Cent. Eur. J. Eng. • 4(3) • 2014 • 287-292
DOI: 10.2478/s13531-013-0162-1

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Central European Journal of **Engineering**

A compact broadband microstrip patch antenna with defected ground structure for C-Band applications

Research Article

Sanyog Rawat[1]*, K. K. Sharma[2]

1 *Amity School of Engineering and Technology, Amity University Rajasthan, Jaipur-303002 (India)*

2 *Malaviya National Institute of Technology, Jaipur-302017 (India)*

Received 12 December 2013; accepted 24 March 2014

Abstract: A novel design of a circular patch antenna having defected ground structure is presented in this communication. The antenna is designed for C-band applications. A wide bandwidth of 60.3% (4.04-7.28) GHz is obtained in the C-band frequency range 4-8 GHz. It is also found through parametric analysis that shape and dimensions of the finite ground plane and slots in the patch are the key factors in improving the bandwidth of the proposed geometry. The antenna is fabricated using FR-4 substrate and parameters like return loss, VSWR and input impedance are measured experimentally.

Keywords: circular patch • wide bandwidth • slot and defected ground

1. Introduction

In the last few years, the microstrip antenna have been in tremendous use for applications such as radars, satellite, Radio frequency identifications (RFIDs), telemetry, aerospace etc. The microstrip antennas in their conventional form have certain limitations like narrow bandwidth, polarization impurity and large size for better performance.

Primarily, the microstrip antennas need to have high gain, compact size, broad bandwidth, flexibility, easy to be fabricated, etc. In particular, bandwidths, polarization, radiation patterns are becoming the most important factors that affect the application of antennas in modern wireless communication systems. Microstrip antenna for applications such as mobile and other portable devices must be small in physical size so that they can be embedded in devices and broadband in nature. The bandwidth enhancements

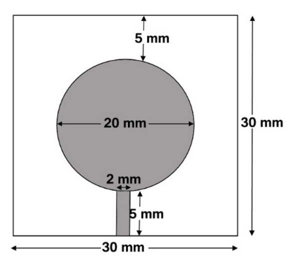

Figure 1. Top view of square geometry

*E-mail: sanyog44@yahoo.com

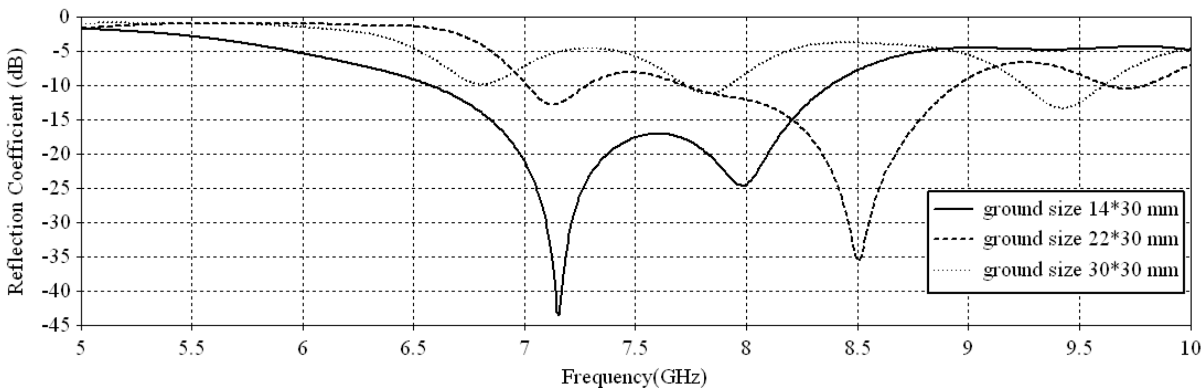

Figure 2. Effect of varying ground dimensions on reflection coefficient as a function of frequency

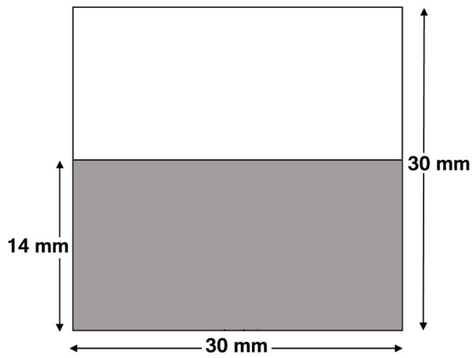

Figure 3. The bottom view of the truncated ground plane

in compact antennas have become a very critical design issue. Researchers in academia and industry have been working in this direction for development of a variety of techniques to build up small broadband antenna designs for different frequency bands. Several techniques have been illustrated in past to obtain broad bandwidth like use of thick substrate, stacked patches, shorting pins, use of active and passive devices, different feeding arrangement and using impedance matching network[1–5]. Recently a new technique of defected ground structure (DGS) is being used to enhance the bandwidth of microstrip antennas. In DGS intentional defects are introduced in the ground plane or slots of different shapes are cut in the ground that give rise to size reduction and desired radiation performance [6, 7]. It is already investigated in past that use of different DGS structure can suppress the cross polarization radiation [8], for dual band and multiband operation also it can be used [9–11]. Compact size antennas have been designed with this technique which offers wideband at the higher frequency for satellite and radar communication [12].

In the present work, novel broadband patch antenna for C-band application is presented. The proposed antenna consists of slotted patch with partial ground. The antenna has a compact size of 30×30×1.59 mm3 and operates over a bandwidth of 4.04-7.28 GHz (60.3%) which falls in the C-band region. The properties such as reflection coefficient, input impedance and VSWR are simulated and experimentally measured. Parametric analysis of the design parameters of proposed geometry has been done and optimized for best results. The proposed antenna design is analyzed by simulation software CST microwave studio suit and tested in free space.

2. Antenna design and results

The antenna geometry has finite ground plane and for its use in modern communication systems the dimension is limited to 30 × 30 mm. The resonant frequency and other radiation parameters for simple circular geometry can be obtained using cavity model based Modal expansion technique [13]. However, the simple circular geometry offers narrow bandwidth and low gain. The initial design consists of, circular microstrip patch antenna of radius 10 mm fed by a 50Ω microstrip line, which is printed on FR4 substrate, has a thickness of 1.59 mm and relative permittivity(ε_r) of 4.4, the substrate and ground dimensions are 30×30 mm as shown in figure 1, the geometry is simulated using finite element method based CST microwave studio. The finite element method has advantages over other computing methods. First, a geometrically complex domain of problem is represented as a collection of geometrically simple sub domains, called finite elements. Second, over each finite element, approximation functions are derived using the basic idea that any continuous function can be represented by a linear combination of alge-

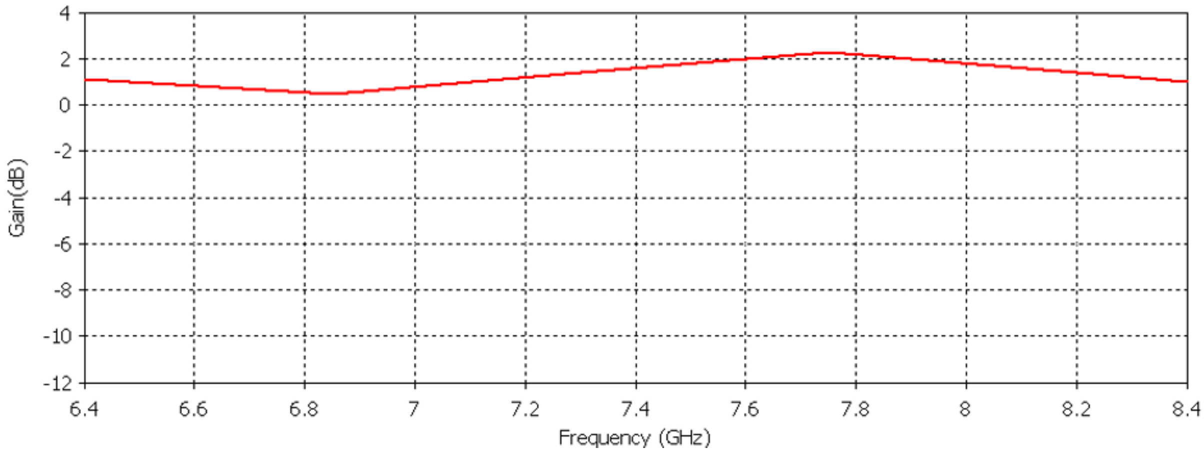

Figure 4. Variation of gain as a function of frequency for ground dimension 14×30 mm

braic polynomials.

The first step of modification involves truncating the ground plane to reduce its size. The effect of varying the ground dimension on reflection coefficient as a function of frequency is shown in figure 2. It may be observed that at ground size of 14×30 mm shown in figure 3 wideband is obtained and the antenna is resonating at dual frequency of 7.15 GHz and 7.98 GHz and offers a bandwidth of 1.79 GHz (6.58-8.37 GHz). The variation of gain with frequency is shown in figure 4 and it may be concluded from above results that the antenna has low gain and higher frequency exceeding the C-Band range. The geometry in present form is not suitable for C-band application and further modifications are required.

The next step of modification involves etching an elliptical slot in the circular patch having semi-minor axis b=3 mm and semi major axis a=4 mm as shown in figure 5. The dimensions of the ground are retained identical to that of the geometry considered in the previous section. The effects of varying the radius of major and minor axis elliptical slot on reflection coefficient as a function of frequency is shown in figure 6.

At a=4 mm and b=3mm the modified geometry is resonating at 6.958 GHz and has impedance bandwidth of 1.21 GHz(6.33-7.54 GHz), as compared to previous geometry resonant frequency is reduced and now the antenna is resonating in the required C-band but bandwidth is also reduced. The variation of gain with frequency for this modified geometry is shown in figure 7 and it shows that gain is still quiet low.

The antenna geometry reported in the previous section is further modified in steps by applying two identical slots of dimension 2×2 mm along the y axis at the patch. The size of the finite ground plane and slot location is also

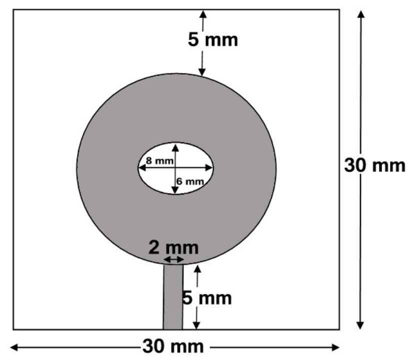

Figure 5. Top view of modified geometry with elliptical slot

optimized to attain best performance. After extensive optimizations the ground was reduced to 4×30 mm and it exhibits wideband behavior. The fabricated prototype of proposed antenna geometry is shown in Fig. 8.

The radiation parameters like refection coefficient (S_{11}) or return loss, VSWR and input impedance of the fabricated prototype is verified experimentally by connecting it to vector network analyzer port operating in S11 mode. The specific port of the analyzer was calibrated for the frequency range of 3 to 8 GHz using the standard open, short and matched load, prior to the measurement. The measured resonant frequencies of this geometry shown in figure 9 are 4.75 GHz and 5.98 GHz. It may be observed that the measured impedance bandwidth of antenna has now approached to 3.24 GHz (60.3%) corresponding to central frequency of 5.36 GHz. The measured VSWR values at two resonating frequencies are ≤ 2 (1.32 and 1.21 respectively) which suggest that antenna geometry has good matching with the microstrip feed line as

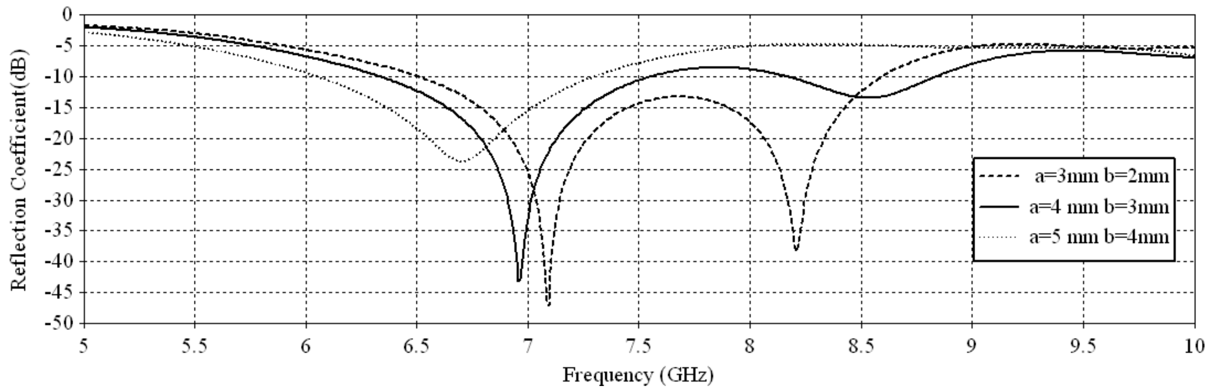

Figure 6. Effect of varying elliptical slot minor axis and major axis radius in patch on reflection coefficient as a function of frequency

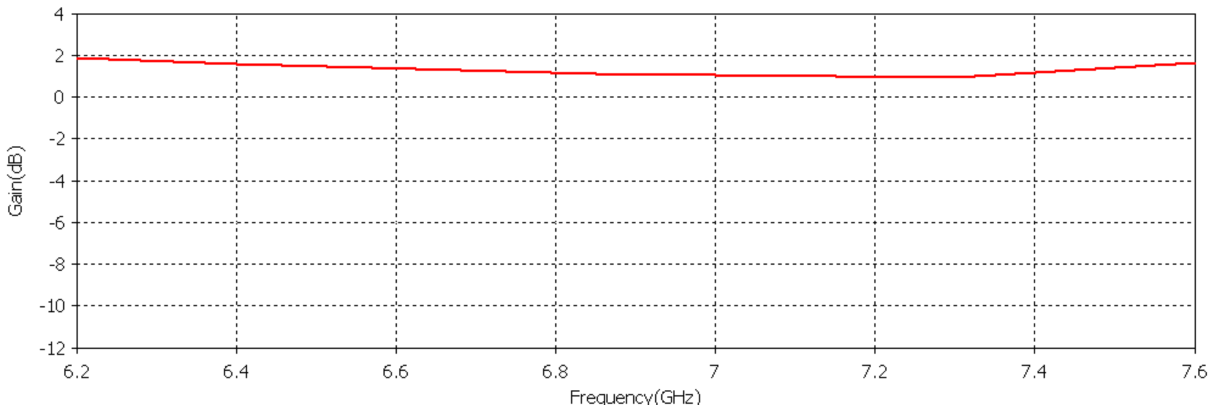

Figure 7. Variation of gain as a function of frequency for modified geometry with elliptical slot in patch

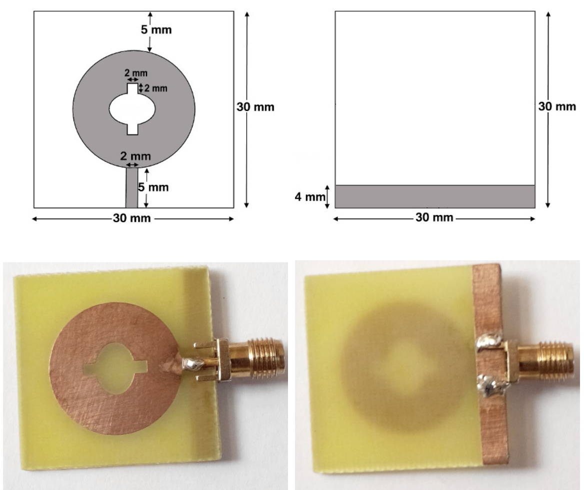

Figure 8. (a) Top view of the proposed geometry (b) Back view of the proposed geometry (c) Top view of designed geometry (d) Back view of designed geometry

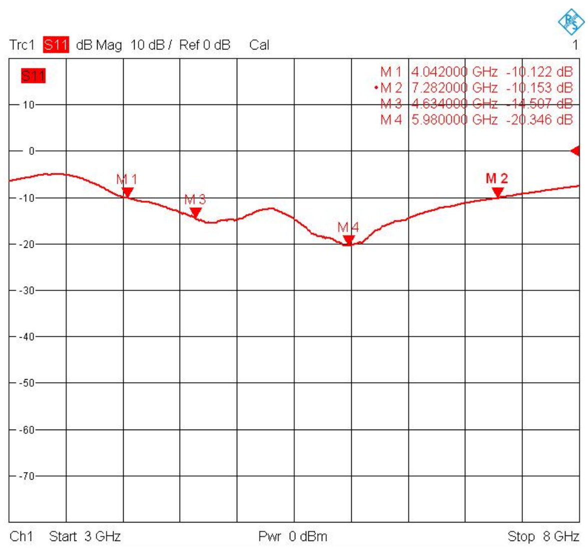

Figure 9. Variation of measured reflection coefficient with frequency for proposed geometry

Figure 10. Variation of measured VSWR with frequency for proposed geometry

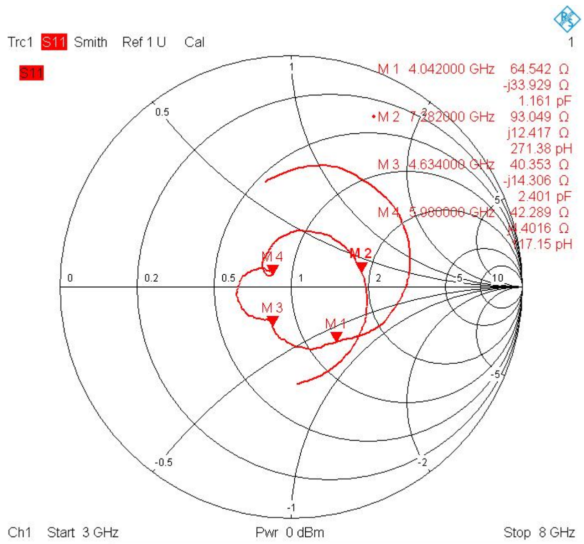

Figure 11. Measured input impedance of proposed geometry

shown in figure 10. The measured input impedance related to two resonant frequencies are (42.35- j4.80) ohm and (42.28+j4.406) ohm respectively as shown in figure 11 which are nearly reaching to 50 ohm impedance of the microstrip feed line.

Figure 12 and 13 shows the radiation patterns of the antenna in both the E-plane and H-plane at the respective resonant frequencies of 4.75 GHz and 5.98 GHz, these plots validate the broadside directive radiation pattern of the antenna.

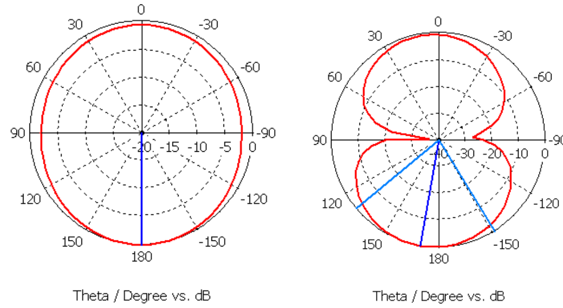

Figure 12. E and H plane radiation pattern at 4.75 GHz.

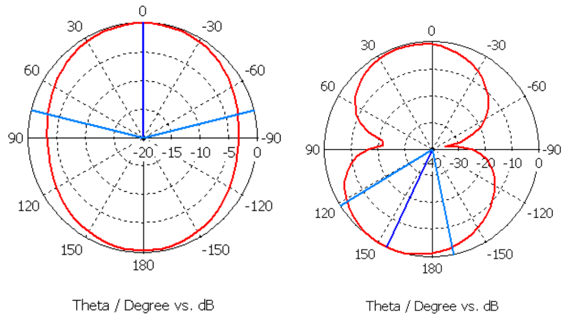

Figure 13. E and H plane radiation pattern at 5.98 GHz

The gain of the antenna as a function of frequency for the frequency range (4-7.5 GHz) is shown in figure 14. It indicates that gain is uniform in nature and nearly 3 dBi. The gain values are smaller than the desired one because bandwidth enhancement for this antenna was given preference over the gain and gain bandwidth product of antenna remains constant. The low value of gain is also due to high tangent loss of FR-4 substrate used.

3. Conclusion

A new design of modified circular patch antenna with defected ground is presented and tested. It has been observed that using the defected ground geometry and optimizing antenna dimensions results in good impedance matching with high impedance bandwidth. The designed antenna operates in the C-band in the frequency range 4-8 GHz giving a wide impedance bandwidth of 60.3%. The proposed antenna is applicable for various wideband communication systems especially working in the C-band.

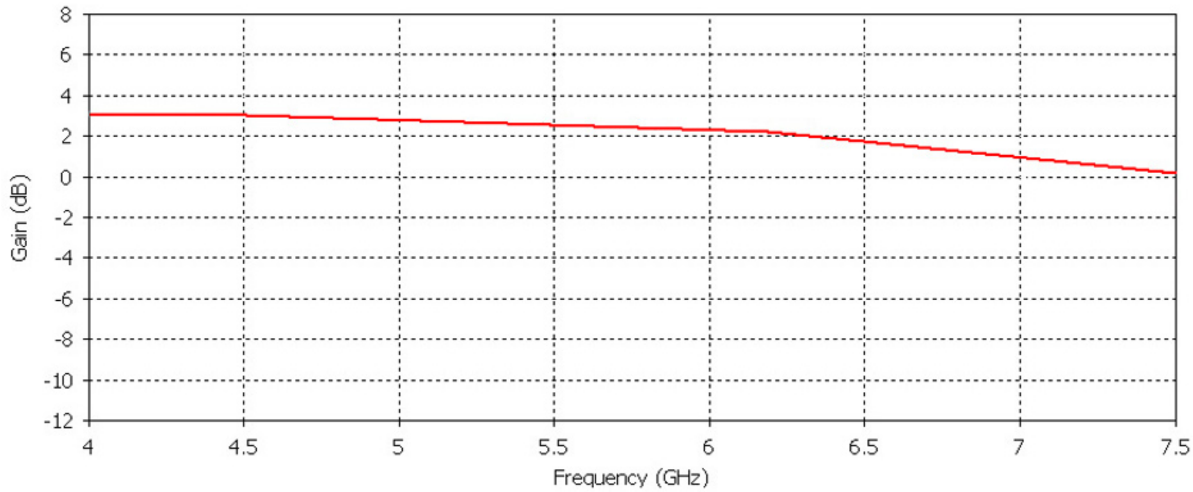

Figure 14. Variation of gain as a function of frequency for proposed geometry

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