IMPROVEMENT IN MICROSTRIP PATCH ANTENNA CHARACTERISTICS USING MULTIPLE LAYERED SUBSTRATE STRUCTURE

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ABSTRACT *— New wireless specifications for the 802.11 also known as Wi-Fi have moved to the 5GHz range due to 2.4GHz range being overcrowded by other applications. This opens up a possibility of this small and efficient antenna design being implemented on to that application. In this paper, we have designed an antenna that provides simultaneous improvements in gain, directivity and bandwidth in an acceptably small package. A sandwiched layer of substrate, high and low was implemented, reflection loss, gain and bandwidth were evaluated. The results were compared with a single layered dielectric substrate patch antenna. Considerable improvements in bandwidth were achieved using this method. Multiple Substrate layers were incorporated into the antenna to increase bandwidth and reduce surface waves that would adversely affect the efficiency. The antenna size was kept at a minimum to minimize any size constraints in the application of the designed antenna. A low permittivity dielectric has a high bandwidth, but a large size and if a high permittivity dielectric is used, the size is reduced but at the expense of bandwidth. By using a multiple layer substrate structure, a combination of both is achieved.*

Index Terms — Microstrip patch antenna (MPA), Multiple Layered, CST.

INTRODUCTION

Antennas are the main component of modern communication system and the modern society may not be the way it is if it weren't from the advancements in this technology. Antennas are used to receive and transmit electromagnetic signals. The transmit side runs an accelerated charge (varying current) through the antenna which creates an electromagnetic disturbance that propagates to the outward environment, the intensity becomes less as it propagates further from the transmitter. While receiving, the antenna can collect these electromagnetic waves and read these signals [1], [2].

A lot of research is being done on the employment of multiple substrates to improve the antenna parameters. In [3] MEMS process was used to fabricate a small sized microstrip patch antenna at 5GHz using multiple substrates, giving it broadband characteristics. The results showed that the antenna Gain was at 1 dBi with a bandwidth of 0.4 GHz at 5.3 GHz frequency. In [4] simultaneous increase in gain and bandwidth of a microstrip patch antenna was achieved by using an electromagnetic band gap (EBG) structure which is essentially a substrate layer that has holes drilled in to suppress the surface waves and hence the loss associated with them. This improved the bandwidth with the use of multiple layered substrates in an EBG structure. Moreover in [5] a Micro Strip Patch Antenna designed at 6.5GHz was presented, multiple layered substrates were incorporated I it as well which raised the gain to 10 dBi.

In this paper a multiple layered substrate design of up to five layers is presented, with high and low layers sandwiched between the base plate and patch. The dimensions of all designs were kept persistent and the effective dielectric constant was also kept the same. The design and results are shown in section II and III. Directivity, Gain and Bandwidth were observed and the results have been tabulated and displayed as figure of merit in section III. A comparison is made between the obtained results in section IV.

II. ANTENNA DESIGN

While designing, the same dimensions were used for all of the arrangements, with just the layers of the patches reformed. The total thickness of the substrate kept the same even with multiple layers [6].

The substrate used for the single layered patch had Silicon, $\epsilon_r = 9.54$, as the dielectric substrate. For multiple layers, to make the effective dielectric constant, two substrates i.e. Glass (Pyrex), $\epsilon_r = 4.82$, and Silicon, $\epsilon_r = 11.9$, were used.

Layered Substrate Patch

Table I illustrates the dimensions used for the patch shown in Fig 1 and 2. The width and length of the ground plane were both kept at 20mm and the thickness of the selected copper plate used in the ground place was 0.5mm. Only the height of the substrate layers was changed for each iteration of the results.

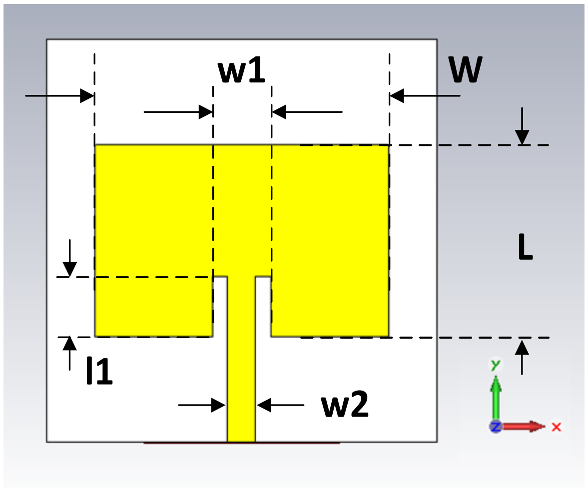

Fig. 1. Single Layered Substrate Microstrip Patch (top view)

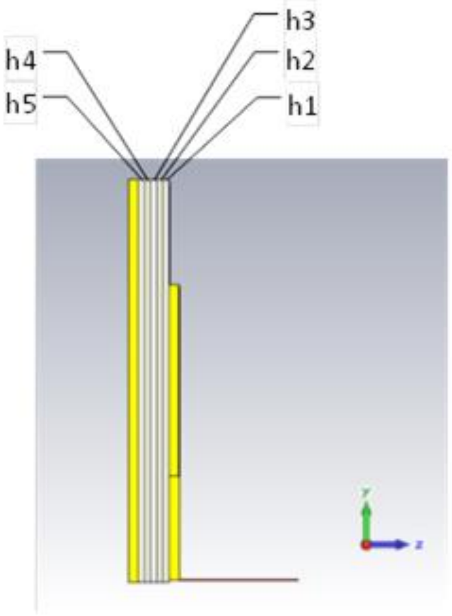

Fig. 2. Single Layered Substrate Microstrip Patch (side view)

III. SIMULATION RESULTS

One Layered Substrate Patch:

A conventional microstrip patch antenna is considered as a base case for comparison between multiple layered structures of the microstrip patch antenna. The antenna dimensions have been mentioned in Table I. For the single layered patch a median layer of silicon with $\epsilon_r = 9.54$ was chosen, this provided us with the results we could use to study the multiple substrate structure through comparison [4]. The results achieved for mismatch parameters, gain, directivity and bandwidth are 4.266 dB, 5.199 dB (Fig 3) and 0.25198 GHz (Fig 4) respectively. These results are shown in Table II as a comparison.

Two Layered Substrate Patch:

The double layered substrate structure had the low permittivity dielectric (Glass (Pyrex), $\epsilon_r = 4.82$) in contact with the patch. The high permittivity dielectric (Silicon, $\epsilon_r = 11.9$) lay just above the ground plane. The dimensions of this antenna have already been mentioned in Table I [4]. The gain (Fig 5 Left) of this antenna improved significantly for the double layered structure (almost 1.5 times), the directivity (Fig 5 Right) however remained almost unchanged for this configuration and the bandwidth also experienced some improvements (around 20%). This was due to the increase in efficiency because of the lowered surface wave loss in multiple layered structures. The results achieved for mismatch parameter, gain, directivity and bandwidth are shown in Table II for comparison.

Three Layered Substrate Patch:

The three layered substrate structure had the high permittivity dielectric (Silicon, $\epsilon_r = 11.9$) in contact with the patch. The low permittivity dielectric substrate (Glass (Pyrex), $\epsilon_r = 4.82$) was sandwiched between the two layers of silicon. The dimensions of this antenna have already been mentioned in Table I [4]. The gain (Fig 7 Left) of this antenna decreased rather than increase for the three layered structure in the given configuration, the directivity (Fig 7 Right) remained unaffected as before. The bandwidth (Fig 8) was the only parameter that improved (7%) which is because of more bowed out fringing fields that result in better radiation. The results achieved for mismatch parameter, gain, directivity and bandwidth are shown in Table II for comparison.

TABLE I. DIMENSIONS

Multiple Layered Substrate Patch Dimensions						
Description	Parameter	Number of Layers				
		1	2	3	4	5
1^{st} Substrate(Si)	Silicon, ϵ_r	9.54	11.9	11.9	11.9	11.9
2^{nd} Substrate(Gl)	Glass (Pyrex), ϵ_r	X	4.82	4.82	4.82	4.82
h1 (Si)	1st Substrate Height(Si)	1.5 mm	1 mm	0.5 mm	0.45 mm	0.3 mm
h2(Gl)	2nd Substrate Height(Gl)	X	0.5 mm	0.5 mm	0.3 mm	0.3 mm
h3 (Si)	3rd Substrate Height(Si)	X	X	0.5 mm	0.45 mm	0.3 mm
h4(Gl)	4th Substrate Height(Gl)	X	X	X	0.3 mm	0.3 mm
h5 (Si)	5th Substrate Height(Si)	X	X	X	X	0.3 mm
L	Patch Length	9.5 mm	9.5 mm	9.5 mm	9.5 mm	9.5 mm
W	Patch Width	15 mm	15 mm	15 mm	15 mm	15 mm
l1	Inset Length	3 mm	3 mm	3 mm	3 mm	3 mm
w1	Inset Width	3 mm	3 mm	3 mm	3 mm	3 mm
l2	Feed Line Length	6 mm	6 mm	6 mm	6 mm	6 mm
w2	Feed Line Width	1.4368 mm	1.4368 mm	1.4368 mm	1.4368 mm	1.4368 mm

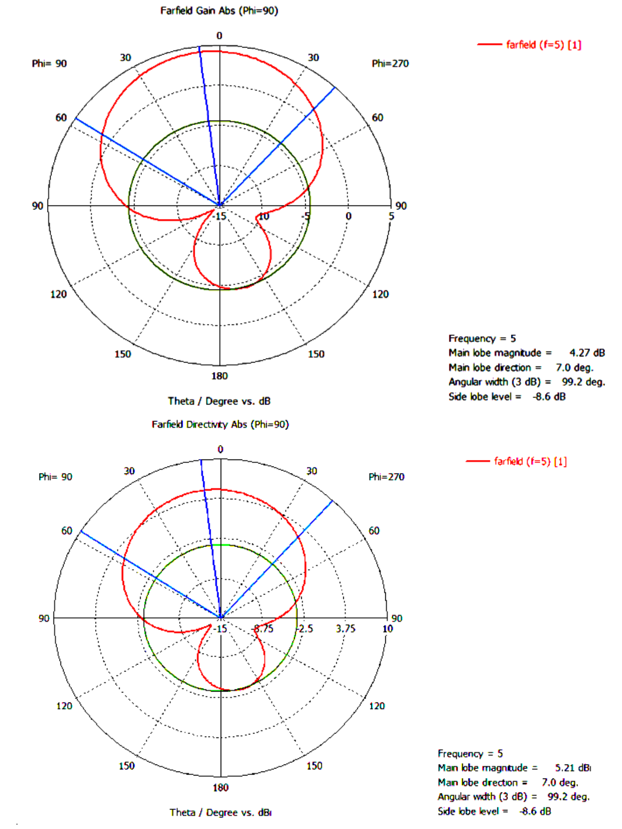

Fig. 3. One Layered Substrate Patch Far-Field Gain (left) and Directivity (Right)

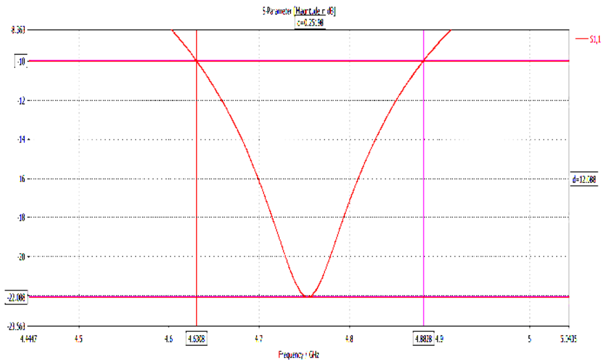

Fig. 4. One Layered Substrate Patch Bandwidth

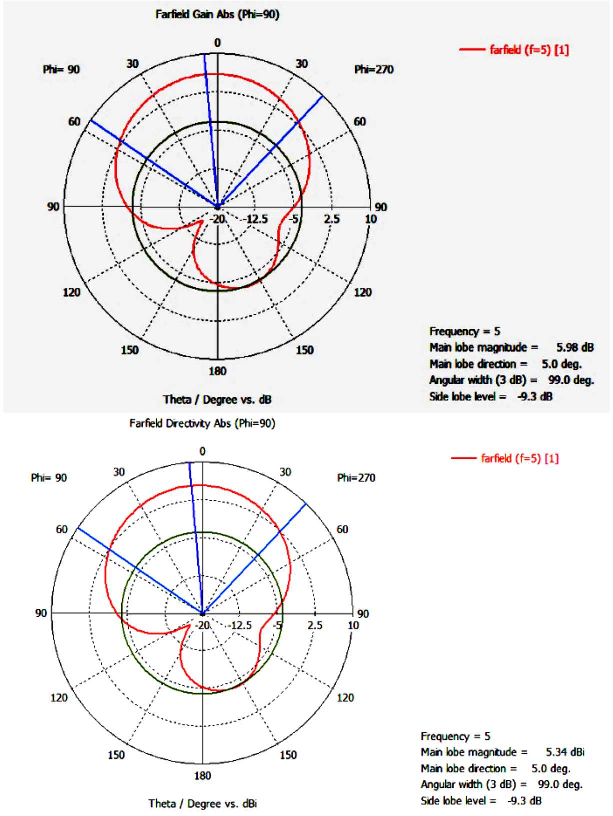

Fig. 5. Two Layered Substrate Patch Far-Field Gain (Left) and Directivity (Right)

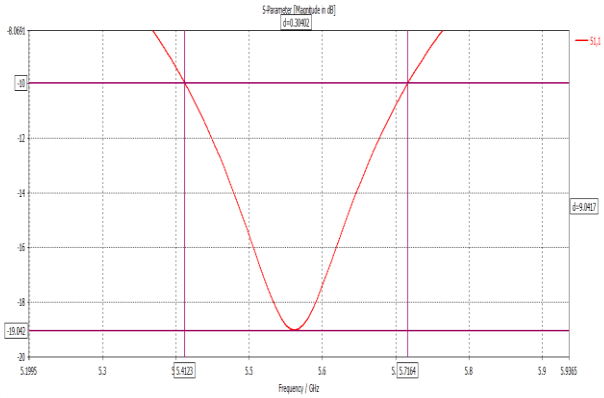

Fig. 6. Two Layered Substrate Patch Bandwidth

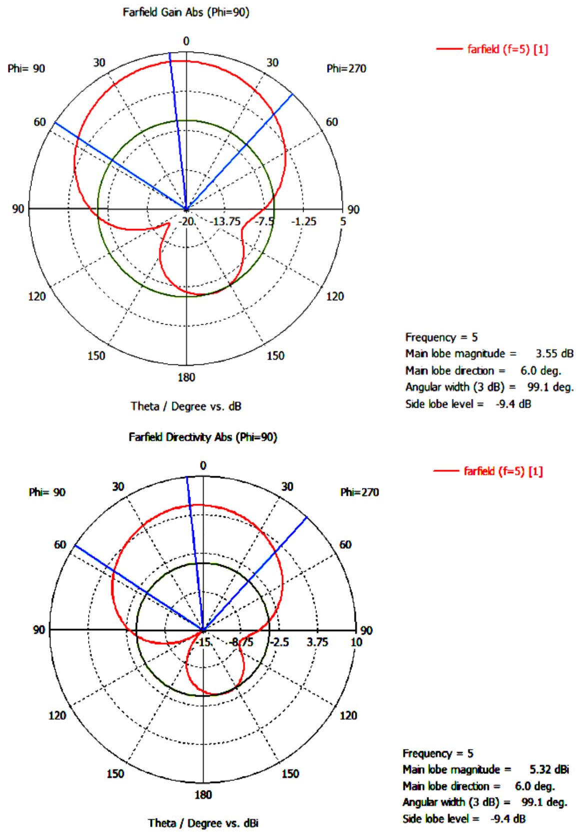

Fig. 7. Three Layered Substrate Patch Far-Field Gain (Left) and Directivity (Right)

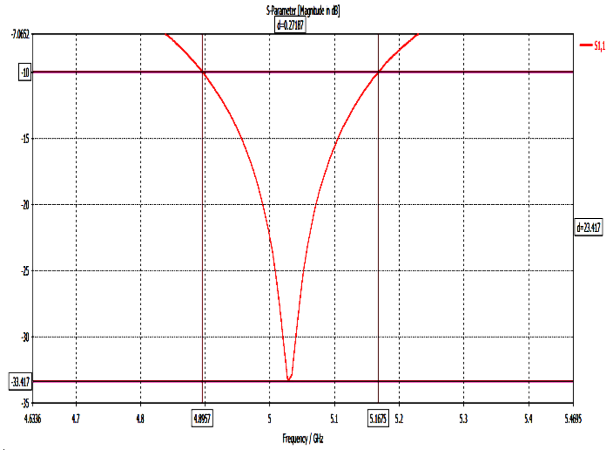

Fig. 8. Three Layered Substrate Patch Bandwidth

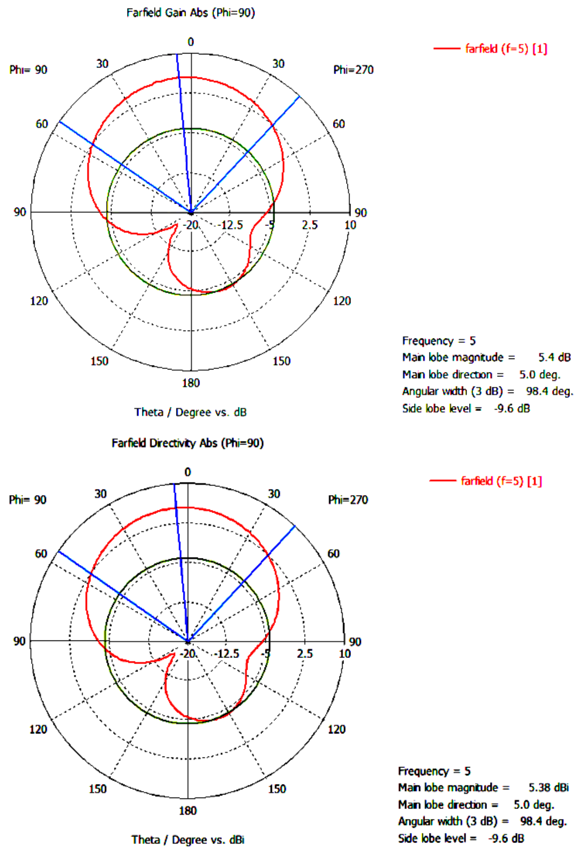

Fig. 9. Four Layered Substrate Patch Far-Field Gain (Left) and Directivity (Right)

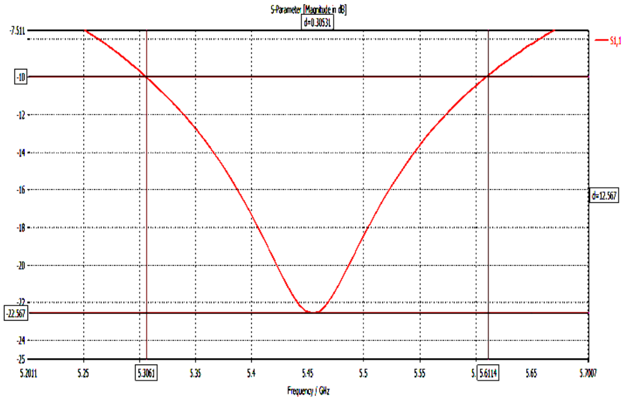

Fig. 10. Four Layered Substrate Patch Bandwidth

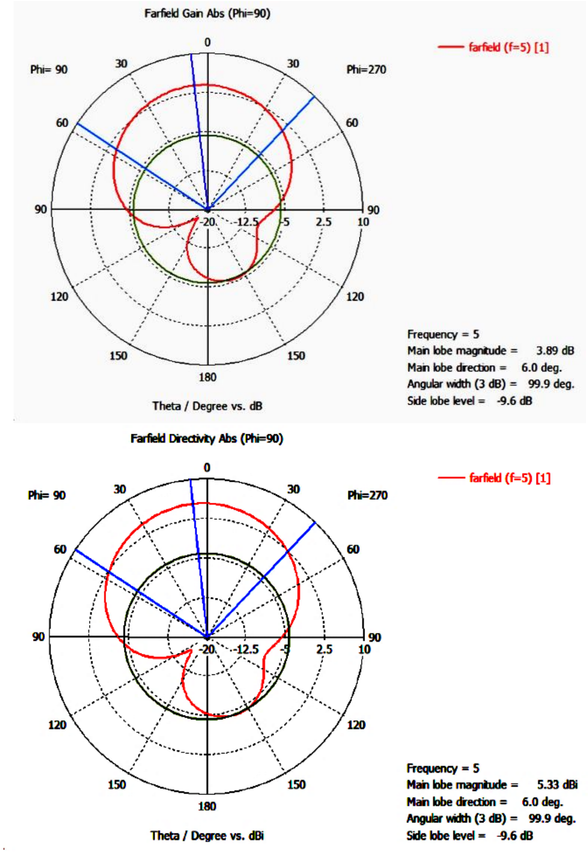

Fig. 11. Five Layered Substrate Patch Far-Field Gain (Left) and Directivity (Right)

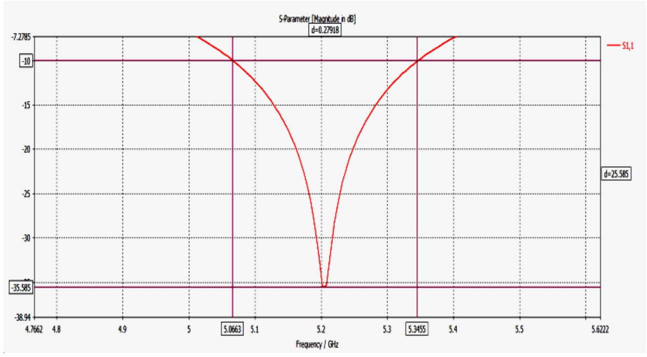

Fig. 12. Five Layered Substrate Patch Bandwidth

TABLE II. RESULTS COMPARISON

Number of Substrate Layers	*Gain*		*Directivity*		*Bandwidth*	
	dB	% Change*	dB	% Change*	GHz	% Change*
1	4.266	N/A	5.199	N/A	0.25198	N/A
2	5.976	140.084	5.338	102.674	0.30402	120.652
3	3.546	83.122	3.546	102.231	0.27187	107.893
4	5.397	126.512	5.397	103.462	0.30531	121.164
5	3.890	91.186	3.890	102.404	0.27918	110.795

Four Layered Substrate Patch:

The four layered substrate structure had the low permittivity dielectric (Glass (Pyrex), $\epsilon_r = 4.82$) in contact with the patch and the high permittivity dielectric (Silicon, $\epsilon_r = 11.9$) right below it, another pair of the same sequence followed to make a four layered structure between the patch and the ground plane. The dimensions of this antenna have already been mentioned in Table I [4].

The gain (Fig 9 Left) of the four layer configuration improved again, the directivity (Fig 9 Right), as before, remained unaffected. The bandwidth (Fig 10) also experienced some improvements (around 21% more). The Gain did not improve as much as it did in 2 layer patch due to a possible limitation reached on substrate layer. The results achieved for mismatch parameter, gain, directivity and bandwidth are shown in Table II for comparison.

Five Layered Substrate Patch:

The Five layered substrate structure consisted of the high permittivity dielectric (Silicon, $\epsilon_r = 11.9$) in contact with the patch. The low permittivity dielectric (Glass (Pyrex), $\epsilon_r = 4.82$) was right below it. Then high then low and then high dielectric constant substrates followed to make this five layered structure. The dimensions of this antenna have already been mentioned in Table I [4].

The gain (Fig 11 Left) of this antenna dipped again as with the three layered structure, the directivity (Fig 11 Right) was not effected as before. The bandwidth (Fig 12) increased ever so slightly. The increase in only bandwidth is due to the patch contact with the high or low substrate. The results achieved for mismatch parameter, gain, directivity and bandwidth are shown in Table II as a comparison.

IV. CONCLUSION AND OBSERVATIONS

A comparison was made between the single layered and multiple layered dielectric substrate patch at 5GHz. It was observed that as the number of substrate layers increase the bandwidth also increases. The gain of the antenna showed significant improvements as well when the number of substrate layers increased.

Table II shows the comparison between the five configurations of substrate that were used for the patches. It was observed that the Gain improves when multiple substrates are incorporated into the same structure. Number of substrate layers has no effect on directivity [5]. The reflection coefficients improve with increase in the number of substrates. Bandwidth improves when the number of substrates is increased but more so in the case of the patch directly in contact with the low permittivity dielectric substrate which can be evaluated in a further working on the subject.

V. FUTURE WORK

A further work could include creating a patch with even more substrate layers and checking for the effect of having the copper patch directly in contact with different substrates noted and tabulated. This would give a better view of the effect of the patch in contact with the substrate affecting the fringing fields, hence the radiation [7], [8].

This antenna design could be employed in the IEEE 802.11ac and 802.11ah standards as this design occupies lesser space compared to the other techniques used for the enhancement of bandwidth and gain. [9]

VI. REFERENCES

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