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Compact Spiral Loaded Printed Monopole Antenna

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Abstract---A novel miniaturized printed monopole structure is proposed. The antenna comprises a printed monopole strip which is loaded by a spiral located on the rearside connected by a via. The inductive loading provided by the spiral enables considerable miniaturization of antenna. A parametric study of key dimensional parameters and groundplane are discussed.

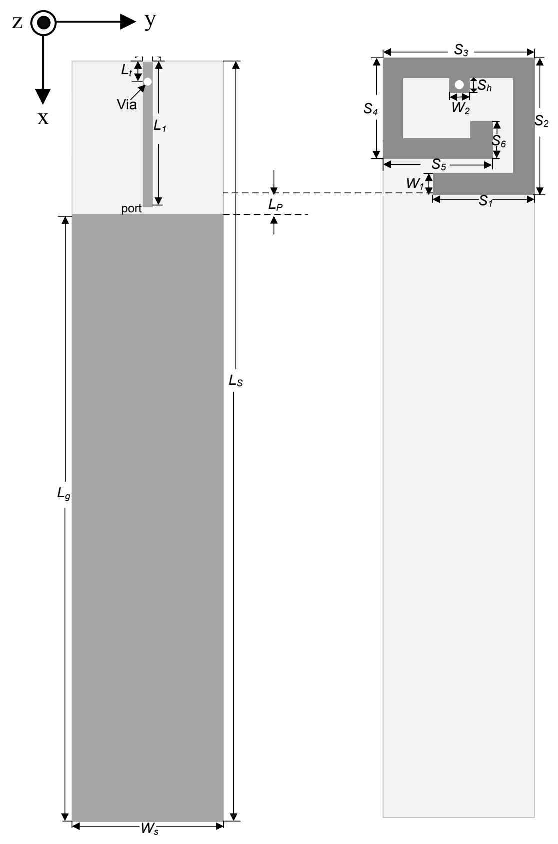
INTRODUCTION

Due to their attractive features, such as low cost, omnidirectional radiation characteristics, simple geometry and ease of fabrication, printed planar monopole antennas have been applied in the broad range of applications including wireless communication systems, sensor networks, radio frequency identification systems (RFID) and imaging systems [1]. As the size of these devices decrease due to advances in IC and component technology, there is an increased demand for antenna integration and miniaturization. A circular disc monopole with a crossed-slot and a meander-line feed was recently reported to achieve miniaturization [2]. Strip loading and tapered 3D meanderline techniques have also been employed to reduce monopole size [3-4]. In [5] a meandered monopole antenna with printed sleeves was proposed for the UHF broadband digital television system. Dual-band and UWB low-profile compact antennas are also recently reported in [6-9].

In this paper, a monopole is loaded by a printed spiral arrangement located on the opposite side of the substrate. By using this technology, the spiral inductively loads the monopole and the resonant frequency is significantly reduced. The compact monopole structure is proposed for sensor, RFID and WLAN systems.

THE GEOMETRY OF THE PROPOSED MONOPOLE ANTENNA

Figure 1 shows the geometry and coordinate system of the proposed compact monopole antenna with dimensional parameters. The antenna port connects to a narrow strip of length L_1 and width S_w. A spiral strip arrangement of width W_1 and length $S_1+S_2+S_3+S_4+S_5+S_6$, is connected to the narrow strip using a via. The spiral is located on the rearside of the strip. The strip is printed on the same side as the ground plane, which is arranged to be fed by circuitry in layers covering the groundplane. Because of the augmentation by the via connected spiral, there is an increased value of the inductance which is used to lower the working frequency. Thus the spiral loading reduces the antenna size. The proposed antenna is fabricated on FR4 substrate with a relatively permittivity $\varepsilon_r = 4.2$, a thickness of 1.52 mm and a loss tangent of 0.02.



(a) (b)

Figure 1 The geometry of the proposed monopole antenna

NUMERICAL AND EXPERIMENTAL RESULTS

By using CST Microwave studio, the optimized parameters of the antenna were found to be as follows: L_g = 94 mm, L_s = 116 mm, W_s = 24 mm, L_1 = 22 mm, L_t = 3 mm, S_w = 1.4 mm, W_1 = 3 mm, S_1 = 15 mm, S_2 = 19 mm, S_3 = 24 mm, S_4 = 15 mm, S_5 = 20 mm, S_6 = 5 mm, W_2 = 2 mm, S_h = 2 mm, L_p = 4.0 mm.

The proposed monopole antenna is fabricated on the substrate of size 116 mm × 24 mm. The narrow strip is connected to the spiral using a via of radius 0.5 mm.

Figure 2 shows the measured and simulated S_{11} for the proposed antenna. The simulated matched bandwidth (S_{11} <-10 dB) is about 310 MHz from 0.823 GHz to 1.133GHz, or 31.7% with respect to the centre frequency of 0.975GHz. The measured impedance bandwidth is about 285 MHz from 0.824 GHz to 1.109 GHz. The simulated results and measured results are in good agreement.

Because of the embedded inductance on the back of the substrate, the working frequency of the proposed antenna can be significantly reduced. The antenna size is considerably smaller than a quarter wavelength monopole. The size of the proposed antenna is 0.073 of a wavelength above the groundplane.

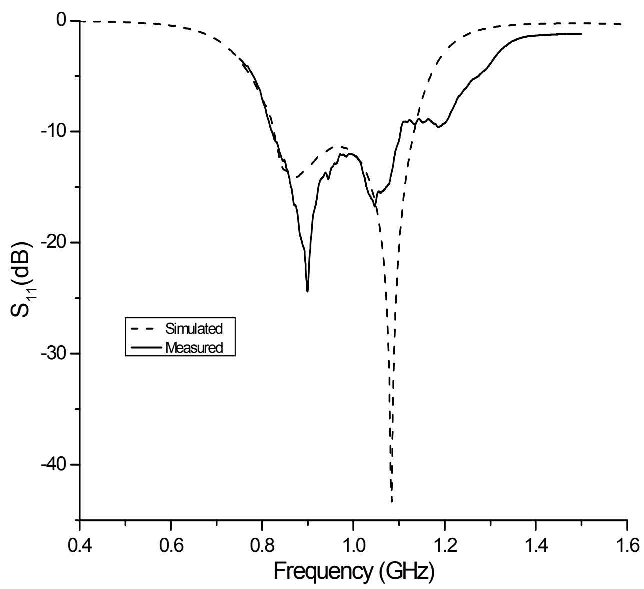


Figure 2 The measured and simulated S_{11} for the proposed antenna

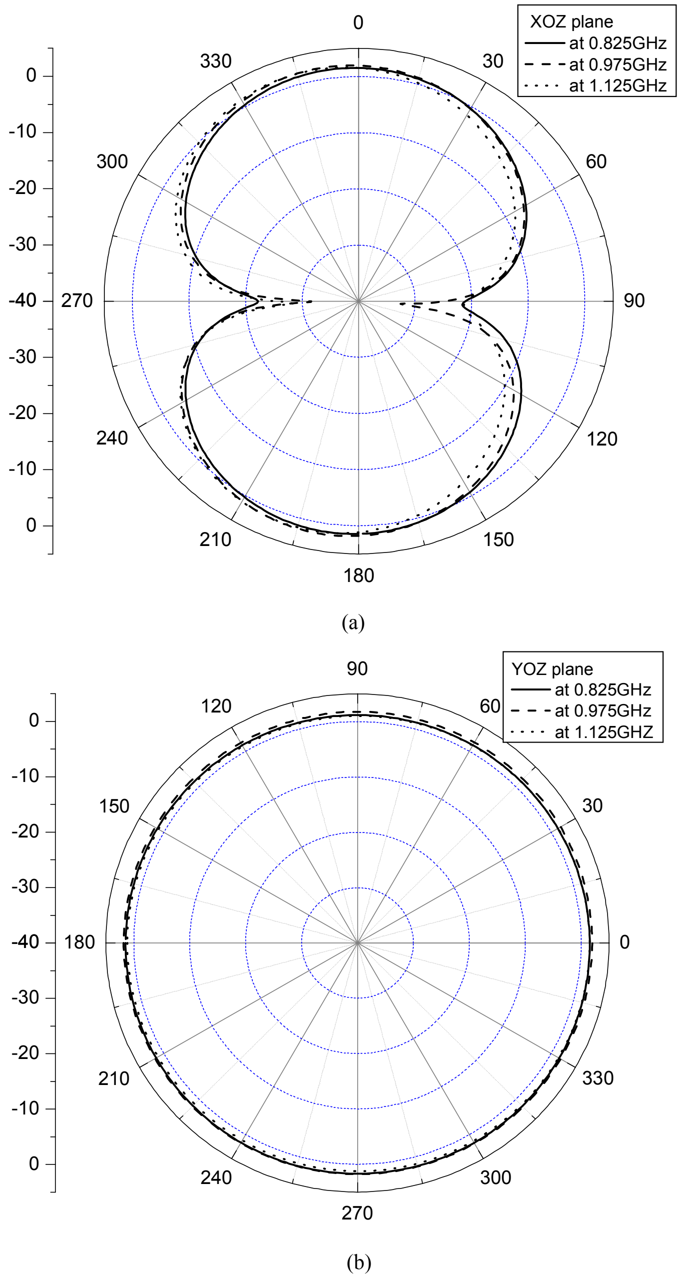


Figure 3 The simulated radiation patterns at (a) XOZ plane and (b) YOZ plane

Figure 3 displays the simulated radiation patterns at 0.825GHz, 0.975GHz, and 1.125GHz, respectively. As seen in Figure 7 (b), the radiation patterns in the YOZ plane are omnidirectional.
The simulated gains are shown in Figure 4. The peak gains are greater than 1.5 dBi in the working frequency range. The average gains are also very stable from 0.825 GHz to 1.12 5 GHz.

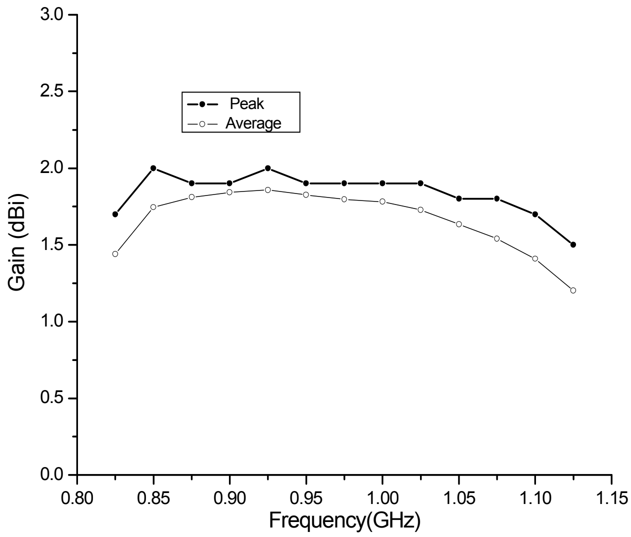


Figure 4 The simulated peak and average gain against frequency.

PARAMETRIC STUDY

Three types of antennas were studied to explain the operation: a narrow printed strip monopole (antenna A), a strip monopole loaded by a rectangular patch on rearside (antenna B), and the proposed spiral-loaded monopole (antenna C). The working frequencies and bandwidths are compared numerically. The impedance characteristics are shown in Figure 5. It is seen that the proposed antenna has a broad matched impedance bandwidth and can significantly reduce the working frequency of the antenna, in comparison with the strip monopole (antenna A) and plate-loaded monopole (antenna B).

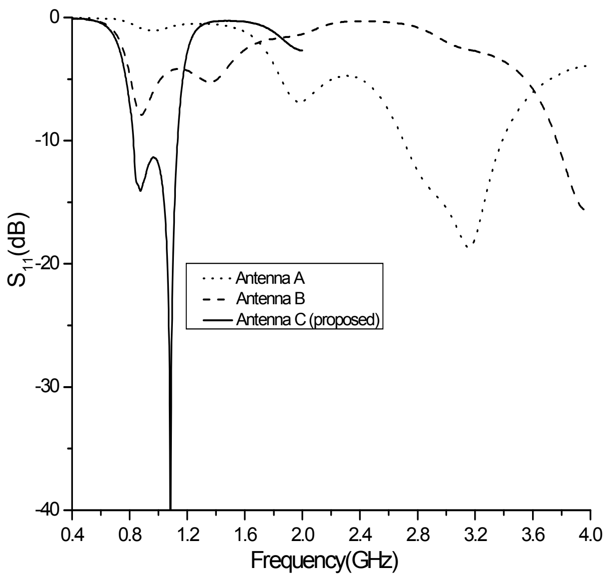


Figure 5 The simulated S_{11} results for the three antenna types

Figure 6 illustrates the effect of the strip width for the spiral patch on the impedance bandwidth. As the strip width W_1 is increased, the impedance bandwidth of the antenna becomes wider until the S_{11} degrades and the frequency of lower edge shifts upwards slightly.

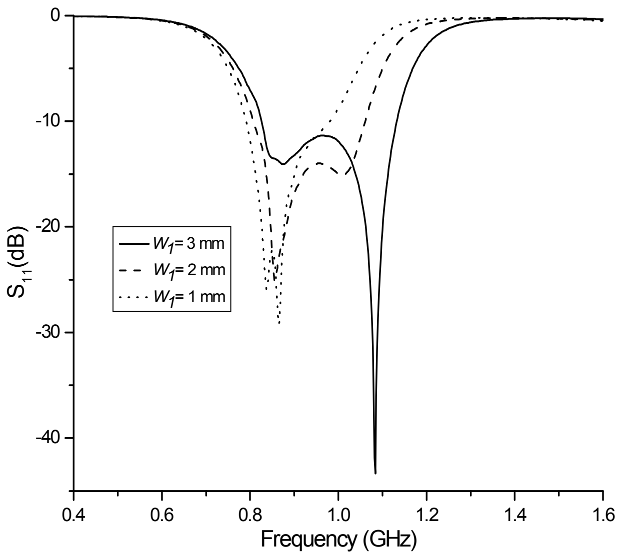


Figure 6 The simulated S_{11} for different spiral widths

Figure 7 shows the impedance characteristics S_{11} for different values of L_p, which is the distance between the edge of the ground plane and the edge of the spiral patch. The plots show minor sensitivity of the antenna to this distance. For L_p = 4 mm, the S_{11} curve is the deeper and impedance matching is best.

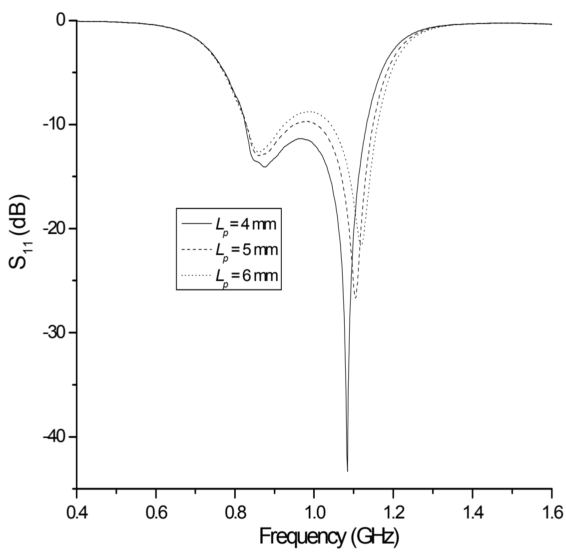


Figure 7 The simulated S_{11} for different L_p

Figure 8 shows the effect of the ground plane length on the impedance characteristics of antenna. It is noted that the dimension of the ground plane has a significant effect on the S_{11} of the antenna. When the size of the ground plane become the longer, from 64mm to 94 mm, in 10 mm steps, the impedance matching is improved and so is the bandwidth.

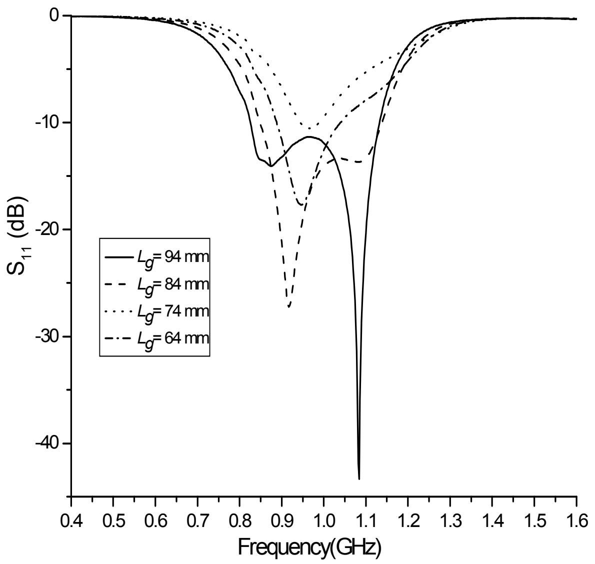


Figure 8 The simulated S_{11} as the ground plane length L_g is varied.

CONCLUSIONS

A novel miniaturized monopole structure is designed, which is loaded by a printed spiral located on the rearside of the monopole. The proposed monopole antenna can significantly reduce the length of monopole. The antenna is suitable for integration into radio frequency circuits with application in RFID sensor and WLAN systems.

ACKNOWLEDGEMENTS

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