Broadband Stacked H-shaped Patch Antenna

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***Abstract*—A broadband U-slot loaded rectangular patch stacked with H-shaped patch antenna is presented in this paper. The resonating behavior of antenna depends on Slot width, slot length of side arm and base arm of U-slot. Similarly , it depends on notch length and width of H-shaped parasitic patch and separation between the two patches. Optimization of these parameters gives impedance Bandwidth of 44.5%. The theoretical results are in good agreement with simulated results.**

***Index Terms*— U-slot, H-shaped, stacked and broadband antenna.**

I. Introduction

Microstrip antenna exhibits narrow bandwidth and low gain that limits its application in practice[12,14]. Several approaches have been made to improve the bandwidth of the patch antenna, such as use of a thick or foam substrate, cutting slots or notches like U-slot, E-shaped, H-shaped patch antennas and two layer electromagnetically coupled stacked structures[1-9]. Several dual frequency and wide band antennas have been reported using stacked structures. A U-slot loaded rectangular patch stacked with H-shaped parasitic patch exhibits dual band with impedance bandwidths of 3.66% and 10.25% at lower and upper resonance respectively [2]. Further optimization of slot and notch dimensions in the two patches of stacked structure[2] is proposed to obtain wideband of 44.5%. Coaxial probe is connected to lower U-slot and feed probe is located close to patch centre for good excitation of antenna over entire range. The modified structure shows great improvement in bandwidth. The structure is simulated using IE3D simulation software[15] and theoretical analysis is carried out using equivalent circuit model[11-13].

II. Theoretical Considerations

The antenna structure is shown in figure.1. The upper parasitic patch is H-shaped and lower one is coaxial probe fed U-slot loaded patch. Due to presence of parasitic element in the stacked configuration, there are two resonant associated with two resonators. These two resonance frequencies are closely spaced to give broadband characteristics. The first resonator is considered as a microstrip patch with dielectric cover which causes a change in resonance frequency and effective dielectric constant. Microstrip patch with a dielectric cover is considered as a single patch with a semi-infinite superstrate with relative permittivity equal unity and single relative dielectric constant (ε_s) given as

$$\varepsilon_s = \frac{2\varepsilon_{ff} - 1 + p}{1 + p}$$

where, $p = 1 + \dfrac{10h_1}{W_{1e}}$

In which W_{ie} is effective width and ε_{ff} is effective dielectric constant of structure. h_1 is height between ground plane and lower patch. W_1 is the width of the patch. A simple rectangular microstrip antenna is considered as a parallel combination of Resistance (R_1), inductance(L_1) and capacitance(C_1), the values of which can be defined as [12]. The equivalent circuit of simple rectangular patch is shown in Fig .2. U-slot loaded patch is analyzed by considering two sections in the patch. First section is an E-shaped patch and second (lower one) as microstrip bend line. The dimensions of both the sections are shown in Fig. 1(b).The Section 1 is analyzed as a patch in which two parallel notches are incorporated. This perturbation in the patch changes the current length which is accounted for by an additional series inductance ΔL_1 and a series capacitance ΔC_1 . So the equivalent circuit of section (1) is modified, in which

$$L_E = L_1 + \Delta L_1$$

and

$$C_E = \frac{C1\Delta C_1}{C_1 + \Delta C_1}$$

The additional inductance ΔL_1 is given as [4]. The capacitance ΔC_1 is calculated as gap capacitance given by [12].

The second section is considered as two microstrip bend line and the values of L_b and C_b are given as [9].

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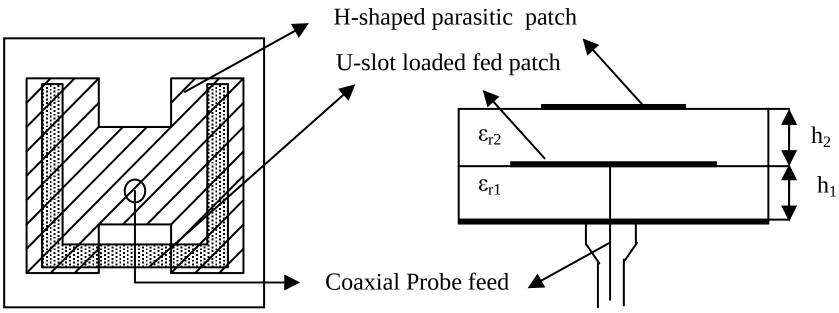
$$\frac{C_b}{w_b} = \left(9.5\varepsilon_{r_1} + 1.25\right)\frac{w_b}{h_1} + 5.2\varepsilon_{r_1} + 7.0 \text{ pF/m}$$

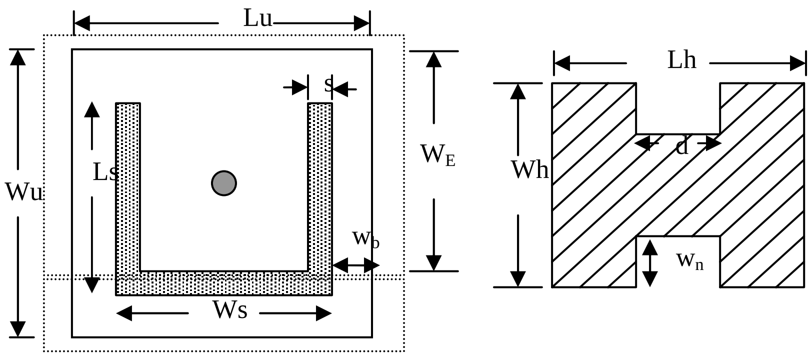
$$\frac{2L_b}{h_1} = 100\left(4\frac{w_b}{h_1} - 4.21\right)\text{nH/m}$$

Combining the above two sections we consider U-slot loaded patch and its equivalent circuit is given as shown in Fig. 3. Now the total impedance of U-slot loaded patch is

$$Z_U = \frac{2Z_b Z_E + Z_b Z_b}{Z_E + 2Z_b}$$



(a) Top and side view of antenna



(a) U-slot loaded lower patch and H-shaped upper patch

Figure 1. Antenna Structure

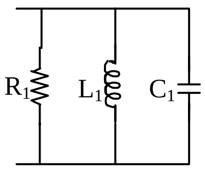


Figure 2. Equivalent circuit of rectangular patch.

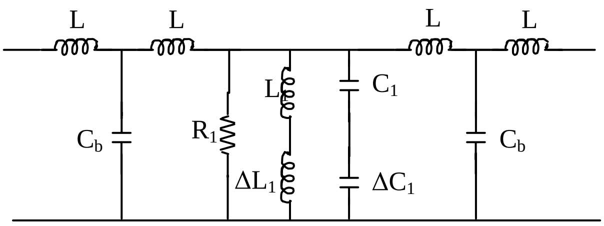


Figure 2. Equivalent circuit of U-slot loaded patch.

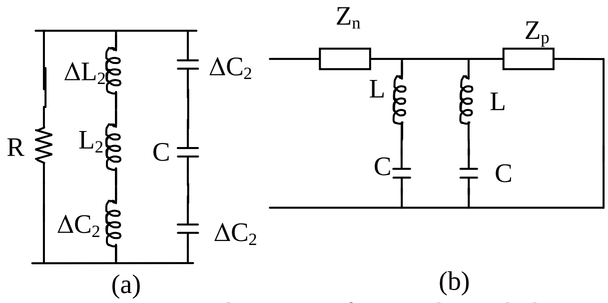


Figure 2.(a) Equivalent circuit of rectangular patch due to notch effect. (b) Equivalent circuit of H-shaped patch.

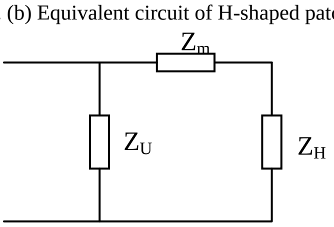


Figure 2. Equivalent circuit of stacked patch antenna.

where, $Z_b = jwL_b + \dfrac{1}{\dfrac{1}{jwL_b} + jwC_b}$

and Z_E is the input impedance of the E-section of U-slot loaded patch.

The upper patch is H-shaped which is obtained when two symmetrical notches are incorporated into rectangular patch, the equivalent circuit is thus shown in figure .4(a), in which ΔL_2 and ΔC_2 are additional inductance and capacitance respectively which originate due to two notches and are given as[1,2]

$$\Delta L_2 = \frac{h_1 \mu_o \pi}{8}\left(\frac{W_2}{w_n}\right)$$

where, $\mu_o = 4\pi 10^{-7}$H/m

and $$\Delta C_2 = \left(\frac{W_2}{w_n}\right) C_s$$

where C_s is the gap capacitance between two side strips [9]. Now the equivalent circuit of H-shaped patch is given as shown in Fig. 4(b) in which 'Z_n' is the impedance of the notch incorporated patch and is calculated from Fig. 4(a), Z_p is the impedance of the initial patch and C_m and L_m are the capacitive and inductive coupling between two resonant circuits. The equivalent circuit of the proposed stacked antenna can be given as shown in Fig. 5, in which only capacitive coupling is considered and is given by [10].

$$C'_m = -\frac{\left(C_{eq} + C'_{eq}\right) + \sqrt{\left(C_{eq} + C'_{eq}\right)^2 - 4C_{eq}C'_{eq}\left(1 - k_c^{-2}\right)}}{2}$$

where,

$$C_{eq} = \frac{\Delta C_1 C_1}{2C_1 + \Delta C_1}$$

and

$$C'_{eq} = \frac{\Delta C_2 C_2}{2C_2 + \Delta C_2}$$

and k_c is the coupling coefficient between two resonators. Thus the total input impedance can be calculated from Fig. 5 as

$$Z = \frac{Z_U \left(Z_m + Z_H\right)}{Z_U + Z_H + Z_m}$$

In which Z_U and Z_H are the impedances of lower and parasitic patches calculated from Fig. 3 and 4(b) respectively and Z_m is the impedance due to mutual coupling between driven patch and parasitic patch.

II. Design Specifications Of Proposed Antenna

Dielectric constant (ε_{r1})	1.1
Dielectric constant (ε_{r2})	1.01
Thickness between ground and lower patch (h_1)	6.0 mm
Thickness between lower and parasitic patch (h_2)	5.5 mm
Length of the fed patch (L_U)	39.4 mm
Width of the fed patch (W_U)	29.4 mm
Length of the slot (L_s)	17 mm
Width of the slot (s)	1.4 mm
Coaxial Probe Feed radius	1.6mm
Length of the parasitic patch (L_H)	26.5 mm
Width of the parasitic patch (W_H)	18 mm
Depth of the notch (w_n)	4 mm
Width of the notch (d)	12.4 mm

III. Discussion Of Results

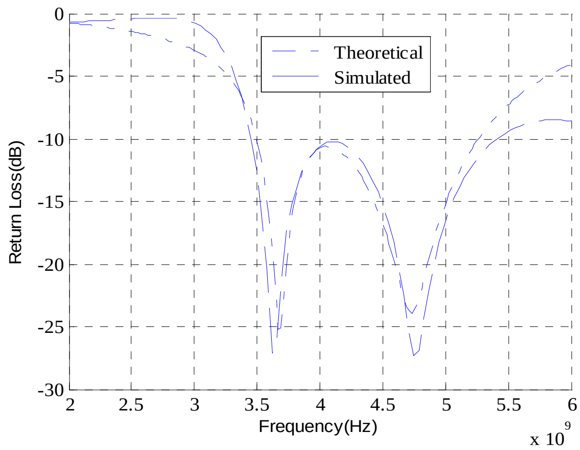


Figure 6.Variation of return loss with frequency for stacked antenna.

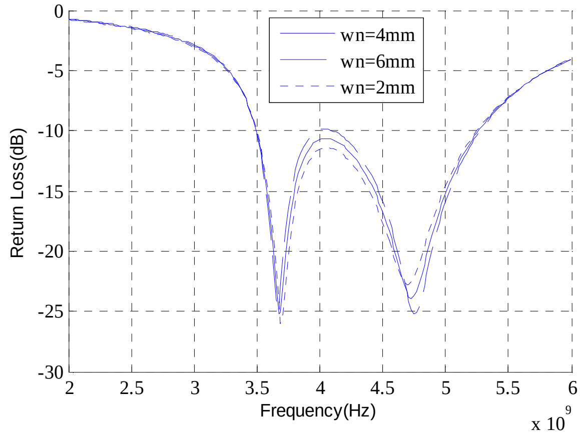


Figure 7.Variation of return loss with frequency for different notch depth in upper H-shaped patch.

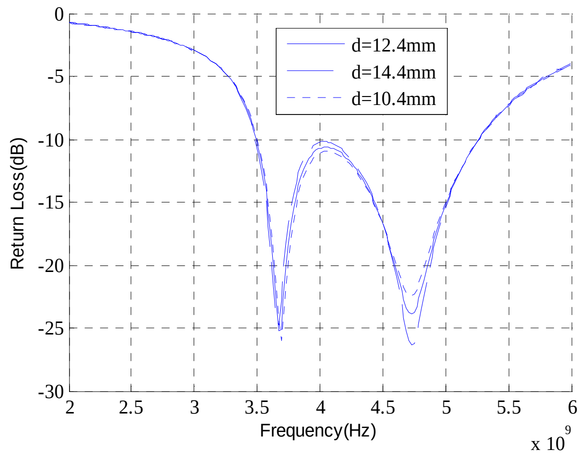


Figure 8.Variation of return loss with frequency for different notch width in upper H-shaped patch.

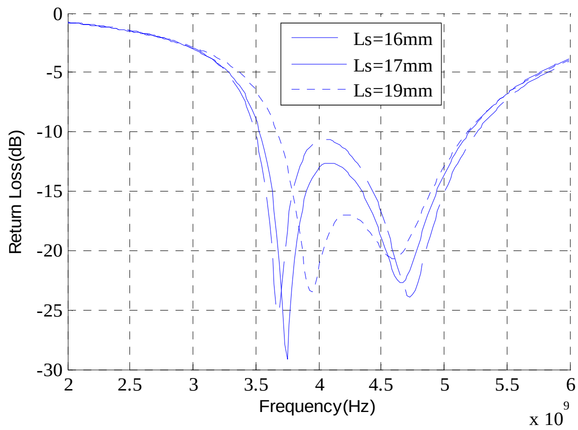


Figure 9.Variation of return loss with frequency for different slot length (side arm) in lower U-slot loaded patch.

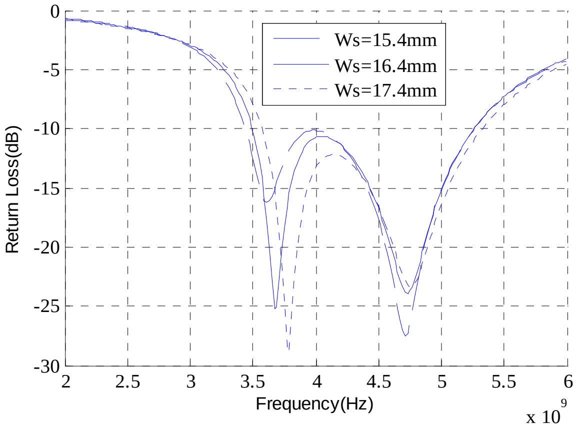


Figure 10.Variation of return loss with frequency for different slot length (middle arm) in lower U-slot loaded patch.

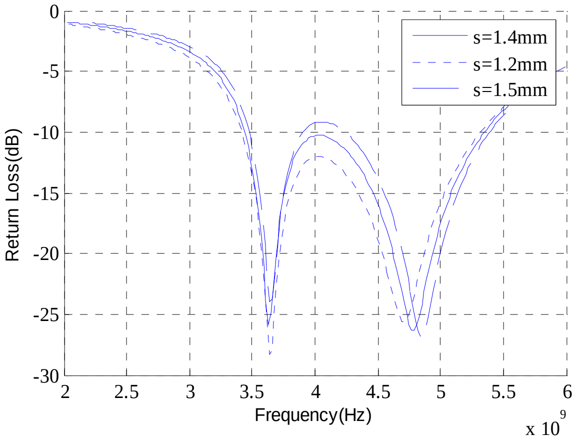


Figure 11.Variation of return loss with frequency for different slot width in lower U-slot loaded patch.

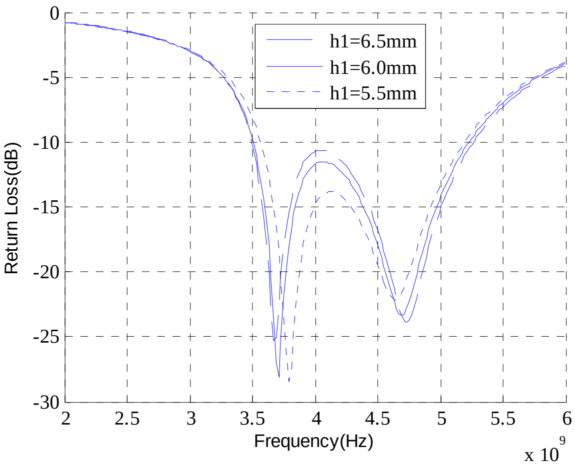


Figure 12.Variation of return loss with frequency for different thickness between ground and lower patch.

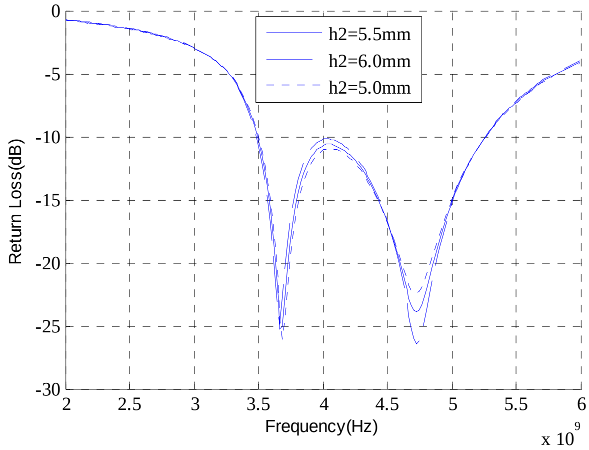


Figure 13.Variation of return loss with frequency for different thickness between lower patch and upper patch.

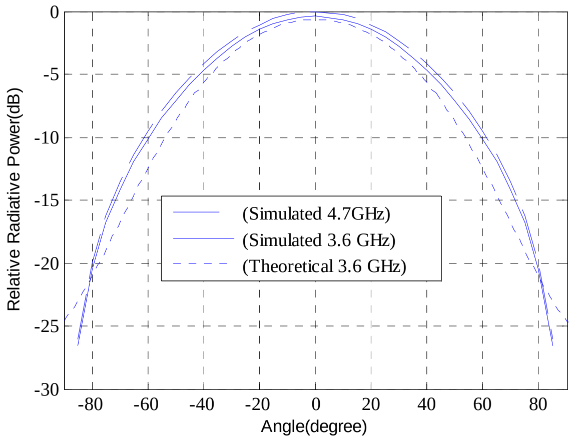


Figure 14.Radiation Pattern.

III. Discussion Of Results

Variation of return loss with frequency is shown for different slot and notch dimensions in lower and upper patches and thickness of the patches. It is observed that, two resonances at 3.6 GHz and 4.7 GHz are closely spaced to exhibit wide band of 44.5% impedance band width. From fig. 7, it is observed that with increase in depth of notch in upper H-shaped patch, there is slight shift in upper resonance with improved matching while lower resonance is almost fixed. No shift is observed in both the resonances , with change in notch width of parasitic patch as seen from fig. 8. lower resonance frequency increases more than upper resonance with increase in slot length of side arm in lower fed U-slot patch as observed from fig. 9, and only lower resonance frequency increases with increase in slot length of middle arm in lower fed U-slot patch while no shift is observed in upper resonance as is seen from fig. 10. case is different for variation of slot width in lower patch as is observed from fig. 11. In this case lower resonance frequency is fixed and upper one increases slightly with increase in slot width. As thickness between ground and lower patch increases lower resonance frequency decreases but resonance increases while there is almost no variation in both the resonances with change in thickness between lower patch and upper patch as is observed from fig. 12 and fig. 13 respectively. Fig. 14 show the radiation pattern is similar for entire range of resonating band. Fig. 14 and fig. 6 displays theoretical and simulated results, which are in close agreement

IV. Conclusion

From the analysis it is found that U-slot loaded patch when stacked with H-shaped patch exhibits broadband resonance with similar radiation pattern for entire range.

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