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# Compact dual-band split-ring antenna for 2.4/5.2 GHz WLAN applications

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**Abstract**

*This paper presents a compact dual-band printed antenna for 2.4/5.2 GHz WLAN applications. The radiating elements of the proposed antenna are composed of rectangular split-ring elements and metallic loadings placed appropriately between the rings. The antenna size is very compact (22 × 26 × 1.6 mm), and it can be integrated easily with other RF front-end circuits. It is demonstrated that the proposed antenna can completely cover the required bandwidths of IEEE 802.11b (2.4-2.484 GHz) and IEEE 802.11a (5.15-5.35 GHz) with satisfactory radiation characteristics. Analysis and design of the proposed antenna was carried out with the Ansoft highfrequency structure simulator. The measurement results of the fabricated prototype antenna are in relatively good agreement with the simulation results.*

**Key Words:** *Split-ring, metallic loading, microstrip antenna, WLAN*

## 1. Introduction

During recent years, there have been rapid developments in wireless local area networks (WLANs) including Bluetooth applications due to the need for fast and uninterruptible access to information. In these applications, compact multifunction antennas play a crucial role in achieving optimum system performance in their communication networks. In particular, dual-band operation in 2.4/5.2 GHz bands for WLANs are desirable for meeting the corresponding IEEE 812.11 a/b standards preferably using only one antenna element. Microstrip antennas, therefore, are highly utilized in these applications owing to their compact, planar, lightweight and low-cost features [1-4].

In this paper, a novel WLAN antenna design based on printed split-ring elements is proposed. These elements with inherent $\mu$-negative behavior, have recently been used as building blocks of various metamaterial structures [5,6], and they were utilized in various filter applications [7-9]. A few split-ring antenna (SRA) designs for WLAN applications have been reported in the past few years [10-12]. In [10], the proposed coplanar waveguide (CPW)-fed antenna consists of circular split-ring elements and covers 2.4/5.2 GHz bands. The proposed antenna in [11] only covers the 2.4 GHz band. In [12], the proposed antenna a monopole type is fed by a microstrip line and can entirely cover the 2.4/5 GHz bands. However, none of the above antennas are electrically small or compact. In my previous work, a dual-band WLAN split-ring antenna was achieved [13]. The proposed antenna in [13] is electrically very small and compact, but cannot entirely cover the 2.4/5.2 GHz bands due to provision of 1.7% and 3.15% bandwidths, respectively. In this study, a similar but simpler element and a broader bandwidth in a novel-type configuration is employed as compared to the design in [13]. The proposed SRA consists of 2 split-ring elements and 4 metallic loadings ($s_1 - s_4$) placed appropriately between the rings. A C-shaped metallic loading is inserted into the inner ring. The antenna is fed by a coaxial feed and there is no additional matching network. The proposed antenna has a fairly compact design which provides dual-band operation at the 2.4/5.2 GHz bands. The antenna also exhibits good radiation pattern performance at each frequency band. The analysis and design of the SRA were carried out using the commercially available high frequency structure simulator (Ansoft HFSS; ANSYS, Canonsburg, PA, USA). An antenna prototype was also fabricated and tested. In this paper, after introducing the SRA and its optimized design parameters, I present the simulation and measurement results of the antenna. Subsequently, the design steps of the antenna are explained.

## 2. Antenna design

The designed SRA configuration is depicted in Figure 1. As seen, the microstrip antenna composed of 2 metallic split-rings covers an area of 12 × 16 mm$^2$ and is placed on a grounded FR4 substrate with a thickness of 1.6 mm and a dielectric constant of 4.7. In addition, each metallic loading ($s_1 - s_4$) inserted appropriately between the ring elements has a size of 0.5 × 0.5 mm$^2$ and there is also a C-shaped metallic loading in the inner ring.

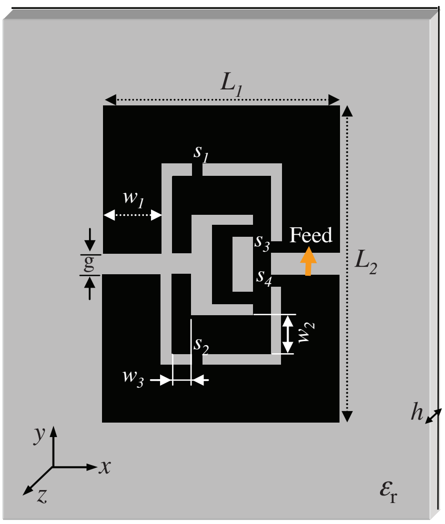



**Figure 1.** Proposed WLAN-SRA design: $s_1 - s_4$ (metallic loads: 0.5 × 0.5), $L_1$ = 12, $L_2$ = 16, $w_1 = w_2$ = 3, $w_3$ = 1, $g$ = 1, $h$ = 1.6 (all in mm); $\varepsilon_r$ = 4.7.

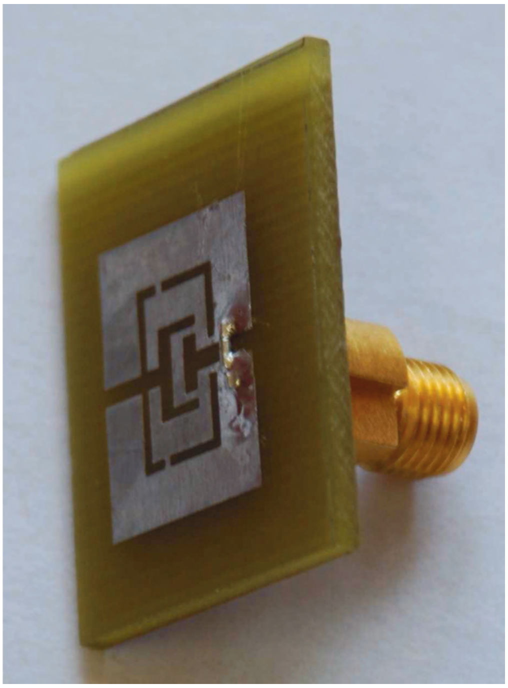


**Figure 2.** Prototype of WLAN-SRA.

The numerical design of the WLAN-SRA carried out using HFSS was fabricated as a prototype and its $S_{11}$-parameters were measured. As shown in Figure 2, the prototype antenna is fed vertically from the center core of the coaxial cable. The center core is connected to one of the splits of the outer-ring element. The center coaxial is soldered to one of the split corners by drilling into the substrate and the metallic shield of the coaxial cable is in contact with the ground plane.

The input impedance characteristics of the SRA are shown in Figure 3, and the return loss characteristics (simulation and measurement) are displayed in Figure 4. As seen, the simulation and measurement return loss characteristics of the SRA are in relatively good agreement with a small frequency shift, which is probably due to the fabrication tolerance differences of the FR4 substrate between the practical and simulated models. In addition, the dielectric constant and dissipation factor are not stable when the frequency increases. When the simulation results are examined, a dual-band operation is seen at 2.43 GHz and 5.28 GHz with 2% and 3.4% bandwidths, respectively, where $|S11| - 10\,\text{dB}$ with $50\,\Omega$ system impedance considered. Hence, the proposed SRA offers a coverage of WLAN bands at 2.4 GHz (2.4 2.484 GHz) and 5.2 GHz (5.15-5.35 GHz) corresponding to IEEE 802.11a and IEEE 802.11b.

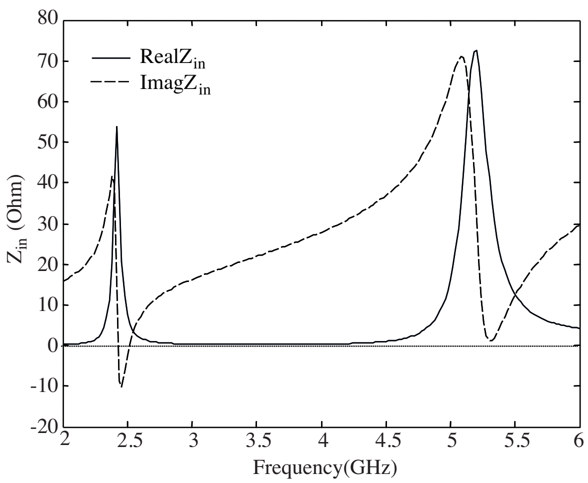



**Figure 3.** Input impedance ($Z_{in}$) characteristics of the WLAN-SRA design.

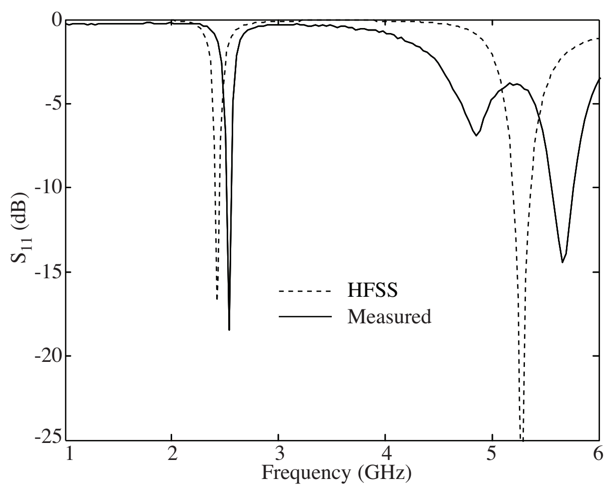
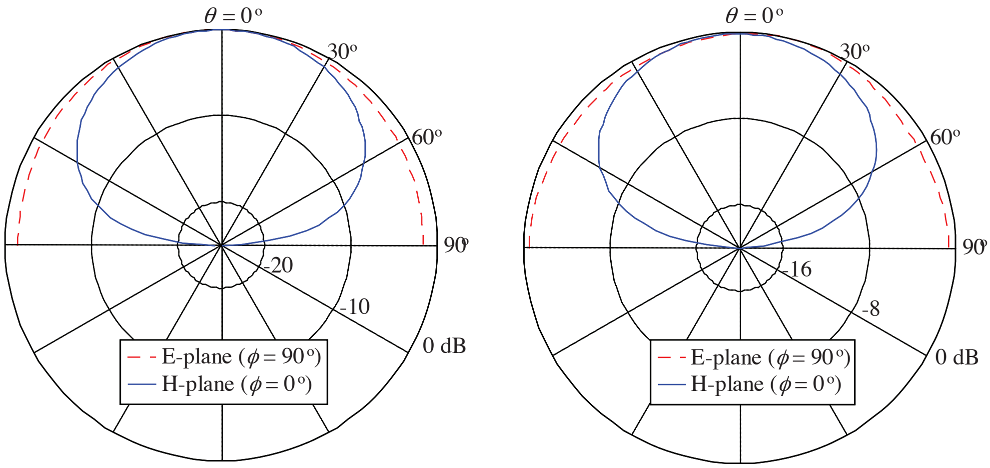



**Figure 4.** Return loss ($S_{11}$) characteristics of the WLAN-SRA design.

In addition, radiation patterns of the SRA for the respective frequencies are shown in Figure 5. As seen, the E-plane patterns demonstrate the desired omnidirectional characteristics at each operational frequency. Nevertheless, the H-plane patterns show relatively directional behavior. The predicted antenna gain is about 2 dBi within the frequency range of interest.

## 3. Design steps

I now present the details of the design steps that resulted in the proposed WLAN antenna (see Figure 1). A series of parametric studies were conducted to achieve the desired antenna performance, particularly tuning the resonant frequencies and impedance levels. In this process, the optimized critical antenna parameters were the substrate thickness and permittivity, ring dimensions, and positions of the metallic loadings.




(a) $f$ = 2.43 GHz (b) $f$ = 5.28 GHz

**Figure 5.** Radiation patterns of the WLAN-SRA design.

The design steps of the WLAN antenna were considered as displayed in Figure 6. The starting configuration (#1) included only 1 ring element with 2 splits. While one of the splits was used for the feed placement, the other was needed to achieve dual-band performance with the inclusion of a secondary split-ring as well as metallic loadings $s_1$ and $s_2$ inserted between the rings (#2). The highly resonant impedance characteristics for configurations #1 and #2 are shown in Figure 7. As can be seen, the inner ring with loadings $s_1$ and $s_2$ provided a dual-band profile around the 2 and 4.2 GHz bands with impedance levels of 1200 Ω and 1900 Ω, respectively. A secondary set of loadings, namely $s_3$ and $s_4$, were placed between the rings near the feeding gap (#3) so as to decrease those high impedance levels. As shown in Figure 8, configuration #3 not only resulted in reduced impedance levels (∼120 Ω), but also shifted the respective frequency bands to 2.3 and 5.2 GHz. Finally, including a C-shaped metallic loading (#4) provided fine frequency and impedance tuning as seen in Figure 8. Hence, the final configuration #4 allowed for the desired dual-band performance at the designated WLAN bands (2.4/5.2 GHz).

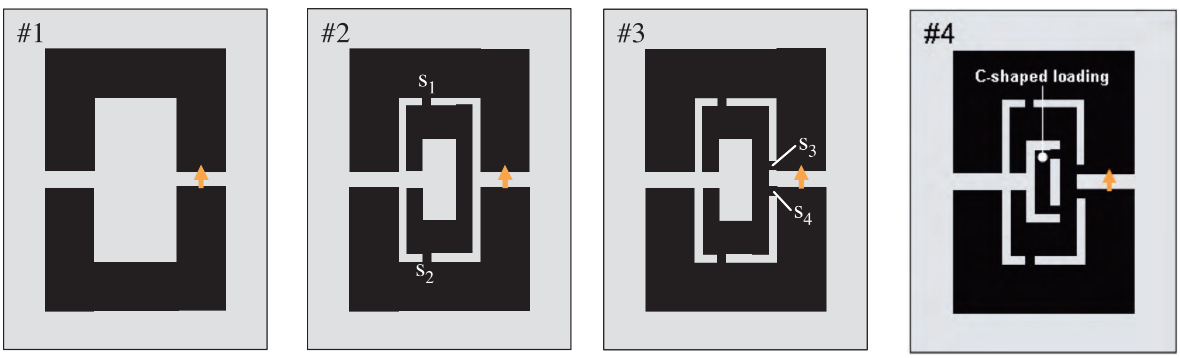



**Figure 6.** Design steps for the WLAN antenna.

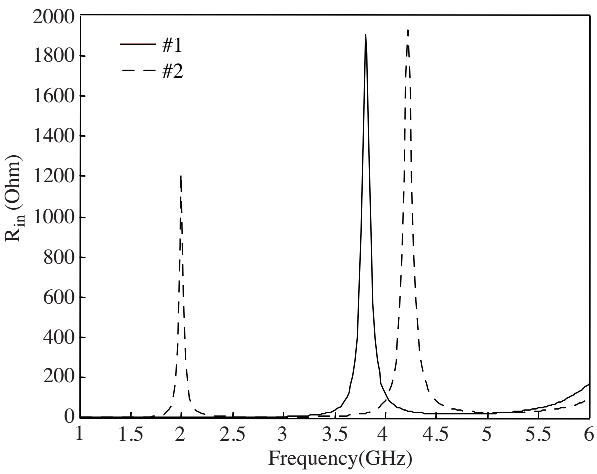



**Figure 7.** Real parts of the input impedances for WLAN antenna design configurations #1 and #2.

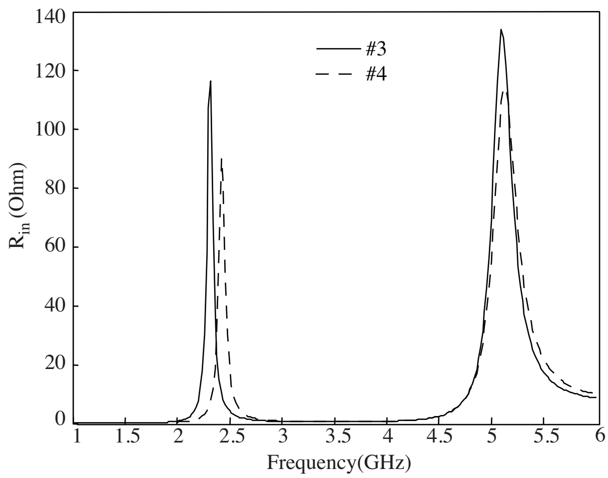



**Figure 8.** Real parts of the input impedances for WLAN antenna design configurations #3 and #4.

# 4. Conclusion

In this paper, a novel dual-band antenna for 2.4/5.2 GHz band WLAN applications was introduced. The proposed antenna is based on split-ring elements with metallic loadings (Figure 1). As the outer ring mainly offers dual frequency operation, the inner ring with loadings ($s_1 - s_4$ and C-shaped) provides frequency tuning and impedance matching. The antenna having a fairly compact design covers WLAN (2.4/5.2 GHz) bands and exhibits a uniform radiation pattern at each frequency band. The measured return loss characteristics of the fabricated antenna demonstrate relatively good agreement with the simulated data from Ansoft HFSS.

# Acknowledgment

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