Dualband Slot Loaded Circular Disk Patch Antenna for WLAN Application

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***Abstract*- Analysis of two parallel slots embedded in circular disk patch antenna has been presented. The proposed antenna exhibits dualband behaviour working at 2.93 and 3.52 GHz suitable for WLAN application. The effect of slots dimension in the patch has been studied. Slots length and substrate thickness have significant effect on frequency ratio f_2/f_1. Typically the frequency ratio is found 1.20 for given value of slots dimensions. Calculated results show good agreement with the simulated data obtained from IE3D.**

***Index Terms* - Circular disk patch, dualband antenna, slots loaded patch and microstrip patch antenna.**

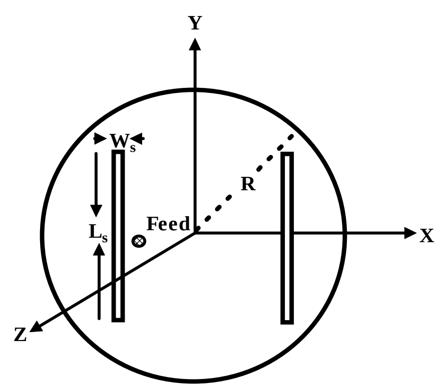
1. INTRODUCTION

Tunable dual frequency patch antennas provide an alternative to wideband antennas where large bandwidth is required for operation at two separate transmit-receive bands.
When a microstrip patch antenna is loaded with reactive elements such as slots [1-3], stubs or shorting pin [4-6], it gives tunable or dual-frequency antenna characteristics.
Recently, dualband antenna is found wide applications in wireless communication. The rapid development in WLAN technology demands the antenna having high performance, dualband and good radiation characteristics. Numerous slot antennas for 2.4/5 GHz operations have been reported [7-13]. Because of many attractive features, microstrip patch antennas have received considerable attention for mobile communication handset.

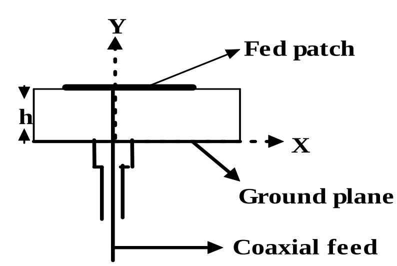
In the present investigation tunable dual frequency slots loaded circular disk patch antenna has been proposed using circuit theory concept. Various antenna parameters are calculated as a function of frequency for different value of slot length, slot width and substrate thickness.

II. CONFIGURATION AND ANALYSIS OF SLOTS LOADED CIRCULAR DISK PATCH ANTENNA

The geometry of proposed antenna is shown in Fig.1. Two parallel slots with dimension ($L_S \times W_S$) have been incorporated in the patch.



(a) Side view



(b) Top view

Fig.1 Parallel slots loaded circular disk patch antenna

A circular disk patch can be analyzed as the parallel combination of resistance, inductance and capacitance and can be given as [14].

$$C_1 = \frac{Q_T}{2\pi R_1 f_r} \quad (1)$$

$$L_1 = \frac{R_1}{2\pi f_r Q_T} \quad (2)$$

and

$$R_1 = \frac{h^2 E_0^2 j_n^2(kx_0)}{2P_T} \quad (3)$$

where

$j_n(kx_0)$ = Bessel functions of order ‘n’

x_0 = feed location from the center of the disk patch

h = thickness between ground plane and fed patch

Q_T = total quality factor of the resonator

P_T = total power loss in the cavity

The resonance frequency of the disk patch antenna can be approximately determined from the equation [15].

$$f_r = \frac{k_{nm}\, c}{2\pi R_e \sqrt{\varepsilon_r}} \quad (4)$$

in which

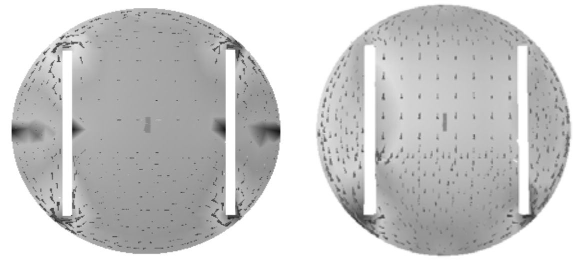
k_{nm} = m^{th} zero of the derivative of Bessel function of order ‘n’

c = velocity of light

R_e = effective radius of the circular disk [14]

ε_r = dielectric constant of the substrate.

The current distribution for proposed dualband antenna is shown in Fig.2. There are two currents flowing in the patch, one is in the initial patch and another is around the slots, which are responsible for the dualband behaviour.



(a) (b)

Fig.2 Current distribution in slots loaded disk patch antenna for lower and upper resonance frequency (a) 2.90GHz (b) 3.56GHz

A slot on the patch can be analysed by using the duality relationship between the dipole and slot [16]. The radiation resistance of the slots can be given as

$$R_r = \frac{\eta_0 \cos^2\alpha}{2\pi}\int_0^{\pi}\left[\frac{\left[\cos\frac{k^2\cos\theta}{2} - \cos\frac{kL_s}{2}\right]^2}{\sin\theta}\right]d\theta \quad (5)$$

The impedance due to the slots can be calculated as [16].

$$Z_r = \frac{jk\cos^2\alpha}{4\pi\omega\varepsilon_0}\int_{-\frac{Ls}{2}}^{\frac{Ls}{2}}\left[\left(\frac{e^{-jkr_1}}{r_1} + \frac{e^{-jkr_2}}{r_2} - 2\cos(kL_S)\frac{e^{-jkr_0}}{r_0}\right)\times \sin k\left(L_S - |y_1|\right)\right]dy_1 \quad (6)$$

where,

$$r_1 = \left[x_1^2 + (L_S - y_1)^2\right]^{\frac{1}{2}}$$

$$r_2 = \left[y_1^2 + (L_S + y_1)^2\right]^{\frac{1}{2}}$$

and $$r_0 = \left[x_1^2 + y_1^2\right]^{\frac{1}{2}}$$

Hence the input impedance due to slots can be calculated by the equation given as [16].

$$Z_{slot} = \frac{\eta_0^2}{4Z_{cy}} \quad (7)$$

in which

$$Z_{cy} = R_r(kL_S) - j\left[120\left(\ln\left(\frac{L_S}{W_S}\right) - 1\right)\cot\left(\frac{kL_S}{2}\right) - X_r(kL_S)\right]$$

The equivalent circuit of the proposed embedded patch antenna is shown in Fig.3, in which Z_1, Z_2 is the impedance of two parallel slots. These values are calculated as using equ. (7).

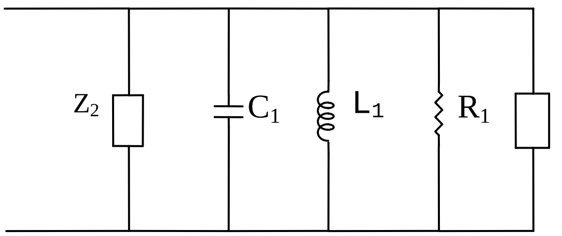


Fig.3 Equivalent circuit of the slots loaded circular disk patch antenna

Now the total input impedance of the proposed antenna can be calculated from Fig. 3 as

$$Z_T = \frac{Z_S Z_P}{Z_P + Z_s} \qquad (8)$$

In which is the input impedance of circular disk patch antenna can be given as

$$Z_P = \frac{1}{\frac{1}{R_1} + j\omega C_1 + \frac{1}{j\omega L_1}}$$

and Z_s is the total impedance of the parallel slots in the disk patch

$$Z_s = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

Using equation (8) one can calculate the various antenna parameters such as return loss, reflection coefficient, VSWR.
The reflection coefficient of the patch can be calculated as

$$\Gamma = \frac{Z_0 - Z_T}{Z_0 + Z_T}$$ The

where Z_0 = characteristic impedance of the coaxial feed (50 ohm)

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

and

$$\text{Return loss} = 20 \log |\Gamma|$$

III. RADIATION PATTERN

The radiation pattern for parallel slots loaded circular disk patch antenna is calculated by considering as rectangular patch as [9]

$$E(\theta) = J^n k_0 R V_0 e^{jk_0 r_1} [J_{n+1}(k_0 R \sin\theta) - J_{n-1}(k_0 R \sin\theta)] \cos n\phi \qquad (9)$$

$$E(\phi) = J^n k_0 R V_0 e^{-jk_0 r_1} [J_{n+1}(k_0 R \sin\theta) - J_{n-1}(k_0 R \sin\theta)] \cos\theta \sin n\phi \qquad (10)$$

where
V_0 = radiating edge voltage
= $h_1 E_0 J_n(R)$
r_1 = distance of an arbitrary far-field point
R = radius of fed disk patch

IV. DESIGN SPECIFICATIONS

Table1: Design specifications for the slots loaded circular disk patch antenna

Substrate material used	RT duriod
Relative permittivity (ε_r)	2.32
Radius of the circular disk(R)	15mm
Length of the slot L_s	20mm
Width of the slot W_s	1.0mm
Feed location (x_0, y_0)	(-0.325mm, -8.625mm)

V. RESULTS AND DISCUSSION

Variation of return loss as a function of frequency is shown in Fig.4. The slots loaded patch antenna exhibits dualband behaviour and shows close agreement with the IE3D simulated results [17].

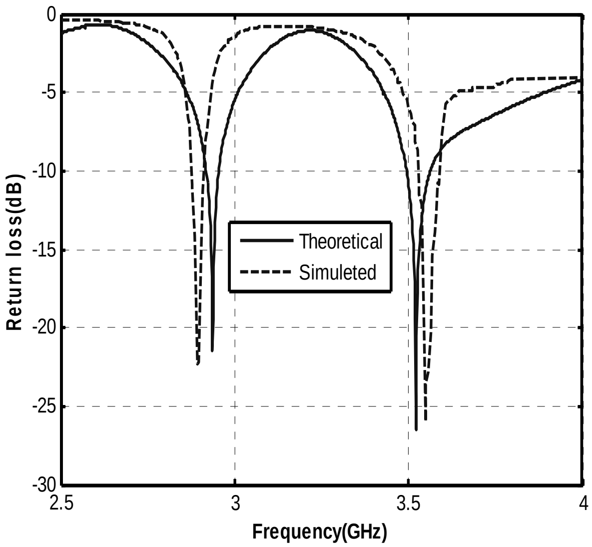


Fig.4. Comparative plot of return loss with frequency for slots loaded disk patch antenna along with simulated results (L_s=20mm, W_s=1mm, h=2.5mm, ε_r =2.32)

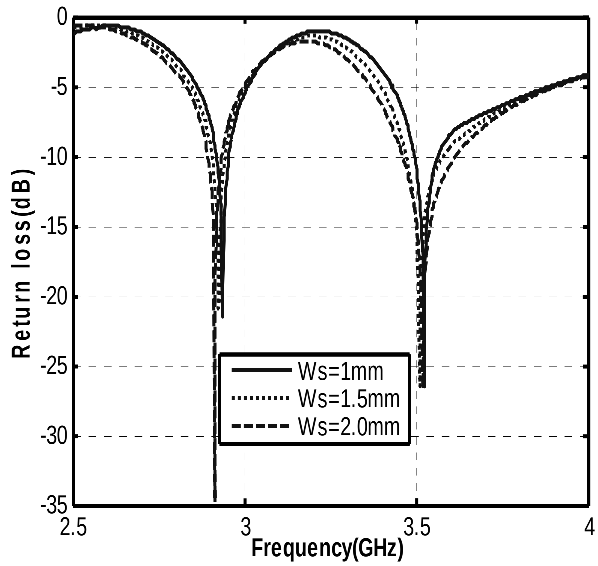


Fig.6.Variation of return loss with frequency for different value of slots width W_s (L_s=20mm, h=2.5mm)

Fig.5 shows the variation of return loss with frequency for different value of slots length (L_s). It is found that upper resonance frequency remains constant while lower resonance frequency shifts towards lower side as the slot length increases. No significant effect is observed in the resonance frequency when the slot width (W_s) varies which is corroborated from Fig.6. However a good matching is found at W_s =2mm.

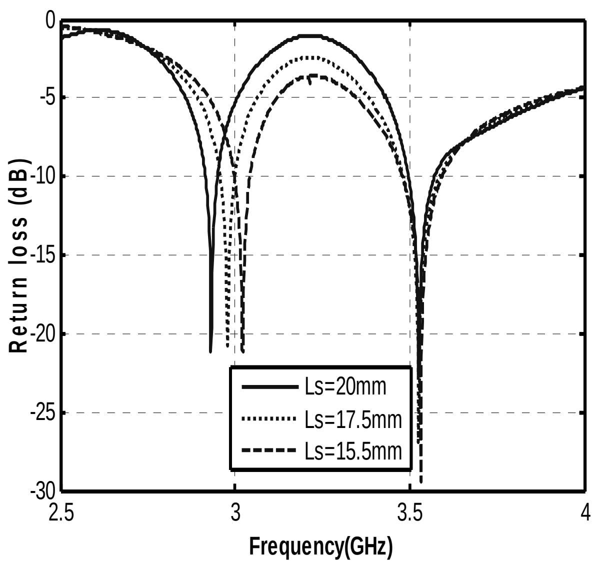


Fig.5.Variation of return loss with frequency for different value of slots length L_s(W_s=1mm,h=2.5mm)

The variation of return loss with frequency for different substrate thickness h is given in Fig.7. From the figure, it is observed that as the value of h increases, lower resonance shifts towards higher side and upper resonance frequency shifts toward lower side and matching condition degrades as h increases.

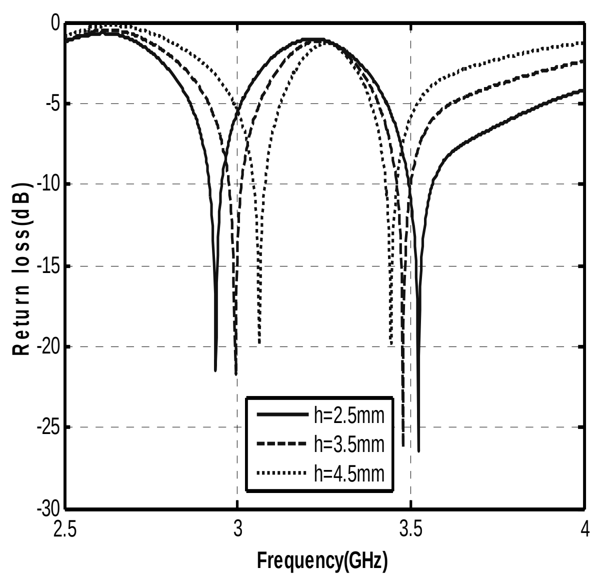


Fig.7.Variation of return loss with frequency for different value of substrate thickness h (L_s=20mm , W_s=1mm)

The frequency ratio (f_2/f_1) is directly proportional to slot length (L_s) and compare well with the simulated results (Fig.8). The frequency ratio varies from 1.16 to 1.20 for increasing value of L_s whereas frequency ratio is found inversely proportional to the thickness h and varies from 1.20 to 1.12 for the given value of slot dimension (Fig.9).

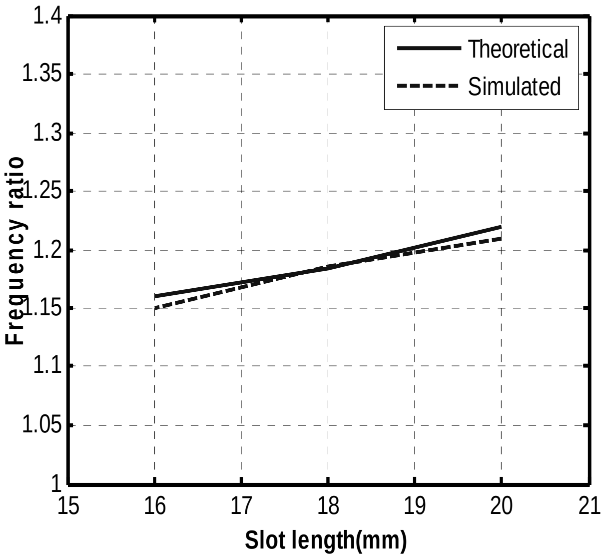


Fig. 8 Variation of frequency ratio with different value of slots length L_s

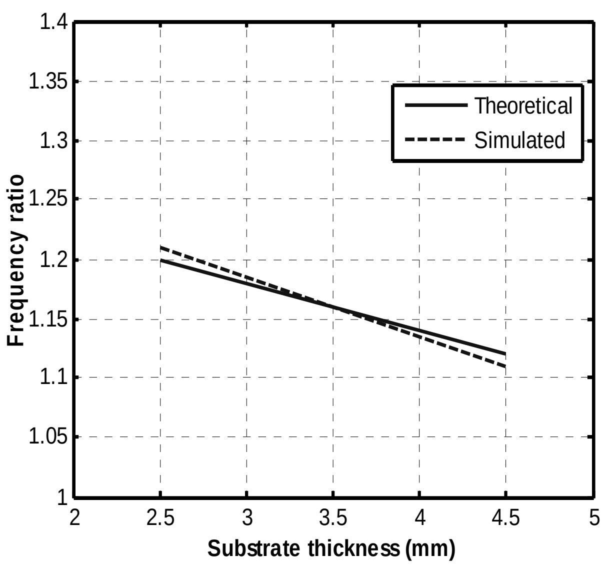


Fig.9. Variation of frequency ratio with different value of substrate thickness h

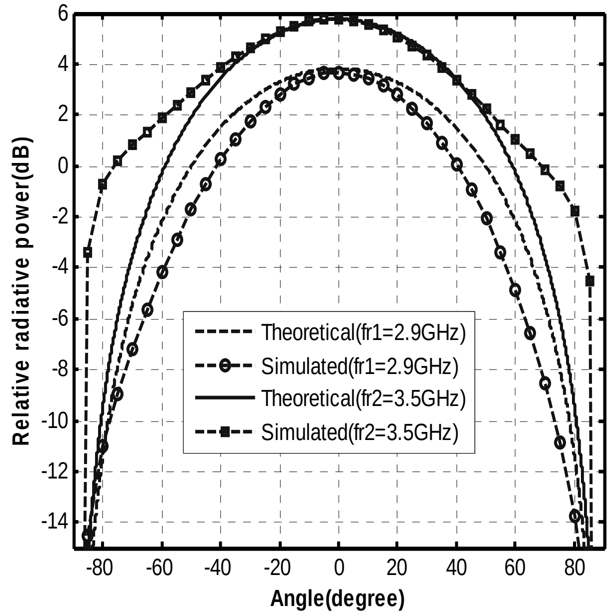


Fig. 10 Radiation pattern for lower and resonance frequency of proposed antenna

From Fig.10 it is found that the radiation pattern of the proposed antenna shows close agreement with the simulated results at both the resonance frequencies. It is quite interesting to note that the radiated power is higher at upper resonance frequency by 2dB as compared to lower resonance frequency.

VI. CONCLUSION

From the analysis it is concluded that the slots loaded circular disk patch antenna can operate at two resonance frequencies 2.93/3.52GHz and useful for WLAN operation. The resonance frequency is highly dependent on the slot dimension as well as substrate thickness.

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