Design of an Ultra-Wideband Antenna using Split Ring Resonator

Abdelghani NACER, Noureddine BOUKLI HACENE

Department of telecommunication, Faculty of Technology, University of Abou Bekr Belkaïd-Tlemcen
Tlemcen, BP 230-Tlemcen 13000, Algeria

Abstract

This paper presents a novel patch antenna using circular split ring resonator for ultra-wideband applications. The radiating element of the proposed antenna is a split-ring resonator (SRR). The geometrical parameters are optimized to reach the best electromagnetic properties, with a small size (30 mm × 39 mm) and a simple geometry. Its electromagnetic parameters are calculated by CST and HFSS software's. The obtained results show that the proposed antenna operates in the UWB band from 3.6 GHz to 44 GHz. The gain is relatively high (above 3 dB in the entire frequency band) and the antenna has an acceptable quasi-omnidirectional radiation pattern.

Keywords: *metamaterial, SRR, antenna, UWB.*

1. Introduction

Recently, a greet interest is given to study of metamaterials in different domains. Metamaterials (MTM) are artificial materials engineered to have properties that may not be found in nature. In 1967, these materials are initially discovered by Victor Veselago [1], but this design cannot be applied in practical application for the next three decades. In 2001, Smith et al. demonstrated, for the first time, the experimental existence of metamaterials [2], their design depends on the works of Pendry which demonstrate that materials with an array of split-ring resonators (SRRs) produce negative permeability over some frequency bands. Combining a two-dimensional (2D) array of SRRs with a 2D array of metallic wires enabled the construction of left-handed materials that exhibit simultaneously negative permittivity and permeability [3].

Owing to the special electromagnetic wave response, particularly in resonant behavior, the SRR has received great attention in the design of antennas, in recent years. Various special circuits have been widely developed [4-7]. For example, to improve the radiation properties, the split ring resonator (SRR) is loaded in antenna [8, 9]. Kim et al. have used SRR to create a reject band in UWB antenna [10]. Furthermore, several researches have validated that the SRR behaves as an electronically small resonator with high quality factor and small electrical size [11-13], so its resonant property may be very useful for constructing ultra-wideband antenna with high-gain.

2. Antenna Configuration

According to the analysis of Marques and al., when an electromagnetic wave polarized in the x-axis propagates in the z-direction, shown as the system of co-ordinates in Fig. 1, an electro-motive force will occur around the SRR [11 , 12] , and the induced current lines can pass from one ring to the other through the capacitive gaps between the two rings. As a result of the total current intensity flowing on both rings, the SRR behaves as an LC circuit.

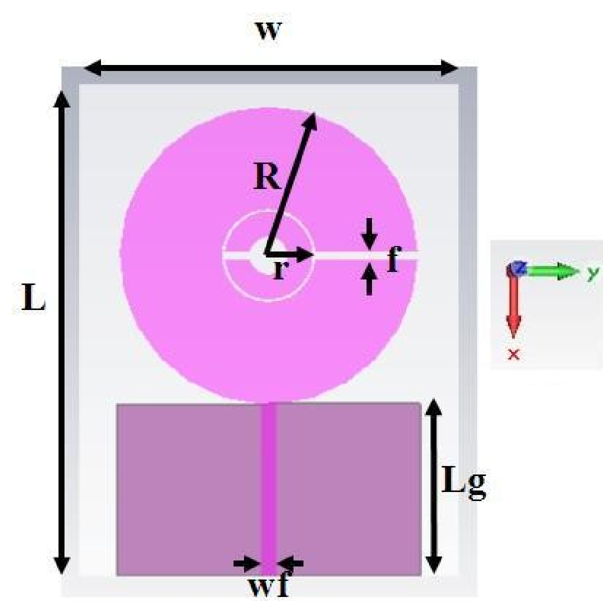


Fig.1 Proposed antenna with SRR.

The proposed antenna is constructed by two concentric rings which have an outer radius R (outer ring) and r (inner ring), with a slot in the two rings of a dimension f. The SRR is connected to a microstrip line (with a width Wf), this line is optimized to be adapted to the feeding port 50 Ω. The substrate (L * W) is on Rogers RT / duroid 5880 with a permittivity εr = 2.2, tan δ = 0.09. The thickness of the substrate is 0.43mm. The ground plane ((W-2*Wg)*Lg) is made on the other side of the substrate which is partly covered. The design of the proposed antenna is shown in Fig. 1.

The optimized values of the geometric parameters are given in Table 1.

Table 1: Margin specifications

Parameters	Dimensions
L	39 mm
W	30 mm
f	0.3mm
Lg	13.66 mm
wf	1.2 mm
R	11.83 mm
r	3.5 mm

3. Simulation and Result

The proposed antenna is simulated by two software tools. The first is High Frequency Structure Simulator (HFSS) which uses the finite element method. The second is Computer Simulation Technology (CST), which uses the finite integration technique.

In Figures 2, we represent the variations of the reflection coefficient as a function of frequency with HFSS and CST.

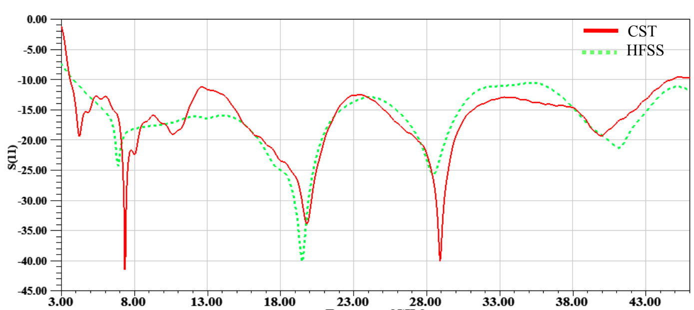


Fig.2. Return loss of the antenna.

Using HFSS, the bandwidth is between 3.96 GHz and 43.22 GHz, three main minimum are observed for the reflection coefficient S11 reaching the values :-22.44 dB, -51.6 dB, -41.78 dB respectively at the following frequencies : 6.96 GHz, 19.9 GHz and 28.8 GHz. With CST, the bandwidth obtained is between 3.6 GHz and 44.57 GHz, three main minimum are observed for the reflection coefficient S11 reach the values :-41.53 dB, -33.9 dB and -40.02 dB respectively at the following frequencies :7.35 GHz, 19.8 GHz and 28.9 GHz.

A good agreement is observed between the two simulation results, with a light difference, it may be due to the difference in methods used by simulators.

In Figure 3, we show the variation of gain as a function of frequency ranging from 5 GHz to 45GHz

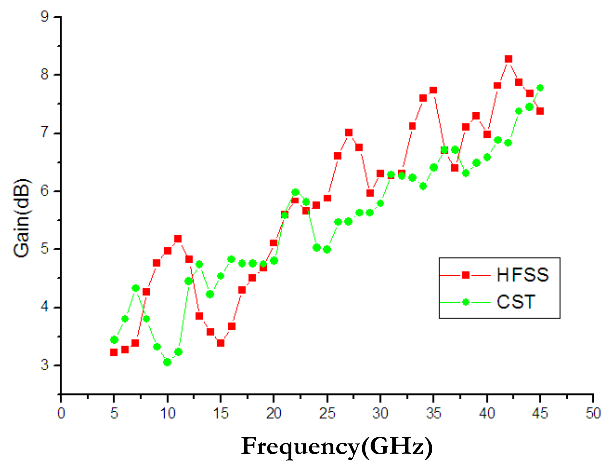
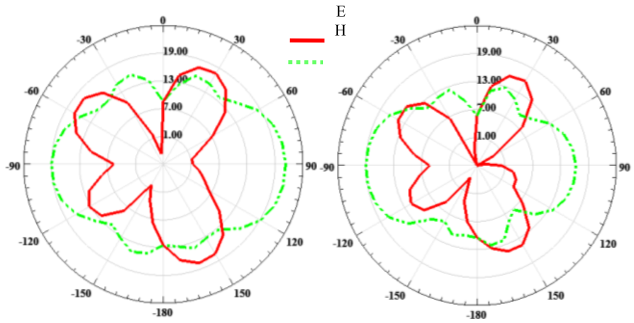


Fig.3. Gain variations.

The gain is always greater than 3.06 dB across the full impedance bandwidth, with a maximum value of 8.27 dB, it indicates that the antenna design is suitable for use in UWB systems.

To study the antenna radiation patterns, two principle planes were selected. These are referred to as the x-z plane (H-plane) and the y-z plane (E-plane). The results showed in figure 4 and figure 5 reveal that the antenna provides an acceptable quasi-omnidirectional radiation pattern suitable for receiving signals from all directions.

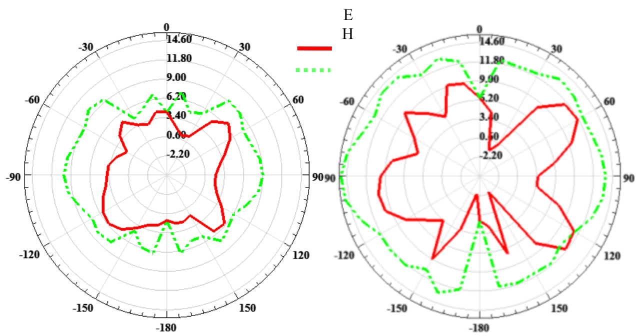
Figure 4 show the radiation pattern (E and H field) at 20 GHz with HFSS and CST.



(a) (b)

Fig.4 Radiation pattern (E and H field) at the frequency 20 GHz
(a) HFSS and (b) CST.

Figure 5 show the radiation pattern (E and H field) at 30 GHz with HFSS and CST.



(a) (b)

Fig.5 Radiation pattern (E and H field) at the frequency 30 GHz
(a) HFSS and (b) CST.

4. Conclusions

The UWB antenna using the split ring resonator has been designed and investigated. The geometrical parameters are optimized to attain the best electromagnetic properties. The antenna operates in a frequency band of 40 GHz (HFSS), 41.1 GHz (CST) with a good adaptation and relatively a high gain which reaches 8.27 dB and 7.79 dB at 42 GHz, 44 GHz for HFSS and CST respectively. The antenna has a quasi-omnidirectional radiation pattern, the antenna has a small size and a simple geometry, therefore low cost and a simple geometry. Thus, it is an attractive candidate for UWB communications applications.

References

[1] Veselago, V.G., "The Electrodynamics of Substances with Simultaneously Negative Values of permittivity and permeability", Soviet Physics USPEKI, Vol. 10, No. 4, 1968, pp. 509-514.

[2] D.R. Smith, W.J. Padilla, D.C. Vier, S.C. Nemat-Nasser, and S. Schultz, "Composite media with simultaneously negative permeability and permittivity", Phys Rev Lett 84 ,2001,pp. 4184–4187.

[3] Pendry, J.B., et al. "Magnetism from conductors and enhanced nonlinear phenomena", IEEE Trans. Microw. Theory Tech., Vol. 47, 1999, pp. 2075–2084.

[4] Chen, J. P., and Hsu, P. "A compact strip dipole coupled split-ring resonator antenna for RFID tags". IEEE Transactions on Antennas and Propagation, Vol. 61, 2013, pp. 5372–5376.

[5] Lihao, H., Huiling, Z., Zhang, H.,Quanming, C. "Reduction of mutual coupling between closely-packed antenna elements with split ring resonator (SRR)".International Conference on Microwave and Millimeter Wave Technology, ICMMT, 2010 ,pp. 1873–1875.

[6] Wang, L., Yuan, M. Q., and Liu, Q. H. "A dual-band printed electrically small antenna covered by two capacitive split-ring resonators". IEEE Antennas and Wireless Propagation Letters, Vol. 10, 2011, pp. 824–826.

[7] Gheethan, A. A., Herzig, P. A., and Mumcu, G. "Compact 2 x 2 coupled double loop GPS antenna array loaded with broadside coupled split ring resonators". IEEE Transactions on Antennas and Propagation, Vol. 61, 2013, pp. 3000–3008.

[8] Cao, W., Zhang, B., Liu, A., Yu, T., Guo, D., and Wei, Y. "Gain enhancement for broadband periodic endfire antenna by using split-ring resonator structures". IEEE Transactions on Antennas and Propagation, Vol. 60, 2012, pp. 3513–3516.

[9] Alici, K. B., and Ozbay, E. "Radiation properties of a split ring resonator and monopole composite". In Physica Status Solidi (B) Basic Research, Vol. 244, 2007, pp. 1192–1196.

[10] Kim, D. O., N. I. Jo, D. M. Choi, and C. Y. Kim, "Design of the ultra-wideband antenna with 5.2 GHz/5.8 GHz band rejection using rectangular split-ring resonators (SRRs) loading", Journal of Electromagnetic Waves and Applications, Vol. 23, No. 17-18, 2009, pp. 2503-2512.

[11] R. Marqués, F. Medina, and R. Raffi El Idrissi, "Role of bi-anisotropy in negative permeability and left handed metamaterials", Physical Review B, Vol. 65, No. 14, 2002, pp. 144440 (1)–144440 (6).

[12] Marqués, R., et al, "Comparative analysis of edge- and broad side coupled split ring resonators for metamaterial design - theory and experiments", IEEE Trans. Antennas Propag.,Vol. 51, 2003,pp. 2572-2581.

[13] Miguel D.S., Jordi N.i, Ferran P., Jordi B. and Ferran M. "Electrically Small Resonators for Planar Metamaterial, Microwave Circuit and Antenna Design: A Comparative Analysis", Appl. Sci., Vol. 2, 2012, pp. 375-395.