Suppression of Higher Frequency Bands and Reduction in the Resonant Frequency of a Simple Square Patch Antenna by Loading an Asymmetrical U-Shaped slot in the Patch

Vikas Gupta

***Abstract*— In this paper a slot has been loaded in square patch antenna which was resonating originally at three different frequency bands viz. 7GHz, 10GHz and 13GHz. The loading of the slot results in the suppression of higher frequency bands and reduction in resonant frequency of original square patch antenna. Reduction in the resonant frequency results in the reduction in the size of patch antenna. The slot loaded patch resonates at 5GHz and the simulation results indicate the return loss at 5GHz is -33.75dBi, VSWR is 1 and gain is 6.2dBi. The paper compares the parameters of original and slotted patch antenna. The IE3D electromagnetic simulation and optimization engine based on MoM has been used for the purpose.**

Index Terms— **Patch, slot, antenna parameters etc.**

I. INTRODUCTION

Compact sizes, low profile, conformal and multiband are the highly desirable attributes of a microstrip patch antenna [1]. Many techniques have been used to reduce the size of antenna, such as using dielectric substrates with high permittivity [2], applying resistive or reactive loading [3], increasing the electrical length of antenna by optimizing its shape [4], Utilization of strategically positioned notches on the patch antenna [5]. Various shapes of slots and slits have been embedded on patch antennas to reduce their size. Slot antennas are used typically at frequencies between 300 MHz and 24 GHz. These antennas are popular because they can be cut out of whatever surface they are to be mounted on, and have radiation patterns that are roughly omni directional. The currents travel around the slot perimeter increasing the electrical length. As such, a slotted small size antenna is made to perform equivalent to its larger counterpart. Earlier, it has been shown that by placing a single U-shaped slot on a microstrip patch, a broadband operation can be obtained [6-7]. The loading of slots on the conducting patch element can cause meandering of the excited patch surface current paths and results in lowering of the resonant frequency, which corresponds to the reduced antenna size [8] compared to the conventional microstrip patch antenna at designed frequency. Reactive loading can be introduced by etching slots on a patch. The slot loading allows one to strongly modify the resonant mode of a rectangular patch, particularly when the slots cut the current lines of the unperturbed mode [9]. Experimental results of the slot-loaded, rectangular patch with five slits have been presented in [10].

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II. ANTENNA DESIGN AND SIMULATION RESULTS

A square patch of dimensions 37.62mm x 37.62mm as shown in the figure 1 has been designed on a substrate of relative permittivity(Er) 2.6, tangent loss 0.0025 and substrate thickness of 1.542 mm using the procedure given in microstrip and printed antenna handbook by Randy Bancroft [11]. All simulations have been performed using electromagnetic simulator IE3DTM.

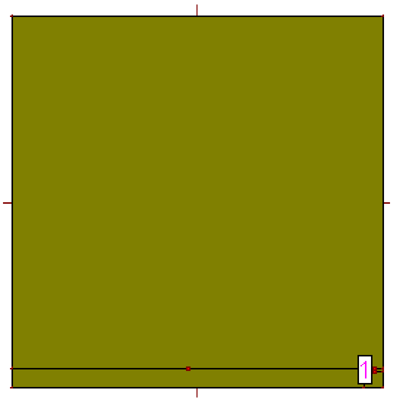

Fig. 1 Original square patch of dimensions 37.62mm x 37.62mm with feed point

The patch has been fed at 17.5mm, -17.5mm feeding point. The return loss of the same has been shown in the figure 2 which shows the antenna resonates at three different resonant frequency namely 7GHz with return loss of -13.4dBi, 10GHz with return loss of -15.5 and 13GHz with return loss of -16.2dBi. The radiation pattern of the antenna at all three resonant frequencies has been shown in the figure 3, 4, and 5.

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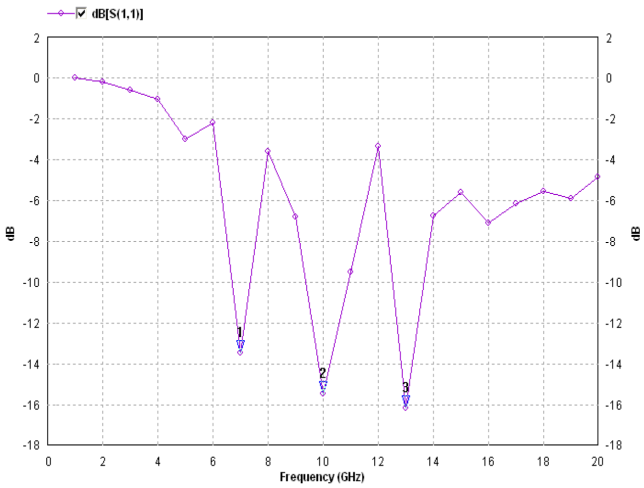

Fig. 2 Return loss of original square patch

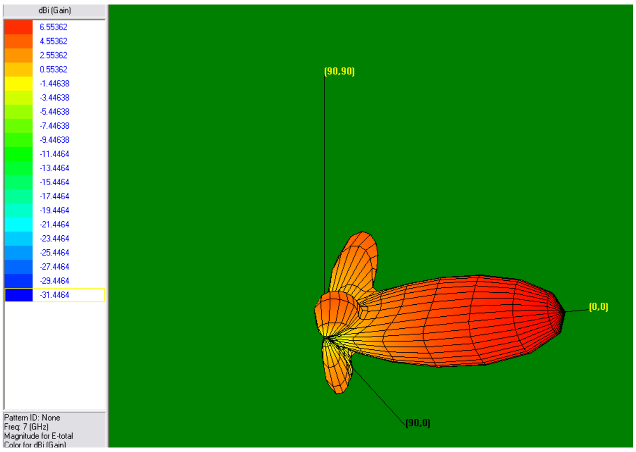

Fig. 3 Radiation pattern of original square patch at 7GHz

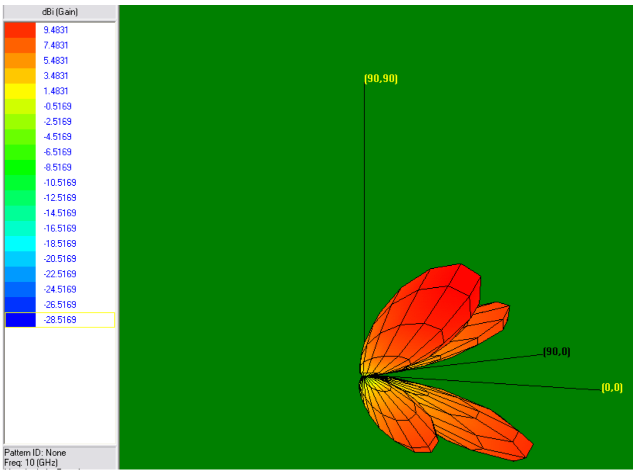

Fig. 4 Radiation pattern of original square patch at 10GHz

Fig. 5 Radiation pattern of original square patch at 13GHz

From these radiation patterns we can find the maximum achieved gain is 6.5 dBi at 7GHz, 9.4dBi at 10GHz and 8.5dBi at 13GHz. The total field gain versus frequency has been shown in the figure 6. The total field directivity of the original patch at all three resonant frequency has been shown in the figure 7.The value of directivity is 10dBi at 7GHz, 11.5dBi at10GHz and 11.5dbi at 13GHz.

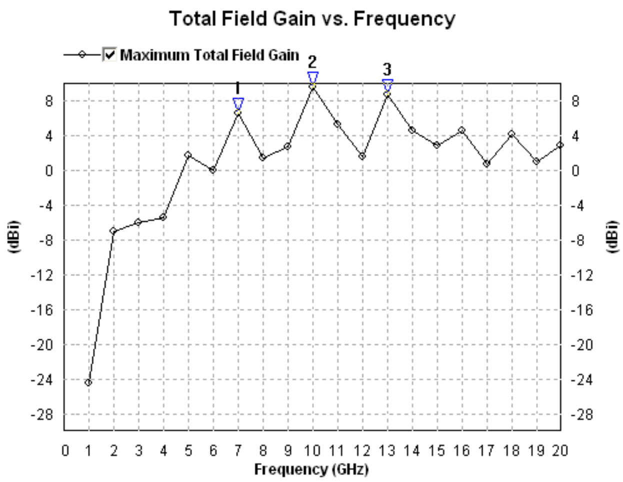

Fig. 6 Total field gain at 7GHz, 10GHz and 13GHz

Voltage Standing Wave Ratio (VSWR) of this original patch antenna is 1.5 at 7GHz, 1.4 at 10GHz and 1.3 at 13GHz.These values may be read from the VSWR plot as shown in the figure 8. Various parameters like s11, VSWR, gain, bandwidth and directivity obtained for original square patch antenna have been put in table 1. Now an asymmetrical U-shaped slot is loaded in the original square patch. The shape and dimensions of this slot has been shown in the figure 9.

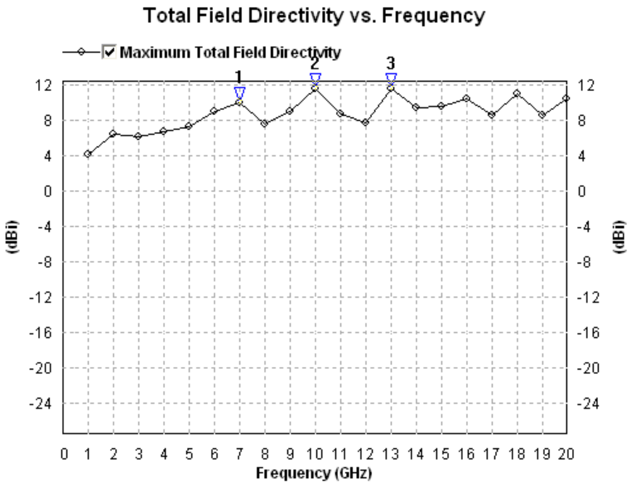

Fig. 7 Total field directivity at 7GHz, 10GHz and 13GHz

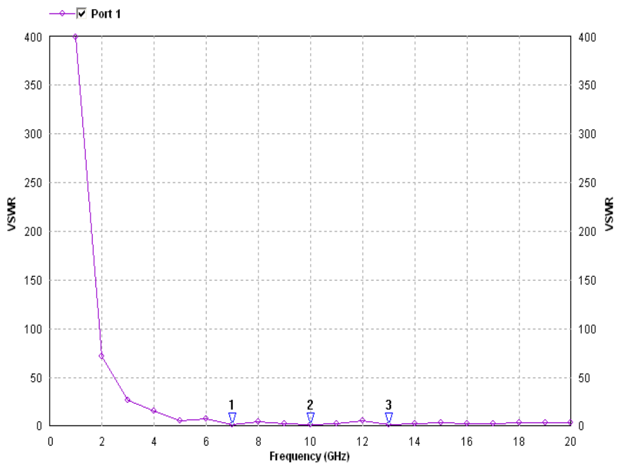

Fig. 8 VSWR plot of original square patch antenna at 7GHz, 10GHz and 13GHz.

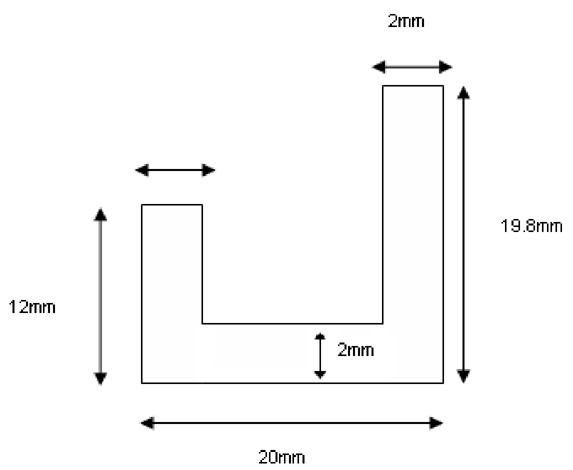

Fig. 9 An asymmetrical U-Shaped Slot to be loaded into the patch

Table 1 showing the diffrerent parameters of unloaded original square patch antenna

Parameters	Resonant frequency of original square patch antenna		
	fr =7GHz	fr=10GHz	fr =13GHz
Return loss (s11)	-13.4dBi	-15.5dBi	-16.2dBi
VSWR	1.5	1.4	1.3
Bandwidth	633MHz	1.534GHz	1.1GHz
Gain	6.5dBi	9.4dBi	8.5dBi
Directivity	10dBi	11.5dBi	11.5dBi

The complete geometry of the square patch loaded with an asymmetrical slot has been shown in the figure 10. The slot loaded patch antenna has been fed coaxially at 14.5mm, -14.5mm.

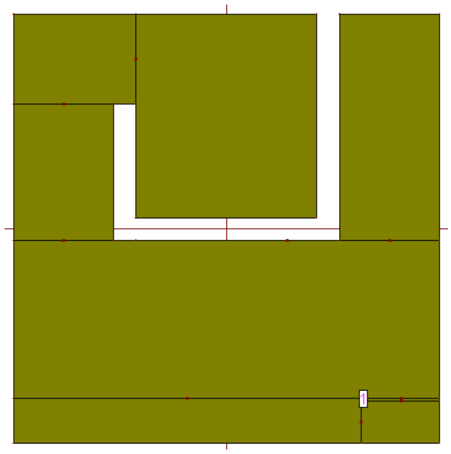

Fig. 10 Slotted Patch antenna with feed point

Simulation results show that the proposed antenna resonates at 5GHz. The value of return loss at 5GHz is -33dBi.The return loss characteristics have been shown in the figure 11.

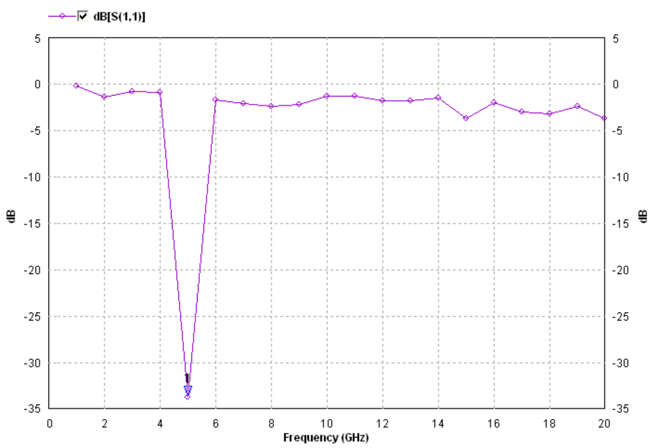

Fig. 11 Return loss of slot loaded patch antenna

The radiation pattern of the proposed antenna at resonant frequency of 5GHz has been shown in the figure 12.The maximum gain at this frequency is 6.3dBi.

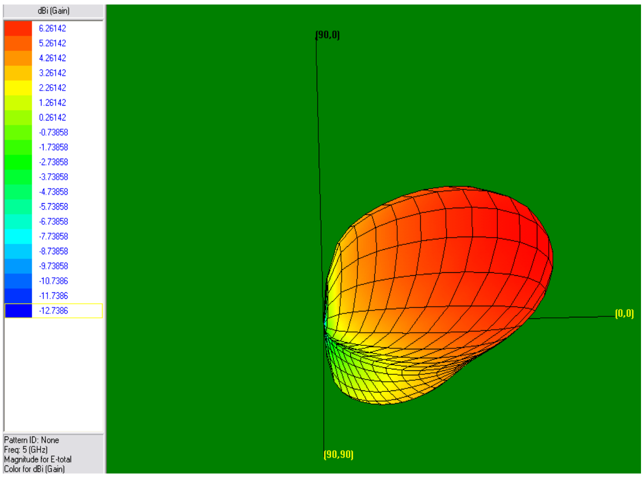

Fig. 12 Radiation pattern of slot loaded square patch at 5GHz

The total field gain versus frequency has been shown in the figure 13. The total field directivity of the slot loaded patch at resonant frequency has been shown in the figure 14.The value of directivity is 7.7dBi at 5GHz. VSWR of this patch antenna is 1at 5GHz.This values may be read from the VSWR plot as shown in the figure 15. Various parameters like s11, VSWR, gain, bandwidth and directivity obtained for original square patch antenna loaded with an asymmetrical U-shaped slot have been put in table 2.

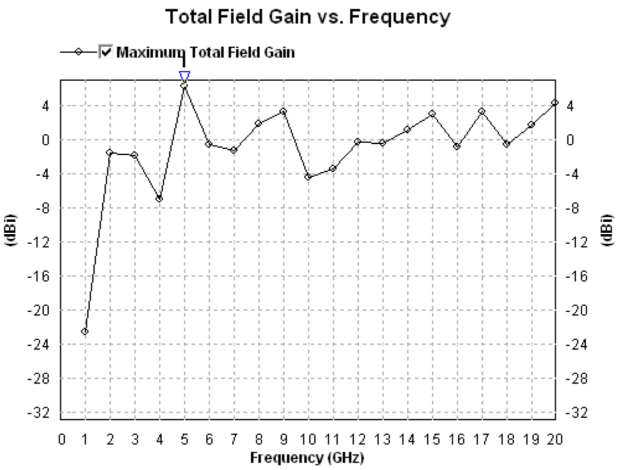

Fig. 13 Total field gain of slot loaded patch antenna at 5GHz

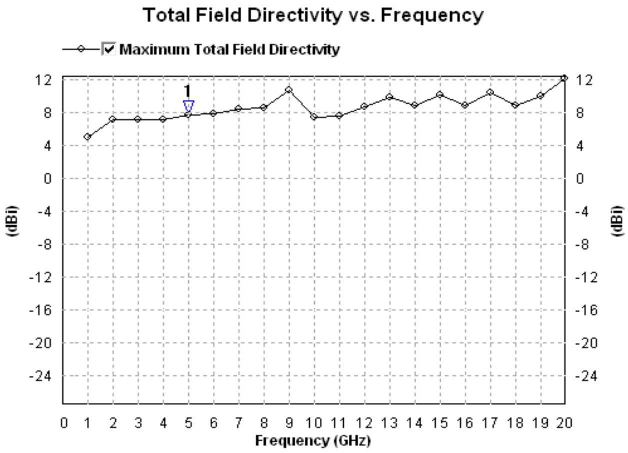

Fig. 14 Total field directivity of slot loaded patch antenna at 5GHz

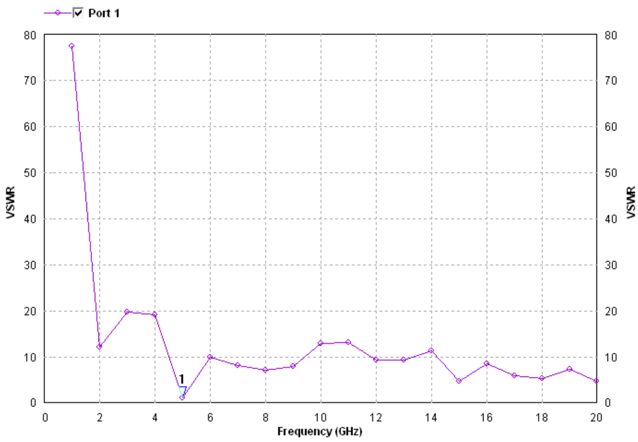

Fig. 15 VSWR plot of slot loaded patch antenna at 5GHz.

Table 2 showing the diffrerent parameters of slot loaded square patch antenna

Parameters	Resonant frequency of slot loaded original square patch antenna
	fr =5GHz
Return loss (s11)	-33.7dBi
VSWR	1
Bandwidth	1.457GHz
Gain	6.3dBi
Directivity	7.7dBi

III. CONCLUSION AND FUTURE WORK

This paper designs, simulates and compares the characteristics of a simple square microstrip patch antenna and the same antenna loaded with an asymmetrical U-shaped slot on it. Three frequency bands of 7GHz, 10GHz and 13GHz on which original square patch antenna was resonating are suppressed after loading this U-shaped slot into it. There is also a reduction of 28.5% in the resonant frequency of original square patch with respect to lowest frequency band of 7GHz when compared with the proposed slotted antenna. Reduction in the resonant frequency leads to the reduction in the size of the original square patch antenna. Mathematical analysis of the proposed design has been left for future work. Other shapes of slots may also be loaded into the simple square patch antenna to decrease the resonant frequency further.

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