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Design of Extended Circular Patch with Rectangular Stub and Circular Slit Used For Ultra Wide Band Application(X-Band)

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Abstract:- *The proposed antenna is one of the best antenna structures, due to its low cost and compact design. In this paper, it was present a new approach to improve the radiation efficiency and the performance of antennas due to miniaturization of the size. Indeed, the performance of ultra wideband antenna which consists of a circular patches printed on an inexpensive FR-4 Epoxy substrate a dielectric constant (ε_r= 4.4) and high (h=1.5mm), the design were presented on geometrical form . The idea was to develop new configurations by modifying Defect Ground Structure . The performance of the designed patch antenna is simulated with CST 2017 software. This study was made for the frequency band of UWB ranging8.43 GHz 10.0 GHz (3.98-13.98GHz) and corresponding VSWR is 1.48 < 2 for entire bandwidth range. The discussed design achieves the return loss of -14.05dB used for X Band application.*

Keywords*: Microstrip, Patch Antenna, Planar, Broadband, Ultra Wide Band, Bandwidth Enhancement, Omni-directional patterns.*

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I. Introduction

Microstrip antenna is the ideal choice for wireless an such typed application due to low profile, light weight, conformal shaping, low cost ,simplicity of manufacturing and easy integration to circuit. However, conventional microstrip patch antenna suffers from very narrow bandwidth, typically about 5% bandwidth with respect to the central frequency. there are numerous and well-known method to increase the bandwidth of antennas, including increase of the substrate thickness, the use of a low dielectric substrate, the use of multiple resonators, and the use of slot antenna geometry. Wireless local area networks (WLAN) are widely used worldwide. The 802.11a standard uses the 5-GHz band which is cleaner to support high -speed WLAN. However, the segment of frequency band used varies from one region of the world to another. Dual frequency microstrip antennas with a single feed are required in various radar and communication systems, such as global positioning system (GPS), WiMAX, WLAN etc.

These communication system applications include fixed broadband local multipoint communication services, small mobile units, laptops and remote -sensing devices. Also, bandwidth should be further enhanced in order to increase the information transfer rate, without sacrificing the performance. There are lots of communication schemes that make use of the large operational bandwidth. For example, the Orthogonal frequency-division multiplexing (OFDM) scheme transmit and receive signals with a number of frequency components. Another example is the transmission of broadband pulse radiating edge.

II. Design Geometry of Microstrip Patch Antenna

In its basic form, a Microstrip patch antenna consists of a radiating patch which is built on the dielectric substrate and substrate is attached on the ground plane as shown in Figure 1. The patch is generally made of conducting material such as copper or gold and can take any possible shape.

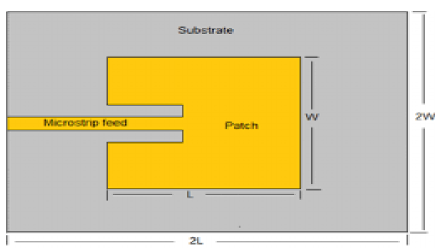

Figure 1. Structure of Microstrip Patch Antenna

The radiating patch and the feed lines are usually photo etched on the dielectric substrate. The relative permittivity of the dielectric substrate is very important for the calculations of the antenna dimensions. In order to simplify analysis, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape. In this paper, the rectangular patch can be used. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation.

III. Antenna Design

The proposed antenna is designed for a resonating frequency of 7.0 GHz. The substrate material FR-Epoxy which has the relative permittivity of ε_r = 4.4. The substrate thickness is designed as 1.5mm. The antenna geometry consist of a half circular patch which is extended an extra rectangular length. Antenna is fabricated on FR-4 Epoxy material and microstrip feed line is used for feeding. A circular shape partial ground plane is used with an elliptical notch just below the feed line. The dimensions of antenna can be calculated by using the following relationship:

a) Width of Patch

$$\boldsymbol{W = \frac{c}{2f_r}\sqrt{\frac{2}{\in_r + 1}}}$$

Where,
c =free space velocity of light.
f_r = resonating frequency.
ε_r= relative permittivity of substrate.

b) Effective dielectric Constant:

$$\boldsymbol{\in_{eff} = \frac{\in_r + 1}{2} + \frac{\in_r - 1}{2}\left[1 + 12h\frac{h}{w}\right]^{\frac{1}{2}}}$$

Where,
h = Thickness of the substrate.
W= Width of the patch.

c) Effective Length

$$\boldsymbol{L_{eff} = \frac{c}{2f_r\sqrt{\in_{eff}}}}$$

d) Patch Length Extension

$$\boldsymbol{\Delta L = 0.412h\frac{(\in_{eff} + 0.33)(\frac{W}{h} + 0.264)}{(\in_{eff} - 0.258)(\frac{W}{h} + 0.8)}}$$

e) Length of Patch

$$\boldsymbol{L = L_{eff} - 2\Delta L}$$

f) Width of Substrate

$$\boldsymbol{W_S = 6h + W}$$

g) Length of Substrate

$$\boldsymbol{L_S = 6h + L}$$

IV. Propose Antenna Modeling

From the above relationships, the proposed antenna can have the following dimensions. The following Table 1. can have the dimensions of the antenna that is listed below:

Table 1 Antenna Design Parameter

Parameter	Design 1 (without slit)	Design 2 (with circular slit)
Resonating Frequency(f_r)	7.0 GHz	7.0GHz
Relative Permittivity(ε_r)	4.4	4.4
Substrate Width(W_S)	27 mm	27 mm
Length of Substrate(L_S)	30 mm	30 mm
Substrate Height(h)	1.5	1.5 mm
Length of Stub (L_{Stub})	5 mm	7 mm
Width of Stub (L_{Stub})	15 mm	18.82 mm

Bandwidth Range	3.98-13.98 GHz	4.7-13.10GHz
VSWR	1.48	1.40
Return Loss	-14.05dB	-15.07dB

V. Method of Feeding:

Feeding technique influences the input Impedance and polarization characteristics of the antenna. There are three most common structures that are used to feed planar printed antennas. These are coaxial probe feeds, Microstrip line feeds, and aperture coupled feeds. Microstrip line fed structures are more suitable compared to Probe feeds, due to ease of fabrication and lower costs. Serious drawbacks of this feed structure are the strong parasitic radiation and it requires a transformer, which restricts the broadband capability of

The antenna in this paper, the Microstrip line feeding can be used to radiate the power of the proposed antenna. The strip line can be united with the patch of the antenna. The basic structure of the Microstrip line feeding can be shown in Figure 2.

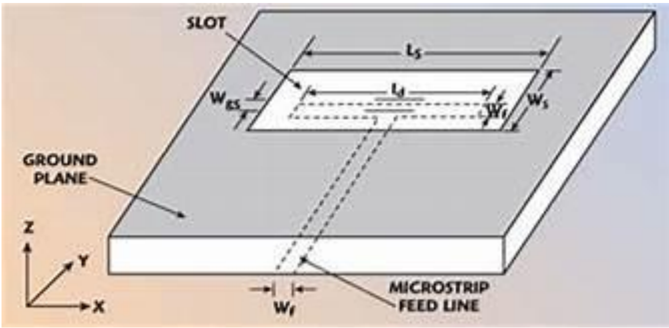

Figure 2. Microstrip Line Feed

VI. Analysis of Proposed Antenna Structure

The proposed Rectangular Microstrip patch antenna can be analysed and simulated by using CST 2017 antenna simulation software. Figure 3(a, b) .Shows the design geometry of the proposed Microstrip patch antenna for X band applications.

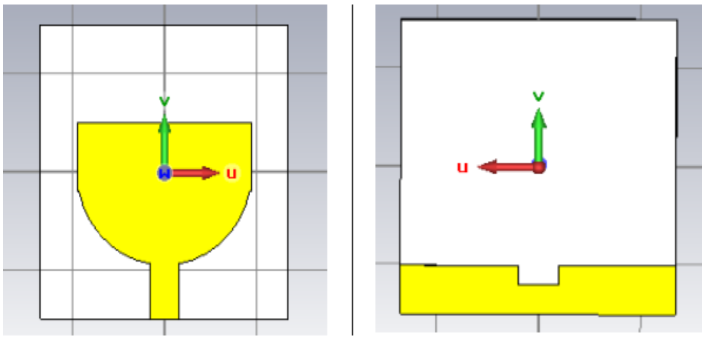

Figure 3.a. Design 1 - Extended Circular Patch Antenna

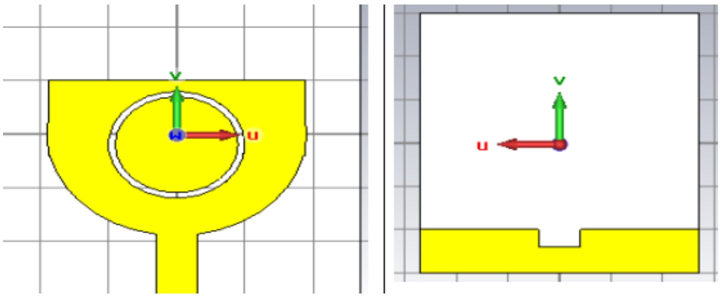

Figure 3. b. Extended Circular Patch with Stub and Slit

VII. Parametric study of the Antenna

Design 1- The antenna geometry consist of a half circular patch which is extended an extra rectangular length. Antenna is fabricated on FR-4 Epoxy material and microstrip feed line is used for feeding. A circular shape partial ground plane is used with an elliptical notch just below the feed line. The return loss of -4.05dB and the bandwidth of 10.0 GHz (3.98- 13.98GHz) and corresponding VSWR is 1.48 < 2 for entire bandwidth range.

Design 2 - This antenna geometry consist of a half circular patch which is extended an extra rectangular length and circular slit . Antenna is fabricated on FR-4 Epoxy material and microstrip feed line is used for feeding. A circular shape partial ground plane is used with an elliptical notch just below the feed line. The discussed design achieves the return loss of -15.07 dB and the bandwidth of 8.43 GHz (4.7- 13.1GHz) and corresponding VSWR is 1.42 < 2 for entire bandwidth range. The simulation results show that the antenna fulfils the requirement of UWB antenna for X- Band Application such as :

1. Used in satellites for the Earth exploration purpose.
2. Used in fixed and mobile satellites for communications from earth to space direction i.e. uplink.
3. Used in meteorological satellites for monitoring weather conditions. It uses 8.175 GHz to 8.215 GHz frequencies for this purpose.
4. Rain fading is dominant in radio frequencies above 10 GHz. Hence X Band does not have much interference from rain fading compare to other higher frequency bands such as Ku band and Ka band.

VIII. Results & Discussion

This work shows the variation of reflection coefficient and gain with respect to the frequency of different antenna parameter dimensions.

For Design 1 – The design achieves the return loss of -4.05dB and the bandwidth of 10.0 GHz (3.98- 13.98GHz) and corresponding VSWR is 1.48 < 2 for entire bandwidth range. Return loss, VSWR, Gain & Directivity and its plot is shown in Figure 4(a, b, c, d).

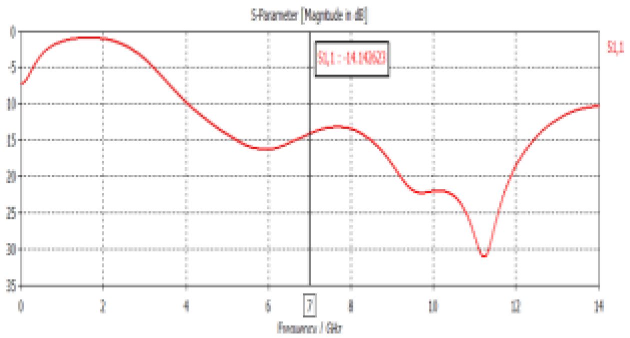

Figure 4. a Return Loss = -14.05 dB

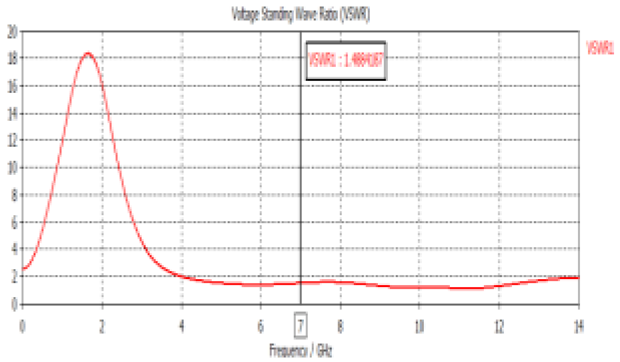

Figure 4. b. VSWR = 1.48

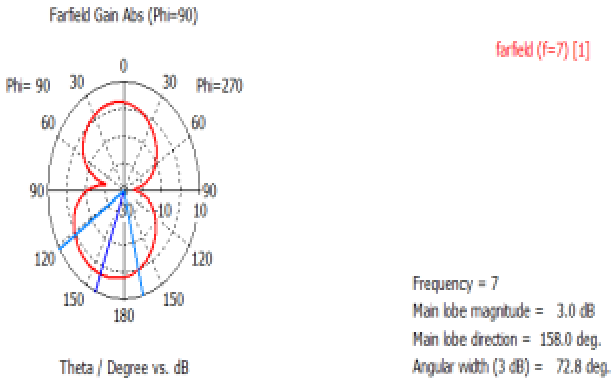

Figure 4. c. Gain = 2.98 dB

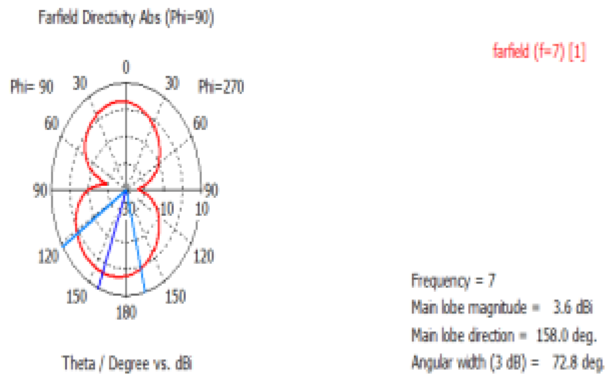

Figure.4 d. Directivity = 3.54 dB

Pattern of Return Loss, VSWR, Gain, Directivity of Simple Circular Patch fr = 7.0 Ghz The position of deep curve in return loss plot at resonating frequency 6.00GHz, 9.72GHz and 11.82 GHz with Return Loss -15.48dB , -35.16dB ,-24.48dB and with VSWR 1.4, 1.03,1.12. For Different variation of parameter Return Loss, VSWR, gain and Band width were changed shown in below Tables.

a) If thickness of substrate is varied at constant Ground Lg= 4mm, fr= 7.0 GHz

Table 2. Variation of h

No. Of Iteration	Substrate Thickness	Dielectric Constant	Operating Bandwidth GHz	Band width GHz	Return Loss(dB)	VSWR
1.	1.4	4.4	3.95-7.87, 8.25-13.16	3.92, 4.91	-12.65	1.6
2	1.5	4.4	3.95-13.067	9.11	-13.25	1.55
3	1.55	4.4	3.95-13.12	9.17	-13.5	1.53
4	1.6	4.4	3.98-13.15	9.17	-13.75	1.51
5	1.7	4.4	3.98-13.58	9.9	14.0	1.49
6	**1.8**	**4.4**	**3.98-13.98**	**10**	**-14.5**	**1.48**

b) Return Loss Plot on Variation of h

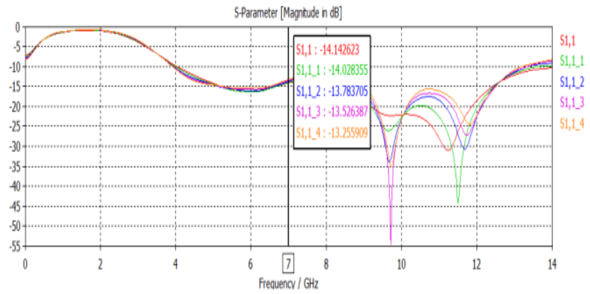

Figure 4. e. RL- Plot

c) If Lg is varied at constant h = 1.8mm

Table 3. Variation of L_g

Sl. No.	L_g(mm)	Return Loss(dB)	VSWR	Directivity(dB)	Gain(dB)	Band Width(GHz)
1	4	-9.75	1.96	3.55	2.94	3.2, 4.95
2	5	-14.05	1.48	3.54	2.98	10
3	6	-14.9	1.43	3.56	3.014	7.29
4	7	-8.95	2.1	3.62	3.01	0.72

d) Simulated Return Loss Plot effect of Lg

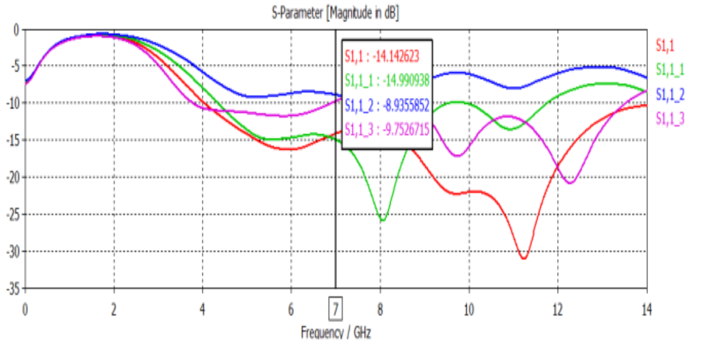

Figure 4. f. RL- Plot- L_g

e) If Notch Width on Ground Plane(WN) is varied.

Table 4. Variation of W_N

Sl.No.	W_N(mm)	Return Loss(dB)	VSWR	Directivity(dB)	Gain(dB)	BW(GHz)
1	3	-16.3	1.36	3.53	2.97	9.2
2	4	-14.05	1.48	3.54	2.98	10
3	5	-11.9	1.67	3.54	2.96	8.7

f) Simulated Return loss Plot on Variation of WN

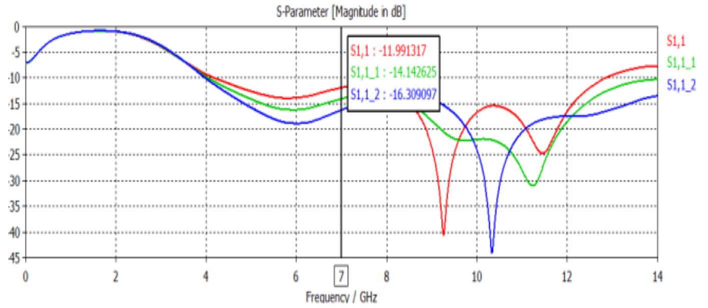

Figure 4. f. RL- Plot- W_N

RLC circuit values Extended Circular MPA with Notch : The Equivalent lumped circuit model of return loss plot for Microstrip patch antenna can be achieved effectively by using series RLC circuit. A series connection of R, L, C can be assumed as band pass filter which only pass certain frequency and reject rest. From the Return loss plot from the valley at which resonance takes place and frequency changed from that point the R, L, and C is calculated with the formula .Equivalent Circuit is shown in Figure 4.g.

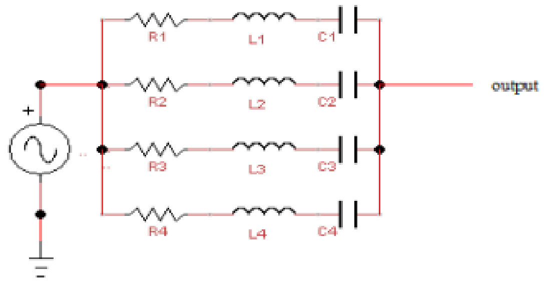

Figure 4. g. Equivalent RLC Model of Proposed Antenna

The Parameter were calculated with the help of Z0 =50 ohm= √(L/C), and the parameter were shown in table 5.

Sl. No	Resonating Frequency f_r(GHz)	Resistance (Ohm)	Inductance(nH)	Capacitance(pF)
1	4.0	R1= 11.4	L1= 1.9	C1= 0.79
2	6.04	R2= 5.79	L2= 1.32	C2= 0.53
3	9.39	R3= 12.65	L3= 0.84	C3= 0.84
4	11.2	R4= 6.7	L4= 0.71	C4= 0.28
5	13.84	R5= 6.42	L5 = 0.57	C5= 0.23

Table 5. RLC value for designed antenna.

For Design 2 – The design achieves the return loss of -15.07 dB and the bandwidth of 8.43 GHz (4.7-13.1 GHz) and corresponding VSWR is 1.42 < 2 for entire bandwidth range. Return loss, VSWR, Gain & Directivity and its plot is shown in Figure 5 (a, b, c, d).

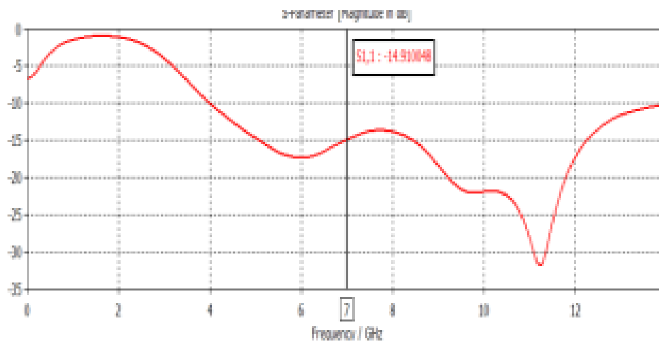

Figure 5.a. Return Loss= -14.9 dB

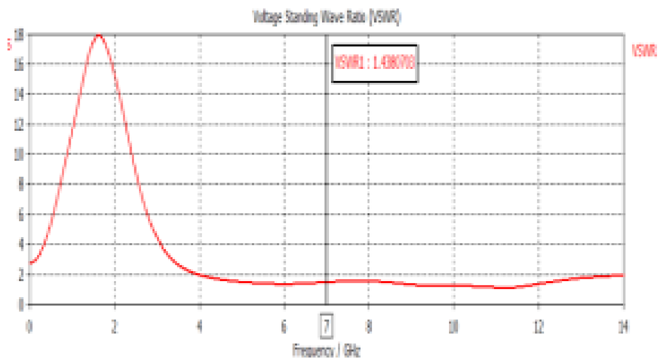

Figure 5.b. VSWR = 1.43

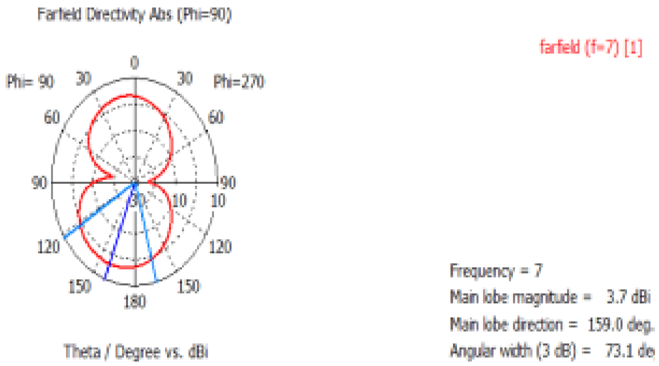

Figure 5.c. Directivity = 3.67 dB

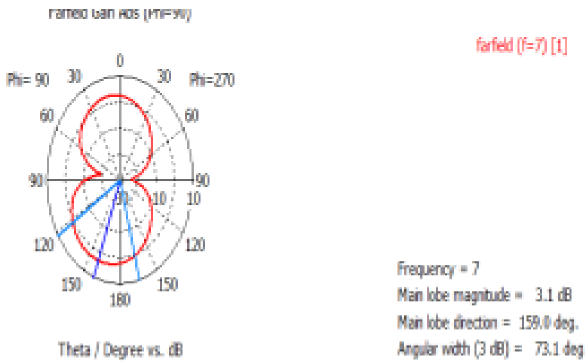

Figure 5.d. Gain = 3.1 dB

Pattern of Return Loss, VSWR, Gain, Directivity of Simple Circular Patch fr = 7.0 Ghz. The position of deep curve in return loss plot at resonating frequency 6.0 GHz, 9.59GHz and 11.24 GHz with Return Loss -17.64dB , -21.9dB ,-31.73 dB and with VSWR 1.31, 1.17,1.05. For Different variation of parameter Return Loss, VSWR, gain and Band width were changed shown in below Tables.

a) If thickness of substrate is varied at constant Ground Lg= 5mm, fr= 7.0 GHz

Table 6. Variation of Substrate thickness

No. Of Iteration	Substrate Thickness	Dielectric Constant	Operating Bandwidth GHz	Band width GHz	Return Loss(dB)	VSWR
1(Purple)	1.55	4.4	3.91-13.0	9.02	-14.24	1.48
2 (Blue)	1.6	4.4	4.0-13.3	9.30	-14.36	1.47
3 (Green)	1.7	4.4	4.0-13.38	9.38	-14.7	1.44
4 (Red)	**1.8**	**4.4**	**3.98-14.0**	**10.02**	**-14.85**	**1.44**

b) Simulated Return Loss Plot on Variation of h

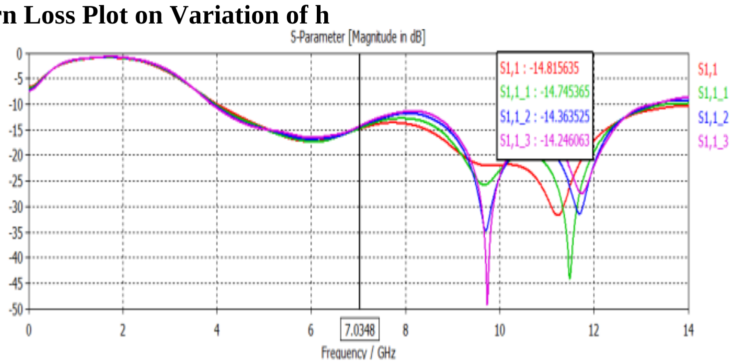

Figure5. e. Retutn Loss plot wrt h

c) If Slit Radius is varied (b & c)

Table 7. Variation of Dimension of Slit

Sl.No	Outer Slit Radius b(mm)	Inner Slit Radius c(mm)	Return Loss (dB)	VWSR	Band Width(GHz)
1	4	3	-16.86	1.33	10.1
2	4	3.5	-17.28	1.31	10.1
3	4	2.5	-16.5	1.34	10.1
4	4	3.8	-18.37	1.27	3.6, 6.0
5	5	3.8	-10.19	1.8	3.1, 5.34
6	5	4.5	-6.3	2.86	2.7, 6.2
7	**3**	**2**	**-14.9**	**1.4**	**10.1**

d) Return Loss Plot on Variation of b &c

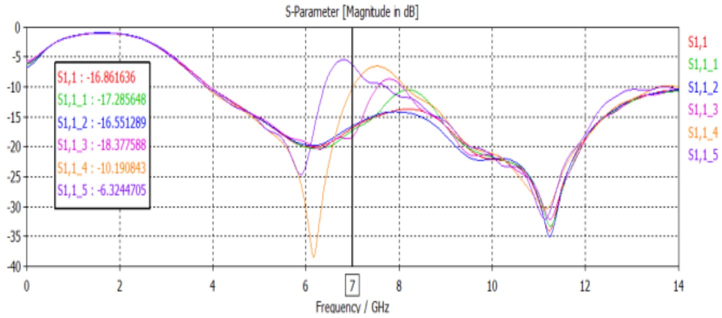

Figure 5. g. Retutn Loss plot wrt Slit dimension

e) If Lg varied at constant Slit Dimension

Table 8. Variation of L_g

Sl.No.	L_g(mm)	Return Loss(dB)	VSWR	Directivity(dB)	Gain(dB)	Band Width(GHz)
1	3	-7.63	2.4	3.67	2.968	0.82, 0.79,
2	**4**	**-10.26**	**1.88**	**3.673**	**3.052**	**3.27, 4.56**
3	**5**	**-14.9**	**1.4**	**3.671**	**3.10**	**10.1**
4	6	-14.78	1.44	3.67	3.12	5.31, 1.72

f) Simulated Return Loss Plot effect of Lg

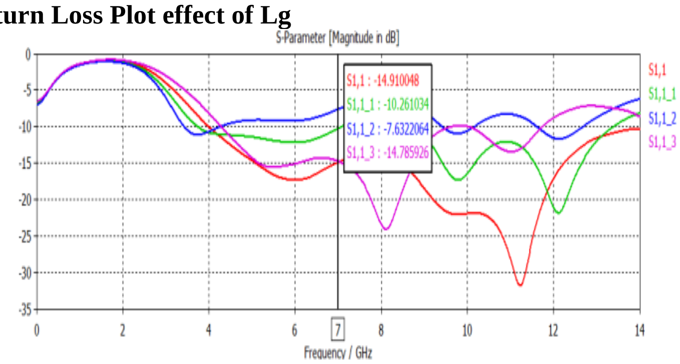

Figure 5. h. Retutn Loss plot wrt Lg

g) If Notch Width is varied on Ground Plane(WN)

Table 9. Variation of WN

Sl.No.	W_N(mm)	Return Loss(dB)	VSWR	Directivity(dB)	Gain(dB)	BW(GHz)
1	3	-17.33	1.31	3.65	3.09	10.1
2	4	-14.9	1.43	3.67	3.101	10.1
3	5	-12.6	1.61	3.66	3.08	8.6

h) Simulated Return loss Plot on Variation of W_N

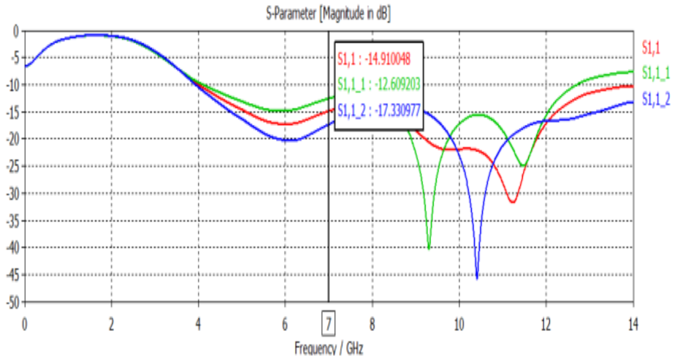

Figure 5. i. Retutn Loss plot wrt W_N

RLC circuit values Extended Circular MPA with Notch and Slit - The Equivalent lumped circuit model of return loss plot for Microstrip patch antenna can be achieved effectively by using series RLC circuit. A series connection of R, L, C can be assumed as band pass filter which only pass certain frequency and reject rest. From the Return loss plot from the valley at which resonance takes place and frequency changed from that point the R, L, and C is calculated with the formula .Equivalent Circuit is shown in Figure.5. j.

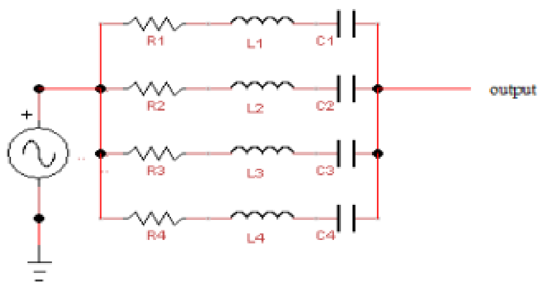

Figure 5. j. Equivalent RLC Model of Proposed Antenna

The Parameter were calculated with the help of Z0 =50 ohm= √(L/C), and the parameter were shown in table 10.

Table 10. RLC value for designed antenna

Sl. No	Resonating Frequency f_r(GHz)	Resistance (Ohm)	Inductance(nH)	Capacitance(pF)
1	4.0	R1= 11.4	L1= 1.9	C1=0.79
2	6.0	R2= 5.79	L2= 1.32	C2= 0.53
3	9.59	R3= 12.65	L3= 0.84	C3=0.38
4	11.24	R4= 6.7	L4= 0.71	C4= 0.28
5	14.0	R5= 6.42	L5 = 0.57	C5= 0.23

IX. Conclusion

These above proposed antenna structure's were simulation carried out using the CST Microwave Studio software. The Simulated results are presented, shows the usefulness of the proposed antenna structure for UWB applications. The simulation results of band notch antenna indicate that the designed antenna fulfils UBW band characteristics for various frequency bands and showing the good return loss and radiation patters as well as bandwidth and gain is also enhance which was shown in above results. The measured data demonstrates that it is in agreement with the simulated data. Antenna bandwidth is broad and at the same time the gain is reasonable high. The compactness of the antenna is very good, due to modified patch and ground plane. First Design achieves the return loss of -14.05dB and the bandwidth of 10.0 GHz(3.98- 13.98GHz) and corresponding VSWR is 1.48 < 2 for entire bandwidth range and the second design achieves the return loss of -15.07 dB and the bandwidth of 8.43 GHz (4.7- 3.1GHz) and corresponding VSWR is 1.42 < 2 for entire bandwidth range. RLC Parameter model are determined for each antenna & for different variation of parameter Rl, VSWR, Gain, and Directivity is also found out. The effect of dielectric substrate permittivity is also studied in this paper. As increment of substrate dielectric constant in antenna design results in the degradation of antenna performance.

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