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ANTENNA FOR LTE/WWAN SMARTPHONE APPLICATION

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Abstract

In this paper, an antenna with single open slot is designed with long term evolution (LTE)/wireless wide area network (WWAN) operation for smart-phone applications and simulated using Ansys High frequency structure simulator (HFSS). The operating frequency ranges of LTE/WWAN are 698-960 MHz and 1710-2690 MHz. The designed antenna is suitable for mobile devices with reduced size and narrow opening which operates in 1/4 wavelength resonant mode. The planar ground size of the proposed antenna is 140×75 mm^2. The substrate material used is FR4 epoxy which has a thickness of 1.6mm. The narrow open slot is made in the ground plane of the size 66×2 mm^2 and excited by the feeding line. L shape metallic plate for good impedance matching and series capacitor for bandwidth enhancement are added to theantenna design. From the simulation of the single open-slot antenna without Partial Ground Structure (PGS), it is observed that the antenna cannot achieve LTE/WWAN bands. To enhance the bandwidth, PGS is added to the antenna design, so that it can cover the dual operating frequency of LTE/WWAN bands. The return loss isachieved below -10dB. The current distribution is also within the antenna design area and the leakage of current is reduced.

Keywords: *Open-slot antenna, L-shape metallic plate, LTE/WWAN bands, Smartphone, Partial Ground Structure, FR4 epoxy, HFSS*

1. INTRODUCTION

In the applications of wireless communication system, adaptability and reliability in antenna design is always in demand. Besides this, performance, size, weight, cost and ease of fitting antenna also causes of main problems. Now-a-days, antenna has undergone many changes in their size, shape and feeding mechanism. Recent years have witnessed an increase of worldwide interest in LTE and WWAN. LTE is a standard for high-speed wireless communication for mobile devices. A WWAN is a form of wireless network. In modern mobile phone, the design process considered the following requirements

- Multiband built–in antenna.
- Small size antenna suitable to small size mobile terminals
- Adaptive antenna and MIMO for transmission of high data rate.

In [1], the hybrid loop/open-slot antenna was designed with 7 × 40 mm2 size to cover LTE bands. The specific feature of the designed antenna is a low profile of 7mm.In the work proposed by Chun-I Lin et al., internal multiband mobile phone antenna was designed using monopole slot antenna which has an

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attractive feature of compact in size. The two printed monopole slots of different lengths cut at the edge of the ground plane was used [2]. In [3], monopole antenna without considering lumped-element was proposed for LTE applications to widen the bandwidth and reduce the occupied space.Tablet devices have recently received much attention by the users. These Metal-casing devicessuch as the tablet computer and smart phone are robust in structure.Loop antenna was designed for these devises with LTE [4].There is a need of adopting the antenna diversity technology at the mobile terminals in order to place antennas in the available limited space [5].

In [6], microstrip slot antenna with three different slots shapes– straight, L, and inverted are cut at the center of the finite ground plate edge for bandwidth enhancement.The quarter-wavelength slot antenna with L-shape horizontal and vertical tuningstub is also published[7]. The printed open slot with asymmetric ground plate produces small size antenna with wideband impedance characteristic [8]. To cover the entire UWB bandwidth various techniques have been developed such as L-/F-shaped probe to feed the patch, modified circular patch, U-/V-slot monopoles, tapered slot, electrically thick substrate using thick foam or air substrate. In this work the bandwidth was achieved up to 15% [9][10]. The antenna design is difficultand complex due to interference between the metal frame and the antenna radiating element [11]. Omnidirectional antenna can work in DCS1800, PCS 1900, UMTS, LTE2300/2500, CDMA 800, GSM850/900 bands [12]. A single open-slot antenna for LTE/WWAN operation is proposed for smart phone applications with 1/4 wavelength resonant mode operation [13].

In this work, an antenna is proposed and designed without PGS and with PGS and the performance was analyzed.

2. PROPOSED ANTENNA DESIGN

2.1 Antenna Structure

In this work, a Single open slot antenna is proposed to meet the following consideration such as

- Compact size
- Good impedance matching
- Good antenna efficiency
- Dual band operation

The compact size and good efficiency shows that this antenna is suitable for Smartphone application. A Single open slot antenna with narrow opening is the best solution for smart phone application. The impedance bandwidth of this antenna is operating in the 1/4 wavelength resonant mode whereas other traditional antenna are operating in 1/2 resonant mode. Open slot is introduced at the top portion of the antenna to achieve good bandwidth and the open-slot is fed by a simple 50 ohms vertical feedline with two horizontally protruded feeding structurefor dual-band operation. L-Shape Metallic plate to the top edge of the ground plane is applied to achieve good impedance matching. A series capacitor is loaded into one of the protruded feeding structuresto excite an additional slot mode in the lower operating band. The proposed antenna feeding structure is shown in the Figure 1 and the antenna parameter specifications for designing the antenna are also given in Figure 1. In the Figure 1 the point A to B is the Vertical Feedline and the point p1 states the Shorting pin which is used to terminate the series Capacitor of the value C=1.5PF. The antenna is designed using the following equations given in (1) to(4).

- To calculate the width of the antenna

$$(w) = \frac{C}{2 f_c \sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

Where C= velocity of light (3×10^8 m/s), f_c =cut-off frequency (2.2 MHz), ε_r = dielectric permittivity (4.4)

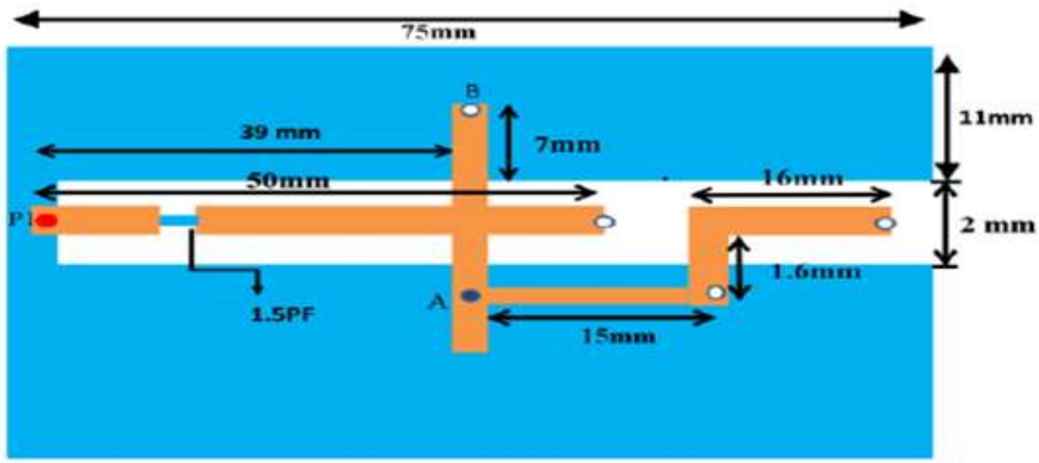

Figure 1.Antenna structure

- To calculate the effective dielectric constant of the antenna

$$(\varepsilon_{eff}) = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r + 1}{2}\left[1 + \frac{12h}{w}\right]^{-\frac{1}{2}} \tag{2}$$

Where h=height of the substrate (1.6)

- To calculate the effective length

$$(L_{eff}) = \frac{C}{2 f_c \sqrt{\varepsilon_{reff}}} \tag{3}$$

- To calculate the length of the patch

$$\Delta L = 0.412h \frac{(\varepsilon_{eff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.25)\left(\frac{w}{h} + 0.8\right)} \tag{4}$$

2.2 Antenna Design Procedure

Step-1

The proposed antenna design consist of single open-slot antenna, which radiates at LTE/WWAN (698-960MHz) in lower band and (1710-2690MHz) in higher band. The material used is FR4 epoxy which has a relative permittivity of 4.4.

Step-2

The antenna is built on the thin 0.8 mm substrate thickness with a planar ground size of 140× 75mm^2. A narrow open-slot of size 66×2 mm^2 is made in the ground plane and excited by the feeding network.

Step-3

The patch is placed centrally along the open slot and the series capacitor C=1.5PF is terminated at the point p1 which is shown in Figure 1 by using the shorting pins. The L-Shaped Metallic plate is placed on the top portion of the antenna which is used for providing good impedance matching.

Step-4

Boundary condition is assigned by using air box for frequency (2.2 GHz) and lumped port (50Ω) excitations are given.

Step-5

The proposed antenna structure is designed and simulated.

2.3 Antenna Design

Single open-slot antenna structure

The design of open slot antenna structure additionally consists of series capacitor and a parasitic patch in order to enhance the bandwidth is shown in Figure 2.

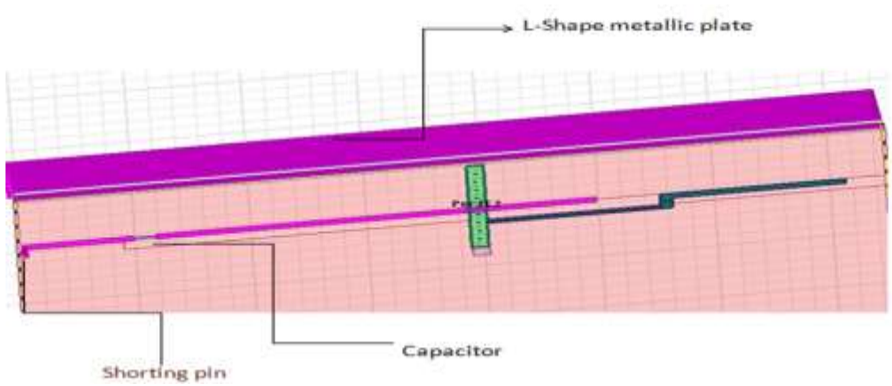

Figure 2. Configuration of the open-slot antenna structure with capacitor and parasitic patches

The return loss plot and the bandwidth obtained is shown in the Figure 3 and Figure 4.

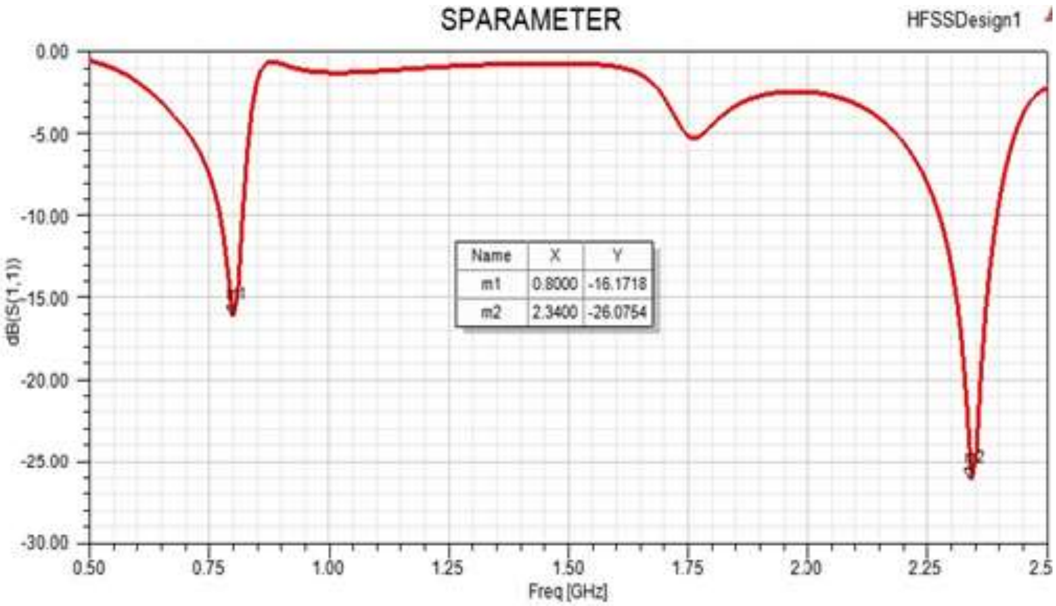

Figure 3.Return loss

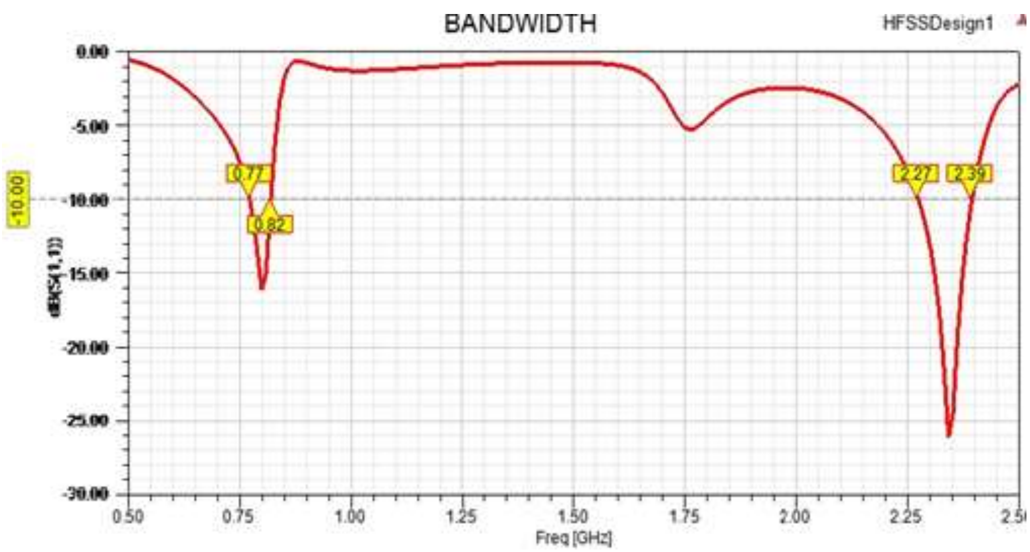

Figure 4.Bandwidth

Though the series capacitor is added to the design the desired LTE/WWAN bandwidth is not achieved, in order to achieve the lower band of 698-950 MHz and the higher band 1710-2690 MHz , the PGS is further added to the structure as shown in the Figure.2 for improving narrow bandwidth and low gain. The working principle of this PGS is integrated on the ground plane with Microstrip line. The any defect etched in the ground plane under the microstrip line is known as PGS. In this paper, the partial ground structure is used by reducing the ground plane size by $60\times130\,mm^2$ .The PGS structure is shown in Figure5.

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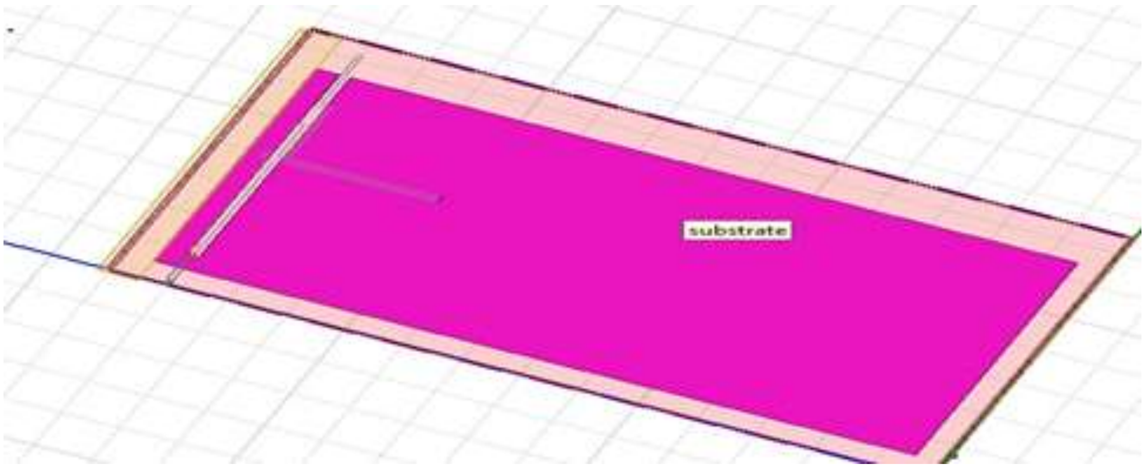

Figure 5. PGS structure of single open-slot antenna

3. SIMULATION RESULTS AND DISCUSSION

The performance of the proposed antenna by its geometrical parameter like Returns loss, Bandwidth, VSWR, Gain and Directivity are analyzed.The obtained return loss and bandwidth of the antenna with PGS is shown in the Figure.6 and Figure 7.

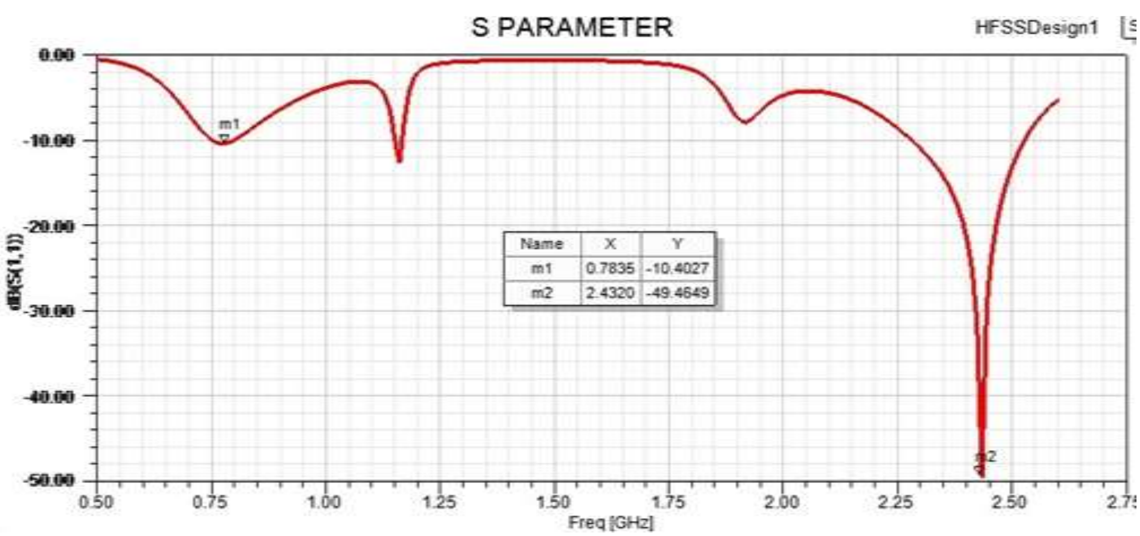

Figure 6. Return loss

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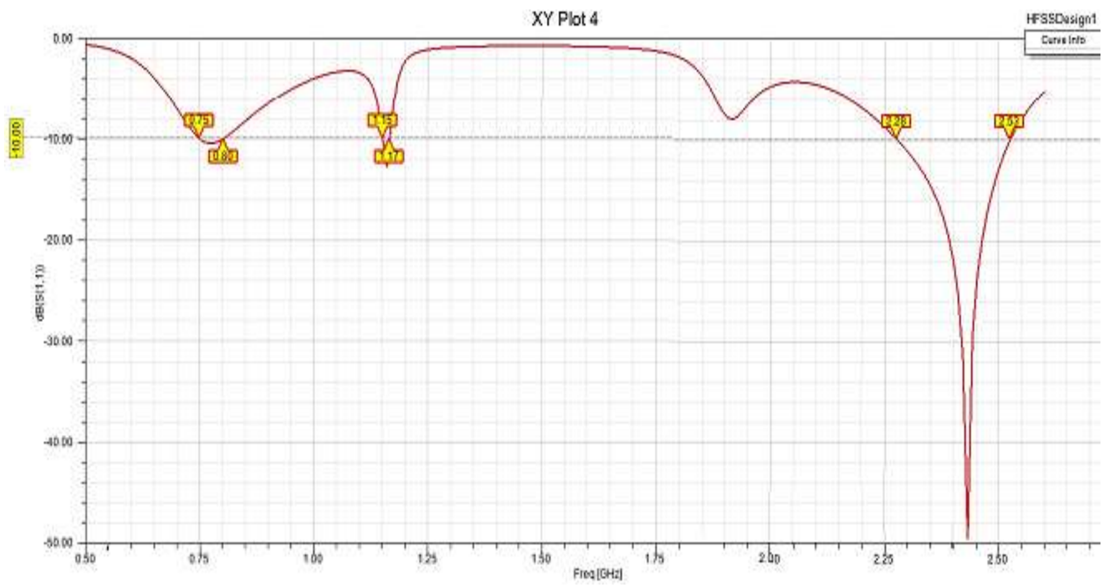

Figure 7. Bandwidth

By using the PGS structure with the single open-slot antenna, the bandwidth gets enhanced. The LTE/WWAN bandwidth coverage is 698-950 MHz and 1710-2690 MHz, this is the desired bandwidth level and the achieved bandwidth is slightly deviated from the desired level as 0.75-0.80 GHz and 2.2-2.5 GHz. The VSWR value achieved is also less than 2.

The 3D-plot of the achieved gain and directivity of the single open-slot antenna without PGS structure is also shown in the Figure 8 and Figure 9. The color value of the 3D plot ranges from dark blue (weak gain or directivity) to yellow, red (strong gain or directivity).

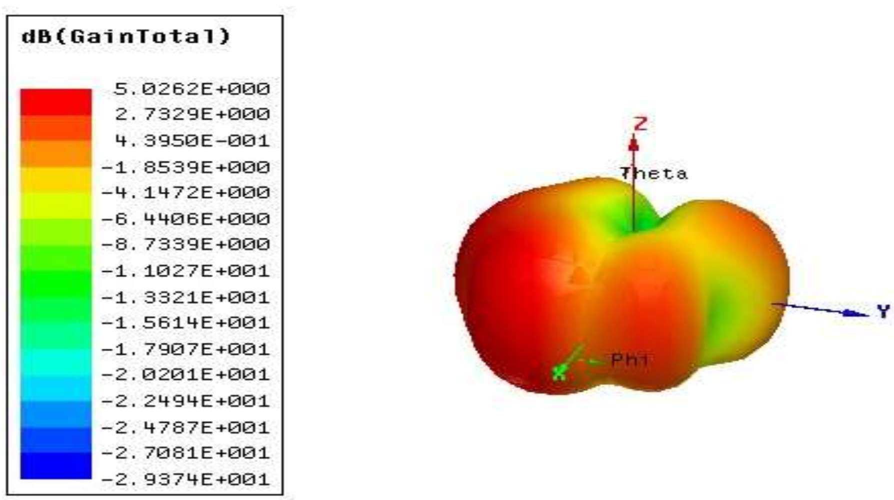

Figure 8.3D-plot of gain in dB

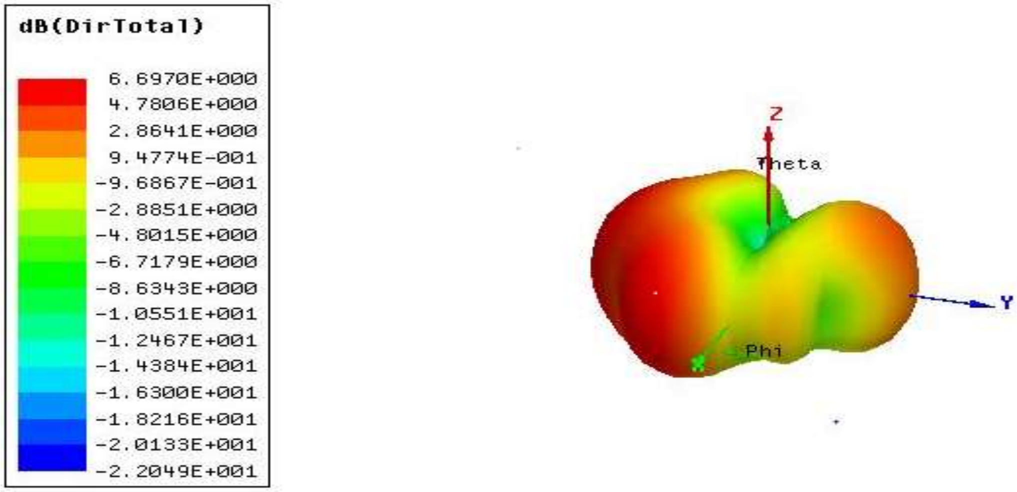

Figure 9. 3D-plot of Directivity in dB

Figure 10 shows the Antenna parameters and values of PGS structure of Single open-slot antenna

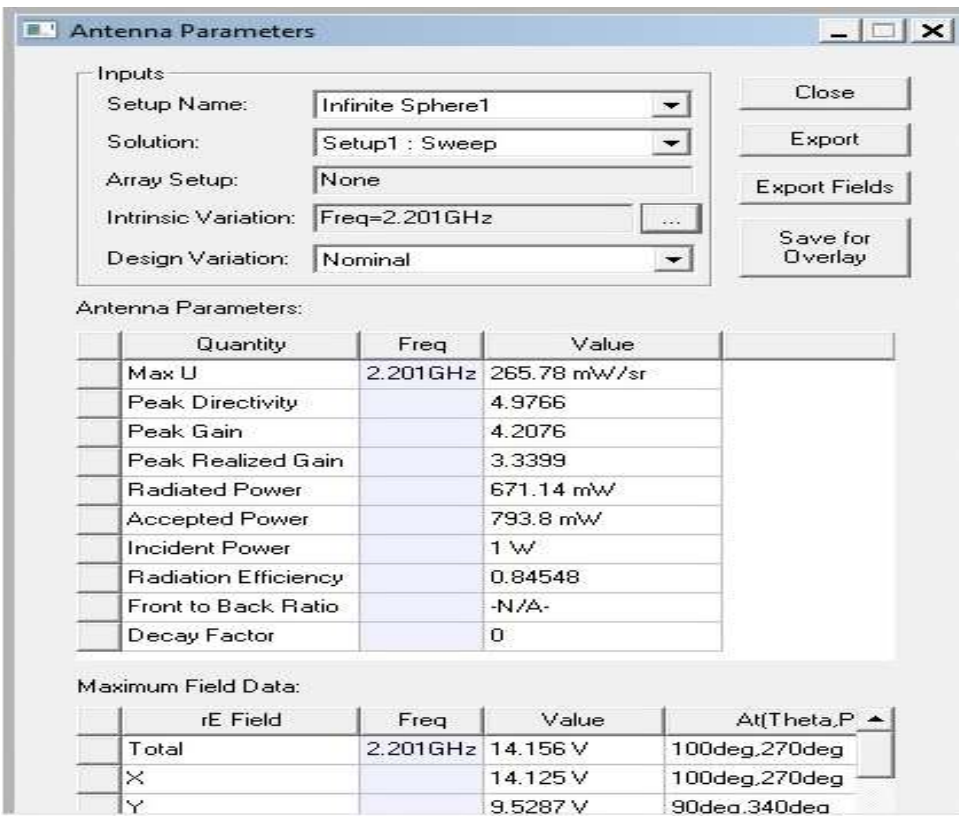

Figure 10. Antenna Parameter

Table.1 shows the comparison of the return loss, VSWR, efficiency, Gain, Directivity between the structure of the single open-slot antenna with and without PGS structure.

The efficiency is calculated by the formula given in equation 5

$$Efficiency = \frac{Gain}{Directiity} \quad (5)$$

Table 1: Performance comparison of the open-slot antenna with and without PGS structure

PARAMETER	RETURN LOSS	VSWR	GAIN	DIRECTIVITY	EFFICIENCY
Structure without PGS	0.8GHz=-18.7dB	1.26	5.06dB	6.69 dB	0.76
	2.2GHz=-20.9dB	1.33			
Structure with PGS	0.8GHz=-12.6dB	1.08	4.12dB	4.69dB	0.87
	2.4GHz=-49.8dB	1.62			

It is inferred that efficiency is higher in the PGS structure and gain get decreased because bandwidth get enhanced than the structure without PGS

4. CONCLUSION

In the proposed methodology, the single open-slot antenna which has a single vertical feed line is designed and analyzed. The antenna covers the operating frequency range of 0.75-0.80 GHz and 2.28-2.5GHz. In this design a parasitic patch, an L-shape metallic plate and series capacitor are used. L-shape metallic plate is used to get good impedance matching and series capacitor is used to enhance the bandwidth. In addition to this structure PGS technique is used to the enhanced bandwidth of LTE/WWAN. The current distribution is also within the antenna design area and the leakage of current is also reduced. Good efficiency of 75% is also achieved. Because of this compact structure, it is one of the best antennas for Smartphone application. Future work is to fabricate a Single open-slot antenna with PGS structure.

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