Design of Novel Radial Folded Microstrip Patch Antenna for WiMAX Application

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Abstract In recent years, the study of microstrip patch antennas (MPA) has made great progress because of its advantages in terms of weight, volume, cost, fabrication, and dimension. This paper presents a novel radial folded microstrip patch antenna, which operates at 3.55 GHz frequency. The microstrip design composed radial folded resonator with partial ground plane. The folded structure is used in order to achieve the compactness, and partial ground is used to suppress the high order harmonic. The proposed antenna shows mono narrowband behavior with the –10 dB bandwidth of 480 MHz (3.3–3.78 GHz), which is one of the 5G bands used for Worldwide Interoperability for Microwave Access (WiMAX) application. The obtained results through simulation depict return loss below –30 dB, VSWR below 0.6, and peak gain of 5.1 dB at operating frequency of 3.55 GHz. These results are obtained through HFSS software.

Keywords Microstrip antenna · Radial folded resonator · WiMAX

1 Introduction

The rapid development in mobile communication and emergence of newer technologies require design of antenna with smaller size, higher gain, lower power loss, high

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bandwidth, and higher data speed. In order to reach tradeoffs amid these requirements, several antenna configurations are developed [1–3]. The advent of integrated devices in modern communication system popularizes microstrip patch antenna due to its properties like light weight, integration compatibility with passive and active devices, low volume, low cost, and easier fabrication. The microstrip patch antenna includes a metallic radiating patch at the top of dielectric substrate with metallic ground on the bottom of the substrate.

The antenna is vital element in wireless system used to transmit and receive the electromagnetic signals through the air media. Nowadays, its use is not limited to only human communication but is used in variety of applications like microwave imaging [4], e-health [5], satellite communication, IoT (Internet of things), radar, military, cognitive radio, energy harvesting, and so on. The individual applications need the antenna performance as per their requirement. Many researches had been already done in the designing of antenna, and many more are going on due to regular escalation in technology with improved performance and addition of newer technologies within the same volume of the equipment, as one can easily see from 1 to 5G wireless communication. In order to achieve these, a variety of antenna designs with numerous radiations patterns and performance parameters had presented [6]. Numerous patch shapes are also researched to realize miniaturized antenna structure, enhanced bandwidth, multiband operations such as Z-shape [4], Koch Fractal [7], T-shape [8], U-shape [9], spline shape [10], and so on.

There are different methods proposed in literature for wideband and narrowband performance. As specific frequency bands are allotted for different applications like for wireless local area network (WLAN), WiMAX, wireless fidelity (Wi-Fi), Global Positioning System (GPS) etc. So, these systems need multi or mono narrowband antennas, and for easier portability microstrip technology is best choice due to its light weight and easier integration capability. In past, many application-specific mono-band antennas are presented like E-shaped microstrip antenna [11] for WLAN (5–6 GHz) application, metamaterial-based antenna with bowtie stub for WLAN (2.45 GHz) [12], Coplanar waveguide-fed antenna for WiMAX (5.5 GHz) application [13], microstrip rectangular patch antenna [14] with defected ground structure comprise of array of complementary split ring slots in ground plane for WiMAX (2.6 GHz), fractal patch antenna with partial ground [15] for WiMAX (3.5 GHz) application.

This paper illustrates a narrowband microstrip patch antenna (MPA) with partial ground plane for WiMAX application at 3.55 GHz. The microstrip line fed is used with quarter wave transformer for impedance matching. The novelty of the work is in terms of patch configuration which shows compactness due to radial folded configuration and its narrowband performance. HFSS software is used for all the simulations in this work. The achieved bandwidth, VSWR, and realized gain show its suitability for WiMAX.

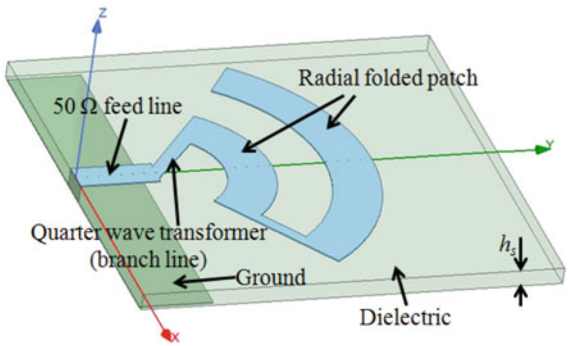

Fig. 1 Three-dimensional view of the proposed radial folded patch antenna

2 Antenna Design Methodology and Configuration

Initially, the dielectric substrate with a particular height and dielectric constant and the desired operating frequency are chosen or known in the typical antenna design procedure. The designed antenna is radial folded microstrip patch. The overall volume of the antenna geometry is $W_s \times L_s \times h_s$, i.e., $40 \times 40 \times 1.6$ mm^3; however, the overall dimension of the radiating patch is only $W_g \times L_p$, i.e., 39×29 mm^2.The proposed antenna system has been simulated on FR4 glass-reinforced epoxy laminate material with relative permittivity, dielectric loss tangent, and height of 4.4, 0.02, and 1.6 mm, respectively. For effective radiation from the antenna, impedance matching must be ensured by the designer in between the radiating patch and feed line for maximum power transfer from the input to the patch and less reflection. Here, a branch line of quarter wavelength is used for the matching purpose. The width of the branch line can be calculated easily after the evaluation of its characteristic impedance $\left(Z_{\lambda/4}\right)$, which can be determined by using (1).

$$Z_{\lambda/4} = \sqrt{Z_o Z_e} \tag{1}$$

Here, Z_o is characteristic impedance of main feed line (50 Ω) and Z_e is input impedance at patch edge. The three-dimensional view of the designed antenna is illustrated in Fig. 1. Figure 2 depicts the top and bottom view of the design with dimensional variables. The optimized dimensional parameters are specified in Table 1.

3 Results

The mono and narrowband antenna presented in this paper use partial ground plane and radiating element as radial folded patch. The simulated results demonstrate the applicability of the proposed antenna for WiMAX band at 3.55 GHz. The operating

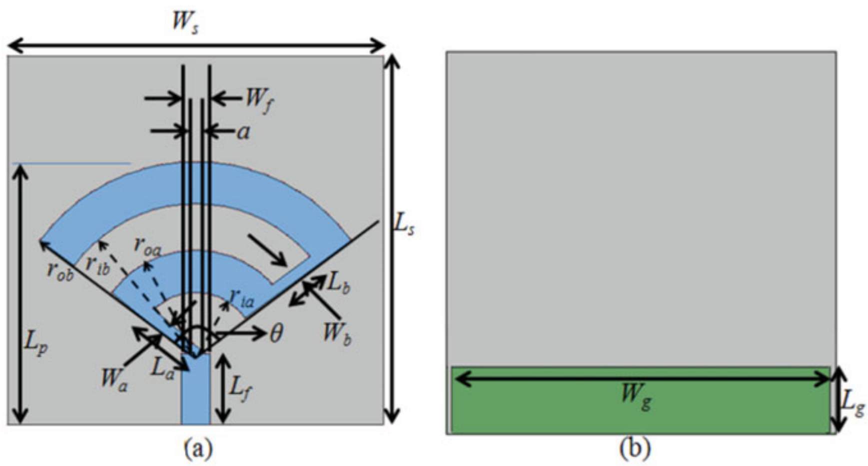

Fig. 2 Two-dimensional view (**a**) radiating patch at top and (**b**) partial ground at bottom

Table 1 Antenna design variables

Variables	Dimension
W_s	40 mm
L_s	40 mm
W_g	39 mm
L_g	7 mm
W_f	3 mm
L_f	7.6 mm
A	2 mm
W_a	1.3 mm
L_a	6.5 mm
r_{ia}	6.5 mm
r_{oa}	11 mm
W_b	1.3 mm
L_b	5 mm
r_{ib}	16 mm
r_{ob}	20.5 mm
L_p	29 mm
Θ	108°

frequency and bandwidth of the antenna are achieved by optimizing the dimensional parameters shown in Table 1. The partial ground concept is utilized in the design to excite the higher mode and enhance the return loss. The effect of the partial ground plane can be easily demonstrated by analyzing the return loss (S11) plot in Fig. 3.

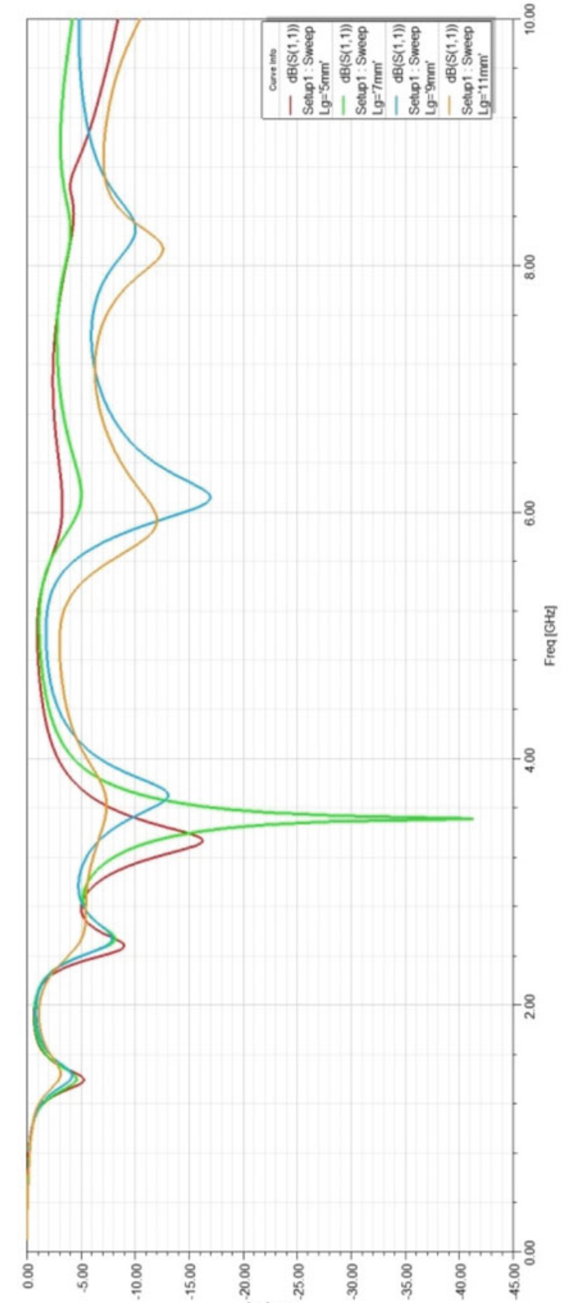

Fig. 3 Simulated return loss (S11) of designed antenna with variation in length of ground conductor (L_g)

The return loss of the final structure with $L_g = 7$ mm, is illustrated in Fig. 4. The designed antenna resonates at 3.55 GHz and shows –10 dB bandwidth of 480 MHz (3.3–3.78 GHz) i.e. 14%. The simulated S-parameter illustrates a return loss at the operating frequency well below –30 dB.

In Fig. 5 VSWR plot is shown, which demonstrates the VSWR level within 6 dB for 3.3–3.78 GHz frequency range; however, the VSWR at 3.55 GHz is below 0.6 dB. Figure 6 illustrates the polar plot of radiation pattern at the resonant frequency 3.55 GHz for 0 and 90 phi angle. The 3-D radiation plot for total gain at 3.3, 3.55 and 3.7 GHz are depicted in Fig. 7, which show peak gain of 5.6, 5.1 and 4.7 dB, respectively. This demonstrates the applicability of the antenna over the bandwidth.

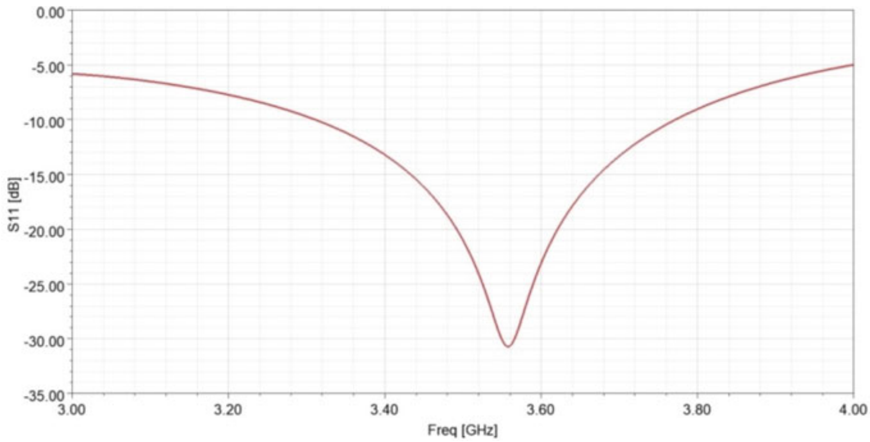

Fig. 4 Simulated S11 plot for proposed antenna configuration ($L_g = 7$ mm)

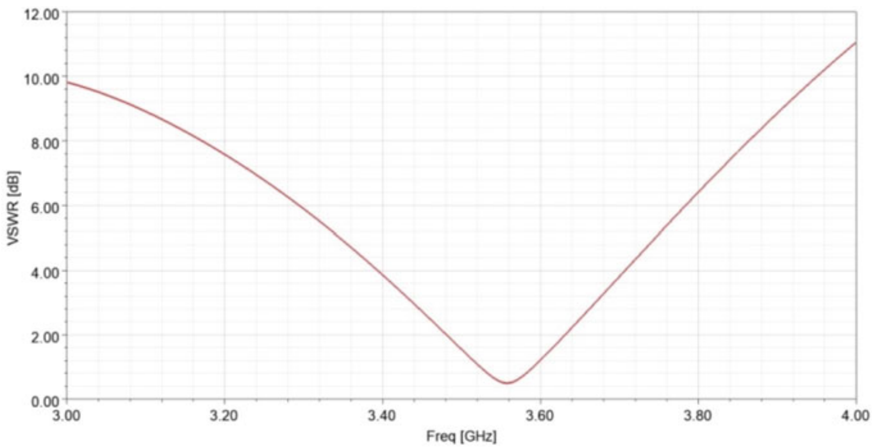

Fig. 5 The simulated VSWR plot of the proposed antenna

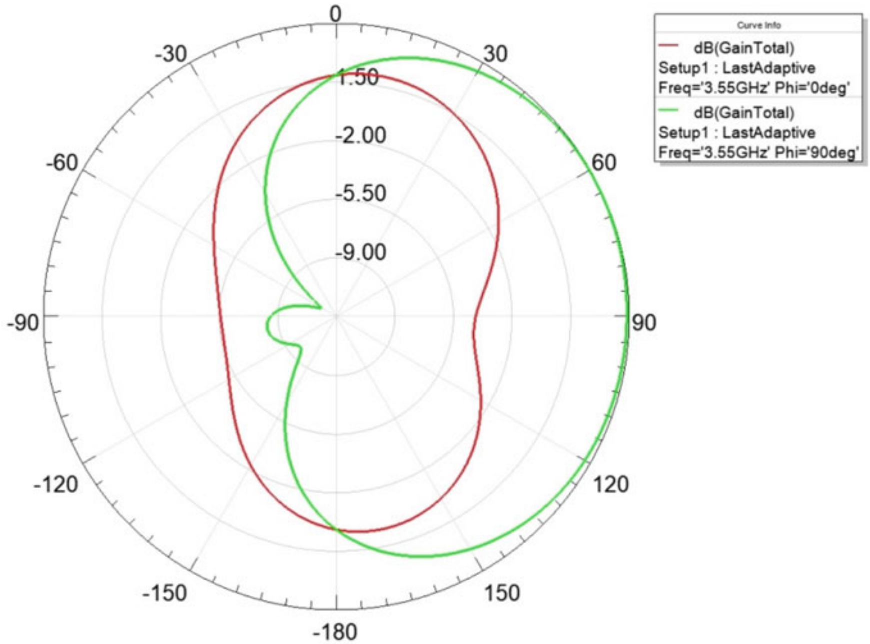

Fig. 6 Polar plot for radiation pattern at 3.55 GHz for phi = 0° and 90°

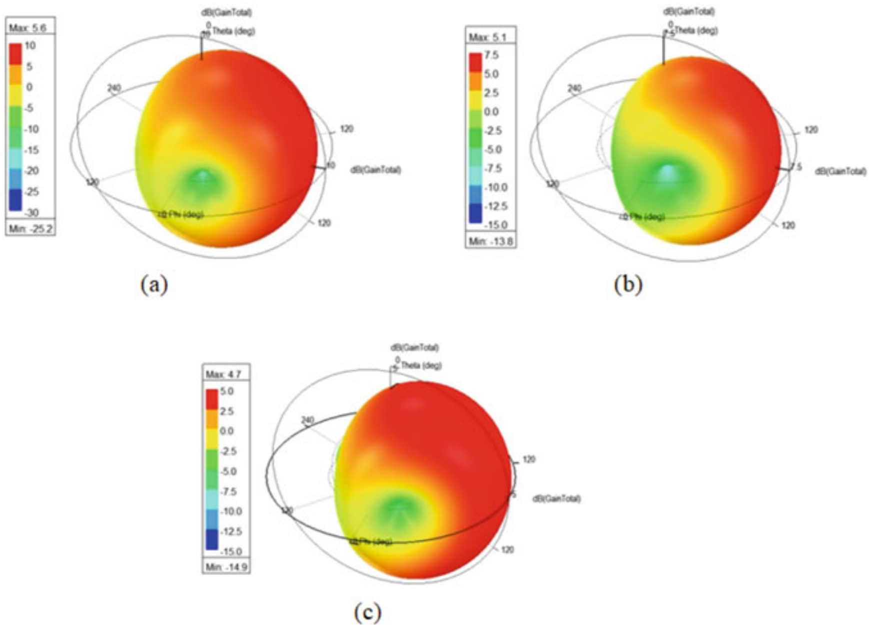

Fig. 7 3-D plot of total gain **a** at 3.3 GHz, **b** at 3.55 **GHz** and **c** at 3.7 GHz

4 Conclusion

In this work, a novel radial folded MPA has been presented. The design of radial folded MPA is done by using HFSS simulator. A radial folded MPA is simulated and it provides 3.55 GHz resonating frequency which is used for WiMAX applications. The folding of the resonator is done in order to achieve miniaturization. The Radial folded MPA gives a gain of 5.1 dB for 3.55 GHz. The VSWR at operating frequency is below 0.6 dB and the −10 dB bandwidth is 480 MHz (3.3–3.78 GHz). This proposed antenna depicts appreciable gain, bandwidth and return loss, which makes the antenna suitable for WiMAX applications.

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