# QR-Code based Chipless RFID System for Unique Identification

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***Abstract*—A fully passive printable Quick Response (QR) code embedded chipless RFID (Radio Frequency Identification) technique is presented for secure identification of alive and non-alive amenity. A series of QR codes are printed in the form of a resonator in passive RFID tag, and the coded information is retrieved through frequency domain reflectometry method for identification. The design is demonstrated over the 3-10 GHz band with embedded multiple QR-code resonators on a single RFID tag. The tag comprises of QR Code resonators, cross polarized transmitting and receiving ultra wide band (UWB) monopole antennas. As a proof of concept, a 42mm x 42mm size standard QR-code resonator is designed and later the design is compressed to 10.5mm x 10.5mm size on a single-sided FR4 PCB. The proposed method proved the tag read by reader from 2 meters of distance.**

***Index Terms*—Chipless RFID, QR Code resonator, QR code based chipless RFID tag.**

## I. Introduction

The QR code system is a growing technology towards identification compared to barcodes due to its fast readability and greater storage capacity. Nowadays, every smartphone has an inbuilt application of QR code scanner to read QR codes and to retrieve the stored information. The stored information can be in any form either web address or personal details. For example, presently any product in the market is labelled with QR Code to facilitate product information for customers. A typical barcode can only store upto 20 digits, whereas QR Code can bear a maximum of 7,089 characters. One major advantage of QR codes over barcode is that they can be scanned from any angle regardless of the position. The information encoded in QR code is within the limits of the three specific squares placed at three corners.

Recently, QR code has been proved as an antenna which resonates at a frequency depending on the structure and is also embedded in RFID Systems in form of an antenna [1]-[3]. From this, different structure of QR code gives different frequencies. In [1], 2.43 GHz QR code antennas was proposed for the replacement of the RFID tag antenna. In [2], a fragment type 915MHz UHF RFID tag was designed combining the QR-barcode printed antenna and RFID. In [3], a QR code antenna is integrated with 2.45GHz RFID tag. In all the above cases, the QR code pattern used as an antenna to transmit or receive the information without any significant identification. In this paper,as a proof of concept the rectangular resonator in chipless RFID [4] has been replaced by a QR code resonator. As a result, identification becomes easier and more flexible to the user with in a short time, in a more compact way and compared to conventional approach[4]. This scheme is a potential approach for quick identification in disaster hit areas.

In passive Chipless RFID tag, the major challenge is to generate a resonant frequency in any defined manner. Slot resonators [5]-[6], Natural resonance [7] and Split ring resonators [8] are some of the works on resonator structure reported previously. In [9], Peano and Hilbert space filling curves with higher iteration used as compact resonator and the latest approach called Pixel encoding where the presence or absence of resonance was indicated by green pixel and white pixel resp., by using lattice based approach with meander line structure [10].

Although the research on Chipless RFID are innumerable, there is no single RFID system which combines the technology of RFID and QR codes. In the present market, 1-D barcodes have been already replaced by QR codes as it is 2-Dimensional. By this, combining the technology of QR codes with RFID will gives the new era of identification towards health care applications. The designed tag also has an added advantage of readable capacity and the same tag readable by both QR code reader and RFID reader. Here, the use of RFID and QR code technology depends on the distance of readability.

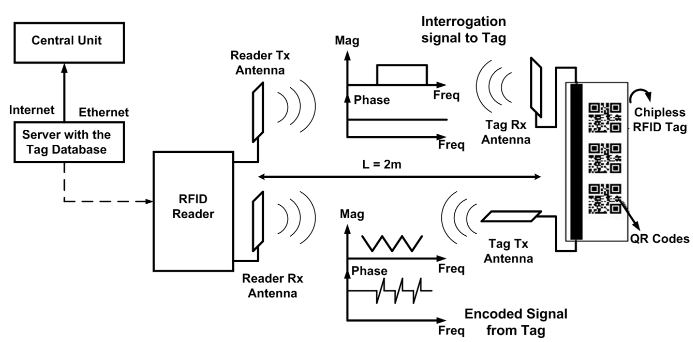


Fig. 1. Scheme of QR-Code based chipless RFID system

Combining RFID and 2D barcodes has been already presented in [11] and also with a patent presented in [12] explains the use of a user defined structure as a barcode coupled with RFID chip on documents for secure identification. Not all 2D barcodes are QR codes-thers's many different kinds.

A lot of sites seem to use the terms 2D barcodes and QR Codes interchangeably, and while QR codes are a type of 2D barcode, not all 2D barcodes are QR codes. Typically, when referring to a non-QR code 2D barcode,called as proprietary barcodes. Essentially, QR codes are able to be scanned across multiple barcode scanning applications, but proprietary codes, such as Microsoft Tag, can only be scanned using a specific application.

The main differences between the proposed design to the previous works on chipless RFID are that, a novel possibility technique to use QR codes in chipless RFID as a resonator and encode data by using QR codes. Due to these differences, the identification became easier from nearer and far distances and less mutual coupling between resonators. As an example, the proposed tag performance is demonstrated by constructing multiple QR code resonators that encodes information both in terms of location and personalized data.

This design proves each alphabet/word in QR code will generate different frequencies depends on their structure. By this, the proposed method will clarify the possible RF identification through QR code in frequency domain.

This paper is standardized as follows. In Section II the working principle of QR-Code based chipless RFID system is explained. Section III handles with the design and testing of the QR code resonators, RFID tag and the reader antennas. The simulation and measured results including test setup of the proposed system are presented in Section IV followed by a conclusion in Section V.

## II. Working Principle

Theme of our proposed system has been depicted in Fig.1. In brief, information encoded through QR codes (transfer from reader to server via internet). Once the disaster hits tag will be scanned by reader in frequency domain and compares with the data base stored in server to find the effected people. The main information is retrieved by matching the received frequency with the simulated QR code frequency in central unit 1.

In addition, adding a cross-polarized ultra wide band (UWB) monopole Tx and Rx antenna with QR code resonator forms a QR code based chipless RFID tag. The full tag behave as a multi stop band filter with specific spectral signature (i.e. each pattern resonate at particular frequencies with certain stop-bands). Compare to conventional chipless tag coded with either 1 (no resonance) /0 (resonance), here each of the QR resonator refer to one particular resonance frequency. These set of frequencies are detected at the reader end and saved it for further comparison at central unit to retrieve the coded information.

Fig.2 and Fig.3 represents the comparative simulation and its response of a rectangular resonator with QR code in Advanced Design System(ADS)EM simulation. The simulation results depicts that the QR code will generate the unique frequency depends on its structure and also produces better results. The size of QR codes can be optimized from 42mm X 42mm conventional size to 10.5mm X 10.5mm according to user.

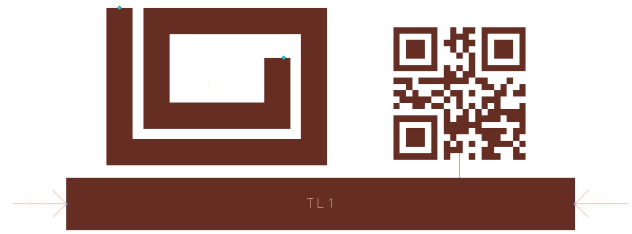


Fig. 2. Simulation structure of Rectangular resonator and QR-Code resonator

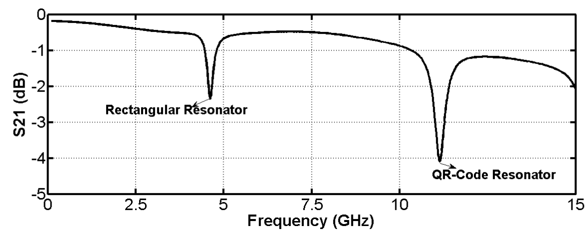


Fig. 3. Performance of Rectangular resonator and QR-Code resonator

To embed the combination of QR codes into a chipless RFID tag, modules of the QR code can be selected to serve as a resonator, the modules selected for the resonator should be metalized by using conductive materials such as copper. The selected modules are directly in contact with both transmitting (Tx) and receiving (Rx) antennas. To find suitable resonating frequency of a QR code for a tag, proper feeding technique can be applied, at a specific position on QR code it gives maximum S21(called selectivity) response. The QR code that gives more selectivity can be selected and metalized to serve as a resonator for the chipless RFID tag.

For the proposed chipless RFID tag, the QR code resonator should be designed with in the frequency band of 3-10 GHz to match with the tag transmitter and receiver antenna. With this aim, the resonant frequency is defined for each QR code with in band. This is explained in Section III. The tag comprises of QR code resonators and cross polarized Tx and Rx ultra wide band monopole antennas. The reader antenna is a log periodic dipole antenna (LPDA) used in place of reader for full system verification.

## III. Design and Test

QR code embedded chipless RFID tag is fabricated on FR4 substrate (Er = 4.4, h=0.8mm, tanD=0.0019). The system consists of a vertically polarized UWB disc loaded monopole receiving tag antenna, a proposed QR code multi resonator circuit and a horizontally polarized UWB transmitting tag antenna. The receiving and transmitting antennas are cross polarized in order to reduce the interpolation and for proper isolation[4], the system also includes the design of LPDA as reader antenna.

For demonstration,3 bit QR code based chipless RFID tag has designed and tested in which 3 bits represents zone, sub zone and user information. The standard QR code version is version 1 of 21 X 21 modules in total. Therefore, the proposed QR code resonators has been presented in two different sizes one is of 42mm X 42mm having each bit of module has dimensions of 2mm X 2mm and another is of 10.5 mm X 10.5 mm having each module has dimensions of 0.5mm X 0.5mm.

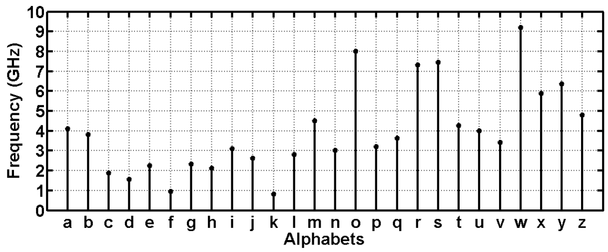


Fig. 4. Resonant frequency of each alphabet QR code resonator

*A. QR-Code Resonator*

To verify the proposed method, all alphabets (a-z) are encoded in form of QR code (exporting JPEG to GDSII and importing GDSII in ADS) format and simulated their frequency response through EM simulation as shown in Fig. 4. It shows that each alphabet represents a unique identification of frequency without any overlap. The design has been verified practically for 42mm X 42mm QR code resonators fabricated and their measured results are shown in Fig. 5 and Fig. 6 respectively.

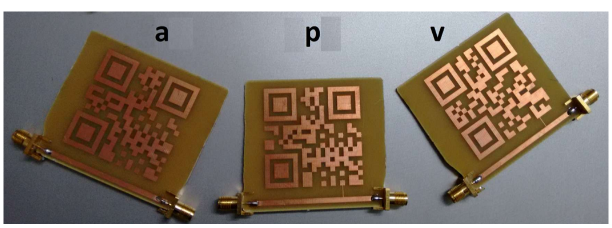


Fig. 5. Fabricated individual QR code resonators

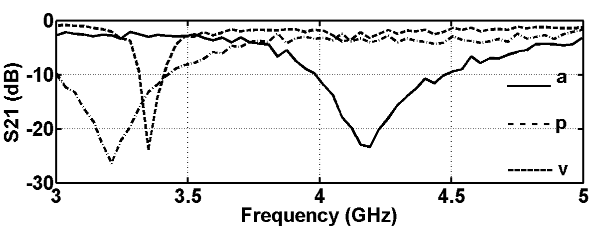


Fig. 6. Resonant frequency of three individual QR code resonators

The simulation results drives to build cascaded QR code multi resonators to encode more information. To demonstrate this, 3 bit QR code tag was fabricated on FR4 and tested as shown in Fig. 7(a) with a total length of 170mm and width of 52mm (each QR code resonator has a dimension of 42mm X 42mm, with gap coupling of 16mm and 4mm from feed line).

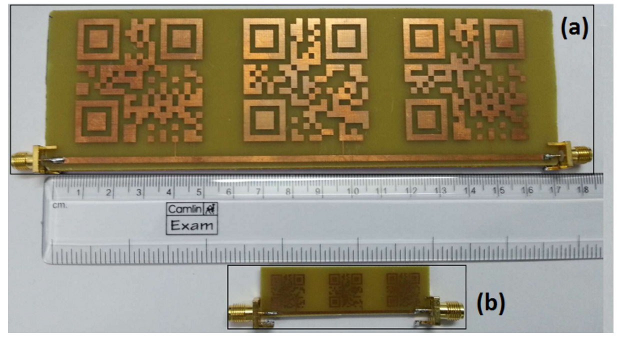


Fig. 7. Fabricated image of 3-bit QR code resonators a) Each 42mm Size b) Each 10.5mm Size

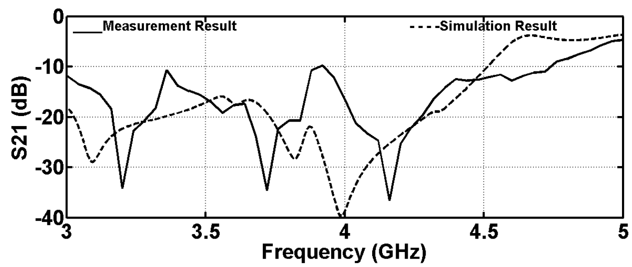


Fig. 8. Simulated and Measured results of 3-bit 42mm X 42mm size QR code resonators

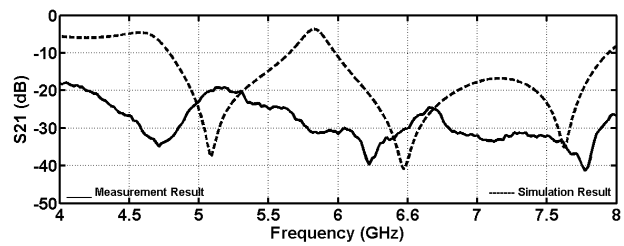


Fig. 9. Simulated and Measured results of 3-bit 10.5mm X 10.5mm size QR code resonators

From Fig. 8 the measured results shows three distinct frequency and closely matches with the EM simulation(with a shifting of 100MHz). To reach the optimum dimension of the tag multiple experiments has been carried out and finally compressed the original 42mm x 42mm QR Code resonator to 10.5mm X 10.5mm. The compressed QR code resonator with its simulated and measured results are shown in Fig. 7(b) and Fig. 9 with a total length of 55 mm and width of 16 mm (Each QR code resonator has a dimension of 10.5 mm X 10.5 mm, with gap coupling of 8mm and 1mm from feed line). These results also shows three distinct frequency and with a shift of 170MHz compared to the simulation. The obtained results shows that, the approach of QR codes to RFID as a resonator has been practically verified with some shifting of frequency due to board inaccuracies and size limitations.

Further, to cover all the alphabets as well as to encode the more number of bits in a single tag the band width of both the tag and receiver antennas has to be wide band i.e., selected from 3-10 GHz. The below subsections B and C explains about the design and testing of tag antenna and reader antenna.

### B. UWB RFID Tag Antenna Design

The circular microstrip ultra wide band (UWB) monopole disc loaded antenna[13] was used in tag. The layout parameters of the antenna are as shown in Fig.10. The designed antenna (36 mm X 27 mm) comprises a 50 ohm microstrip feed (2.2 mm width) loaded with a circular disc on the top layer and a ground plane at the bottom to get wide band. The simulation and measurement results are shown in Fig. 11(a) with fabricated antenna in Fig. 11(b) and covers a desired bandwidth of 3-10 GHz, the simulated gain of the antenna is 4.4dBi.

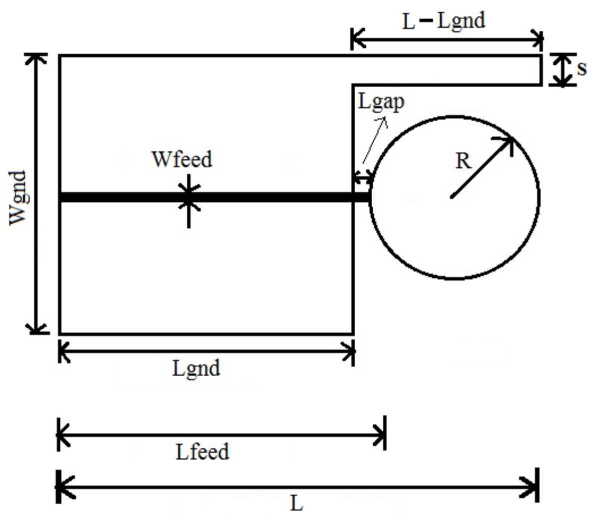


Fig. 10. Layout parameters of a UWB monopole antenna (Lgnd=19.67mm, Wgnd=27.6mm, Wfeed=2.4mm, Lgap=0.33mm, R=8mm, S=5.46mm, L=37.22mm, Lfeed=20mm)

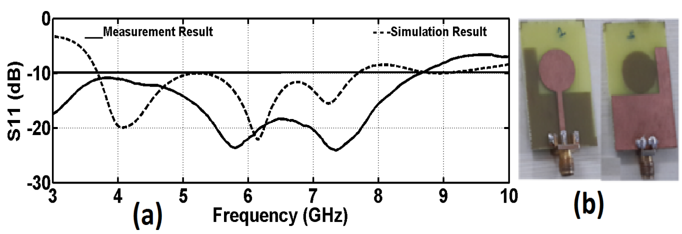


Fig. 11. (a) Simulated and measured results of UWB monopole Antenna (b) Fabricated UWB monopole antenna

### C. UWB RFID Reader Antenna Design

For RFID reader, the log periodic dipole antenna (104mm X 60mm) was designed on both the sides of a FR4 substrate to achieve good bandwidth and radiation pattern, the theory and design equations can be found in [14], The dimensions of a novel LPDA antenna are shown in Fig.12, the simulated gain of the antenna is 6.12dBi. The simulated and measured results with the fabricated antenna are shown in Fig.13(a) and Fig.13(b).

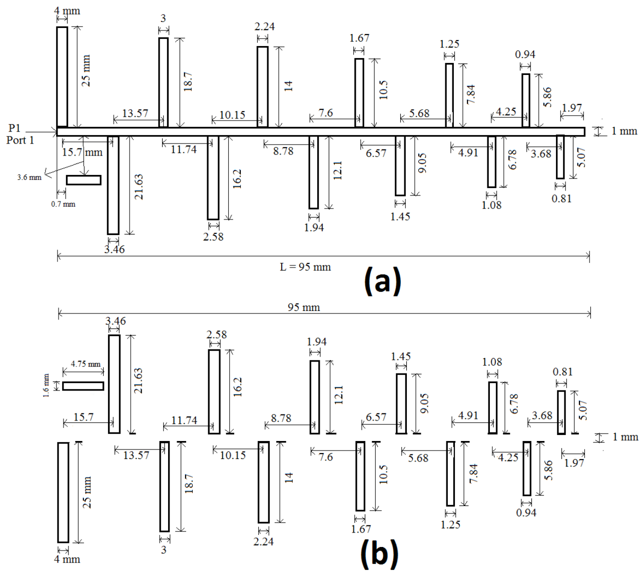


Fig. 12. Layout parameters of LPDA antenna (a) Top view (b) Bottom view

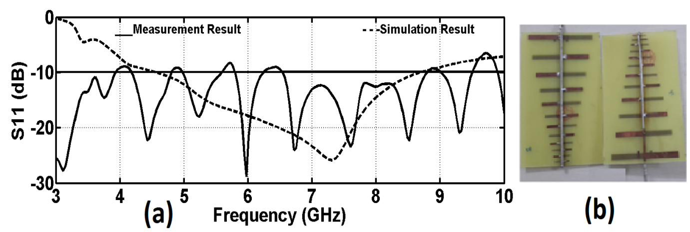


Fig. 13. (a) Simulated and measured results of LPDA antenna (b) Fabricated LPDA antenna

## IV. QR CODE BASED CHIPLESS RFID TAG FIELD TRIALS

From the test setup shown in Fig.14 the RFID tag field measurement has two LPDA antennas as reader transmitter (Tx) and receiver (Rx) antennas and QR code resonators with two UWB monopole antennas as tag Rx and Tx antennas. The total tag size of 3-bit 42 mm and 10.5 mm QR Code based chipless RFID tag are 32cm X 6.6cm and 20cm X 6.6cm respectively as shown in Fig.15 and their test results are shown in Fig.16 and Fig.17 respectively.

The band of frequency 3-10 GHz has been transmitted from PNA-X Keysight network analyzer to QR code based chipless RFID tag through LPDA transmitter antenna and the coded information is received through LPDA receiver antenna and displayed in network analyzer as S21 as shown in Fig.14.

The measured results shows a three distinct resonance for both 3 bit 42 mm and 10.5 mm QR Code tag with a reading distance of 2 meters. Therefore, the approach towards chipless RFID tag based on QR codes has proved with successful reading range upto 2 meters.

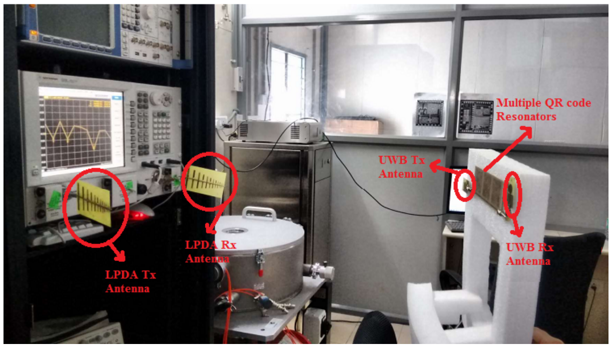


Fig. 14. Experimental setup for testing the QR code based chipless RFID tag

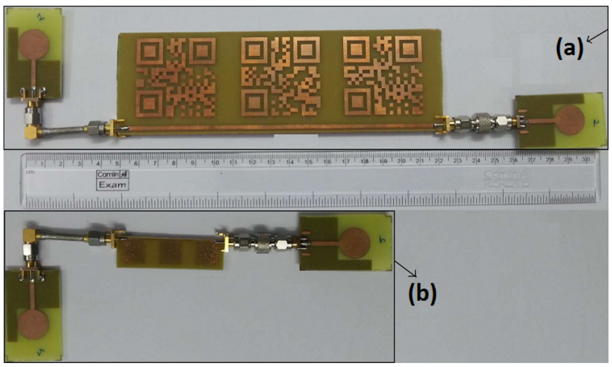


Fig. 15. Fabricated 3-bit QR code based chipless RFID tag (a) 42mm size QR code (b) 10.5mm size QR code

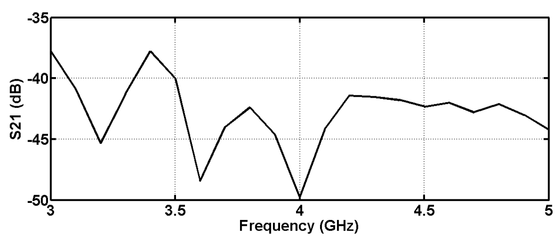


Fig. 16. S21 measurement of fabricated 3-bit 42mm X 42mm size QR code based chipless RFID tag

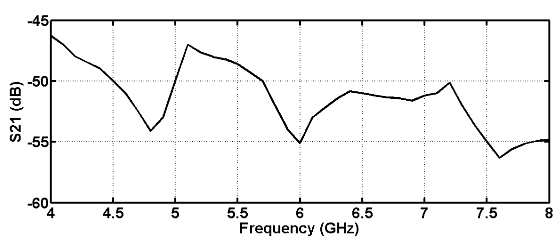


Fig. 17. S21 measurement of fabricated 3-bit 10.5mm X 10.5mm size QR code based chipless RFID tag

The presence of frequency offset is due to the printed circuit board and substrate inaccuracies. Therefore, after receiving frequency set from the reader, QR code information will be retrieved through look up table method. Hence, the proposed QR code embedded chipless tag technique provides a secure identification and enhances the data capacity.

This proof of concept leads to the possible way of using the proposed design in disaster. The mentioned application is just an example focused from the design. The proposed design gives the accessibility to know the details of person by reading the tag and also to get the information about the people who stucked in building from 2 meters of distance in disaster hit an area.

## V. CONCLUSION

Multiple QR code embedded chipless RFID technique has been presented and successfully demonstrated by adding antennas. The prototype of 3-bit QR Code resonator and tag shows three distinct resonant frequencies and seems to have a potential application in multi bit secure chipless RFID technology. Further, this system can be extended by minimizing the size of antennas and concentrating on accuracy of the design. In future, The proposed tags can be printed on flexible substrate at lower cost with added features incorporating temperature and humidity sensor.

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