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Frequency Shift Coded microstrip shorted stub resonators for Chipless RFID tag applications

Sumi M(1), S. Mridula (2), Anju Pradeep(2) and Binu Paul(2)
(1) Dept. of Electronics and Communication, N S S College of Engineering, Palakkad, Kerala, India
(2) Division of Electronics Engineering, School of Engineering, Cochin University of Science and Technology, Cochin- 22, Kerala, India

Abstract

A passive high security chipless RFID tag designed using two shorted stub resonators is presented in this paper. The tag identity is encoded in the spectral domain using Frequency Shift Coding technique. 100 different code words are possible in 1.98 to 3.67 GHz band. Bistatic detection approach is used to decode the tag identity from either the amplitude or group delay information.The tag consists of two cross polarised wide band antennas integrated to shorted stub resonators, for transmission and reception of signals. The resonators are designed and fabricated on substrate C-MET LK4.3 of dielectric constant 4.3 and loss tangent 0.0018. Measured results on realized prototypes are provided to ensure the reliability of the proposed design.

1 Introduction

Radio frequency identification (RFID) is an electronic tagging technology which utilizes radio frequency waves to remotely detect and identify a device or an object containing an encoded tag. It serves as a radio technology to achieve internet of things (IoT) vision to create a worldwide network of smart objects[1]. If all objects are equipped with radio tags, they could be identified and inventoried. To fulfil these functions, RFID tags must be data dense, inexpensive and energy efficient [2]. However, their widespread use is limited due to the high cost of silicon chip required. Hence, cost effective solutions are of great need. Today, RFID systems are being developed with tags that do not contain silicon chips. These tags are known as 'chipless' tags.

Compared to conventional tags, chipless RFID tag uses an entirely different technique to encode data. Each chipless RFID tag contains a planar passive circuit which reflects back a unique electromagnetic signal to the reader, thus revealing the identity of the tag. Spectral signature based chipless RFID tag encodes data in the frequency spectrum with its unique spectral signature using multiresonating structures.The tag identity is encoded in spectral domain either as amplitude attenuation or group delay variation. Different approaches for designing spectral signature based chipless tags are reported in [3]-[9]. In these tags, each data bit is identified as the presence or absence of a resonance at a predetermined frequency. Majority of the tags are designed on microstrip based resonators. Capacitively tuned dipole for RFID barcode was first reported by Jalaly and Robertson [3]. An eight bit chipless RFID tag using quarter wave open stub resonator is reported in [4]. The tag encodes eight bits in a frequency band from 2.08 GHz to 4.03 GHz. An eight bit chipless RFID tag based on Open-Loop Resonator is reported in [5]. It reports a multiresonator which requires a frequency band of 3.3 GHz to 5.8 GHz to encode eight bits.Chipless RFID tag using U slot resonator is proposed in [6]. Chipless RFID tags using a set of spiral resonators for various applications are proposed by Stevan Preradovic [7]-[8].

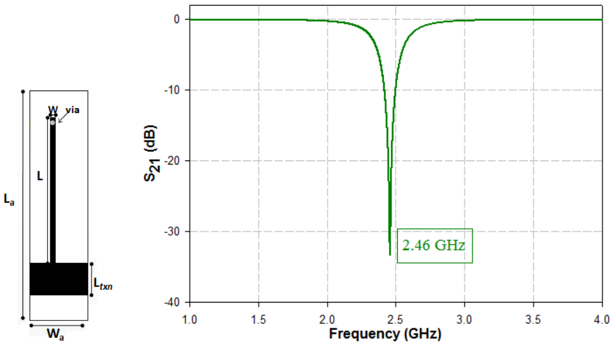
Most of these designs use absence or presence coding technique to encode the tag identity. In absence or presence coding technique, maximum bits that can be represented by an RFID tag is limited by the number of resonators. The bit encoding capacity of the tag can be enhanced using Frequency Shift Coding (FSC) technique, by encoding more than one bit per resonator [9]. This method is more appropriate in the case where large data encoding is required with less number of resonators. Another advantage is the design of high security tags, ie; the tags appear to be similar, but the identification code will be different.

This paper focuses on the design of chipless tags using FSC technique. The paper is organized as follows. Section II presents the basic theory of multiresonator design using shorted stub resonators. Section III presents the details of Frequency Shift Coding. Section IV discusses the experimental results and conclusions are drawn in Section V.

2 Resonator Design

The resonator structure has evolved from a single shorted stub resonator. A half wavelength long stub ($\lambda_g/2$) connected to microstrip transmission line at one end and shorted to ground at the other end through a via of diameter 0.8 mm is shown in Fig.1(a). The bottom plane acts as ground. Fig.1(b) shows the simulated transmission characteristics of the shorted stub resonator.

The resonant frequency can be tuned by varying the length (L) of the stub. The simulated transmission characteristics



(a) (b)

Figure 1. Shorted stub resonator and its simulated transmission characteristics L_a = 60, W_a = 15, L_{txn} = 7, L = 34.57, W = 1, diameter of the via = 0.8 (All dimensions in mm), Substrate: loss tangent = 0.0018, ε_r = 4.3, h = 1.6 mm]

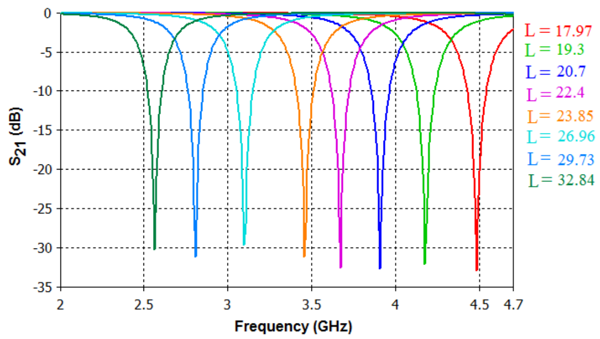


Figure 2. Simulated transmission characteristics for various values of L (mm) of shorted stub resonator shown in Fig.1(a)

shown in Fig.2 illustrates the shift in resonant frequency from 2.56 GHz to 4.48 GHz as length is varied from 32.84 mm to 17.97 mm. This property of achieving multiple resonances by varying the length of the shorted stub is used for designing the multiresonator.

3 Frequency Shift Coding Applied to Multiresonator with Two Shorted stub resonators

To code the identity of the tag, two approaches can be adopted. Absence or presence of resonance based coding or Frequency shift coding technique. In absence or presence coding technique, one resonator represents one bit of information. The presence of resonance at a particular frequency is used to encode a logic 1 and the absence of resonance is used to encode a logic 0. So with n resonators only 2^n combinations are possible. Frequency shift coding technique allows an enhancement in coding efficiency, by encoding more than one bit per resonator [9]. Here resonators are assigned with different frequency band (Δf) and each frequency band is divided into different resolution bandwidth (δf). Δf can be selected depending on the available frequency spectrum and the number of resonators. δf is the required frequency band for each resonator to successfully represent its resonant frequency. Therefore, one resonator can represent more number of states. So this technique allows an enhancement in coding efficiency, by encoding more than one bit per resonator. Moreover the tags appear to be similar, since there is only a slight variation in length of shorted stub from tag to tag, but the identification code will be different. This helps in design of high security tags.

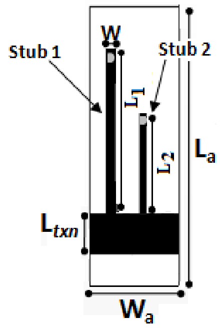
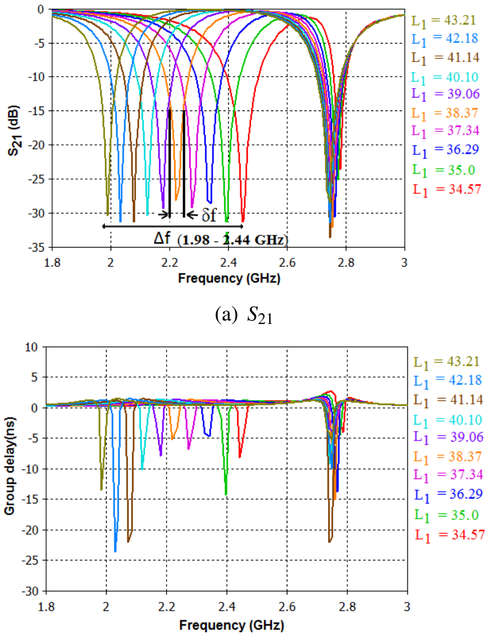


Figure 3. Layout of multiresonator with two shorted stubs [L_a = 60, W_a = 15, L_{txn} = 7, W = 1, diameter of the via = 0.8 (All dimensions in mm) Substrate: loss tangent = 0.0018, ε_r = 4.3, h = 1.6 mm]

Table 1. Frequency band (Δf) and resonant frequency (f) of multiresonator with two shorted stubs (All values in GHz)

	Δf_1 (1.98- 2.44)	Δf_2 (2.65 - 3.67)
f_1	1.98	2.65
f_2	2.03	2.72
f_3	2.07	2.82
f_4	2.12	2.92
f_5	2.17	3.02
f_6	2.22	3.14
f_7	2.27	3.25
f_8	2.33	3.39
f_9	2.39	3.52
f_{10}	2.44	3.67

Fig.3 shows the layout of multiresonator with two shorted stubs whose length (L_i) is individually varied for FSC. The frequency band (Δf) and resonant frequency(f) of each resonator are listed in Table.1. Variation of the length of the first stub, keeping the length of the second stub constant, results in ten different resonant frequencies as shown in Fig.4. Similarly, variation of length of the second stub, keeping the length of the first stub constant, results in ten different resonant frequencies.



(a) S_{21}

(b) Group delay

Figure 4. Simulated transmission characteristics of tuning the first shorted stub in multiresonator with two shorted stubs shown in Fig.3(L_2 = 31 mm, L_1 in mm)

Figure 5. Photograph of fabricated multiresonator with two shorted stubs

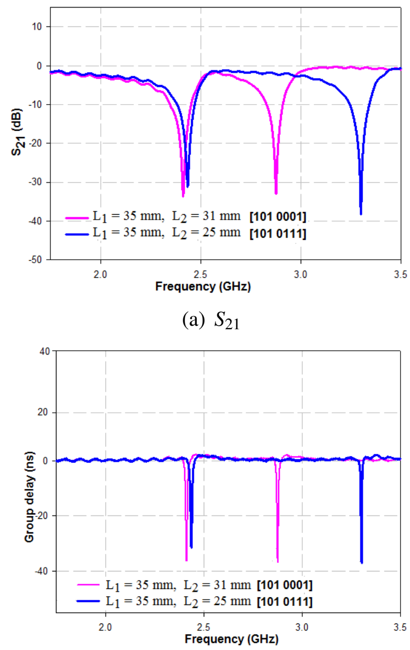
4 Experimental results

4.1 Experimental results of Multiresonator

Fig.5 shows the photograph of fabricated multiresonator with two shorted stubs. The resonator is fabricated on substrate C-MET LK4.3 of dielectric constant 4.3 and loss tangent 0.0018. Measurements are conducted using the PNA E8362B vector network analyser. The device under test (multiresonator) is connected between the two ports of the vector network analyser. The measured resonator response of the multiresonator with two shorted stubs for two different configurations are shown in Fig.6

4.2 Bistatic measurement setup

The block schematic of bistatic measurement setup is shown in Fig.7. The set up proposed by S. Preradovic et.al



(a) S_{21}

(b) Group delay

Figure 6. Measured Transmission characteristics of the resonator with two shorted stubs for two different configurations

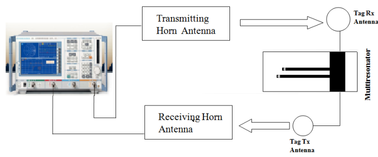
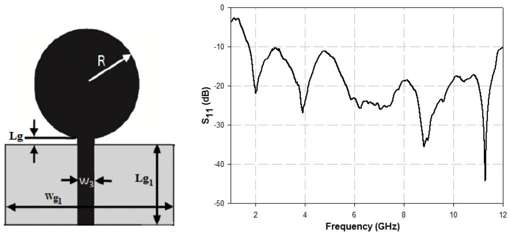


Figure 7. Block schematic for the bistatic measurement setup

[7] is used. The tag is fully passive and hence requires an external source of electromagnetic signal for identification. Two cross polarized medium gain (10 dB) horn antennas are used at the reader for transmission of the continuous wave (CW) interrogation signal and reception of the retransmitted signal. Two wide band antennas, one for receiving the interrogation signal from reader and the other for retransmitting the encoded signal from the multiresonator to the reader, are incorporated to increase the read range. Various types of antennas for chipless RFID tag applications are reported in literature [4],[7],[8].

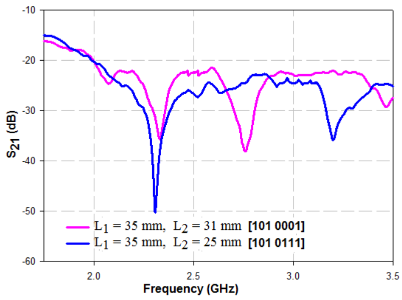
The tag can be designed to operate in various frequency bands. To cater to the different frequency band requirements, the microstrip disc monopole antenna is opted due to its simple structure and wide band operation. Fig.8 shows the geometry and measured reflection characteristics of the disc monopole antenna. The operating band is from 1.9 GHz to 12 GHz.

The tag is placed 15 cm away from the horn antennas. The tag receives the interrogation signal through the receiving monopole antenna and encodes its spectral signature us-

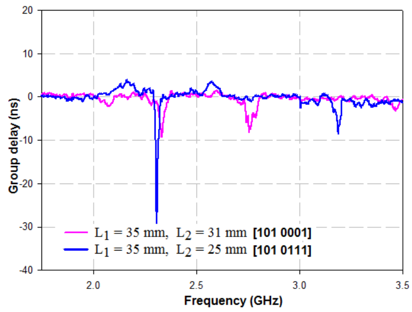


(a) (b)

Figure 8. (a) Disc monopole antenna [R = 15, W_3 = 3, L_g = 0.6, W_{g1} = 40 and L_{g1} = 20 (All dimensions in mm), ε_r = 4.3, loss tangent = 0.02, h = 1.6 mm] (b) Measured reflection characteristics of disc monopole antenna



(a) S_{21}



(b) Group delay

Figure 9. Measured bistatic response of the multiresonator with two shorted stubs for two different configurations

ing the multiresonator. The encoded signal is then sent back to the reader by the transmitting monopole antenna. To provide isolation between the transmitting and receiving signals, the transmitting and receiving antennas are cross polarized. The measured bistatic response of the multiresonator with two shorted stubs for two different for the bit combinations (101 0001, 101 0111) are shown in Fig.9.

5 Conclusion

A chipless RFID tag based on half wavelength long shorted stub resonator is presented in this paper. Frequency shift coding technique is used to encode the tag identity. Orthogonally polarized circular monopole antenna is employed for transmission and reception purpose to reduce interference. The concept is validated from the measurements using bistatic approach. The bit encoding capacity can be further increased by adding more shorted stub resonators to the multiresonator.

6 Acknowledgements

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