



SECURE DATA TRANSMISSION BY BARCODE MODULATION IN COMMUNICATION SYSTEM

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Abstract

The idea of 2-D standardized barcode is of extraordinary importance for use in wireless data transmission between handheld electronic devices. In a common setup, any file or document from one cell phone is transferred to another cell phone as a barcode and it is then captured and decoded through the second call phone. In this paper, a new methodology for data transmission using 2-D barcode is introduced, and its execution is assessed in contrast with other standard methods of barcode modulation. In this advanced technique, orthogonal frequency-division multiplexing (OFDM) modulation is used together with differential phase shift keying (DPSK) over adjacent frequency domain elements. A particular point of this study is to build up a framework that is demonstrated tolerant to camera movements, picture blur, and light leakage inside neighboring pixels of a LCD.

Keywords: Barcode modulation, OFDM, DPSK, LCD

1. INTRODUCTION

Exchanging of information through near field communication (NFC), say through bluetooth, is subjected to numerous assaults like man in the center assault. In any case, the viewable pathway visual channel lessons the obstruction from different applications, and consequently can be utilized as a part of short range communication frameworks like exchanging of information from a PDA, PC, tablet, or different devices. A comparison of different 2D barcode formats that are utilized as a part of cellular telephone applications can be found in [2]. This thought was before actualized in [3], where information is exchanged through a progression of QR code. But, the bit rate accomplished is less than 10 kbps. Later in [5], data is transmitted between a computer monitor and digital camera. Barcodes have assumed a remarkable part in empowering various recognizing confirmation techniques since their improvement in 1952 [1]. Honestly scanner tag is a clear and astute system for putting away machine discernable automated data on paper or item bundles. As squeezing needs to exchange significantly more data speedier and with high reliability have ascended,



there have been various improvements that were made on the main scanner tag plot. Development of two dimensional (2D) or structure scanner labels opened another front for these functional codes what's more, their application in more unpredictable data exchange situations like securing contact data, URLs notwithstanding different things, in which QR codes [2] have ended up being continuously surely understood. An examination of 2D scanner tag for each performance camera phone applications can be found in [3].

A huge part of the attempts in cross section scanner tag progression have been dedicated to standardized distinguishing pieces of proof appeared on a bit of paper as that is the way they are commonly used. With the substitution of books with tablets and advanced book per users one could inspect that re-course of action of the paper with LCD may open another promising front for more Extensive employments of 2D scanner labels as a mean of data trade. In expansion not in the least like the static paper, the LCD may show time-contrasting institutionalized recognizable pieces of proof for the inescapable trade of surges of data to the tolerating electronic device(s) as depicted in Fig. 1. This thought has been completed in [6] where transmission of data between two telephones through a movement of 2D QR codes is analyzed, achieving bit rates of fewer than 10 kbps for forefront mobile phones. Here a bit rate of 14 Mbps is accomplished. Numerous thoughts have been executed for this sort of LCD-camera based communication systems [5]-[8]. The LCD camera relative developments at the time of image capturing may introduce motion blur

distortions. This sort of distortions extremely influences the execution of Quadrature Phase Shift Keying (QPSK) Orthogonal Frequency Division Multiplexing (OFDM) modulation. To keep away from this, DPSK-OFDM is utilized [9]. Here information is stored in phase difference of adjacent frequency components. Thus any phase distortions due to motion blur, will influence the adjacent frequency components insignificantly. Later the thought was further created in [5] in which a PC screen what's more, a mechanized camera are used for transmission what's more, assembling with bit rates of more than 14 Mbps finished in docked transmitter and beneficiary conditions over distance of up to 4 meters. Regardless, this rate drops to somewhat more than 2 Mbps when the distance is extended to 14 meters. The unrivaled execution of the later use is refined using a more fruitful alteration and coding arrangement for the general believed is to use the inverse Fourier change (IFT) of data like OFDM to manage LCD pixels. While picture dark and light spillage massively diminishes the execution of QR decoders they restrictedly affect OFDM equalization. Other than their execution debasement is restricted to known parts of the decoded data.

2. PROPOSED METHOD

DATA TRANSFER CAPACITY

There are many factors affecting the amount of data that can be extracted from a particular LCD, some of them depend on the LCD design itself and others on the camera working as the receiver. Moreover, there are some limitations due to the system's processing



capability and power consumption. Although in practice, it might be challenging to obtain a fair assessment of the system's performance, it is important to know what affects the transfer rate and what can be done about each limiting factor in this data transmission medium. The data capacity of an LCD may be calculated by considering for instance the maximum number of bits in a raw image as shown on the LCD. A display having M_D the rows and N_D columns, showing a color image in L_D channels (typically L_D for red, green and blue) and color bit depth of B_D bits per channel, would have the maximum information of:

$$C_I = M_D \times N_D \times L_D \times B_D \text{ bits per image} \quad (1)$$

This is the maximum information that can be shown on the LCD on a single image due to the discrete nature of the data shown. A refresh rate R of for the LCD leads to a data rate of $C_V = R \times C_I$. For a state of the art cell phone with a high resolution display having 16M colors, the parameters would be $M_D=1136$, $N_D = 640$, $P_D = 3$, $B_D = 8$ and $R_D = 60\text{Hz}$ resulting in $C_I \approx 17\text{Mbits}$ and $C_V \approx 1\text{Gbps}$, which is an extremely high data rate even when compared to current radio frequency wireless technologies. Unfortunately, this rate cannot be achieved due to the limitations.

A. Camera Limitations

A digital camera could be considered as a device which digitally samples a 2D signal. For correct sampling of consecutive frames in time, camera capture rate should be 2 times the display refresh rate (R_D) unless there is a synchronization system in place

to activate the camera shutter when the image is stabilized on the display (exactly between frame changes). As it is not normally the case, if the camera capture rate is for example $R_c = 8$ Hz then the display refresh rate could not exceed 4 Hz. To satisfy the Nyquist criteria for image resolution, each pixel of the image shown on the LCD should be sampled by 2 or more pixels in the camera. The image sensor uses limited number of bits per channel for conversion of each color pixel, resulting into quantization noise. To limit the effect of this noise on the overall detection performance it should be maintained 6-10dB below system noise level, which on the other hand must be maintained well below signal power level, depending on the modulation method used, in order to have acceptable bit error rates (BER).

B. Power Limitations

The capacity of every communication channel depends on the power of the signal sent through that medium as predicted by Shannon theorem, and in this case the power would be limited by the intensity of light an LCD can generate. Increasing this intensity would improve signal to interference and noise ratio (SINR) in the receiver. Like RF power transmitters, LCD displays are limited in terms of the maximum power leading to the Peak to Average Power Ratio (PAPR) limitation, which is a common challenge for OFDM signals. When maximum available intensity is fixed, higher PAPR yields lower average intensity and thus lower SINR. Therefore transmission of OFDM signals over an LCD requires a trade-off between the average power transmitted and the



resulting distortion due to clipping of the peaks, another issue that is addressed in this study. Although various PAPR reduction methods are available, they would affect QPSK-OFDM and DPSK-OFDM methods in a same manner, and DPSK modulation would still be superior when the same method of PAPR reduction is used. Further discussions on clipping OFDM signals can be found.

C. Inter-Symbol Interference (ISI)

When a barcode is printed on paper, a white pixel does not affect its neighboring black pixels provided that the print quality is good and the resolution is high enough. On the other hand, when data is shown on an LCD, light that is passing through white pixels may leak into neighboring black pixels making them look gray. The straightforward solution to this problem is to increase the size of the pixels so that they have minimal effects on each other. This is called barcode granularity in QR coding. On a lower level this is exactly the way a printed barcode is generated, where each printed dot is not corresponding to a data symbol but rather many printer dots contribute to a single black symbol. In the case of LCD, each pixel $k \times k$ set is assigned the same color to generate just one symbol, isolating the center pixel from bordering pixels that may be affected by neighbors. Unfortunately this method greatly decreases the transfer rate because the $M \times N$ independent data symbols reduce to which leads to a K^2 to 1 rate decrease. The inter-symbol interference could happen in the receiver camera as well becoming a major obstacle for increasing the pixel density of barcodes. Moreover, any movements

between camera and LCD during the capture of an image for barcode processing results in motion blur which is translated into ISI as neighboring pixels affect each other in the captured image.

At first this effect might not be evident based on common experiments with 2D barcodes like QR codes. These codes are decoded successfully without major efforts in terms of stability of code or camera. While performance of some QR code detection algorithms are studied and first read rate performances of some 2D barcodes have been studied, the research is rather focused on user experience as an important factor, which is to determine if the user is able to decode the barcode at first try. In fact, performance of 2D barcode decoders are measured by the frames processed per second, thus when a barcode scanner tries to decode a stationary 2D barcode, multiple frames are processed within a second and a successful decode will be reported if only one frame is captured in good conditions. To investigate if a relative barcode camera motion affects the performance of the decoder, the following experiment was conducted. Alphanumeric strings of various lengths of number π were encoded into QR Codes of increasing dimensions, in a way to fill the barcode capacity as shown in Fig. 3. Error correction level is set to medium (M) which is capable of correcting roughly 15% error rate. Consecutive frames were captured using a hand-held camera phone, first by fixing the camera and then by holding it in one hand by a non-experienced user. Camera focus was locked the same way in both cases and normal office lighting and a distance of 12 cm were maintained. Moreover, the



width of rectangular QR code pixels was. 312 mm regardless of the code capacity. As a result the largest QR code which had 121×121 pixels was 37.7 mm in width which is double the density of ordinary QR barcode. Encoding and decoding of the QR codes were accomplished using ZXing open-source libraries.

In order to limit the effect of perspective distortion, camera and barcode are held parallel in the docked case, and although this angle cannot be guaranteed in the handheld scenario, the performance drop would be negligible as reported. The captured images taken at 10 frames per second were processed to detect the QR code, and the percentage of decodable images are shown in Table I. As can be seen from these results, for smaller QR codes it does not make any difference if the camera is held by hand or fixed as all the frames would be detected successfully. However, as the size of the QR code increases, more and more frames are dropped in the moving case compared to the fixed camera setup. In any setup studied, user experience would not be a problem as there was at least one detectable frame within one second of recording onset.

D. Interference, Distortion, and Noise

When a camera is used to take a picture of a 2D barcode, certain image artifacts could impact the result of data extraction method. These artifacts are mainly due to the following:

Moreover, nonlinear distortions exist in a typical optical wireless data transmission setup due to transmitter and receiver physical limitations that are

discussed in [21]. These undesirable effects should be addressed to ensure the feasibility of the algorithm under realistic scenarios, while preserving the ability for attaining high data transfer rates.

DPSK-OFDM

While LCD technology is improving on pixel to pixel isolation, some of the image capture distortions still remain, causing neighboring pixels of the barcode mix up in the image and resulting in some kind of Inter Symbol Interference. The main idea in resolving this problem is to interpret the barcode image as a wireless radio signal for which ISI reduction techniques have already been proven successful. One of the best and most feasible modulation methods capable of coping with severe conditions in band limited communication channels is the so-called Orthogonal Frequency Division Multiplexing or OFDM. The general idea is that when dealing with band-limited, power-constrained, multipath channels, it is more efficient to transfer a bunch of narrow-band signals in parallel instead of a single high bandwidth signal.

A. Similarities of Barcode and Wireless RF Channel

For simplicity each 2D image is reformulated into a 1D row vector containing all pixels in the 2D image. Each row can be considered as a time domain signal which has Pulse Amplitude Modulation (zeros are black and ones are white pixels). Consider taking a picture of this single row, in a band limited channel which has a combination of camera focus problems, resolution limitations, light leakage from white to



black pixels, among other things. Moreover in a multipath channel in which the camera moves during image capture and mixes up the image of several neighboring pixels, the resulting image will suffer from high ISI. To solve these problems in a time domain radio signal, OFDM method is used to essentially divide the channel into multiple orthogonal low bandwidth channels and the low rate data is sent into these channels in parallel. So in case of the 1D data the inverse Fourier transform is used for displaying the data instead of using the PAM modulated process, where Hermitian symmetry conditions should be met to have real-valued outputs. As a result, most artifacts only affect the high frequency components leaving low frequency components intact for data transmission.

This idea may be generalized to 2D signals to meet the requirement for transferring the entire image at once. Instead of 1D inverse Fourier transform, the 2D version is used such that the effect of artifacts acting on two axes would be confined to high frequency components. The exact modulation scheme will be discussed later in this study.

In general each sub-carrier in an OFDM signal is modulated using M-quadrature amplitude modulation (M-QAM). Thus proper phase shift of each element should be estimated and compensated for before demodulation. This generally requires specific conditions on the channel characteristics like fast fading where pilot tones are used for channel estimation or slow fading where most methods would require multiple symbols in seeking similar channel

responses (i.e., similar transfer functions) [23] and [24].

When using OFDM for transmission of data as images, all the channel equalization computations should be based on a single OFDM frame due to the independent channel response between subsequent frames, unless the frame rate is very high. In fact each frame is distorted by LCD-Camera relative motion during its own capture time. To mitigate this problem the phase difference between adjacent elements is used to convey data. Using DPSK modulation prior to applying the inverse Fourier transform in OFDM modulation, data would not have to be stored in the absolute phase of the received elements but rather in its phase difference to the neighboring element, which eliminates the requirement for channel estimation and equalization if the channel response does not vary abruptly between adjacent subcarriers.

A. Transmitter

One of the advantages of using OFDM is its effective computation method which uses the Inverse Fast Fourier Transform (IFFT) to modulate input data into orthogonal frequencies. The modulated signal should be real-valued in order to be shown on an LCD, so the input to the IFFT algorithm should have Hermitian symmetry. This requirement is shown in the following equation:

$$T(M - m, N - n) = T(m, n)^* \quad (2)$$

Where $0 \leq m < M$ and $0 \leq n < N$, and $*$ denotes the complex conjugate operator. Fig. 4 shows the



elements relationship in order to have a real-valued IFFT for T matrix. In this configuration, only regions 1 and 2 are used for data transmission independently, and regions 3 and 4 are calculated accordingly to have a real-valued IFFT. Moreover, the symmetry requirements for elements that have been deliberately set to zero would be automatically satisfied.

Constellation Mapping: The input data is decomposed into 2-bit symbols. Each symbol is converted to a complex phase by the following rules:

$$11 \rightarrow e^{j\frac{1\pi}{4}}, 10 \rightarrow e^{j\frac{7\pi}{4}}, 01 \rightarrow e^{j\frac{3\pi}{4}}, 00 \rightarrow e^{j\frac{5\pi}{4}}$$

Therefore the first bit modulates the real component and the second bit modulates the imaginary component of the phase for each data symbol. These symbols are placed in a matrix which contains the absolute phase elements that are going to be modulated using DPSK.

Differential PSK: Matrix is transferred into a differential matrix using the following method:

- $D(0,0) = S(0,0)$;
- $D(0, n) = D(0, n-1) \times S(0, n) \quad 1 \leq n < N - 2$;
- $D(m, n) = D(m-1, n) \times S(m, n) \quad 1 \leq m < \frac{M}{2} - 1, 0 \leq n < N - 2$.

Subsequently, the DPSK modulated matrix is divided into two matrices:

- $D^1(m, n) = D(m, n)$;
- $D^2(m, n) = D(m, n + \frac{N-2}{2})$;

Where $0 \leq m < \frac{M}{2} - 1, 0 \leq n < \frac{N}{2} - 1$. These two matrices are used to fill regions 1 and 2 of the matrix T. Regions 3 and 4 of are generated based on the Hermitian symmetry requirement, and all the remaining strips on are set to zero. These small regions, especially around region 1 (left top corner), may be used for special data transmission such as frame rate or type of error correction coding used.

Inverse FFT: Considering is the frequency domain representation of the signal, the IFFT is applied on it to have the time domain signal referred to as D_t . This signal would have zero mean because $T(0, 0) = 0$, so it should be adjusted in order to use the full dynamic range of pixels.

PAPR Adjustment: is a real-valued 2D signal with high peak to average ratios. In fact, the probability of having a high PAPR increases as the number of frequency components increases as can be seen in Fig. 5. There are several methods to limit the PAPR of OFDM signals which might be applied here with slight modifications for 2D signals. One of the most practical methods would be soft clipping of the signal in which a threshold level of based on signal average power level is set such that:

$$\text{ClippRatio} = \frac{A_{max}}{\sqrt{P_{avg}}} \quad (3)$$

Where P_{avg} is average power per element in the OFDM signal before clipping. Any components with higher amplitude than

A_{max} are consequently clipped to A_{max} resulting in a 2D matrix D_c .



Amplitude Adjustment: The pixel levels in the PAPR adjusted image need to be transformed into LCD dynamic range levels for efficient utilization of transmission power. Normally the intensity levels on the LCD goes from 0 to I_{max} . So D_c values are transformed linearly to this range using the following equation:

$$D_a(i, j) = \frac{D_c(i, j) - \text{Min}(D_c)}{\text{Max}(D_c) - \text{Min}(D_c)} \quad (4)$$

Thus the average power of is maximized for LCD projection.

Finder Patterns: Proper demodulation of data requires precise extraction of the modulated data from captured image and compensating for any perspective distortions. General finder patterns used with 2D barcodes may be used here like the 1, 1, 3, 1, 1 pattern used in QR-codes, for which fast and efficient detection algorithms have already been developed. A sample 128×128 image generated by the preceding method is shown in Fig. as it would be shown on the LCD of the transmitting device.

A. Cyclic Extension

OFDM systems require cyclic extension to prevent inter carrier interference (ICI). To be sufficient, the length of the added cyclic extension must be more than the time spread of the channel. In case of the 2D barcode, periodic extension of the image generated by 2D-IFFT is required to prevent ICI. The length of this extension is determined by the impulse response of the channel, which in turn depends on the image blur and the amount of movement anticipated between LCD and camera. However, since in this

study the channel response is modeled in the frequency domain, frequency domain filtering is applied on the barcode, and effective cyclic extension is achieved by frequency domain multiplication which results in time domain cyclic convolution. Hence in all the following simulations the length of the cyclic extension is the same for DPSK-OFDM and QPSK-OFDM ensuring ICI elimination in the longest channel responses simulated.

B. Receiver

After displaying the generated image of Fig. 6, the receiver uses its camera for sampling and registering the acquired image so that a fairly acceptable copy of is created at the receiver end. The effects of interference, noise and distortions encountered in this step are addressed in the simulation section. To obtain the transmitted data successfully, the following steps should be taken into consideration at the receiver end.

Image Capture: Digital camera and display systems have a limited refresh rate which tends to be more than 23 Hz for different standards. In a synchronous system the camera can capture each displayed frame at the exact moment when it is fully stable. However if the receiver does not know when a new frame is ready on the display, the sampling rate should be at least twice the display rate to ensure capture of at least one acceptable frame. Moreover the relative distance and angle between camera and display is bounded by the Nyquist criteria where each pixel on the display frame should map into a minimum of 2×2 block in the camera.



Image Registration: The first step in processing the captured image is to extract the displayed image from background which depends on predefined finder patterns put into the image. For example, data matrix guidance lines are used. Because measurement errors in finder pattern location and perspective correction errors are not part of this study, the simulated images and their distorted received signals are ideally registered isolating the effects of blur and camera movement on error rate of different schemes.

FFT: Applying Fast Fourier Transform on the registered image results in frequency domain data which is comprised of the differential phase modulated elements stored in R_f matrix.

DPSK Demodulation: The original constellation mapped data can be extracted using phase differences between respective elements, but first data corresponding to regions 1 and 2 should be concatenated together to form matrix corresponding to the transmitted matrix T.

$$\bullet R_d(0, 0) = R(0, 0);$$

$$\bullet R_d(0, n) = R(0, n) \times R^*(0, n-1) \quad 0 < n < N-2.$$

$$\bullet R_d(m, n) = R(m, n) \times R^*(m-1, n) \quad 0 < n < N-2, \quad 0 < m < \frac{M}{2} - 1.$$

The resulting would be a distorted copy of in transmitter path.

Detection: Now that the phase differences have been extracted, each input bit may be calculated using the constellation map of the transmitter. Each element is evaluated using its real and imaginary components.

The sign of the real component determines the first bit and the sign of the imaginary component determines the second bit.

C. Error Correction

Error correction coding is often used in communication systems to correct for the different number of bits lost in the transmission process. For example, Reed-Solomon (RS) coding is used in QR codes, where depending on the level of error correction used, error rates of 7% up to 30% can be corrected at the receiver end. While the selection of error correction coding has a great influence on the overall performance of the communication system, they are generally used on top of the modulation-demodulation scheme and after source coding. Therefore, based on the achievable error rates without error correction coding, one can select an appropriate coding scheme to create a reliable communication channel. As a result, when considering the BER performance plots provided in the simulation section (IV), it should be noted that error rates in excess of 30% are not correctable even with the most redundant RS codes defined in [2] and would consequently be considered a non-reliable channel for this kind of transmission. [4] discussed about Improved Particle Swarm Optimization. The fuzzy filter based on particle swarm optimization is used to remove the high density image impulse noise, which occur during the transmission, data acquisition and processing. The proposed system has a fuzzy filter which has the parallel fuzzy inference mechanism, fuzzy mean process, and a fuzzy composition process. In particular, by using no-



reference Q metric, the particle swarm optimization learning is sufficient to optimize the parameter necessitated by the particle swarm optimization based fuzzy filter, therefore the proposed fuzzy filter can cope with particle situation where the assumption of existence of “ground-truth” reference does not hold. The merging of the particle swarm optimization with the fuzzy filter helps to build an auto tuning mechanism for the fuzzy filter without any prior knowledge regarding the noise and the true image. Thus the reference measures are not need for removing the noise and in restoring the image. The final output image (Restored image) confirm that the fuzzy filter based on particle swarm optimization attain the excellent quality of restored images in term of peak signal-to-noise ratio, mean absolute error and mean square error even when the noise rate is above 0.5 and without having any reference measures.

D. Computational Complexity

An important issue regarding the applicability of such a system would be the computational power required to implement the system. Although a thorough investigation of such requirements and any optimization process can be subject to further study, it should be noted that the proposed DQPSK-OFDM system has a limited processing overhead compared to the equivalent QPSK-OFDM system which is already implemented and tested. More specifically, on the transmitter side, although the differential modulation is described by complex multiplications, it can be easily implemented using a small look-up table taking current phase and data to be modulated as inputs. However, in the receiver side about

$M \times N$ multiplications are required to extract phase differences before detection which is not prohibitive compared to the complexity of the 2D FFT preceding it which is in the order of $M \times N \times \log(M \times N)$.

3. RESULTS

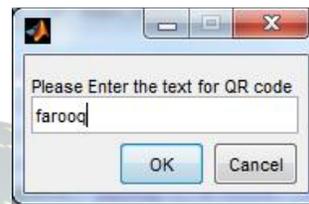


Figure 1: Entering Text for QR code

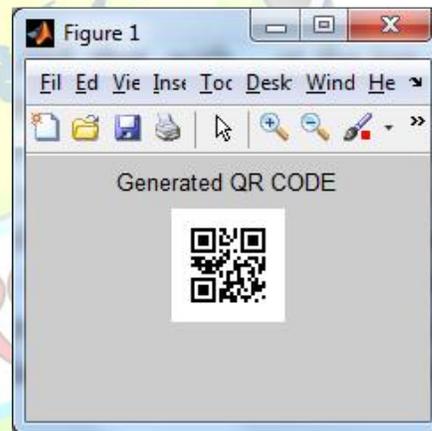


Figure 2: Generated QR code

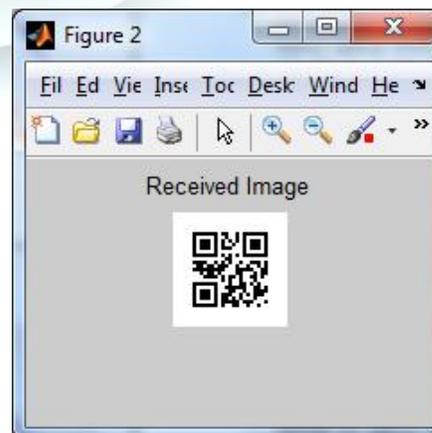


Figure 3: Received image



Figure 4: Retrieved text image

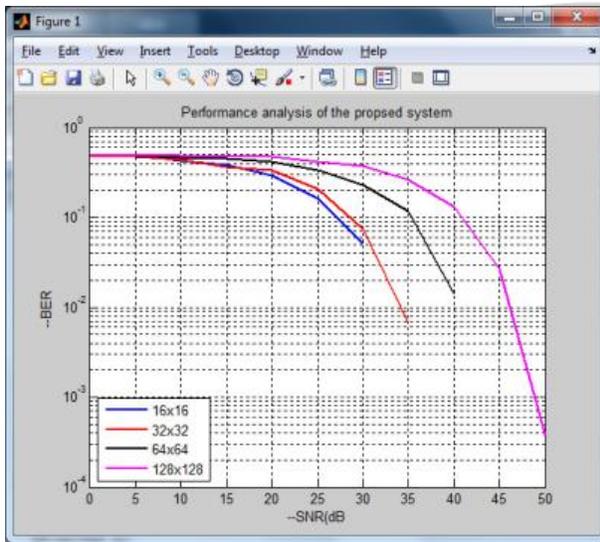


Figure 5: In this we are using IFFT and FFT in OFDM system for transmitting the bar code. Instead of IFFT and FFT we are using DWT and IDWT for the better results.

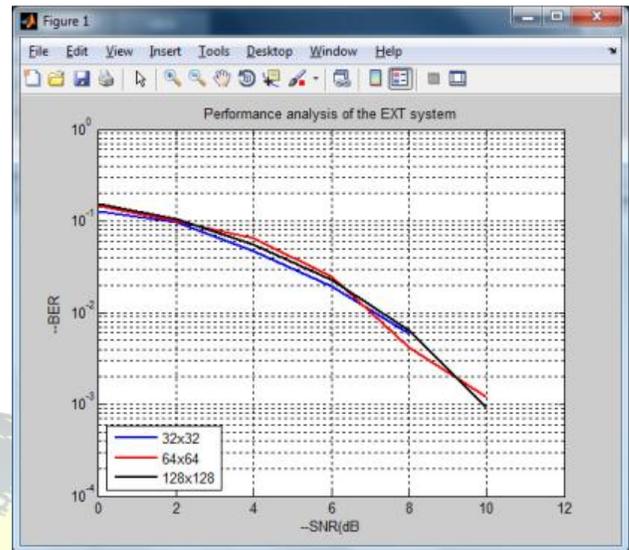


Figure 6: Performance analysis

4. CONCLUSION

In this paper Differential Phase Shift Keying was consolidated with Orthogonal Frequency Division Multiplexing in order to modulate data stream into visual two dimensional barcodes. It was demonstrated that QPSK-OFDM modulation has genuine weaknesses in the moderation of camera LCD developments where the phase of every component changes ceaselessly. On the other hand, addition of a differential phase modulator before OFDM to modulate the data stream into phase differences of adjacent elements (DPSK-OFDM) causes the motion effect impact to progressively debilitate due to its steady change from component to component, adding to a little phase from the perfect stage in the received signal.

It was observed that under relative LCD-camera movements that produce error rates in abundance of 30% in PAM and QPSK-OFDM, the proposed



arrangement of DPSK-OFDM will keep up an error rate less than 8% which is correctable by utilizing error correction coding. . Future inquiries in a determination to this issue need to address the best decision of differential example to advance execution for different movement situations. Additionally, extension of the present two-bit per image constellations increases data transfer capacity , and its BER execution assessment would be required. Nevertheless, a study on the impact of point of view revision mistakes on the BER execution of this calculation contrasted with alternate ones could expand our comprehension of its materialness to true situations.

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