Analysis of U-slot loaded Patch for Dualband Operation
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Abstract
The analysis of U-slot loaded patch is carried out using equivalent circuit concept. The antenna exhibits dual resonance and the separation between two resonances is sensitive to the dimension of the slot. The theoretical results are compared with the simulated data using IE3D software which are in close agreement. Further radiation pattern is found to be invariant with the slot dimensions.

Index Terms: Microstrip antenna, patch antenna, U-slots loaded patch and dual band antenna.

1. INTRODUCTION
Microstrip antenna inherently has a low bandwidth that limits its application in practice. Several approaches have been made to improve the bandwidth of the single layer patch antenna, such as use of a thick or foam substrate [1-2]. Further a dual band antenna is a better option to accomplish the requirement of broadband microstrip antenna (MSA).

Various kind of microstrip antennas were proposed to provide dual band operation such as radial slot antenna [3], rectangular microstrip slot antenna with a π-shaped slot [4], and hybrid dielectric resonator antenna [5]. The reactively loaded antenna is one of the popular techniques to obtain the dual band operation. Dual resonance is obtained by introducing the slots parallel to the radiating edge of the patch [6], co-axial or microstrip stubs at the radiating edges [7-8], cutting the square slot in the patch [9-10]. These dual band microstrip antennas provide a tunable frequency ratio for various applications.

In this paper analysis of U-slot loaded rectangular microstrip antenna (RMSA) using equivalent circuit concept is presented. A U-slot adds a capacitive component in the input impedance that compensates for the inductive component of coaxial probe. The aim of the paper is to study the effect of U-slot on the antenna parameters such as input impedance VSWR and return loss etc.

2. THEORETICAL CONSIDERATIONS
A simple microstrip antenna is considered as a parallel combination of resistance(R), inductance (L) and capacitance (C) the values of which can be defined as [11].

U-slot loaded patch is analyzed by considering two sections in the patch. First section is an E-shaped patch [12] and second (lower one) as microstrip bend line. The dimensions of both the sections are shown in Fig-1. 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 $\Delta L$ and a series capacitance $\Delta C$ . So the equivalent circuit of section (1) is modified, in which

$$L_2 = L_1 + \Delta L$$

and

$$C_2 = \frac{C_1 \Delta C}{C_1 + \Delta C}$$

The additional inductance $\Delta L$ is given as [13]. The capacitance $\Delta C$ is calculated as gap capacitance given by [14].

The second section is considered as two microstrip bend line and the values of $L_b$ and $C_b$ are given as [15].
The values of capacitance and inductance of the microstrip bend line are given as

\[ \frac{C_b}{w_b} = (9.5 \varepsilon_r + 1.25) \frac{w_b}{h} + 5.2 \varepsilon_r + 7.0 \text{ pF/m} \]  

\[ \text{and } \frac{2L_b}{h} = 100 \left( 4 \sqrt{\frac{w_b}{h} - 4.21} \right) \text{ nH/m} \]  

Combining the above two sections we consider U-slot loaded patch and its equivalent circuit is given as shown in Fig. 2. Now the total impedance of U-slot loaded patch is

\[ Z_T = \frac{2Z_pZ_b + Z_bZ_p}{Z_p + 2Z_b} \]  

where \( Z_b = j\omega L_b + \frac{1}{j\omega C_b} \) and \( Z_p \) is the input impedance of the patch.

### 3. DESIGN SPECIFICATIONS OF U-SLOT LOADED PATCH

Length of the patch (L) is 5 cm and width is 7 cm, thickness of dielectric substrate is 15 mm having dielectric constant \( \varepsilon_r = 1 \). Length and width of the slot is taken 3.2 cm and 0.4 cm respectively. Antenna is fed at -1.495 cm along Y-axis.

### 4. DISCUSSION OF RESULTS

Variation of return loss as a function of frequency for a given slot dimensions (\( d = 4 \text{ mm}, \ell_s = 3.2 \text{ cm} \)) is shown in Fig. 3, along with the simulated results using IE3D software[16]. It is found that the antenna resonates at two frequencies \( f_1 = 1.385 \text{ GHz} \) and \( f_2 = 2.385 \text{ GHz} \) for which the current distribution is shown in Fig. 4 for lower and upper resonances respectively. It may be mentioned that both theoretical and simulated data are found to be approximately in close agreement.

The variation of return loss as a function of frequency for different value of slot width ‘d’ is shown in Fig. 5 for a given value of slot length \( \ell_s = 3.2 \text{ cm} \) (\( w_s = 3 \text{ cm} \)). It is observed that both lower and upper resonance frequency shift to higher frequency side with increasing value of slot width (d). It is further observed that matching and bandwidth improve with increasing value of ‘d’ at upper resonance whereas matching degrades with increasing value of d at lower resonance.

Variation of return loss as a function of frequency is shown in Fig. 6 for different value of slot length for constant value of slot width (d= 4mm). It is observed that both lower and upper resonance frequency shift to lower frequency side with increasing value of slot length.

It is interesting to note that ratio of the two resonances depend on the dimensions of the slot. It is found that ratio of two resonances (upper/lower i.e. \( f_2/f_1 \)) decreases with increasing slot width for a given slot length of \( \ell_s = 3.0 \text{ cm} \), whereas the ratio of two resonances increases with increasing value of slot length for a given slot width of d=4 mm. The dependence of ratio of two frequencies allows flexibility in the design of the dual band antenna.

### 6. REFERENCES


Fig. 1 U-slot loaded patch
Fig. 2 Equivalent circuit of U-slot loaded patch

![Equivalent circuit of U-slot loaded patch](image)

Fig. 3 Variation of return loss with frequency

![Variation of return loss with frequency](image)

(i) Lower resonance

(ii) Upper resonance

Fig. 4 Current distribution

![Current distribution](image)

Fig. 5 Variation of return loss with frequency for different value of slot width (d) (ls=3.0 cm)

![Variation of return loss with frequency for different slot width](image)

Fig. 6 Variation of return loss with frequency for different value of slot length (ls) (d= 4 mm)

![Variation of return loss with frequency for different slot length](image)