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SPECTRAL EFFICIENCY MAXIMIZATION IN MISO-OFDM SYSTEMS USING RATE ADAPTIVE BIT LOADING AND TRANSMIT ANTENNA SELECTION TECHNIQUES

VINOTH BABU KUMARAVELU*, RAMACHANDRA REDDY G, BALA KRISHNA NALLAGATLA

School of Electronics Engineering, VIT University,
Vellore Campus, Vellore, 632 014, Tamil Nadu, India
*Corresponding Author: vinothbabu.k@vit.ac.in

Abstract

A high spectral efficient system is expected to meet the growing demands of multimedia applications through a wireless medium. In this paper, a low complex high spectral efficient Reduced Multiple Input Single Output (R-MISO)-Orthogonal Frequency Division Multiplexing (OFDM) system is proposed. The proposed system exploits the benefits of Rate Adaptive Bit Loading (RABL), Transmit Antenna Selection (TAS) and Space Frequency Block Codes (SFBC) to get high spectral efficiency through a constrained available spectrum. The performance of the proposed system with different configurations of R-MISO is analyzed with the average Signal to Noise Ratio (SNR) gain, Bit Error Rate (BER), outage probability, spectral efficiency and data rate. The performance of the proposed system has greatly enhanced by utilizing TAS and RABL techniques. The obtained simulation results validate this statement.

Keywords: MISO, OFDM, SFBC, RABL, Antenna selection (AS), Spectral efficiency.

1. Introduction

The key aim of next generation wireless communication systems is to provide high data rates to oblige the growing demands of internet and multimedia applications. Wireless channel is the major challenge for providing high data rates in wireless standards. It is due to the probability of occurrence of deep fade in a wireless channel is so high [1]. MIMO is one of the suitable solutions to battle the impacts of profound deep fade [2, 3].

Nomenclatures

$BER(m)$	Instantaneous BER of m^{th} subcarrier
$b(m)$	Number of bits loaded on m^{th} subcarrier
b_T	Target total bits to be transmitted through one OFDM symbol
C	Required transmission rate
D	SFBC matrix
E_T	Total energy constraint
g_m	Average SNR of m^{th} subcarrier
H	Channel matrix
$H(m)$	Channel gain on m^{th} subcarrier
I	Mutual information of a channel
L	Total number of subcarriers
M	Modulation index
M_T	Total number of available transmit antennas
M_R	Total number of available receive antennas
N_T	Total number of selected transmitting antennas
p, q	Indexes of the selected transmit antennas
R_C	Code rate
$SNR^{'}(m)$	Received SNR of m^{th} subcarrier
$X_I[m]$	Modulated symbol of m^{th} subcarrier and I^{th} OFDM symbol
X_I	Detected symbol
$Y_I^1[m]$	Received symbol on m^{th} subcarrier

Greek Symbols

$\varepsilon(m)$	Amount of energy required to transmit data on m^{th} subcarrier
γ_{SN}	SNR
Γ	SNR gap

Abbreviations

AS	Antenna Selection
AWGN	Additive White Gaussian Noise
ISI	Inter Symbol Interference
LTE	Long Term Evolution
LTE-A	Long Term Evolution- Advanced
MBWA	Mobile Broadband Wireless Access
MIMO	Multi Input Multi Output
NBTAS	Norm Based Transmit Antenna Selection
QAM	Quadrature Amplitude Modulation
Wi-MAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Networks

Furthermore, MIMO strategy can be capable of exploiting spatial diversity and smoothing channel fluctuations to improve the spectral efficiency and reliability of a communication system. This improvement can be achieved without incurring additional transmit power or bandwidth [4]. In frequency selective fading channels, narrow band MIMO systems severely suffer from the ISI [2]. Multi carrier systems like OFDM can completely mitigate the effect of ISI using Cyclic Prefix (CP) and it converts the frequency selective fading channel to a number of flat fading channels [5]. The blend of these two technologies, termed MIMO-OFDM is a solid prospect for cutting edge wireless standards like, IEEE 802.11 (WLAN), IEEE 802.16 (WiMAX), IEEE 802.20 (MBWA), LTE, LTE-A [6]. The LTE-A system supports maximum of 8 transmit antennas at Base Station (BS). Space Time Block Code (STBC) and Space Time Trellis Codes (STTC) are the two popular schemes for MIMO technology to provide full spatial diversity [7]. These are originally developed for flat fading channels. The main difference between STBC and STTC is, STBC does not provide coding gain but STTC can provide full diversity gain and coding gain. In STTC, when the number of antennas and modulation order increases, the complexity also increases exponentially. STBC is good for indoor and flat fading applications. For frequency selective fading channels, SFBC scheme is employed for MIMO-OFDM and it additionally adds frequency diversity to the system [8]. However, not all SFBCs can achieve full rate transmission. For example, SFBC system with two transmit antenna can achieve rate 1 and SFBC system with three transmit antennas can achieve rate ½ only [9].

A noteworthy drawback in realizing full MIMO system is the cost of implementing more expensive multiple Radio Frequency (RF) chains [10]. Every RF chain comprises a low noise amplifier, frequency up or down converters, Analog to Digital (A/D), Digital to Analog (D/A) converters and filters etc. If the number of antennas increases at transmitter or receiver, proportionally the RF chains increases between transmitter and receiver. These more RF chains increases the hardware size, cost and signal processing complexity of the MIMO system. To overcome the drawback of full MIMO system, we go for Reduced MIMO (R-MIMO) system [11]. The proposed system uses AS technique, where fewer expensive RF chains are used than the actual number of antenna elements and only process signals from a dynamically selected subset of antennas. The AS can be done at the transmitter or at the receiver or both together. It also provides full diversity and preserves the diversity order as in the case when all the available antennas are used [12]. So, R-MIMO system significantly reduces the cost and complexity of a full MIMO system without any performance degradation. The question is how to choose the optimum antenna arrays among all the available antennas? A good approach is to select the antenna subset that has high channel gain between the transmitter and receiver.

In recent literatures, there has been impressive research on AS schemes. Zhuo Chen et al. achieved full diversity gain by combining TAS with STTC [13]. Be that as it may, they have not performed an analytical error rate analysis. Gore and Paulraj analyzed the maximum capacity of MIMO systems with full channel knowledge at the transmitter side in combination with STBC and AS [14]. Some fast AS algorithms with good trade-offs in performance and complexity are proposed in [15, 16]. Zhang and Dai proposed fast transmit antenna selection algorithms based on instantaneous Channel State Information (CSI) or channel correlation matrices [17]. Zhang Y et al. proposed a TAS algorithm using the cross entropy optimization method to maximize the channel capacity [18]. All these algorithms, suffer by a number of issues. The algorithms that requires full channel knowledge at the transmitter, increases the feedback information and delay. The algorithms based on channel statistical information, do not attempt to explore the benefits of full CSI. You C et al. performed AS based on high and low SNR regimes with two different algorithms [19]. These algorithms are complex and very sensitive to the choice of threshold. The performance of different TAS schemes has been studied in [20, 21]. These schemes require a high rate feedback channel. Rajashekar R et al. compared different TAS techniques namely Euclidean Distance based AS (EDAS) and Capacity Optimized based AS (COAS) in [22]. They proved that the performance of EDAS is poor compared with the COAS technique. Trivedi Y.N and Chaturvedi A.K analyzed the Reduced MISO system performance with three different TAS schemes and proved that Norm Based scheme 1 approach is giving better performance when compared to other schemes [23].

To enhance the spectral efficiency of conventional MIMO-OFDM system further, we also utilize Adaptive Bit Loading (ABL) technique, where different modulation order and power are allocated to each subcarrier based on its SNR [24]. ABL techniques are broadly classified into two types: Margin Adaptive (MA) [25] and Rate Adaptive (RA) [26]. The objective of MA based schemes is to minimize overall transmit power with total data rate constraint. The objective of RA based schemes is to maximize the net data rate with total transmitted power constraint. The RA is mainly used for multimedia applications. The primary inspiration of this paper is to design a low complex, high spectral efficient system to meet the future demands of multimedia applications. The proposed system is a combination of RABL, SFBC, OFDM and TAS. In this work, a low complex, Norm Based Transmit Antenna Selection (NBTAS) technique is used to get R-MIMO system, without any performance degradation. The water filling based RABL techniques are very popular to improve the performance of Single Input Single Output (SISO) systems. In this work, SFBC and NBTAS based RABL-Optimum Water Filling Algorithm (RABL-OWFA) is used to improve the performance of the proposed system. The simulation results validate this statement.

The rest of the paper is constructed as follows: The proposed system model is described in section 2. The NBTAS scheme is explained in section 3. In section 4, RABL-OWFA is described. The simulation results and discussions are given in section 5 and section 6 concludes the paper.

2. System Model

Figure 1 shows the block diagram of the proposed system. The user data in the form of bits is modulated by the *M*-ary QAM. The modulated symbols for the I^{th} OFDM symbol of length *L* can be given as,

$$\boldsymbol{X_I} = \left[X_I[0], X_I[1], X_I[2].....X_I[\mathrm{L}-1]\right]^T \tag{1}$$

where *T* represents transpose operation. These symbols are given as the input to the SFBC encoder block. Here, we use SFBC coder for two transmitter antennas and one receiver antenna to achieve a full rate system [10]. The input symbols are encoded based on SFBC technique as follows [27],

$$\boldsymbol{D}=\begin{bmatrix} X_I[2m] & X_I[2m+1] \\ -X_I[2m+1]^* & X_I[2m]^* \end{bmatrix}=[\boldsymbol{D_1}\ \boldsymbol{D_2}] \tag{2}$$

where $m=0,1,....,\frac{L}{2}-1$.

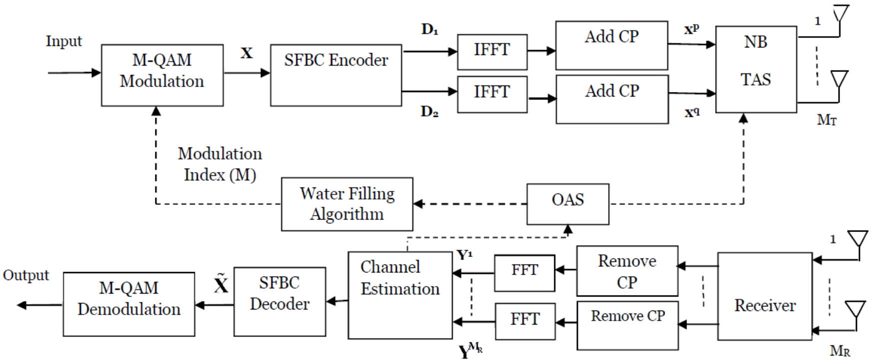

Fig. 1. Block diagram of the proposed system.

The symbols coded in the first (***D₁***) and second (***D₂***) columns of the matrix ***D*** are transmitted through the selected two transmit antennas. It can be seen that each modulated symbol is transmitted in two different frequencies and antennas. It explores spatial and frequency diversities to each transmitted symbol. The outputs obtained from each column are given to separate IFFT block and two different OFDM symbols are generated for the same set of L modulated symbols. CP is added to the IFFT output for reducing the effect of ISI. These OFDM signals are transmitted through independent and identically distributed (i.i.d) frequency selective multipath fading channels. After removing CP, apply *L* point FFT to the received signal to get the demodulated symbols as,

$$Y_I^1[m]=X_I^p[m]H^{1,p}[m]+X_I^q[m]H^{1,q}[m]+W_I^1[m]\,,m=0,1,....,L-1 \tag{3}$$

$W_I^1[m]$ is the AWGN at the receiver. p and q denote the indices of the selected transmit antennas. $H^{1,p},H^{1,q}$ are the fading channels corresponding to the p^{th} and q^{th} transmitter antennas respectively.

Knowing CSI at the receiver, TAS can be done at the receiver and feedback the selected antenna indices to the transmitter. Using RABL-OWFA, find the modulation index (*M*) corresponding to each subcarrier and fed back the index to *M*-QAM modulation block at the transmitter. Here, we are feeding back the indices of the selected antennas and *M* values, which reduce the feedback bits and delay [28].

The transmitted modulated symbols can be decoded as [12, 29],

$$X_I[2m] = \frac{1}{\left\|H[m]\right\|^2}\left\{\left|H^{1,p}[2m]\right|^2 + \left|H^{1,q}[2m]\right|^2\right\} X_I[2m] + \\ H^{1,p}[2m]^* W_I^1[2m] + H^{1,q}[2m] W_I^1[2m+1]^*$$

$$X_I[2m+1] = \frac{1}{\left\|H[m]\right\|^2}\left\{\left|H^{1,p}[2m]\right|^2 + \left|H^{1,q}[2m]\right|^2\right\} X_I[2m+1] + \\ H^{1,q}[2m]^* W_I^1[2m] - H^{1,p}[2m] W_I^1[2m+1]^* \tag{4}$$

where,

$\left\|H[m]\right\|^2 = \left|H^{1,p}[2m]\right|^2 + \left|H^{1,q}[2m]\right|^2$ and $m = 0,1,....,\frac{L}{2}-1$

Consider an (M_T, M_R) MIMO systems, where M_T and M_R represent the total number of available transmit and receive antennas respectively. The goal is to select 2 (N_T=2) out of M_T transmit antennas, where N_T represents the number of selected transmit antennas. The generalized SFBC decoded symbols of L subcarriers from M_R receive antennas can be given as [12, 29],

$$X_I[2m] = \frac{1}{\left\|H[m]\right\|^2}\left\{\sum_{i=1}^{M_R}\left(\left|H^{i,p}[2m]\right|^2 + \left|H^{i,q}[2m]\right|^2\right)\right\} X_I[2m] + \\ \sum_{i=1}^{M_R} H^{i,p}[2m]^* W_I^i[2m] + \sum_{j=1}^{M_R} H^{i,q}[2m] W_I^i[2m+1]^*$$

$$X_I[2m+1] = \frac{1}{\left\|H[m]\right\|^2}\left\{\sum_{i=1}^{M_R}\left(\left|H^{i,p}[2m]\right|^2 + \left|H^{i,q}[2m]\right|^2\right)\right\} X_I[2m+1] + \\ \sum_{i=1}^{M_R} H^{i,q}[2m]^* W_I^i[2m] - \sum_{i=1}^{M_R} H^{i,p}[2m] W_I^i[2m+1]^* \tag{5}$$

Finally, the transmitted data is extracted by performing M-QAM demodulation for the SFBC decoder output.

3. NBTAS

The received signal for the m^th^ sub channel of a (M_T, M_R) MIMO-OFDM system is given as [12],

$$\begin{bmatrix} Y^1[m] \\ Y^2[m] \\ . \\ . \\ . \\ Y^{M_R}[m] \end{bmatrix} = \begin{bmatrix} H^{1,1}[m] & H^{1,2}[m] & . \; . \; . & H^{1,M_T}[m] \\ H^{2,1}[m] & H^{2,2}[m] & . \; . \; . & H^{2,M_T}[m] \\ . & . & . \; . \; . & . \\ . & . & . \; . \; . & . \\ . & . & . \; . \; . & . \\ H^{M_R,1}[m] & H^{M_R,2}[m] & . \; . \; . & H^{M_R,M_T}[m] \end{bmatrix} \begin{bmatrix} X^1[m] \\ X^2[m] \\ . \\ . \\ . \\ X^{M_T}[m] \end{bmatrix} + \begin{bmatrix} W^1[m] \\ W^2[m] \\ . \\ . \\ . \\ W^{M_R}[m] \end{bmatrix} \tag{6}$$

where $m = 0,1,....,L-1.$ In simple way, Eq. (6) can be written as,

$$\boldsymbol{Y} = \boldsymbol{H}\,\boldsymbol{X} + \boldsymbol{W} \tag{7}$$

In $\boldsymbol{H}$ matrix, columns represents the transmit antennas and rows represents the receive antennas. Knowing perfect $\boldsymbol{H}$ at the receiver side, NBTAS scheme is executed at the receiver. In NBTAS scheme, the transmit antennas are selected based on their Frobenius norm values. The main goal is to select 2 transmit antennas out of M_T available transmit antennas. This operation is equal to, selecting two columns with highest Frobenius norms out of M_T columns of $\boldsymbol{H}$. The Frobenius norm of a particular column (transmit antenna) is given as,

$$Z_j = \sum_{i=1}^{M_R} \left| H^{i,j}[m] \right|^2, \; j = 1,2,..,M_T \tag{8}$$

The indices of selected two transmit antennas are fed back to the transmitter using a separate feedback channel. This greatly reduces the amount of feedback. The instantaneous received SNR at mth sub channel of a conventional (M_T, M_R) SFBC-OFDM system is given as [12],

$$SNR(m) = \frac{\gamma_{SN}}{M_T M_R R_C} \sum_{i=1}^{M_R} \sum_{j=1}^{M_T} \left| H^{i,j}[m] \right|^2 \tag{9}$$

where $\gamma_{SN} = \frac{E_S}{N_0}$, E_S is the energy of a symbol at the transmitter and N_0 is variance of the AWGN, R_C is the code rate. The instantaneous received SNR at the mth sub channel with NBTAS scheme is given as [12],

$$SNR'(m) = \frac{\gamma_{SN}}{N_T M_R R_C} \sum_{i=1}^{M_R} \sum_{j=1}^{N_T} \left| H^{i,j}[m] \right|^2 \tag{10}$$

The average SNR gain achieved from the NBTAS is the ratio of the average SNR obtained from the NBTAS scheme to the average SNR obtained from the conventional scheme without antenna selection. It is given as [12],

$$SNRGain_{NBTAS} = \frac{E\left\{ SNR'(m) \right\}}{E\left\{ SNR(m) \right\}} \tag{11}$$

where E is the expectation operator.

$$SNRGain_{NBTAS} = \frac{M_T}{N_T} \frac{E\left\{ \sum_{i=1}^{M_R} \sum_{j=1}^{N_T} \left| H^{i,j}[m] \right|^2 \right\}}{E\left\{ \sum_{i=1}^{M_R} \sum_{j=1}^{M_T} \left| H^{i,j}[m] \right|^2 \right\}} \tag{12}$$

The instantaneous BER of m^{th} subcarrier of the NBTAS scheme with M-QAM modulation over a non flat fading channel can be given as [12],

$$BER(m)=\frac{2}{\alpha}(1-\frac{1}{\sqrt{2^{\alpha}}})erfc\left\{\sqrt{\frac{1.5\gamma_{SN}}{2(2^{\alpha}-1)}\sum_{i=1}^{M_R}\left(\left|H^{i,p}[m]\right|^2+\left|H^{i,q}[m]\right|^2\right)}\right\} \tag{13}$$

where $\alpha=\log_2 M$ is the number of bits per symbol assigned for each subcarrier and *erfc*(.) is the complementary error function.

The outage probability of a system can be defined as the probability of failure to reach a required transmission rate (C) on all sub channels. It is given as [12],

$$P_{OP}=P(I\leq C) \tag{14}$$

where I is the mutual information of a channel. It can be given as,

$$I=\frac{1}{L}\sum_{m=0}^{L-1}I[m] \tag{15}$$

Here $I[m]$ is the m^{th} sub channel information, which is given as,

$$I[m]=\log_2\left(1+\frac{\gamma_{SN}}{2}\sum_{i=1}^{M_R}\left(\left|H^{i,p}[m]\right|^2+\left|H^{i,q}[m]\right|^2\right)\right) \tag{16}$$

4. RABL-OWFA

The objective of RABL is to maximize the number of bits subjected to the total energy constraint. It is mathematically expressed as,

$$\text{Maximize } b_T=\sum_{m=0}^{L-1}b(m) \tag{17}$$

$$\text{Subject to } \sum_{m=0}^{L-1}\varepsilon(m)\leq E_T \tag{18}$$

where b_T is the maximum number of bits in a OFDM symbol, $b(m)$ represents number of bits transmitted through m^{th} subcarrier and $\varepsilon(m)$ indicates amount of energy on m^{th} subcarrier. E_T is the total energy constraint. OWFA increases the number of bits transmitted on each subcarrier by optimum energy allocation. Based on OWFA, the relation between energy on m^{th} subcarrier and its corresponding sub channel SNR is given as,

$$\varepsilon(m)+\frac{\Gamma}{g_m}=K,\ m=0,1,.....,L-1 \tag{19}$$

where K is constant, Γ is SNR gap and

$$g_m = \frac{\left|H^{1,p}(m)\right|^2 + \left|H^{1,q}(m)\right|^2}{2\sigma_m^2} \tag{20}$$

is average m^{th} subcarrier SNR. The constant value K is given as [6],

$$K = \frac{1}{L}\left[E_T + \sum_{m=0}^{L-1}\frac{\Gamma}{g_m}\right] \tag{21}$$

The steps involved in RABL-OWFA scheme is explained below:

Step 1: Sort the sub channels based on the channel gains

$$g_1 > g_2 > \ldots\ldots > g_L$$

Step 2: Compute the constant

$$\tilde{K} = E_T + \sum_{m=0}^{L-1}\frac{\Gamma}{g_m} \tag{22}$$

and let $i=L$

Step 3: Compute

$$K = \frac{\tilde{K}}{i} \tag{23}$$

Step 4: Calculate energy associated with each sub channel using Eq. (19)

$$\varepsilon(m) = K - \frac{\Gamma}{g_m}, m = 0,1,2,\ldots.,L-1$$

Step 5: Check sub channel energy is negative using Eq. (19). If it is true, compute constant

$$\tilde{K} = \tilde{K} - \frac{\Gamma}{g_i} \tag{24}$$

and $i=i-1$ and go to step 2. Otherwise go to step 6.

Step 6: Calculate number of bits allocated to each sub channel by

$$b(m) = 0.5\log_2\left(1 + \frac{\varepsilon(m)g_m}{\Gamma}\right), m = 0,1,\ldots,L-1 \tag{25}$$

5. Simulation Results and Discussion

The performance of the proposed scheme is tested for frequency selective fading channel with 10 (N=10) taps. The channel coefficients are modelled with complex Gaussian random processes with zero mean and variance $1/N$. The number of OFDM symbols is taken as 1000 and the number of subcarriers is taken as 128. The system bandwidth is assumed to be 5 MHz. The code rate is 1 and the target

BER is 10^{-4}. The channel is assumed to be static during one OFDM symbol. It is also assumed that the receiver has the perfect CSI. The simulations are performed for one receiver antenna and two selected transmit antennas (N_T=2) out of M_T available transmit antennas.

The average SNR gain for SFBC-OFDM with R-MISO is obtained from Eq. (12) is shown in Fig. 2. For M_T=3, the average SNR gain is 1.09 dB, whereas for M_T=5, it is 3.73 dB. It is clear that the average SNR gain increases when the number of available transmitting antennas (M_T) increases. The SFBC-OFDM system with no antenna selection is labelled as $2:2\times1$. The system which selects 2 out of 4 or 8 transmitting antennas are labelled as $4:2\times1$ or $8:2\times1$ respectively.

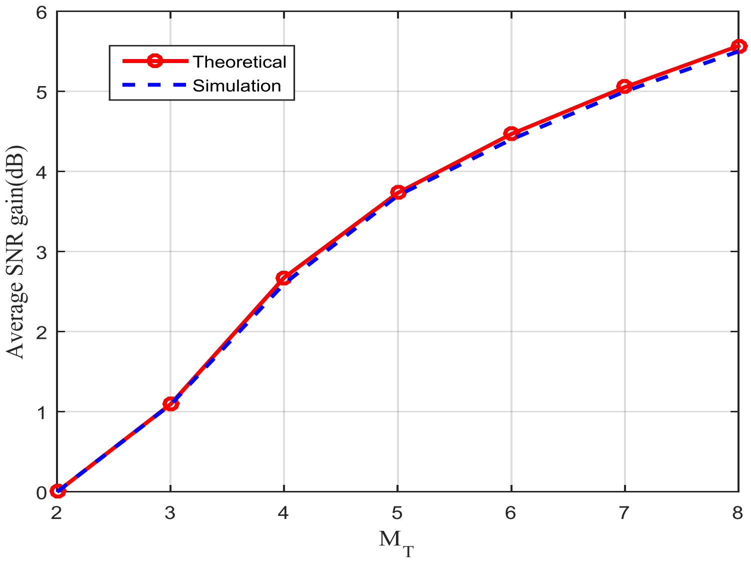

Fig. 2. Average SNR gain for SFBC-OFDM with R-MISO.

Figure 3 shows the average BER comparisons of SISO-OFDM system and SFBC-OFDM with different configurations of R-MISO. It is assumed that 8-QAM ($\alpha = 3$) is performed on each subcarrier. The theoretical BER values are calculated based on the closed form expression in Eq. (13). These values are perfectly matched with the Monte Carlo simulation results of the proposed system. Based on the obtained results, we can observe that the transmit diversity gain increases the BER performance and it also improves the overall system performance. For example, the target BER is observed at 22.5 dB SNR in case of SFBC-OFDM system without antenna selection $(M_T = N_T = 2)$. But for SFBC-OFDM system with $M_T = 4$ and $M_T = 8$, the target BER is achieved at 15.92 dB and 9.56 dB SNR values respectively. This analysis clearly shows that the antenna selection improves the system performance. To attain the target BER, $8:2\times1$ system achieves transmit diversity gain of 6.36 dB and 12.94 dB respectively over $4:2\times1$ and $2:2\times1$ systems.

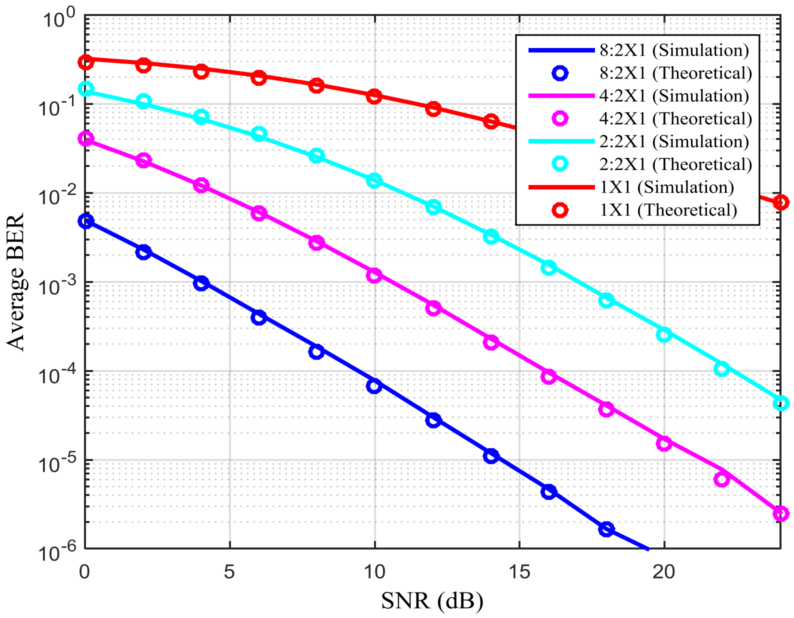

Fig. 3. Average BER performance comparison of proposed system with different configurations of R-MISO.

Figure 4 shows the Monte Carlo simulation results of the average outage probability to achieve the transmission rate (C) of 3 bits/s/Hz on each subcarrier. Here, we have compared the outage probability values of 1×1 system and the proposed system with various configurations of R-MISO. From these results, it is observed that the outage probability of the proposed system is significantly decreased with the increase in M_T. For example, the average outage probability 10^{-1} is observed at 21.82 dB SNR in case of $2:2\times1$ system. But for $4:2\times1$ and $8:2\times1$ systems, the same outage probability is observed at 15.47 dB and 8.9 dB SNR values respectively.

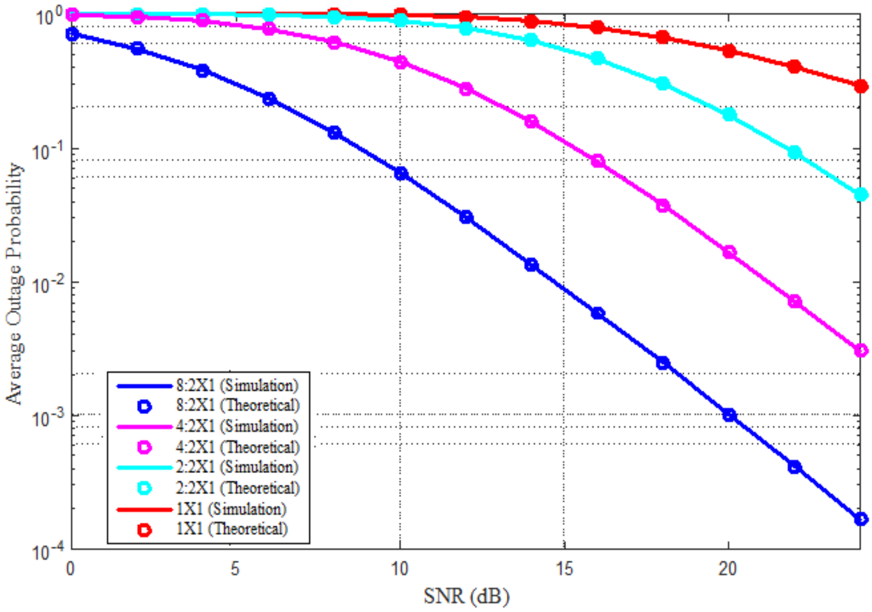

Fig. 4. Average outage probability comparison of proposed system with different configurations of R-MISO.

The average number of bits per subcarrier vs. SNR for the proposed system with various configurations of R-MISO is shown in Fig. 5. From the obtained simulation results, we can observe that the number of bits transmitted on each subcarrier is rapidly increasing in proposed systems when compared with the conventional systems. At 14 dB SNR, the average number of bits transmitted on each subcarrier in 1×1 and $2:2\times1$ systems are 1 and 2 respectively. But, in $4:2\times1$ and $8:2\times1$ systems, the average number of bits transmitted on each subcarrier is 4 and 6 respectively. This analysis clearly shows that the combination of RABL and NBTAS techniques highly increases the transmitted bits per subcarrier. Here we can also observe that increase in M_T, increases the transmitted bits per subcarrier.

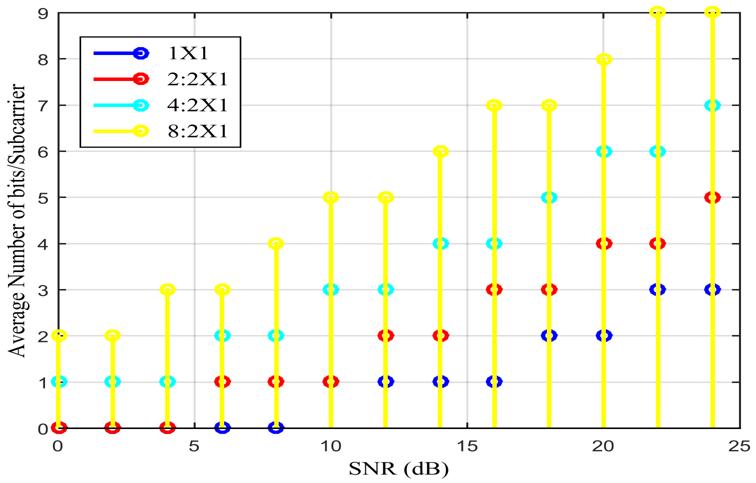

Fig. 5. Average number of bits per subcarrier of the proposed system with different configurations of R-MISO.

In Fig. 6, the average spectral efficiency (bits/s/Hz) vs. SNR (dB) is compared between SISO system and the proposed system with different configurations of R-MISO. From these results, it is clear that $8:2\times1$ system provides high spectral efficiency even for low SNR values when compared to $4:2\times1$, $2:2\times1$ and 1×1 systems. For example, the average spectral efficiency of 3 bits/s/Hz is obtained at 4.68 dB for $8:2\times1$ system. But for $4:2\times1$, $2:2\times1$ and 1×1 the same spectral efficiency is obtained at 11.43 dB, 17.68 dB and 22.94 dB of SNR values respectively.

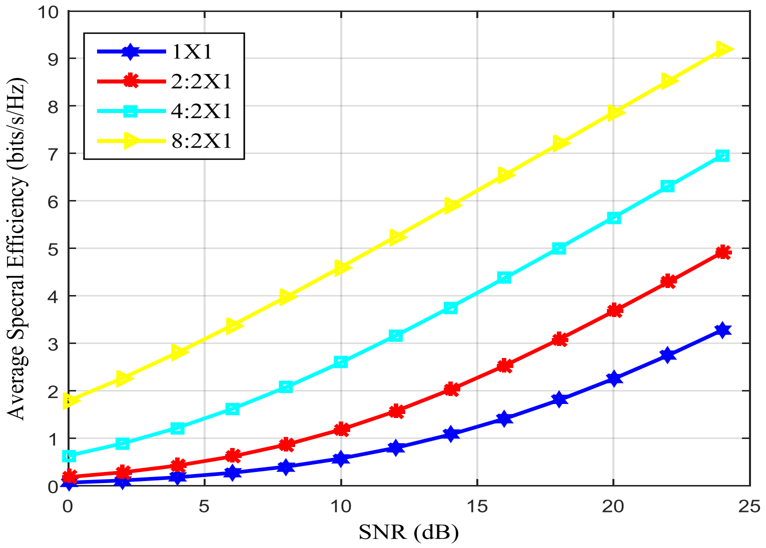

Fig. 6. Average spectral efficiency comparison of proposed system with different configurations of R-MISO.

Figure 7 shows the average data rate (Mbps) vs. SNR (dB) comparison between SISO system and the proposed system with different configurations of R-MISO. From the simulation results, it is clear that $8:2\times1$system offers high data rates when compared to $4:2\times1$, $2:2\times1$and 1×1systems. At 15 dB SNR with 5 MHz limited radio spectrum, $8:2\times1$system achieves 31.1 Mbps data rate. But $4:2\times1$, $2:2\times1$and 1×1systems achieve only 20.3 Mbps, 11.4 Mbps and 6.24 Mbps data rates respectively.

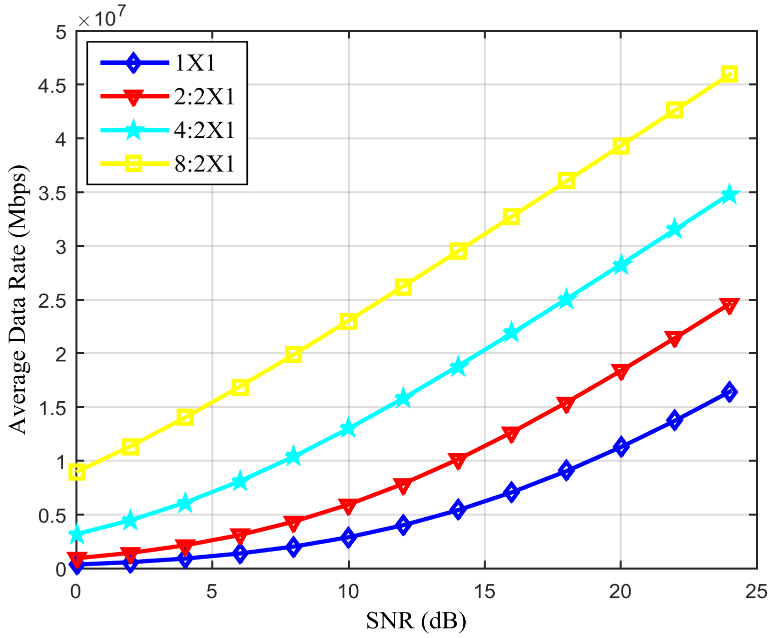

Fig. 7. Average data rate comparison of proposed system with different configurations of R-MISO.

6. Conclusion

In this paper, a low complex high spectral efficient R-MISO-OFDM system is proposed for future demands of multimedia applications. The performance of the proposed system with different configurations of R-MISO is analysed over a frequency selective fading channel with 5 MHz limited bandwidth. The obtained results clearly show that RABL and TAS techniques greatly improve the BER, outage probability, spectral efficiency and data rate performances of the system. The proposed $8:2\times1$system provides high spectral efficiency and high data rates when compared with $4:2\times1$, $2:2\times1$ proposed systems. The $8:2\times1$ system achieves 3 bits/s/Hz spectral efficiency at 4.68 dB SNR. It achieves 31.1 Mbps data rate at 15dB SNR. The simulations are performed on the assumption that perfect CSI is available at the receiver. The effect of imperfect CSI and delayed feedback can be considered as future work.

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