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Compact Dual Band Microstrip Antenna for Ku-Band Application

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Abstract: A new design of dual band compact microstrip antenna is proposed for Ku-band applications. Dual band is achieved using three pairs of thin slits from the sides of a rectangular patch and feeding with a microstrip feedline. The antenna has a compact structure and the total size is 9.50 by 10 by 0.254 mm. The result shows that the return loss of -23.83 dB is achieved at the first resonant frequency of 12.54 GHz and -14.04 dB is obtained at the second resonant frequency of 14.15 GHz. The antenna gives a stable radiation performance with gain greater than 4 dBi over the frequency band.

Key words: Microstrip antenna, Ku-band, Dual band

INTRODUCTION

Microstrip antennas have been one of the most innovative topics in antenna theory and design in recent years and are increasingly finding application in a wide range of modern microwave systems (Pozar, 1992). Inherently they have numerous advantages like easy to fabricate using standard integrated circuit techniques, have a low profile, are conformal and can be easily integrated in arrays and with electronic components. Nevertheless, microstrip antennas typically suffer from narrowband radiation (a few percent of center frequency), low gain, poor polarization purity, tolerance problem and limited power capacity. However, applications such as frequency tuning take advantage of the inherent narrow bandwidth of the microstrip antenna.

Systems such as satellites, Global Position System (GPS) are required to operate at two different frequencies apart too far from each other. Microstrip antennas can avoid the use of two different single band antennas. Variety of methods has been proposed to obtain dual frequency operation. Among them, loading slits (Wong *et al*., 1998; He *et al*., 2008), using slots in the patch (Pongchompoo *et al*., 2009; Guo *et al*., 2000; Nguyen *et al*., 2009; Chen and Yung, 2009), loading the patch with shorting pins (Tang *et al*., 1997; Wong and Pan, 1997; Pan and Wand, 1997), using stacked patches (Augustin *et al*., 2006; Zaid *et al*., 1999; Dahele *et al*., 1987; Wang *et al*., 1990) or using resonator (Hady *et al*., 2008) are the mostly exploited ones. In addition, there are planar antennas of special geometries to achieve dual-band operation (Choo and Ling, 2003).

Dual frequency operation of microstrip antennas have been studied by a number of researchers using stacked patches with two separate feeds for each frequency band and polarization. In these structures, a combination of two different feeds is observed. These feeds are composed of two separate microstrip lines, one via and one microstrip (Kim *et al*., 1999), two separate probes and one microstrip and one aperture. In general, stacked patches suffer from disadvantages such as thick substrate, difficult manufacturing and high cost. On the other hand, using single feed antennas can reduce complexity and cost of the receiver front-end.

In this study, a simple new compact design of single layer single patch element with microstrip feed line is proposed for dual frequency operation in Ku-band. The design and optimization have done to operate at downlink frequency of 12.54 GHz and uplink frequency of 14.15 GHz. The most obvious application in the Ku-band is aircraft, spacecraft and satellite based communication system.

ANTENNA MODELING

The initial geometry of the proposed microstrip antenna was first designed implementing the equations from the transmission line model (TEM) approximation in which microstrip radiating element is viewed as a transmission line resonator with no transverse field variations. The approximation states that the width and length of the patch antenna can be modeled according to the specified central frequency by using the following equations (Garg *et al*., 1980):

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$$W = \frac{c}{2f_o}\sqrt{\frac{\varepsilon_r + 1}{2}} \quad (1)$$

$$L = \frac{c}{2f_o\sqrt{\varepsilon_e}} - 2\Delta l \quad (2)$$

where, W is the width of the patch, L is the length of the patch, f_o is target center frequency, c is the speed of light in a vacuum and the effective dielectric constant can be calculated by the equation:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r + 1}{2}\sqrt{\left(1 + \frac{10h}{W}\right)} \quad (3)$$

where, ε_r is the dielectric constant of the substrate and h is the thickness of the substrate. Because of the fringing field around the periphery of the patch, electrically the antenna looks larger than its physical dimensions. Δl takes this effect in account and can be expressed as:

$$\Delta l = 0.412h\frac{(\varepsilon_r + 0.3)(w/h + 0.264)}{(\varepsilon_e - 0.258)(w/h + 0.8)} \quad (4)$$

As the antenna is fed with the microstrip, the length of the feed line is also calculated. The input impedance of the antenna must be matched to the feed line by choosing the correct position for the feeding point.

After taking account the design requirements such as bandwidth and dielectric constant, the antenna is initially designed to operate in dual frequency at Ku-band and consequently optimized to obtain the most preferable size of the patch using full wave method of moments IE3D electromagnetic simulator.

ANTENNA DESIGN

The geometry of the proposed antenna is shown in Fig. 1. The patch is fed from the left side by a 0.1 mm wide and 8 mm long microstrip feed line. The feed line along with the radiating patch as well as the ground plane is etched on a Rogers RT/Duroid 5880 substrate with ε_r = 2.2, dielectric loss tangent tan δ = 0.002 and thickness of 0.254 mm. The antenna has a compact structure and the total size is 9.50 by 7.96 by 0.254 mm.

The radiating patch is basically a rectangular structure with three pair of slits with different lengths and widths. From the top the slits are 0.09, 0.16 and 0.1 mm wide, respectively. The length of the slits varied according to the resonant frequencies. There are also two notches on the upper side of the patch and between the lower two slits. The depths of these notches are of 0.70 mm from the left side and 0.38 mm from the left side of

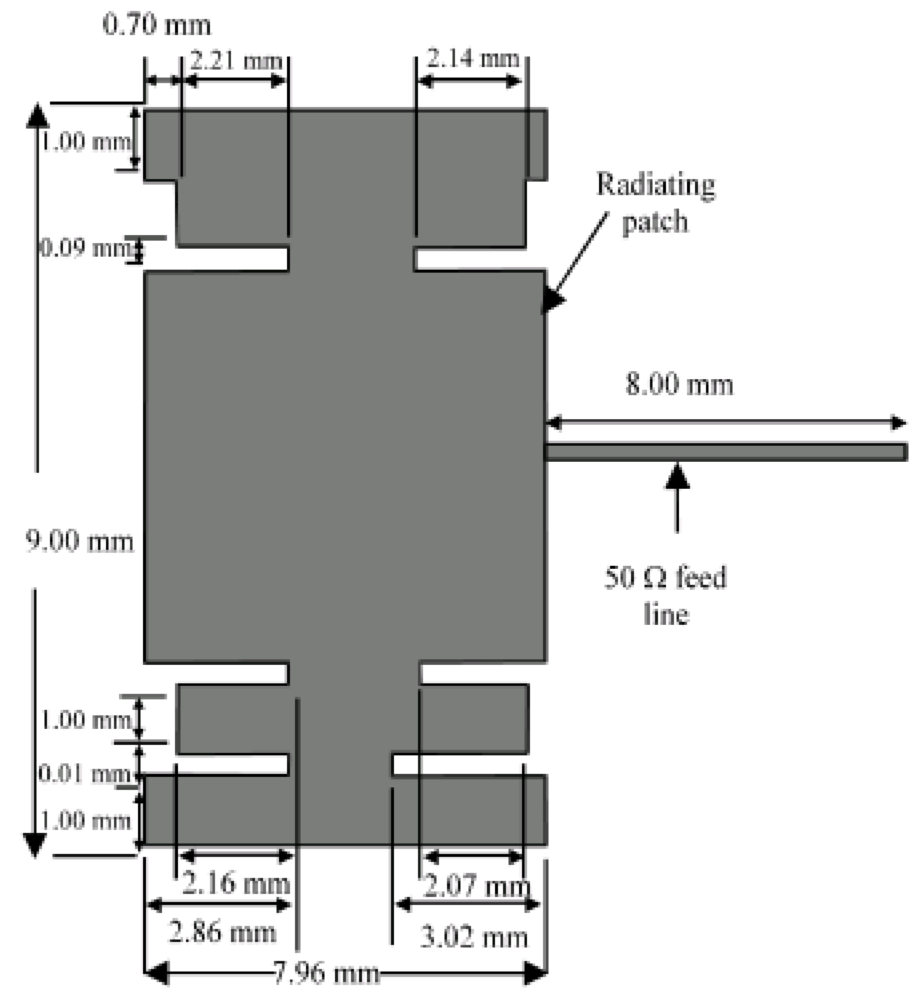

Fig. 1: Antenna geometry of the patch antenna (top view)

the patch. These are cut to tune the antenna to the upper resonant frequency. Because of the slits current lines are changed. The current has to flow around the slits. So the effective length of the current lines becomes longer and the antenna size is comparatively minimized. The antenna is designed to match to 50 Ω and an infinite conducting ground plane is assumed in the simulation.

RESULTS AND DISCUSSION

The antenna performance was studied by the IE3D-Full-Wave EM Simulation Package version 12.0. The simulated return loss of the proposed antenna is depicted in Fig. 2.

The graph shows the maximum return loss of -23.83 and -14.04 dB at the resonant frequencies of 12.545 GHz and 14.151 GHz, respectively. The graph also depicts that below -10 dB the single layer antenna attained the bandwidth of 90 MHz from 12.48 to 12.57 GHz and as well the bandwidth of 60 MHz from 14.13 to 14.19 GHz.

The resultant maximum gain is distinctly over 5 dBi across the operating frequency of 12.48 to 12.57 GHz and 14.13 to 14.19 GHz as shown in Fig. 3.

Figure 4a and b shows the E and H plane radiation patterns of the proposed antenna at 12.54 and 14.15 GHz, respectively. Moreover, the antenna shows a broad Half Power Beam Width (HPBW) of almost 92 degrees in the E-plane and 75 degrees in the H-plane at the frequency of 12.54 GHz which is able to avoid precise main beam alignment.

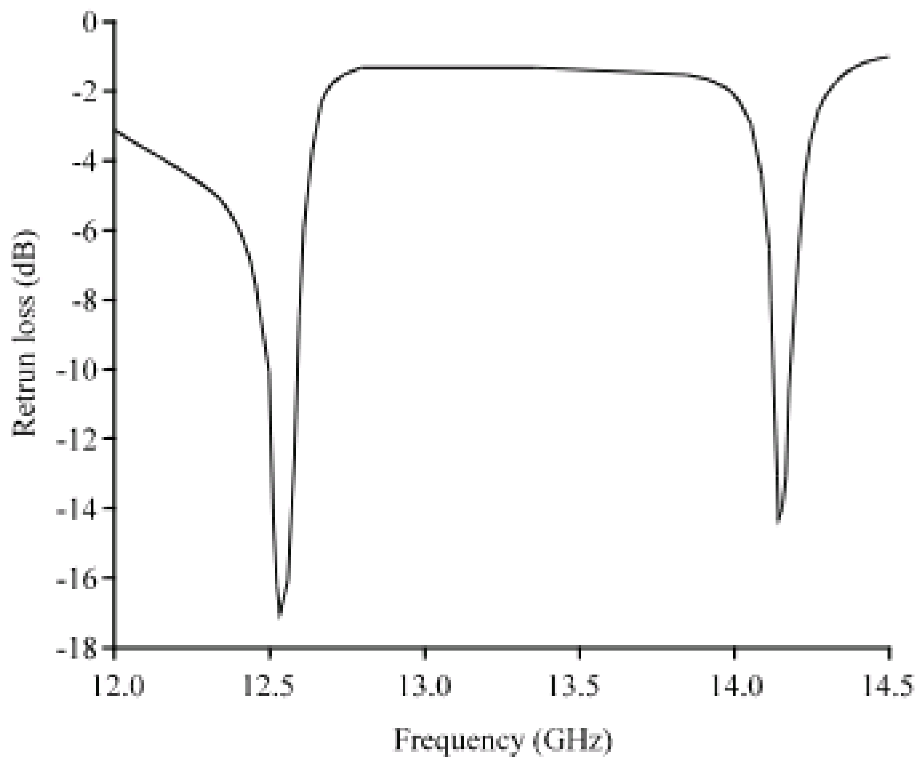

Fig. 2: Return loss of the proposed antenna

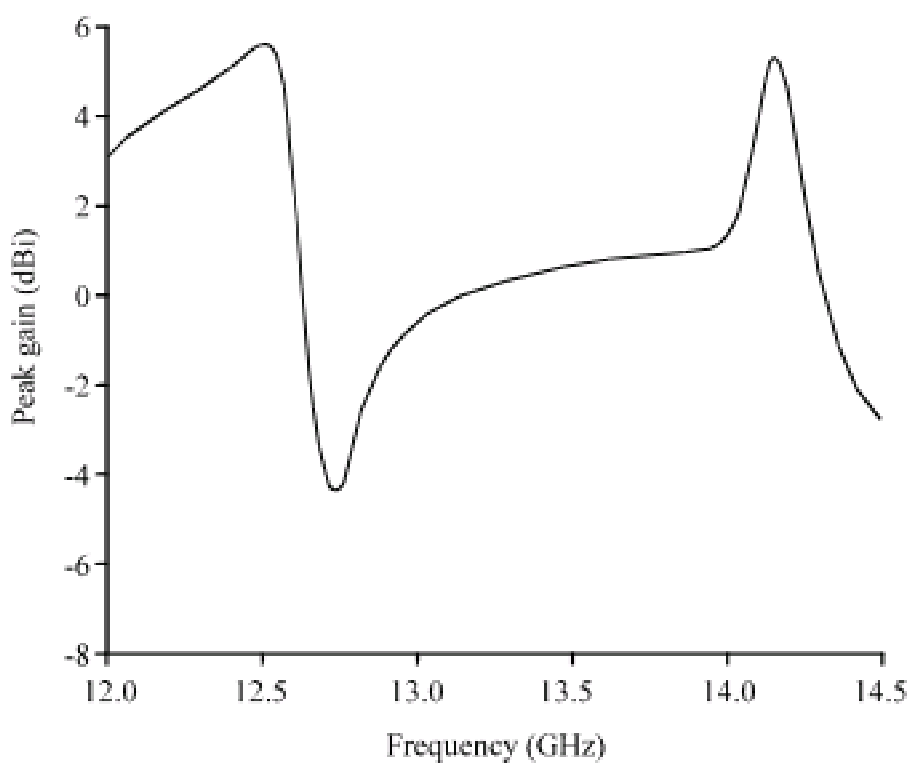

Fig. 3: Gain vs. frequency response of the proposed antenna

In Fig. 5a and b, the current distribution at frequencies of 12.54 and 14.15 GHz has been presented. It is observed that the surface currents are concentrated at the edges of the slots and relatively less strong in the plain area.

It is evident from the return loss and gain curve that the proposed microstrip antenna is entirely capable of transmitting and receiving in desired Ku band of 12.54 and 14.15 GHz, respectively with a good peak gain characteristics than He *et al.* (2008), Nguyen *et al.* (2009), Chen and Yung (2009) and Pongchompoo *et al.* (2009).

It can be clearly seen from the radiation pattern that the designed antenna produces broadside or omni directional radiation pattern and almost symmetrical radiation pattern with no back lobe radiation has been observed. There are some significant advantages if a patch antenna has a symmetrical radiation pattern. One is that the maximum power direction would always be at the broadside direction and would not shift to different directions at different frequencies. Another advantage is that when constructing an antenna array, the radiation pattern would be more stable across the operating bandwidths.

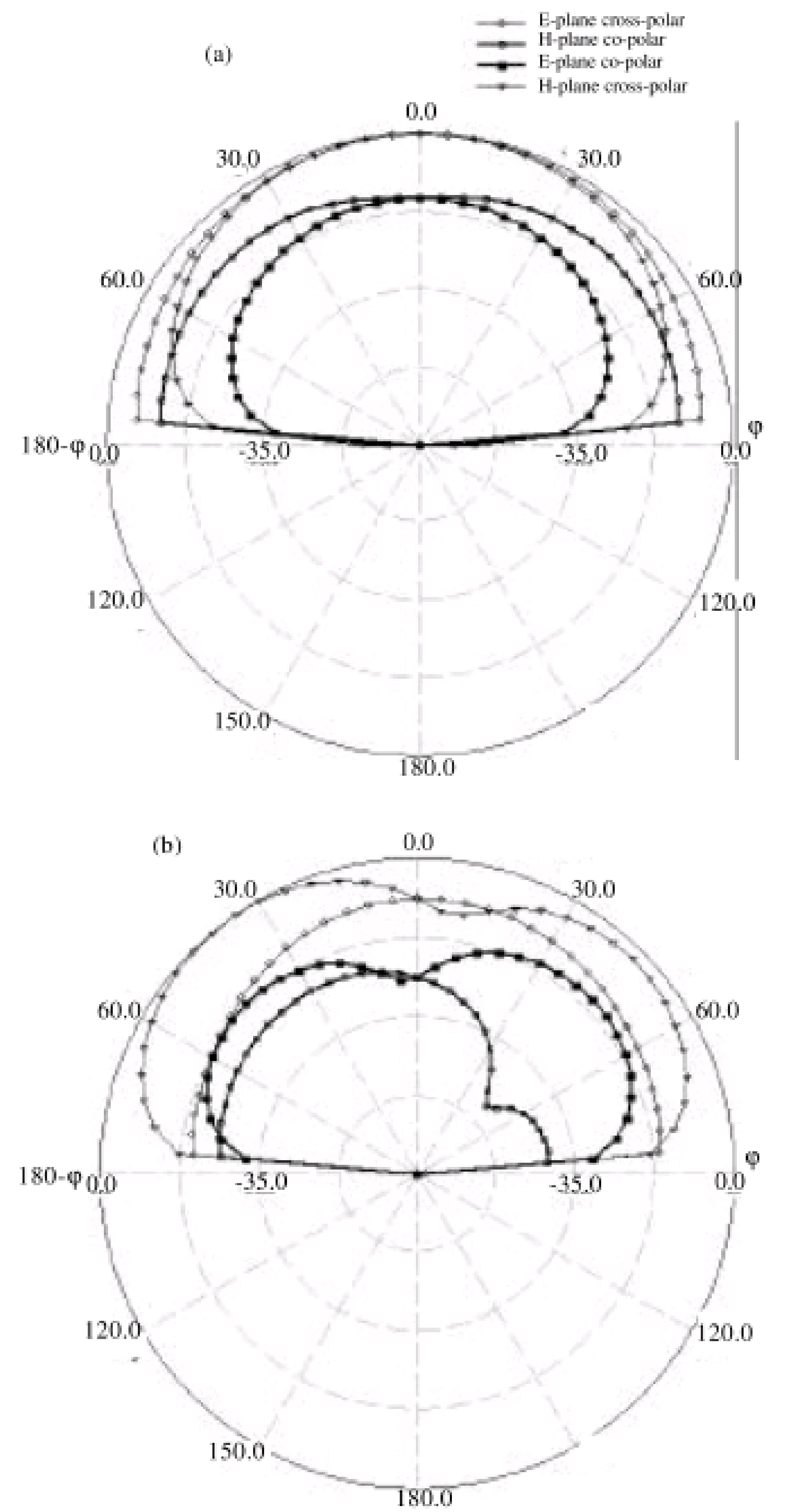

Fig. 4: Radiation pattern of the proposed antenna at (a) 12.54 Ghz and (b) 14.15 GHz

The current distribution demonstrates that at f = 12.54 GHz, due to the presence of the slits, the surface currents are forced to travel around it and so the current density at the neck area is pretty strong than other areas. But the situation is different at f = 14.15 GHz. Here, the current direction at the centre and slot edges of the patch is altered, in addition to the increased excitation and

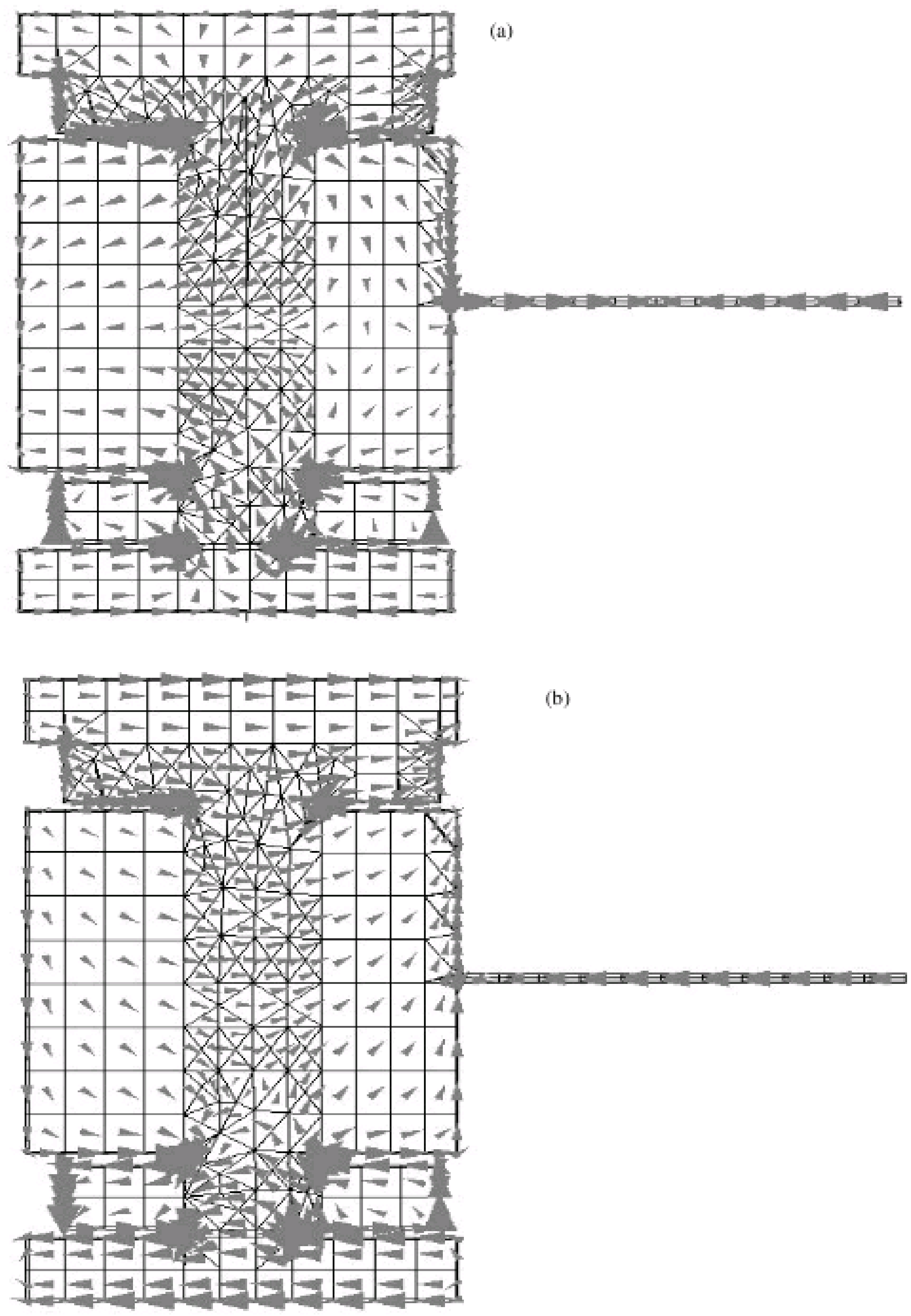

Fig. 5: The current distribution. (a) 12.54 GHz and (b) 14.15 GHz

direction change at the top and bottom of the radiating patch. Therefore, cutting slits around the patch allow to modify strongly the resonance frequency of a rectangular patch by cutting the current lines of the unperturbed mode and making it compact in shape.

CONCLUSION

In this study, a new configuration to execute dual frequency operation at Ku-band with three pairs of slit using microstrip feed line has been proposed. The design and simulation has been carried out by using commercially available simulation software: Zeland IE3D. Good results have been found at dual frequencies 12.54 GHz as downlink and 14.15 GHz as uplink. This antenna is nominated to be applied for the satellite applications which require simultaneous transmit/receive functionality at widely separated frequency bands.

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