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12-Bit Chip-less RFID Tag with High Coding Capacity per Unit Area

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Abstract—This paper presents a novel, low cost and highly compact chip-less radio frequency identification (CRFID) tag. The tag consists of multiple circular and rectangular metallic closed loop resonators, with an overall size of 12×12 mm². Plane wave is used to excite the tag. Its frequency response is analyzed against radar cross section (RCS) from 4 to 20 GHz. It can encode a 12-bit sequence and has a high code density of 8.33 bits/cm². Due to its compactness, the proposed tag has potential for different RFID applications.

Keywords—Chip-less, RFID, product identification, miniaturization, FSS, tag, IoT.

I. INTRODUCTION

Different types of well-known RFID technologies are commercially available [1], for various applications such as employee cards, traffic monitoring and toll collections etc. It is expected that around 75 billion products will use RFID tags in the near future [2]. Most recently, Chip-less radio frequency identification (CRFID) has gained much attention due to its extremely low cost.

A traditional RFID tag is embedded with a battery powered silicon chip along with transmit and receive antenna system. Whereas, a CRFID is made up of only RF circuit without any silicon or batteries and generates an electromagnetic signature to uniquely identify itself. A plane wave of desired polarization is impinged upon CRFID tag to measure its RCS [3]. The RCS is digitally processed in order to extract the coded information related to the tag for identification [4]-[5].

Several CRFID tags [6]-[10] have been proposed to address challenges such better frequency utilization, miniaturization, and improved code density etc. In [6] for example, a tag of 3×3cm² size encodes 19 bits using different techniques for code enhancement. Polarization insensitive CRFID tag with 3.8 bits/cm² is presented in [7]. A 25×25cm² tag having octagonal resonators is presented in [8], with very low bit density. A Bow-Tie tag of [9] encodes 8-bits in a small form factor attaining 4 resonant peaks in a rather wide frequency band. A spectrum efficient tag [10] with a large size and very low frequency utilization has also been presented.

In this paper, a novel, highly compact, CRFID tag is introduced. The tag neither use any active device nor surface mount device (SMD). The presented tag is encodes 12 bits with a size of 12×12 mm² from 4 to 20 GHz frequency band.

II. RESULTS AND DISCUSSION

The proposed CRFID tag structure is shown in Fig. 1. It is designed using an FR-4 substrate with thickness 2 mm, dielectric constant 4.3, and a loss tangent of 0.025. Optimized parameters of the tag are given in Table I.

Front side of the tag consists of two circular rings surrounded by three rectangular closed loop rings. Back side of the tag is fully covered by a conductor plane. The spacing between any two rings is kept 0.25 mm. The idea behind using multiple closed ring resonators is to create desired number of RCS minima’s at different frequencies. Hence, five resonances are expected from this tag, two from circular rings and three from rectangular.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>w</th>
<th>w1</th>
<th>w2</th>
<th>w3</th>
<th>w4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value (mm)</td>
<td>12</td>
<td>9.5</td>
<td>8</td>
<td>6.5</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Table I: Optimized Parameters of Proposed Tag
To verify the assumed five point resonance, first a dual circular ring tag was simulated. The RCS response for this dual-ring resonator (not shown here for brevity) indicates that there are two points where its value is minimum, at 11.9 and 17.6 GHz. To achieve even better and longer bit-sequence, three more closed loop rings of rectangular shape are introduced. Simulated RCS response of the complete five ring tag is shown in Fig. 2. It can be observed that there have indeed three more RCS minimums appeared in the plot at 6.765 and 15 GHz points. However, there is one extra parasitic resonance at around 5 GHz. This extra parasitic resonance is believed to be an average resonance of all the rings combined. Consequently, there are six resonances in total representing a 12-bit code sequence. This tag can be associated with an ID: 101010101010. The code density is calculated to 8.33 bits/cm².

III. CONCLUSION

A highly compact and low cost chip-less RFID tag was designed and presented in this paper. The tag consisted of a combination of circular and rectangular metallic closed loop rings. The tag can encode 12-bit sequence bearing a long ID. It has a dimension of 12×12 mm² with a high code density of 8.33 bits/cm². It has an operational frequency band from 4 to 20 GHz. The proposed tag has great potential for use in different radio identification and IoT based applications.

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