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Design, Analysis and Evaluation of Results of Vivaldi Antenna for Millimeter Band Application

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***Abstract* - Characteristics of the antenna is one of the most important factors which should be considered in millimetre band. Extremely high frequency (EHF) has a number of applications that make it attractive for a variety of applications such as ground penetrating radars (GPR), remote sensing and phased arrays. This paper offered the design of a tapered slot Vivaldi antenna for millimetre wave application of which operates in GHz to achieve high performance in terms of bandwidth and directivity. Designed Vivaldi Antenna works in the frequency band of 42.2-50 GHz. All simulations are carried out by CST microwave studio software to obtain the voltage standing wave ratio (VSWR). Obtained VSWR Ranges from 1 to 2 and high directivity level ranges from 5.3 dBi at 45 GHz to 5.47 dBi at 48.5 - 50 GHz which shows the Progress in directivity and upper frequency range coverage. The Proposed Vivaldi antenna displays steady radiation pattern throughout the frequency band. The VSWR characteristic and Far-field radiation pattern are plotted to realize the antenna Mechanism.**

Keywords **-**Vivaldi antenna, Exponentially, TSA, GPR, Radar, Bandwidth, Dielectric, Frequency , VSWR , Return loss , Radiation pattern , Directivity , Gain, Far-field.

I. INTRODUCTION

The Vivaldi antenna is appropriate for a special category of Tapered slot antenna (TSA) which having exponential flares profile. In the area where the separation between conductors is lesser related to the free-space wavelength , the waves are strongly bound and if the separation rises, the bond turn out to be gradually weaker and the waves become radiated away from the antenna[2].It is economical to manufacture and can deal with high directivity and wideband Performance [3]. The Vivaldi antenna, initially presented by Gibson in 1979[4] contains of a tapered slot arrangement where the slot Boundary has an exponential profile. The Vivaldi antenna has the benefits of being a very simple and compact planar Configuration, which has a high directivity, wide bandwidth, and linear polarization. Vivaldi antenna delivers a flat Transition between the radiated plane wave and guided wave which is drifting in the slot transmission line. Desired impedance and pattern bandwidths have been realized by width, optimizing length and tapered shape of aperture. The detection of the buried object located near the ground surface as well as small and low-contrast landmines needs to use higher frequencies to achieve a better resolution. The TSA attracts much attention in GPR application due to its low cost, low weight, simple fabrication, compactness, wideband properties and end-fire radiation. A compact TSA for GPR applications, which has large bandwidth and small size, besides, more stable in the energy.

II. ANTENNA GEOMETRY & DESIGN PARAMETERS

Taper of the slot line transmission line can be described as an exponential function, earning the antenna the name exponentially tapered slot antenna or Vivaldi antenna [5], the antenna utilizes a micro strip feed to excite the slot line. The micro strip feed uses one conductor of the slot line as a ground plane and connects to the other side via a shorting pin, which is done at the narrowest part of the slot. The gradualness of the taper is described by a constant referred to as taper rate. The taper rate dictates the beam width of the antenna [17]. The maximum separation between the slot line conductors is equivalent to a free space half wavelength of the lowest operating frequency. Vivaldi antenna is considered as Two dimensional exponential curve, can be better understand by given below Fig.1 and equation where ‘S’ is the distance between origin and y-intercept, but in antenna prospective view ‘S’ is the half Of the slot width of Vivaldi.

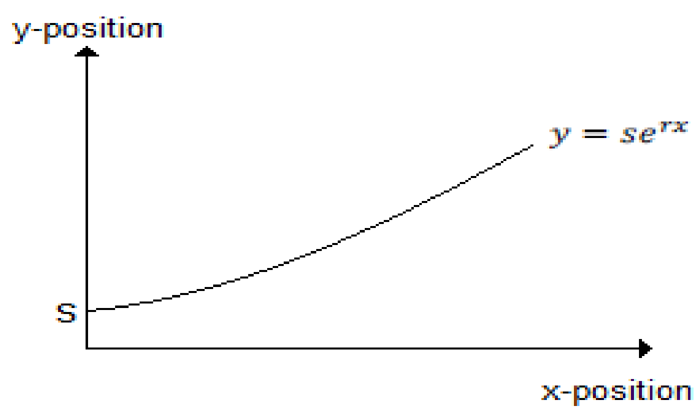

Fig.1: Two dimensional Cartesian plots for exponential curve

Now this equation ($y = se^{rx}$) converted into parametric

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Equation in three dimension with set up of this given equation (1), (2) and (3)

$$\upsilon (t) = t \quad (1)$$

$$\nu (t) = se^{rx} \quad (2)$$

$$\omega (t) = 0 \quad (3)$$

Where υ, ν and ω are the three positions.
Now keeping in mind above figure and equations it can be transformed into tapered exponential profile of Vivaldi Antenna which can be defined by equation (4)

$$f(x) = c_1 e^{Rx} + c_2 \quad (4)$$

Where Coefficient c_1 and c_2 is given by equation (5) and (6)

$$c_1 = \frac{y_2 - y_1}{e^{Rx_2} - e^{Rx_1}} \quad (5)$$

$$c_2 = \frac{y_1 e^{Rx_2} - y_2 e^{Rx_1}}{e^{Rx_2} - e^{Rx_1}} \quad (6)$$

As the electrical length of the antenna increases with frequency the gain increases. The length of antenna will be the addition of taper length, balun length, feed length, backwall offset and width must be equal to λ_0, where λ_0 is the free space wavelength at the low frequency. The exponential taper profile is determined by (x_1, y_1) and (x_2, y_2) Where R is the Rate of tapering, (x_1, y_1) is the starting point of taper and (x_2, y_2) is end point of Taper.

W is the width of tapered slot antenna which must satisfy the Given equation (7)

$$W < \frac{c}{f_H \sqrt{\varepsilon_e}} \quad (7)$$

Where ε_e is the effective relative dielectric constant.
Now to transform the above equation into real Antenna we are using CST microwave studio [2] [6]. The Structure of the proposed Vivaldi Antenna is shown in Fig.2 and Fig.3 respectively. Fig.2 displays the front view of Proposed designed antenna and fig.3 displays the 3D view of proposed designed antenna.

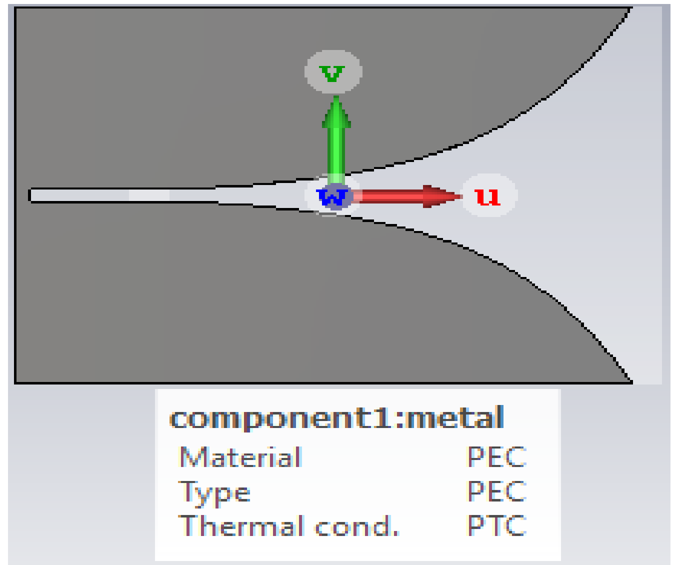

Fig.2: Front view of designed Vivaldi Antenna

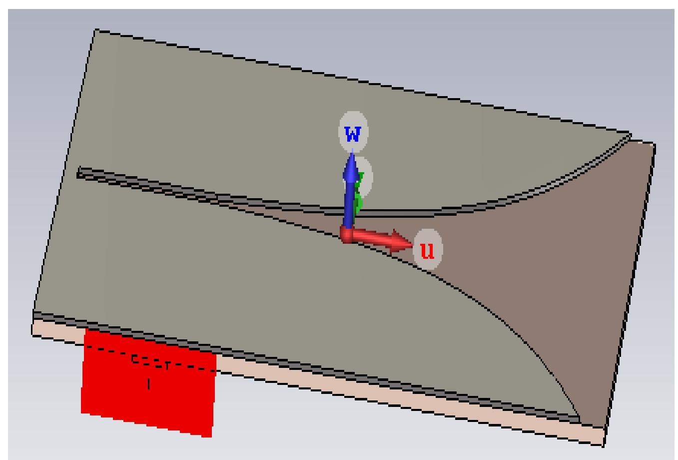

Fig.3: 3D view of designed Vivaldi Antenna

Geometry of Vivaldi antenna [7][8] A tapered slot patch dimensions with thickness 't' and substrate of dimensions with thicknesses 'h' are shown in below fig. 4. Permittivity value ε_r is taken as 3.78 and loss tangent $\tan\delta$ is considered as 0.001 for better performance of designed antenna. Thickness of micro-strip line and tapered slot patch is taken as 0.035 mm. The antenna was optimized In order to

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achieve a transition that has low return loss over a wide frequency band of 42.2-50 GHz, the impedances of the micro strip line and the slot line must be matched to each other to reduce the reflections. The characteristic impedance of a slot line increases with increasing slot width, so the width of slot line must be selected to be as small as possible to achieve an impedance value close to 40Ω. The width, characteristic impedance and guided wavelength of slot-line are calculated with procedures suggested in [9]. The strip-line feed used in a Vivaldi antenna is either connected directly to the transmitter/ receiver circuitry or is fed by a coaxial cable attached to a connector. The strip-line width and guided wavelength is calculated using formulas given in [10].

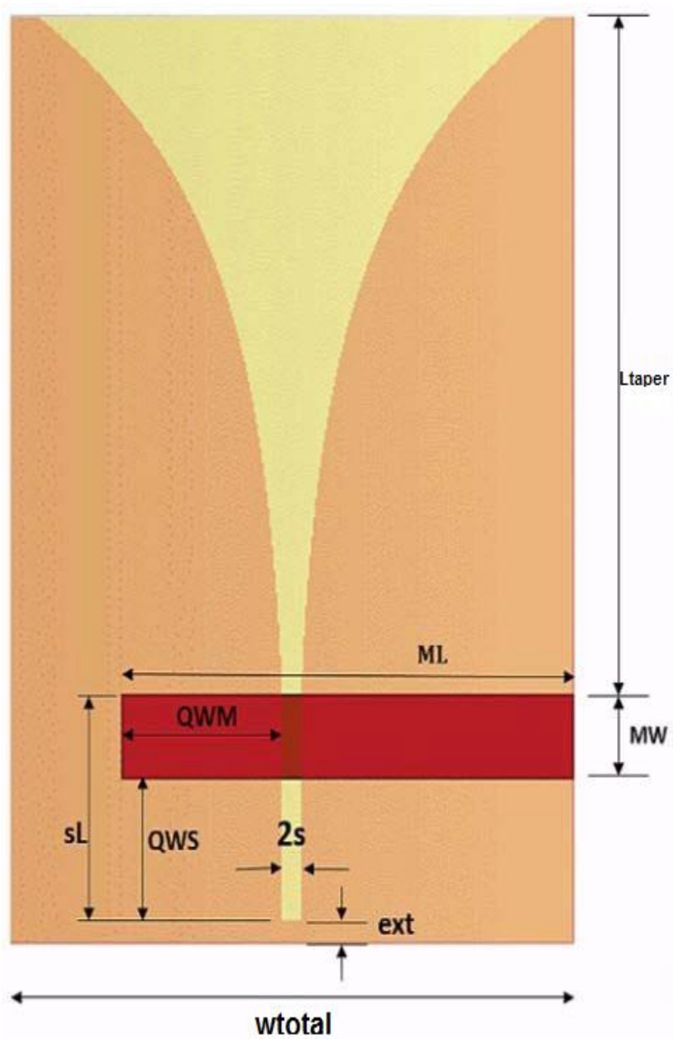

Fig.4: Geometry of the proposed antenna.

The material used in substrate is low cost PEC (Perfect electric conductor) material is used for exponential tapered section and for microstrip section.

The design parameters are given in Table1 shown below.

Antenna Design Parameters		
Index	***Value***	***Unit***
r	1.1208	mm
s	0.05	mm
sL	1	mm
TL	3	mm
subw	3	mm
ext	0.1	mm
s	0.05	mm
sL	1	mm
TL	3	mm
QWM	0.9	mm
h	0.1	mm
ML	*QWM + s + subw /2*	mm
MW	0.25	mm
QWS	0.75	mm

III. RESULTS AND DISCUSSIONS

The Vivaldi antenna is simulated mathematically with the CST software to examine VSWR, the return loss and far-field radiation characteristic over the frequency band of 42.2-50 GHz. The term VSWR is a quantity that defines how well an antenna is impedance matched to the transmission line it is associated to. Fig.5 shows the VSWR behaviour over the frequency range of 42.2 - 50 GHz. It is clearly seen that VSWR at frequencies 45 GHz, 43.378GHz, and at 48.407 GHz are found to be 1.0046, 1.4371, and 1.6641 respectively. All the obtained VSWR value is less than 2 which is required.

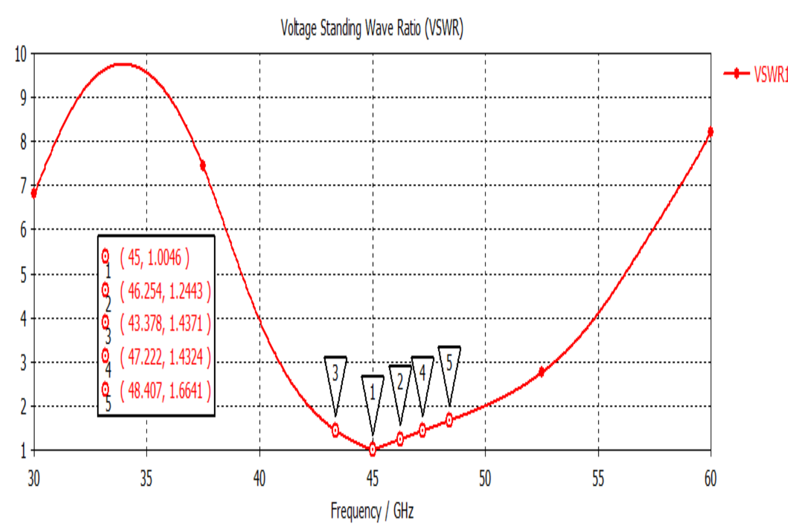

Fig.5: VSWR.

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The Fig.6 shows the S-parameter of the antenna. The return loss of the antenna is minimum at 45 GHz

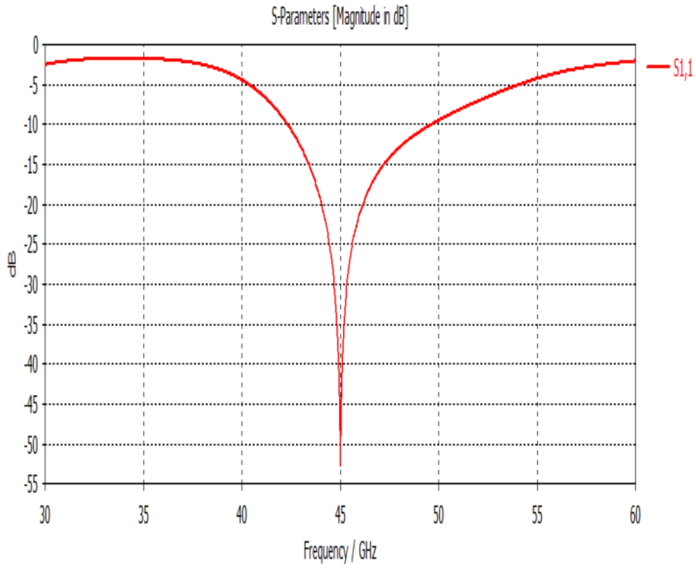
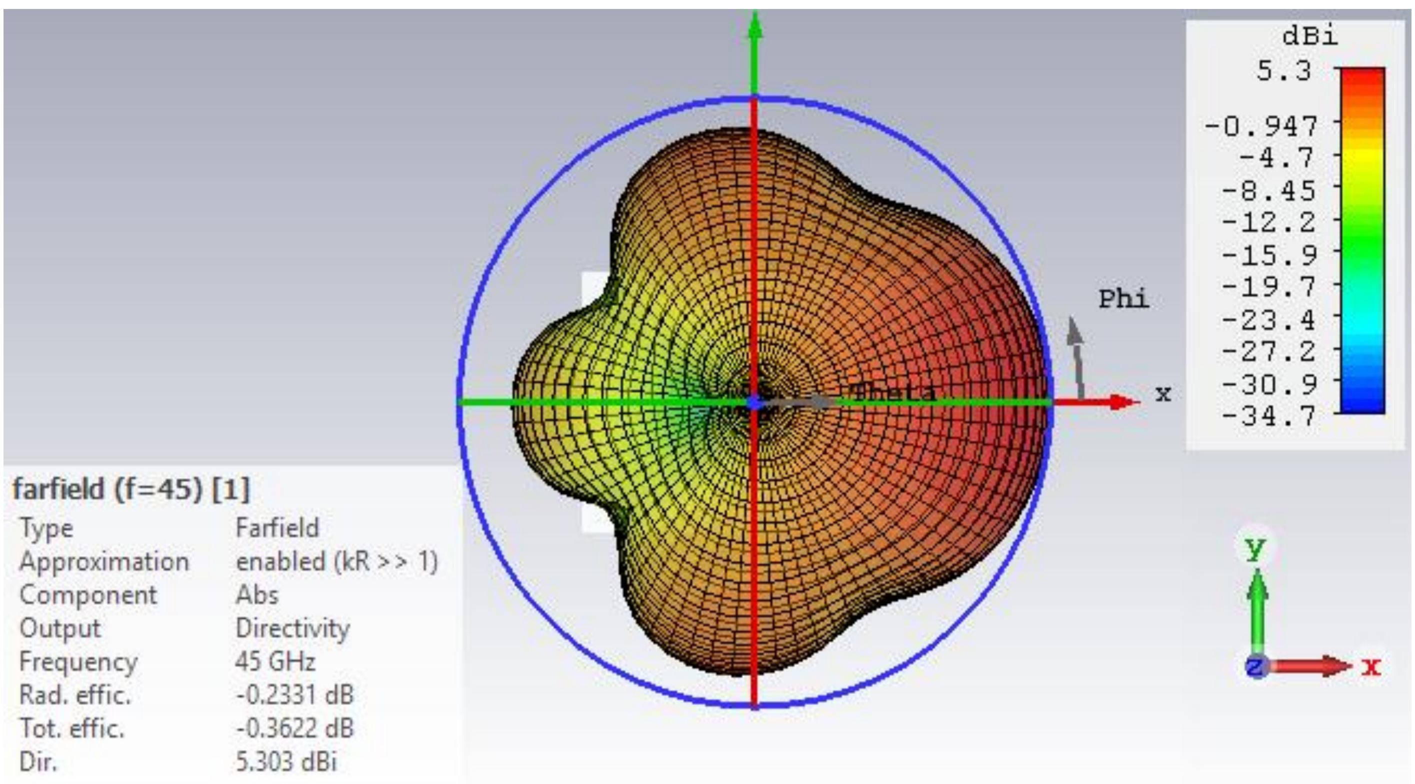


Fig.6: Return loss (S11) and steady state parameters.

Fig.7 shows the far field radiation pattern study at three different frequencies 45, 47, 48.5 GHz. 3-D view. Red color pattern in 3-D view shows the maximum directivity along the x-axis at three different frequencies. The directivity of these main lobes is different for the selected frequencies. It is maximum in case of 48.5 - 50 GHz (5.47 dBi) and minimum in case of 45 GHz (5.30 dBi) along both positive x-axis and negative x-axis. Also Directivity is found to be 5.44 dBi in case of 47 GHz frequency. Additionally it can be observed the radiation pattern is symmetric along the x-axis. The use of this outcome delivers us an extensive flexibility at the time of design of Vivaldi Antenna at Extremely high frequency. These simulated results will play important role in application where need particular directivity along the required direction.



(a)

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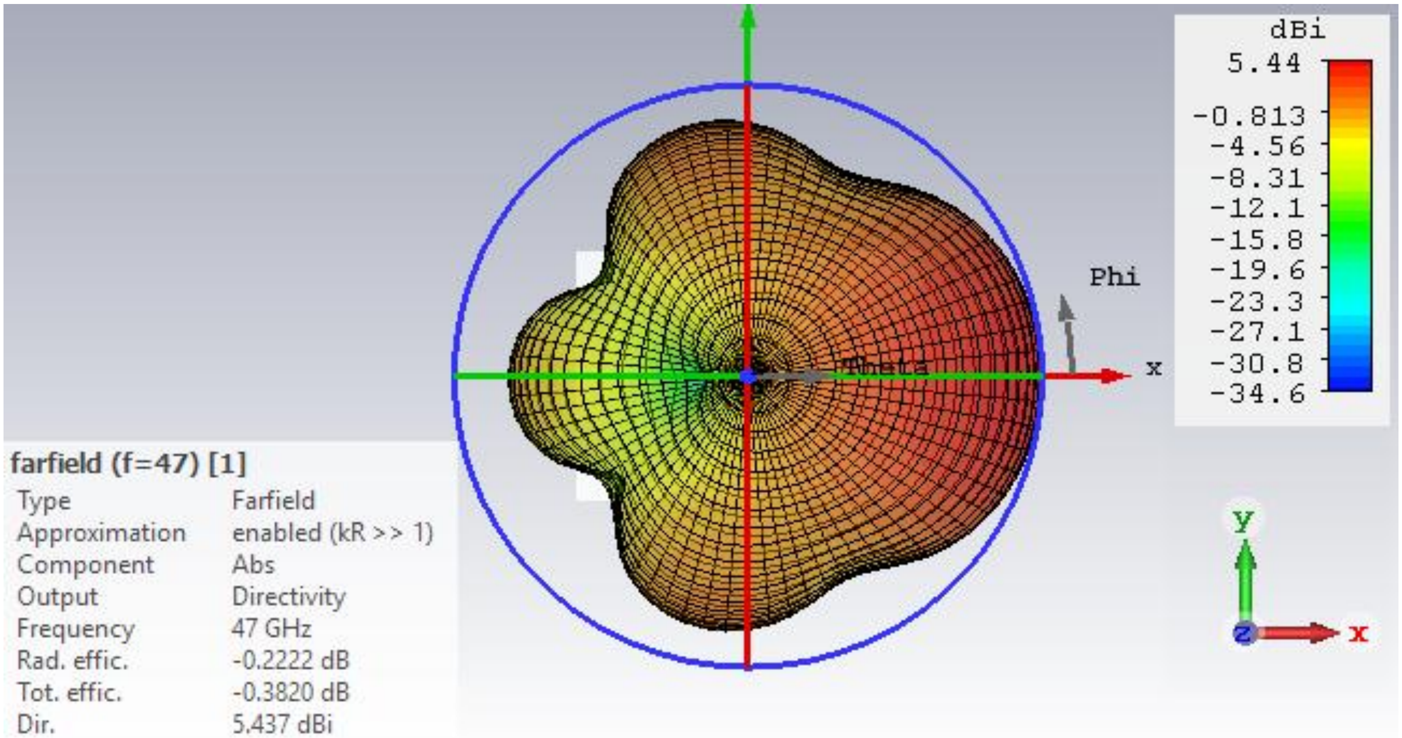
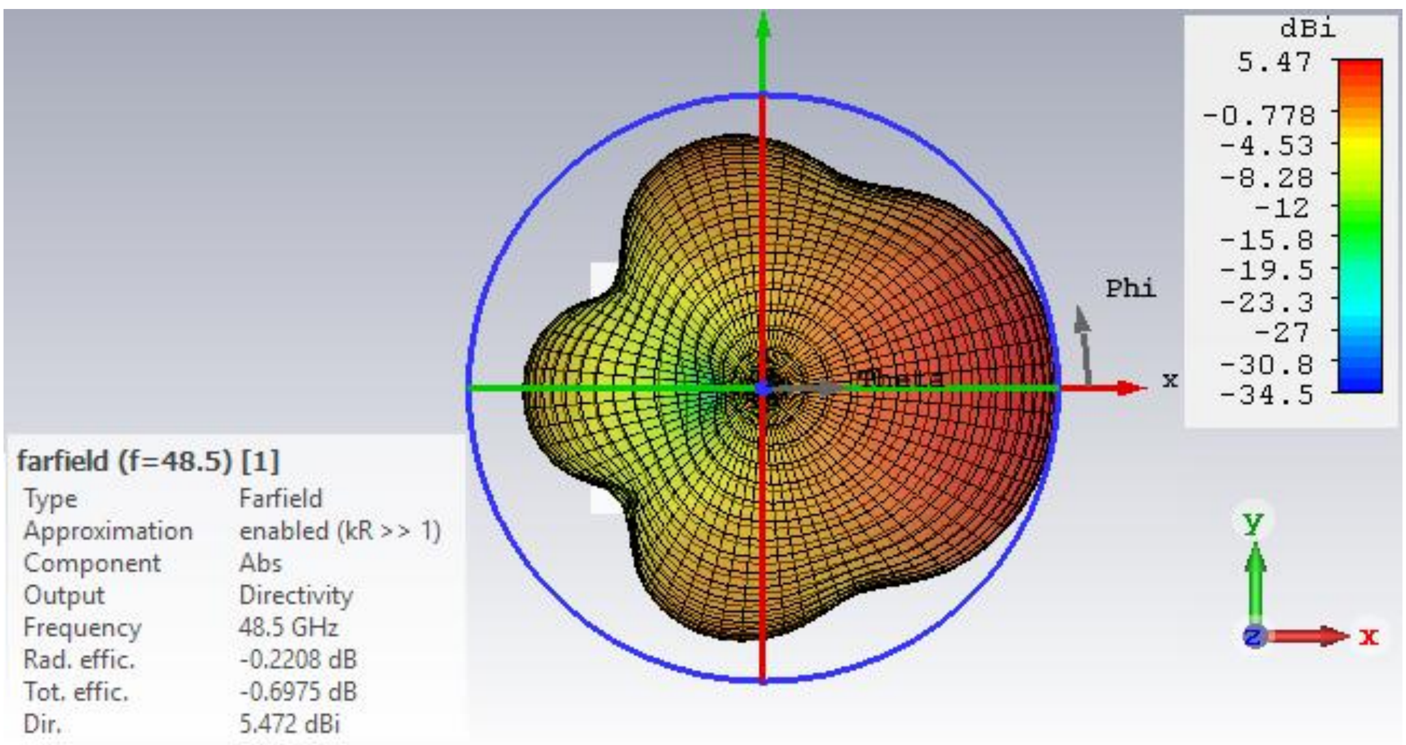


(b)



(c)

Fig.7: Simulated radiation patterns of the Vivaldi antenna. (a) 45 GHz. (b) 47GHz. (c) 48.5GHz.

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Fig.8 shows the realized gain of the proposed Vivaldi Antenna, it is observed that due to the loading of the corrugation on the edges of tapering and grating elements on the slot area, the realized gain of the antenna improved significantly throughout the operating frequency band of 42.2-50 GHz. radiation minimizes in the direction other than the bore sight direction which results in the improved realized gain and directivity of antenna in the bore sight direction. The realized Gain was achieved by three different frequencies at 45, 47, 48.5 GHz. the realized gain is maximum in case of 47 GHz (5.06 dB) and minimum in case of 48.5 GHz (4.77 dB) along both positive x-axis and negative x-axis. Also realized gain is found to be 4.94 dB in case of 45 GHz frequency.

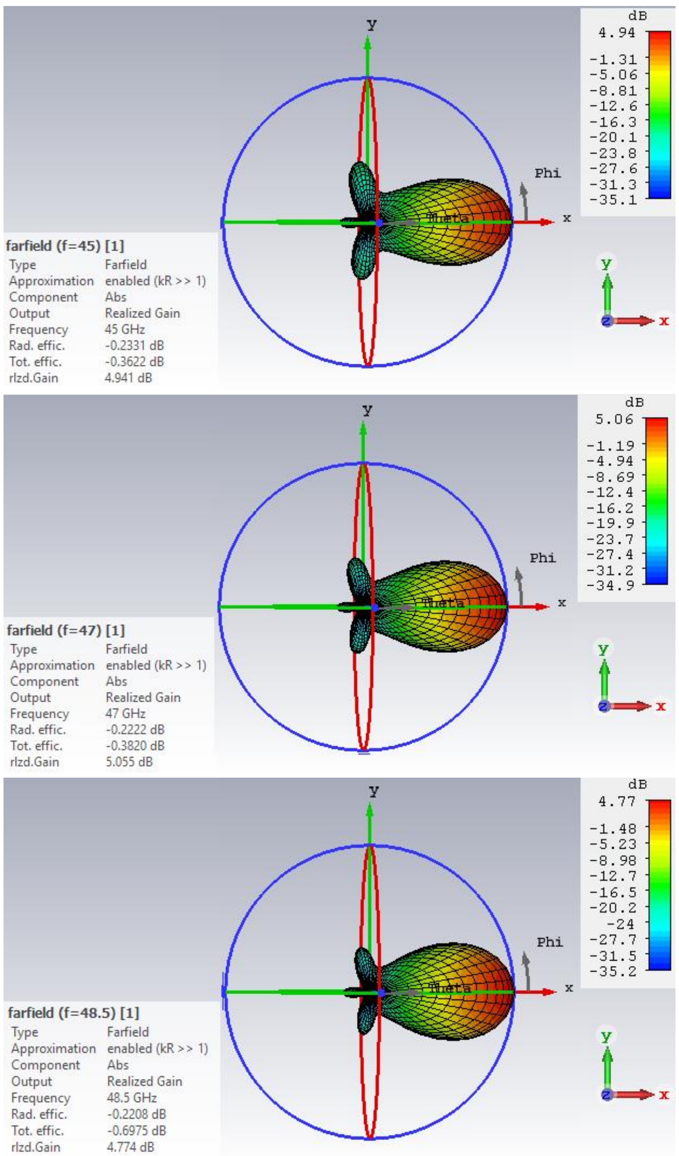

Fig.8: The realized gain for three different frequencies

IV. CONCLUSION

In this paper, a Vivaldi antenna was simulated with at a- Extremely high frequency range from 42.2-50 GHz , so that can define how well is an antenna is impedance matched to the Transmission line it is associated with. Also far field radiation characteristics have been analyzed. The designed Vivaldi antenna has a wide bandwidth, impedance matching and relatively high directivity at the 45 GHz and the realized Gain of 4.9 dB, Additional enhancement are needed to increase the achieved low values of gain by transforming the antenna geometry structure and by means of new type of materials with lesser loss at high frequencies. VSWR and the radiation pattern of the antenna has been plotted to realize the antenna operating principles. The proposed antenna can be used not only in GPR "Imaging and Diagnosis" but also it can be used in various optical applications where need wave's generation at Extremely high frequency.

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