Design and Simulation of Circularly Polarized Compact Microstrip Patch Antenna for C-Band Applications

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***Abstract*—A probe-fed, slotted rectangular patch antenna has been proposed. Bandwidth enhancement has been achieved by suitably cutting slots into the rectangular patch, and efficiently exciting the slot by short circuiting the conducting patch through the dielectric substrate beyond the edge of the slot. Proposed antenna is suitable for various ground based and airborne applications in C-Band. It is demonstrated that the proposed antenna exhibits three resonances in C-Band and a peak gain of 7 dBi. The antenna structure is described and simulation results are presented.**

***Keywords*— Microstrip patch antenna, bandwidth enhancement, gain, dielectric substrate, simulation**

I. INTRODUCTION

In rapidly expanding market for wireless communication and applications, microstrip antenna has become widely popular as it is low profile, conformable to the hosting surfaces, light weight and can be easily integrated with the electronic system. Microstrip antennas are widely used in military, radar systems, mobile communications, global positioning system (GPS), remote sensing etc. Taking benefit of the added processing power of today's computers, electromagnetic simulators are emerging to perform both planar and 3D analysis of high-frequency structures. Electromagnetic (EM) simulation has long been an essential modelling tool for RF/microwave design. The proposed antenna is designed and simulated using method of moments (MoM) based IE3D full wave electromagnetic simulation software from Zeland Inc. [1].

Microstrip patch antenna in general consists of a radiating conducting patch printed on a grounded dielectric substrate. The patch is a very thin metal disk. To overcome its limitation of narrow impedance bandwidth by generating more than one resonant frequencies, many techniques have been suggested in past decades e.g., different shaped-slots, [2]-[5], stack, multi layers [6], two folded parts to the main radiated patch [7], and use of air substrate [8] have been proposed and investigated. In the design presented in this paper, slotting of the radiating patch has been used, because, as compared to other techniques, slotting offers the promise of saving space while giving good performance, if done appropriately.

II. ANTENNA GEOMETRY AND DESIGN PROCEDURE

The antenna has a simple rectangular structure as shown in Fig. 1. The dielectric chosen is Rogers RT Duroid substrate having ε_r =2.2 and a thickness of 1.57 mm. The dimensions of patch are approximated by using basic design approach described for microstrip patch antenna as listed below –

Width of patch:

$$W = \frac{c}{2 f_0 \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \qquad - (1)$$

Effective dielectric constant:

$$\varepsilon_{r_{eff}} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left[1 + 12\frac{h}{W}\right]^{\frac{-1}{2}} \qquad \text{- (2)}$$

Effective length is given by

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}} \qquad \text{- (3)}$$

Length extension (ΔL) is given by

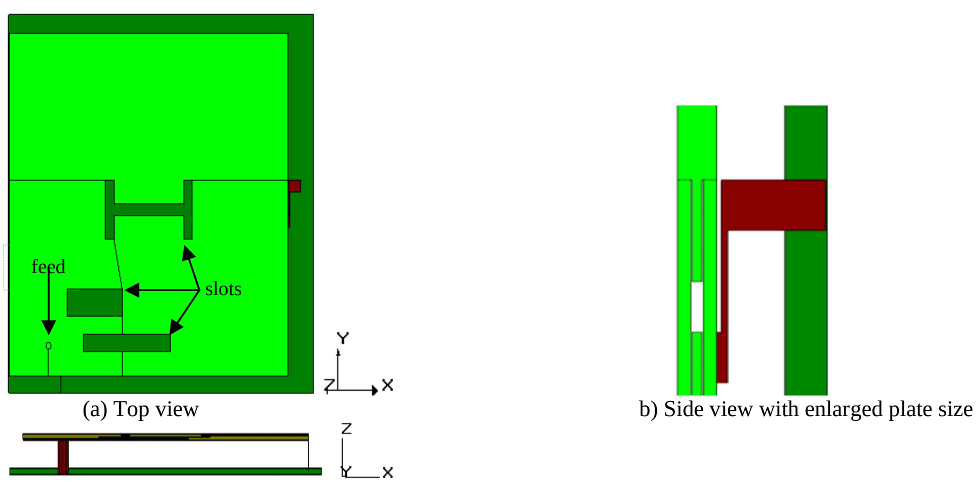
$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \qquad \text{- (4)}$$

Actual length of patch:

$$L = L_{eff} - 2\Delta L \qquad \text{- (5)}$$

Where;
c = $3x10^{18}$ m/s.
h = height of substrate.
ε_r = dielectric constant of the substrate

Now, to obtain more than one resonance frequency over the band of interest, different configurations of slots were incorporated into the patch to perturb the surface current path with the effect of producing the desired characteristics. The configuration giving better results is being presented in Fig. 1. Use of slotting instead of other techniques mentioned in Section I, also maintains single layer structure, and thus preserves thin profile characteristic of microstrip patch antenna for which it is opted for. The fields of the probe feed excite the slot. For efficient excitation of the slot, the conductor has been short circuited through the dielectric substrate beyond the edge of the slot with a bent shorting plate as shown in Fig. 1(a) and Fig. 1(b). A centre fed slot antenna has a very high radiation resistance, and a matching network may be needed to match the antenna to the characteristic impedance of the probe feed [9]. So, off-centre feeding is used in the design presented.



(a) Top view

b) Side view with enlarged plate size

(c) Front view

Fig. 1 Structure of the Proposed Antenna

III. RESULTS AND DISCUSSION

The behavior of the antenna is simulated and optimized using Zeland IE3D software available in our department. The IE3D (Zeland Software) is an integrated full wave electromagnetic simulation and optimization package for the analysis and design of microstrip antennas based on method-of-moments and it is used to solve the problems assigned to it [1]. It is a computational power-house that when given an input file performs all the calculations necessary to obtain the fields and/or currents at each grid point in the model. Simulators offer a more accurate reflection of how microstrip antennas actually perform.

Simulated results are presented in Figure 1 to Figure 6. Return loss vs. frequency curve in Fig. 2(a) shows three bands having return loss better than -10 dB. Correspondingly, VSWR vs. frequency curves also show three bands having voltage standing wave ratio lower than 2:1.

Circular polarization of an antenna is observed from its axial ratio graph and if it is below 3 dB, antenna is said to have good circular polarization. To increase the bandwidth of circular polarization, the reduction of the Q value is needed [10]. This can be confirmed using the closed-form expressions for the Axial Ratio bandwidth (ARBW) and Return Loss bandwidth (RLBW), respectively, as given by [11]

$$ARBW = \frac{AR-1}{\sqrt{AR}Q} \qquad \text{-(6)}$$

And

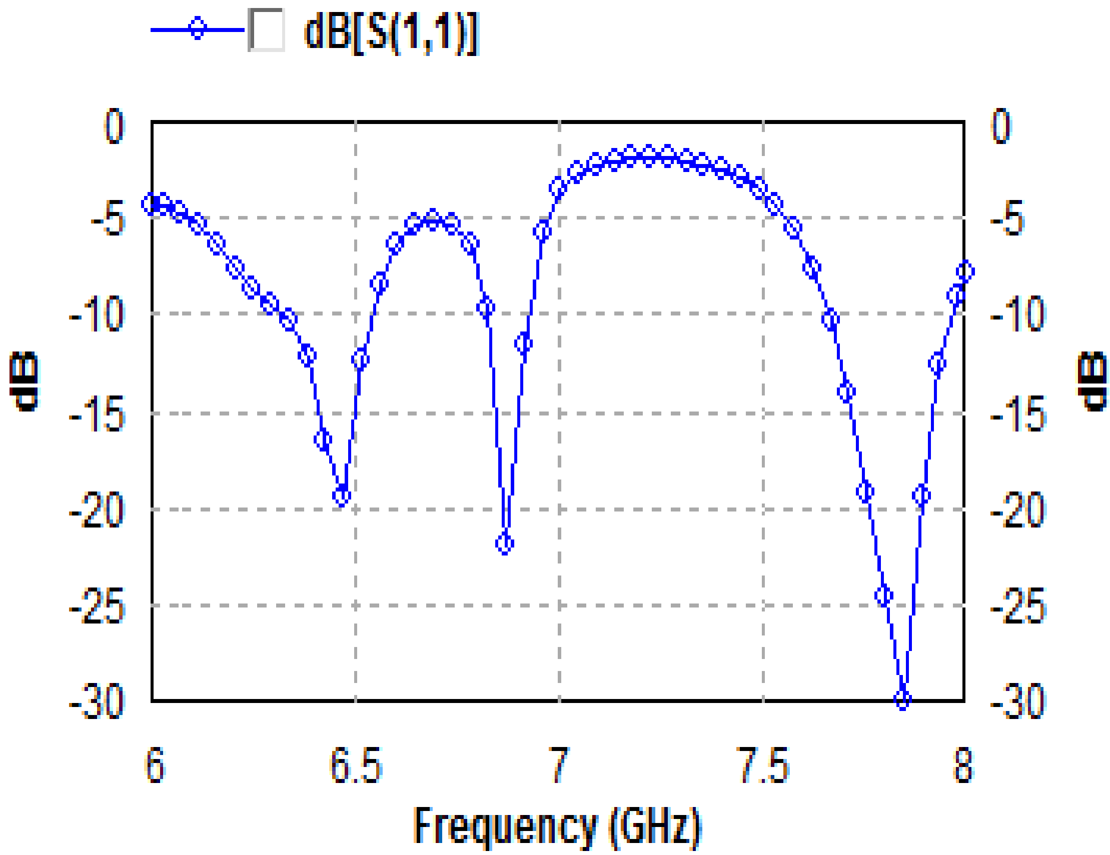
$$RLBW = \frac{\sqrt{2(VSWR-1)}}{Q} \qquad \text{-(7)}$$

Here, Q is quality factor and represents the losses associated with the antenna. Microstrip patch antenna has a very high antenna quality factor (Q). A large Q leads to a narrow bandwidth and low efficiency. And Q is directly proportional to the dielectric constant ε_r and inversely related to height of the substrate. Thus, it is clear that to keep value of Q low, height h of substrate should be increased and ε_r of substrate be decreased. For a singly-fed CP patch antenna, the perturbation amount inversely varies with the total unloaded Q-factor [12].

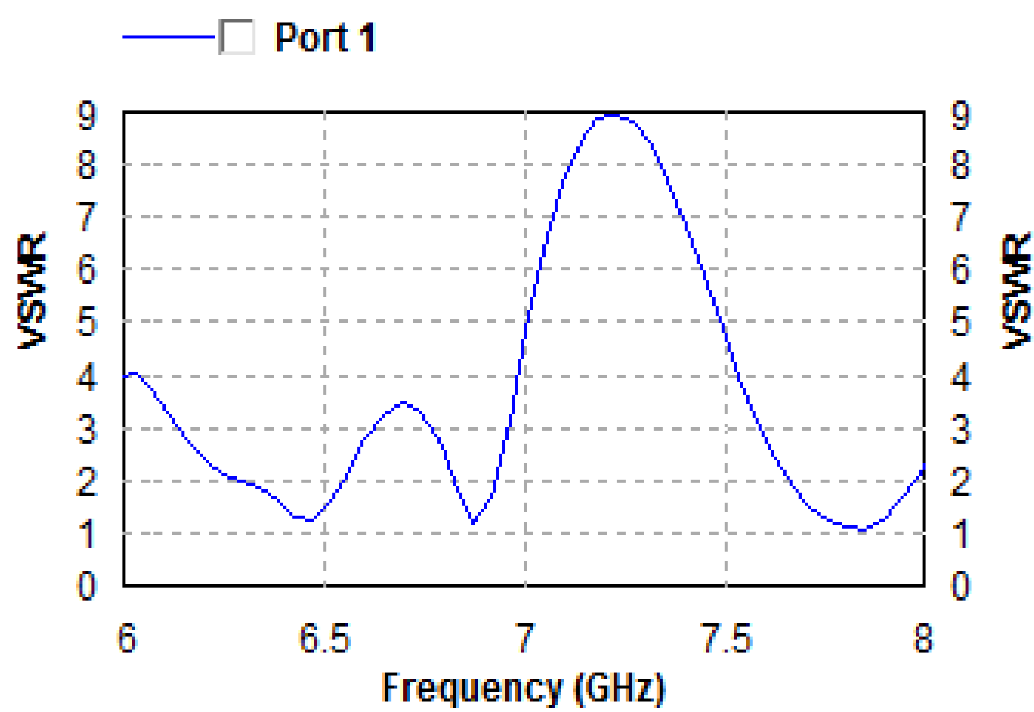
We have chosen to use low dielectric substrate, but keep the substrate height low so as to keep the antenna size small. Instead, careful slotting has been done for perturbation so as to achieve desired results. As can be seen in Figure 5, current has to bend around the slot. The axial ratio graph shown in Figure 4 is well below 3 dB, which shows circular polarization.

Depending on the material they come in contact with, radio signals are reflected or absorbed. If antenna has linear polarisation, it will be able to hit the problem in only one plane, and if the reflecting surface does not reflect the signal exactly in the same plane, that signal strength will be lost. However, circularly polarized antennas send and receive radio signals in all planes. Thus, the signal strength is not lost, but is transferred to a different plane and is still utilized. Similarly, radio signal can be absorbed depending on the material they come in contact with. Different materials absorb the signal from different planes. Thus, circularly polarized antennas provide a successful link because it is transmitting on all planes.

Antenna's directivity and gain plots are introduced in Figure 3(a) and 3(b) respectively. Antenna achieves considerably high directivity (Figure 3(a)) and simulated results show a peak gain of 7 dBi (Figure 3(b)). These three bands are useful for various wireless applications of C-Band, such as, object identification for surveillance applications, location tracking applications, cordless phones, typical satellite TV frequencies that mainly transmit at C-band and several other ground based and airborne applications.

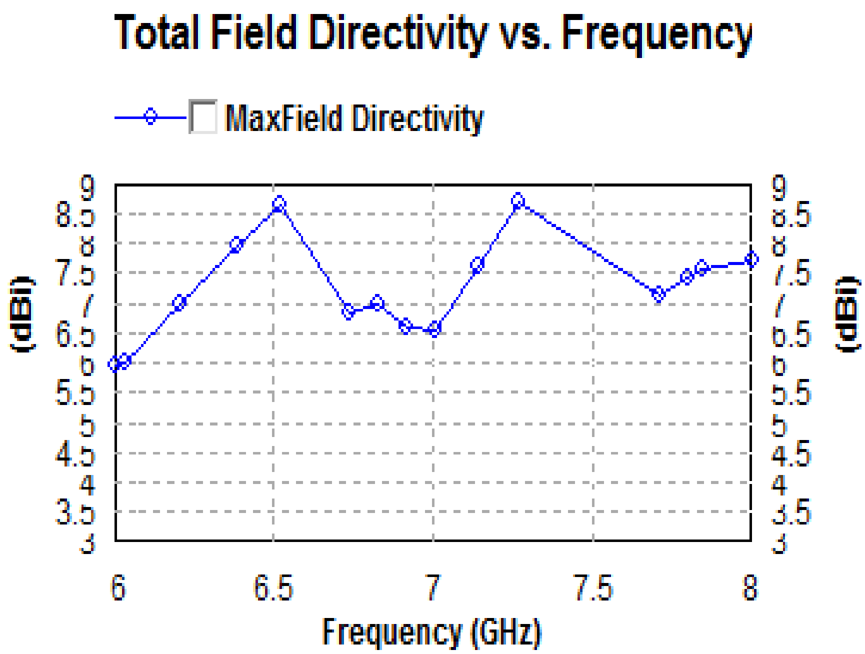


(a)

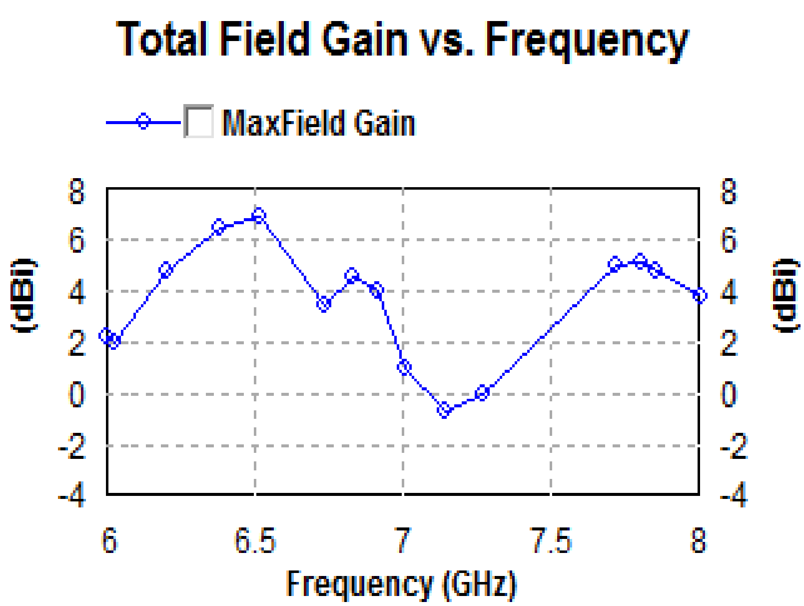


(b)

Fig. 2 Simulated (a) Return Loss(dB), and (b)Voltage Standing Wave Ratio vs. Frequency curves for the proposed antenna



(a)



(b)

Fig. 3 Simulated (a) Directivity and (b) Gain curves vs. frequency

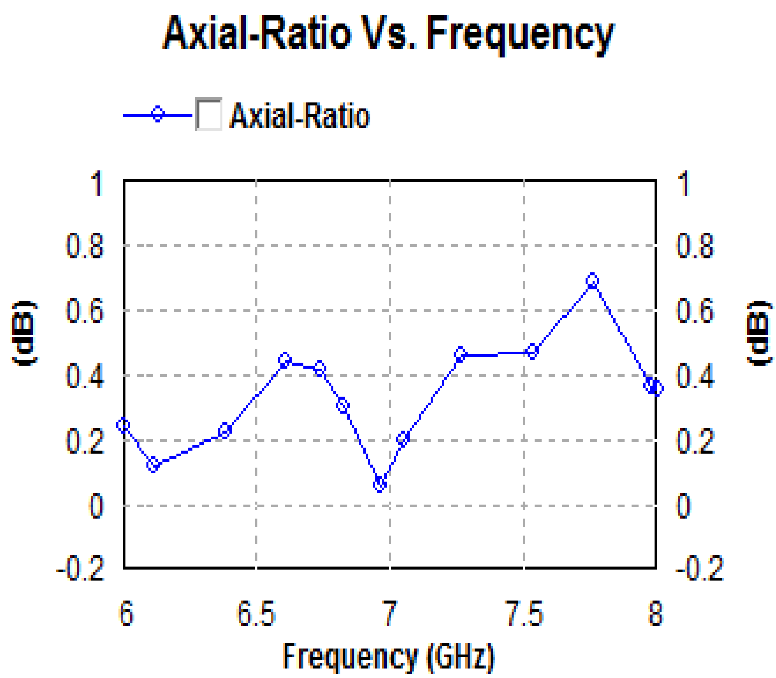


Fig. 4 Simulated Axial Ratio graph

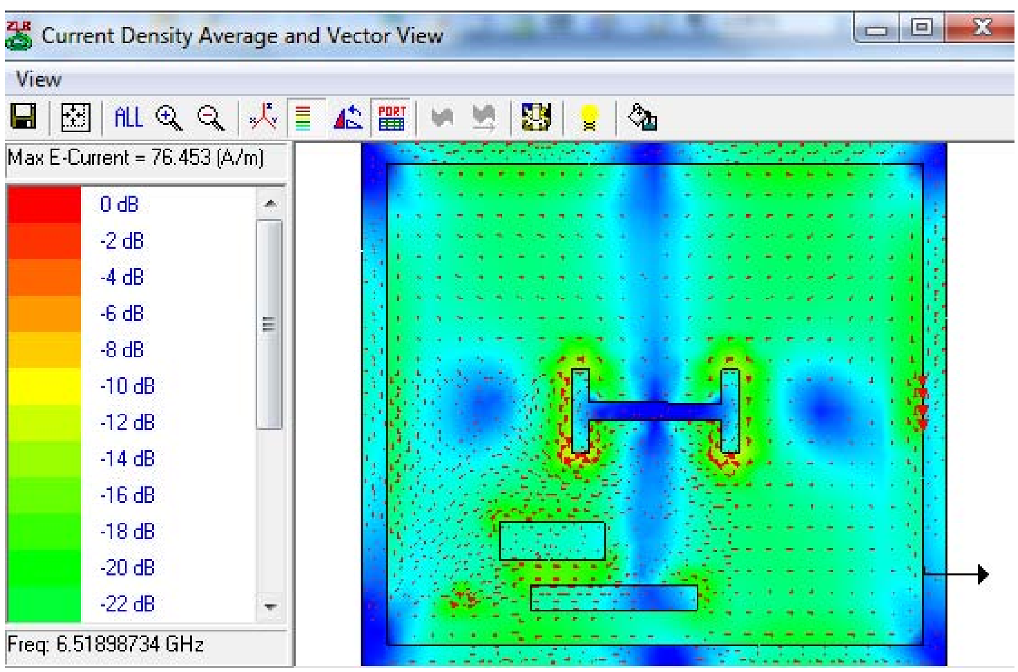
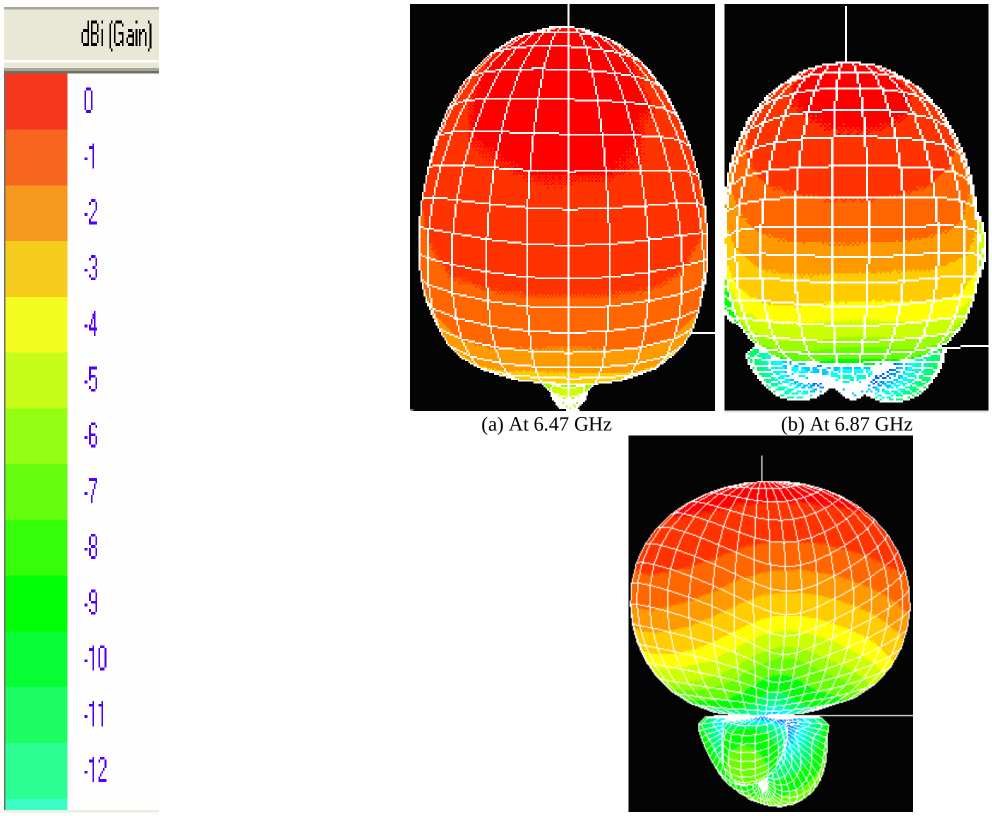


Fig. 5 Current Density Distribution over antenna surface



(a) At 6.47 GHz (b) At 6.87 GHz

(c) At 7.84 GHz

Fig. 6 True 3D Radiation Patterns

IV. CONCLUSIONS

Requirements for conformal antennas (non-protruding) for airborne systems, increased bandwidth requirements and multifunctionality have led to heavy exploitation of microstrip or slot type antennas. The antenna proposed in this paper exhibits circular polarisation and operates in three resonance bands at 6.47 GHz, 6.87 GHz and 7.84 GHz over the C-Band, with return loss better than -10 dBi (VSWR<2:1). The antenna achieves good directivity, radiation patterns and a peak gain of 7 dBi. The simulated results show that the antenna exhibits good electrical performance and thus can be considered as a suitable candidate for various airborne and ground based applications in the C-Band.

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