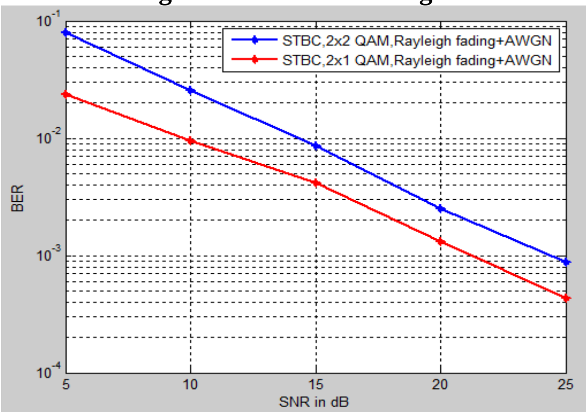

Fig.6 The BER Performance comparison for STBC systems over wireless Rayleigh fading channel.

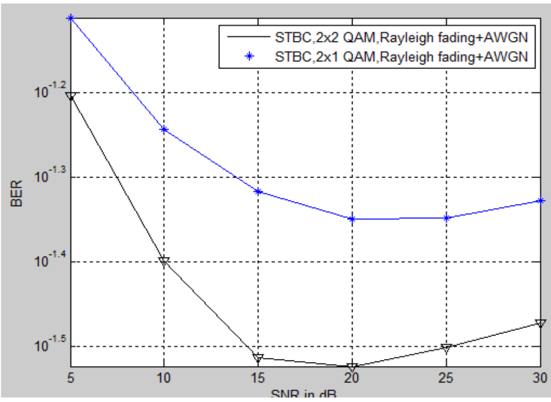

Fig.7 Average Power performance Comparison of STBC system in Rayleigh fading channel.

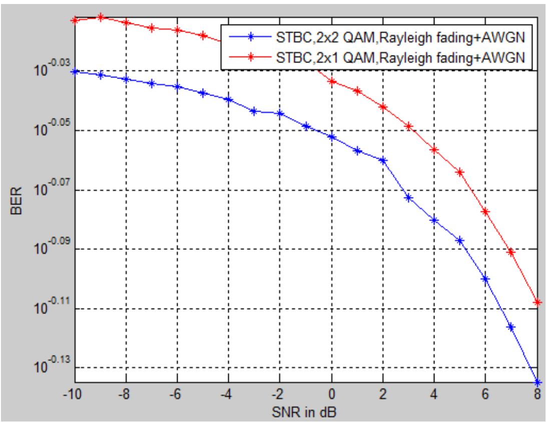

Fig.8 The BER performance comparision of STBC configuration in Rayleigh fading channel (2/5 convolution code rate)

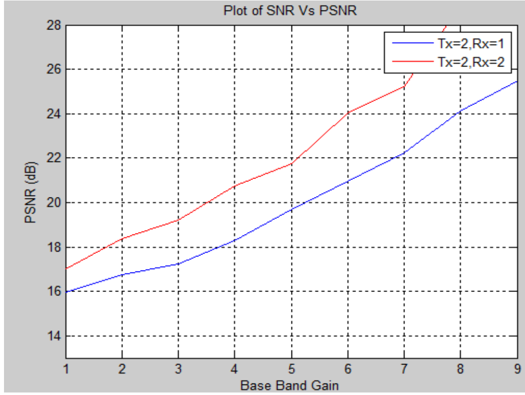

Fig.8 SNR Vs PSNR Plot

VII. CONCLUSION

A 2x2 low rate system has been developed using Xilinx system Generator in order to obtain BER and SNR results. Evaluation performance of the transmission at several implementation steps utilizing Alamouti space time coding for the transmission of image has been observed. Alamouti 2x2 STBC link can achieve a significant performance improvement in comparison to the 2x1 STBC case. The space time codes provide more redundancy. BER for the STBC system comes out to be 0.0031. Simulation results show that the quality of the reconstructed image can be significantly improved for the wireless bit error channel model.

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