A High Gain Broadband Antenna Array Based on Metamaterial Split Ring Resonator (SRR) Reflector

Yacine BOUSSAADIA[1], Mohamed TELLACHE[1], Abderrahmen BELOUNIS[2], Mourad DRIF[1], Fayçal AMRANI[1].

[1]Affiliation of Laboratory of Instrumentation (LINS) Faculty of Electrical Engineering, University of Science and Technology Houari Boumediene Algiers, Algeria.

[2]Laboratoire de robotique parallélisme et systèmes embarqué (LRPE), Université des Sciences et de la Technologie Houari Boumediene Algiers, Algeria.

E-mail : yacineboussaadia19@gmail.com

Abstract – In this work, a broadband antenna array operating from 2.86 to 4.3 GHz was developed and designed. In order to improve its radiation properties, a split ring resonator (SRR) metamaterial was used as a reflector for the proposed antenna array. The simulations show a good result, especially in terms of gain along the bandwidth of the proposed antenna array, where its gain reached 8.66 dBi, which increased with 5.92 dBi, and the directivity reached 9.83 dBi, which enhanced with 6.36 dBi at frequency 3.5 GHz. The simulation results also showed a noticeable improvement in terms of bandwidth, as the antenna bandwidth expanded by 27 % GHz when the reflector was integrated, and it began to operate on the range of 2.75 to 4.58 GHz.

Keywords - Metamaterial, SRR reflector, broadband antenna array, high gain.

I. INTRODUCTION

During the last decades, wireless applications have received great interest from researchers due to the large demand for wireless electronic devices such as phones and computers. The antenna is a very important element in these devices, it is the element responsible for transmitting and receiving signals wirelessly.

Patch antennas are the most widely used in modern wireless electronic devices due to their advantages compared to others. Among its advantages it is mechanically robust, compact, and easy to be analysed and designed [1]. These antennas are very popular and there is such an interesting improvement researches for its performance and radiation characteristics [2-4].

Among the undesirable drawbacks of patch antennas is that they provide low radiation power and low gain [1]. The application of split ring resonator (SRR) metamaterial reflector on antennas provides a good solution in order to increase the gain and improve antenna performance. The radiation characteristics of a dual-band patch antenna operating in 2.4 GHz and 5.8 GHz bands have been improved based on frequency selective surfaces (FSS) in [5]. In [6]

The gain of a circularly polarized broadband antenna is improved using non-uniform metamaterial (NUM) reflector. In [7] the gain is enhanced and the bandwidth is expanded for the patch antenna using a band-stop FSS reflector. An artificial magnetic conductor (AMC) and frequency selective surfaces (FSS) was used to improve the radiation characteristics of a dual-band monopole antenna that operates in the WiMAX (3.5 GHz) and WLAN (5.8 GHz) bands in [8].

In this paper, a broadband patch antenna array was developed using split ring resonator (SRR) metamaterial reflector to improve its radiation characteristics.

This work organized as. Section 2 presents the design of the proposed antenna array and split ring resonator (SRR) metamaterial. The simulation results and their analysis are presented in section 3. Finally, conclusions are drawn in section 4.

II. DESIGN AND DEVELOPMENT OF A BROADBAND ANTENNA ARRAY AND SRR METAMATERIAL REFLECTOR

In this work, a broadband circular patch antenna array 1x2 was designed. The impedance matching between the radiating element and the feed line was improved using the inset feed technique as shown in Fig.1. In order to expand the bandwidth, the length of the ground plane was reduced as presented in [7]. The dimensions of this antenna have been optimized to operate in the frequency band from 2.86 to 4.3 GHz.

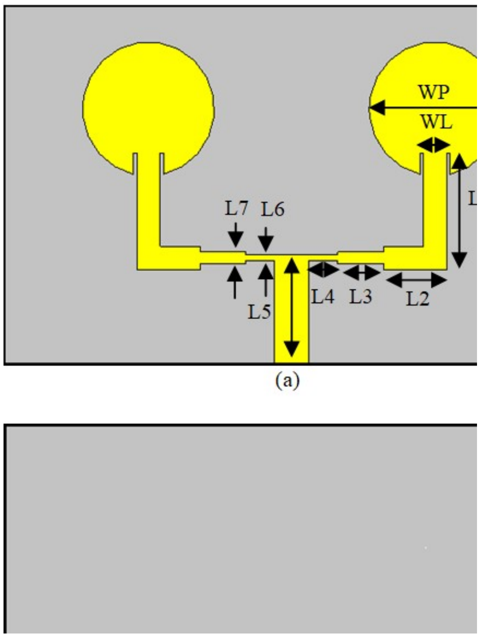


Fig. 1. Antenna array structure; (a) Top view; (b) Bottom view.

In order to improve the gain and radiating characteristics of the proposed antenna array, we proposed adding an (SRR) metamaterial reflector. Fig.2 shows the structure of the band-stop (SRR) metamaterial reflector, where its dimensions have been optimized to work well in the desired frequency range 2.8 to 4.1 GHz. FR-4 substrate with permittivity of 4.3, loss-tangent of 0.025 and thickness of H = 1,6 mm was used to manufacture the antenna array and the (SRR) metamaterial reflector.

TABLE 1. DIMENSIONS OF THE ANTENNA ARRAY AND THE REFLECTOR.

dimension	WP	WL	L1	L2	L3	d	L7
Value (mm)	23	2.6	10	5.5	4	21.4	1
dimension	L4	L5	X1	X2	W	WG	L6
Value (mm)	2.5	9.25	2	0.72	17.55	9	0.5

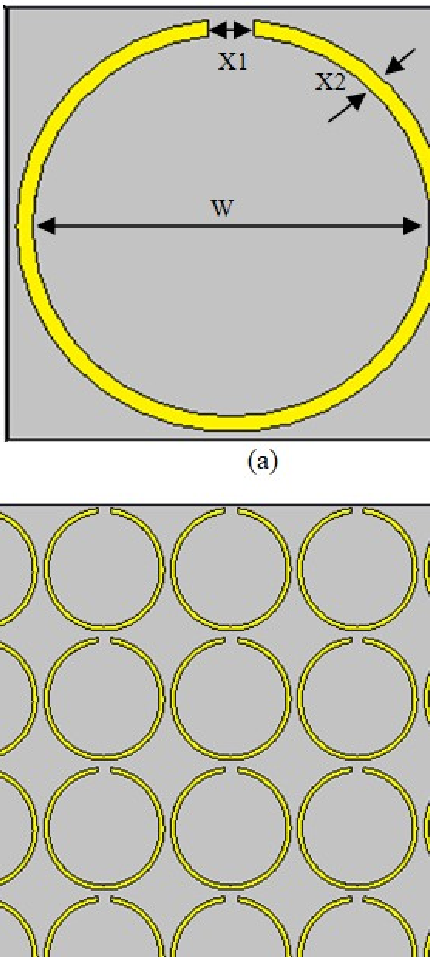


Fig. 2. SRR structure; (a) SRR unit cell. (b) SRR reflector.

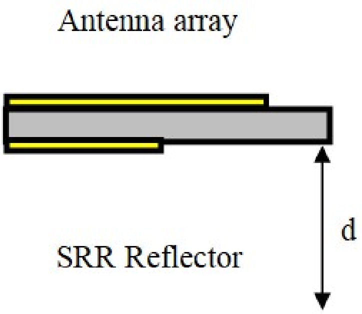


Fig. 3. Proposed antenna array with SRR reflector.

The dimensions of the antenna array and reflector are shown in Table 1. The reflector is placed behind the antenna as shown in Fig.3, the separation distance about the two is 21.4 mm.

III. RESULTS ANALYSIS

In order to evaluate the performance of the proposed antenna array and reflector, a Microwave CST Simulator was used.

The simulated results for the transmission coefficient of the SRR metamaterial reflector shown in Fig.4 prove that the SRR reflector works well in the desired frequency range from 2.86 to 4.3 GHz, with a resonant frequency of 3.5 GHz.

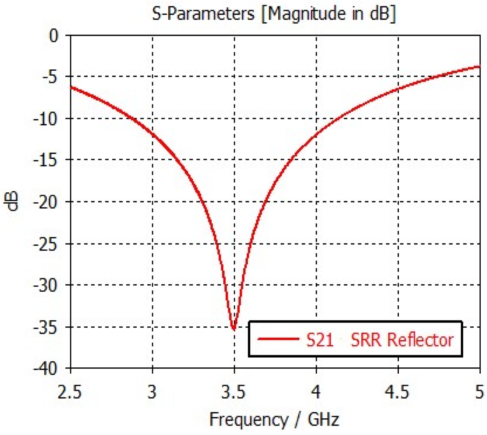


Fig. 4. Transmission coefficient of the SRR reflector.

Fig. 5 illustrates the antenna's simulated reflection coefficient with and without the SRR metamaterial reflector, it shows that the proposed antenna array works well in the frequency band from 2.86 to 4.3 GHz without reflector. And when adding the reflector, the bandwidth has increased with 0.39 GHz works in the frequency band from 2.75 to 4.58 GHz.

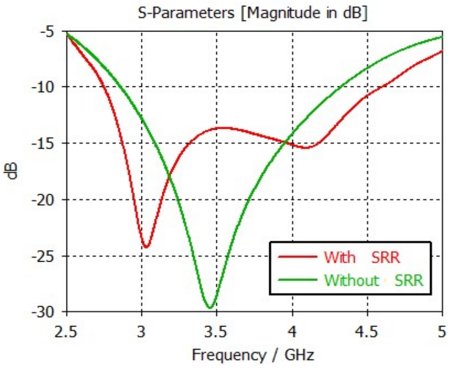


Fig. 5. Reflection coefficients of the antenna array without and with.

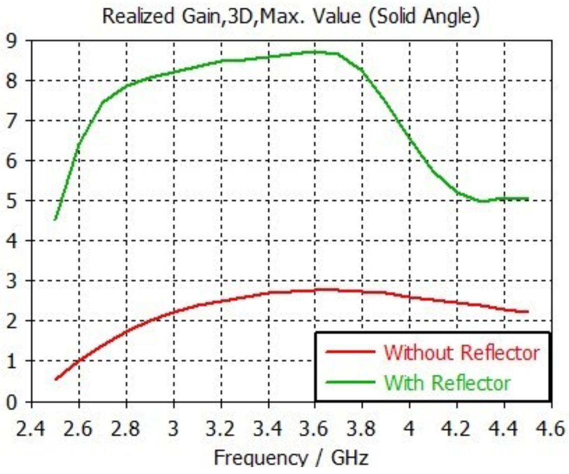
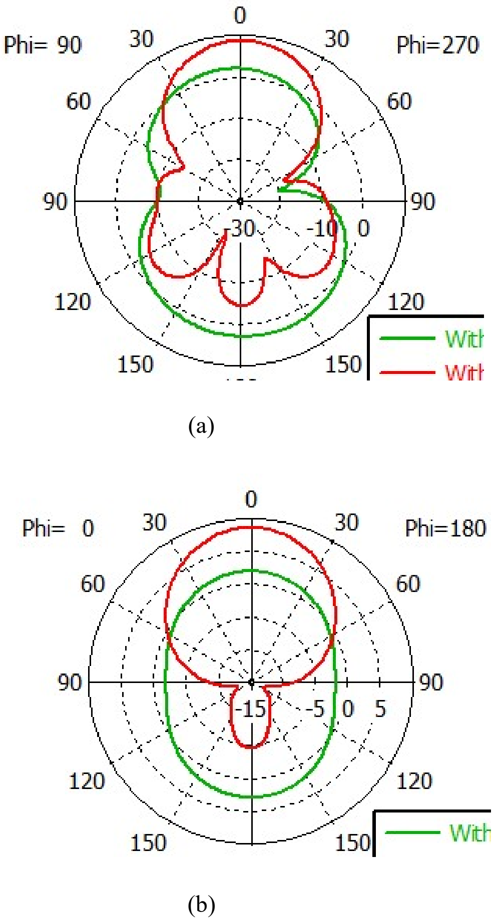


Fig. 6. Realized gain of the antenna array with and without the reflector.



(a)

(b)

Fig. 7. Radiation patterns of the antenna array without and with reflector at 3.5 GHz; (a) E-Plane. (b) H-Plane.

The simulated gain results of the antenna with and without SRR reflector is depicted in Fig.6. These results prove that the proposed structure provides high gain in the desired frequency range after adding the reflector, as the gain reached 8.66 dBi at frequency 3.5 GHz.

Fig.7 shows the simulated radiation patterns of the antenna with and without reflector at the frequency 3.5 GHz. From these results, we notice that the back lobes were significantly reduced after adding the reflector.

At the frequency 3.5 GHz, Table 2 compares the bandwidth, directivity, and gain of the antennas with and without SRR reflector.

TABLE 2. COMPARISON OF RADIATION PARAMETERS OBTAINED FROM SIMULATION.

Antenna	**Without Reflector**	**With Reflector**
frequency	3.5 GHz	3.5 GHz
Gain	2.74 dBi	8.66 dBi
directivity	3.47 dBi	9.83 dBi
bandwidth	2.86-4.3 GHz	2.75-4.58 GHz

IV. CONCLUSION

This paper presents the design of a broadband antenna array operating in the frequency range from 2.86 to 4.3 GHz. A reflector was designed based on the split ring resonator (SRR) metamaterial. When the antenna array was combined with the reflector, a significant improvement was observed in its performance, especially in terms of gain and directivity, as the gain reached 8.66 dBi and the directivity reached 9.83 dBi at the frequency of 3.5 GHz. Also, the frequency band, has expanded by 0.39 GHz and the antenna began to operate in the range from 2.75 to 4.58 GHz.

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