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TRANSPARENT WATER DENSE DIELECTRIC PATCH ANTENNA

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ABSTRACT

The proposed antenna is a transparent water dense dielectric patch antenna which is fed by an L-shaped probe. The operating mechanism of the proposed antenna is similar to the standard metallic patch antenna. A study reveals that the gain of the antenna can be increased if the water patch is brought close to the L-shaped probe but the distance between the water patch and the L-shaped probe should be atleast 1 mm. A maximum gain of 7.3 dBi, return loss of 18.4 dB and impedance bandwidth of 575 MHz was achieved. It had symmetrical unidirectional patterns.

Keywords: water patch, distilled water, liquid antenna, dense dielectric patch antenna, L-probe, transparent patch antenna.

INTRODUCTION

Various liquids like mercury, liquid crystal, eutectic gallium indium [EGaIn] and water have been used due to many interesting properties that they possess, like transparency, liquidity and many more. Out of all these materials water is the most popular material due to various properties such as easy availability, safety and low cost. Generally, water which is used for designing antennas can be divided into two types: salt water and pure water. Salt water is generally used as a conductor to support the current flow whereas pure water is usually used to construct dielectric resonator antenna (DRA) where it is commonly used as dielectric. Since water has high dielectric loss, the radiation efficiency of these antennas is reduced.

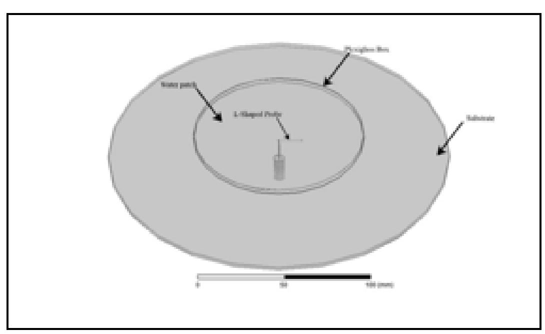
Lately, a new patch antenna has been designed called as Dense Dielectric Patch Antenna (DDPA). As compared to the standard patch antenna, the metallic patch is replaced by high permittivity thin dielectric slab. Since the permittivity of the supporting substrate is much lower than the dielectric patch, the waves get stuck between the ground plane and the dielectric patch. Hence, the boundary can be proximately seen as an electric wall. The outcome in exhibits that a cavity mode is excited in the area between the ground plane and dielectric patch. This shows the working principle of the DDPA resembles the working principle of metallic patch antenna.

As we all know that at room temperature pure water is a dielectric and has high permittivity at microwave frequencies. Subsequently, by applying the design of the DDPA, a novel DDPA made of water is proposed in this paper. In this water antenna, the antenna operates neither as a conductor for current flow nor as a dielectric resonator. It has just been used to provide a boundary condition similar to that of an electric wall. The required cavity mode can be excited when it is combined with the ground plane. In this paper an L-shaped probe has been used to apply feed to the water dielectric patch antenna. By using the L-probe, it makes the manufacturing of the antenna easy as the probe does not need to be connected to the water patch. Also since the pure water is transparent hence the antenna is also transparent.

Furthermore the paper has been divide into 3 sections. Section II is for geometry and design of the proposed antenna and section III states the simulated and measured results. Finally section IV gives a conclusion.

ANTENNA GEOMETRY AND DESIGN

Figure-1 displays the geometry of the proposed transparent water dense dielectric patch antenna. In order to realize the antenna a substrate whose radius is 100 mm, height is 2 mm and dielectric is 4.4 is chosen. Below the substrate there is a ground plane whose radius is 100 mm and is a perfect electric conductor. Now a circular slot is cut in the center of the ground plane with radius as 3 mm. Cut another circular slot in the center of the substrate with radius of 0.5 mm and height of 2 mm. Construct a cylinder below the center of the substrate with radius as 3 mm and height of 10 mm. Construct another cylinder under the previous cylinder with radius as 3 mm and height of 5 mm. Now draw an L-probe whose radius is 0.5 mm, has a vertical height of 26 mm and horizontal height of 14 mm. The L-probe should start from cylinder 2 and it should go all the way up through the cylinder 1, ground plane and substrate. Now create a patch which is 16 mm above the substrate. The patch will be stored in a container made of plexiglass whose dielectric constant is 3.5, outer radius is 50 mm, inner radius is 49.8 mm and thickness is 0.2 mm. It will be a hollow container in which distilled water will be stored whose dielectric constant is 81 and has a radius of 49.8 mm.



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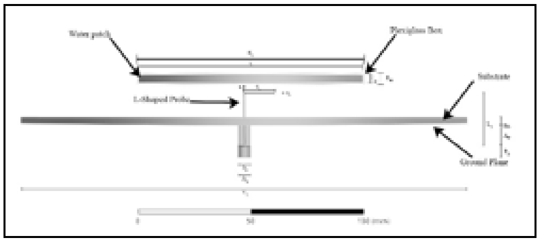

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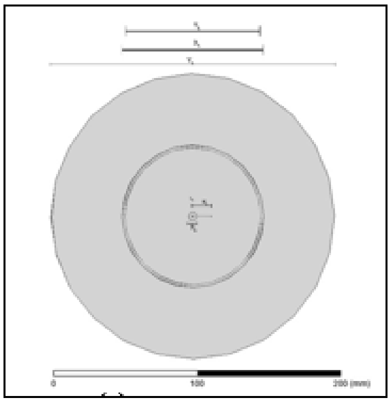
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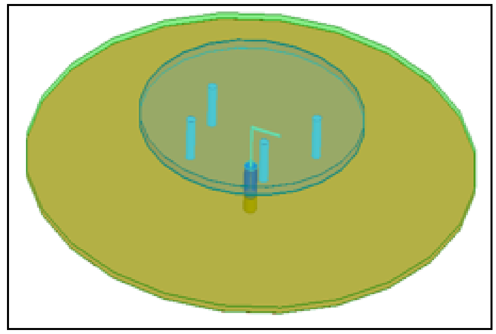
Figure-1. Geometry of the proposed L-probe transparent water dielectric patch antenna. (a) Overall geometry, (b) Side view, (c) Top view of the water patch with L-Probe.

Table-1. Dimensions of water dielectric patch antenna designs (units: mm).

S. No.	Parameters	Value
1.	AL	6
2.	AH	10
3.	YL	100
4.	BH	-0.1
5.	RL	99.6
6.	RH	2.6
7.	LL	1
8.	LH	26
9.	PL	3
10.	PH	5
11.	TL	100
1.2	TH	3
13.	KL	14
14.	KH	1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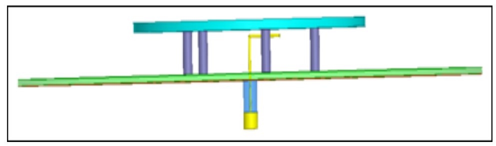
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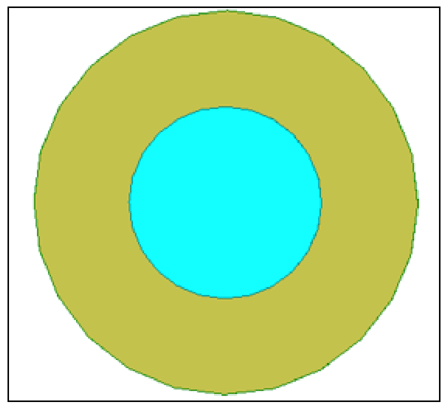
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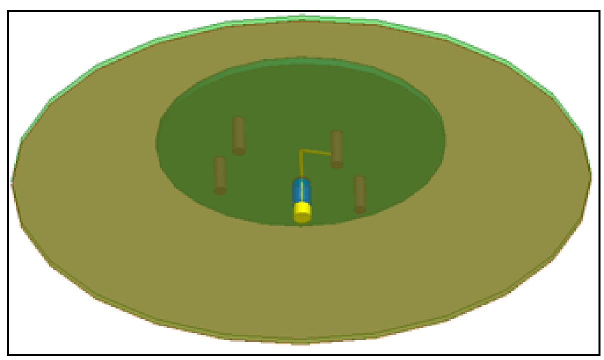
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Figure-2. Geometry of the proposed L-probe transparent water dielectric patch antenna. (a) Overall geometry, (b) Side view, (c) Top view of the water patch with L-probe. (d) Bottom view.

In our proposed antenna there is a water patch at the top of the design, now practically it is not possible to hang our water patch in air, so in that case we place 4 cylinders at different coordinates on the ground plane as shown in the above figures and assigned them a material

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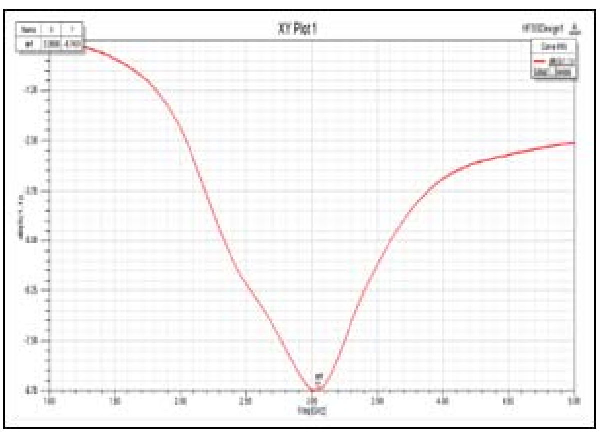
known as "Teflon based" having dielectric constant of 2.08 and since it is a non-radiating material we won't be getting any deflections on the results.

RESULT AND DESIGN

(a) Feed constant and gap increase by 1mm

Table-2. Dimensions of water dielectric patch antenna (Feed constant gap increase) designs (units).

S. No.	Parameters	Value
1.	AL	6
2.	AH	10
3.	YL	100
4.	BH	-0.1
5.	RL	99.6
6.	RH	2.6
7.	LL	1
8.	LH	27
9.	PL	3
10.	PH	5
11.	TL	100
12.	TH	3
13.	KL	10
14.	KH	1



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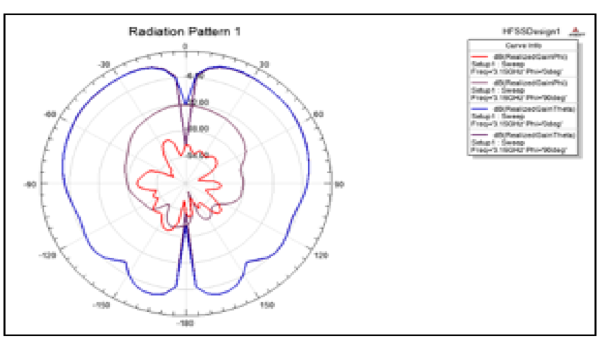

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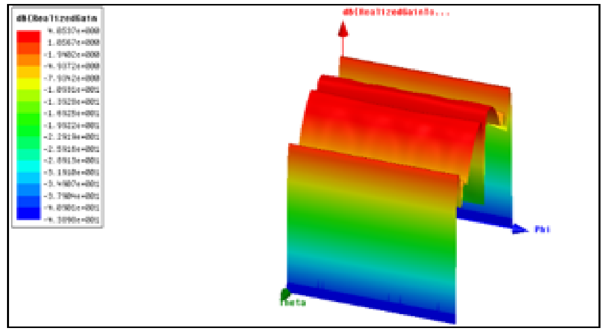

(c)

Figure-3. Results of the L-probe transparent water dielectric patch antenna when feed is constant and gap is increased (a) S Parameter, (b) Radiation pattern, (c) 3-D Polar plot.

Basically in this case we used the initial parameters and make the gap constant between L probe and water patch but instead of that we increased the height of feed from 26mm to 27mm which also changes the position of L-Probe from -0.5 , 0 , 13.5 to -0.5 , 0 , 14.5.

(b) Feed constant and gap increase by 10mm

Table-3. Dimensions of water dielectric patch antenna (Feed constant gap increase) designs (units: mm).

S. No.	Parameters	Value
1.	AL	6
2.	AH	10
3.	YL	100
4.	BH	-0.1
5.	RL	99.6
6.	RH	2.6
7.	LL	1
8.	LH	36
9.	PL	3
10.	PH	5
11.	TL	100
12.	TH	3
13.	KL	10
14.	KH	1

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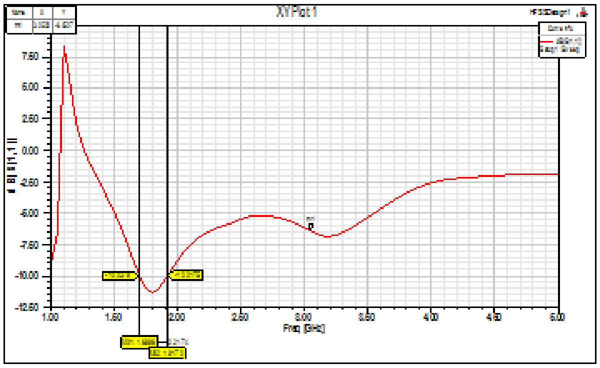

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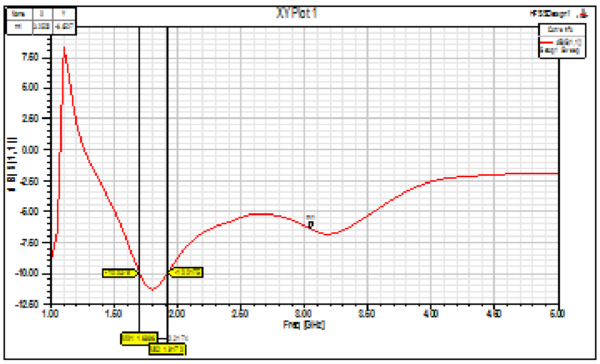

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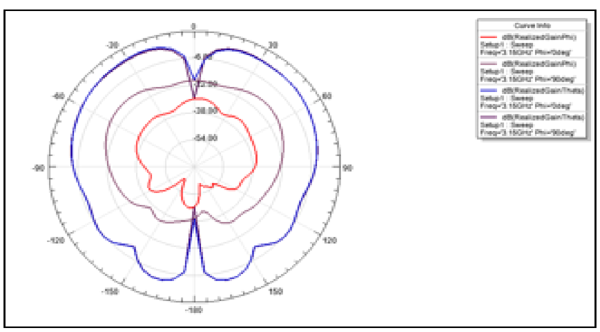

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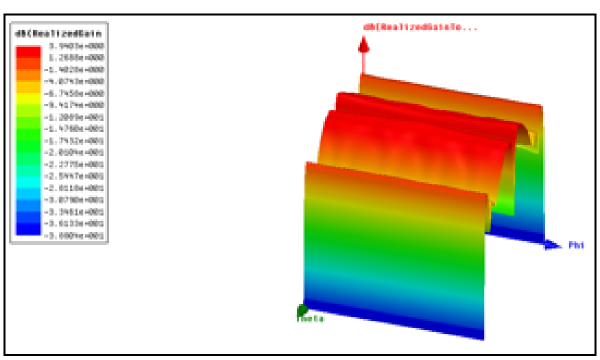

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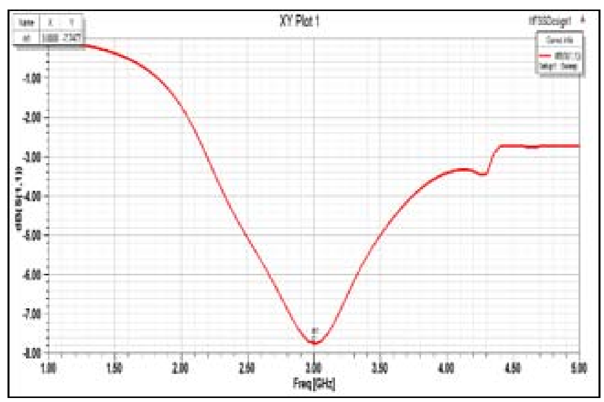
Figure-4. Results of the L-probe transparent water dielectric patch antenna when feed is constant and gap is increased (a) S Parameter (b) Impedance bandwidth (c) Radiation pattern (d) 3-D Polar plot.

Basically in this case we used the initial parameters and make the gap constant between L probe and water patch but instead of that we increased the height of feed from 26mm to 36mm which also changes the position of L-Probe from -0.5 ,0 ,13.5 to -0.5 ,0 ,23.5.

(a) Water patch diameter increase by 1mm

Table-4. Dimensions of water dielectric patch antenna (Water patch radius increase) designs (units: mm).

S. No.	Parameters	Value
1.	AL	6
2.	AH	10
3.	YL	100
4.	BH	-0.1
5.	RL	101.2
6.	RH	2.6
7.	LL	1
8.	LH	26
9.	PL	3
10.	PH	5
11.	TL	102
12.	TH	3
13.	KL	10
14.	KH	1



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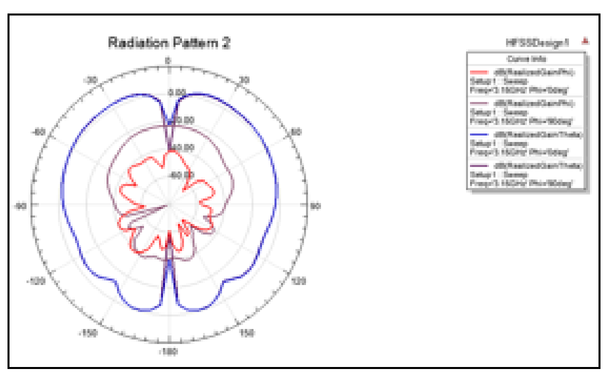

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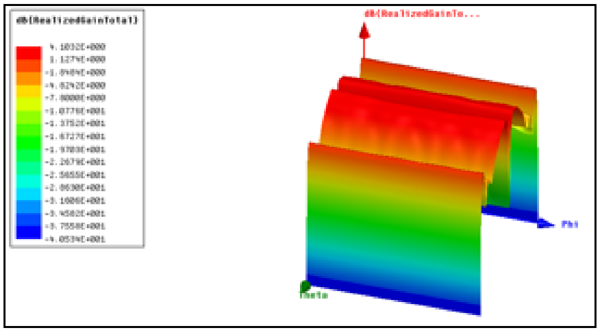

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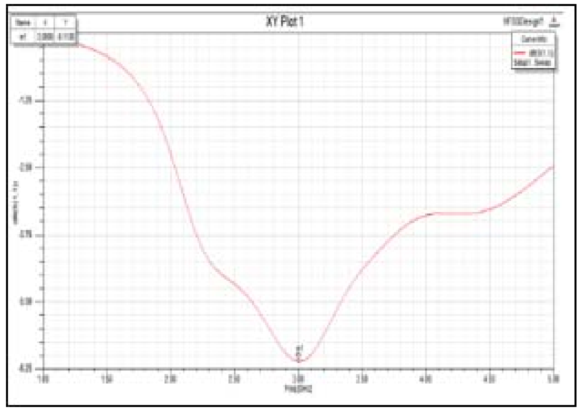
Figure-5. Results of the L-probe transparent water dielectric patch antenna when radius of water patch increases (a) S Parameter, (b) Radiation pattern (c) 3-D Polar plot.

By increasing the diameter of the water patch antenna by 1mm taking initial parameters as a reference such that the diameter of water patch will be RL=101.6m and TL=102mm, using these values we will implement the simulation and we got our results as shown in the Figure-5.

(b) Water patch diameter increase by 10mm

Table-5. Dimensions of water dielectric patch antenna (Water patch radius increase) designs (units: mm).

Values	Parameters	Value
1.	AL	6
2.	AH	10
3.	YL	100
4.	BH	-0.1
5.	RL	119.6
6.	RH	2.6
7.	LL	1
8.	LH	26
9.	PL	3
10.	PH	5
11.	TL	120
12.	TH	3
13.	KL	10
14.	KH	1



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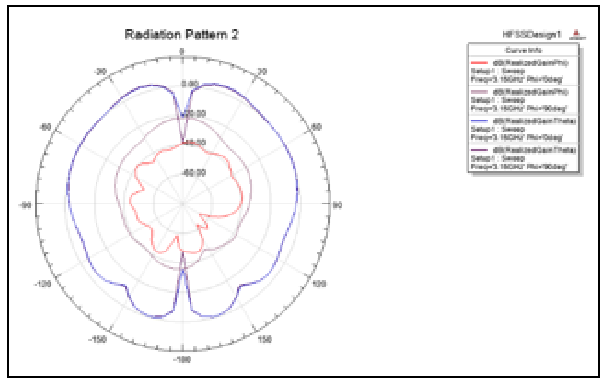

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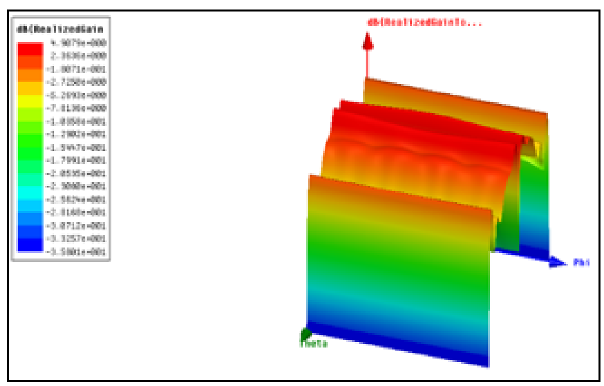

(c)

Figure-6. Results of the L-probe transparent water dielectric patch antenna when radius of water patch increases (a) S Parameter, (b) Radiation pattern (c) 3-D Polar plot.

By increasing the diameter of the water patch antenna by 10mm taking initial parameters as a reference such that the diameter of water patch will be RL=119.6m and TL=120mm, using these values we will implement the simulation and we got our results as shown in the Figure-6.

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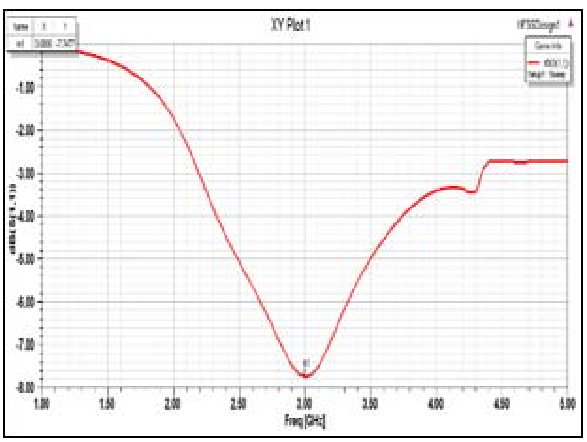
(a) Water patch diameter decrease by 1mm

Table-6. Dimensions of water dielectric patch Antenna (Water patch radius decrease) designs (Units: mm).

S. No.	Parameters	Value
1.	AL	6
2.	AH	10
3.	YL	100
4.	BH	-0.1
5.	RL	97.6
6.	RH	2.6
7.	LL	1
8.	LH	26
9.	PL	3
10.	PH	5
11.	TL	98
12.	TH	3
13.	KL	10
14.	KH	1



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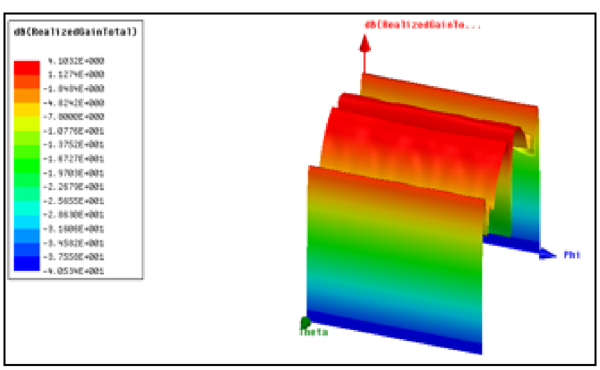
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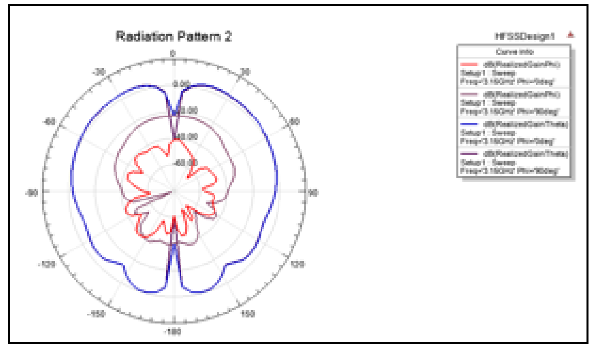

(c)

Figure-7. Results of the L-probe transparent water dielectric patch antenna when radius of water patch decreases (a) S Parameter, (b) Radiation pattern (c) 3-D Polar plot.

By decreasing the diameter of the water patch antenna by 1mm taking initial parameters as a reference such that the diameter of water patch will be RL=97.6m and TL=98mm, using these values we will implement the simulation and we got our results as shown in the Figure-7.

(b) Water patch diameter decrease by 10mm

Table-7. Dimensions of water dielectric patch antenna (Water patch radius decrease) designs (units: mm).

S. No.	Parameters	Value
1.	AL	6
2.	AH	10
3.	YL	100
4.	BH	-0.1
5.	RL	79.6
6.	RH	2.6
7.	LL	1
8.	LH	26
9.	PL	3
10.	PH	5
11.	TL	80
12.	TH	3
13.	KL	10
14.	KH	1

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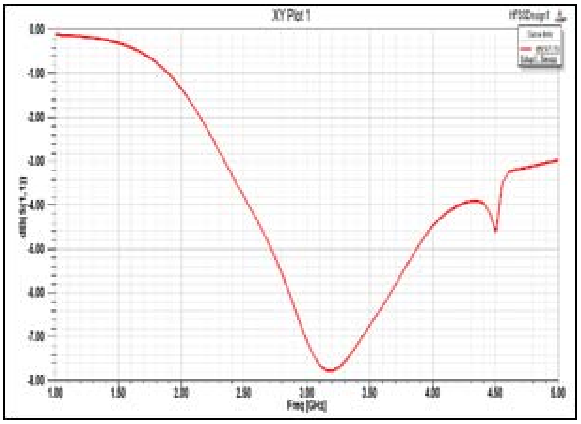

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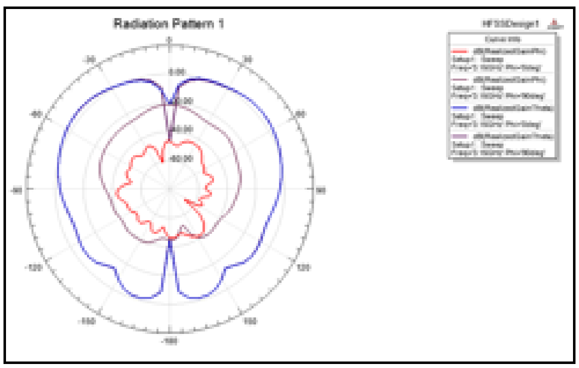

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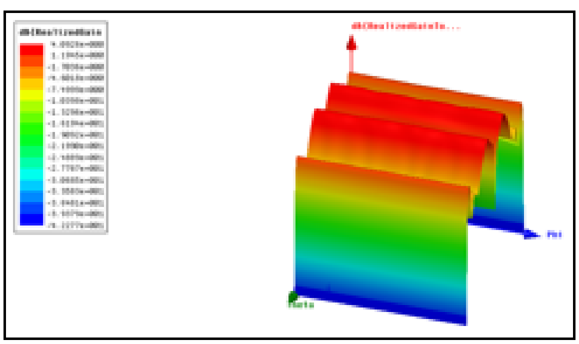
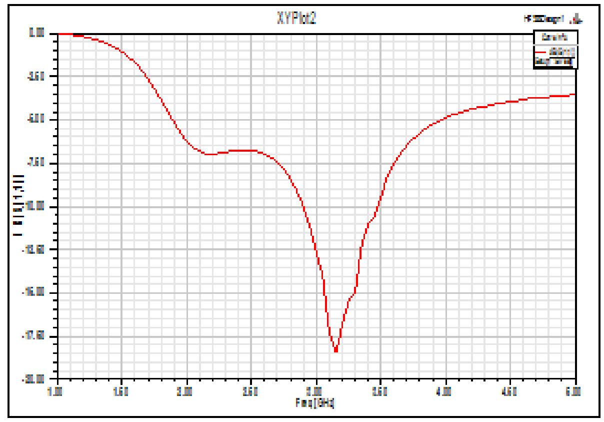


Figure-8. Results of the L-probe transparent water dielectric patch antenna when radius of water patch decreases (a) S Parameter, (b) Radiation pattern (c) 3-D Polar plot.

By decreasing the diameter of the water patch antenna by 10mm taking initial parameters as a reference such that the diameter of water patch will be RL=79.6m and TL=80mm, using these values we will implement the simulation and we got our results as shown in the Figure-8.

Feed constant gap decrease

The simulated distributions of electric field can be shown in the figure. The electric field noticeable all around substrate between the ground plane and water patch is stronger than that in the water dielectric patch. The field is emanated from the two open finishes of the water dielectric patch. Hence it is affirmed that the design of the water dielectric patch operates as a patch antenna.



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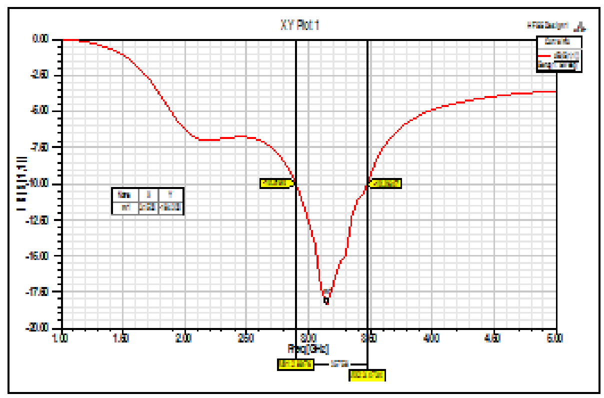

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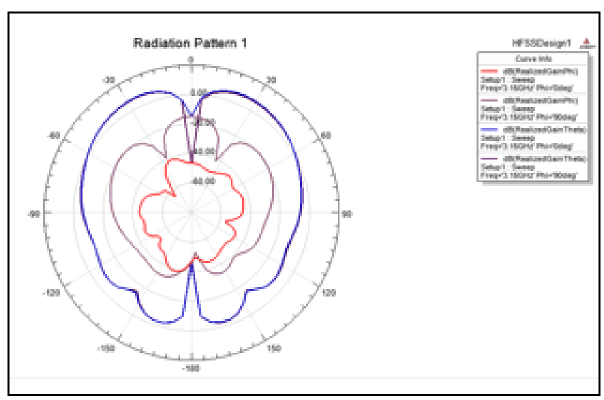

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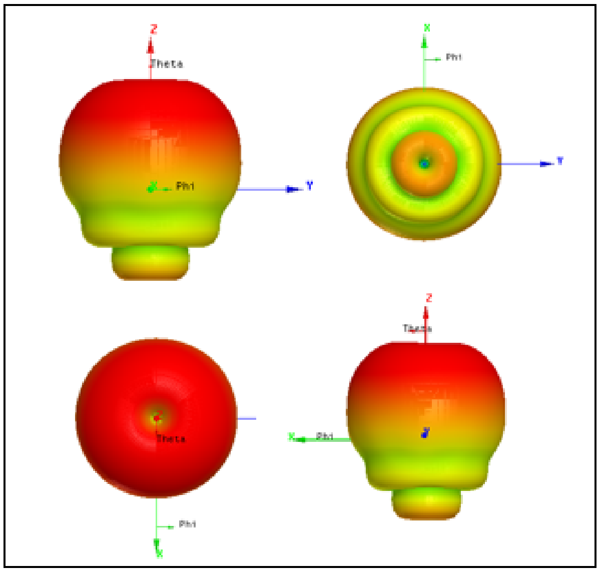

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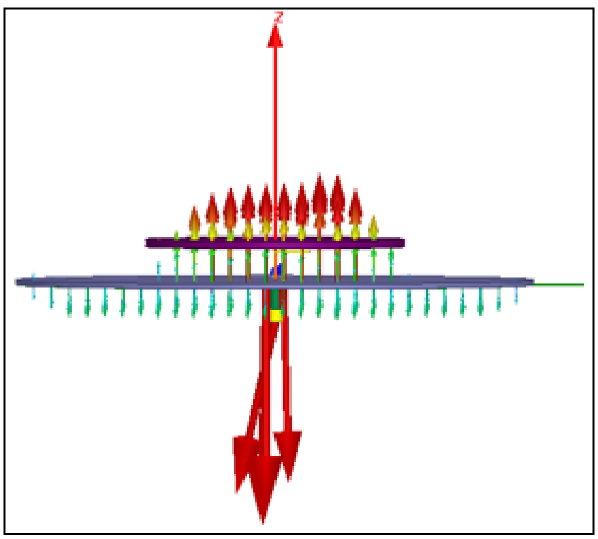

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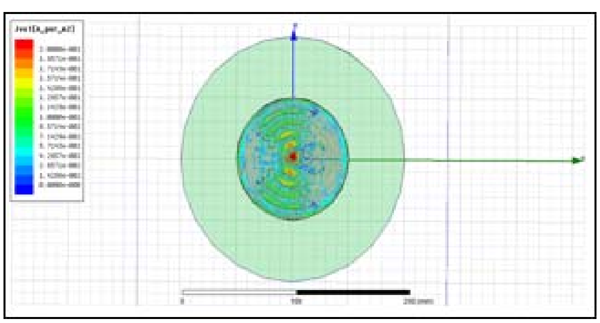

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Figure-9. Results of the L-probe transparent water dielectric patch antenna when feed is constant and gap is increased (a) S Parameter, (b) Impedance BW (c) Radiation plot, (d) 3-D Polar plot(include side, top and front view), (e) Current distribution (J Volume) on ground Plane, (f) Magnitude distribution on water patch.

As the antenna works in a patch mode, a small amount of energy goes through the water patch which does not result in much loss of efficiency of the antenna. As we can see in the figure that $|S_{11}|$ is equal to -18.4 dBi and the impedance bandwidth is equal to 575 MHz. The maximum gain is equal to 7.2944 dB.

Table-8. Parameter analysis.

Parameters	i (a)	i (b)	ii (a)	ii (b)	iii (a)	iii (b)	iv
Max U	0.20969(W/sr)	0.197156(W/sr)	204.689281 mW/sr	0.246361(W/sr)	0.186527(W/sr)	0.204193(W/sr)	0.4268(W/sr)
Peak Directivity	3.05154	3.11715	3.083621	4.11578	2.77271	3.03391	5.35662
Peak Gain	4.2	3.9403	4.1032	4.9079	4.1032	4.0926	7.2944
Radiated Power	0.863534(W)	0.794827(W)	834.169177 mW	0.75221(W)	0.845392(W)	0.845782(W)	1.00128(W)
Accepted Power	0.851535(W)	0.791816(W)	810.124132 mW	0.737732(W)	0.828685(W)	0.832569(W)	0.985546(W)
Incident Power	1(W)	1(W)	1(W)	1(W)	1(W)	1(W)	1(W)
Radiation Efficiency	1.01409	1.0038	1.029681	1.01963	1.02016	1.01587	1.01596
Front to Back Ratio	5.34032	5.22334	4.992384	3.86834	4.83237	10.2945	16.5039
Return Loss	-8.7326 at 3.05 GHz	-6.5407 at 3.0500 GHz	-7.7477 at 3 GHz	-6.1138 at 3.0 GHz	-8.0327 at 3.05 GHz	-7.7761 at 3.2 GHz	-18.400 at 3.15GHz
Impedance Bandwidth	NIL	0.2174 GHz or 217.4 MHz	NIL	NIL	NIL	NIL	0.5758 GHz or 575 MHz

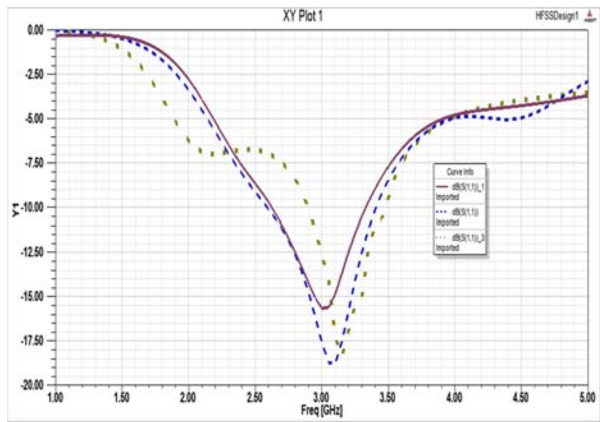

Figure-10. Three resonating frequencies at three different gap decrease of 10mm (Violet Line), 12mm (Blue Short Dash) and 14.5mm (Green Dots).

CONCLUSIONS

A transparent water dense dielectric patch antenna fed by an L-shaped probe has been proposed. In distinction with the rumored water monopoles and the water material resonator antennas, the planned water stuff patch antenna made by pure water ions has the similar regulation and working compared with the standard gold or metallic bearing patch antenna. Along with water patch we used L-Probe feeding technique also. The performance of the proposed antenna has been investigated, which demonstrates that by keeping the feed constant and decreasing the gap between L-probe and water patch our antenna has been realized. Animpedancebandwidthof575 MHz, return loss of -18.400 at 3.15GHz and peak gain of 7.2944 has been obtained.

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