Progress In Electromagnetics Research Letters, Vol. 55, 61–66, 2015

A Novel Polarization Independent Chipless RFID Tag Using Multiple Resonators

Das Laila[1, *], Riny Thomas[1], Chakkanattu M. Nijas[2], and Pezholil Mohanan[2]

Abstract—A novel polarization independent RFID tag employing multiple resonators is proposed. The prototype of the tag is fabricated on a low-cost substrate of dielectric constant 4.4 and loss tangent 0.02. Designing a reader for chipless RFID is a hard task since both the polarization and operating frequency agility have to be implemented. The new tag design proposed in this paper is polarization independent, making the design of the reader easier. A prototype of a 3 bit data encoded tag is demonstrated using single structure which can be extended to any order by cascading. This new design is experimentally validated in the frequency domain using monostatic measurement with magnitude response to decode the information.

1. INTRODUCTION

Radio frequency identification (RFID) is an automated contactless data capturing technology which utilizes radio frequency (RF) waves for data transmission between a transponder (tag) and an interrogator (reader) of a RFID system. The weaknesses of the conventional RFID tags are mainly due to the use of an integrated circuit (IC) and the reliability of the connection between the antenna and the IC. Although the traditional RFID systems based on the use of silicon RFID chips are very common and extensively used in practice, some of their limitations, such as cost and robustness, are driving many researches towards alternative solutions, namely chipless RFID. The most promising way for RFID is to directly print on a product or package like a bar code.

Chipless technology does not require any IC or communication protocol. It simply uses the tag information embedded into the electromagnetic signature (EMS) of the structure. The challenge is to be able to store more information within a passive structure, using a low-cost substrate. With this approach, the chipless RFID is quite similar in function to the optical bar code, and hence it is also known as RF bar code technology. But chipless RFID is rather more than that. It has the advantage of non-line-of-sight (NLOS) interrogation, has a great potential in terms of low cost and compatibility with green technology concepts, and can also be developed to have sensing capabilities.

Commercially available chipless RFID tags are developed by RFSAW, and it is based on the surface acoustic waves (SAWs) [1]. These tags are not fully printable. Fully printable chipless RFID tags based on group delay encoding [2, 3] and multiresonators [4] have been reported. Many designs are now available and one can classify the tags depending on their coding. The tags can be coded in the time domain [5–11], or in the frequency domain [12–17]. Currently, the best performance in terms of coding capacity and miniaturization is achieved by frequency encoded chipless tags. However, the reliability of the reading system irrespective of the polarization of the electromagnetic wave was not considered for the design of the tag. The polarization of the reflected wave is related to the orientation of the current

Received 10 June 2015, Accepted 3 August 2015, Scheduled 19 August 2015
* Corresponding author: Das Laila (lailacusat@gmail.com).
[1] Department of Electronics, Model Engineering College, Thrikkakara, Cochin-22, Kerala, India. [2] Centre for Research in ElectroMagnetics and Antennas (CREMA), Department of Electronics, Cochin University of Science and Technology, Cochin-22, Kerala, India.

paths on the conductors of the resonator. In most of the scatterers, the surface currents on the metal elements generate only a reflected wave in the polarization of the incident signal. This is particularly the case for a right shorted dipole [18], a C-like resonator [19], a circular [16], or rectangular ring. As a result, to detect the tag regardless of its orientation, the reader needs to have polarization agility, making the design more complex in terms of signal processing and antenna feeding. Moreover, the calibration task becomes more complex if more than one polarization is used, because the detection environment has to be well known for each polarization.

A chipless RFID tag with multiple resonators is discussed in this paper. The proposed tag is symmetric and polarization independent. The tag is encoded in frequency and can be easily decoded due to the large difference between reflected power level corresponding to the presence and absence of a bit. The readable range of the tag is up to 40 cm because it uses a low-cost FR-4 substrate.

2. TAG DESIGN

The polarization independent tag is composed of multiresonators. The top vies (a) and side view (b) of the basic structure are shown in Figure 1. To encode data within a frequency band, the classical way is to create some notches or peaks in the backscattering signal at specific frequencies, which can be controlled by changing the physical dimensions of the resonators. The microstrip based structure consists of three strip resonators with the lengths of the multiresonators chosen to operate in Ultra Wide Band (UWB) frequency range, i.e., 3.1 GHz to 10.6 GHz. The dimensions are shown in Table 1.

The width of resonator (w) is fixed at 0.5 mm, and interelement gap (d) is 3 mm. The inter element gap is optimized to 3 mm to reduce the mutual coupling which is crucial while coding the tag. Due to the symmetry of the structure, any of the resonators in the basic model will resonate for random incident wave polarization. The tag is fabricated on low cost FR-4 epoxy substrate of thickness 1.6 mm

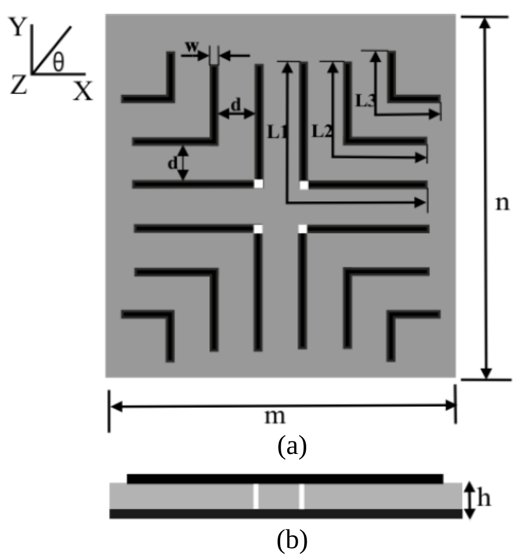

Figure 1. Basic structure of RFID tag with multistrip resonator, white square at the centre indicates short circuit to bottom metal plate. (a) Top view. (b) Side view.

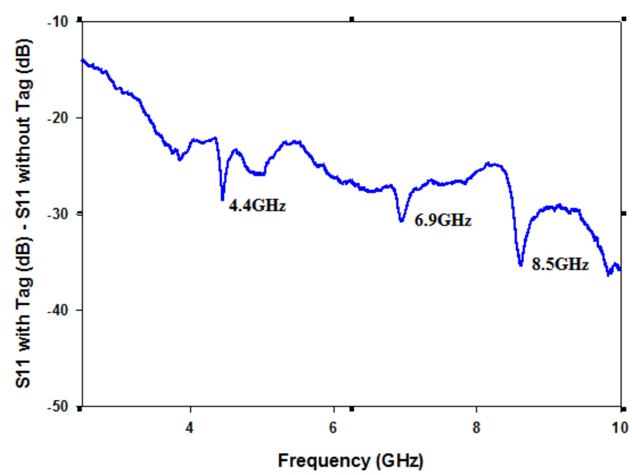

Figure 2. The back scattered field response of the tag element I.

Table 1. Dimension of basic structure.

Dimension	L_1	L_2	L_3	d	w	m	n
Value (mm)	22	14	10	3	0.5	30	32

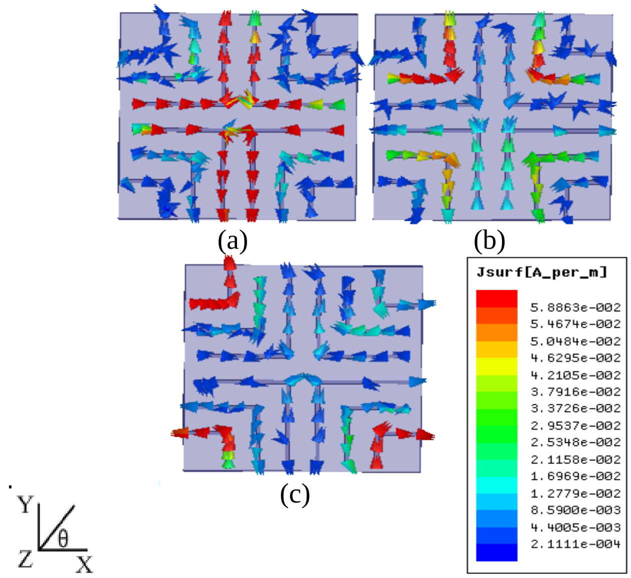

Figure 3. Simulated current distribution at frequencies, (a) 4.4 GHz, (b) 6.9 GHz, (c) 8.5 GHz.

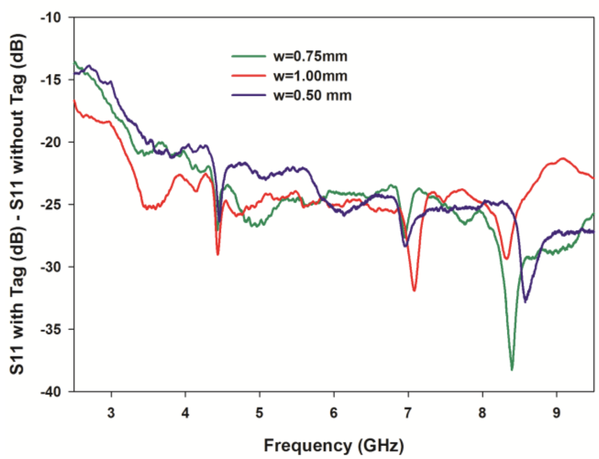

Figure 4. Measured result for different width (w) values.

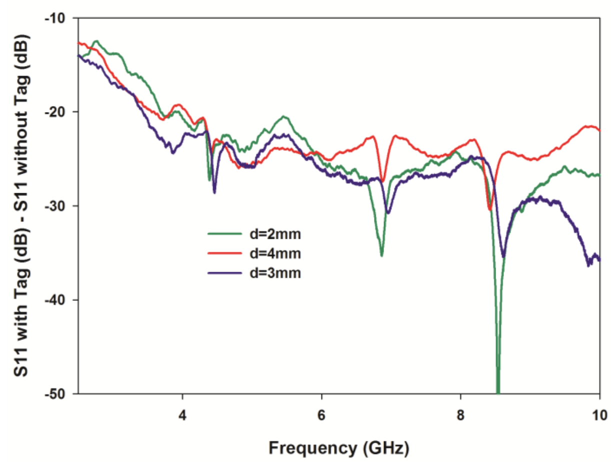

Figure 5. Measured result for different gap (d) values.

Table 2. Dimension of cascaded structure.

Value (mm)	L_1	L_2	L_3	w	d
Element I	22	14	10	0.5	3
Element II	20	13	8	0.5	3

with relative permittivity 4.4 and loss tangent 0.02. The structure is simulated using Ansoft HFSS. The backscattered field response of the tag element I is shown in Figure 2. Each resonator independently resonates at its half wavelength frequency. Plane wave excitation with polarization along the Y axis is applied in the simulation. The corresponding current patterns at three different frequencies are depicted in Figure 3. The parametric study based on the variation of width (w) and gap (d) between the resonators is shown in Figures 4 and 5 respectively.

The curves show that as strip width increases, the higher frequencies are affected, but to reduce coupling between resonators, the width is optimised to 0.5 mm. Similarly, it is seen that the first resonance frequency is independent of the gap between resonators but this has considerable effect on higher frequencies. The gap is optimised to 3 mm.

The structure resonates at 4.4 GHz, 6.9 GHz and 8.5 GHz. The unit cell structure consisting of three resonators operating at different frequencies can be frequency encoded using 3 bits. The bit coding can be increased to 6 bits by cascading two structures having different dimensions. The dimensions are given in Table 2.

3. RESULTS AND DISCUSSION

The measurement was carried out using Agilent PNA E8362B with 1 mW output power. The measurement setup inside the anechoic chamber is shown in Figure 6. A linearly polarized medium gain (10 dB) horn antenna is used for transmission and reception of the interrogation signal. Calibration

Figure 6. Measurement setup inside the anechoic chamber.

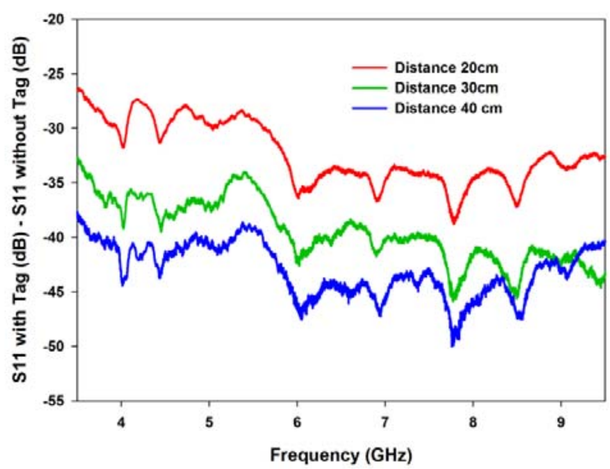

Figure 7. Measured result for different distances.

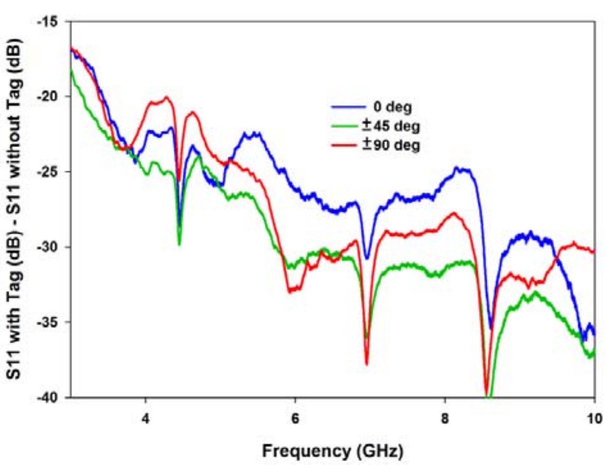

Figure 8. Measured result for multiple resonator for different theta values.

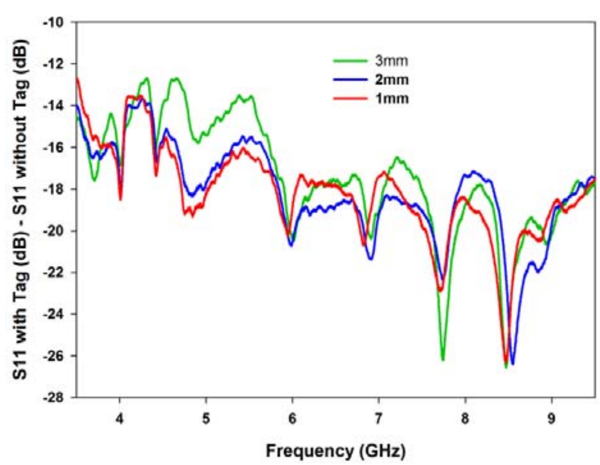

Figure 9. Measured result for different separation between elements I & II.

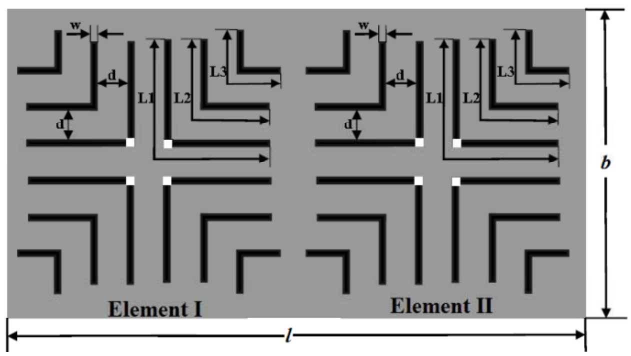

Figure 10. Cascaded structure of multiple strip resonator, where $l \times b = 62 \times 32\,\mathrm{mm}^2$.

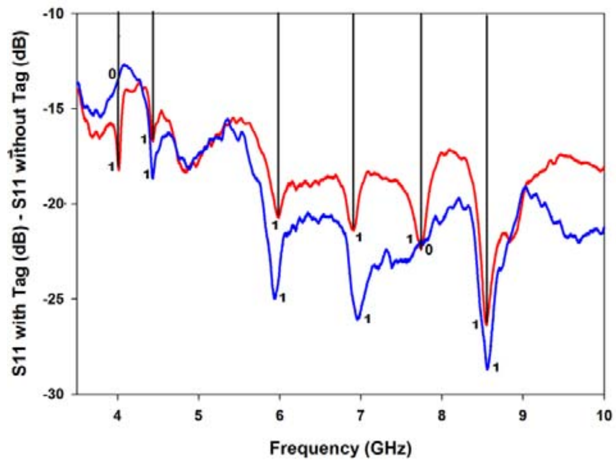

Figure 11. Measured result for the tag ID "111 111" and "011 101".

procedure for the proposed system can be done by subtracting S_{11} without tag from S_{11} with tag.

The performance of the chipless RFID tag system at different distances is shown in Figure 7. It is clearly observed that the amplitude of the spectrum reduces as the distance increases whereas the resonance is preserved because of the lossy substrate used. The distance between the horn antenna and tag is set to 40 cm. Identification of each bit is very clear from magnitude measurements. To validate the polarization independent property, measurements are taken at different polarizations. The plots at different angles for the basic structure are shown in Figure 8. For all the cases, information can be easily decoded.

To increase coding density, elements I and II are cascaded. The cascaded tag's size is shown as $l \times b = 62 \times 32\,\mathrm{mm}^2$. The separation between the elements has less effect on the resonances. It is optimized to 2 mm and the variation study of this is shown in Figure 9. It can be seen that the basic structure is kept as such and an additional resonator having strips with different dimensions is placed aside. The cascaded structure of the multistrip resonator is shown in Figure 10.

The cascaded structure resonates at 4 GHz, 4.4 GHz, 5.9 GHz, 6.9 GHz, 7.7 GHz and 8.5 GHz corresponding to the bit pattern 111 111. It was necessary to encode data to obtain a unique ID. This can be done by introducing or removing the resonances of the multi resonator. The plot for the coded and uncoded bit pattern is shown in Figure 11.

4. CONCLUSION

A novel polarization independent RFID tag with muliresonators is proposed. Due to the structural symmetry of the resonator, backscattered signals are identical in different angular excitations, and data are encoded in the frequency spectrum. The structure is implemented on a low-cost substrate (FR4), and the polarization independent property reduces the cost of design of the reader. Bit encoding capacity of the tag can be further extended by placing more resonators working in the frequency band ranging from 3.1 and 10.6 GHz, i.e., in the Ultra Wide Band (UWB) range.

REFERENCES

1. Hartmann, C. S., "A global SAW ID tag with large data capacity," *Proc. IEEE Ultrason. Symp.*, Vol. 1, 65–69, Munich, Germany, Oct. 2002,
2. Nair, R., E. Perret, and S. Tedjini, "Chipless RFID based on group delay encoding," *IEEE Int. Conf. on RFID-Technologies and Applications*, 214–218, Sitges, Spain, Sep. 15–16, 2011.

3. Gupta, S., B. Nikfal, and C. Caloz, "Chipless RFID system based group delay engineered dispersive delay structures," *IEEE Antennas Propag. Lett.*, Vol. 10, 1366–1368, 2011.
4. Preradovic, S., I. Balbin, N. C. Karmakar, and G. F. Swiegers, "Multiresonator-based chipless RFID system for low-cost item tracking," *IEEE Trans. Microw. Theory Tech.*, Vol. 57, No. 5, 1411–1419, May 2009.
5. Chamarti, A. and K. Varahramyan, "Transmission delay line based ID generation circuit for RFID applications," *IEEE Microw. Wireless Compon. Lett.*, Vol. 16, No. 11, 588–590, Nov. 2006.
6. Mandel, C., M. Schussler, M. Maasch, and R. Jakoby, "A novel passive phase modulator based on lh delay lines for chipless microwave RFID applications," *IEEE MTT-S Int. Microw. Wireless Sens., Local Positioning, RFID, Workshop*, 1–4, 2009.
7. Nair, R., E. Perret, and S. Tedjini, "Temporal multi-frequency encoding technique for chipless RFID applications," *IEEE MTT-S Int. Microw. Symp. Dig.*, 1–3, 2012.
8. Shrestha, S., M. Balachandran, M. Agarwal, V. Phoha, and K. Varahramyan, "A chipless RFID sensor system for cyber centric monitoring applications," *IEEE Trans. Microw. Theory Tech.*, Vol. 57, No. 5, 1303–1309, May 2009.
9. Zheng, L., S. Rodriguez, L. Zhang, B. Shao, and L. Zheng, "Design and implementation of a fully reconfigurable chipless RFID tag using inkjet printing technology," *IEEE Int. Circuits Syst. Symp.*, 1524–1527, 2008.
10. Ramos, A., D. Girbau, A. Lazaro, and S. Rima, "IR-UWB radar system and tag design for time-coded chipless RFID," *EUCAP*, 2491–2494, 2012,
11. Balbin, I. and N. Karmakar, "Phase-encoded chipless RFID transponder for large-scale low-cost applications," *IEEE Microw. Wireless Compon. Lett.*, Vol. 19, No. 8, 509–511, Aug. 2009.
12. Jalaly, I. and I. Robertson, "RF barcodes using multiple frequency bands," *IEEE MTT-S Int. Microw. Symp. Dig.*, 1–4, 2005.
13. McVay, J., A. Hoorfar, and N. Engheta, "Theory and experiments on Peano and Hilbert curve RFID tags," *Proc. SPIE*, Vol. 6248, Artical ID 624808, May 2006.
14. Vena, A., E. Perret, and S. Tedjini, 'Chipless RFID tag using hybrid coding technique," *IEEE Trans. Microw. Theory Tech.*, Vol. 59, No. 12, 3356–3364, Dec. 2011.
15. Vena, A., E. Perret, and S. Tedjini, "A fully printable chipless RFID tagwith detuning correction technique," *IEEE Microw. Wireless Compon. Lett.*, Vol. 22, No. 4, 209–211, Apr. 2012.
16. Vena, A., E. Perret, and S. Tedjini, "High capacity chipless RFID tag insensitive to the polarization," *IEEE Trans. Antennas Propag.*, Vol. 60, No. 10, 4509–4515, Oct. 2012.
17. Preradovic, S. and N. Karmakar, "Design of fully printable planar chipless RFID transponder with 35-bit data capacity," *Eur. Microw. Conf.*, 13–16, 2009.
18. Jalaly, I. and I. Robertson, "RF barcodes using multiple frequency bands," *IEEE MTT-S Int. Microw. Symp. Dig.*, 1–4, 2005.
19. Vena, A., E. Perret, and S. Tedjini, "Chipless RFID tag using hybrid coding technique," *IEEE Trans. Microw. Theory Tech.*, Vol. 59, No. 12, 3356–3364, Dec. 2011; C. J. Kaufman, Rocky Mountain Research Lab, Boulder, CO, Private Communication, May 1995.