Secure Data Transmission using Barcode Modulation and Demodulation in Mobile Devices

M. Mani Kumar Reddy\textsuperscript{1}, A. Valli Bhasha\textsuperscript{2}
\textsuperscript{1}PG Scholar, Dept of ECE (DECs), KSRMCE, Kadapa, AP, India.
\textsuperscript{2}Assistant Professor, Dept of ECE, KSRMCE, Kadapa, AP, India.

Abstract: 2D barcodes have enjoyed a significant role in mobile applications like online payment, aadhar cards, etc. Almost every camera enabled smart phones can scan barcodes. A barcode can be transferred from one mobile to another by capturing images. But the relative movements during capture can induce motion-blur distortions in the captured image. This problem can be solved by using orthogonal frequency division multiplexing (OFDM) modulation along with differential phase shift keying (DPSK). In this technique, a large number of closely spaced orthogonal sub-carriers carry the data on several parallel data streams or channels. The sub-carriers are modulated with any of the conventional modulation technique. Here DPSK modulation is used to modulate the sub-carriers. The modulation is performed in the message which is encoded as the barcode. Inverse fast Fourier transform (IFFT) is applied to make the N sub-carriers into orthogonal. This modulated message is encoded into barcode and then it is transmitted. The camera acts as the receiver. The barcode is captured and then fast Fourier transform (FFT) is applied onto the decoded message. Then, original message is retrieved by performing demodulation. Since data is stored in phase difference, adjacent elements are less affected by the motion blur distortions.

Keywords: Barcode, Data Transfer, Differential Phase Shift Keying, Orthogonal Frequency-Division Multiplexing (OFDM) Modulation.

I. INTRODUCTION

Barcodes have played a great role in facilitating numerous identification processes since their invention in 1952. In fact barcode is a simple and cost-effective method of storing machine readable digital data on paper or product packages. As pressing needs to transfer even more data faster and with high reliability have emerged, there have been many improvements that were made on the original barcode design. Invention of two dimensional (2D) or matrix barcodes opened a new front for these cost-effective codes and their application in more complex data transfer scenarios like storing contact information, URLs among other things, in which QR codes have become increasingly popular. A comparison of 2D barcode performance in camera phone applications can be found. Much of the efforts in matrix barcode development have been dedicated to barcodes displayed on a piece of paper as that is the way they are normally used. With the replacement of books with tablets and e-Book readers one could contemplate that replacement of the paper with LCD may open another promising front for broader applications of 2D barcodes as a mean of data transfer.

Moreover unlike the static paper, the LCD may display time-varying barcodes for the eventual transfer of streams of data to the receiving electronic device(s) as depicted in Fig. 1. This idea has been implemented in where transmission of data between two cell phones through a series of 2D QR codes is studied, achieving bit rates of under 10 kbps for state of the art mobile devices. Later the idea was further developed in which a computer monitor and a digital camera are used for transmission and reception with bit rates of more than 14 Mbps achieved in docked transmitter and receiver conditions over distances of up to 4 meters. However, this rate drops to just over 2 Mbps when the distance is increased to 14 meters. The superior performance of the later implementation is achieved using a more effective modulation and coding scheme for mitigation of image blur and pixel to pixel light leakage. The general idea is to use the inverse Fourier transform (IFT) of data like OFDM to modulate LCD pixels. While image blur and light leakage greatly reduce the performance of QR decoders they have a limited effect on OFDM modulation. Furthermore their performance degradation is confined to known portions of the decoded data. This prior knowledge on non-uniform error probability may be used for adaptive error correction coding based on data region. There is an increasing interest in design and implementation of LCD-Camera based communication systems as indicated.

Copyright © 2017 IJIT. All rights reserved.
M. MANI KUMAR REDDY, A. VALLI BHASHA

This would require additional investigations in determining optimal modulation and demodulation schemes for this type of innovative communications medium. The OFDM modulation uses orthogonal frequency subcarriers to transfer data and can confine image blur, which is essentially a low pass filter, to high frequency components such that low frequency data bits are transmitted intact. This method requires high phase coherence to detect the data bits correctly. The current study extends this idea through additional modifications on the modulation scheme in a way to mitigate LCD-camera relative movements during the capture of a single frame, which results in motion blur distortion on the captured images. This kind of distortion as would be detailed later severely degrades the performance of Quadrature Phase Shift Keying (QPSK) modulated OFDM signals.

![Diagram of the algorithm used for data transfer. Data stream is supposed to include source coding and error correction coding.](image)

The required movement tolerance is achieved by putting data in phase differences of adjacent frequency components leading to a DPSK-OFDM scheme which would be called simply the DPSK method throughout this study. Observing that any phase distortion due to motion blur would affect neighboring frequency components negligibly, data may be transmitted reliably even in the vicinity of high LCD, camera relative motion. A diagram of the system envisioned is shown in Fig. 2. This method also eliminates the channel estimation requirements resulting in lower processing power. To maximize data transmission rate, one should consider extracting maximum data from a single image shown on an LCD and then increase the rate at which consecutive frames will be decoded. In consideration of this issue, any method that is introduced should efficiently utilize the available bandwidth considering motion distortions. Previous studies have demonstrated the feasibility of such systems and have addressed the effects of single distortions like linear misalignment, defocus blur and vignetting on the modulation methods under consideration, but they have not provided a comparative assessment of these systems in a controlled environment. Moreover, no comparisons were made in case of LCD camera motions which greatly affect the performance of the system in applications that involve handheld camera-phone receivers. As a consequence, this study introduces DPSK-OFDM as a means of mitigating LCD camera motion distortions and sets a series of simulations based on mathematical modeling for blur and motion on the received images in a way that the distortion would be the same for PAM (Pulse Amplitude Modulation), QPSK-OFDM and DPSK-OFDM modulations. As a result, a reliable comparison can be made between these major modulation methods regardless of other parameters affecting the performance of such practical systems.

II. RELATED WORK

The impact of clipping noise on optical wireless communication (OWC) systems employing orthogonal frequency division multiplexing (OFDM) is investigated. The two existing optical OFDM (O-OFDM) transmission schemes, asymmetrically clipped optical OFDM (ACO-OFDM) and direct-current-biased optical OFDM (DCO-OFDM), are studied. Time domain signal clipping generally results from direct current (DC) biasing and/or from physical limitations of the transmitter front-end. These include insufficient forward biasing and the maximum power driving limit of the emitter. The clipping noise can be modeled according to the Buss gang theorem and the central limit theorem (CLT) as attenuation of the data-carrying subcarriers at the receiver and addition of zero-mean complex-valued Gaussian noise. Analytical expressions for the attenuation factor and the clipping noise variance are determined in closed-form and employed in the derivation of the electrical signal-to-noise ratio (SNR). The validity of the model is verified through a Monte Carlo bit-error ratio (BER) simulation. Finally, the BER performance of ACO-OFDM with DCO-OFDM is compared for different clipping levels and multi-level quadrature amplitude modulation (M-QAM) schemes. The impact of clipping noise on Optical Wireless Communication (OWC) systems employing Orthogonal Frequency Division Multiplexing (OFDM) is investigated. The two existing Optical OFDM (O-OFDM) transmission schemes, Asymmetrically Clipped Optical OFDM (ACO-OFDM) and Direct Current-biased Optical OFDM (DCO-OFDM), are studied.

Time domain signal clipping generally results from Direct Current (DC) biasing and/or from physical limitations of the transmitter front-end. These include insufficient forward biasing and the maximum power driving limit of the emitter. The clipping noise can be modeled according to the Buss gang theorem and the Central Limit Theorem (CLT) as attenuation of the data-carrying subcarriers at the receiver and addition of zero-mean complex valued Gaussian noise. Note that display modules consume most of the power in digital media devices. So techniques to minimize power consumption in the display are inevitably required. Several image processing techniques for power saving in display panels have been proposed, beyond circuit-level power savings. Unfortunately, such techniques focus on reducing backlight intensity for TFT-LCDs while preserving the same level of perceived quality. So they cannot be applied to power saving in emissive display devices such as OLED. The idea of barcodes has been implemented, where transmission of data between two cell phones through a series of 2D QR codes is studied, achieving bit rates of under 10 kbps for state of the art mobile devices. Later the idea was further developed in which a computer monitor and a digital camera are used for transmission and reception with bit rates of more than 14 Mbps achieved in docked transmitter and receiver conditions.
Secure Data Transmission Using Barcode Modulation and Demodulation in Mobile Devices

over distances of up to 4 meters. However, this rate drops to just over 2 Mbps when the distance is increased to 14 meters.

Drawbacks:
1. Camera limitations
2. Power limitations
3. Inter symbol interference

III. PROPOSED METHODOLOGY

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). 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.

B. 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:

\[ T(M-m,N-n) = T(m,n)* \]  

Fig. 4 shows the elements relationship in order to have a real-valued IFFT for 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.

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

- \( 11 \rightarrow e^{j \pi} \), \( 10 \rightarrow e^{j \pi/2} \), \( 01 \rightarrow e^{j \pi/4} \), \( 00 \rightarrow e^{j 0} \)

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. The IFFT of this matrix would have real-valued output on display. Bended lines show location of complex conjugate pairs. These two matrices are used to fill regions 1 and 2 of the matrix. 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.

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

3. 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:

\[ \text{ClippRatio} = \frac{A_{\text{max}}}{\sqrt{P_{\text{avg}}}} \]  

(2)

It is average power per element in the OFDM signal before clipping. Any components with higher amplitude than are consequently clipped to resulting in a 2D matrix.

4. 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 1. So values are transformed linearly to this range using the following equation:

\[ D(i,j) = \frac{D(0) - \text{Min}(D,C)}{\text{Max}(D,C) - \text{Min}(D,C)} \]  

(3)

Thus the average power of is maximized for LCD projection.

5. 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, 3, 1, 1 pattern used in QR-codes, for which fast and efficient detection algorithms have already been developed. A sample image generated by the preceding method is shown in Fig. 6 as it would be shown on the LCD of the transmitting device.

C. 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.

D. 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:

1. 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 block in the camera.

2. 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.

3. 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 matrix.

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

5. 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.

E. 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
Secure Data Transmission Using Barcode Modulation and Demodulation in Mobile Devices

excess of 30% are not correctable even with the most redundant RS codes defined in and would consequently be considered a non-reliable channel for this kind of transmission.

F. 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 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.

Algorithm of proposed methodology:
Step 1: The message to be transmitted is first converted in to digital data
Step 2: The digital data is mapped with 2 bits per symbol constellation
Step 3: The mapped data is DPSK modulated and IFFT is performed on the modulated data and is clipped and dynamically adjusted and Barcode is generated for the stipulated message and that generated barcode is transmitted to the receiver section
Step 4: At the receiver side FFT is performed to the received data
Step 5: DPSK demodulation is performed at the receiver side to receive the message of what is transmitted at the receiver side
Step 6: Retrieval of the original message is performed by decoding the received barcode data

IV. RESULTS

Fig 2. Analysis. The first step is to enter the text to generate a QR code. Our main aim is to retrieve the entered text back. So, now I have entered “jyoshna 1 2 4”.

Fig 3. Analysis: The text which was entered is generated as a QR code as shown in the above Fig.

Fig 4. Analysis. The generated QR code is captured by the receiver and this is analysed to extract the text entered

Fig 5. Analysis: Finally the above QR code is analysed and the original text is retrieved as shown in above Fig.

Fig 6. The first step is to enter the text to generate a QR code. Our main aim is to retrieve the entered text back. So, now I have entered “svist college 1 2 3”
Generate QR Code
Fig 7. Analysis: The text which was entered is generated as a QR code as shown in the above Fig.

Received image

Fig 8. Analysis: Finally the above QR code is analysed and the original text is retrieved as shown in above Fig.

Advantages And Applications:
1. Barcodes eliminate the possibility of human error. The occurrence of errors for manually entered data is significantly higher than that of barcodes.
2. A barcode scan is fast and reliable, and takes infinitely less time than entering data by hand.
3. Using a barcode system reduces employee training time
4. Barcodes are extremely versatile.

V. CONCLUSION AND FUTURE WORK
In this paper Differential Phase Shift Keying was combined with Orthogonal Frequency Division Multiplexing in order to modulate data stream into visual two dimensional barcodes. It was shown that QPSK-OFDM modulation has serious shortcomings in the mitigation of camera LCD movements where the phase of each element changes continuously. 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 to increasingly weaken because of its gradual change from element to element, contributing to a small deviation from the ideal phase in the received signal. It was observed that under relative LCD-camera motions that generate error rates in excess of 30% in PAM and QPSK-OFDM, the proposed system of DPSK-OFDM will maintain an error rate less than 8% which is practically correctable using error correction coding. Future inquiries in a
resolution to this problem have to address the best choice of differential pattern to optimize performance for various motion scenarios. Moreover, extension of the current two-bit per symbol constellations increases data transfer capacity, and its BER performance evaluation would be required. Nevertheless, a study on the effect of perspective correction errors on the BER performance of this algorithm compared to the other ones could augment our understanding of its applicability to real world scenarios.

VI. REFERENCES