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A design of multi-band antenna based on active metamaterials

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ABSTRACT

A design of multi-band antenna based on active meta-materials is presented in this paper. The proposed structure consists of monopole antenna integrated with active rectangular complementary split ring resonator (CSRR). The simulations are performed by electromagnetic software where dimensional parameters of the structure are varied and optimized. The considered antenna covers a multi wide frequency band from 3.14 to 3.35 GHz, 5.67–6.3 GHz and 7.58–9.5 GHz. Its performances are discussed in terms of reflection coefficient (S11), gain and radiation patterns.

1. Introduction

In the field of wireless communication systems, printed antennas capable of operating at multi-band frequency range are in demand. Many antenna designs with good features such as low profile, light weight have been developed and presented in the literature [1] [2].

Coplanar antennas have been introduced due to their attractive performances such as low radiation loss, low dispersion, wide bandwidth and easy integration with active devices without via holes [3] [4]. Moreover, monopole antenna has been reported by many researchers since it offers many advantages over the conventionally microstrip antenna namely the wideband frequency range [5].

The concept of metamaterials characterized by a negative permittivity and a negative permeability simultaneously has been studied since several years. Originally, they were proposed theoretically by Veselago [6] and an experimental verification showed the negative effective refractive index in a certain frequency band [7]. This concept has been extended to the transmission line domain. Metamaterials are periodic structures formed by symmetrical cells. There are several metamaterial structures such as split ring resonator (SRR) [8], complementary split ring resonator (CSRR) [9], high impedance surfaces (HIS) [10] and the composite right-left handed (CRLH) materials [11].

In this work, we propose a new method to design an active metamaterial. It is the integration of one or several active components (e.g. diode) in the CSRR structure gaps. Thus, by changing the metamaterial from passive to active, limits created by the passivity (losses, limited bandwidth) can be overcome and new effects can also be discovered.

We aim to investigate this prototype in the design of a monopole antenna incorporated with a rectangular CSRR to cover a multi-band frequency.

The paper is organized as follows: section (2) presents the design and the configuration of the proposed prototype. In Section (3), several simulations have been conducted to show the performances of the considered antenna in terms of different parameters such as the reflection coefficient, the gain and the radiation patterns. Section (4) concludes the paper.

2. Design and configuration

In this section, we present the design and the configuration of a monopole multi-band antenna incorporated with an active rectangular CSRR.

We begin by presenting the antenna geometric parameters which deposited on FR4-epoxy with 1.6 mm of substrate thickness and 4.4 of the effective permittivity $\mathcal{E}_{eff}$ value. The patch is fed by a coplanar line with 50 Ω input impedance. The length L, the width of the patch antenna *g*1 and the width *W* of the feeding line are 7 mm, 0.7 mm and 3 mm, respectively. The parameters values of the antenna, which are the patch circular radius *r_antenna*, the gap between the ground plane and the antenna patch *g*, are 10 mm and 0.5 mm respectively. Moreover, the substrate width *W_substrate*, the substrate length *L_substrate* and the ground length *L_ground* are chosen to be 20 mm, 30 mm, and 4.5 mm, respectively (Figs. 1 and 2).

In addition, the active CSRR cell unit size is 10*12 mm^2 and it is deposited on a dielectric substrate with a permittivity $\mathcal{E}_r = 2.2$ and the thickness h = 0.768 mm. The detailed configuration is shown in Fig. 3.

The parameters of the active CSRR are:

- $L1 = 11$ mm
- $L2 = 9$ mm

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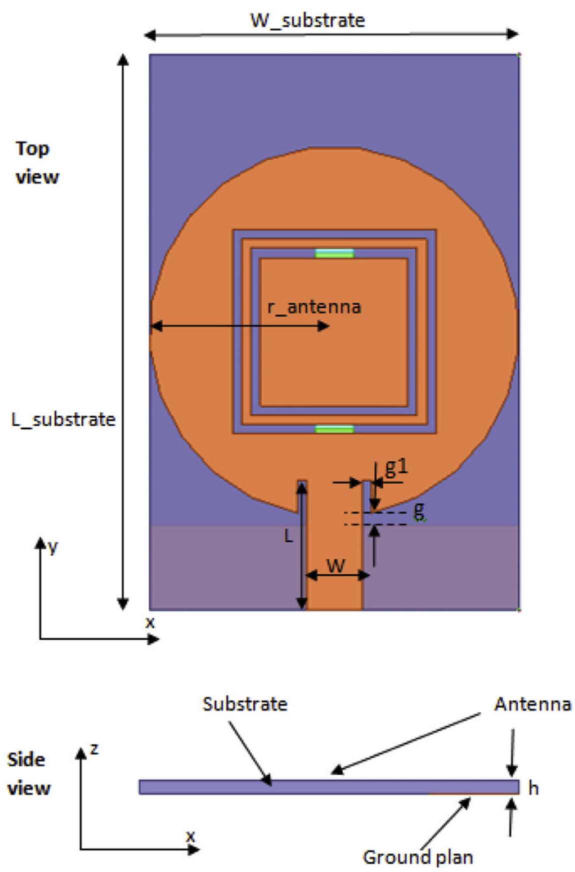

Fig. 1. The layout of the proposed monopole antenna: Top view.

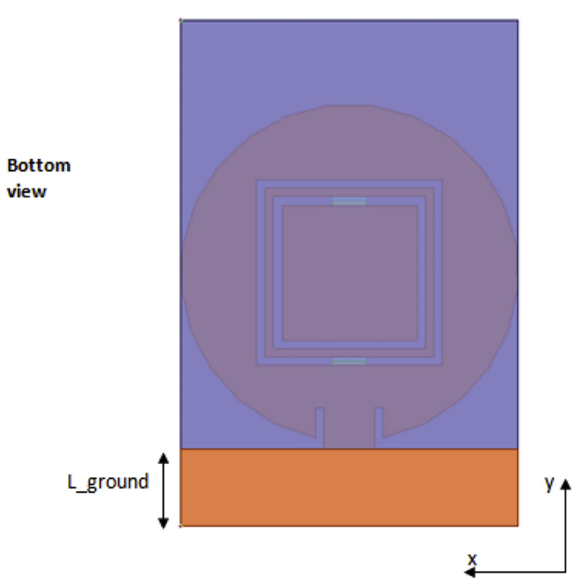

Fig. 2. The layout of the proposed monopole antenna: Bottom view.

- $a = b = c = 0.5$ mm
- $g = 2$ mm
- $b_R = b_C = 0.25$ mm

For getting an active metamaterial, we incorporate one or several active components (e.g. diode) in the CSRR structure. The active component used is a varicap diode that it is modulated by a capacity C in series with a resistance R as presented in Fig. 4. Indeed, author in Ref. [12], presents the behavior of the reflectivity and transitivity as a function of the different parameters values.

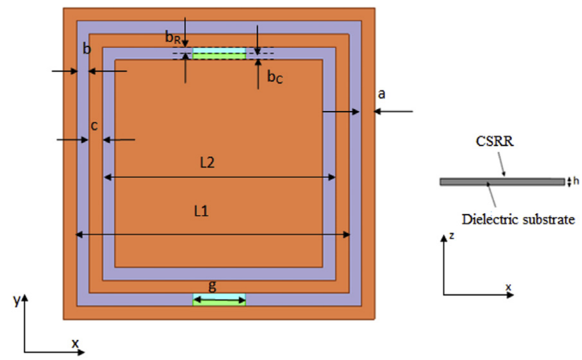

Fig. 3. The layout of the active CSRR.

Fig. 4. RF varicap diode with a equivalent circuit model.

For the simulation process, we use electromagnetic software that used the finite element method (FEM).

- For the active CSRR:

We include the wave guide model with active CSRR as presented in Fig. 5, with the following parameters:

- The field E is along the y-axis.
- The field H is along the z-axis.
- The vector K is according to the x-axis.
- The field H is perpendicular to the axis of the strip.

So, the electric field E excites the cut mode of the active CSRR and the charges of opposite signs accumulate at the two ends of each active CSRR strip and thus, the intense E field created in the gap contributes to the resonance.

- For the antenna:

The antenna is put in the radiation box (wave plane), it is excited by lumped port (Fig. 6).

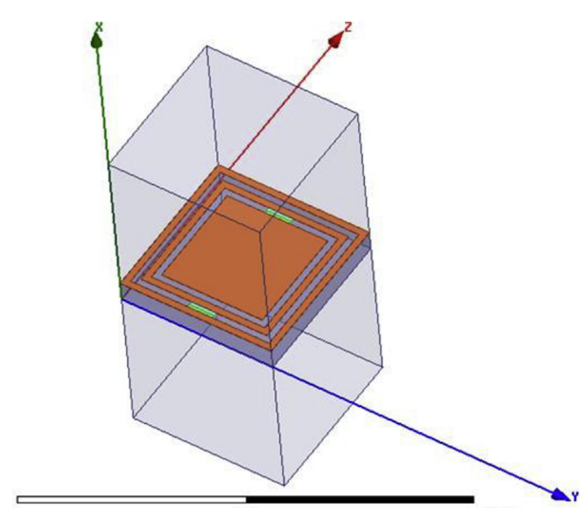

Fig. 5. The wave guide model with single active CSRR.