S.C. BASARAN / IU-JEEE Vol. 11(1), (2011), 1287-1290

DUAL WIDEBAND SPLIT-RING MONOPOLE ANTENNA DESIGN FOR WIRELESS APPLICATIONS

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Abstract: *In this paper, a microstrip monopole antenna with dual wideband is presented for simultaneously satisfying Personal Communication Systems (PCS), Universal Mobile Telecommunication Systems (UMTS), Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX) applications. The novel antenna configuration consists of split-ring elements and metallic loadings appropriately placed between the rings. The proposed split-ring monopole antenna (SRMA) fed by a three-stage meandered microstrip line has fairly small dimensions and provides the dual resonances in the 1.85-2.97 GHz and 4.86-5.36 GHz bands. Also, the antenna exhibits almost omni-directional radiation patterns in the E/H plane at the respective bands. Analysis and design of the proposed microstrip antenna is carried out by means of Ansoft High Frequency Structure Simulator (HFSS) and CST Microwave Studio.*
Keywords: *Split-ring, microstrip antenna, wideband, WLAN*

1. Introduction

Recent advancements in wireless technology and significant growth in consumer demands have significantly increased the popularity of wireless communication applications. Personal Communication Systems, Universal Mobile Telecommunication Systems, Wireless Local Area Network, and Worldwide Interoperability for Microwave Access are the most important wireless applications. The increase in variety of mobile communication equipment, such as phone cells, laptops and wireless modems, requires design of adaptable and functional miniature antennas. In this context, wireless communications in various frequency bands in accordance with IEEE standards is applicable by means of only one antenna element provided the element itself performs multi-band or broad-band operation. To achieve this, planar monopole antennas are good candidates for wide-band applications, as they exhibit wide impedance bandwidth, compact and simple structure and ease-of-fabrication [1-4]. Furthermore, the omni-directional radiation pattern characteristics of monopole antenna make them very suitable for indoor applications such as airplane, shopping center, hospital etc. In this paper, a novel dual wideband antenna design based on printed split-ring elements is proposed. These elements were first introduced as the building blocks of metamaterial structures [5], and circular disk and spiral split-ring resonators were utilized in compact planar UWB antenna design [6]. Furthermore, rectangular split-ring elements with metallic loadings inserted between the rings were considered in dual-band antenna designs for WLAN applications in our previous works [7, 8].

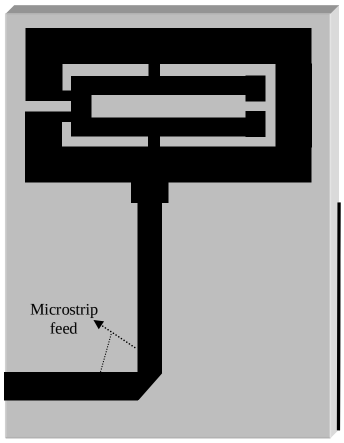


Figure 1. Proposed SRMA design (top view is shown).

In this study, though being similar to the [7, 8] considering split-ring element, SRMA with novel design has wider impedance bandwidths than [7, 8] and covers PCS, UMTS, WiMAX bands in addition to WLAN bands. The proposed split-ring monopole antenna with novel configuration consists of two split-ring elements and metallic loadings (s_1–s_4)

Received on: 10.12.2010
Accepted on: 06.10.2011

appropriately placed between the rings as shown in Figure 1. The antenna is fed directly by a three-stage meandered microstrip feed-line and the back side of the substrate is half-covered by the ground plane as part of the monopole structure. The proposed antenna has a fairly compact design which provides 46% and 9.3% bandwidths at 2.41 GHz and 5.36 GHz center frequencies, respectively. Moreover, the antenna exhibits almost omni-directional radiation patterns in the E/H-planes at the operational frequency bands. The analysis and design of the SRMA have been carried out using Ansoft High Frequency Structure Simulator and CST Microwave Studio. In the paper, after explaining the design steps of the SRMA, I present simulation results of the antenna.

2. Design Steps

In this section, the design steps of the proposed antenna are presented and the optimum antenna performance is evaluated. A series of parametric studies was carried out to achieve desired antenna performance, particularly tuning the resonant frequencies and return-loss characteristics. In this process, the optimized critical antenna parameters were the substrate's thickness and permittivity, dimensions of the ring elements as well as the ground plane, microstrip feed-line, and positions of the metallic loadings.

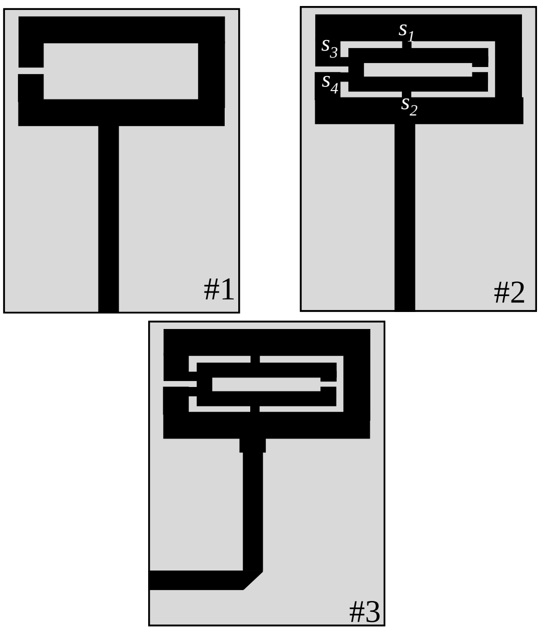


Figure 2. Design steps of the proposed antenna.

The configurations of the design steps are shown in Figure 2, while Figure 3 displays the corresponding frequency responses. The first configuration (#1) consists of a metallic ring element and a microstrip feed-line. This configuration provides a dual-band operation at 2.4–2.7 GHz / 3.2–3.7 GHz frequency bands where $|S_{11}|<-10$ dB criterion with 50 Ω system impedance is considered. With the inclusion of a secondary split-ring as well as metallic loadings (s_1–s_4) inserted between the rings (#2), the first band is shifted to around 2 GHz center frequencies and there has been no significant difference in the second band. Finally, by meandering the lover part of the microchip feed-line (#3), a dual-band performance is achieved at 1.85–2.97 GHz and 4.86–5.36 GHz bands. Hence, PCS (1.8 GHz), UMTS (1.9 GHz), WLAN (2.4 and 5.2 GHz), and WiMax (2.6 GHz) bands are covered by the proposed SRMA design.

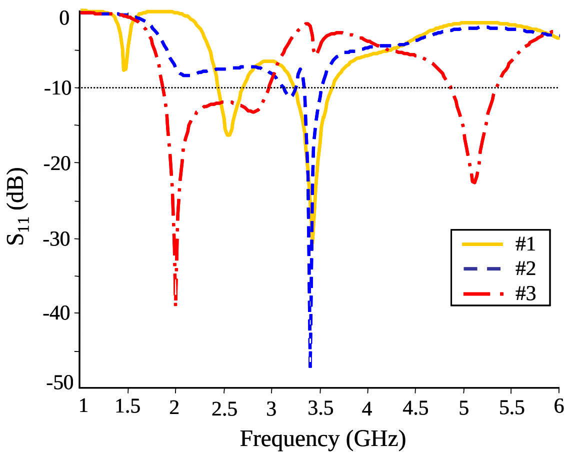


Figure 3. Return loss (S_{11}) characteristics of the SRMA configurations #1, #2, and #3.

3. Antenna Design

The WLAN antenna configuration #3 is re-displayed in Figure 4 with its optimized parameters. As seen, the SRMA composed of two metallic split-rings covers an area of 28×15 mm^2 and placed on a half-grounded FR4 substrate with 0.4 mm thickness and dielectric constant of 4.4. As shown in Figure 3, the outer ring is rather wider than the inner ring and each metallic loading (s_1–s_4) inserted appropriately between the ring elements has a size of 1×1 mm^2. On the other side of the dielectric substrate, a ground plane of 32×24 mm^2 in size is printed below the microstrip feed-line. The first and second stages of the feed-line are 13 mm and 16.5 mm in length, respectively, while both stages are 2.5 mm in width. Upper part of the microstrip feed line which contacts the antenna is 2 mm in length and 3.5 mm in width.

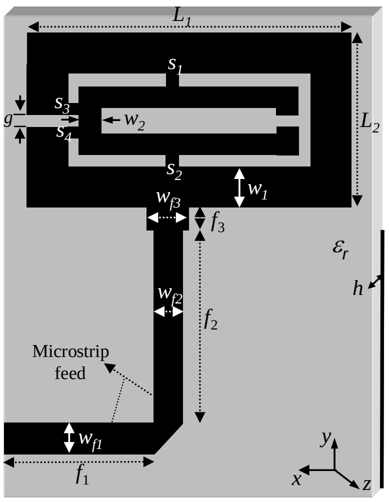


Figure 4. Proposed Multi-band SRMA design: s_1 ,s_2, s_3, s_4 (metallic loadings: 1×1), L_1=28, L_2=15, w_1=3.5, w_2=2, g=1, f_1=13, f_2=16.5, f_3=2, h=0.4 (all in mm), ε_r=4.4.

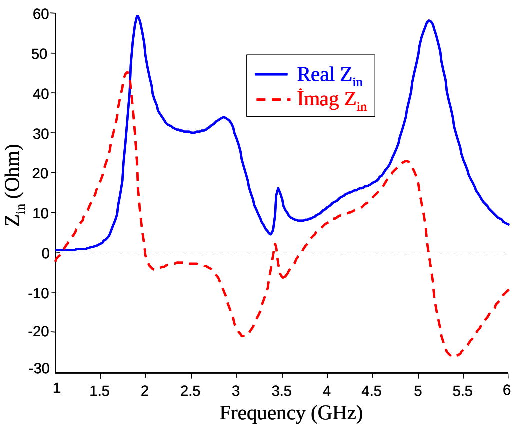


Figure 5. Input impedance (Z_{in}) characteristics of the SRMA design.

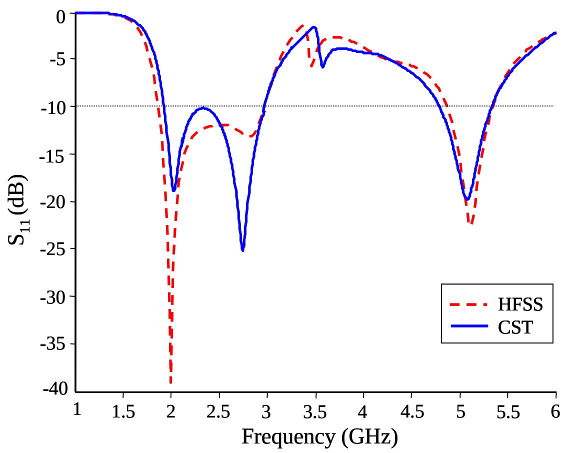


Figure 6. Return loss (S_{11}) characteristics of the SRMA design.

The input impedance and return loss characteristics of the SRMA design are displayed in Figures 5 and 6, respectively. As shown, for the HFSS simulated design, a fairly broad-band performance is achieved at 1.85–2.97 GHz and 4.86–5.36 GHz frequency bands in which $|S_{11}|$ <–10 dB criterion with 50 Ω systems impedance is considered. I also carried out simulations using CST Microwave Studio as an additional validation; as seen, both simulations agree quite well. Thus, various mobile communication services, such as PCS (1.85–1.99 GHz), UMTS (1.92–2.17 GHz), WLAN (2.4–2.48 GHz / 5.15–5.35 GHz) and WiMax (2.5–2.69 GHz), can be easily covered by the proposed antenna simultaneously. Radiation pattern of the SRMA for 1.9 GHz, 2.05 GHz, 2.44 GHz, 2.6 GHz, and 5.2 GHz are shown in Figure 7. As seen, E/H plane pattern demonstrate almost omni-directional characteristics at each operational frequency as desired for indoor applications. Figure 8 shows the simulated antenna gain for the SRMA. The computed antenna gain is about 9 dBi in the PCS and UMTS operational frequency bands, 7 dBi in the WLAN (2.4 GHz) band, 6 dBi in the WiMax band, and 8 dBi in the WLAN (5.2 GHz) band.

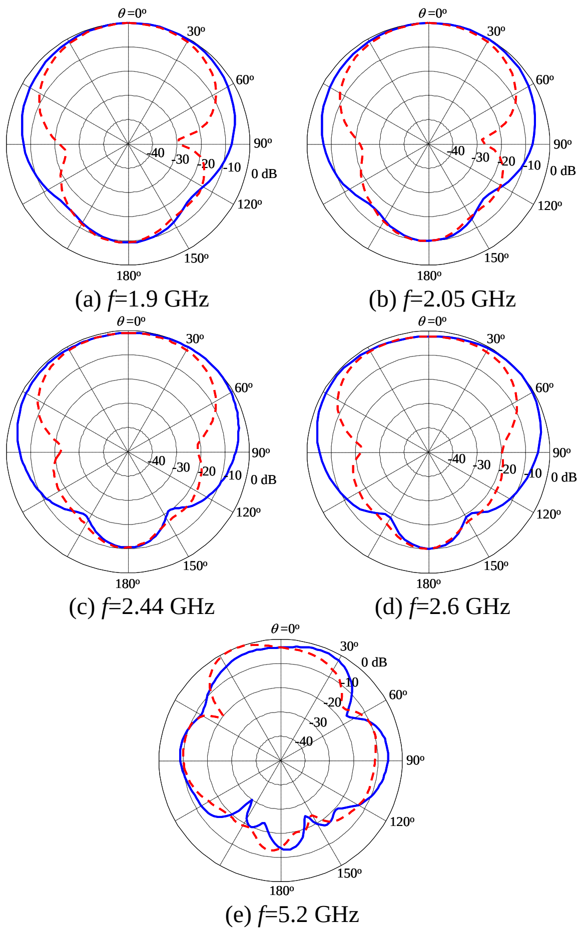
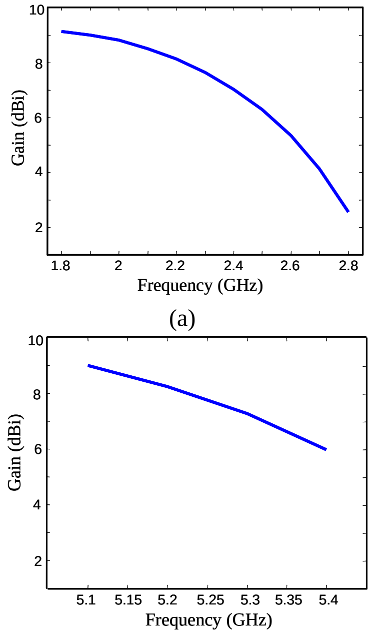


Figure 7. Radiation patterns of the SRMA design.



(a)

(b)

Figure 8. Simulated antenna gains against frequency for the proposed antenna in the
(a) 1.8–2.8 GHz; and (b) 5.1–5.4 GHz bands.

4. Conclusions

In the paper, a novel dual wideband monopole antenna has been introduced. The optimum antenna configuration which is fed by a tree-stage meandered microstrip line consists of two split-ring elements and metallic loadings appropriately placed between the rings. Analysis results of the antenna which are obtained using well-known HFSS and CST commercial software packages are in good agreement within the desired frequency bands. The proposed antenna provides 46% and 9.3% impedance bandwidths at 2.41 GHz and 5.36 GHz, respectively. Hence, the antenna offers coverage of almost all PCS, UMTS, WiMAX and WLAN frequency bands corresponding to IEEE standards. Also, the antenna exhibits almost omni-directional radiation patterns with predicted gains of 5–9 dBi over the bands of interest.

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