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***Abstract*—Stacking of parasitic patch layers on rectangular micro strip patch antennas and its effect on the bandwidth and gain of the antenna are analyzed. For that two different frequencies 2.4 GHz and 11.5 GHz have been chosen from S band and X band respectively and stacking of patch layers have been done up to a certain limit assuming the minimum requirement of gain of 10 dB for S band antenna array and 12 dB for X band antenna array. So in both the cases, at first a 2x2 rectangular patch antenna arrays have been optimized to reach up to the gain requirement and then the stacking of parasitic layers have been done and results are checked and analyzed one by one.**

Keywords*— Patch antenna, Micro strip antenna, Bandwidth Improvement, Stacking of Patches, S band , X band , Antenna array, Parasitic patch layer.

1. Introduction

Patch antenna is one of the most popular and most commonly used micro strip antennas. It is widely used in portable wireless devices for the ease of fabricating it on printed circuit boards. The micro strip is actually a very thin metallic strip placed on a ground plane with a dielectric material in between patch and ground plane. When the antenna is excited, the electromagnetic waves generated within the dielectric undergo reflections and the energy is radiated from the edges of the metal patch. These multiple patch antennas can be used to make a high gain antenna array. Micro strip patch antenna has lower fabrication cost, smaller size, lower mass and they are even capable of dual or tri band operations. But using micro strip patch antenna provides also some challenges towards us as a form of its lower gain, lower power handling capability, inherently lower band width, lower efficiency due to dielectric loss and conductor loss etc.

There are different bandwidth improvement techniques already available to us to improve the bandwidth of a microstrip patch antenna. Some of the popular bandwidth improvement techniques are aperture coupled, sequentially rotated array, stacking of patches, proximity coupled etc. Aperture coupled and proximity coupled are actually two different feeding techniques to the microstrip patch antenna. They are also called non-contacting feeding because in those cases the feed is not directly connected with the patch itself or via any usual microstrip line. In case of sequentially rotated array, the array elements are nothing but just rotated at a particular angle value to enhance the bandwidth of the antenna array though it is not a very effective way of bandwidth improvement. And stacking of patches is what the domain of our interest here is to work on. It is a layer of just metallic patches, printed on a substrate layer and those are not connected to any of the feed. Each of those patches are positioned aligned with antenna axis for each of the radiating antenna elements of its lower substrate level. These types of patches are also known as parasitic patches.

So, using stacking technique, the bandwidth of the antenna arrays will be observed and analyzed here and it will be an investigation to find out the limitations of the bandwidth improvement techniques by patch stacking.

2. Analysis of Designs at 2.4 GHz

At first case, the S band frequency 2.4 GHz is considered to go ahead with. So, the baseline is established using 2x2 array of single layer conventional rectangular patch antennas at 2.4 GHz, designed using Rogers 5880. Its patch length 38.5mm , patch width 44mm and substrate height 3.2mm , total ground plane length for array 162mm , total ground plane width for array 155mm.

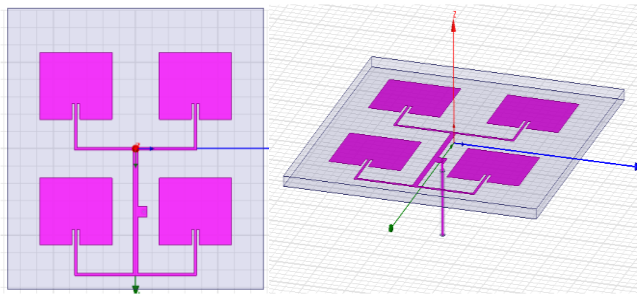

Fig-1:Design of 2x2 patch antenna array at 2.4 GHz

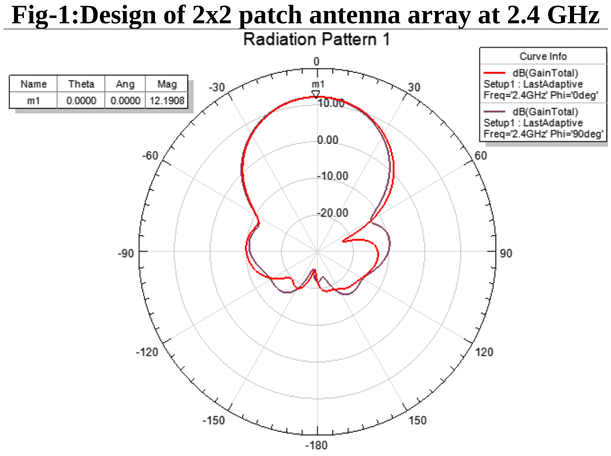

Fig-2:Gain = 12.19 dB.

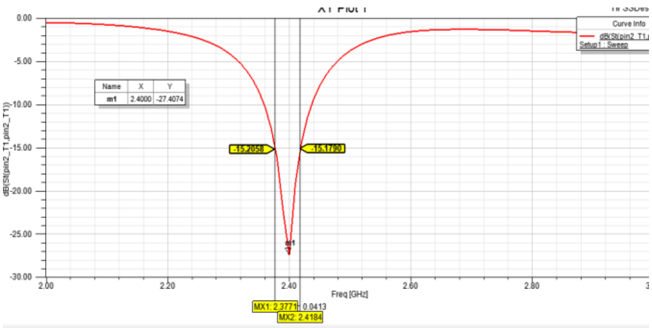

Fig-3: Return loss = -27.4 dB , Bandwidth = 0.0413 GHz = 41.3 MHz

2.1 Stack layer 1:

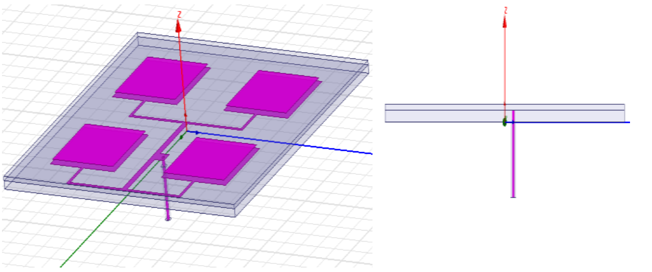

Fig-4: Design of antenna array at 2.4 GHz with 1 layer

Design Parameters	Values
Lambda	125 mm
Ground plane length	145 mm
Ground plane width	140 mm
Substrate height	3.2 mm
Patch width	39 mm
Patch length	37 mm
Air gap height	0 mm
Spacing between patches	0.54 lambda
Parasitic patch length	35.5 mm
Parasitic patch width	36.5Mm

Table -1

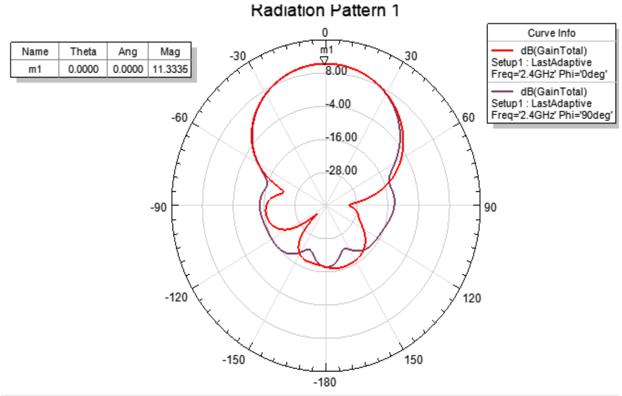

Fig-5: Gain = 11.33 dB.

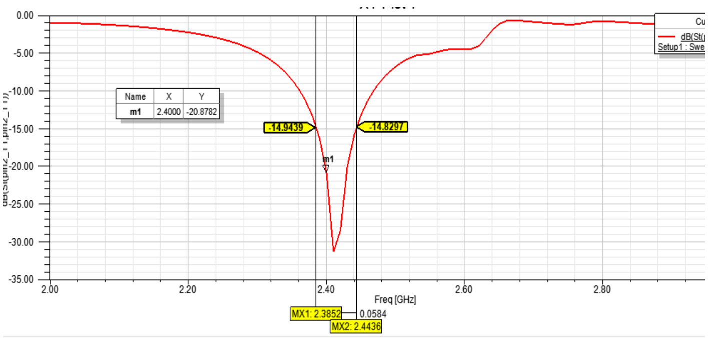

Fig-6: Return loss = -20.87 dB , Bandwidth = 0.0584 GHz = 58.4 MHz

2.2 Stack layer 2:

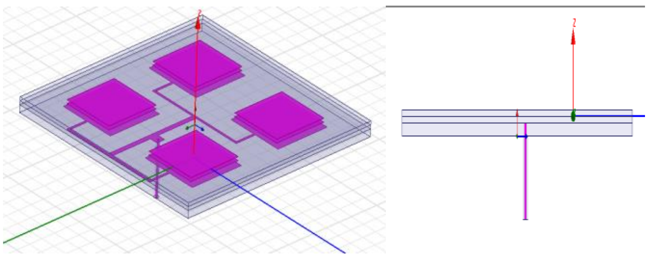

Fig-7: Design of antenna array at 2.4 GHz with 2 layers

Design Parameters	Values
Lambda	125 mm
Ground plane length	145 mm
Ground plane width	140 mm
Substrate height	3.2 mm
Patch width	39 mm
Patch length	39 mm
Air gap height	0 mm
Spacing between patches	0.54 lambda
Parasitic patch length	37.5 mm
Parasitic patch width	35 mm

Table -2

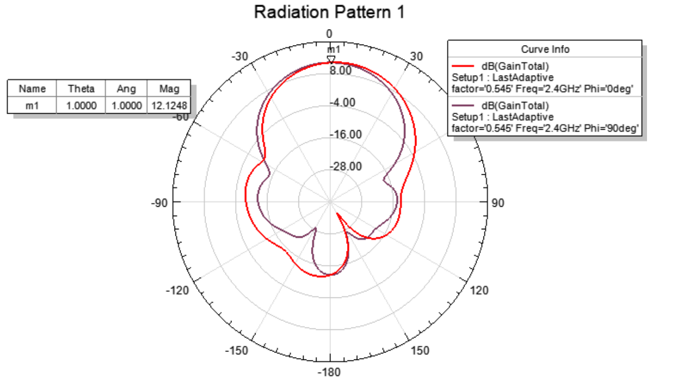

Fig-8: Gain = 12.12 dB.

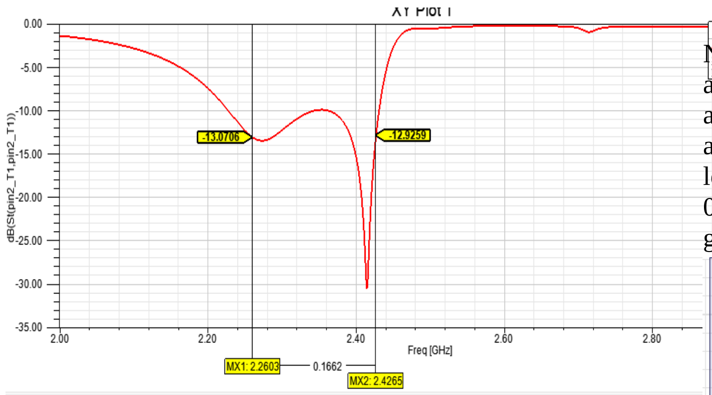

Fig-9: Return loss = -30 dB , Bandwidth = 0.1662 GHz = 166.2 MHz

2.3 Stack Layer 3:

Further stacking is not possible because the gain curve is getting disturbed and even the minimum 10 dB gain is not reached and because of the presence of this multiple layers of Duroid and patches within the near field region of the antenna array, the return loss is also very affected for this case.

2.4 Percentage Change in Bandwidth:

No. of layers	Percentage change in BW
1	+39.7%
2	+184.5%

Table -3

2.5 Bandwidth Variation Over No. of Layers:

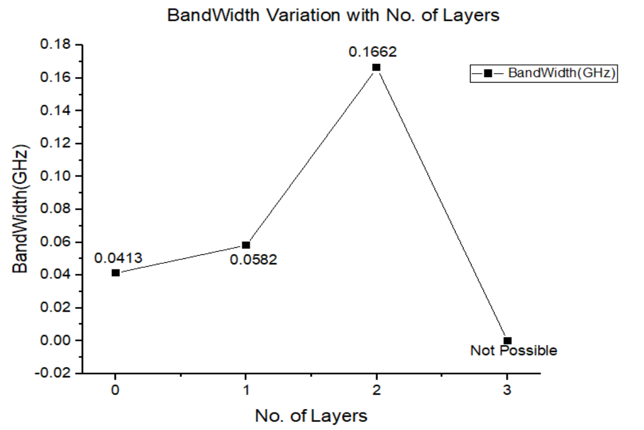

Fig-10

2.6 Gain Variation over NO. of Layers:

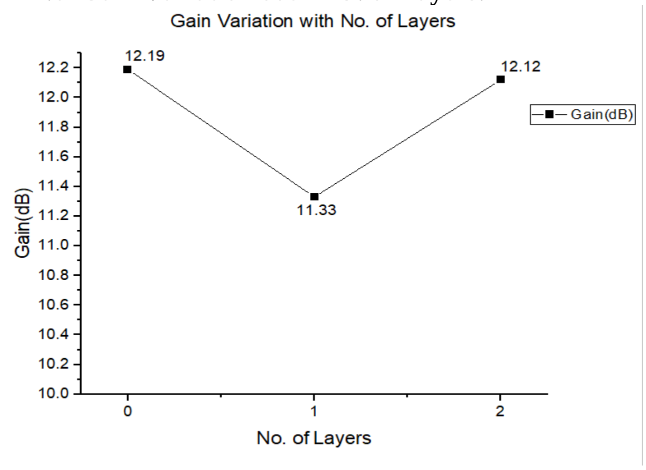

Fig-11

3. Analysis of Designs at 11.5 GHz:

Now, the X band frequency 11.5 GHz is considered to go ahead with. So, now the baseline is established using 2x2 array of single layer conventional rectangular patch antennas at 11.5 GHz, designed using Rogers 5880. Its patch length 8.3mm , patch width 10mm and substrate height 0.254mm , total ground plane length for array 35mm , total ground plane width for array 32mm.

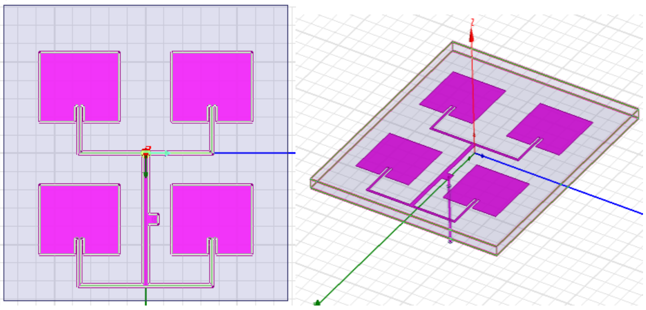

Fig-12: Design of 2x2 patch antenna array at 11.5 GHz

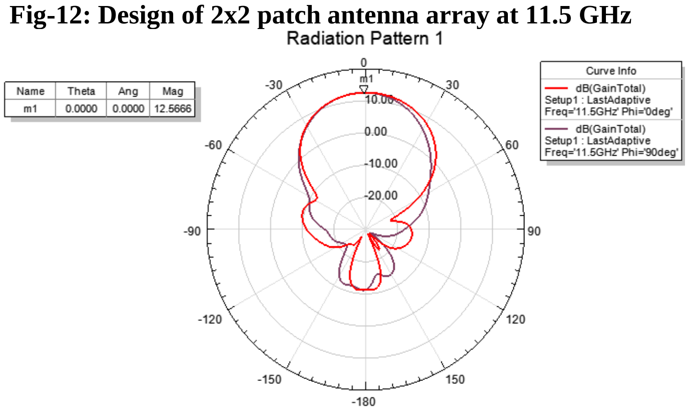

Fig-13: Gain = 12.56 dB.

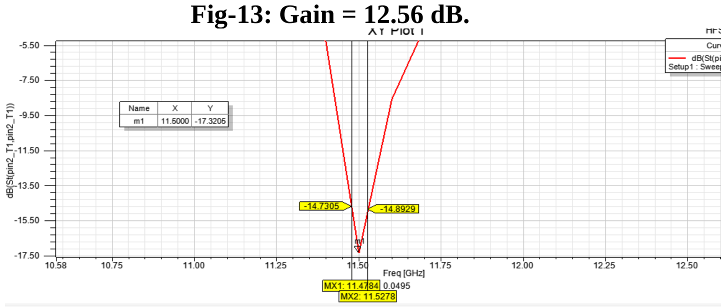

Fig-14: Return loss = -17.32 dB , Bandwidth = 0.0495 GHz = 49.5 MHz

3.1 Stack layer 1:

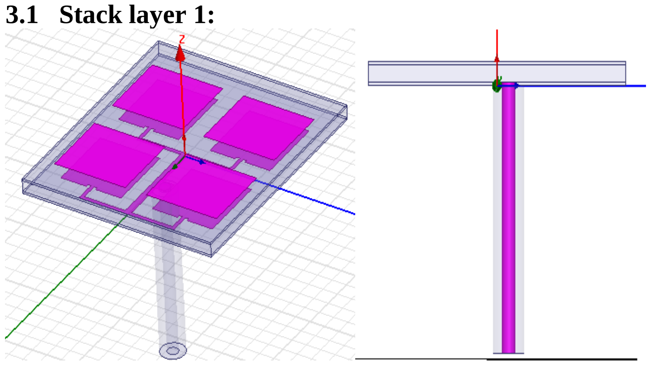

Fig-15

Design Parameters	Values
Lambda	26.2 mm
Ground plane length	30 mm
Ground plane width	26 mm
Substrate height	0.254 mm
Patch width	8.32 mm
Patch length	8.62 mm
Air gap height	1.3 mm
Spacing between patches	0.485 lambda
Parasitic patch length	8.83 mm
Parasitic patch width	9.8 mm

Table - 4

Design Parameters	Values
Lambda	26.2 mm
Ground plane length	30 mm
Ground plane width	26 mm
Substrate height	0.254 mm
Patch width	8.32 mm
Patch length	8.62 mm
Air gap height	0.5 mm
Spacing between patches	0.485 lambda
Parasitic patch length	8.5 mm
Parasitic patch width	9.5 mm

Table - 5

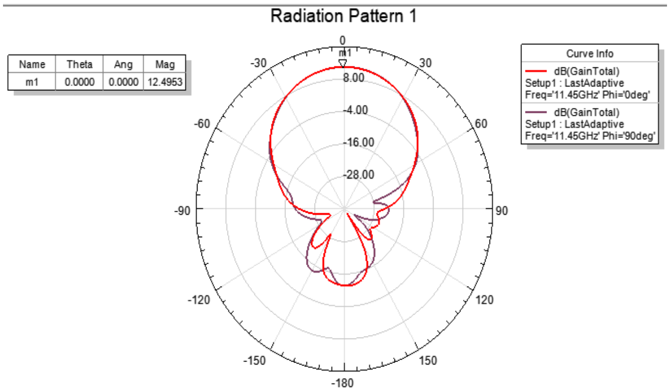

Fig-16: Gain=12.49 dB

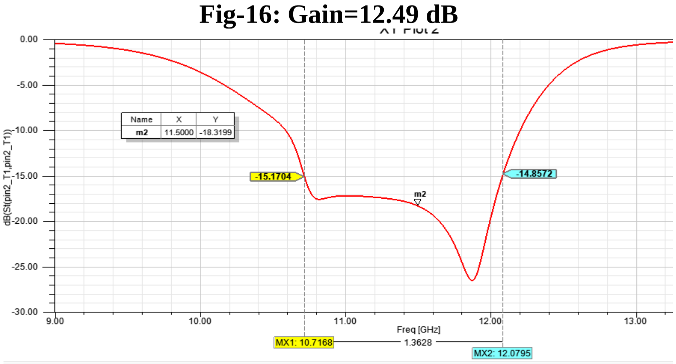

Fig-17: Return Loss= -18.31 dB , Bandwidth = 1.36 GHz

3.2 Stack Layer 2:

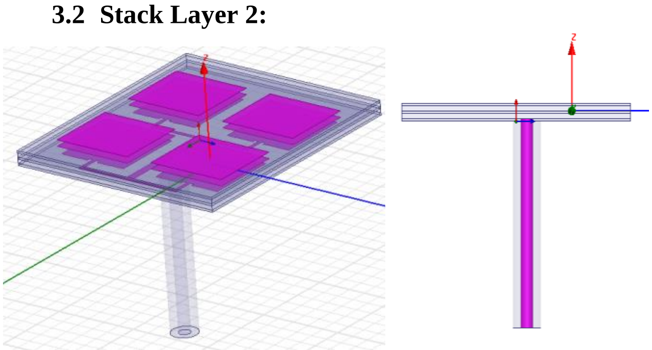

Fig-18

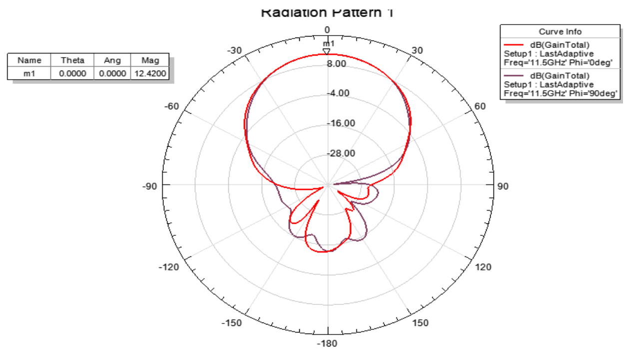

Fig-19: Gain=12.42 dB

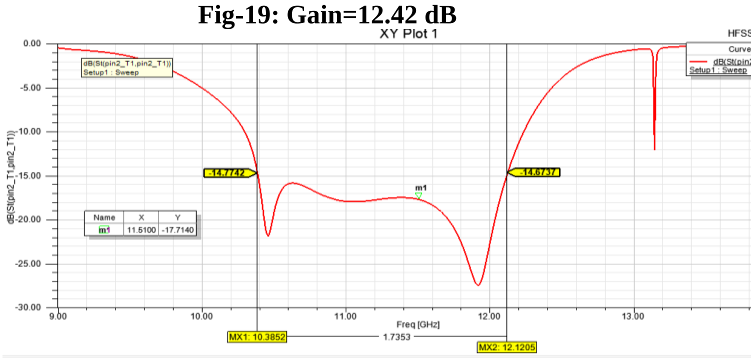

Fig-20: Return Loss= -17.71 dB , Bandwidth = 1.735 GHz

3.3 Stack Layer 3:

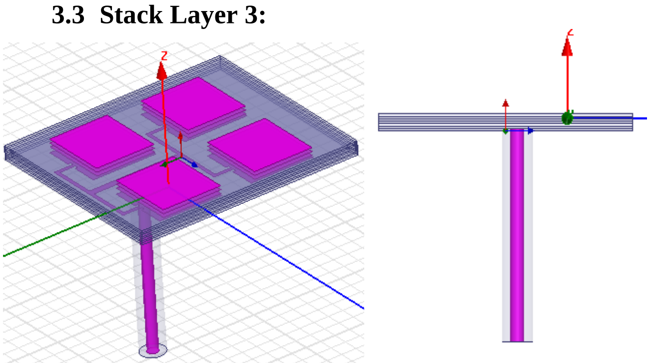

Fig-21

Design Parameters	Values
Lambda	26.2 mm
Ground plane length	30 mm
Ground plane width	26 mm
Substrate height	0.254 mm
Patch width	8.32 mm
Patch length	8.62 mm
Air gap height	0.2 mm
Spacing between patches	0.485 lambda
Parasitic patch length	8 mm
Parasitic patch width	9 mm

Table - 6

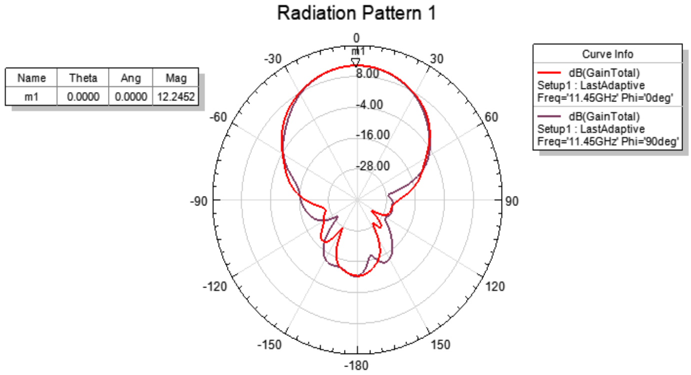

Fig-22: Gain=12.24 dB

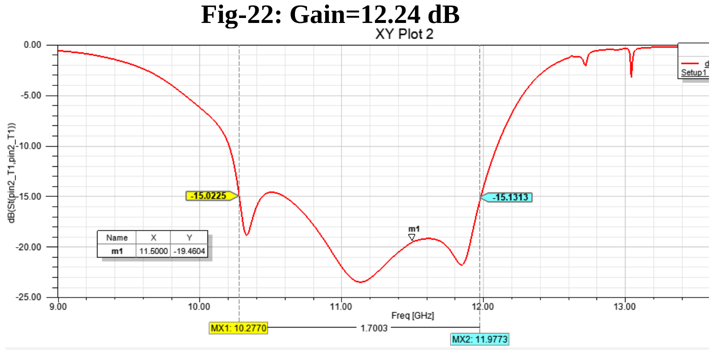

Fig-23: Return Loss = -19.46 dB , Bandwidth = 1.700 GHz

3.4 Stack Layer 4:

Further stacking is not possible because the gain curve is getting disturbed and even the minimum 12 dB gain is not reached and because of the presence of this multiple layers of duroid and patches within the near field region of the antenna array, the return loss is also very affected for this case.

3.5 Percentage Change in Bandwidth:

No. of Layers	Increment in BW
1	+2647%
2	+27.57%
3	-2%

Table -7

3.6 Bandwidth Variation Over no. of Layers:

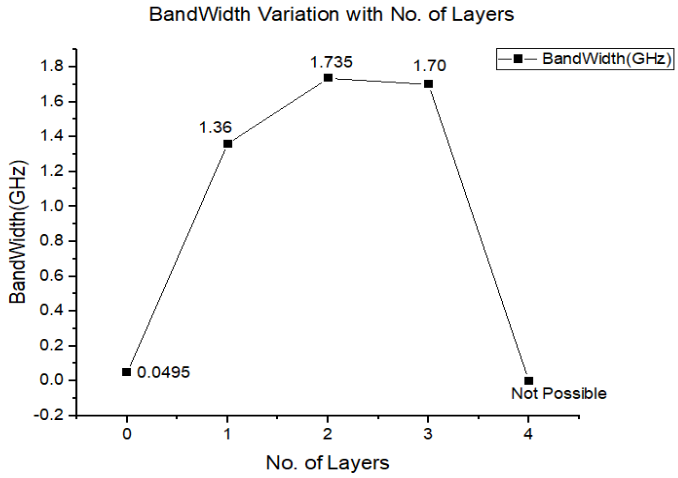

Fig-24

3.7 Gain Variation Over No. of Layers

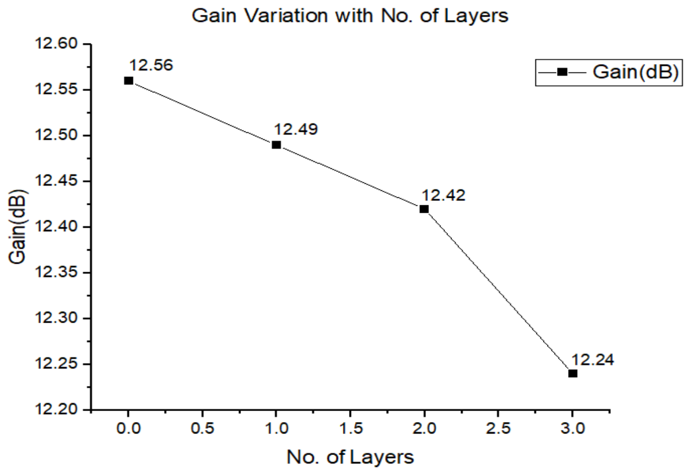

Fig-25

4. CONCLUSION

Stacking techniques provides good method for bandwidth improvement but it has some limitations. As some substrates layers and metallic patch surfaces are placed within the reactive near field region of the primary antenna element so it hampers the gain and the return loss of the antenna by a very significant fraction so, we need to have a very good amount of gain and need to have result loss as low as possible before adding those extra layers.

And on the other side, it is not that the number of parasitic patch layers can be increased up to as many number as we want. It has certain limits after which if we want to add an extra layer, it can be seen that the gain and return loss are highly affected which is not acceptable otherwise there must be some physical restriction which will not allow us to do so.

References

1. Rathi V, Kumar G, Ray KP. Improved coupling for aperture coupled microstrip antennas. IEEE Transactions on Antennas and Propagation. 1996;44(8):1196-1198

2. Kumar G, Gupta KC. Nonradiating edges and four edges gap-coupled with multiple resonator, broad band microstrip antennas. IEEE Transactions on Antennas and Propagation. 1985;33:173-178

3. A New Approach for Bandwidth Enhancement Technique in Microstrip Antenna for Wireless Applications D. Yoharaaj1, Raja Syamsul Azmir2 and Alyani Ismail3 Department of Computer and Communication System Engineering, Faculty of Engineering, Universiti Putra

4. Kumar G, Ray KP. Broadband Microstrip Antennas. Artech House; Boston; 2003

5. Targonski SD, Waterhouse RB, Pozar DM. Design of wideband aperture stacked patch microstrip antenna. IEEE Transactions on Antennas and Propagation. 1998;46(9):1245-1251

6. Gain and Bandwidth Enhancement Techniques in Microstrip Patch Antennas - A Review by Alok Kumar Research Scholar CT Group of Institutions Jalandhar Punjab , Nancy Gupta Assistant Professor CT Group of Institutions Jalandhar Punjab , P.C. Gautam Scientist ‘E’ DRDO Chandigarh Punjab.

7. Reddy KTV, Kumar G. Stacked square microstrip antennas for wideband circular polarization. In: National Conf. on Communications, NCC. Kanpur: Indian Institute of Technology; 2001. p. 125-128

8. Chew WC. A broadband annular ring microstrip antenna. IEEE Transactions on Antennas and Propagation. 1982;30:918-922

9. Vlasits T. Performance of a cross aperture coupled single feed circularly polarized patch antenna. Electronic Letters. 1996;32(7):612-613
10. Awida MH, Suleiman SH, Fathy AE. Substrate-integrated cavity-backed patch arrays: A low-cost approach for bandwidth enhancement. IEEE Transactions on Antennas and Propagation. 2011;59(4):1155-1163

11. Latif SI, Shafai L, Sharma SK. Bandwidth enhancement and size reduction of microstrip slot antennas. IEEE Transactions on Antennas and Propagation. 2005;53(3):994-1003

12. Arya AK, Kartikeyan MV, Patnaik A. Efficiency enhancement of microstrip patch antenna with defected ground structure. In: International Conference on Recent Advances in Microwave Theory and Applications, Microwave; 2008.