Low complexity detection and PAPR reduction in SFBC BICM-OFDM system

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***Abstract*—This paper is concerned with a multi input multi output 2X2 antenna system based on almounti transmission. For higher data rate transmission orthogonal frequency division multiplexing is also incorporated with MIMO system. One of the main drawback of MIMO-OFDM system is the high decoding complexity which increases with the number of transmitted symbol per code word. This paper proposes a lower complexity detection scheme based on list sphere decoding using tree search. Here a list of candidates is selected based on tree search which is done in an unconstrained fashion and these list of candidates is considered for the detection process there by reducing the computational complexity. SFBC BICM OFDM system will suffer from high Peak average power ratio so PAPR reduction based on clipping and amplification is also done.**

Keywords— **Orthogonal frequency division multiplexing, Multi input multi output, Peak average power ratio, Digital video broadcasting.**

I INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multicarrier modulation scheme, which divides the entire frequency selective fading channel into many orthogonal narrow band flat fading sub channels[2]. In OFDM system high-bit-rate data stream is transmitted in parallel over a number of lower data rate subcarriers and do not undergo ISI due to the long symbol duration. For broadband systems, orthogonal frequency division multiplexing (OFDM) appears promising for its immunity against delay spread. Multiple-input multiple-output (MIMO) wireless communication systems are based on signal processing with multiple antennas at both transmitter and receiver side. MIMO processing can increase the limits of the channel capacity, adding spatial diversity or canceling interference [5]. This versatility has caused MIMO techniques to be incorporated in many of the current wireless communications systems. The second generation of terrestrial digital video broadcasting (DVB-T2) has been the first broadcasting standard to include a multi-antenna system as an optional technique. This consists of a multiple-input single-output (MISO) transmission scheme for two transmit antennas based on the Alamouti transmit diversity technique. On the other hand, the DVB-T2 MISO technique is a pure diversity approach which forms a subset of MIMO since it only includes two antennas at the transmitter side. Therefore, DVB-T2 does not fully exploit the capacity of MIMO channels.

Space-time coding is one of the main methods in order to exploit the capacity of multiple-input multiple-output (MIMO) channels. Both time and spatial domains are used by STC 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. If STC is joined to multi-carrier modulation, such as orthogonal frequency-division multiplexing (OFDM), space frequency block coding (SFBC) can be performed [6]. Thereby, 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[9]. The main drawback of MIMO system is 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 can be used. 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). Moreover, the computation of the LLRs for the whole set of transmitted symbols is unfeasible, specially for large constellation sizes[1]. Hence, the soft MIMO detector has to select a group of candidates to be fed to the decoder in order to compute the required LLRs. Here a soft detection scheme based on list sphere decoding is done where a list of candidates is selected based on tree search and these selected candidates are used during the detection process. Computational complexity of the detection process is very low since we are using only selected candidates .Soft information is calculated only for this selected symbols.

Another main drawback related to OFDM is the high peak to average power ratio (PAPR). PAPR problem results from the modulation itself where multiple sub carriers are added to form the signal to be transmitted. Thereby, the systems are constrained to a limited peak power due to the limitation of the dynamic range over which the transmitter amplifier operates linearly. PAPR cause distortion and saturation in power amplifiers, resulting in inter symbol interference. The main problem with the amplifiers is the decrease in efficiency which is directly given by peak to average power ratio[3]. As a result a high power amplifier needs to be used. If the maximum amplitude of the time domain signal is large, it may push the amplifier into the non-linear region which breaks the orthogonality of the sub-carriers and will result in a substantial increase in the error rate. This paper discusses about a simple PAPR reduction technique in SFBC OFDM based on clipping and differential scaling. In this method the complex amplitudes are clipped and confined in a certain amplitude range and then the signal amplitudes are scaled so as to reduce the PAPR[8].

II SYSTEM MODEL

The basic structure of the LDPC-coded BICM-OFDM system is depicted in Fig. 1.

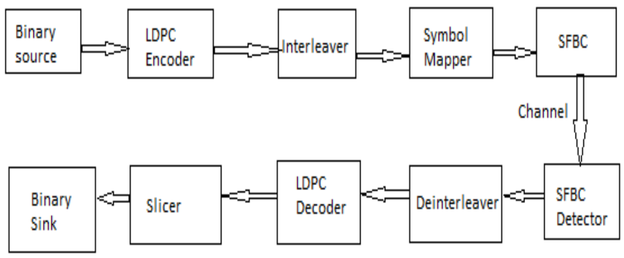

Fig. 1 SFBC coded BICM OFDM system

The bit stream is coded, interleaved and mapped onto a complex constellation. Next, a vector of symbols is coded into space and frequency forming the code word which is transformed into the time domain by an inverse fast Fourier transform (IFFT) block and transmitted after the addition of a cyclic prefix[1]. 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

$$Y = HX + Z,$$

Where H is the channel matrix and Z addictive Gaussian noise. 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). The binary input is given to the low density parity check encoder, so that the error can be reduced. To scramble the data bits interleaver is used so that standard error correcting codes can be applied. Filtering is done to reduce noise. To achieve a signal of correct domain and shape symbol mapper is used which maps the signal on to the complex constellation. This transmission scheme is usually combined with bit-interleaved coded modulation (BICM) giving good diversity results in a wireless communication link. An N-point IFFT is used to for OFDM modulation and converting the signal to a time domain signal.[1] 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. The IFFT output is converted to serial and a cyclic prefix is then added. Since perfect channel state information at receiver has been used training symbols have not been added for synchronization and channel estimation. The symbol is transmitted by a 2X2 antenna. The detection is done by using the almounti scheme. The transmitted symbols arrive at the receiving antenna through the fading paths h1 and h2. The signal received has the form

$$X1=s1h1+s2h2$$

$$X2= s1^{*}h2-s2^{*}h1$$

The receiver performs the reverse process .The receiver section consists of FFT, Soft SFBC decoding, Filter or Interleaver, low density parity check (LDPC) Decoder, Slicer. 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. A diversity combiner is used at the receiver for detection [1]. Space frequency block decoding is done by taking the output from the de-multiplexers at the output of FFT block. The space frequency block decoder output is given as input to the filter. The output of soft SFBC detector is given to the filter in order to reduce the noise of the signal. The output from the filter is given to the low density parity check decoder. The slicer is mainly used to reduce the noise of the signal.

III LIST SPHERE DETECTION

The main idea behind sphere decoding is to limit the number of possible code words by considering those code words that are within a sphere that are within a sphere centered at the received signal vector. The code word is to be separated from the set of all possible code words. This is to be done for any arbitrary signal which is the centre of the sphere [1]. The complexity of separating these signals should be small enough such that the overall complexity of the sphere decoding is lower than that of the full search. This can be done since the ML decoding candidates are the elements of a lattice. A lattice generated by a basis consists of all linear combinations of the basis elements with integer coefficients. Sphere detection is to find the closest point of a lattice to a given point.

In list sphere detection a list of candidates is selected in an unconstrained fashion and these candidates are used in the detection process. In this paper list sphere is done based on a tree search. Tree structure for the signal constellation is drawn and the list of the candidates is found using tree search. The sphere search is started from the highest level of the tree $i = NT$, the root of the tree, with an unlimited sphere. At each level i the algorithm analyze the children nodes with their λi and select one of the nodes within the search sphere, which wasn't extended so far. The selected node is extended by analyzing its children nodes in the layer $i - 1$. Whenever a leaf node is reached ($i = 0$), the radius is readjusted and the analyzed leaves are stored for the calculation of the L-values. Whenever all children nodes from a parent node within the sphere were extended, the search level is increased and the search continued. As soon the root is reached again, the search is completed.

IV PEAK AVERAGE POWER RATIO IN SFBC OFDM

One of the main drawback of the OFDM system is the peak average power ratio. For an OFDM signal the peak average power ratio is defined as :

$$PAPR[x(t)] = \frac{P_{PEAK}}{P_{AVERAGE}} = 10log_{10}\frac{\max[x(n)]}{E[x(n)]}$$

The peak value of some of the transmitted signal is larger than the typical value. The two possible combination of MIMO OFDM system is space time block coded OFDM and space frequency block coded OFDM, both suffer from high PAPR. In this paper we reduce PAPR in SFBC OFDM based on clipping and scaling approach. In this approach amplitude of complex OFDM signal is clipped and scaled such that the PAPR is reduced without much degradation in bit error rate during transmission [6]. Amplitude clipping is considered as the simplest technique which may be under taken for PAPR reduction in an OFDM system. A threshold value of the amplitude is set in this case to limit the peak envelope of the input signal. Signal having values higher than this pre-determined value are clipped and the rest are allowed to pass through un-disturbed [3]. The problem in this case is that due to amplitude clipping distortion is observed in the system which can be viewed as another source of noise[7]. This distortion falls in both in – band and out – of – band. Filtering cannot be implemented to reduce the in – band distortion and an error performance degradation is observed here. On the other hand spectral efficiency is hampered by out – of – band radiation. Out – of – band radiation can be reduced by filtering after clipping but this may result in some peak re – growth. A repeated filtering and clipping operation can be implemented to solve this problem. The desired amplitude level is only achieved after several iteration of this process.

Based on the amplitude of the scaling signal three type of differential scaling techniques are there [4]. The amplitude of the clipped signals are scaled in different manner. The three technique are scale up scale down and scale up down.

Scale up : In this method amplitude of the signal is scaled by a factor of α. Which lead to the increase of the average value without affecting the peak value thereby reducing the resulting PAPR. The PAPR reduction function can be defined as:

$h(x) = \alpha xp, \text{ if } x > \alpha xp$

$= \beta x, \text{ if } x < A$

$= x, \text{ if } A \leq x \leq \alpha xp.$

Where xp is the peak value of amplitude occurring in an OFDM symbol block, λ is a factor deciding the clipping threshold in terms of peak value and α is a scaling factor whose value is greater than one and lies in the range [0 A].

Scale down: In this method amplitude of the signal is scaled by a factor of γ which lead to decrease in peak value. The PAPR reduction function can be defined as:

$h(x) = \alpha xp, \text{ if } x > \alpha xp$

$= \gamma x, \text{ if } B \leq x \leq \alpha xp$

$= x, \text{ if } x < B$

Where xp is the peak amplitude of the OFDM block signal,α is the factor deciding the clipping threshold in terms of percentage of peak value and γ is the scaling factor whose value is less than one and lays in the range [β αxp]. The peak power reduction is higher than average power reduction. Peak average power will fall down because of average power reduction.

Scale up down: This method combine advantage of both the approaches, scale up and scale down. By this method PAPR can be reduced considerably. The PAPR reduction function can be defined as:

$h(x) = \alpha xp, \text{ if } x > \alpha xp$

$= \gamma x, \text{ if } B \leq x \leq \alpha xp$

$= \beta x, \text{ if } x < A = x, \text{ if } A \leq x \leq B$

Where xp is the peak value of the amplitude occurring from the OFDM block,α is the factor deciding the clipping threshold in terms of percentage of peak value and β is the scaling factor whose value is greater then one and lays in the range [0 A] and γ another scaling factor whose value is between [β αxp] whose value is less than one.

PAPR can be described by its complimentary cumulative distribution function, which computes the power from a time domain signal. The amount of time the signal is above the average time level or the probability that a signal is above the average power level is represented by CCD.

V RESULT

The performance of BICM coded OFDM system is analyzed by plotting its bit error rate curve which is given below.

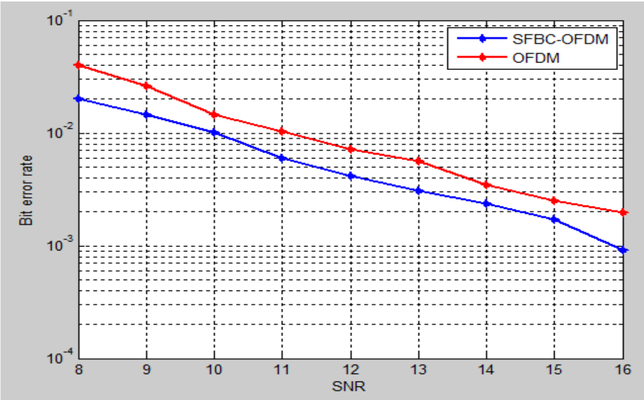

Fig 2. SNR versus BER curve

From the graph it is seen that the error rate of BICM coded system is much less than that of normal OFDM system. The performance of the system is improved by incorporating multiple antennas at both transmitter and receiver. Fig. 3 shows the CCDF as a function of PAPR distribution when scale up technique is used.

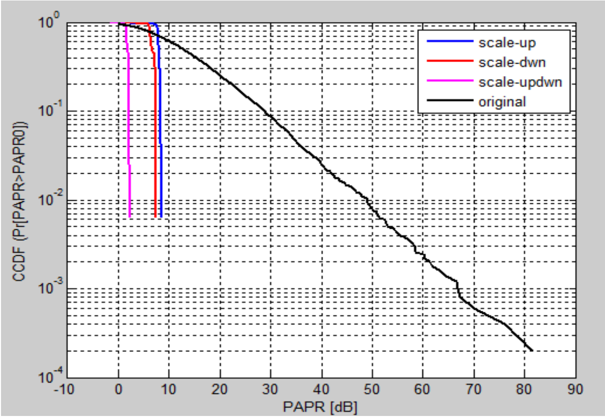

Fig 3. PAPR's CCDF using clipping and amplification technique

The graph shows that the probability of average power to the average power is about 8db in scale up technique. Lower amplitude signals are scaled up to maintain the ratio of average power to peak power. The probability of average power to the average power is about 7db in scale down technique. Higher amplitude signals are scaled down to maintain the ratio of average power to peak power. In the case of scale up down technique the probability of average power to the average power is about 3db. Lower amplitude signals are scaled up and higher amplitudes are scaled down to maintain the ratio of average power to peak power.

VI CONCLUSION

A low complexity detection algorithm with fixed complexity which is independent of channel and noise conditions is done. The proposed scheme will provide a near ML detection at lower complexity than normal soft detection schemes. In order to reduce the complexity in soft detection list fixed complexity sphere decoding based on tree search is used to give a low complexity detection. PAPR reduction based on clipping and amplification is performed in BICM OFDM system. By using this method PAPR is reduced considerably. Scale up down technique is the efficient one since it combines the advantage of both the scale up and scale down technique thereby reducing the PAPR considerably.

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