International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET23102137

Design of Microstrip Antenna for Satellite Applications at K-Band

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ARTICLEINFO

Article History:

Accepted: 10 May 2023
Published: 25 May 2023

Publication Issue
Volume 10, Issue 3
May-June-2023

Page Number
331-342

ABSTRACT

The Abstract-Satellite application's five-band microstrip patch antenna is suggested, and it is modelled using the HFSS studio software. The suggested microstrip patch antenna is constructed using templates that are square and rectangular in shape. The most crucial component of virtually every wireless advanced communication system is the microstrip patch antenna, which is crucial in transforming electrical signals into EM wave signals for electromagnetic transmission. This work develops an antenna that can function in the Ku/k/ku bands at frequencies between 10 GHz and 40 GHz. The majority of antennas for satellite applications are designed to have good wide bandwidth, high gain, and small size characteristics. Adjust and perfect the length using a rectangle and square patch of 4.3-4.4 dielectric constant substrate. Resize and improve the field's length; The microstrip patch antenna is made to operate in several frequency bands, including the ku, k, and ka bands.

Keywords : K-BAND, HFSS, RF, MIMO, BEAM WIDTH.

I. INTRODUCTION

Wireless technology is required part of everyone's life today. We cannot imagine technological advancement without them. As we advance in wireless communication, there is a great need for "smart" antenna design and innovation to improve the performance characteristics of wireless technology. Also, by using various antennas with features such as frequency tuning and transmission, there is a price that can meet the needs of different applications for low frequency antennas. James Hall and David M. Pozar, have worked on microstrip patch antennas, some with multiple contributions. The author has been working for many years to develop new models or somehow replace old antennas; increase bandwidth. However, many of these innovations suffer from disadvantages associated with the size, height, or overall volume of products, as well as improved bandwidth, which often suffers from the destruction of other products. The purpose of this article is to present a general technique for developing a narrowband antenna.

Typically, the feed lines and radiating elements are photoetched onto the dielectric substrate. The radiating patch can be shaped whatever you like: square, rectangular, thin strip (dipole), circular, elliptical, triangular, etc. The most popular shapes are square, rectangular, dipole (strip), and circular because to their simplicity in analysis and manufacture as well as their appealing radiation properties, particularly low cross-polarization radiation. Microstrip dipoles are desirable for arrays because they naturally have a wide and small width and take up less space[1].

EM wave generation process. Remember that EM fields are created by electric charges. If the sources are time-varying, EM waves will spread away from them and radiation will be thought to have occurred. You may think of the process of conveying electric energy as radiation. Through the use of antennas, which are conducting or dielectric structures, waves are effectively launched into space. Although theoretically any structure could emit electromagnetic waves, not all structures are effective radiation sources[2].

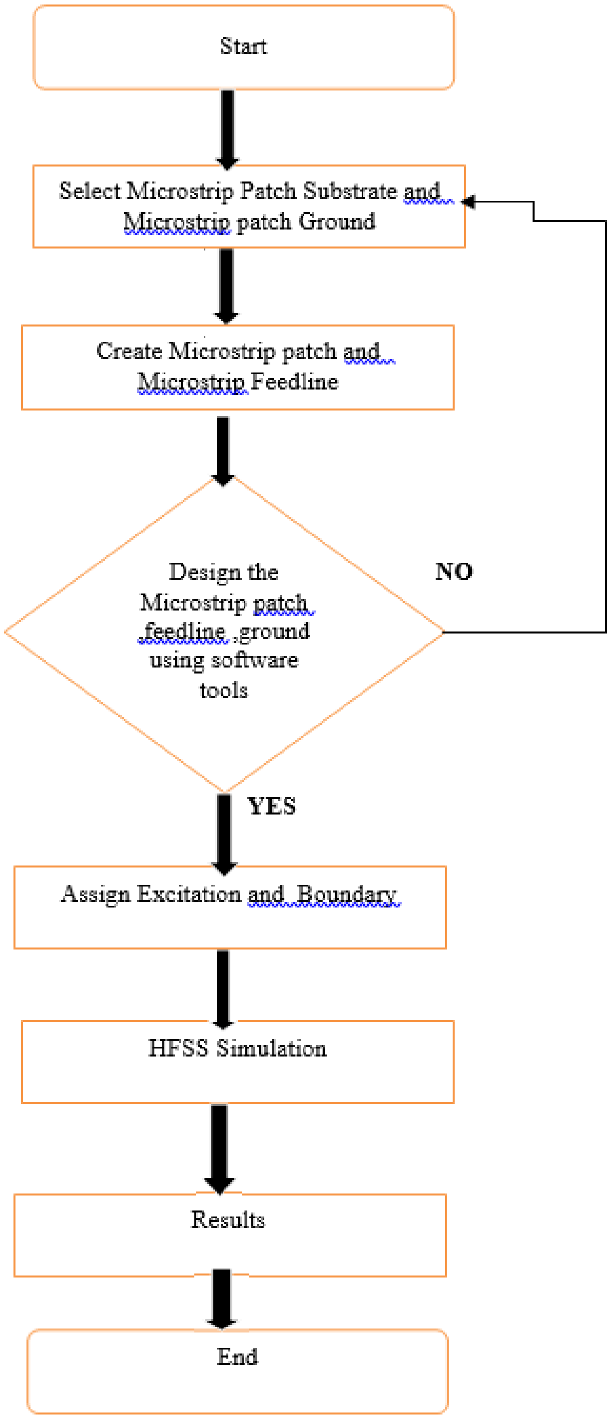
Low-profile antennas may be necessary in high-performance aircraft, spacecraft, satellite, and missile applications where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints. Many other governmental and commercial applications currently have comparable requirements, including wireless communications and mobile radio. These antennas are compatible with MMIC designs, low profile, conformable to planar and nonplanar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, and very versatile in terms of resonant frequency, polarisation, pattern, and impedance when the specific patch shape and mode are chosen. Patch antennas are another name for microstrip antennas that is frequently used[2Both direct and indirect feeding techniques using microstrip antenna technology are possible. In the direct method, connectors like microstrip lines are used to connect radio frequency (RF) power directly through the patch port. Direct contact methods include coaxial probes and microstrip lines. Electromagnetic field coupling is utilised in indirect method materials to transfer energy between microstrip lines and power lines.The width of the feed line plays a significant role in obtaining the lowest return losses in the direct feeding method, where power losses are minimised and signal loss is regulated by line width. Typically, the port impedance for RF is 50ohms.These indirect techniques include proximity and aperture coupling.

The plan has the smallest return loss at five different frequencies, and compared to the current model, the plan's gain is larger and the VSWR can operate at less than 2 dB at five different frequencies, meaning it transmits waves very well.

II. SYSTEM MODEL

A. DRAWING MODEL

After the design is incorporated into the current project, the electromagnetic model can be drawn. The general idea is to create a model as a collection of 3D objects. You can assign an object to any 3D object. You can create 3D objects using drawing templates, draw 1D and 2D objects, and use them to create 3D objects. The object is drawn in the 3D Modeler window. Anyone can bring work from outside machines. Switch to the modeler window associated with a particular design: 1. Select the design you like in the Project Manager window2. Click[solver Name]>3D Model Editor to focus the modeling window on the selected design.



II.ANTENNA DESIGN METHODOLOGY

III. MICROSTRIP PATCH ANTENNA

One of the most crucial uses for microstrip antennas is in satellite systems. Small, inexpensive, and low-profile antennas are necessary for cellular transmission. All of these requirements are met by microstrip patch antennas, and numerous varieties of microstrip antennas have been created for mobile communications. Due to the distance between the earth and the satellite, satellite communication, there must be a balanced electrical structure and can be achieved using a circle or a circle, meaning one or two feeds [12]. Microstrip patch antennas are generally used in narrowband applications. It has a wide beam made by etching a design onto a metal surface of a dielectrically insulating substrate, with a continuous layer of a ground plane made of metal along the strip's side. The shapes of microstrip patch antennas vary, many shapes are square, rectangle, circle, triangle, etc., but can also be irregular shape. Regular shapes are generally chosen for ease of analysis, ease of design, good electrical properties, and low power consumption [13]. The radiation in the microstrip patch Antenna comes from the ground plane and the patch's edge's fringing region.For optimal antenna performance, a thick substrate with a low dielectric constant is ideal since it offers more bandwidth, greater efficiency, and better electricity. However, in this case, the antenna size will increase. Therefore, to reduce the size, it is necessary to use a substrate with a narrow bandwidth and a lower high dielectric constant. Therefore, appropriate trade-offs must be made during the Design procedure to improve antenna performance within the bounds of a fixed operating frequency and body size [14].

A. DESIGN FORMULAS:

Microstrip Lines and Power Lines and Effective Geometry Based on the simple model described, a design process leading to the design of microstrip antennas is described. Based on the previously reported simplified formulation, a design process is detailed that results in workable designs for rectangular microstrip antennas and the height h of the substrate. The quality of electricity is enhanced by breadth [16].

$$w=\frac{u_0}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}}$$

where u_0 is light's speed in free space. is the patch width, the EM wave moving at a speed that is nearly equal to the speed of light in empty space, and the frequency that will be chosen as the microstrip patch antenna's resonant frequency since it has the lowest return losses. The equation's representation of the microstrip patch antenna's physical length can be understood. (1) [16].

$L=L_{effi}-2\Delta L$ (1)

where L_{effi} is the electrical length of the patch antenna, L is the extended length, and L is the physical length of the microstrip patch.[16]

$L_{ele}=C/(2f_r\sqrt{\epsilon_{reff}})$ (3)

,ϵ_{reff} is the positive dielectric constant [16].

$\epsilon_{reff}=(\epsilon_r+1)/2+(\epsilon_r-1)/2\,[1+12\,H/w]^{(-1/2)}$ (4)

where H stands for Height of Substrat.

$\Delta L/h=0.412(\epsilon_{reff}+0.3)(w/h+0.264)/(\epsilon_{reff}-0.258)(w/h+0.8)$ (5)

B. MICRO STRIP ANTENNAS DESIGN METHODS

DESIGN STRUCTURE:

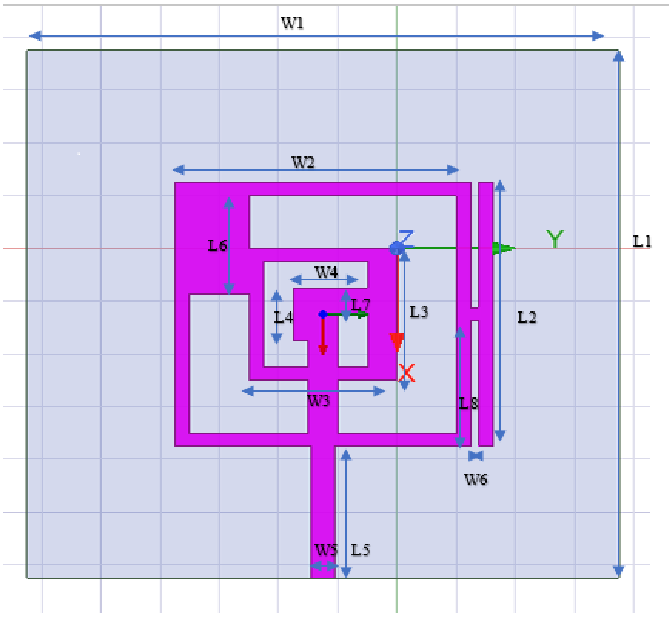


Fig.1-Design structure of microstrip patch antenna

L_5	Feed-linerectangle length	2.90
W_5	Feed-linerectangle width	0.4
W_3	Patch middle rectangle width	2.5

W_4	Patch inner rectanglewidth	2
L_1	Ground and substrate square length	10
L_3	Patch middle rectangle length	2.5
L_4	Patch inner rectangle length	1
L_6	patch outer slot rectanglelength	1.5
L_7	patch inner slotrectangle length	2
L8	Stub slot rectanglelength	2.375
W8	Stub slot rectangle width	0.125

Table -1

he substrate of the microstrip patch antenna has a rectangular shape, measuring 5 mm in length and 5 mm in width. This shape makes the antenna easy to analyse. The microstrip patch antenna handles the majority of the design work.

For the first band of frequencies, an L-shaped microstrip patch antenna slot has been included, the first band frequency range achieved in these range 14.43-14.59GHz ,having resonate frequency in these range is 14.5GHz ,the scattering parameters at resonate frequency is -12.2682dB ,the voltage standing wave ratio is 1.84 .There two different rectangle that can be designed in L-shaped design the first rectangle strip having length of 2.65mm and second rectangle of length of 2.00mm and having the width of the both rectangle slot is 1mm.The both rectangle slot can be merged ,to make it unite the rectangles to get the L-shaped .

The second microstrip patch antenna slot of J-shaped has been added to achieved first band of frequencies, the second band frequency range achieved in these range 16.68-17.14GHz ,having resonate frequency in these range is 16.9GHz ,the scattering parameters at resonate frequency is -14.9270dB ,the voltage standing wave ratio is 1.45. There three different rectangle slots that can be designed in outer J-shaped design the first rectangle strip having length of 2.00mm and second rectangle of length of 4.5mm,the third rectangle of length of 3.5mm and having the width of the three rectangle slot rectangle slot is 1mm. The three rectangle slot can be merged ,to make it unite all the rectangles to get formation of outer J -shaped.

The Third microstrip patch antenna slot of inner J-shaped has been added to achieved first band of frequencies, the third band frequency range achieved in these range 17.23-17.74GHz ,having resonate frequency in these range is 17.5GHz ,the scattering parameters at resonate frequency is -23.2127dB ,the voltage standing wave ratio is 1.44. There three different rectangle slots that can be designed in inner J-shaped design the first rectangle strip having length of 1.5mm and second rectangle of length of 2.25mm,the third rectangle of length of 0.75mm and having the width of the three rectangle slot rectangle slot is 0.5mm. The three rectangle slot can be merged ,to make it unite all the rectangles to get formation of inner J -shaped.

The fourth microstrip patch antenna slot of I-shaped has been added to achieved first band of frequencies, the fourth band frequency range achieved in these range 23.08-25.81GHz ,having resonate frequency in these range is 24.4GHz ,the scattering parameters at resonate frequency is -15.4889dB ,the voltage standing wave ratio is 1.41. There single rectangle that can be designed in I-shaped design the rectangle strip having length of 1mm having the width of the both rectangle slot is 0.5mm.The rectangle slot can be merged ,to make it unite the rectangles to get the I-shaped .

The fifth microstrip patch antenna slot of T-shaped stub for impedance matching has been added to achieved fifth band of frequencies, the first band frequency range achieved in these range 26.67-30.22GHz ,having resonate frequency in these range is 28.0GHz ,the scattering parameters at resonate frequency is -12.2127dB ,the voltage standing wave ratio is 1.64. There two different rectangle that can be designed in T-shaped design the first rectangle strip having length of 0.125mm,the width of the first rectangle slot is 0.125mm and second rectangle of length of 5.00mm and having the width of the second rectangle slot is 0.5mm.The both rectangle slot can be merged ,to make it unite the rectangles to get the I-shaped .

The feed-line with a feed-line width (FW) of 0.5mm and a feed-line length (FL) of 2.5mm is the final component of the microstrip patch antenna design,all rectangle slots of the antenna merged together to form an proper design of the antenna ,which can work for satellite applications in the K-Band.

IV. STIMULATION RESULTS

The scattering parameters of all different bands as given below The first band existing from 14.43-14.59GHz ,with resonate frequency is 14.5GHz,having the s-parameter loss -12.2682dB.the voltage standing wave ration in this frequency is 1.84,the antenna gain 2.55 decibels with respective istropic antenna .The bandwidth of the first band is 0.16GHz. The second band existing from 16.68-17.14GHz ,with resonate frequency is 16.9GHz,having the s-parameter loss -14.9270dB.the voltage standing wave ration in this frequency is 1.45,the antenna gain 2.17 decibels with respective istropic antenna. The bandwidth of the second band is 0.46GHz

The third band existing from 17.23-17.74GHz ,with resonate frequency is 17.5GHz,having the s-parameter loss -23.2127dB.the voltage standing wave ration in this frequency is 1.44,the antenna gain 5.56 decibels with respective istropic antenna designed. The bandwidth of the third band is 0.16GHz The fourth band existing from 23.08-25.81GHz ,with resonate frequency is 24.4GHz,having the s-parameter loss -15.4889dB.the voltage standing wave ration in this frequency is 1.41,the antenna gain -7.85 decibels with respective istropic antenna . The bandwidth of the fourth band is 0.16GHz The fifth band existing from 26.67-30.22GHz ,with resonate frequency is 28.00GHz,having the s-parameter loss -12.2127dB.the voltage standing wave ration in this frequency is 1.64,the antenna gain -5.96 decibels with respective istropic antenna. The bandwidth of the fifth band is 0.16GHz The s-parameters with less than 10dB down the wave can propagate through the space and it can be used for all practical applications ,voltage standing wave ratio with less than 2 will minimum reflections and positive gain indicates the wave can travel through the space without attenuations. The above measured from fig.2,fig.3 and fig.4.

The gain in three dimensional view in fig.5(a) the first band resonance frequency 14.5GHz ,minimum gain is measured in first band is -23.7 decibels with respective to isotropic antenna and maximum gain in the first band of frequency is 3.9 decibels with respective to isotropic antenna. In fig.5(b) the second band resonance frequency 16.9GHz ,minimum gain is measured in second band is -14.8 decibels with respective to isotropic antenna and maximum gain in the second band of frequency is 2.7 decibels with respective to isotropic antenna. In fig.5(c) the third band resonance frequency 17.5GHz ,minimum gain is measured in third band is -19.4 decibels with respective to isotropic antenna and maximum gain in the third band of frequency is 5.9 decibels with respective to isotropic antenna. In fig.5(d) the fourth band resonance frequency 24.4GHz ,minimum gain is measured in fourth band is -26.3 decibels with respective to isotropic antenna and maximum gain in the fourth band of frequency is 3.9 decibels with respective to isotropic antenna. In fig.5(e) the fifth band resonance frequency 28.0GHz ,minimum gain is measured in fifth band is -21.3 decibels with respective to isotropic antenna and maximum gain in the fifth band of frequency is 5.1 decibels with respective to isotropic antenna.

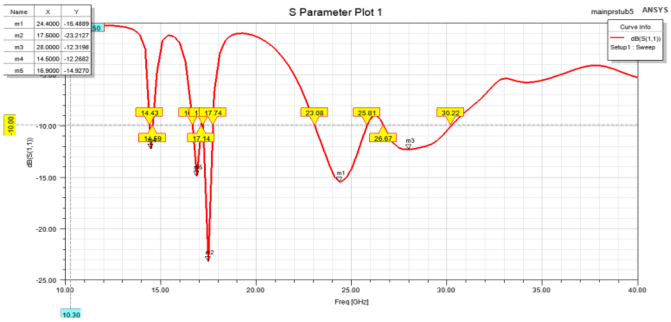


Fig.2. s_(_11) in the Ku, K, and Ka bands

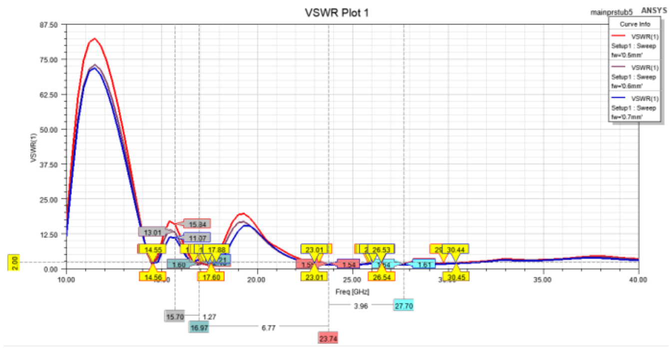


Figure 3. VSWR for the Ku, K, and Ka bands

An antenna gain parameter is crucial. The antenna's positive gain shows that it is acceptable for all real-world applications. Antenna gain is a measurement that takes antenna radiation and directivity into account [23]. Additionally, it is shown as the ratio of the radiation intensity that would be produced if the isotope emitting antenna received energy to the intensity in one direction. The ratio of the radiation intensity of the practical antenna whose directive gain is to be calculated to the radiation intensity of the reference antenna is the definition of directive gain of the antenna at a particular direction. The isotropic radiator is used as the reference antenna. The above definition is valid under the conditions that both antennas are assumed to be radiating same amount of average radiated power.as directivity increases beam width decreases and vice-versa,antenna or antenna system must have high directivity for point-to-point communications.

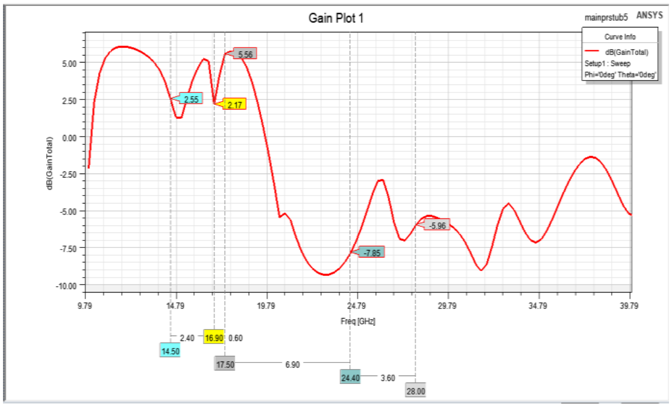


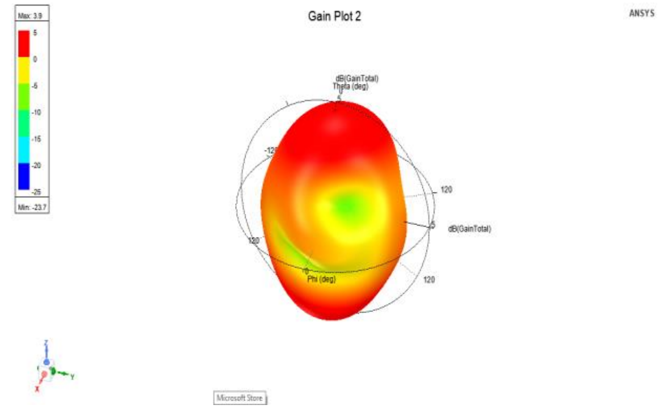
Figure 4 displays the antenna's frequency response.

Fig.4. gain(G) vs frequency(f) ismicrostrip patch antenna one of the important parameters to required for performance measurement if the gain is positive than it good antenna for practical applications ,the positive gain of the microstrip patch antenna tells that it converts the given electrical signal into electromagnetic wave. [24]. Also, good gain is necessary for good wave propagation. The three-dimensional (3D) gain pattern of an electromagnetic wave can be seen below in Figure, depending on how well the antenna is working. 5. (a) represents the 3D gain pattern at 14.5 GHz ,Figure 5. (b) represents at 16.9 GHz, Figure 5.(c) shows 3D gain graph for 17.5 GHz, Figure 5.(d) shows 24.40 GHz and Figure 5.(e) shows 28.00 GHz

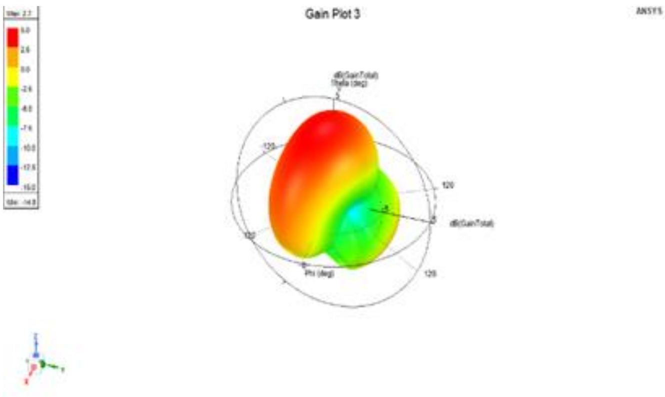
The radiation pattern is dumbly shaped The red color in the three dimensional radiation pattern represents having good gain useful for practical applications ,where as yellow color representing the moderate gain of the three dimensional pattern and lastly the blue colors distribution pattern represents the lower the gain of the antenna this area of the region not used for practical applications.

The designed antenna can works in k-band E-field. The first band frequency 14.5GHz . The antenna's highest gain in the first band is 3.5715, while its minimum gain is -3.5745.and beam width of the antenna n these band is 82.6761degrees.

The second band frequency 16.9GHz The antenna's greatest gain in the second band is 2.1743 while its minimum gain is -9.4428. and beam width of the antenna these band is 64.1886degrees.



(a)



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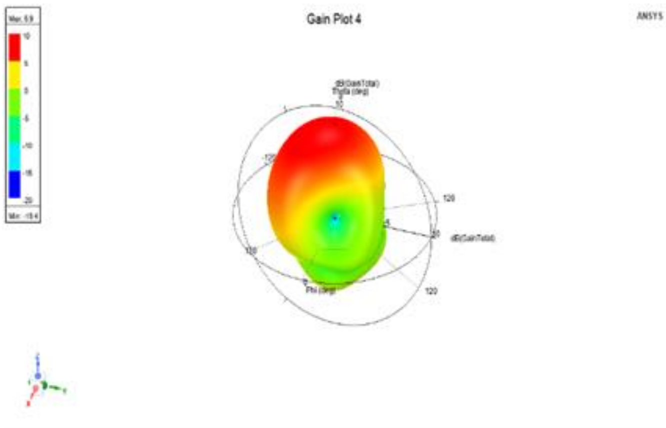

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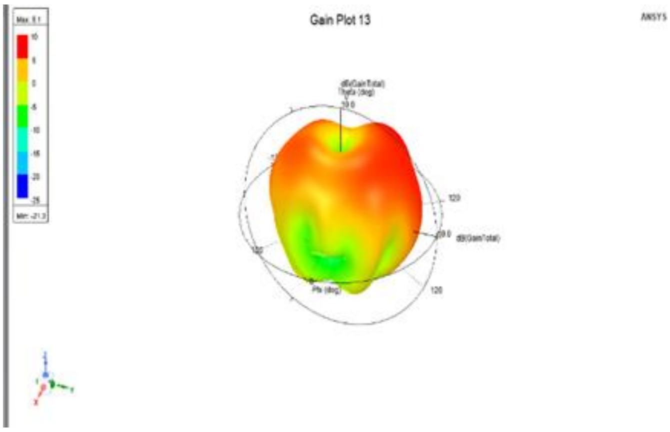

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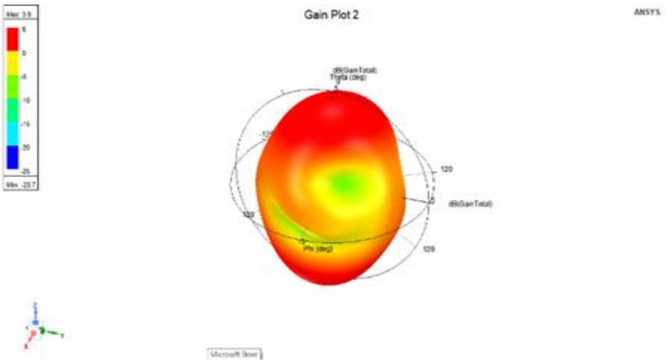
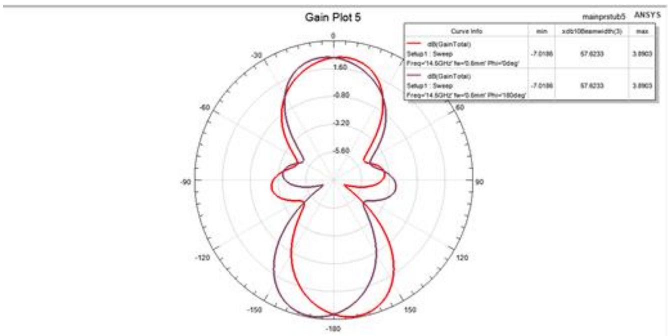
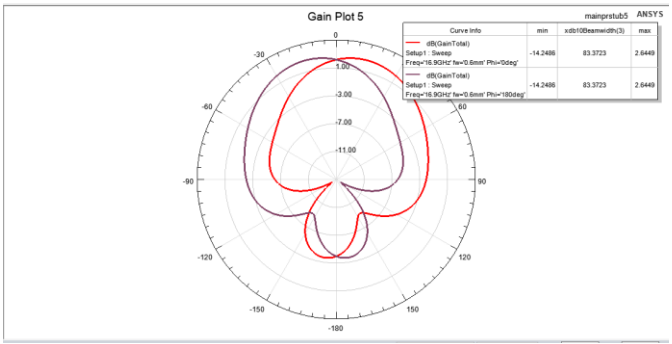


(e)

Figure 5. shows (a) 3D gain graph at 14.5 GHz, (b) 3D gain graph at 16.9 GHz and (c) 17.5 GHz means (d) it's at 24.40 GHz, (e) it's at 28.00 GHz



(a)



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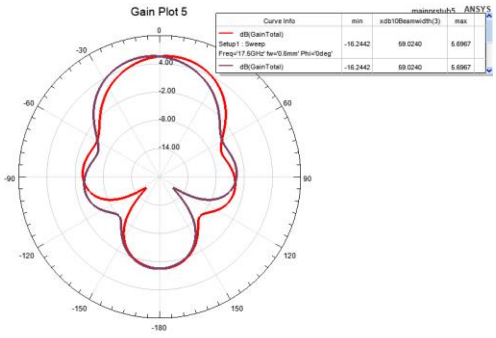

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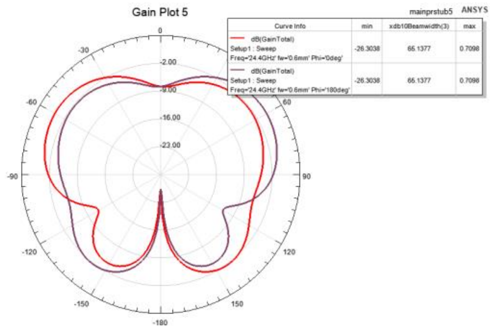

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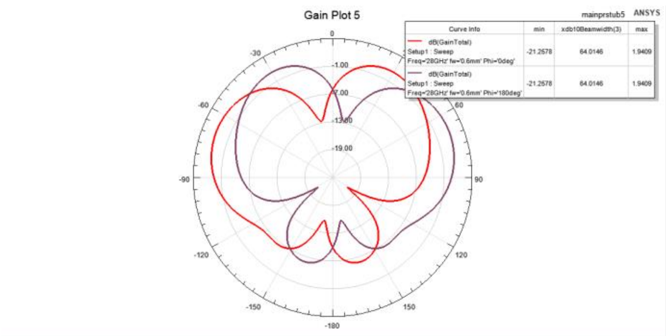


(e)

Figuring 6. magnetic field at 16.9 GHz (a) electric field at 14.5 GHz (b) ,(C) magnetic fields at 17.5 GHz (d). 24.40 GHz of magnetic field (e). 28.00 GHz of magnetic field

The third band frequency 17.5GHz the antenna has a -5.1096 minimum gain and a 5.6853 maximum gain in the third band.and beam width of the antenna these band is 74.1126degrees.

The fourth band frequency 24.4GHz The antenna's highest gain in the fourth band is 1.7758, while its minimum gain is -26.3038. and beam width of the antenna these band is 128.4716degrees.

The fifth band frequency 28.0GHz The antenna's minimum gain is -9.9989, while its highest gain in the fifth band is 3.9168.and beam width of the antenna these band is 77.8282degrees.

The designed antenna can works in k-band H-field. The first band frequency 14.5GHz The antenna's highest gain in the first band is 3.8903, while its minimum gain is -7.0186. and beam width of the antenna n these band is 57.6233degrees.

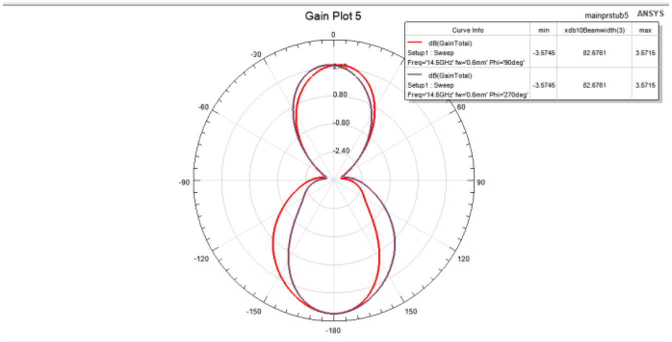
The second band frequency 16.9GHz The antenna's highest gain in the second band is 2.6449, while its minimum gain is -14.2486. and beam width of the antenna these band is 83.3723degrees.

The third band frequency 17.5GHz The antenna's minimum gain is -16.2442, while its highest gain in the third band is 5.6967.and beam width of the antenna these band is 59.0240degrees.

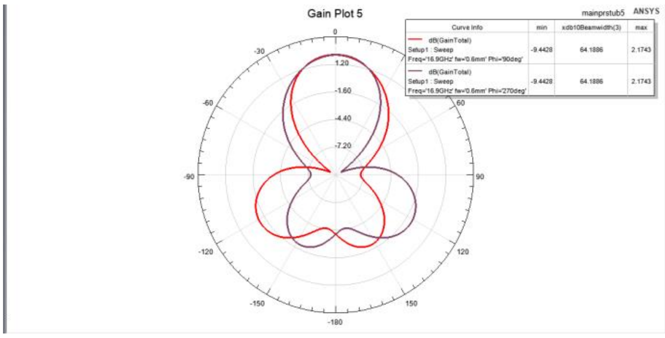
The fourth band frequency 24.4GHz The antenna's maximum gain in the fourth band is 0.7098, while its minimum gain is -26.3038. and beam width of the antenna these band is 65.1377degrees.

The fifth band frequency 28.0GHz The antenna's minimum gain is -21.2578, and its highest gain in the fifth band is 1.9409.and beam width of the antenna these band is 64.0146degrees.

The electromagnetic field of the antenna looks at the directional energy emitted by the antenna. he antenna's design structure may be shown in two dimensions (2D) or three dimensions (3D) [26]. A component of the 3D model may be the 2D model.A common method is used to determine antenna power. The electric field (E-Field) and magnetic field (H-Field) can be observed from vertical polarisation or horizontally along the E plane with = 90 degrees for the yz plane, assuming the microstrip patch antenna is constructed from the xy plane. The polarization direction along H-plane is ∅ = 0^0 for the xzplane. The Ku, k, and Ka bands' H-fields are depicted in Figure 6. while Figure 7 shows the radiation for the five bands..



(a)



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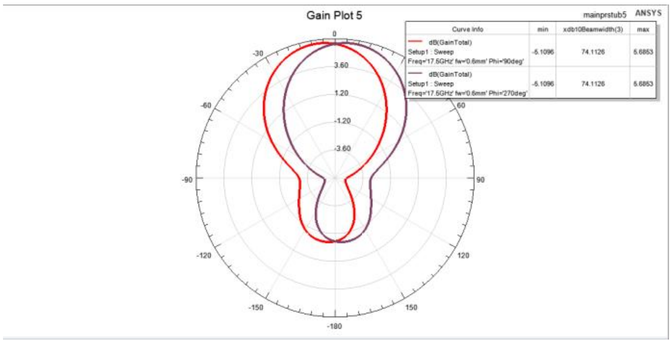

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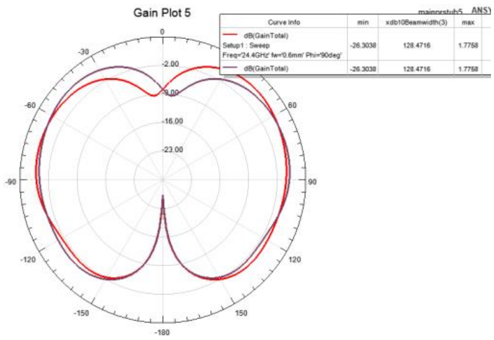

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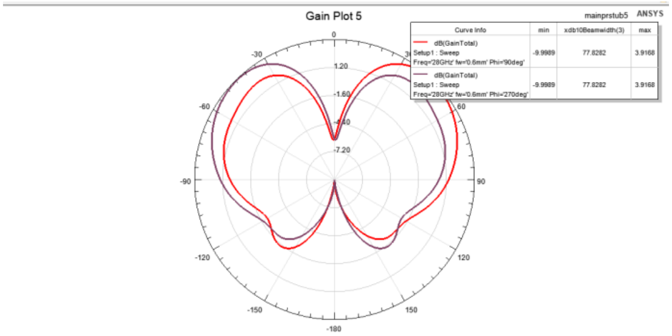

(e)

Figure 6.Electric fields at 14.5 GHz, 16.9 GHz, and 17.5 GHz, respectively, are shown in (a), (b), and (c). (d). Electric field (e) at 24.40 GHz. Electric field at 28.00 GHz

Electric and magnetic field components can describe the evaluation of linear polarization antennas. The first has the electric field vector and the direction of the maximum electric current, while the second has the magnetic field vector and the direction of the maximum electric current [27]. shows the polar coordinates of the antenna pattern and may indicate that there is an order of five frequencies. The beam width in the electric field is 82.6761 degrees for Ku band and 128.4716 degrees for k band and 47.16.4716 degrees compared to 64.,4716 degrees for the Ka band. In addition, the beam width in the H-plane domain is 83.3723 degrees for Ku-band, 65.1377 degrees for K-band and 59.0240 degrees for Ka-band and 83.3723 degrees.8282 do it. The radiation pattern of two dimensional plane in polar plot is when the antenna gain at different frequencies is measured using software tool ,the measured E-field gain of lobe in terms their magnitudes is given respective frequencies are 14.5, 16.9, 17.5, 24.4 and 28.0GHz, the gain of main lobe given below 3.5715,2.1743,5.6853,1.7758 and 3.9168 decibels with respective to the isotropic antenna, respectively.

The radiation pattern of two dimensional plane in polar plot is the antenna gain at different frequencies is measured using software tool ,the measured H-field gain of lobe in terms their magnitudes is given respective frequencies 14.5, 16.9, 17.5, 24.40 and 28.00GHz, and the gain of main lobe given below 3.8903,2.6449,5.6967,0.7098and 1.9409 decibels with respective to the isotropic antenna respectively.

V. CONCLUSION AND FUTURE SCOPE

The five-band microstrip patch antenna of square shape ,the first slot of rectangle strip has been added to achieve the required or desired band of frequencies. The first slot dimensions having width of 1mm,length1 of 2.65mm,length2 of 2.00mm.the second rectangle slot added to the patch to achieve next band of frequencies ,the dimensions are width of 1mm,length1 is 2.00mm,length2 is 4.5mm, and length is 3.5mm and need to change global axis.

The third rectangle slot added for patch to achieve the next band of frequencies ,further more to get low voltage standing wave ratio, more gain ,the dimensions of rectangular slot of width is 1mm,length1 is 1.5mm,length2 is 2.25mm,length3 is 0.75mm.the fourth slot was added to get further band of frequencies and to have good return losses. The dimensions are width is 0.5mm and length is 1mm.

The feed-line is added to connect to external port of the antenna ,the feed-line is major role power matching to the source to achieve mismatch between source and the patch ,in order to achieve minimum losses of s11 ,have to be proper dimensions ,the feed-line width [FW] is 0.6mm and length of the feed–line is 2.5mm,at a height of 1mm. a ground is connected to the patch of size ,having dimensions of width is 10mm and length of 10mm

The feed-line width should be maintained to achieve return losses and play major role for obtaining required band of frequencies .the total antenna size of width 10mmm and length of 10mm and it uses FR4 material or fabrication, the proposed antenna achieved with minimum return losses ,low value of voltage standing wave ratio ,the gain what have got positive which is suitable for all practical applications and having good radiation pattern. The antenna successfully stimulated using HFSS software it can operated k band since it has very good positive gain and low S-parameter losses and for broadcast communications ,antenna or antenna system must have low directivity .

The microstrip patch antenna can operate at 14.5 GHz in the Ku band, 16.9 GHz in the Ku band, and 17.50 GHz in the Ka band. An acceptable return loss of the antenna of -23.2127 dB for the 17.5 GHz Ku band, with a wide Ku band of 0.6 GHz (17.14 GHz to 17.14 GHz). shows its width 0.51 GHz, the overall gain is 5.9 dBi and the VSWR is similarly 1.44 dB. Also, the K band at 24.4 GHz has a s-parameters loss of -15.4889 with bandwidth of 2.73 GHz (23.08 GHz to 25.81 GHz) K bandwidth, and VSWR match 1.41 decibels with respective to the measure .of isotropic antenna. The antenna having different band of frequencies has the s-parameter values of port one-one at 28.00GHz is -12.3198 decibels in the range of (26.67 to 30.222)GHz ,having bandwidth of 3.55GHz, next band has the s-parameter values of port one-one at 14.5GHz is -12.2682 decibels in the range of frequencies (14.43 to 14.59)GHz ,having bandwidth of 0.16GHz.since the wave propagation needs to be increased, the 3D gain model for Ku-band shows a positive value of 5.9 dBi, a positive value of Ka-band gain of 5.1 dBi and a k-band gain of 3.1dBi. The Ku-band of E-Field is 82.6761 degrees, the k-band is 128.4716 degrees, and the Ka-band is 77.8282 degrees. The Ku-band of H-Field is 83.3723degrees, the k-band is 65.1377 degrees, and the Ka-band is 64.0146 degrees.

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Cite This Article :

V. Nagaraja, Dr. B Anuradha, " Design of Microstrip Antenna for Satellite Applications at K-Band, International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Print ISSN : 2395-1990, Online ISSN : 2394-4099, Volume 10, Issue 3, pp.331-342, May-June-2023. Available at doi :

https://doi.org/10.32628/IJSRSET23102137

Journal URL :

https://ijsrset.com/IJSRSET23102137