Optimization of Micro strip Patch Antenna with Zig-Zag Slot in Broadband Communication

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Abstract*: In this paper designed and analysis of the rectangular Microstrip patch antenna for GSM band with frequency band 5.1 GHz. Primarily the designed a conventional unslotted rectangular microstrip patch antenna and measure its different parameters using simulation tools .again introduced a Zig –Zag slotted antenna with dielectric substrate 2.2 and used the centre resonance frequency of 5.1 GHz. The substrate height of the FR4 was 0.787 mm.The comparison results of slotted and unslotted antenna are achieved large bandwidth and gain.The bandwidth of 35.2 % and achieved gain is 7.18 dBi in this poposed designed antenna. To model the probe feed for the microstrip patch we used a lumped port with port impedance equal to 50 ohm. The Zig-Zag antenna developed and its performance are utilized by Zealand IE3D tools. This antenna is used in GSM application and many other communication systems.

Index Terms: Bandwidth, Gain, zig-zag slot, Return loss, wireless communication.

I. INTRODUCTION

Most common antenna used in different range of frequency field of application are Microstrip antennas, and they are sometimes applied is in the millimetre-wave frequency band as well as broadband applications [1, 2, 3,4].Microstrip patch antennas having the metal conductive patch that is placed on the head of a grounded dielectric material of thickness *h*, with relative permittivity and permeability ε_r and μ_r respectively are shown in Figure .1 (usually $\mu_r = 1$). The metallic microstip patch may be of different shapes like circle,oval,rectangular,cube etc.The common rectangular type structure as shown in Figure 1.

The major advantages of this microstrip patch antenna is that it has low profile structure, easily constructed and overall it can be suitable for all feeding techniques[5,6]. If the dielectric substrate is very thin, the antenna may be broken or bent like a cylindrical structure. Generally a substrate thickness is about 0.02 λ_0 .The metallic patch is generally fabricated by a photolithographic etching process in microstrip antenna design. Not only that the construction relatively easy and Other advantages include the fact that the microstrip antenna is usually lightweight (for thin substrates) and durable.

II. PATCH ANTENNA DESIGN METHODOLOGY

Three most important parameters to design of the a patch antenna are:

Frequency of operation (f_0): This design based on GSM frequency on 5.1GHz .Hence, the designed antenna has been operated in this frequency range. The centre resonance frequency used to design the antenna is 5.1GHz .The electromagnetic field propagation is considered in free space path, where it travels at the speed of light $v_o = 3\times10^8$ m / s .In UHF band, the following expression is used:

$$\lambda = \frac{300}{f_{(MHz)}}$$

Hence, the wavelength of the antenna when operating at 5.1GHz is 5.9 cm

Dielectric constant of the substrate (ε_r): Generally the value of the Dielectric substrate of the antenna are normally in the range of $2.2 < \varepsilon_r < 12$ [7,8,9]. The dielectric substrate can be selected for this antenna is RT Duroid 5880 substrate having the value of dielectric constant (ε_r) of 2.2 A substrate with a low dielectric value has been used since it will increase the bandwidth of the antenna.

Thickness of dielectric substrate (h): To design a compact microstrip patch antenna it is most desirable that it should not provides large antenna size and not provides undesired radiation .So thickness of the substrate and dielectric value are most carefully taken in this work, it is most important requirement that the antenna is not bulky. Hence the thickness of the substrate, resonance frequency and dielectric substrate are :

- $f_0 = 5.1$GHz
- $\varepsilon_r = 2.2$
- $h = 0.787\ mm$
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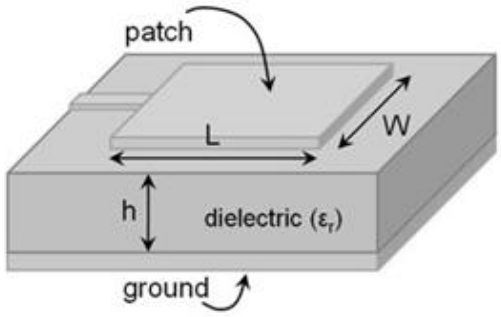

Fig.1.Microstrip antenna geomerty

Step 1: Design of the Patch width (*W*): The width of the antenna is found by the equation [10]:

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}}$$

Substituting $c = 3 \times 10^8 \text{m/s}$, $\varepsilon_r = 2.2$ and f_0 = 5.1GHz .we get W=23.25 mm

Step 2: Calculation of Effective dielectric constant (ε_{reff}) : $\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$

Ref. to (10), we get: ε_{reff} =2.1

Step 3: Calculation of the Effective length (L_{eff}) :

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

Substituting $\varepsilon_{reff} = 2.1$, c=3×10^8 m/s and f_o=5.1GHz, we get: $L_{eff} = 20.28$ mm

Step 4: Find the extended length (ΔL) : The length extension as:

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

$$\Delta L = 0.4146 \text{ mm}$$

Step 5: Determination of the Patch length (L):

$$L = L_{eff} - 2\Delta L \qquad L = 19.43 \text{ mm}$$

Step 6: Selection of the feed location (X_f, Y_f):

It is found that at feed location, the value of the input impedance is approximately 50 Ω and the feed location as $y_f = \frac{w}{2}$ and $x_f = \frac{L}{2\sqrt{\varepsilon_{ff}}}$

Using this above equations and trial method to match at feed position is ($X_f = 6.7, Y_f = 11.62$). [10]

III. SIMULATION AND RESULTS

USING IE3D SIMULATOR SOFTWARE

The Zig-Zag slotted antenna is simulated by IE3D software tools whose function is works using MoM techniques.The different values of return loss according to the variation of resonance frequency at 5.1GHz is found minimum return loss is -25.98 dB. fig.2.

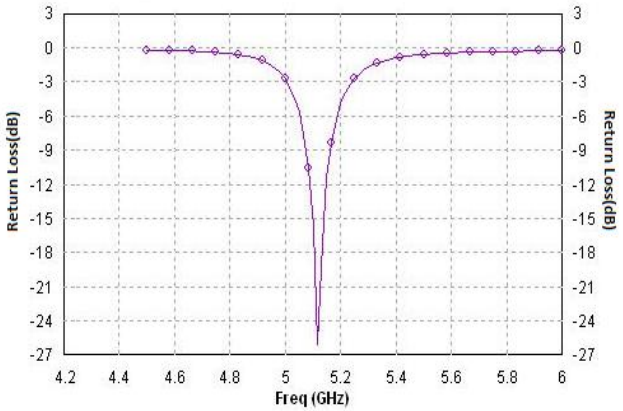

Fig.2. Return Loss with. Frequency characteristics for Table 1

TABLE I
Antenna Performance

Feed point (x_f,y_f)	Return Los (dB)	Frequency (GHz)	BW (MHz)	Gain (dB)
2.8,1	-18	5.1	68.3	6.91
3,1	-25.98	5.1	70.1	7.07
3,1.5	-24.29	5.1	69.2	6.81
3.5,2	-25.03	5.1	69.8	6.62

The frequency vs. VSWR graph for antenna shows at frequency 5 GHz, VSWR is1.0dB fig.3

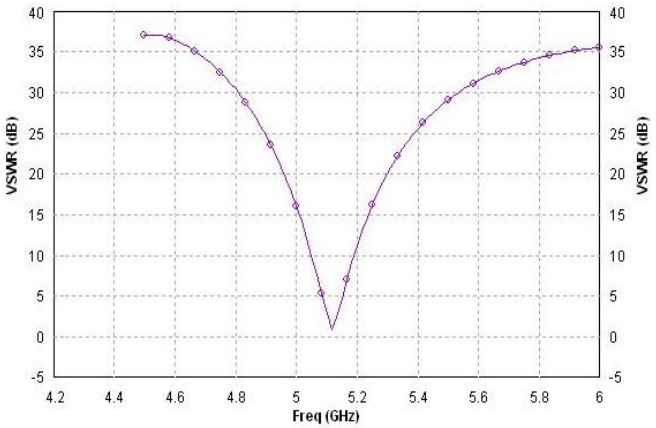

Fig.3. VSWR vs. Frequency characteristics

The antenna efficiency vs. frequency characteristics of the rectangular patch antenna shown in Figure.4. Simulated efficiency is 86.76%

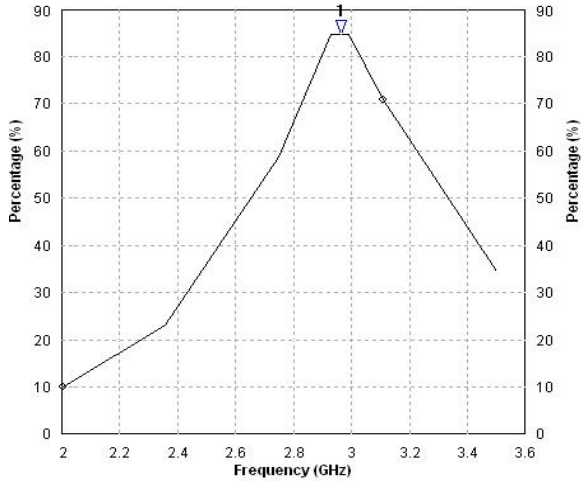

Fig.4. Efficiency vs. Frequency

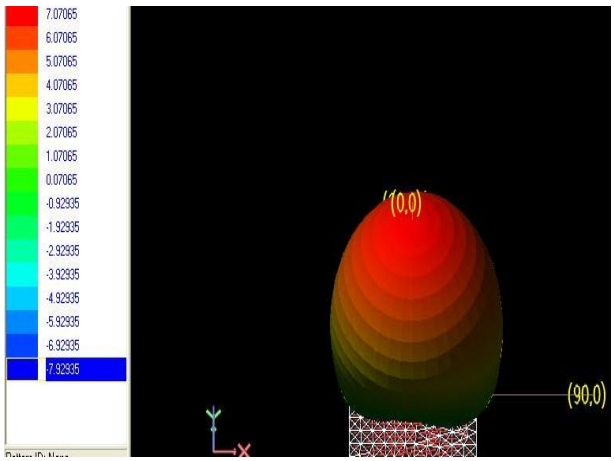

Fig 5.The radiation pattern of microstrip antenna

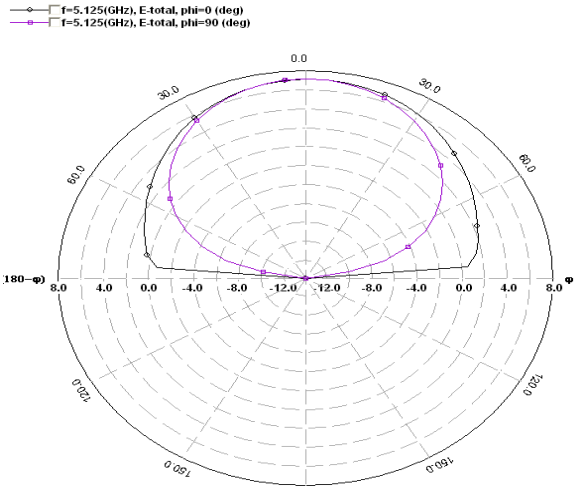

Fig 6.The radiation pattern of microstrip antenna

IV. DESIGN OF ZIG-ZAG SLOTTED SHAPED MICROSTRIP ANTENNA

To construct of the patch antenna, the three most important parameters are patch width, patch length and centre frequency. In this work the resonance frequency at 5.1GHz the selected value of FR4 Dielectric substrate value with 4.6 and thickness of the substrate is 0.787mm.The geometry of the zig-zag slotted antenna shown in figure.7 below.

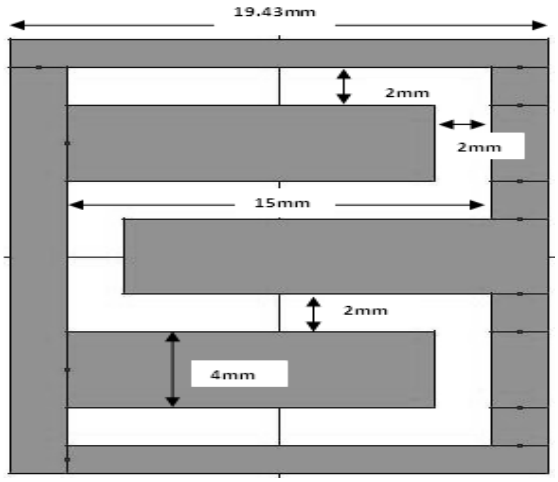

Figure.7. zig-zag slotted microstrip antenna

V. PARAMETER ANALYSIS

Here the analysis the effect of various antenna parameters on the performance of the zig-zag shaped Micro strip Patch antenna. We obtained that the various antenna parameters such as antenna gain, bandwidth, and return loss and radiation pattern of antenna are varied with the different position of feed line.

VI. EXPERIMENTAL RESULTS

The designed Zig-Zag shaped antenna and simulated results are analyzed and optimized the various values of the antenna dimensions and corresponding values of gain and bandwidth.

TABLE III
Performance for zig-zag slotted Antenna

Feed point	Return Loss (dB)	Frequency (GHz)	Band width (MHz)	Gain (dBi)
0,11.1	-27.35	5.4	70	7.10
0,-11	-28.42	5.4	90	7.08
0,10.9	-24.15	5.4	80	6.52
0,11	-36.18	5.4	100	7.18
0,10.7	-19.50	5.4	78	6.10

We obtained that the minimum return loss is -36.18 dB at 5.4 GHz. Shown in fig.8.

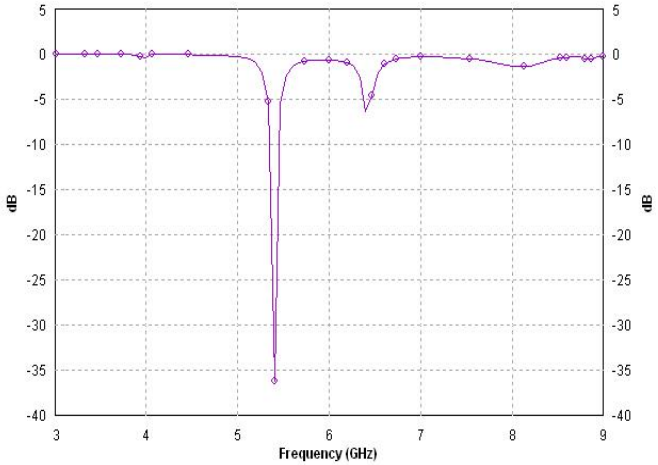

Figure.8.Return loss Vs Frequency curve

Simulated bandwidth is 100 MHz which is 42.6% more than that of the unslotted patch antenna. The maximum gain is 7.18dBi shown in fig.9.

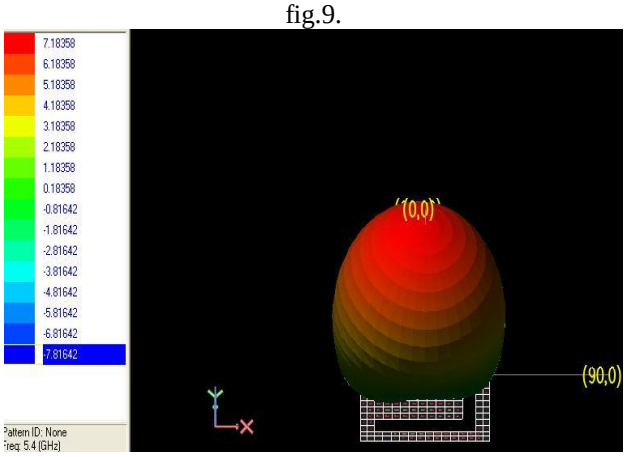

Figure.9.3-D Radiation pattern at 5.4MHz

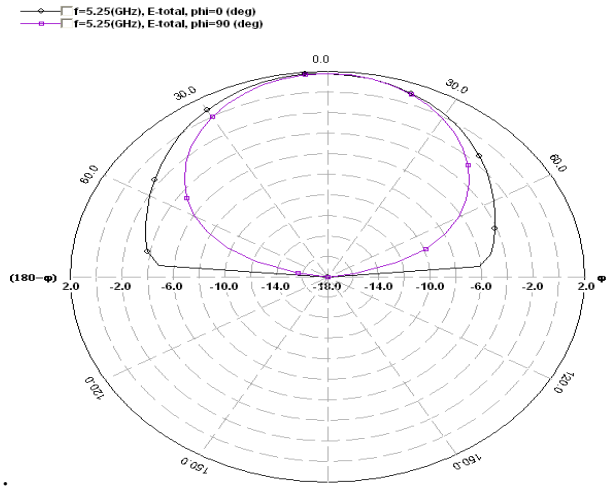

Figure.10.2-D Radiation pattern at 5.4MHz

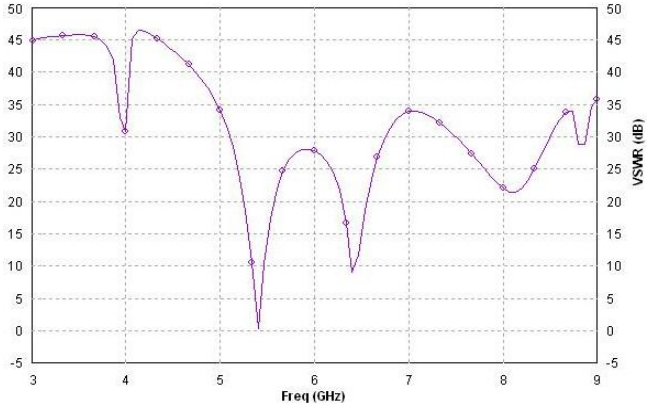

Figure.11 The calculated VSWR is 1.01 at 5.4MHz

VII. CONCLUSION

The conventional rectangular Patch antenna and zig-zag slotted antenna are analysed and observed from the result of simulation that the bandwidth of the designed zig–zag shaped antenna has been enhanced increased by 35.2% and maximum achieved gain is 7.18dBi .This zig-zag antenna has been improved the VSWR which is 1.01 at operating frequency 5.4MHz.This design antenna can be use in wireless communication such as mobile communication, space communication etc.

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