Design and Optimization of Multiband Microstrip Patch Antenna with Defected Ground Structure

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Abstract— In this paper, we present a fractal shape slot based patch antenna for multiband operations. The fractal shape slot is designed on the rectangular patch and the antenna is fed through a microstrip line. The proposed design and feeding technique allows the antenna to operate at multiple frequencies in the range of 1-8 GHz. The proposed antennas have been modeled, designed and simulated using Computer Simulation Technology (CST) Microwave Studio. It is demonstrated through simulation that the microstrip patch antenna is resonating on frequencies: 2.858 GHz, 3.354 GHz, 4.4981 GHz, 5.583 GHz and 7.335 GHz with return loss of -22.999 dB, -21.0433dB, -11.5568 dB, -12.184 dB and -44.1674 dB respectively. This patch antenna is operating in different. These bands are suitable for WLAN and WiMAX as well as for C Band applications. Parametric study is also included to give an overview for the performance of proposed design.

Key words: Multiband Microstrip Patch Antenna, Defected Ground Structure

I. INTRODUCTION

Rising demand for multiple frequency operation in wireless communication creates there requirement of low profile, Microstrip Patch Antennas which are dominating the present day technologies. Microstrip Patch Antennas are easy to fabricate, less in weight, and can be made conformable with planar and non- planar surfaces. Microstrip Patch Antennas are capable of producing multi resonances, adaptable for wide range of wireless applications such as Personal Area Networks (PAN), Wireless Local Area Networks, mobile phones etc. But they also possess certain disadvantages like poor gain, narrow bandwidth, sensitivity to fabrication errors and excitation of surface waves.

Generally, radiating patch is normally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate, Figure1 depicts the microstrip patch antenna with dimensional specifications. Parameter ‘L’ is the length of the patch in the antenna which is the non-radiating edge. Parameters ‘W’ and ‘t’ are width of the substrate below the patch and thickness of the patch. The dielectric medium and the dielectric constant ‘ϵr’, determines the coupling of signal.

Microstrip Patch Antennas can also have shapes like square, rectangular, circular, triangular, elliptical and fractal designs. Length L of the patch is usually $0.3333\lambda o < L < 0.5\lambda o$, where λo is the free-space wavelength. The thickness of the patch must be very small for better radiation and it is selected to be very thin such that $t << \lambda o$ [1]. The patch antenna is an array of two radiating narrow slots, each of width W and height h, separated by a distance L. Thickness of the dielectric medium ‘h’, determines the power to surface waves is usually $0.003\lambda o \leq h \leq 0.05\ \lambda o$. Dielectric constant of the substrate ϵr is typically in the range $2.2 \leq \epsilon r \leq 12$[3].

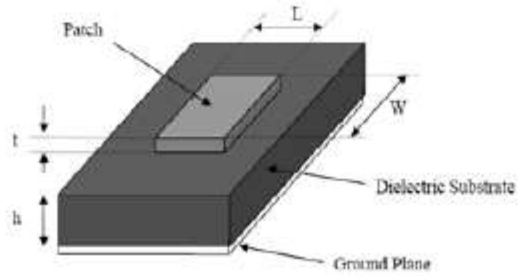

Fig. 1: Microstrip Patch Antenna

To reduce the size of MPA, substrate with higher dielectric constants are used which are less efficient and result in narrow bandwidth. A thick dielectric substrate with low dielectric constant provides larger bandwidth, better radiation and greater efficiency. But such configuration leads to a larger antenna size. Hence a trade-off must be realized between the antenna performance and antenna dimensions.

When the radiating patch is excited properly, radiation mechanism is takes place in microstrip patch antenna. MPAs radiate because of the fringing fields existing between the patch edge and the ground plane. The open edges of the patch antenna can be compared to wire dipole antenna. The only difference is that their electric (E) and magnetic (H) fields due to slots are reversed compared to the E and H of the wire dipole.

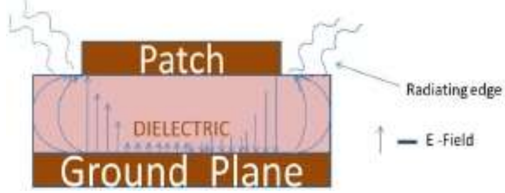

Fig. 2: fringing effects in microstrip patch antenna

Figure 2 shows the simple arrangement as Microstrip Patch Antenna’s electric field lines along its structure. Magnetic current density around the side of the patch radiates into free space. Slots in the microstrip patch antenna can be viewed in Figure2; they are responsible for the radiation of EM waves via the radiating edge. The microstrip patch antenna can be considered as two radiating slots along the length of the patch with width ‘w’ and height ‘h’. Slots are separated by the patch with very low impedance of length ‘l’ which acts like a quarter wave transformer, and its length is $\lambda/2$ [2].Maximum radiation is in the direction perpendicular to the ground plane. Slots radiate the same fields with magnetic current density M, with same magnitude and phase along the slots. The other two slots along width ‘w’ have same current density. They have same magnitude but opposite phase thus radiated electric and magnetic Fields cancel each other and so these two slots are called non- radiating slots. When the electric fields are in parallel, the antenna gain is high, hence maximum power is transferred.

II. DESIGN PROCEDURE & SIMULATION OF DESIGNED ANTENNA

A. Design Procedure

The various steps involved for designing procedure of a microstrip patch antenna with inset feed in microwave CST studio suite is mentioned below.

- Calculation of the dimension of the patch antenna, substrate, ground plane, effective dielectric constant, input impedance etc.
- By using these parameter we starts for designing a patch antenna in CST microwave studio suite firstly we are drawing a substrate after that ground plane, patch antenna, gap between the patch and microstrip feed and feedline.
- The last step involves simulation and optimization of patch antenna.

The picture of a microstrip patch antenna with line feed is shown below:-

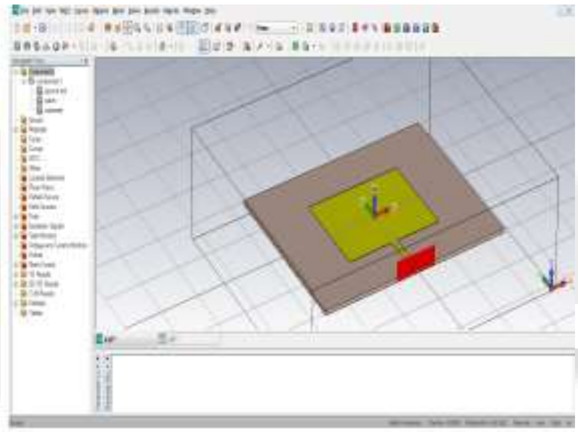

Fig. 3: Excitation of microstrip patch antenna

1) Step 1: Calculation of the Width (W):

The width of the Microstrip patch antenna is given as:

$$Width = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}}$$

Where c = 3.00e+008 m/s, εr = 4.3 and *fo* = 1.8 GHz

Width = 51.1913 mm

2) Step 2: Calculation of Effective dielectric constant (εreff):

The effective dielectric constant is:

$$\varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right]$$

$\varepsilon reff$ = 4.0571

3) Step 3: Calculation of the Effective length (Leff):

The effective length is:

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

Where $\varepsilon reff$ = 4.0571, *c* = 3.00e+008 m/s and *f0* = 1.8 GHz

Leff = 41.3725 mm

4) Step 4: Calculation of the length extension (ΔL):

The length extension is:

$$\Delta L = 0.412\ h\ \frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}$$

Where $\varepsilon reff$ = 4.0571, *W* = 51.1913 mm and *h* = 1.6 mm

ΔL = 0.74366 mm

5) Step 5: Calculation of actual length of patch (L):

The actual length is obtained by:

$$L = L_{eff} - 2\Delta L$$

Where *Leff* = 41.3725 mm and Δ*L* = 0.74366 mm

L = 39.8851 mm

B. Simulation Setup and Results

The software used to design and simulate the Microstrip patch antenna is CST Microwave Studio. It is a full-wave electromagnetic test system in view of the methods of moments. It analysis 3D and multilayer structures of general shapes. It has been broadly utilized as a part of the outline of MICs, RFICs, patch antenna, wire antenna, and other RF/wireless antenna. It can be utilized to compute and plot the S11 parameters, VSWR, current distributions and in addition the radiation pattern.

The microstrip patch antenna is resonating on frequencies: 2.858 GHz, 3.354 GHz, 4.4981 GHz, 5.583 GHz and 7.335 GHz with return loss of -22.999 dB, -21.0433dB, -11.5568 dB, -12.184 dB and -44.1674 dB respectively.

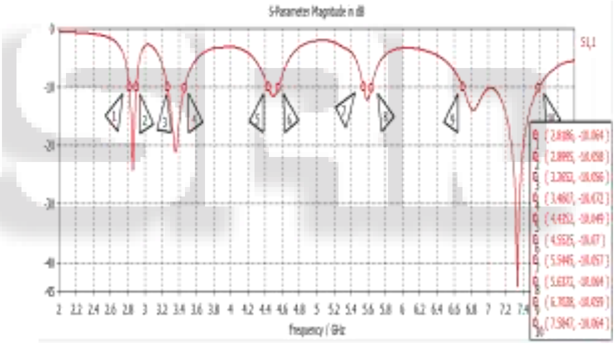

Fig. 4: Return loss and bandwidth of the designed microstrip patch antenna

The bandwidth of the antenna can be said to be those range of frequencies over which the return loss is greater than -10 dB (corresponds to a VSWR of 2). Thus, the bandwidth of antenna can be calculated from return loss versus frequency plot. The bandwidth of the proposed patch antenna for the different bands mentioned in the table 1 which are in the range of WLAN, WiMAX and C band standards.

The 3D radiation pattern of antenna at different frequencies is shown in figure 5.

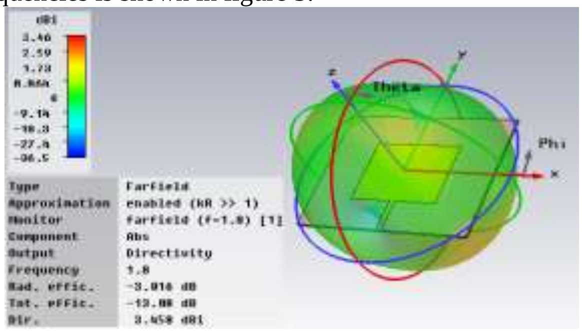

Fig. 5(a) 3D radiation pattern at 1.8 GHz frequency

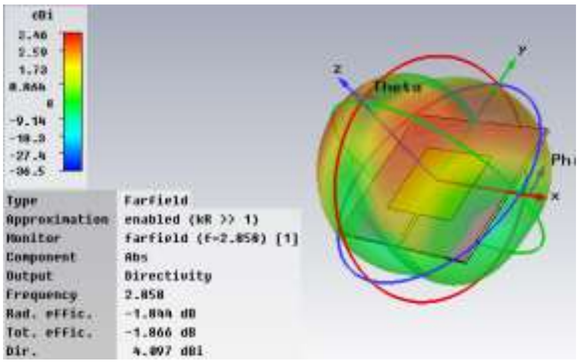

Fig. 5(b) 3D radiation pattern at 2.858 GHz frequency

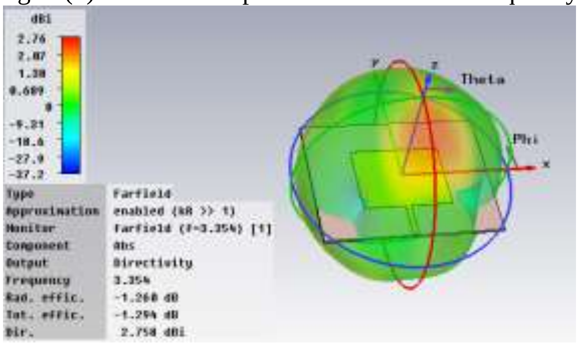

Fig. 5(c) 3D radiation pattern at 3.354 GHz frequency

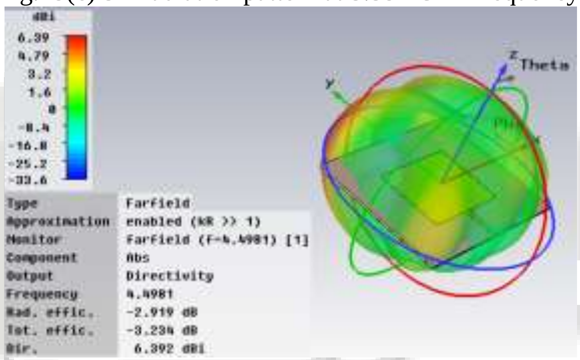

Fig. 5(d) 3D radiation pattern at 4.4981 GHz frequency

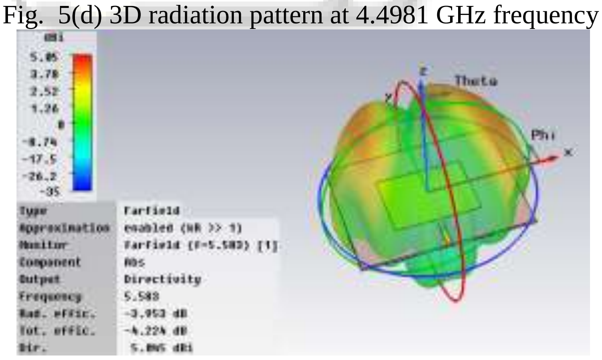

Fig. 5(e) 3D radiation pattern at 5.583 GHz frequency

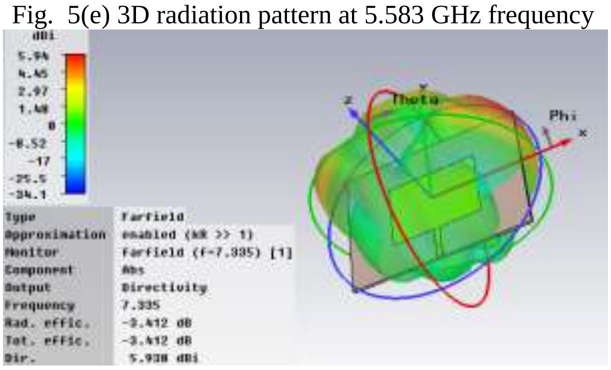

Fig. 5(f) 3D radiation pattern at 7.335 GHz frequency

Ideally, VSWR must lie in the range of 1-2 which is achieved in Fig. 6 for the multiple frequencies.

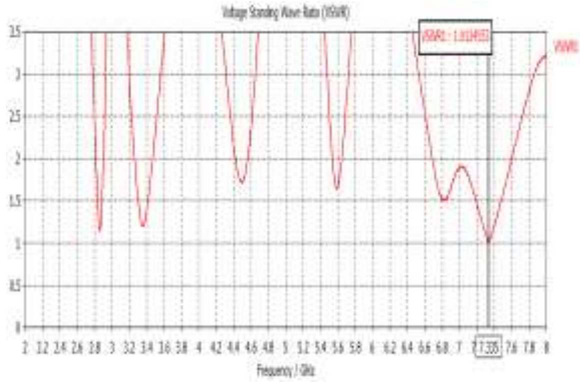

Fig. 6: VSWR of designed microstrip patch antenna

The 3D current distribution plot shows the relationship between the co-polarization (desired) and cross-polarization (undesired) components. Moreover it gives a clear picture as to the nature of polarization of the fields propagating through the patch antenna. Fig. 7 clearly shows that the patch antenna is linearly polarized.

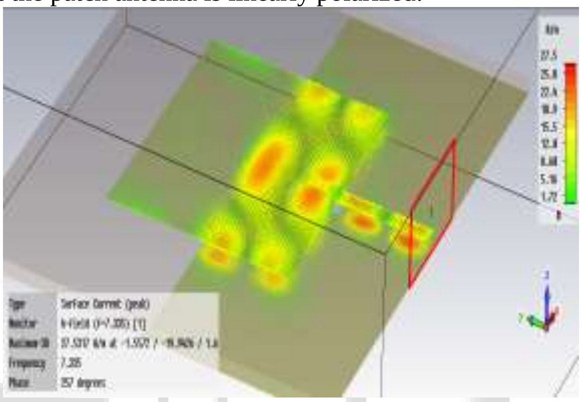

Fig. 7: Surface current of designed microstrip patch antenna

Obtained resonant Frequencies	Lowest cutoff frequency	Highest cutoff frequency	Bandwidth (in MHz)	Directivity (in dBi)	Return loss (in dB)	VSWR
2.858	2.8186	2.8995	80.9	4.097	-22.999054	1.1538361
3.354	3.2652	3.4607	195.5	2.758	-21.043314	1.1946251
4.4981	4.4352	4.5525	117.3	6.392	-11.5568	1.17186408
5.583	5.5445	5.6372	92.7	5.045	-12.184316	1.16522664
7.335	6.7028	7.5847	881.9	5.938	-44.16744	1.0124553

Table 1 Conclusion of Obtained Results after Simulation of Patch Antenna

III. CONCLUSION

The work in this thesis focused on the design of a multiband microstrip patch antenna. The proposed antennas have achieved good impedance matching, stable radiation patterns, high gain and high bandwidth. As we can easily analyze from the table 1 that the proposed Microstrip Patch Antenna will work in the frequency range of 2-8GHz. which covers the frequency of operation of WLAN, WiMAX, and wireless communication through satellite as well as the frequency of operation of RADAR that's why it is multipurpose microstrip patch antenna.

REFERENCES

[1] "Antenna Theory,3rd edition" by Constantine A. Balanis, Wiley Publications.
[2] V. Mohan Kumar N. Sujith, "Enhancement of Bandwidth Gain of a Rectangular Microstrip Patch Antenna", Project Thesis, National Institute of Technology, Rourkela, 2010.
[3] "Microstrip Antenna Design Handbook" by R.Garg, Prakash Bhartia, Inder Bahl, Apisak Ittipiboon.
[4] International Journal of Research in Engineering and Technology (IJRET) eissn: 2319-1163 pissn: 2321-7308, Volume: 02 Issue: 07 | Jul-2013, Design and Optimization of Microstrip Patch Antenna with Defected Ground Structure & Circular Slot on The Patch.
[5] International Journal of Engineering Trends and Technology (IJETT) – Volume 4 Issue 8- August 2013 ISSN: 2231-5381, Microstrip Patch Antenna for 2.4 GHZ Wireless Applications
[6] IJECCT 2012, Vol. 2 (2), An Approach to Design and Optimization of WLAN Patch Antennas for Wi-Fi Applications