Broadband Stacked Antenna Design with Hybrid Structure for C-band Communication

Swati Kandoria, Garima Saini

Abstract*: Two low profile antennas using FR4 and Rogers RT/duroid 5880 as dielectric materials are proposed in this manuscript. To obtain the broadband response the strip-slot hybrid structure is introduced. The two antennas proposed in this manuscript consist of four strips that are segregated through three narrow tapered slots. Using the aperture couple microstrip feed line proper impedance matching is obtained and the slotted patch structure is excited. The simulated bandwidth of 45% is obtained by using the Rogers RT/duroid 5880 as dielectric material with stacked patch structure and gain obtained to be 9.02dB resonating at 4.2GHz of frequency. Proposed design using FR4 as the dielectric material has two resonance frequencies at 4.8GHz and 6.2GHz. The simulated bandwidth of 50% at 4.8GHz and 38.71% at 6.2GHz is obtained with gain of 6.040dB at 4.8GHz. A prototype of the same antenna using the FR4 as dielectric material is also constructed and tested, the tested results shows an impedance bandwidth of 21.87%

***Keywords*: Antenna feed; Broadband antennas; C Band; microstrip antennas; stacked**

I. INTRODUCTION

For transmitting and receiving waves the metallic device which is used is called as an antenna or in other words between the free space and transmission line or waveguide the transitional circuit used is antenna. The antenna emits the energy as electromagnetic waves from current which are supplied by the radio transmitter to antenna terminal during transmission [1]. Antenna should adjust to increasing demands of more effective and increased data rate of communication system. Therefore, from past few decades enhancing the bandwidth of antennas and gain are the topic of interest for research purpose. For gain enhancement antenna arrays is the latest research area. The advancement of broadband system in wireless communication area has insistence design of antennas that can function properly over a higher frequency range. Broadband antennas are referred to as the antennas having wide bandwidth. The term broadband" is a comparative calculation of bandwidth. Over an octave when the pattern of antenna does not change remarkably then it is classified as broadband antenna. Thus the broadband antenna definition depends upon the particular antenna. Broadband antenna normally requires shapes that remains similar in dimensions, however alternatively utilize materials with clean boundaries. Clean physical systems tend to provide patterns and enter impedance that still exchange easily with frequency. This easy concept could be very crucial in designing broadband antenna. The overall broader bandwidth is obtained by addition of slot or either the parasitic elements; due to which additional resonances are introduced. By using thicker substrate having low relative permittivity. The most basic slot design is U slot, the slot is cut in patch, various types of slots can be used namely H, F, E, L etc. The inductance instigated by the probe/feed is equilibrized by the slot. These types of designs are single patch designs and have a single substrate. The drawback of this type of design is high cross polarization at the end of frequency bands in H-plane. Up to 25% of the bandwidths can be obtained. Another similar design as the slot design is the L-shaped fed design. The middle of the coaxial feed/probe is bent into an L shape. This design also introduces resonance frequencies, 30% of the bandwidth can be obtained by using this design. Aperture coupled designs are also used to obtain the higher bandwidth; the patch is fed across an aperture by a microstrip line. Stacked patches were instigated for broadband design. This is another technique to obtain broadband response [2]-[20]. In stacked patch design multiple layers are used in which bottom is fed whereas the upper conducting portion/patch is parasitic in nature. The broadband characteristics are achieved due to the higher coupling between the two resonances of conducting patches. This multilayer design can also be implemented for having dual frequency operations. the technique of using stacked patches for twin band operation may be extended to multi bands by means of honestly stacking patches in multilayers. From different literature it can be found out that about 50% of the bandwidth can be achieved from the multilayer design with proper feeding techniques.

II. DESIGN PROCEDURE

Antenna Structure

The proposed antenna design consists of three metallic layers; bottom layer with the feedline; middle ground layer having a coupling aperture and top layer with patch. Two layers of same dielectric constant are used as substrate among these three metallic layers. The top radiating patch is excited though the coupling aperture at the ground plane. Complete size of lower and upper dielectric is given as L × W × h. FR4 and RT/duroid 5880 are used for substrate to design two designs of antenna. The details of the design are explained as follows.

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Fig1. (a) Shows the design of the radiating patch, which depicts that slotted hybrid structure of patch is used. The patch is composed of four strips arranged periodically and are separated by three small sized slots of different widths given by g_1, g_2, g_3. The width and length of the strips is given by w_1, w_2, w_3, w_4, l respectively. Patch of size 30mm × 40 mm is considered and slots are being cut on this dimension of the patch. FR4 based antenna design and RT/duroid 5880 antenna design has same radiating patch structure.

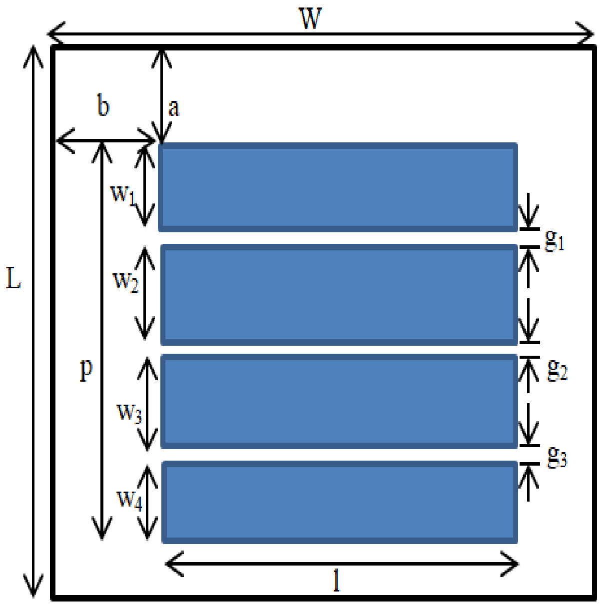


Fig.1 (a): Upper layer with radiating patch having slotted hybrid structure

In Fig.1 (b), (c) a coupling aperture is lacerated onto middle ground layer, and is kept below and parallel to initial slot present on uppermost layer. Size of coupling aperture FR4 substrate is given by Ws×Ls and dimension for RT/duroid 5880 is given by Wr× Lr.

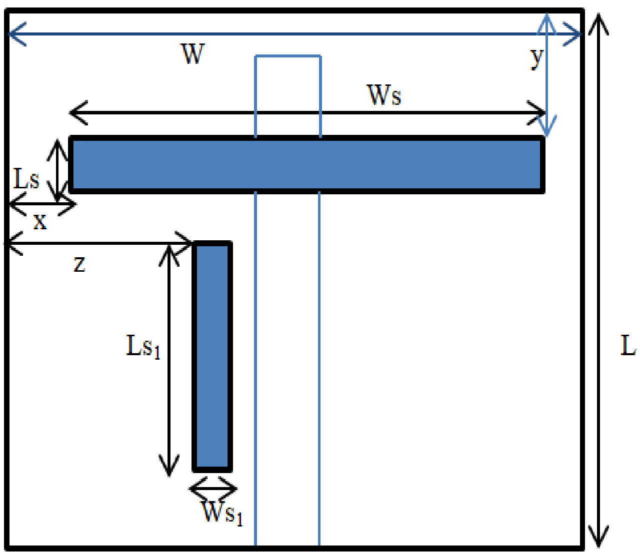


Fig.1 (b): Ground layer having the coupling aperture using FR4 as dielectric material

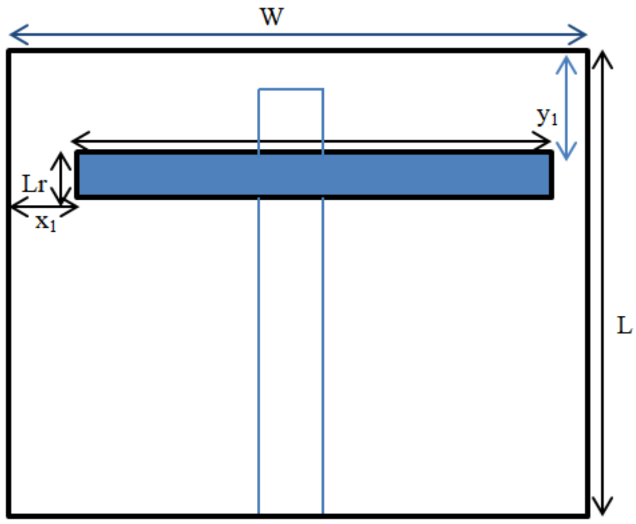


Fig.1(c): Ground layer having the coupling aperture using Rogers RT/duroid 5880 as dielectric material

The radiating patch and bottom feed has the same dimensions for both the dielectric materials. There is a slight difference in the slot position placed on the ground plane while using the two dielectric materials which is depicted in Fig.1 (b) and (c) respectively. In Fig.1 (d) lower bottom layer structure with feed line of two proposed antennas is shown. Width and length of the lower bottom layer feed is given by L_{feed}, W_{feed}. The 50Ω microstrip feeding line is printed on foundation layer of lower dielectric, and it is uniform with respect to x-axis.

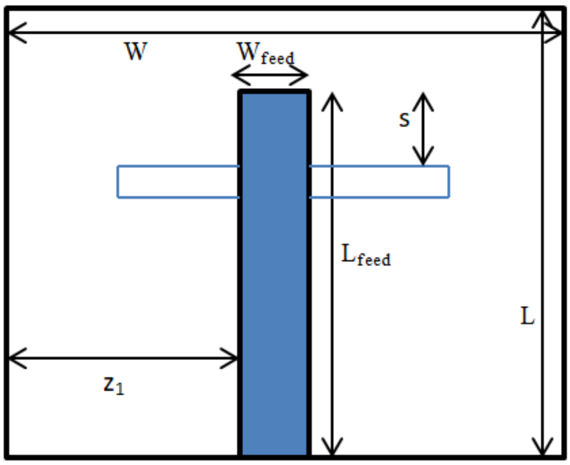


Fig.1 (d): Stripline feeding on bottom layer

The broader impedance bandwidth can be achieved by optimizing the various parameters and dimensions of the slotted patch design and also of the feeding structure. Better impedance bandwidth performance can be obtained by adding a slot in the thin metallic ground in case of FR4 as a dielectric material. However, no additional slot was required when Roggers RT/duroid 5880 is used as the dielectric material. FR4 and Roggers RT/duroid 5880 are used as the lower and upper substrate having dielectric constants of 4.4 and 2.2 respectively for two antenna designs. Fig.1 (d) shows the side view of the proposed antenna where optimized air gap is considered in between the two substrates. To keep the gap a non-metallic plastic material is used that would not affect the results obtained from simulation.

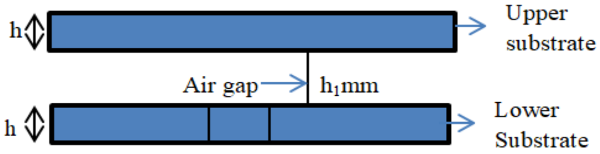


Fig.1 (d): Side view of antenna

Table 1

Optimized values of proposed antenna (in mm)

L	W	h	w_1	w_2	w_3	w_4	g_1	g_2	g_3
50	50	3	10	6.65	7.25	4.35	0.35	0.75	0.65
Ws	Ls	l	p	Ws_1	Ls_1	W_{feed}	L_{feed}	s	h_1
38.45	2	40	30	2	14	4.8	42	6.5	4
Wr	Lr	x	y	z	a	b	x_1	y_1	z_1
38.45	2	8	14.5	16	10	8	8	17	21.5

III. RESULTS AND MEASUREMENTS

The proposed antenna designs using FR4 and Roggers RT/duroid 5880 as substrate materials are simulated and examined using frequency domain 3D full-wave electromagnetic field solver (Ansys HFSS). The gap between the two dielectrics has been optimized by carrying parametric study of effect on bandwidth and gain of proposed antenna with variation of air gap. The best suitable results and proper matching was obtained at a gap of 4mm between the two dielectrics.

A. Reflection coefficient of proposed antenna

When FR4 is used as the dielectric material two closely resonating frequencies are obtained at 4.8GHz and 6.2 GHz that illustrates the broadband response of proposed antenna. The simulated impedance bandwidth of 2.4GHz from 4.244 GHz to 6.647 GHz at return loss of 33dB and 24dB is obtained. Gain of 6.404dB and 5.4308 dB is achieved at the two resonating frequencies respectively Fig.2 shows the simulated reflection coefficient of proposed antenna.

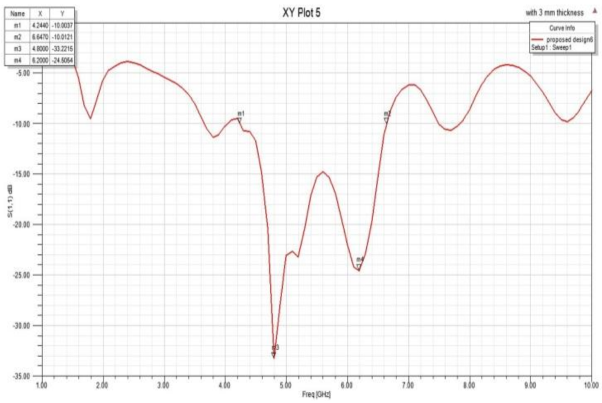


Fig.2: Simulated reflection coefficient using FR4 as dielectric material

When Roggers RT/duroid 5880 is used as the dielectric material the broadside bandwidth of around 2.7GHz from 3.806 GHz to 6.509 GHz at a return loss value of 22dB is achieved. The simulated antenna has a resonance frequency of 4.2 GHz. A simulated gain of 9.034dB is obtained. Fig.3 depicts the simulated S(1,1) results of the proposed antenna

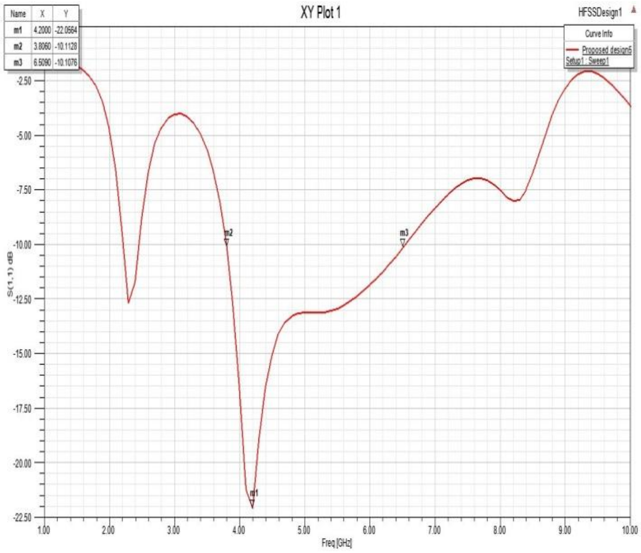


Fig.3: Simulated value of reflection coefficient using Roggers RT/duroid 5880 as dielectric material

B. Proposed antenna current distribution

Fig.5 shows current distribution of antenna proposed, from Fig.5 (a), (b) and (c) respectively it can be interpreted that current is drifting through the stripline allowing the patch at upper dielectric substrate to be electromagnetically coupled to radiate. The stripline used for feeding has the greater amount of the current flowing through it as clear from the figures.

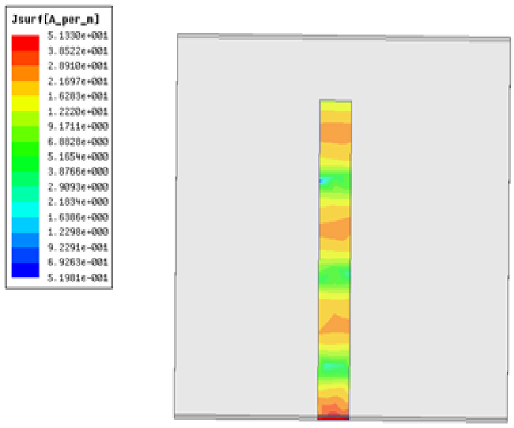


Fig.5 (a): Bottom feed line

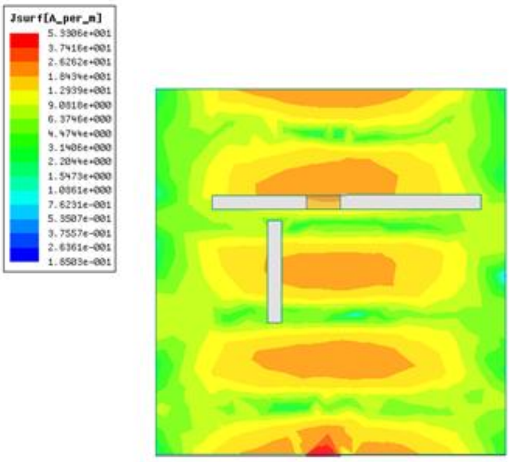


Fig.5 (b): Ground with coupling aperture

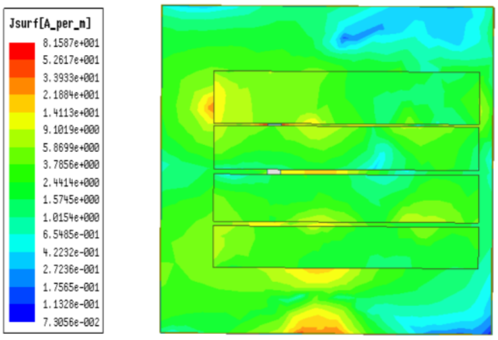


Fig.5 (c): Top radiating patch

C. Proposed antenna using FR4 Radiation Pattern

Antenna proposed using FR4 as substrate material has two resonating frequencies at 4.8GHz and 6.2GHz. Fig.6 shows the radiation pattern of the antenna in E and H planes.

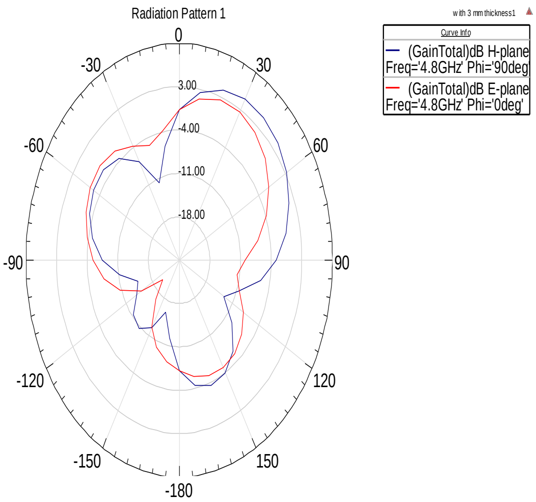


Fig.6 (a): Radiation pattern of antenna in E and H plane at 4.8 GHz frequency

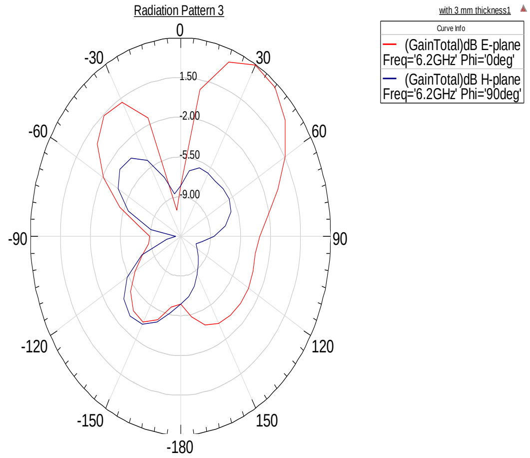


Fig.6 (b): Simulated Radiation pattern of antenna at 6.2GHz frequency in E and H plane

D. Proposed antenna using Roggers RT/duroid Radiation Pattern

The antenna resonates at a frequency of 6 GHz. The radiation pattern of the simulated antenna is shown in Fig.7

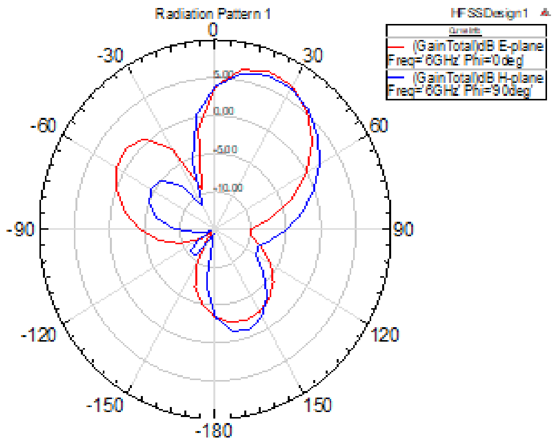


Fig.7: Simulated radiation pattern of antenna at 6GHz frequency in E and H plane.

As it can be seen from the radiation pattern plots that broadside radiation pattern is not obtained and a tilted response is obtained, this is due to the fact that the main purpose of this manuscript is to achieve a broader bandwidth with optimized gain values. Therefore, in order to achieve the desired bandwidth and gain parameters the excitation is done off centered. That is why the radiation pattern obtained is tilted.

E. Measured results

The prototype of the FR4 proposed antenna is also fabricated and is tested on Anritsu MS46322A 20GHz Vector Network Analyzer (VNA). The antenna design using FR4 as substrate material is fabricated only since Roggers RT/duroid 5880 is a costly material and is not easily available. The fabricated antenna shows multiple resonance frequencies at 4.7GHz, 5.4GHz and 6.2 GHz. The impedance bandwidth of 1.05GHz from 3.9GHz to

4.95GHz is obtained. Moreover an additional impedance bandwidths of around 750MHz from the frequency range of 6.9GHz to 8GHz and 700MHz from 5.05GHz to 5.75GHz. The deviation in fabricated and simulated results is because of the fabrication error that inculcates during the antenna fabrication. Fig.8 shows the comparative graph between fabricated and simulated reflection coefficient value of antenna.

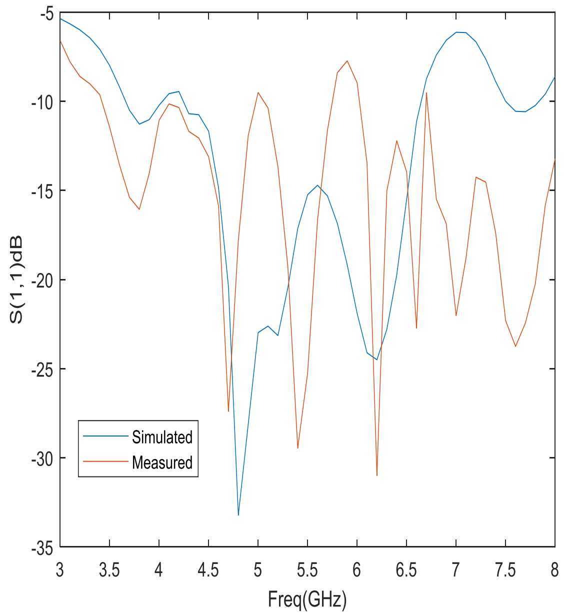
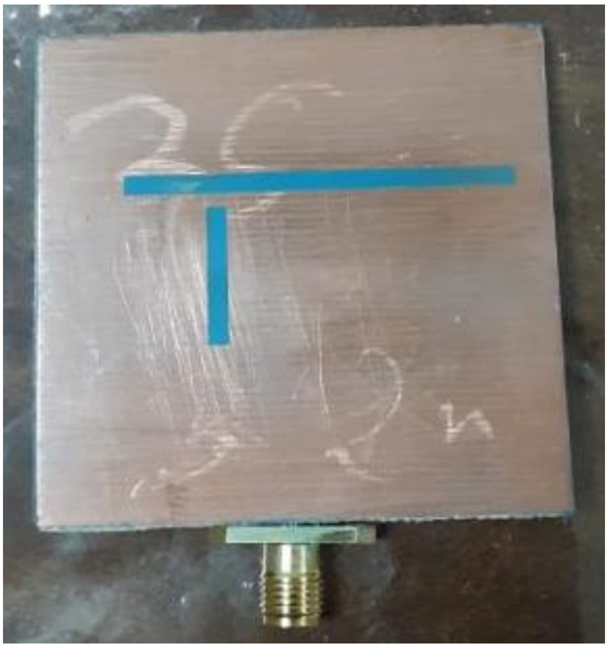
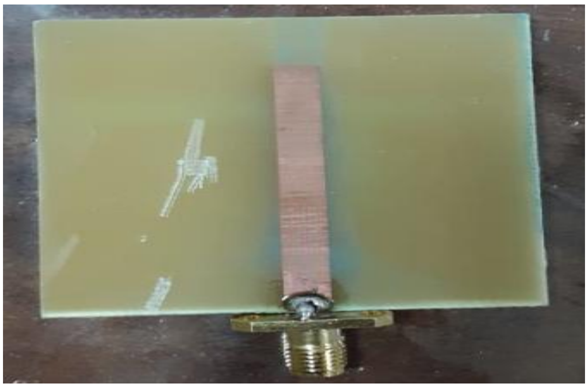


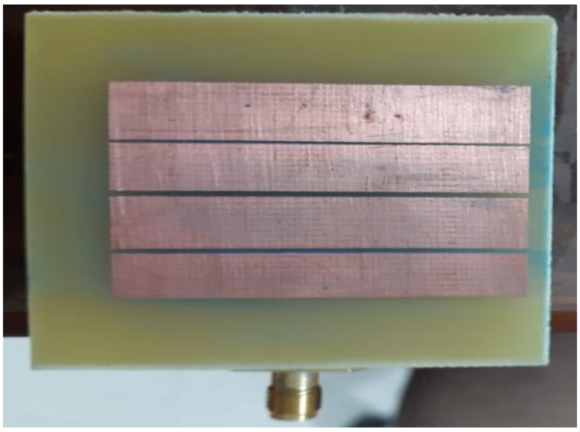
Fig.8: Simulated and measured S(1,1) of the proposed antenna



(a)



(b)



(c)

(d)

(e)

Fig.9: Fabricated antenna photographs: (a) Ground plane with coupling aperture; (b) Foundation layer with stripline feed; (c) Upper substrate layer with radiating patch; (d) Fabricated antenna testing connected to VNA; (e) Side view of the fabricated antenna

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The proposed antenna designs are compared with different microstrip antenna designs the comparison of proposed design with other designs is shown in Table2.

Table 2: Comparison Of Proposed Antenna With Other Antenna Designs

ANTENNA	SIMULATED RESULTS	MEASURED RESULTS	SIMULATED % BANDWIDTH	MEASURED % BADNWIDTH
[15]	2.34 GHz	2.13 GHz	-	41.1%
[16]	2.12 GHz	-	20.23 %	-
[17]	2.1 GHz	-	15%	-
Proposed antenna using Roggers RT/duroid 5880	2.7 GHz	-	45%	-
Proposed antenna using FR4	2.4 GHz	1.05GHz	50%	21.87%

IV. CONCLUSION

The two designs proposed provide a broadband response of 2.7GHz in the frequency range of 3.806-6.509GHz at the resonating frequency of 6GHz and a gain of 9.02dB using RT/duroid 5880 and an impedance bandwidth of 2.4GHz in the frequency range of 4.2440-6.6470GHz having two closely resonating frequencies at 4.8GHz and 6.2GHz and a gain of 6.040dB. There is a shift in the return loss parameter at around 5GHz frequency due to which the fabricated antenna provides a bandwidth of 1.05GHz from 3.9GHz to 4.95GHz. The decrement in the bandwidth is due to the fabrication error incorporated during the fabrication of the antenna. The antenna responses are also compared with other antenna designs and it can be analyzed from the results that the given antenna can be used for ultra wideband communication, WLAN and WiMAX applications.

REFERENCES

1. Constantine A. Balanis, “Antenna Theory: Analysis and Design”, Third Edition, John Wiley & Sons, pp. 1-70,283-365, 811-820, 865-869, 2016.
2. A.A. Deshmukh, D. Singh, P. Zaveria, M. Galaa and K. P. Ray, “ Broadband Slot cut Rectangular Microstrip Antenna”, IEEE 6th International Conference On Advances In Computing & Communications, pp. 53-59, 2016.
3. M. S. Ellis, Z. Zhao, J. Wu, X. Ding, Z. Nie, and Qing-Huo Liu, “A Novel Simple and Compact Microstrip-Fed Circularly Polarized Wide Slot Antenna With Wide Axial Ratio Bandwidth for C-Band Applications”, IEEE Transactions on Antennas and Propagation, Vol. 64, No. 4, pp. 1532-1555, 2016.
4. MD. M. Hasan, M. R.I. Faruque, and M. Tariqul Islam, “A Mirror Shape Chiral Meta Atom for C-Band Communication”, IEEE Access, Vol. 5, pp. 21217-21222, 2017.
5. D. Cheng, J. Wang, Y. Wei, C.Y. Jin, K. Cui, M. Li, “Design of dual-band and high gain waveguide slot antenna”, International Journal of Electronics and Communications ,pp. 208–212, 2019.
6. P. Chaurasia, B. K. Kanaujia, S. Dwari, M.K. Khandelwal, “Design and analysis of seven-bands-slot-antenna with small frequency Ratio for different wireless applications”, International Journal of Electronics and Communications, pp. 100-109, 2019.
7. A. Kumar, S. Raghavan, “Design of a broadband planar cavity-backed circular patch antenna” International Journal of Electronics and Communications, Vol. 82, pp. 413–419, 2017
8. A.A. Deshmukha, Shefali Pawar, Amita Mhatre and Vivek Chaudhary, “Design of Compact F-shape Microstrip Antenna for Dual Polarized Broadband Response”, 8th International Conference on Advances in Computing and Communication, Vol. 143, pp. 80-86, 2018.
9. C.W. Hsiao and W. Chen, “Broadband Dual-Polarized Base Station Antenna for LTE/5G C-band Applications”, 2018 Cross Strait Quad-Regional Radio Science and Wireless Technology Conference (CSQRWC), 2018
10. S. Kumar, T. Bhandari, “A Hexagonal Broadband Compact Microstrip Monopole Antenna for C Band, X Band and Ku Band Applications”, International Conference on Computing, Communication and Automation, pp. 1532-1536, 2017.
11. M. Abdelwahab, A. Gomaa, M. Mohana and M. Hindy, “A Simple design of Broadband rectangular Microstrip patch antennas with improved performance”, International Journal of Science, Engineering and Technology Research, Vol. 6, Issue 6, pp. 958-969, 2017.
12. 12.Ullah and S. Koziel, “A Broadband Circularly Polarized Wide-Slot Antenna with a Miniaturized Footprint”, IEEE Antennas and Wireless Propagation Letters, Vol. 17, No. 12, pp. 2454-2458, 2018.
13. M.M. Ali, M. Tarikul Islam, M. Samsuzzaman, M.T. Islam, “Rectangular with Half Circle Cut-out Microstrip Patch Antenna for C-Band Applications”, IEEE 4th International Conference on Advances in Electrical Engineering, pp. 90-93, 2017.
14. W. Li, Z. Zeng, Baiqiang, Longfang Ye, Yanhui Liu, and Qing Huo Liu, Fellow, IEEE, “Compact Dual-Polarized Printed Slot Antenna”, IEEE Antennas and Wireless Propagation Letters, pp. 2816-1819, Vol. 16, 2017
15. 15.A. Kandwal, J.V. Chauhan , B. Luadang, “Coupled C-band stacked antenna using different dielectric constant substrates for communication systems”, ELSEVIER International Journal of Engineering Science and Technology, Vol.19, pp. 1801–1807, 2016.
16. 16. W. Sun, Yue Li, Z. Zhang, and Z. Feng, “Broadband and Low-Profile Microstrip Antenna Using Strip-Slot Hybrid Structure”, IEEE Antennas and Wireless Propagation Letters, Vol. 16, pp. 3118-3121, 2017.
17. 17.A. Anand , P. Suraj, “Design of a Stacked Microstrip Patch Antenna for X band Communication” 4th IEEE International Conference on Recent Advances in Information Technology, 2018.
18. 18. L. Minz, R. Shahid Aziz, M. Tayyab Azim, S. Park, “Wideband Aperture-Coupled Stack-Patch Antenna Design with Characteristic Mode Analysis,” IEEE International Conference on Consumer Electronics-Asia, 2018.
19. 19. K. Ravi, P. Yadav, “Designing of Microstrip Patch Antenna by Using via Hole for Bandwidth Enhancement in C and X Band Application” IEEE Second International Conference on Intelligent Computing and Control Systems (ICICCS), pp. 388-393, 2018.
20. 20.P. Kumar, G. Saini, “Gain Enhancement of Modify 2x2 MIMO Antenna Using Superstrate Layer”, International Journal for Scientific Research & Development, Vol. 5, No. 02, pp. 2039-2041, 2017.

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