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Complementary Split-Ring Resonators based Dual-Band Microstrip Antenna for WLAN Applications

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Abstract: In this paper, an electrically small dual-band microstrip antenna has been presented which is based on complementary split ring resonators. The patch is loaded with side-by-side complementary split-ring elements which are used as the main radiator of the antenna and microstrip line feeding has been used. The purpose of CSRR loading in this work is to achieve multiple resonant frequencies with an optimized patch size. The analysis of the proposed microstrip antenna has been carried out by means of transmission-line model and simulation is done using CST Microwave Studio 2010. The proposed antenna covers 2.4/5.2 GHz WLAN bands with bandwidths 340.24 MHz and 441.53 MHz respectively.

Keywords: Wireless Local Area Network (WLAN), Complementary Split Ring Resonator (CSRR), Split Ring Resonator (SRR), Voltage Standing Wave Ratio (VSWR)

I. INTRODUCTION

With the evolution of wireless communication technologies such as WLAN, it is therefore entailed to promote multiband antennas that are adept of performing under various standards in distinct frequency bands. Moreover, these antennas constrained to be low-profile, highly efficient, and electrically small so as to integrate them into contemporary wireless terminals. Although conventional microstrip antennas are low-profile and efficient, but possess narrow band-width. For that reason, it is prerequisite to modify either the feed structure or the antenna element (patch) or both to attain an electrically small antenna for dual-band applications as in [1]. This work comprises of two side-by-side CSRR structures on a single patch fed by a microstrip line.

The CSRRs which are the dual counterparts of SRRs are the meta-materials possessing negative effective permittivity. A time varying electric field applied parallel to the ring axis of CSRR, (rather than a magnetic field as in case of SRRs) is required to operate CSRRs as in [2]. The dual-bands have been obtained due to the capacitances engendered by the voltage gradients between the CSRR gaps and the inductance produced by the current flowing along CSRR coils as in [3]. The reduced ground structure has been employed so as to reduce harmonics. The suggested antenna covers WLAN 2.4/5.2 GHz wireless communication standards and has a compact size, so it can be easily integrated with other RF front-end circuitry in small size portable mobile and wireless handsets for modern and emerging communications as in [4].

II. MATHEMATICAL ANALYSIS

A. TRANSMISSION LINE MODEL

The analysis of microstrip antenna is done using transmission line model in which patch is considered as a transmission line resonator having no transverse field variations and the radiation takes place primarily from the fringing fields at the open circuited ends as in [5]. As some of the wave traverses in the substrate while some in the air, an effective dielectric constant ϵ_{reff} has been introduced considering fringing and the propagation of wave along the line. In order to include the effective dielectric constant, it is assumed that the centre conductor of the microstrip line i.e. patch, has its original dimensions with height above the ground plane.

$$\frac{W}{h}>1 \quad \epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \tag{1}$$

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \tag{2}$$

$$L_{eff} = L + 2\Delta L$$

The frequency at which the microstrip patch antenna resonates is given by

$$f_r = \frac{1}{2L_{eff}\sqrt{\epsilon_{reff}}\sqrt{\mu_0\epsilon_0}} \tag{3}$$

The width and length of the patch is given by

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r+1}} = \frac{\upsilon_0}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \tag{4}$$

$$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}}\sqrt{\mu_0\epsilon_0}} - 2\Delta L \tag{5}$$

Finally, the length and width of ground is given by

$$L_g = 6h+L$$

$$W_g = 6h+W$$

Where,
h= substrate thickness
L = Length of patch
W= Width of patch
L_{eff} = Effective length
C= speed of light
ϵ_r= relative permittivity
ϵ_{reff} = effective permittivity

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B. CSRR

The resonant frequency of CSRR [2] can be calculated by

$$f_{LC}=\frac{1}{2\pi(\sqrt{LsC})} \quad (6)$$

Where, Ls is shunt inductance and C is capacitance

$$Ls=L_0/4 \quad (7)$$

Where, L_0 is total inductance

$$L_0=2\pi r_0 L_{pul} \quad (8)$$

Where, L_{pul} is the per unit length inductance, r_0 is average radius of CSRR

C. STUB

In order to match the load impedance to the characteristic impedance of the microstip line, open-circuit stub has been employed whose length can be calculated using the formula:

$$\beta l = \pi$$

Where, β is phase difference, l is the length of the stub

III. ANTENNA CONFIGURATION

In order to attain the desired antenna performance, we have realized a set of parametric studies. The dimensions of the complementary ring elements as well as microstrip feed-line width have been varied for required resonant frequencies and return loss characteristics. Using CST Microwave Studio 2010, the design of the proposed antenna was simulated and the final dimensions of the antenna are shown in Table I (in millimetres):

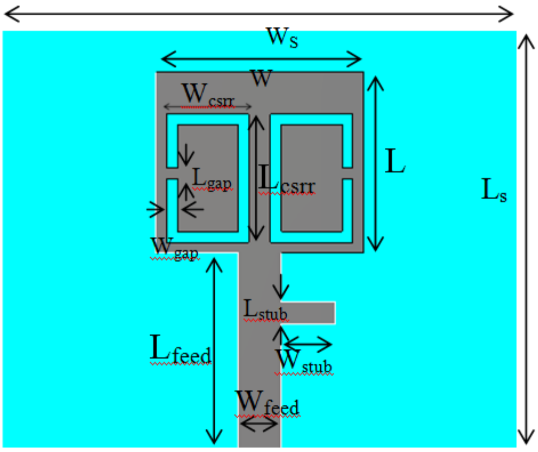

Fig. 1. Front view

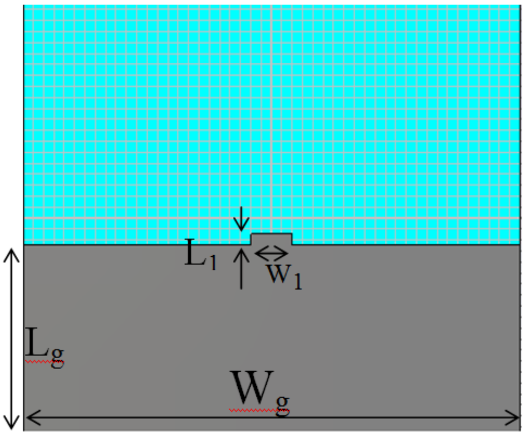

Fig. 2. Back view

TABLE I DIMENSIONS OF PROPOSED ANTENNA STRUCTURE

Dielectric constant of substrate (ϵ_r)	4.4
Thickness of substrate(h)	1.57
Length of substrate(L_s)	38.89
Width of substrate(W_s)	47.88
Length of patch(L)	16.73
Length of ground(L_g)	18.44
Width of ground(W_g)	47.88
Length of Stub(L_{stub})	2
Width of Stub(W_{stub})	5
Length of CSRR ring (L_{csrr})	11.88
Width of the ring(W_{csrr})	7.62
Length of Split gap(L_{gap})	1
Width of Split gap(W_{gap})	1

IV. SIMULATION AND RESULTS

The following parameters have been observed on simulating the proposed antenna design using CST Microwave Studio 2010.

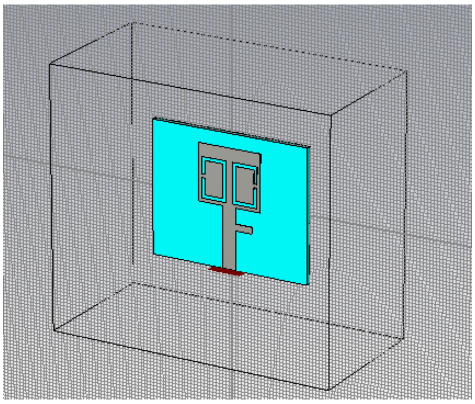

Fig. 3. Simulated design of the antenna

A. RETURN LOSS

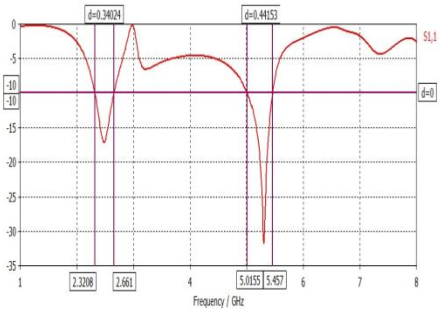

Fig.4. Plot of Return Loss vs. frequency

The proposed antenna attains dual resonant modes over the frequency ranges of 2.48 GHz and 5.30 GHz with reflection coefficient less than -10 dB as shown in Fig. 4, thereby covering the two WLAN bands in 2.4 (2.4–2.484 GHz) and 5.2 (5.15–5.35 GHz) simultaneously according to IEEE standards. The bandwidth attained for these two bands is 340.24 MHz and 441.53 MHz respectively.

B. VSWR

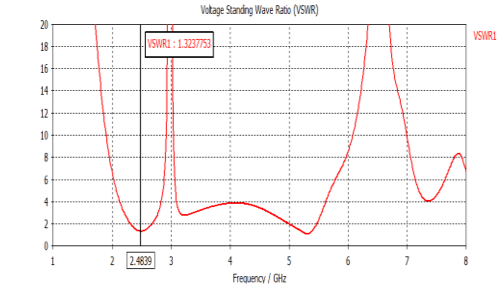

Fig. 5. Plot of VSWR vs. frequency at 2.48 GHz

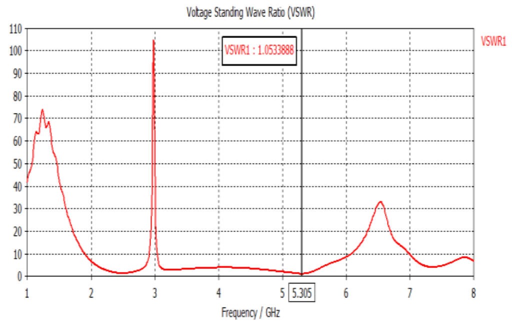

Fig.6. Plot of VSWR vs. frequency at 5.30 GHz

The VSWR vs. Frequency graph of the proposed antenna has been shown in Fig. 5 and Fig. 6 respectively which demonstrates that the VSWR value lies below 2 at both resonant frequencies as desired.

C. CURRENT DISTRIBUTION

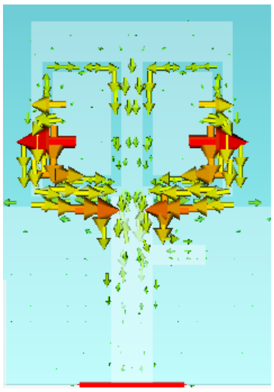

Fig. 7. Current density at 2.48 GHz

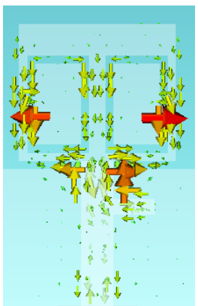

Fig. 8. Current density at 5.30 GHz

Current analysis of antenna has been shown in Fig. 7 and Fig. 8 respectively which demonstrates that at the two resonant frequencies, the CSRR elements act as the main radiator of the antenna as the surface current flow mainly concentrates in the CSRR rings.

D. RADIATION PATTERN

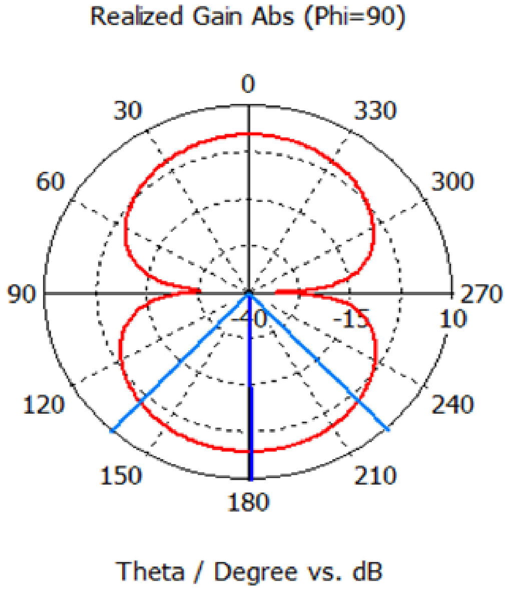

Fig. 9. Polar plot of Gain at 2.483 GHz

The polar plot of realised gain at 2.483 GHz is shown in Fig. 9. The magnitude of main lobe is 2.3dB with half-power beamwidth (3dB) of 85.5 deg.

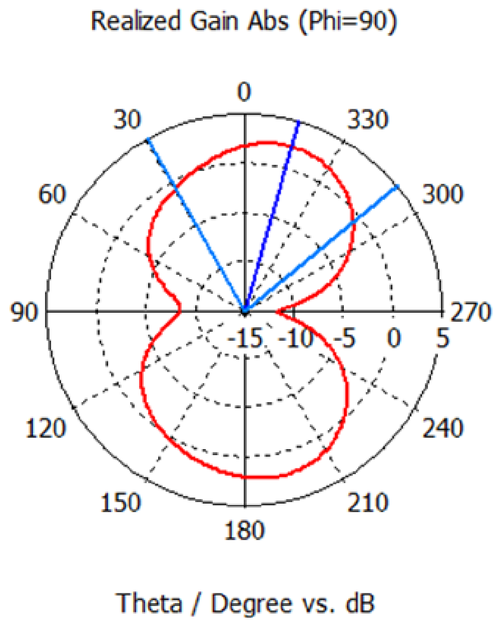

Fig. 10. Polar plot of Gain at 5.30GHz

The polar plot of realised gain at 5.30 GHz is shown in Fig. 10. The magnitude of main lobe is 2.2dB with half-power beamwidth (3 dB) of 79.4 deg.

V. CONCLUSION

In this paper, dual-band WLAN antenna with microstrip line feeding has been suggested in which complementary split-ring elements have been loaded on the patch. The simulated antenna performances obtained by CST Microwave Studio 2010 have been analysed. The compact antenna design resonates well at designated WLAN bands (2.4/5.2 GHz) with bandwidths of 340.24 MHz and 441.53 MHz respectively.

FUTURE WORK

The simulated antenna will be fabricated using PCB technology and thereafter will be tested on Vector Network Analyser and anechoic chamber. For the enhancement of the bandwidth and improvement in the return loss characteristics of microstrip patch antenna, different structures of CSRR will be designed. The antenna performance will also be investigated by incorporating different patch structures and feeding techniques. To extend this design for multiband antenna will be one of the main aim.

REFERENCES

[1] S.C. Basaran, U. Olgun, K. Sertel, "Multiband monopole antenna with complementary split-ring resonators for WLAN and WiMAX applications", Electronics Letters, vol. 49, no. 10, pp. 636-638, 2013.

[2] J. D. Baena et al. ,"Equivalent-Circuit Models for Split-Ring Resonators and Complementary Split-Ring Resonators Coupled to Planar Transmission Lines", IEEE transactions on microwave theory and techniques, vol. 53, no. 4, April, 2005

[3] J. H. Lee, Y. C. Oh, N. H. Myung ,"A Novel Compact Microstrip Bandstop Filter Based on Complementary Split-Ring Resonators", Proceedings of Asia-Pacific Microwave Conference, 2006.

[4] I.Ben Issa, M. Essaaidi, "Compact multi-band square complementary split ring resonator patch antenna for wireless applications", Mediterranean Microwave Symposium (MMS), pp. 1-4, 2013.

[5] C. A. Balanis, "Antenna theory analysis and design", 2nd edition, John Wiley & sons, Inc, New York, 1997.