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Alamouti Space Time Coding for 2X2 MIMO Wireless Channels using PSK Modulation Technique

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A B S T R A C T

This paper proposes Alamouti space time coding schemes for MIMO wireless channels. The MIMO channels compose a system having a number of multiple transmitting and receiving antennas The space time encoding scheme starts with selection of encoding scheme after that, then numbers of symbols to be sent are selected, followed by selection of code rate, modulation scheme and number of receivers. The modulation schemes selected are 2-PSK, 4-PSK, 8-PSK and 16-PSK. The BER vs SNR graph is plotted using the MATLAB GUI coding for 2 X 2 MIMO wireless channels. The number of symbols transmitted were 5000. The BER rate decreases as we move towards higher PSK modulation scheme but on the account of increased complexity in the encoding scheme

Keywords: Alamouti Coding, BER, MIMO (Multiple Input Multiple Output), PSK Modulation, SNR, Wireless Communication

1. Main text

Alamouti coding is a space-time block coding technique used in wireless communication systems with multiple-input multiple-output (MIMO) channels. It was proposed by Prof. Siavash Alamouti in 1998 and provides a simple and effective way to achieve diversity and increase the data rate in wireless communication. The basic idea behind Alamouti coding is to transmit the same information over multiple antennas in such a way that it can be decoded at the receiver using simple linear processing. The Alamouti scheme uses two transmit antennas and one receive antenna, but it can be extended to multiple antennas at both the transmitter and receiver.

In the Alamouti scheme, the input data is first split into two parts and each part is transmitted from the two antennas. The transmitted signal at time t is given by:

s(t) = [x1(t) x2(t)] [a1(t) -a2*(t)]………………….(1)

where x1(t) and x2(t) are the two parts of the input data, a1(t) and a2(t) are the complex channel gains between the two transmit antennas and the receive antenna at time t, and a2*(t) is the complex conjugate of a2(t).

At the receiver, the received signal is first demodulated and then processed using the following decoding matrix:

[1 0; 0 a2*(t)] [y1(t) y2(t)] = [x1(t) x2(t)]…………..(2)

where y1(t) and y2(t) are the received signals at time t.

The decoding matrix takes advantage of the orthogonality between the two transmitted signals to recover the original data. The first row of the matrix simply scales the first received signal by 1 and the second row scales the second received signal by the complex conjugate of the second channel gain, which cancels out the interference caused by the second transmitted signal. Alamouti coding provides diversity gain by transmitting the same information over two antennas and using simple linear processing at the receiver to recover the original data. It is a powerful technique for increasing the data rate and improving the reliability of wireless communication systems, especially in MIMO channels.

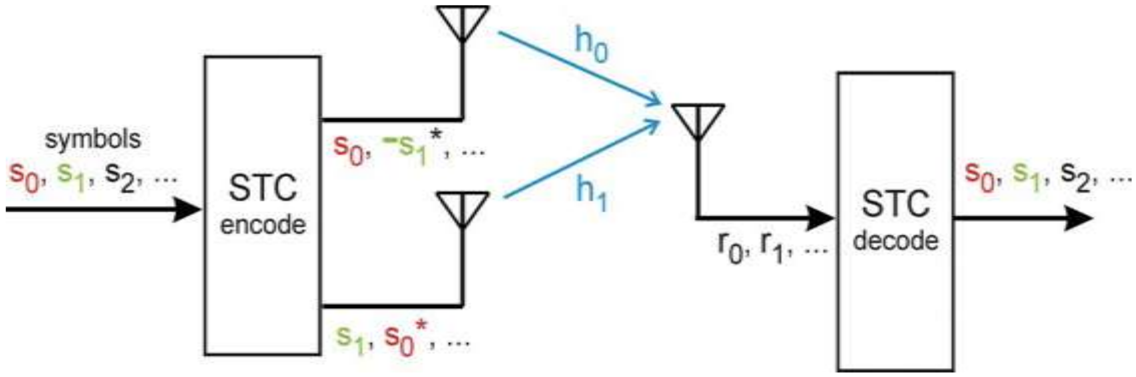


Fig. 1 Simplified Alamouti Space Time Coding (STC) block diagram

A simplified block diagram using Alamouti STC is shown in Fig. 1. In this system, two different symbols are simultaneously transmitted from the two antennas during any symbol period. During the first time period, the first symbol in the sequence, s0, is transmitted from the upper antenna 1 while the second symbol, s1, is simultaneously transmitted from the lower antenna 2. During the next symbol time the signal -s1* is transmitted from the upper antenna and the signal s0* is transmitted from lower antenna. Note that ( )* is the complex conjugate operation.

Table 1 Bit Pattern for two antennas at different time durations

	t + 4T	t + 3T	t + 2T	t + T	t
Antenna 0	….S4	-S3*	S2	-S1*	S0
Antenna 1	….S5	S2*	S3	S0*	S1

At the receiver, a single antenna receives a combination of the two transmitted signals after transmission through the multipath environment. The channel coefficient, h0, represents the magnitude and phase of the transmission path between transmit antenna 1 and the receive antenna. The channel coefficient, h1, represents the path between transmit antenna 2 and the receive antenna. The channel coefficients, h0 and h1, are complex numbers that represent the total amplitude and phase of their respective channels including all multipath effects.

During the first symbol time, the received signal, r0, is the combination of both symbols, s0 and s1, but is modified by the channel coefficients, h0 and h1. During the next symbol period, the receiver measures r1 which contain modified versions of s0 and s1. The received signals, r0 and r1, as a function of the transmitted signals and channels coefficients can be represented as

ro = ro(t) = h0S0 + h1S1 + n0

r1 = r1(t + t) = - h0S1* + h1So* + n1 ………………….(3)

In order to recover the actual transmitted symbols, s0 and s1, the receiver requires knowledge of the channel coefficients, h0 and h1. These channel coefficients are often estimated at the receiver by measuring known signals embedded in the transmitted waveforms. Combiner is then used to reconstruct the two combined signals Then it is sent to the maximum likelihood detector

S0 = A (h0*r0 + h1*r0)

S1 = A (h1*r1 - h0*r1)

A = 1/ (│ho│2+│h1│2)…………………………………(4)

Diversity technique does not improve the system data rate but rather improves the signal quality. The sequence shown in Fig.1 uses encoding performed in space and time (space–time coding). The encoding may also be done over the space and frequency domains. In this case, instead of two consecutive symbol periods transmitted from two separate antennas, two frequency carriers may be used (space–frequency coding). Utilization of diversity in MIMO channels requires a combination of the transmit and receive diversity described above. The diversity order would then be equal to the product of the number of transmit and receive antennas if the channel between each transmit-receive antenna pair fades independently.

2. Simulation Algorithm

The simulation algorithm will be as follows

I. A wireless communication system with n antennas at the base station and m antennas at the remote. At each time slot t, signals c_t^i, i= 1,2…..,n are transmitted simultaneously from the n transmit antennas.

II. The channel is assumed to be a flat fading channel and the path gain from transmit antenna i to receive antenna j is defined to be $\alpha_{i,j}$.

III. at time t, the signal r_t^j received at antenna j is given by

   a. $r_t^j = \sum\alpha_{i,j} c_t^i + \eta_t^j$ where the noise samples are independent samples of a zero mean complex Gaussian random variable with variance η/2 per complex dimension.

IV. A space time block code is defined by a p x n transmission matrix G.

   a. $G_2 = \begin{matrix} X_1 & X_2 \\ -X_2^* & X_1^* \end{matrix}$ for 2 receiving antennas.

V. So, the ith column of represents the transmitted symbols from the ith antenna & the tth row of C represents the transmitted symbols at time slot t. Note that C is basically defined using G

VI. Since p time slots are used to transmit k symbols, we define the rate R of the code to be R= k/p

VII. Maximum likelihood detection amounts to minimizing the decision matrix.

   a. $\sum_{j=1}^{M}$[$|r_1^j$- $\alpha_{1,j}s_1$- $\alpha_{2,j}s_2|$^2+$|r_2^j$- $\alpha_{1,j}s_2^*$- $\alpha_{2,j}s_1^*|$^2] over all values of s.

VIII. Break down this matrix into two parts, s1 & s2.

IX. The transmission using two transmit antennas employs the 8-PSK constellation and the code G2. For three and four transmit antennas, the 16-QAM constellation and the codes H3and H4 respectively, are used.

X. Since H3 and H4 are rate 3/4 codes, the total transmission rate in each case is 3 bits/s/Hz. It is seen that at the bit error rate of 10^{-5} the rate 3/4 16-QAM code G4 gives about 7 dB gain over the use of an 8-PSK G2 code.

3. Simulation Results

The flowcharts for simulation are shown in Fig.2.

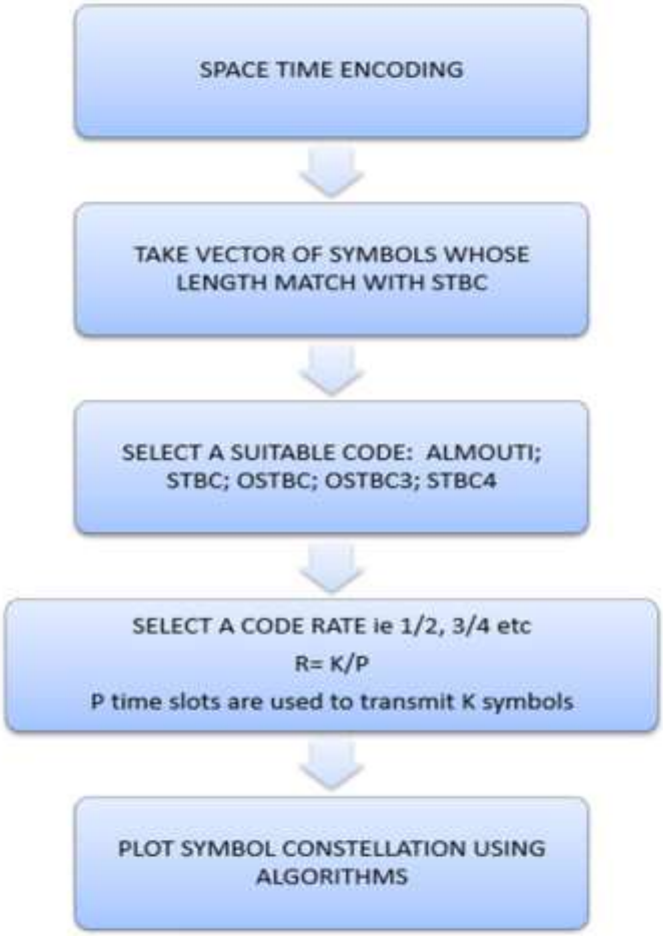
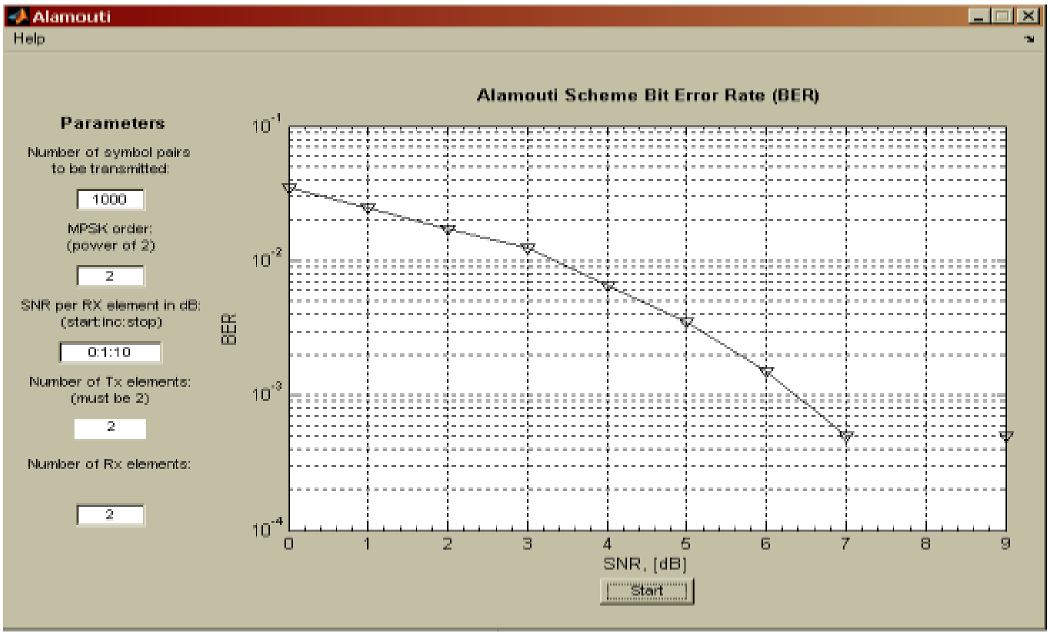


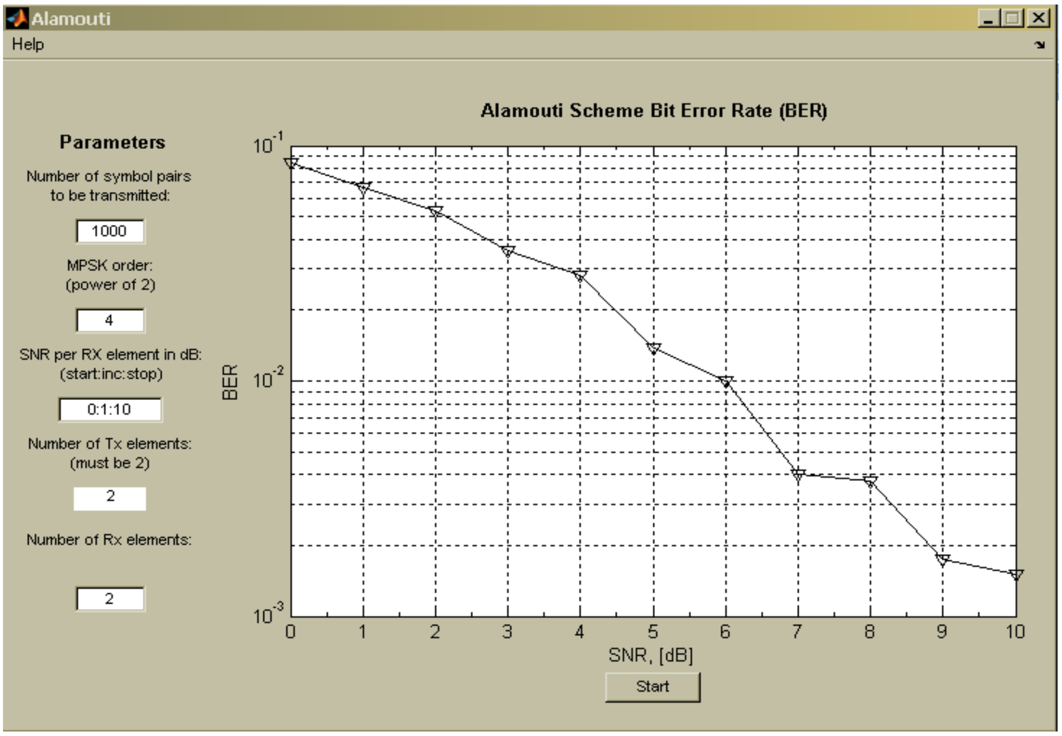
Fig.2 Flowchart for Space time encoding

The coding starts the selection of vector symbols for transmission and apart from Alamouti we have many other space coding techniques so we select the appropriate coding scheme followed by selection of code rate.

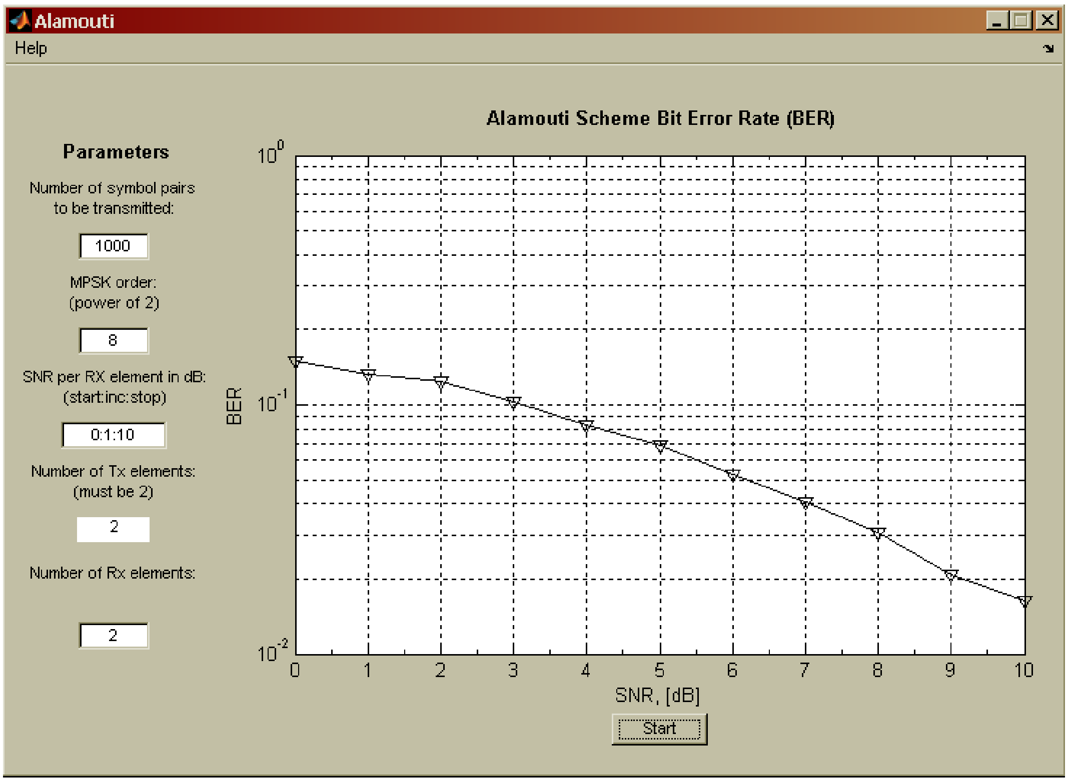
The Alamouti Space Time Coding Scheme is a technique used in Multiple-Input Multiple-Output. The GUI is prepared on MATLAB for coding, The input parameters include number of symbols to be transmitted, PSK order (2,4,8, 16), the range of SNR and the selected 2 X 2 MIMO wireless channel with two transmitting and two receiving antennas. Fig.3 shows the simulation on MATLAB for different PSK schemes



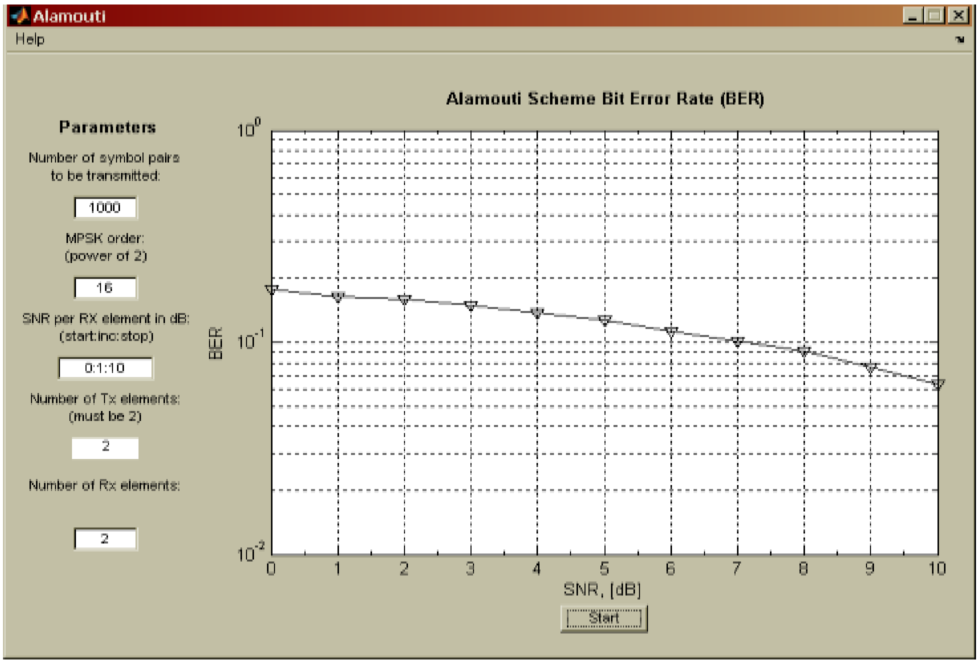
(a)



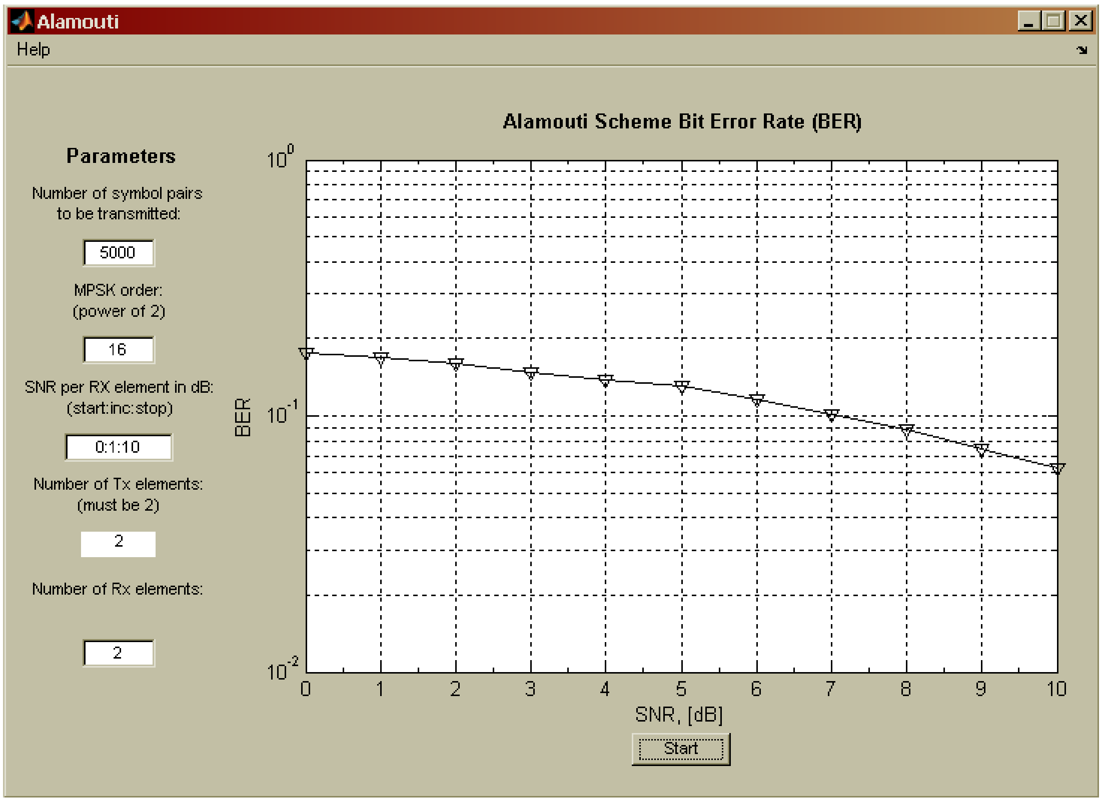
(b)


Alamouti
Help
Alamouti Scheme Bit Error Rate (BER)
Parameters
Number of symbol pairs to be transmitted:
1000
MPSK order: (power of 2)
8
SNR per RX element in dB: (start:inc:stop)
0:1:10
Number of Tx elements: (must be 2)
2
Number of Rx elements:
2
BER
10^0
10^{-1}
10^{-2}
0 1 2 3 4 5 6 7 8 9 10
SNR, [dB]
Start

(c)


Alamouti
Help
Alamouti Scheme Bit Error Rate (BER)
Parameters
Number of symbol pairs to be transmitted:
1000
MPSK order: (power of 2)
16
SNR per RX element in dB: (start:inc:stop)
0:1:10
Number of Tx elements: (must be 2)
2
Number of Rx elements:
2
BER
10^0
10^{-1}
10^{-2}
0 1 2 3 4 5 6 7 8 9 10
SNR, [dB]
Start

(d)



(e)

Fig.3 MATLAB GUI results for (a) 2-PSK (b) 4-PSK (c) 8-PSK (d) 16-PSK (e) for 5000 transmitted symbols

4. Conclusion

MIMO systems are designed to be used with M_PSK or M-QAM modulation techniques for high throughput and high data rate, due to space diversity the number of transmitting and receiving antenna increases , the chances of having a higher BER also increases for high modulation rates, the Alamouti scheme is used for spacetime coding it can be observed that as the M-PSK order increase the BER decreases. The digital modulation schemes are employed with MIMO systems to get low latency, high date rate , more bandwidth and more number of bits to be transmitted at the same time

References

[1] M. O. Damen, A. Tewfik, and J. C. Belfiore. Construction of a space-time code based on number theory. IEEE Trans. Inform. Theory, 48:753–760, Mar 2002.

[2] A. Fr¨0lich and M. Taylor. Algebraic Number Theory. Cambridge University Press,1991. [5]. D. Gesbert, M. Shafi, D. shan Shiu, P. J. Smith, and A. Naguib. From theory to practice: An overview of mimo space-time coded wireless systems. IEEE Journal on Selected Areas in Communications, 21(3):281–302, Apr 2003.

[3] F. Oggier, G. Rekaya, J.-C. Belfiore, and E. Viterbo. Perfect space-time block codes.2004. [7]. L. Poo. Space-time coding for wireless communication: A survey. [8]. L. Yang and G. B. Giannak are. Analog space-time coding for multi-antenna ultra-wideband transmissions. IEEE Trans. on Communications, 52(3):507–517, Mar2004 IEEE Transaction on Communications. 2001; 49(1): 1–4.

[4] Sharma N,Papadias CB. Improved Quasi-Orthogonal codes through constellation rotation. IEEE Transaction on Communications. 2003; 51(3): 332–5.

[5] Su W,Xia XG. Signal constellations for Quasi-Orthogonal Space–Time Block Codes with full diversity. IEEE Transactions on Information Theory. 2004; 50(10)

[6] Liu L, Jafarkhani H. Application of Quasi-Orthogonal space-time block codes in beamforming. IEEE Transactions on Signal Processing.2005; 53(1): 54–63.

[7] Jafarkhani H,Hassanpour N. Super-Quasi-Orthogonal Space–Time Trellis Codes for Four Transmit Antennas. IEEE Transaction on Wireless Communications. 2005; 4(1)

[8] Liang XB. A Complex Orthogonal Space-Time block code for 8 transmit antennas. IEEE Communication Letters. 2005; 9(2): 115-7

[9] Tarokh V, Seshadri N, Calderbank AR. Space-Time Codes for high data rate wireless communication: performance criterion and code construction. IEEE Transactions on Information Theory. 1998; 44(2): 744–765.

[10] Baro S, Bauch G, Hansmanna A. Improved codes for spacetime trellis-coded modulation. IEEE Communications Letters. 2000; 4: 20–22.