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Switchable dual band equilateral triangular microstrip patch antenna using pin diode

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Abstract

Purpose – The purpose of this paper is to study and calculate the electrical characteristic of an equilateral triangular microstrip patch antenna that is proposed for dual frequency operation using the pin diode. The electrical characteristic of an equilateral triangular microstrip patch antenna is proposed for dual-frequency operation. Spur lines and ON/OFF condition of the pin diode are utilized to switch the resonant frequency of the patch. The presence of spur lines excites the surface current of the patch which is dependent on the resonant frequency of an equilateral triangular microstrip patch. Insertion of the diode in the spur lines gives a better result and compactness in patch design, which improves the miniaturization in size of patch.

Design/methodology/approach – Antenna Design Aspects: A basic structure of an equilateral triangular microstrip antenna (ETMA) having two spur lines and one pin diode positioned in between the spur line is considered in this paper. The design parameters are chosen on the basis of substrate materials having relative permittivity less than three. Specification of the antenna is given in Table I. Substrate material used is RT Duroid 5,880; relative permittivity of the substrate er is 2.2; thickness of dielectric substrate h is 1.5 mm; sides of equilateral triangular patch a are 10 mm, spur width s is 0.5 mm; and spur length b is 2.0 mm.

Findings – This paper gives an account of achieving polarization swiftness with coplanar waveguide (CPW) feed. The miniaturized size of the antenna is 35×30 mm^2. Switchable microstrip equilateral triangular antenna has been demonstrated for dual-frequency operations. The resonant frequency of an ETMA can be adjusted by setting the diode in an ON and OFF state. The design improves the miniaturization in size with a discussion of radiation density. The excited patch surface current is limited to flow around just the mid of the patch in simple ETMA with a single slit cut. It is observed that for an ETMA, when the diode is in the ON state at 9.16 GHz, the excited patch surface current is highly distributed in the patch compared to when the diode is in the ON state at 11 GHz. Similarly, it is observed that the excited surface patch current is highly distributed when the diode is in the OFF state in both frequencies (9 and 11.96 GHz). The mode is changed by the use of a switch at time and it is suitable for wireless communication applications.

Originality/value – Spur lines and the ON/OFF condition of the pin diode are utilized to switch the resonant frequency of the patch. The presence of spur lines excites the surface current of the patch which is dependent on the resonant frequency of an equilateral triangular microstrip patch. Insertion of the diode in spur lines gives a better result and compactness in patch design, which improves the miniaturization in size of the patch.

Keywords Simulation, Bandwidth, Microstrip antenna, PIN diode

Paper type Research paper

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1. Introduction

Microstrip antenna has many striking features, such as light weight, less volume, low-production cost and low profile. Microstrip antenna has many applications in wireless mobile communication, satellite, global positioning system (GPS), wireless local area network (WLAN) and Rocket Aircraft. In addition, microstrip antenna has a benefit of a compact cost feed network. However, microstrip antenna has a disadvantage of narrow bandwidth. This issue is overcome by dual- or multi-frequency microstrip antenna as is described in Dahele *et al.* (1987), Wang *et al.* (1990). The shape of the equilateral microstrip antenna is considered because of its smaller size than the rectangular patch designed for the same frequency. Slotted equilateral triangular microstrip antenna (ETMA) has improved the bandwidth and gain than the equilateral microstrip antenna (Pushpanjali *et al.*, 2006; Lu *et al.*, 1999).

The shape of the equilateral triangular microstrip patch can reduce the size up to 94 per cent, and this is because an ETMA operates at its fundamental resonant mode, whose null-voltage point is at two-thirds of the distance from the triangular tip.

Multi- or dual-frequency operation of a single-feed triangular patch antenna with a pair of spur lines was proposed by Lu and Wong (1998 and 1999).

The first study of an ETMA done in 1978 by Helszain and James (Liu and Chang, 2009) reported theoretical and experimental investigation on the ETMA. Dual-frequency operation of a single-feed ETMA with a pair of a narrow slots has been proposed, in which frequencies were varied by controlling the length of the slot spacing (Deshmukh and Ray, 2010; Verma and Soni, 2005).

Here, the authors propose an ETMA with two spur lines. The horizontal side of spur lines is common and one of the vertical lines is loaded with the pin diode. The ON and OFF conditions of the pin diode make various electrical characteristics of the antenna switchable; the diode can be ON or OFF, giving the switchable resonant condition. The antenna is fabricated and simulated on an IE3D. The detailed investigation is given in the following sections.

2. Theoretical considerations

Here, the coaxial feed technique is used, which can be used in any place to match with its input impedance (usually 50 ohm). To operate in the fundamental mode TM_{10}, the length of equilateral triangular patch must be slightly less than $\lambda/2$, where λ is wavelength in the dielectric medium and is equal to $\lambda_0/\sqrt{\varepsilon_{eff.}}$

The resonance frequency corresponding to various modes is given by the following:

$$f_{ri} = cKmn/2\pi(\varepsilon r)1/2 = \frac{2c}{P_e\sqrt{\varepsilon_r}}(m^2 + mn + n^2)^{\frac{1}{2}}$$

where c is the velocity of light in free space, K_{mn} is the wave number and P_e is the effective perimeter of the modified patch.

Spur lines considered in an ETMA play a vital role in the bandwidth enhancement. Embedding a pair of spur lines in the ETMA, a new resonant mode with a lower resonant frequency than that of fundamental mode TM_{10}, can be excited and it gives better results and compactness to the design. Due to the presence of spur lines, the excited patch surface current path is lengthened, and thus the resonant frequency of the triangular patch is lowered.

3. Antenna design aspects

A basic structure of an ETMA having two spur lines and one pin diode positioned in between the spur line is considered in this study. The design parameters are chosen on the basis of the substrate material having relative permittivity less than three. Specification of the antenna is given in Table I.

A simple ETMA with a single slit cut is designed and compared to a simple ETMA with two spur lines cut in the same side of an ETMA with a horizontal line common with the pin diode, as shown in Figures 1 and 2, respectively.

Substrate material used	RT Duroid 5880
Relative permittivity of the substrate	$\varepsilon_r = 2.2$
Thickness of dielectric substrate	h = 1.5 mm
Sides of Equilateral triangular patch	a = 10 mm
Spur width	s = 0.5 mm
Spur length	b = 2.0 mm

Table I. Specifications of antenna

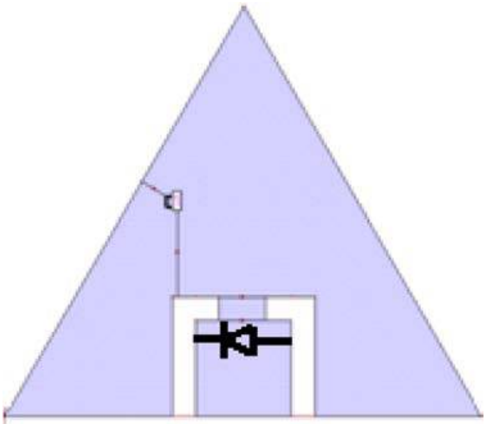

Figure 1. ETMA with two spur lines

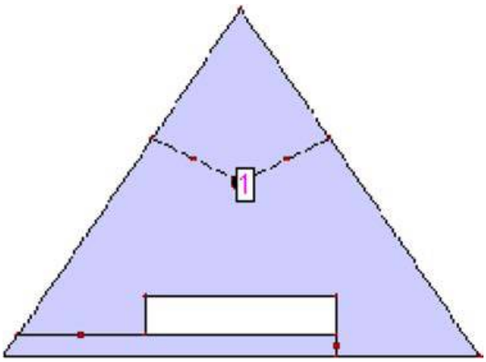

Figure 2. ETMA with a single slit cut

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Resonant frequency of an ETMA with a single slit cut is 11.10 GHz, as shown in Figure 3. In case of a simple ETMA with two spur lines cut in the same side of an ETMA with a common horizontal line, the resonant frequency of an ETMA without the pin diode are 9.07 and 12.01 GHz. In the case of a simple ETMA with two spur lines cut in the same side of an ETMA with a common horizontal line, the resonant frequency of an ETMA with pin diode is 8.23 and 11.67 GHz, as shown in Figure 4. Simulation work is

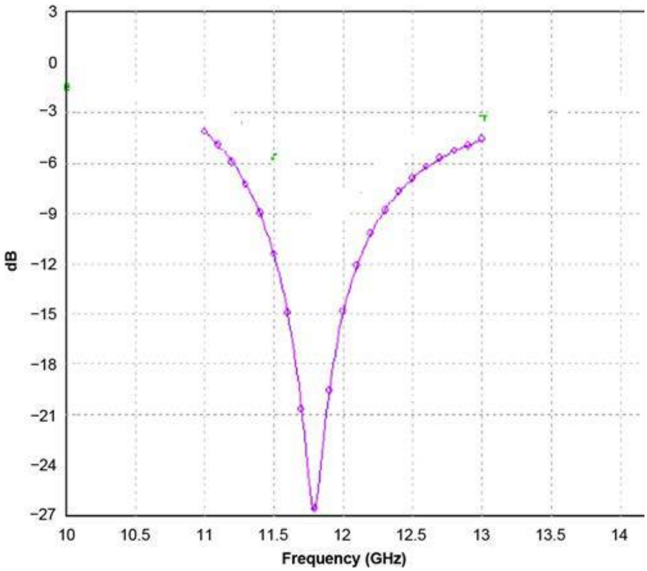

Figure 3.
Resonant frequency of an ETMA with a single slit cut

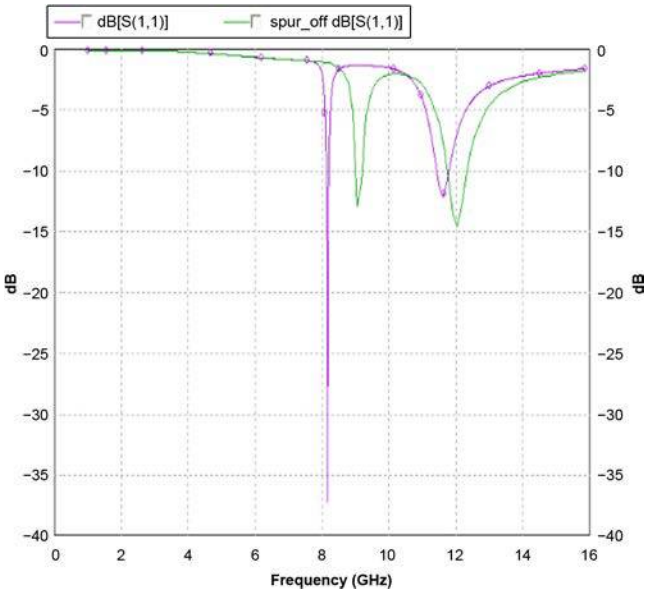

Figure 4.
Resonant frequency of an ETMA with two spurs lines and a diode

carried out by IE3D software; in this work, two spur lines are embedded in the patch. Implementation of the DC bias circuit is easy and convenient because the gaps available in between the spur line is suitable to insert a pin diode. Electrical characteristics of equilateral triangular microstrip patch are changed accordingly by the ON/OFF state of the pin diode. To isolate the DC bias circuit from RF signal, a capacitor is used.

The ETMA is fed by a 50 Ω coaxial cable. Feed point is located away from bottom of the triangular patch. The diode has an ohmic resistance of 2 ohm in the forward state and a capacitance of 0.1 pF in the reverse bias state.

4. Experiment results

In Figure 4, simulated return loss of an ETMA with the diode for two operating frequencies f_{off} and f_{on} is shown in Table II.

4.1 Current distribution results

Current distribution of a simple ETMA with a single slit cut is shown in Figure 5, which shows less radiation intensity.

Current distribution of a simple ETMA with two spur lines cut in the same side of an ETMA with a common horizontal line, when diode is ON at 9.16 and 11 GHz, is shown in Figures 6 and 7, respectively, which shows a good radiation intensity at 9.16 and at 11 GHz a low radiation intensity.

Current distribution of a simple ETMA with two spur lines cut in the same side of an ETMA with a common horizontal line, when diode is OFF at 9 and 11.96 GHz, is shown in Figures 8 and 9, respectively, which shows a good radiation intensity at 9 and at 11.96 GHz both.

Diode OFF condition Band (f_2-f_1)		Diode ON condition Band (f_2-f_1)	
Band 1	Band 2	Band 1	Band 2
0.22 GHz	0.6 GHz	0.12 GHz	0.16 GHz
9.21-8.99	12.3-11.7	8.28-8.16	12.01-11.4

Table II. Result showing Diode OFF & ON

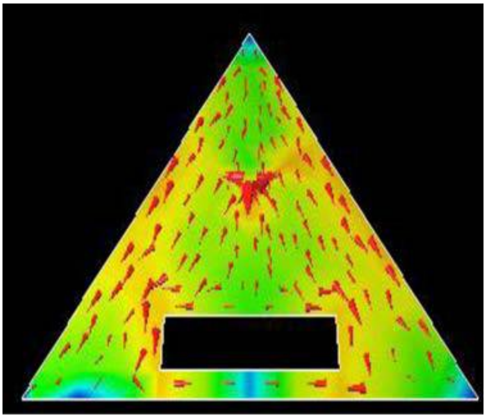

Figure 5. Current distribution of a simple (ETMA) with a single slit cut

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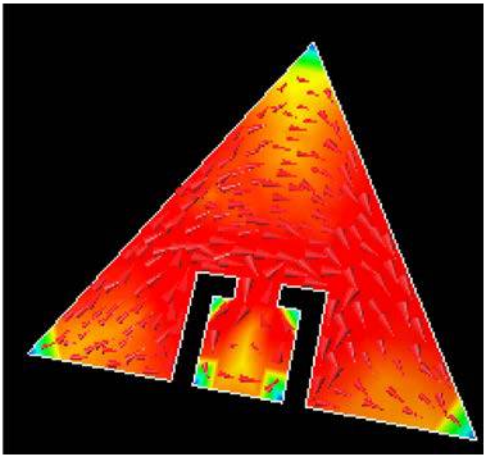

Figure 6.
Current distribution of an ETMA with two spur lines when the diode is ON at 9.16 GHz

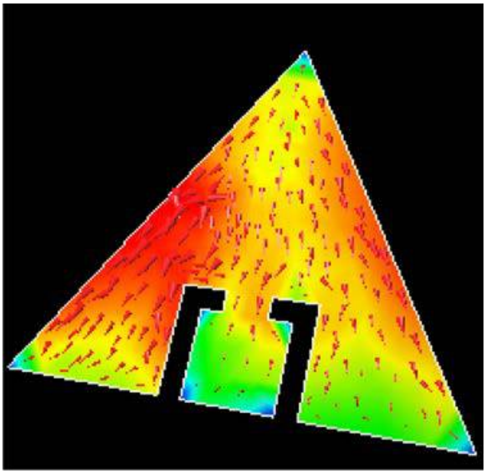

Figure 7.
Current distribution of an ETMA with two spur lines when the diode is ON at 11 GHz

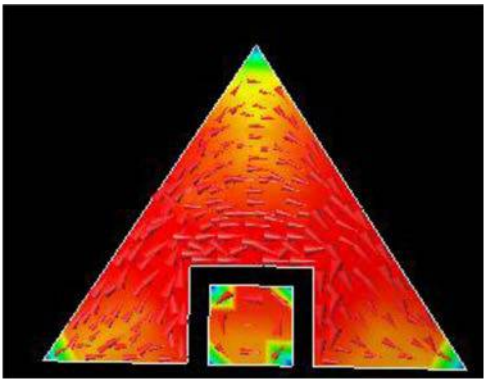

Figure 8.
Current distribution of an ETMA with two spur lines when the diode is OFF at 9 GHz

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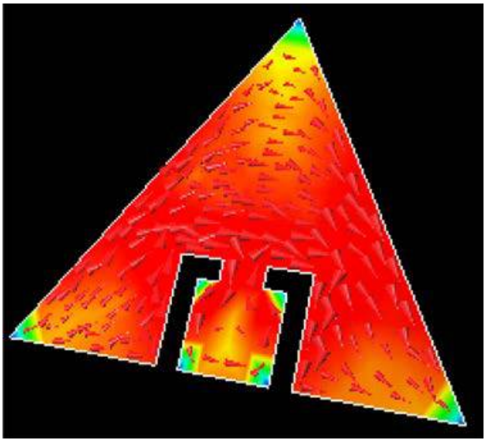

Figure 9. Current distribution of an ETMA with two spur lines when the diode is OFF at 11.96 GHz

5. Conclusion

This paper gives an account of achieving polarization swiftness with coplanar waveguide (CPW) feed. The miniaturized size of the antenna is 35×30 mm^2. Switchable microstrip equilateral triangular antenna has been demonstrated for dual-frequency operations. The resonant frequency of an ETMA can be adjusted by setting the diode in an ON and OFF state. The design improves the miniaturization in size with a discussion of radiation density. The excited patch surface current is limited to flow around just the mid of the patch in simple ETMA with a single slit cut. It is observed that for an ETMA when the diode is in the ON state at 9.16 GHz, the excited patch surface current is highly distributed in the patch compared to when the diode is in the ON state at 11 GHz. Similarly, it is observed that the excited surface patch current is highly distributed when the diode is in the OFF state in both frequencies (9 and 11.96 GHz). The mode is changed by the use of a switch at time and it is suitable for wireless communication applications.

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