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Binary Weightbook Design for MIMO OFDM System Using Quantized Feedback

Sadguna Kumari V[1], AM Prasad[2]

[1]UCEK, JNTUK, Kakinada, A.P, India

[2]Professor & HOD, Department of Electronics and Communication Engineering, UCEK, JNTUK, Kakinada, A.P, India

Abstract: ***A particularly promising candidate for next-generation fixed and mobile wireless systems is the combination of MIMO technology with Orthogonal Frequency Division Multiplexing (OFDM). OFDM is a subset of frequency division multiplexing in which a single channel utilizes multiple sub-carriers on adjacent frequencies .MIMO wireless systems are of interest due to their ability to provide substantial gains in capacity and quality. Transmit Beam forming and Receive combining are simple methods for exploiting significant diversity that is available in MIMO wireless systems. Orthogonal Frequency Division Multiplexing (OFDM) effectively deals with detrimental effects caused due to frequency selective fading, which is the major challenging issue in wireless communications. Optimal performance of MIMO-OFDM systems require complete knowledge about the channel and this is hard to realize hence a feedback path is to be established from transmitter to the receiver. The optimum Binary Weightbook is designed which uses quantized feedback from receiver to the transmitter. The performance of Binary Weightbook is almost same as the Grassmannian Weightbook which uses unquantized feedback..***

Keywords: Multiple-Input Multiple-Output (MIMO), Orthogonal Frequency Division Multiplexing (OFDM), Transmitter diversity, Quantized feedback, Binary Weightbook, Grassmannian Weightbook.

1. Introduction

OFDM is a Frequency Division Multiplexing (FDM) scheme used as a digital Multi-carrier modulation method. A large number of closely spaced orthogonal sub carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

In OFDM the high speed data stream is divided into N_C narrowband data streams, N_C corresponding to the subcarriers or sub channels. The symbol duration is made longer by adding a cyclic prefix to each symbol. As long as the cyclic prefix is longer than the channel delay spread, OFDM offers Inter-Symbol Interference (ISI) free transmission.

Multiple Input Multiple Output (MIMO)-Orthogonal Frequency Division Multiplexing (OFDM) has attracted researchers interest as they improve the parameters of the wireless communication like transmission rate, transmission reliability and transmission range simultaneously.

Closed loop systems make use of feedback concept to improve the performance of wireless communication[2] Closed loop Transmit beamforming is of prior importance as it enhances the quality of the wireless link thereby improving the throughput of the system. Achieving maximum diversity in MIMO-OFDM systems is by making use of beamforming at the transmitter and combing at the receiver side[12]-[15] which is the simplest way.

Binary weightbook[1] is a form of finite alphabet weightbooks[5],[10] which reduces the computational complexity for finding the optimum beamforming weight vector compared to the weightbooks that use infinite alphabet weightbooks like Grassmannian weightbook. Binary weightbook design for MIMO-OFDM systems uses quantized feedback .This reduces the storage requirements of the weightbook.[3],[14]

2. System Model

A block schematic of the MIMO OFDM [13],[14] using Binary Weightbook with N_t transmitting and N_r receiving antennas is as shown in the Fig 2.1 .Here the symbol s is pre-encoded using the beamforming weight vector $w = [w_{1,}, w_2 .... w_{N_t}]^T$ from a Binary Weightbook W. Here $(.)^T$ denotes the transpose and w_i =1 or -1.

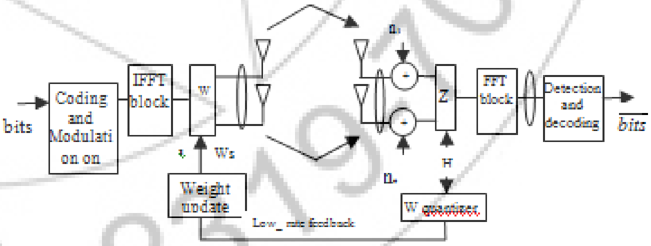

Figure 2.1: System Model

The Trellis-Coded symbols[8] are applied to the IFFT- based OFDM modulators, followed by their transmission over N_t transmitting antennas after multiplying with optimum weight vector. Here the weightbook consists of 2^F beamforming vectors, where F is the number of feedback bits. The receiver sends the feedback to the transmitter by selecting the beamforming vector w from the weightbook W.

The transmitted symbols are received by the N_r receiving antennas followed by the FFT based demodulation.

Maximum Ratio combining (MRC) [16] detection scheme is employed at the receiver side. The output signal at the receiver is given as

$$r = \sqrt{\frac{E_s}{N_t}} z^H Hw.s + z^H n$$

Here E_s is the energy of the signal and N_t is the number of transmitting antennas. H is the $N_t \times N_r$ channel matrix. MRC combining vector at the receiver Z is equal to Hw.

3. Weight Book Design

3.1 Grassmannian Weightbook

Grassmannian line packing: Grassmannian line packing is the problem of optimally packing one-dimensional subspaces. It is similar to the problem of spherical code design with one important difference: spherical codes are points on the unit sphere while Grassmannian line packings are lines passing through the origin in a vector space. Grassmannian line packing forms the basis for our quantized beamforming codebook design.

Grassmannian Beamforming Criterion: Design the set of codebook vectors $\{w_i\}_{i=1}^{N}$ such that the corresponding codebook matrix w maximizes [10]

$$\delta(W) = \min_{1 \le k < l \le N} \sqrt{1 - \left| w_k^H w_l \right|}$$

This criterion captures the essential point about quantized beamforming codebook design for Rayleigh-fading MIMO wireless systems. Grassmannian line packings are the key to codebook construction. Thus, beamforming codebooks can be designed without regard to the number of receiver antennas by thinking of the codebook as an optimal packing of lines instead of a set of points on the complex unit sphere. One benefit of making the connection between codebook construction and Grassmannian line packing is that it provides an approach for finding good codebooks, namely, leveraging work that has already been done on finding optimal line packings.

The codebook matrix W must satisfy

$$W = \arg\max_{X \in I_{M_t}^{N}} \delta(X)$$

where $I_{M_t}^{N}$ is given by the set of matrices for codebook.

3.2 Binary weightbook design:

Defining Binary Phase Shift Keying (BPSK) mapping, BPSK(.), as follows

BPSK(0) = 1

BPSK(1) = −1.

Then, define inverse BPSK mapping, $BPSK^{-1}(.)$, as

$BPSK^{-1}(1) = 0$

$BPSK^{-1}(-1) = 1$

Binary Weightbook design is to maximize the minimum distance of the unified code. The Binary Weightbook is designed in such a way that the minimum distance between the corresponding code must be less than or equal to $\frac{N_t}{2}$

$$d_{\min}(u) = \frac{N_t}{2}$$

For a Binary Weightbook W number of beamforming vectors is equal to 2^F ,where F is the number of feedback bits .Length of the beamforming vector is equal to number of transmitting antennas. Given N_t and F, we will design a code C of which the column vectors are the 2^F codewords. Then, the corresponding Binary Weightbook can be found using BPSK mapping.

Case(i)

- Binary Weightbook when number of transmitting antennas(N_t) is equal to 3 and number feedback bits(F) is equal to 1

$$W = \begin{pmatrix} 1 & 1 \\ 1 & 1 \\ 1 & -1 \end{pmatrix}$$

Here F=1 , number of beamforming vectors is equal to 2^1.The minimum Hamming distance for the unified code is one. Since this code achieves the bound, it is optimum

Case(ii)

- Binary Weightbook when number of transmitting antennas(N_t) is equal to 3 and number feedback bits(F) is equal to 2

$$W = \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & 1 & -1 \end{pmatrix}$$

Here F=2, number of beamforming vectors is equal to $2^2 = 4$.

Selection of Beamforming weight vector : Beamforming weight vector w from the Weightbook W in Binary Weightbook design is found by

$$w = \arg(\max_{w \varepsilon W} \| Hw \|^2)$$

$$= \arg(\max_{w \varepsilon W} \sum_{i=1}^{M_r} | \sum_{j=1}^{M_t} h_{i,j} w_j |^2)$$

here ||.|| indicates the norm and H indicates the channel matrix. $h_{i,j}$ indicates the channel for ith receiving and jth transmitting antenna .

4. Simulation Results

Comparison between performance of MRC (Maximum Ratio Combining) and Binary Weightbook for MIMO OFDM Systems

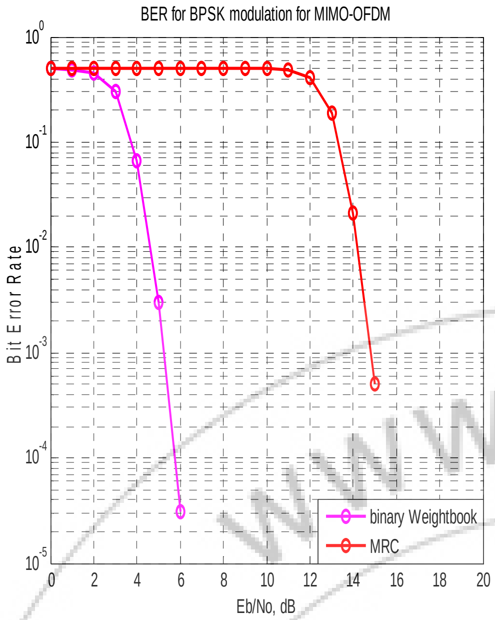

Figure 4.1: Performance Comparison of MRC and Binary Weightbook.

MIMO OFDM systems with MRC and Binary Weightbook techniques are designed. Fig.4.1 shows Binary Weightbook gives better performance compared with MRC. Modulation scheme employed here is BPSK (Binary phase shift keying).

Comparison between performance of Binary Weightbook and Grassmannian Weightbook for MIMO OFDM Systems:

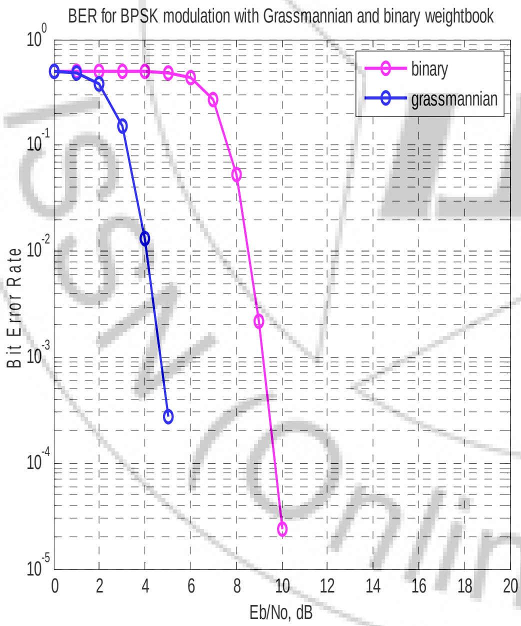

Figure 4.2: Performance Comparison of Binary Weightbook and Grassmannian Weightbook.

MIMO OFDM systems with Binary Weightbook and Grassmannian Weightbook techniques are designed. Fig.4.2 shows Grassmannian Weightbook gives better performance compared with Binary Weightbook. Modulation scheme employed here is BPSK (Binary Phase Shift Keying).

Comparison between performance of MIMO and MIMO OFDM systems:

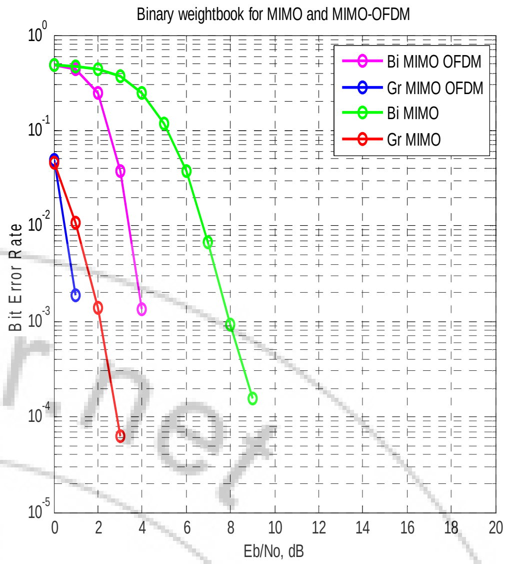

Figure 4.3: Performance Comparison of MIMO and MIMO OFDM.

Binary Weightbook and Grassmannian Weightbook are designed for MIMO and MIMO OFDM systems. Fig.4.3 shows MIMO OFDM system gives better performance compared with MIMO system. Modulation scheme employed here is BPSK (Binary phase shift keying).

Comparison between performance of Binary Weightbook when receiver Antennas equal to 1 and 2

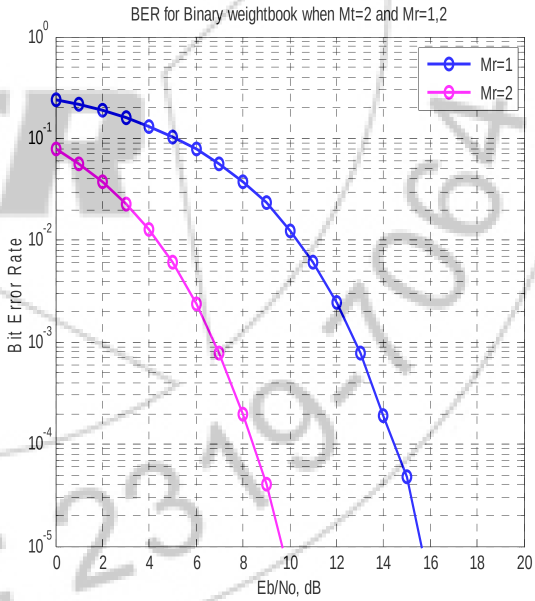

Figure 4.4: Performance comparison of Binary Weightbook when M_r=1, 2.

Binary Weightbook with 1 and 2 receiver antennas is designed. Fig.4.4 shows as the receiver antennas increases the performance of the system increases. Modulation scheme employed here is BPSK (Binary Phase Shift Keying).

Comparison between performance of Binary Weightbook when M_t=2, M_r=2 and M_t=4, M_r=4

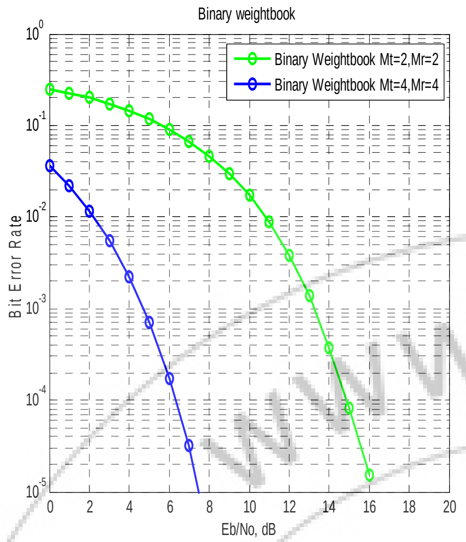

Figure 4.5: Performance comparison of Binary Weightbook when M_t=2, M_r=2 and M_t=4, M_r=4.

Binary Weightbook for M_t=2, M_r=2 and M_t=4, M_r=4 is designed. Fig4.5 shows as the M_t and M_r increases the performance of the system increases. Modulation scheme employed here is BPSK(Binary Phase Shift Keying).

5. Conclusion

The performance of Grassmannian Weightbook is almost similar to that of Binary weight book design. But the computational complexity for finding the optimum beamforming weight vector and the storage requirement for the Binary Weightbook can be reduced compared with that of Grassmannian Weightbook.

References

[1] "Binary Grassmannian Weightbooks for MIMO Beamforming Systems Young Gil Kim", and Norman C. Beaulieu, IEEE TRANSACTIONS ON COMMUNICATIONS, VOL. 59, NO. 2, FEBRUARY 2011

[2] Coding for MIMO Communication Systems Tolga M. DumanArizona State University, USAAli GhrayebConcordia University, Canada

[3] D. J. Love, R. W. Heath Jr., and T. Strohmer, "Quantized antenna weighting codebook design for multiple-input multiple-output wireless systems," in Proc. 40th Allerton Conf. Communications, Control, andComputing, Moticello, IL, Oct. 2002.

[4] D. J. Love, "Transmit diversity quantization methods for multiple-input multiple-output wireless systems," M.S. thesis, Univ. Texas at Austin, May 2002

[5] "E-UTRA physical channels and modulation (Release 8)," 3GPP TS 36.211 V8.8.0, 2009.

[6] Equal Gain Transmission in Multiple-Input Multiple-Output Wireless Systems David J. Love, Student Member, IEEE, and Robert W. Heath, Jr., Member, IEEE

[7] Grassmannian Beamforming for Multiple-Input Multiple-Output Wireless Systems David J. Love, Student Member, IEEE,

[8] G. Bauch and J. Hagenauer, "Smart versus dumb antennas-capacities and FEC performance," IEEE Commun. Lett., vol. 6, pp. 55–57, Feb. 2002

[9] IEEE 802.16e-2005: IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems - Amendment 2: Physical Layer and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, Feb. 2006

[10] J. B. Anderson, "Antenna arrays in mobile communications: Gain, diversity, and channel capacity," IEEE Antennas Propagat. Mag., vol. 42,pp. 12–16, April 2000.

[11] MIMO-OFDM WIRELESS COMMUNICATIONS WITH MATLAB_ Yong Soo Cho Chung-Ang University, Republic of Korea, Jaekwon Kim Yonsei University, Republic of Korea Won Young Yang Chung-Ang University, Republic of Korea Chung G. Kang Korea University, Republic of Korea

[12] P. A. Dighe, R. K. Mallik, and S. S. Jamuar, "Analysis of transmit -receive diversity in Rayleigh fading," IEEE Trans. Commun., vol. 51 pp. 694–703, Apr. 2003.

[13] R. W. Heath Jr. and A. Paulraj, "A simple scheme for transmit diversity using partial channel feedback," in Proc. 32nd Annu. Asilomar Conf. on Signals, Systems, and Computers, vol. 2, Nov. 1998, pp. 1073–1078.

[14] R. Samanta and R. W. Heath, Jr., "Codebook adaptation for quantized MIMO beamforming systems," in Proc. 39th Asilomar Conf. Signals,Systems, Computer, 2005, pp. 376–380.

[15] SThoen, L. Van Perre, B. Gyselinckx, and M. Engels, "Performance analysis of combined transmit-SC/receive-MRC," IEEE Trans. Commun., vol. 49, pp. 5–8, Jan. 2001.

[16] T. K. Y. Lo, "Maximum ratio transmission," IEEE Trans. Commun., vol. 47, pp. 1458–1461, Oct. 1999.

Author Profile

Sadguna Kumari V is M.TECH Student, University College of Engineering, JNTUK, Kakinada, A.P, India.

AM Prasad is Professor & Head of the Department, Department of Electronics and communication Engg., University College of Engineering, JNTUK, Kakinada, A.P, India.