MULTIRESONATOR CIRCUIT USING Λ/4 SIR FOR CHIPLESS RFID TAGS

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ABSTRACT

a compact multi resonator circuit for Chipless rfid tag is presented in this paper. The basic resonator is a shorted λ/4 Stepped Impedance Resonator (SIR). The tag is designed and simulated using High Frequency Structure Simulator and a 6 bit prototype is fabricated on rtduroid(εr=2.2 and tanδ=.0008) Substrate in area of 4.5x2cm2. Data is coded as amplitude variations in the frequency domain. Harmonic separation in the desired band by proper tuning of design parameters and ease of coding by simply adding or removing the shorts are achieved with λ/4 SIR.

KEYWORDS

Chipless RFID, Multiresonator, spectral signature, stepped impedance resonator

1. INTRODUCTION

Automated detection, tracking, identification etc., are ever interested topics in the field of wireless communication and hence radio frequency identification, in which communication relies on Radio Frequency waves between the reader and tag. Conventional RFID tags contain integrated circuits to carry data. Chipless RFID is an emerging technology in this scenario. Though in its infancy, a lot of research is carrying out on this topic. Main objectives are reducing the cost of tags by eliminating silicon chips, identifying good resonators and developing better reading techniques.

Chipless RFID tags can be classified into three: frequency domain (spectral signature based), Amplitude/phase backscatterer and time domain reflectometry (TDR) based tags[1-2]. Spectral signature based chipless tag which uses multiple resonators is a multi-stop band filter that encodes data in the frequency spectrum. In Amplitude/Phase backscatter modulation based chipless RFID tags, data encoding is performed by varying the amplitude or the phase of backscattered signal based on the loading of the chipless tag. TDR based chipless RFID tags are interrogated by sending a signal from the reader in the form of a pulse and listening to the echoes of the pulse sent by the tag. In this paper frequency domain tags with reception-retransmission antennas are concentrated which are rather simple in design and coding. A multiple spiral resonator based Chipless RFID tag is presented in [3]. The spiral resonators are compact and provide ease of coding after fabrication of the tags by simply shorting the resonators. But the usable bandwidth is limited due to harmonics. In [4] C M Nijaset .al presented a λ/4 open stub

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resonator based Chipless RFID tag. It also has limited usable bandwidth due to harmonics. In [5] a number of modified complementary split ring resonators (MCSRR)placed along the transmission line as data bit encoding element. A novel data detuning technique is also presented. In [6] a dual multi-resonant dipole antenna performs as multiresonator.

In this paper a multiresonator circuit for chipless RFID tag using l/4 stepped impedance resonator is proposed. The basic resonator is compact, has harmonic separation capability, has flexible design and has ease of coding. The tag is designed and fabricated on RTDuroid (εr=2.2, $\tan\delta$=0.0008) substrate. A 6 bit multi resonator is prototyped and the tag size is 4.5 x 2 cm2. Either frequency shift coding or presence/absence technique is applicable depending on the number of items.

2. MULTIRESONATOR CIRCUIT DESIGN

Stepped impedance resonators are very interesting structure due to their flexible design. Size and harmonic frequency separation can be independently controlled by choosing impedance ratio (K) and length ratio (α) properly [7]. The structure of the basic resonator is shown in figure 1.

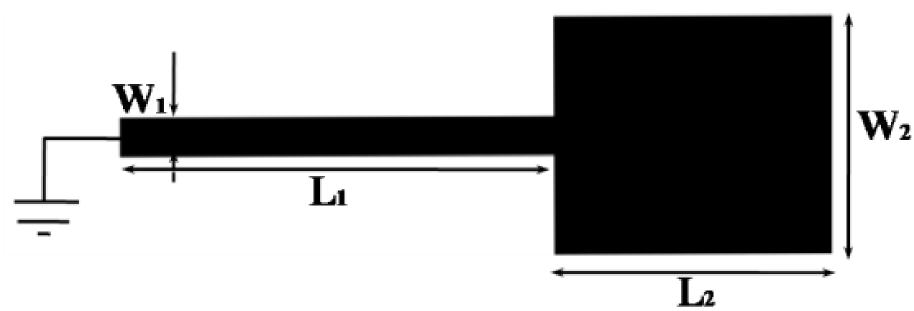

Fig 1: Basic stepped impedance resonator in fundamental mode

The $\lambda/4$ stepped impedance resonator shown in Figure 1 gets excited in fundamental mode when it is grounded and in first harmonic frequency when the short is removed. In this work only the fundamental mode is used. Equation 1 represents the fundamental mode of $\lambda/4$ SIR.

$$K\cot(\alpha.\theta_t)=\tan[(1-\alpha).\theta_t] \qquad (1)$$

where $\alpha = \theta_2/(\theta_1+\theta_2)$,$\theta\_t=\theta_1+\theta_2$ and θ_1,θ_2 are electrical length corresponding to L_1 and L_2, respectively. Figure 2 shows how the separation between fundamental and first harmonic frequency can be controlled by properly setting the impedance and length ratio. This property is effectively utilized here to remove the harmonic frequencies from the desired band.

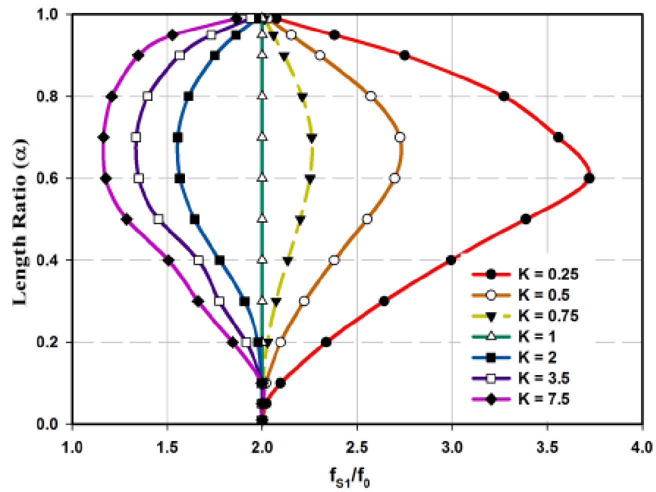

Fig 2: Dependence of fundamental and first harmonic separation on K and α

The resonators are arranged on both sides of 50 microstrip transmission line. When the received signal travel from one port to the other the present resonators absorbs energy at their resonance frequencies and the signal at the output port has a unique signature of the tag. The presence of dips in the frequency spectrum used indicates the presence of the particular resonator and can be considered as '1' and correspondingly absence as '0'. For tagging large number of items frequency shift coding can be used as described in [2].

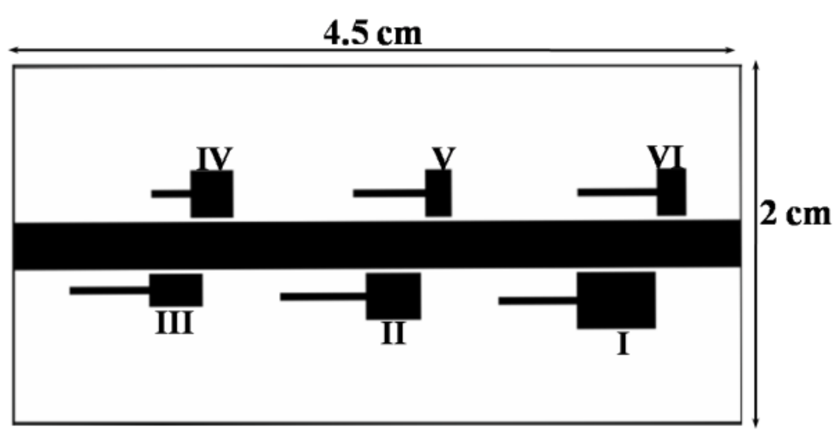

Fig 3: Geometry of the Multiresonator, height=1mm

Design of a six bit multiresonator section is presented in this section. The substrate used for fabrication is RTduroid (εr=2.2 and tanδ=.0008) with a thickness of 1mm. The geometry of the multiresonator circuit is shown in Fig 3 and the parameters of the resonators are given in Table I. Note the high impedance end of each resonator is shorted to excite the fundamental mode.

Table I: parameters of the resonators in the multiresonator circuit shown in Fig 3

Resonators	I	II	III	IV	V	VI
k	0.35	0.4	0.5	0.4	0.4	0.5
α	0.5	0.4	0.4	0.3	0.3	0.3
L1	5.05	5.53	5.14	5.12	4.65	4.59
L2	3.56	3.56	3.45	1.9	1.7	1.8
W1	0.5	0.5	0.5	0.5	0.5	0.5
W2	3.03	3.56	2.13	3.07	3.06	2.16

2. MULTIRESONATOR CIRCUIT DESIGN

A single SIR coupled to a microstrip transmission line and the response of the system in frequency domain is simulated in HFSS and the S12 is shown in Fig 4.

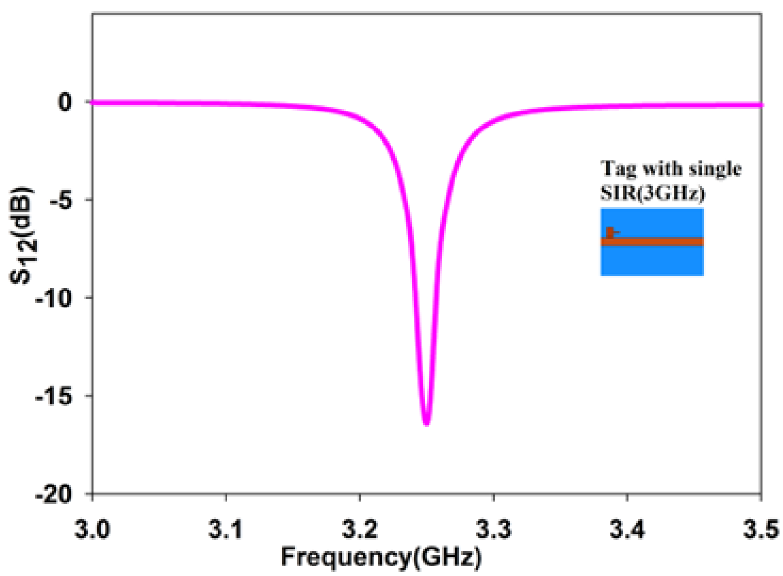

Fig 4: S_{12}(dB) of Single SIR coupled microstrip line

A 6 bit multi resonator circuit is simulated using HFSS. Simulation studies of coupling effects between microstrip line, between adjacent resonators, and different codes are conducted. Finally a prototype is also fabricated on RTduroid (εr=2.2 and tanδ=.0008). The simulation and measurement results are discussed in this section.

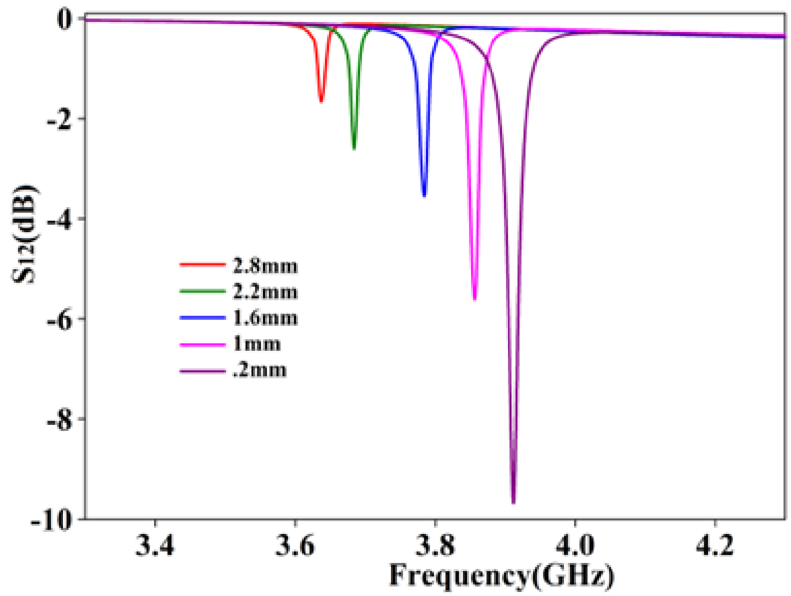

Fig 5: Coupling effect between a single resonator and microstripline

Coupling effect between the resonator and microstrip line for different distances is shown in Fig 5. Of course there is frequency shift and magnitude variation due to the capacitive effect due to the gap. For RFID applications narrow, deep resonances are desirable. With a minimum gap maximum identifiable dip is obtained. The optimum case of 0.3mm is selected.

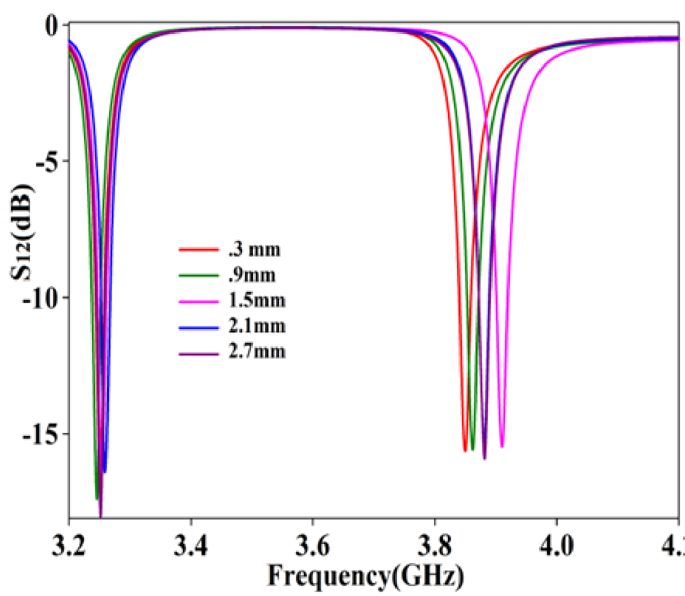

Fig 6: Coupling effect between two adjacent resonators

Effect of coupling between two adjacent resonators for different distances is shown in Fig 6. For distances greater than 0.3mm between the resonators shows good performance. Larger separation always provides good isolation but distance between the resonators must be accountable for the compactness of the tag.

Performance of multiresonator circuit with six resonators when signal is given between its two ports and observing S12 is shown in Fig 7. Results for two different codes are shown. The frequency dips are clearly identifiable so that the data can be easily decoded.

Finally the measurement result of fabricated multiresonator circuit of Fig 8 is shown in Fig 9. All the six resonances can be distinguished clearly.

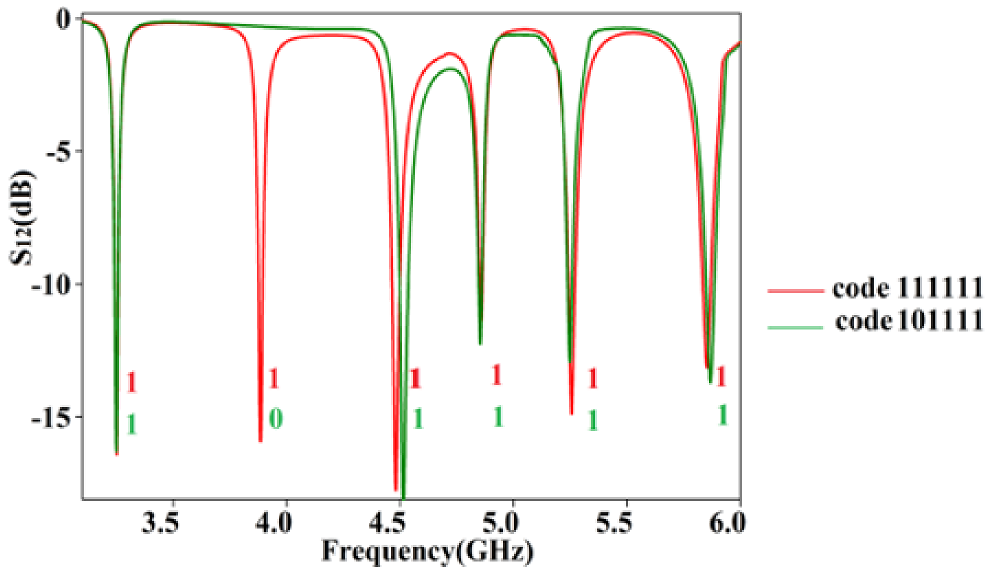

Fig 7: Simulated S12(dB) of the 6 bit multi resonator circuit for two different codes

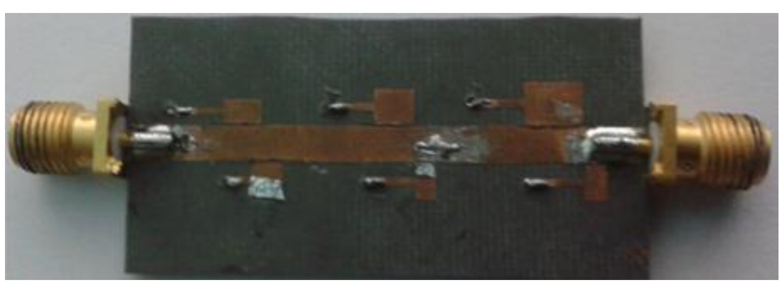

Fig 8: Fabricated Multiresonator circuit with all the resonators shorted

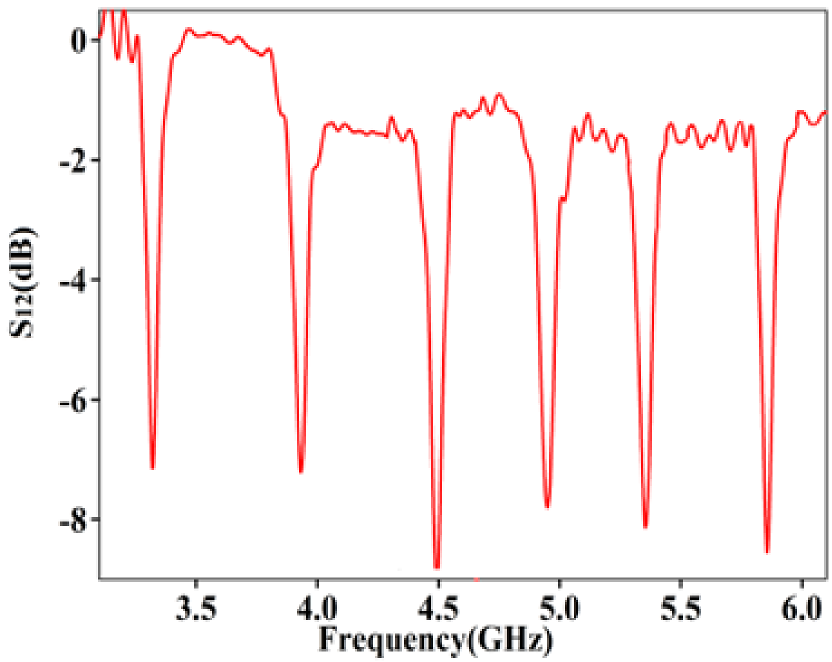

Fig 9: Measured S12 of 6 bit multi resonator circuit for the code 111111

More efficient bandwidth utilization can be achieved by using frequency shift coding technique and is very reliable particularly for this resonator due to its flexible design. More closely spaced and specially arranged resonators can enhance bandwidth as well as surface utilization. These two points and the complete tag measurement will be included as future works

3. CONCLUSIONS

6 bit Multiresonator circuit for Chipless RFID application is realized in an area of 4.5x2.5 cm2. Harmonic separation in the desired band is achieved. Presence/absence technique for Coding is done by simply removing or adding the short circuit. Frequency shift coding is also reliable for large number of items due to the flexible design of the basic resonator.

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