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LDPC based Full Rate Full Diversity Space Frequency Block Coded system under DVB-T2 standard

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***Abstract*—DVB-T2 or DVB-NGH, are future generation wireless communication standards including multi-antenna transmission and reception in order to increase bandwidth efficiency and receiver robustness. Space time coding is one of the main methods in order to exploit the capacity of multiple-input multiple-output (MIMO) channels. Since STC techniques use both time and spatial domains for coding data symbols, diversity and spatial multiplexing can be combined achieving robustness at the receiver with a higher data rate transmission. Full-rate full-diversity (FRFD) space-time codes (STC) such as the Almouti code are studied for that purpose. However, despite their larger achievable capacity, most of them present high complexity for soft detection which hinders their combination with soft-input decoders in bit-interleaved coded modulation (BICM) schemes. The low density parity check based SFBC MIMO transmission and reception scheme based on DVB-T2 is done here. This article presents a novel low complexity soft detection scheme for the reception of FRFD space-frequency block codes in BICM orthogonal frequency division multiplexing (OFDM) systems. The proposed detector maintains a reduced and fixed complexity. The model is implemented using MATLAB. The proposed detector maintains a reduced and fixed complexity. Finally a combination of selective mapping algorithm and DCT Transform is done in the same scheme for the modification of OFDM system which results in low complexity with reduced PAPR noise system.**

***Keywords*— *STC, FRFD, SFBC, BICM, DVB-T2, PAPR* .**

I.INTRODUCTION

Based on recent research results and a set of commercial requirements, DVB(Digital Video Broadcasting) consortium has recently developed a new digital terrestrial television standard named DVB-T2. This new specification has increased the robustness and the spectral efficiency of its predecessor (DVB-T) using space time codes and multiple input multiple output (MIMO) channels [1].

If STC (Space Time Code) is joined to multi-carrier modulation, such as orthogonal frequency-division multiplexing (OFDM), space frequency block coding (SFBC) can be performed. This way, codeword are fed into adjacent carriers of the two consecutive OFDM symbols, translated to the time domain and transmitted through several transmit antennas. This transmission scheme is usually combined with bit-interleaved coded modulation (BICM) giving good diversity results in a wireless communication link [4]. In order to achieve the full MIMO diversity-multiplexing frontier, the proposals for the future generations of terrestrial, portable and mobile digital video broadcasting standards, such as DVB-NGH, focus on the combination of both diversity and spatial multiplexing through full-rate full-diversity (FRFD) codes [6][8].

The main drawback of full-rate codes arises from their very high decoding complexity, which grows exponentially with the number of transmitted symbols per codeword. In order to reduce the complexity of the detection process, hard detection techniques such as sphere decoding (SD) or low complexity STC designs [8][9] can be used. Nevertheless, when iterative decoders, such as turbo or low-density parity check (LDPC) codes, are included in the reception chain, soft information on the conditional probabilities for all possible transmitted symbols is required in the form of log-likelihood ratios (LLR). Hence the design of efficient detection algorithms is one of the greatest challenges when implementing full-rate SFBC.

Normally PAPR is considered to be one of the challenges in any OFDM system. Two possible combinations of spatial diversity and OFDM techniques are space-time-block-coded (STBC) OFDM and space-frequency-block coded (SFBC) OFDM systems. Both combinations suffer from high- PAPR problem. Here we use SFBC OFDM system. Hence we aim to reduce the PAPR in SFBC OFDM system using a new scheme which is a combination of existing two method.

In this thesis report the first chapter contains introduction to SFBC MIMO transmission and reception scheme based on DVB-T2 is done here. The second caper contains the literature survey of the thesis related to the LDPC based SFBC MIMO system and its technical challenges. The third chapter presents the proposed system and a low complexity soft detection algorithm for the reception of FRFD space-frequency block codes in BICM orthogonal frequency division multiplexing (OFDM) systems. The fourth and fifth chapter includes the technical challenges faced by a LDPC based SFBC MIMO system in a DVB-T2 scenario. That is the effect of PAPR and ICI on BER performance of a DVB-T2 based system. The sixth chapter investigate the complexity value and the performance characteristics of system with effect of PAPR and ICI reduction through extensive simulations in MATLAB and. The last chapter includes the conclusion obtained from the analysis of the result.

I. SFBC BICM OFDM SYSTEM

Digital Video Broadcasting-Terrestrial (DVB-T) is the most widely deployed digital terrestrial television system worldwide with services on air. In order to increase its spectral efficiency and to enable new services the DVB consortium has developed a new standard named DVB-T2. The latest coding, interleaving and modulation techniques have been included in this system to provide capacity and robustness in the terrestrial transmission environment. The first remarkable novelty lies on the error correction strategy that DVB-T2 uses is a combination of LDPC and Bose-Chaudhuri-Hocquenghem (BCH) codes as channel codes, which offer excellent performance resulting in a very robust signal reception. LDPC-based forward error correction (FEC) techniques can offer a significant improvement compared with the convolutional error correcting scheme used in DVB-T. DVB-T2 also specifies a transmitter diversity method, known as Alamouti coding, which improves coverage in small scale single-frequency networks.

Regarding the modulation, DVB-T2 uses the same OFDM technique. The new standard has introduced longer modes (16K and 32K) with the aim of increasing the length of the guard interval without decreasing the spectral efficiency. On the other hand, three cascaded forms of interleaving have been included: bit, time and frequency interleaves. Therefore, DVB-T2 is a complex bit-interleaved coded modulation (BICM) OFDM communication system with multi-antenna transmission and reception in order to increase bandwidth efficiency and receiver robustness.

If STC is joined to multi-carrier modulation, such as orthogonal frequency-division multiplexing (OFDM), space frequency block coding (SFBC) can be performed. This transmission scheme is usually combined with bit-interleaved coded modulation (BICM) giving good diversity results in a wireless communication link. In order to achieve the full MIMO diversity-multiplexing frontier a combination of diversity and spatial multiplexing [6], [7] through full-rate full-diversity (FRFD) codes [8] is used. The main drawback of full-rate codes arises from their very high decoding complexity, which grows exponentially with the number of transmitted symbols per codeword. In order to reduce the complexity of the detection process, hard detection techniques such as sphere decoding (SD) or low complexity STC designs [8], [9] can be used.

The aim of the existing system is to detect the low complexity of full rate SFBC in BICM-OFDM systems and its assessment in an LDPC-based BICM scenario. The basic structure of the LDPC-coded BICM-OFDM system is depicted in Fig.3. 2. As can be seen, the bit stream is coded, interleaved and mapped onto a complex constellation. Next, a vector of Q symbols s is coded into space and frequency forming the code word X, which is transformed into the time domain by an inverse fast Fourier transform (IFFT) block and transmitted after the addition of a cyclic prefix. At the receiver side, the prefix is removed, a fast Fourier transform (FFT) is carried out and the resulting signal Y of dimensions $N \times T$ can be represented mathematically as $Y = HX + Z$,

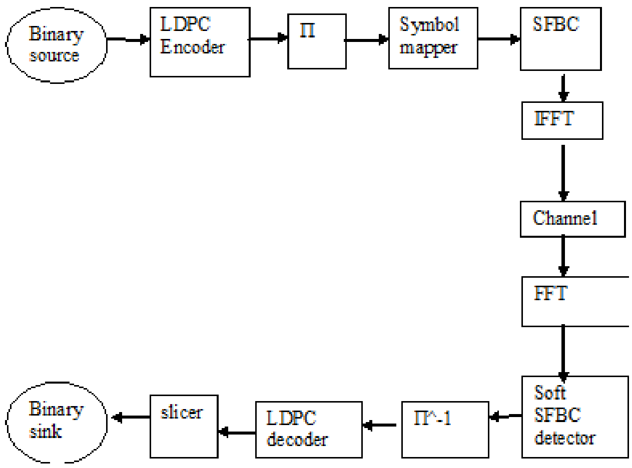

Fig1: LDPC- based SFBC MIMO transmission and reception based on DVB-T2

A. *Transmitter section*

The transmitter section consists of low density parity encoder (LDPC), Interleaver or filter, symbol mapper, space frequency block coding (SFBC), IFFT. The combination of LDPC encoder. Interleaver and symbol mapper performs the Bit Interleaved Coded Modulation (BICM).

1. LDPC Encoder***:***
The binary input is given to the low density parity check encoder. The low density parity check encoder is an input matrix. The binary values such as 0 and 1 are added to the matrix. So that even if any losses occurred during the transmission of signals, it will affect only the added binary values. so that the error can be reduced .

2. Filter:
In order to reduce the noise of the signal, the output of the low density parity check (LDPC) encoder is given to the filter .Here the bit stream is interleaved in to the complex constellation.

3. Symbol Mapper ***:***
To achieve a signal of correct domain and shape, the signal is given to symbol mapper which maps the signal on to the complex constellation.

4. Space Frequency Block Coding ***:***
If Space time coding (STC) is joined to multi-carrier modulation, such as orthogonal frequency-division multiplexing (OFDM), space frequency block coding (SFBC) can be performed. **S**pace time coding is one of the main methods in order to exploit the capacity of multiple-input multiple-output (MIMO) channels. Since STC techniques use both time and spatial domains for coding data symbols, diversity and spatial multiplexing can be combined achieving

robustness at the receiver with a higher data rate transmission. As a result, STC techniques have been incorporated in many of the last-generation wireless communications systems, including the new generation of terrestrial and mobile digital video broadcasting (DVB) standards. This way, code words are fed into adjacent carriers of the two consecutive OFDM symbols, translated to the time domain and transmitted through several transmit antennas. This transmission scheme is usually combined with bit-interleaved coded modulation (BICM) giving good diversity results in a wireless communication link.

5. IFFT
An N-point IFFT is used to for OFDM modulation and converting the signal to a time domain signal. Before taking the IFFT, zero padding is incorporated which allow selecting different OFDM sizes and allocates any desired number of subcarriers for carrying data and pad the remaining including the centre dc carrier with zeros. Zero padding is necessary to avoid inter-carrier interference (ICI) in OFDM systems showing that using all subcarriers for data is not realistic. The output of IFFT is converted to serial and a cyclic prefix is then added. Since perfect channel state information at receiver has been assumed, training symbols have not been added for synchronization and channel estimation

B. RECEIVER SECTION

The receiver performs the reverse process .The receiver section consists of FFT, Soft (Space frequency block coding (SFBC), Filter or Interleaver, low density parity check (LDPC) Decoder, Slicer.

1. FFT
The receiver performs the reverse process. Firstly the cyclic prefixes appended to each OFDM symbol are removed. Then the time domain signal is converted back into frequency domain signal through the FFT process.

2. Soft SFBC Detector
A diversity combiner is used at the receiver for detection. It takes the output from the de-multiplexers at the output of FFT block and performs space frequency block decoding. The output of space frequency block decoder is input to the filter.

3. Filter :
The output of soft SFBC (SPACE FREQUENCY BLOCK CODING) detector is given to the filter in order to reduce the noise of the signal.

4. LDPC Decoder:
The input from the filter is given to the low density parity check decoder. The low density parity check decoder is also a matrix. Here also the binary values such as 0 and 1 are added to the matrix. So that even if any losses occurred during the transmission of signals, it will affect only the added binary values. so that the error can be reduced. The receiver section performs the reverse process of the transmitter section.

5.Slicer :
The slicer is mainly used to reduce the noise of the signal. The slicer slices the noise from the signal. So that finally the output of LDPC decoder is given to the slicer**.**

C. Transmission scheme used -Almouti Scheme

The DVB-T2 standard describes a transmit diversity method with two antennas based on a modified Alamouti coding scheme (Alamouti, 1998). The coding algorithm is generically called space–frequency block coding (SFBC) since the Alamouti scheme is used in spatial and frequency domain .The Alamouti SFBC approach processes the of the antennas and modified values ([*-b0**, *a0**]) at the other one, thus increasing the transmit diversity while keeping the symbol rate.

II. FIXED-COMPLEXITY SOFT DETECTION

The maximum likelihood decoder for a MIMO receiver operates by comparing the received signal vector with all possible noiseless received signals corresponding to all possible transmitted signals. Under certain assumptions, this receiver achieves optimal performance in the sense of maximizing the probability of correct data detection. However, the complexity of this decoder increases exponentially with the number of transmit antennas, making it impossible to implement for large array sizes and high order digital modulation schemes.

This section provides a very brief overview of how the proposed method- List fixed sphere decoder(LSD) differs from the standard sphere decoder(SD)

D. Existing method-Sphere Decoder(SD)

The main idea of the Sphere Decoder is to reduce the computational complexity of the maximum likelihood detector by only searching over only the noiseless received signals that lie within a hypersphere of radius R around the received signal. Normally, this algorithm is implemented as a depth first tree search, where each level in the search represents one transmit antenna's signal. This is illustrated in Figure 2 below. If at a given level, a given branch exceeds the radius constraint, then that part of the tree can be removed from further consideration. Unfortunately, it is difficult to estimate how much of the tree needs to be searched in advance, since this depends on both the noise and the channel conditions. This means that the complexity of the sphere decoder is not fixed, but will typically vary with time.

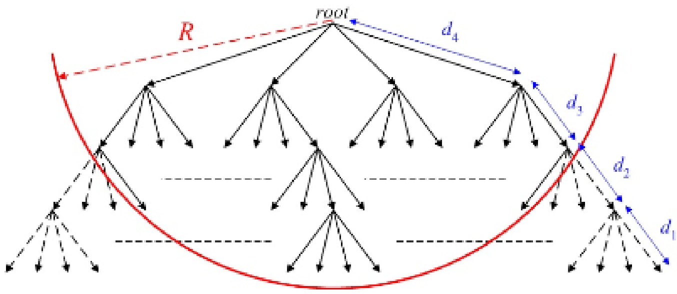

Figure 2: The Tree Structure and Sphere Constraint for the Sphere Decoder.

E. Proposed method-List Fixed Sphere Decoder(LFSSD)

The main idea behind the list Fixed Sphere Decoder is to perform a search over only a fixed number of possible transmitted signals, generated by a small subset of all possible signals located around the received signal vector. This ensures that the detector complexity is fixed over time, a major advantage for hardware implementation. In order for such a search to operate efficiently, a key point is to order the antennas in such a way that most of the points considered relate to transmit antennas with the poorest signal-to-noise (SNR) conditions. Antennas with higher SNR conditions are much more likely to be detected correctly, based only on the received signal. Figure7. 3 below shows a hypothetical subset S in 4 transmit antenna, 4 recieve antenna system with 4-QAM constellations used at each transmit antenna. The number of points considered per level (i.e. transmit antenna) is (n1,n2,n3,n4) = (1,1,2,3). In each level, the ni closest points to the received signal are considered as components of the subset S. In this case, the Euclidean distance of only 6 transmitted vectors would be calculated, whereas the total number of possible vectors, 256, is much larger.

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II. PAPR OF THE SYSTEM

A major drawback of OFDM at the transmitter is the high peak-to-average power ratio (PAPR) of the transmitted signal. The PAPR of the OFDM signal X (t) is defined as:

PARP= PPEAK /PAVERAGE

These large peaks require linear and consequently inefficient power amplifiers. To avoid operating the power amplifiers with extremely large back-offs, we must allow occasional saturation of the power amplifiers, resulting in in-band distortion and out-of-band radiation. There are many solutions to reduce the PAPR of an OFDM Signal. The first is distortion technique, such as clipping, companding and so on. This technique is simple, but it is inevitable to cause some performance degradation. The second is coding technique. It is an efficient method to reduce the PAPR for a small number of sub carriers, but it is inefficient significantly for a large number of sub carriers. The third kind is probabilistic technique or the redundancy technique which is including selective mapping (SLM).Here a new PAPR reduction .In this paper,a new techniques for PAPR reduction of OFDM signals have been proposed. These techniques combine the SLM technique and DCT transform. The scheme 1 is composed of DCT matrix transform followed by conventional SLM, while DCT transform is used before conventional SLM processing unit in proposed scheme 2.

A. SLM Technique

In selective mapping (SLM) technique the actual transmit signal with lowest PAPR is selected from a set of sufficiently different signals which all represents the same information. SLM Technique is very flexible as they do not impose any restriction on modulation applied in the sub carriers or on their number. Block diagram of SLM Technique is shown below. Let's define data stream after serial to parallel conversion as X=[X0, X1--------, XN-1] $^{T.}$ Initially each input Xn (u) can be defined as equation:

$$x_n^{(u)} = \bar{x}_n . b_n^{(u)}$$

Where n=0,1,2…..N-1 and u=0,1,2…..U to make the U phase rotated OFDM data blocks. All U phase rotated OFDM data blocks represented the same information as the unmodified OFDM data block provided that the phase sequence is known. Output data of the lowest PAPR is selected to transmit. PAPR reduction effect will be better as the copy block number U is increased. SLM method effectively reduces PAPR without any signal distortion. But it has higher system complexity and computational burden.

B. DCT Transform.

The Discrete Cosine Transform (DCT) is a Fourier-like transform, which was first proposed by Ahmed et al. (1974) [12]. The idea to use the DCT transform is to re-duce 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 .

C. Proposed scheme

The main idea of the proposed scheme is to use a combination of two appropriate methods. One is the DCT matrix transform technique and the other is the SLM technique. The technique is similar to the scheme pro-posed in literature [13]. The transmitter block is showed in Figure 3. We call this scheme is scheme 1. In the transmit end, the data stream is firstly transformed by DCT matrix, then the transformed data is processed by the SLM unit. If data block passed by DCT matrix before IFFT, the autocorrelation coefficients of IFFT input is reduced, then the PAPR of OFDM signal could be reduced.

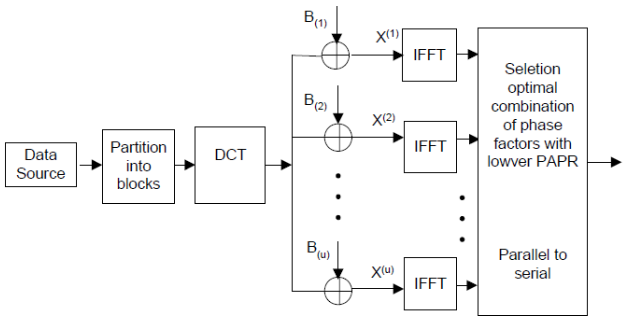

Fig .3. Block Diagram of proposed SLM scheme 1.

In this paper the next scheme is, we use DCT matrix after SLM to further reduce the PAPR of signal. We call this scheme as scheme 2. In his fashion, the autocorrelation of the signal, which has been processed by SLM, is reduced by DCT matrix transform. The PAPR of fine output signal is further reduced. The block of transmitter is showed in Figure 4.

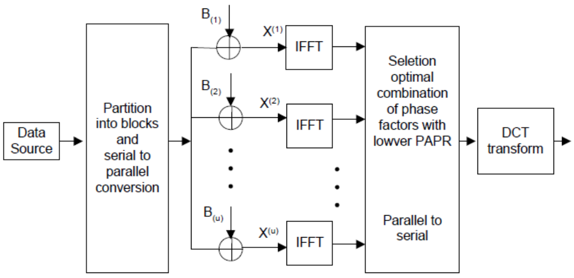

Fig .4. Block Diagram of proposed SLM scheme 2

III. SIMULATION RESULTS

The platform used for implementation is MATLAB. The performance of the overall system has been assessed by means of the bit error rate (BER) after the LDPC decoder. The DVB-T2 parameters used in the simulations are: 64800 bits of length of the LDPC block, R = 2/3 of LDPC code rate, 16-QAM modulation, 2048 carriers as FFT size and 1/4 of guard interval. In the system model described in the work the binary source of data is initially BCH coded. Then the BCH coded data is LDPC coded. For encoding the data using LDPC code a parity check matrix is needed. This matrix is composed of zeros and ones. The parity check matrix has a property such that its number of zeros will always be greater than number of ones. Fig. 5. Shows visualisation of location nonzero element in parity chek matrix.

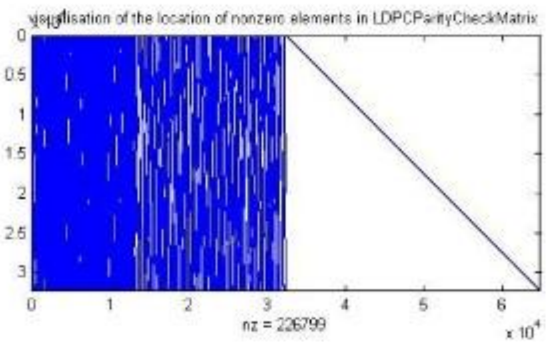

Fig. 5. Shows visualisation of location nonzero element in parity check matrix

Space frequency block coding is achieved by doing multicarrier modulation on space time code. SFBC BICM orthogonal frequency division multiplexing system is designed for a single OFDM transmitter and receiver. The signal is transmitted through an AWGN channel. The modulation used is 16 QAM modulation.Scatterplot of the QAM modulated data is ploted. Fig 6. shows the scatter plot of modulated data. FRFD code used for coding SFBC is Almouti code.Fig 7 shows the performance plot for Almouti coded system. The BER plot for LDPC coded OFDM system is obtained. Transmitted signal and signal mixed with noise is shown in Fig 8.

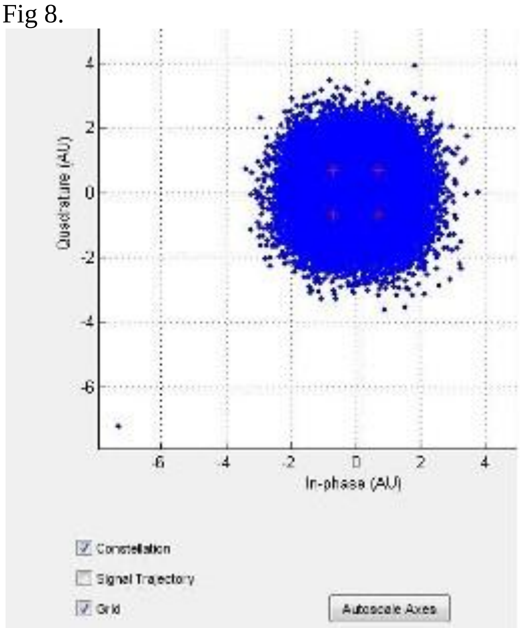

Fig.6. Scatter plot for modulated data

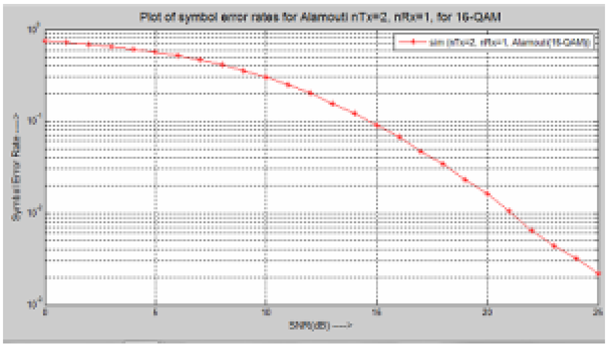

Fig.7. Perfomance plot of Almouti code

The complexity of the soft detection has been studied by comparing the proposed detection with existing detection scheme.ie proposed LFSD(List Fixed Sphere Decoding) Soft detection is compared with existing SD(Sphere decoding).complexity is studied by analysing the time required for soft detection. The existing detector has a complexity of 2.4841e+003,while the new method has 1.3636e+003.

The PAPR reduction performances are evaluated by computer simulation. Simulation results state that the PAPR reduction performance is greatly improved com-pared to conventional SLM.

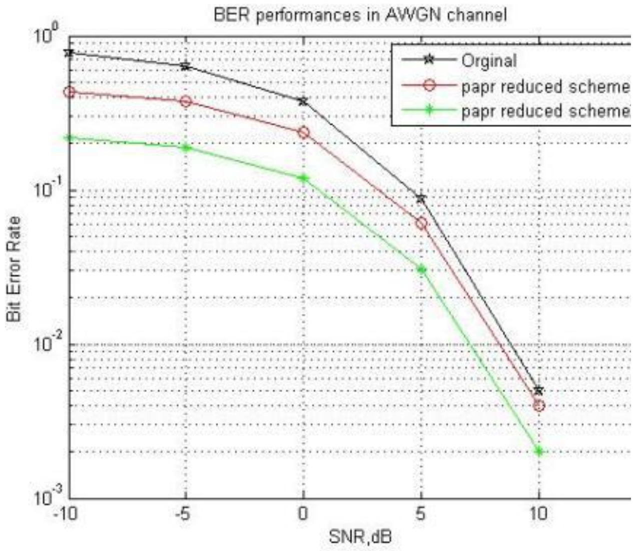

Fig .8. Shows the performance of original system is compared with PAPR reduced system.

IV. CONCLUSION

Full-rate full-diversity (FRFD) space-time codes (STC) such as the Almouti code are studied. However, despite their larger achievable capacity, most of them present high complexity for soft detection, which hinders their combination with soft-input decoders in bit-interleaved coded modulation (BICM) schemes. This article presents a low complexity soft detection algorithm for the reception of FRFD space-frequency block codes in BICM orthogonal frequency division multiplexing (OFDM) systems by considering the effect of PAPR. The proposed detector maintains a reduced and fixed complexity with sufficient reduction in PAPR.PAPR reduction is achieved using a new scheme which is a combination of SLM and DCT Method. Complexity and simulation based performance results are provided which show that the proposed detector performs better in a variety of DVB-T2 broadcasting scenarios.

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