Miniaturized patch Antennas with complementary split-ring Resonators and reactive impedance surface.

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Abstract—the new design of patch antenna with complementary split-ring resonators (CSRRs) and reactive impedance surface (RIS) is presented in this paper. The meta-resonator (CSRRs) and the meta-surface are able to miniaturize the antenna size. This antenna is designed, including a circularly-polarized antenna.

Key words: Microstrip antenna , split-ring resonator (SRR), miniaturized antenna reactive-impedance surface (RIS), circular polarization .

I. INTRODUCTION

Now the metamaterials have been a field of intense research activity. Use of metamaterials for antennas is one of the most important applications currently being investigated, including both the resonant-type small antennas and the transmission-line type leaky-wave antennas [1]-[2]. Split-ring resonator (SRR) and its dual, complementary split-ring resonator (CSRR), have been the popular resonators which are widely used to synthesize metamaterials [3], [4]-[5]. This paper presents a comprehensive investigation into the patch antennas loaded by CSRRs over an RIS based on some preliminary research shown in [6]. The CSRR is embedded on the top surface as a high-quality factor resonator which can couple the field to the antenna patch and make it radiate. As a dipole it essentially generates wave propagating along the plane of ring surface and relies on the edges of patch for radiation. The coupling between the CSRR and patch

mainly comes from the capacitive coupling through the ring slot and the magnetic coupling through the split of the outer ring. By properly feeding the antenna, the inherent half-wavelength patch resonant mode can still be well excited. It is interesting to note that the interaction between the CSRR-inspired resonance and the patch resonance is very weak when they are orthogonally polarized. Under this condition circular polarization (CP) is attainable when they share the same operating frequency with a 90° phase delay in excitation.

II. STRUCTURES OF RECTANGULAR PATCH ANTENNAS

The proposed antenna shows advantages in terms of compact size, low fabrication cost, low-cross polarization level. The antenna is shown in Fig.1 with the geometrical parameters are: $a_1 = 5$ mm, $a_2 = 5.68$ mm, $h_1 = 0.4$ mm, $h_2 = 2.6$ mm, $s_1 = 4.9$ mm, $l_2 = 12.4$ mm, $w_2 = 19.2$ mm, $l_1 = 34$ mm, $w_1 = 34$ mm.

Fig.1: Configuration of the rectangular patch antenna with the reactive impedance surface.

The RIS, which is composed of a periodic array of metallic square patches printed on a metal-backed dielectric substrate, is introduced below the top surface. It is a three-layer structure where the top and bottom dielectric substrate is “MEGTRON 6” with a relative permittivity of 4.02 and a measured loss tangent of 0.009 at 5.9 GHz.

Fig.2: Simulated reflection coefficients $|S_{11}|$.

An inductive RIS is able to store the magnetic energy which thus increases the inductance of the circuit. There-fore, it can be used to miniaturize the size of a patch type antenna which is essentially an RLC parallel resonator. At the same time it is shown in [7] the inductive RIS is also able to provide a wider matching bandwidth therefore it is more suitable for antenna application.

Fig.3: Matching impedance for rectangular patch antenna with reactive impedance surface.

Fig.4: simulated far-field patterns in 3D.

III. PATCH ANTENNA LOADED WITH CSRRS AND RIS.

In this section, the characters of the CSRR-loaded patch antenna over an RIS will be investigated and discussed in de-tail using an antenna model loaded with two CSRRs which are face-to-back oriented. An equivalent circuit for the proposed structure is derived to gain an insight into the working principle. The design of CSRRs is summarized. The features and influence of the RIS is also presented. It is noted that the major results presented in this section have already been published in [8].

Fig.5. (a) topology and (b) its equivalent circuit model of the CSRR.

Fig. 6 shows the geometrical layout of the proposed antenna with two CSRRs face-to-back oriented with respect to the direction of the ring split. This configuration is chosen here since it is simpler than the side-by-side configuration which will be discussed later. A coaxial probe-feeding is utilized and placed in the center of the microstrip patch. Due to this center feeding no patch resonances can be excited.

Fig.6.configuration of the proposed CSRR-loaded patch antenna over an RIS.

It would be helpful to know the characters and design methodology for the CSRRs while designing the proposed CSRR-loaded patch antennas. The

CSRR can be represented by an LC resonator tank as shown in Fig. 5 when the loss is neglected. Its inherent resonance frequency is determined by

$$f_0 = \frac{1}{2\pi\sqrt{L_r C_r}} \quad (1)$$

Where the capacitance of the CSRR is approximately equal to that corresponding to a metallic disk surrounded and backed by the ground plane.

Fig.7. Simulated reflection coefficients |S11|.

Fig.8: Matching impedance of the proposed CSRR-loaded patch antenna over an RIS.

Fig.9: simulated far-field patterns in 3D.

The coupling is through both the electric and magnetic couplings. Since the orientation of the CSRR coincides with the patch antenna polarization

plane, which facilitates the interaction between them, the coupling is substantially enhanced.

Fig.10. simulated electric field distribution at the resonance frequencies.

The simulated radiation pattern at this frequency indicates that this first resonance is also polarized in circular. The electric field distribution at the resonance frequencies is shown in Fig. 10 when the maximum electric field is localized in the patch rectangular. The Fig. 7 is presented the reflection coefficient |S11| at the frequency 2.52 GHz and the matching impedance for the antenna is shown in Fig. 8.

IV. CONCLUSIONS

A comprehensive study on the CSRR-loaded patch antennas over an RIS has been presented in this paper. The employment of the meta-resonator and the meta-surface enables the antenna miniaturization. These antennas can be designed to perform specified functions, such as the circularly-polarized radiation. The antenna radiation characteristics can be easily controlled by changing the configuration of the CSRRs. Wide-band operation by combining different resonances is also feasible, which is under our current investigation.

[1] C. Caloz and T. Itoh, *Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications*. New York: Wiley-IEEE Press, 2005.

[2] H. R. Stuart and A. Pidwerbetsky, "Electrically small antenna elements using negative permittivity

resonators,"IEEE Trans. Antennas Propag., vol. 54, no. 6, pp. 1644–1653, Jun. 2006.

[3] R. Marques, F. Martin, and M. Sorolla, *Metamaterials With Negative Parameters: Theory, Design and Microwave Applications*. New York: Wiley, 2008.

[4] F. Falcone, T. Lopetegi, J. D. Baena, R. Marques, F. Martin, and M. Sorolla, "Effective negative-epsilon stopband microstrip lines based on complementary split ring resonators," IEEE Microw. Wireless Compon. Lett., vol. 14, no. 14, pp. 280–282, Jun. 2004.

[5] J. Bonache, I. Gil, J. Garcia, and F. Martin, "Complementary split ring resonators for microstrip diplexer design," Electron. Lett., vol. 41, no. 14, Jul. 2005.

[6] Y. Dong and T. Itoh, "Miniaturized patch antenna loaded with complementary split-ring resonators and reactive impedance surface," in Proc. Eur. Conf. Antennas Propag. 2011 (Eucap 2011), Rome, Apr. 2011, submitted for publication.

[7] H. Mosallaei and K. Sarabandi, "Antenna miniaturization and band-width enhancement using a reactive impedance substrate," IEEE Trans. Antennas Propag., vol. 52, no. 9, pp. 2403–2414, Jun. 2004.

[8] Y. Dong and T. Itoh, "Miniaturized patch antenna loaded with complementary split-ring resonators and reactive impedance surface," in Proc. Eur. Conf. Antennas Propag. 2011 (Eucap 2011), Rome, Apr. 2011, submitted for publication.