DATA TRANSMISSION USING IMAGE STEGANOGRAPHY IN QUICK RESPONSE (QR) CODE

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ABSTRACT

DATA TRANSMISSION USING IMAGE STEGANOGRAPHY IN QUICK RESPONSE (QR) CODE

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Secure transmission of data is a vital area of research due to increasing identity theft issues. In this study, texts and images that are encoded by a transmitter device are steganographed into Quick Response (QR) codes and sent to a receiver. The security of this data transmission is then evaluated and compared to a previously used method. Specifically, the Differential Phase Shift Keying (DPSK) modulation method was run in conjunction with the Orthogonal Frequency Division Multiplexing (OFDM) technique, and its transmission efficiency was compared to the Phase Amplitude Modulation (PAM) method. The transmission efficiency was measured by performance timing, lenient behavior to camera movements, and picture blurring due to both added noise during transmission and light spreading in the adjacent pixels of a Liquid Crystal Display (LCD) display. In addition, result of image transmission with and without image compression were compared. Results showed that the DPSK modulation method exhibits superior transmission efficiency across all three parameters compared to the PAM method and image compression degrades quality of received image with minimizing image size.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BER	Bit Error Rate
CCD	Charged Couple Device
CMOS	Complementary Metal-Oxide Semiconductor
CRC	Cyclic Redundancy Check
DAB	Digital Audio Broadcasting
DPSK	Differential Phase Shift Keying
DVB-T	Digital Video Broadcasting-Terrestrial
DWT	Discrete Wavelet Transform
FDM	Frequency Division Multiplexing
FDMA	Frequency Division Multiplexing Access
HCCB	High Capacity Color Barcode
HDTV	High Definition TV
ICI	Inter Carrier Interference
IFT	Inverse Fourier Transform
ISBN	International Standard Book Number
ISI	Inter-Symbol Interference
JPEG	Joint Picture Editing Group
LASER	Light Amplification by Simulated Emission of Radiation
LCD	Liquid Crystal Display
OFDM	Orthogonal Frequency Division Multiplexing
PAM	Phase-Amplitude Modulation
PAPR	Peak to Average Power Ratio

PDF	Portable Data File
PTS	Partial Transmit Sequence
QR codes	Quick Response codes
RFID	Radio Frequency Identification
SDT	Signal Distortion Technique
SINR	Signal to Interference and Noise Ratio
SLM	Selective mapping
SNR	Signal to Noise Ratio
SST	Signal Scrambling Technique
TI	Tone Injection
TR	Tone Reservation
UPC	Universal Product Code
UPS	United Parcel Service

CHAPTER 1

INTRODUCTION

Effort made in barcode development has been mainly devoted to barcodes displayed on a piece of paper or packaging as it is a widely-used application of barcodes. Changing technology has replaced books with e-Book readers and tablets. The same trend can also be followed with replacing traditionally used paper with Liquid Crystal Display (LCD) in the near future. The use of the LCD can create an opportunity for a 2-dimensional (2-D) barcode to have a faster data transfer. The LCD can display a series of the different barcodes, which can be used to transfer long streams of information on the receiver's mobile device. This is shown in Figure 1.

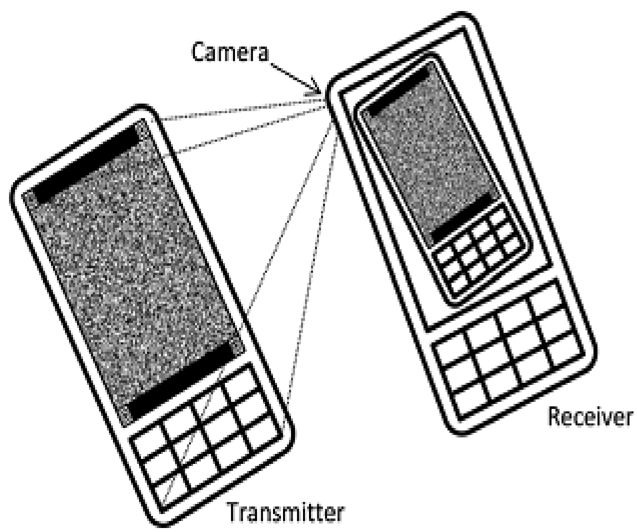

FIGURE 1. Data transfer between two handheld devices using number of 2-D barcodes.

Barcode data transfer has been proven to be a vital factor in the different processes of identifying the information sent over the network since their development in the 1950s [1]. The barcode is a simple and inexpensive method of storing the data on readable surfaces, which cannot be readable with human eyes. Due to the increasing demand of transferring even more data with faster rates as well as the need for less noise during the transmission of the data, the possible chances of the improvements on the traditional barcode scheme were increased. The development of a new barcode method called two-dimensional barcode or matrix barcode opened a new door for the economical codes and their use in more complex data transmission. The information that can be transferred includes contact information including name, number, email, and home address. Also, the transfer of any URL information can be accomplished with the help of the Quick Response codes (QR codes).

In this study, data sharing between two mobile devices through a sequence of 2-dimensional Quick Response (QR) codes is analyzed. In this method, the transfer rate of 10 kbps is achieved for regularly used mobile phones. Further improvement done on this idea includes a display and digital cameras, which are used as a transmitter and receiver, respectively. After this improvement, data transfer speed greater than 14 Mbps has been attained in a fixed scanner (receiver) and portable transmitter over distances of up to 4 meters. However, with the increase in distance of 10 meters, the transmission rate drops down to 2 Mbps. Better performance has been achieved in the latest implementation using a more efficient way of modulating data, and a coding method for modification of the image distortion and inter pixel light spreading.

The Inverse Fourier Transform (IFT) is applied to the data obtained by Orthogonal Frequency Division Multiplexing (OFDM) method to modulate the LCD pixel data. On the other hand, the image distortion and light leakage rate significantly affects the performance of the QR decoders. In addition, this performance degradation is limited to the few known segments of the decoded QR data. The awareness on random error occurrence can be expended for the adaptive error rectification method based on the degraded data regions. With the changing time, there is a visible increase in the interest for the design and application of the LCD and mobile camera communication systems.

OFDM mainly uses the orthogonal frequency subcarriers to transfer the information. Transmission is done at a high frequency so the low-frequency compost does not get affected during the transmission. It requires high phase coherence to identify the information bits correctly at the receiver side. This idea can be stretched through additional changes in the modulation technique to minimize the distortion due to the LCD and camera relative motion during capturing one frame. This type of degradation in the information due to the distortion can affect the overall performance of the Differential Phase Shift Keying (DPSK) modulated Orthogonal Frequency Division Multiplexing (OFDM) signals.

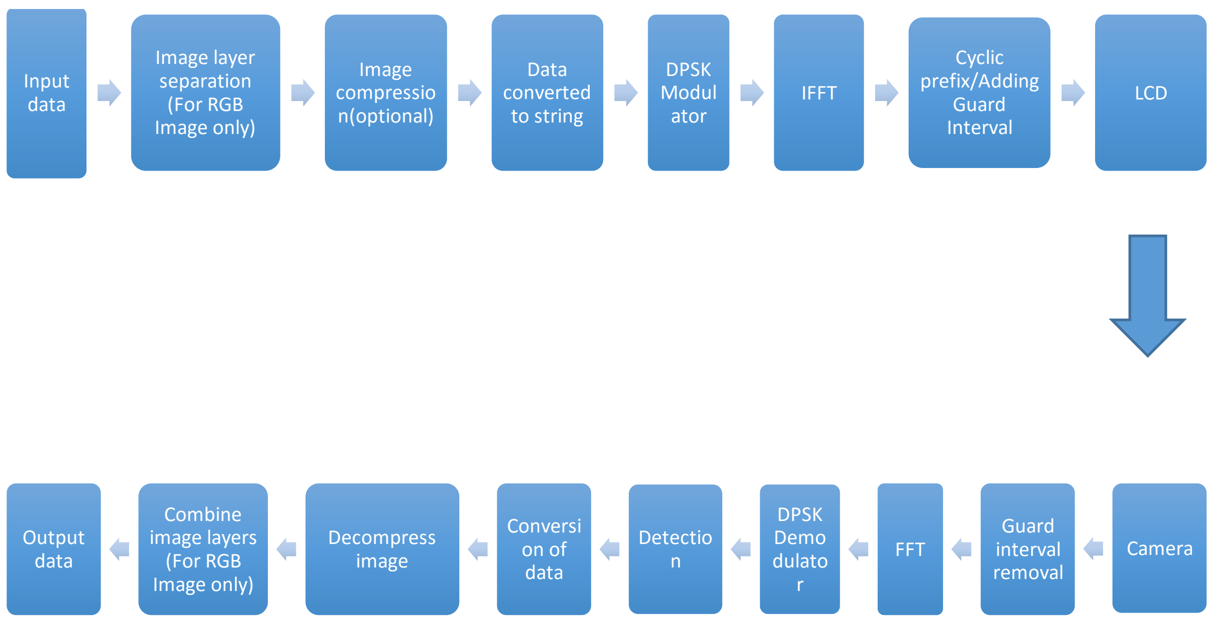

FIGURE 2. Diagram of system used for data transmission between two mobile devices.

The proposed system's lenient behavior for LCD and camera movement is accomplished by putting data in the phase difference of neighboring frequency components that lead up to the DPSK-OFDM method. Phase distortion is mainly occurring due to the motion haze, although the high intensity LCD and camera motion are present. The system to be implemented in this study is shown in the form of the diagram in Figure 2. In this system, elimination of the channel approximation requirements results in less power consumption in the process of obtaining results. In Figure 2, input and output data stream blocks are capable of source coding and error correction coding.

To attain the maximum information transfer rate, an efficient way to take out the maximum information from the single frame LCD as well as increase the rate of decoding frames is needed without losing the data. To resolve this issue, any method that is used in this transmission should be capable of effectively utilizing the available bandwidth considering motion distortions

In M. Mondal and J. Armstrong's research, they have verified the viability of such systems and gave insight on the consequences of signal misrepresentations such as linear misalignment, defocus distortion, and shading away the edges of the picture during modulation [2]. Their study does not provide comparative assessment in the controlled conditions. In addition, no assessments were made for LCD camera movement, which has a noteworthy effect on the functioning of the arrangement that requires a handheld mobile camera on a receiver side or transmitter side. As a result, this project introduces the DPSK-OFDM technique as a way of reducing the effect of the LCD camera's relative movement distortions. By performing a sequence of simulations based on the mathematical modeling for distortion and motion added in the images, the distortion would be approximately the same for Phase Amplitude Modulation (PAM), Quadrature Phase Shift Keying (QPSK)-OFDM, and DPSK-OFDM modulations. As a result, a dependable evaluation can be performed among the major modulation techniques irrespective of the factors disturbing the functioning of such practical systems.

CHAPTER 2

BACKGROUND--TWO-DIMENSIONAL BARCODES

Two-dimensional (2-D) barcodes have proven to be an effective method for labelling where central databases are infeasible and physical surface area is limited. The potential roles of these 2-D barcodes have certainly not been exhausted, and there are several promising applications emerging with the ever-expanding digital world.

Camera phones encompass one of the newest domains entered by the barcode, as well as one of the most exciting. Several recent press releases indicate the growing popularity of this application [2-4]. In April 2007, BBC News presented the High Capacity Color Barcode (HCCB) for cell phone scanning and indicated that the symbol would appear on DVDs within a year [2]. Fujitsu recently introduced an encoding technology that embeds data invisibly into a picture to be decoded specifically by mobile phones [4]. This was in response to aversion toward the obtrusive appearance of Quick Response (QR) symbols on advertisements. QR code and Data Matrix decoders for cell phones are increasing in popularity, and a high percentage of Japanese people have used QR codes for cell phone applications.

To capitalize on the barcode possibilities presented through personal wireless devices such as cell phones, many considerations must be made. Although a high data-density is appealing to corporations looking to advertise, the user experience must be considered.

While capturing the barcode with a cell phone camera, a few aspects need to be taken into consideration such as cell phone processor sizes and distortion present during the image capture. To create a barcode system that is practical for use with a cell phone, it is imperative that the probability of decoding failure is low so that the consumer finds it easy and enjoyable to use.

Recent reviews of barcode scanning and decoding with cell phones have been disappointing. It might be worth considering camera phone specifics when designing a symbology, as opposed to forcing an ill-suited symbology into the desired application. Although the High Capacity Color Barcode (HCCB) shows promise in this domain and claims to be suited to camera phone applications, its data-density is inferior to some other symbologies despite its use of eight different colors. Perhaps a combination of bandwidth-efficient coding, the use of color, and consideration to cell phone-specific applications could yield a superior code for this function. Investigations into this area are worthwhile, especially since the processing power of cell phones has been increasing and will continue to do so.

There are other applications and potential symbology improvements. If 2-D barcode systems are to be adopted by industries to provide a simple and convenient interface between the paper and digital domains for their consumers, aesthetics will play a role. The ideal barcode is as flexible in size, shape, and color as possible. This will allow it to blend discreetly into packaging, advertisements, or company logos. Fixed architectures, fiducials, and other position locator markings lessen the appeal of most current symbologies.

There are many possibilities for 2-D barcodes in the near future. A barcode designed judiciously to have a high data-density, a reasonable decoding complexity, a flexible size and appearance, and sufficient robustness to noise and distortion has the potential to take barcodes from their specialized functions in industry to a universally employed interface between printed and digital domains.

The design of a data-dense, robust, flexible, and easily decodable 2-D barcode will allow barcode systems to penetrate new markets and succeed in new applications. Given the technology available, there are no obvious obstacles to achieving such a code, and therefore the

R&D process should not be delayed. Before delving into a new barcode design, it is worth looking at current symbologies and identifying their features and limitations.

Symbology Background

The first barcode patent was issued to Joseph Woodland and Bernard Silver in 1952 [5]. Since their major debut in grocery stores as the distinguished Universal Product Code (UPC), barcodes have evolved significantly and are prominent in the world today.

Barcode symbology refers to the mapping between the message and the barcode. The first barcodes employed one-dimensional symbologies, meaning that encoding was done in only one spatial dimension (along one axis). Two-dimensional symbologies revolutionized barcode technology by also encoding data in the second dimension of the surface. Today, further advancements are being made to take 2-D symbologies away from their traditional encoding schemes in order to increase data-density and enhance performance.

One-Dimensional/Linear Symbologies

There are several distinguished linear barcodes in addition to the ubiquitous UPC such as the well-known International Standard Book Number (ISBN) used to uniquely identify each edition of every published book and book-like product [6]. As illustrated in Figure 3, one-dimensional barcodes (linear barcodes) encode data along the straight axis using lines and spacing with change in the width to denote different characters. A UPC code is an example of linear barcodes. A UPC (shown in Figure 3) code consists of twelve numeric digits, which are uniquely assigned to item; identification of a product can be done by just scanning. International Standard Book Number (ISBN) is also another example of the linear barcodes. ISBN (shown in Figure 4) is globally unique numerical commercial book identifier. It has a length of either 10 or 13 digits.

The provisions comprise of performing an actual encoding of numerical data and marking up the spacing between bars to provide accurate information at the receiver side. Linear barcodes can be characterized as continuous or discrete, in addition to that two-bar size or many bar sizes.

FIGURE 3. UPC code.

FIGURE 4. ISBN code.

In continuous barcodes, if the first character is displayed with the bar, the second character will be displayed with the space or vice versa. In discrete symbologies, character starting and ending with the bars are counted as data and spacing is ignored.

Two width symbologies have been designed in a such way that one bar is thin and another bar is thick, which is 2 or 3 times wider than the slim one, so there would not be a possibility of error during decryption of the information. Many width symbologies use bars and spaces that are in the specific multiple of one fixed standard width of bar.

One dimensional barcodes are read or decrypted using barcode scanners. The barcode scanners are either handheld or fixed scanners. Handheld scanners are mainly used in stationary item scanning, and fixed scanners are used at a billing counter at major stores in which item barcodes need to be physically scanned with the item in front of the fixed scanners. Barcode scanners adopt either Light Amplification by Simulated Emission of Radiation (LASER) or Charged Couple Device (CCD) technology to read a barcode.

LASER scanners were the first type to be used in barcode scanners. LASER scanners use a laser diode to throw an infrared light beam on the barcode surface; barcode surfaces must be straight in front of the scanner for accurate results. A photodiode is used to measure the strength of the reflected light from the barcode surface. The ideal scanning distance typically ranges between 6 to 12 inches depending upon the lighting conditions present.

CCD scanners use a stationary flood of light, usually LEDs (Light Emitting Diodes), to reflect the symbol image back onto an array of photo sensors. The optimal scanning distance usually ranges from physical contact to six inches. CCD scanners are generally less expensive than LASER scanners and have a durability advantage, primarily because they contain no moving parts. As a result, CCD scanners are surpassing LASER scanners as the preferred technology for reading linear barcodes.

Linear barcodes are widely used in libraries, major outlets such as Costco, Ralphs, Jetro, Sam's Club, and many more stores. Although advancements in the barcode technology are increasing, linking an item to a specific barcode in a database needs to be done physically. Though Radio Frequency Identification (RFID) tags may prove beneficial for some productions over barcodes to manufacturers in some domains.

In the near future, for better accuracy, barcode systems can be replaced in certain places with RFID tags, replacing 2-dimensional barcodes. RFID tags do not need to pass from the sight of the scanner; they can be read through a solid surface. Each RFID tag has its unique number to identify the object attached to the number. RFID tags will cost more compared to the present barcode system. RFID tags can also lead to identity theft as thieves can scan the tag through clothing without the knowledge of the card holder.

Linear barcodes play a well-established role in industry that is not currently threatened by higher density barcodes. However, there are a multitude of other applications for which linear barcodes are insufficient because a central database is simply not feasible, or surface area is limited.

Two-Dimensional Barcodes

To fulfill the demand for a higher data-density barcode system, two-dimensional symbologies were developed. The ability to encode a portable database in a limited spatial area has allowed barcodes to prevail in applications originally prohibited by the linear symbology. The health care industry benefited by being able to label unit-dose packages with the labelling of other medicines and tools to follow. The electronics industry also began using two-dimensional barcodes to label small parts. Several other industries have followed with a variety of applications.

The two-dimensional concept was initiated in 1984 when the Automotive Industry Action Group created a standard way of representing transport and documentation labels, which comprised of four Code 39 barcodes (a linear symbology) stacked on top of each other [7]. Then in 1988, Code 49 was introduced by the Intermec Corporation to become the first truly two-dimensional barcode on the market. Such as the stacked Code 39 barcode, Code 49 also used the idea of layering linear barcodes along the vertical axis, as can be seen in Figure 6. PDF 417 is also a type of 2-D barcode. PDF 417 (shown in Figure 5) is a stacked one dimensional barcode symbol type, which is widely used, mainly transport industry, ID cards and stock administrating firms. In Figure 5, the 417 shows that configuration of each code comprises of 4 bars and spaces, and each PDF 417 barcode is 17 units long. In Figure 6, Code 49 type of 2-D barcodes is shown. Code 49 encodes 128- character ASCII values. It is mainly used in the healthcare, pharmaceutical, laboratory, and electronics industries.

FIGURE 5. PDF 417 code.

FIGURE 6. Code 49.

Several different two-dimensional barcodes have been introduced since Code 49. For the most part, they can be categorized as having either a stacked or a matrix symbology. However, many barcodes do not fit into either of these categories, particularly those most recently developed.

Stacked Symbologies

A stacked symbology is the most primitive of all possible two-dimensional schemes and perhaps the most intuitive when starting with a linear barcode system. Several linear barcodes of a given symbology are truncated and then layered vertically to create the stacked symbology. A much higher data-density than the linear code is achieved at the price of less vertical redundancy. In Figure 7, a type of stacked symbologies 16k is shown. Code 16K is a multi-row bar code and has a surface area of 2.4 cm^2; 77 ASCII characters or 154 digits can be encoded or accommodated. The number of rows varies between two and sixteen.

Codablock, another type of stacked barcode is shown in Figure 8. Codablock F is the 2D extension of Code 128. It has number of rows ranging from 2 to 44, and number of symbol characters per row ranging between 4 to 62.

FIGURE 7. Code 16k.

FIGURE 8. Codablock.

Stacked barcodes were optimized to be read using a laser scanner in which the laser beam is swept several times horizontally as it makes its way down the barcode vertically. Certain symbologies, such as Codablock, allow the barcode to be read by a linear barcode reader (a standard moving beam laser) with very little modification. CCD imagers are also used to read stacked-symbology barcodes. The scanning requirements and constraints are specific to the code symbology. In Figure 9, a type of stacked barcode, Ultracode, is displayed. Ultracode barcode is different from traditional 2-D barcodes and error correcting barcodes, which have a thin and long aspect ratio such as in existing 1-D barcodes (linear barcodes). Ultracodes are mainly used for direct printing on the surface with low accuracy at the receiver side.

FIGURE 9. Ultracode.

Another type of stacked barcode, DataGlyph is shown in Figure 10. DataGlyph method encodes the data in the form of the arrows in any one of two directions, which corresponds to the zero or one bits in the data being encoded. In Figure 10, the generated pattern is covered in the background of image so that the figure does not look like barcode.

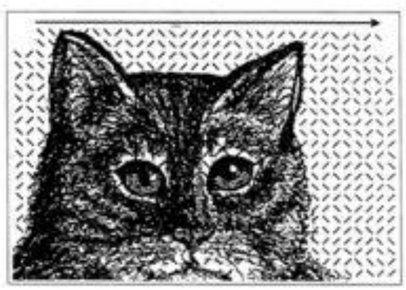

FIGURE 10. DataGlyph.

Many stacked-symbology barcodes continue to be used in various industries such as Code 16K (Figure 7) and Codablock (Figure 8) in the health care industry; PDF 417 (Figure 5) used in transportation, personal identification and inventory management domains [1]. However, despite its successes, more efficient encoding methods have made the stacking technique obsolete.

Matrix Symbologies

Matrix codes (Figure 11) encode data through the positioning of equal-dimension spots within a matrix (dark spots on a light surface). The symbology usually includes patterns that indicate the orientation of the barcode, and often convey the size and printing density of the barcode as well. CCD imagers and camera capture devices are used to scan matrix barcodes. Maxicode is machine readable barcode created and used by United Parcel Service (UPS). It is mainly used for managing tracking updates of packages. It is a type of barcode but it uses hexagonal dots in place of bars.

FIGURE 11. Maxicode.

There are several matrix symbologies in the public domain, as well as many proprietary ones. United Parcel Service (UPS) developed its own well-known matrix symbology, Maxicode (or UPS code), in 1992 to label and track packages [8]. Maxicode is made up of interlocking hexagons and includes a central bull's-eye marking to aid in acquisition (see Figure 11). The code requires a very high resolution printer, but can be read by a CCD scanner or camera when even up to 25% of the symbol is destroyed.

Matrix symbologies are often created with specific practical constraints in mind. For instance, the Aztec code was designed to be easily printed and decoded, the QR code was designed to rapidly read the data using the charged couple device array cameras, and the Data

Matrix was created to achieve a very high data-density. As a result, matrix symbologies tend to be more application-specific than stacked symbologies.

Matrix symbologies generally offer many advantages over stacked symbologies, primarily because they use space more efficiently and scatter redundancy to increase robustness. However, the drawbacks of matrix codes are prompting the creation of symbologies that diverge from the traditional matrix model. Although most new symbologies do not fit either the stacked or matrix definitions, many resemble matrix codes in some way, and often employ many of the same concepts.

Other Two-Dimensional Symbologies

Several 2-D barcodes cannot be categorized as having either a stacked or a matrix symbology. DataGlyphs, for instance, are made up of forward and backward slashes (/ and \), representing binary ‘0’s and ‘1’s, respectively. INTACTA.CODE is a propriety code that converts binary files and software into a very high-density machine-readable symbol of scattered dots (Figure 12). Advancements in computer imaging techniques and devices have made colored barcodes more feasible for a variety of applications. As a result, some barcodes use color to increase data-density, such as the HCCB (High Capacity Color Barcode,), the Ultracode (Figure 14), and the Hue Code.

The newest barcode symbologies offer more unique features and are difficult to categorize. Developments continue as demands on current barcode systems grow and new barcode applications emerge. There are advantages and drawbacks to each barcode design, and symbologies are usually designed for specific requirements and constraints. There has been significant progress in recent years, and development is expected to continue in the barcode symbology domain [2].

Specifics of Notable Two-Dimensional Barcodes

It is worth examining the more notable 2-D barcodes. Whether they have gained popularity in certain fields of use, or offer unique features to the user, they can give insight into what has already been accomplished as well as potential improvements for the future. Six significant 2-D symbologies are briefly described and then compared.

INTACTA.CODE

INTACTA.CODE is a registered and patented code developed by INTACTA Technologies, Inc. that converts binary files into a graphical representation, thus securing information over electronic media and in printed form. The development of INTACTA.CODE (shown in Figure 12) was initiated by the defense industry, where privacy is of critical importance. In addition to security, INTACTA Technologies places emphasis on bandwidth efficiency (to efficiently increase data-density) and error-correction abilities, while being easy and practical to adopt for various applications [9].

FIGURE 12. INTACTA.CODE symbol.

INTACTA.CODE looks like a random arrangement of dots (Figure 12). Each byte of information contained in the symbol is represented by a small pattern of black and white dots. Prior to encoding, the data is compressed and encrypted by the INTACTA software, with a high level of flexibility left to the user. The barcode can then be created in a printable or a digital format. Also, because the code is not based on a fixed architecture, it can be formed into any desired continuous shape.

INTACTA.CODE can be read by any off-the-shelf scanner and is decoded by proprietary software. The data-density depends on the printing and scanning resolutions. INTACTA.CODE achieves 1000 bytes/inch 2 (1240 bits/cm 2) at 300 dpi resolution and 3800 bytes/inch 2 (4712 bits/cm 2) at 600 dpi resolution, assuming equal printing and scanning resolutions. INTACTA Technologies has indicated that a color INTACTA.CODE is also possible, but such a symbol has yet to be presented publicly.

Data Matrix

As its name suggests, Data Matrix employs a matrix symbology. It was patented in 1991 and achieves a high data-density compared to other barcodes of its time [10]. The Data Matrix symbol is also variable in size, giving it a significant advantage over several fixed-architecture barcode symbols. A Data Matrix symbol consists of a matrix of equal-sized squares as illustrated in Figure 13. It is read by CCD camera / scanner.

The perimeter of the Data Matrix symbol indicates the density of data contained within the matrix. The product of the number of light squares and dark squares of the first and second sides corresponds to the number of bits of information contained in the symbol while the solid dark lines on the third and fourth sides indicate the height, length, and area of the symbol. Because of the information contained in the perimeter, the Data Matrix code can be scanned from any orientation as well as at an angle using a camera capture device.

FIGURE 13. Data Matrix symbol.

Instead of representing individual bits by individual light/dark squares, the Data Matrix symbology compresses the input data by defining a maximum range of characters that may appear in an input string and removes redundancy to decrease the number of squares needed to represent that string. For this reason, the compression process depends on the type of input character anticipated.

Robustness is increased by scattering redundant data throughout the symbol. This is accomplished by randomly positioning redundant cells (squares in the symbol) as far as possible from the root cell encoded. The user can specify the redundancy level (up to 400%). Convolutional coding was originally applied, but Reed-Solomon error correction algorithms are now used, allowing the Data Matrix barcode to be decoded when up to 60% of the symbol is damaged.

The data-density achieved by a Data Matrix symbol is subject to the dimensions of the symbol, the size of the pixels (which will depend on the scanning resolution), and the amount of redundancy included. In theory, the symbol can store 500 characters in a square milli-inch. This is impractical when taking printing and scanning resolutions into account. More realistically, using 600 dpi and 4 dots per module, a data-density of approximately 1838 bits/cm 2 is achieved.

HCCB (High Capacity Color Barcode)

The HCCB (High Capacity Color Barcode) is one of the newest barcode symbologies to be introduced. It is a proprietary code by Microsoft Corp. that is awaiting a patent to be issued in the United States. By using color, the HCCB achieves a high data density and has been designed with consumer cell phone applications in mind.

Triangular symbols are arranged compactly throughout the symbol as seen in Figure 14. The triangles are separated by white spacing that serves to reduce aliasing effects and other distortions. A similar symbol structure using geometric shapes other than triangles is also possible for the HCCB, but triangles are currently being used because they are more efficiently packed.

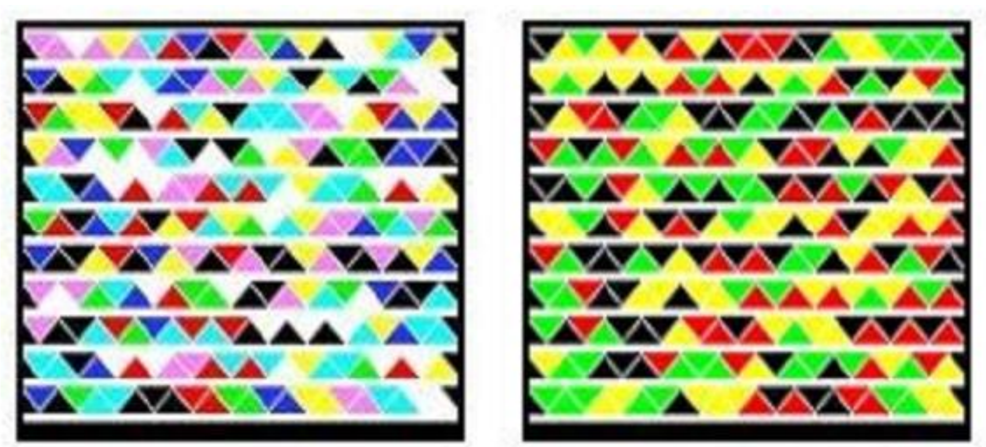

FIGURE 14. HCCB symbols.

The HCCB includes CRC (Cyclic Redundancy Check) error-detection and Reed-Solomon coding for error-correction. A reference color palette is included in the HCCB symbol to allow for a weighted adjustment that reflects or compensates for variations in dynamic range perceived by the camera/scanning device. Should the reference palette on the barcode symbol be damaged, the necessary adjustments can still be made based on past scanned range of the different color value obtained.

Data-density varies in relation to the color scheme chosen. Microsoft offers its HCCB in black and white, with four different colors, and with eight different colors. Other schemes, such as grayscale, are also possible and may be available in the future. Using the eight-color design at 600 dpi resolution, a data-density of 2000 bytes/inch 2 can be achieved (2480 bits/cm 2).

The HCCB can be read in a variety of ways, including using a Web cam, a video camera, a flat-bed scanner, a digital camera, or a business card reader scanner. Microsoft is promoting potential cell phone applications, highlighting that the HCCB outperforms QR code and Data Matrix formats for cell phone scanning and decoding.

Quick Response (QR) Code

FIGURE 15. QR code.

QR codes are an important type of the 2-D barcodes. It was initially meant to be used in Japan's automobile industry. A QR code is machine readable barcode, it can provide all details related to product. QR codes mainly use one standard encoding method out of four methods (numeric, alphanumeric, kanji, and binary) to efficiently store data; two encoding methods may be used at a time for more data transmission.

QR codes gained reputation in all barcode-using industries, as it provides fast decoding and more data storage compared to UPC barcodes. QR code applications include package tracking, product marketing, and product details.

QR codes are made up of black squares with white background (shown in Figure 15), which can be decoded using device such as a camera and acquired image is processed using Reed-Solomon (RS) error correction method and accordingly corrected image is obtained. Furthermore, data is being extracted from image using the black square patterns and white background of image.

Advantages of QR Codes

- More data storage capacity: While conventional bar codes can store a maximum of approximately 20 digits, QR code can manage to store several dozen to several hundred times more data. QR code can store and transmit all types of information, such as numeric and alphanumeric characters, Kanji, Hiragana, symbols, binary, and control codes. Maximum 7,089 characters or symbols can be contained in one QR code symbol.
- More data transmitted in less space: Since QR code carries information both horizontally and vertically, QR code can accommodate the same amount of information in approximately one-tenth the space compared to traditional barcodes.
- High error correction rate: QR code possesses high error correction capability. Damaged or partially dirty QR code can be restored using different error correction methods. At present, up to 30% damaged QR code can be fully recovered as shown in Figure 16, damaged QR code can deliver the original data without data loss if it is damaged below 30% of the QR code.

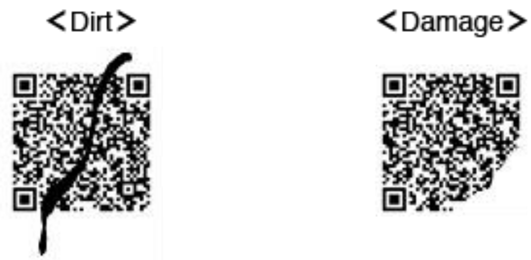

FIGURE 16. Partially dirty and damaged QR codes.

- Flexible with the orientation of the scanner: QR code is capable of any direction decoding (360 degree), and high speed reading. It possesses this capability because of the positon detection square located at three corners of the QR code. Three position detection square provides assurance for the high-speed decoding and avoiding the background interference effects.

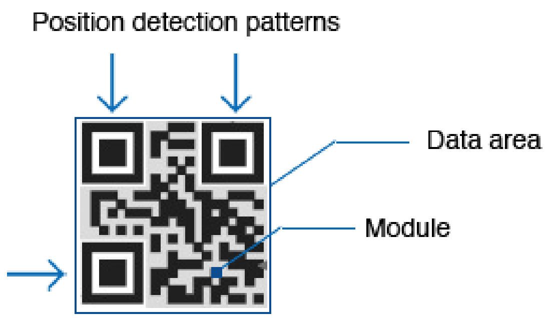

FIGURE 17. QR code with the inner structure.

In Figure 17, QR codes with three different position detection pattern block and data area in the QR code are shown.

By looking at the possible advantages of using QR code compared to other barcodes, it possesses flexibility for the scanner orientation, high data transfer in small space compared to other barcodes discussed earlier in this chapter, and high error correction rate available. Due to this advantages QR codes will be used as a transmission barcode method for better performance with high accuracy.

Image Steganography

When text data or an image is encoded and it is hidden in another image, this process is called image steganography. In this project, any sort of text string or an image is encoded in the form of a QR code image. QR codes are images in which another data is hidden. Specifically, String data is directly encoded using a QR code encoder; a grey scale image matrix is converted into the string format then the QR code is created. For RGB (color) images, three layers of red, green and blue needs to be separated, then after each matrix is converted in to string. In Figure 18, QR code for r layer of the RGB image in the 8x8 dimension is shown, which will be decoded in string format.

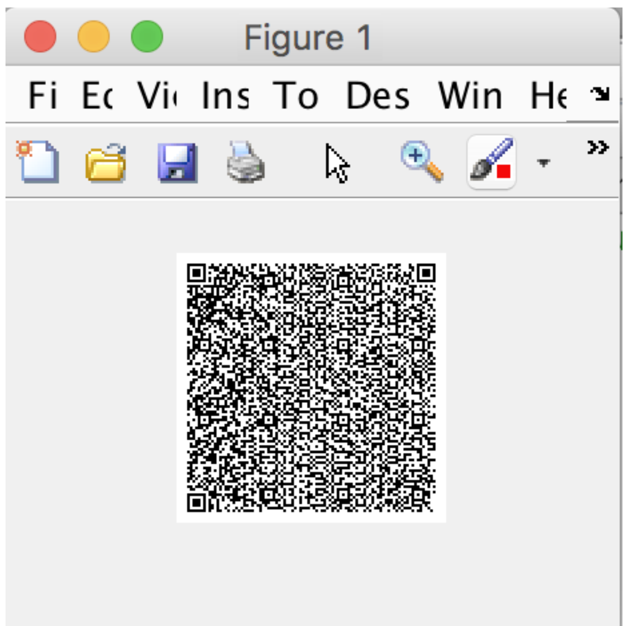

FIGURE 18. QR code for r layer of 8x8 size image.

CHAPTER 3

DATA TRANSFER CAPACITY

There are several various factors present that affect the amount of data that can be pulled out from a mobile LCD. Factors effecting the performance are the design and quality of the LCD display, quality of the camera on the receiver mobile, system's data processing power, and power consumption during the process as this will be mainly used as the portable way to transfer data. In real time, it may be a challenging task to obtain impartial performance analysis of the system, it is crucial to know what disturbs the transfer rate and what actions can be taken to control the factors affecting the performance. The data display size can be calculated using the maximum number of bits in an image shown on the LCD.A display having a R_D number of rows, C_D number of columns, displaying a color image in N_D number of channels(mostly N_D=3,as color image three types of color channels red, blue, and green), and color bit depth of S_D bits per channel, would give the maximum information of on LCD as seen in Equation (1). :

$$T_I = R_D \text{ X } C_D \text{ X } N_D \text{ X } S_D \text{ bits per one image on LCD} \tag{1}$$

The T_I shows maximum bits that can be shown on the LCD in one single frame of an image due to the distinct nature of the data shown on the LCD. A refresh rate Z_D for the LCD leads to $T_F = Z_D \times T_I$. For a regularly used iPhone 7, the parameters would be R_D =1334, C_D =750, N_D = 3, S_D = 8 and Z_D = 60Hz resulting in $C_I \approx$ 24 Mbits and $C_F \approx$ 2Mbits, which is a comparably higher data rate for the transmission in respect of the radio frequency wireless technology. As this is an ideal scenario, in real time these results are affected by limitations that are discussed in following sections.

Receiver Camera Limitations

A receiver side mobile camera can be counted as a device that digitally samples a 2D signal. According the law of sampling, the camera capture rate should be around twice as much as the display refresh rate (Z_D) except if there is any system placed to activate a camera shutter when the image is stable on the display in every frame.

To fulfill conditions of the Nyquist criteria to achieve proper image resolution, each pixel shown on the transmitter side LCD should be sampled by two or more pixels in the receiver camera. The image sensor adopts a partial number of bits per channel for translation of each color pixel, which results in to the quantization error. To bound the effect of the quantization error on the overall process of receiving the data, it should be kept six to ten dB below system noise level. It should also be kept under a signal power level to achieve a proper BER with respect to the modulation method used.

Power Limitations

The strength of every transmission depends on the power of the signal sent in to the environment to transmit data as per the Shannon law. In this study, power is bound with the brightness of the LCD display of the transmitter. By increasing the strength of the light, Signal to Interference and Noise Ratio (SINR) on the receiver side can be improved. Such as generally used RF power transmitter, LCD displays are bound to the extreme power, which leads to the Peak to Average Power Ratio (PAPR) limitation. PAPR is the main confront for OFDM signals. When the maximum attainable intensity is achieved, higher PAPR returns lower average intensity, which results in lower Signal to Noise Ratio (SNR). Therefore, communication of the OFDM waves over an LCD need a trade-off between the average power transmitted and the resultant distortion due to the trimming of the peaks. Presently, there are various PAPR reduction methods available, it would also impose the same effects on the QPSK-OFDM and DPSK-OFDM. In addition, the DPSK modulation method would perform better than the reduction method used in PAPR.

Inter-Symbol Interference (ISI)

When a barcode is printed on any surface such as paper or a package with high resolution, a white pixel does not create any negative effect on the neighboring black pixels. On the contrary when a barcode is displayed using a LCD, another factor comes into the picture, which effects the performance. Light intensity may affect neighboring pixels while passing through the white pixels by leaking a light.

The simple solution to this problem is to increase the number of the pixels displaying the same color, indirectly increasing the size of matrix. For this case, each n x n set of pixels are used to display the same color in each pixel to denote only one symbol. Separating the center pixel from the set of n x n pixels removes the affected pixels due to the neighboring effect and gives the exact data. This method drastically decreases the transfer rate as n x n pixels are used to display one symbol. The R X C data symbols transfer rate reduces by $\frac{R}{n}$ X $\frac{C}{n}$,which indicates the decrease in the rate by n^2 to 1.

Furthermore, any movements between the camera and LCD during the reception of the data by capturing the image may lead to motion noise, which is translated in ISI as it affects the adjacent pixels during reception

Interference, Distortion, and Noise

During the process of the reception of the image using a mobile camera, certain image objects can affect the results of the data extraction process.

These objects are primarily due to the following mentioned factors:

- Space and viewpoint between camera and the LCD
- Relative motion between the mobile camera and LCD
- Lens not adjusted properly
- Unwanted light sources
- Dust and scratches on the LCD
- Noises (E.g. AWGN, Gaussian noise)

In addition to this, nonlinear distortion exists in a typical optical wireless data transmission setup due to the limitation of the transmitter and receiver.

CHAPTER 4

DEVELOPMENT IN OFDM ASSEMBLIES

The development in the OFDM method can be divided in three categories

1. Frequency division multiplexing
2. Multicarrier communication
3. Orthogonal Frequency Division Multiplexing

Frequency Division Multiplexing

Frequency division multiplexing is a method of multiplexing data signals in which different data signals are bunched together and sent via a common communication medium. In frequency division multiplexing, signal multiplexing is performed by allocating non-overlying frequency ranges or channels for different signals to each client of a transmission network. A guard band is placed between each channel to provide safety by not overlapping with neighboring channels. Frequency Division Multiplexing (FDM) is mainly used to accommodate several users on one physical communication channel (for example old analog telephone system). This whole process is called Frequency Division Multiplexing Access (FDMA). Due to underdeveloped digital filtering technology in the past, it was difficult to separate different signals that were narrow or had negligible guard band.

Multicarrier Communication

Multicarrier communication is unable to transfer data at a high speed in a channel. In this method, a stream of data signal is divided into multiple signals over given frequency range. Each of these shortened data signals are modulated with distinct carrier signals. Now these modulated signals are sent over the given channel. Each shortened data modulated signals has a narrow bandwidth, but by combining shortened signals together, a wide bandwidth for transmission is received. On the receiver side, each shortened signal is sent to the demultiplexer after all the demodulated shortened signals are combined to create an original signal. On the receiver side, the original signal occupies a wider bandwidth. This method has many advantages including a capability to minimize delay spread, and the efficient usage of the provided bandwidth. In contrary, it obtains high-pitched PAPR.

Orthogonal Frequency Division Multiplexing

Orthogonal Frequency Division Multiplexing (OFDM) is a modified version of the multicarrier communication. In this method, a signal is made from a few modulated carriers, which are placed close with each other. Carriers are orthogonal and independent with other carriers. When a modulation is performed on the carriers, it spreads out on either side. In addition to this spreading, OFDM signals are sent with small spacing, which is shown in Figure 19. Due to signals with small spacing, a receiver should be capable enough to gather the entire signal and accurately demodulate the received signal. At the receiver side, a filter is used with the guard band as signals are transmitted close to each other to separate the signal and transmit it. During the reception, each carrier sideband may overlap with neighboring signals, which can be eliminated as each carrier is orthogonal to other carriers and help to get a signal without interference, which occurs due to the closely placed signals. This is perfectly achieved by making the carrier spacing and reciprocal of the symbol period equal.

Two signals are called orthogonal when the integral part of their product over one period cycle is equals to zero. In Figure 19, three transmitted signals are shown. When one signal has a maximum value (peak value), the other two signals have a zero value, which proves that signals have a phase difference of π or $n\pi$. So, it can be said that all three signals are orthogonal to each other.

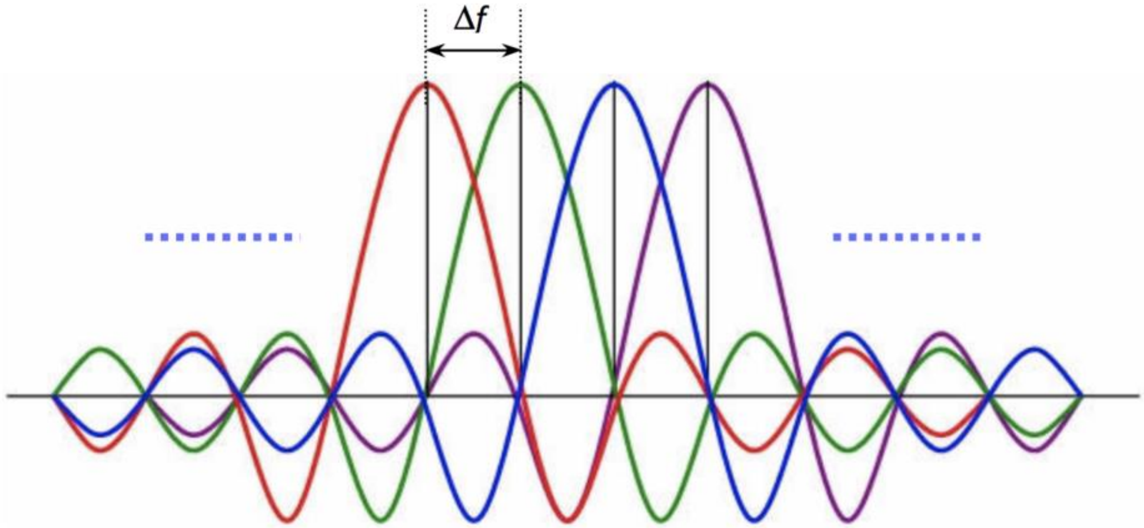

FIGURE 19. Signals orthogonal to each other in OFDM.

Cyclic Prefix

Cyclic prefix is mainly used to safeguard OFDM signals from intersymbol interference by acting as a guard interval or buffer region. Cyclic prefix will be linked to the start of the data symbol during the transmission, and it will be detached before the modulation is performed at the receiver end.

Synchronization

Synchronization is a crucial process in any wireless communication system. Synchronization must be executed on the receiver side of the OFDM systems before the demodulation process starts on the sub carriers. To perform a synchronization between the transmitter and receiver, it requires symbol timing and carrier frequency spacing. Symbol timing is considerably different then the single carrier signal, as the best suitable sampling time cannot be found. In real time, there are hundreds of samples of signals as it is directly related to the number of subcarriers present in the OFDM system. Some variance in the sampling time is acceptable in the OFDM system. In this system, there is endurance for sampling time error when cyclic prefix is used in the system. On the receiver side, carrier frequency synchronization must be performed with high precision because if it is not done properly, it will result in the loss of the orthogonality between subcarrier and other subcarriers, which degrades the performance of the system.

Application of OFDM

- Digital Audio Broadcasting (DAB)
- Digital Video Broadcasting-Terrestrial (DVB-T)
- High Definition TV (HDTV)
- Wireless LAN
- Mobile broadband wireless access technologies (IEEE 802.16 and 802.20)

Peak to Average Power Ratio (PAPR) Reduction Technique

To reduce a PAPR in the OFDM system, there are different techniques available. These are mainly divided into two categories: the signal scrambling technique and signal distortion technique.

The signal scrambling technique can be categorized as the following:

- Block coding technique
- Selected Mapping
- Partial transmit sequence
- Interleaving technique
- Tone Reservation (TR)
- Tone Injection (TI)

And Signal distortion technique can be categorized as the following:

- Peak windowing
- Envelope scaling
- Clipping

The Signal Scrambling Technique (SST) works with the margin information that helps in reducing the effective throughput as it initiates redundancy. While the Signal Distortion Technique (SDT) leads band interference and system complexity, it also minimizes high peak amplitude noticeably by distorting the signal before amplification. The disadvantage of the SDT is the distortion the OFDM amplitude. This type of internally produced obstruction is introduced lowers the BER. Another disadvantage of SDT is that the presence of nonlinear distortion raises the level of out of band radiation.

CHAPTER 5

DPSK-OFDM

While technology for the isolation of the pixel to pixel in LCD is developing, few captured image still having a distortion, which causes the adjacent pixels of the barcode to mix up in the image and it results in the ISI. The simple way to solve this problem is to accept the image barcode as a wireless radio signal, for which intersymbol interference reduction method has been already developed. One of the greatest and most realistic modulation technique capable of working with several critical situations in the band limited communication channels is none other than Orthogonal Frequency Division Multiplexing (OFDM). Overall idea is that, while working with limited power, limited band allocation, and multipath channels present, then it is more effective to send a group of narrow banded signal in parallel at a time instead of sending a signal with high bandwidth.

Similarities Between Barcode and Wireless Radio Frequency Channel

In general, each 2-dimesnional image is converted into a 1-dimesnional row vector, which has all pixel value of original image. Each individual row can be counted as a time domain signal which has a PAM (zeros represent black and ones represent white). Such as real time scenario, take a picture of this one row with the band limited channels, which includes camera focusing problem, LCD resolution limitations, and light spreading into neighboring pixels issue. In addition to that, in a multipath communication in which camera movement and pixels value mixing with neighboring pixels results in elevated presence of ISI in the signal. To overcome this issue in the time domain radio signal, OFDM technique is used to split the channel into the number of small orthogonal channel with the low bandwidth and data is sent with lower data transfer rate in these channels in parallel. In OFDM all fragmented small signals are orthogonal to each other. Due to the 1-D data modulation method is changed to inverse Fourier transform to display the transmitted data in place of the Phase-Amplitude Modulation (PAM). Because of this, most signal modules only affect the high frequency component leaving the low frequency component untouched for the data transmission.

In general, in each sub-carrier, OFDM signal is modulated using a M-quadrature amplitude modulation. In which appropriate phase shift for each element should be assessed and adjusted before the modulation has been performed. When OFDM method is used for the transmission of data in the form of images

Transmitter

Most positive aspect of using of OFDM is, it uses Inverse Fast Fourier Transform (IFFT) method to modulate input data string into the orthogonal frequencies. The modified signals should represent real value as it needs to display on LCD. For the accurate representation on the display it should follow Hermitian symmetry. The Equation (2) represents Hermitian symmetry:

$$F\,(X-x\,,\,Y-y) = F(x\,,\,y)^{*} \tag{2}$$

In the equation, $0 \leq x < X$ and $0 \leq y < Y$ is assumed and * represents complex conjugate operator. Figure 20 shows the elements relationship to have a real value real valued IFFT for F matrix.

Constellation Mapping

The data fed to the transmitter is decomposed into 2-bit symbols. Later, each symbol is converted to complex phase by trailing these rules:

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

With the application of the rules, the first bit modulates as a real component and second component modulates as an imaginary component of the phase for each data symbol.

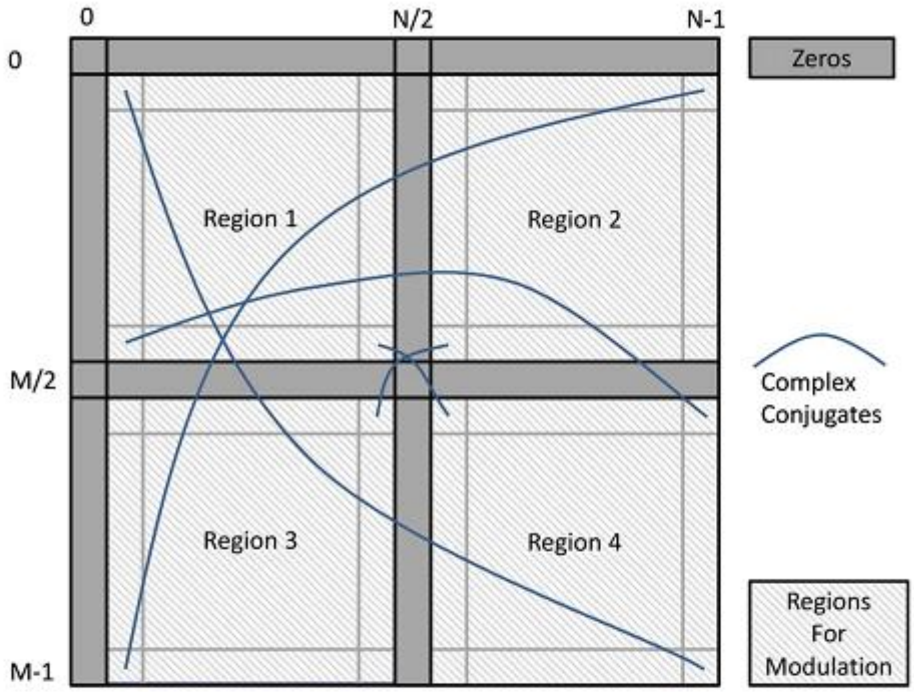

FIGURE 20. Hermitian symmetric matrix.

Hermitian symmetric matrix is used for the DPSK-OFDM modulation process. The Inverse Fast Fourier Transform (IFFT) of the Hermitian symmetric matrix would give real valued output on the display. Figure 20 shows the elements relationship to obtain real valued Inverse FFT for the F. Only regions 1 and 2 are used for the independent data communication, region 3 and 4 needs to be calculated to obtain real valued Inverse FFT. In the Figure 20 curved lines are showing the location of the complex conjugate pairs. Shaded region represents the modulation area of the data and grey colored region represents zero valued data which can be used for error correction.

These symbols are placed in a $\frac{R-2}{2}\ X\ \frac{C-2}{2}$ matrix M which contains the absolute phase elements which are going to be modulated using DPSK method.

Differential Phase Shift Keying

Matrix M is transferred into a differential matrix N using the Equations (4-6)

$$N(0,0) = M(0,0) \tag{4}$$

$$N(0,c) = N(0,c-1) \times M(0,c) \quad 1 \le c < C-2 \tag{5}$$

$$N(r,c) = N(r-1,c) \times M(r,c) \quad 1 \le r < \frac{R}{2}-1,\ 0 \le c < C-2 \tag{6}$$

Afterwards, the modulated matrix N is divided into two matrices using Equations (7-9):

$$N1(r,c) = N(r,c) \tag{7}$$

$$N2(r,c) = N\left(r, c+\frac{C-2}{2}\right); \tag{8}$$

$$\text{Where } 0 \le r < \frac{R-2}{2},\ 0 \le c < \frac{C-2}{2}. \tag{9}$$

These two matrices are used to fill regions 1 and 2 of the matrix H. Regions 3 and 4 of matrix H are generated using the Hermitian symmetry requirement and remaining area on the matrix H is set to zero. These zero-valued small regions can be used to transmit special data such as a guard data, error correction code data, and frame rate.

Inverse FFT

By taking into the consideration that matrix H is the representation of the signal in the frequency domain, the IFFT is applied on it to obtain a time domain signal N_i. This signal will have a H (0, 0) =0, so it needs to be adjusted to utilize the maximum range of pixels.

PAPR Adjustment

N_i is a real valued 2- Dimensional signal with high peak to average ratios. The probability of having a high PAPR increases as number of frequency components increase. There are different methods available to limit the PAPR of OFDM signals, anyone of that methods with little modifications can be used for 2-D signals. Best available option for method can be clipping.

In this soft clipping is performed in such way that threshold level V_{max} according to average signal power is set.

$$\text{Clip Ratio} = \frac{\text{Vmax}}{\sqrt{P_{avg}}} \tag{10}$$

Where P_{avg} is average value of power per element in OFDM signal before clipping performed. Matrix N_f has a maximum amplitude of V_{max} value in all pixels as all amplitude higher then V_{max} clipped to V_{max}.

Amplitude Adjustment

The pixel levels in the PAPR fine-tuned image (N_f) needs to be transformed into dynamic pixel range of LCD for maximum performance with the effective use of transmission power. Usually, intensity level in the LCD has ranges between 0 and L_{max}. For that N_f matrix values are transformed linearly into this range using Equation (10).

$$N_a(\text{i}, j) = \frac{N_f(i,j) - \text{Min}(N_f)}{\text{Max}(N_f) - \text{Min}(N_f)} L_{max} \tag{11}$$

Finder Patterns

Proper demodulation of data needs accurate extraction of the modulated data from the received image and counteracting any possible distortions. Generally, finder patterns used with 2D barcodes may be used here such as the 1:1:3:1:1 pattern used in QR codes, for which fast detection and efficient algorithm have been developed in past.1:1:3:1:1 is shows the way width of the white and block used to represent the QR code [11].

Cyclic Extension

Cyclic extension is required in the OFDM systems to counteract the Inter Carrier Interference (ICI). Length of the added cyclic extension must be more than the time spread of channel. In 2-D barcode, periodic extension of the image generated by 2-D IFFT is needed to block ICI. The length of the extension is calculated using the image distortion, and projected movement between LCD and camera. Though, we have modeled channel response in a frequency domain, frequency domain filtering is performed on the signal, and effective cyclic extension is achieved by frequency domain multiplication which gives time domain cyclic convolution as a result.

Receiver

Receiver side uses camera for the reception of the image generated from QR code encoder Sampling and registering the obtained image for the proper reception of the image D_a at the receiver. The effects of interference, noise and distortions occurred can be focused in the simulation section of the receiver side. For proper reception of the image, following steps needs to be lookout at the receiver side.

Image Capture

Digital camera and display systems have a refresh rate limitation. In synchronous system, camera should capture image at a moment when it is fully focused. However, all time receiver cannot know when it can get fully focused frame, the sampling rate should be more than twice of the display rate to ensure that at least one proper frame is captured. In addition to that relative distance and angle between camera and display values are bounded in a specific range using the Nyquist criteria. In Nyquist criteria, each pixel on the display is mapped to minimum 2 x 2 block on the camera.

Image Registration

The initial step needs to perform on the captured image is to extract the displayed image using predefined finder patterns put into the image. Due to the presence of the measurement errors in finder pattern location and perspective correction errors are not part of this study, the stimulated images and their distorted received signals are ideally for isolating the effects of blur and camera movement on error rate of different schemes.

Fast Fourier Transform(FFT)

Applying the Fast Fourier Transform on the received image gives data in the frequency domain which are differentially phase modulated elements stored in R_f matrix.

DPSK Demodulation

The originally mapped data can be extracted using the phase differences between respective elements, but data corresponding to regions 1 and regions 2 should be concatenated together, to form matrix R corresponding to the transmitted matrix F using Equations (12-14).

$$R_d\ (0,0) = R\ (0, 0) \tag{12}$$

$$R_d\ (0, c) = R\ (0, c) \times R^*\ (0, c\text{-}1)\ \ 1 \leq c < C\text{-}2 \tag{13}$$

$$R_d\ (r, c) = R\ (r, c) \times R^*\ (r\text{-}1, c)\quad 1 \leq r < \frac{R}{2}\text{-}1,\ 0 \leq c < C\text{-}2 \tag{14}$$

The resultant matrix R_d will be a distorted copy of matrix M in transmitter path.

Detection

After the extraction of the phase difference, each bit of the image pixels can be calculated using the constellation diagram of the transmitter. Each component is calculated using its real and imaginary part. Real component regulates first bit and the sign of the imaginary component regulates second bit.

Compression

Image compression is performed to reduce the number of data bits to be transmitted. Data compression makes transmission of data faster compare to uncompressed image. Compression are mainly divided in two categories lossy and lossless. For instance, discrete wavelet transform and progressive coefficient reduction method wavelet difference reduction is lossless compression; JPEG (Joint Picture Editing Group) is lossy compression method.

Error Correction

Error correction methods are used in almost every communication system to correct or recover the lost bits during the transmission. For instance, Reed-Solomon (RS) coding is used in QR codes, depending upon the level for error correction applied, error correction can be achieved between 7% to 30% at the receiver side. Whereas the selection of the error correction has a significant effect on the overall performance of the system, they are used after the application of the modulation-demodulation scheme and after source coding. A selection of the appropriate coding method for a trustworthy communication system can be performed, based on the attainable error rated without any error correction method.

Computational Complexity

In important factor to lookout for the use of such communication system is to calculate computational power required to implement the system. However detailed investigation of such requirements and any performance improvement process is the topic of the further study. The proposed DQPSK-OFDM system has a limited processing overhead compared to the equivalent QPSK-OFDM system which is implemented and tested. On the transmitter side the differential modulation described by complex multiplications can performed using small look-up taking current phase and data to be processed as an input. Conversely, Receiver needs to process R X C multiplications to obtain phase difference before the detection of the data, which is not unreasonable compared to performance complexity exhibited by 2-D FFT of the order R X C X *log* (R X C).

CHAPTER 6

PROPOSED METHODOLOGY

The set of procedures includes data encode, display sequence of image, image acquisition, processing, storage of image matrix and communication of image matrix using mobile phone. On the receiver side reader, mobile needs to locate the transmitted data. After locating the data, received image should be enhanced error correction needs to perform on it for accurate results. Afterward the image recognition step needs to be performed as the captured image may have some data, which does not require to be sent. Subsequently the data is converted into the barcode format. Then the receiver device captures the barcode and error correction, geometrical correction is performed on that image. Finally, decoder module in the device decode the data from the image and provides transmitted data to user. In the Figure 21 system performance block diagram is shown.

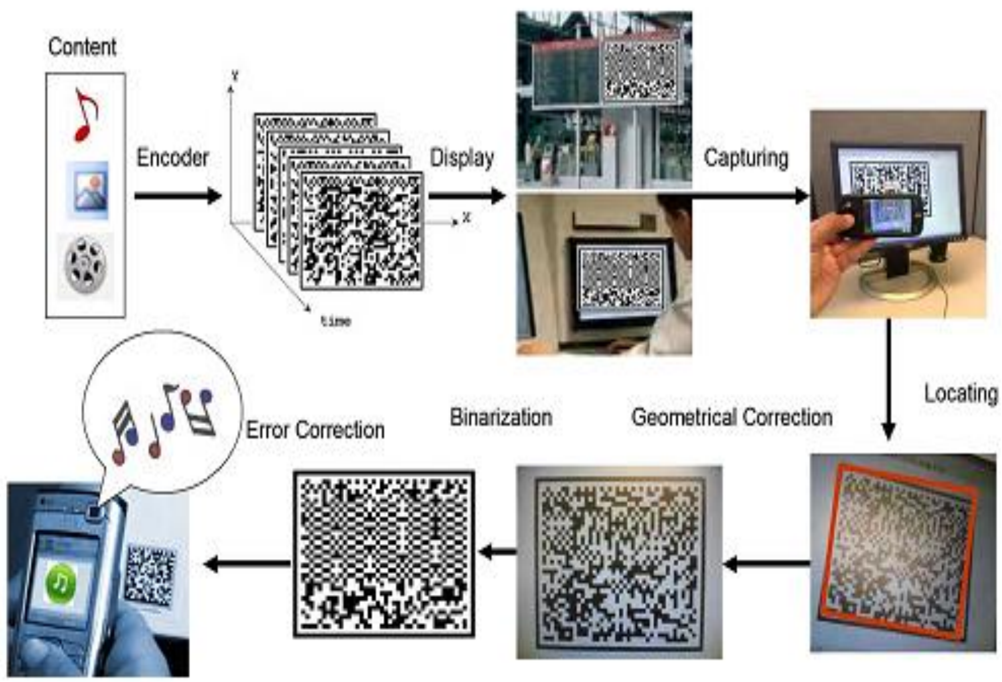

FIGURE 21. Proposed system performance sequence.

Data Encoding and Display

In the Figure 21, the provided input data needs to be encoded using the DPSK-OFDM method. After the data encoding is done it is converted into the barcode Then the generated barcode is displayed on the screen in the form of the sequence of the barcodes.

Object Location

Object location is important task in the receiving data as for the decoding the data, object or barcode image is crucial. On traditional desktop, different methods are available to use. However, for mobile portability few factors need to be taken in consideration such as power consumption, processing time and weight limitation. In QR code, three orientation detection corner are provided which saves time and makes process faster compare to other 2-D barcodes.

Image Improvement

Camera phones often have a low-quality Complementary Metal-Oxide Semiconductor (CMOS) sensor with fixed or low grade focusing technology. Compare to digital camera, captured image through mobile devices have degraded image quality. Adaptive binarization method is applied on the image for the removal of the shadows. Distortion added in the image due to the motion during the image capture also needs to be removed. Due to power limitation, coding method used should be vigorous enough to counteract for the adverse effects caused by image degradation.

Barcode Format

The analysis of the most common 1-D and 2-D barcodes revealed important characteristics for barcodes to be considered. These characteristics are: (a) quiet zone around the symbol or barcode, (b) an appropriate finder pattern, (c) orientation marks to compensate rotation, (d) the shape of the data modules within the barcode, and (e) the usage of colors in data modules. The barcode format to be used for the matrices in this thesis must meet three requirements. First, it should provide fast recognition and decoding. Second, it should provide a high storage capacity.

Finally, it should be robust against false positives. Considering the lessons learned from the analysis of the existing one- and two-dimensional barcode formats, as well as the requirements specified above, a new barcode format has been designed.

In short, this barcode format has the following characteristics: (a) three black and two white bars alternating on each side of the barcode form the finder pattern, (b) one additional white bar with the double size of the bars in the finder pattern around the symbol represents the quiet zone, (c) square data modules (shape), (d) use of 8 different colors to encode a bit sequence into a data module (resulting in 3 bits per module), (e) no usage of orientation marks (rotation with less than 45° is therefore theoretically supported), and (f) a module on each corner used to indicate the offset information when the barcode is not filled with modules (indicated by the letters A, B, C, and D).

Furthermore, the barcode format prescribes 4,096 modules (= 64 in width * 64 in height) for each 2-D matrix. This is the largest number of modules, which still can be decoded reliably by our prototype.

Recognizer Module

After defining the format of the 2-D matrices. The recognizer reads a sequence of frames (captured by the camera) and generates a sequence of 2-D matrices. Therefore, it obviously depends on the format specification and must know how the format looks like to recognize a barcode within a frame. Based on the format shown in Figure 15, the main idea for the recognizer is to find two points on each of the four sides of the barcode. If there can be found two points on each side which correspond to the finder pattern, then the actual frame contains a barcode and its exact location can be determined. Once these points are found, one can draw a line through the two points on each side. The resulting four lines intersect in four points, namely the corner points which are important for the decoder module. These four lines also delimit the content of a barcode, so the decoder can process the payload.

Decoder Module

Once a sequence of 2-D matrices is recognized in a sequence of frames, the last step according to the workflow in Figure 2 is to read that sequence of 2-D matrices and output the original content. The latter task is accomplished by the decoder module. First, the decoder depends on the format specification. It has to know how much modules are in the width and height of the barcode; how many colors are used to encode information and which color represents which bit sequence. Furthermore, it has to know if it should read all modules or just a part of them, which is indicated by the offset information. Second, the decoder depends on the corner points of the 2-D matrix calculated by the recognizer module.

QR code can encode all types of data including characters, numbers, binary, special characters and multimedia and so forth. QR code has maximum data storage capacity in one frame for a numeric is7089 characters, for alphanumeric is 4296 characters, and for binary it is 2953 bytes. With the help of RS (Reed-Solomon) error correction method up to 30% error correction rate can be achieved.

CHAPTER 7

SIMULATION

Proposed system is implemented in MATLAB for text data, grey scale image and RGB image. QR code generator takes only string as an input so image matrix needs to be converted into string format. As grey scale images are 2-D images, image matrix can be directly converted to string and then QR code is generated. For RGB image, three layer of image matrix (red, green, and blue) needs to be separated as we need to convert matrix to string. In this study, system has been implemented for 1-dimesnsional data (string),2-dimesnional data (grey image) and 3-dimesional data (RGB image).

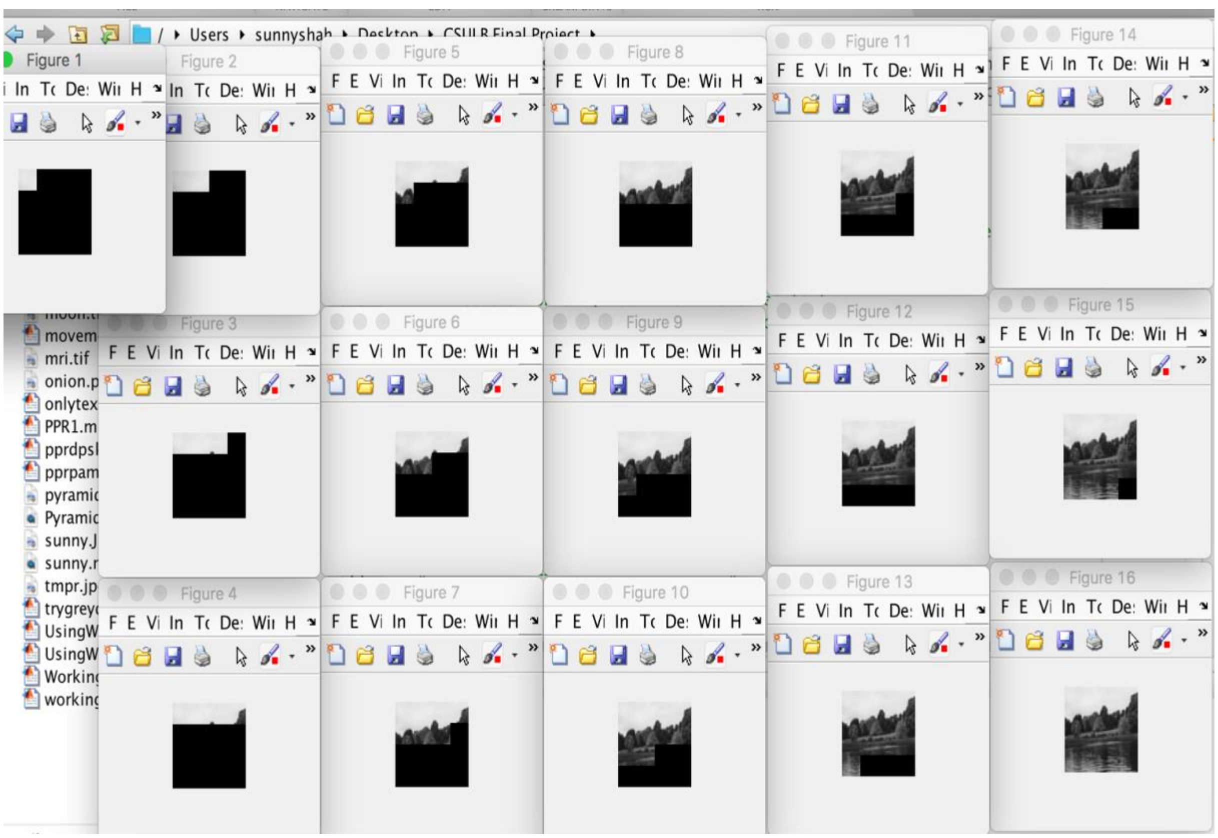

FIGURE 22. 64x64 image regenerated using each 16x16 image block.

QR code has a size limitation for input data. QR code has 1 to 40 versions with different module sizes. In this project version 1 is used, which has module size of 21x21.Due to input data size limitation image is being divided into small 16x16 blocks. Each block is treated as an image; it is encoded into QR code at transmitter and QR code is decoded at receiver. After decoding QR code each small block of image is connected to regenerate original image.

In Figure 22, grey scale is being resized to 64x64 for ease of transmission. From this 64x64 image, 16x16 image block is taken into another matrix and that matrix data is encoded and transmitted separately as a QR code. At the receiver side image is decoded from QR code. Each small block of image is stitched on one blank matrix of size 64x64 for regeneration of original image. In the Figure 22, it is clearly visible each 16x16 image block is stitched on one zero valued matrix. For 64x64 image 16 times 16x16 image blocks are generated and connected to create original transmitted image, which is shown in Figure 22. In this project, real time image capturing has been also added. Secure data information like banking details, credit card details, business proposals etc. can be transmitted using a webcam.

In this project, QR code of different version can be used and higher data transfer rate can be achieved. For instance, QR code of version 40 provides 177x177 modules, which is ten times greater than the version 1 size. version 40 can provide faster encoding performance compare to version 1 of QR code.

According to Automatic identification and data capture technique paper, currently 2-D barcodes adopts PAM as a desired modulation technique [12]. For the comparison, suggested system and PAM system are created in MATLAB.

In Figures 23and 24, performance graph of the two system has been shown with 3 different data sizes(16x16,32x32,64x64). In graph of PAM system with the increase SNR (Signal to Noise Ratio) BER (Bit Error Rate) drops down drastically after little bit linear movement. With the increase in the image matrix size, graph shows slow drop down in BER compare to small matrix image.

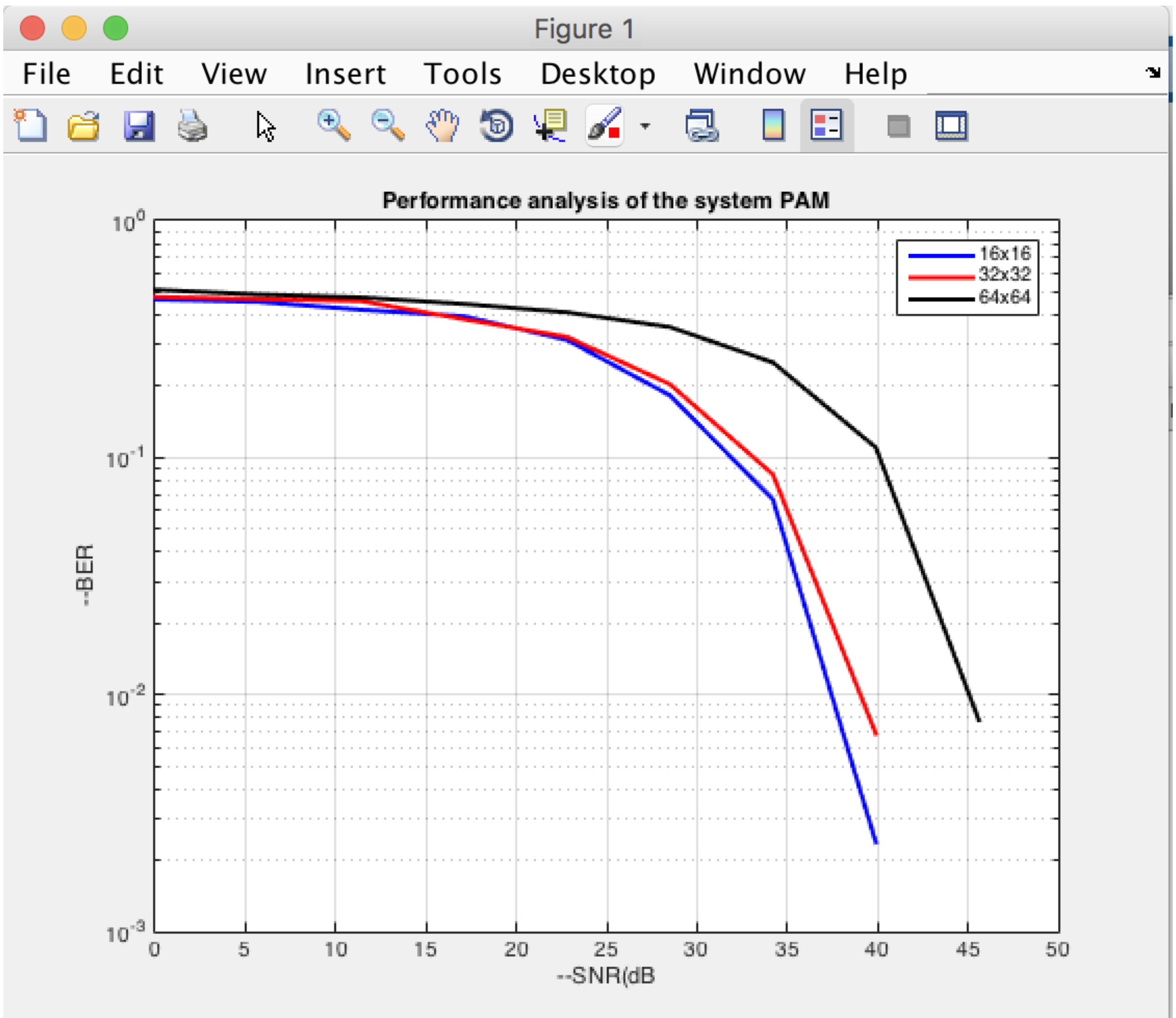

FIGURE 23. BER v/s SNR graph for PAM system for different sizes of image.

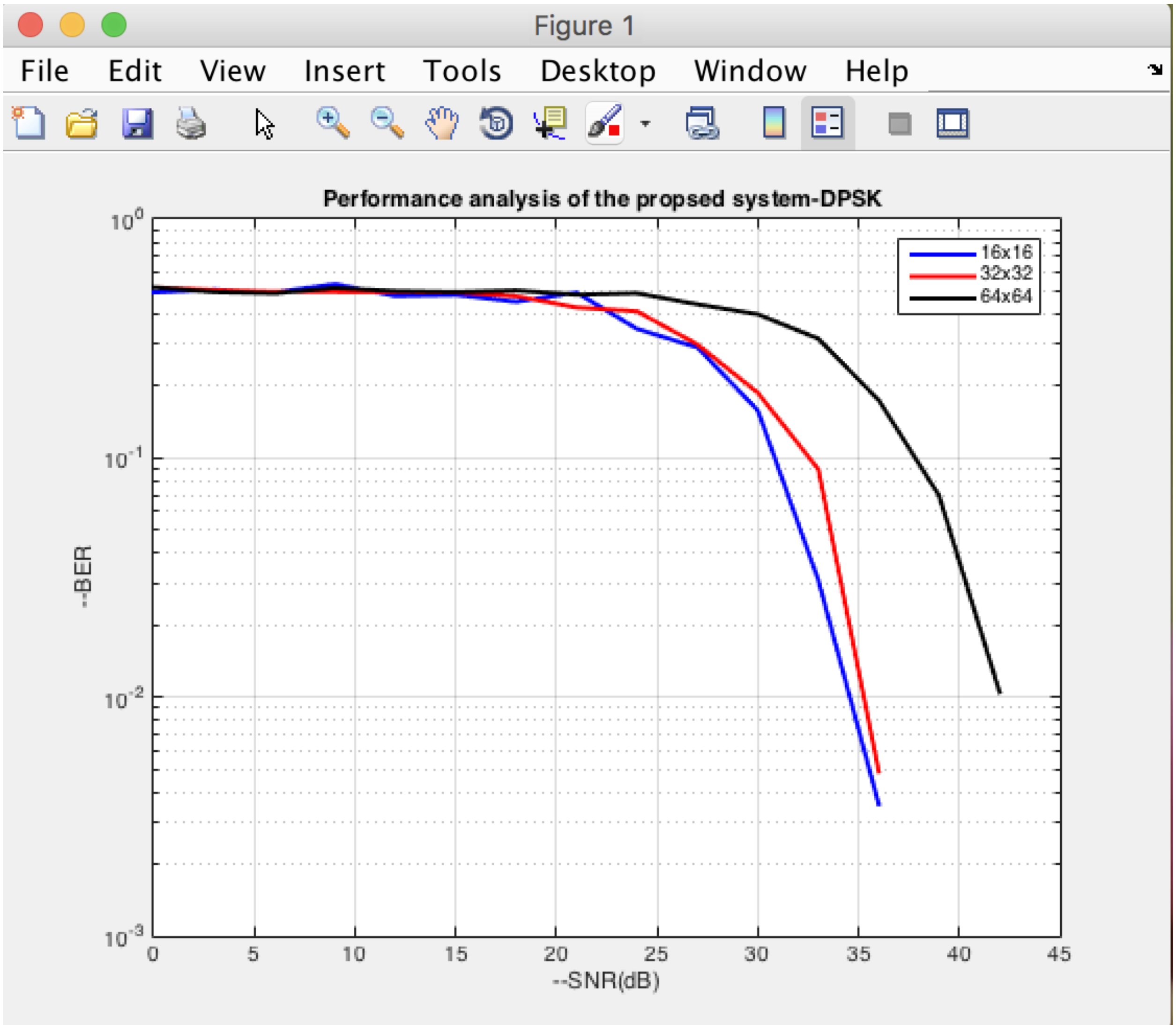

FIGURE 24. BER v/s SNR graph for DPSK system for different sizes of image.

In the graph of the DPSK method (Figure 24), all the image matrix shows almost linear behavior for the SNR value up to 20. Compare to PAM all image matrix size shows lower BER value compare to the PAM method. For instance, 16x16 image matrix has a lowest BER of $4x10^{-2}$ has a SNR of 36 ,whereas PAM method has 6 $x10^{-2}$ has a SNR of 40. Which shows that by using DPSK method in place of PAM method, lower the BER and SNR achieved which results in better system accuracy.

In Figure 25, comparison of BER V/S Sigma (%) graph results for PAM and DPSK system has shown. In Figure 25, red line shows the curve for the PAM method graph and blue line represents curve of DPSK system. Sigma represents standard deviation when the Gaussian low pass filter is applied on the image. The graph depicts that with the increase in the sigma value almost zero be can be achieved, which is far better compare to the PAM system.

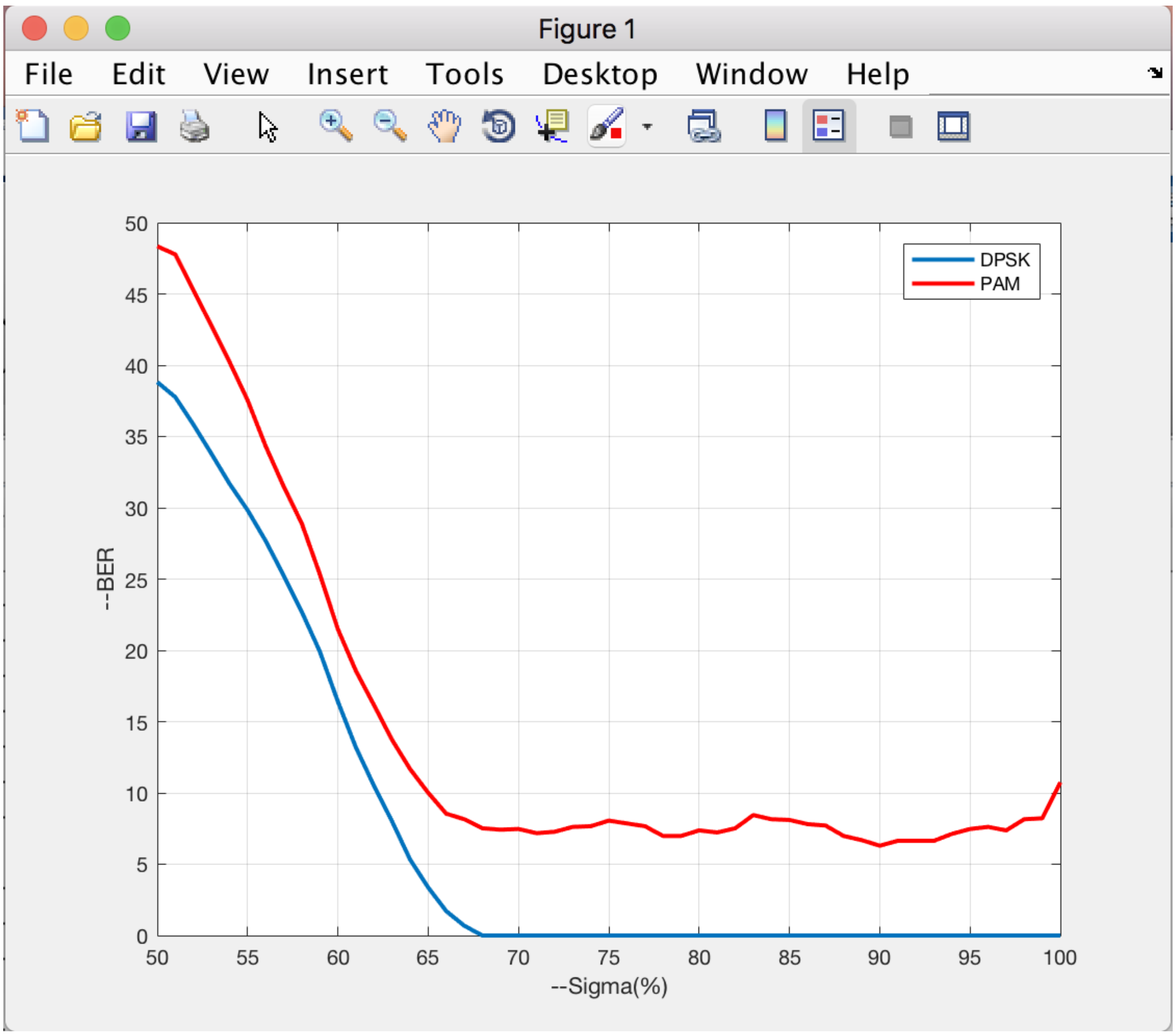

FIGURE 25. BER v/s SIGMA graph for DPSK and PAM method.

In Figure 26 graph of BER V/S Rotation (theta) for DPSK and PAM method has been shown. Rotation (theta) represents the angle the linear motion of a camera by range of pixels, with an angle of THETA degrees in a counter-clockwise direction. In the graph, it is clearly visible that with DPSK method BER around 7 can be achieved for the 0˚ while the PAM shows the BER for same angle around 20.

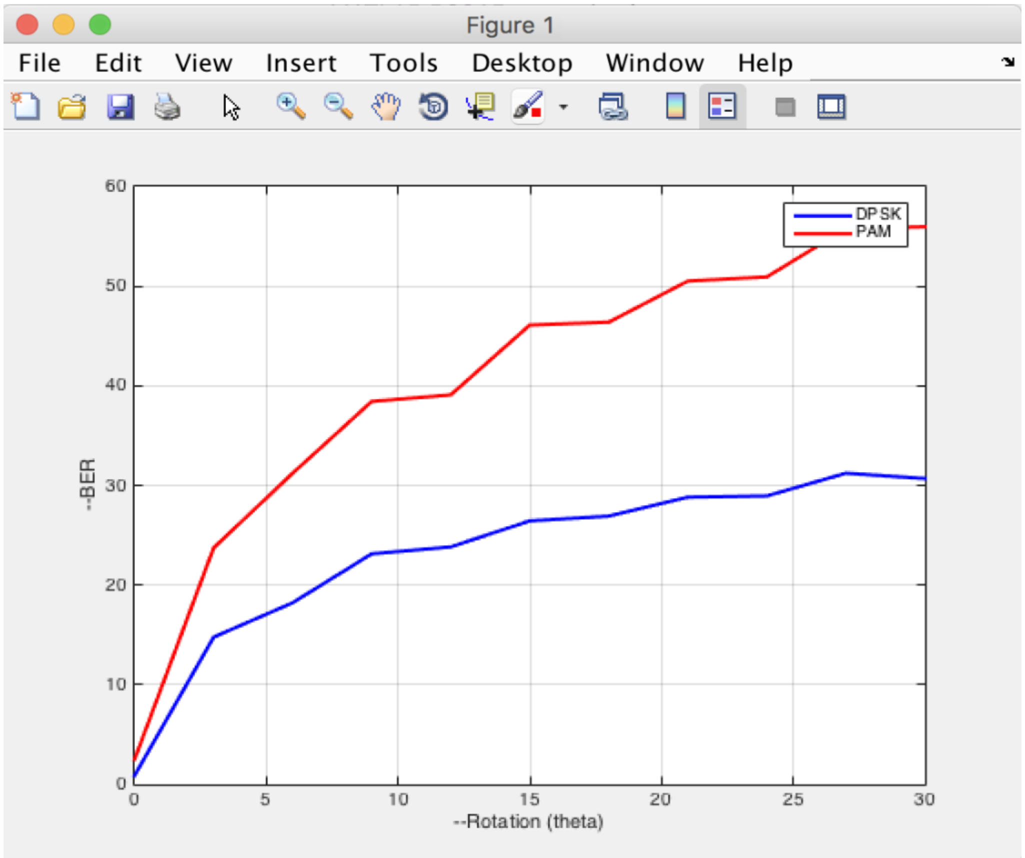

FIGURE 26. BER v/s Rotation(theta) graph for the DPSK and PAM method.

In Table 1, performance time comparison for the different types of data has been made for DPSK and PAM modulation method. Data types taken into consideration are string, grey scale image, and RGB image. In Table 1, two different size string, two different sizes of image and one real time webcam image performance timing for both methods have been compared.

TABLE 1. DPSK and PAM Method Performance Time

Data type	PAM	DPSK
5-character string	2.060s	1.977s
27-character string	2.1s	2.027s
128x128 scaled grey image -16x16 image blocks	9.683s	9.239s
128x128 scaled RGB image -16x16 image blocks	22.495s.	21.415s
Real time Webcam image(720x1280)	25.593	24.465

In Table 2, performance time comparison for different compression method for RGB and gray image of size 32x32. From the results, it is clearly visible that, uncompressed image requires less timing for transmission and reception as compression and uncompressing process are not performed. For RGB image, performance timing is nearer to twice of gray scale image, although computation in RGB image is three time of gray scale image.

TABLE 2. Performance Time for Different Types of Image Compression Methods

Type of transmitted image	Gray	RGB
without compression	5.395s	10.397s
compression using DWT	6.254s	14.197s
compression using Wavelet difference reduction	6.1s	12.648s
JPEG compression	13.236s	23.55s

In Table 3, received image size after performing decompression on the received image for different compression methods are compared. For image without compression, transmitted and received image size are same. While compression using, Discrete Wavelet transform (DWT) method provides reduction in the received image size and DWT is a lossless compression. Joint Picture Editing Group (JPEG) compression method also provides significant reduction in the image size but it is lossy compression so lots of image details will be lost.

TABLE 3. Received Image Size for Different Compression Methods

Type of transmitted image	**Gray**	**RGB**
Without image compression	852 bytes	2390 bytes
compression using DWT	633 bytes	2162 bytes
compression using Wavelet difference reduction	772 bytes	2355 bytes
JPEG compression	617 bytes	1907 bytes

CHAPTER 8

CONCLUSION

In this study, texts and images were steganographed into a sequence of Quick Response (QR) codes by a transmitter and were sent to a receiver using a system based on MATLAB. Specifically, the Differential Phase Shift Keying (DPSK) method was used in conjunction with the Orthogonal Frequency Division Multiplexing (OFDM) technique to modulate the data; the transmission efficiency of the DPSK method was then calculated and compared to the Phase-Amplitude Modulation (PAM) method. The transmission efficiency was measured by performance timing, lenient behavior to camera movements, and picture blurring due to both added noise during transmission and light spreading in the adjacent pixels of a Liquid Crystal Display (LCD) display. In addition, result of image transmission with and without image compression were compared.

The results showed that the performance of the DPSK was 5% faster than the PAM method. It was clearly visible in the graph that the PAM modulation method creates more impact on the results due to camera LCD movement. In addition to that, the impact on the data due to transmission errors was beyond the correctable range of the QR code. On other hand, use of the DPSK method with the OFDM system, for the modulation of the set of information, weakens the motion effect created due to LCD movement. Motion effects of LCD display contributes to the comparatively small deviation from the transmitted signal.

The results showed that transmission of image without compression is gives same amount of image data bytes at receiver side while compressed image provides less blocks but the image quality degrades due to compression and transmission of data is faster after excluding compression and decompression time.

Overall, the results demonstrated that the DPSK modulation method exhibits better transmission across all four parameters. Future research should continue to explore better methods for more efficient and secure modulation.

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