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The Performance Analysis of MIMO OFDM System with Different M-QAM Modulation and Convolution Channel Coding

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***Abstract*—The MIMO-OFDM technology is under the significant considerations for the development of 4G wireless communication systems. The combination of OFDM with MIMO delivers a significant performance improvement in terms of many parameters like data transmission rate, smaller bit error rate (BER), and increased reliability.**

In this paper, a good performance in terms of low BER is achieved with the use of better channel coding technique and modulation scheme. Here, OFDM with 64 QAM modulation and convolution coding with the code rate ¾ is combined with Orthogonal Space Time Block Coding (OSTBC) - a spatial diversity technique which effectively reduces BER. Using MATLAB/Simulink, the performance analysis is carried out by varying the MIMO antenna configuration like 2x2, 3x3, and 4x4 under different fading channel like Rayleigh, Rician fading channels and their effects on BER is examined.

Keywords—OFDM; MIMO; BER; Convolution coding; QAM; OSTBC.

I. INTRODUCTION

There is ahuge demand for providing reliable high-speed wireless communication links to support a wide range of applications. Providing such reliable links is challenging as, in a wireless environment, transmitted signals are received through multiple paths adding destructively and causing serious performance degradations termed as fading. In addition, the medium is normally shared by many different users/applications leading to the possibility of significant interference. Further, high-speed wireless applications have other challenges namely-limitations of available bandwidth, transmit power's constraints, hardware complexity and cost implications. Due to limited frequency spectrum/steady increase of new wireless applications and expansion of existing ones, it may be difficult to accommodate all of them.

In view of the large demands for speedy and reliable communications over wireless channels, future broadband communication systems should provide low complexity data processing, higher data rate, and stronger performance. However, a broadband channel hasdisadvantages liketime-selective and frequency-selective fading. To sort out these challenges, one reliable solution is to combine two powerful technologies, namely, multiple-input multiple-output (MIMO) antennas and orthogonal frequency division multiplexing (OFDM) modulation [1].

As compared to the single antenna systems, the use of the multiple antennas at the transmitter and receiver in wireless systems gives enhanced performance capabilities. The multiantenna system- MIMO ensures higher data transmission rates, wider coverage and higher reliability without using additional frequency spectrum. A reliable performance can be obtained through diversity. The same is achieved in MIMO systems by repetition coding that sends the same information symbols at different time slots from different transmit antennas. Space time block coding (STBC) is a method to achieve high diversity performance which simultaneously transmit the same data over different antennas at different times. Orthogonal space time block code (OSTBC), a variant of space time block coding uses a simple maximum likelihood decoding at the receiver enabling significant error rate improvements.

A multicarrier modulation technique (OFDM) divides input data stream to a number of parallel sub streams and transmitted over the individual subcarriers that are orthogonal to each other. Hence, the wideband frequency selective channel is divided into a number of parallel narrow band sub-channels leading to flat fading. The orthogonality between the subcarriers allows the overlapping of the subcarriers thus preventing the interference between them. The close spacing of the subcarriers enables the efficient utilization of the bandwidth.

The performance of MIMO-OFDM is enhanced by using channel coding technique. This MIMO OFDM uses convolution coding with the code rate ¾ under different multipath fading channels like AWGN in conjunction with Rayleigh and Rician fading channel.

II. SYSTEM MODEL

The modeling of the MIMO OFDM is as shown in the figure 1. The system performance in terms of the bit error rate (BER) is analyzed in MATLAB/Simulink. In this model, the information sequence is generated using Bernoulli binary generator. The forward error correction includes convolution coding, puncturing and interleaving. The output is then converted into OFDM symbols and transmitted over multiple antennas using orthogonal space time block coding technique over the multipath fading channel. At the receiving end, the signal is decoded using OSTBC decoder and then demodulated by OFDM and QAM demodulator. The Viterbi algorithm is used to obtain the transmitted information sequence.

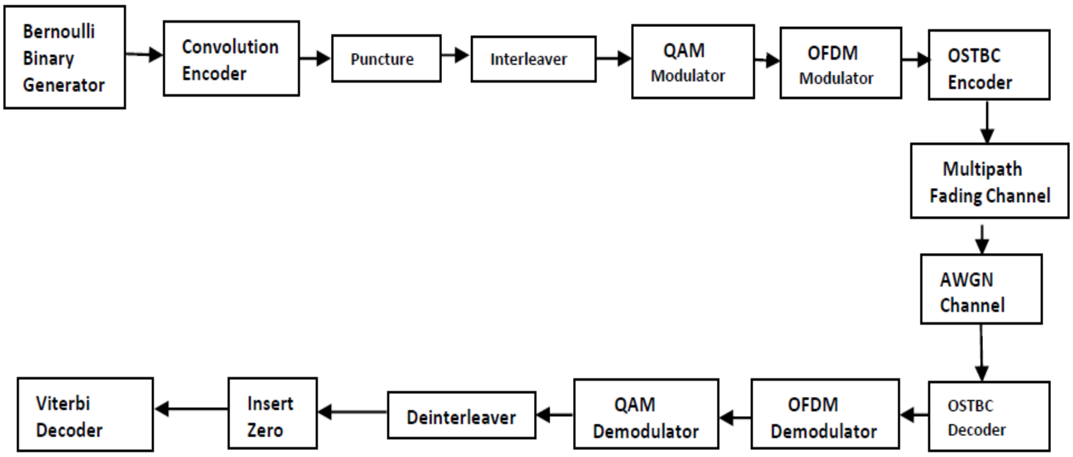

Fig. 1: Block Diagram of MIMO OFDM system

With reference to the above block diagram, the details regarding the sub-blocks are as explained below:

A. Convolution Coding

The main reason for applying error correction coding in the wireless system is to reduce the probability of bit error. The bit errors introduced by the transmission of the signal over the channel is either detected or corrected by the decoder at the receiver. In the convolution encoder with the code rate ½, the input given at a rate of k bits per second gives output data bits at 2k bits per second. The convolution encoder structure used is (171,133) in octal number represents the code generator polynomials with the constraint length of K=7.At the receiver, the decoder uses Viterbi algorithm to recover the information sequence through maximum likelihood decoding.

B. Puncturing

Puncturing is used to create variable code rates by removing the selected bits and retaining others depending on the puncture vector used. The code rate of ½ is used to obtain a ¾ code rate using the puncture vector [110101]. This puncture vector allows the four bits with the 3rd and 5th bit removed for every six bits transmitted. Puncturing eliminates the redundant bits in the convolution encoding thus optimizing transmission bit rate.

C. Interleaving

To improve the performance of the coding in fading channels, coding is combined with the interleaving to overcome the effects of burst errors. Interleaving helps to spread burst errors over many codewords so that each received codeword has only few simultaneous bit errors that can be corrected easily.The matrix interleaver accepts the input row-wise and gives output bits column-wise. Then the general block interleaver will re-arrange the bits without repeating or eliminating them.

D. Orthogonal Frequency Division Multiplexing

The discrete implementation of multicarrier modulation - Orthogonal frequency division multiplexing (OFDM) eliminates the inter symbol interference (ISI) using the cyclic prefix. The individual subcarriers are orthogonal to each other so that the overlapping of the subcarriers does not cause any interference with the adjacent subcarrier [2].

The input bits is modulated by using QAM modulator wherein, the bits are converted to symbols. The symbols are passed through the serial to parallel converter which correspond to the QAM symbols transmitted over each subcarrier. The output of serial to parallel converter is the discrete frequency components. These frequency components are converted to the time domain samples by using the IFFT on these N symbols. The IFFT yields the OFDM symbol consisting of the sequence x[n] of length N [3].

The cyclic prefix is added to the OFDM symbol so that ISI between the data blocks can be eliminated. For the subcarriers of N=64, a cyclic prefix of length 16 is added. The received signal is passed through the channel. At the receiver the cyclic prefix is removed. The time samples are serial-parallel converted and passed through FFT. The FFT output is passed through a QAM demodulator to recover the data. The OFDM decomposes the wideband channel into a number of narrowband sub channels with different QAM symbols sent over each sub channel [3]. The Fig.2 shown below shows the implementation of OFDM system

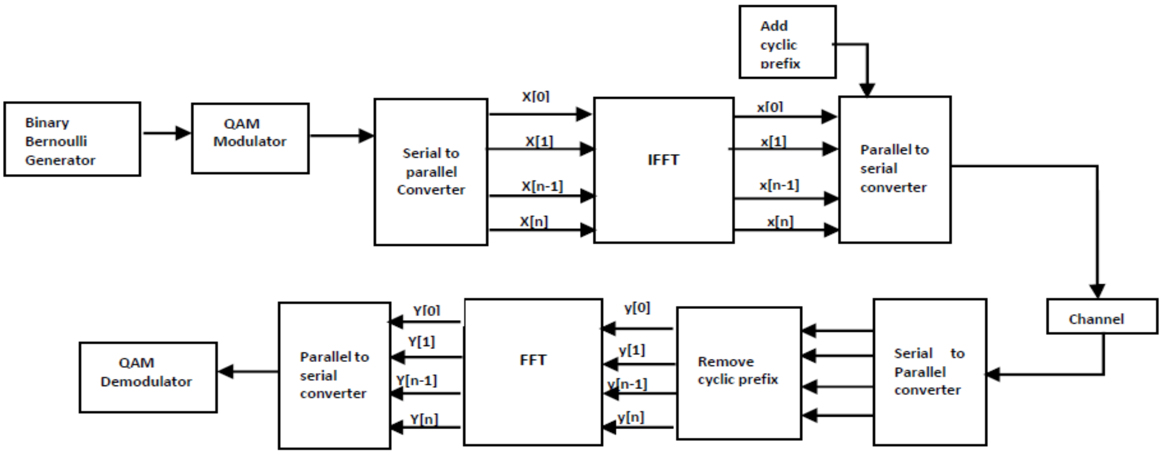

Fig. 2: Block Diagram of OFDM system

E. Space Time Block Coding (STBC)

In STBC multiple copies of the same data are transmitted over a number of antennas.The redundancy results in higher chance of being able to use one or more received copies of data to correctly decode the received signal.STBC can achieve maximal diversity gain with optimal decoding complexity for a given number of transmit and receive antenna. The first STBC with two transmit antennas and one receive antenna was discovered by Alamouti, and is now widely known as the Alamouti code. Alamouti's code uses a complex orthogonal design and satisfies the condition for complex orthogonality in both space and time dimensions [4].The code matrix is given by (1)

$$C_2 = \begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix} \quad (1)$$

A general class of space time block codes called as orthogonal space time block coding (OSTBC) can be used to construct the code matrix for more than two antenna system.

For the 3 transmit antennas and rate ½ is given by (2) [4]:

$$C_3 = \begin{bmatrix} s_1 & s_2 & s_3 \\ -s_2 & s_1 & -s_4 \\ -s_3 & s_4 & s_1 \\ -s_4 & -s_3 & s_2 \\ s_1^* & s_2^* & s_3^* \\ -s_2^* & s_1^* & -s_4^* \\ -s_3^* & s_4^* & s_1^* \\ -s_4^* & -s_3^* & s_2^* \end{bmatrix} \quad (2)$$

For a higher code rate of ¾ is given by (3) [4]:

$$C_3 = \begin{bmatrix} s_1 & s_2 & \frac{s_3}{\sqrt{2}} \\ -s_2^* & s_1^* & \frac{s_3}{\sqrt{2}} \\ \frac{s_3^*}{\sqrt{2}} & \frac{s_3^*}{\sqrt{2}} & \frac{-s_1 - s_1^* + s_2 - s_2^*}{2} \\ \frac{s_3^*}{\sqrt{2}} & \frac{-s_3^*}{\sqrt{2}} & \frac{s_2 + s_2^* + s_1 - s_1^*}{2} \end{bmatrix} \quad (3)$$

For the 4 transmit antennas and rate ½ is given by (4) [4]:

$$C_4 = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2 & s_1 & -s_4 & s_3 \\ -s_3 & s_4 & s_1 & -s_2 \\ -s_4 & -s_3 & s_2 & s_1 \\ s_1^* & s_2^* & s_3^* & s_4^* \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_3^* & s_4^* & s_1^* & -s_2^* \\ -s_4^* & -s_3^* & s_2^* & s_1^* \end{bmatrix} \quad (4)$$

For code rate of ¾ is given by (5) [4]:

$$C_4 = \begin{bmatrix} s_1 & s_2 & \frac{s_3}{\sqrt{2}} & \frac{s_3}{\sqrt{2}} \\ -s_2^* & s_1^* & \frac{s_3}{\sqrt{2}} & \frac{-s_3}{\sqrt{2}} \\ \frac{s_3^*}{\sqrt{2}} & \frac{-s_3^*}{\sqrt{2}} & \frac{-s_1 - s_1^* + s_2 - s_2^*}{2} & \frac{-s_2 - s_2^* + s_1 - s_1^*}{2} \\ \frac{s_3^*}{\sqrt{2}} & \frac{-s_3^*}{\sqrt{2}} & \frac{s_2 + s_2^* + s_1 - s_1^*}{2} & \frac{s_1 + s_1^* + s_2 - s_2^*}{2} \end{bmatrix} \quad (5)$$

In MIMO OFDM, the OFDM symbol of length N is encoded in the codeword matrix of size N x M_t, where N=Number of sub-channels plus Cyclic prefix length and M_t M_t =Number of transmit antennas.

After passing through MIMO channel, thereceived signal is decoded by the OSTBC decoder. The decoder uses a simple maximum likelihood decoding algorithm. The signal received at the receiver of whichr_t^j is a signal at time t at the j-th antenna is given by (6):

$$r_t^j = \sum_{i=0}^{Mt}(x_t^i h_{i,j} + n_t^j) \qquad (6)$$

r_t^j is the signal received by the antenna at the receiver antenna j at time t; x_t^i is the signal transmitted by the transmitter from the antenna i at time t;$h_{i,j}$ is the channel coefficient and $n_t^j$is the channel accepted coefficient.

III. SIMULATION

Fig. 3 shows the Simulink block diagram of MIMO OFDM. The information sequence generated by the Bernoulli binary generator is encoded using convolution encoder with the coding gain of ½.The single bit output codes is combined to produce punctured codes with the rate other than ½ .Here, the rate ½ implementation is converted to ¾ code rate called as puncturing. The punctured code is then interleaved to make the forward error correction much more effective in overcoming the burst errors. The matrix interleaver and general block interleaver is used. The code word is mapped by QAM modulation, 64 QAM modulation is used. The output is given to the OFDM modulator with N=64 subcarriers and a cyclic prefix of 16 is added resulting in the OFDM symbol. The OFDM symbols is transmitted over the multiple antennas using orthogonal space time block coding technique over the fading channel. At the receiver, the data is demodulated and decoded to recover the information sequence. The bit error rate is calculated using error rate calculation.

IV. RESULTS

The simulation of MIMO OFDM system is performed for different M-QAM levels using efficient channel coding technique under different multipath fading channels varying the number of transmitting and receiving antennas.

Fig. 4 shows the BER comparison of M-QAM modulation used in the OFDM system. It shows that as the modulation level is increased, BER is increased. 64 QAM outperforms higher M-QAM levels.

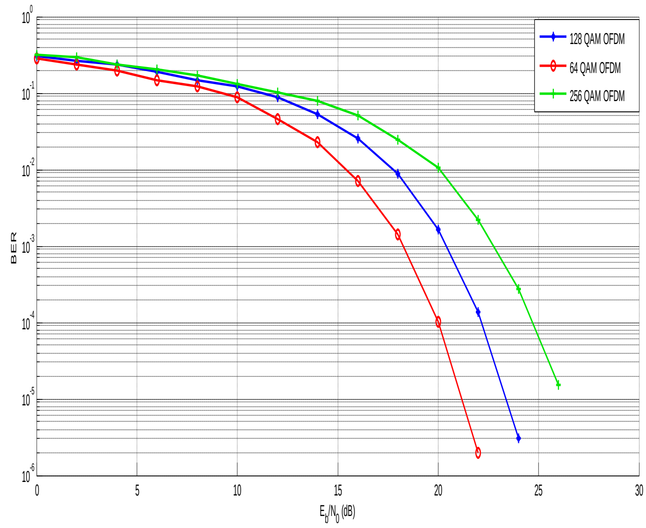

Fig. 4: BER plot of M-QAM in OFDM

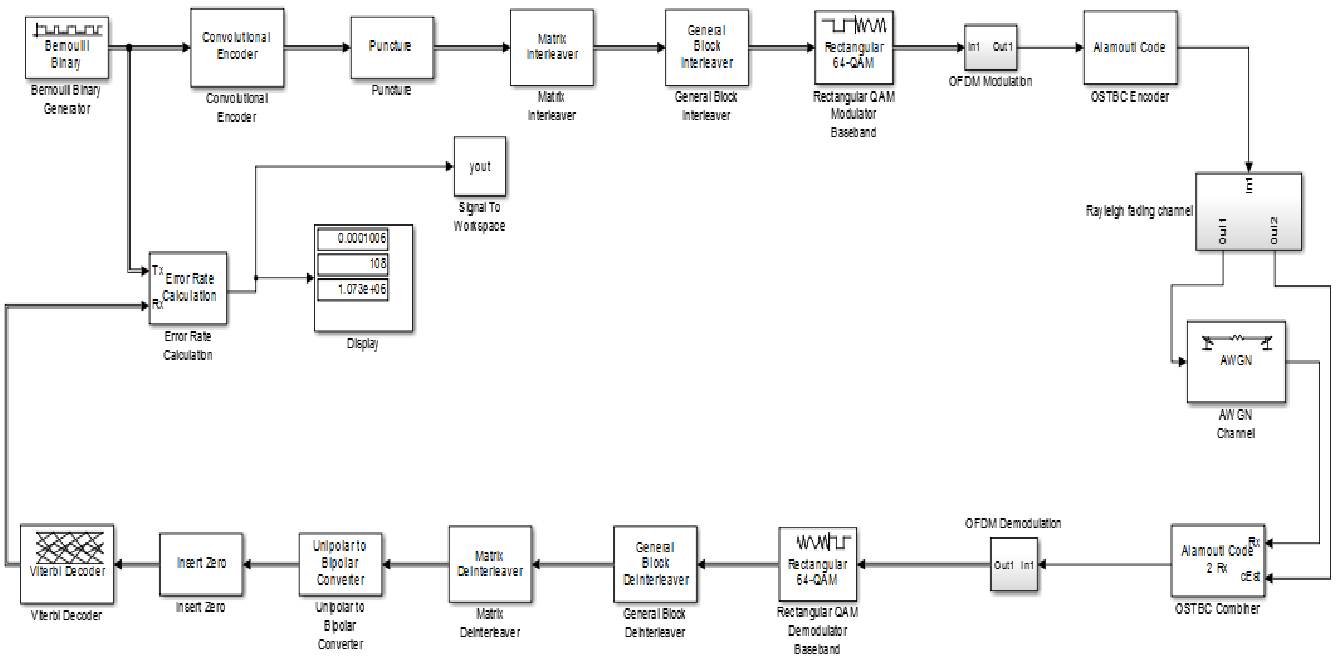

Fig. 3: Simulink Block Diagram of MIMO OFDM

Fig.5 and Fig.6 shows the BER of MIMO OFDM system without channel coding for different transmit and receive antennas. The performance of MIMO OFDM improves as transmit and receive diversity increases.

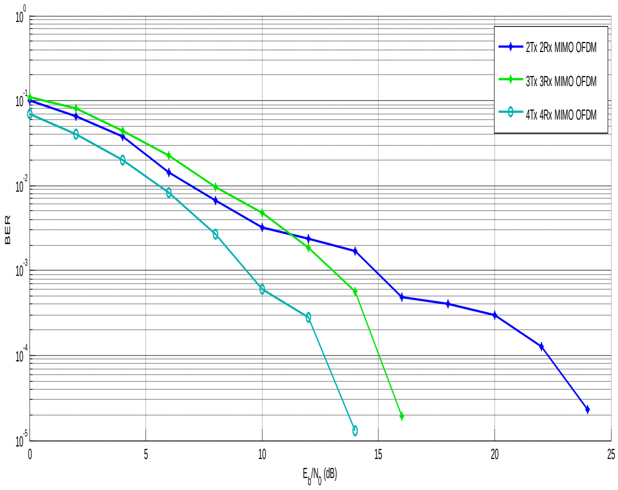

Fig. 5: BER for 2x2, 3x3, 4x4 64-qam MIMO OFDM under Rayleigh fading channel

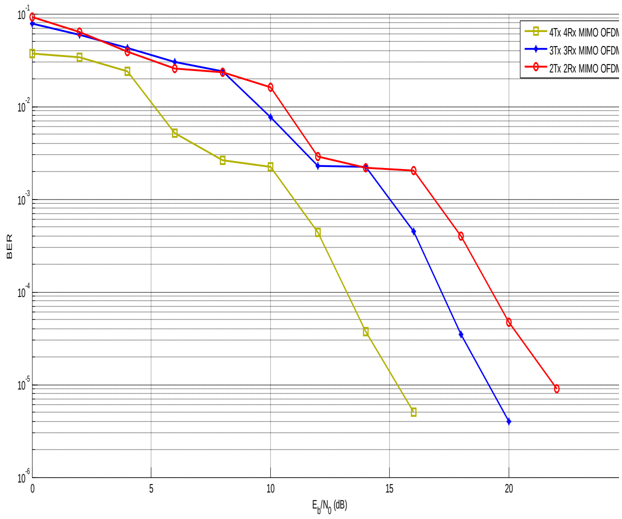

Fig.6: BER for 2x2, 3x3, 4x4 64-qam MIMO OFDM under Rician fading channel

Fig. 7 and Fig. 8 shows the BER comparison of MIMO OFDM system with convolution coding of code rate ¾ .The performance is improved with the inclusion of channel coding in MIMO OFDM.

When examined under Rayleigh and Rician fading channel, performance of MIMO OFDM for with/without channel coding is better under the Rayleigh fading channel.

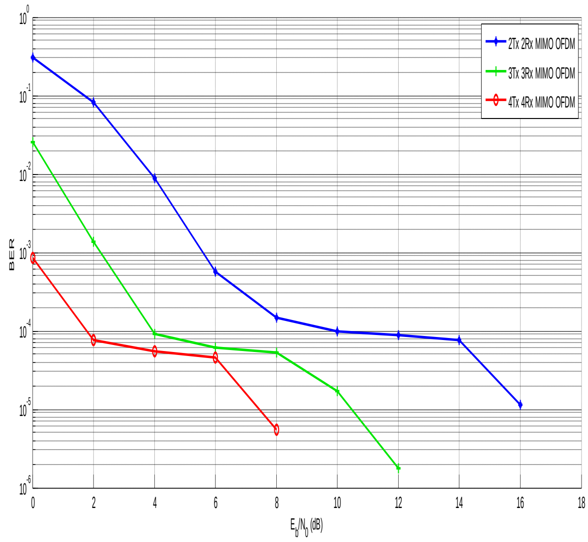

Fig. 7: BER of 2x2, 3x3, 4x4 64-qam MIMO OFDM with convolution coding under Rayleigh channel

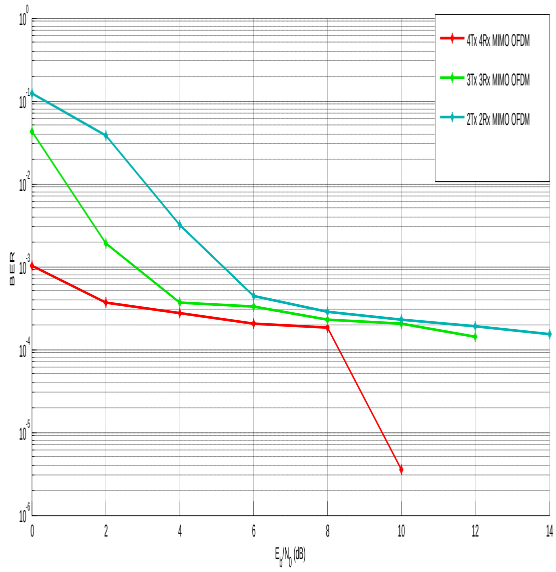

Fig. 8: BER for 2x2, 3x3, 4x4 64-qam MIMO OFDM with convolution coding under Rician fading channel

V. CONCLUSION

The performance of MIMO OFDM system is analysed for different M-QAM modulation with convolution channel coding by varying the number of transmit and receive antennas. Lower modulation order and higher transmit and receive diversity reduces bit error rate (BER) resulting in better/improved performance. In addition to the above, the results show that convolution coding scheme under Rayleigh multipath fading channel improves performance with less Signal-to-Noise ratio (SNR).

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