Compact Inverted U – Slot On A Patch Antenna With A Heterogeneous Substrate

Padmavati S , Lalitha Y S

Abstract : The main aim of this paper is to obtain a compact inverted U - slot on a patch antenna with a heterogeneous substrate for wireless application. The proposed inverted U – slot is integrated in the square shape patch antenna on a heterogeneous substrate for size reduction up to 47.4% with respect to conventional square shape patch antenna and to obtain enhanced bandwidth by multiband resonances frequencies from 1.33GHz to 8.2GHz. A proposed antenna is fabricated with a heterogeneous substrate and multiband nature of the compact inverted U - slot on a patch antenna with a heterogeneous substrate is studied using Ansoft HFSS 13.0 software. This procedure is approved tentatively and estimated results were in great concurrence with recreated results. The S11 parameters of U shape, Inverted U shape, C shape and inverted C shape is compared.

Index Terms: Compact, Enhanced bandwidth, Inverted U – slot, Microstrip feed line, Return loss, VSWR, Wireless applications.

1 INTRODUCTION

In recent year's rapid development in wireless communication demands the antennas for different systems and standards with properties such as compact, broadband and multiple resonant frequencies [1]. Numerous strategies have been used to achieve compact size of antenna such as using high value of effective permittivity of the substrates, by applying resistive loading, expanding the electrical length of antenna by advancing its shape and slotting the patch of antenna [2-3]. The microstrip patch antennas are broadly used for wireless applications due to some attractive properties such as light in weight, low cost, conformal in structures which are easily integrated with solid state devices. However, microstrip patch antennas have some drawbacks such as narrow bandwidth, low efficiency and low gain etc. There are several techniques to enhance the bandwidth of antennas like use of impedance matching, feeding techniques, various shapes of slots, multiband antennas and using heterogeneous substrates [4-7]. We have proposed another way to deal with a compact square shape microstrip patch antenna on a heterogeneous substrate by creating an inverted U – shape slot on a patch antenna with a heterogeneous substrate. The geometry of aninverted U – shape slot is simple and performs better than U shape, C shape and inverted C shape slots. In this paper we further investigated the process within depth the impacts of structure parameters. We also provided the proposed antenna with an optimized design that achieves a size reduction of47.4% with multiband resonance frequencies.

2 ANTENNA CONFIGURATION AND DESIGN CONCEPT

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2.1 Geometry

A inverted U - shape slot of dimensions L2,W2 and a square shape patch of dimensions L1 and W1 are imprinted on a grounded substrate of thickness h1 = 3.2 mm and effective permittivity ε_1= 4.4 with loss tangent of tan δ = 0.02 with microstrip line feed are shown in figure1. Further a substrate of thickness h2 = 1.6mm and effective permittivity ε_2= 3 is inserted in a rectangular slot with dimensions L3, W3 are shown in figure 2 to create a heterogeneous substrate and to achieve multiband characteristics. To optimize the configuration described above the Ansoft HFSS 13.0 software is used. The different shapes like C type slot, U type slot and inverted C type slot have been carved on the driven patch are shown in figure 3 with 50Ω microstrip line feed.

2.2 Working Principle

In this work, the FR4 epoxy material is partially removed below the patch to produce a heterogeneous substrate that consists of a mixture of Air and Taconic substrate. The excitation of surface waves is suppressed and multi resonance frequencies can be created by such heterogeneous substrate as shown in figure 2. A semi – static model dependent on arrangement capacitors is utilized to lessen the compelling permittivity of the substrate.

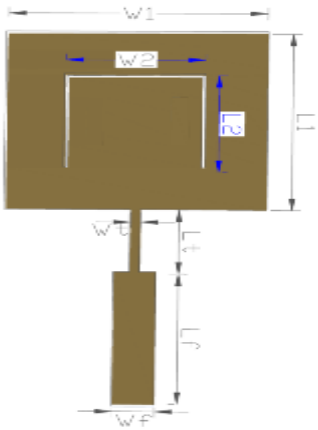


Figure1. *Geometry of top view of proposed antenna, W1=L1=38.04mm.W2=L2=20mm.Wt=1.46mm.Lt=17.97mm.Wf=6.118mm.Lf= 28.54mm.*

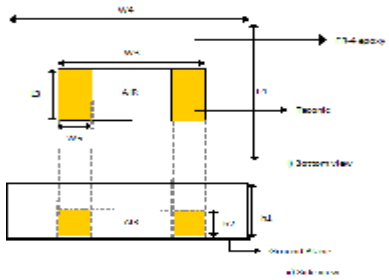
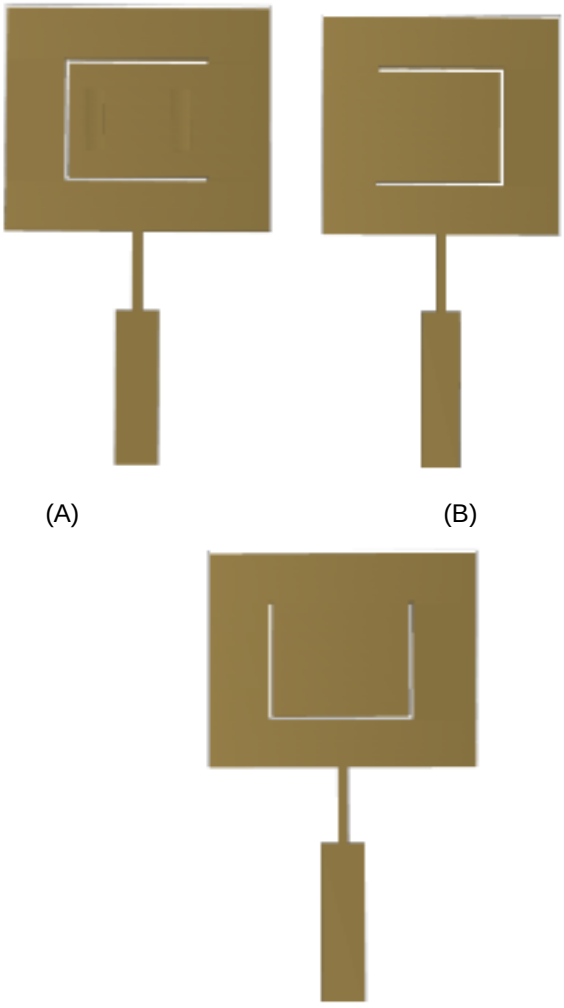


Figure2. *Geometry of bottom and side view of proposed antennaW3=15mm.L3=10.04mm.W4=76.3mm.L4=127.85mm. W5=2.5mm.*



(A) (B)

(C)

Figure3. *Geometry of various shapes on a heterogeneous substrate*
(A) C - type slot (B) Inverted C - type slot (C) U - type slot.

The experimental setup and fabricated top view and bottom view of proposed antenna are shown in figure 4.

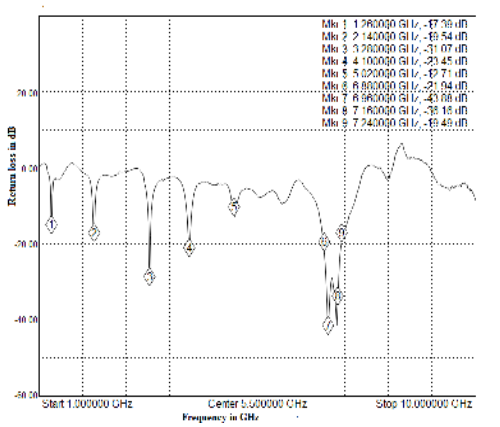
(A)

(B) (C)

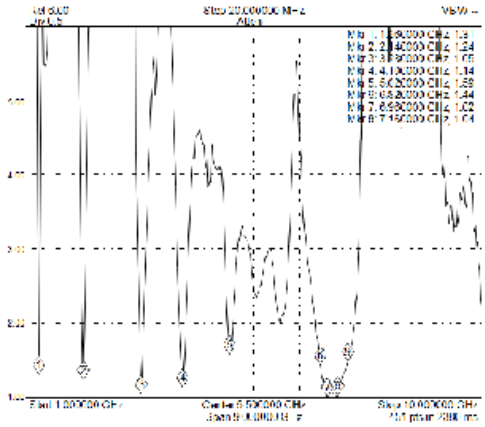
Figure4. *(A) Experimental setup (B) Fabricated top view and (C) Fabricated bottom view of proposed antenna.*

3 PARAMETRIC STUDY AND DISCUSSION OF RESULTS

All the proposed antennas have been recreated using Ansoft HFSS 13.0 software. Through simulation, the antenna parameters such as return loss, bandwidth, radiation pattern and size reduction of all proposed antennas were studied and also verified using scalar network analyzer. From the results it is cleared that by etching inverted U- shape slot on a heterogeneous substrate, the resonant frequency has dropped significantly, resulting in a reduction in size. The bandwidths of the antennas have been enhanced due to a heterogeneous substrate. Also all the proposed antennas are resonating for multiple frequencies. The inverted U-shape slot on a heterogeneous substrate is good compared to other slots on a heterogeneous substrate. Hence the measured results of this antenna are quoted in figure 5. And the comparisons of return loss characteristics of various slots on a heterogeneous substrate are shown in figure 6.



(A)



(B)

Figure5.*(A) Measured return loss, (B) Measured VSWR characteristics of inverted U- shape slot antenna on a heterogeneous substrate.*

The performances of the proposed antenna results are compared with homogeneous substrate antenna are shown in Table1.

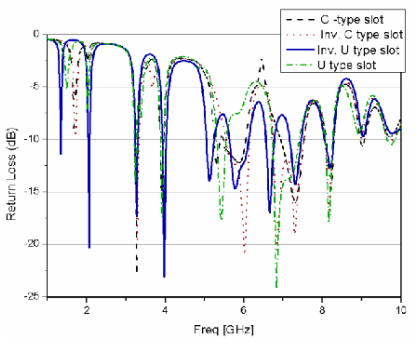
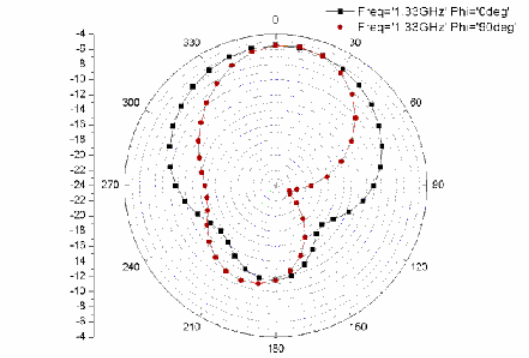
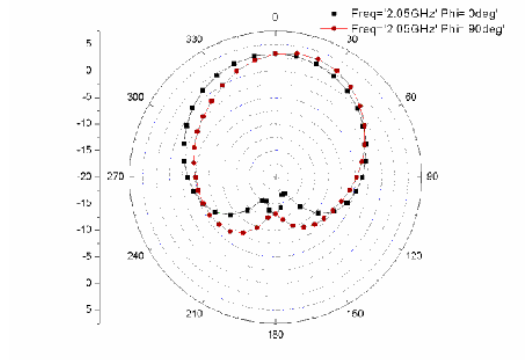


Figure6. *Comparisons of return loss characteristics of various slots on a heterogeneous substrate.*

The inverted U-shape slot on a heterogeneous substrate gives size reduction of 47.4% to 14.5% with multiple resonance frequencies (f_1=1.33GHz, f_2=2.05GHz, f_3=3.27GHz, f_4=3.97GHz, f_5=5.11GHz, f_6=5.79GHz, f_7=6.67GHz, f_8=7.32GHz and f_9=GHz) and overall bandwidth is 29.78% (1% + 2.18% + 2.14% + 2.26% + 3.52% + 8.54% + 3.37% + 4% + 2.77%) .The higher frequency bandwidth is mainly due to a heterogeneous substrate and inverted U- shape slot in the patch is responsible for reducing the resonant frequency of the antenna. The radiation pattern of inverted U- shape slot on a heterogeneous substrate at 1.33GHz and 2.05GHz are shown in figure 7.

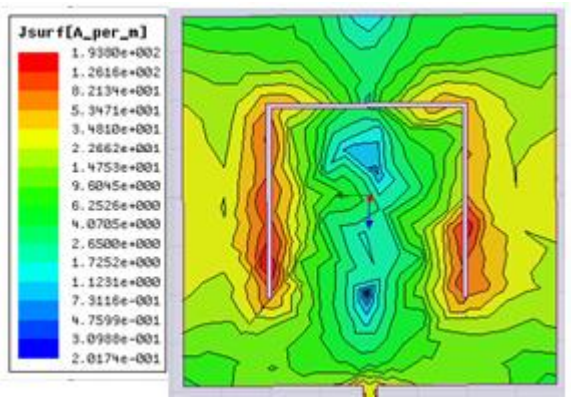


(A)

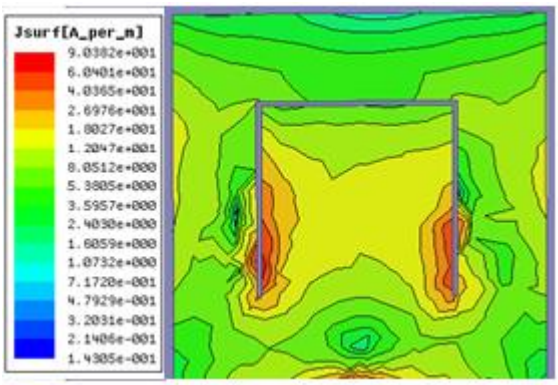


(B)

Figure7. *Radiation pattern at lower resonant frequencies (A) f_{r1}= 1.33GHz (B) f_{r2}=t 2.05GHz.*



(A)



(B)

Figure8. Surface current distribution at lower resonant frequencies
(A) f_{r1}= 1.33GHz (B) f_{r2}= 2.05GHz.

***Table 1**. Analogy between homogeneous substrate antenna and the proposed antenna.*

Sl .No	*Antenna Config.*	*Resonant Frequency in GHz*	*Return Loss in dB*	*Bandwidth (MHz)*	*Size Reduction in %*
1	*Homogeneous antenna*	*2.45*	*-25.66*	*85*	*NA*
2	*Inverted U-shape slot antenna on a heterogeneous substrate.*	*1.33*	*-11.37*	*20*	*47.4*
		2.05	*-20.29*	*45*	*14.5*
		3.27	*-17.34*	*70*	*NA*
		3.97	*-23.14*	*90*	*NA*
		5.11	*-13.95*	*180*	*NA*
		5.79	*-14.69*	*495*	*NA*
		6.67	*-16.97*	*225*	*NA*
		7.32	*-14.25*	*292.5*	*NA*
		8.20	*-12.68*	*225*	*NA*

Figure 8 illustrates the surface current distribution of proposed antenna at lower resonant frequencies. The first resonance frequency is responsible for size reduction of 47.4% because of more surface current distribution due to an inverted U – shape slot in the patch and second resonance frequency is responsible for 14.5% of size reduction is mainly due to a heterogeneous substrate.

4 CONCLUSION

A compact inverted U – slot on a patch antenna with a heterogeneous substrate is designed, recreated and studied. A heterogeneous substrate is responsible for multiband frequencies with enhanced bandwidth and an inverted U-shape slot in the patch is responsible for low frequency operation with a good 47.4% of reduction in size compared to homogeneous substrate antenna. The proposed antenna indicates broadside radiation pattern and this antenna is better as it uses low cost substrate materials and finds applications in L, S and C bands such as GPS (global positing systems), radio, radar communication and Wi-Fi devices.

5 REFERENCES

[1] Deshmukh, A. A., & Ray, K. P. “Compact Broadband Slotted Rectangular Microstrip Antenna”, IEEE Antennas and Wireless Propagation Letters, 8, 1410–1413, 2009.

[2] Kin-Lu Wong, "Compact and Broadband Microstrip Antennas", John Wiley & Sons, pp 12-14, 2002.

[3] Lo, T. K. and Y. Hwang, “Microstrip antennas of very high permittivity for personal communications,” 1997 Asia Pacific Microwave Conference, 253–256, 1997.

[4] M. Siva Ganga Prasad, P. Poornapriyaetal., “Design of Dual and Triple band Antennas using U-slots on Stacked Patches “International Journal of Modern Engineering Research(IJMER), Vol. 2, Issue 3, pp-824-829, May-June 2012.

[5] Richard H. Chen and Yi-Cheng Lin, “Miniaturized Design of Microstrip-Fed Slot Antennas Loaded With C-Shaped Rings,” IEEE antennas and wireless propagation letters, vol. 10, 2011.

[6] Padmavati S. T and Lalitha Y. S., “Design and Simulation of Dual Band Microstrip Patch Antenna with Heterogeneous Substrate”, International Conference on Communication and Signal Processing, April 4-6, 2019.

[7] S. T. Padmavati and Y. S. Lalitha, “Multiband Microstrip Patch Antennas using Heterogeneous Substrate for Wireless Applications,” International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8 Issue-12, October, 2019.