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Design Of Vnrvjiet Logo Patch Antenna For X-Band Range Applications

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ABSTRACT
Micro strip patch antenna is widely used in wireless communication. Specifically, the X-Band antenna is used in military and medical applications. The core of the VNRVJIET Logo is representing the Knowledge of excellence. A 'V' Shaped slot is removed from the patch and an ellipse slot is tilted 90 degrees is removed from the patch and is positioned at the center top of the 'V' Slot which shows knowledge as a flame with no shades. The core of the center is the source of radiation which is coaxial to the feed line patch of the antenna. Four vertical slots adjacent to the core of the antenna will improve the radiating performance. These four Vertical slots are pillared on the horizontal slot. The proposed antenna is radiated at 8GHz which can be used in X- band applications. This paper discussed reflection co-efficient (S_{11}), Voltage standing wave ratio (VSWR), gain, directivity, electric field distribution and current distribution parameters. The length and width of the antenna is 60mm×50mm. The antenna return loss observed at -26.33dB. The VSWR value observed is 1.10 at 8.52 GHz frequency. A peak gain of 6dB and directivity '10' is achieved with the designed antenna. The distribution of both electric field and current field is also discussed in this paper. The designed antenna can be used for military and medical applications.
Keywords: *Current distribution, Directivity, Electric field distribution, Gain, Microstrip patch antenna, Reflection coefficient, Resonating frequency and VSWR.*

INTRODUCTION

Microstrip patch antenna is a low profile, high gain and reliable device for wireless communication applications. This antenna easily mounts on complex structural surfaces and is more feasible to the circuit boards. And specifically, the proposed developed X-Band antenna is suitable for military and medical applications. The microstrip patch antenna declines its bandwidth performance. The proposed antenna exhibits improved bandwidth for X-band applications. The bandwidth is improved by adding more slots to the radiating component. The ground plane is also influenced by improving bandwidth. The proposed antenna exhibits high gain and bandwidth. So, this antenna can operate at high power. With high bandwidth, the antenna transmitting ability is relatively richer when operating in wide band era[1][2]. The microstrip patch antenna for X-Band applications has been presented in the relevant study. The design techniques for X-Band applications were discussed in the reference papers. This paper focused on high gain and high bandwidth patch antenna design parameters and its parameter analysis. High frequency structure simulator is used for simulation studies. FR4 substrate (Flame Retardant ε_r=4.4) is used for the proposed microstrip patch antenna. The antenna radiating patch is deposited on FR4 substrate, which is excited with line feed with 50Ω, to enhance the efficiency of the radiation. The line feed with 50 Ω exhibits an excellent impedance matching by narrowing the reflection energy and enhances the power transfer and specifically, the feeding structure is reduced[2][3]. False feed radiation minimization and lowering the surface waves by optimally tunning the dimensions of the antenna. The feed point is considered at different distinct locations to increase radiating energy of the proposed antenna. This antenna radiates at 8.52GHz frequency can be used for X-Band applications specifically in Military wireless communication applications.

Relevant work:

M. M. Islam; M. T. Islam; M. R. I. Faruque; W. Hueyshin developed an X- Band Microstrip patch antenna in Printed circuit board with 40mm×40mm dimensions. The author achieved two resonant frequencies with rectangular and circular slots. The reflection coefficient (S_{11}) 17.14dB and -14.29 dB. The author observed 78.85% radiation efficiency and peak gain is 4.31 dB and impedance bandwidth are 1.59GHz [1]. K Sudhaman, T Godhavari, R Anusha, developed a microstrip patch antenna resonating at 10.3GHz at that frequency the gain observed is 5.01dB and a return loss is-29.21dB [2]. Srilali Siragam, proposed nano composite marvels to fabricate microstrip patch antenna for X band applications resonating at 8.51GHz and 8.49GHz frequency. S_{11} is observed at 25.94dB and 19. 97dB. The overall gain of the antenna is 2.14 and its directivity is 3.58 [3]. Pankaj Palta, et.al, developed a microstrip patch antenna for X-band Applications. The antenna dimensions are 5.2cm×5.3cm×0.15cm (Length× Width× thickness). The directivity observed is 12.016 dB. The reflection coefficient is -20.5 dB [4]. Kiran Katke, S. K. Popalghat developed a microstrip patch antenna for X band applications. The antenna resonates at 9 GHz frequency. VSWR is observed at 1.07. Bandwidth is 425.2 MHz. S_{11} are -24.16 dB, gain observed is 6.9dB [5]. Bing Ma,et.al developed a microstrip patch antenna for satellite communication. The antenna gain achieved is 23.9 dB at 8.2 GHz. S11 is observed at 8.23 dB [6].

Hiwa Taha Sediq et.al, designed a microstrip patch antenna 26mm×22mm for medical applications. The antenna has an impedance bandwidth of 2.58 to 10.95 GHz. This antenna resonate at 3.6GHz, 5.4GHz, 3.1-10.6GHz. The gain achieved is 7.21dB at 20.95GHz [7]. Manish Varun Yadav, et.al, “designed an antenna for X- band applications. It is resonating at 2.8Ghz and 12GHzfrequencies. Central frequency is observed at 7.4GHz and overall gain at 3.98dB [8]. Mohamed AlyAboul-Dahab et.al developed an antenna resonating at 10 GHz, the author observed that with increasing thickness of the conductor and changing the space between loops, the resonance frequency is increasing but bandwidth is decreasing [9]. M.Samsuzzaman and M.T. Islam, proposed an inverted S-shaped patch antenna operating at X- band region. This antenna with dimensions (20×17.2) resonates at 8.95, 11.06, 11.85GHz frequency. To increase the gain two elliptical slots are used in the ground plane of the antenna. and its bandwidth is 450 MHz [10]. Vishali Sharma, Mukh Raj Yadav, H. Ravishankar Kamath developed a patch antenna (46.7mm×25mm) FR4 substrate is used. Achieved VSWR 1.1263 at 8GHz. Bandwidth obtained is 200MHz. return losses are11.96dB. 4.54dBi gain is achieved [11]. Supriya Jana, Shirshendu Pandit, Geetali Chakrabarty proposed patch antenna. This antenna is radiating at multiple frequencies, return losses are observed at multiple frequencies. Observed VSWR at multiple frequencies [12]. Mrs.Vishalatchi.K, et.al., developed patch antenna operates at the frequency of 400 MHz and2.4GHz [13].

Design Specifications:

The Width (50mm) and height (1.6mm) of the proposed microstrip patch antenna is impacted on the effective dielectric constant. The substrate material (FR4) is the effective dielectric constant of 4.4. With higher the dielectric constant, the strength of the electrical breakdown is also raised to a higher value. The proposed antenna is sustainable to higher rate of voltage values and much higher current is distributed.

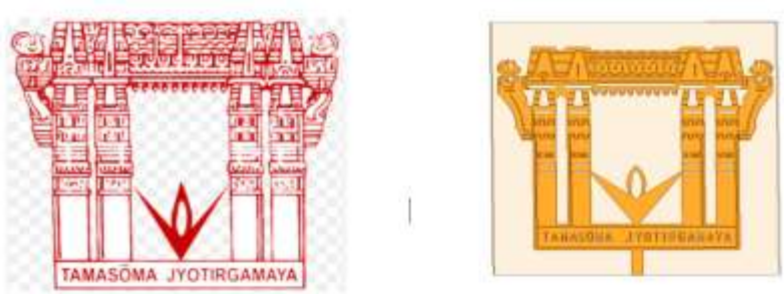

Fig.1. (a). Reference logo (b)Microstrip Patch antenna

In general, FR4 substrate influences the bandwidth and gain of the antenna. A shift in the reflection coefficient is traced specifically at lower frequencies with change of the dielectric constant. Owing to this, the effective dielectric constant is estimated with Eq.1.

Effective dielectric constant (ε_{eff}):

$$\varepsilon eff = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}[1+12\frac{h}{w}]^{-1/2} \qquad \text{Eq.1}$$

ε_{reff} = Effective dielectric constant
ε_r = Dielectric constant of substrate
h = Height of dielectric substrate
w = Width of the patch

Patch Length:

The patch length determines the proposed antenna resonating frequency. The patch length is estimated using Eq.2

$$L = \frac{C}{2f}(\varepsilon_r)^{-0.5} \qquad \text{Eq.2}$$

Effective length (L_{eff}):

The patch length of the proposed antenna is influenced by the fringing effect. The patch length and width are significant to improve the performance of the antenna. It has been observed that the fringing fields at the edges of the patch are subjected to fringing. Four vertical and two horizontal radiating slots for the proposed antenna is considered to improve the performance of the antenna. The height of the substrate is also influencing the fringing of the antenna. The fringing is subjected to the length of the patch (L), height of the substrate (h) and 'ε_r' of the FR4 substrate. The fringing is significantly minimized with (L/h) value, which is less than unity value. This impacts on the antenna resonating frequency. Owing to this fringing effect, the waves are distributed into the air and to the FR4 substrate, effective dielectric constant is estimated using Eq.1 to for lower frequencies. The change of the patch length is depending on the effective dielectric constant εeff and the ratio of Width and height. The effective length is estimated using Eq.3.

$$L_{eff} = L+2(\Delta L) \qquad \text{Eq.3}$$

ΔL is estimated using eq.3

$$\Delta L = 0.412h\left(\frac{\epsilon_{reff}+0.3\left(\frac{W}{h}+0.264\right)}{(\epsilon)\left(_{reff}-0.258\right)\left(\frac{W}{h}+0.8\right)}\right) \qquad \text{Eq.4}$$

L_{eff} is tuned to improve the radiated energy and subsequently energy loss is minimized so that the gain of the antenna is increased. The signal strength is observed in the specified direction with negligible energy loss. The input energy is fully transformed into radio waves by tuning the length of the antenna meticulously. So that the range of communication is increased with the proposed antenna. The orientation of the electric field is also impacted by the length of the antenna. The performance of the antenna is significantly improved with tuned length of the antenna.

The effective length is estimated using equation No.5

$$Leff = \frac{c}{2fo\sqrt{\varepsilon eff}} \qquad \text{Eq.5}$$

The extension length of the antenna (ΔL) is estimated to be using eq.6.

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon reff+0.3)}{\varepsilon reff-0.258)} \qquad \text{Eq.6}$$

Table.1. Antenna design parameters

Parameter	**Dimensions in mm**
Substrate Width	50

Substrate length	60
Patch width	48
Patch Length	47.4
The height of the dielectric substrate	1.6
Length of the feedline	6
Width of the feedline	2

Working Principle:

The core of the VNRVJIET Logo is representing the Knowledge of excellence. A 'V' Shaped slot (two triangles are intersected with the base of the triangle. The base size is 2mm and the adjacent sides are 4.5mm) is removed from the patch and an ellipse slot (Major axis is 1.2mm and the minor axis is 0.6mm) tilted 90 degrees is removed from the patch and is positioned at the center top of the 'V' Slot which shows knowledge as a flame with no shades. The core of the center is the source of radiation which is coaxial to the feed line patch of the antenna. Four vertical slots (54mm×3mm) adjacent to the core of the antenna which will improve the radiating performance of the antenna. These four Vertical slots are pillared on the horizontal slot (48mm ×3mm). These slots represent, innovate, synthesize and manage to meet the challenges of society.

Concentric circles on the vertical slots are used to enhance the transmission power of the radiating energy throughout the patch, which represent imparting knowledge to society. The words 'Tamasoma Jyotirgamaya'on the horizontal slot is anchoring the spreading of radiation as a knowledge and minimizing the reflection coefficient value. The Small 'v' slots are tagged to the above horizontal slot and a series of half circles are considered coaxial to the small 'v' slots to distribute the radiating power like igniting minds of the people. Two vertical bands (5mm ×3mm) are at the upper periphery coupling the vertical and horizontal bands to improve the gain of the antenna, which improves the signal strength of the radiating patch. These tags represent the outcome of the VNRVJIET. The reflection coefficient values are minimized, and the transmitting power, gain is increased with the design patch which is related to the dissemination of knowledge to society. This radiating patch is etched on the FR4 Substrate with dielectric constant of 4.4.

RESULTS AND DISCUSSION:

The antenna is designed using HFSS software. VNRVJIET logo is taken as a reference and the microstrip patch is designed using the antenna parameters. The length and width of the patch is tuned to achieve improved characteristics of the antenna. The line feed is applied to excite the patch, The antenna resonating frequency, return losses, VSWR, gain, bandwidth, voltage distribution and current distribution are analyzed.

a. Reflection Co-efficient (S11)

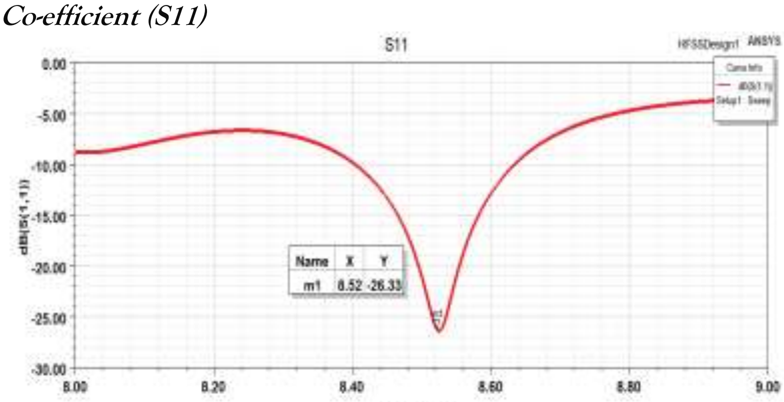

Fig.2. Reflection coefficient Vs Frequency

The above diagram depicts Reflection Co-efficient (S_{11}) of the antenna (Logo), which radiates at 8.52GHz with return loss of -26.33dB at resonating frequency. The signal strength of the proposed antenna is increased with minimum reflection coefficient value of 26.33 is observed at 8.52 GHz frequency. This represents energy transfer efficiency to the X-band communication system within the range of 8-12 GHz.

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b. VSWR (Voltage Standing Wave Ratio)

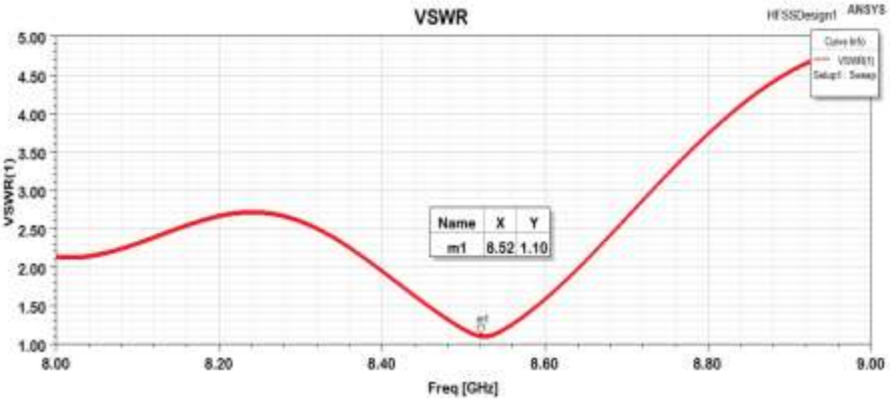

Fig.3. VSWR Vs Frequency

The VSWR value is 1.10 at 8.52 GHz frequency. This value lies within the acceptable range of 1.2 to1.5. The VSWR value represents significantly negligible amount of energy is reflected. This represents the antenna as a good match with the transmission line. VSWR value 1.10 enhances the performance of the proposed antenna for X-Band applications.

c. Gain

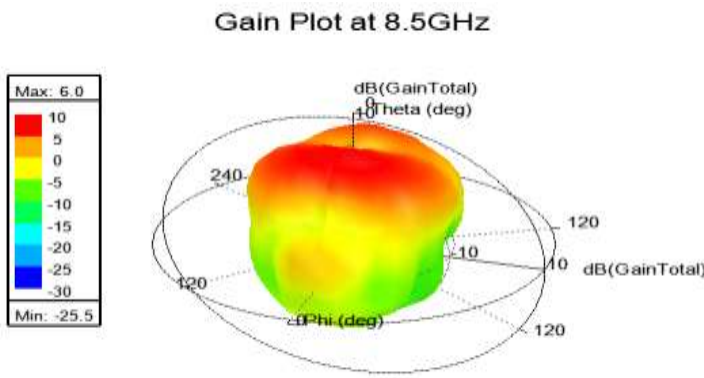

Fig.4. Gain Plot

The proposed antenna produced a Peak Gain of 6dB at 8.52GHz frequency. This gain enhances the power of radiating energy and enhances the range of signals in communication devices. With gain value the proposed antenna radiating energy is focused into a narrow beam. This antenna receives much higher power than with an isotropic antenna [9]. The radiating signal will not be obstructed by the obstructions like tress and building, so there will be no signal drop with the achieved gain value. High gain value greater than 8dB significantly decline the performance of the antenna.

d. Directivity

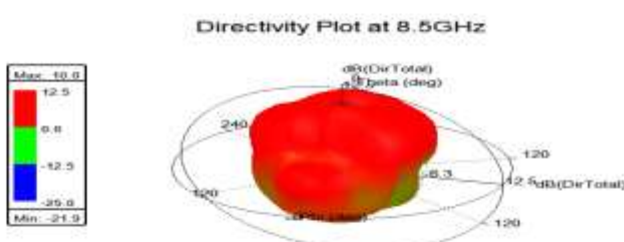

Fig.5. Directivity Plot

The directivity of the proposed antenna is achieved 10 at 8.52GHz. This directivity value is greater than the overall gain of the antenna, because of the internal losses. With high directivity the radiating energy is focused on a particular direction and is perpendicular to the patch of the antenna [10]. It has been observed that the proposed antenna is much radiates from the fringing fields at the edges of the patch. The width of the patch is 48mm, dielectric constant of the substrate ε_r=4.4, thickness of the substrate1.6mm, and the ground plane are impacting on the directivity of the proposed antenna. The maximum directivity is observed in the direction which is longitudinal to the microstrip patch antenna .

Fig.6. Electric field distribution

The simulation study shows that when the patch is excited, the electric field is distributed throughout the patch. It has been observed that the maximum (Positive) and minimum (negative) electric field are observed throughout the patch of the antenna. Based on the applied phase, the maximum and minimum electric field orientation is tilting from periphery to the center of the patch [11][12]. The electric field is zero at the center of the patch, maximum (positive) at one side, and minimum (negative) on the opposite side. It should be mentioned that the minimum and maximum continuously change side according to the instantaneous phase of the applied signal.

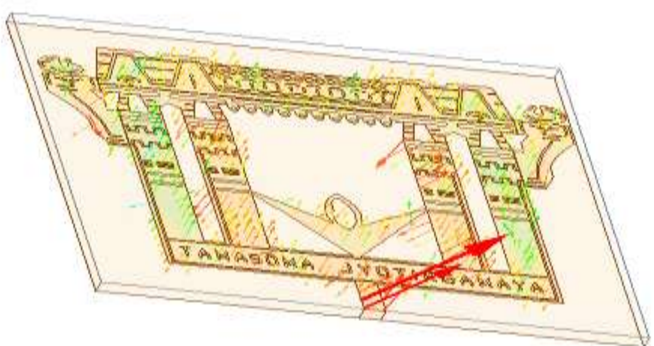

Fig.7. Current distribution

Fig.7.Represents the current distribution of the proposed patch antenna. Maximum current is distributed at the periphery of the patch and specifically, at the centre region of the patch antenna. this determines the amount of radiation of the antenna specifically, the orientation of the current distribution represents the proposed antenna polarization [13]. The bandwidth is significantly improved by joining the exciting modes.

Table 1. Comparison between proposed and some existing antennas

References [Year]	**Dimensions in mm (L x W)**	**ϵ_r**	**Height (h) (mm)**	**Design (Radiator)**	**Feed**	**Resonating Frequency (fr) (GHz)**	**Peak Gain (dB)**
2[2020]	3.8 mm X 20 mm	4.4	2.5	E-Shaped	MSL	10.3	6
5[2024]	9.9×11.6	2.2	1.6	Rectangular	MSL	9	6

6[2021]	6 × 12	3.55	1.524	Double square	MSL	2.8 to 8 GHz	5.9
7[2023]	26x22	2.2	1	Fractal antenna	MSL	2.58 to 21	7.21
8[2020]	29.5x23.5	4.3	1.57	S/C/X band	MSL	10	3.98
9[2016]	40 ×40	2.2	1.575	Rectangular	MSL	8.2	5.7
10[2014]	20×17.2	4.6	1.57	S-shaped slot	MSL	8.95, 11.06, 11.85	4.45, 3.99, 4.17
Proposed work	**60×50**	**4.4**	**1.6**	**Multiple slots**	**MSL**	**8.52**	**6**

*MSL-Micro Strip Line

ref.2 is developed an E-shaped antenna the antenna resonates at 10.3 GHz with gain is 6dB. Ref.5 is radiating at 9GHz, the gain achieved with rectangular same as with proposed antenna. ref.6 is radiating at multiple frequencies, but the maximum radiating frequency and the gain value is close with the proposed design. ref.8,9,10 are resonating at higher frequencies, but the gain achieved is 66% & 75% less than the proposed design. The S-shaped antenna designed with ref.10 is radiating at multiple frequencies but achieved maximum gain which is less than 74.16 % than the proposed design.

CONCLUSION:

This paper presents a VNRVJIET logo antenna for X-Band applications. This antenna radiates at 8GHz frequency. A well-realized gain of 6dB is achieved. The novel antenna properties show significant ability to use in wireless applications. The simulation outcomes of the reflection coefficient S_{11} are -26.33dB at 8GHz resonating frequency. The VSWR value is 1.10 at 8.52 GHz frequency. This represents the antenna as a good match with the transmission line. VSWR value 1.10 enhances the performance of the proposed antenna for X-Band applications. This value lies within the acceptable range of 1 to 2. The proposed antenna shows a peak gain of 6dB at 8.52GHz frequency. This gain enhances the power of radiating energy and enhances the range of signals in communication devices. The directivity of the proposed antenna is achieved '10' at 8.52GHz. This directivity value is greater than the overall gain of the antenna, because of the internal losses. The electric field is distributed throughout the patch. It has been observed that a mmaximum current is distributed at the periphery of the patch and specifically, at the centre region of the patch antenna. This determines the amount of radiation of the antenna specifically, the orientation of the current distribution represents the proposed antenna polarization. Based on the simulated results, the proposed antenna is a good match to X-Band applications specifically in the domain of defence and medical era.

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