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LINEAR MICROSTRIP RESONATOR FOR UWB RFID TAG

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ABSTRACT: The data storage capacity is directly proportional to the number of bits on board of the tag. The main challenge in UWB tag development is to maintain higher number of bits while keeping the tag within the standard size. Higher number of bits also ensures more security and anti-tempering protection of the tagging. In addition, reducing the dimensions of the tag can lead to the possibilities of fully replacing the existing barcode identification system. A new type of planar shorted parallel coupled line microstrip resonator which can replace the existing planar rectangular type resonator has been proposed in this paper. The theoretical approximation and simulation have been performed. A 20-bit resonator has been designed and developed that works between 4.6GHz and 8.1GHz. It is found that the bit density per unit area (cm^2) is about 6.67 bit/cm^2 has been achieved. The simulation has been performed by CST MWS 2017. The results would motivate the researchers to develop a higher bit density UWB passive RFID tag.

Keywords: RFID Tag, UWB, Barcode, Planar Microstrip Resonator, Rectangular Type Resonator

1. INTRODUCTION

Since the first application of the radio frequency for identification in WWII, research on Radio Frequency Identification (RFID) is getting higher interest every day. Nowadays, the main focus in the UWB RFID research is how to fully replace the existing conventional barcode system. In many applications, the RFID is omnipresent such as toll and fare collection, palate identification, item tracking, etc. To cope with these applications with several challenges such as environmental issues, standards defined by different societies and read range; several proposals have been made. Different dedicated frequency bands have also been used to fit different applications. 13.5 MHz band which is used for toll and fare collection has a read range up to 40 cm and uses the near field communication. For the item tracking and palate identification, the far field passive type tag technologies are desirable because the read range need to go as high as 10 m. There other technologies use mainly UHF (900 MHz), microwave (2.4 GHz) and UWB (3.1-10.7 GHz).

In all these technologies, the reader and the tag follow dedicated communication protocol where the data bits are exchanged during the transmission (Tx) and reception (Rx). Since the passive nature of the tag, reader has to maintain a relatively constant radiated interrogation signal power to read the tag. Currently, mass production in RFID market circles around the UHF band. Around 10 trillion units of UHF RFID product are sold each year [1]. However, item tracking and product identification is still a challenge for the UHF RFID. The classical RFID system has some drawbacks i.e. it has antenna on board with the tag and silicon chip. These issues make the classical RFID a very unlikely contender for the replacement of the optical barcode system. On the other hand the chipless RFID system (mainly chipless type tag) has no such limitations. In fact, this type of tags are getting tremendous attention to the researchers and getting popular every day. Consequently the chipless UWB RFID tags are at the forefront of the research to replace the optical barcode system.

For the purpose of bit encoding, the author in [2] utilized the transient domain information. The tag was built using surface acoustic wave (SAW) materials. When the reader sends the interrogation pulses to the SAW based tag, it reflects the signal utilizing several reflectors placed with similar distance from each other. This system creates a pulse train where each pulse has specific time delay to each other. This scenario can be described as the pulse position modulation (PPM). Moreover, the tag can be identified by controlling or knowing the time or space difference info. Through this technique a 256 number of bits can be accumulated. In [3] and [4], approaches have been taken to reduce the space area of the tag. However, nowadays the number of bits on board of a passive chipless tag is inadequate.

There are mainly two types of UWB passive tag: (i) Time domain based and (ii) spectral domain based. The proposed resonator falls into the second criteria. With the special design of the structure, the resonator can help the tag to encode data bits in the spectral (frequency) domain. The authors in [5] has proposed a rectangular spiral resonator based tag that can encode data bits up to

35 bits. So far, this design can be considered as one of largest bits density for the UWB chipless RFID system. Another good point about this type of tag is, it can be encoded for both magnitude and phase response in the spectrum. However, the numbers of bits are totally depending on the size and number of resonator on board of the tag. So, to employ 35 bit, the tag dimension becomes large (7 cm × 15 cm) and this type of tag also performs bad in the presence of metallic object in the vicinity.

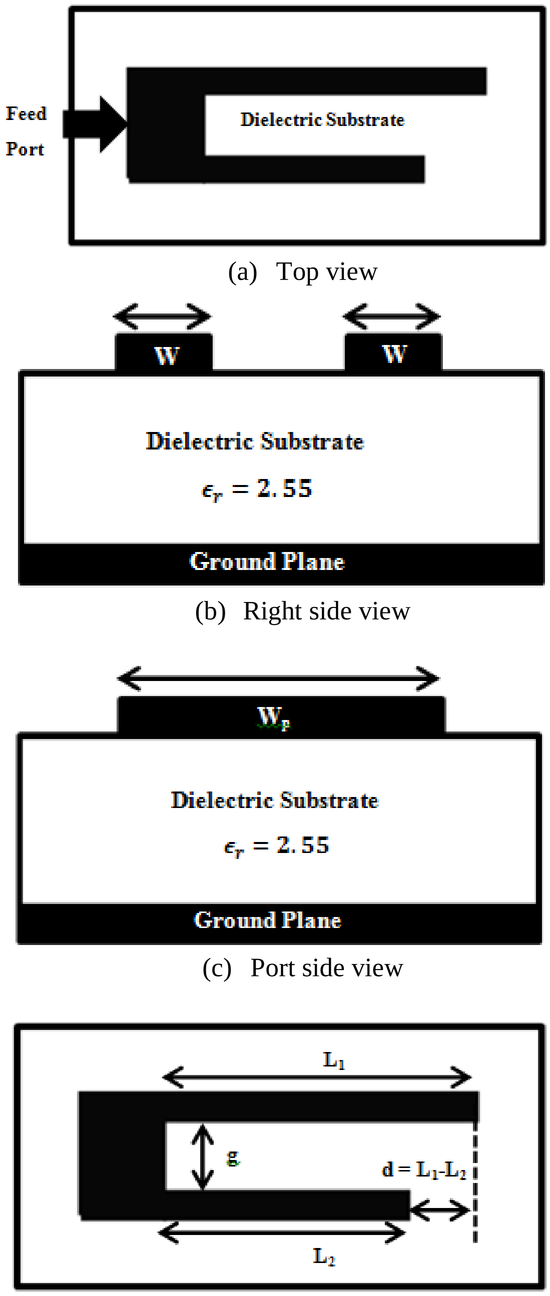
In [6], the authors have utilized the techniques to produce different phase profile to encode bits. Here the author has used an antenna that is broadband in nature. The antenna acts as a reflector and connected to a load that is complex in nature. When this setup produces different phase profile, each can be considered as a bit to be identified. Authors in [7] have used the same technique with several antennas. Each antenna is attached with stabs that can be adjusted is length. The adjustability produces different phase profile and different profiles can be encoded as different bits. However, at the present time, coding capacity is not significant (few bits). Also in several literatures [8]-[14], different shapes of resonators have been proposed that can be used in UWB passive tag.

Nevertheless, it is still a big challenge to integrate a big number of data/bits on a passive tag of the size of a debit/credit bank ATM card (5.5 cm × 8.5 cm). In this research, a proposal has been made to alter the structure of the existing spiral resonator used in the UWB passive resonators type tag (Fig.1). This is a planar shorted parallel line type resonator. By developing this resonator, an approach has been made to increase the bit capacity of the UWB passive tag and decrease the area/bit on the tag. At first the resonator has been designed and verified. After this, the designed resonator is used to develop a passive UWB tag.

2. RESONATOR STRUCTURE CIRCUIT MODELING

Fig.1 shows the top, left and right side views of the proposed resonator. There are two parallel planar microstrip lines having same width (W) and different lengths L_1 & L_2 ($L_1 > L_2$) shorted by another line of width, Ws. There is a slot gap (g) in between the lines.

In microwave theories, the significance of the microstrip transmission line is well established. In passive RFID system, tag is mainly based on the transmission line theory [15], [16].



(a) Top view

(b) Right side view

(c) Port side view

(d) Significance of 'd' and 'g'

Fig.1 Different view of the resonator geometry

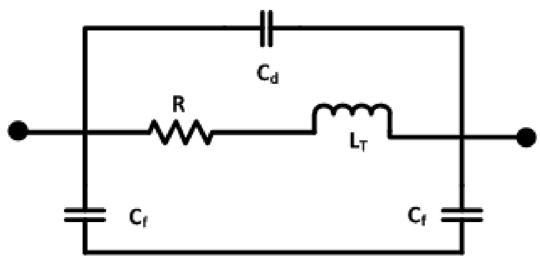
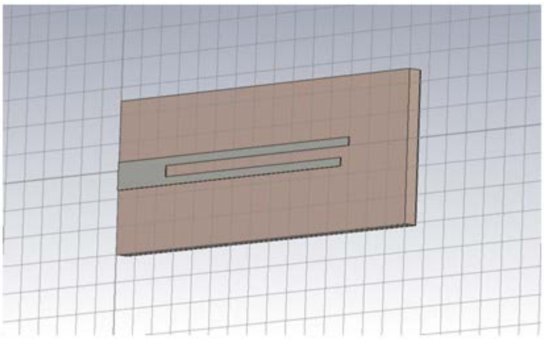


Fig.2 Equivalent circuit model of the resonator

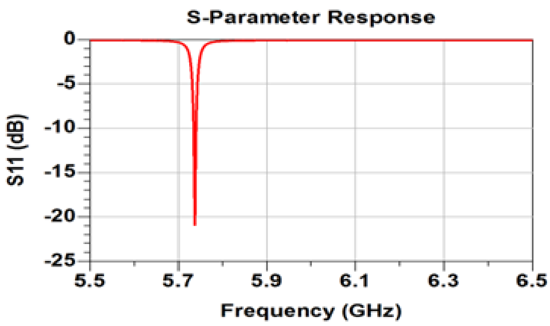
As it can be seen in Fig.2, the equivalent circuit of the resonator corresponds to the LC equivalent circuit model of a bandstop filter, the resonance frequency can be estimated as in Eq. (1) [17]. The circuit parameters of C_d = distributed capacitance, R = resistance of loop, L = distributed inductance, and C_f = fringing capacitance. The mutual inductance of each loop is neglected here.

$$\omega_0 = \sqrt{\frac{1}{L_T C_T}} \quad (1)$$

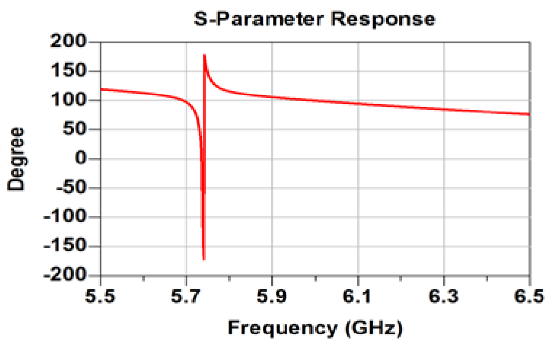
Where, C_T is the total addition of the fringing and distributed capacitance. L_T is the summation of the mutual and distributed inductance.



(a) Resonator structure in CST MWS



(b) Magnitude

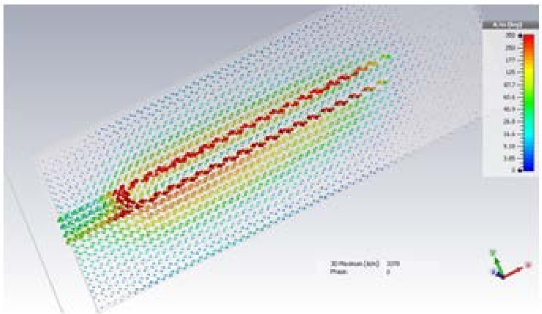


(c) Phase response

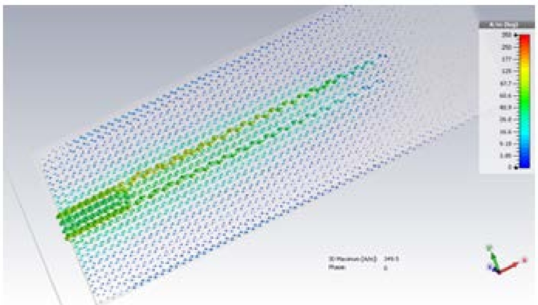
Fig.3 Resonator geometry and its S-parameter

The obtained simulation results by using CST MWS 2017 software are summarized in Fig.3. The substrate material is Taconic TLX-8 which has relative permittivity (ε_r) of 2.55, loss tangent (δ) of 0.0019, copper thickness (t) of 35 µm and the substrate thickness (h) is 0.5 mm.

Fig.3 (a) shows the resonator geometry in CST MWS. It can be seen from Fig.3 (b) and (c) that the magnitude and phase of the S_{11} parameter have same resonance frequency at 5.74 GHz. Fig.4 (a) gives the surface current at the resonance frequency of 3378 A/m whereas it can be seen from the Fig.4 (b) that the simulated surface current at non-resonant frequency of 5 GHz is as low as 349.5 A/m which is 10 times lesser than that at the resonant frequency of 5.74GHz.



(a) At resonant frequency

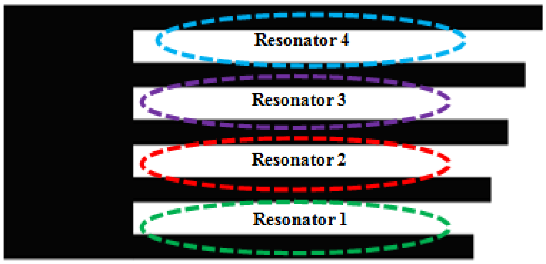


(b) At non resonant frequency

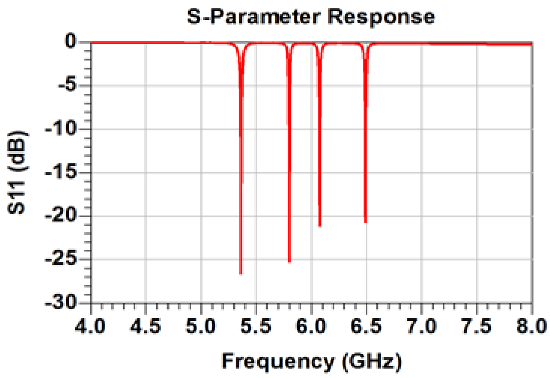
Fig.4 Surface current of the resonator

3. MULTI-BIT RESONATOR AND TAG CONSTRUCTION

The above approaches are to justify that the proposed structure gives resonances for a single bit. A multi-bit resonator has been designed with the above theories and approximations. Fig.5 shows the multi-bit structure with a possible 4 bit resonance and gives the S_{11} responses on the approach.



(a) Multi-bit Structure



(b) S_{11} Magnitude

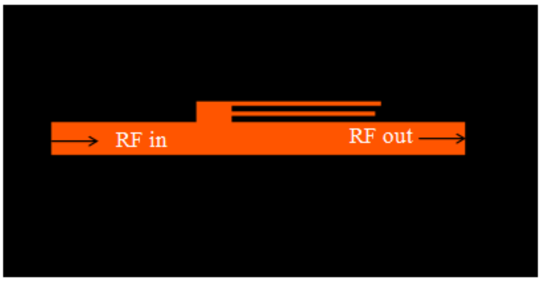
Fig.5 Multi-bit resonator structure and its response

3.1 Multi-Bit Design

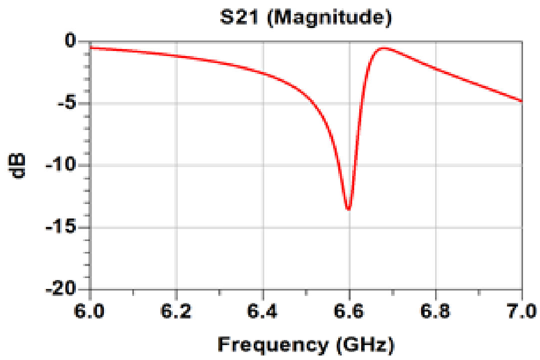
For one single bit, two shorted parallel lines are necessary. Addition of one more parallel line will give two bit resonance and so on. Fig.5 (a) shows a structure which has five different length parallel lines with four different resonators. Simulated S_{11} response can be found out in Fig.5 (b). There are four distinct dips (or changes for phase) in the spectral domain. This indicates that that there is a presence of four resonators in the proposed structure.

3.2 Tag Construction

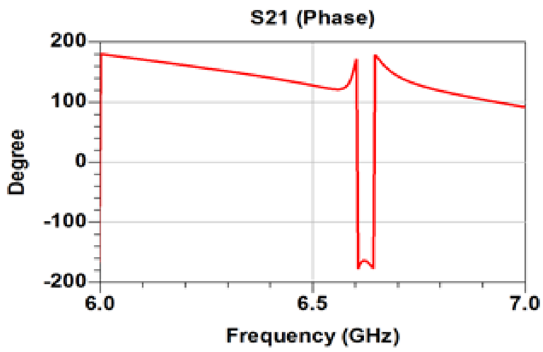
Fig.6 (a) represents the structure consists of one resonator shorted with the transmission line (TL) of 2.26 mm width. From Fig.6 (b) and (c), it can also be concluded that if proposed resonator is shorted with the transmission line in this manner it can give dip(s) in the magnitude and phase in the spectrum. Of course, it can also be seen from the Fig.6 (b) and (c) that there is a shift in the resonant frequency of the structure. It is already seen in Fig.3 (a) that the resonance frequency is 5.74 GHz. The same dimension of the structure in Fig.3 is used to connect with the TL. The resonance frequency has been shifted to 6.6 GHz. Since one TL is connected with the resonator structure, it changes the values of the distributed capacitor and inductor of the structure and shifts the frequency from 5.74 GHz to 6.6 GHz. With the help of the responses from Fig.5, more resonators are connected with the TL. These results justify that this shape of structure can be used as a resonator. This shape has been added to the transmission line as shown in Fig.7. Fig.7 (a) comprises a 20-bit resonator with TL. Simulation of s-parameters has been presented in Fig.7 (b) that includes the S_{21} response for 20 distinct dips in the spectrum.



(a) Layout



(b) Magnitude

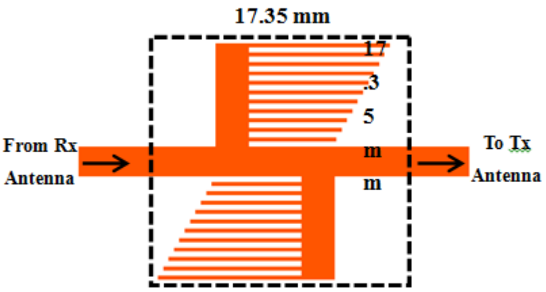


(c) Phase response

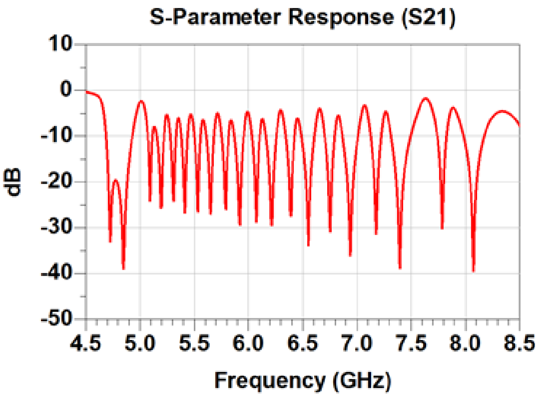
Fig.6 Single bit resonator

Fig.7 (a) discloses the dimension of proposed resonator that has an area of 17.35mm × 17.35mm. Both side of the TL has 10 different resonators that resonate in different frequencies. The highest length of the top side on the 20-bit resonator is

10.5 mm in length. The adjacent parallel line has 10.1 mm length (d = 0.4 mm). The last parallel line (11th) has the length of 6.5 mm. Similarly, in the bottom side of the TL, the highest length of the parallel line is 10.7 mm and the lowest one is 6.7 mm. This gives an area of 301 mm^2 for 20 bit on board. In term of the area/bit, it is 15.05 mm^2/bit. In other words, it can be also written that the bit density is 6.67 bits/cm^2.



(a) Structure of 20-bit resonator



(b) S_{21} responses

Fig.7 Structure of 20-bit resonator and its response

Table 1 shows a comparison with the other exiting work. From the table, it can be concluded that the number of bit can be increased with the proposed resonator for the UWB tag. The occupied area/bit is the figure of merit here for the bench mark. Comparison with other recent relevant works reveals that with the help of the proposed resonator, area/bit can be reduced and it will allow to include more bits on board.

4. CONCLUSION

The presented 20-bit planar linear coupled line microstrip resonator for UWB RFID tag is well validated and justified through design and simulation. The designed resonator has been realized on the Taconic TLX-8 RF substrate which has an area of 301 mm^2 for 20 bits. The proposed design is capable of reducing one third area of the substrate instead of the conventional structure. The bit density of the resonator area is 6.67 bits/cm^2. Consequently, these findings will help the researchers to design a comparatively smaller size UWB tag.

Table 1 Comparison with existing works

Literature	mm^2/bit	bits
Preradovic, et al., [6]	137	35
Vena et al., [11]	26.67	22.9
Blischak & Manteghi, [10]	63	12
Kalansuriya, et al., [9]	164	4
Reza Rezaiesarlak & Manteghi, [13]	24	24
Proposed Design (20-bit)	15.05	20

5. ACKNOWLEDGEMENTS

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