A Double U-Slots Microstrip Antenna for Triple-bands Operation

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ABSTRACT
In this paper, a design of double U-slots microstrip antenna with triple bands operation is presented. The antenna geometry is fed with a coaxial line feed technique. The feed is connected between the two arms of U-slots. The two slots are created on patch which is placed on the dielectric substrate of FR4 material with the overall dimensions of 74 mm × 67 mm × 1.6 mm. The proposed antenna geometry's performance is investigated in the frequency range of 5 GHz to 10 GHz. This geometry exhibits three resonances at 6.64 GHz, 8.21 GHz, and 9.18 GHz. However, in this work we presented U-Slot antenna which excites dual band operation with improved performance. The bandwidth at second resonant frequency was obtained broad as compared to the conventional patch antennas (2~3%). The proposed geometry was fabricated and tested for its validation. Measured results fairly agree with the simulated values.

Keywords
Microstrip Antenna, Slot Antennas, U-Slot, Triple Bands Antenna.

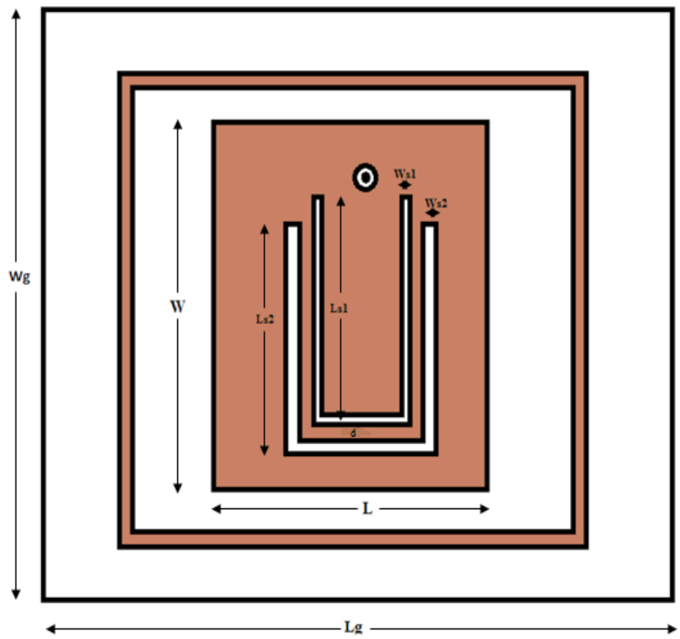
1. INTRODUCTION
Initially, the microstrip antennas were developed only for the space communication, but today due to their advantageous nature, these are used in government as well as in some commercial applications [1-2]. In trans-receivers, planar antennas play a vital role in the field of wireless communications. Some of them are microstrip patch antennas, folded dipole antennas, and slot antennas with each type having their own properties and usage. Among all these planar antennas the microstrip patch antennas have more advantages and better prospects, such as they are lighter in weight, low volume, low profile, smaller in dimension, ease of fabrication and conformity. Moreover, these microstrip patch antennas can provide dual and circular polarizations, dual-frequency operation, frequency agility, broad band-width, and feed line flexibility, and beam steering & omni-directional patterning also [2].

However, the serious problem of patch antennas is their narrow bandwidth due to surface wave losses, lower gain, low cross polarization and large size of patch for better performance and also narrow scanning range, and due to these problems it has created a need for an antenna with an enhanced bandwidth and gain. To realize a broad bandwidth & high gain, many antennas using the various techniques have been reported [3-17] with dual and multiple bands [18-19]. For example, by using the phase array patch structures, the multilayered structures or the parasitic radiators, it is possible to design the patch antennas with a broad bandwidth [1-4].

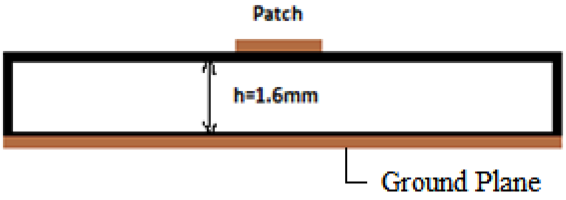
In this work, U- slot microstrip antenna has been investigated thoroughly for exciting triple bands with a gain of 5.65 dB. Although, the proposed U-slots geometry exhibits multiple S_{11} bands, but only three resonances are useful as gain is positive at these frequencies. The antenna presented in this work is taken from [10]. The antenna presented here is similar to [10] with an additional U-slot to have second & third resonances. More details of this geometry are discussed in following sections.

Section 2 presents the basic geometry of the proposed antenna. Optimization of the final geometry is presented in Section 3. Experimental validation of the work is presented in Section 4. The conclusion and possible extension of the work is presented in Section 5.

2. ANTENNA DESIGN
The proposed antenna geometry with coaxial line feeding is shown in Figure 1 and its optimized dimensions are listed in following Table 1. In this proposed design the two U-Slots are added to excite the multiple resonances and also to enhance the gain & bandwidth of respective resonance band. The proposed geometry was designed and optimized on the substrate of glass epoxy (FR 4) with thickness of 1.6 mm, dielectric constant of 4.4, and a loss tangent equal to 0.01. The antenna is simulated using Ansoft's High Frequency Structure Simulator (HFSS) v.13 [20] which is electromagnetic simulation software. The detailed optimization procedure of the proposed antenna and its optimum dimensions, and characteristics are presented in Section 3.



(a) Top view of U-slot antenna



(b) Cross sectional view

Figure 1: Geometry of the proposed antenna

Table 1: Dimensions of the optimized geometry

Parameter	L_g	W_g	L	W	L_{s1}	Ws_1	L_{s2}	W_{s2}	d
Values (mm)	74	67	24	36.5	22	1	20	2	0.5

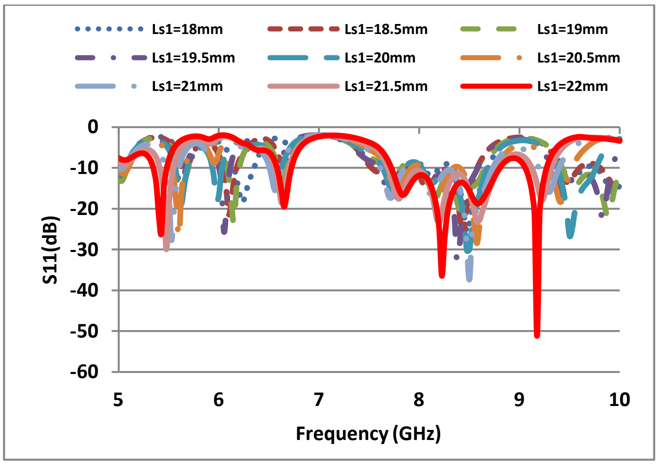
3. GEOMETRY OPTIMIZATION

In this section parametric study is conducted to optimize the proposed antenna geometry. The key design parameters used for the optimization are length of the outer & inner U-slot arms, width of the outer & inner U-slot arms, gap between outer & inner U-slots, and with only outer or inner U-slot. The detailed analysis & effect of these parameters on the geometry performance is investigated in the following subsections. All simulations were carried out with the help of HFSS software.

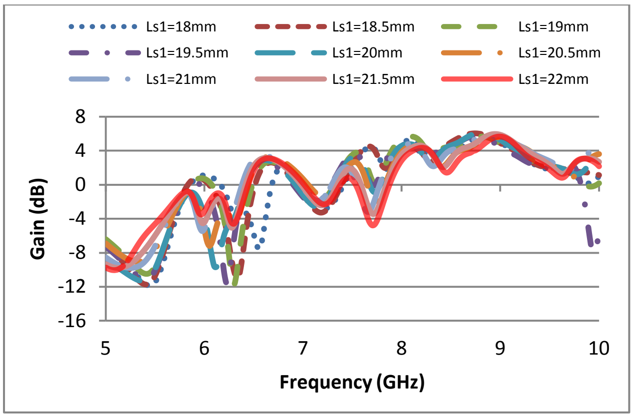
3.1 Effect of Length of U-Slot Arms

3.1.1 Effect of Length of Inner U-Slot (L_{s1})

The length of inner U arms is changed from 18 mm to 22 mm in steps of 0.5 mm keeping all the parameters constant. The effect of length variation on reflection coefficient (S_{11}) and gain characteristics of antenna are shown in Figure 2 (a) & (b), respectively. From this study it can be noticed that the first and third resonances shift towards left as the value of inner U-arm length increases. The maximum gain of 5.2 dB was obtained.



(a) Effect of inner U-slot length variation on reflection coefficient characteristics.

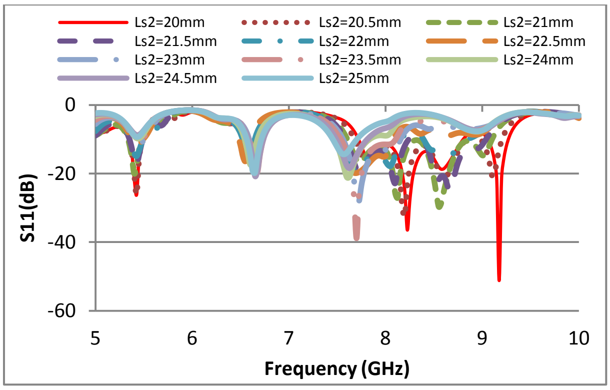


(b) Effect of inner U-slot length variation on gain characteristics.

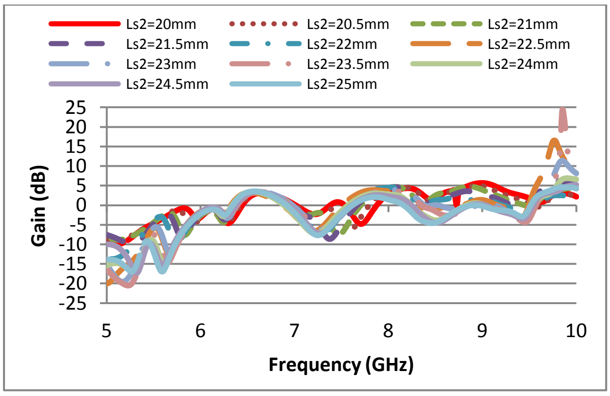
Figure 2: Reflection and gain vs. frequency characteristics.

3.1.2Effect of Length of Outer U-Slot (L_{s2})

In this case, the length of outer U-arm was varied from 20 mm to 25 mm in steps of 0.5 mm with all other parameters kept constant. From this study it can be noted that the third & second resonances are shifted towards left with increase in the length of outer U-arm. However, the first resonance has been shifted towards right. The results (S_{11} and gain vs. freq.) are presented in Figure 3 (a) & (b), respectively. From Figure 3 it may be noted that the optimum results can be obtained for Ls2=20 mm.



(a) Effect of outer U-slot length variation on reflection coefficient characteristics.



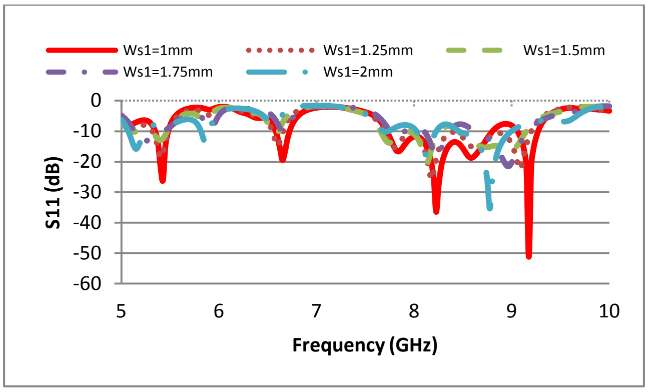
(b) Effect of outer U-slot length variation on gain characteristics.

Figure 3: Reflection and gain vs. frequency characteristics.

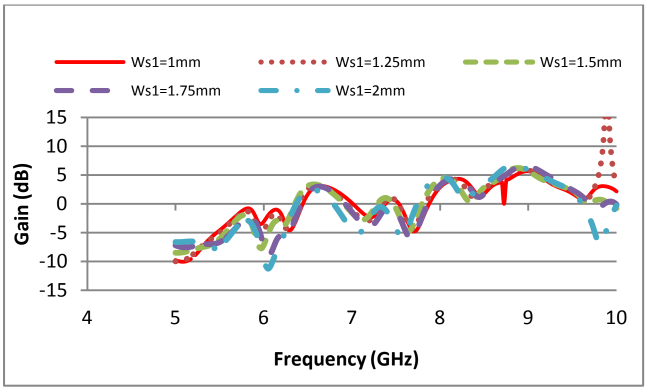
3.2 Effect of Width of U-Slot arms

3.2.1 Effect of Width of Inner U-Slot (W_{s1})

In another effort, the width of outer U-slot arm is varied from 1 mm to 2 mm in steps of 0.25 mm keeping all the parameters constant. From these variations it is observed that the increase in the width of inner slot results in the drop of performance of antenna. From Figure 4 (a) & (b) it can be noticed that the geometry exhibits optimum performance for W_{s1}= 1 mm.



(a) Effect of inner U-slot width variation on reflection coefficient characteristics.

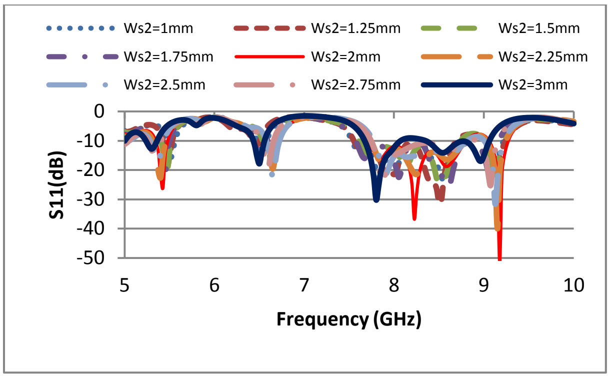


(b) Effect of inner U-slot width variation on gain characteristics.

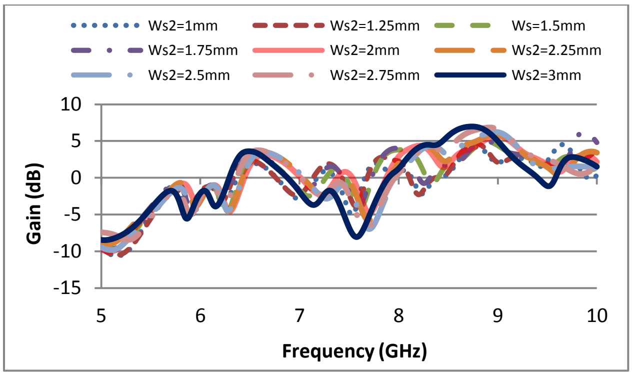
Figure 4: Reflection and gain vs. frequency characteristics.

3.2.2Effect of Width of Outer U-Slot (W_{s2})

Here, the effect of outer U-slot's width on geometry performance was investigated. The width of these two arms is changed from 1 mm to 3 mm in steps of 0.25 mm keeping all the parameters constant. From this study it can be noted that the third & second resonance is shifted towards left as the value of length changes with first resonance shifted towards right. From following figure it is important to note that the optimum results with higher gain & better reflection coefficient characteristics are obtained at the W_{s2}= 3mm.



(a) Effect of outer U-slot width variation on reflection coefficient characteristics.

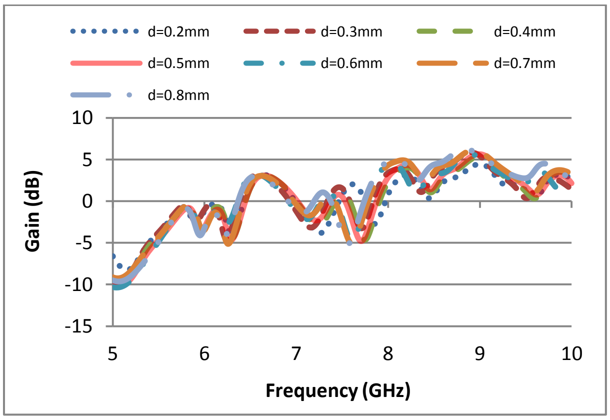


(b) Effect of outer U-slot width variation on gain characteristics.

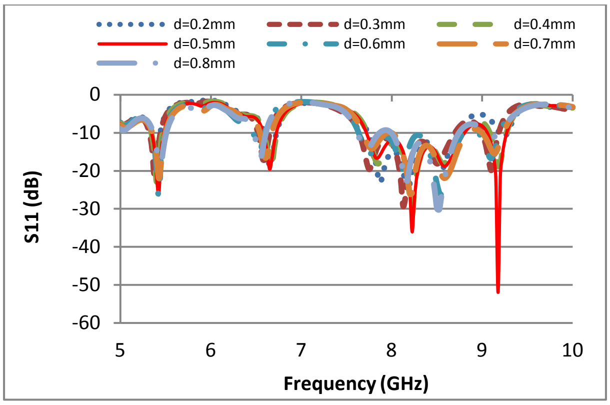
Figure 5: Reflection and gain vs. frequency characteristics.

3.3 Effect of Spacing Between Two U-Slots (d)

In yet another effort, the spacing between the U-slots was investigated. The spacing between these slots is varied from 0.2 mm to 0.8 mm in steps of 0.1 mm keeping all the parameters constant. The optimum results were obtained for the gap of 0.5mm. From this study it can be noted that the third & second resonances shift towards left as the gap between slots increases. The maximum gain obtained for the optimum case is 6.22 dB when the spacing between two slots is 0.5 mm.



(a) Effect of spacing between two U-slots variation on reflection coefficient characteristics.



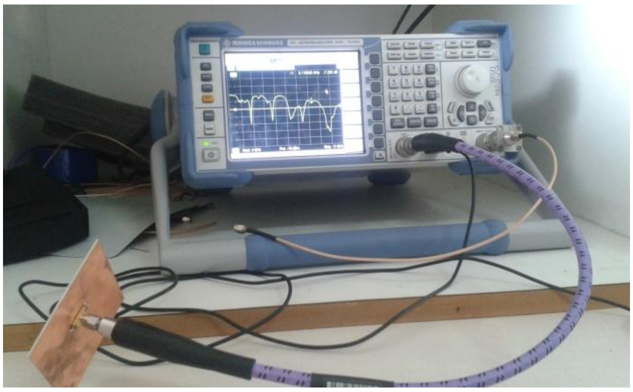
(b) Effect of spacing between two U-slots variation on gain characteristics.

Figure 6: Reflection and gain vs. frequency characteristics.

4. EXPERIMENTAL VALIDATION OF THE GEOMETRY AND DISCUSSIONS

The basic geometry of the double U-slots microstrip antenna shown in Figure 1 with its optimized dimensions presented in Table 1 was fabricated and tested. The substrate used for the fabrication of antenna is the FR 4 glass epoxy material with the thickness of 1.6 mm, dielectric constant (ε_r) of 4.4, and the loss tangent (tan (δ)) = 0.01. A photograph of the fabricated prototype antenna is shown in Figure 7 (a) and its reflection coefficient characteristics (S_{11}) measurement setup is shown in Figure 7 (b). Reflection coefficient characteristics (S_{11}) of measured and simulated values are compared in Figure 8. The measured results fairly agree with the simulated values. Radiation patterns of the antenna at three resonance frequencies are presented in Figure 9. From these plots it is clear that the patterns are stable at all three resonant frequencies.

(a) Fabricated prototype



(b) S_{11} measurement setup

Figure 7: Photographs of the fabricated antenna and its measurement setup.

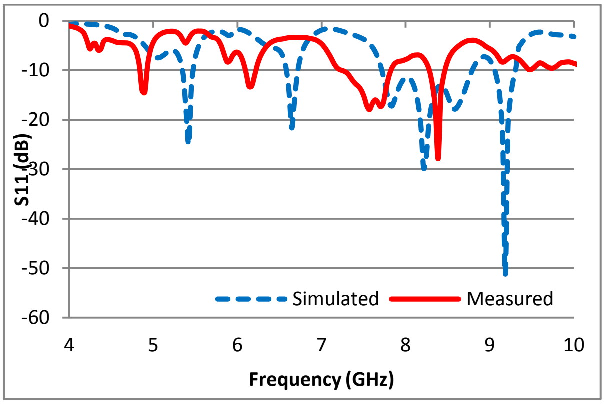
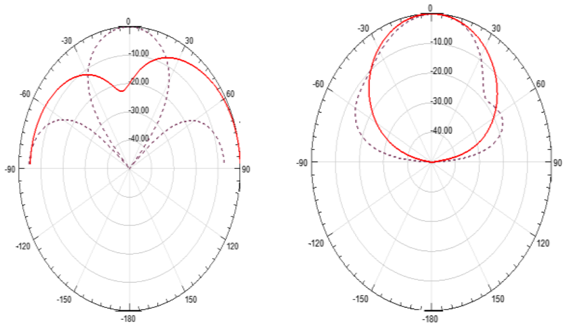
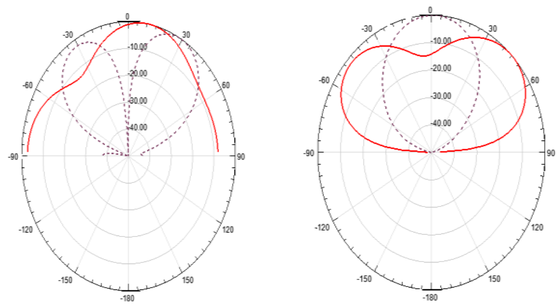


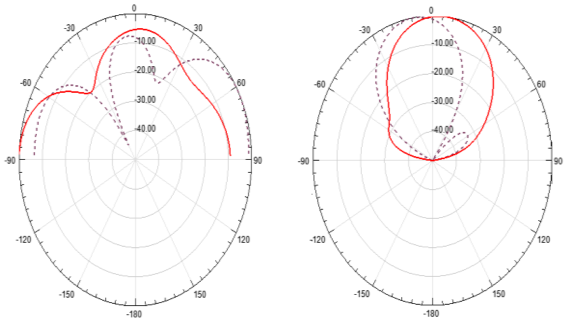
Figure 8: Return loss characteristic plot of the proposed antenna shown in Figure 1.



(a) E-plane and H-plane patterns at 6.6 GHz



(b) E-plane and H-plane patterns at 8.2 GHz



(**a**) E-plane and H-plane patterns at 9.1 GHz

Figure 9: E and H plane radiation patterns at different frequencies in operating band. Note: Solid lines: Co-polns. Dashed lines: Cross polns.

5. CONCLUSIONS

In this paper, a microstrip antenna with triple bands loaded by two U-slots has been presented. The addition of U-slots on patch geometry helps in achieving proper bandwidth, gain, and radiation characteristics. The proposed antenna offers broader impedance bandwidth at second resonant frequency as compared to the conventional patch antenna (2~3%). The operating frequencies of the proposed antenna may be fine tuned by changing the slot dimensions and gap between them. Further study includes analysis of the antenna for its modeling and possible enhancement of bandwidth at first resonance.

The future work includes the investigation of effect of patch and outer U-slot location on improvement of bandwidth as well as gain of double U-slot antenna with the multiband operation.

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