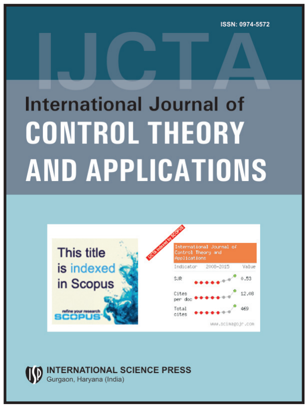

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Triangular Shaped Frequency Reconfigurable Monopole Antenna with Defected Ground Switching

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Abstract: A triangular shaped frequency reconfigurable antenna with DGS is proposed in this work. The defect in the ground plane is fine tuned with conducting switches to get the frequency switchable characteristics in the operating band. Multiple switches are arranged in the ground plane and exploring the defected ground switching in the proposed design. The switches in the ground plane will enable the change of current path, thereby changing the resonant frequencies. A maximum tunable frequency ratio of 5% achieved in this design and the corresponding reflection loss and radiation characteristics are presented in this work.

Keywords: Defected Ground, Frequency Reconfigurability, Monopole Antenna, Triangular Patch.

1. INTRODUCTION

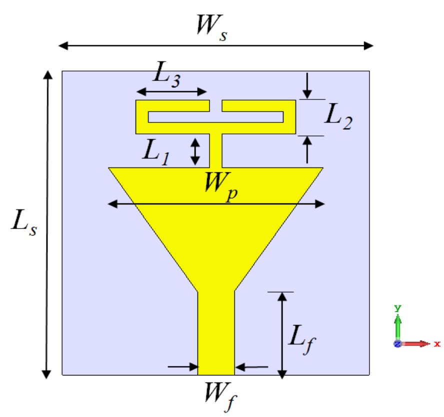
The ever end demand of electronics in the wireless communication leading the innovative modules in the design and development of communication systems. The customers all over the world are asking compact gadgets with powerful interfacing to all sorts of communication modules. The designed modules are operating at fixed operating frequencies and at limited operating bands. Finding solution for switching between different operating bands, without any interference and degradation in antenna performance is most difficult job.

Tunable microwave devices with special materials based designs can provide solution for this kind of problems. Especially materials like liquid crystals and liquid crystal polymers will come under the tunable and flexible materials. The characterization and the synthesis of liquid crystal materials are cost effective so, the alternate techniques is using tunable microwave devices like PIN diodes, Varactor diodes etc. Many techniques were presented literature and some of them are mentioned in this section. The frequency reconfigurability is achieved in [1-2] by using a bow-tie radiating element on either side of the substrate and p-i-n diodes are placed on the arms of the radiating element. Current flowing length of the antenna is varied using these diodes. By using varactor diodes around the axis of antenna and by controlling the operating modes of the diodes, frequency reconfigurability is achieved in [3-4] and achieved a 32% tuning range. GaAs FET switches are used in [5-8] to vary the length of the current path and achieved the reconfigurable characteristics. With four sector-shaped patches surrounding a center-fed patch presented in [9-10] is exhibiting frequency reconfigurable characteristics using eight varactor diodes. In [11-12], by positioning the varactors, the propagating modes are controlled which matches the specific mode and other modes are tuning to be mismatched. The feasibility of using the multiple control circuitry on the antenna circuitry is discussed in [13-14] using the reed switches.

In this paper, a design of compact dual frequency reconfigurable antenna is presented. The experiments are carried using the triangular monopole elements. The defected ground is extended to defected ground switching for enabling the frequency reconfiguration. Design procedure is mentioned in Section 2. The simulation characteristics are mentioned in Section 3 and concluded in Section 4.

2. ANTENNA GEOMETRY

The proposed antenna is designed on a general-purpose FR-4 printed circuit board material available with relative permittivity of 4.4 and having compact dimensions $L_s \times W_s$. A triangular patch of having its top side length 'W_p'. An inverted triangular shape patch is considered as a radiating element for this antenna. Its top side length is 'W_p' having the height of 11mm from the feed line which is having a width 'W_f' which corresponds to 50ohms impedance. A rectangular split-ring stub is appended to the triangular radiating element using a small vertical stub of length 'L_1'. The ground plane of the partially etched with the dimensions of $L_g \times W_s$. A conducting strip of length 'W_s' and width 'G_2' is placed at a gap 'G_1' apart from the ground. These features can be seen in Figure 1(a) and Figure 1(b). Further, in the partially etched ground plane, a small rectangular notch of dimensions of $l \times w$ is provided for impedance matching purpose. Four conducting switches are bridged to form different defected ground switching combinations and these devices are placed in the gap between the partial ground and a conducting strip which is placed apart. The geometrical parameters are mentioned in Table 1. These several defected ground switching combinations are simulated in CST Microwave Studio using FIT numerical method.



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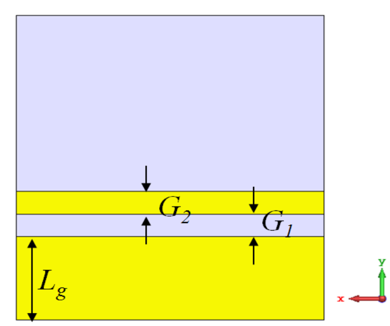
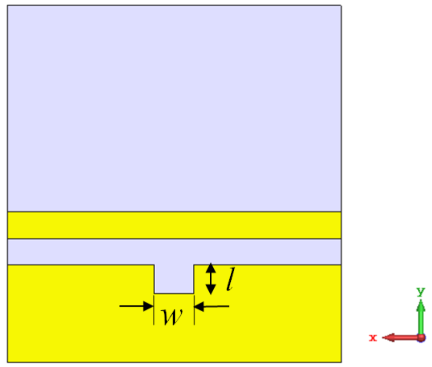


(b)

Figure 1: Triangular Monopole with DGS (a) Front view (b) back view

Table 1
Dimensions of the proposed reconfigurable antenna

Parameter	L_s	W_s	L_f	W_f	W_p	L_1	L_2
Value in mm	27	25	7.4	3	21.25	3	3
Parameter	L_3	G_1	G_2	w	l	w_1	w_2
Value in mm	6	2	2	3	2.2	3.05	7

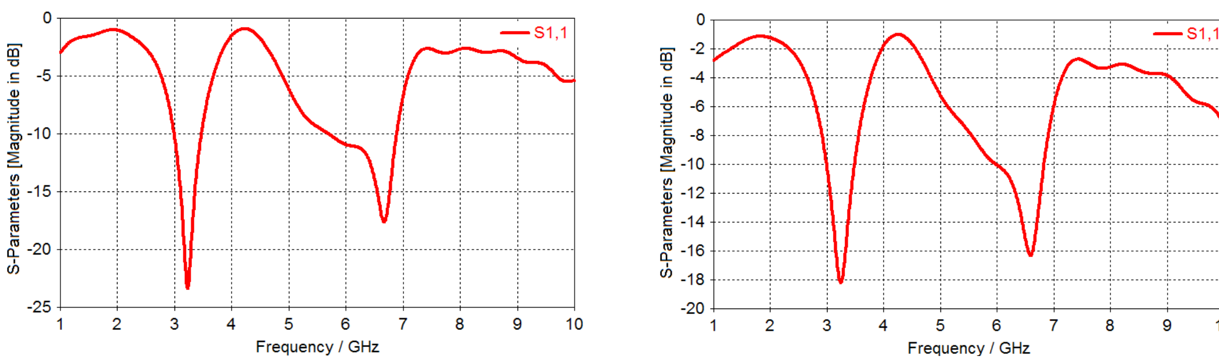


(a) **(b)**

Figure 2: Defected Ground Switching (a) Slot Loaded DGS (b) Conducting Switches in DGS

3. SIMULATION RESULTS

The various combinations of defected ground switching are evaluated using four conducting strips is evaluated for possible combinations are evaluated. The gain and radiation patterns, field distributions are presented under this section.

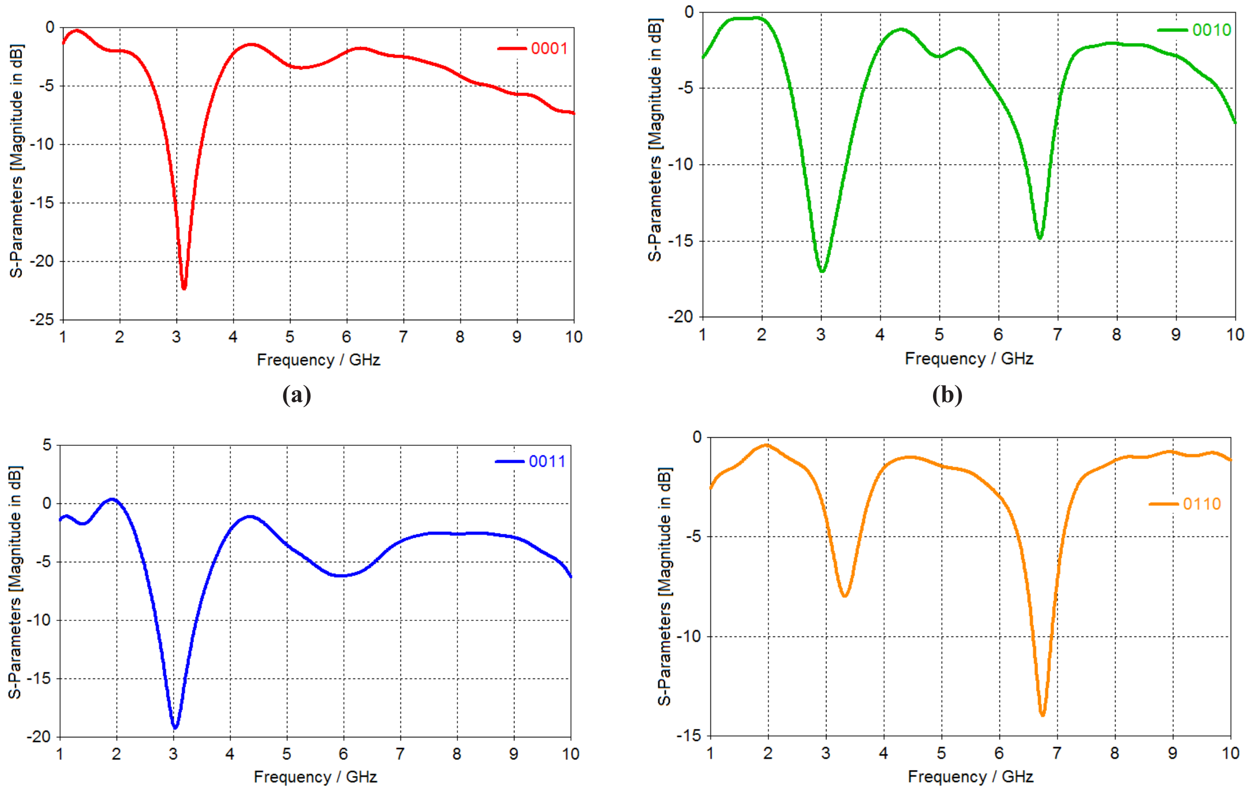


(a) **(b)**

Figure 3: Return loss Vs Frequency characteristics of (a) Triangular monopole antenna (b) with rectangular notch in ground plane

The return loss characteristics of the basic triangular monopole antenna is shown in Figure 3(a) is having the resonant frequencies at 3.235 GHz with return loss of –23.28 dB, and at 6.679 GHz where the return loss is found to be –17.57 dB. The dual band nature can be seen for the design with partial ground with a strip placed at some distance away from the ground conductor. The first band occurs around 2.99 GHz-3.47 GHz and another band at the range 5.68 GHz-6.88 GHz respectively. When a rectangular notch is created in the ground plane, then slight frequency shift is occurred. The first band is consisting of the range 2.99-3.48 GHz with resonant frequency of 3.24 GHz (S11 = –18.18 dB) and the second operating band is occurring from 5.98-6.82 GHz with resonant frequency of 6.598 GHz (S11 = –16.285 dB). The upper cut-off frequency is observed to be slightly shifted further increasing the operating band than earlier case.

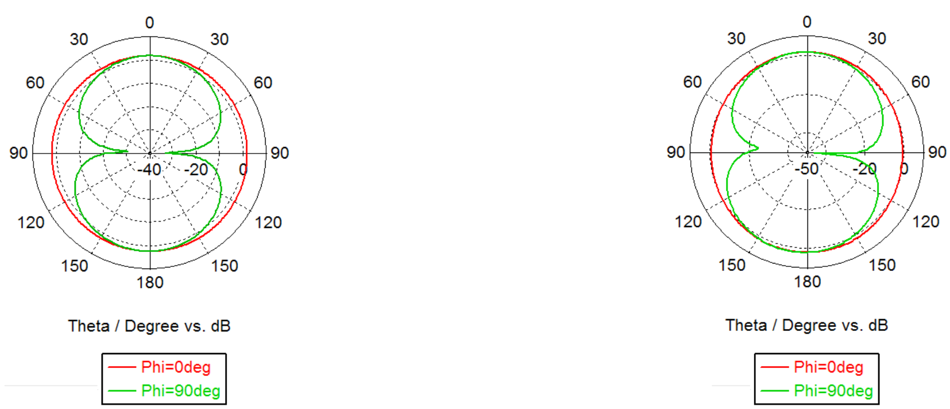
The ground plane of the proposed antenna is modified to provide the various defected ground switching structures, which can be operated using the PIN diodes, varactors or MEMS devices. Totally, the four switching devices are provided, which arises a total of 16 cases out of which some cases are giving the similar results due to the symmetrical geometries. The evaluated cases are presented in Figure 4. For the case 0001, the return loss characteristics is showing the single operating band with bandwidth ranging 2.83 GHz-3.43 GHz and the



(a) (b) (c) (d)

Figure 4: Return loss Vs Frequency characteristics of various switching cases of defected ground switching for S4 S3 S2 S1 switches (1-ON, 0-OFF) (a) 0001 (b) 0010 (c) 0011 (d) 0110

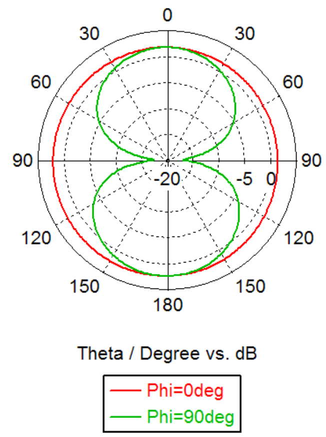
inimum resonance is obtained at 3.13 GHz with S11 of −22.376dB. This switching case represents the only one of the extreme switches are turned ON. When either of the middle S2 or S3 turned ON and remaining are at OFF condition, (0010 or 0100) then the antenna is operating in two bands at 3.016 GHz, 6.69 GHz band with bandwidths 2.704 GHz-3.418 GHz and 6.462 GHz-6.86 GHz respectively. When two adjacent switches present on the any one half-section are turned ON such that 0011 or 1100 then single resonant characteristics can be seen at 3.021 GHz center frequency with band 2.687 GHz-3.398 GHz. When the middle switches S2, S3 turned ON and remaining are switched OFF, in such case the operating band is shifted to 6.752 GHz center frequency (S11 = −13.984 dB) with operating band from 6.58 GHz to 6.901 GHz.



(a) (b)

Figure 5: 2D-radiation patterns of basic triangular monopole antenna (a) at 3.23 GHz (b) 6.67 GHz

The two-dimensional radiation patterns are plotted in Figure 5 in Phi = 0 deg, Phi = 90 deg planes. Phi = 0 deg patterns are following the omni-direction and the Phi = 90 deg is following the dumbbell shaped structure. The main lobe magnitude is found to be 2.22 dB for 3.23 GHz and directs the energy in 177 degrees. At frequency 6.67 GHz, it is having the gain value of 1.78 dB with the angular 3dB beam width of 78.7 degrees. Similarly, the 2D radiation patterns are plotted in two principle cut planes are shown in Figure 6 for several defected ground switching cases.



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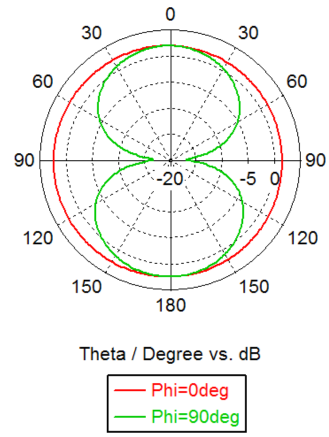

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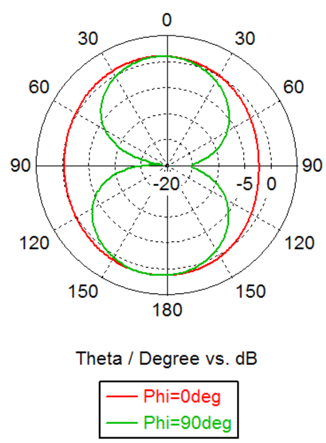

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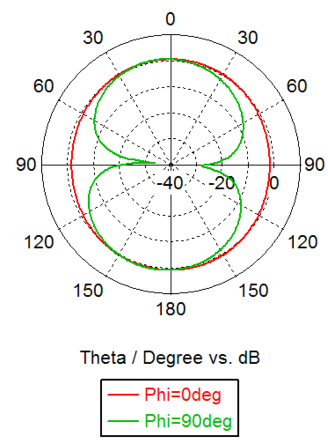
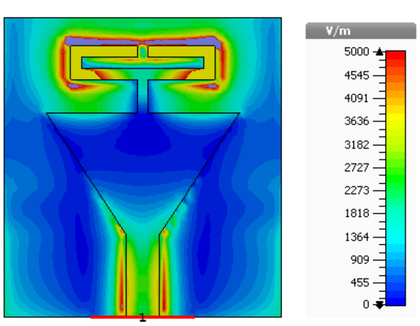


(d)

Figure 6: (a) 2D-radiation patterns of proposed reconfigurable antenna for the switching case 0001 at 3.13 GHz (b) for case 0010 at 3.01 GHz (c) Switching case 0010 and *f* = 6.69 GHz (d) Switching case 0110 and *f* = 6.74 GHz



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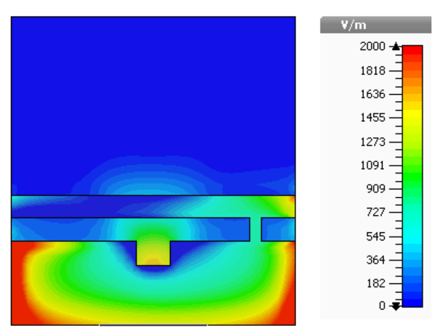

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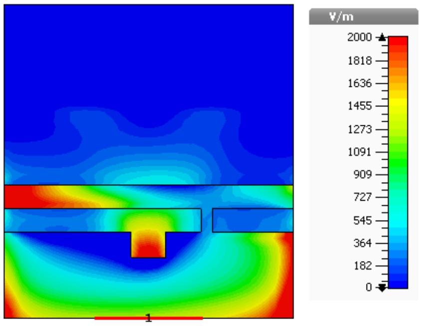

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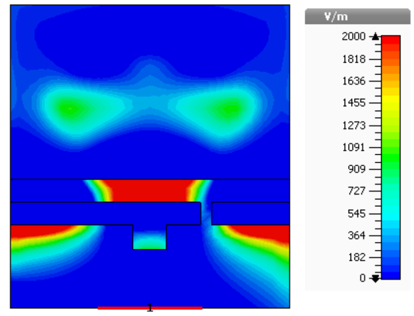

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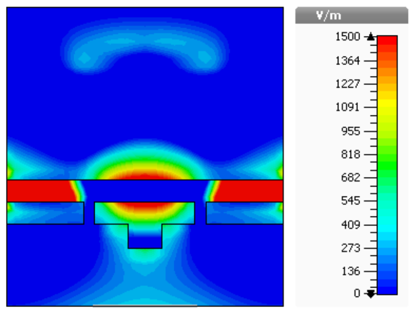

(e)

Figure 7: Electric field distributions of the proposed antenna: (a) on the top of the patch (b) on the ground plane for case 0001 (at 3.13 GHz) (c) for case 0010 at 3.016 GHz (d) for case 0010 at 6.69 GHz (e) for the case 0110 at 6.74 GHz

The electric field distribution characteristics for the proposed reconfigurable antenna are shown in Figure 7. More E-field density can be found near the extended split-ring stub and also the field is propagating at the edges of the feed line. When the extreme switch alone set to conducting mode, the field propagation is shown in Figure 7(b). The field distributions at dual bands are shown in Figure 7(c) & Figure 7(d). Field is observed to be symmetrically distributed when the switches S2 and S3 both will turn ON which is evident from Figure 7(e). The consolidated antenna parameters are presented in Table 2.

Table 2
Performance characteristics of proposed defected ground switching reconfigurable antenna

Defected Ground Switching Cases				*Operating band (in GHz)*	*Resonant Frequency (GHz)*	*Gain (dB)*	*Directivity (dBi)*	*Total Radiation Efficiency (in %)*
S4	*S3*	*S2*	*S1*					
0	0	0	1	2.83-3.43	3.13	2.323	2.318	98.2
0	0	1	0	2.704-3.418	3.016	2.476	2.281	98.4
				6.462 -6.86	6.69	1.636	2.81	73.1
0	1	1	0	6.58-6.901	6.752	1.382	2.848	68.5
0	1	0	0	2.704-3.418	3.016	2.476	2.281	98.4
				6.462 -6.86	6.69	1.636	2.81	73.1
1	0	0	0	2.83-3.43	3.13	2.323	2.318	98.2

4. CONCLUSION

A frequency reconfigurable antenna is proposed in this paper. The proposed antenna is having compact dimensions of 27mm x 25mm and can be fabricated on a general-purpose FR-4 PCB. The triangular shaped patch with extended split-ring stub. The operating characteristics are showing the dual band performance which can be suitable for the WiMAX and IEEE 802.11 standard extended sub band of Wi-Fi and IOT applications. Proposed antenna is shows the gain more than 1.3dB and good radiation efficiency more than 95% is obtained at the lower band and the more than 65% which requires further improvements for appropriate radiation in the upper band.

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