A Compact and Multiband Microstrip Patch Antenna with Defected Ground Structure

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Abstract
A compact, single layer and single probe-fed microstrip patch antenna has been designed and analyzed for multi-frequency operation. The design of the microstrip patch antenna is achieved by modifying the ground plane with an inverted "L" shaped slot and a stair-like slit. Four resonating frequencies are obtained at 2.80 GHz, 7.20 GHz, 9 GHz and 10.20 GHz. Compared with the conventional patch antenna, the designed antenna can achieve a compactness of 90.32%. The designed microstrip antenna is simulated using MOM based software Ansoft Designer V2.2 and the simulated result is experimentally verified using standard microwave test bench. A good agreement is obtained between both the results. The designed microstrip antenna can be operated in S band, C band and X band of frequencies.

Keywords
Compactness, Microstrip patch antenna, Multi-frequency operation, Percentage bandwidth, Slots and Slits

I. Introduction

In recent years, to fulfill the miniaturization requirements of portable communication devices, much attention have been given to compact microstrip patch antennas. A reduced-sized microstrip patch antenna finds applications in personal mobile communication equipments and other miniaturized communication devices. Since the resonant length of a microstrip patch antenna is inversely proportional to its resonating frequency, the size of a conventional regular MSA operating in UHF band is quite large in size. Thus in order to design reduced sized antennas at these frequencies; certain modifications need to be done on the conventional configurations of microstrip patch antennas [1-2].
Using a high permittivity substrate is considered to be an effective method to achieve a reduced size microstrip patch antenna at a fixed operating frequency. It has also been studied that loading the microstrip patch antenna with a shorting pin can yield size reduction of microstrip patch antenna [3-6]. Reducing the size of the MSA is a major concerned topic of research. Several research works has been proposed in recent years to obtain compactness of the antenna [7-12].
In wireless communication it is desirable for an antenna to operate at more than one frequency. This is because there are many numerous telecom operators operating at various frequencies. Also MSA with multiband operation finds applications in military security systems. The major challenge in designing a multiband MSA is to design it in such a way that the ratio of resonant frequency between each successive band should be greater than 1.2 to avoid interference between the neighbouring frequencies. As each and every communication system operates at different bands of frequencies there is an increasing demand for a single antenna that can be operated at various frequencies. Since integrating more than one antenna in a communication device increases the size of the device, it is always desirable to integrate one single antenna that can be operated over various frequencies, and thus maintaining the compactness of the communicating device. The simplest technique used to obtain multiband MSA is by using specific slots or slits on the ground plane as well as on the radiating patch. This paper deals with the effort of designing a compact tetra-frequency microstrip antenna.

II. Antenna Design

The conventional antenna is designed by taking a square shaped ground plane of dimension 20 mm X 20 mm as shown in Fig 1. The radiating patch is of dimension 9mm X 10 mm as shown in Fig 2. The coaxial probe feed position is shown in Fig 1 and Fig 2. The antenna is designed using easily available FR4 epoxy substrate material having a thickness (h) of 1.6 mm with a dielectric constant of 4.4. In this design coaxial probe feed technique is used because it is the simplest among all the feeding techniques.

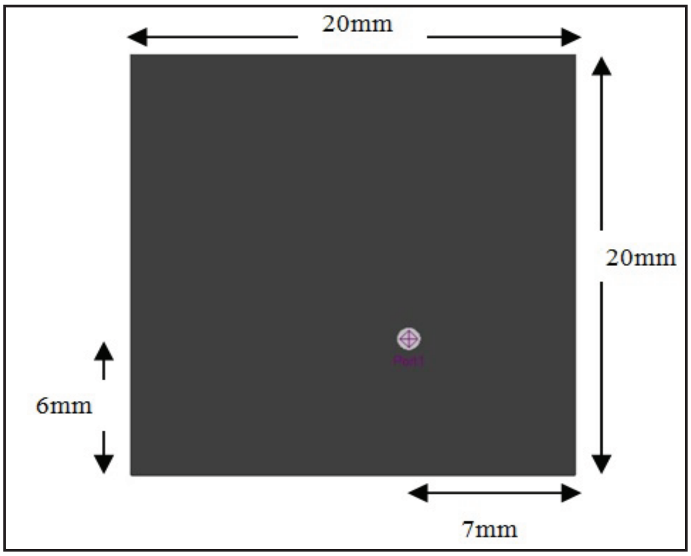

Fig. 1: Ground Plane of Conventional Antenna

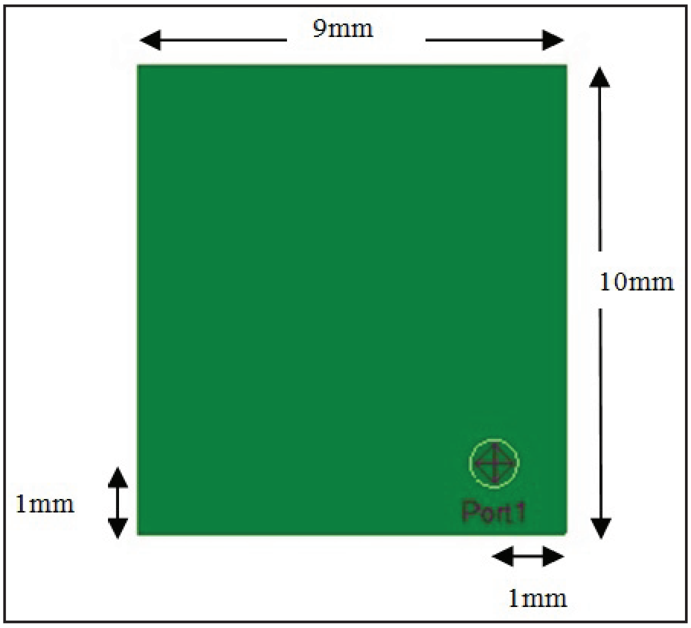

Fig. 2: Radiating Patch of Conventional Antenna

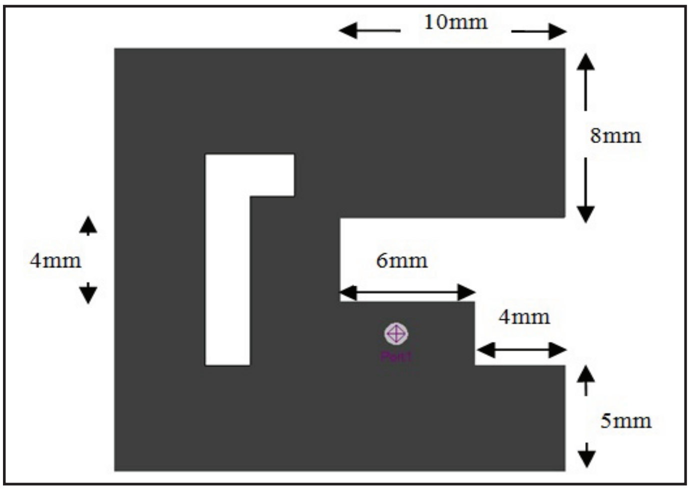

Fig. 3: Ground Plane of Final Proposed Antenna

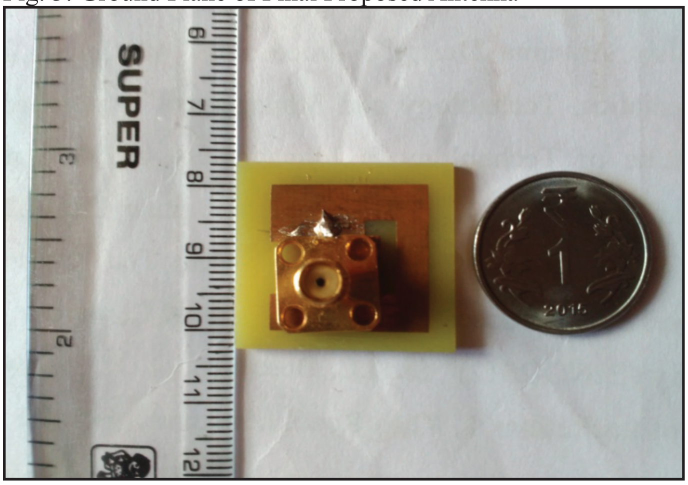

Fig. 4: Fabricated Inverted View of the Ground Plane of Final Proposed Antenna

The conventional antenna is then modified by introducing an inverted "L" shaped slot and stair-like slits on the ground plane of dimension as shown in Fig 3. No modification is done on the radiating patch. Thus the design can be termed as a defected ground structure.

The final proposed design was fabricated and Fig. 4 and Fig. 5 depict the photographs of the fabricated antenna. Fig. 4 shows the bottom view of the antenna while Fig. 5 shows the top view of the antenna.

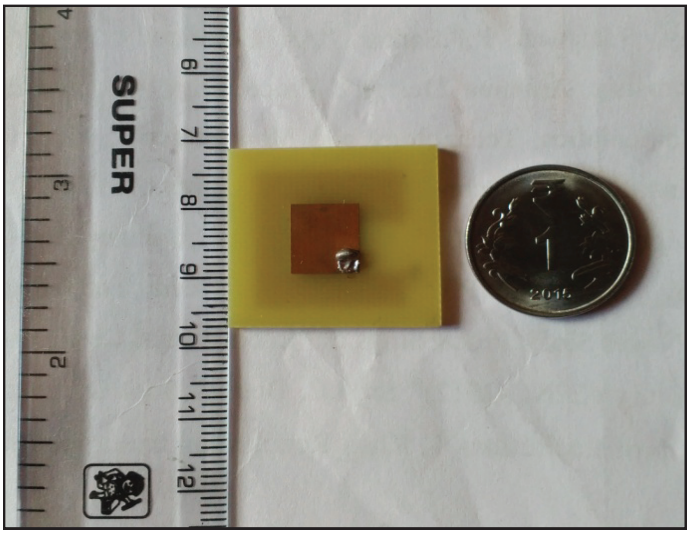

Fig. 5: Fabricated Top View of the Radiating Patch of Final Proposed Antenna

III. Results

The variation of reflection coefficient with frequency for the conventional reference antenna is shown in Fig. 6.

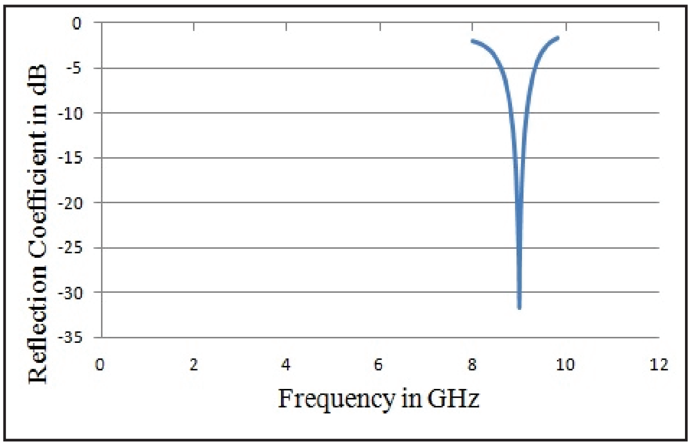

Fig. 6: Reflection Coefficient vs Frequency of Reference Antenna

The resonating frequency is obtained at 9GHz.The -10dB impedance bandwidth obtained in this case is 0.33 GHz which corresponds to a percentage bandwidth of 3.67%.

Fig 7 shows the simulated variation of return loss with frequency for the final proposed antenna. Three resonating frequencies are obtained at 3.32 GHz, 4.91 GHz and 7.26 GHz. The -10dB impedance bandwidth obtained for the three resonating frequencies are 910 MHz, 860 MHz and 430 MHz respectively which corresponds to a percentage bandwidth of 27.41%, 17.51% and 5.92% respectively. The fabricated antenna was measured and the measured result is also plotted in the same Fig 7 for comparison with the simulated result.

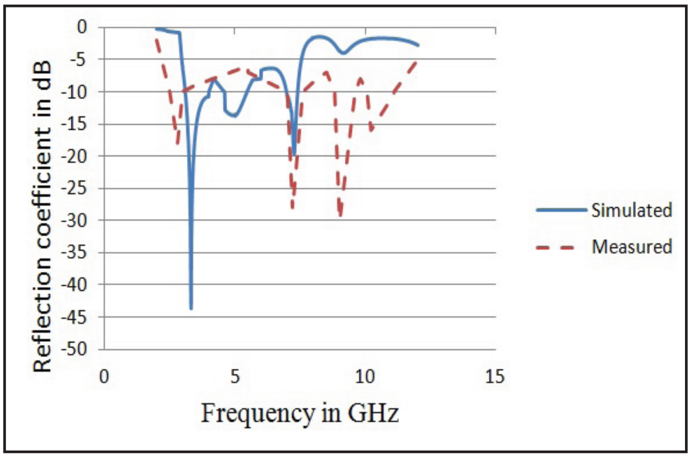

Fig. 7: Reflection Coefficient vs Frequency of the Proposed Antenna

The simulated radiation patterns for the proposed antenna at the resonating frequencies are shown below.

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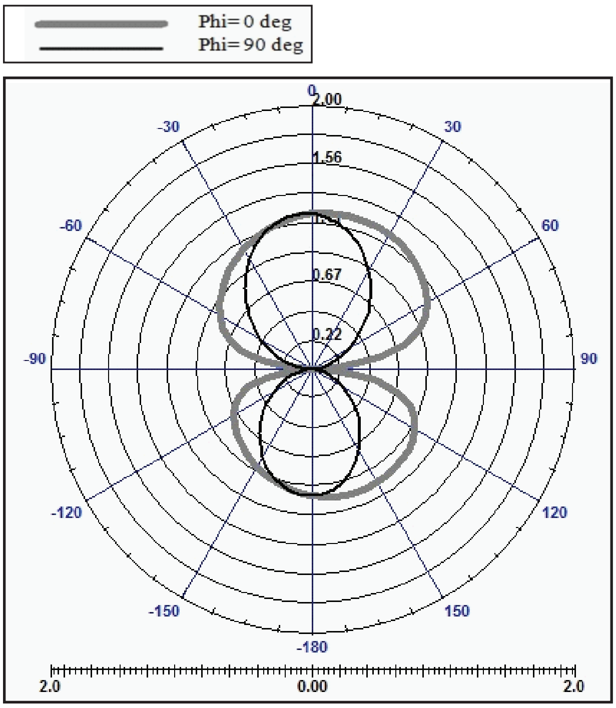

Fig. 8: Radiation Pattern of Proposed Antenna at 3.32 GHz

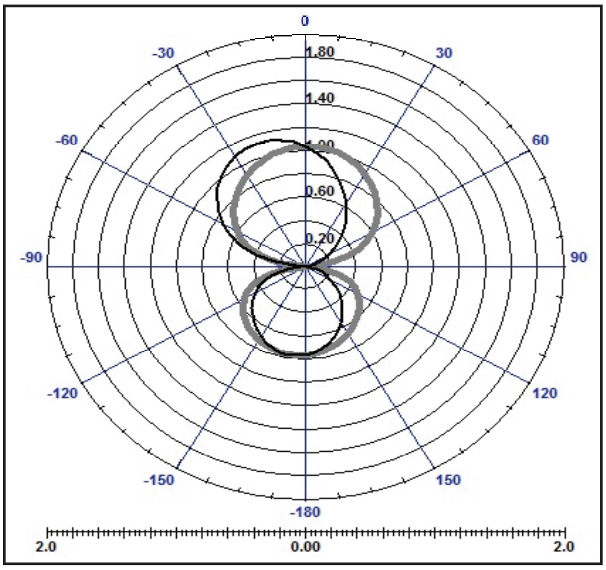

Fig. 9: Radiation Pattern of Proposed Antenna at 4.91 GHz

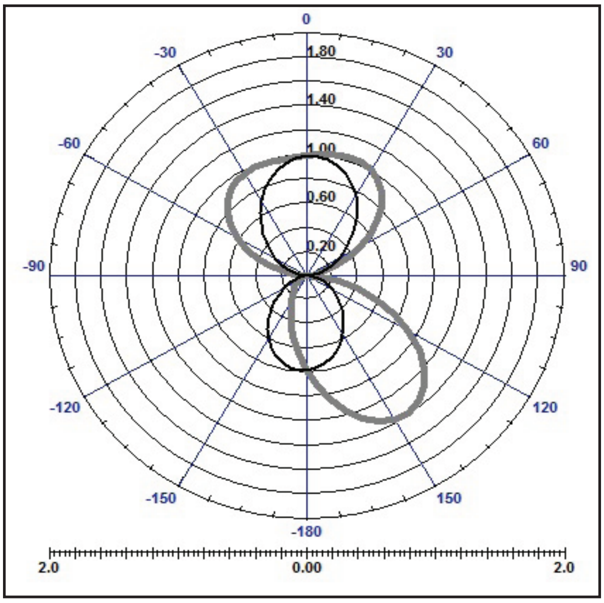

Fig. 10: Radiation Pattern of Proposed Antenna at 7.26 GHz

The 3D input gains at the resonating frequencies are shown in Fig 11-13.

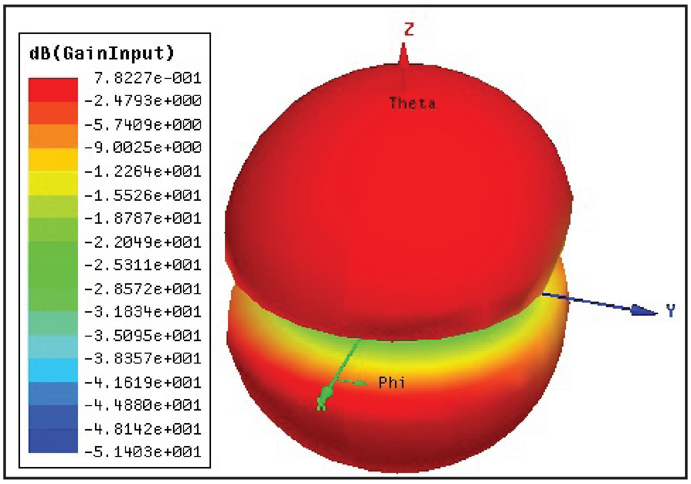

Fig. 11: 3D Input Gain of Proposed Antenna at 3.32 GHz

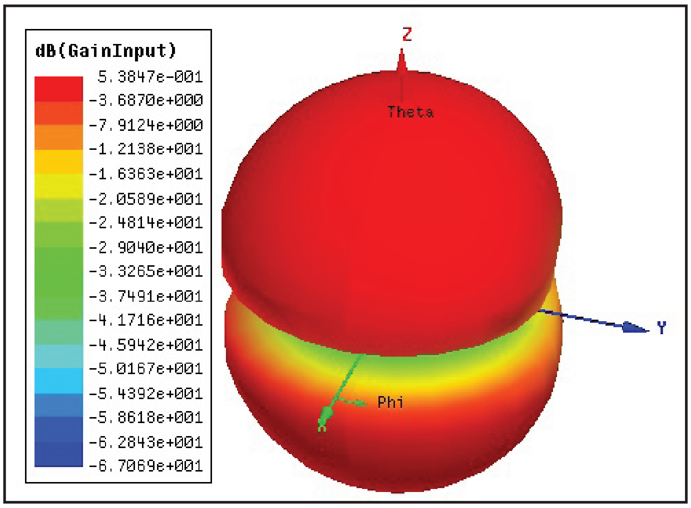

Fig. 12: 3D Input Gain of Proposed Antenna at 4.91 GHz

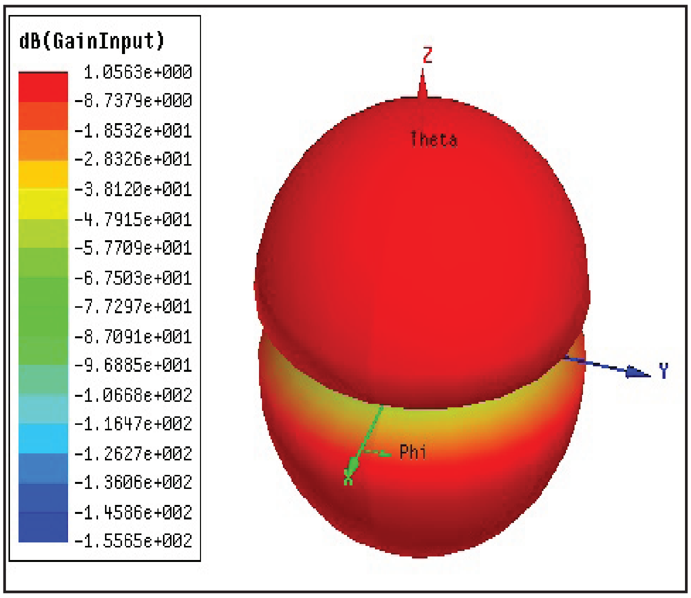

Fig. 13: 3D Input Gain of Proposed Antenna at 7.26 GHz

From fig. 14 it can be observed that the VSWR at the resonating frequencies of 3.32 GHz, 4.91 GHZ and 7.26 GHz are 1:1, 1:1.52 and 1:1.20 respectively.

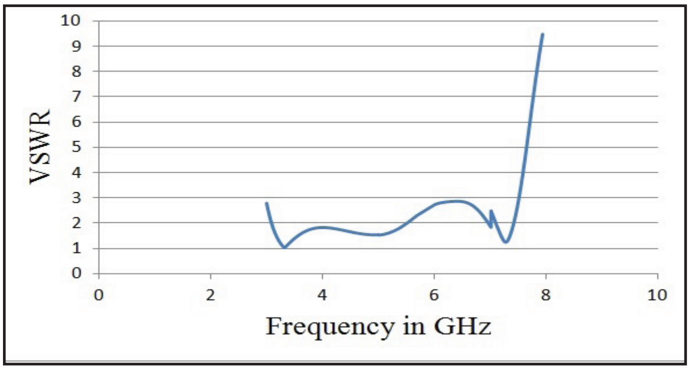

Fig. 14. VSWR vs Frequency of Reference Antenna

IV. Conclusion

The deigned antenna results in four resonating frequencies at 2.80 GHz, 7.20GHz, 9 GHz and 10.20 GHz with percentage bandwidth of 17.85%, 8.61%, 8.88% and 10.09% respectively. It should also be noted that the ratio of resonant frequency between each successive band is acceptable to avoid interference between successive bands of operation. Also the compactness of the antenna achieved is 90.32%.

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