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A PLANAR PARALLEL SLOTTED CIRCULAR DISK PASSIVE UWB-RFID TAG

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ABSTRACT

The research on chipless RFID is getting popular everyday due to its ease of construction and cheap manufacturing. However, the existing dimensions reported in the open literature are still too large and the detection techniques are also complex in nature. In this paper, a new passive UWB tag structure and a corresponding relatively simple detection technique have been proposed. The structure contains a number of slots inserted in a planar circular disk. Two different tags have been designed and simulated, the first with one slot and the second with five different slots. Taconic TLX-8 has been chosen as the substrate material of structure having a dielectric constant of 2.55 and 0.5mm of height. The backscattering information from the tag has been utilized for the detection of the tag bits on board. The tag structure justification has been done by the surface current response and the detection method is employed to extract the bits. A good agreement has been found in the simulation. For five bit system, bit ‘10000’ and bit ‘11111’ have been successfully extracted. This will motivate RFID researchers to employ more bits on the tag and will provide the encoding the bits with ease.

Keyword: backscatter, chipless RFID, passive UWB tag, planar circular disk, slots.

INTRODUCTION

The first implementation of radio frequency identification (RFID) was to identify whether the airplane is allied of from foe in WWII. From that moment, the technique has got a lot of attention for the researchers. There are many applications that involve RFID such as: inventory management, toll collection, object identification [1]. In everyday consumer item tacking such as packaging, drugs, books etc. barcode technology is omni-present. The RFID technology has many advantages over the existing barcode system i.e. no effect of wear and tear; and atmospheric conditions, no need of line of sight (LOS) etc. The only thing prohibits the RFID technology to completely overcome the barcode system is the cost effectiveness of the RFID system since the barcode can be fully printed and can be attached on any object [2].

Basically, the RFID system has three main parts: (i) RFID Tag (that to be attached on any object to be identified), (ii) RFID reader (to read the attached tag) and (iii) the communications interface (the channel/frequency by which the reader and the tag communicate) [3]. An RFID system mainly centers on the design, type and characteristics of the tag. On the basis of power supply, the tag can be classified into three types: Active type (has battery on board to supply necessary power to run the circuitry on the tag), semi-active type (has battery on board to keep the memory circuit alive but depends on the reader interrogation signal energy to perform encoding/decoding operation) and passive type (has no power supply on board, fully dependent on the reader interrogation signal strength to perform all necessary operations). Since active and semi-active tags have battery on board and chip on board, they are costly. Due to this fact they are very far to be a candidate that can fully replace the barcode system. On the other hand the chipless RFID tags can be chipped or chipless in nature. Because of passive and chipless nature, this type of tag can be cheap and is now at the forefront of the research to replace the barcode system [4].

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] have 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 (7×15 cm^2) and this type of tag also performs badly 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 (5.5×8.5 cm^2). In this

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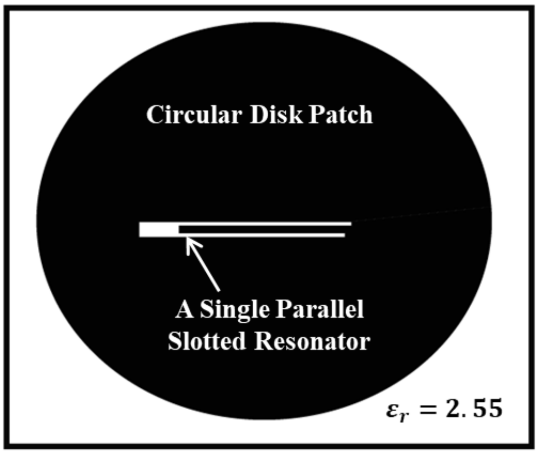
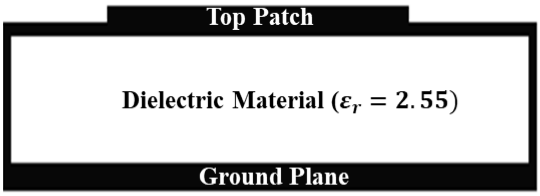
research, a proposal has been made to use the parallel slot lines with slot connected in one side inserted inside a disk as a UWB passive resonators type tag (seen in Figure 1). This slot type resonator has never been used before to make a passive type tag. By developing this resonator, an approach has been made to increase the bit capacity of the UWB passive tag.

DESIGN OF THE RESONATOR AND TAG

Figure-1 shows the construction (geometry) of the tag with a single parallel slotted resonator (single resonator). The black color is the copper and the white color is the dielectric substrate material. The structure has a circular top (copper) patch with a parallel slot resonator inserted in it (Figure-1a). The bottom layer is also totally filled with copper as a ground plane. Layer between the top patch and ground plane is the substrate material (a microstrip structure).



(a) Top view

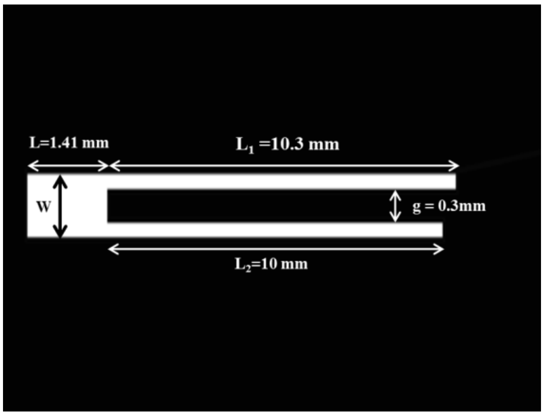


(b) Cross-sectional view

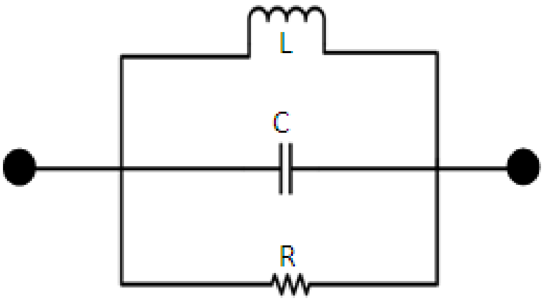
Figure-1. Structure of the proposed tag.

In [15], [16] and [17] the authors had successfully modeled the slots on a substrate. Yet, no approach has been done to put the slots parallel as cascaded to build an UWB tag. Figure-2 illustrates the structure and the equivalent lumped circuit model of one and multiple slot resonator(s). It can be seen in Figure-2(a) that the two different length of L_1 mm and L_2 mm (L1 > L2 and L1 = L2+ 0.3 mm) slots are paralleled and connected with another slot that has a width and length of W and L respectively. Each slot has a width of 0.3 mm. Figure-2(b) shows the corresponding equivalent circuit for one parallel slot where the capacitance (C), inductance (L) and resistance (R) are in parallel [16]. Figure-2(c) and (d) show the cascaded parallel slots to form a passive tag and its equivalent lumped circuit model respectively. The circuit in Figure-2(d) resonates independently for each resonator and also it gives a combined resonance for the whole structure. The resonance for the whole structure is not relevant in this analysis and ignored by taking only the individual responses of individual slot resonators. The individual or the combined response can be estimated by (1) [18],

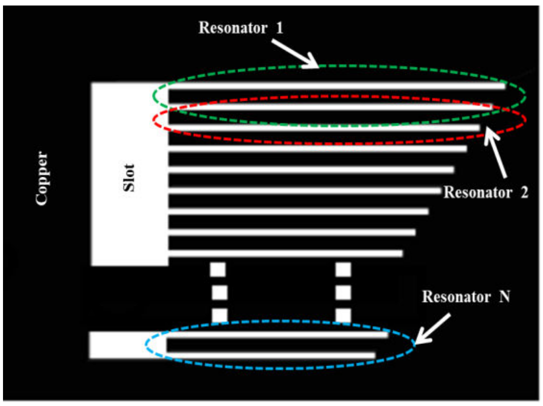
$$\omega = \frac{1}{\sqrt{LC}} \qquad (1)$$



(a) Single Resonator Slot



(b) Equivalent Circuit (single resonator)



(c) Multiple Resonators

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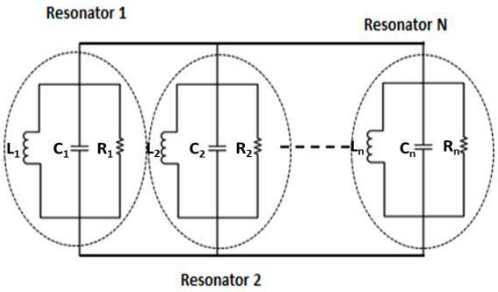


(d) Equivalent circuit (multiple resonators)

Figure-2. Resonator structures and their equivalent circuits.

Two tags are prepared, one has one parallel slot resonator and another has five on board. The substrate material is Taconic TLX-8 with a height of 0.5mm and dielectric constant of 2.55 is used in this design. The modeling and simulation has been done using CST MWS 2017. The circular disk has a diameter of 15mm. One complete resonator needs two different lengths of parallel slots. The dimensions of the structure are given in Table-1.

Table-1. Dimensions of different slot length.

Resonator	Slots	Length (mm)
1	L_1	10.3
	L_2	10
2	L_1	10
	L_2	9.7
3	L_1	9.7
	L_2	9.4
4	L_1	9.4
	L_2	9.1
5	L_1	9.1
	L_2	8.8

BIT DETECTION TECHNIQUE

Figure-3 shows the steps of the tag detection technique that has been employed here. In Figure-3, the tag has been excited by a UWB pulse, $S_T(t)$ transmitter from the reader antenna in time domain. The length of the signal is 15ns.

The reader send the signal to the tag and waits for the backscattering signal back from the tag, $S_R(t)$ in time domain also. The signal $S_R(t)$ contains three types of different information with different time duration, antenna rejection, $S_{AR}(t)$; structure mode, $S_{SM}(t)$ and tag mode, $S_{TM}(t)$. It can be written as (2).

$$S_R(t) = S_{AR}(t) + S_{SM}(t) + S_{TM}(t) \tag{2}$$

Antenna rejection and the structure mode are not relevant for this analysis. So, with the proper time frame selection, $S_{TM}(t)$ needs to be separated. Since the signal is in time domain, the last step is to fast furrier transform (FFT) of this specific time frame to extract bits in frequency domain. In the FFT response, the number of peaks represents the number of parallel slots/bits presents on the tag [19, 20].

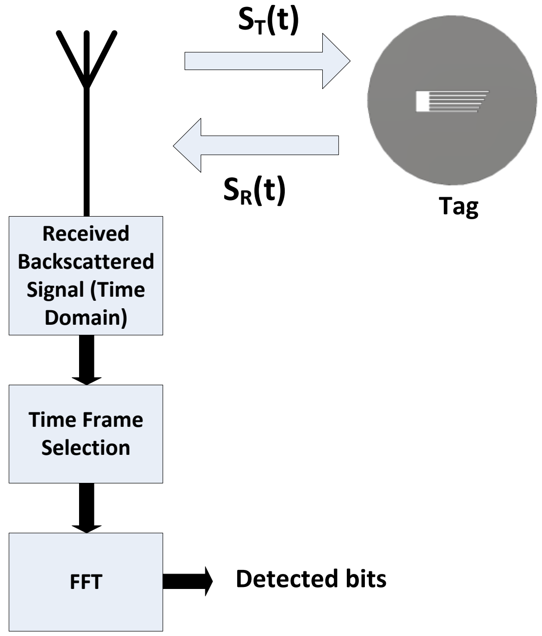


Figure-3. Bit detection technique of the proposed tag.

RESULT AND DISCUSSIONS

Figure-4 shows the setup of the RFID system with reader and tag in CST MWS 2017. Here the distance is kept as 30 cm between the tag and the reader antenna. At first the tag has been exited by the plane wave excitation. This is to check the surface current at resonant frequencies of the corresponding slots. At the corresponding resonant frequencies the surface current will be higher than that of the no-resonant frequencies. For both one resonator and five resonator design, the simulation has been done. Figure-5 shows the results.

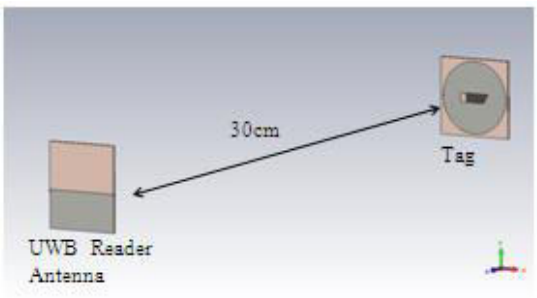
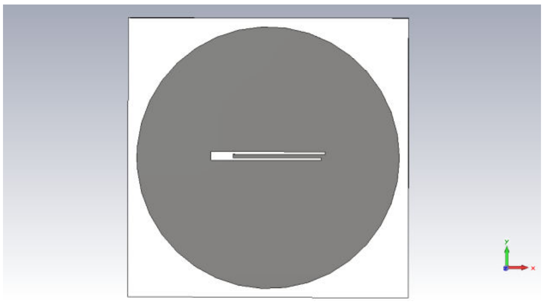
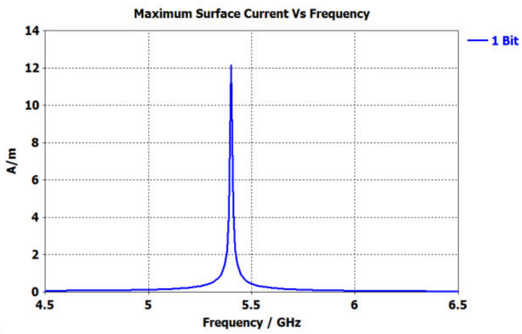


Figure-4. Simulation setup in CST MWS.

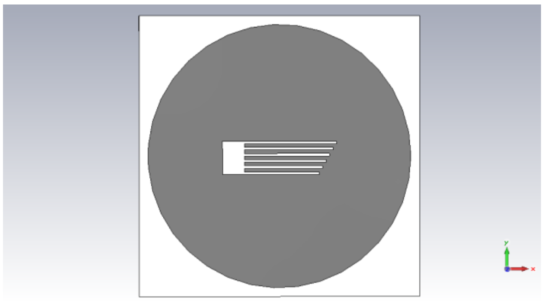
From Figure-5 (b), it is seen that for the one bit structure (shown in Figure 5a) the surface current has one high peak of 12.1A/m at 5.4GHz. The rest of the response does not contain any more peaks and this justifies that there is only one resonator is present on board. Figure-5(d) shows the surface current response shown in Figure-5(c). From Figure-5(c), it is seen that the structure contains five resonators of different lengths. Consequently, the surface current response in Figure-5(d) shows that there are five distinct peaks at different frequencies. This also justifies that there is a presences of five resonators on board of the tag.



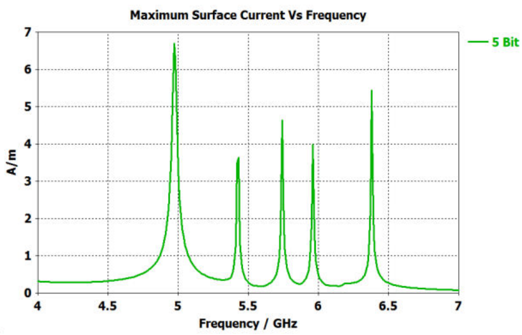
(a) One resonator tag



(b) Surface current response



(c) Five resonator tag



(d) Surface current response

Figure-5. The one and five bit structure and their surface current response.

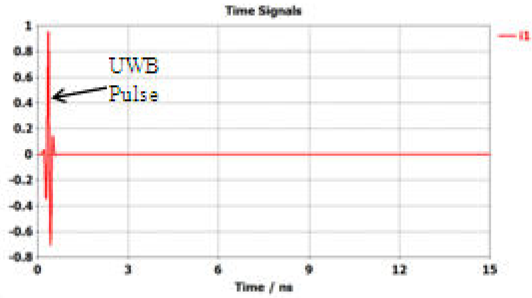


Figure-6. Transmitted UWB pulse.

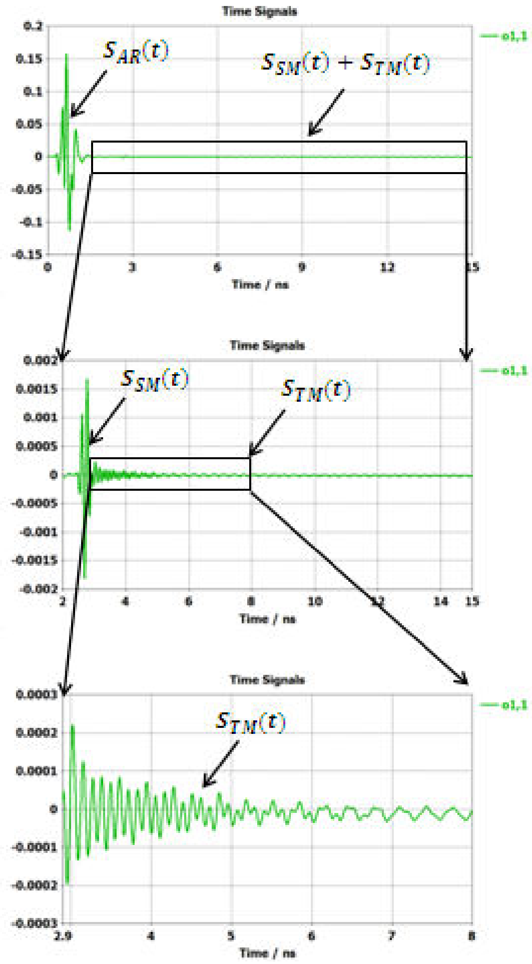
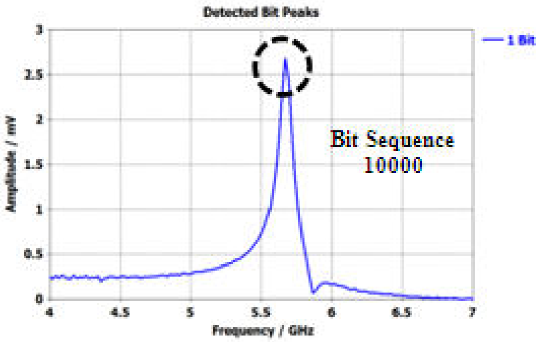


Figure-7. Time frame selection process.

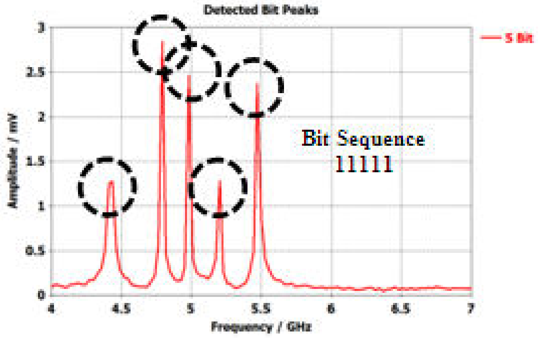
Through the surface current response, it has been justified that the number of resonance follows the number of resonators on board of the tag. As discussed in section 3, the next step refers to Figure-4. The reader antenna sends the UWB pulse towards that tag and gets the backscattering signal back from the tag. Figure-6 shows the transmitted time signal from the reader antenna. Described in (2), the received signal contains three different information and a time frame selection process need to be done to separate the signals. This scenario is shown in Figure-7.

In Figure-7, the first figure is the received signal from the tag. This received signal contains a combination of $S_{AR}(t) + S_{SM}(t) + S_{TM}(t)$. From 0 to 1.5ns, it contains the $S_{AR}(t)$ information. Rest of the signal contains $S_{SM}(t) + S_{TM}(t)$ information. From 1.5ns to 2.9ns the information is for the structure mode ($S_{SM}(t)$) and from 2.9ns to 8ns is the concerning tag mode information.

With this selection, the structure mode information is only taken and rest is rejected. The selected time domain information is extracted from CST into Matlab 2015b and an FFT is performed. For both one bit and five bit tag this FFT has been performed and the results are shown in Figure-8.



(a) Extracted bit sequence 10000



(b) Extracted bit sequence 11111

Figure-8. The extracted different bit sequence by FFT from TD signal.

From Figure-8, it can be observed that the bit detection process detects exactly same number of bits as it was on board of the tag. For one bit structure, after performing the tag detection, gives one peak at the response (Figure-8a). Similarly the response gets five bits while using the backscattered signal from the tag with five slots on board and can be seen from Figure-8(b). If it is considered as a five bit encoding system than for the one slot structure the encoded bits can be written as 10000. Similarly, for five slot structure it can be encoded as 11111.

CONCLUSIONS

A new planar parallel slotted circular disk passive chipless tag structure is proposed. Two different tags are designed and simulated for one bit and five bits. Through Surface current response the tag's slots/bits are justified at first. Later on with the tag detection technique proposed here, the bits are extracted successfully. This proposed new structure and detection technique will help the researchers to employ more bits on board of a passive tag and will contribute in the research on the replacement of the existing optical barcode system.

ACKNOWLEDGEMENT

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