

# PARALLEL SLOT LOADED PROXIMITY COUPLED MICROSTRIP ANTENNA FOR WIRELESS COMMUNICATION APPLICATION

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## ABSTRACT

*Microstrip antennas are very promising due to their integration capability but lack in bandwidth. In many communication applications they need to operate in broadband as well as dual-band. An L-strip fed slot loaded antenna has been presented. The circular radiating patch using RT-Duroid with  $\epsilon_r = 2.2$  is located at  $.09 \lambda_0$  (11mm) above ground plane. The variation of slot length and horizontal length of the L-strip has been investigated in the circular disk patch antenna for the return loss. The antenna shows dual band as well as wideband behaviour. It is found that antenna attains impedance bandwidth of 45% (Return loss < -10dB) in the frequency range (3.46GHz-5.5GHz). A parametric study has been carried out in investigation which is based on cavity model and circuit theoretic approach. The theoretical results are compared with the simulated results obtained from IE3D simulation software [18] which are in close agreement.*

**KEYWORDS:** Microstrip Patch Antenna , Proximity coupled, Slot Loaded, Wideband.

## I. INTRODUCTION

During the recent year, the dual band as well as wideband microstrip antenna has its wide application in many communication system. One of the important application of this kind of application of these antenna are wireless communication system(1.8GHz-5.6GHz).Microstrip antenna is attractive candidate for wireless communication system due to their numerous advantages such as low cost, light weight and easily printed onto circuit board. However the major drawback of the microstrip antennas are their narrow bandwidth typically a few percent [1]. Many efforts have been devoted to bandwidth widening techniques of microstrip antennas, including the use of impedance matching [2], multiple resonators [3], and a thick substrate [4]. For dual band applications slot loaded antenna is best candidate, but it also lacks in bandwidth. The dual band characteristic can also be obtained by exciting two different modes with suitable feed point [5-6]. A slot has special advantage because of its simple structure and wider bandwidth [7-9].Design and development of compact printed antenna for wireless communication are reported in [10-11].

Here we have proposed new parallel slot loaded L-strip proximity coupled circular microstrip antenna configuration as shown in figure.1 that can have dual band as well as wideband operation. Feeding method used is proximity coupling. An L-shape strip has an excellent feeding structure suitable for wideband patch antenna with a thick substrate. The patch and microstrip is capacitive in nature. This capacitor cancels out the inductance due to the feed strip itself .This capacitor can be designed for impedance matching of the antenna, as well as for the tuning the patch for improve the bandwidth. Bandwidth of the order of 13% has been achieved using this method [12]. The parametric study has been carried out using model expansion cavity model and circuit theory approach by varying the feed location and length and width of the slot. Dual frequency is tuned by changing the dimension of the

slot. The characteristics including the return loss are considered. The theoretical analysis for L-strip proximity fed microstrip antenna and Slot loaded circular disk patch antenna are discussed in section 2.1 and section 2.2 respectively. Section 2.3 and section 2.4 describe the design specification and result obtained from proposed antenna.

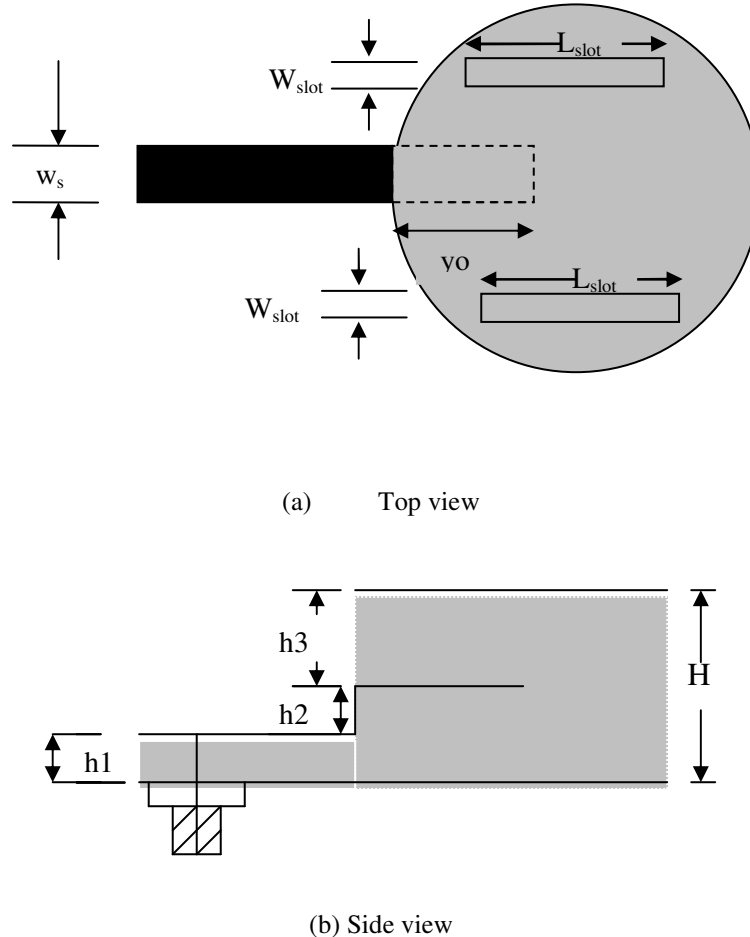


Fig. 1: Geometry of L-strip fed proximity coupled circular microstrip antenna

## II. THEORETICAL ANALYSIS

The L-strip proximity coupled circular microstrip antenna is investigated using both model expansion cavity model and circuit theory concepts. The broadband performance of proposed antenna is achieved by employing a thick substrate. In our design a RT-Duroid ( $\epsilon_r = 2.2$ ) of thickness 11 mm is used to support the radiating patch. By using the L-strip, we couple the energy from microstrip line to the patch as the separation between them is too large. Figure 2 shows the equivalent circuit of proposed antenna. The horizontal part of L-strip of length  $y_0$  under patch is kept less than quarter wavelength ( $y_0 < \lambda_0 / 4$ ) which provides a capacitance to suppress the inductance introduced from the vertical part of L-strip. Vertical part of L-strip is the series combination of resistance  $R_s$  and inductance  $L_s$ . The series resistance  $R_s$  is arises due to finite conductivity of copper used.

### 2.1. Analysis of L-strip Proximity Fed Microstrip Antenna

Figure 2 shows the equivalent circuit of proposed antenna. The expression for the series resistance  $R_s$  and inductance  $L_s$  is given as [13]

$$L_s = 0.2h_2 \left[ \ln \left\{ \frac{2h_2}{(W_s + T_s)} \right\} + 0.2235 \left\{ \frac{(W_s + T_s)}{h_2} \right\} + 0.5 \right] (nH) \quad (1)$$

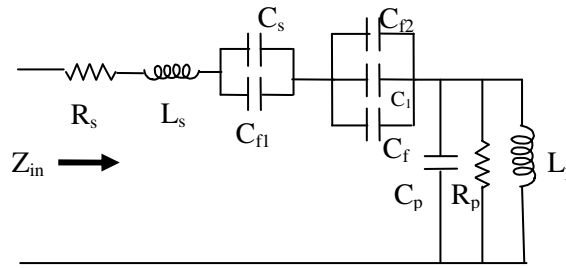


Fig. 2: Equivalent circuit of L-strip fed circular microstrip antenna

$$R_s = \frac{4.13h_2 \sqrt{\frac{f\rho}{\rho_o}}}{(W_s + T_s)} \quad (2)$$

Where  $W_s$  is width and  $T_s$  is thickness of the strip in mm,  $h_2$  is the vertical height of L-strip,  $f$  is the operating frequency,  $\rho$  is the specific resistance of strip ( $\Omega$  cm) and  $\rho_0$  is the specific resistance of copper. All antenna metallization is taken as perfect except vertical portion. There is a capacitance  $C_{s1}$  arising due to vertical electric field between horizontal part of L-strip and ground plane in series with above  $L_s$  &  $R_s$  and is calculated as

$$C_{s1} = \frac{\epsilon_r \epsilon_o W_s y_o}{h_1 + h_2} \quad (3)$$

Where  $y_0$  is the penetration of L-strip into patch,  $\epsilon_r$  is the relative dielectric constant,  $\epsilon_0$  is the dielectric constant of vacuum and  $h_1$  is the height between ground plane and microstrip antenna. The horizontal portion of L-strip and patch are perfect conductor separated by a distance ( $h_3$ ) which gives a capacitance ( $C_1$ ) in series with the vertical portion of L-strip and calculated as

$$C_1 = \frac{\epsilon_r \epsilon_o W_s y_o}{h_3} \quad (4)$$

There is a fringing capacitance between open end of L-strip and ground plane ( $C_{f1}$ ), open end of L-strip and patch ( $C_{f2}$ ) and between radiating edge of patch and L-strip ( $C_{f2}$ ). These extra capacitance ( $C_f$ ) is due to fringing fields, which can be considered as a small increase in the length of the L-strip. These fringing capacitances are calculated by evaluating extended effective length of L-strip and patch. The extension in the length of an open ended microstrip plan is given as [13]

$$l_e = \frac{0.412h_2(\epsilon_e + 0.3)\left(\frac{W_s}{h_2} + 0.264\right)}{(\epsilon_e - 0.258)\left(\frac{W_s}{h} + 0.8\right)} \quad (5)$$

Where  $\epsilon_e$  the effective dielectric constant of material is buried under the microstrip line and ground plane and is given as [14]

$$\epsilon_e = \frac{\epsilon_r \left(1 + \frac{h_2}{h_1}\right)}{\left(1 + \epsilon_r \frac{h_2}{h_1}\right)} \quad (6)$$

The associated fringing capacitance ( $C_f$ ) is calculated as [13] where  $l_e$  is extension in effective length of L-strip feed,  $c$  is the velocity of light in vacuum, and  $Z_0$  is the characteristics impedance

$$C_f = \frac{le(\epsilon_{r_{eff}})^{\frac{1}{2}}}{cZo} \tag{7}$$

of field and  $\epsilon_{r_{eff}}$  is the effective dielectric constant [15]. The fringing field capacitance between horizontal part of L-strip and ground plane ( $C_{f1}$ ) is calculated by putting  $h = h_1 + h_2$  and the two capacitances between patch and horizontal part of L-strip (both  $C_{f2}$ ) is calculated by putting  $h = h_3$ . In the calculation of fringing capacitance between patch and L-strip the curvature of patch is ignored. The equivalent circuit of proposed antenna is shown in figure 2. The whole structure of L-strip acts as a series LC resonance elements which are connected in series with a parallel RLC resonant element of the patch. The microstrip patch can be equated to a parallel combination of resistance ( $R_p$ ), inductance ( $L_p$ ) and capacitance ( $C_p$ ) as shown in figure 2 and calculated as [16]

$$R_p = \frac{J_n^2 k(a - y_o)}{G_T J_n^2(ka)} \tag{8}$$

$$C_p = \frac{Q_T}{(2\pi f_{res} R_p)} \tag{9}$$

$$L_p = \frac{R_p}{(2\pi f_{res} Q_T)} \tag{10}$$

Where  $Q_T$  is the total quality factor,  $G_T$  is total conductance of patch [16] of radius  $a$  incorporating radiation loss, conduction loss and dielectric loss and  $f_{res}$  is the resonant frequency of the patch [14]. Thus the total input impedance of the patch [13]

$$Z_{in} = R_s + j\omega L_s + \frac{1}{j\omega C_{total}} + \frac{1}{[\frac{1}{R_p} + j\omega C_p + \frac{1}{j\omega L_p}]} \tag{11}$$

Where  $C_{total}$  is the total capacitance arising due to L-strip (i.e.  $C_1, C_{s1}, C_{s2}, C_{f1}$  and  $C_{f2}$ ) and is calculated as [13]

$$C_{total} = \frac{(C_1 + 2C_{f2})(C_{s1} + C_{f1})}{C_1 + 2C_{f1} + C_{s1} + C_{f2}} \tag{12}$$

## 2.2. Analysis of Slot Loaded Circular Disk Patch Antenna

When the slot is embedded under the patch, having the dimension ( $L_{slot} \times W_{slot}$ ) using the duality relationship between the dipole slot [17]. The radiation resistance of the slot on the circular disk patch can be given as

$$R_r = 60\{C + \ln(kL_{slot}) - C_i(kL_{slot}) + 0.5 \sin(kL_{slot})[Si(2kL_{slot}) - 2Si(2kL_{slot})] + 0.5 \cos(kL_{slot})[C + \ln(\frac{kL_{slot}}{2}) + C_i(kL_{slot}) - 2C_i(kL_{slot})]\} \tag{13}$$

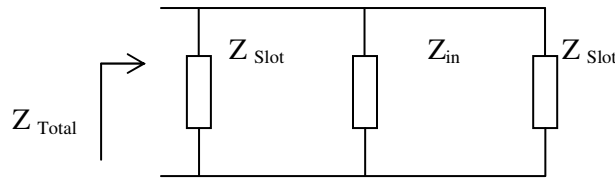
In which  $C$  is Euler's constant = 0.5772 and  $S_i$  and  $C_i$  are the sine and cosine integrals. Now the total input impedance of the slot is given as

$$Z_{slot} = \frac{\eta_o^2}{4Zcy} \tag{14}$$

Where  $R_r$  is the real part and equivalent to the radiation resistance of the slot and  $X_r$  is the input reactance of the slot and is given as [17].

$$X_r = 30\{2S_i(kL_{slot}) + \cos(kL_{slot})[2S_i(kL_{slot}) - S_i(2kL_{slot})] - \sin(kL_{slot})[2C_i(kL_{slot}) - C_i(2kL_{slot}) - C_i(\frac{2kW_{slot}^2}{L_{slot}})]\} \tag{15}$$

Thus the equivalent circuit of the parallel slot loaded L-strip fed circular microstrip antenna can be given as shown in fig.3



**Fig. 3:** Equivalent circuit of slot loaded CMSA

Hence the total input impedance of the proposed antenna can be calculated from fig. 3.

$$Z_{Total} = \frac{Z_{SLOT} \times Z_{in}}{Z_{SLOT} + 2Z_{in}} \tag{16}$$

The total reflection co-efficient of the proposed antenna is given as

$$\Gamma = \frac{Z_{Total} - Z_0}{Z_{Total} + Z_0} \tag{17}$$

Where  $Z_0$  is the characteristic impedance of the feed (50 ohm)

And the VSWR is calculated as

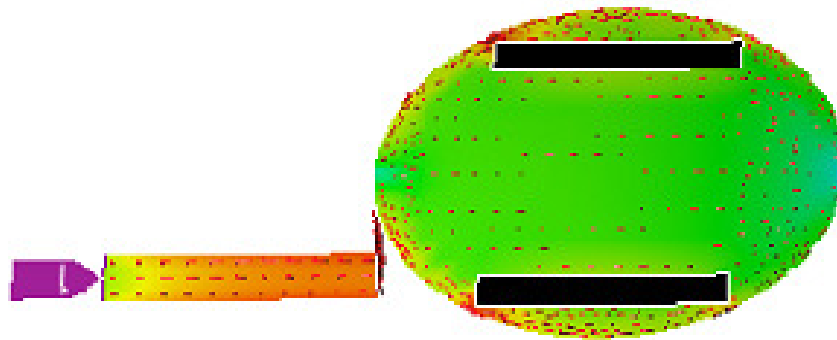
$$VSWR = \frac{1 + |\Gamma|}{1 - |\Gamma|} \tag{18}$$

$$ReturnLoss = 20 \log[|\Gamma|] \tag{19}$$

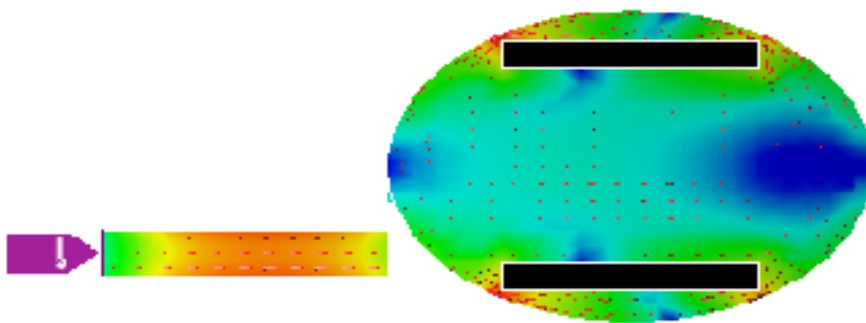
### 2.3 Design Specification

**Table 1.** Design specification for the parallel slot loaded circular disk patch antenna.

Substrate material	RT-Duroid
Relative permittivity of the substrate ( $\epsilon_r$ )	2.2
Thickness of the dielectric substrate (H)	11.0 mm
Radius of circular disk patch (a)	17 .0 mm
Length of the slot ( $L_{slot}$ )	18mm
Width of the slot ( $W_{slot}$ )	3mm
With of the L-strip( $W_s$ )	5mm
Thickness of the L-strip( $T_s$ )	0.2mm
Feed length ( $y_0$ )	3.5mm



(a)Current Distribution at 2.4GHz



(b)Current Distribution at 4.7GHz

Fig 4: Current Distribution for parallel slot loaded Circular Microstrip antenna

### 2.4. Results and Discussions

The results were obtained using numerical discussion given in section 2 and values given in section 3. Figure 5 shows variation of return loss with frequency for different lengths of L-strip. Three resonances may be seen. The antenna exhibits broadband and dual-band characteristic at the same time. The upper two resonances form a broadband and lower resonance dual band. Centre resonance frequency get affected due to  $y_0$  indicating its dependence. As  $y_0$  increases associated capacitance increases consequently decreasing the resonance frequency.

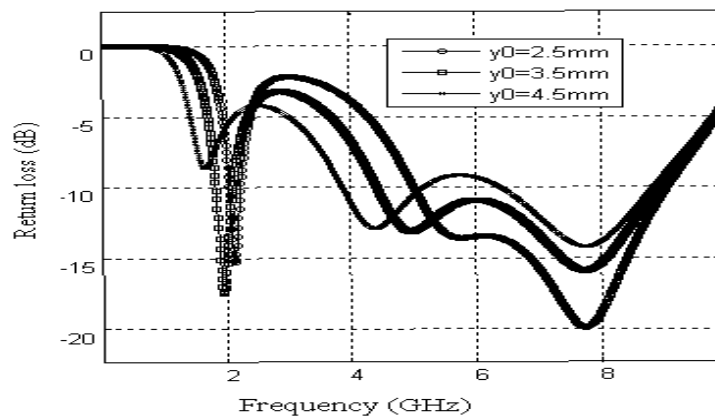


Fig 5: Variation of return loss with frequency for different  $y_0$  (calculated)

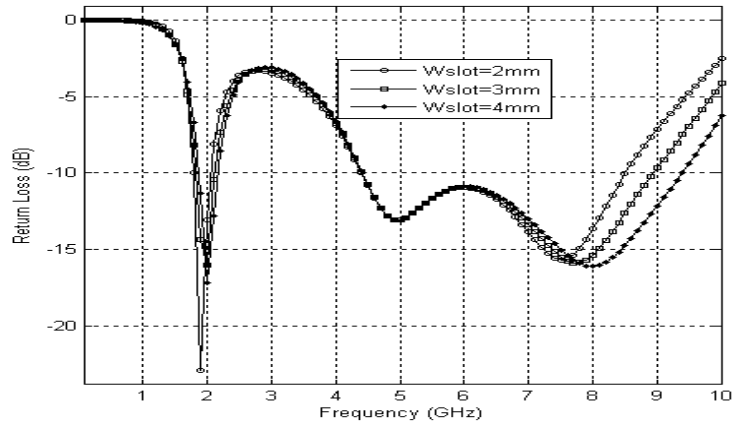


Fig. 6: Variation of return loss with frequency for different slot width (calculated)

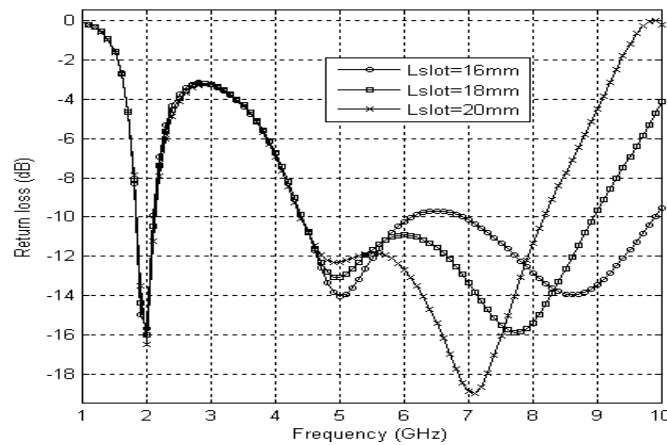


Fig 7: Variation of return loss with frequency for different lengths of slot (calculated)

An attempt has been made to study the behaviour of antenna on slot dimensions. Variation of return loss with frequency for different slot width is given in figure 6. Slot width improves matching at the given value of highest resonance frequency but opposite effect is seen on lowest resonance. The behaviour of the antenna with variation of slot length is shown in figure 7. The highest resonance frequency changes rapidly with slot length. Which indicates that slot on the antenna behaves like a dipole. The simulated return loss variation is given in figure 8. This also shows three resonances- first due to patch, second due to L-strip and third due to slot. The simulated result also exhibits dual band and broadband characteristic.

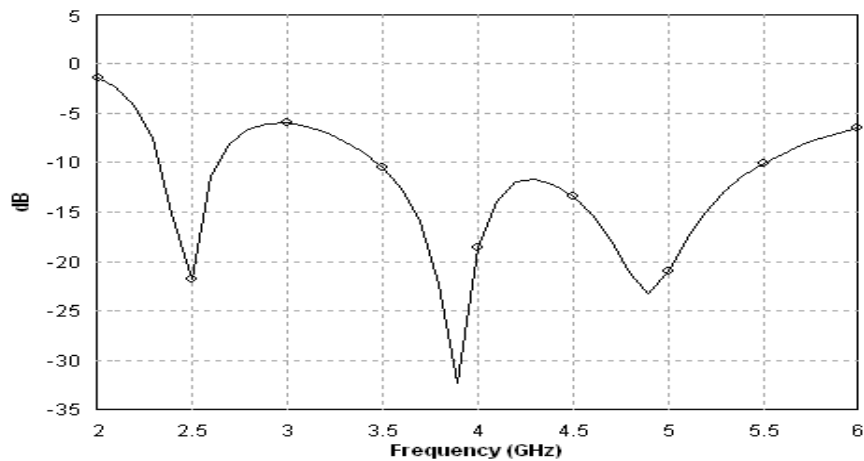


Fig. 8: Variation of return loss with frequency (Simulated)

### III. CONCLUSION

The parallel slot loaded L-strip fed circular microstrip antenna has been designed and analyzed using cavity model based circuit theoretic approach. The antenna may operate for dual band and broadband operation simultaneously. Using a RT-Duroid ( $\epsilon_r = 2.2$ ) of thickness 11 mm, as a supported substrate, an impedance bandwidth of 45 % (return loss < -10dB) has been obtained. The proposed antenna shows wideband characteristic in the frequency band of 3.46GHz-5.5GHz. Here, after a large number of simulations, a wideband as well as dual band antenna is designed which is useful for different wireless communication application.

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