Design Of Broadband Microstrip Circular Patch Antenna Loaded With Mushroom-Type Arrays

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ABSTRACT:

With the development of 5G communication, the wideband and high-gain antennas are in great demand. However, the conventional microstrip antenna suffers from the drawback of narrow bandwidth, which restricts its applications in wireless communication. This project presents a broadband microstrip circular patch antenna with a simple geometry. Two mushroom-type arrays are placed along with the two radiating edges of a main radiating circular patch. The antenna is constructed on a RT/Rogers 5880 substrate and co-axial feeding technique is employed. The current distributions on the patches are uniform so that high gain is achieved over the entire operating bandwidth. The proposed antenna is validated and analysed using ANSYS HFSS software. The simulated results shows that the antenna operates at 12.38 GHz to 16.82 GHz bandwidth below|S11| -10 dB with less return loss and a peak gain of around 9.48 dB is achieved. Hence the proposed antenna has a wider bandwidth of 4.44 GHz in Ku-band frequency range and so, can be used in Ku-band frequency applications. Also, the proposed antenna is easy to fabricate and it is a low-profile antenna.
Keywords - Broadband, Microstrip Patch Antenna, Mushroom-type Arrays.

INTRODUCTION

An antenna is defined as a metallic device which radiates or receives electromagnetic waves. It can be used in variety of applications such as radio broadcasting, broadcast television, two-way radio, communication receivers, radar, cell phones, satellite communications etc. There are different types of antennas such as wire antennas, aperture antennas, reflector antennas, lens antennas, microstrip antennas, array antennas etc. Microstrip antennas are low-profile antennas. It consists of a very thin metallic strip (patch) placed on a ground plane with a substrate material in-between. Thefeed lines are placed on the substrate by the process of photo-etching. The patch or micro-strip is often chosen to be square, circular or rectangular in shape for the ease of analysis andfabrication.The advantage of microstrip patch antenna are light weight, low cost and ease of installation and can be used in space craft, air craft and low-profile applications above 100 MHz. However, it suffers from a major disadvantage like inefficient radiation and narrow bandwidth.

With the development of 5G communication, the wideband and high-gain antennas are in great demand. However, the conventional microstrip antenna suffers from the drawback of narrow bandwidth, which restricts its applications in wireless communication. A variety of methods were employed to broaden bandwidth of microstrip patch antennas, such as cutting slots inside the patch [1], applying parasitic strips around the patch [2], using hybrid-coupling method [3], and stacking patches on multi layered substrate [4].The aforementioned methods are effective for broadening the bandwidth of microstrip patch antennas, but they bring out new challenges in other aspects, such as size reduction, gain improvement, planar structure, and good radiation performances.

As one of the representative metamaterials, mushroom structures are widely applied in the design of broadband antennas. One of the basic applications of mushroom structure is mushroom antennas. A low-profile broadband mushroom antenna was presented in [5], and an impedance bandwidth of 25% was obtained because of dual resonance modes that were excited simultaneously. Loading mushroom-like rectangular patches on the top of a planar slot antenna, a dual-band antenna was achieved for wireless local area network applications [6]. However, most of the aforementioned antennas are constructed on multi layered substrate.On

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the basis of our previous work, mushroom-type arrays are loaded along with the two radiating edges of a circular patch on the same substrate, resulting in broad bandwidth.

EXISTING METHOD

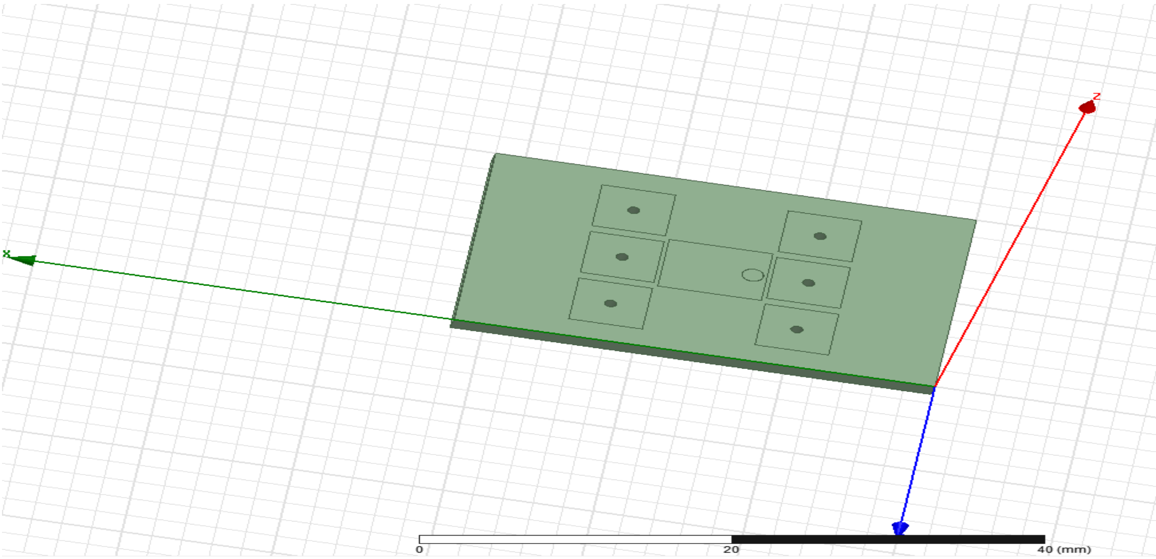

Figure 1 Existing antenna design

The geometrical configuration of the existing mushroomloaded patch antenna is described in Figure 1, which comprises three parts: a main radiating rectangular patch, two parasitic mushroomtype arrays symmetrically placed along with the two radiating edges of the main radiating patch, and a ground plane with size of 32mm x20mm. The main radiating patch occupies an area of 6.9mm x 5.6mm. As for the mushroom-type structure, an array includes three mushroom units, and all of the mushroom units are identical in size. One mushroom unit is composed of a square patch with periodicity 5.6mm and a center-placed metallized via with diameter 0.8mm. The gap between mushroom units is 0.7mm, and the coupling gap between the main radiating patch and mushroom-type structure is 0.3mm. This antenna is constructed on a RT/Rogers 5880 substrate with thickness of 1.524 mm, and coaxial feeding method is employed.

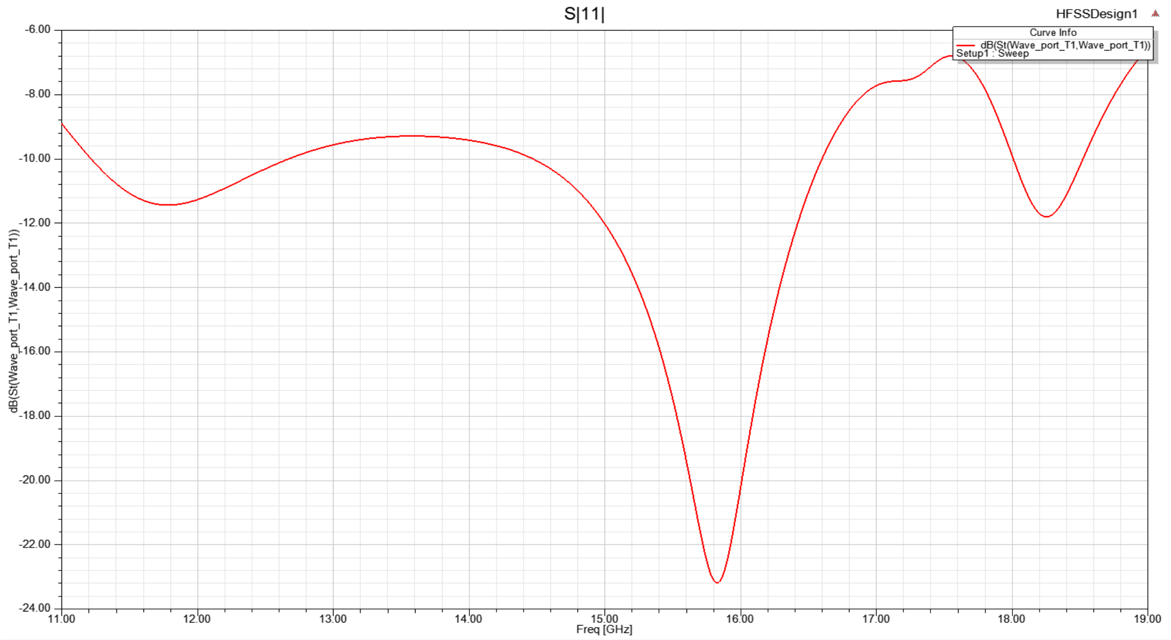

Figure 2 Simulated |S11| of the existing antenna design

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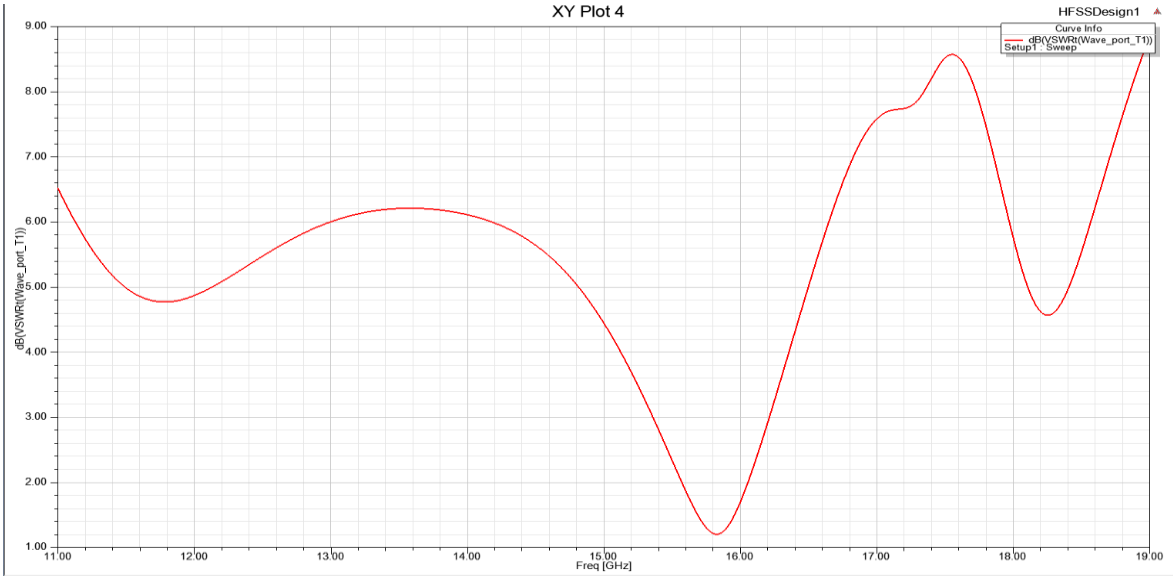

Figure 3 Simulated |S11| VSWR of the existing design

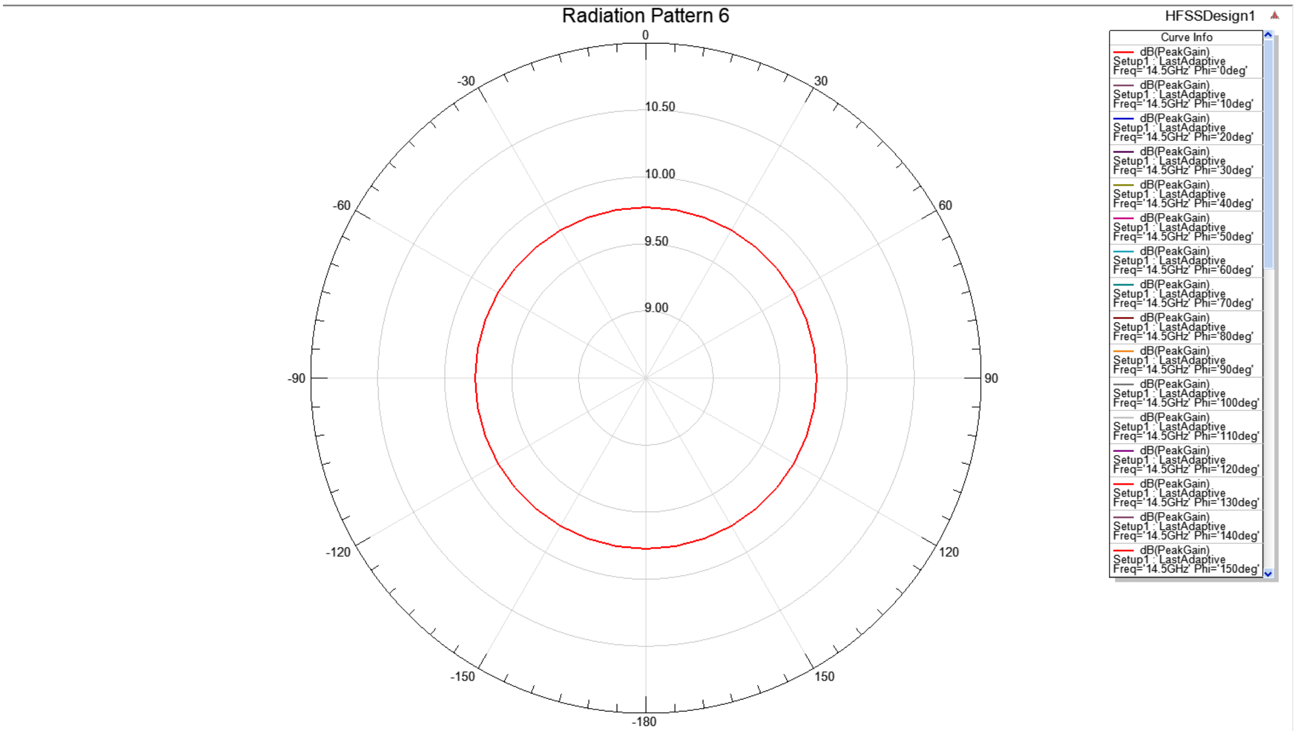

Figure 4 Simulated gain of the existing design

From Figure 2, Figure 3 and Figure 4, the antenna operates from 14.48 GHz to 16.6 GHz at |S11|-10 dB. Hence the impedance bandwidth below |S11| -10 dB is 2.12 GHz and fractional bandwidth is 13%. Also, the reflection coefficient is -23.17 dB, VSWR is 1.09 dB and Return loss is -27.29 dB.

Thus, the existing microstrip patch antenna design suffers from the disadvantage of narrow bandwidth below |S11| -10 dB with high reflection coefficient, high VSWR and high return loss.

PROPOSED METHOD

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On basis of the previous method, instead of a rectangular patch antenna, a circular patch antenna is used in order to increase the bandwidth of the antenna below |S11| -10 dB and to reduce the reflection coefficient, VSWR and return loss of the antenna.

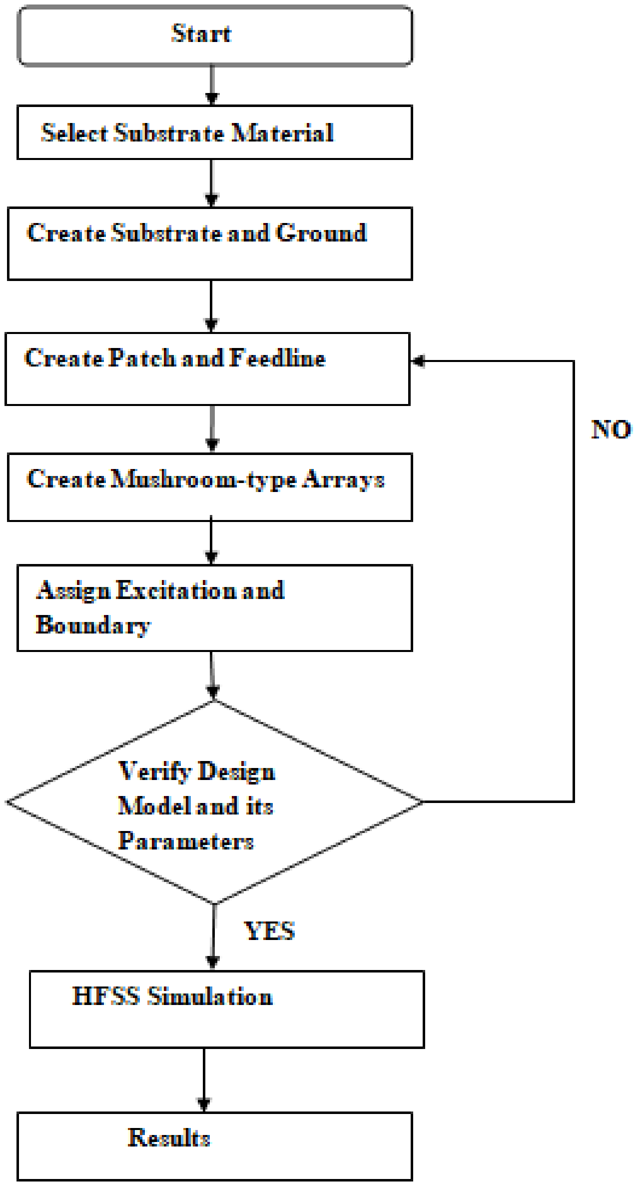

Figure 5 Flow chart for the proposed antenna design

The above Figure 5 shows the flowchart for the proposed antenna design. Here the substrate material is chosen to be RT/Rogers 5880. The patch used is a circular patch and co-axial feeding technique is employed. Initially the substrate material is selected. Then ground plane and substrate are drawn. After that patch is drawn along with the feedline. Then mushroom- arrays are drawn. Then boundries are assigned and excited over E- plane. Then the design is saved, verified and validated. If the validation is complete, the simulation is processed and results are obtained.

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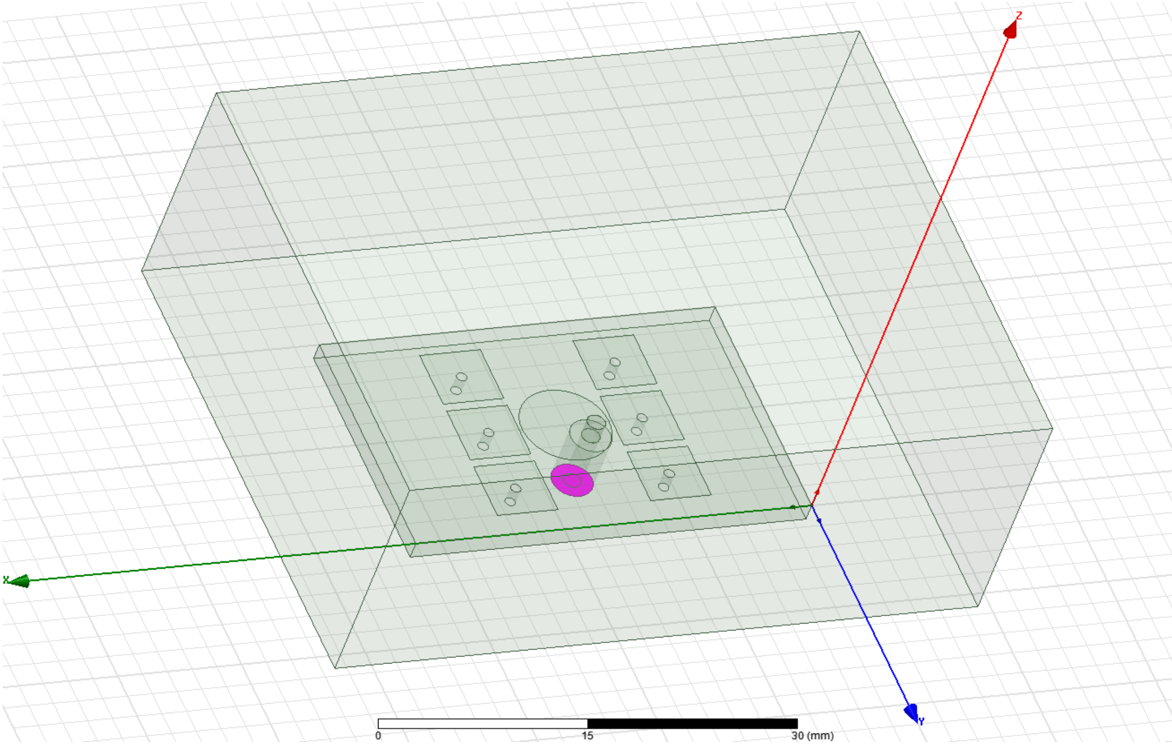

Figure 6 Proposed antenna design (entire structure)

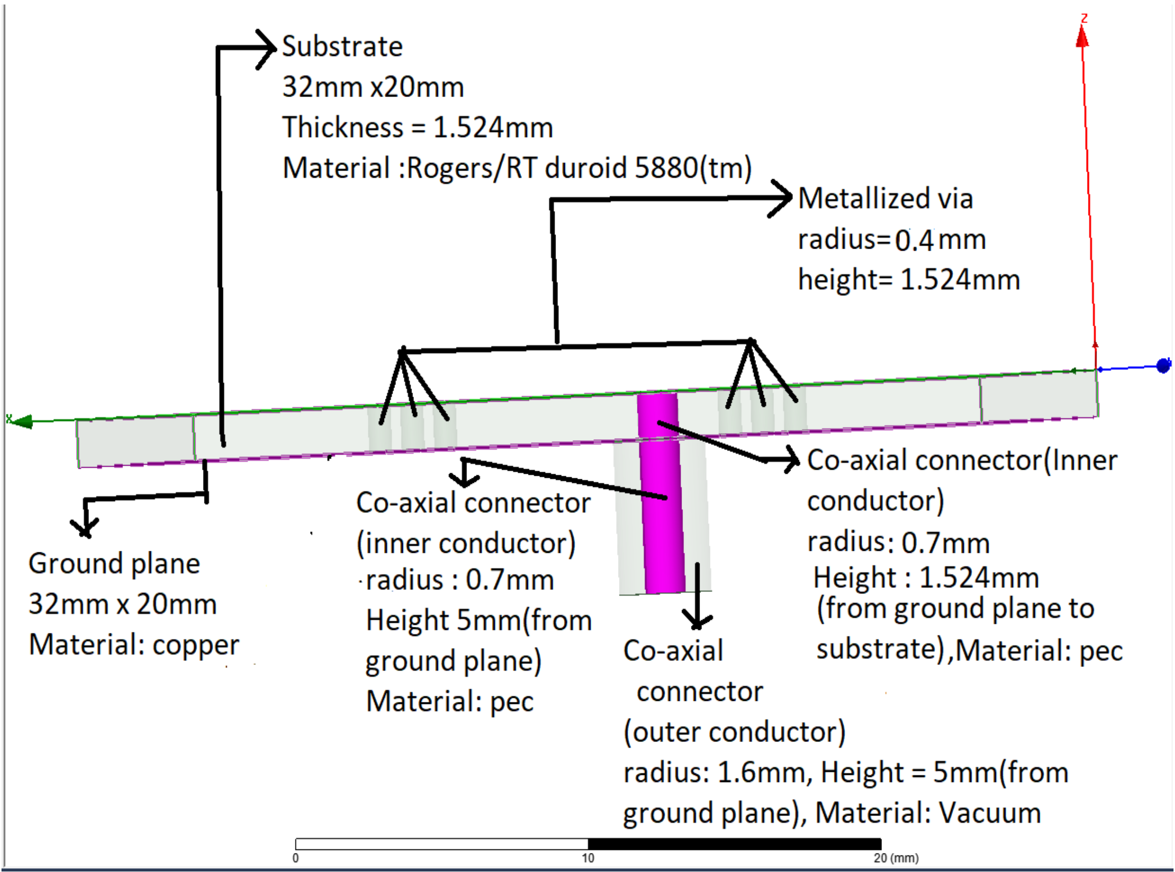

Figure 7 Proposed antenna design (Side view)

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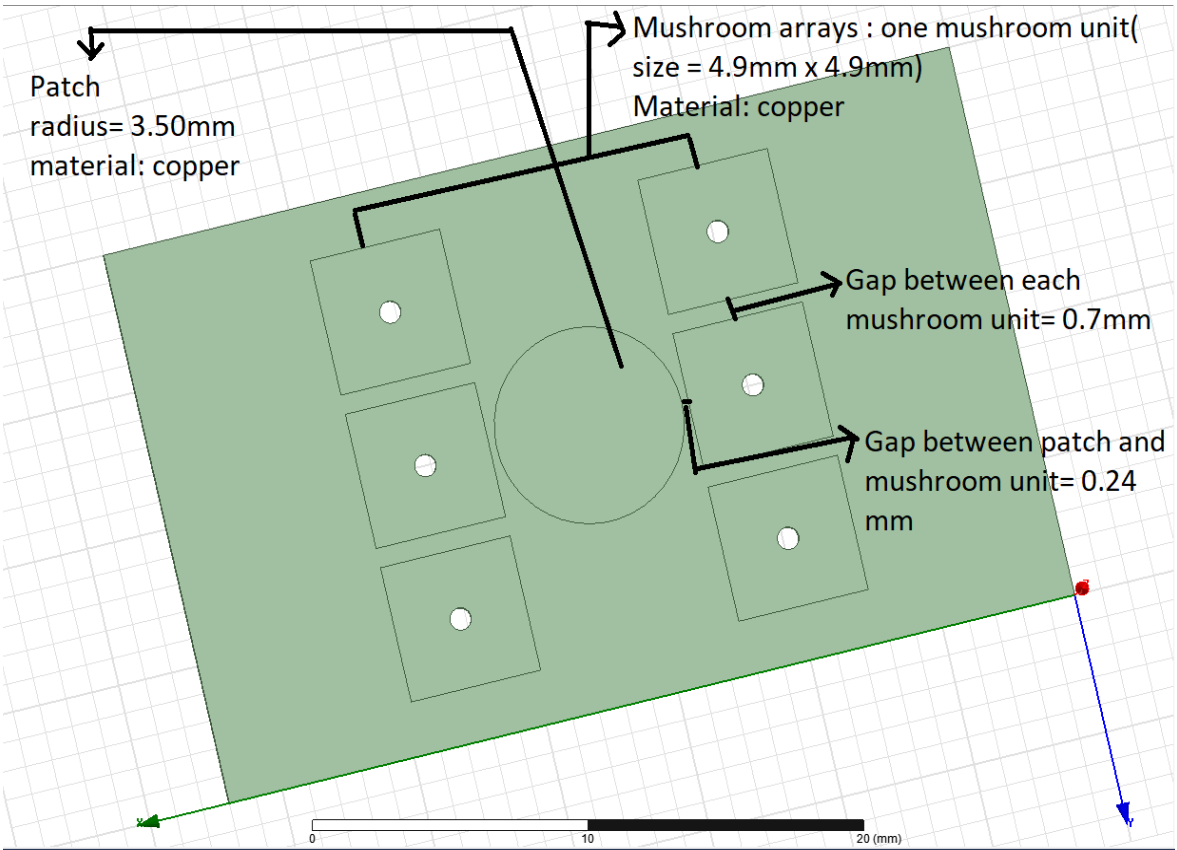

Figure8Proposed antenna design (Top view)

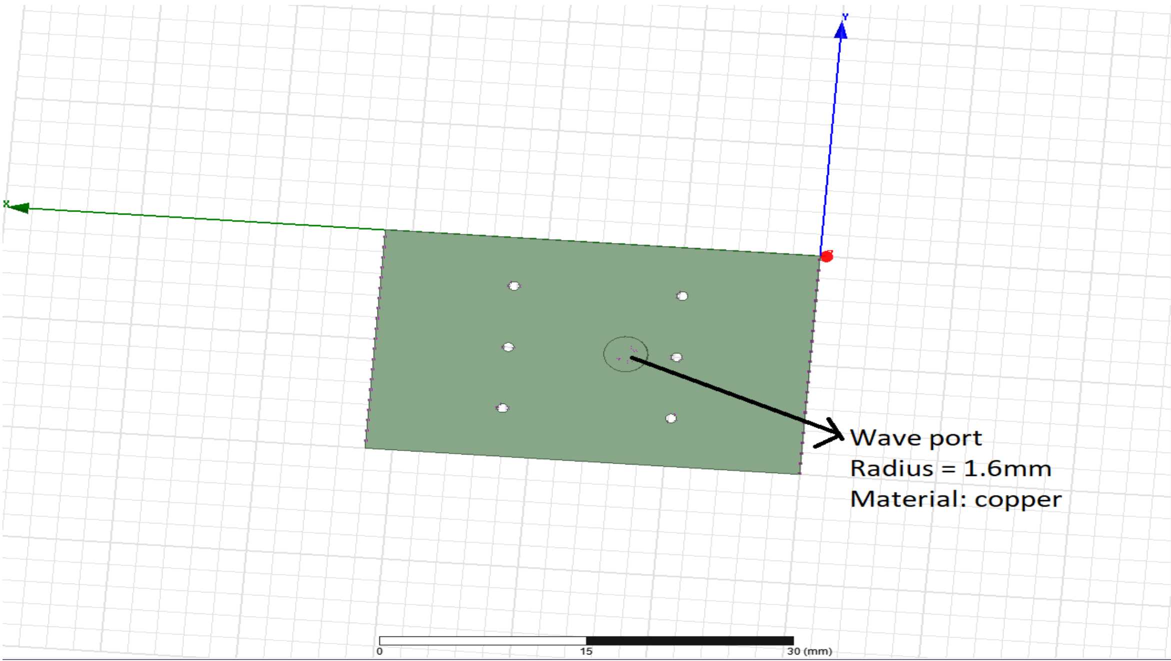

Figure 9Proposed antenna design (bottom view)

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PARAMETER	DIMENSIONS
Ground plane	32mm x 20mm
Main radiating circular patch	Radius = 3.50 mm
Mushroom-type arrays (each mushroom unit)	4.9mm x 4.9mm
Substrate	32mm x 20mm with 1.524mm thickness
Radiation box	40mm x 20 mm with 20 mm thickness
Metallized via	Radius = 0.4mm
Co-axial connector (inner conductor)	Radius = 0.7mm
Co-axial connector (outer conductor)	Radius = 1.6mm

Table 1 Dimension Table of the proposed antenna

The above Figure 6,7,8 and 9 respectively shows the proposed antenna design and Table 1 shows the dimension of the proposed antenna.Initially a ground planewith size of 32mm x20mm is created.The main radiating circular patchwith radius of 3.50mm is drawn. As for the mushroom-type structure, an array includes three mushroom units, and all of the mushroom units are identical in size. Hence each mushroom unitwith periodicity 4.9 mm and a center-placed metallized via respectivelyis drawn. The center placed metallized via consists of an upper circle, cylinder with substrate height and a bottom circle with 0.8mm diameter respectively. Note that the gap between mushroom units is 0.7mm, and the coupling gap between the main radiating patch and mushroom-type structure is 0.6mm.This antenna is constructed on a substrate material RT/Rogers 5880with thickness of 1.524 mm. Co-axial feed is drawnin the main radiating patch where the inner conductor of the coaxial connector extends through the substrate and is soldered to the radiating patch, while the outer conductor is connected to the ground plane. Note that the material used for the inner conductor is pec and the radius of the inner conductor is 0.7mm, while the radius of the outer conductor is 1.6 mm. All the mushroom units with their upper circle of the metalized via are subtracted respectively and the ground plane is subtracted with the all the bottom circles of the metallized via. Same way all the cylinders of the metallized via are subtracted with the substrate. Boundries are assignedfor the main radiating patch, mushroom arrays and ground plane respectively over perfect E- plane. Port is drawn at the bottom of the outer conductor of the coaxial feed and the excitation is assigned through the wave port so that it is distributed to the mushroom arrays through the metallized via.Radiation boxis drawn with area of 40mm x 20mm and boundry for all faces is assigned over radiation.Solution frequency of 14.5 GHz is setup and frequency sweep from 11 GHz to 19 GHz.The design is validated and analysedand the simulated results are obtained using ANSYS HFSS software.

RESULTS AND DISCUSSION

BANDWIDTH

FORMULA

BW= fH-fL

FBW= (fH-fL)/fC

where, BW= Bandwidth, fH= higher cut-off frequency, fL= lower cut-off frequency, fC= central frequency and FBW= fractional bandwidth.

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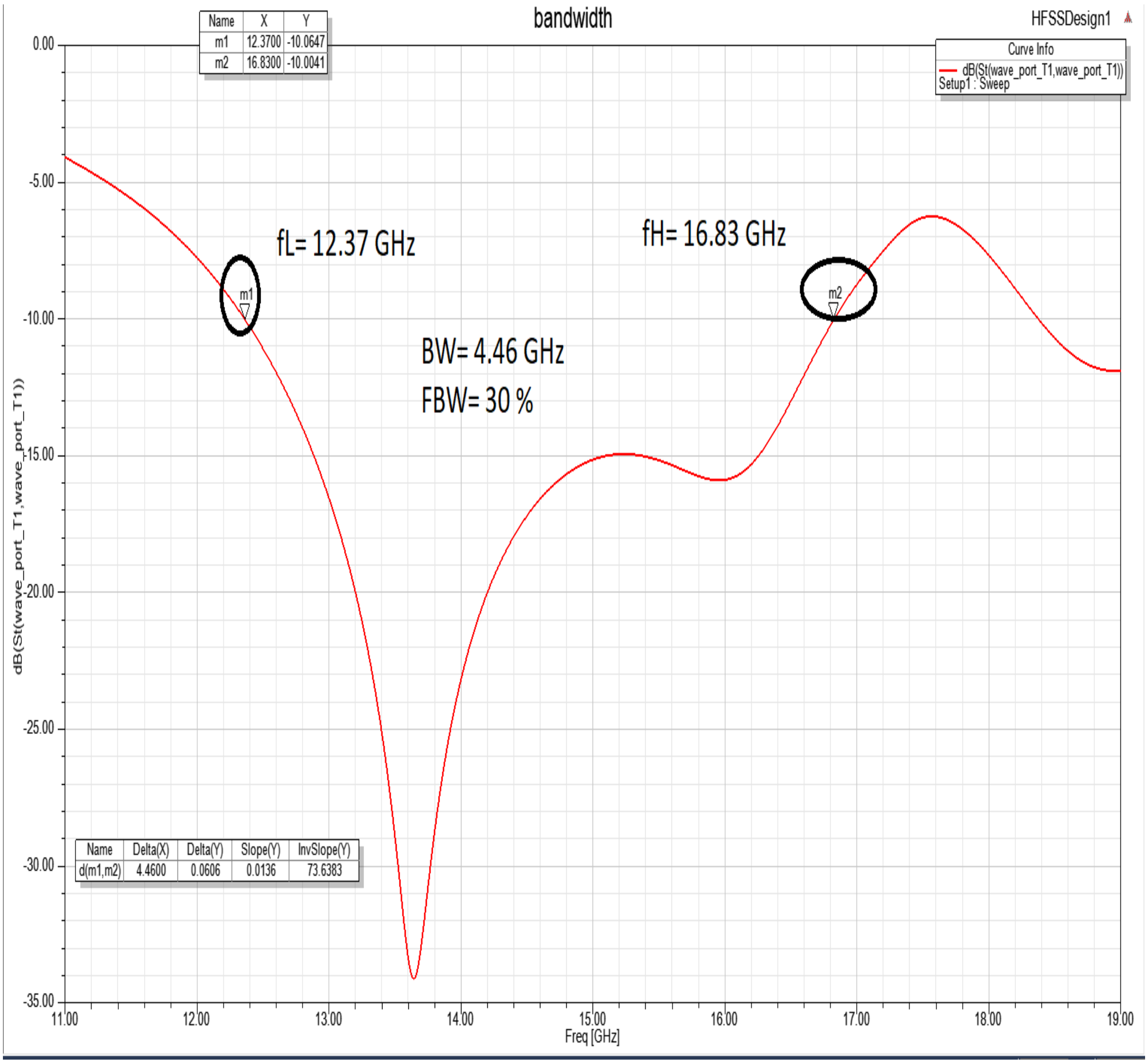

Figure 10Simulated |S11| Bandwidth of the proposed antenna

FromFigure 10, the bandwidth of the antenna below |S11| -10 dB ranges from 12.37 GHz to 16.83GHz whereas in existing method it ranges from 4.48 GHz to 16.6 GHz.

Hence, the impedance bandwidth BW=4.46 GHz whereas in existing method it is 2.12 GHz.

Fractional bandwidth FBW=30% whereas in existing method it is 13%.

Therefore, the impedance bandwidth and fractional bandwidth is increased in the proposed method than that of the existing method.

REFLECTION COEFFICIENT AND RETURN LOSS

FORMULA

RL=-20 log 10| Γ |

where, RL= return loss and Γ= reflection coefficient

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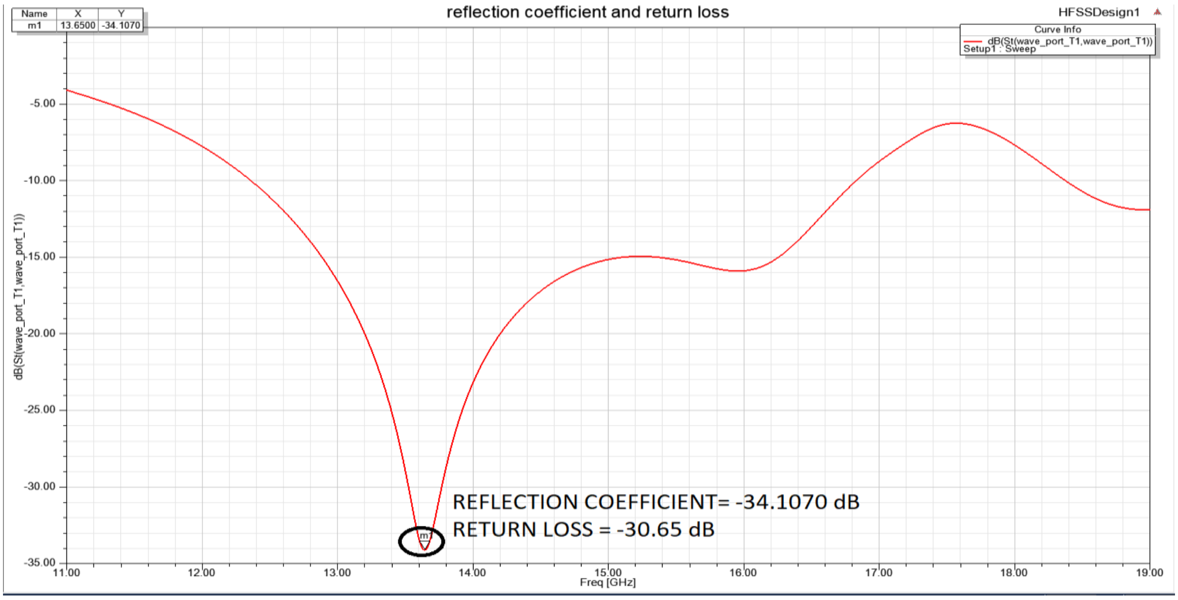

Figure 11Simulated |S11| reflection coefficient and return loss of the proposed antenna

FromFigure 11, the reflection coefficient Γ = -34.1070 dB and return loss RL= -30.65 dB whereas in existing method reflection coefficient is -23.17 dB and return loss is -27.29.

Hence reflection coefficient and return loss is less in the proposed method than that of the existing method.

VSWR

FORMULA

VSWR = 1+|Γ | / 1- |Γ |

Where, VSWR= Voltage wave standing ratio and Γ= reflection coefficient.

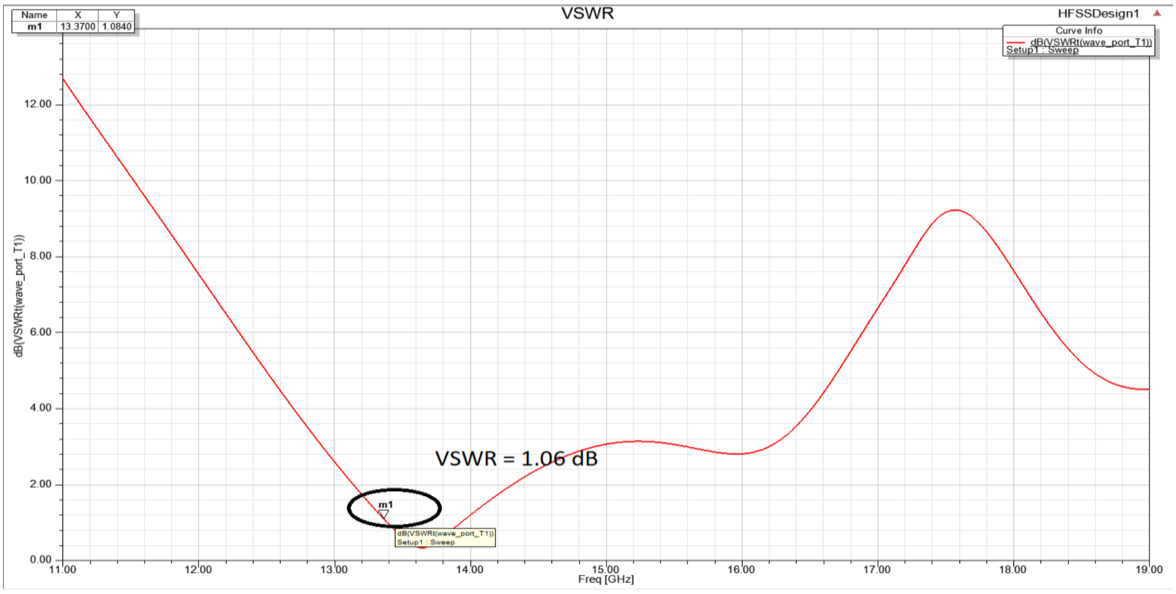

Figure 12Simulated VSWR of the proposed antenna

FromFigure 12, Voltage wave standing ratio VSWR=1.06 dB whereas in existing method it is 1.09 dB.

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Therefore, VSWR is less in proposed method than that of the existing method

GAIN

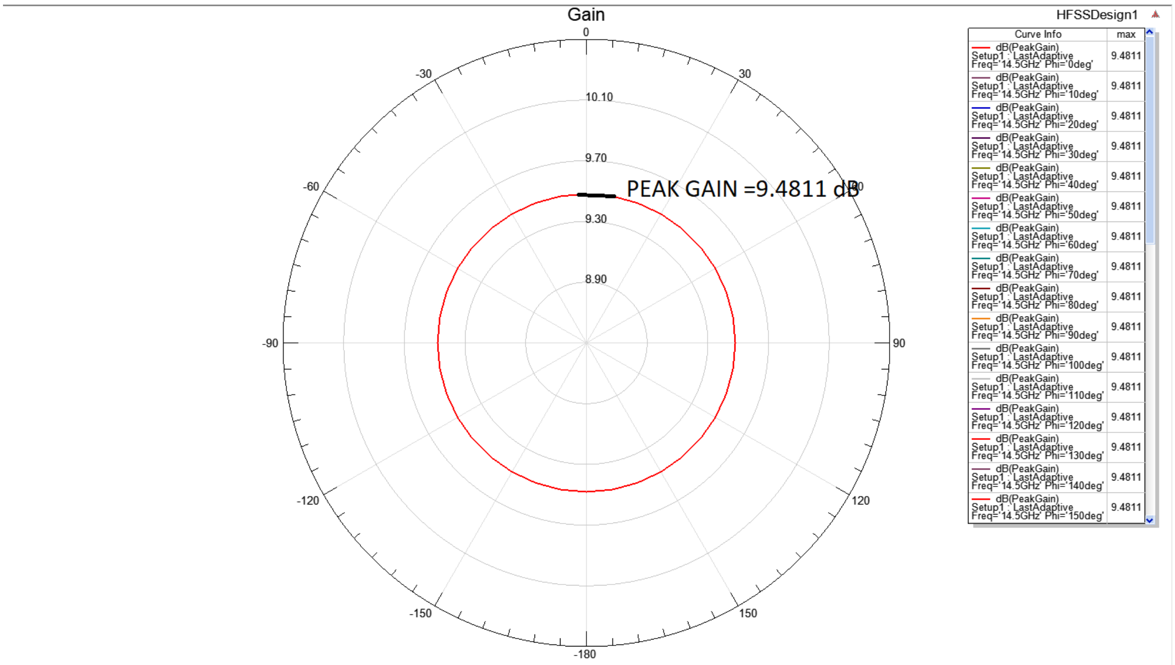

Figure 13Simulated far-field radiation gain of the proposed antenna

FromFigure 13, the peak gain of the antenna is 9.4811 dB

RADIATION PATTERN

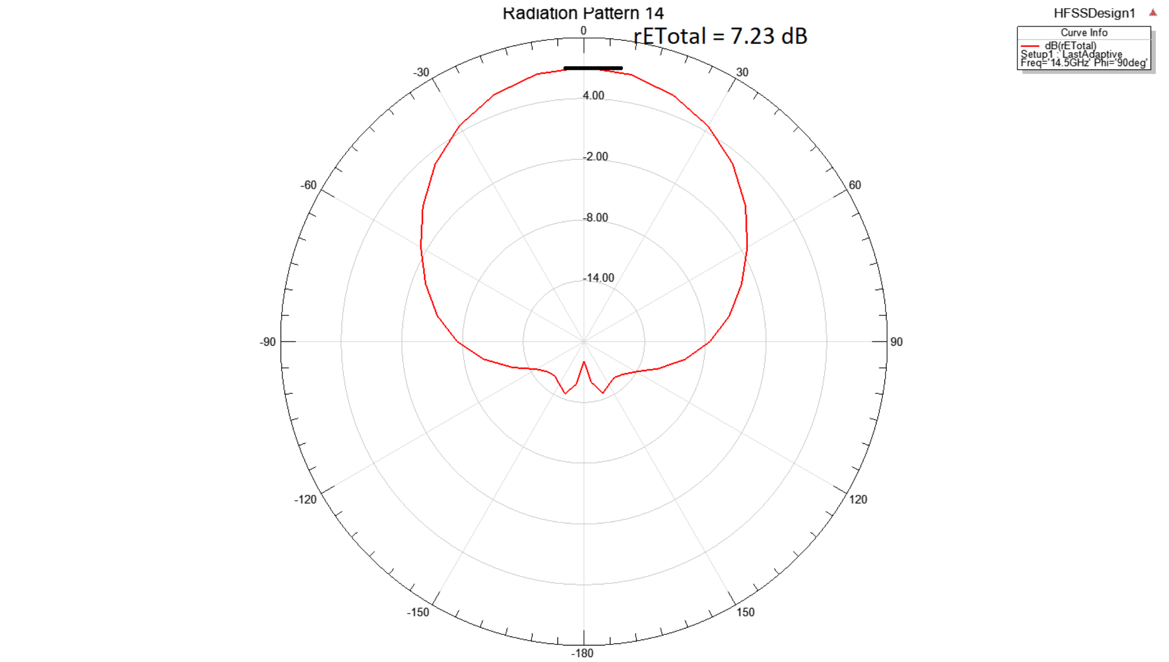

Figure 14Simulated far-field radiation pattern of the proposed antenna

FromFigure 14, the total radiated electric field (rETotal) = 7.23 dB.

DIRECTIVITY

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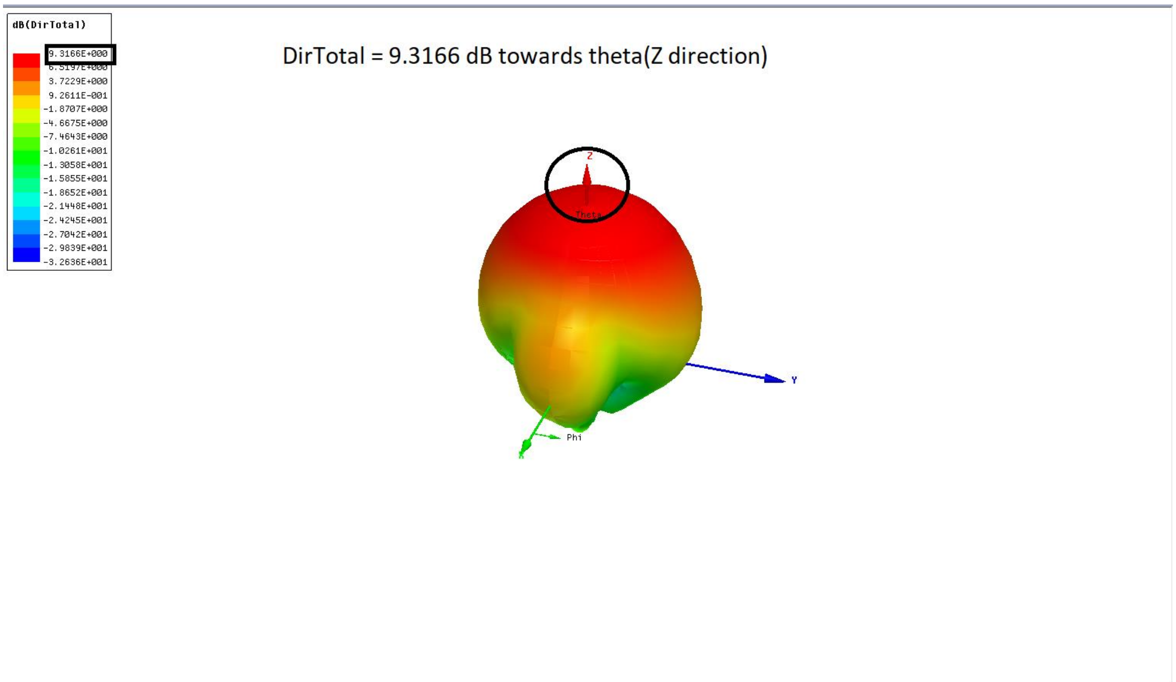

Figure 15Simulated far-field 3D polar plot of the proposed antenna

FromFigure 15,the total directivity of the antenna is 9.3166 dB and the maximum directivity is towards theta (Z direction).

DESIGN NAME	Bandwidth at|S11|-10 dB	Return loss	VSWR	Gain
Existing design (Rectangular patch antenna with square shaped mushroom arrays)	2.12 GHz	-27.29 dB	1.09	9.7 dB
Proposed design (Circular patch antenna with square shaped mushroom arrays)	4.46 GHz	-30.65 dB	1.06	9.48 dB

Table 2 Comparison between existing and proposed antenna

The above Table 2 shows the comparison of the existing and proposed design. Among the twodesigns, the proposed antenna has wide bandwidth, less return loss, less VSWR and high gain. Therefore, maximum power is transmitted to the antenna with minimum reflection.

Hence the bandwidth of the proposed antenna lies in Ku band frequency range and hence can be used in Ku band frequency applications. Ku band frequency applications include uplink and downlink frequency in satellite communication.

[1] CONCLUSION

Thus, the proposed mushroom type circular patch antennais designed and simulated successfully. The simulated results shows that the bandwidth of the antenna below |S11| -10 dB has increased and ranges from 12.37 GHz to 16.83 GHz and has a bandwidth of 4.46 GHz. Hence the fractional bandwidth is 30%. The refection coefficient and VSWR of the antenna has also reduced which are -34.1070 dB and 1.06 respectively. The return loss of the antenna is 30.65 dB, hence there is no reflection and 100% power is transmitted to the

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antenna. Also, the maximum total electric field andmaximum total directivity lies towards theta i.e., Z direction and are 7.2341 dB and 9.3166 dB respectively.The antenna also produces peak gain of around 9.4811 dB. Hence the proposed antenna has wider bandwidth below |S11| -10 dB and high gain and so, it can be used in Ku-band frequency applications. The proposed antenna also has an added advantage of ease of fabrication and it is of a low profile.

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