Multi – Band Planar Metamaterial Monopole Antenna with Defected Ground Plane for Mobile Applications

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Abstract: This paper presents a compact and Multiband planar monopole antenna with defected ground structure for mobile applications. The monopole antenna is developed with microstrip feed line and two metamaterials and defected ground plane to enhance the channel capacity. A low-cost FR4 epoxy substrate material is used with constant values of relative permittivity 4.4 and dielectric loss tangent 0.02. The designed antenna possesses an overall compact dimension of 83 mm x 56 mm, fabricated on the 1.56 mm thick substrate. The Multiband operations at desired frequencies are used to evaluate the overall gain and impedance of transmits or receives and increase the performance. The parameters such as radiation patterns and return loss are found using the defected ground structure. Antenna is designed and simulated by using Ansoft HFSS v13 simulator; the antenna is to be fabricated to validate the simulated results with the measured results.

Key words: Monopole antenna, metamaterial, defected ground structure

I .INTRODUCTION

In modern communication system, the demand for compact size antennas is increasing because of their wideband and multiband characteristics [1]. This attracts researchers towards microstrip antennas due to their low weight, low cost, low profile and conformal shape [2, 3]. Modern systems support different wireless applications and can be operated on various frequency bands. Hence, there is a need for multiband/wideband antennas [4, 5]. Nowadays due to advancement in wireless technologies, the need for wideband antennas is increased. So different applications can be obtained on a single device such as data, text, audio, video or multimedia streaming [6]. In wireless communication to increase the data rate, FCC (Federal Communication Commission) released the unlicensed radio communication band (3.1 GHz–10.6 GHz) [7]. This band is used for the Wireless Personal Area Networks (WPAN) [8]. The bandwidth of antenna should be ≥ 1.5 GHz (25%), to satisfy the UWB (Ultra-Wideband) operations [9]. Antennas designed for UWB can be useful to work under various applications such as WLAN (2.4 GHz– 2.48 GHz, 5.15 GHz–5.85 GHz), WiMAX (2.5 GHz–2.7 GHz, 3.4 GHz–3.69 GHz, 5.25 GHz–5.85 GHz), X band satellite communication (7.1 GHz–7.76 GHz) and point to point high speed wireless communication (5.925 GHz–8.5 GHz) [10, 11]. In recent years, a lot of research has been proposed by the researchers in the field of wideband antennas. Many techniques are used to achieve wideband characteristics such as defected ground plane, partial ground plane, monopole patch, fractal patch, and micro strip patch [6–8, 12–14]. A wideband dual-frequency CPW-fed triangular monopole antenna for DCS and WLAN application has been designed to achieve the bandwidth of 34.7% (4.08 GHz–6.03 GHz) [14]. A wideband fractal antenna with combination of fractal geometries is investigated to achieve the bandwidth of 72.37% (1.64 GHz– 3.5 GHz) [13]. A microstrip patch antenna is designed for wireless application with bandwidths of 4.13% and 8.82% at the frequencies of 2.45 GHz and 5.125 GHz, respectively [2]. A CPW-fed slot antenna is designed to improve the impedance bandwidth to 52% (4.27 GHz–7.58 GHz) [15]. An L-shaped slotted patch antenna is designed with the wideband of 4.7 GHz [16], and a double L-slotted microstrip patch antenna is designed for broadband applications such as WLAN and WiMAX [17]. Monopole antenna I also constructed using CPW structure [18]. A trip; band micro strip antenna is constructed using asymmetrical slotted line [19]. Dual band antennas are designed for various applications [20, 21, 22]. In this paper, a design of a compact monopole antenna with metamaterial and defected ground plane (DGP) for Multiband applications is designed. The Multiband characteristics of antenna have been improved by employing the defects partially in the ground plane. The smaller size is obtained by adding metamaterial structure of two complementary split ring resonators adjacent to the feed line. The proposed antenna exhibits Multi bandwidth and is capable of covering different mobile application such as 4G and 5G applications. The structure, simulation and experimental details are discussed in Sections II and III.

ANTENNA DESIGN

The design and schematic configuration of the patch of proposed monopole antenna is shown in Figure. 1. The figure 1a shows the monopole antenna with metamaterial and b shows defected Ground Structure. The proposed antenna is designed using a low cost FR4 (glass epoxy) substrate with dielectric constant (εr) 4.4 and thickness (h) 1.6 mm. The initial geometry of antenna is composed of a rectangular patch as shown in Fig. 1(a), and the dimensions of patch (WP × LP) are calculated by using following equations [20], where fr (4 GHz) is the resonant frequency, c (3 × 108 m/s) the velocity of light, and h (1.6 mm) the thickness of substrate.

The effective dielectric constant of a microstrip line is given approximately by

$$\varepsilon_{eff} = \frac{\varepsilon+1}{2} + \frac{\varepsilon-1}{2}\frac{1}{\sqrt{1+12h/W}}$$

The Characteristic Impedance is given by

$$Z_0 = \frac{60}{\sqrt{\varepsilon}}\ln\left(\frac{8h}{W}+\frac{W}{4h}\right)(\Omega) \qquad \text{for } \frac{W}{h} \le 1$$

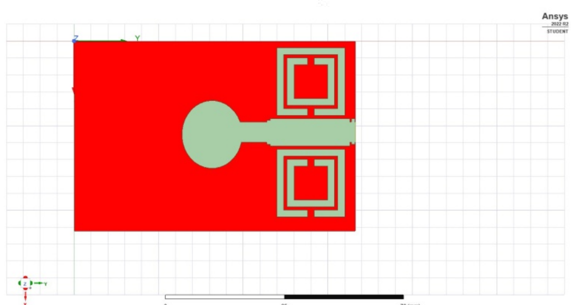
$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon}\left[\frac{W}{h}+1.393+0.667\ln\left(\frac{W}{h}+1.444\right)\right]}(\Omega) \qquad \text{for } \frac{W}{h} \ge 1$$

The width of microstrip line is given by

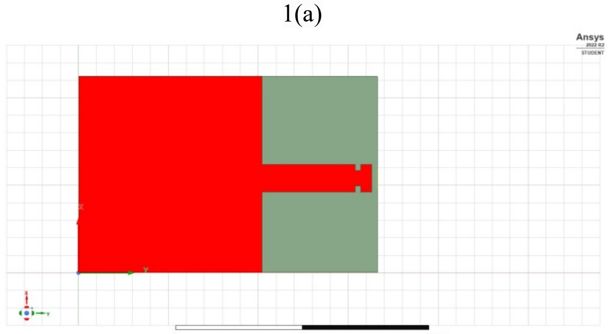
$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

The effective length of microstrip line is given by

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}}$$



1(a)



1(b)

Figure1. Proposed Patch antenna (a) monopole antenna with metamaterial (b) Defected Ground Structure

The table 1 shows the dimensions of the proposed patch antenna, both the top and bottom side.

Table 1 Dimensions of proposed antenna dimension

Parts	Size
Width of the patch	56mm
Length of the patch	83mm
Dielectric constant of the substrate (ϵ_r)	4.4
Thickness of the substrate	1.56mm
Circular patch radius	10.2 mm
Outer ring of SRR	20 X 20mm
Inner ring of SRR	14 X 14 mm
Rectangular patch 1	Length= 9mm, Breadth=6.1mm
Rectangular patch 2	Length=25mm , Breadth=8mm
Gap between outer and inner ring of SRR	1mm
Inner gaps in SRR	10X 10mm
Opening of SRR	2mm
DGS	Length=32.1mm, Breadth=56mm
Gap between DGS	8mm

III RESULT AND DISCUSSION

In this section, various parameters are investigated which influence the performance of the designed antenna. The simulation of the antenna is done using Ansoft HFSS software. The figure 2 shows the S11 parameter of the mono pole antenna. It works at two frequencies 2.4 GHz and 3.49 GHz. This is suitable for mobile communication at 4G and 5G.

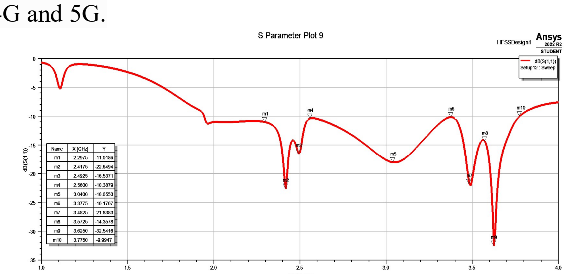


Figure2. S11 parameter of the Proposed Patch antenna

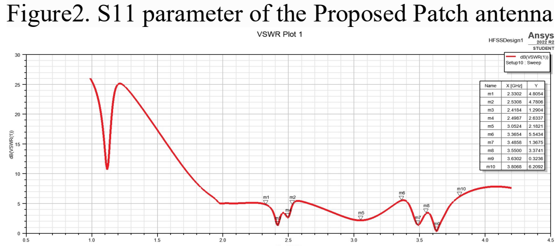


Figure 3. VSWR of the Proposed Patch antenna

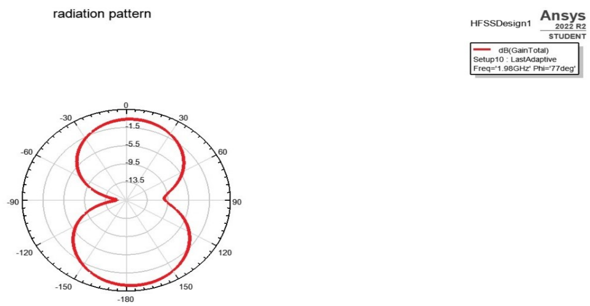


Figure 4. Radiation pattern of the Proposed Patch antenna

The figure 3 figure 4 shows the VSWR and radiation pattern of the proposed antenna respectively. The VSWR is below 2 for two frequencies 2.4 GHz and 3.49 GHz.

IV CONCLUSSION

The monopole patch antenna with metamaterial and DGS is being simulated using HFSS software simulation tools. The monopole patch antenna is working at two mobile frequencies of 4G and 5G technology applications. The simulated frequencies are around 2.5 GHz and 3.5 GHz, which is suitable for 4G and 5G mobile applications. The band widths of the antenna at the two resonant frequencies are 0.28 GHz and 0.42 GHz respectively. The overall dimension of the antenna is 83 mm x 56 mm. They are also dimensionally small and have impressive performance characteristics.

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