A Novel Low Profile Dual-Frequency Shorted Patch Antenna

Hrudya B Kurup, Sruthi Dinesh, Ramsha M, Stephen Rodrigues

Abstract*: *Dual-frequency planar antennas can substitute large bandwidth patch antennas, where there is a requirement for large bandwidth to cover two separate transmit receive bands. In this paper a novel single-feed, single layer, double-band, compact short loaded patch antenna is studied theoretically and experimentally. Besides the compactness, this design provides, dual frequency operation with a small frequency ratio of 1.3 between the two resonant bands. Various radiation characteristics are simulated as well as experimentally studied and good concurrence is observed between the simulated and measured results.

Keywords: Microstrip patch antenna, Dual-band antenna, quarter-wave patch, shorted patch antenna.

I. INTRODUCTION

The recent developments in the wireless communication systems and integrated circuits sector resulted in the requirement of compact antennas with various capabilities. As a result of which the role of multiband antennas are becoming more and more important. Multi-band antennas have advantages like more flexible frequency coverage, multi-functionality, and frequency diversity. Some of the methods to achieve compactness along with multi-frequency operation involve use of short [1, 2], while some others achieve it through geometric modification of patch [3, 4] Loading of a microstrip patch antenna using shorting wall either partially or completely or by using a short near the feed pin, the size of the radiating patch can be significantly reduced for a particular frequency as shown in [5, 6]. In this paper a slot and short loaded rectangular microstrip patch antenna capable of dual-band operation is reported and discussed .

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II. THEORETICAL FORMULATION AND EQUIVALENT CIRCUIT

A. Antenna Structure

The proposed antenna structure consist of a ground plane and a patch on either sides of the dielectric substrate along with a coaxial feed. A metallic pin connecting the ground and the patch is drilled into the structure. A cross sectional view of the proposed structure is shown in Fig.1. These type of modified patches using a single shorting pin have resulted in considerable reduction in the size of the printed patch [7 – 8]. Such antennas are electrically thin and occupy only very less volume. The various design parameters of these kind of antennas heavily depends on pin position, and its dimensions for a fixed feed position.

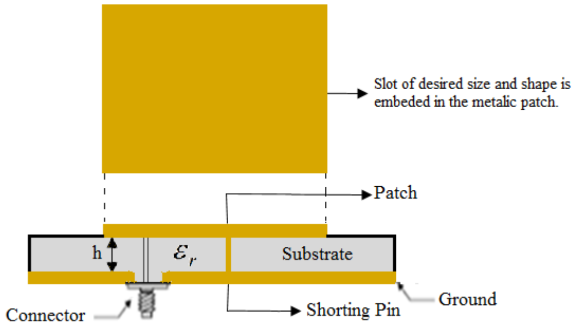

Fig. 1.Side view of the proposed structure.

B. Equivalent Circuit

To model the equivalent circuit, a probe fed slot and short loaded patch antenna can be considered as a combination of equivalent circuit of the patch along with reactance of the slot, feed pin and the short. This can effectively be analyzed using transmission line theory, where the rectangular patch antenna can be considered as a parallel circuit consisting the resistance (R), capacitance (C), and inductance (L), of the patch where R, L and C of the patch is given by

$$R = \frac{Q}{\omega_r C}$$

$$L = \frac{1}{C\,\omega_r^2}$$

$$C = \frac{\varepsilon_e \varepsilon_0 LW}{2h} \cos^{-2}\left(\frac{\pi Z_0}{L}\right)$$

Where

Z_0 = Probe feed location (along the Z axis)

The narrow slot in the patch can be analysed by virtue of the dipole and slot duality relationship as shown in [9] and the equation can be reduced to the form $Z_s = R_s + jX_s$, where R_s the real part of the equation, is equal to the radiation resistance of the slot, whose value is very small and can be neglected in this analysis.

Imaginary part X_s indicates the input reactance caused by the slot, which is more capacitive in nature as analysed in [10].

In this case due to slot loading, an inductance Ls in series & a capacitance Cs in parallel are additionally introduced resulting in an increase in the equivalent inductance & capacitance of the structure. However since the slot is thin and the width is fixed, the reactance introduced by the slot is more capacitive in nature. [11][12]

Short and the feed pin in the structure can be analysed by modelling each of them as small segments of transmission line having a length equivalent to the height/thickness of the microstrip antenna. This creates an inductance L and capacitance c which is added in series and parallel to the antenna equivalent circuit.[13] The inductance L serve as self-inductance of all shorting pin, while the parallel addition of capacitance C is because of the coupling of field between feed probe and short due to its close placement. There is also an equivalent series resistance R and a shunt conductance G, whose values are too small to be considered in this analysis. The values of this inductance and capacitance depends on the radius of the short and feed pin as well as the distance between them. Thus the equivalent circuit of the structure can be comprehended as a parallel circuit of resistance (R), capacitance (C), and inductance (L), of the patch, capacitive reactance of the slot (jX_s) and the inductive reactance induced by the shorting pin along with the capacitive reactance caused by the coupling between the short and the feed (jX_p). The antenna equivalent circuit as analysed above is as shown in figure.2.

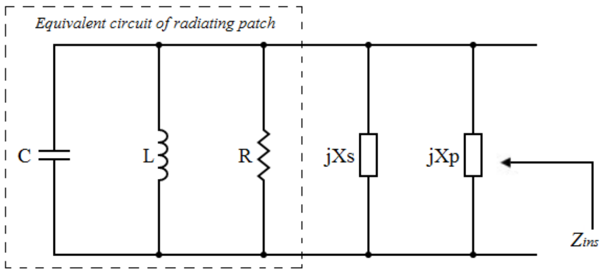

Fig. 2.Electrical equivalent circuit of the structure.

The electrical equivalence of the radiating patch can thus be computed using the above given equations and can be reduced to the form $Z_{in} = R - jX$. Therefore the input impedance of the antenna can be calculated from fig as

$$Z_{ins} = \frac{(R - jX)(jX_s)(jX_p)}{\{(R - jX)(jX_s) + (R - jX)(jX_p) - X_s X_p\}}$$

Where X_s and X_p are the reactance of the short and feed pin which is given by

$$X_s = X_p = \frac{\eta_0 \omega h}{2\pi c} \ln\left[\frac{4c}{\varepsilon \omega d \sqrt{\varepsilon_r}}\right]$$

The Z_{ins} value thus obtained can be used to compute the reflection coefficient and return loss using the equations given below

$$\text{Refelection Coefficient } (\tau) = \frac{Z_0 - Z_{ins}}{Z_0 + Z_{ins}}$$

Where Z0 = Characteristic impedance of the feed pin The Return loss is then computed using the equation

$$\text{Return Loss } = 20 \log|\tau|$$

III. DESIGN DETAILS AND HARDWARE IMPLEMENTATION

The antenna structure is designed and simulated using CST microwave studio. An archetype of the software optimized structure is then constructed tested and assessed to experimentally verify the simulation results. The antenna is constructed using FR-4 as base dielectric material. The aerial view of the fabricated antenna is as shown in fig.3. The structure has a coaxial feed at a desirable location to excite the structure.

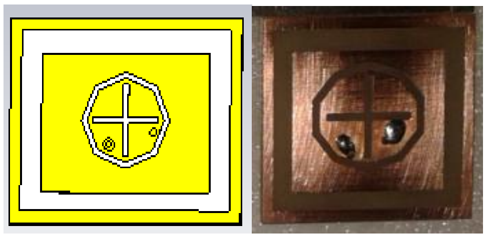

Fig. 3.a. **The designed patch b. Fabricated antenna.**

The patch antenna thus exited with dominant mode is then short circuited at the zero potential plane to realize a shorted microstrip antenna. These two pins (the feed probe and shorting pin) thus helps in achieving design flexibility as insertion of pins on the nodal lines of (0, 3) strongly affects the (0, 1) mode frequency without affecting the (0, 3) mode. This helps in tuning the input impedance for (0, 3), if the feed probe position is determined first, for the preferred impedance of (0, 3) mode. [14]. The resultant resonant modes is mainly due to the reactive loading in the patch, which provides a capacitive and inductive load at the lower and higher resonant frequencies. Various other design parameters like shorting pin position, radius and number of pins, slots of optimum dimensions etc. also helps in tuning the desired range of frequencies as well as impedance bandwidth. The proposed antenna specifications are as given in table-I.

Table- I: Design specifications details

Dielectric substrate used.	FR-4
Relative permittivity of substrate (ε_r)	4.4
Height of the base structure (h)	1.6mm
Top patch length L_p	28mm

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Top patch width W_p	36mm
Radius of the feed pin r_s	0.5 mm
Shorting pin radius r_p	0.6 mm

IV. RESULTS AND DISCUSSION

The present antenna is constructed and studied using the dimensions given in table 1.

The performance parameters of the designed antenna is optimized by adjusting the dimensions as well as the location of shorting pin with respect to the feed probe.

These values are fixed after performing a number of simulation runs. The computed and measured return loss of the antenna is shown in fig.4.

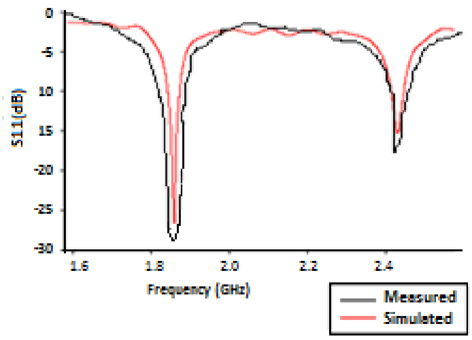
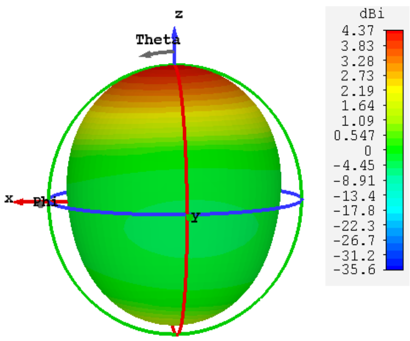


Fig. 4.Comparative return loss plot

It is noted that the distance between the feed and the short plays a vital role in proper matching of the antenna with the feed probe. Two resonant modes are obtained with good impedance matching at 1916 MHz and 2.44 GHz. The impedance bandwidth for lower band covers the operating bandwidth (1.87-1.94 MHz) for pcs band whereas the upper band has a bandwidth (2.42-2.47 MHz). By the contemporaneous use of slots and shorting pins a frequency ratio of 1.3 is obtained between the two operating bands. Depending upon the number of vias the frequency ratio can vary from 1.3 to 3, as shown in [15].



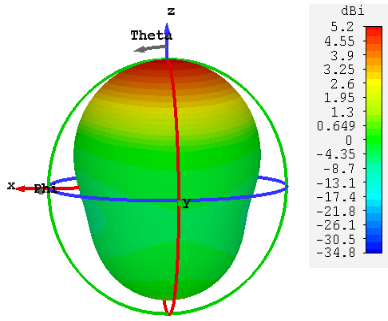


Fig. 5.Simulated 3D far-field at 1.9 GHz and 2.45 Ghz

The software computed 3D far-field antenna radiation characteristics in the xyz plane at 1.9GHz, 2.45GHz is obtained as shown in Fig.5. It can be seen from the plots that the patch is mainly operated in (0, 1) and (0, 3) modes as the antenna is predominantly radiating in the broadside direction. The far-field patterns of the antenna, is also measured in XY and YZ plane at the resonant centre frequencies. The measured 2D patterns of the antenna are as shown in fig 5.The peak measured gain of the antenna over the frequency bands are respectively 2.5dBi and 1.9dBi with gain variations less than 1.5dBi .

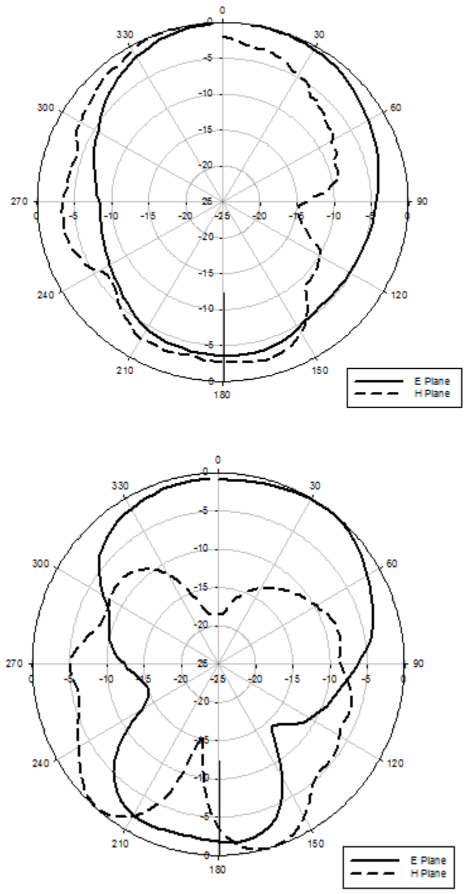


Fig. 6.Measured far-field patterns of the antenna at 1.9 GHz and 2.4 GHz .

V. CONCLUSION

The design of a new single microstrip patch antenna using single shorting pin which can work in the GSM 1900 and ISM 2.4 GHz has been proposed and analysed. The structure is simple and easy to fabricate. Theoretical and experimental aspects of the antenna are also discussed. Good radiation characteristics is observed during simulation with respect to the various parameters, which is the verified experimentally using measured results. Dual band operation and compactness of antenna makes the proposed structure a suitable candidate for mobile applications.

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