International Journal of Electrical and Electronics Research ISSN 2348-6988 (online)
Vol. 3, Issue 1, pp: (302-311), Month: January - March 2015, Available at: www.researchpublish.com

Transmission of Images via Trigonometric Transforms

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Abstract: **In this paper we presented the quality of Peak to average power ratio (PAPR) reduction using two methods – discrete cosine transform and Discrete sine transform. These methods are applied on Karhunen –Loeve (KL) Transformed images which are applied with different trigonometric transforms, using software MATLAB. The quality of the compressed image is determined by values of (PSNR) peak signal to noise ratio. The values are presented in appropriate diagrams. Based on the obtained data, we compared the quality of signal by computing the complementary cumulative distribution function(CCDF).It was found that using the trigonometric transforms gives better results as compared with simple coded orthogonal frequency division multiplexing of signal. The work presented in this paper explains as to, how the quality of the signal varies with the trigonometric transforms which is applied on the grayscale test image.**

Keywords: **KL Transform, AWGN, Complementary cumulative distribution function, Peak signal to noise ratio, OFDM, Wavelets.**

I. INTRODUCTION

Development of digital images led to the creation of several methods to store digital pictures and transmit them over a channel. In order to transmit the images it is needed to reduce the size of storage needed for high resolution still digital images, hence it is necessary to perform compression. Compression is the process of eliminating data redundancy or converting data into a form that occupies less storage space. The JPEG (Joint Photographic Experts Group) method is a standard procedure for image compression. It is an established method for the compression of both black and white and coloured images in real (natural) scenes. It is used for the compression of natural images and paintings, but it is not efficient for the compression of text images, freehand or technical drawings. Together with GIF (Graphics Interchange Format). One of the methods used for JPEG compression is the Discrete cosine transformation(DCT).The "power" of compression lies in the quantization of DCT coefficients with a uniform scalar quantizer, entropy coding . A robust code scheme for progressive image transmission is proposed for additive white Gaussian noise (AWGN) [1]. Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital communication, used in applications such as digital television and audio broadcasting, DSL Internet access, wireless networks, power line networks, and 4G mobile communications. OFDM is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data [2] on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate inter symbol interference (ISI) and utilize echoes and time-spreading (on analogue TV these are visible as ghosting and blurring, respectively) to achieve a diversity gain, i.e. a signal-to-noise ratio improvement..

OFDM modulation has been adopted by several wireless multimedia transmission standards, such as Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB-T), because it provides a high degree of immunity to multipath fading and impulsive noise. High spectral efficiency and efficient modulation and demodulation by IFFT/FFT are also advantages of OFDM.

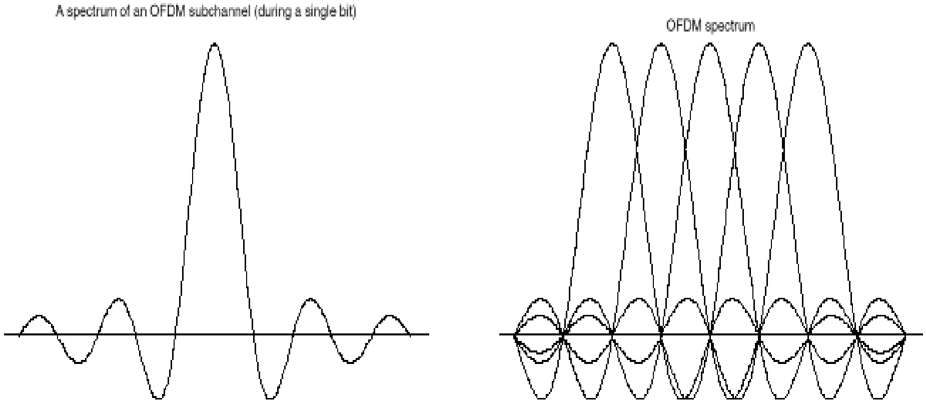


Figure.1. OFDM Spectrum

OFDM divides frequency-selective channel into several parallel non frequency selective narrow-band channels, and modulates signal into different frequencies as shown in Fig.1. It can significantly improve the channel transmission performance without employing complex equalization schemes. It also has broad application prospect in wireless image and video communications [3, 4]. OFDM has orthogonally modulated sub-carriers which unexpectedly give large PAPR and tends to reduce the power efficiency of a RF amplifier. There are still some challenging issues, which remain unresolved in the design of OFDM systems. To reduce PAPR, the sequence of input data is rearranged by Trigonometric transforms for the reduction of PAPR and then fed to further process in the proposed system. In simulation results, the proposed method shows the improvement on PAPR, and also the high performance on bit error rate (BER) of an OFDM system. Orthogonal Frequency Division Multiplexing has become very popular in wireless communications. The IEEE802.11a specifications for wireless local area networks (LANs) are based on OFDM (with TDMA for multiple access).So also it has wide application prospect in wireless image and video communication. The IEEE802.16 specifications for broadband wireless at frequencies below 11GHz include both OFDM/TDMA and OFDMA .

To improve the BER performance of the OFDM system, several error correcting codes have been applied to OFDM. LDPC codes have attracted much attention particularly in the field of coding theory. LDPC codes are a class of linear block codes which provide a reliable transmission for coding performance that is very close to the Shannon's limit and can outperform Turbo codes at long block length but with relatively low decoding complexity. It was originally invented by Gallager in 1963 [5] and rediscovered by Mackay and Neal recently [6]. The combination of the high spectral efficiency OFDM modulation technique and Low Density Parity Check (LDPC) coding will be a good candidate for high speed broadband wireless applications. The BER performance of the Low Density Parity Check Coding- Coded Orthogonal Frequency Division Multiplexing system (LDPC-COFDM) is influenced by the sub channels which have deep fade due to frequency selective fading. According to this combination, several algorithms were introduced into LDPC-COFDM system to improve the BER by adaptive bit loading and power allocation of each subcarrier [7,8].There are several developed techniques to reduce the PAPR in OFDM systems [9,10] such as clipping [11], companding [12, 13], Partial Transmit Sequence (PTS) [9], Selected Mapping (SLM) [14] and coding [l5]. The clipping technique is the simplest one that can be used in OFDM systems, but it causes additional clipping noise, which degrades the system performance. An alternative technique to mitigate the PAPR problem is based on signal transformations. This technique involves a signal transformation prior to amplification, then an inverse transformation at the receiver prior to demodulation. In [16] trigonometric transforms were suggested as alternatives for the FFT to reduce the PAPR. The authors in [16] concluded that OFDM systems with trigonometric transforms provide higher PAPR reduction than the standard Fast Fourier Transform (FFT) based system.

The Set Partitioning in Hierarchical Trees (SPIHT) algorithm has been introduced by Said and Pearlman [17]. It is algorithm based on the wavelet transform, and restricts the necessity of random access to the whole image to small sub images. The principle of the SPIHT is partial ordering by magnitude with a set partitioning sorting algorithm, ordered bit plane transmission, and exploitation of self similarity across different scales of an image wavelet transform. The SPIHT is used for image transmission over the OFDM system in several research works [18,19] because the SPIHT has a good rate-distortion performance for still images with comparatively low complexity and it is scalable or completely embeddable.

The paper concentrates on two targets 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 character 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.

II. MATERIALS AND METHODS

A. The KL- transform:

In the theory of stochastic processes, the Karhunen–Loève theorem (named after Kari Karhunen and Michel Loève), also known as the Kosambi–Karhunen–Loève theorem[20] is a representation of a stochastic process as an infinite linear combination of orthogonal functions, analogous to a Fourier series representation of a function on a bounded interval. There exist many such expansions of a stochastic process: if the process is indexed over [a, b], any orthonormal basis of $L^2([a, b])$ yields an expansion thereof in that form. The importance of the Karhunen–Loève theorem is that it yields the best such basis in the sense that it minimizes the total mean squared error. In contrast to a Fourier series where the coefficients are real numbers and the expansion basis consists of sinusoidal functions (that is, sine and cosine functions), the coefficients in the Karhunen–Loève theorem are random variables and the expansion basis depends on the process. In fact, the orthogonal basis functions used in this representation are determined by the covariance function of the process. One can think that the Karhunen–Loève transform adapts to the process in order to produce the best possible basis for its expansion. In the case of a centered stochastic process $\{X_t\}_{t \in [a, b]}$ (centered means $\mathbf{E}[X_t] = 0$ for all $t \in [a, b]$) satisfying a technical continuity condition, X_t admits a decomposition where Z_k are pair wise uncorrelated random variables and the functions e_k are continuous real-valued functions on [a, b] that are pair wise orthogonal in $L^2([a, b])$. It is therefore sometimes said that the expansion is bi-orthogonal since the random coefficients Z_k are orthogonal in the probability space while the deterministic functions e_k are orthogonal in the time domain. The general case of a process X_t that is not centred can be brought back to the case of a centred process by considering $X_t - \mathbf{E}[X_t]$ which is a centred process. Moreover, if the process is Gaussian, then the random variables Z_k are Gaussian and stochastically independent. This result generalizes the Karhunen–Loève transform. An important example of a centered real stochastic process on [0, 1] is the Wiener process; the Karhunen–Loève theorem can be used to provide a canonical orthogonal representation for it. In this case the expansion consists of sinusoidal functions. The above expansion into uncorrelated random variables is also known as the Karhunen–Loève expansion or Karhunen–Loève decomposition. The empirical version (i.e., with the coefficients computed from a sample) is known as the Karhunen–Loève transform (KLT), principal component analysis, proper orthogonal decomposition (POD), Empirical orthogonal functions (a term used in meteorology and geophysics).

B. Additive white Gaussian noise (AWGN) :

Additive white Gaussian noise is a basic noise model used in Information theory to mimic the effect of many random processes that occur in nature. The modifiers denote specific characteristics:

- 'Additive' because it is added to any noise that might be intrinsic to the information system.
- 'White' refers to idea that it has uniform power across the frequency band for the information system. It is an analogy to the color white which has uniform emissions at all frequencies in the visible spectrum.
- 'Gaussian' because it has a normal distribution in the time domain with an average time domain value of zero.

Wideband noise comes from many natural sources, such as the thermal vibrations of atoms in conductors (referred to as thermal noise or Johnson-Nyquist noise), shot noise, black body radiation from the earth and other warm objects, and from celestial sources such as the Sun. The central limit theorem of probability theory indicates that the summation of many random processes will tend to have distribution called Gaussian or Normal. AWGN is often used as a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. However, it produces simple and tractable mathematical models which are useful for gaining insight into the underlying behavior of a system before these other phenomena are considered. The AWGN channel is a good model for many satellite and deep space communication links. It is not a good model for most terrestrial links because of multipath, terrain blocking, interference, etc. However, for terrestrial path modeling, AWGN is commonly used to simulate background noise of the channel under study, in addition to multipath, terrain blocking, interference, ground clutter and self interference that modern radio systems encounter in terrestrial operation.

*C. **Wavelets:***

The fundamental idea of wavelet transforms is that the transformation should allow only changes in time extension, but not shape. This is affected by choosing suitable basis functions that allow for this. Changes in the time extension are expected to conform to the corresponding analysis frequency of the basis function. The higher the required resolution in time, the lower the resolution in frequency has to be.

In other words, the basis function Ψ can be regarded as an impulse response of a system with which the function x(t) has been filtered. The transformed signal provides information about the time and the frequency. Therefore, wavelet-transformation contains information similar to the short-time-Fourier-transformation, but with additional special properties of the wavelets, which show up at the resolution in time at higher analysis frequencies of the basis function. The difference in time resolution at ascending frequencies for the Fourier transform and the wavelet transform is shown below in fig.2.

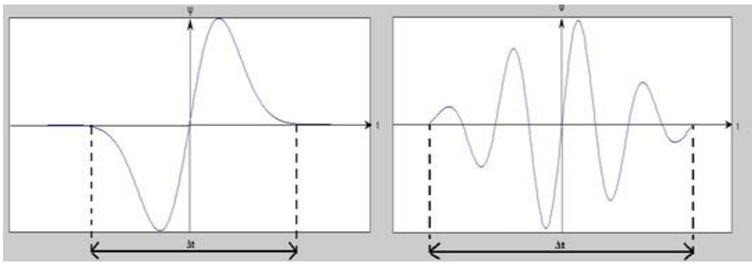


Figure: 2 Wavelet transformation

D. SPIHT:

To improve the BER performance of the OFDM system, several error correcting codes have been applied to OFDM. LDPC codes have attracted much attention particularly in the field of coding theory. LDPC codes are a class of linear block codes which provide a reliable transmission for coding performance that is very close to the Shannon's limit. The SPIHT algorithm defines and partitions sets in the wavelet decomposed image using a special data structure called a spatial orientation tree. A spatial orientation tree is a group of wavelet coefficients organized into a tree rooted in the lowest frequency (coarsest scale) sub band with offspring in several generations along the same spatial orientation in the higher frequency sub bands. The tree is defined in such a way that each node has either no offspring (the leaves) or four offspring at the same spatial location in the next former sub band level. The pixels in the lowest frequency sub band-tree roots are grouped into blocks of 2x2 adjacent pixels. SPIHT describes this collocation with one to four parent-children relationships. The SPIHT algorithm consists of three stages: initialization, sorting and refinement. It sorts the wavelet coefficients into three ordered lists: the list of insignificant sets (LIS), the List of Insignificant Pixels (LIP), and the List of Significant Pixels (LSP). At the initialization stage the SPIHT algorithm first defines a start threshold based on the maximum value in the wavelet pyramid, then sets the LSP as an empty list and puts the coordinates of all coefficients in the coarsest level of the wavelet pyramid (Le. the lowest frequency band; LL band) into the LIP and those which have descendants also into the LIS. In the sorting pass, the algorithm first sorts the elements of the LIP and then the sets with roots in the LIS. For each pixel in the LIP it performs a significance test against the current threshold and outputs the test result to the output bit stream. All test results are encoded as either 0 or 1, depending on the test outcome, so that the SPIHT algorithm directly produces a binary bit stream. If a coefficient is significant, its sign is coded and its coordinate is moved to the LSP. During the sorting pass of LIS, the SPIHT encoder carries out the significance test for each set in the

LIS and outputs the significance information. If a set is significant, it is partitioned into its offspring and leaves. Sorting and partitioning are carried out until all significant coefficients have been found and stored in the LSP.

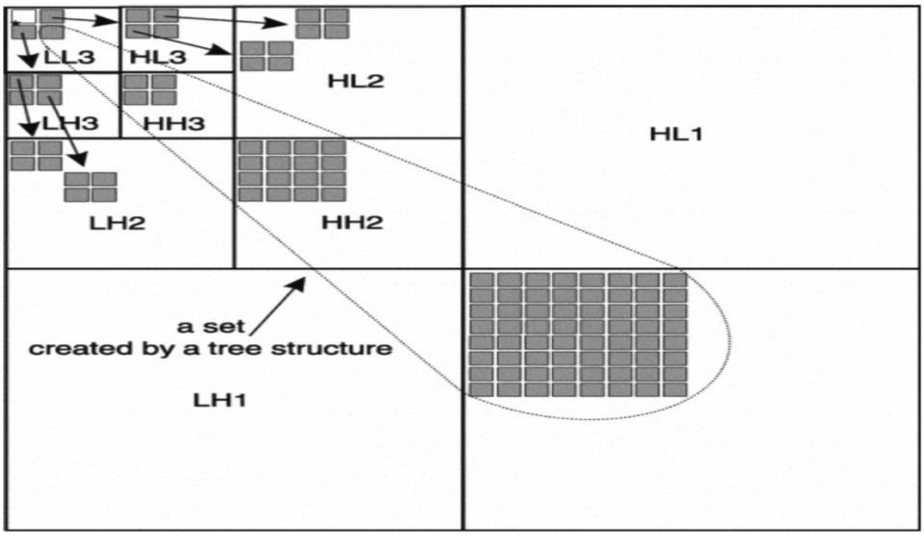


Figure.3. SPIHT Structure

After the sorting pass for all elements in the LIP and LIS, SPIHT does a refinement pass with the current threshold for all entries in the LSP, except those which have been moved to the LSP during the last sorting pass. Then the current threshold is divided by two and the sorting and refinement stages are continued until a predefined bit-budget is exhausted. Details of SPIHT algorithms are presented in [16].

E. PAPR reduction strategies:

A number of methods are available for PAPR reduction but each of these methods provides some advantages.

Here we introduce a new PAPR reduction strategy that is based on trigonometric transforms and KL-transforms. In this technique, the KL-transformed images are applied with the DCT and DST and then the signal with the least PAPR is selected for transmission.

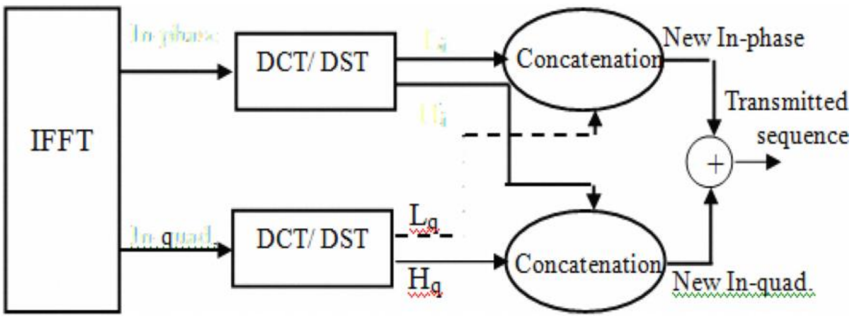


Figure.4. Transform and replacement block

The proposed modifications will be in the transform and replacement block as shown in Fig.4. The SPIHT coder is chosen as the source coding technique due to its flexibility of code rate and simplicity of designing optimal system. The SPIHT divides the image stream into several layers according to the importance of progressive image stream. 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 OFDM. Finally the modulated data are fed into an IFFT circuit, such that the OFDM signal is generated.

The proposed method can be explained as follows:

Step-1: The output of IFFT is split into two components; in-phase and in-quadrature.

Step-2: Then, either the DCT or the DST is applied to both components, separately.

Step-3: 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.

Step-4: 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.

Step-5: Finally, the new components are added to produce the OFDM signal as shown in Fig. 4.

Step-6: Each data block is padded with a cyclic prefix (CP) of a length longer than channel impulse response to mitigate the Inter-Block Interference (lBI).

Step-7: The continuous COFDM signal is generated at the output of the digital to analogue (D/A) converter.

III. RESULTS AND DISCUSSIONS

Fig.5 represents the grayscale image which is an 8 bits per pixel test image, 'Cameraman' from the MATLAB tool box, which has a resolution of 256 x256 pixels and the Fig.6 represents wavelet transformed image of the same.

Figure.5. grayscale image

Figure.6. Wavelet image

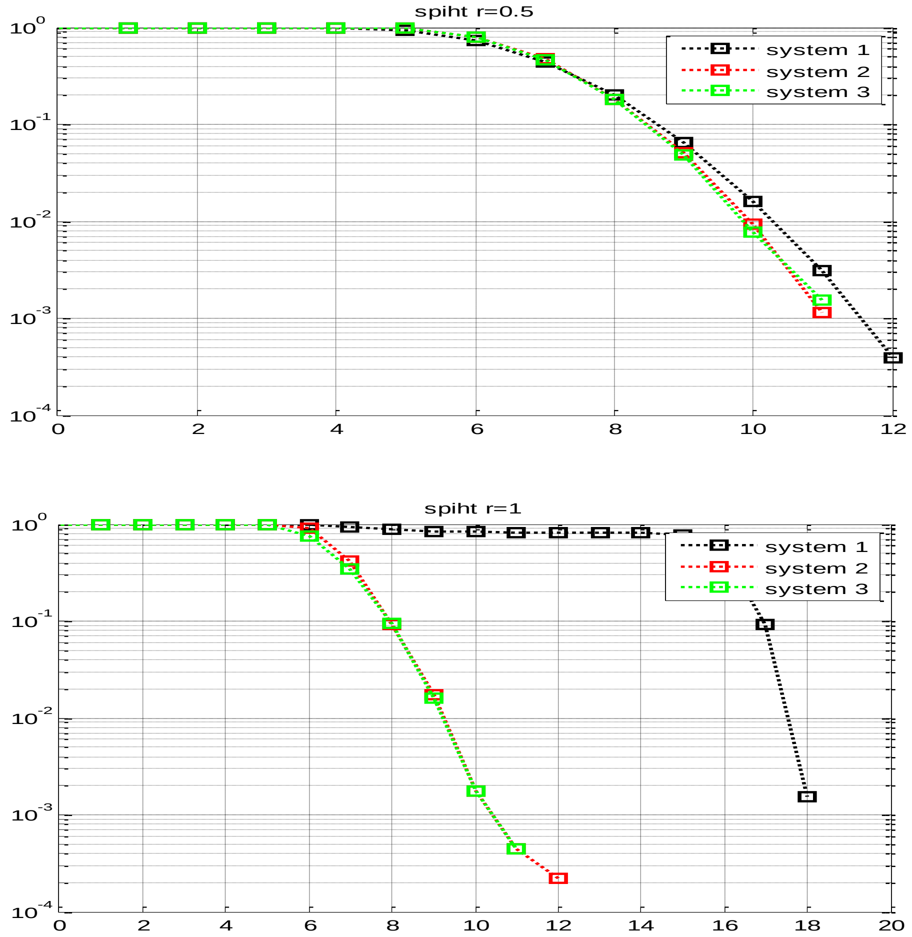
Simulation were carried out for the following three schemes :

Scheme I:system of Coded OFDM

Scheme II:system I with the DCT transform

SchemeIII :system I with the DST transform.

Fig.7 shows the relationship between CCDF and PAPR for the three schemes at different SPIHT rates:0.5and 1 respectively.The figure.7(a) reveals that system with DST has better reduction in the PAPR than that with the DCT nearly upto 0.25dB.It is also noted that the PAPR can be achieved by increasing the value of SPIHT rate as the data increased and the statistical distribution is clearer from figure 7(b).



(a) SPIHT rate=0.5 **(b) SPIHT rate=1**

Figure.7. PAPR Vs CCDF

The PSNR curves were also plotted for the same as shown in the Fig.8.which indicate that as the SPIHT compression ratio increases, the PSNR also increases denoting that it will have more capability to reproduce a better reconstructed image.

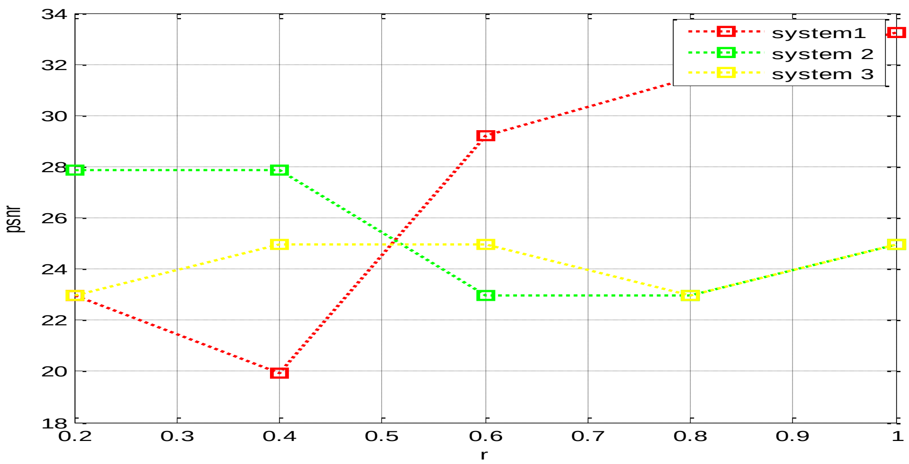
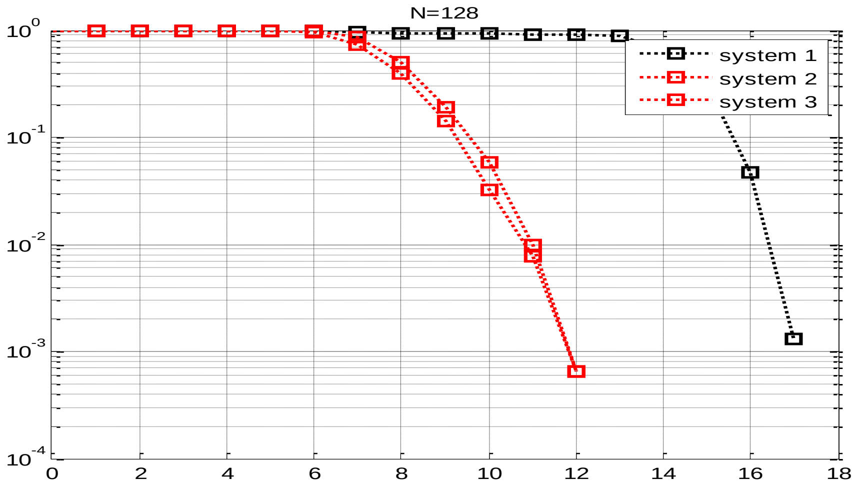


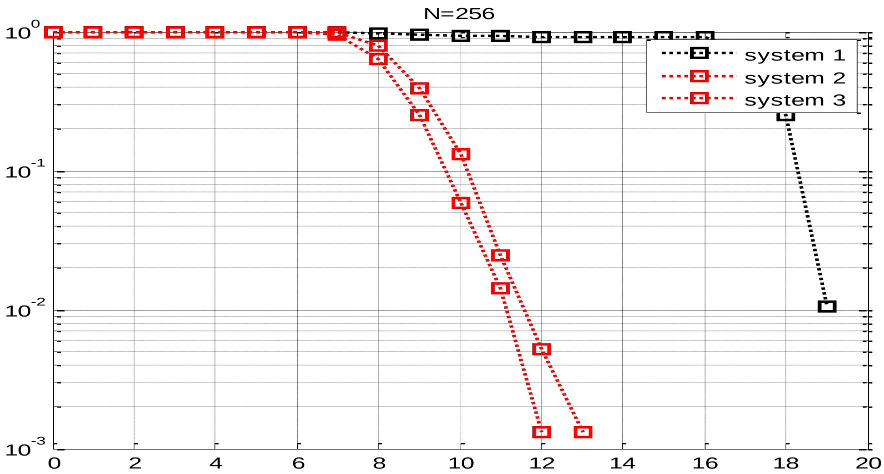
Figure.8. SPIHT compression ratio(r) Vs PSNR

Finally , the impact of the number of subcarriers on the performance of the three schemes is shown in Fig.9.

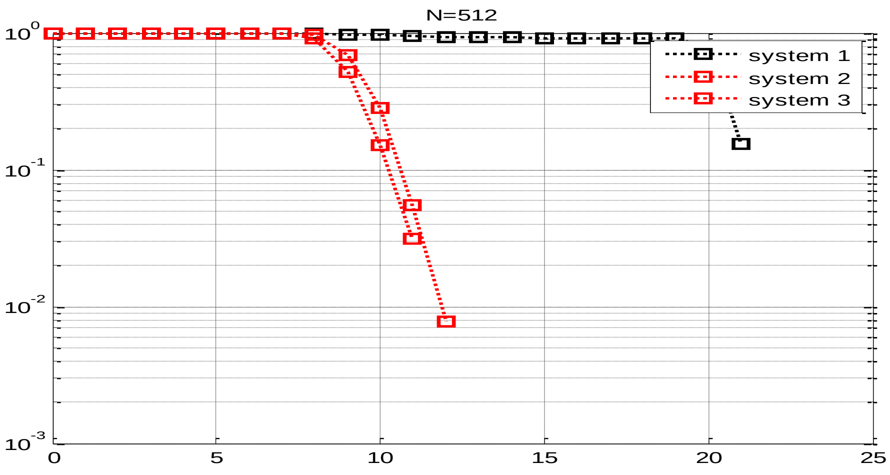
It is clear that ,the scheme three provides a significant PAPR reduction , especially for a large number of subcarriers.



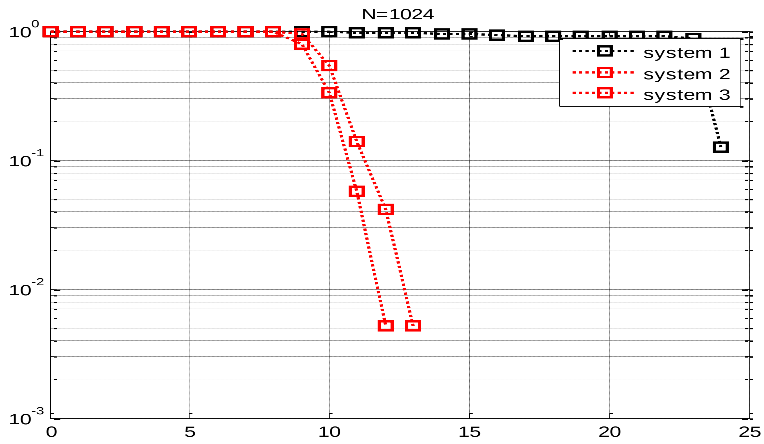
(a)



(b)



(c)



(d)

Figure.9 CCDF VsPAPR for different number of subcarriers (N)

IV. CONCLUSION

In this paper, various graphical analysis are presented to show the effectiveness of the proposed system to reduce the PAPR. By observing the measured PAPR we found that the scheme three, the one with DST, performs better than the other two schemes .This is investigated through simulations over AWGN channel. The PSNR curves also indicate that its values do not degrade in spite of reducing the PAPR. The SPIHT rate utilised is 0.5 and 1 and the number of subcarriers (N) is considered to be 256. This work shows the performance of the system using gray scale image whose features were enhanced by using the KL-transform. The proposed system is also shown to outperform several existing schemes like simple coded OFDM scheme for wireless channels. Hence the statistical analysis can prove to be important to apply on the colour images in future.

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