Implementation of Multiple Input Multiple Output System Prototype Model in Different Environment

Mrs. Madhavi Belsare[1], Chandrahas Soman[2], Madhur Surve[3], Dr. P. B. Mane[4]

***Abstract*- Demands of next generation wireless communication are fulfilled by MIMO (Multi-input multi-output) system since it provides high bit rates, reliability, small error rates, increased channel capacity i.e. bandwidth efficiency, power efficiency. Hence it is future of wireless communication. System can be implemented in using various hardware environments like a microcontroller, a DSP (Digital Signal Processing) processor, an FPGA (Field Programmable Gate array) and an ASIC (Application Specific Integrated Circuit). Aim of the paper is to study various hardware implementation strategies, merits and demerits of using various environments. Based on this study, microcontroller based prototype model is finalized and developed. Performance of this model is observed under the effect of Rayleigh channel .**

***Keywords*- ASIC, Diversity, DSP, FPGA, MIMO channel, multipath fading, Rayleigh Fading Channel, STBC, STTC**

I. INTRODUCTION

In 1980s First Generation cellular phones came into the world. They were using analog transmission. It was the first successful attempt. It gave freedom to user to communicate with another from anywhere anytime. In 1990s the Second Generation was introduced. They were using digital transmission giving better performance.

Due to popularity of wireless cellular phones, a lot of industries showed interest in establishing new standards for communication, like GSM, EDGE etc. 1G and 2G phones were primarily implemented for speech, but customers' demands kept on increasing. Now a day they require high speed multimedia communication.

While progressing from one generation to next a lot of problems were faced. We should consider the trade off between complexity and performance and trade off between cost and performance etc. although there are some unique problems regarding wireless transmission which do not occur in wired communication like mobility, portability, connectivity, interference from other users.

In Fig. 1 multiple paths taken by the signal in a wireless channel is shown. Line of sight (LOS) is the direct path between transmitter and receiver. LOS is strongest, dominant and more deterministic signal amongst received signals. Scattering occurs when wave is passing through large number of objects smaller than wavelength and reflection occurs when wave meets an object which is larger than wavelength. Absorption, refraction and diffraction also affect propagation. Due to all these phenomena the signal takes different paths to reach receiver. As a result multipath fading takes place.

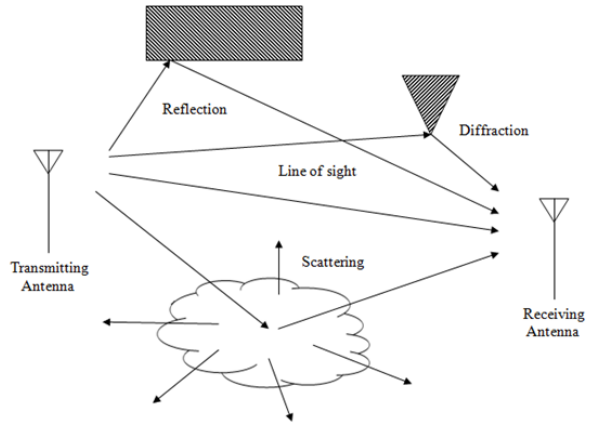

Fig. 1. An example of multiple paths taken by the signal in a wireless channel

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ISSN: 2278 – 909X

To attack this issue Diversity techniques have been introduced. What diversity techniques do is, they replicate the signal and retransmit it to reduce the possibility of outage [1], which is complete loss of data. Replication of signal is done by changing its parameters such as time, frequency, location of origin etc.

Channel coding can be accomplished by using STBC (Space Time Block Coding) or STTC (Space Time Trellis Coding). STBC includes temporal as well as spatial diversity technique. The aim of STBC is to achieve the maximum diversity, maximum coding gain and highest possible throughput. Moreover STBC provides encoding scheme for multiple transmit antennas that give very low complexity in encoding and decoding. STTC is one kind of TCM (Trellis Coded Modulation) which reduces the noise by using structural redundancy. STTC is different from STBC as it has memory. The drawback of STTC is it increases circuit complexity. In this paper STBC coded MIMO is implemented.

MIMO systems have multiple antennas at transmitting and receiving end [2]. Terms multiple inputs and multiple outputs are brought into play by considering channel as reference. Fig. 2 shows N*M MIMO system where N represents number of transmitting antenna and M represents number of receiving antenna. Symbols are transmitted via different antennas using time diversity as well as space diversity i.e. same symbols through all antennas in different time slot. This ensures reliability of transmission that means at least one symbol of repeated symbols will reach the receiving antennas. Signal travels through multiple paths while going from transmitter to receiver. MIMO technology improves bit error rate using these multiple paths. Different combining schemes are used at receiver side and each scheme is irrespective of diversity technique.

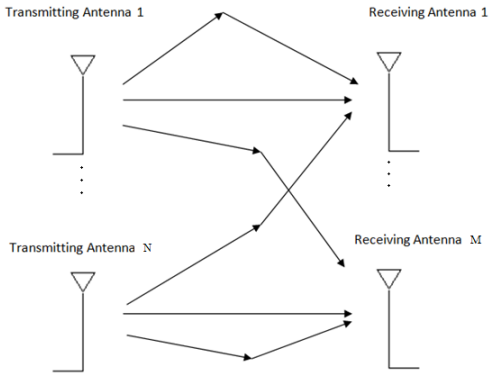

Fig. 2. Block diagram of MIMO system

In fig. 3, at 1st time slot one antenna transmits signal x1 and other transmits signal x2. At next time slot replication of previous signals like –x2* and x1* are transmitted by 1st and 2nd antenna respectively.

Antenna	Time slot	
	X1	-X2*
	X2	X1*

Fig. 3 Signal value at different time slots and at different antenna

When it comes to wireless system, for analysing the noise present in the channel there are two statistical models Rayleigh's and Rician fading channels. These models are different than the statistical models we see for wired communication.

In Section II implementation of STBC coded MIMO system on different hardware platforms is discussed. Section III discusses implementation issues and performance comparison. Simulation results of proposed system are discussed in Sction IVfollowed by Summary and Conclusion in Section V.

II. IMPLEMENTATION on HARDWARE PLATFORM

Implementation of STBC coded MIMO [3] system on different hardware platforms is discussed in this section considering Rayleigh Fading Channel [4].Also here 2*2 MIMO system is taken into account.

A. IMPLEMENTATION with a DSP PROCESSOR:

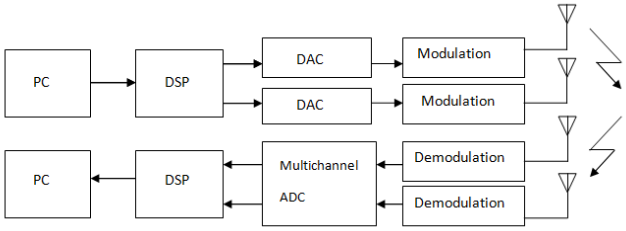

Fig. 4. Implementation of MIMO system using DSP.

Fig.4 shows a block diagram of implementation of MIMO using DSP. Data to be transmitted is sent from transmitter side PC to DSP. STBC encoding and Channel effect are performed by DSP. Those signals are converted into analog by using pair of DAC. This analog encoded signal is modulated by using different modulation schemes mostly QPSK [5] and then transmitted.

Exact reverse procedure is performed at receiver side. Received dada is demodulated and converted into digital form using multichannel ADC. One more DSP processor is used to implement different combining techniques to decode signal. Decoded signal is sent to receiver side PC.

B. IMPLEMENTATION with an FPGA:

Two FPGAs are used one at transmitter side and one at receiver side as shown in Fig. 5. STBC encoding and Rayleigh Channel effect is given in transmitter side FPGA.

ISSN: 2278 – 909X

Like microcontroller, STBC decoding is done at receiver side FPGA. Algorithms can be implemented using various hardware description languages like VHDL, verilog, ABEL (Advanced Boolean Equation Language) [6].

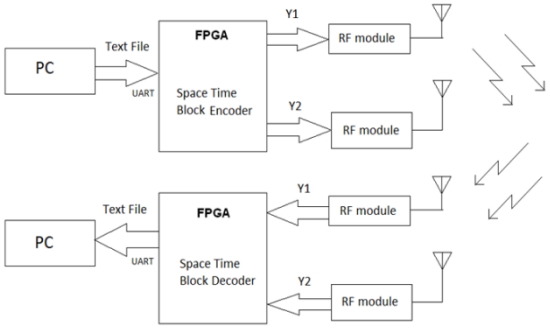

Fig. 5. Implementation of MIMO system using FPGA.

C. *IMPLEMENTATION with an ASIC:*

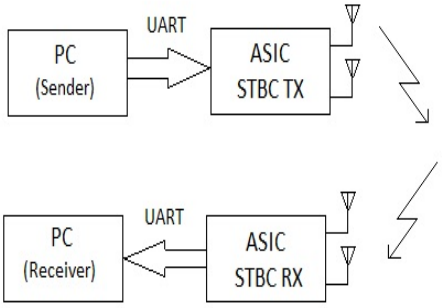

Fig. 6. Implementation of MIMO system using ASIC.

ASIC implementation can be done in different ways. ASICs are classified into Full Custom ASICs and Semi Custom ASIC. In Full Custom ASIC each mask is designed by the customer. So it is advisable to use Semi Custom ASIC in which some masks are fabricated to form gates, flip flops or multiplexers.

Thus in ASIC implementation, data from transmitter PC is encoded with STBC and modulated inside it and transmitted through antennae to the receiver. At the receiver exact reverse procedure takes place as shown in Fig. 6.

D. IMPLEMENTATION with a MICROCONTROLLER:PROPOSED SYSTEM

The first and important step in this approach is selection of the microcontroller [7]. There are various parameters which are of concern in the selection process. In Fig. 7 at transmitter side, microcontroller is receiving text file from PC. Encoding of text file is done using STBC. Coded signals Y1 and Y2 are transmitted using two RF modules. Modulation is done by RF modules only.

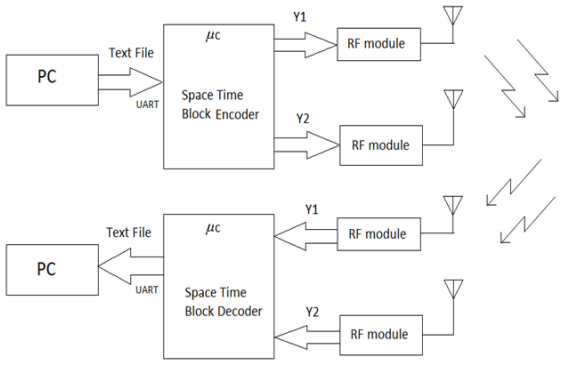

Fig. 7. Implementation of MIMO system using microcontroller.

Space time block decoder is nothing but a combiner circuit which separates out symbols from received signal stream.

At the receiver demodulation is performed at the RF module and decoding and removal of channel effect is done by Maximum Likelihood Detector implemented in the microcontroller and send signal to the receiver side PC.

III. COMPARISON of DIFFERENT HARDWARE ENVIRONMENTS

Using a microcontroller is efficient in a way since it is an application specific and has its own flash and RAM. Also it uses Embedded C language which is commonly used language. Software tools are also easily available in case of a microcontroller. Moreover it does not require any power rails and does not work on power sequencing. Though if a controller becomes obsolete then it is difficult to replace it, sometimes we need to change whole design. Also design using controller may become tedious and circuit may become large and bulky because of physical addition of required peripherals. But using a controller for implementation is a cost saver.

DSP is useful in implementation of complex algorithm. In a DSP, modification of a program is easy. Hence better results are easily obtained. It uses adaptive algorithm to achieve high accuracy. It also stores digital signals and is able to transport them. It is programmed by MATLAB which is common simulation tool. But it suffers from bandwidth limitation as well as speed limitation.

FPGA is appropriate for quicker implementation and for large, complex logic designs. FPGA is reprogrammable device so variety of MIMO algorithm can be studied. It performs well in pipelined design. Even though design is complex, circuit will be less bulky because peripherals are added logically. Xilinx is used as a software tool for simulations which is easily available. FPGA ICs are costly so whole implementation is expensive. Sometimes algorithm written may not be synthesizable.

ASIC design provides lesser space, less power consumption and greater security. Its initial cost is high but if it is produced in larger amount, cost per unit decreases.

Major drawback of ASIC implementation is we have to develop testing method for each design.

ISSN: 2278 – 909X

From above discussion of comparison of different environments, it is observed that developing prototype model using microcontroller is suitable as far as complexity and cost is considered. Hence a prototype MIMO system is developed using microcontroller as shown in fig. 4.

IV. SIMULATION RESULTS of PROPOSED SYSTEM

As input to the system is text file and it is taken from microcontroller, buffer is required to store the data and scheduler is essential to determine the input data rate of the system. Then data undergoes STBC coding technique.

Buffers are also needed to store the data coming from both the antennas. The coded data is recovered at receiver side using STBC decoding technique. Fig. 8 shows the steps followed while simulating our proposed system.

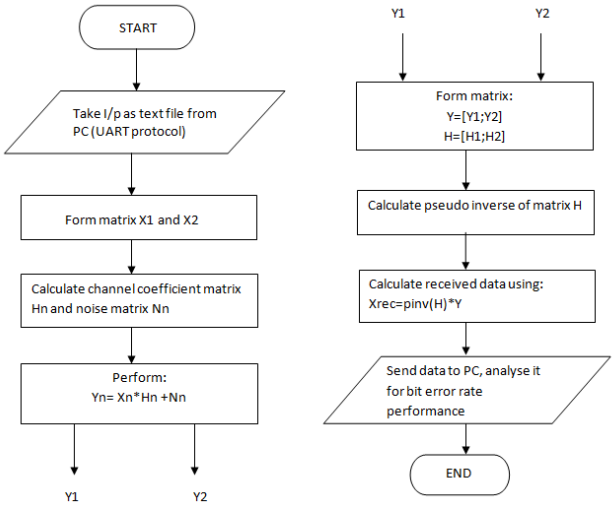

Fig. 8 Flowchart for simulation of proposed system

While transmitting 16 symbols of 4 bits, at the receiver side we observed one bit error in 8 symbols giving BER (Bit Error Rate) of 0.125.

V. CONCLUSION

Microcontroller is basically used to implement simpler algorithms.DSP, FPGA, ASIC are used where more complex algorithms come into picture. Small change in design can be done by changing code for microcontroller, FPGA and DSP. Use of ASIC makes us to build new IC if change in previous design is needed. ASIC, FPGA and DSP implementation require less area on board accordingly minimizes size of device.

Bit error rate parameter of system is dependent on coding schemes and combining schemes and not on the hardware platform used. Selection of hardware platform is done by considering timing constraints, cost, availability of simulation software tools, available board area and complexity of design.

Implementation of MIMO can be done efficiently using combination of various hardware platforms. Finally, developed wireless platform is useful in carrying test and measurement. [8]. In this way better utilisation of resources along with improved bit error rate can be achieved.

Implementation of 2*2 MIMO system on microcontroller we examined BER up to 0.125.

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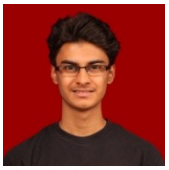
ISSN: 2278 – 909X



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ISSN: 2278 – 909X