DUAL-BAND SPLIT-RING ANTENNA DESIGN FOR WLAN APPLICATIONS

S. Cumhur Başaran[1] Yunus E. Erdemli[2]
e-mail: cbasaran@akdeniz.edu.tr *e-mail: yunusee@kou.edu.tr*

[1]Akdeniz University, The Vocational School of Technical Sciences
07058 Antalya, Turkey
[2]Kocaeli University, Electronics and Computer Education Department
41380 Kocaeli, Turkey

Key words: Split-ring, microstrip antenna, WLAN, finite-element method, HFSS

ABSTRACT

A dual-band microstrip antenna based on split-ring elements is introduced for WLAN (2.4/5.2 GHz) applications. The proposed split-ring antenna (SRA) has a fairly compact design and provides almost %2 impedance-bandwidth at each frequency band without a need for additional matching network. The HFSS-simulated antenna performance is presented in the paper.

I. INTRODUCTION

Wireless local area networks (WLANs) are becoming increasingly popular since they provide high speed connectivity with easy access in wireless communication systems. WLAN antennas, in particular, play a crucial role in achieving optimum system performance. In that sense, dual-band operation in the 2.4/5.2 GHz bands are desired to meet the corresponding IEEE standards in WLAN applications, preferably using only one antenna element. To achieve such a performance, microstrip antennas are highly utilized due to their compact, planar, lightweight, and low-cost features [1–4].

In this paper, we propose a novel WLAN antenna design based on printed split-ring elements. These elements with inherent μ-negative behavior have recently been used as building blocks of various metamaterial structures, providing highly-resonant frequency responses [5–8]. The proposed split-ring antenna (SRA) consists of three split-ring elements and metallic loadings appropriately placed between the rings as shown in Fig. 1. The antenna itself has fairly small dimensions and provides dual-band operation at 2.4/5.2 GHz bands. The analysis and design of the SRA have been employed via the HFSS simulator. In the paper, the simulated antenna performance (impedance and pattern) is presented.

II. ANALYSIS METHOD

The analysis and design of the proposed SRA have been carried out using Ansoft HFSS v.10.0 simulator, which is based on the finite-element method (FEM). The FEM is a well-known frequency-domain technique which is highly capable of modeling 3D complex structures with inhomogeneities [10]. In FEM analysis, the structure at hand is first meshed into prism or tetrahedron elements, where unknowns of the problem are usually electric field vector components specified along edges of the elements. The discretized FEM functional is then minimized for each unknown to generate the system matrix, which is mainly sparse. Finally, the FEM system is solved for the edge unknowns via a direct or an iterative solver [10]. In particular, for open (radiation or scattering) problems the computational domain is truncated by an absorbing boundary condition (ABC) or a perfectly-matched layer (PML) to simulate the free-space. Alternatively, rather complicated but more accurate truncation can be realized by hybridizing the FEM with the boundary-integral (moment) method [10].

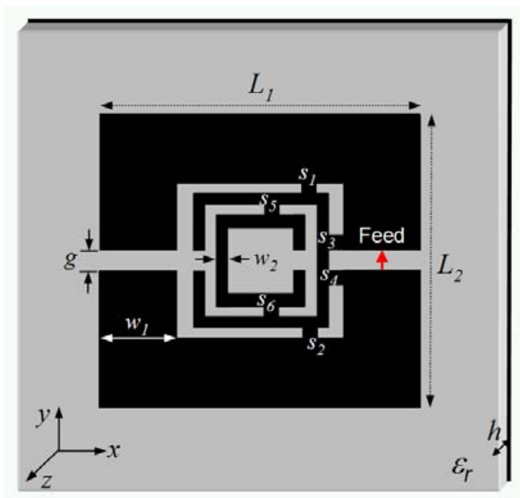

Figure 1. Proposed SRA configuration: S_1–S_6 (metallic loads: 0.5×0.5), L_1=14, L_2=15, w_1=4, w_2=0.5, g =1, h=1.6 (all in mm), ε_r=4.4.

III. ANTENNA DESIGN

The designed SRA configuration is depicted in Fig. 1. As seen, the microstrip antenna composed of three metallic split-rings covers an area of 14×15 mm^2 and placed on a grounded FR4 substrate with 1.6 mm thickness and dielectric constant of 4.4. The outer-most ring with two splits is rather wider than the inner rings with one split each. The antenna is fed by a current-probe placed in one of the splits in the outer ring. The probe basically represents practical coaxial feeding [9] and in this proposed configuration, there is no additional matching network. Also, there are several metallic loadings (S_1–S_6) inserted appropriately between the ring elements.

Impedance and return loss characteristics of the SRA are displayed in Fig. 2 and Fig. 3, respectively. As shown, a dual-band operation is achieved at 2.43 GHz and 5.23 GHz with %1.7 and %3.15 bandwidths, respectively, where $|S_{11}|<-10$ dB criterion with 50 Ω system impedance is considered. The corresponding bands, where impedance levels vary between 50−100 Ohms, may seem rather narrow, but we note that this performance is achieved without additional matching network, with which broader bandwidth performance is expected.

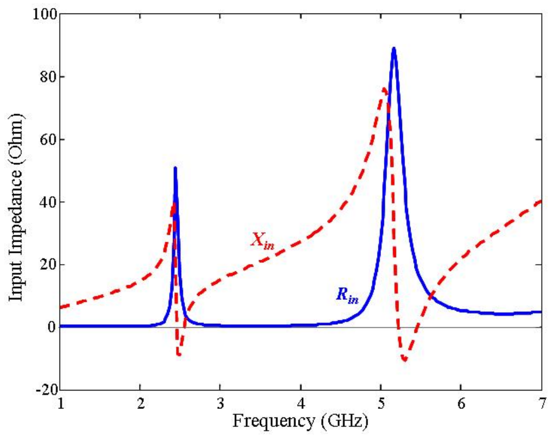

Figure 2. Input impedance characteristics of the SRA.

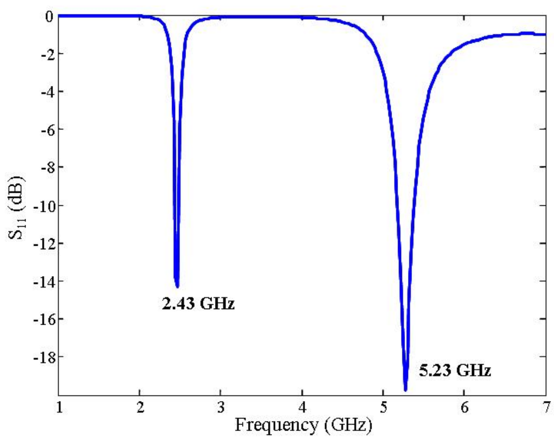

Figure 3. Return loss characteristics of the SRA.

In addition, radiation patterns of the SRA for 2.43 GHz and 5.23 GHz are shown in Fig. 4 and Fig. 5, respectively. As seen, E-plane patterns demonstrate omni-directional characteristics at each operational frequency as desired in WLAN applications. Nevertheless, H-plane patterns show relatively directional behavior.

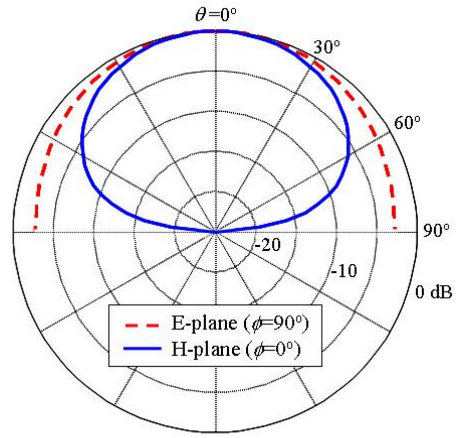

Figure 4. Radiation pattern of the SRA for *f*=2.43 GHz.

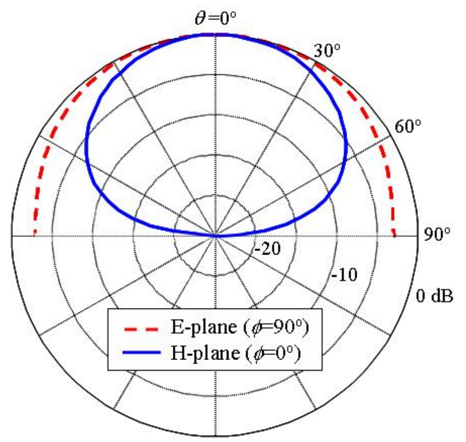

Figure 5. Radiation pattern of the SRA for *f*=5.23 GHz.

A series of parametric studies were carried out to achieve the presented antenna performance, particularly tuning the resonant frequencies and impedance levels. In this process, optimized critical antenna parameters were substrate thickness and permittivity (h, ε_r), ring dimensions (L_1, L_2, w_1, w_2), positions of the metallic loadings (S_1–S_6) as seen in Fig. 1. In the first step of the design, only the outer-most ring with two-splits was considered, resulting in a single frequency operation around 3.8 GHz with 1000 Ω impedance levels. To achieve operation at WLAN frequencies (2.4/5.2 GHz), additional split rings with metallic loadings were implemented in the design. Previously, such loadings were shown to provide frequency-tuning and/or dual frequency operation in split-ring filters [7, 8]. In fact, as the placement of a second ring (in the middle) with metallic loads S_1/S_2 resulted in a dual frequency operation around 1.9/4.2 GHz bands. Additional loadings S_3/S_4 caused reduction of the impedance levels to 20–30 Ω range, and tuned the dual bands to 2.2/5.1 GHz. Finally, including a third ring (the inner-most) with loadings S_5/S_6 provided fine frequency and impedance tuning, thus achieving dual frequency operation at 2.43/5.23 GHz bands with impedance levels of 50−100 Ω. The positions of the loadings were manually optimized to achieve the desired characteristics. The numerical details of those parametric studies will be presented at the conference.

IV. CONCLUSION

In the paper, we have introduced a novel WLAN antenna based on microstrip split-ring elements with metallic loads (Fig. 1). As the outer-most ring mainly offers dual frequency operation, the inner rings with loadings provide frequency-tuning and impedance matching. Thus, quite miniature SRA performs dual-band operation at 2.4/5.2 GHz bands. The HFSS-simulated antenna performance has been presented in the paper. Fabrication of the SRA is in progress, and the measurements are expected to be presented at the conference.

REFERENCES

1. W.-J. Liao, Y.-C. Lu and H.-T. Chou, A Multiband Microstrip Dipole Antenna, IEEE Antennas and Propagation Society International Symposium, Vol. 1A, pp. 462-465, July 3-8, 2005.
2. H.-M. Chen, J.-M. Chen, P.-S. Cheng and T.-F. Lin, Feed for Dual-Band Printed Dipole Antenna, Electronics Letters, Vol. 40, No. 21, pp. 1320-1322, Oct. 14, 2004.
3. H. Rmili, J. M. Floc'h, P. Besnier and M. Drissi, A Dual–Band Printed Dipole Antenna for IMT–2000 and 5–GHz WLAN Applications, Proceedings of the 9th European Conference on Wireless Technology, Nov. 6-10, 2006.
4. H.-R. Chuang and L.-C. Kuo, 3D FDTD design analysis of a 2.4- GHz Polarization-Diversity Printed Dipole Antenna with Integrated Balun and Polarization-Switching Circuit for WLAN and Wireless Communication Applications, IEEE Transactions on Microwave Theory and Techniques, Vol. 51, No. 2, pp. 374-381, Feb. 2003.
5. J. B. Pendry, A. J. Holden, D. J. Robins and W. J. Stewart, Magnetism from Conductors and Enhanced Nonlinear Phenomena, IEEE Transactions on Microwave Theory and Techniques, Vol. 47, No. 11, pp. 2075-2084, Nov. 1999.
6. D. R. Smith, W. J. Padilla, D. C. Vier, S. C. Nemat-Nasser and S. Schultz, Composite Medium with Simultaneously Negative Permeability and Permittivity, Physical Review Letters, Vol. 84, No. 18, pp. 4184-4187, 2000.
7. Y. E. Erdemli and A. Sondas, Dual-Polarized Frequency-Tunable Composite Left-Handed Slab, Journal of Electromagnetic Waves and Applications, Vol. 19, No. 14, pp. 1907-1918, 2005.
8. C. Cenk, A. Sondas and Y. E. Erdemli, Tunable Split Ring Resonator Microstrip Filter Design, Mediterranean Microwave Symposium, Genova, Italy, Sep. 19-21, 2006.
9. A.-C. Chen, C.-L. Tang and Z.-H. Lu, A Loop Antenna for WLAN Application, IEEE Asia-Pacific Conference Proceedings, Vol. 2, Dec. 4-7, 2005.
10. J. L. Volakis, A. Chatterjee and L. C. Kempel, Finite Element Method for Electromagnetics, IEEE Press & Oxford University Press, New York, 1998.