Progress In Electromagnetics Research Letters, Vol. 53, 95–100, 2015

Microstrip Monopolar Patch Antenna for Bandwidth Enhancement

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Abstract—A microstrip monopolar patch antenna with shorting vias in the circular patch and coupled ring for bandwidth enhancement is proposed. The bandwidth of the proposed antenna with shorting vias in the annular coupled ring is over 40% wider than that of the antenna without shorting vias in the annular ring. The proposed antenna provides a wide bandwidth because of four resonant modes, including the TM_{01} mode of the circular patch, TM_{01} mode of the coupled annular ring, TM_{02} mode of the circular patch, TM_{02} mode of the coupled annular ring. These modes can generate an omnidirectional pattern in the azimuth plane like a monopole antenna. A prototype was fabricated to confirm the simulation verdictions. Measured results show that 10-dB return loss bandwidth of 38.4% from 4.42 to 6.52 and average gain of 5 dBi acrossing the operating band are achieved for the proposed antenna with a low profile of 0.027 wavelength.

1. INTRODUCTION

Monopole antennas are charming for wireless communication systems because they can generate omnidirectional radiation pattern in the azimuth plane. However, the traditional monopole antenna has a height of about $0.25\lambda_0$ (where λ_0 is referred to the wavelength in free space), which is too high for some applications when a low profile is needed.

For achieving a low-profile and monopole-like radiation pattern, a center-fed circular patch antenna with omnidirectional radiation patterns is proposed in [1], but the proposed antenna has a narrow bandwidth of 1.5% for a thin substrate with 0.0152 wavelength or 5% for a thick substrate of 0.058 wavelength. A patch antenna is shorted to the ground plane with thin wires, which is called monopolar wire-patch antenna is proposed in [2]. The antenna generated omnidirectional radiation patterns with a reduced height of $0.06\lambda_0$. However, the bandwidth of the proposed antenna is less than 3%.

Several useful techniques are used for the bandwidth enhancement of the monopolar patch antennas in [3–11]. The height of these antennas is about $0.1\lambda_0$ (or even higher), which is too large for some applications such as conformal radiator.

In 2009, a center-fed monopolar circular patch antenna with a coupled annular ring is proposed in [12] by Al-Zoubi et al. The antenna has a very low profile and is easy for fabrication. But, its bandwidth is only 12.8% and has a shortcoming of a large radius of about $0.72\lambda_0$, because of higher order resonant mode (TM_{02} mode of the circular patch and TM_{02} mode of the coupled ring). In 2013, a center-fed microstrip monopolar patch antenna with shorting vias was proposed in [13]. It achieves a bandwidth of 18%, which is still narrow for some application.

In January 23, 2014, Liu et al. proposed a monopolar circular patch antenna loaded with shorting vias and a coupled annular ring in [14] to achieve a wider bandwidth by coupling three modes. The antenna achieves a bandwidth of 27.4% with a very low profile and has an omnidirectional pattern like a monopole antenna.

Received 4 March 2015, Accepted 25 May 2015, Scheduled 28 May 2015

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In this paper, we propose a new wideband microstrip monopolar patch antenna, which has wider bandwidth than that in [14]. By placing shorting vias both in the circular patch and the coupled annular ring, four modes can be generated to achieve a wide band. A prototype is fabricated, and measured results show that the antenna obtains a bandwidth of 38.4% with a profile of $0.027\lambda_0$ with respect to its center frequency 5.47 GHz and has a gain of about 5 dBi.

2. ANTENNA DESIGN

Considering a microstrip monopolar patch antenna that has shorting vias both in the circular patch and the annular ring as shown in Figure 1, TM_{01} mode of the circular patch has been produced by placing shorting vias close to the null point of the electric field of the TM_{02} mode of the circular patch in [13]. Moreover, in [14] by adding an annular ring around the circular patch, TM_{02} mode of the annular ring is produced. In this paper, by adding shorting vias close to the null point of the electric field of the TM_{02} mode of the coupled annular ring, as is shown in Figure 1, a new resonant mode of the TM_{01} mode of the annular ring can be generated to add to three modes that have been produced in [14]. As a result, without any loss of radiation character, four resonating modes can be produced to achieve a

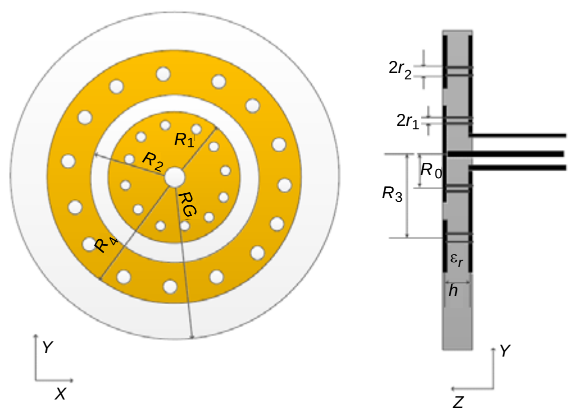

Figure 1. Geometry of the microstrip monopolar patch antenna with shorting vias both in circular patch and coupled annular ring.

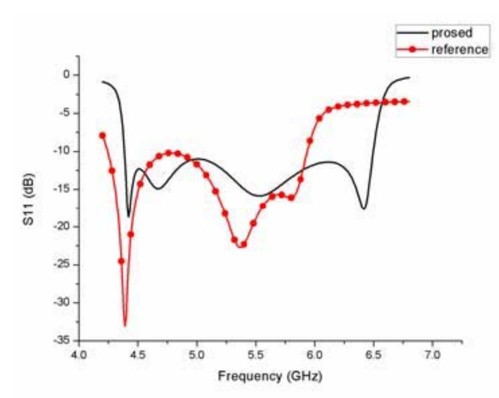

Figure 2. Reflection coefficients for the proposed antenna (solid line) and reference antenna (dotted line).

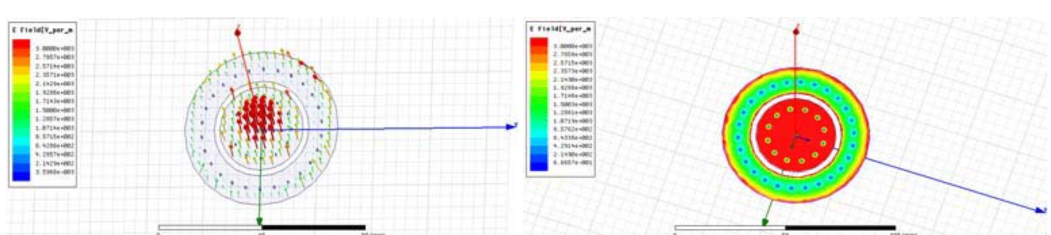

Figure 3. Simulated electric field distribution of the TM_{01} mode of the circular patch at 4.42 GHz.

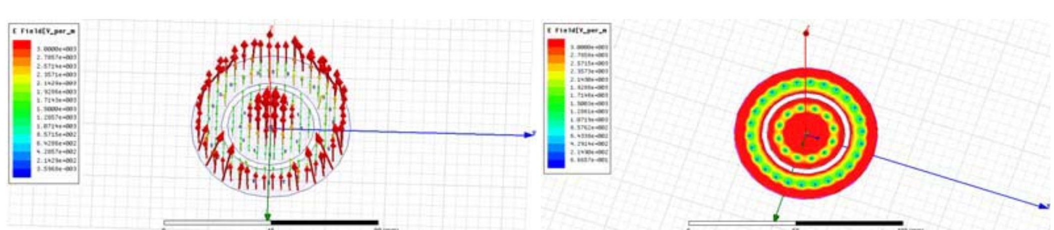

Figure 4. Simulated electric field distribution of the TM_{01} mode of the annular ring at 4.67 GHz.

wider band than the antenna without shorting vias in the annular ring [14]. We start our design based on [14], and use it as a reference antenna. Our antenna is similar to it, the biggest difference is that $N = 26$ shorting vias are added in the coupled annular ring. In the design of the proposed antenna, the resonant frequencies of the four modes must be tuned to be appropriate rightly close to form a wide bandwidth and the coupling degree between the circular patch and the coupled annular ring must be proper. So, we need to tune seven parameters, R_0, R_1, R_2, R_3, R_4, r_1, r_2, simulation (a commercial High Frequency Structure Simulator (HFSS)) is carried out to find the optimized parameter.

The antenna is fed in the middle of the patch by a coaxial probe with an SMA connector. To make a fair comparison with [14], the antenna is fabricated on a grounded circular substrate with a relative permittivity of $\varepsilon_r = 2.65$, a thickness of $h = 1.5$ mm, and a semi-diameter of $R_g = 60$ mm, which is the same as the antenna in [14]. The circular patch has a radius of $R_1 = 18.5$ mm, and a series of $M = 12$, shorting vias with a radius of $r_1 = 0.3$ mm are located at $R_0 = 13.15$ mm with respect to the center of the patch. A parasitic annular ring with an inner radius of $R_2 = 21.05$ mm and an outer radius of $R_4 = 34.05$ mm is employed to load the patch. It is noticeable that a series of $N = 26$ shorting vias with a radius of $r_2 = 0.4$ mm are located at $R_3 = 26.7$ mm.

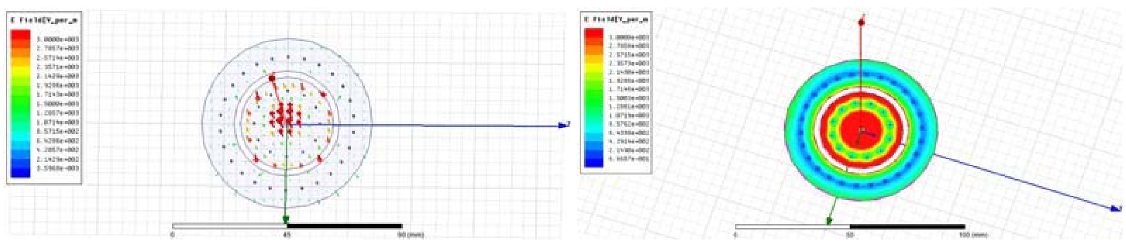

Figure 5. Simulated electric field distribution of the TM_{02} mode of the circular patch at 5.52 GHz.

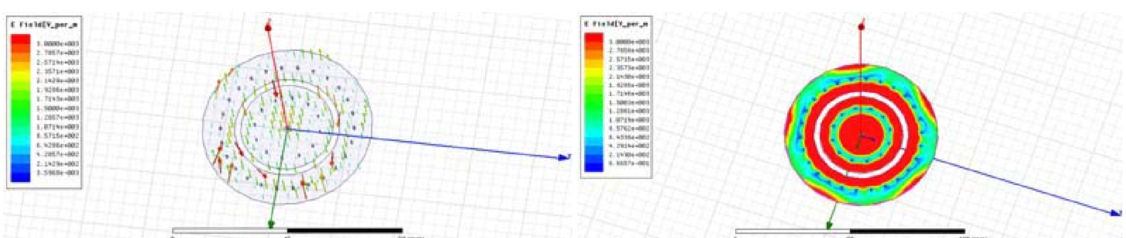

Figure 6. Simulated electric field distribution of the TM_{02} mode of the annular ring at 6.42 GHz.

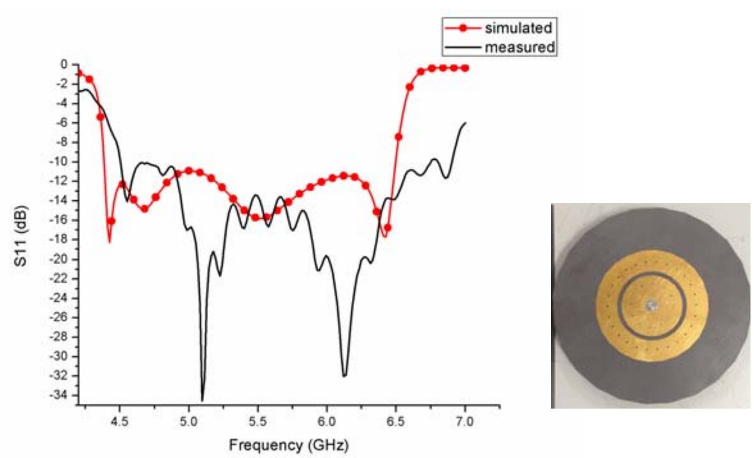

Figure 7. Reflection coefficients for the fabricated antenna and the photograph are shown in the inset.

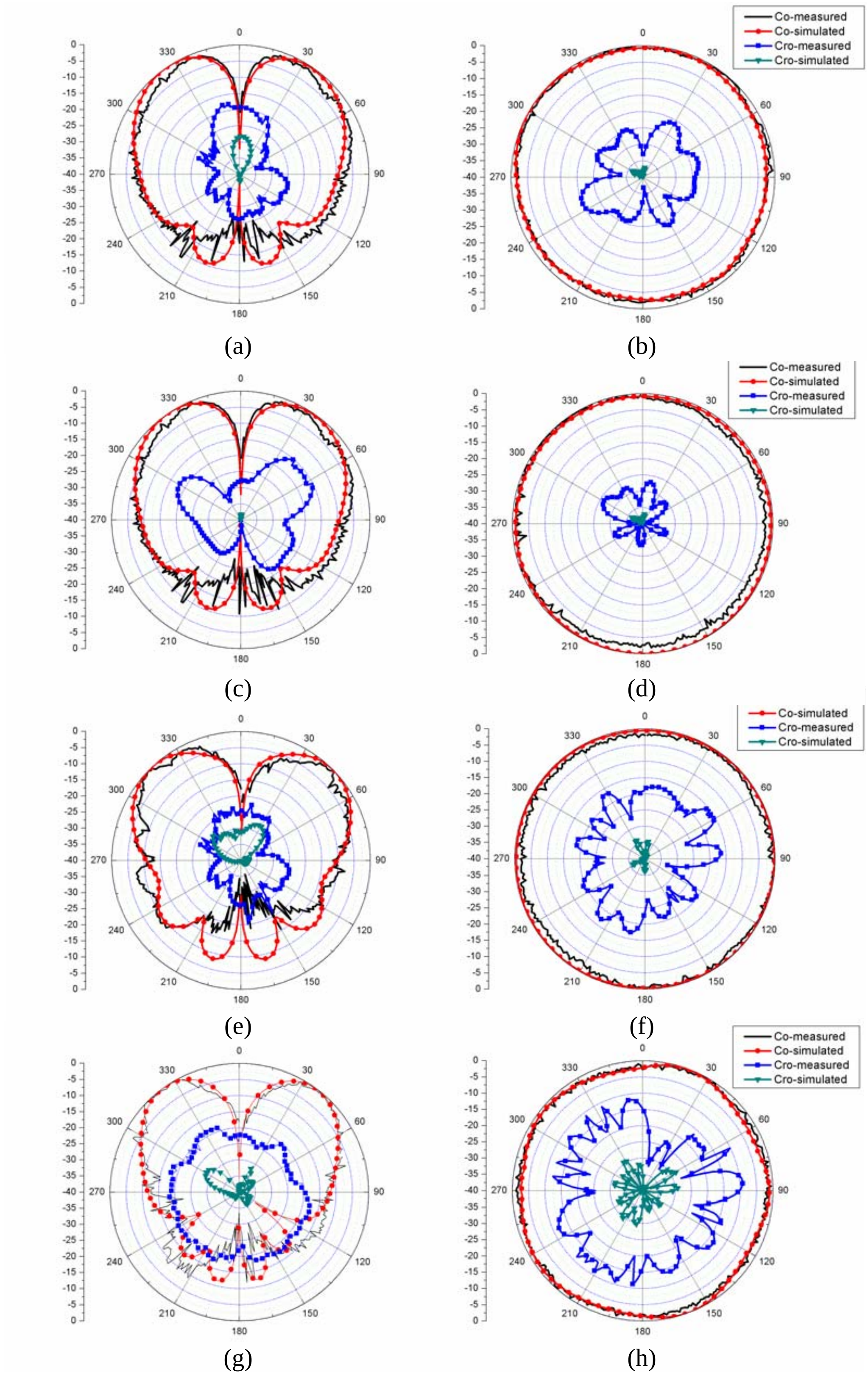

Figure 8. Elevation plane radiation patterns for the fabricated antenna at: (a) 4.42 GHz, (c) 4.67 GHz, and (e) 5.25 GHz, (g) 6.42 GHz. Azimuth plane radiation patterns at: (b) 4.42 GHz, (d) 4.67 GHz and (f) 5.25 GHz, (h) 6.42 GHz.

3. SIMULATION AND ANALYSIS

Simulated reflection coefficient for the proposed antenna is shown in solid line in Figure 2, in which four resonant modes are observed, while reflection coefficient for the reference antenna is shown in dotted line in which only three resonant modes are observed. With the increasing of frequency, the mode of the proposed antenna is the TM_{01} mode of the circular patch, TM_{01} mode of the annular ring, the TM_{02} mode of the circular patch and TM_{02} mode of the annular ring.

The electric fields for the circular patch and the parasitic annular ring are shown in Figure 3–Figure 6, electric fields distribution for the TM_{01} mode of the circular patch are shown in Figure 3, electric fields distribution for the TM_{01} mode of the annular ring are shown in Figure 4, electric fields distribution for the TM_{02} mode of the circular patch are shown in Figure 5, electric fields distribution for the TM_{02} mode of the annular ring are shown in Figure 6. The difference between the electric fields distribution of TM_{01} mode and TM_{02} mode is that TM_{01} mode has identical directions at the two sides of the vias, while TM_{02} mode has adverse directions at the two sides of the vias.

4. EXPERIMENT

The prototype of the proposed antenna with a substrate which has a relative permittivity of $\varepsilon_r = 2.65$, thickness of $h = 1.5$ mm, and tangent loss of 0.001, whose optimal geometrical parameters can be found in II, is constructed and measured. The reflection coefficients are shown in Figure 7. Measured results show that the reflection coefficient is less than 10 dB in the band from 4.42 to 6.52 GHz. The fractional bandwidth is 38.4% with respect to its center frequency of 5.47 GHz. Simulated results agree well with the measured results, although a difference is observed. The elevation plane and azimuth plane radiation patterns for the antenna operating at 4.42, 4.67, 5.52, 6.42 GHz are shown in Figure 8. It shows that the antenna produces a conical radiation pattern in the elevation plane and an omnidirectional radiation pattern in the azimuth plane, similar to those generated by a monopole antenna. The cross polarization is low in both plane. The maximum gains for the antenna are given in Figure 9. Measured result shows that the antenna produces a gain of about 5 dBi. The measured gain is a little higher than the simulated one due to fabrication and measurement error.

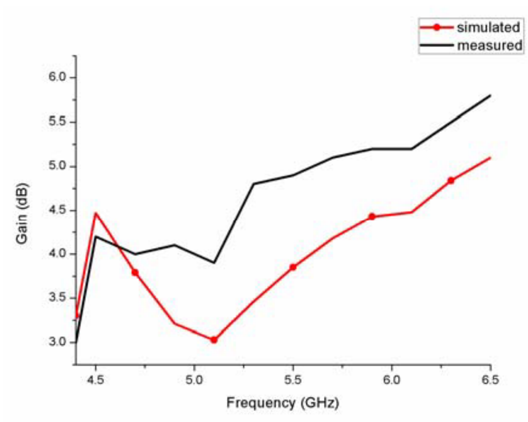

Figure 9. Simulated and measured maximum gain of the proposed antenna.

5. CONCLUSION

A novel wideband center-fed microstrip monopolar patch antenna is proposed and fabricated. The proposed antenna consists of a circular patch and a coupled annular ring. The bandwidth of the proposed antenna can be improved by placing shorting vias both in the patch and the annular ring. The proposed antenna provides wide band as a result of quadruple-resonance behavior. Measured result shows that the antenna has a bandwidth of 38.4% with a very low profile and produces a monopole-like radiation pattern with a gain of about 5 dBi. The bandwidth of the proposed antenna is over 40% wider than that of the antenna without shorting vias in the annular ring in [14].

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