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DESIGN AND IMPLEMENTATION OF MIMO-OFDM FOR 4G MOBILE COMMUNICATIONS

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Abstract: In mobile communication environment, the wireless channel is time varying due to the mobility of the wireless terminals and multipath propagation. Basically in all space time block coded orthogonal frequency domain multiplexing scheme the channel remain static with in the whole codeword length .STBC scheme is one of the most effective approach that uses transmit diversity to avoid the undesired effect arises in the wireless fading channel .Orthogonal designed STBC can achieve full transmit diversity .the transmitted symbols can be decoded separately instead jointly, which greatly facilitate the receiver design .As the system uses orthogonal code for transmission cant achieve full transmission rate with more then two transmit antenna, hence the alternative method is proposed .in order to improve the performance of OFDM system with multiple transmit antenna in the double selective fading channel ,the design of four transmit antenna based space-time-frequency coded OFDM scheme is introduced in this work for enhancing the performance. The STFC-OFDM system can be designed using verilog HDL and simulated using modelsim software.

INTRODUCTION

In the last few years wireless services have become more and more important as the demand for higher network capacity and performance has been increased. Orthogonal frequency domain multiplexing (OFDM) is one of the most competitive schemes for the digital broadband communication system in the multipath fading environment. It can effectively avoid the negative impact of the inter symbol interference (ISI)caused by the multipath propagation .In most wireless channel ,there is no direct line of sight (LOS) propagation exists between the transmission antennas and receive antennas .It may be due to natural and constructed obstacles. The transmitted signals may arrive at the receiver over many paths. This causes multipath fading at a specific location and the strength of the wave changes randomly.

Multiple antenna technology can be employed in the OFDM system to achieve the spatial diversity and also increase the spectral efficiency [4].STBC-OFDM system performs well in the scattering rich environment. For rich scattering environment channel, it is possible to increase the data rate by transmitting separate information stream on each antenna For example by using four transmit and receive antenna, four times the capacity of a single antenna system can be achieved. The key challenges faced by future wireless communication system are to provide high data rate wireless access at high quality of service (QoS). QOS is improved through space diversity by transmitting some signal over multiple antennas. since OFDM offers the possibility of coding in both time and frequency domain, two methods have been introduced, one is space-time coded OFDM (STC-OFDM) and other is space frequency coded OFDM (SFC-OFDM) [2][3], these systems performs block coding in both time and frequency domain simultaneously, by assuming that the channel response between adjacent OFDM frame and sub carrier are approximately same. So the channel assumption of STFC_OFDM is much more relaxed then either STC-OFDM or SFC-OFDM system. STFC-OFDM system is used for high speed data transmission over wireless link [5].It has been shown that, the maximum achievable diversity order increases linearly not only with the number of transmit and receive antenna but also with the number of multipath provided. The advantage of the proposed system can be listed as (1) maximum transmission diversity (2) high coding gain (3) low decoding complexity

PRELIMINARIES

STFC-OFDM system model:

STFC-OFDM system is broadly classified into two categories one is Space time frequency block coded (STFBC) and other is Space time frequency trellis coded (STFTC). The advantage of STFBC over STFTC is that their low decoding complexity which is independent upon the transmission rate [7] [8] and the other advantage is that the construction of STFBC is easier than that of STFTC. To improve the performance of OFDM system with multiple transmit antenna in the double selective fading channel, the design of four transmit antenna based Space-time-frequency coded OFDM scheme has been proposed.

A brief review on this scheme is illustrated by the schematic diagram of 4-transmit antenna STFC-OFDM system in figure-1.Assume that $X(k,l)$ is the frequency domain input symbol sequence, where k is the sub-carrier number with $0 \le k \le N-1$, and l is the OFDM frame number. $X_e(m,l)$ and $X_o(m,l)$are the half length vectors denoting the even and odd component vectors of $X(k,l)$ with $0 \le m \le N/2-1$.

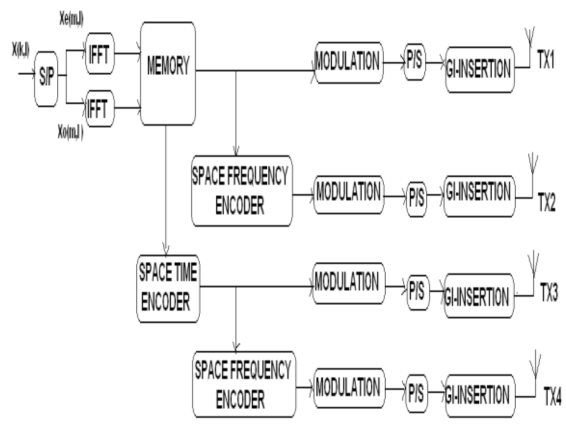


Figure-1:-The diagram of the transmitter end in the four antenna STFC-OFDM scheme.

The STFC-OFDM scheme performs block coding in both time and frequency dimensions simultaneously and from the analysis in [6], the equivalent transmitted codeword is given by

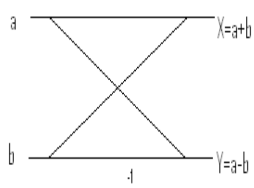
$$S=\begin{bmatrix} X(2m,l) & X^*(2m+1,l) & X^*(2m,l+1) & X(2m+1,l+1) \\ X(2m+1,l) & -X^*(2m,l) & X^*(2m+1,l+1) & -X(2m,l+1) \\ X(2m,l+1) & X^*(2m+1,l+1) & -X^*(2m,l) & -X(2m+1,l) \\ X(2m+1,l+1) & -X^*(2m,l+1) & -X^*(2m+1,l) & X(2m,l) \end{bmatrix} \quad (0 \le m \le N/2-1)$$

Each column of S denotes the transmitted signals for different antennas. The design of STFC-OFDM system starts with by taking 8 bits of input data .these 8 bit data sequence i.e. X (n) be splitted into two N/2 point data sequences F_1 (n) and F_2 (n).

Let F_1 (n) contain even number of samples of X (n) and F_1 (n) contain odd number of samples of X (n) .thus we can write

F_1 (n) =X (2n) ; n=0, 1… (N/2)-1
F_2 (n) =X (2n+1) ; n=0, 1… (N/2)-1

This splitting operation is called decimation .so the first 4-even bits enters into the 1^{st} IFFT block and rest 4-odd bits enters into the 2^{nd} IFFT block. By using radix-2 DIT-FFT algorithm and using sign bit i.e. when data is positive sign bit is 0 and when data is negative sign bit is 1.so with this form each IFFT block, 12 bits are coming out and sum of 24 bits are stored in the memory block, which is given below.



a	b	X	Y
0	0	0 (000)	0 (000)
0	1	1 (001)	-1 (101)
1	0	1 (001)	1 (001)
1	1	2 (010)	0 (000)

The purpose of IFFT is used to convert the frequency domain signal in to time domain signal, it supports orthogonality and the phase difference between the adjacent symbols should be 90.the memory performs the two operations i.e. the write and read operations. The write signal specifies a transfer in operation and the read signal specifies a transfer out operation. When memory enable is inactive, the memory chip is not selected and no operation is performed. When the memory enable input is active the read/write input determines the operation to be performed. The memory operation is given below

Memory enable	Clock	Read	Write	Function
0	0	X	X	none
1	1	0	1	input will store into memory
1	1	1	0	memory content move to outside

The space-time encoder takes a certain number of bits at its input side and produces a less number of bits at its output. The output contains the data bits as well as redundant bits. The schematic diagram is given below in figure-2

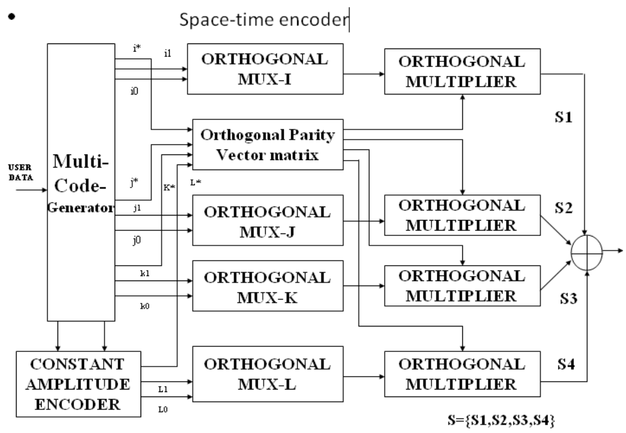


Figure-2 :Block diagram of space time encoder

The space time encoder takes the first 7 bits of data from memory and applied to the multimode generator .The multimode generator consists of two blocks 1)serial to parallel converter 2)gold sequence spreder.The serial to parallel converter converts the data bits into number of branches according to the length of the gold sequence .gold sequence generator block uses 2-PN sequence generator block to generate the preferred pair of sequences and then XOR’s these sequences to produce the gold sequence, as shown in the fallowing figure-3

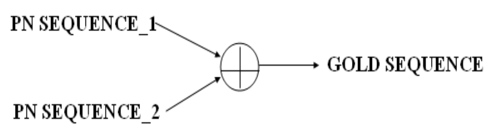


Figure-3:generation of gold sequence

At constant-amplitude encoder, three parity bits (L*,L1,L0) are generated from the three groups of parallel bits (I*,I1,I0),(J*,J1,J0),(K*,K1,K0) according to the fallowing equations :-

L*=~ (I*^J*^K*)
L1= (I1^J1^K1)
L0= (I0^J0^K0)

Each orthogonal multiplexer i.e.I, J, K&L takes two inputs and produces four outputs as

The orthogonal multiplexer-I output is
I= (0, 0, I1, I0). The orthogonal multiplexer-J output is
J= (0, 1, J1, J0). The orthogonal multiplexer-K output is K= (1, 0, K1, K0).
The orthogonal multiplexer-L output is
L= (1, 1, L1, L0).

The input to the orthogonal parity vector matrix is I*, J*, K*, L*, which produces four outputs. Then orthogonal multiplier multiplies the output of orthogonal multiplexer and orthogonal parity vector matrix as shown below.

$$s = b \begin{bmatrix} c_i \\ c_j \\ c_k \\ c_l \end{bmatrix} = [i_* \ j_* \ k_* \ l_*] \begin{bmatrix} c_i \\ c_j \\ c_k \\ c_l \end{bmatrix} = i_* \cdot c_i + j_* \cdot c_j + k_* \cdot c_k + l_* \cdot c_l.$$

Where,'b'represents Orthogonal Parity Vector Matrix and 'C' is the Walsh-Hadamard Matrix. Finally the output of this type of encoder contain four bits i.e. S1, S2, S3, S4 which contain both data as well as redundant bits.

The space frequency encoder operation is similar to that of space time encoder. Modulation is used to transmit the bits to a longer distance. As we can not transmit the bits directly, therefore we group the bits into symbols. In order to avoid the ISI, guard band is inserted in between symbols and it does not contain any information .this guard band is used for synchronization purpose at the receiver. Finally the symbols are transmitted to a longer distance by the transmitter.

STF coding:

Let $x_n^{\mu}(p)$ be the data symbol transmitted on the pth sub carrier from the µth transmit antenna during the nth OFDM symbol interval. As defined, the symbols

$$\{x_n^{\mu}(p),\ \mu = 1, \ldots, N_t,\ p = 0, 1, \ldots, N_c - 1\}$$

are transmitted in parallel on N_c sub carriers by N_t transmit antennas. Notice that three variables µ,n and p,and have been introduced to, respectively, index the antenna- (space-), time-, and frequency- dimensions associated with the transmission of $x_n^{\mu}(p)$. Thus, $x_n^{\mu}(p)$ can be viewed as a point in a three-dimensional (3-D) space-time-frequency (STF) parallelepiped.

Recalling that each $x_n^{\mu}(p)$ is a point in 3-D, we define each STF codeword as the collection of transmitted symbols within the parallelepiped, spanned by N_t transmit antennas, N_x OFDM symbol intervals, and N_c sub carriers. Thus, one STF codeword contains $N_t N_x N_c$ transmitted symbols $\{x_n^{\mu}(p),\ \mu = 1, \ldots, N_t,\ p = 0, 1, \ldots, N_c - 1\}$, which for mathematical convenience can be organized in a block matrix

$$X := [X(0) \quad X(1) \quad \ldots \quad X(N_c - 1)] \in \mathbb{C}^{N_t \times N_c N_x}$$

where

$$X(p) := \begin{bmatrix} x_0^1(p) & \cdots & x_{N_x-1}^1(p) \\ \vdots & & \vdots \\ x_0^{N_t}(p) & \cdots & x_{N_x-1}^{N_t}(p) \end{bmatrix} \in \mathbb{C}^{N_t \times N_x}.$$

OFDM yields parallel X(p)transmissions over different frequencies. Because each X(p)an be thought of as being transmitted using an ST system, the N_c provides a model for our 3-D STF (transmission) system as shown in the fallowing figure.

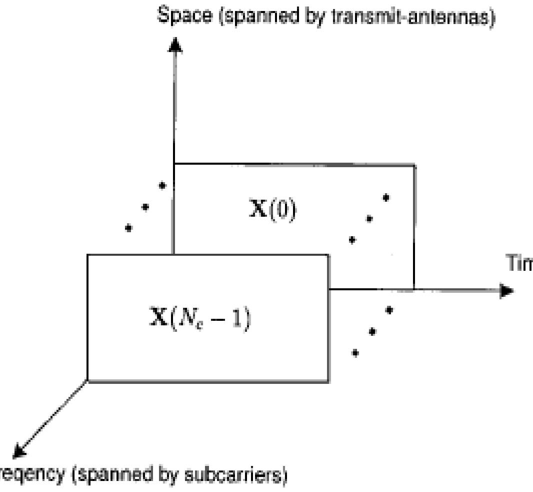


Figure-4: Illustration of STF-coded transmission

It is important to point out that the transmissions of $x_n^{\mu}(p)$ are separable in both time and frequency but not in space. in the above equation X is described by three dimensions, STF coding simultaneously encodes information over space, time, and frequency. When we are transmitting N_I information symbols uses N_c sub carriers and occupies N_x OFDM symbols. Therefore, the STF code rate is defined as

$$R = \frac{N_I}{N_c N_x}.$$

Where R is code rate, N_I is the information symbol, N_c is the sub carrier and N_x OFDM symbols

SIMULATION RESULTS

In this paper, we have designed four Tx-antennas based STFC-OFDM system .The design is coded in verilog HDL and functionally simulated in modelsim and synthesized in FPGA.The synthesis report, output is given in the fallowing table-1&2 and figure-5

Table-1: Synthesis report

HDL Synthesis Report

Macro Statistics	
# Adders/Subtractors	: 9
1-bit adder	: 9
# Latches	: 1
7-bit latch	: 1
# Xors	: 2
1-bit xor2	: 2

Table -2: Device utilization report

Device utilization summary:-

Selected Device : 3s250epq208-4
Number of IOs: 7
Number of bonded IOBs: 4 out of 158 2%
CPU : 57.11 / 61.33 s | Elapsed : 57.00 / 61.00 s
Total memory usage is 170080 kilobytes
Number of errors : 0 (0 filtered)
Number of warnings : 44 (0 filtered)
Number of infos : 2 (0 filtered)

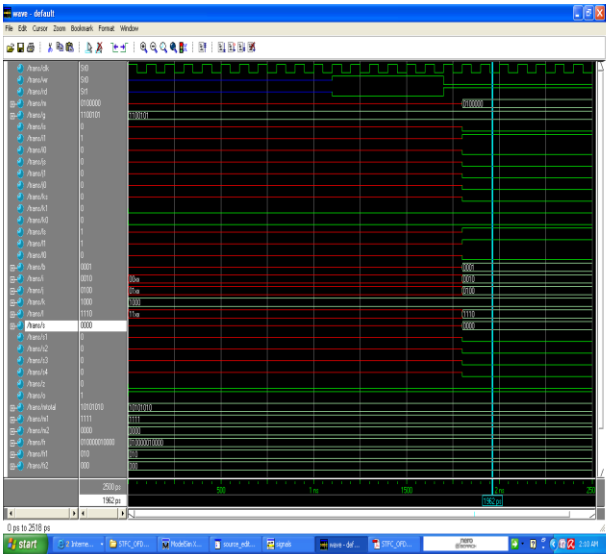


Figure-5:-simulation results

CONCLUSION

In this paper we propose design of four Tx-antenna based STFC-OFDM system. This system performs well in wireless environment. In order to utilize the bandwidth effectively and efficiently space time encoder and space frequency encoder is incorporated in this paper. Simultaneously the BER is also improved which is a grate advantageous as compared to other system.

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Short Bio Data for the Author

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