1.3 Image Compression Technique

SPIHT is computationally very fast and among the best image compression algorithms known today. Embedded Zero tree Wavelet (EZW) given by Shapiro gives excellent compression performance. SPIHT is the further enhancement of EZW devised by Said and Pearlman which includes faster implementation. It defines parent-children relationships between the self-similar sub-bands and hence called 'Set Partitioning in Hierarchical Trees'.

The proposed method concentrates on two objectives, reducing the PAPR of the OFDM signal and improving the quality of the reconstructed images. It considers the trigonometric transforms as a way for reducing the PAPR by using the characteristics of the DCT/DST energy focused in the low component. The data of OFDM signal is modulated by IFFT then using DCT/DST, which can reduce the PAPR. Compared with the means of Selected Mapping (SLM)-OFDM and Partial Transmit Sequence (PTS)-OFDM, OFDM system modified by DCT/DST maintain the system orthogonal properties, which will not result in additional noise and will not transmit the side information.

2. Previous Schemes for PAPR Reduction

There are many techniques developed to reduce the PAPR in OFDM systems categorized into 'signal distortion method' and 'signal scrambling method' some of these are:

i. Clipping [4]: The clipping technique is the simplest one used in OFDM systems from the type Signal Distortion for reducing PAPR, since this method creates additional clipping noise and degrades the performance, hence not used.

ii. Companding [5, 6]: Companding also termed as 'non-linear companding transforms' is the scheme transforming the amplitude or power of the Gaussian-distributed OFDM signals into uniform distribution without changing the average power, this scheme adjust both small and large signals without bias and they are able to offer better system performance in term of PAPR reduction and bit error-rate (BER) for OFDM systems. But, companding technique is a distortion technique [13].

iii. Partial Transmit sequence (PTS) [7]: This technique is from the type signal scrambling for PAPR reduction. PTS is the scheme in which the input data is divided into smaller disjoint sub-blocks multiplied by rotating phase factors and then added to form OFDM symbol for transmission. Hence, this scheme is used to design an optimal phase factor for sub-block set that minimizes the PAPR. In [10] trigonometric transforms were suggested as an alternative for the FFT to reduce PAPR and modified the OFDM symbols before transmission using the PTS, this brings redundancy in the system.

iv. Selected Mapping (SLM) [8]: This technique is also from the type signal scrambling for PAPR reduction. The basic idea of this technique is to generate several OFDM symbols as candidates and then select the one with the lowest PAPR for actual transmission. But, using this technique results in additional side noise.

v. Coding [9]: The block coding technique is to transmit only the code-words with low PAPR. This technique gives good PAPR reduction performance. The difficulty in using the coding technique is that for the OFDM systems with large sub-carriers, either it encounters design difficulties or the consequent coding rate becomes prohibitively low.

Hence, from the above it can be concluded that for OFDM PAPR reduction techniques are based on computational complexity, bandwidth expansion, spectral release and performance characteristics.

For image transmission over the OFDM system SPIHT algorithm is suggested in several research works [14, 15] because the SPIHT has a good rate-distortion performance for motionless images with comparatively low complexity and it is scalable or completely embeddable.

3. Set Partitioning in Hierarchical Trees (SPIHT) Algorithm

The SPIHT algorithm has been introduced by Amir Said and William Pearlman in 1996 article named as 'SPIHT'. Image compression is a typical application of wavelets in digital signal processing which minimizes the size in bytes of a graphics file without degrading the quality of the image. Compression offers a means to reduce the cost of storage and increase the speed of transmission. One of the Image compression algorithm based on Discrete Wavelet Transform (DWT) is Embedded Zero tree Wavelet (EZW) given by Shapiro which gives excellent compression performance, both in terms of statistical PSNR and subjective human perception of the reconstructed image. SPIHT is the further development of EZW algorithm. One of the most important characteristics of DWT is multi-resolution decomposition. There are various wavelet based image compression algorithms which are JPEG 2000, MPEG, EZW, SPIHT, etc.

In this paper we will deal with EZW since SPIHT is advancement in EZW algorithm for image compression. JPEG and MPEG produce annoying visual degradation when operating at low bit-rates because they introduce errors in visually important parts of the image structure and also introduces the blocking artifacts in the reproduced image.

3.1 EZW Algorithm

Embedded Zero Tree Wavelet (EZW) is used as an EZW [16] encoder which is specially designed to use with wavelet transforms. This encoder encodes the decomposed image by recognizing the priority of decomposed image pixel. The encoding process is performed using two passes namely: dominant pass and subordinate pass. The dominant pass generates any one of four possible combinations they are, significant positive (SP), significant negative (SN), isolated zero (IZ), and zero-tree root (ZR). Depending on the current threshold, the coefficients are encoded as 0 or 1 in the subordinate pass. The decoding unit reconstructs the values by identifying the symbols as positive, negative, zero tree and isolated zero tree. Inverse transformation is the process of recovering back the image data from the obtained image values. The image data transformed and decomposed under encoding side is re-arranged from higher level decomposition to lower level with the highest decomposed level been arranged at the top.

3.2 Set Partitioning In Hierarchical Trees

Said and Pearlman [17] further enhanced the performance of EZW by presenting a more efficient and faster implementation called set partitioning in hierarchical trees. SPIHT is one of the best algorithms in terms of the peak signal-to-noise ratio (PSNR) and execution time. Set partitioning in hierarchical trees provide excellent rate distortion performance with low encoding complexity.

SPIHT introduces three lists:

a) List of Significant Pixels (LSP),
b) List of Insignificant Pixels (LIP) and
c) List of Insignificant Sets (LIS).

First initialization is done, and then algorithm takes two stages for each level of threshold: 1. the sorting pass (in which lists are organized) and 2. The refinement pass.

LIS is further divided into two types of sets of insignificant pixels:

Type A (all descendants are zero)
Type B (all grandchildren and further descendants are zero).

SPIHT algorithm defines four types of sets, which are sets of coordinates of coefficients:
O(i,j): set of coordinates of all offspring of node (i,j); children only
D (i,j): set of coordinates of all descendants of node (i,j); children, grandchildren, great-grand, etc.
H (i,j): set of all tree roots (nodes in the highest pyramid level); parents
L (i,j): D (i,j) – O(i,j) (all descendants except the offspring); grandchildren, great-grand, etc.
To find the number of passes we use the formula
n= [$\log_2$c max]
We find initial threshold as $T_0=2^n$.

The SPIHT algorithm forms a hierarchical quad tree data structure for the wavelet transformed coefficients. The set of root node and corresponding descendants are together called as spatial orientation tree (SOT).

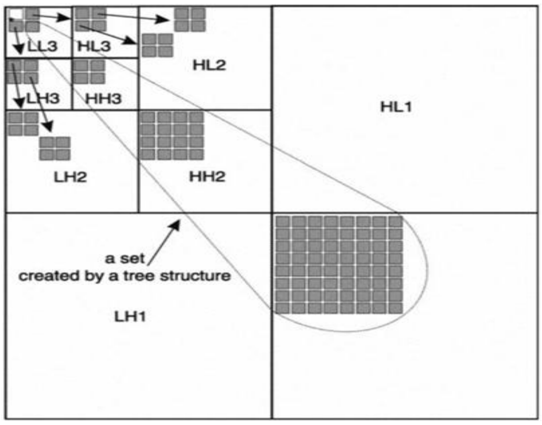

Figure 1: Parent-children dependency and spatial orientation trees across wavelet sub-bands in SPIHT

Algorithm consists of both encoding and decoding process.

Encoding:
Step 1: initialization
Choose threshold T_0=2[$\log_2$c max]
Step 2: load the LIP with {(0,0),(0,1),(1,0),(1,1)}
Step 3: load LIS with descendants i.e. {D (0,1),D (1,0),D(1,1)}.
Step 4: LSP=Empty.
Step 5: Process LIP
If (0,0)>T_0,we transmit 1 and load LSP with(0,0);
if (0,0)>0 we transmit 0.
Step 6: Process LIS if D(0,1),D(1,0),D(1,1)<T0 transmit 0.
We get a bit stream.

Decoding:
Step 1: Initialization
n= [$\log_2$c max]
Step 2: Find threshold $T_0=2^n$.
Step 3: consider LIP, LSP and LIS.
Step 4: consider the encoded bit steam
Step 5: Process LIP
Receive the bit stream, if 1st bit is 1 combine next bit to 1 i.e. 1 0 this indicates ist element of LIP is significant positive.
If next bit is 0 we take it as insignificant
Step 6: reconstruct the 1st element of LIP value by $(3/2)*2^n$. Step 7: if D(0,1),D(1,0),D(1,1)<T0 we get 0
Step 8: Finally again load LIP, LSP, LIS.

4. OFDM System Descriptions with Proposed Modification

The block diagram of the proposed LDPC-COFDM system is illustrated in Fig-2.

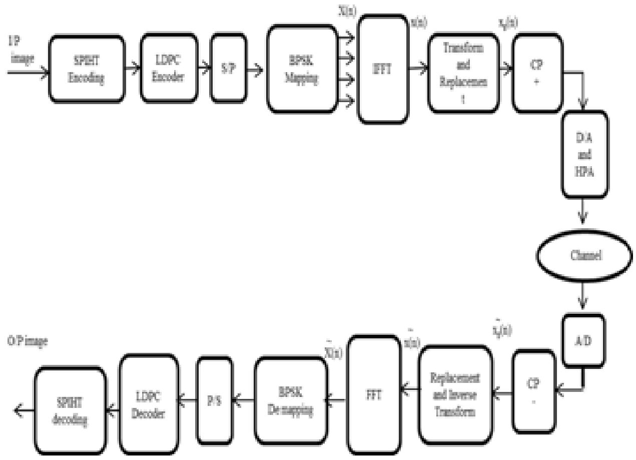

Figure 2: The LDPC COFDM system model with Trigonometric transforms

As will be shown in the following sections, the proposed modifications will be in the transform and replacement block. The SPIHT coder is chosen as the source coding technique due to its flexibility of code rate and simplicity of designing best system. The SPHIT divides the image stream into several layers according to the importance of progressive image stream. Then the image stream is converted to a binary format. Afterwards the information bits will be LDPC encoded at the LDPC encoder. The OFDM considered in this paper utilizes N frequency tones (number of subcarriers) hence the baseband data is first converted into parallel data of N sub-channels so that each bit of a code-word is on different subcarrier. The N subcarriers are chosen to be orthogonal, then, the transmitted data of each parallel sub-channel is modulated by Binary phase Shift Keying (BPSK) modulation because it provides high throughput and best performance when combined with the OFDM.

Finally, the modulated data are fed into IFFT circuit, such that the OFDM signal is generated. The resulting OFDM signal can be expressed as follows:

Where X_n is a discrete time sample,

$$x(t) \cong x[n] = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n e^{j2\pi f_n t} \quad ,0 \le t \le T$$

The output of IFFT will be split into two components; in-phase and in-quadrature as shown below:

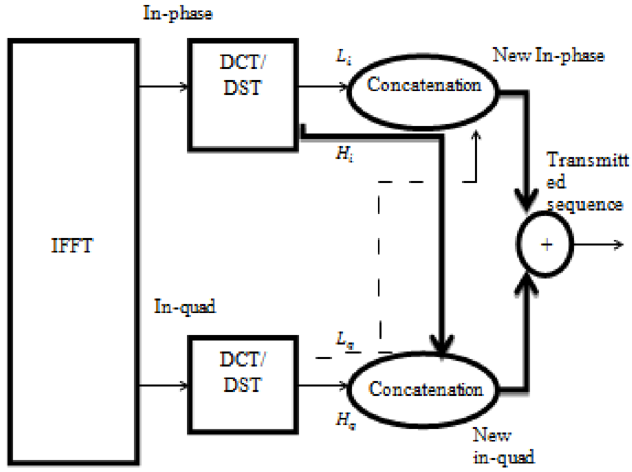

Figure 3: The trigonometric transform and replacement Process

Then, either the DCT or the DST is applied to both components, separately. The first half of samples of the in-phase component after the transform (Li) is concatenated with the first half of samples of the in-quadrature component after the transform (Lq) to form the new in-phase component. Similarly, the second half of samples of the in-phase component after the transform (Hi) is concatenated with the second half of samples of the in-quadrature component after the transform (Hq) to form the new In-quadrature component. Finally, the new components are added to produce the OFDM signal as shown in Fig-3. This sequence after this process will be called x_g (n) with the subscript d referring to the trigonometric transformation process. Each data block is padded with a cyclic prefix (CP) of a length longer than channel impulse response to mitigate the inter-Block Interference (IBI). The continuous COFDM signal x_g (t) is generated at the output of the digital to analog (D/A) converter. According to [18], the PAPR of transmitted analog signal can be expressed as follows:

$$PAPR = \frac{max|x_g(t)|^2}{E[|x_g(t)|^2]}$$

Where E [.] is the average power. Generally, the PAPR is considered for a single OFDM symbol, which has a time duration T. This duration comprises a number of samples equal to ($N_f + N_g$), where N_g is the guard interval length. At the receiver, the guard interval is removed and the time interval [0, T] is evaluated. There placement and inverse transform are then applied to the received samples. Afterwards, the OFDM sub-channel demodulation is implemented by using a (FFT) then the Parallel-to-Serial (P/S) conversion is implemented. This received OFDM symbols are demodulated at the demodulator. The demodulated bits will be decoded with each LDPC encoded block and data bits are restored. These data will be converted into image format, such that SPIHT decoder can be obtained.

To verify the efficiency of the proposed method; trigonometric transforms will be added to the OFDM system to reduce the PAPR, the analysis will be distributed into two methods: one with DCT and other with DST and these will be compared with COFDM and SPIHT coder will be set as source coding. The three transmission schemes will be designed as:

1 The system which consists of coded OFDM.
2 The system 1 with the DCT transforms for the transmitted signal.
3 The system 1 with the DST transforms for the transmitted signal.

Simulation will be carried out based on the above three schemes. The complementary cumulative distribution (CCDF) curves will be presented for the proposed SPIHT LDPC COFDM with Trigonometric transforms. This CCDF is a statistical sign about the signal power distribution. Also, there will be comparison between DCT and DST that which of the schemes give better reduction of the PAPR from the simulation results. At last, the effect of the SPIHT compression ratios on the Peak Signal-To-Noise Ratio (PSNR) of the received image will also be studied. This PSNR is mathematically defined as follows:

$$PSNR= 10\, log_{10} \left(\frac{Peak^2}{MSE}\right)$$

Where, MSE is the mean squared error between the original and the reconstructed image, and Peak is the maximum possible magnitude for a pixel inside the image.

5. Conclusion

In this paper, a review is presented on various methods to reduce the PAPR of the OFDM system and the efficient use of trigonometric transforms in the coded OFDM with LDPC and SPIHT as a compression technique for image transmission. The PSNR for the received images at different rates will also be studied. The practicality of the proposed system will be studied and proved using simulations over the AWGN channel.

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