Study of meander dipole antenna coupled with magnetic metamaterial cells for UHF RFID system

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ABSTRACT

In this paper, the impact of associating Split Ring Resonator (SRR) cells with meander dipole antenna is investigated. The antenna loaded with SRRs exhibits a shifting down of the resonance frequency from 1.97 GHz to 0.866 GHz, a broadband width of 11.16% ranging from 0.830GHz to 0.933 GHz and realized gain about 4.44 dB. The volume size is 0.17λ×0.17λ×0.023λ. Hence, the SRR cells are a good candidate for miniaturization. The simulation was performed in 3D EM simulation of high-frequency components CST.

KEYWORDS

SRR, meander dipole antenna, UHF band, RFID system.

1 INTRODUCTION

Nowadays, several types of research are becoming interested in the difficult choice between the sizes and operating frequency for Ultra High Frequency (UHF) applications, they are also interesting for the use of a small printed antenna for many applications such as telecommunication, communication systems and Radio Frequency Identification (RFID) system [1, 2]. For that, the meander antennas [3] have been widely used and applied since the concept was introduced by Rashed and Tai [4, 5]. The RFID system in the UHF band becomes more attractive in several service industries, purchasing, manufacturing company and material flow systems [6].

The UHF RFID systems are used in different regions of the world (e.g.866-869 MHz in Europe, 840.5-844.5 MHz and 920.5-924.5 in China, 856-867 MHz in India, 908.5-914 MHz in Korea, 865-868 MHz and 920-925 MHz in Hong Kong, 920-926 MHz in Australia) [7].

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The problem of this band is the need of a large antenna which led researchers to find a solution to reduce the size while maintaining its performance. It exists many methods of minimizing the size of the antenna such as the use of short circuit PIFA [8,9], slot antenna [10-12], fractal shapes [13], meander antenna, and metamaterials [14-16] to decrease the resonance frequency and keep the performance of the antenna. SRR gave the best results for miniaturization, it is introduced by Pendry et al. in 1999 [17], to exhibit a resonance frequency (866 MHz) and to give the best result in terms gain and efficiency. This work treats the influence of the SRR cells of the meander dipole antenna by the simulation. The present paper falls into two parts: At the first section, the physical and design for the structure alone are presented and simulated. The second section shows the simulation for the resulting antenna presenting the return loss, the realized gain, radiation pattern and the effects of the location and the number of cells for this antenna.

2 DESIGN OF THE MEANDER DIPOLE ANTENNA

2.1 Meander dipole antenna without SRR

The basic structure consists of a meander antenna printed on FR4 substrate (ε_r=4.4, h=0.8mm and tang$\delta = 0.025$). The dimensions of the meander dipole antenna are shown in Fig.1 and the Table 1 simulated frequency, realized gain and radiation pattern are respectively shown in Fig 2, 3 and 4.

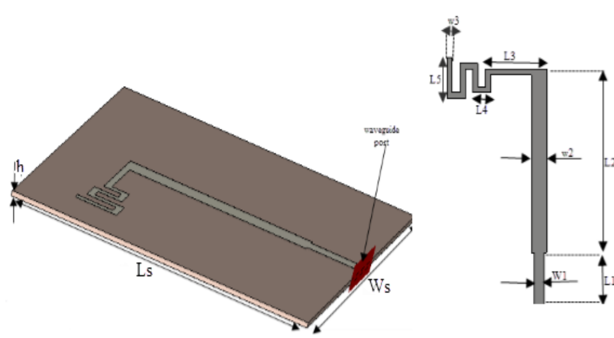

Figure 1: Geometries of the meander dipole antenna.

Table 1: Dimensions of the meander dipole antenna

W1	2 mm
W2	3 mm
W3	1 mm
L1	9 mm
L2	31 mm
L3	12 mm
L4	1.5 mm
L5	7 mm
Ls	60 mm
Ws	60 mm
h	0.8 mm

Table 1 summarized the dimensions of the antenna without SRR.

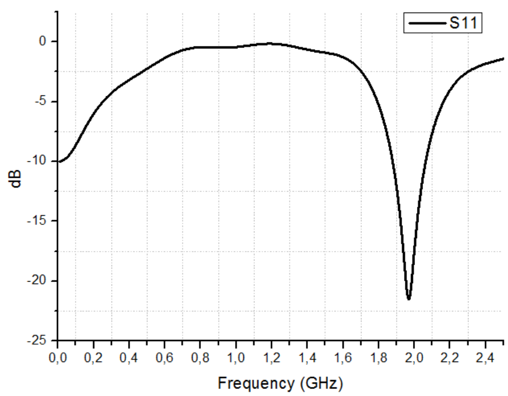

Figure 2: Reflection coefficient of the antenna without SRR.

Fig. 2. Shows the return loss of the meander dipole antenna without SRR. The resonance frequency is 1.97 GHz with frequency ranging from 1.89 GHz to 2.04 GHz.

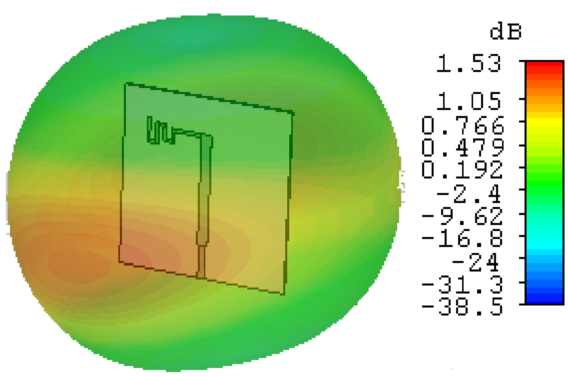

Figure 3: Realized gain of the antenna without SRR.

This figure presents that the realized gain of the meander dipole antenna without SRR at 1.97 GHz is 1.53 dB.

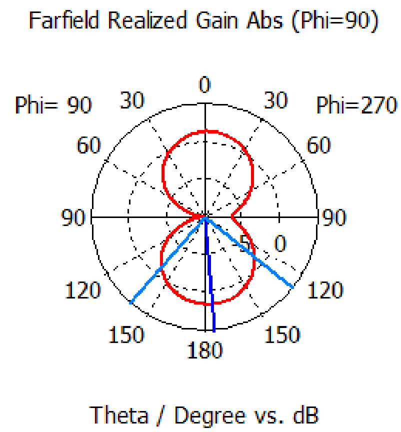

Figure 4: Radiation pattern of the antenna alone in plane E.

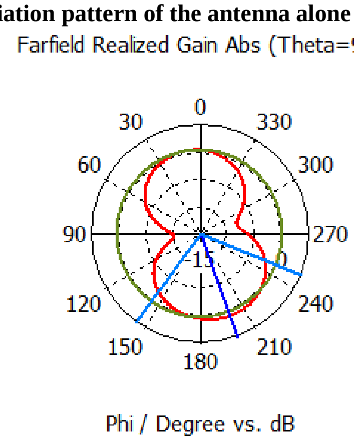

Figure 5: Radiation pattern of the antenna alone in plane H.

Figs. 4 and 5 show the simulated radiation pattern of the antenna without SRR in plane E and Plane H respectively. We can notice that the simulated 3dB beam width for this antenna is 93° and 103.4° at plane E and H, respectively.

2.2 The meander dipole antenna with SRR cells:

There is still a problem occurs by the surface waves and leakage waves that limit the performance of the antenna. To decrease the resonance frequency and to increase the gain of the antenna, the use of SRR cells is the right solution to overcome this limitation and to achieve the European UHF band (866-869 MHz). The association of the SRR cells serves to reduce the resonance frequency, to modify the radiation pattern by focusing the energy in one direction. The proposed antenna in this paper shown in Fig. 6 has a meander dipole antenna. This antenna is integrated on an FR4 substrate 60×60×0.8 mm, then added with two SRR cells of external dimensions 25×25mm. The distance between the SRR cells and the meander dipole antenna is 0.2mm. The resulting antenna is working at a frequency of 0.866 GHz. The dimensions of SRR cells and the antenna design are depicted in Fig. 6.

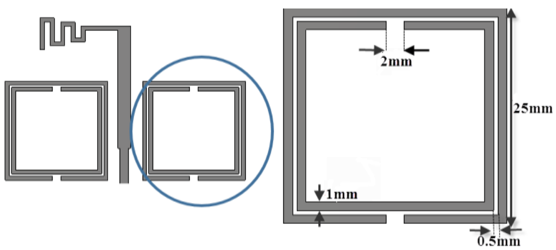

Figure 6: The resulting antenna design

The proposed antenna with SRR cells exhibited better results in terms of return loss, with -17 dB against -22dB, diminution of the resonance frequency in 800 MHz. The S11 parameters for two designs are shown in Fig. 7.

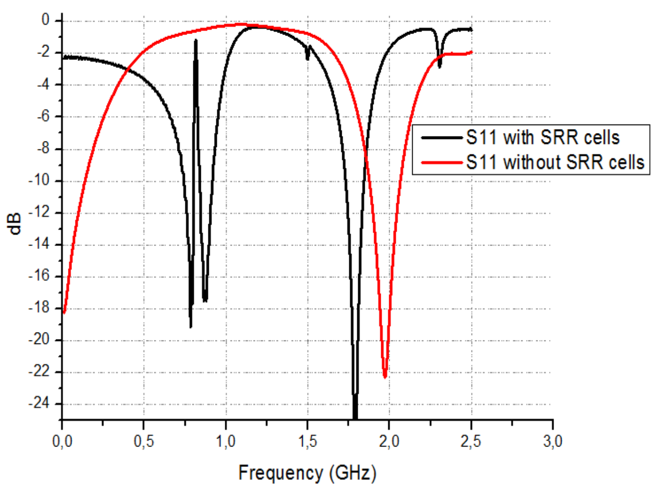

Figure 7: The Reflection coefficient of the antenna with and without SRR cells.

Fig. 7 presents the impact of SRR cells of the resonance frequency from 1.97 GHz to the desired frequency 0.866 GHz, i.e. a decrease about 1.094 GHz. Hence, we concluded that the resonance frequency is reduced by 44% when compared with the original design having a frequency bandwidth of 800 MHz. we can notice also the introducing of SRR cells of the proposed antenna allows to create several resonance frequencies.

To understand the performance of a number of cells, we examined the effects on the realized gain when varying the number of SRR cells. The simulation of the realized gain for one or two cells are presented in Figs.8 and 9.

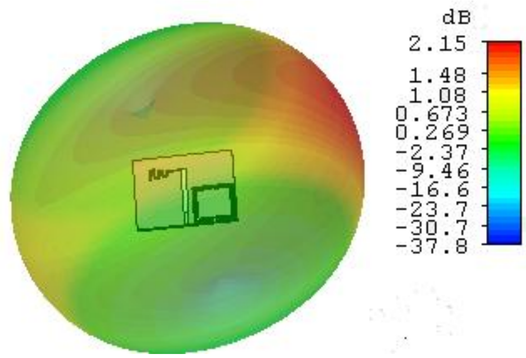

Figure 8: The realized gain of the antenna with one SRR cells.

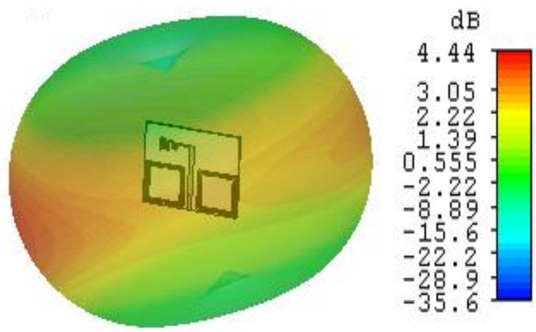

Figure 9: The realized gain of the antenna with two SRR cells.

Figs. 8 and 9 show that the antenna with two SRR cells exhibits the better results in term of gain with a simulated gain of about 4.44 dB at 0.866 GHz. while the antenna with one SRR cell is about 2.15 dB.

To better understand the effect of the location of the SRR cells on the realized gain, The SRRs were placed on the same side as shown in fig 10 and 11.

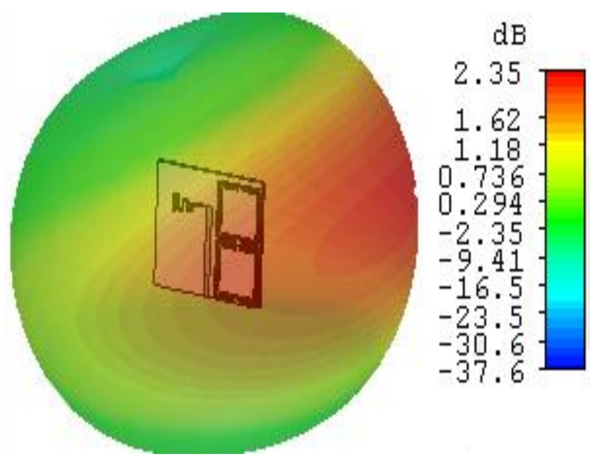

Figure 10: The realized gain of the antenna with two SRR cells.

The figure 10 shows that the realized gain of the proposed antenna with Two SRR cells placed in the same side is about 2.35 dB at 0.866 GHz.

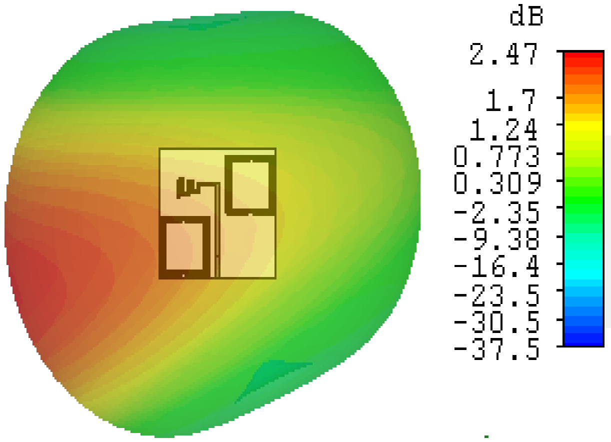

Figure 11: The realized gain of the proposed antenna at 0.866 GHz.

The figure 11 shows that the realized gain of the proposed antenna at 0.866 GHz is about 2.47 dB. The two SRR cells were placed at opposite corners along the diagonal line of the antenna.

We can notice that the better place of the SRR cells is shown in figure 9 i.e. when the SRR were placed around the feed line of the antenna.

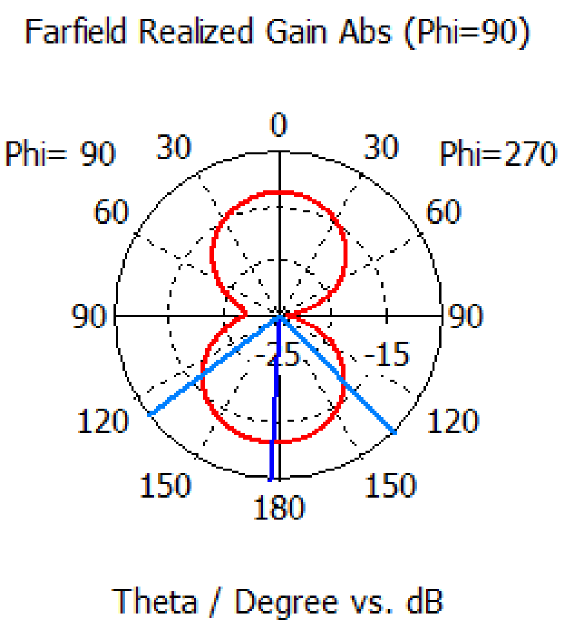

Figure 12: Simulated radiation pattern in E plan at 866 MHz.

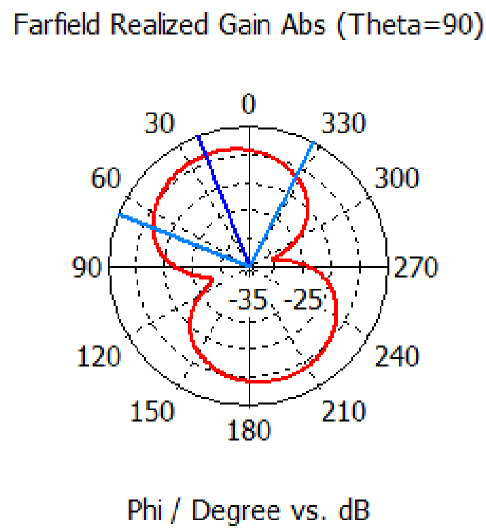

Figure 13: Simulated radiation pattern in H plane at 866 MHz.

Figs 12 and 13 present the radiation pattern of the resulting antenna in plane E and H respectively comparing with the antenna alone. The beam width in 3dB is increased by the presence of two SRR cells, from 103.4° to 95.1° in plane H. The diagrams of the resulting antenna become more directive compared to the alone antenna.

Table 2: Summarized table of the antenna without and with SRR cells

	Without SRR cells	With SRR cells
f_r (GHz)	1.97	0.866
R_l (dB)	-22	-17.5
fmin (GHz)	1.89	0.83
fmax (GHz)	2.04	0.933
BW (MHz)	150	100
Gain (dB)	1.53	4.4
Directivity (dBi)	3.1	5.8
Efficiency (%)	49	75

Table 2 summarizes the results of the antenna with and without SRR cells in terms of the resonance frequency, Return loss, bandwidth, Gain, Directivity and the efficiency. These results provide the effect of SRR cells of the meander dipole antenna.

3 CONCLUSION

In summary, A small antenna with a gain about 4.4 dB at 0.866 GHz was proposed. Two SRR cells are coupled with meander dipole antenna to achieve the UHF band, in particular, the resonance frequency f_r=0.866 and to improve the antenna's gain. The global size of this antenna is 60×60×0.8 mm. The effect of adding one or two SRR cells to this antenna and the effect of the location of the SRR cells are discussed. The simulation results obtained with the CST software. As the perspective, we will carry out the measurements of this antenna in order to validate the results of simulation as well as to fix an application in the UHF RFID system.

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