Energy Efficient Colour Image Transmission using DWT-OFDM System

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Abstract: In many applications retransmission of lost packets are not permitted .OFDM is a multi-carrier modulation scheme having excellent performance which allows overlapping in frequency domain. With OFDM there is a simple way of dealing with multipath relatively simple DSP algorithms.

In this paper, an image frame is compressed using DWT, and the compressed data is arranged in data vectors, each with equal number of coefficients. These vectors are quantized and binary coded to get the bit steams, which are then packetized and intelligently mapped to the OFDM system, such that poorer subchannels can only affect the lesser important data vectors. we consider only one-bit channel state information available at the transmitter, informing only about the subchannels to be good or bad. For a good subchannel, instantaneous received power should be greater than a threshold P_{th}. Otherwise, the subchannel is in fading state and considered Bad for that batch of coefficients. Note that the data transmitted through deeply faded subchannels are highly prone to error and are likely to be discarded at the receiver. Thus, the binary channel state information gives an opportunity to map the bit streams intelligently and to save a reasonable amount of power. By using MAT LAB simulation we can analysis the performance of our proposed scheme, in terms of system energy saving without compromising the received quality in terms of peak signal-noise ratio.

Keywords: DWT-OFDM system, fading broadcast channel, channel state feedback, energy saving

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I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM)[1] is a multi-carrier system where data bits are encoded to multiple sub-carriers, while being sent simultaneously. This results in the optimal usage of bandwidth. A set of orthogonal sub-carriers together forms an OFDM symbol. To avoid ISI due to multi-path, successive OFDM symbols are separated by guard band. This makes the OFDM system resistant to multipath. Multiplexing (OFDM) is a special case of multicarrier transmission, where a single data stream is transmitted over a number of lower rate subcarriers. The main reason to use OFDM is to increase the robustness against the selective fading or narrowband interference. In single carrier system if signal get fade or interfered then entire link gets failed where as in multicarrier system only a small percentage of the subcarriers will be affected. The total signal bandwidth, in a classical parallel data system, can be divided into N non-overlapping frequency sub-channels. Each sub-channel is modulated a separate symbol and then N sub-channels are frequency multiplexed. The general practice of avoiding spectral overlap of sub-channels was applied to eliminate inter-carrier interference (ICI). This resulted in insufficient utilization of the existing spectrum. An idea was proposed in the mid 1960s to deal with this wastefulness through the development of frequency division multiplexing (FDM) with overlapping sub-channels. The sub-channels were arranged so that the sidebands of the individual carriers overlap without causing ICI. To achieve this, the carriers must be mathematically orthogonal. From this constraint the idea of Orthogonal Frequency Division Multiplexing (OFDM) was born. In OFDM, individual subchannels are affected by flat fading, so for a period of time, condition of the sub channels may be good, or they might be deeply faded. The packets which are transmitted through these faded subchannels are highly prone to be lost at the receiver due to non-acceptable errors. OFDM system provides an opportunity to exploit the diversity in frequency domain by providing a number of subcarriers, which can work as multiple channels for applications having multiple bit streams.

A key observation is that, the unequal importance level of the compressed image coefficients can be combined intelligently with the binary channel state feedback to achieve an improved transmission performance in delay-sensitive applications. This feedback can also be used further for energy saving in the transmission process with little or no trade-off in transmission performance.

Recently, the Joint Photographic Expert Group (JPEG2000)[2] has developed a new discrete wavelet-based image compression standard, commonly referred to as JPEG2000 . Our preliminary study on discrete wavelet-based image compression (using JPEG2000)says that the wavelet transform step consumes more than 60 % of the CPU time during image compression process. By optimizing algorithmic features of the transform step, performance and energy requirements of the entire image compression process can be significantly improved. For this reason, we target the wavelet transform step to minimize the energy consumption.

In this paper, we explore the possibility of transmitting JPEG2000 compressed (DWT) image frames through the block fading OFDM channels with binary channel state feedback, where, unlike in conventional layered coded frame transmission, retransmission of lost packets are not allowed. Depending on the binary channel feedback and a predefined acceptable received power threshold, the good and Bad (deeply faded) channels are sorted, and the coefficients in order of their importance levels are mapped to the subchannels belonging to the good ones. As an energy saving measure, if a coefficient is mapped onto a Bad subchannel, we propose that, it is discarded at the transmitter itself. Since our mapping scheme ensures that the discarded coefficients are of rather lesser importance, in most cases the transmitted frame could be reconstructed at the receiver with some distortion, without needing retransmissions. An application scenario of our proposed scheme could be real-time image/video transmission in peer-to-peer broadband communication systems.

Prior work on DWT-OFDM system [3]in studied the transmission of DWT compressed still image over OFDM multipath channels. The image sample goes first through a transform, which generates a set of frequency coefficients. The transformed coefficients are then quantized (or divided by a certain fixed value) to reduce the volume of encoded data. The output of his step is a stream of integers, each of which corresponds to an index of a particular quantized binary. Encoding is the final step, where the stream of quantized data is converted to a sequence of binary symbols in which shorter binary symbols are used to encode integers that occur with relatively high probability. This helps reduce the number of bits transmitted. In that approach, the high pass coefficients were simply discarded before transmission. In contrast, in our approach, we consider the possibility of transmitting the low pass as well as high pass coefficients. We also explore the possibility of energy saving in transmission process over fading channel environment by discarding the coefficients of lower importance level through an informed decision process. In our proof of concept study, we generate four coefficients, after the first level DWT. Each coefficient in the form of a data vector is mapped on to a subchannel . We compare the energy saving and reception quality performance, by sending all coefficients over the mapped subchannels versus discarding the ones that are mapped on to the bad channels. Our results show that, up to 60% energy saving is possible at the low fading margins with a considerably high gain in the quality (PSNR) of the received image.

This paper is organized as follows: The system model in section2.Formulation and analysis in section3.Results analysis in section 4 and finally conclusions in section5.

II. PROCEDURE FOR PAPER SUBMISSION

In our system model, an image frame is compressed using DWT, and the compressed data is arranged in data vectors, for each data vector gives equal number of coefficients. These vectors are packetized and mapped to the OFDM system and then quantized and binary coded to get the bit streams. At each time only one bit channel state information is available at the transmitter, because it checks the each bit individually either good or bad by threshold $P_{th.}$ For a good subchannel, instantaneous received power should be greater than a threshold P_{th}. Otherwise, the subchannel is in fading state and considered bad for that batch of coefficients. The less power data will be discarded at receiver when it transmitted through deeply faded subchannels .Thus, the power saving is achieved in image transmission. Below clearly explains each section of the DWT-OFDM block diagram.

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A. DWT-OFDM SYSTEM

The proposed model is for transmission of DWT compressed data over OFDM channels in fading environment andillustrated in Fig. 1. The steps involved are as follows:

- DWT is applied on an image frame of original size $S_1 \times S_2$ pixels, producing four sub- images: HL, LH, HH, and LL, each of the size $\frac{S1}{2} \times \frac{S2}{2}$pixels.
- From these sub-images four coefficient vectors are generated, each of length $\frac{S1.S2}{2}$.
- The coefficient vectors are uniformly quantized and binary coded with L bits/coefficient to form four bit streams.
- The bit streams are packetized and mapped on the OFDM system through fading channels.
- Finally sends to receiver.

B. Packetizing and mapping onto the OFDM System

As mentioned in fig.1.bit streams are packetizied by chopping them into vectors of size N-bits.Each packet containing four vectors ,for each vector have to add one training bit to estimate subchannel of the receiver[4]. For this paper taking an example of OFDM with IFFT size 128, system has 32 packets are arranged in parallel to get 128 bit streams (see Fig. 1). Each bit vector in a packet is m-ary modulated, and 32 packets are simultaneously transmitted through different subchannels set. . By the feedback from system decides the subchannel condition either it is good or bad, and accordingly rearrange the data vectors to map them to the IFFT module. For quality receiption and energy saving implement a new mapping scheme. The reverse process is done at the receiver with suitable treatments due to the discarded or lost data vectors

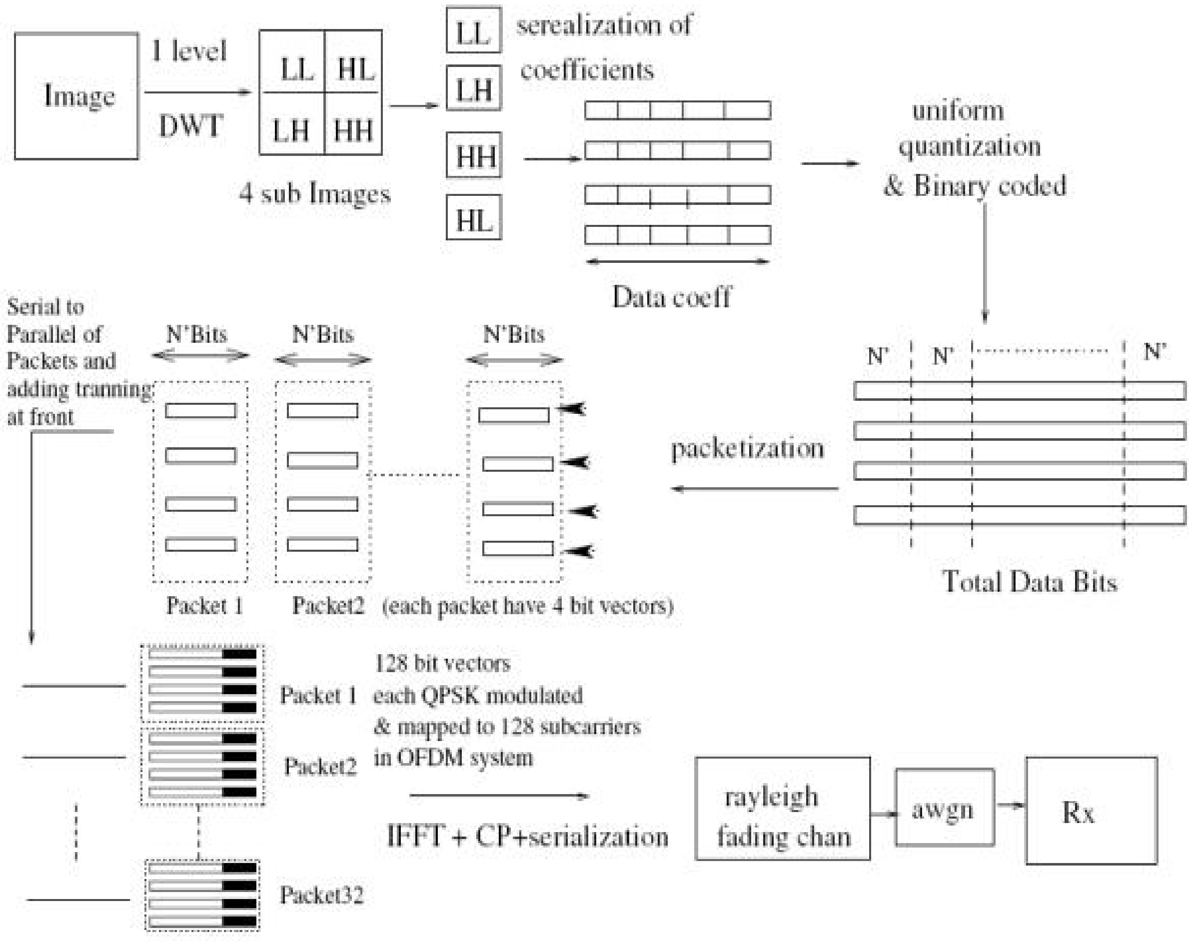

Fig.1.DWT-OFDM SYSTEM

1) Proposed Mapping scheme

For intelligent mapping [5] of the data vectors, subchannel states are fed back to the transmitter in binary form (i.e, one-bit per subcarrier: good(1) or Bad (0)). This simple feedback approach also has very less complexity, as it involves only comparison of received signal power with a predefined threshold P_{th}. In a slow fading scenario, a Bad channel feedback implies the data sent through that subchannel would have been below an acceptable quality. Accordingly, in our energy saving transmission policy, those data mapped on to the bad subchannels are discarded at the transmitter. Additionally, at the receiver, to discard a data vector, the receiver checks if the received power of a data vector is below an acceptable threshold. Retransmission of discarded coefficients is avoided. Instead, the discarded coefficients at the receiver are replaced by

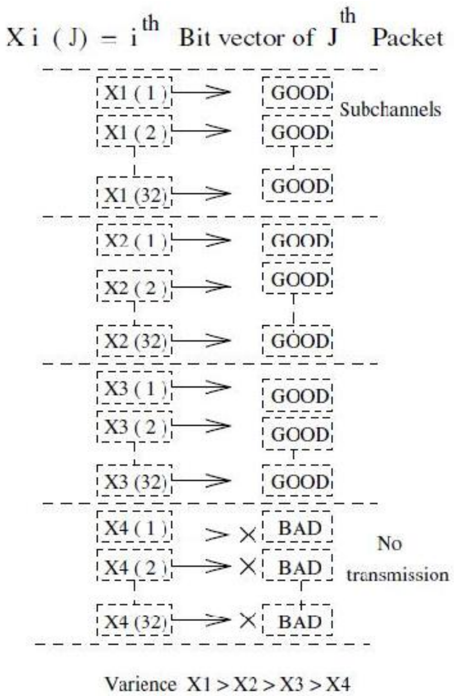

Fig.2.Packet mapping based on channel state DWT-OFDM system .

the average coefficient values of their respective sub-images, which introduces some distortion. To reduce the distortion due to discarding some data, propose a mapping scheme which takes care of the importance level of the mapped data such that the less important data (i.e., in general for DWT image, low pass filtered components are more important: the ones with lower variance levels) are mapped to the bad subchannels. As described in Fig. 2, arrange the bit vectors from all 32 packets such that they are spaced as apart as possible in frequency domain. The subchannels are grouped in to good and bad categories, as depicted in Fig. 2. For this group formation we scan all the subchannels and collect the bad subchannels in order, while maintaining the order of the good ones .The average distortion per coefficient in a packet produced by this scheme is denoted by D for the analysis purpose. The chosen threshold value P_{th} affects the selection of data vectors that are to be discarded at the transmitter. Thus, the quality of reception and the amount of power saved are also changed. It may be mentioned here that the chosen P_{th} corresponds to a particular fading margin.

C. *Channel model*

In this study we use block fading channel model[6] as in. The channel model is illustrated in Fig. 3, where M is the coherence bandwidth in terms of number of subchannels. In a block fading environment, M consecutive subchannels will simultaneously be either bad or good. Each such set consisting M subchannels is called a sub-band. We denote total number of such sub-bands in the OFDM system as N. Thus, the total number of subchannels in the system is N × M. All sub-bands are independently faded with Rayleigh-distributed envelop, which corresponds to the block fading approximation in frequency domain[7]. Our proposed mapping scheme generates a situation of subcarrier assignment for each data vector in a packet. Analysis of this environment is presented in Section 3.

III. FORMULATION AND ANALYSIS

We now formulate the average distortion and energy savings in our proposed transmission scheme. We measure the system performance by probabilistic analysis of the average distortion in a block fading environment. Distortion involved for various loss events. As described in section 2-B1, in the proposed scheme we arrange the data vectors and subchannels in such a way that only the specific loss events can take place. For example, it is unlikely to happen that the data vector with higher importance is transmitted through a bad subchannel, resulting in a loss, while the lesser important data is mapped to a good subchannel and received correctly .Thus, the proposed mapping scheme gives an opportunity to reduce the distortion as much as possible for a given channel condition. Observe that, only a few loss events can take place. Let x_1, x_2, x_3, and x_4 are the data vectors corresponding to the four sub-images obtained from original frame using DWT compression. Also, let $\sigma_{x_1}^2$,$\sigma_{x_2}^2$,$\sigma_{x_3}^2$, and $\sigma_{x_4}^2$ are the respective variances. Without any loss of generality, assume that the variances $\sigma_{x_1}^2$ to $\sigma_{x_4}^2$ are in descending order of magnitude. Thus, the corresponding importance levels are also in descending order. These data vectors are mapped over different subchannels in such a way that only a few specific loss events are possible. The corresponding likelihood of loss events would be: only x_4 is lost; x_3 and x_4 are lost; x_2, x_3, and x_4 are lost; and all x_1, x_2, x_3, and x_4 are lost. Thus, according to our mapping strategy only four combinations of the loss events are possible. The respective distortion associated would be as follows.

The distortion when no data coefficients are lost or discarded is given by:

$$D_{1111} \equiv D_4 = \frac{4\Delta^2}{12}$$

Where Δ is the step size of the quantizer and $\frac{4\Delta^2}{12}$ is the total quantization noise. The distortion when only x_4 is lost or discarded is given by:

$$D_{1110} \equiv D_3 = \sigma_{x_4}^2 + \frac{3\Delta^2}{12}$$

Similarly, the distortion when x_3, and x_4 are lost or discarded is given by:

$$D_{1100} \equiv D_2 = \sigma_{x_4}^2 + \sigma_{x_3}^2 + \frac{3\Delta^2}{12}$$

the distortion when x_2, x_3, and x_4 are lost or discarded is given by:

$$D_{1000} \equiv D_1 = \sigma_{x_4}^2 + \sigma_{x_4}^2 + \sigma_{x_2}^2 + \frac{\Delta^2}{12}$$

and, the distortion when x_1, x_2, x_3, and x_4 are lost or discarded is given by:

$$D_{0000} \equiv D_0 = \sigma_{x_4}^2 + \sigma_{x_3}^2 + \sigma_{x_2}^2 + \sigma_{x_2}^2$$

where D_i = distortion when only i number of data vectors out of the four are received in a packet (i = 0, 1, 2, 3, 4). In general, we can write:

$$D_i = \begin{cases} \frac{i\Delta^2}{12}, \text{if } i = 4, \\ \sum_{i+1}^{4} \sigma_{x_i}^2 + \frac{i\Delta^2}{12}, \text{otherwise.} \end{cases} \quad (1)$$

A. *Block fading channel behavior*

The performance of the proposed scheme depends on probability of the loss events[8]. In this section, the probabilities of loss events are determined with respect to the channel fading parameter. As mentioned in section 2-B, the packets are mapped in such a way that the channel fading can be considered independent for all the four data vectors in any

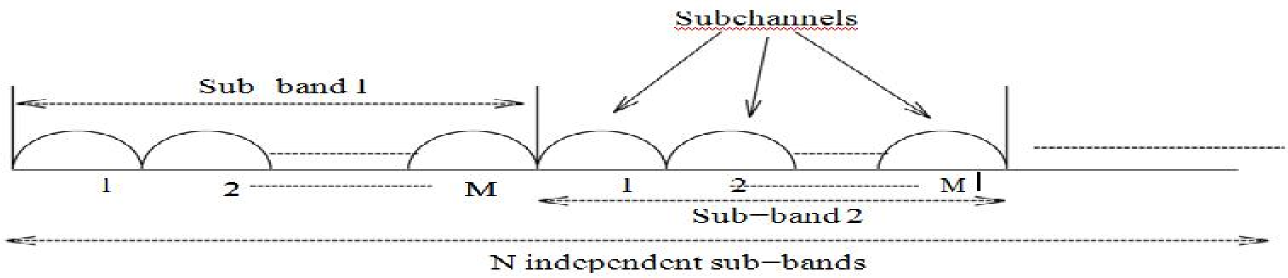

Fig. 3. The concept of block fading channels in OFDM system

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packet. For Rayleigh fading channel, the received power P is exponentially distributed with probability density function (pdf) given by

$$fP(a) = \frac{1}{P}\exp\left(-\frac{a}{P}\right) \quad (2)$$

where P be the average received power. If F is the fading margin, it is related to the receiver threshold sensitivity P_{th} as:

$$F = \frac{\bar{P}}{P_{th}}, \quad (3)$$

Let P be the probability that a sub-band is deeply faded. Using eq.2, P can be expressed as:

$$P = \int_0^{P_{th}} fP(a)da = 1 - \exp\left(-\frac{1}{F}\right). \quad (4)$$

In our interleaved coefficient mapping scheme, all the four subchannels per group of four coefficients are from different sub-bands. Thus, p will also be the probability of a subchannel to be bad. Let P_i = probability associated with the loss event i, for i = 0, 1, 2, 3, 4, which produces distortion D_i. Thus, for an arbitrary received packet we can write:

$$P_i = \binom{4}{i} p^{4-i}(1-p)^i. \quad (5)$$

Then, the average distortion of the proposed scheme can be written as:

$$\overline{D} = \sum_{i=0}^{4} D_i P_i, \quad (6)$$

Where D_i , P_i can be determined by eq. (1),(5) respectively.

B. Energy saving measure

In the proposed scheme the less important data vectors are discarded at the transmitter to save power if corresponding subchannel is in fading state. Denoting the percentage of data not transmitted in a packet as a measure of the percentage of energy saving, using (5) we can write energy saving expression as:

$$\%\, energy\ saved = 100 \times \sum_{i=0}^{4} iP_i/4 . \quad (7)$$

IV. RESULTS

The formulas are mentioned in section 3, As per the formulas, we have present analysis of formulas and simulated results in this section. For simulations we transmitted standard Lena image of size 256 × 256 pixels. At here we have taken OFDM system with N × M = 128 subcarriers. By these subcarriers 32 packets are transmitted in simulation process. In this packets are distributed in frequency domain and time domain. The packets are transmitted back to back , data will be corrupted due to time delay in process. So, we had give time interval for each packet while transmitting through subcarriers. We simulated block fading channel with number of sub-bands N = 4 and the coherence bandwidth equivalent to 32 subcarriers (M = 32). QPSK modulation scheme is used. Thus, 128 × 2 bits per OFDM symbols are transmitted through a subchannel.

The variances of data vectors obtained for 'Lena' image provide the conditional distortion values associated with different loss events given by (1). The conditional distortions are plotted against the loss events in Fig. 4. We can observe the effective distortion variation according to the importance of the data vectors. Analytically obtained distortion measure and percentage energy saving, given by (6) and (7), respectively, are plotted against the P_{th} in Fig. 6, where the analyzed results are supported by simulated values. From Fig. 5, it can be concluded that the distortion in reception process increases with power threshold P_{th}. The Figure that the energy saving is also increasing by restricting lesser important data from transmission through bad subchannels. In the worst case, it follows that we can save more than 60 percent power. Transmission of Lena image through the OFDM system provides simulation data, showing PSNR and energy saving variations (quality) in Fig. 6. The receiver rejects a coefficient for which the instantaneous SNR is below an acceptable threshold. It can be noted from Fig. 6.

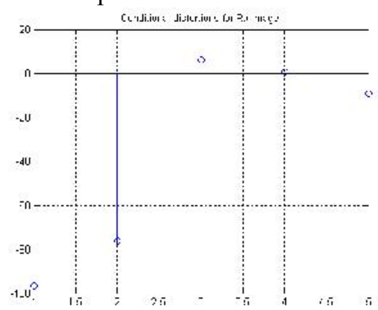


Fig. 4. Conditional distortions for Lena image.

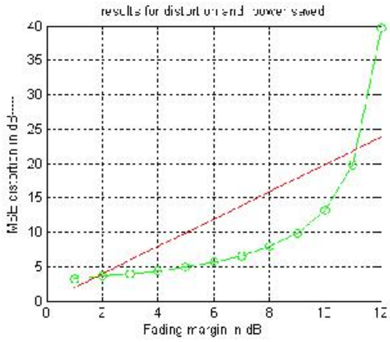


Fig.5. Simulation and analytical results for distortion and % power saving

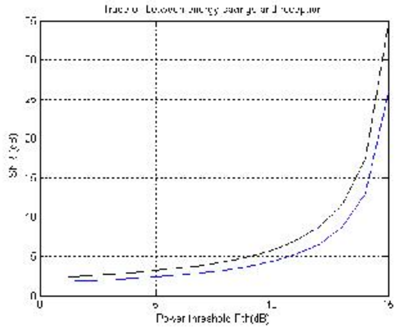
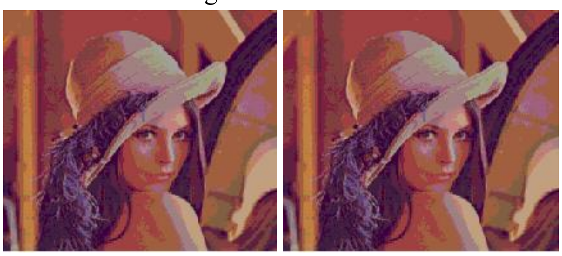


Fig.6.Trade-off between energy saving and reception

It can be further noted that, we restrict the transmission depending upon the instantaneous received power of the sub-channels, and a decision is made based on the value P_{th}. Thus, the amount of power saved and the corresponding degradation in quality for a higher P_{th} can be controlled. It would be user dependent to choose between the reception quality and energy saving, as both are controlled by the parameter P_{th}.

a .Source Image b. PSNR 21 dB.



c. PSNR 28 dB d. PSNR 38 dB.

Fig..Transmitted Lena image and its received version at different PSNRs.

Fig. 7.shows the received Lena images with different PSNR. Note that, PSNR = 21 dB corresponds to a reasonably poor image quality. Thus, at a given channel SNR, an arbitrary choice of P_{th} may lead to an unacceptably poor reception quality.

V. CONCLUSION

In this paper present a energy saving approach to transmission of discrete wavelet transformation based compressed image frames over the OFDM channels. Based on one-bit channel state information at the transmitter descriptions in order of descending priority are assigned to the currently good channels. For intelligent mapping of the data vectors, subchannel states are fed back to the transmitter in binary form (i.e., one-bit per subcarrier: 'good' (1) or 'bad' (0)). We propose a energy saving approach, where the compressed coefficients are arranged in descending order of priority and mapped over the channels starting with the good ones. The coefficients with lower importance level, which are likely mapped over the bad channels are discarded at the transmitter to save power without significant loss of reception quality. By using MAT LAB simulation analyze the performance of our proposed scheme, in terms of system energy saving without compromising the received quality in terms of peak signal-noise ratio.

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