Analysis and Design of RFID Antenna Based on Broadside-Coupled SRR

Amina Bendaoudi[1], Mohamed Debab[2], Mohammed Berka Zoubir Mahdjoub[3]

[1]Department of Mechanical Engineering, Ozyegin University, Istanbul, Turkey

[2]Department of Mechanical Engineering, Ozyegin University, Istanbul, Turkey, layth.ismael@ozu.edu.tr,ORCID: 0000-0002-1850-3998

[3]Department of Materials Engineering, University of Technology, Baghdad, IRAQ, 130006@uotechnology.edu.iq

ABSTRACT

This Paper Presents A New Structure Of Circular Patch Antenna With Slots That Operate In Rfid Applications Microwave. Additionally, It Utilizes Broadside-Coupled Complementary Split Ring Resonator (Bc-Srr) In The Ground Plane In Order To Obtain An Rfid Antenna Technology That Operates Around 2.45 Ghz And 5.80 Ghz. The Circular Patch Antenna Is Composed Of An Arlon Ad430 Substrate With The Dielectric Permittivity Of 4.3, Loss Tangent Of 0.003, And Thickness Of 5Mm. The Parameters Examined In This Paper Are The Resonant Frequency, Reflection Coefficient, And The Radiation Pattern Of The Proposed Antenna. The Results Obtained By Ansoft Hfss Were Compared To Those Obtained By Cst Mws (Computer Simulation Technology-Micro Waves Studio).

Keywords: *Radio Frequency Identification; Complementary Broadside Coupled SRR resonators; Metamaterial; Circular patch.*

1. INTRODUCTION

Recently, antenna researchers worldwide have been attracted by the single/double negative metamaterials, also called zero-index materials, due to their peculiar properties. These artificially engineered homogeneous media provides unusual and useful phenomenon due to their controllable electric and magnetic responses [1]. Metamaterial is artificial metallic structures having simultaneously negative permittivity and permeability, and consequently, have a negative index of refraction. It gains its properties from structure rather than composition [2]. The first researches concerning the properties of metamaterials are made by Victor Veselago in 1968. Later Smith [3] implements first left-handed materials consist of periodic split-ring resonators (SRR's) and long strips [4].

The metamaterial structures that are used for improving patch antenna performance are Split Ring Resonators (SRR) or the Complementary Split Ring Resonator (CSRR) [5].

An RFID, Radio Frequency Identification, system is generally composed from a reader, and one or more transponders or tags. The communication between the reader and the tag is achieved by modulated backscattering of the reader's carrier wave signal [6]. In 1990, RFID became prevalent in many industry services, such as access control, document tracking, distribution logistics, automotive systems, and animal tracking [7]. The RFID system is used in many applications as access control, logistic, bank, health, and transport [6].

The microstrip patch antennas generally meet most of these requirements and hence, have better prospects than conventional antennas [8]. They are famous to be low profile, low weight, ease of fabrication, conformable to planar and non-planar surfaces and mechanically robust [6]. The studies have focused very quickly to the development of filters, phase shifting and antenna with new performance one of the promising applications in the field of antenna design is metamaterial antennas [9].

This paper is focused on the use the magnetic resonator called Broadside Coupled SRR "BC-SRR" should therefore eliminate the magneto-electric coupling so the E field does not respect the symmetry of the structure.

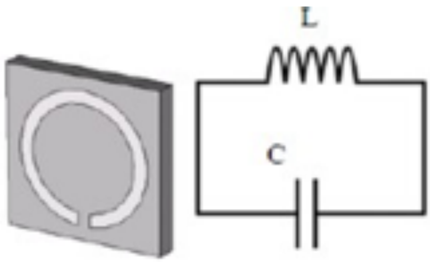
Wang et al. proposed tuning the electromagnetic response in the microwave region through subunit-cell relative displacements between the two layers comprising a broadside coupled SRR (BC-SRR) structure under magnetic excitation [10].

A circular patch antenna is being widely used in RFID technologies and other microwave applications. Use of BC- SRR helps in improving various properties and to overcome the drawbacks of patch antennas, such as increasing radiation efficiency and providing the good adaptation of antenna. We propose a modification in conventional antenna geometric by introducing slots in the circular patch with a ground plane periodically etched by BC-SRR.

2. THEORY

Antenna Design

Concept of Broadside Coupled Split Ring Resonator (BC-SRR)
The equivalent circuit model of the SRR shows that the capacitive gaps in the structure are of the greatest importance in determining its resonance frequency [11]. The SRR dimensions will decide the notch frequency. The strong magnetic coupling of propagating electromagnetic field from SRR will suppress the radiation at notch frequency [12].



(a) (b)

Figure 1. Topology of the Split Ring Resonator (a) SRR resonator cell proposed, (b)Equivalent resonant curcuit.

The split rings are coupled by means of a strong distributed capacitance in the region between the rings (the slots are meaningfully wider than the distance between the rings). The BC-SRR is shown in Fig.2 [13].

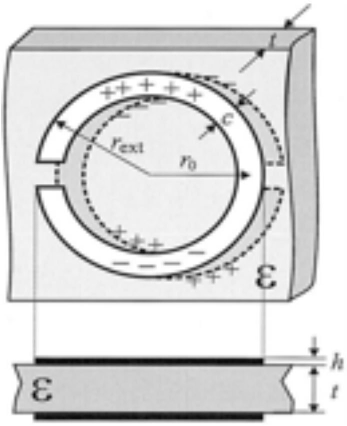


Figure 2. Broadside coupled SRR (BC-SRR).

The whole device then behaves as a circuit driven by an external electromotive force. The total capacitance of this LC circuit will be the series capacitance of the upper and the lower halves (with respect the line containing the ring gaps) of the SRR and the resonance frequency w0 is given by [13]:

$$\omega_0 = \sqrt{\frac{2}{\pi r_0 L C_{pul}}} \qquad (1)$$

where is the per unit length Cpul capacitance between the rings, L is the total inductance of the SRR, and r0 is the average radius of the considered SRR.The analysis of the BC-SRR can be simplified by neglecting of the cross-polarization effects so, the resulting equations can be summarized as follows [13]:

$$m_z = \alpha_{zz}^{mm} B_z^{ext} \qquad (2)$$

$$p_y = \alpha_{yy}^{ee} E_y^{ext} \qquad (3)$$

$$p_x = \alpha_{xx}^{ee} E_x^{ext} \qquad (4)$$

The BC-SRR polarizabilities have been obtained in a self-consistent way, they can be used in a local field theory in order to determine the macroscopic constitutive parameters of media consisting of a regular array of SRRs. This local field theory makes use of the well-known Lorentz theory [13].

The configuration of the proposed patch-slot circular antenna is illustrated in Fig.3. Its structure is based on an Arlon AD430 dielectric substrate which has permittivity of 4.3 and height h=5mm. The characteristics impedance of coaxial cable 50ohm has matched with the input impedance of the conventional patch antenna. The resonance frequency is fr = 3.65GHz [14].

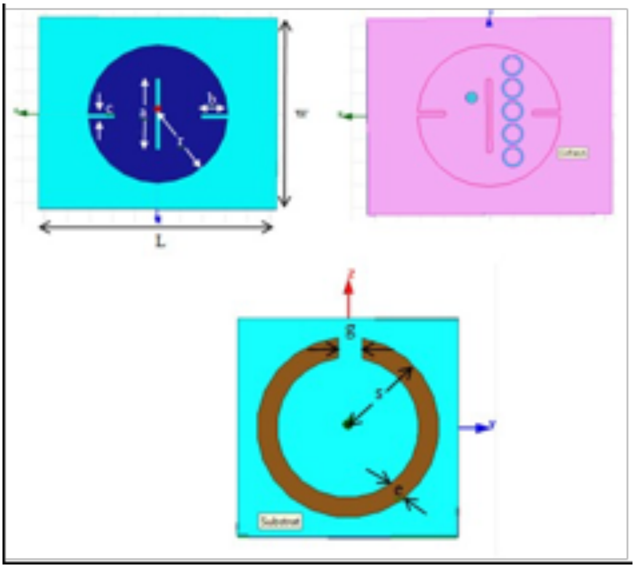


Figure 3. Layout of the proposed antenna.

The proposed antenna consists of antenna with ground plane periodically etched CSRR. The complementary SRR must produce a negative effective permeability around the resonant frequency of the antenna. The network is homogeneous and periodic that contains five SRRs circular with a periodicity to order 1mm. The dimensions of the patch-slot circular antenna are tabulated in Table 1. The geometrical dimensions of the BCSRR unit cell are; radius of the split ring s=2.3 mm, width of the rings e=0.5mm and gap at the split of ring is g=0.5 mm. The dimensions of circular split ring resonator are chosen in such a way that it resonates at the same frequency as that of the proposed antenna.

Table 1. Dimensions Of The Patch-Slot Circular Antenna.

Parameters	W	L	h	a	b	c	r
Values (mm)	43	53	5	16	6	1	16

3. RESULTS AND DISCUSSION

HFSS tool was used as a platform to design of the antenna, to match the radiation parameters as, input impedance, return loss, gain, directivity and radiation pattern. The obtained results have been compared to those obtained by CST.

Antenna in the absence of slots and CSRR

The simulated S-parameters result is illustrated in Fig.4.

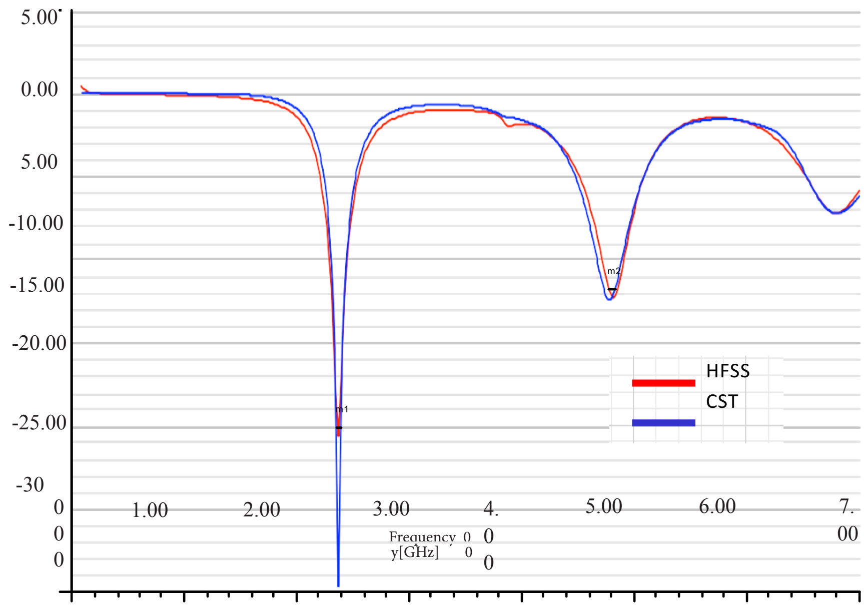
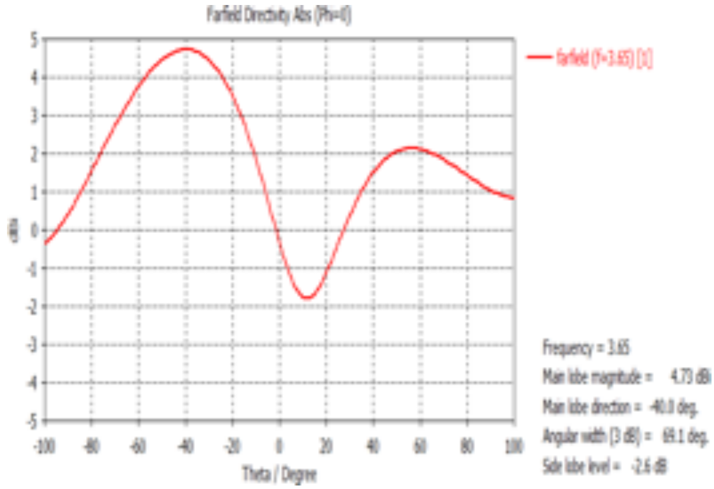


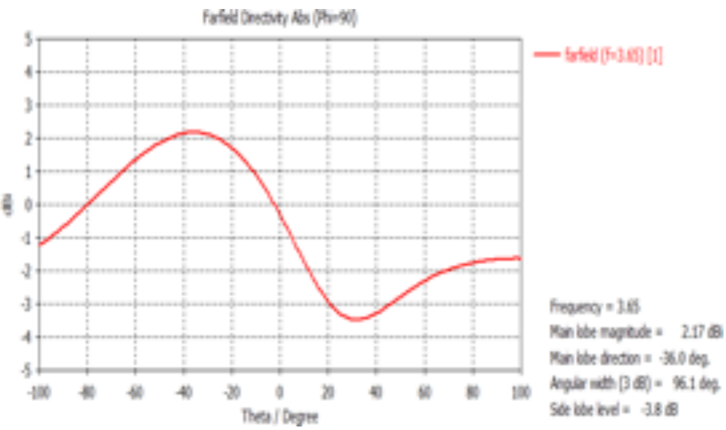
Figure 4. Reflexion coefficient of the antenna without slot.

It can be seen from this figure that, the circular patch antenna without slot and without CSRR has a double resonance. Based on the results given by HFSS, the first resonance at 2.38 GHz, with S11=-20 dB and the second at 4.82 GHz with S11= -12.68 dB. From the results given by CST, the first resonance at 2.38 GHz, with S11=-29.20 dB and the second at 4.78 GHz with S11= -12.70 dB.

The simulated radiation patterns result is illustrated in Fig.5.



(a)



(b)

Figure 5. Simulated Gain by CST, (a) for Phi=00 (b) for Phi=900.

From the results given by CST, the maximum directivity attained by the antenna is 2.17 dB and the maximum gain of
4.73 dB. HFSS tool was used as a platform to design of the proposed antenna (Figure 4), to match the radiation parameters as, reflexion coefficient, gain and radiation pattern. The obtained results have been compared to those obtained by CST.

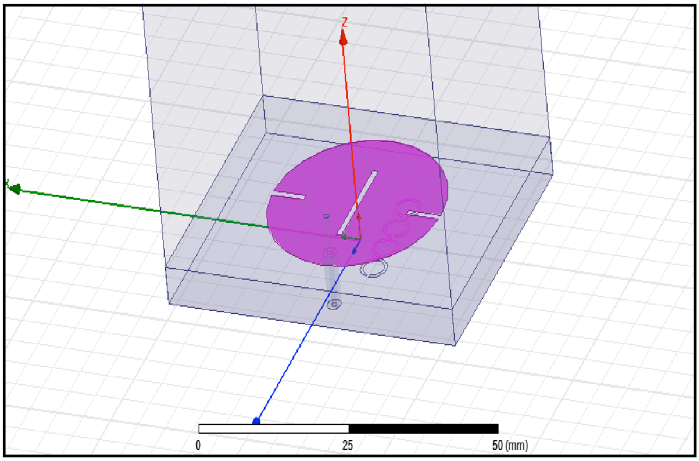


Figure 6. Simulation model of proposed antenna by HFSS.

Antenna in the presence of slots and CSRR
The simulated S-parameters results are illustrated in Fig.7.

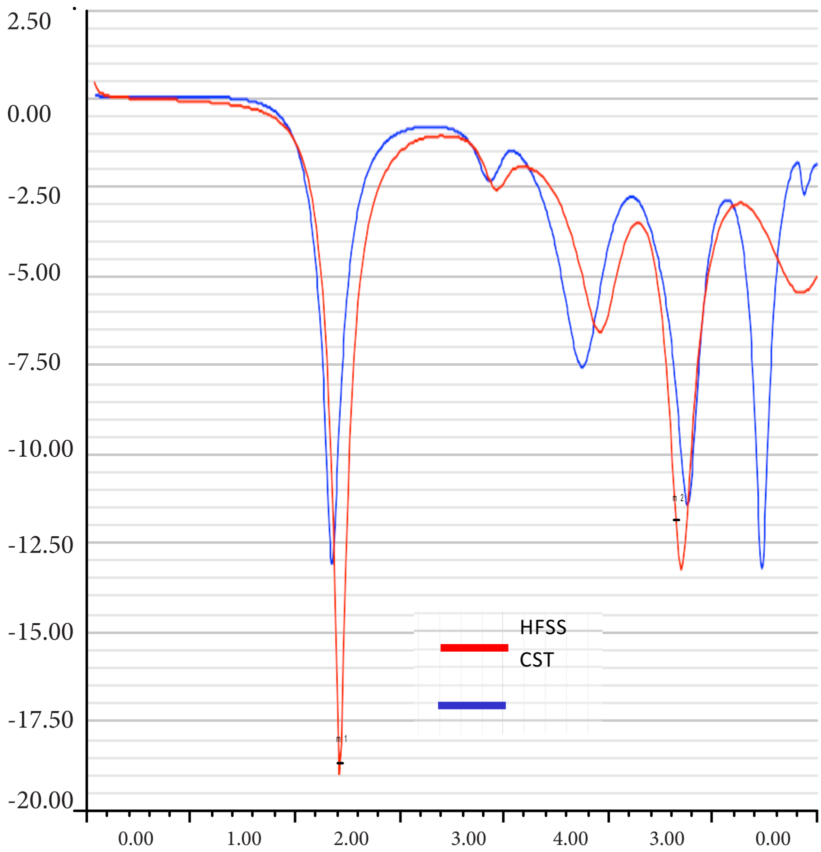
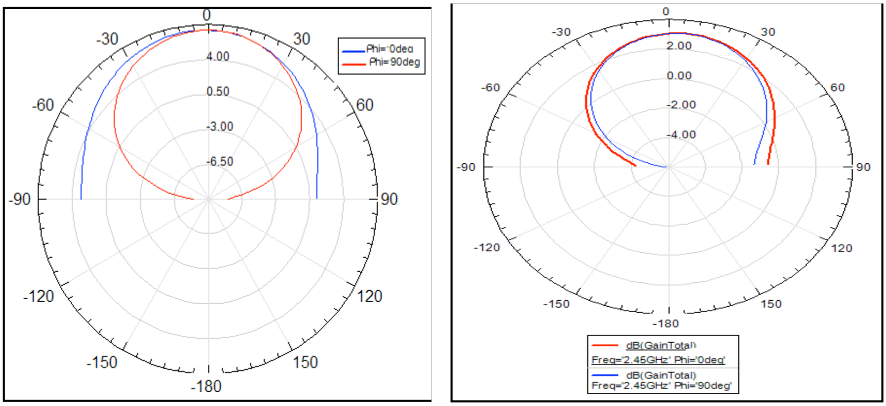


Figure 7. Illustrate the radiation patterns around 2.45 GHz and 5.80 GHz at E-plane and H-plane respectively.



(a) (b)

Figure 8. Realized radiation pattern at 2.45 GHz (a) by HFSS and (b) by CST

We notice slight difference between the results obtained by the HFSS simulator and those obtained by CST in terms of the resonance frequency, the antenna impedance, and the gain. This difference is due to the meshing technique used during the simulation and to the numerical method of each simulator uses.

Table 2. Comparison Of Parameters Result Of Circular Antenna With And Without Slot AnBC-SRR.

	Conventional antenna		Proposed antenna	
	HFSS	CST	HFSS	CST
Optimal frequency (GHz)	2.38	2.38	2.44	2.41
	4.82	4.78	5.66	6.50
Reflection coefficient (dB)	-20	-29.20	-19	-13.08
	-12.68	-12.70	-13.50	13.40
Gain (dB)	/	4.73	3.08	6

From the comparison table 2, the results indicate that the BC-SRR resonator has an effect on the conventional antenna by shifting the frequency regions to a different value as well as affecting the S11 parameters. Thus multiband operation is achieved by coupling two BCSRR units having selected parameters with the circular patch. It has been concluded that the association between BC-SRR and the slot leads to an improvement in terms of the bandwidth and the gain.

4.CONCLUSION

The present work reports the development of a multiband circular patch antenna by utilizing Broadside Coupled Split Ring Resonator (BCSRR) units. Split ring resonator array is used to produce the negative magnetic permeability. This antenna makes use of the resonant property of metamaterial BCSRR units for multiband frequency designing. Since the magnetic resonant frequency of the BCSRR depends on the effective capacitance and inductance of its rings. The radiating frequencies can be designed to other desired values by making changes in dielectric thicknesses and in ring parameters. The multiband frequency operation in antenna based on BCSRR is manifested and the results presented and simulated by using: HFSS and CST. The results indicate that the metamaterial has an effect on the conventional circular patch antenna by shifting the frequency regions to a low-value where the structure will be able to ameliorate performance in terms of reflection coefficient and radiation patterns in both the H-plane and E-plane. The antenna presents good performances. This antenna system is suitable for RFID applications microwaves.

REFERENCES

[1] Jamal MR. ’’A Proposed Design of Unit Cell of Metamaterial for 5G Mobile Communication’’. TELKOMNIKA. Vol 15(3): pp1145–1148 , 2017.

[2] Smith, D., Padilla, W., Wier, D., Nemat-Nasse, S., Schultz, S.: ”Composite medium with simultaneously negative permeability and permittivity’’. Phys. Rev. Lett. Vol 84, pp 4184–4187, 2000.

[3] A.Bendaoudi, Z. Mahdjoub,”Comparative study of patch antenna loaded with slot split-ring resonators on different substrate materials. Photonic Network Communications”, Vol 35, pp195-203, 2018.

[4] A.Bendaoudi, Z. Mahdjoub, ’’Regular paper Performance Enhancement of Rectangular Patch Antenna by Loading Complementary Multi-Ring SRR’’. J. Electrical Systems Vol 14(1), pp143-155, 2018.

[5] M. Ihamji LASTI E. Abdelmounim LASTI, H. Bennis, M. Lotfi, M. Latrach: “A New Design of a Miniature L- slot Microstrip Antenna for RFID Tag”, Conference ICCWCS’17, November 2017, Larache, Morocco.

[6] Mahdi Abdelkarim, Seif, Lassad Larach, Ali Gharsallah; “Improvement of the Frequency Characteristics for RFID Patch Antenna based on C-Shaped Split Ring Resonator”. International Journal of Advanced Computer Science and Applications, Vol. 9, No. 2, 2018.

[7] Chirag arora1 , shyam s. pattnaik2 and rudra narayan baral:” Metamaterial inspired DNG superstrate for performance improvement of microstrip patch antenna array”. International Journal of Microwave and Wireless Technologies, 2018.

[8] E. Ekmekci, A. C. Strikwerda, K. Fan, G. Keiser, X. Zhang, G. Turhan-Sayan, and R. D. Averitt ; “Frequency tunable terahertz metamaterials using broadside coupled split-ring resonators”. Phys. Rev. B 83, 193103, 2011.

[9] Seif Naoui, Lassaad Latrach, Ali Gharsallah ; “RFID Antenna by Using Metamaterials With Negative Effective Permeability”. 978-1-4799-8172-4, 2015 IEEE.

[10] S.CHAKRABARTI and S.ANANTHA RAMAKRISHNA, “From effective medium dispersion to photonic band gaps”.. Pramana – J. Phys., Vol. 78, pp. 483–492, 2012.

[11] Madhav M. Venkateswara Rao1, T. Anilkumar, “Conformal Band Notched Circular Monopole Antenna Loaded with Split Ring Resonator B. T. P”. Wireless Pers Commun, Vol.103, Issue 3, pp 1965–1976, 2018.

[12] Ricardo Marqués, Francisco Mesa, Jesús Martel, Francisco Medina ; ’’Comparative Analysis of Edge- and BroadsideCoupled Split Ring Resonators for Metamaterial Design—Theory and Experiments”. IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 51, NO. 10, 2003.

[13] Arshad Wahab, Jiadong Xu: ’’U-slot Circular Patch Antenna for WLAN. Application’’. TELKOMNIKA Indonesian Journal of Electrical. Engineering Vol 14(2), pp 323-328, 2015.