Design and Optimization of DGS based T-Stub Microstrip Patch Antenna for Wireless Applications

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ABSTRACT
A compact microstrip patch antenna with wide operational bandwidth is presented.The proposed design consists of rectangular patch antenna in ring shaped with U-slots cut in ground.Antenna is fed by microstrip line.The performance of rectangular patch antenna has been discussed and analyzed by modification of the width and length of patch dimensions as given in the previous work [1].The design proposed that antenna is having good bandwidth, gain and return loss in frequency band between 3.5-5 GHz.At resonant frequency 2 GHz antenna has bandwidth of 10% and return loss up to -44 dB which are good as compare to reference results. Proposed antenna has been analyzed using IE3D and simulated results are presented in terms of bandwidth, gain and return loss at different frequencies.

Keywords
Microstrip line, DGS U-shape, Ring Patch antenna, Slots cutting.

1. INTRODUCTION
In today world of wireless communication, recent developments in wireless communication industry continue to derive requirement of small, compatible and affordable microstrip patch antennas. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate such as a printed circuit board with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. Some patch antennas do not use a dielectric substrate and instead made of a metal patch mounted above a ground plane using dielectric spacers. The resulting structure is less rugged but has a wider bandwidth because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle. They are often mounted on the exterior of aircraft and spacecraft or are incorporated into mobile radio communications devices. Microstrip antennas are best choice for wireless devices because of characteristics like low profile, low weight, ease of fabrication and low cost. Since it is common practice to combine several radios into one wireless and use single antenna. Microstrip antenna suffers from disadvantages like they have less bandwidth and gain. For obtaining multiband and wideband characteristics,different techniques have been used like cutting slot in patch, fractal geometry and DGS. In order to increase bandwidth DGS has been used. DGS may be realized by cutting shape from ground plane. Shape can be simple or complex. When DGS has been applied to antenna equivalent inductive part due to DGS increases and this cause high effective dielectric constant hence bandwidth reduced. It is to be noted that within particular area of ground different DGS can produce different resonant frequencies and different bandwidth. In this paper two radiating u slot in ground plane have been cut out. Hence new resonances along with effective current paths are generated in ground plane, as result wideband characteristics have been obtained.

2. LITERATURE SURVEY
A wide band frequency antenna [1] was obtained for mobile communication. Radiation patch and ground of proposed antenna was considerably modified. By two modified U-slots in the ground plane and a modified ring-shaped radiation patch, using a T-stub, wide frequency band can be achieved. By introduction of variable slots in the patches of antenna [2] there occur less chances of mutual coupling between adjacent elements. It had been shown that an enhanced bandwidth was achieved. The incorporation of U-slots in the patch [3] provided can provide a wider bandwidth than conventional patch antenna by placing a variable capacitor and an inductor at the antenna input. A frequency tunable microstrip antenna [4] was presented by adding U-slot on the patch. This antenna had a planner compact structure, so it can be incorporated in to wireless terminals easily. The antenna had good impedance matching at resonant frequency and measured return loss can reached -43 dB in operating frequency band. A double L-slots microstrip antenna for Wi-MAX and WLAN application had been proposed [5]. The co-planer waveguide fed considered the work comprise of two rectangular patch elements each embedded on two L-slots. That design results in a reduction in size and weight and further allows easy integration in hand-held devices. The parametric study of considered design showed that radiation pattern, return loss, voltage standing wave ratio and gain were optimized within the band operation. A novel tri frequency monopole antenna [6] for multiband operation was proposed. For achieving bandwidth enhancement defected ground structure had been used which has rectangular patch with dual inverted L shaped strips. Above design found its application in WIMAX and WLAN. A single patch beam steering antenna with U-slot [7] was designed, fabricated. Simulated results proved that the proposed antenna was able to steer the maximum beam direction in the y-z plane.. The structure of the proposed antenna was based on a two- layer stacked ECMSA [8]. The radiation patch of ECMSA was loaded with gaps and stubs to disturb the surface electric current for the sake of exciting multiple modes. The impedance bandwidth increased up to 36%. The proposed antenna was a U-shaped square patch [9] combined with two parasitic tuning stubs, were fed by a coplanar waveguide (CPW). The total sizes of dimensions of parameters for the antenna were introduced and their effects on the frequency characteristics had been investigated through a parametric study. Simulations and results indicate that the antenna achieved an ultra wideband impedance bandwidth (S_{11}, 210 dB) as high as 129%.The radiation patterns of the antenna were measured and presented. The gain range from 1.6 to 3 dB against frequency had been obtained. These characteristics make the antenna suitable for UWB application. A conventional L-probe [10] fed microstrip patch antenna was modified so that it may be more easily fabricated with its own good features preserved. Instead of

bending a probe in to the L-shape. The measured results showed that the proposed antenna has a relatively large bandwidth like a conventional L-probe design. Although the position of a feed and a patch were inverted, this fact is found to have a little effect on the proposed antenna. A microstrip patch antenna using the defected ground structure (DGS) to suppress higher order harmonics was presented [11]. An H-shaped defect on ground plane with only one or more unit lattices had been utilized and yielded band stop characteristics. Comparing with a conventional microstrip patch antenna without DGS unit cell, the radiated power of DGS patch antenna at harmonic frequencies had been decreased. The book main objective is to introduce [12], in a unified manner, the fundamental principles of antenna theory and to apply them to analysis, design, and measurement of antennas. Because there are so many methods of analysis and design of antenna structures Application of are made to some of the most basic and practical configurations, such a dipole antennas, fractal geometry antennas, microstrip patch antennas, horn antennas and reflector antennas.

3. ANTENNA DESIGN

In this paper a rectangular shaped ring patch antenna has been proposed. Return loss, bandwidth, gain and directivity achieved after simulating reference antenna [1]. Slot antenna presented in this paper has good bandwidth and return loss as compare to [1]. The design of the conventional antenna is shown in Fig 1(a). The antenna has 20mm(y=axis) x 8mm(x=axis) rectangular patch. The dielectric material selected for this design with dielectric constant 4 and substrate height of 1mm. According to reference paper [1] 20x8 mm^2 is a very compatible size of patch in fig (1). The above antenna has been designed by using transmission line model which is most accurate method. Procedure to obtain the dimension of patch and ground [12] which is followed and modified in reference design [1] can be obtained.

The steps [12] to obtain the dimensions are as follows

Step 1: Determination of the Width (W)

The width of the microstrip patch antenna is given by (1)

$$W = \frac{\lambda_0}{f_o\sqrt{(\epsilon_r + 1)/2}} \qquad (1)$$

Step 2: Calculation of effective dielectric constant, ε_{reff} , which is given by equation (2)

$$\varepsilon_{reff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (2)$$

Step 3: Calculation of the length extension ΔL, which is given by (3)

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (3)$$

Step 4: Now to calculate the length of patch by (4)

$$L = \frac{\lambda_0}{f_o\sqrt{\epsilon_{reff}}} - 2\Delta L \qquad (4)$$

Where the effective length of the patch L_{eff}

$$L_{eff} = \frac{\lambda_0}{f_o\sqrt{\epsilon_{reff}}} \qquad (5)$$

Step 5: Calculation of Ground Dimensions

$$L_g = 6h + L \qquad (6)$$

$$W_g = 6h + W \qquad (7)$$

In this paper dimensions of patch are same with respect to reference paper [1] and work has been carried out to modify the patch structure to obtain improved results in respect to return loss and bandwidth at same frequency.

4. PARAMETRIC ANALYSIS

4.1 Basic Designs with Microstrip Line

The geometry of Basic Design antenna which is in rectangular shaped design, compatible size. It is a conventional design which is simulated in IE3D Software. It has a rectangular patch and FR-4 Substrate, which is feeding by Microstrip Line for IMT/Broadband applications are depicted in Fig 1. The dimensions of designed antenna with microstrip line feed and height of substrate, tangent loss all are mentioned in table 1. These dimensions are optimized in order to obtain best results. This antenna has very small dimensions.

Table 1: Dimensions of the Reference rectangularpatchantenna

Subject	Dimensions
Ground size	34×20mm^2
Patch size	24×8mm^2
Loss Tangent (tan δ)	0.02
Feed Line size	5×2mm^2
Substrate used	FR4
Thickness	1 mm
Feeding Technique	Microstrip line feed

It is observed from Fig 1 as shown below a conventional antenna is following rectangular characteristics.

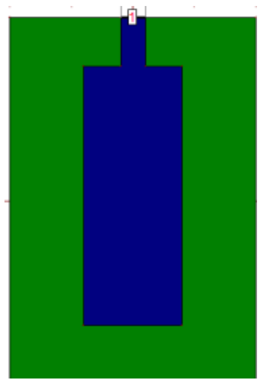


Fig 1: Conventional Geometry of Antenna

4.2 Reference Design of Antenna

In this design, rectangular shaped ring patch antenna is taken and T- Stub has been applied in the rectangular ring patch [1]. Return loss, bandwidth, gain and directivity are analyzed after simulating the proposed antenna in IE3D environment. Since there are different disadvantages of microstrip patch antenna, hence to overcome them different techniques like reduction in patch size, DGS, slot cutting on patch have been applied. In this design T-Stub geometry has been applied on rectangular ring patch. DGS is applied on ground plane by cutting two U-slots cuts.Further variations in patch dimensions are made and results are compared. In this design rectangular patch is taken having length of 24mm. By cutting slots, rectangular shaped ring patch antenna has been formed. This Slot antenna presented has good bandwidth and return loss as compare to Reference antenna. The design of the conventional antenna is as shown in Fig 1. The antenna has rectangular patch dimensions 20mm along y-axis and 8mm along x-axis. The dielectric material FR-4 selected for this design with dielectric constant 4.4 and substrate height of 1mm. As per patch dimensions given in 20×8 mm^2 is a very compatible size of patch as shown in Fig 2. The proposed antenna has been designed by using transmission line model which is most accurate method.

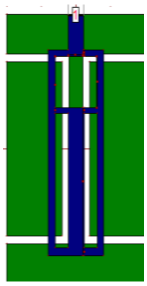


Fig 2 Reference Design of Antenna

Table 2 shows dimensions of antenna feed line with dimension of patch. These dimensions of patch have been modified to obtain improved results in respect to return loss and bandwidth at same frequency.

Table 2: Shows Dimensions of Antenna Feed Line with Dimension of Patch.

Variable	Value
Length of Patch	24 mm
Width of Patch	8 mm
Length of ground	34 mm
Width of ground	20 mm
Thickness of substrate	1 mm
U-slots DGS	24mm along y-axis, 9mm along x-axis
Substrate used	FR4- epoxy
Feed Point	(0, 17, 0)

4.3 Effect of Adding Length in Patch Strip of Antenna

Microstrip Patch Antenna has been designed which operates on resonant frequency 3.5 GHz and 4 GHz, to get the better bandwidth as well as the better return loss as compared to the bandwidth and return loss found in the reference design. Also the proposed design has been made in such a way so that it can operate on a wide range of frequency. In order to achieve dual band antenna with a larger bandwidth as well as with a better return loss, ground has been etched by shape of the two U-Slots and patch has been designed in the shape of a T-Stub in ring shaped patch. A square slot cavity has been filled with a 7 mm long and 2.2 mm width strip. By doing this, area of above the Stub strip increases by 7 mm, T bands have been removed, and this antenna is fed by microstrip line as shown in Fig 3. Further the antenna parameters have been optimized to get the best possible result. In this design, there is no change in DGS is made. The geometry of proposed antenna is shown in Fig below:

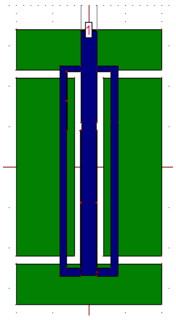


Fig 3 Stub Enlarged to 7 mm up to Microstrip Line Antenna

4.4 Effect of decreasing Patch Strip Length of Wide Band Antenna

In this design, the dual band MSA has been designed by cutting a slot on the patch and hence increasing patch strip length. This causes antenna to resonate at frequency bands 4.2 GHz. The design specifications of antenna are obtained and are mentioned in table 3. By changing different parameters like slot length and width, results are analyzed.

Table 3: Parameters of Wideband MSA

Variable	Value
Height	1mm
T-Stub rectangular enlarged to 3.5mm from centre of T (a)	3.5mm
T- Stub enlarged to 3.5 mm from strip line side (b)	3.5mm

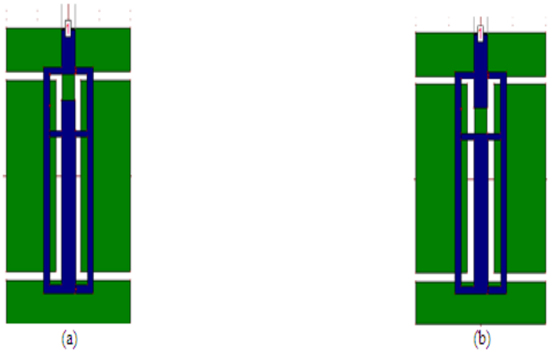


Fig 4 (a) T-Stub rectangular enlarged to 3.5mm from centre of T Antenna (b) T- Stub enlarged to 3.5 mm from strip line side Antenna.

The proposed antenna can efficiently radiate on the two central frequencies with a larger bandwidth as well as with a better return loss. In Design (a), patch has been etched in the shape of a T-Stub in ring shaped patch area below Microstrip Line (MSL) has been cut by 3.5 mm. and In Design (b), patch has been etched in the shape of a T-Stub in ring shaped patch and the area of above the T-Stub strip cut by 3.5 mm, Above the T-Stub instead of square slot cavity has been look like as U-slot below as showing in Fig 4 (b). After that the antenna parameter has been optimized to get the best possible result. In these two configurations, no change in DGS shape has been made.

5. RESULTS AND DISCUSSION

In this paper results of proposed rectangular microstrip patch antenna designs are discussed. By making a rectangular ring microstrip patch antenna with T-stub using DGS, results are analyzed. Further effect of varying different parameters of patch like strip width and length results are compared. All simulations were carried out in IE3D electromagnetic simulation engine.

5.1 Conventional Rectangular Microstrip Patch Antenna

In this section the simulation results of the Conventional microstrip patch antenna is discussed. The simulation design which is discussed in previous paper has no slotting on patch and no defected ground. The Fig 1 below shows the S-parameter of the design.

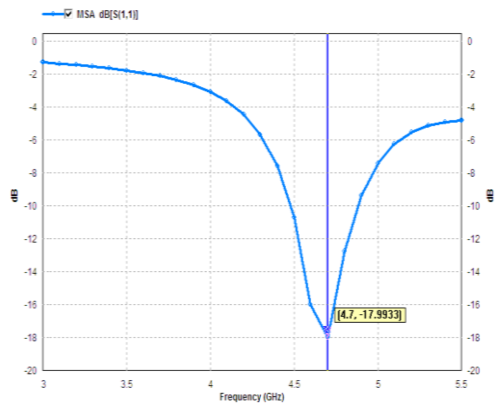


Fig 6: S-parameter Plot of Conventional Antenna

It is observed from above that Fig 6 than Conventional MSA resonates at 7 GHz with -17.99 dB of returns loss and a bandwidth of 370 MHz

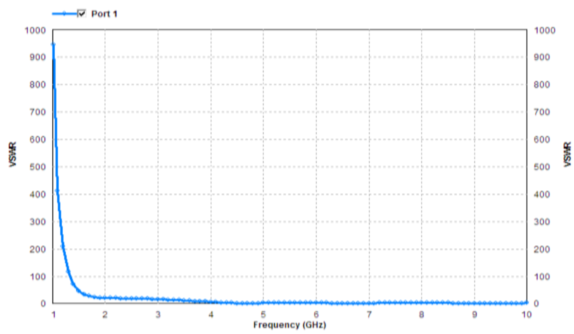


Fig 7: VSWR of Conventional MSA

From the Fig 7 it is observed that Conventional MSA is having VSWR is less than two but greater than one at resonance frequency.

It is observed from belove Fig 8 gain of Conventional Antenna at a resonant frequency of 7 GHz is 30 dBi.

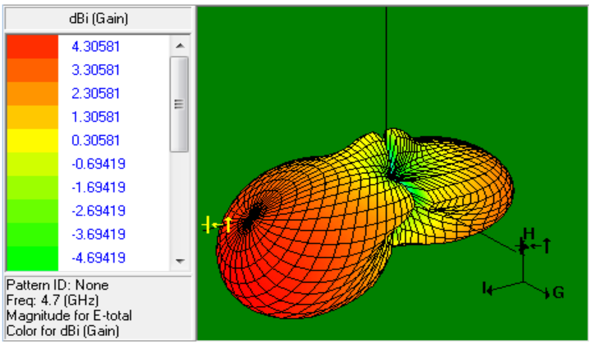


Fig 8: Gain of Conventional MSA

5.2 Rectangular Ring Patch MSA with T-Stub and U-Slots DGS

In this section the results of the rectangular ring patch MSA have been discussed. This antenna has a T-Stub in ring patch and double U-Slot as shown in Fig. This antenna is designed using procedure given in paper five. This design has same geometry as given in [1]. Fig 8 below shows the S-parameter plot of the corresponding antenna.

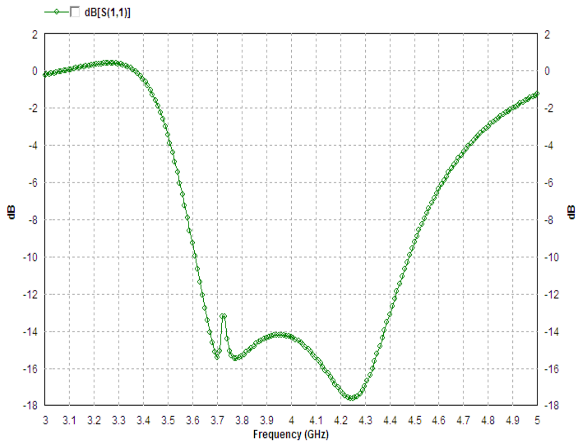


Fig 9: S-Parameter of Reference Design

As it can be seen from the simulation results that resonance frequency of this antenna has been reduced as compare to previous design of conventional antenna. The antenna resonates at 25 GHz with -17.44 dB returns loss and bandwidth of 860 MHz Bandwidth is 60% improved as compared to previous design. The results have the fluctuating waveform other than the resonating frequency.

From Fig 10 it has been observed that gain of Reference Antenna at 25 GHz is 2.81 dBi. From simulation it is seen that the 2.011 dBi gain of antenna has reduced as compared to 30 dBi gain of previous Conventional MSA.

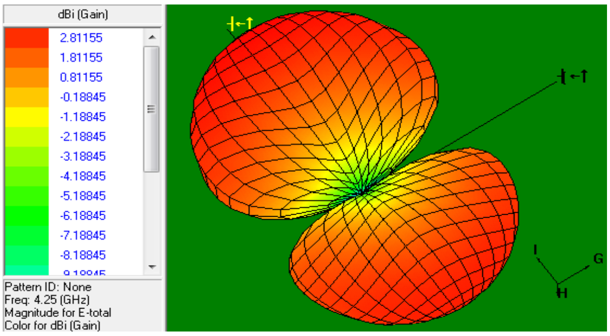


Fig 10: Gain of Reference MSA

5.3 Dual Band Ring Patch Antenna

To achieve improved result patch has been etched in the shape of a T-Stub in ring shaped patch the area of above the Stub strip increases by 7 mm, a square slot cavity has been filled with a 7 mm long and 2.2 mm width strip. T joint has been removed and ground has been etched by shape of the two U-Slots and this antenna is feed by microstrip line as shown in

Fig 3. The S-parameter given below:

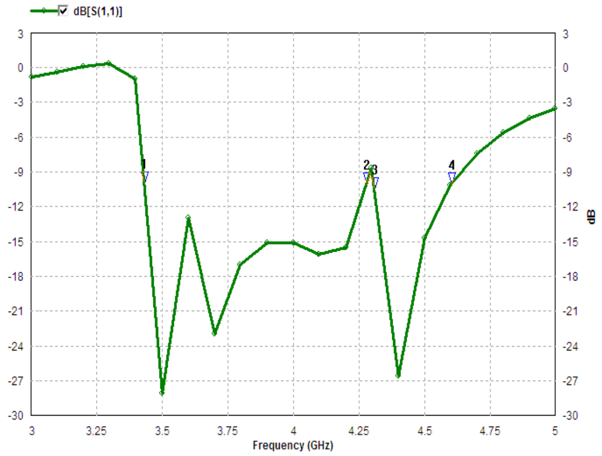
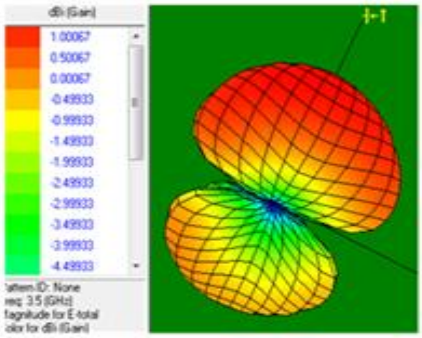
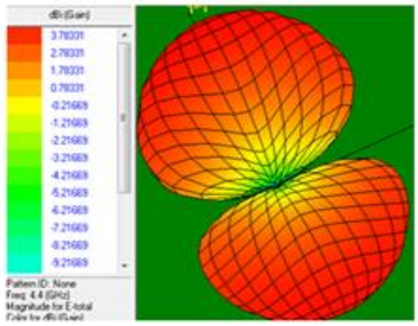


Fig 11: S-Parameter of Dual Band Full Strip Length Antenna

Fig 11 is showing the optimization plot of S-Parameter of results of antenna as shown in Fig. The simulated antenna has better results as compared to the previous simulation results. The antenna resonates at 3.5 GHz with -28.10 dB, 850 MHz Bandwidth and 4 GHz with -26.54 dB returns loss and bandwidth obtained in this case is 300 MHz Results show that Bandwidth in this case has improved as compared to Conventional design with multi bands. This antenna resonates at dual bands.



(a)



(b)

Fig 12: Gain Plot of Dual Band Ring patch Antenna at Gain (a) at 3.5 GHz (b) Gain at 4 GHz

Fig 12 is showing gain of Conventional Antenna. This antenna has a gain of 1.006 dBi at 3.5 GHz and 3.78 dBi at 4 GHz. It had to design with new idea to increase gain. It can be seen from simulation result the gain of this antenna has been reduced as compared to previous Conventional MSA.

5.4 Decreasing Patch Strip Length of Wide Band Microstrip Patch Antenna

In this section wide band MSA has been designed in which the patch has been etched in the shape of a T-Stub in ring shaped patch and also the area below Microstrip Line (MSL) has been cut by 3.5 mm and antenna ground has been etched by shape of the two U-Slots as shown Fig 4 (a), This antenna has a resonating band from 3.63 GHz - 38 GHz.

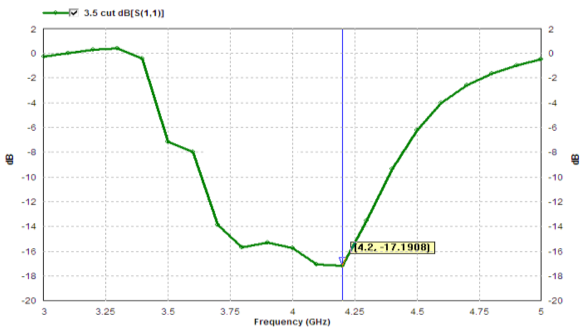


Fig 13: S-Parameter of T-Stub Rectangular Enlarged to 3.5mm from Centre of T (a)

It is observed from above Fig 13 is showing the optimization plot of S-Parameter of T-Stub rectangular enlarged to 3.5mm from centre of T (a) as showing in Fig 4(a). The antenna resonates is having a resonant band from 3.63 GHz to 83 GHz with -17.19 dB of returns loss and bandwidth of 750 MHz, Bandwidth performance has decreased as compared to previous design. Now antenna is resonating in a band of 750 MHz.

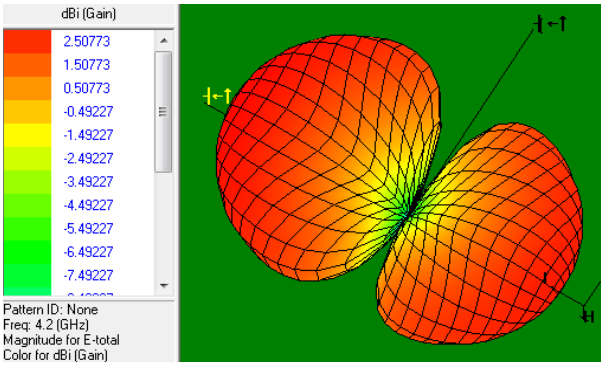


Fig 14: Gain Plot of T- Stub Rectangular Enlarged to 3.5 mm from Centre of T (a) at 2 GHz

It is observe from Fig 14 this antenna has a gain of. 2.50 dBi at 2 GHz. Results of the design as shown in Fig has been shown in Fig in which The patch has been etched in the shape of a T-Stub in ring shaped patch the area of above the T-Stub strip cut by 3.5 mm, the ground remain same. Above the T-Stub instead of square slot cavity has been looked like as U-slot below as showing in Fig 4 (b). This antenna has resonating band 3 GHz - 5 GHz. The analysis waveform given below:

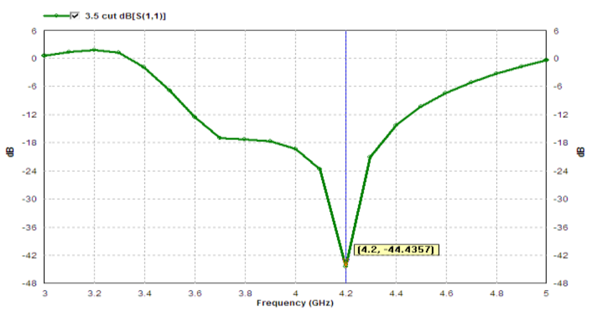


Fig 15: S-Parameter of T- Stub Enlarged to 3.5 mm from Strip Line Side Antenna (b)

It is observed Fig 15 that this antenna gives better results. The antenna resonates at 4.2 GHz with -44 dB returns loss and bandwidth obtained 970 MHz, Bandwidth has improved up to 12% as compared to Reference design (860 MHz) (Fig 8) and as compared to first basic design (370 MHz) improved up to 160% (Fig 6).This antenna resonating frequency at 4.2 GHz finds application for International Mobile Telecommunications (IMT) standards. The performance of return loss also minimized.

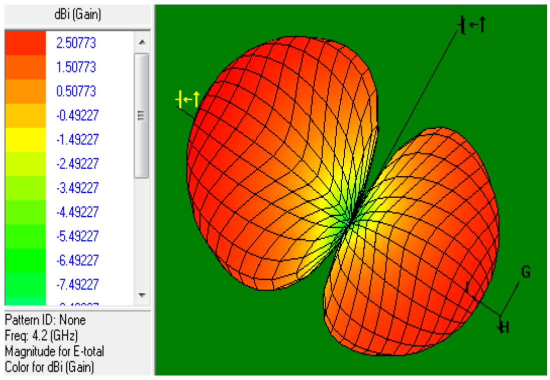


Fig 16: Gain-Parameter of T- Stub Enlarged to 3.5 mm from Strip Line Side of Antenna (b)

Fig 16 is showing Gain-Parameter of T- Stub enlarged to 3.5 mm from strip line side of Antenna. At a resonant frequency of 2 GHz, 2.507 dBi of gain is obtained. The difference between gain of entire antenna designs shows that gain does not change a lot.

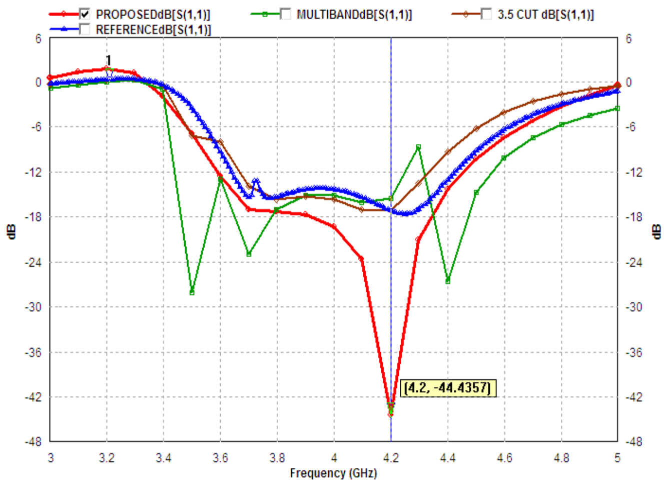


Fig 17: Comparison of Return Loss all Designed Antennas

It is observed from above Fig there is comparisons of entire simulated antenna with conventional antenna and reference antenna. By using return loss of colors waveforms.

It is observed from above Fig there is comparisons of entire simulated antenna with conventional antenna and reference antenna. By using return loss of colors waveforms.
In Fig 17 Bandwidth and Return loss is comparing of all new designed antennas with reference antenna. All return loss curve has divided with color.

Table 4: Optimization of Parametric Analysis of Slotted Proposed Antenna.

Antenna Design	Resonant Frequency (GHz)	Return Loss (dB)	Gain (dBi)	Bandwidth (MHz)
Conventional Design	4.7	-17.99	4.33	370
Reference	4.25	-17.44	2.68	860
7mm increase	3.5	-26.54	1.006	850
	4.4	-28	3.78	300
3.5 mm cut below MSL	3.6	-16	2.40	750
	4.2	-17.50	2.77	
3.5 mm cut above T Stub	**4.2**	**-44.4**	**2.50**	**970**

6. CONCLUSION

A novel compact microstrip ring patch antenna, fed by microstrip line is presented for Microwave application. The microstrip ring patch consists of a T-stub and a U-slot designed on patch. The patch has total size equal to 24X8mm2. The measured return loss indicates that the antenna exhibits wide band Characteristics. The bandwidth characteristics of antenna with respect to the geometrical parameters are investigated. The proposed antenna shows an impedance bandwidth as high.

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