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Design & Analysis of Microstrip Antenna with Multi-frequency Operations

Manish Rai, Sandeep Kumar, Jayanta Ghosh

Abstract*—*In this paper the theoretical and simulated results of rectangular microstrip are presented which can be utilized for multi-frequency operation. For this purpose, two rectangular microstrip antennas are designed with center frequencies 9 GHz and 5.67 GHz. Various parameter such as width, dielectric constant & effective length are calculated. Then the antenna impedance is matched to 50 ohm of coaxial fed for maximum power transfer. Now the designed structure is rearranged for multi-frequency operation by connecting two microstrip antennas at corner with corner excitation. The operating frequency, return loss and radiation pattern of the proposed structure are investigated. We observe a drastic reduction in resonant frequency. The radiation pattern for each resonating frequencies is nearly same. The frequency ratio (the ratio of second or higher resonating frequency to the first resonating frequency) of the proposed antenna is observed to be increased. The entire simulation work is done on IE3D software

Keywords*—*Microstrip Antenna, Rectangular, Multi-frequency, Return loss, Frequency Ratio.

I. INTRODUCTION

Microstrip antenna has its remarkable advantage over conventional antennas, such as small size, low weight, easy to fabricate, compatibility to planar and non-planar surfaces, ease of being integrated with circuits, mechanically robust, simplicity of creating antenna array and suitable for multi-frequency operation.[1] These attractive features made patch antennas more applicable in many noticeable communication systems. But communication now a days, is not limited to a single frequency band. Different frequency bands are being utilized for the same communication systems, which suggest the need for the antenna working in multi-frequency band with small size, low weight etc.[2]

In the present paper a conventional single frequency microstrip antenna is designed for 9 GHz and which is working in X band. Another single frequency microstrip antenna is designed for 5.75 GHz for WLAN range (5725 – 5825 MHz). Then two microstrip antenna is connected at corner with corner excitation.[4] This modified microstrip antenna is working in three frequency bands 5.77 GHz, 7.32 GHz and 7.80 GHz with increasing frequency ratio (the ratio of second or higher resonating frequency to the first resonating frequency).

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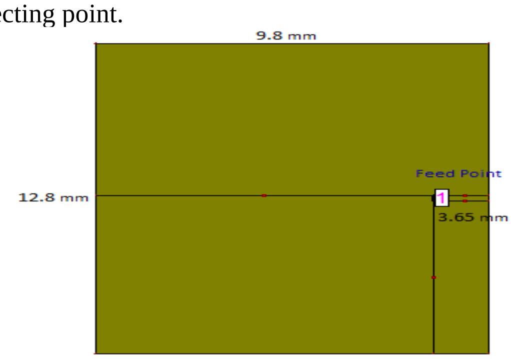
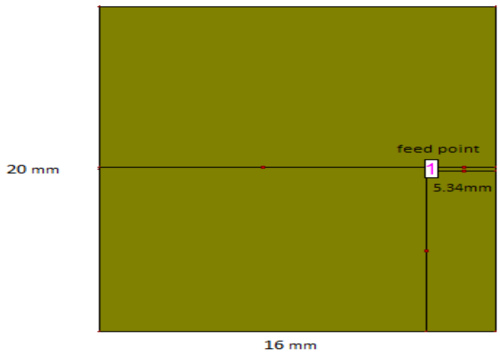
II. THEORETICAL CONSIDERATION

Fig. 1(a) shows the microstrip antenna for frequency9 GHz. The antenna has been provided a probe feeding with probe(diameter 1 mm). The feeding point is at (W/2, L/2) from the edge of the patch which gives a maximum matching of 50 ohm coaxial probe. Fig. 1(b) shows the microstrip antenna for frequency 5.67 GHz. The probe feeding is provided at (W/2, L/2) from the edge. Fig. 1(c) shows the modified patch for multi-frequency operation. In this antenna the above two conventional single frequency antenna is connected at the corner. Feeding is provided at the connecting point.



(a)



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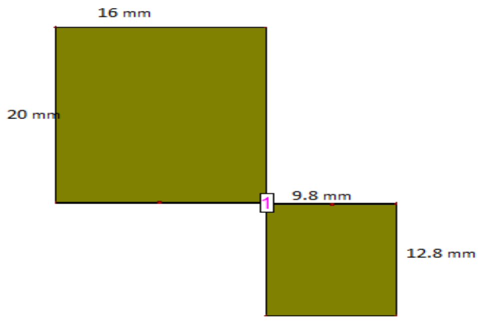

(c)

Fig. 1 (a) Antenna 1 configuration (b) Antenna 2 configuration (c) Modified Antenna 3

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A. *Theoretical analysis of Rectangular patch*

The parameters of rectangular microstrip antenna such as width, effective dielectric constant, effective length, length extension and acutal length are calculated using the equation 1,2,3,4,5 Respectively.[1]

$$w = \frac{c}{2f_0\sqrt{(1+\varepsilon_r)/2}} \quad (1)$$

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\sqrt{1 + \frac{10h}{w}} \quad (2)$$

$$l_{eff} = \frac{c}{2f_0\varepsilon_e} \quad (3)$$

$$\Delta l = 0.412h\frac{(\varepsilon_e + 0.3).(\frac{w}{h} + 0.264)}{(\varepsilon_e - 0.258).(\frac{w}{h} + 0.8)} \quad (4)$$

$$l = l_{eff} - 2\Delta l \quad (5)$$

In which
L = length of the rectangular patch
W = width of the rectangular patch
h= thickness of the substrate material
f_0 = resonant frequency

B. *Dimension of Antennas*

The dimension of antennas e.g. length , width, dielectric constant, height, resonant frequency etc. has been calculated using above formulas which has been tabulated below.

Table. 1 Dimension for the antenna 1 designed for 9 GHz

Parameter	Value
Length of the radiator patch (L)	9.8 mm
Width of the radiator patch (W)	12.8 mm
Relative dielectric constant (ε_r)	2.4
Thickness of substrate (h)	1.6 mm
Resonant frequency(f_0)	9 GHz

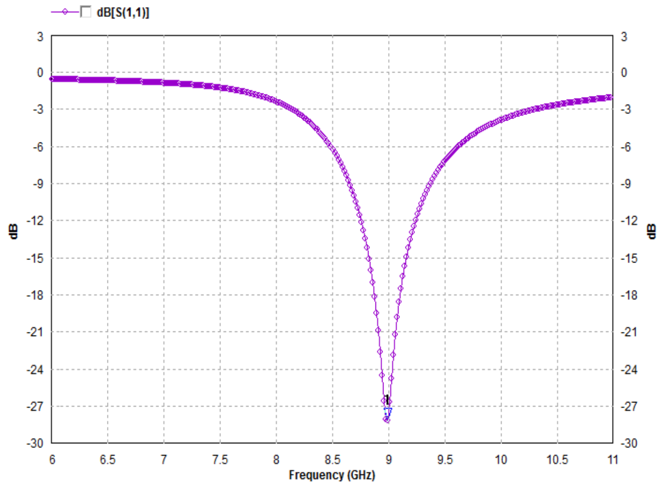
Table. 2 Dimension for the antenna 2 designed for 5.67 GHz

Parameter	Value
Length of the radiator patch (L)	16 mm
Width of the radiator patch (W)	20 mm
Relative dielectric constant (ε_r)	2.4
Thickness of substrate (h)	1.6 mm
Resonant frequency(f_0)	5.67Hz

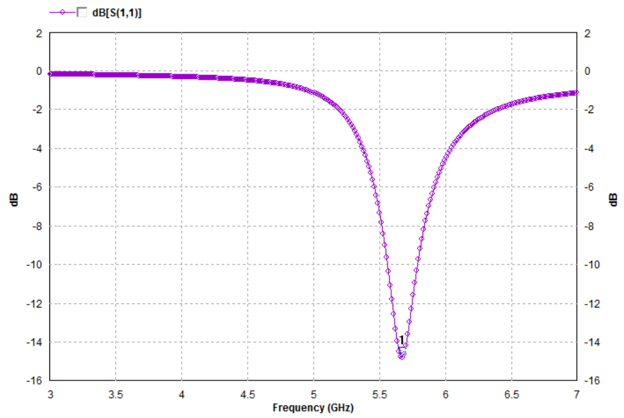
III. RESULT AND DISCUSSION

A. *Return Loss Plot*

For the parametric analysis the dimension of the reference patch structure is given in the table below. The S_{11} (input reflection coefficient) plot for the given patch is drawn by the simulation using IE3D software.



(a)



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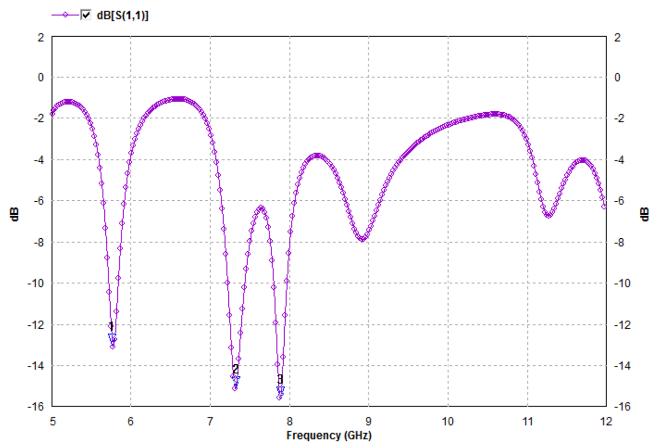

(c)

Fig 2 (a) Return loss plot for antenna 1 (b)Return loss plot for antenna 2 (c) Return loss plot for antenna 3

Simulated result of return loss of the conventional antenna 1 is given in fig 2(a). This antenna is giving a return loss of -28.1 dB at 9 GHz with a bandwidth of 620 MHz. Return loss of conventional antenna 2 is given in fig 2(b) which shows a return loss of about -16 dB at 5.75 GHz . Its corresponding 10 dB bandwidth is 227 MHz. Fig. 2(c) shows the modified multi-frequency microstrip antenna.

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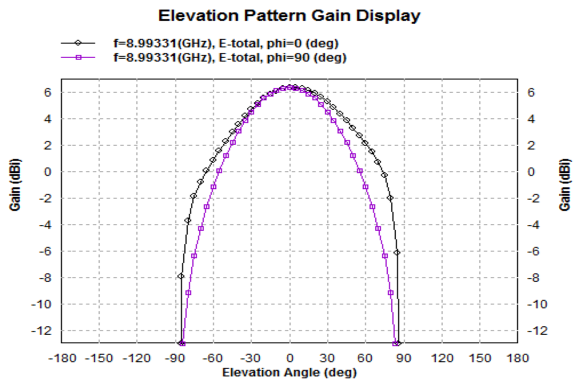
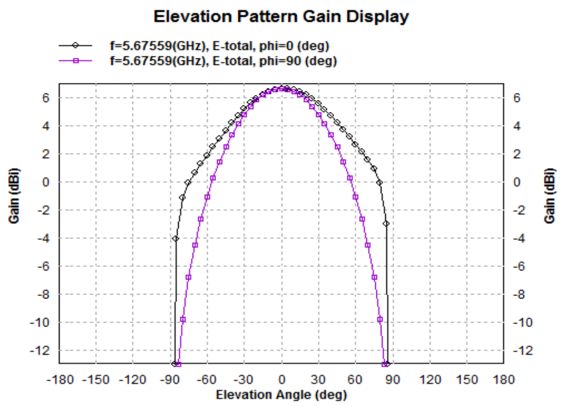
For this antenna, the first resonant frequency is obtained at 5.77 GHz with return loss of about -13.0 dB. The second and the third resonant frequencies are obtained at 7.32 GHz and 7.80 GHz respectively with return losses of about -15.05 dB and -15.37 dB. The corresponding 10 dB bandwidth obtained for antenna 3 at 5.77 GHz, 7.32 GHz and 7.80 GHz are 120 MHz, 210 MHz and 150 MHz respectively.

B. Radiation Pattern

The radiation patterns of the above conventional and modified antennas are simulated at their resonant frequencies. The corresponding E – plane radiation patterns for conventional antenna 1 and antenna 2 are given in fig 3.



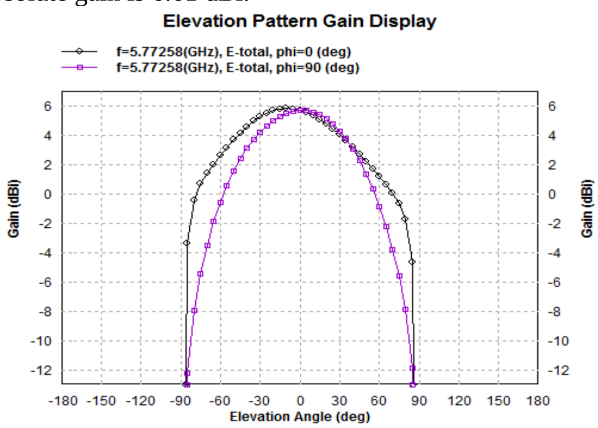
(a)



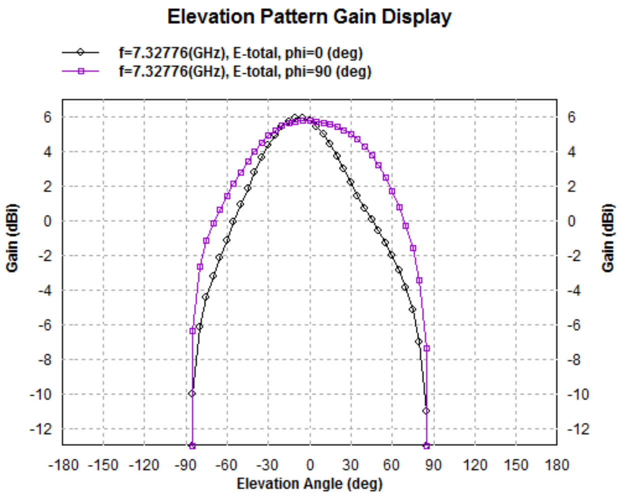
(b)

Fig 3 (a) Radiation pattern for antenna 1 at 9 GHz (b) Radiation pattern for antenna 2 at 5.67 GHz

From the fig 3(a), the 3 dB beamwidth for antenna 1 is about 80^0 and the absolute gain is 6.31 dBi. From the fig 3(b), the 3 dB beamwidth for antenna 2 is about 70^0 and the absolute gain is 6.61 dBi.



(a)



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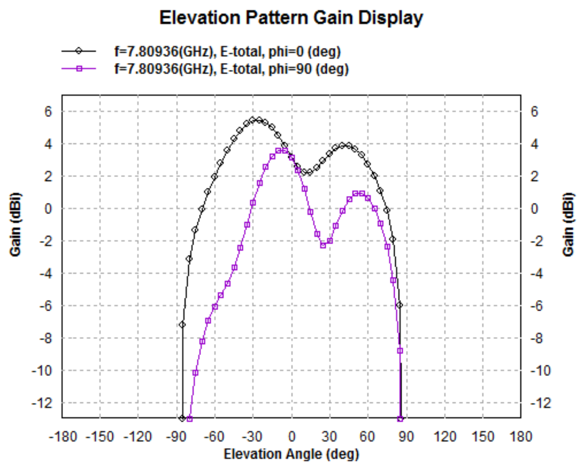

(c)

Fig 4(a) Radiation pattern for antenna 3 at 5.77 GHz (b)Radiation pattern for antenna 3 at 7.32 GHz (c)Radiation pattern for antenna 3 at 7.80 GHz

The above figure 4 shows the two dimensional radiation pattern of the multi-frequency antenna 3. The 3 dB beamwidth of antenna 3 at 5.77 GHz, 7.32 GHz and 7.80 GHz are 100^0, 102^0 and 118^0 respectively and corresponding absolute gain are 5.79 dBi, 5.86 dBi and 5.38 dBi respectively. The above radiation patterns show similar variation of radiation performance of antenna which is desirable for multi-frequency.

All the simulated results are summarized in the table below. From the above table it is clear that for antenna 3 increased value of frequency ratio are obtained. Radiation pattern for all the multiple frequencies are nearly similar. Therefore the radiation performances for all the multiple frequencies are similar.

Table 3 Simulated results for antenna 1, 2 and 3

Antenna structure	Resonant frequency (GHz)	Return loss(dB)	10 dB BW(MHz)	Frequency ratio	Absolute gain(dBi)
1	9	-28.1	620	-	6.31
2	5.67	-14.8	227	-	6.61
3	5.77	-13	120	-	5.79

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3	7.32	-15	210	1.26	5.86
3	7.80	-15.3	150	1.35	5.38

IV. CONCLUSION

Two conventional single frequency antennas are design at 9GHz and 5.67GHz. A multi-frequency antenna is proposed by connecting two antennas with corner excitation. The simulation shows operation at 5.77GHz, 7.32GHz and 7.80GHz with consistency of radiation patterns. The antenna shall be suitable for wireless communication system applications

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