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Diminutive Square Patch U-Slot Antenna Design

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Abstract*— This A novel technique for reducing the antenna dimensions results in a diminutive square patch slot antenna which facilitates small size and high gain. For this process many design topologies have been proposed. Some of them are capacitive loaded monopole antenna, planar inverted-F antenna (PIFA) and low profile multi element miniaturized monopole antenna (LMMMA).These techniques reduce the size but with leads to lower gain. The diminutive square patch slot antenna is accomplished by inserting the u-slot above the square patch antenna. This square patch antenna is then connected by the lumped elements in a compact manner to obtain a high gain diminutive square patch u-slot antenna. The proposed antenna achieves a measured gain is 55.2dB at the center frequency of 2.5GHz.

Keywords*— Diminutive square patch, lumped elements, polarization, radiation pattern, u-slot antenna.

I. INTRODUCTION

In modern wireless communication devices, there is an increasing demand for antennas with small, light-weighted, low profile and have vertically polarized omnidirectional radiation pattern in the horizontal plane [6].For near ground communications [13] where both the transmit and receive antennas are placed near the ground is by many orders of magnitude lower than any other antenna orientation configurations[12]. As the antenna size reduction [13] is obviously major problem in wireless communication devices. Therefore several methods have been investigated for extremely short monopole antennas [2]-[3] with very high lateral dimensions, while maintaining high radiation efficiency. With the development of wireless communication devices and mobile phone technology [4]-[5], it has become significant to provide low profile antennas with omnidirectional radiation pattern. There are various size reduction techniques used in the design of small antennas in which reactive inductive loading and reactive capacitive loading. In [7], electrically small antennas are further investigated and the performance such as impedance matching, the radiation pattern, the radiation efficiency, quality factor (Q), and polarization to be reported. In [8], the antenna is characterized with fractal geometries and the performance, it can be summarized that increasing the fractal dimension of the antenna leads to a higher degree of miniaturization. Antenna miniaturization can generally be categorized into two methods are Miniaturizing the antenna topology using space filling compression technique and Antenna miniaturization using magneto-dielectric materials [9]. For certain applications, where the bandwidth can be compromised, it is found that by a comprehensive analysis of a new wide bandwidth compact antenna called wide compact (WC) J-pole antenna provided 50 % impedance bandwidth [10]. Although these exist many antenna miniaturization techniques [11], most of them cannot provide high gain. However it is difficult to implement in practice, because these antennas include a multilayer geometry. In [1] circularly polarized u-slot patch antenna produces low gain. Recently, a low profile antenna called diminutive square patch slot antenna in which the techniques such as in-plane capacitive coupling, shorting pin achieves improved polarization purity and high gain with antenna miniaturization.

II. ANTENNA DESIGN TECHNIQUE

The following steps were used to design proposed diminutive square patch u-slot antenna with three layers of total dimension is 3.393 x0.0474mm using CST as,

1) The antenna dimensions (length and width) were calculated by using the formula as given by,

$$L = \frac{\lambda o}{2} = 2\Delta L \quad = 3.393\text{mm} \tag{1}$$

where ΔL denotes the dimension of the patch and L denotes the actual length of the antenna.

$$\Delta L = 0.412h \frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \quad = 1.69\text{mm} \tag{2}$$

where h represents the height of the substrate.

2) Width of the antenna is calculated by using the formula is given by,

$$W = \frac{c}{2f_0}\sqrt{(\varepsilon_r+1)/2} \quad = 0.0474\text{mm} \tag{3}$$

where ε_r represents the dielectric constant, fo represents the frequency range and C represents the velocity of light.

3) The three layers (bottom, middle, top) were designed in CST with length as 3.393mm and width as 0.0474mm.

4) The vertical feeding pin and shorting pin were inserted in the middle and top layer respectively. The diameters of the pins were 0.5mm. The u-slot is inserted in the top layer of the antenna.
5) In newly developed diminutive square patch u-slot antenna, the same equivalent circuit model is to be followed by changing the lumped elements values corresponding to their enlarged gain value.
6) The inductors L1=5nH, L2=5nH were placed in the feeding pin and shorting pin respectively and the additional inductors are L3=1.9nH, L4=1nH were inserted in the top and middle layers respectively.
7) The shunt capacitor C1=0.788pF was placed in the metallic patch. Here the additional capacitors C2=1pF, C3=1pF were inserted into the layers because the metallic trace is narrow.
8) The resistor R=1.5Ω was inserted into the top layer.
9) The effective dielectric constant (ε_{reff}) is given by,

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{1/2} \quad = 2.21 \tag{4}$$

10) Antenna input impedance and admittance of the antenna were obtained is given by,

$$X_f = L/2\sqrt{(\varepsilon_{reff})} \quad = 1.14\text{m}\Omega, \quad Y_f = w/2 \quad = 0.237\text{mho} \tag{5}$$

Where Xf and Yf is the antenna input impedance and admittance.

11) Return loss and Mismatch loss is given by,

Return loss=-20log S_{11}=-20.173dB, Mismatch loss = -20 log (1- $S_{11}{}^2$) = -40.427dB (6)

III. RESULT AND DISCUSSION

We designed the diminutive square patch u-slot antenna topology using CST software as shown in below figure.

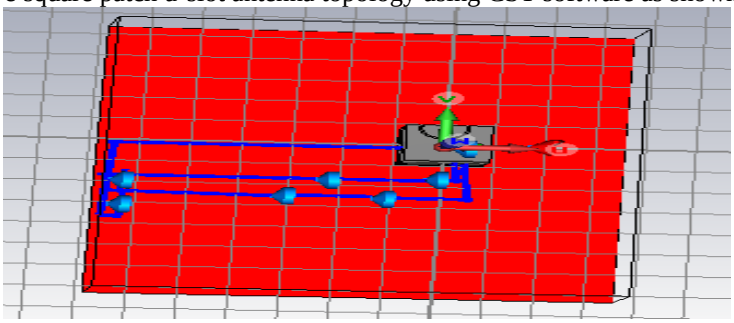

Fig. 1 Design of diminutive square patch U-slot antenna with lumped elements

Fig. 1 shows the design of diminutive square patch U-slot antenna consists of three layers. The layers are ground plane, metallic trace and the metallic patch. This design is based on the equivalent circuit model. The values of the inductance and capacitances are related to the diameter of two pins and the width, length and height of metal sheets, respectively. Here vertical feeding pin and shorting pin are inserted in the middle and top layer. The diameters of the pins are 0.5mm. The substrate used in this design has a dielectric constant of 2.2 and dielectric loss tangent of 0.0009.This design is done by using (Computer Simulation Technology) CST.

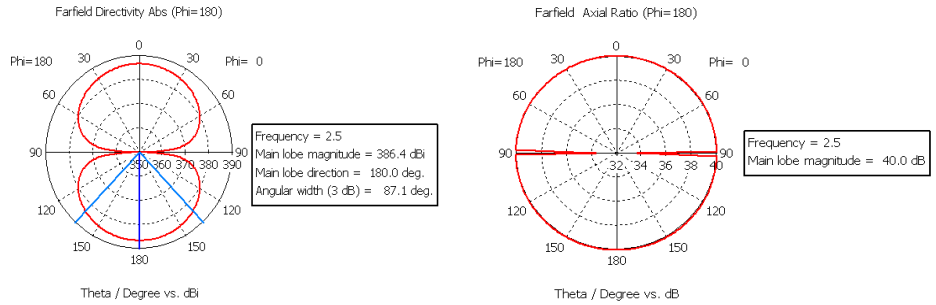

Fig. 2 Simulated (a) Farfield directivity abs (phi=180˚) and (b) Farfield axial ratio (phi=180˚)

In the above fig. 2(a) shows farfield directivity absolute value at phi=180˚. It provides the figure of eight radiation pattern and the main lobe magnitude value as 386.4dB. Here the frequency range as 2.5 GHz. Fig. 2(b) shows the farfield directivity axial ratio at phi=180˚.The main lobe magnitude as 40dB. The gain of this diminutive square patch slot antenna is 55.2 dB.

IV. CONCLUSIONS

In this paper, a design technique of diminutive square patch u-slot antenna is done using CST and the radiation pattern performance of the E-plane and H-plane system and S-parameter value is found. The newly developed diminutive square patch slot antenna topology provides better reduction in size, improved polarization purity and very high gain compared to other existing antennas. The reduced size of the diminutive square patch u-slot antenna is suitable for mobile radio communications, wireless communications with high gain.

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