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A New Method for PAPR Reduction in MIMO-OFDM Using Combination of OSTBC Encoder and DCT Matrix

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Abstract: ***Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) is an attractive air-interface solution for next generation wireless local area networks (WLANs), wireless metropolitan area networks (WMANs), and fourth generation mobile cellular wireless systems. However one of the main disadvantage associated with MIMO-OFDM systems is the high peak-to-average power ratio (PAPR) of the transmitter's output signal on different antennas. High Peak to Average Power Ratio (PAPR) for MIMO-OFDM system is still a demanding area and difficult issue. So far numerous techniques based on PAPR reduction have been proposed. In this paper a new technique based on the combination of Orthogonal Space Time Block Code (OSTBC) Encoder and Discrete Cosine Transform based Selective Level Mapping as method of PAPR reduction technique has been proposed and simulated. The results have been verified in terms of various graphs and plots and are compared with earlier results of embedded transform techniques. Simulations show that better results are obtained in the proposed technique***

Index terms: - Multiple Input Multiple Out (MIMO), Peak to Average Power Ratio (PAPR) ,Orthogonal Space Time Block (OSTBC) Encoder, Discreet Cosine Transform (DCT), Complementary Cumulative Distribution Function (CCDF).

I. INTRODUCTION

The key challenge faced by future wireless communication systems is to provide high-data-rate wireless access at high quality of service (QoS). Combined with the facts that spectrum is a scarce resource and propagation conditions are hostile due to fading (caused by destructive addition of multipath components) and interference from other users, this requirement calls for means to radically increase spectral efficiency and to improve link reliability. Multiple-input multiple-output (MIMO) wireless technology [1] seems to meet these demands by offering increased spectral efficiency through spatial multiplexing gain, and improved link reliability due to antenna diversity gain. Even though there is still a large number of an open research problem in the area of MIMO wireless, both from a theoretical perspective and a hardware implementation perspective, the technology have reached a stage where it can be considered ready for use in practical systems. In fact, the first products based on MIMO technology have become available, for example, the pre-IEEE802.11n wireless local area network (WLAN) systems by Airgo Networks, Inc.,Atheros Communications, Inc., Broadcom Corporation, Marvell Semiconductor, Inc., and Metalink Technologies, Inc. Current industry trends suggest that large-scale deployment of MIMO wireless systems will initially be seen in WLANs and in wireless metropolitan area networks (WMANs). Corresponding standards currently under definition include the IEEE 802.11n WLAN and IEEE 802.16 WMAN standards. Both standards define air interfaces that are based on the combination of MIMO with orthogonal frequency division multiplexing (OFDM) modulation (MIMO-OFDM). Ongoing fourth-generation (4g) mobile cellular system prestandardization efforts in Europe, which are carried out in the context of various "Integrated Projects," funded by the European Commission within its Sixth Framework Program (FP6), also show strong support for a MIMO-OFDM air interface. In MIMO-OFDM system, a number of antennas are placed at the transmitting and receiving ends and the distances are separated far enough. The idea is to use spatial multiplexing and data pipes by developing space dimensions which are created by multi transmitting and receiving antennas. The transmitted signal bandwidth is so narrow that its frequency response can be assumed as being flat [2] The main advantage of using MIMO-OFDM system include high power spectral efficiency, robustness to channel fading, immunity to impulse interference, uniform average spectral density, capability of handling very strong echoes, lesser non linear distortion and use of small guard intervals [3]. This paper investigates one of the bottleneck problems that exist in OFDM wireless communication system i.e. High Peak-Average Power Ratio (PAPR of OFDM signal), and a new technique have been proposed to reduce it. The occurrences of high peaks in the transmitted OFDM signal cases the degradation of the system performance due to various non-linear effects like spectral spreading, intermodulation, and signal constellation that exist inherently in power amplifiers [4].In this paper a new technique based on the combination of OSTBC Encoder and DCT transform based Selective Level Mapping have been implemented . The OFDM modulator has been implemented by Inverse Fast Fourier Transform (IFFT).The output of IFFT is given to the OSTBC encoder with variable number of transmit and receive antennas and DCT transform is applied after that .The DCT transform spreads the signal there by reducing the peak

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II. MIMO-OFDM SYSTEM

Traditionally, multiple antennas (at one side of the wireless link) have been used to perform interference cancellation and to realize diversity and array gain through coherent combining. The use of multiple antennas at both sides of the link offers an additional fundamental gain — spatial multiplexing gain, which results in increased spectral efficiency. The signaling schemes used in MIMO systems can be roughly grouped into spatial multiplexing [1], which realizes the capacity gain, and space time coding [5], which improves link reliability through diversity gain. Most multi-antenna signaling schemes, in fact, realize both spatial-multiplexing and diversity gain. A framework for characterizing the trade-off between spatial-multiplexing and diversity gains in flat-fading MIMO channels was proposed in [6] In an OFDM-based MIMO system, spatial multiplexing is performed by transmitting independent data streams on a tone-by-tone basis with the total transmit power split uniformly across antennas and tones. Although the use of OFDM eliminates ISI, the computational complexity of MIMO-OFDM spatial-multiplexing receivers can still be high. This is because the number of data-carrying tones typically ranges between 48 (as in the IEEE 802.11a/g standard) and 1728 (as in the IEEE 802.16e standard) and spatial separation has to be performed for each tone. Recently, a new class of algorithms that alleviate this problem was proposed in [7]. The basic idea underlying these algorithms is to exploit the fact that the matrix-valued transfer function in a MIMO-OFDM system is “smooth” across tones because the delay spread in the channel is limited. Computational complexity reductions are obtained by performing channel inversion in the case of a minimum mean-squared error (MMSE) receiver. While spatial multiplexing aims at increasing spectral efficiency by transmitting independent data streams, the basic idea of space-time coding [5.] is to introduce redundancy across space and time to realize spatial diversity gain at the transmitter. This is achieved by applying forward-error-correction coding and interleaving across tones; most practical systems employ bit-interleaved coded modulation [8]. The problem can, however, be approached in a more systematic fashion through space-frequency codes [9], which essentially spread the data symbols across space (antennas) and frequency(tones), Figure 1shows a MIMO-OFDM system with *N* subcarriers (or tones). The individual data streams are first passed through OFDM modulators. Each modulator performs an IFFT on block of length *N*. Then, it is followed by a parallel to serial conversion. After that, a cyclic prefix of length *cp L* ≥ *M* is appended. The CP contains a copy of the last *cp L* samples of the output of the *N*-point IFFT, where *M* denotes the length of the discrete-time channel impulse response. The resulting OFDM symbols with length *cp N* + *L* are launched simultaneously from the individual transmit antennas. The CP is a guard interval that serves to eliminate interference between OFDM symbols. It also turns the linear convolution into circular convolution such that the channel is diagonalized by the FFT. At the receiver, the individual signals are passed through OFDM demodulators. Each modulator removes the CP and then performs an *N*-point FFT. The outputs of the OFDM demodulators are finally separated and decoded.

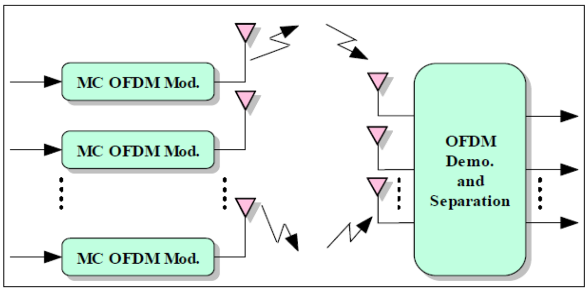

Figure 1: Block Diagram for Simplified MIMO-OFDM System.

III. PAPR PROBLEM

The transmit signals in a MIMO-OFDM system can have high peak values in the time domain since many subcarrier components are added via an IFFT operation. Therefore, OFDM systems are known to have a high PAPR (Peak-to-Average Power Ratio), compared with single-carrier systems. The peak-to-average power ratio (PAPR) is a related measure that is defined as the peak amplitude squared (giving the peak power) divided by the RMS value squared (giving the average power) [10]

$$PAPR = \frac{|x|_{peak}{}^2}{x_{rms}{}^2} = C^2 \qquad (1)$$

As mentioned in [11], the PAPR can be estimated from its KN samples where K is called the oversampling factor. These samples may be obtained from the KN-point IFFT of the QPSK modulated symbols with (K-1) N zero padding. In [12], it is shown that if no oversampling is used, then, the difference between the continuous time PAPR and the discrete time PAPR of an OFDM signal can be as high as 1 dB. However, when an oversampling factor of 4 is used, the difference is negligible. Therefore, it may be concluded that an oversampling factor of 4 is enough to estimate the continuous time PAPR The reason for high PAPR in an OFDM signal is that in time domain, a multicarrier signal is sum of many narrowband signals. At some time instances, this sum is large and other times it is small, which means that the peak value of the signal is substantially larger than the average value[4] OFDM signal is the sum of multiple sinusoidal having frequency separation 1/T where each sinusoidal gets modulated by independent information. Mathematically, the transmitted signal is

$$x(t) = \sum_0^{N-1} a_N \, e^{j2\pi Nt/T} \qquad (2)$$

For simplicity, let us assume that a_N =1 for all N sub carriers. The peak value of signal is

$$\max\,[x(t)x^*(t)] = \max\,\left[\ \sum_0^{N-1} a_N e^{j2\pi Nt/T} \sum_0^{N-1} a_N^* \, e^{-j2\pi Nt/T}\ \right] \qquad (3)$$

$$= \max\,[a_N a_N^* \sum_0^{N-1} \sum_0^{N-1} 1.e^{j2\pi Nt/T} \, e^{-j2\pi Nt/T}] \qquad (4)$$

$$= N^2 \qquad (5)$$

The mean square value of the signal is

$$E\,[x(t)x^*(t)] = E\,[\sum_0^{N-1} a_N e^{j2\pi Nt/T} \sum_0^{N-1} a_N^* \, e^{-j2\pi Nt/T}\ ] \qquad (6)$$

$$= \mathrm{E}\,[a_N a_N^* \sum_0^{N-1} \sum_0^{N-1} 1.\, e^{j2\pi Nt/T}\, e^{-j2\pi Nt/T}] \quad (7)$$

$$=\mathrm{N} \quad (8)$$

The peak to average power ratio for an OFDM system with N Subcarriers given the same modulation is,

$$\mathrm{PAPR}= \frac{N^2}{N}=\mathrm{N} \quad (9)$$

The above value corresponds to maximum value of PAPR when all sub-carriers are equally modulated and peak value hits maximum. As Per IEEE 802.11a specification, we have N= 52 used subcarriers. The maximum PAPR is thus 52(~ 17 dB).The high PAPR of OFDM means that if the signal is not to be distorted many of components in the transmitter and receiver must have dynamic range. In particular the output amplifier of the transmitter must be very linear over a wide range of signal levels. Intermodulation resulting from any non-linearity results in two major impairments: out-of-band (OOB) power and in-band distortion. In wireless communications OOB power is usually more important, because of the near-far problem; interference from the OOB power of a close transmitter may swamp reception from a distant transmitter. For this reason the specifications on OOB power in wireless are very stringent. High value of PAPR brings disadvantages like an increased complexity of A/D and D/A converters and a reduced efficiency of RF power amplifiers. In a practical system, before transmission, OFDM signal is passed through a power amplifier that is always peak power limited. If the squared magnitude of the OFDM signal is larger than the saturation point of the power amplifier at any time instant, then the signal will be clipped. Clipping destroys the orthogonality between subcarriers resulting in an increase in the Bit Error Rate (BER) when compared with the non clipped case [4]

IV. ADAPTIVE MIMO SYSTEM WITH OSTBC ENCODER AND DISCREET COSINE TRANSFORM

The OSTBC Encoder block encodes an input symbol sequence using orthogonal space-time block code (OSTBC). The block maps the input symbols block-wise and concates the output codeword matrices in the time domain. The block supports time and spatial domain for OSTBC transmission. The system uses variable number of transmit and receive antennas. The number of transmit and receive antennas are adaptive and change either manually or according to an adaptation algorithm, based on the difference between target and actual frame –error rates of the overall system.OSTBCs [13],[14] are attractive techniques for MIMO wireless communications. They exploit full spatial diversity order and employ symbol-wise maximum likelihood (ML) decoding. The OSTBC Combiner block at the receiver side provides soft information of the symbols that the system transmits, which can be utilized for decoding or demodulation of an outer code. The OSTBC Encoder block encodes the information symbols from the QPSK Modulator by using complex orthogonal codes [15] for two, three, and four transmit antennas. The number of transmit antenna is given to this block as an input. The output of this block is an (Ns×Nt) variable-size matrix, where the number of columns (Nt) corresponds to the number of transmit antennas and number of rows (Ns) corresponds to the number of orthogonal code samples transmitted over each transmit antenna in a frame. The Adaptive MIMO channel is a variable-size MATLAB function block with variable-size signal implementation. The maximum Doppler shift property of the system object is set to 100.The object uses this value so the MIMO channel behaves like a quasi-static fading channel, i.e., it keeps relatively constant during one code block transmission and varies along multiple blocks. The input of this block is an (Ns×Nt) variable-size matrix, where the number of columns (Nt) correspond to the number of selected transmit antennas and number of rows (Ns) corresponds to the number of orthogonal code samples that the system transmits over each transmit antenna in a frame. The first output of this block, the signal chGain, is an (Ns× Nt× Nr) variable-size channel gain array, where the third dimension (Nr) corresponds to the number of selected receive antennas. The second output of this block, the signal chOut, is an (Ns× Nr) variable-size channel output matrix. The basic idea to use DCT transform in MIMO-OFDM is to reduce the autocorrelation of the input sequence to reduce the peak to average power problem and it requires no side information to be transmitted to the receiver. The out-put of the OSTBC Encode is combined with DCT matrix. The DCT matrix spreads the signal thereby reducing the peak

V.PROPOSED ALGORITHM

The algorithm for new method proposed in this work is as follows:

i. Choose the no of sub-carriers ‘N’ and oversampling factor ‘of’

ii. Multiply both to obtain K (in this work k=512)

iii. Select the QPSK constellation symbols and define the rotation factor value range

iv. Generate the OFDM symbols in the frequency domain as an array of 0’s and 1’s

v. Take the IFFT of generated OFDM symbols.

vi.Pass the IFFT generated signal through the OSTBC Encoder having variable number of transmit antennas (in this work we take numTx=2,3,4)

vii. Calculate the PAPR for each transmit antenna path (numTx=2,3,4)

viii. Apply the DCT Transform to each path

ix. Calculate the Complementary Cumulative Distribution Function(CCDF) of original signal.

x. Define the different M-ary phase modulations (M=2,4,8,16)

xi. Calculate the PAPR using Selective Level Mapping (SLM) with different M values.

xii. Calculate the signals CCDF with M=2,4,8,16 and for each transmit antenna path.

xiii. Plot the CCDF values with different M values and compare the results

VI. RESULTS AND DISCUSSIONS

In this work a new method based on the combination of OSTBC Encoder and Discrete Cosine Transform have been implemented. Sixty four carriers have been used and oversampling factor is eight. The specifications in this work has been made as per International Telecommunication Union (ITU).The following simulation results illustrate the effect of implementing basic SLM (without OSTBC Encoder), OSTBC Encoder with number of transmit antennas=2,3,4 for various M-Ary phase modulations (M=2,4,8,16) and compares it with original signal.The graphs are plotted between CCDF and PAPR0 (db) .

The simulation result for basic SLM(without OSTBC Encoder) have been shown in figure2. With CCDF(Pr[PAPR>PAPR0]) equal to max (i.e 1), it can be shown that PAPR decreases with increasing values of M .For M=16 PAPR reduces to 7.1db as compared to original signal of 10.3 db, thus there is a reduction of 3.2 db.

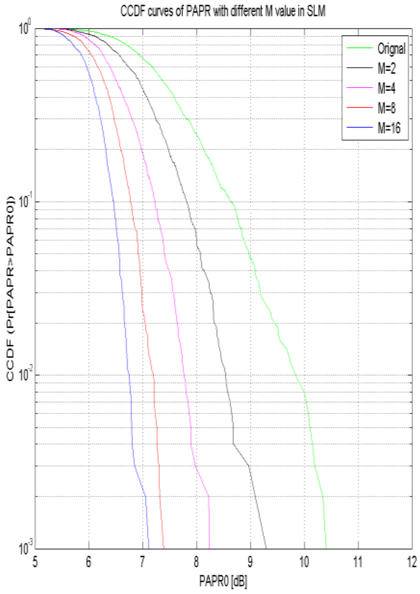

Figure 2: Plot for conventional SLM (without OSTBC Encoder)

Figure 3 shows the simulation result for new proposed method based on the combination of OSTBC Encoder and DCT matrix with number of transmit antennas equal to 2.Simulation results show the huge variation in the reduction of PAPR as compared to the original signal with the increasing values of M. For M=16 PAPR reduces to 6.3db as compared to original signal of 10.4 db, thus there is a reduction of 4.1 db, which is a significant development

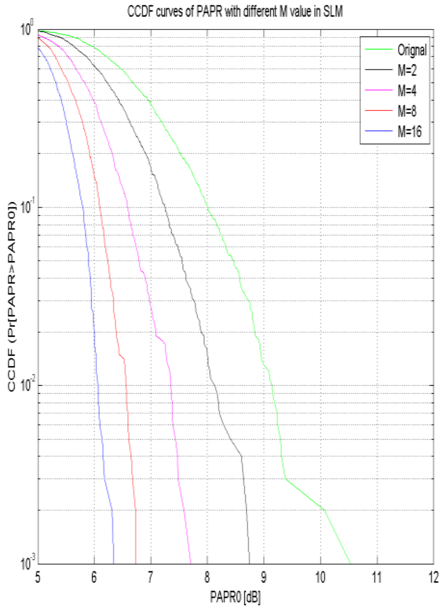

Figure 3 : Plot for combination of OSTBC Encoder and DCT matrix (numTx=2)

Figure 4 shows the simulation results when number of transmit antennas are changed to 3.Again it is shown that PAPR decreases with the increasing values of M, for M=16 PAPR reduces to 6.2 as compared to original signal of 10.55 showing a reduction of 4.35 db which is again a significant development.

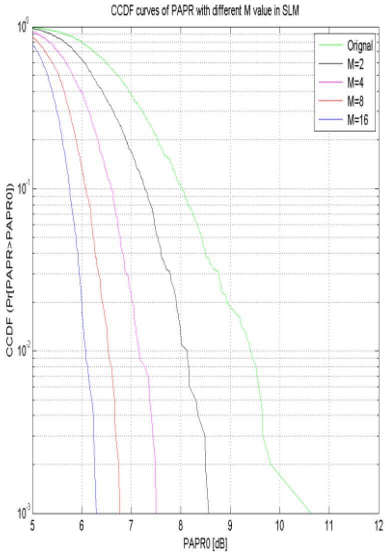

Figure 4: Plot for combination of OSTBC Encoder and DCT matrix (numTx=3)

Figure 5 shows the simulation results when the number of transmit antennas are changed to 4.Simulations show a greater reduction in PAPR with the increasing values of M .For M=16 PAPR reduces to 6.18db as compare to original signal of 9.7db showing a reduction of 3.52db.

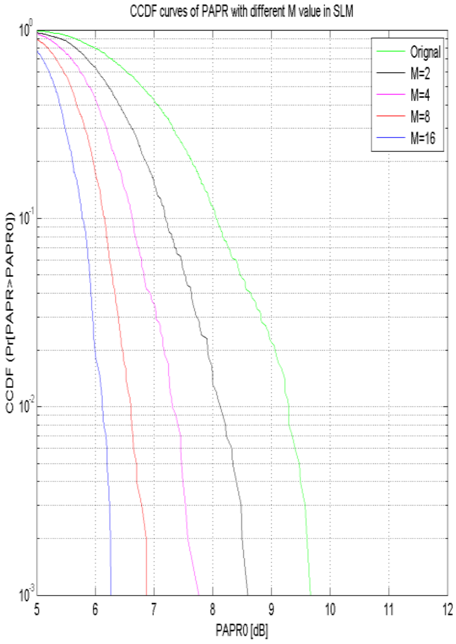

Figure 5 :Plot for combination of OSTBC Encoder and DCT matrix (numTx=4)

The above results have been more precisely given in tabular form for different M values and is shown in table 1. The PAPR of the original OFDM signal is calculated using the proposed techniques.Subsequently,the PAPR for different values of M is calculated using the suggested technique.For the higher values of M there is significant reduction in PAPR.

Table 1. PAPR comparison for various M-ary Phase modulations and original OFDM signal for different proposed techniques

M	PAPR due to Basic SLM (without OSTBC) (db)	PAPR Due to OSTBC +DCT (numTx= 2) (db)	PAPR Due to OSTBC +DCT (numTx= 3) (db)	PAPR Due to OSTBC +DCT (numTx= 4) (db
Original signal	10.3	10.4	10.55	9.7
M=2	9.2	8.8	8.6	8.67
M=4	8.2	7.8	7.5	7.8
M=8	7.4	6.8	6.82	6.9
M=16	7.1	6.3	6.2	6.18

VII. CONCLUSION

The paper ivestigates one of the bottleneck problem that exist in MIMO-OFDM systems i.e high peak to average ratio and suggests a new technique to overcome it.The new technique is based on the combination of OSTBC encoder and DCT matrix.The proposed OSTBC Encoder uses variable number of transmit antennas that are adaptive and change either manually or according to an adaptation algorithm. Simulation results show a greater reduction in PAPR for the proposed scheme as compared to earlier conventional SLM technique. Also the PAPR decreases significantly for higher values of M as compared to original signal OFDM signal. The proposed scheme has a lot of scope in next generation network systems. Moreover with this improvement it can be considered as a potential candidate for high speed data transmission systems.

REFERENCES

1. A.J Paulraj, R.U Nabar, and D.A.Gore, " Introduction to Space-Time wireless communications, Cambridge, UK Cambridge, univ press,2003
2. N.Chan and G.T.Zhou, "Peak-to-average power ratio reduction in OFDM with blind selected pilot tone modulation," Proc.IEEE Intl.Conference on Acoustics,Speech, and siginal processing, Mar 2005
3. H.Ochiai and H.Imai, "Performance analysis of deliberately clipped OFDM signals," IEEE Trans commum,vol.50, pp 89-101, Jan 2002
4. Mehboob ul Amin,et al, "Multiple Input Multiple Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) Based Image Transmission Using Hadamard Transform as PAPR Reduction Technique," International Journal of Engineering and advanced Technology (IJEAT) vol 2, Issue 4,pp 550-553,April 2013
5. V.Taron, N Seshadri, and A.R Calderbank, "Space-Time codes for High Data Rates wireless communication : Performance critorian and code construction." IEEE Trans.Info.Theory,Vol.44 no.2, Mar-1998, pp 744-65.
6. L.Zheng and D.N.C.Tsc, "Diversity and Multipexing: A Fundamental Trade Off in Multiple Antenna channels," IEEE Trans.Info theory, vol 49,no.5, May 2003, pp 1073-96
7. M.Borgmann and H Bolckei, "Interpolation-Based Efficient Matrix Inversion for MIMO-OFDM receivers," Proc. 38th Asilomar conf. signals,syst,and computers,Pacific Grove, C.A.Nov.2004,pp 1941-47
8. G.Caire, G.Taricco,and E.Biglien, "Bit-Interleaved Coded Modulation", IEEE Trans.Info.Theory, vol.44,no.3,May 1998,pp 927-46
9. H.Boclcskei and A.J Paulraj, "Space-Frequency coded Broadband OFDM systems," Proc IEEE wireless commum.and Networking conf. , Chicago, Sept 2000, pp 1-6
10. T Rouphael, RF and Digital Processing for Softwere Defined Radio,Ist Edition Print Book,Nov 2008
11. K.yong, S.chang, "Peak-to-Average power control in OFDM using standard Arrays of linear Block codes,"IEEE communication letters, vol,7 no 4,April 2003
12. C.Tellamura, Computation of Continous-Time PAR of an OFDM signal with BPSK subcarriers,IEEE communication letter,vol 5,no.5,may 2000.
13. S.M.Alamouti, "A simple transmit diversity technique for wireless communication," IEEE journal on selected Areas in communications, vol 16,no.8,pp-1451-1458,oct,1998
14. V.Tarokh, H.Jafarkhami and A.R.Calderbank, "Space-time block codes from orhogonal designs," Information Theory, vol.45,no.5, pp.1456-1467,jul,1999
15. M.Jankiraman, Space-Time codes and MIMO systems.Artech House Publishers,2004.
16. M. E. Gärtner and H. Bölcskei, "Multi-User Space-Time/Frequency Code Design," Proc. IEEE ISIT, Seattle,WA, July 2006.
17. Yong soo Cho, Jeakwonkin,Won Young Yang," MIMO – OFDM wireless Communication with MATLAB," Joh Wilong and Sons (Asia) PVT Ltd. 2010
18. G.L Stuber, JR Barry, S.W.mclaughlin, M.A.Ingram, T.G Pratt, "BroadBAND MIMO-OFDM wireless Communications," Proceedings of the IEEE, VOL .92 No.2, Februry 2004

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