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

M. Noman[1], Usman A. Haider[1], Hidayat Ullah[1], Farooq A. Tahir[1], Muhammad U. Khan[1], Qammer H. Abbasi[2]
[1]Research Institute for Microwave and Millimeter-wave Studies, School of Electrical Engineering and Computer Science, National University of Sciences and Technology, Islamabad, Pakistan (farooq.tahir@seecs.edu.pk)
[2]James Watt School of Engineering, University of Glasgow, Glasgow, G12 8QQ, U.K

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 mm^2. 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/cm^2. 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 3×3cm^2 size encodes 19 bits using different techniques for code enhancement. Polarization insensitive CRFID tag with 3.8 bits/cm^2 is presented in [7]. A 25×25cm^2 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 mm^2 from 4 to 20 GHz frequency band.

I. TAG DESIGN

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.

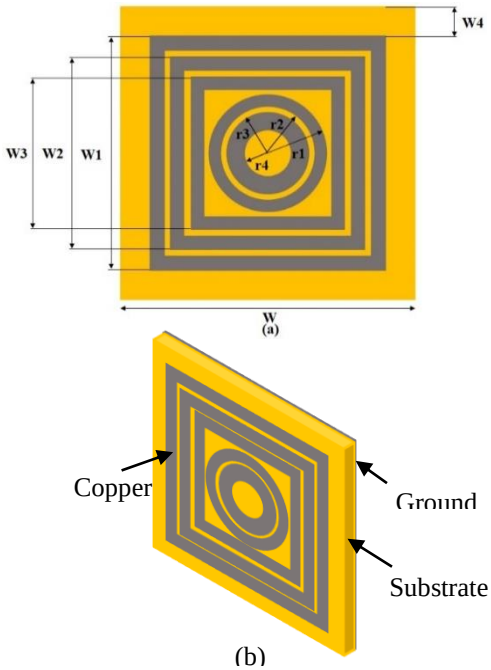

Fig. 1 Structural diagram of the proposed chip-less RFID tag: (a) front view (b) perspective view

TABLE I. OPTIMIZED PARAMETERS OF PROPOSED TAG

Parameter	w	w1	w2	w3	w4
Value (mm)	12	9.5	8	6.5	1.25
Parameter	r1	r2	r3	r4	-
Value (mm)	2.5	2	1.75	1	-

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.

II. RESULTS AND DISCUSSION

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, 7.65 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/cm^2.

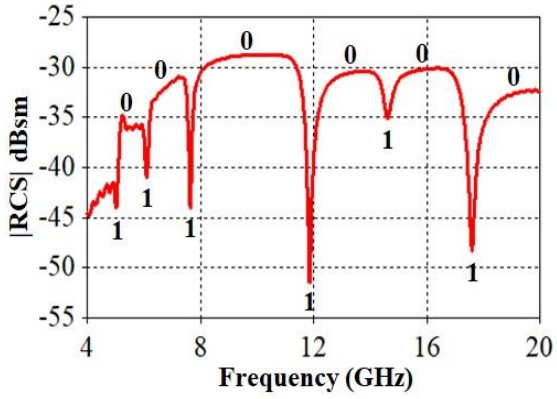

Fig. 2 Simulated RCS response of the proposed CRFID tag

To further investigate the effect of different elements of the tag, surface current distribution, as shown in Fig. 3, is provided. It can be observed that the inner rings are mostly responsible for higher frequency resonances while at lower frequencies, the outer rings get into effect. A more comprehensive and thorough current distribution analysis is not provided for brevity purpose.

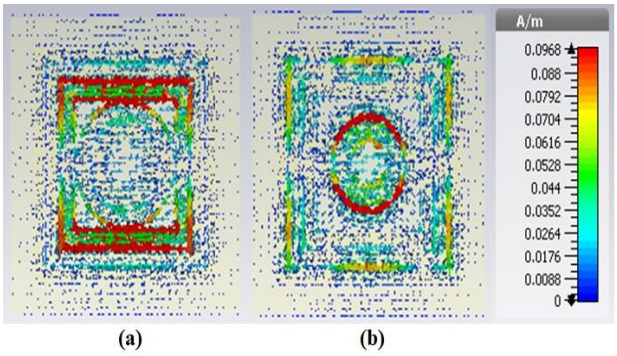

Fig. 3 Surface current distribution at (a) 7.65 GHz (b) 17.6 GHz

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 mm^2 with a high code density of 8.33 bits/cm^2. 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.

IV. Acknowledgement

This work was supported by Higher Education Commission (HEC) of Pakistan though National Research Program for Universities (NRPU) [Project No. 10038/Federal/ NRPU/R&D/HEC/ 2017]. The authors, therefore, acknowledge the support of HEC with thanks.

V. References

[1] R. Rezaiesarlak and M. Manteghi, CHIPLESS RFID: Springer, 2016.

[2] M. M. Khan, F. A. Tahir, M. F. Farooqui, A. Shamim and H. M. Cheema, "3.56-bits/cm ^{2} Compact Inkjet Printed and Application Specific Chipless RFID Tag," in IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 1109-1112, 2016.

[3] MARTINEZ, M., WEIDE, D. V. D. Circular polarization on depolarizing chipless RFID tags. In IEEE Radio and Wireless Symposium (RWS). Austin (TX, USA), 2016, p. 145–147. DOI: 10.1109/RWS.2016.7444388.

[4] DOBKIN, D. M. The RF in RFID: Passive UHF RFID in Practice. Elsevier Inc, 2008. ISBN: 978-0-7506-8209-1.

[5] M. M. Khan, F. A. Tahir and H. M. Cheema, "High capacity polarization sensitive chipless RFID tag," 2015 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, Vancouver, BC, 2015, pp. 1770-1771.

[6] A. Vena, E. Perret, and S. Tedjini, "High capacity chipless RFID tag insensitive to the polarization," IEEE Trans. Antennas Propag., vol. 60, no. 10, pp. 4509–4515, Oct. 2012.

[7] VENA, A., PERRET, E., TEDJINI, S. Chipless RFID tag using hybrid coding technique. IEEE Transactions on Microwave Theory and Techniques, 2011, vol. 59, no. 12, p. 3356–3364. DOI: 10.1109/TMTT.2011.2171001.

[8] D. Betancourt, K. Haase, A. Hübler, and F. Ellinger,"Bending and folding effect study of flexible fully printed and late-stage codified octagonal chipless RFID tags," IEEE Transactions on Antennas and Propagation, vol. 64, pp. 2815-2823, 2016.

[9] M. U. Ali Khan, R. Raad, J. Foroughi, F. E. Tubbal and J. Xi, "Novel Bow-Tie Chip-less RFID Tag for Wearable Applications," 2019 19th International Symposium on Communications and Information Technologies (ISCIT), Ho Chi Minh City, Vietnam, 2019, pp. 10-13.

[10] Anuar, Mirza and Seng, Lee Yeng and Shakhirul, MS and Wee, FH and Gan, "Design Chipless Textile Tag for RFID Application," Journal of Physics: Conference Series, vol.1339,pp. 012028, 2019.