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## BARCODE MODULATION METHOD FOR DATA TRANSMISSION IN MOBILE DEVICES

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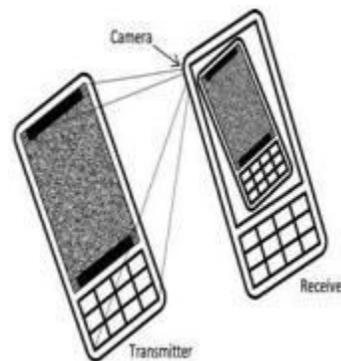
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**ABSTRACT** The concept of 2-D barcodes is of great relevance for use in wireless data transmission between handheld electronic devices. In a typical setup, any file on a cell phone, for example, can be transferred to a second cell phone through a series of images on the LCD which are then captured and decoded through the camera of the second cell phone. In this study, a new approach for data modulation in 2-D barcodes is introduced, and its performance is evaluated in comparison to other standard methods of barcode modulation. In this new approach, orthogonal frequency-division multiplexing (OFDM) modulation is used together with differential phase shift keying (DPSK) over adjacent frequency domain elements. A specific aim of this study is to establish a system that is proven tolerant to camera movements, picture blur, and light leakage within neighboring pixels of an LCD.

**INTRODUCTION** Barcodes have played a great role in facilitating numerous identification processes since their invention. 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

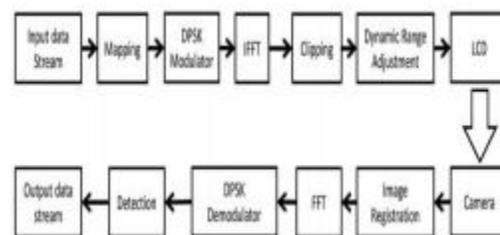
popular. A comparison of 2D barcode performance in camera phone applications can be found in. Much of the efforts in matrix barcode development have been dedicated to barcodes displayed on a piece of paper as that is the way they are normally used. With the replacement of books



With tablets and e-Book readers one could contemplate that re-placement 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 This idea 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 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 nonuniform 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

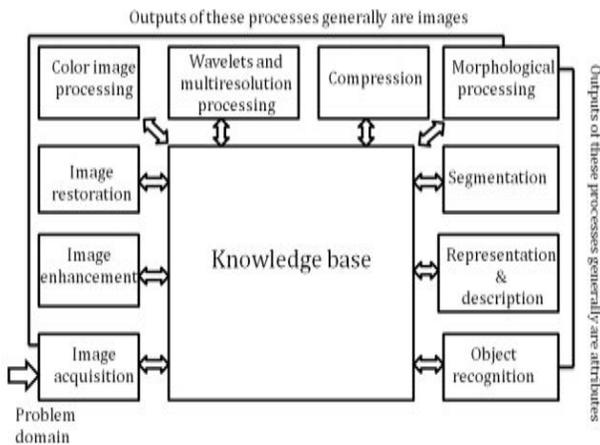
systems as indicated. This would require additional investigations in determining optimal modulation and demodulation schemes for this type of innovative communications medium. The OFDM modulation uses orthogonal frequency subcarriers to transfer data and can confine image blur, which is essentially a low pass filter, to high frequency components such that low frequency data bits are transmitted intact. This method requires high phase coherency to detect the data bits correctly.

## FUNDAMENTAL STEPS IN DIGITAL IMAGE PROCESSING



**IMAGE:** The word image is also used in the broader sense of any two-dimensional figure such as a map, a graph, a pie chart, or an abstract painting. In this wider sense, images can also be rendered manually, such as by drawing, painting, carving, rendered automatically by printing or computer graphics technology, or developed by a combination of methods, especially in a pseudo-photograph.





## LITERATURE REVIEW: BARCODES

have played a great role in facilitating numerous identification processes since their invention in 1952 [1]. 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 [2] have become increasingly popular. A comparison of 2D barcode performance in camera phone applications can be found in [3]. 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 book 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 [4] 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 [5] 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 nonuniform error probability may be used for adaptive error correction coding based on data region as in [5]. There is an increasing interest in design and implementation of LCD-Camera based communication systems as indicated in [6]–[8]. 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 coherency to detect the data bits correctly.

### **Example of applications**

The following list is a summary of existing OFDM based standards and products. For further details, see the Usage section at the end of the article.

### **Cable**

- ADSL and VDSL broadband access via POTS copper wiring.
- DVB-C2, an enhanced version of the DVB-C digital cable TV standard.
- Power line communication (PLC).
- ITU-TG.hn, a standard which provides high-speed local area networking over existing home wiring (power lines, phone lines and coaxial cables).
- Trail Blazer telephone line modems.
- Multimedia over Coax Alliance (MoCA) home networking.
- Wireless The wireless LAN (WLAN) radio interfaces IEEE 802.11a, g, n and HIPERLAN/2. The digital radio systems • DAB/EUREKA 147, DAB+, Digital Radio Mondiale, HD Radio, T-DMB and ISDB-TSB.
- The terrestrial digital TV systems DVB-T and ISDB-T.
- The terrestrial mobile TV systems DVB-H, T-DMB, ISDB-T and Media FLO forward link.

- The wireless personal area network (PAN) ultra-wideband (UWB) IEEE 802.15.3a implementation suggested by Wi Media Alliance.

The OFDM based multiple access technology OFDMA is also used in several 4G and pre-4G cellular networks and mobile broadband standards:

- The mobility mode of the wireless MAN/broadband wireless access (BWA) standard IEEE 802.16e (or Mobile- Wi MAX).
- The mobile broadband wireless access (MBWA) standard IEEE 802.20.
- The downlink of the 3GPP Long Term Evolution (LTE) fourth generation mobile broadband standard. The radio interface was formerly named High Speed OFDM Packet Access (HSOPA), now named Evolved UMTS Terrestrial Radio Access (E-UTRA).

### **Key features**

The advantages and disadvantages listed below are further discussed in the Characteristics and principles of operation section below.

### **Summary of advantages:**

- Can easily adapt to severe channel conditions without complex time domain equalization.
- Robust against narrow-band cochannel interference.
- Robust against inter symbol interference (ISI) and fading caused by multipath propagation.
- High spectral efficiency as compared to conventional modulation schemes, spread spectrum, etc.
- Efficient implementation using Fast Fourier Transform (FFT).

- Low sensitivity to time synchronization errors. Tuned sub-channel receiver filters are not required (unlike conventional FDM). Facilitates single frequency networks (SFNs); i.e., transmitter macro diversity.

### Summary of disadvantages:

- Sensitive to Doppler shift.
- Sensitive to frequency synchronization problems.
- High peak-to-average-power ratio (PAPR), requiring linear transmitter circuitry, which suffers from poor power efficiency.
- Loss of efficiency caused by cyclic prefix/guard interval.

### Linear transmitter power amplifier:

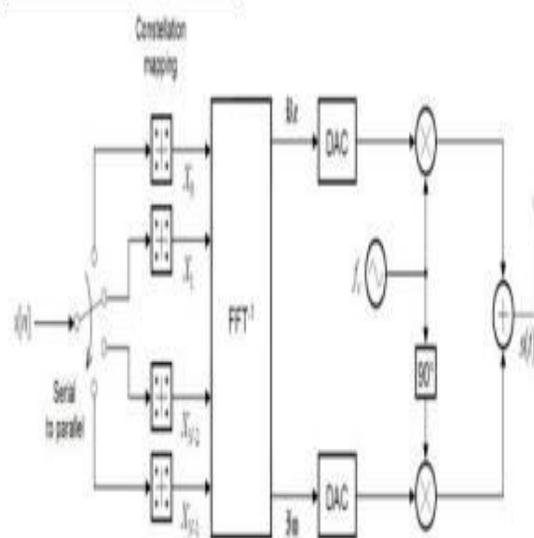
An OFDM signal exhibits a high peak-to-average power ratio (PAPR) because the independent phases of the sub-carriers mean that they will often combine constructively. Handling this high PAPR requires:

- a high-resolution digital-to-analogue converter (DAC) in the transmitter
- a high-resolution analogue-to-digital converter (ADC) in the receiver
- A linear signal chain. Any non-linearity in the signal chain will cause inter modulation distortion that
  - raises the noise floor
  - may cause inter-carrier interference
  - Generates out-of-band spurious radiation.

The linearity requirement is demanding, especially for transmitter RF output circuitry where amplifiers are often designed to be non-linear in order to minimize power consumption. In practical OFDM systems a small amount of peak clipping is allowed to limit the PAPR in a judicious trade-off against the above consequences. However, the transmitter output filter which is required

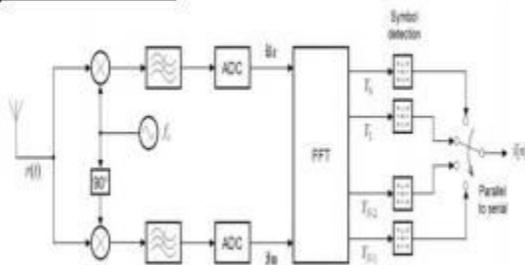
to reduce out-of-band spurs to legal levels has the effect of restoring peak levels that were clipped, so clipping is not an effective way to reduce PAPR. Although the spectral efficiency of OFDM is attractive for terrestrial and space communications, the high PAPR requirements have so far limited OFDM applications to terrestrial systems.

### TRANSMITTER:



An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with baseband data on each sub-carrier being independently modulated commonly using some type of quadrature amplitude modulation (QAM) or phase-shift keying (PSK). This composite baseband signal is typically used to modulate a main RF carrier. is a serial stream of binary digits. By inverse multiplexing, these are first demultiplexed into parallel streams, and each one mapped to a (possibly complex) symbol stream using some modulation constellation (QAM, PSK, etc.). Note that the constellations may be different, so some streams may carry a higher bit-rate than others.

## RECEIVER:



The receiver picks up the signal, which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency. This also creates signals centered on  $f_c$ , so low-pass filters are used to reject these. The baseband signals are then sampled and digitized using analogue-to-digital converters (ADCs), and a forward FFT is used to convert back to the frequency domain. This returns parallel streams, each of which is converted to a binary stream using an appropriate symbol detector. These streams are then re-combined into a serial stream,  $\hat{r}(t)$ , which is an estimate of the original binary stream at the transmitter.

### Introduction to MATLAB:

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

**Introduction** - describes the components of the MATLAB system.

**Development Environment** - introduces the MATLAB development environment, including information about tools and the MATLAB desktop.

**Manipulating Matrices** - introduces how to use MATLAB to generate matrices and perform mathematical operations on matrices.

**Graphics** - introduces MATLAB graphic capabilities, including information about plotting data, annotating graphs, and working with images.

### MANIPULATING MATRICES

Entering Matrices The best way for you to get started with MATLAB is to learn how to handle matrices. Start MATLAB and follow along with each example. You can enter matrices into MATLAB in several different ways:

- Enter an explicit list of elements.
- Load matrices from external data files.
- Generate matrices using built-in functions.
- Create matrices with your own functions in M-files.

Start by entering Dürer's matrix as a list of its elements. You have only to follow a few basic conventions:

- Separate the elements of a row with blanks or commas.
- Use a semicolon, ; , to indicate the end of each row.
- Surround the entire list of elements with square brackets.

To enter Dürer's matrix, simply type in the Command Window

```
A = [16 3 2 13; 5 10 11 8; 9 6 7 12; 4 15 14 1]
```

MATLAB displays the matrix you just entered.

```
A = 16 3 2 13  
     5 10 11 8  
     9 6 7 12  
     4 15 14 1
```

This exactly matches the numbers in the engraving. Once you have entered the matrix, it is automatically remembered in the MATLAB workspace. You can refer to it simply as A.

## Expressions

Like most other programming languages, MATLAB provides mathematical expressions, but unlike most programming languages, these expressions involve entire matrices. The building blocks of expressions are:

- Variables
- Numbers
- Operators
- Functions

User Interface Controls The Layout Editor component palette contains the user interface controls that you can use in your GUI. These components are MATLAB uicontrol objects and are programmable via their Callback properties. This section provides information on these components.

## Push Buttons

- Sliders
- Toggle Buttons
- Frames
- Radio Buttons
- Listboxes
- Checkboxes
- Popup Menus
- Edit Text
- Axes
- Static Text
- Figures

## Push Buttons

Push buttons generate an action when pressed (e.g., an OK button may close a dialog box and apply settings). When you click down on a push button, it appears depressed; when you release the mouse, the button's appearance returns to its nondepressed state; and its callback executes on the button up event.

## Properties to Set

String - set this property to the character string you want displayed on the push button.

Tag - GUIDE uses the Tag property to name the callback subfunction in the application M-file. Set Tag to a descriptive name (e.g., close\_button) before activating the GUI. Programming the Callback

When the user clicks on the push button, its callback executes. Push buttons do not return a value or maintain a state.

## Toggle Buttons

Toggle buttons generate an action and indicate a binary state (e.g., on or off). When you click on a toggle button, it appears depressed and remains depressed when you release the mouse button, at which point the callback executes. A subsequent mouse click



returns the toggle button to the nondepressed state and again executes its callback.

### Programming the Callback

The callback routine needs to query the toggle button to determine what state it is in. MATLAB sets the Value property equal to the Max property when the toggle button is depressed (Max is 1 by default) and equal to the Min property when the toggle button is not depressed (Min is 0 by default).

From the GUIDE Application M-File The following code illustrates how to program the callback in the GUIDE application M-file.

```
Function          varargout          =
togglebutton1_Callback(h,eventdata,handles
,varargin)
button_state = get(h,'Value');
if button_state == get(h,'Max')
% toggle button is pressed
elseif button_state == get(h,'Min')
% toggle button is not pressed end
```

### Adding an Image to a Push Button or Toggle Button

Assign the CData property an m-by-n-by-3 array of RGB values that define a truecolor image. For example, the array a defines 16-by-128 truecolor image using random values between 0 and 1

```
(generated by rand).
a(:,:,1) = rand(16,128);
a(:,:,2) = rand(16,128);
a(:,:,3) = rand(16,128);
set(h,'CData',a)
```

### Radio Buttons

Radio buttons are similar to checkboxes, but are intended to be mutually exclusive within a group of related radio buttons (i.e., only one button is in a selected state at any given

time). To activate a radio button, click the mouse button on the object. The display indicates the state of the button.

Implementing Mutually Exclusive Behavior Radio buttons have two states - selected and not selected. You can query and set the state of a radio button through its

**Value property:** Value = Max, button is selected. Value = Min, button is not selected.

To make radio buttons mutually exclusive within a group, the callback for each radio button must set the Value property to 0 on all other radio buttons in the group. MATLAB sets the Value property to 1 on the radio button clicked by the user. The following subfunction, when added to the application M-file, can be called by each radio button callback. The argument is an array containing the handles of all other radio buttons in the group that must be deselected. function mutual\_exclude(off) set(off,'Value',0) Obtaining the Radio Button Handles. The handles of the radio buttons are available from the handles structure, which contains the handles of all components in the GUI. This structure is an input argument to all radio button callbacks. The following code shows the call to mutual\_exclude being made from the first radio button's callback in a group of four radio buttons.

```
function varargout =
radiobutton1_Callback(h,eventdata,handles,
varargin) off =
[handles.radiobutton2,handles.radiobutton3,
handles.radiobutton4]; mutual_exclude(off)
% Continue with callback After setting the
radio buttons to the appropriate state, the
```

callback can continue with its implementation-specific tasks.

## Edit Text

Edit text controls are fields that enable users to enter or modify text strings. Use edit text when you want text as input. The String property contains the text entered by the user. To obtain the string typed by the user, get the String property in the callback. function edittext1\_Callback(h,eventdata,handles,varargin) user\_string = get(h,'string'); % proceed with callback...

Obtaining Numeric Data from an Edit Text Component

MATLAB returns the value of the edit text String property as a character string. If you want users to enter numeric values, you must convert the characters to numbers. You can do this using the str2double command, which converts strings to doubles. If the user enters non-numeric characters, str2double returns NaN. You can use the following code in the edit text callback. It gets the value of the String property and converts it to a double. It then checks if the converted value is NaN, indicating the user entered a non-numeric character (isnan) and displays an error dialog (errordlg). function edittext1\_Callback(h,eventdata,handles,varargin) user\_entry = str2double(get(h,'string')); if isnan(user\_entry) errordlg('You must enter a numeric value','Bad Input','modal') end % proceed with callback...

## Triggering Callback Execution

On UNIX systems, clicking on the menubar of the figure window causes the edit text callback to execute. However, on Microsoft Windows systems, if an editable text box has focus, clicking on the menubar does not

cause the editable text callback routine to execute. This behavior is consistent with the respective platform conventions. Clicking on other components in the GUI execute the callback.

## Static Text

Static text controls displays lines of text. Static text is typically used to label other controls, provide directions to the user, or indicate values associated with a slider. Users cannot change static text interactively and there is no way to invoke the callback routine associated with it.

## Frames

Frames are boxes that enclose regions of a figure window. Frames can make a user interface easier to understand by visually grouping related controls. Frames have no callback routines associated with them and only uicontrols can appear within frames (axes cannot).

## Programming the Popup Menu

You can program the popup menu callback to work by checking only the index of the item selected (contained in the Value property) or you can obtain the actual string contained in the selected item

This callback checks the index of the selected item and uses a switch statement to take action based on the value. If the contents of the popup menu is fixed, then you can use this approach. Function

```
varargout =  
popupmenu1_Callback(h,eventdata,handles,  
varargin)  
val = get(h,'Value');  
switch val  
case 1 % The user selected the first item  
case 2 % The user selected the second item
```

% etc.

**Enabling or Disabling Controls** You can control whether a control responds to mouse button clicks by setting the Enable property. Controls have three states:

on - The control is operational

off - The control is disabled and its label (set by the string property) is grayed out.

inactive - The control is disabled, but its label is not grayed out.

When a control is disabled, clicking on it with the left mouse button does not execute its callback routine. However, the left-click causes two other callback routines to execute: First the figure WindowButtonDownFcn callback executes. Then the control's Button Down Fcn callback executes. A right mouse button click on a disabled control posts a context menu, if one is defined for that control. See the Enable property description for more details.

## **Axes**

Axes enable your GUI to display graphics (e.g., graphs and images). Like all graphics objects, axes have properties that you can set to control many aspects of its behavior and appearance. See Axes Properties for general information on axes objects.

### **Axes Callbacks**

Axes are not uicontrol objects, but can be programmed to execute a callback when users click a mouse button in the axes. Use the axes Button Down Fcn property to define the callback.

### **Plotting to Axes in GUIs**

GUIs that contain axes should ensure the Command-line accessibility option in the

Application Options dialog is set to Callback (the default). This enables you to issue plotting commands from callbacks without explicitly specifying the target axes. Figures are the windows that contain the GUI you design with the Layout Editor. See the description of figure properties for information on what figure characteristics you can control

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