Design of Compact Microstrip Antenna for S-Band Microwave Communication

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ABSTRACT
A single layer, single feed compact rectangular antenna is proposed. Resonant frequency has been reduced drastically by cutting three unequal rectangular slots at the edge of the patch & also small rectangular slots connected with the middle of the every patch. Antenna size has been reduced by 47.4% with an increased frequency ratio when compared to a Conventional square microstrip patch antenna.

Keywords

Compact, Patch, Slot, Resonant frequency, Edge of the patch.

1. Introduction
In recent years demand for small antennas on wireless communication has increased the interest of research work on compact microstrip antenna design among microwaves and wireless engineers [1-3]. To support the high mobility necessity for a wireless telecommunication device, a small and light weight antenna is likely to be preferred. For this purpose Compact Microstrip antenna is one of the most suitable application. The development of antenna for wireless communication also requires an antenna with more than one operating frequency. This is due to many reasons, mainly because there are various wireless communication systems and many telecommunication operators using various frequencies [4-6]. Therefore one antenna that has multiband characteristic is more desirable than having one antenna for each frequency band. To reduce the size of the antenna one of the effective technique is cutting slot in proper position on the microstrip patch. The work to be presented in this paper is also a compact microstrip antenna design obtained by cutting three rectangular slots on the patch but here in addition to the rectangular slots a small piece of rectangular patch is developed within the area of rectangular slot to increase the return loss and gain-bandwidth performance of the slotted antenna (Figure 2). To reduce the size of the antenna substrates are chosen with higher value of dielectric constant [7-8]. Our aim is to reduce the size of the antenna as well as increase the operating bandwidth. The proposed antenna (substrate with ε_r = 4.4) has a gain of 4.79 dBi and presents a size reduction of 47.4% when compared to a conventional square microstrip patch. The simulation has been carried out by IE3D [11] software which uses the MOM method. Due to the Small size, low cost and low weight this antenna is a good candidate for the application of S-Band microwave communication in the frequency range of 2-4 GHz.

The S band is part of the microwave band of the electromagnetic spectrum. It is defined by an IEEE standard for radio waves with frequencies that range from 2 to 4 GHz, crossing the conventional boundary between UHF and SHF at 3.0 GHz [10]. The S band is used by weather radar, surface ship radar, and some communications satellites, especially those used by NASA to communicate with the Space Shuttle and the International Space Station. The 10-cm radar short-band ranges roughly from 1.55 to 5.2 GHz.

2. Antenna Design
The configuration of the conventional printed antenna is shown in Figure 1 with L=20 mm, W=20 mm, substrate (PTFE) thickness h = 1.5875 mm, dielectric constant ε_r = 4.4. Coaxial probe-feed (radius=0.5mm) is located at W/2 and L/3. Assuming practical patch width W= 20 mm for efficient radiation and using the equation [9],

$$f_r = \frac{c}{2W} \times \sqrt{\frac{2}{(1+\varepsilon_r)}} \qquad \ldots 1$$

We determined the resonant frequency f_r (= 4.56 GHz). Where, c = velocity of light in free space. Using the following equation [9] we determined the practical length L (=20 mm).

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

where,
$$\frac{\Delta L}{h} = 0.412 \times \left[\frac{(\varepsilon_{reff} + 0.3)\times(W/h + 0.264)}{(\varepsilon_{reff} - 0.258)\times(W/h + 0.8)}\right] \qquad \ldots 3$$

$$\varepsilon_{reff} = \left(\frac{\varepsilon_r + 1}{2}\right) + \frac{\varepsilon_r - 1}{\left(2\times\sqrt{\left(1 + 12\times\frac{h}{W}\right)}\right)} \qquad \ldots 4$$

and
$$L_{eff} = \left[\frac{c}{2\times f_r \times\sqrt{\varepsilon_{reff}}}\right] \qquad \ldots 5$$

Where, L_{eff} = Effective length of the patch, $\Delta L/h$ =Normalized extension of the patch length, ε_{reff} = Effective dielectric constant.

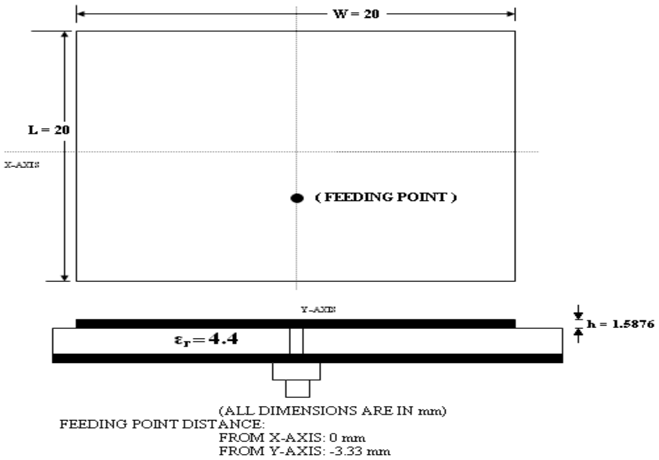

Figure 1: Antenna 1 configuration

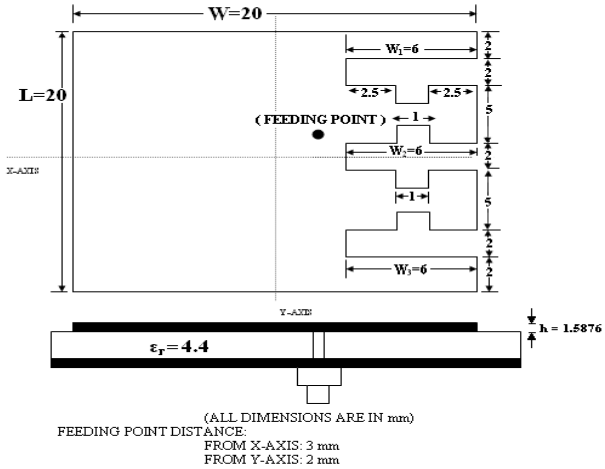

Figure 2: Antenna 2 configuration

Figure 2 shows the configuration of antenna 2 designed with similar PTFE substrate. Three unequal rectangular slots (L1, L2, L3) whose dimensions and the location of coaxial probe-feed (radius=0.5 mm) are shown in the figure 2.

3. RESULTS AND DISCUSSION

Simulated (using IE3D [11]) results of return loss in conventional and slotted antenna structures are shown in Figure 3-4. A significant improvement of frequency reduction is achieved in antenna 2 with respect to the conventional antenna1 structure.

In the conventional antenna return loss of about -17.7 dB is obtained at 3.410 GHz. Corresponding 10 dB bandwidth is 53.7 MHz. The second resonant frequency is obtained at f_2 = 6.77 GHz. Corresponding 10 dB bandwidth obtained for Antenna 1 at f_2 202.1MHz. Due to the presence of slots in antenna 2 resonant frequency operation is obtained with large values of frequency ratio. The first resonant frequency is obtained at f1= 2.95 GHz with return loss of about -13.02 dB. The second, third resonant frequency is obtained at f_2 = 3.48 GHz, f_3 = 6.68 GHz with return losses -18.13 dB, -11.04 dB respectively. Corresponding 10 dB bandwidth obtained for Antenna 2 at f_1, f_2, f_3 are 18.14MHz, 56.72 MHz and 57.90 MHz respectively.

The simulated E plane and H-plane radiation patterns are shown in Figure 5-14.

For the antenna 1 (Conventional Antenna) radiation patterns are shown in Figure 5-8. The simulated E plane radiation pattern of antenna 1 (Conventional Antenna) for 3.41 GHz is shown in figure 5.

The simulated H plane radiation pattern of antenna 1 (Conventional Antenna) for 3.41 GHz is shown in figure 6. The simulated E plane radiation pattern of antenna 1 (Conventional Antenna) for 6.77 GHz is shown in figure 7. The simulated H plane radiation pattern of antenna 1 (Conventional Antenna) for 6.77 GHz is shown in figure 8. The simulated E plane radiation pattern of antenna 2 (Slotted Antenna) for 2.95 GHz is shown in figure 9.

The simulated H plane radiation pattern of antenna 2 (Slotted Antenna) for 2.95 GHz is shown in figure 10.

The simulated E plane radiation pattern of antenna 2 (Slotted Antenna) for 3.48 GHz is shown in figure 11.

The simulated H plane radiation pattern of antenna 2 (Slotted Antenna) for 3.48 GHz is shown in figure 12.

The simulated E plane radiation pattern of antenna 2 (Slotted Antenna) for 6.68 GHz is shown in figure 13.

The simulated H plane radiation pattern of antenna 2 (Slotted Antenna) for 6.68 GHz is shown in figure 14

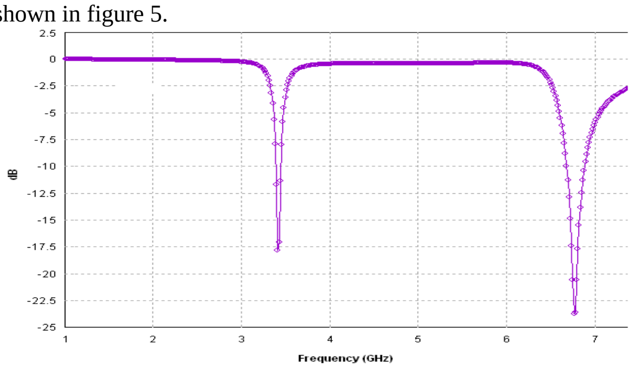

Figure 3: Antenna 1 Return Loss vs. Frequency (Conventional Antenna)

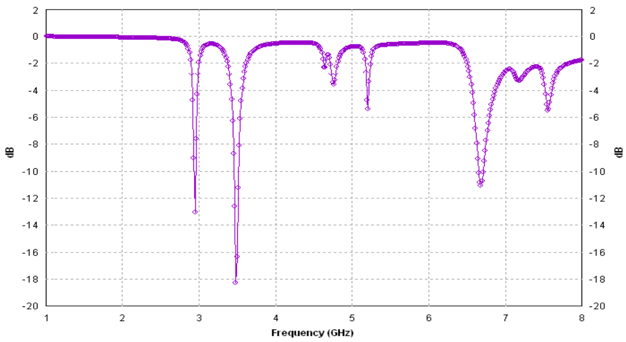

Figure 4: Antenna 2 Return Loss vs. Frequency (Slotted Antenna)

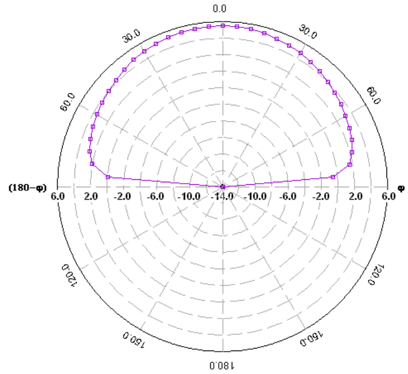

Figure5: E-Plane Radiation Pattern for Antenna1 at 3.41 GHz

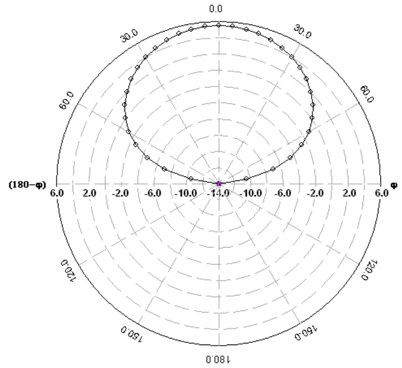

Figure 6: H-Plane Radiation Pattern for Antenna1 at 3.41 GHz

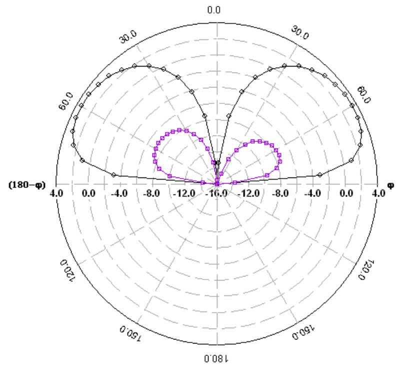

Figure 7: E-Plane Radiation Pattern for Antenna1 at 6.77 GHz

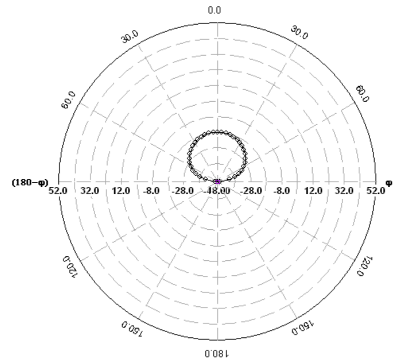

Figure 8: H-Plane Radiation Pattern for Antenna1 at 6.77 GHz

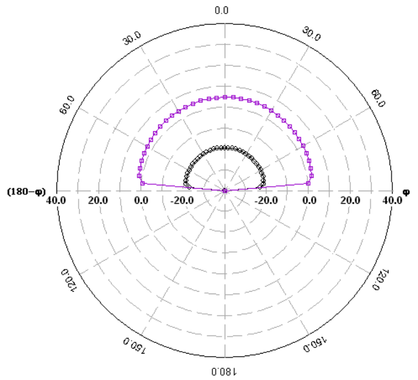

Figure 9: E-Plane Radiation Pattern for Antenna2 at 2.95 GHz

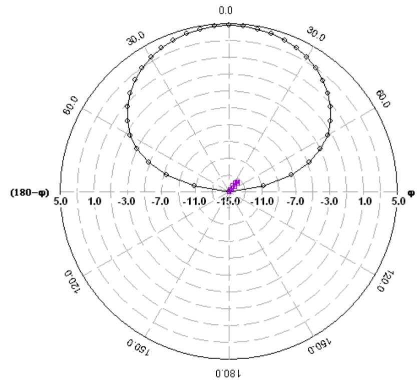

Figure 10: H-Plane Radiation Pattern for Antenna2 at 2.95 GHz

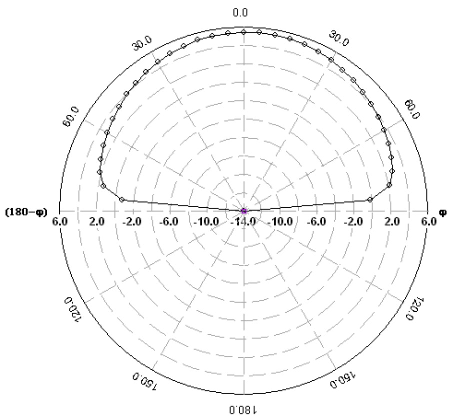

Figure 11: E-Plane Radiation Pattern for Antenna2 at 3.48 GHz

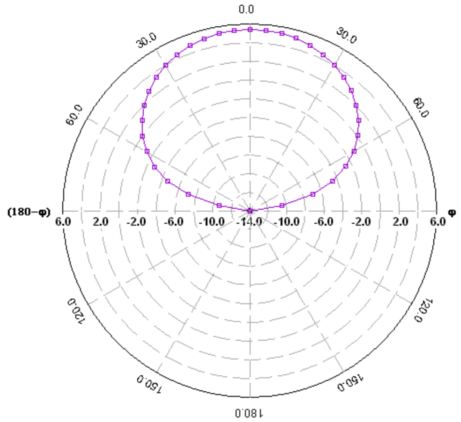

Figure 12: H-Plane Radiation Pattern for Antenna2 at 3.48 GHz

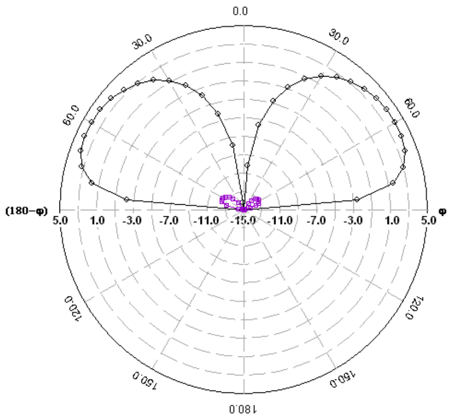

Figure 13: E-Plane Radiation Pattern for Antenna2 at 6.68 GHz

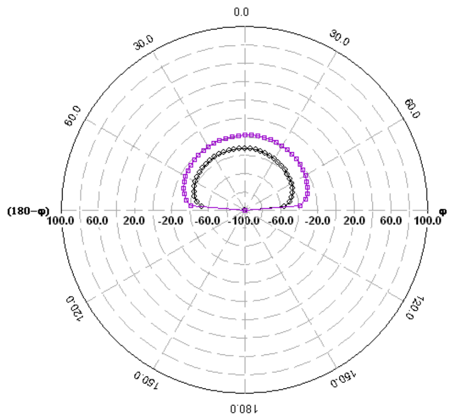

Figure 14: H-Plane Radiation Pattern for Antenna2 at 6.68 GHz

All the simulated results are summarized in the following Table1 and Table2.

TABLE I:
SIMULATED RESULTS FOR ANTENNA 1 AND 2

ANTENNA STRUCTURE	RESONANT FREQUENCY (GHZ)	FREQUENCY RATIO	3 DB BEAM WIDTH (^{0})	ABSOLUTE GAIN (DBI)
1	f_1= 3.41		171.06 ^{0}	5.43
	f_2= 6.77	f_2/ f_1=1.985	170.40 ^{0}	3.23
2	f_1= 2.95		152.3 ^{0}	4.79
	f_2= 3.48	f_2/ f_1=1.180	156.9 ^{0}	5.44
	f_3= 6.68	f_3/ f_1=2.264	171.2 ^{0}	4.09

TABLE II:
SIMULATED RESULTS FOR ANTENNA 1 AND 2

ANTENNA STRUCTURE	RESONANT FREQUENCY (GHZ)	RETURN LOSS (DB)	10 DB BANDWIDTH (MHZ)
1	f_1= 3.41	-17.7	53.7
	f_2= 6.77	-23.7	202.1
2	f_1= 2.95	-13.02	18.14
	f_2= 3.48	-18.13	56.72
	f_3= 6.68	-11.04	57.9

4. Conclusion

Theoretical investigations of a single layer single feed micro strip printed antennas have been carried out using Method of Moment based software IE3D. Introducing slots at the edge of the patch size reduction of about 47.4% has been achieved. The 3dB beam-width of the radiation pattern 152.3° which is sufficiently broad beam for the applications for which it is intended. The resonant frequency antenna presented in the paper for a particular location of feed point (3mm, 2mm) considering the centre as the origin) was quite large as is evident from table1. Alteration of the location of the feed point results in narrower 10dB bandwidth and less sharp resonances.

5. Acknowledgement

We acknowledge gratefully the financial support for this work provided by AICTE (India) in the form of a project entitled "DEVELOPMENT OF COMPACT, BROADBAND AND EFFICIENT PATCH ANTENNAS FOR MOBILE COMMUNICATION".

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