Wideband Monopole Antenna with Rotational Circular SRR

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Abstract This paper presents a technique to achieve two narrow bands and wideband metamaterial monopole antenna with Rotational Split Ring Resonator (R-SRR). To realize the additional bands and widen the impedance bandwidth of the conventional monopole antenna, parametric analysis of the gaps and SRR positions are performed. Three bands are achieved covering the operating bands of GSM, WLAN, WiMAX and 5G applications. The proposed antenna has the overall size of 14.6 × 11 mm^2 and designed on an FR4 substrate due to its low profile, light weight and low cost. Simulated results are presented and discussed. The proposed design can be applied to GSM, WLAN, WiMAX and 5G applications and have advantages of compactness, miniaturization and simple design.

Keywords R-SRR · GSM · WLAN · WiMAX · 5G

1 Introduction

The rapid development of wireless communication systems has increased the number of wireless applications users. Most of these applications such as GSM, CDMA, WLAN, WiMAX, operate in multiple frequencies and involve in transmitting and

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receiving large amount of data. Thus, more attention is given to antenna design with compact size, multiband and wideband characteristics [1–6]. To achieve the multi functionality and high data transmission performance of antenna, various methods have been proposed, which include modifying the antenna from single band to multiband [3], narrow band to wideband [6, 7] and wideband to ultrawideband [5]. In [3], a CSRR was adopted on the ground plane of microstrip antenna to realize multiband. Proper matching was achieved at the designed frequency. However, the design is insufficient of lower frequency bands such as GSM. The antenna in [7] achieved a wide bandwidth using metamaterial cells in the lower band frequency, but the design is possesed with complex resonant circuits.

In this paper, a simple wideband with two narrow bands on the lower frequency band metamaterial monopole antenna with offset SRR is proposed for simultaneously satisfying GSM, WLAN, WiMAX and future 5G bands. As shown in Fig. 1, the rectangular monopole antenna was designed originally to radiate at a single band and fed by a 50 Ω microstrip line with partial ground plane. Subsequently, by introducing SRR on the back plane, two narrow bands and a wideband are achieved. Detailed of antenna dimensions, parametric analysis and results discussion are provided in other sections.

2 Antenna Design

Figure 1 shows the geometry of the proposed triple band antenna with rotational SRR for GSM/WiMAX/WLAN/5G applications. The antenna design was simulated using the CST Microwave Studio and fabricated using FR-4 Substrate with a thickness of 0.8 mm and relative permittivity of 4.4. In Fig. 1a, the 50 Ω microstrip feed line and the rectangular monopole are printed on the top/front side of the substrate, while the partial and R-SRR are printed on the bottom side of the substrate as shown in Fig. 1b.

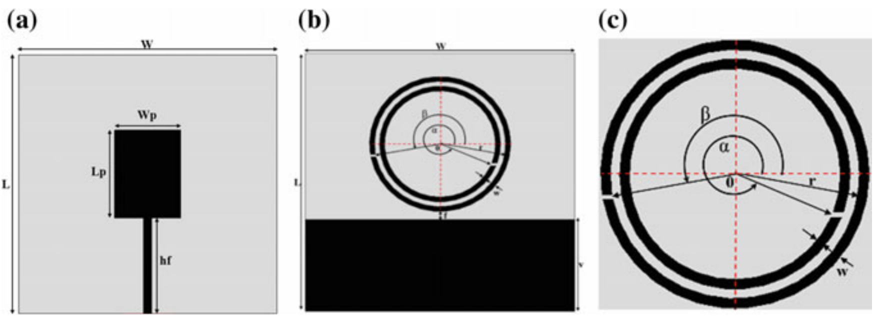

Fig. 1 Antenna configuration. **a** Top view, **b** bottom view, **c** rotational SRR. W = L = 43 mm, Wp = 11 mm, Lp = 14.6 mm, hf = 15.9 mm, f = 1 mm, r = 22 mm, w = 0.8 mm

By varying the position of f to the higher value, fundamental resonant frequency is shifted to the lower frequency, thus, the optimum value of f is determined at the 1 mm from the partial ground plane (Fig. 1).

Similarly, when the radius of the outer ring (r) is increased, the resonant frequency decreased, while when the width and the spacing (w) are increased, the resonant frequency of the proposed antenna is also increased. Proper parametric studies were conducted on each parameter while keeping other parameter constant. Thus, the choice of the presented parameters are selected and discussed. Moreover, the position of the gap plays an important role in determining the required number of bands and the bandwidth coverage. It can be seen from Fig. 2, that by varying the angle α and β, different bands were generated. The initial position of the outer gap β and inner gap α were simulated at 180° and 0° respectively. The parametric results can be referred to in Fig. 2.

Figure 3 shows the equivalent circuit, which consists of passive inductance L and capacitance C. The resonance frequency of the R-SRR is determined by adopting Eq. (1):

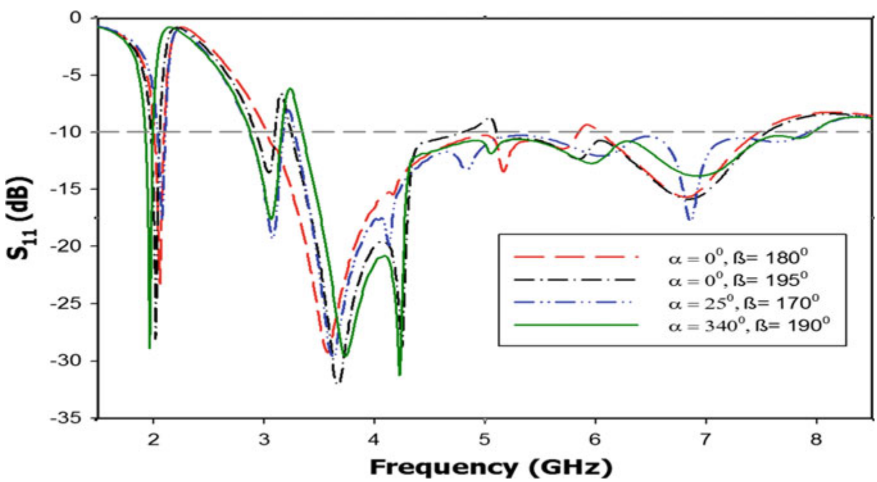

Fig. 2 Simulated reflection coefficient S_{11} for the proposed antenna with changing dimensions of α and β

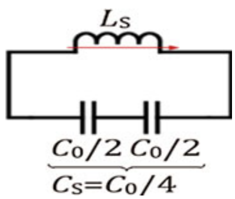

Fig. 3 SRR equivalent-circuit model

$$f = \frac{1}{2\pi\sqrt{L_s C_S}} \quad (1)$$

where C_s is the series capacitance of the upper and lower halves of the SRR, while L_S stands for the inductance and can be approximated using the single ring with the values of width (w) and radius of the ring.

3 Results and Discussion

The Simulated Reflection Coefficient (S_{11}) for the proposed metamaterial monopole antenna with and without the SRR is shown in Fig. 4. The conventional monopole antenna operates at 3.7817 GHz with a bandwidth of 1.5 GHz (3.2–4.7) GHz. Moreover, the use of the SRR on the ground plane have improved the impedance bandwidth significantly to 4.62 GHz (3.3–8.0) GHz. Beside increasing the bandwidth, SRR also creates additional two narrow bands covering lower frequency bands. The first 10-dB bandwidth of the lower band reflection coefficient reaches 80 MHz (1.9–2.0) GHz while the second lower bandwidth covers 290 MHz (2.87–3.16). Wideband is achieved at the higher frequency with bandwidth of 4.62 GHz (3.34–7.96). The radiation patterns in E and H plane of monopole antenna with and without R-SRR are plotted in Fig. 5a and b respectively. Based on the overall point of view of the radiation patterns, the conventional monopole antenna behaves relatively similarly with the metamaterial antenna at the lower bands. These bands operate bidirectionally, due to the simultaneous radiation of the SRR, ground plane and the patch antenna. Table 1 shows the summary performance of the proposed monopole antenna with and without the R-SRR in terms of the frequency, bandwidth and gain.

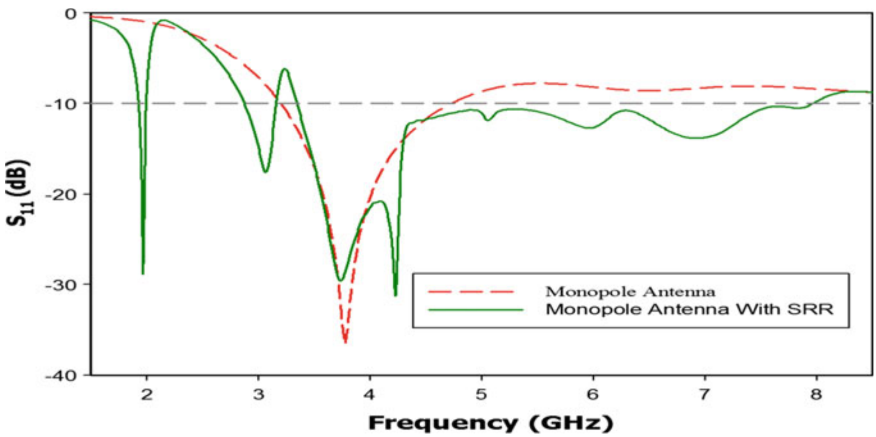

Fig. 4 Comparison between the simulated reflection coefficient for the monopole antenna and the proposed metamaterial monopole antenna α = 340° and β = 190°

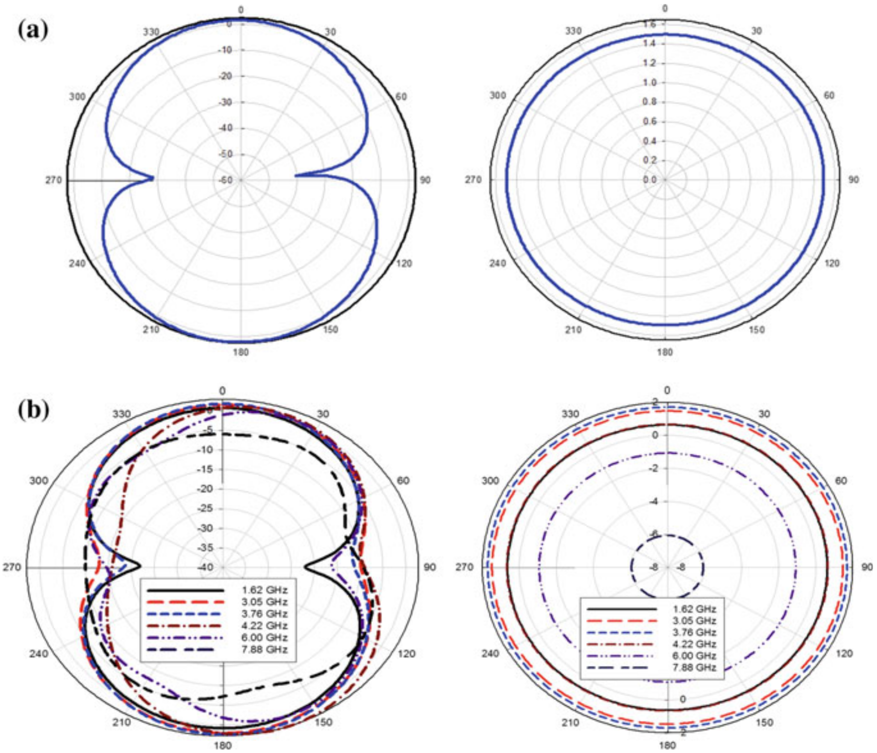

Fig. 5 Simulated E-plane and H-plane radiation patterns of **a** monopole antenna at 3.77 GHz, **b** proposed metamaterial antenna at various frequencies

Table 1 Summary performance for the proposed monopole antenna with and without the R-SRR

Antenna type	Frequency (GHz)	Bandwidth (GHz)	Antenna gain (dB)
Monopole antenna	3.78	1.5 GHz (3.2–4.7)	2.24
Monopole with CSRR	1.96	80 MHz (1.9–2.0)	0.88
	3.05	260 MHz (2.9–3.16)	2.132
	3.76	4.61 GHz (3.35–7.96)	2.49
	4.22		2.91
	5.03		1.57
	6.00		3.96
	6.90		4.42
	7.88		2.58

4 Conclusion

In this paper, a simple metamaterial monopole antenna with a rotational SRR backed plane for GSM/WLAN/WiMAX triple mode (narrow bands and wideband) operation has been presented. By employing the R-SRR on the ground plane, impedance bandwidth is increased remarkably and sufficiently covers the 3.5/4.5/5.2/5.8/6–8 GHz WLAN/WMAX/5G bands and simultaneously generates additional bands covering the 1.9 GHz GSM and 3.0 GHz bands. The proposed antenna has the advantages of low profile, size reduction and shows omnidirectional radiation patterns at lower frequency due to the radiation from the SRR and monopole antenna.

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