

## Stacked V-Slot Loaded Patch Antenna

\*J A Ansari<sup>1</sup>, Satya Kesh Dubey<sup>1</sup> and Prabhakar Singh<sup>1</sup>, R. U. Khan<sup>2</sup>, Babau R. Vishvakarma<sup>2</sup>

<sup>1</sup>Department of Electronics & Communication, University of Allahabad, Allahabad, India,

<sup>2</sup>Department of Electronics Engineering, I. T. BHU, Varanasi, 221005, India

E-mail: [jaansari@rediffmail.com](mailto:jaansari@rediffmail.com), [brvish@bhu.ac.in](mailto:brvish@bhu.ac.in)

**Abstract** — The analysis of V-slot loaded antenna stacked with simple patch is carried out using equivalent circuit model. It is found that stacked patch antenna exhibits enhanced bandwidth that depends on various dimensions of the V-slot. The proposed theoretical results are compared with simulated and reported experimental results which are in good agreement.

**Index Terms** — Patch antenna, V-slot loaded patch, stacked antenna, wideband microstrip antenna

### I. INTRODUCTION

One salient feature of the microstrip patch is its ease of integrating with electronic devices. Printed antenna can be fabricated on the same substrate used to develop microwave amplifiers and photonic devices, thereby making the transmitter and receivers module in a small size [1]. But, a classical microstrip patch antenna has a very narrow bandwidth that precludes its use in typical communication systems. However if the bandwidth could be widened, a broadband microstrip antenna would be very useful in the commercial applications such as 2.5G and 3G wireless systems, wireless local area networks (WLAN) and Bluetooth personal networks. Therefore various designs have been proposed to improve their bandwidth, including different shapes such as probe fed U-slot patch antenna [2], W-shaped patch antenna [3], H-shaped patch antenna [4], star shaped patch antenna [5], C-shaped microstrip antenna [6] and patch antenna with U-shaped parasitic elements [7].

Stacking is one of the most popular techniques to enhance the bandwidth [8]. It is found that if a new shaped patch antenna such as U-slot loaded patch, E-shaped patch, S-slot loaded patch etc. stacked with rectangular patch also increases the band width [9-10].

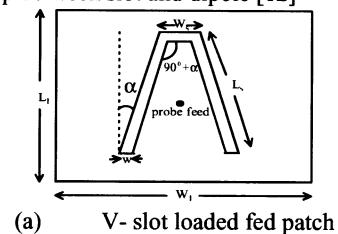
In the present paper a V-slot loaded patch stacked with a rectangular patch ( $L_1 \times W_1$ ) is analysed using equivalent circuit model based on modal expansion cavity model, in which the performance of V-slot loaded stacked patch is studied as a function of V-slot thickness (w), slot length ( $L_s$ ) and V-slot base width ( $W_s$ ). The theoretical results so obtained are compared with the simulated and experimental results [11].

### II. THEORETICAL CONSIDERATIONS

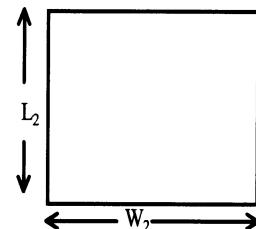
#### A. Analysis of V-slot loaded patch antenna

Configuration of V-slot loaded patch stacked with rectangular patch coaxially fed at the center of the patch is shown in Fig. 1. A V-slot loaded patch can be

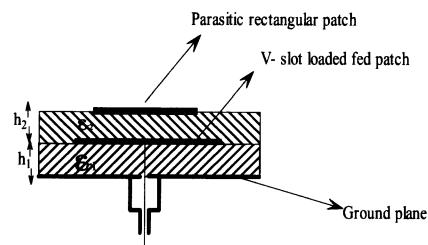
analysed as two slots at radiating edges at an inclined angle ' $\alpha$ ' and a base slot at nonradiating edge. An inclined slot in the patch can be analysed using duality relationship between slot and dipole [12]



(a) V-slot loaded fed patch



(b) Rectangular stacked patch



(c) Side view of the proposed antenna

Fig.1 Configuration of two layers V-slot loaded patch stacked with rectangular patch

Fig. 2 shows the equivalent circuit of V-slot loaded patch, in which  $R_p, L_p, C_p$  are the resistance, inductance and capacitance of the fed patch respectively,  $Z_{sv}$  is the impedance due to inclined slot and  $Z_{bv}$  is the impedance due to base slot.

#### B. Analysis of V-slot loaded patch antenna stacked with rectangular patch

When V-slot loaded patch antenna is stacked with rectangular patch ( $L_2 \times W_2$ ) the equivalent circuit is modified as shown in Fig. 3.

Two layer stacked patch antenna has been analysed with two constitutive resonators. One resonance is due

to the resonator between ground and driven patch and second resonance is due to driven and stacked patch. In the proposed configuration stacked dielectric layer works as a superstrate for the driven patch and hence changes the effective dielectric constant consequently changing the resonance frequency.

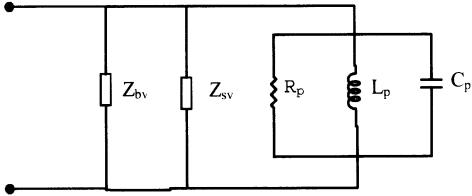


Fig. 2 Equivalent circuit of V-slot loaded patch

The effective permittivity for driven patch due to stacked dielectric layer is given as [13]

$$\epsilon_{re} = \frac{\epsilon_{re} + 1}{2} + \frac{\epsilon_{re} - 1}{2} \left[ 1 + \frac{10h_1}{L_1} \right]^{-\frac{1}{2}} \quad (6)$$

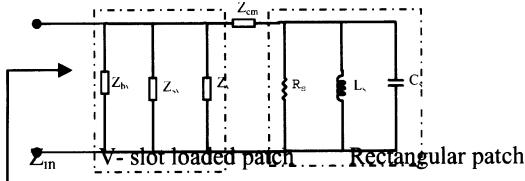


Fig. 3 Equivalent circuit of V-slot loaded stacked patch where ' $h_1$ ' is the thickness between ground and fed patch and

$$\epsilon_{re} = \frac{\sum_{i=1}^2 h_i}{\sum_{i=1}^2 \epsilon_{ri}}$$

Now, we can calculate the resonant frequency of the lower patch as [13]

Thus the value of resistance ( $R_p$ ), inductance ( $L_p$ ) and capacitance ( $C_p$ ) for the fed patch can be calculated as [14]. Similarly the value of resistance ( $R_s$ ), inductance ( $L_s$ ) and capacitance ( $C_s$ ) for the parasitic patch can be calculated. The equivalent circuit of the proposed stacked antenna can be given as shown in Fig.3; in which inductive coupling is very small hence neglected and only capacitive coupling ( $C_m$ ) is considered which is given as [15] and  $Z_{cm}$  is the impedance due to coupling between V-slot loaded patch and stacked patch.

Now the total input impedance of V-slot loaded stacked rectangular microstrip antenna is given as

$$Z_{in} = \frac{Z_{vp}(Z_{cm} + Z_s)}{Z_{vp} + Z_{cm} + Z_s} \quad (13)$$

in which

$$Z_{vp} = \frac{Z_{bv}Z_{sv}Z_v}{Z_{bv}Z_{sv} + Z_{sv}Z_v + Z_{bv}Z_v}$$

and

$$Z_v = \frac{1}{\frac{1}{R_p} + j\omega C_p + \frac{1}{j\omega L_p}}$$

$Z_s$  is the impedance due to stacked patch which is given as

$$Z_s = \frac{1}{\frac{1}{R_s} + j\omega C_s + \frac{1}{j\omega L_s}} \quad (14)$$

Now using the value of total input impedance one can calculate the different antenna parameters such as VSWR, return loss etc.

### III. DESIGN SPECIFICATIONS

The design specifications for the proposed antenna are given as:

Substrate material used- Foam, Dielectric constant ( $\epsilon_1, \epsilon_2$ ) -1.05, Thickness between ground and fed patch ( $h_1$ ) -5 mm, Length of the fed patch ( $L_1$ ) -37 mm, Width of the fed patch ( $W_1$ ) -28 mm, Length of the V-slot ( $L_s$ ) -19 mm, Base width of the V-slot ( $W_s$ ) -7.2 mm, Thickness of the V-slot ( $w$ ) -2.1 mm, V-slot angle ( $\alpha$ ) -10°, Thickness between fed and parasitic patch ( $h_2$ ) -5 mm, Length of the driven patch ( $L_2$ ) -37 mm, Width of the driven patch ( $W_2$ ) -19.4 mm.

### IV. DISCUSSION OF RESULTS

The return loss as a function of frequency for single V-slot loaded patch is shown in Fig.4 in which theoretical, simulated and experimental values are shown.

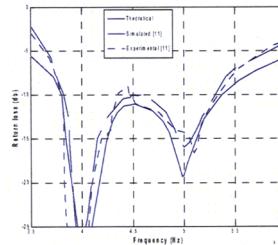


Fig.4 Comparison of theoretical along with simulated and experimental return loss for single layer V-slot loaded patch. ( $\epsilon_r=1.05, \alpha=6^\circ, L_s=20.7$  mm,  $W_s=8.8$  mm,  $w=2.1$  mm,  $L=35.5$  mm,  $W=26$  mm,  $h=5.8$  mm)

The antenna exhibits wideband characteristics and proposed theoretical results are found to be in good agreement with the simulated and experimental results [11] (bandwidth=38.39%). When V-slot loaded antenna is stacked with simple patch, the theoretical and simulated results of return loss is modified as shown in Fig. 5. It is observed that antenna exhibits enhanced bandwidth of 48.7 % and both the theoretical and simulated results are in close agreement. However the bandwidth also depends on V-slot thickness ( $w$ ) (Fig.6). Typically the bandwidth decreases with increasing value of V-slot length ( $L_s$ ) of

V-slot loaded stacked patch. However the bandwidth is found to be maximum i.e. 51.7 % at the lowest value of slot length ( $L_s=18.5$  mm).

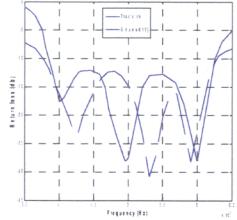


Fig. 5 Comparison of theoretical and simulated results for return loss versus frequency for V- slot loaded patch stacked with simple patch. ( $\epsilon_r = 1.05, \alpha = 10^0, L_s = 19\text{mm}, W_s = 7.2\text{mm}, h_1 = 5\text{mm}, \epsilon_{r1} = 1.05, w = 2.1\text{ mm}, L_1 = 37\text{ mm}, W_1 = 28\text{ mm}, h_2 = 5\text{ mm}, \epsilon_{r2} = 1.05, L_2 = 37\text{ mm}, W_2 = 19.4\text{ mm}, h_2 = 5\text{ mm}$ )

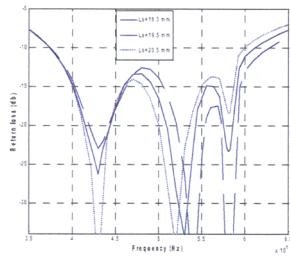


Fig. 6 Variation of return loss with frequency for different V- slot length (L<sub>s</sub>)

When  $\epsilon_r=1.1$  and  $L_s=20$  mm and keeping other parameters of the antenna as same as in previous cases, the the antenna exhibits lower bandwidth of 47.1% (Fig.7). The proposed theoretical results are found to be in good agreement with simulated as well as experimental results [11].

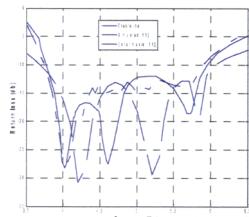


Fig. 7 Comparison of theoretical along with simulated and experimental return loss for V- slot loaded patch stacked with rectangular patch( $\epsilon_r = 1.1, \alpha = 10^0, L_s = 20\text{mm}, W_s = 7.2\text{mm}, w = 2.1\text{ mm}, L_1 = 37\text{ mm}, W_1 = 28\text{ mm}, h_1 = 5\text{ mm}, \epsilon_{r1} = 1.1, L_2 = 37\text{ mm}, W_2 = 19.4\text{ mm}, h_2 = 5\text{ mm}$ )

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