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Performance Analysis of Relay Aided TCOFDM

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Abstract*—Orthogonal Frequency Division Multiplexing (OFDM) is used in many communication systems as it enhances the data rate with reduction in bandwidth. For providing better data rate at cell edges intermediate nodes known as relay nodes are incorporated between the source and destination. The main objective of relay aided OFDM is to transmit the OFDM signal with low bit error rate (BER) in a noisy environment. To reduce the BER normally with the standard OFDM a forward error correcting (FEC) code is used. This paper analyses the BER performance of an Amplify & Forward (AF) relay aided OFDM encoded using turbo codes (TC).

***Index Terms*—OFDM, AF relaying, Turbo codes, BER**

I. INTRODUCTION

Nowadays people aim at transmitting information in a quicker pace, wirelessly, accurately and also reliably. Many techniques have been evolved which is capable of transmitting information with higher data rates. OFDM is one such method where orthogonal carriers are used for data transmission. The problem associated with OFDM is that as the distance between the source and destination increases the information is subjected to distant dependent fading. As a result of this the users far away from source is likely to compromise with less data rates. This is also the case in an urban scenario, where due to the effect of shadowing cell edge users are subjected to scarce data rate. One solution is to restructure the cellular architecture or to deploy more number of basestations (BS). Both these solutions are expensive. Hence an alternate choice is to deploy low power nodes between the source and destination. These nodes are the relay nodes. Relay aided OFDM is used widely now in communication scenarios. The main objective in a relay aided transmission is to reduce the bit errors. The BER is generally affected by the factors such as noise, interference and distortion. To improve the BER generally the procedure is to i) make the signal strong, ii) employ a robust modulation scheme and iii) perform FEC [1]. In this paper an AF relaying scheme is adopted along with QAM and turbo coding to reduce the BER of OFDM. The paper will give a comparative analysis of performance of standard OFDM, coded OFDM and relayed OFDM in AWGN channel.Section II focuses on OFDM, its principles, advantagesand disadvantages.Section III gives a review of relaying strategy, section IV gives a description on turbo coding and decoding, Section V deals with the simulation model used and parameters and section VI addresses the performance evaluation of AF relay aided TCOFDM.

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

OFDM is a multicarrier modulation technique. Here the entire bandwidth is subdivided into number of subcarriers. The higher data streams are split into lower data streams and are transmitted in the subcarriers. The specialty of the subcarriers is that they will be orthogonal to each other such that there will be no overlapping of the information [2].The block illustration of OFDM is given in Fig.1. The upper part forms the transmitter and the lower forms the receiver. Initially the information is given to serial to parallel (S/P) block where the serial data is converted into parallel format. The parallelstream of bits isthen mapped into symbols using any of the robust modulation schemes like QPSK, QAM etc. After that the mapped symbols are given to the IFFT block where the mapped symbols are modulated into different subcarriers.This is then converted to serial bit stream by the parallel to series (P/S) block. A cyclic prefix (CP) is added. Here the last part of the OFDM symbol will be pasted in front of the OFDM symbol thereby reducing the intersymbol interference (ISI).The OFDM symbol is then fed to the channel where it gets corrupted by the noise. At the receiver the data corrupted by the channel noise is first fed to the CP removal block where the CP is removed. Then the data is converted into parallel format and is applied to the FFT block for demodulation of carriers. Demodulation of the incoming symbol is done and the data is serialized to yield the output. The advantages of OFDM are high spectral efficiency, immunity to fading, efficient modulation and demodulation since FFT and IFFT areused. The major disadvantages of OFDM are high PAPR and need for frequency and timing synchronization.

III. RELAYING

The users far from the base station (BS) suffer from coverage problem due to pathloss and shadowing effects. This type of fading is known as the distance dependent fading. In order to mitigate the effect of this type of fading either the cell size has to be reduced or new BS has to be installed. Both these solutions are not cost effective. That is inorder to reduce the cell size the cell structure has to be restructured which is tedious.

Also installation of new BS will incur high operational costs. To combat the effect of distance dependent fading in a cost effective manner the solution is to place intermediate nodes in between the mobile station (MS) and BS. Such

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intermediate nodes are the relays. These intermediate nodes are low power nodes.

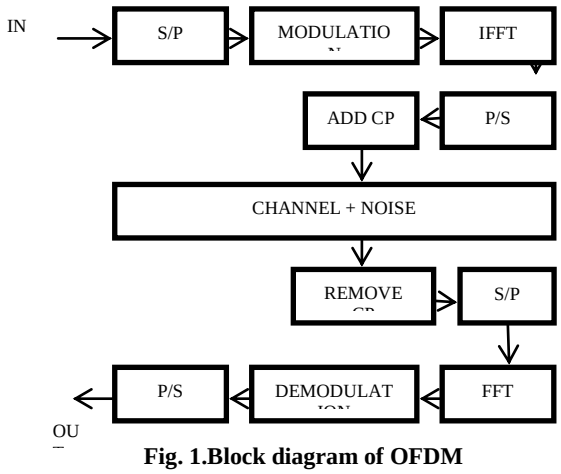

Fig. 1.Block diagram of OFDM

The relays shorten the direct path into smaller links [3]-[4]. Thus the effect of pathloss and shadowing becomes negligible. This also improves reliability. The first type of relays that were in use were the analog repeaters and nowadays researchers are trying to use MS that lie closer to BS as the relays, this accounts for user cooperation. Fig. 2illustrates one hop relay. 'S' denotes the source, 'D' denotes the destination and 'R' denotes the relay. The relays are generally of two types. They are

1. Fixed relays
2. Mobile relays

The fixed relays are deployed in the cells. They also require adequate amount for installation hence a few will be deployed. The mobile relays are mobile in nature and they can be placed in vehicles. Compared to fixed relays they require only less amount of power. User cooperation is one such mobile relay where the users closer to BS who have stronger direct link with BS relays the information to users that are far from BS. There are two relaying strategies. They are amplify-and-forward (AF) anddecode-and-forward (DF). In AF relaying, the relay amplifies the information and is forwarded to the destination. The disadvantage with this strategy is that if there is any noise it will also get amplified and forwarded. In DF relaying, the information is first decoded and is then re-encoded and forwarded. The disadvantage with this scheme is that if the information is correctly decoded then only it will be re-encoded and forwarded. The advantages of relaying are:

i. Combats the effect of distance dependent fading.
ii. Cost effective
iii. Better datarate
iv. Improved reliability

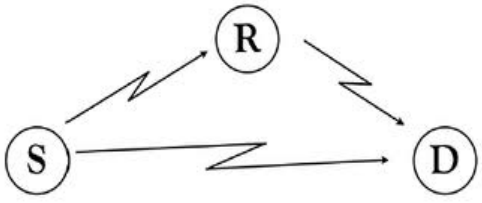

Fig. 2. One hop relay

The relay aided OFDM model is given in Fig. 3. All other blocks remain the same. Additional that is that a relay node will be in the channel.

IV. TURBO CODES

The turbo codes are special form of convolutional coding. In convolutional coding a single parity is transmitted with the message. Here an additional parity is also sent with the message. Parity bits are generated using generator polynomials [5]. The turbo encoder is given in Fig.4. Convolutional coding of data is carried out in encoders 1 and 2 i.e; first the input is directly encoded by convolutional coding at encoder 1which gives the first output. The same input is interleaved and is then encoded at the second encoder which gives the second output.Turbo codes can be decoded by either Viterbi algorithm or BCJR algorithm. In this paper BCJR algorithm is chosen for decoding. The turbo decoder does the reverse operation of the turbo encoder which is shown in Fig. 5.

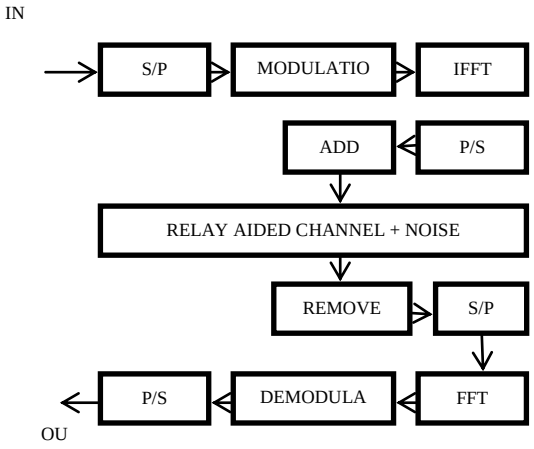

Fig. 3. Block diagram of relay aided OFDM

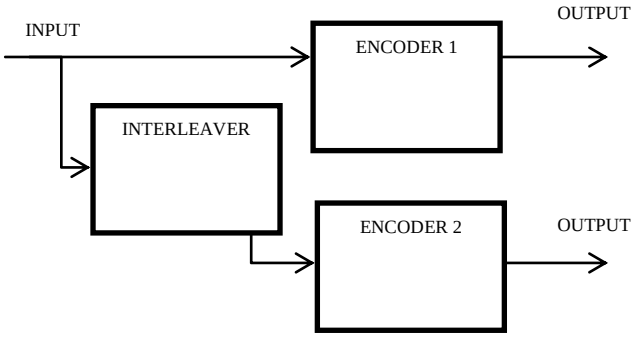

Fig. 4. Turbo Encoder

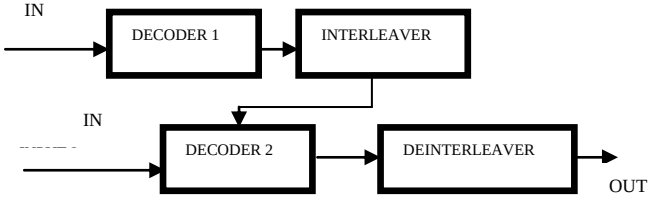

Fig. 5. Turbo decoder

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The input of the turbo decoder is a sequence of received code values. There are two component decoders which are operated by BCJR algorithm. Decoder 1 will take the encoder 1 output and decoder 2 will take encoder 2 outputs. The decoder 2 will also have the interleaved output of decoder 1. The output of decoder 2 will then be deinterleaved to give the decoded output.

V. SIMULATION MODEL

The combination of OFDM transmission and turbo codes is called as the TCOFDM. TCOFDM can yield significant improvement in terms of lower energy needed to transmit data. The AF relay aided TCOFDM block illustration is given in Fig. 6. Blocks mentioned in Fig. 6 are already mentioned in section II, III and IV

A. Simulation Algorithm

The performances of AF relay aided TCOFDM is analyzed using the simulation tool MATLAB 2013a. The simulation procedure carried out is illustrated in the following Fig. 7[6], [10].

B. Simulation Parameters

Table 1 shows the various simulation parameters used for the simulation of the system in MATLAB.

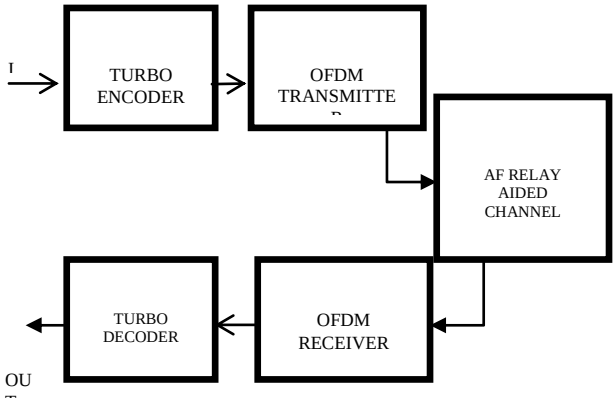

Fig.6. AF relay aided TCOFDM

TABLE 1. SIMULATION PARAMETERS

Parameters	values
input bits	90000
modulation index	8
Modulation type	QAM
ifft length	16
cp length	16
af amplification	1.2

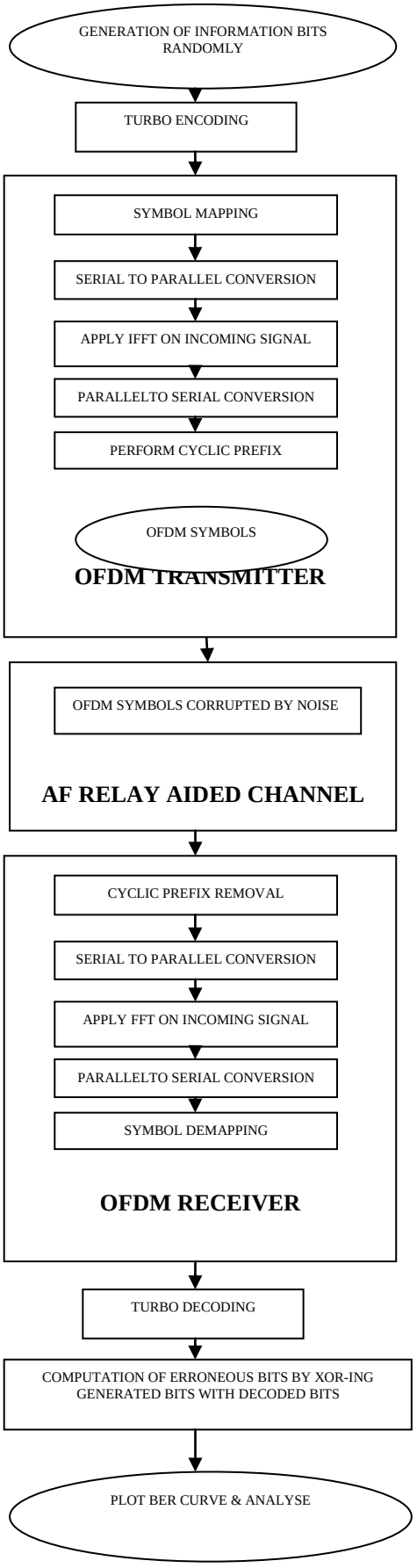

Fig. 7. Illustration of the simulation work

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VI. PEFORMANCE ANALYSIS OF TCOFDM

Simulations are done to obtain a desired BER performance. Initially the block given in Fig.1 was simulated. The error performance of standard OFDM is shown in Fig. 8 which gives a BER of 10^{-4} at 14 dB.In order to improve the error performance of the standard OFDM, block diagram given in Fig. 3 was simulated. The AF relay aided OFDM has shown an error performance shown in Fig. 9.The comparison curve showing both standard OFDM and AF relay aided OFDM is given in Fig. 10.From this it is clear that by making the signal strong BER can be improved. In Fig. 10 upto 12dB relayed OFDM gives better BER but after 12 dB the performance of relay OFDM is poor, because AF relay amplifies the noise along with the signal. BER is normally affected by noise, interference, distortion etc. which can be improved by making the signal strong, robust modulation and efficient channel coding. is shown in Fig. 11.

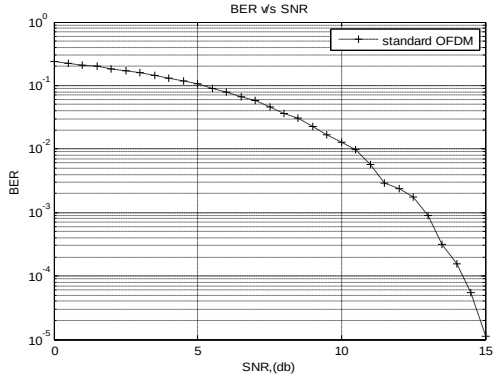

Fig. 8. BER curve of standard OFDM

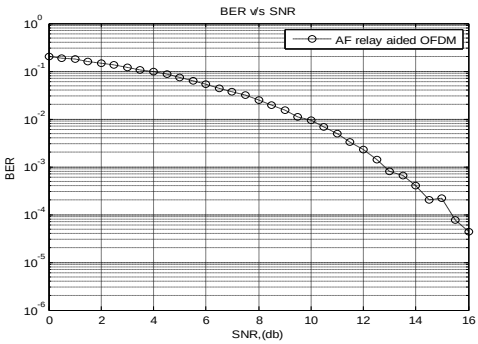

Fig. 9. BER curve of AF relay aided OFDM

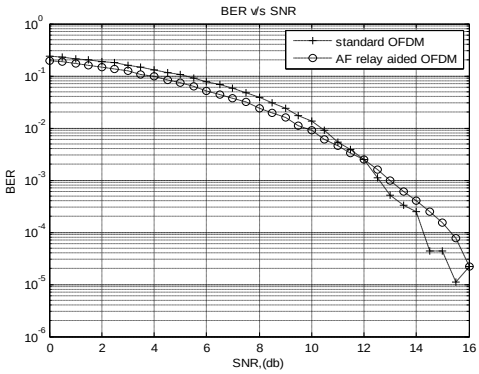

Fig. 10. Comparison of BER curve of standard OFDM and AF relay aided OFDM

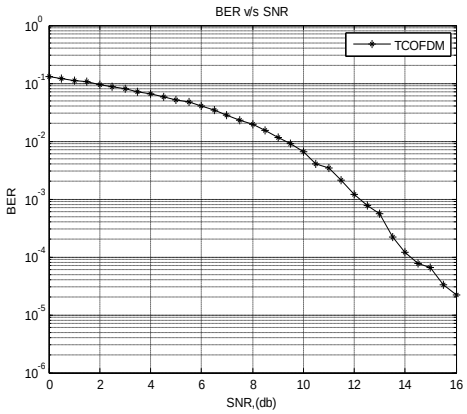

Fig. 11. BER curve of TCOFDM

Hence for the improvement in BER the OFDM is coded using turbo coding. TCOFDM was simulated and its performance

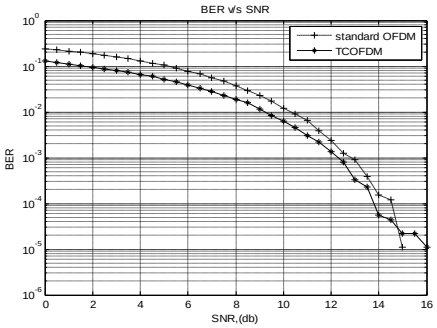

Fig. 12. Comparison of BER curve of standard OFDM and TCOFDM

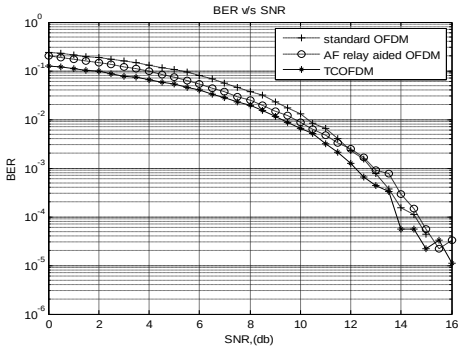

Fig. 13.Comparison of BER curve of standard, AF relayed and TCOFDM

It is superior to that of standard and relay OFDM. Fig. 12 shows the performance comparison of coded OFDM and uncoded OFDM. From the figure it is clear that coded OFDM gives better performance. Fig. 13 shows the comparison of BER of standard OFDM, AF relayed and TCOFDM. From this it is clear that by amplifying the signal i.e; by making the signal strong and also by performing channel coding BER can be improved [7]-[9]. The BER performance forAF relayed TCOFDM is shown in Fig. 14. It gives a BER of 10^{-4} at approximately 12 dB. The Fig. 15 shows the comparison curve of performances. From this it is evident that AF relay aided TCOFDM is superior to that of standard, relay OFDM and coded OFDM and gives a far better BER performance.

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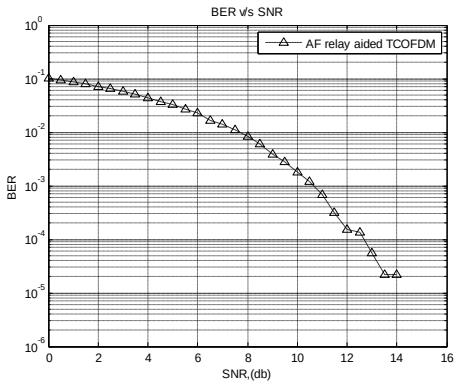

Fig. 14. BER curve of AF relay aided TCOFDM

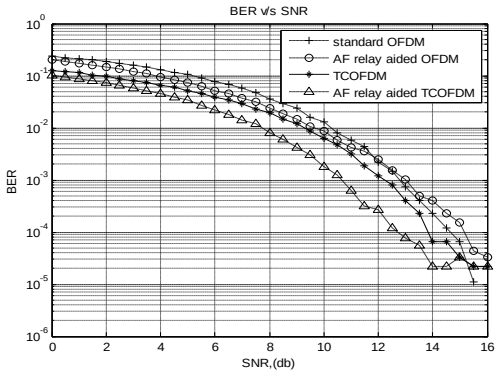

Fig. 15. Comparison of BER curve of standard, AF relayed, TCOFDM and AF relay aided TCOFDM

VII. CONCLUSION

This paper was aimed at improving the BER performance of OFDM. From the review of related literature it was found that by making the signal strong or by channel coding BER can be improved.Performance analysis of standard OFDM was done then to improve it AF relaying was done which yielded better BER.Then turbo coding was done on OFDM which also improved the BER performance. By comparing BER of standard OFDM with relayed and coded OFDM it was clear that both yielded better BER. Hence AF relay aided TCOFDM was simulated which has given superior performance compared to all. Future work comprises the performance analysis of AF relay aided TCOFDM under other channels like Rayleigh and rician.

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