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Comparative analysis of Reconfigurable Patch Antenna Array for different Liquid Crystal Substrates

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Abstract

This paper presents the frequency reconfigurable patch antenna array based on tunable liquid crystal and the comparison of tuning range with four liquid crystal (LC) substrates namely BL037, BL006, E7 and GT3-24002. Both the conventional and reconfigurable antennas are designed to operate at 2.45 GHz frequency. The proposed structure satisfies tuning range of 1.70%, 2.56%, 2.28% and 4.09% for LC material BL037, BL006, E7 and GT3-24002 respectively. Using Liquid crystals we can cover several frequency bands and overcome the problem of narrow band antenna .The designed antenna has various applications in S band. The antenna design and simulation is done with the help of HFSS software.

1. Introduction

In past few years there has been a huge growth of wireless communication systems. For this purpose the multifunctional antennas are required. Reconfigurable antennas are best suited for such applications [1]. Reconfigurable antennas have freedom to adjust their characteristics such as polarization, frequency and radiation pattern. There are four main approaches to construct the reconfigurable antenna: optical, material, electrical and mechanical tuning [2]. Among these, material tuning through LC technology [3-7] is the most suited because of low cost and low loss of LC with increasing frequency. LC possess anisotropy property .This property can be derived from a permittivity tensor which depends on the direction of the applied electric field.

In this paper we propose a 1x2 inset fed patch antenna array based on the LC substrate. Antenna array is used to increase the antenna gain and LC substrate is used for tunability. The detailed comparative analysis has been performed with LC material BL037 ($\varepsilon_\perp$=2.35, $\varepsilon_\parallel$=2.61), BL006 ($\varepsilon_\perp$=2.62, $\varepsilon_\parallel$=3.11), E7 ($\varepsilon_\perp$=2.72, $\varepsilon_\parallel$=3.17), and GT3-24002 ($\varepsilon_\perp$=2.5, $\varepsilon_\parallel$=3.3) [8].

2. Properties of Liquid Crystals

LC is an anisotropic material which carries both properties of a crystal and a liquid. In LC the molecules align themselves according to the direction of the electric field. Due to this change of alignment permittivity of material changes. For the case of no bias voltage LC shows the minimum permittivity represented by $\varepsilon_\perp$ .When bias voltage is applied then permittivity is represented by $\varepsilon_\parallel$. Hence the dielectric anisotropy is defined as the difference between parallel and perpendicular permittivity [9] as follows:

$$\Delta\varepsilon = \varepsilon_\parallel - \varepsilon_\perp \,, \tag{1}$$

Figure 1. shows the orientation of LC molecules with applied bias voltage.

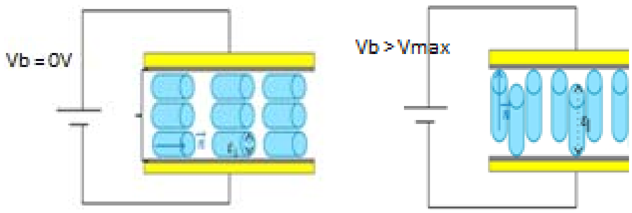


Figure 1. Tunable LC without and with bias voltage [8]

3. LC Based Reconfigurable Antenna Design and Simulation

Figure 2. shows the final structure of reconfigurable patch antenna array

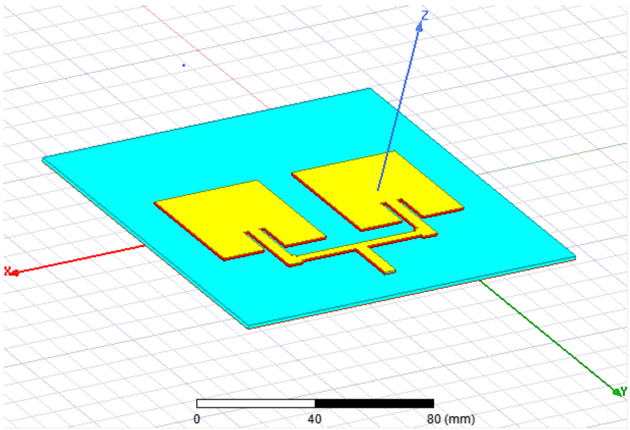


Figure 2. Design of patch antenna array based on LC

In this design, antenna dimensions are determined considering the operating resonant frequency as 2.45 GHz, height of the dielectric substrate as 1.515 mm and permittivity ε_r of the dielectric RT/Duroid 5880 as 2.2 [10]. Final and optimized dimensions of the antenna are shown in Table.1.

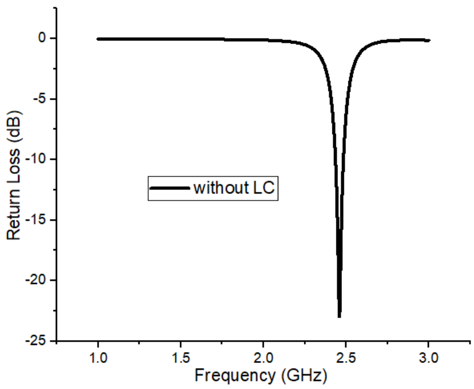
Microstrip antenna designed above has the limitation of fixed frequency which can be overcome by making the antenna reconfigurable. For this purpose LC substrate of low permittivity (without bias) is inserted between the patch and RT/Duroid 5880 substrate which changes the frequency. When the DC voltage is applied the dielectric permittivity of the LC material changes again and so the resonance frequency.

Table 1. Dimensions of antenna parameters

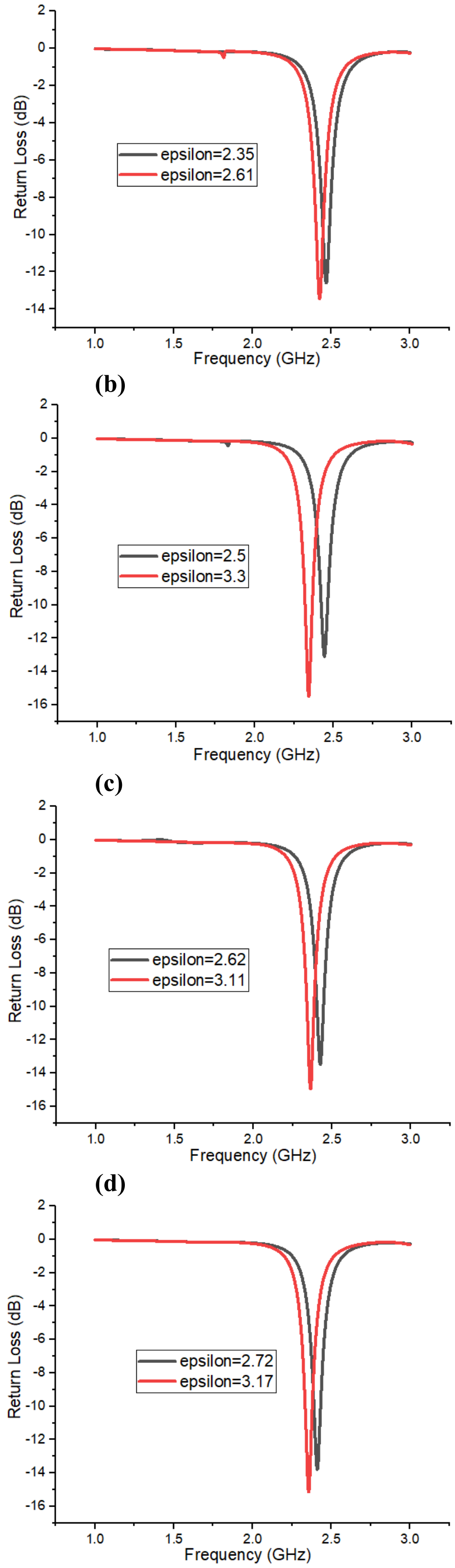
Design Parameters	Dimensions (mm)
Patch Width	46.2
Patch Length	39.7
Inset Distance	11.86
Inset Gap	2.3
Feed Length	19
Feed Width	4.9
Roger Substrate Height	1.515
LC Substrate Height	1

4. Results and Discussion

Figure 3. shows the return loss S_{11} plotted as a function of frequency in the range of 2-3 GHz demonstrating the impedance matching conditions for patch antenna array without LC and with different LC materials as BL037, BL006, E7 and GT3-24002. It can be shown that the return loss of the patch antenna array without LC reaches the maximum value of -22.95 dB at resonating frequency 2.45 GHz. After inserting the LC between substrate and patch the resonating frequency shifts to the small amount and return loss reaches the value of -12.60,-13.47,-13.78,-13.08 dB for different LC materials BL037, BL006, E7 and GT3-24002 respectively . In this case no bias voltage is applied to the LC materials .Whereas when the bias voltage is applied the resonating frequency of the antenna shifts further and return loss reaches the value of -13.43.-15.03, -15.12.-15.49 dB respectively.



(a)



(b)

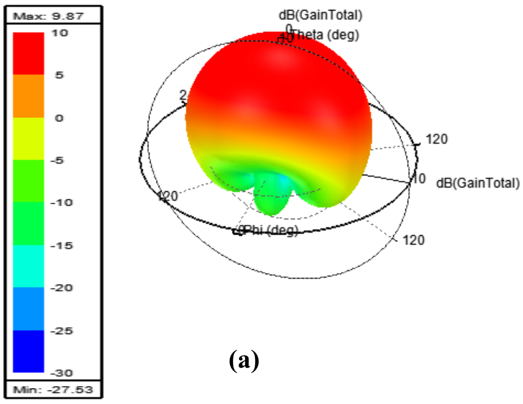
(c)

(d)

(e)

Figure 3. Return Loss of 1x2 antenna array (a) without LC (b) with BL037 LC (c) GT3-24002 LC (d) BL006 LC (e) E7 LC

Figure 4. shows the 3D polar plot for antenna gain in the azimuth plane for all the LC materials with varying permittivity.



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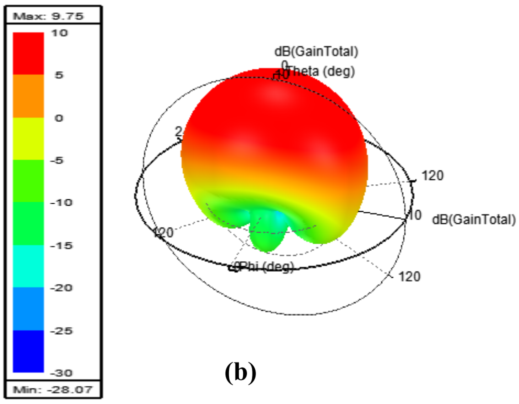
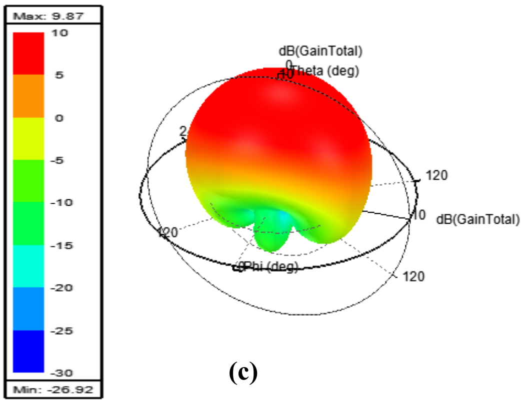


(b)



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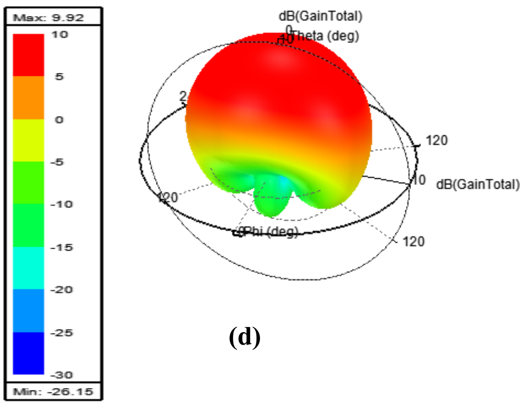

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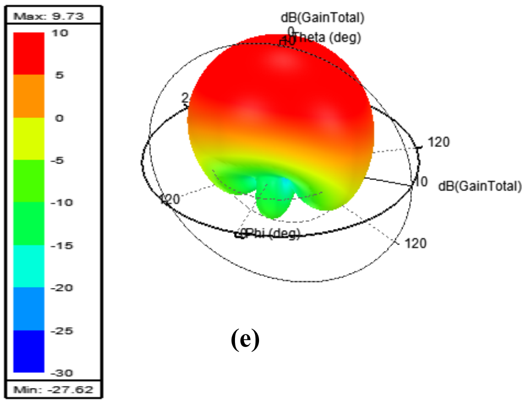

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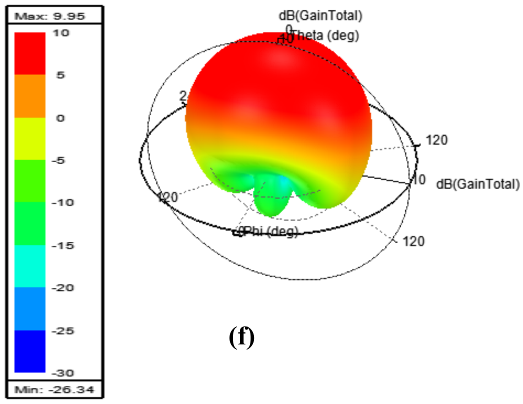
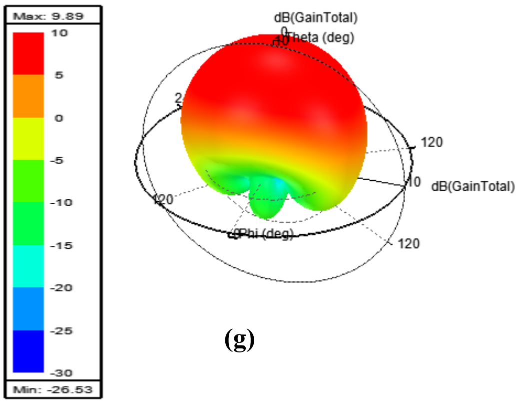
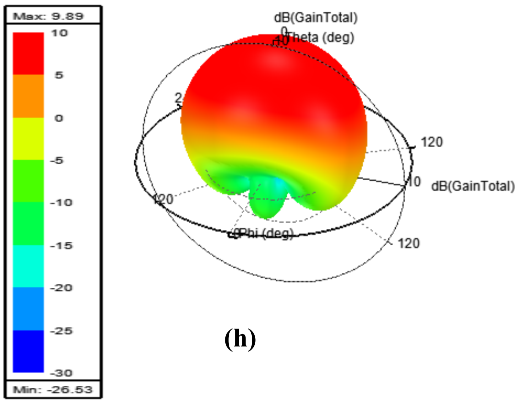


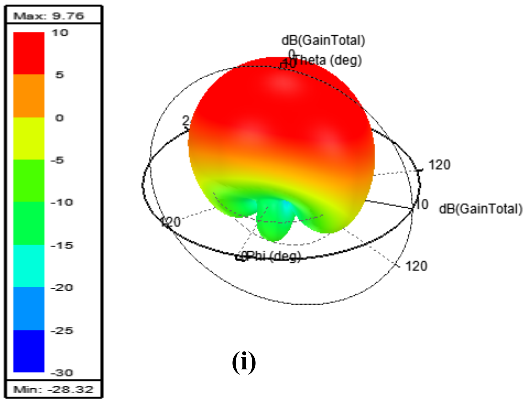
(f)



(g)



(h)



(i)

Figure 4. 3D radiation patterns for 1x2 patch antenna array (a) without LC and with LC E7 (b) 3.17 (c) 2.72, GT3-24002 (d) 2.5 (e) 3.3, BL037 (f) 2.35 (g) 2.61, BL006 (h) 2.62 (i) 3.11

Finally the comparative analysis for tuning range of inset fed patch antenna array with various LC materials is shown in Table 2.

Table 2. Comparison of patch antenna array for various LC materials

LC/Dielectric Constant		Freq (GHz)	S_{11} (dB)	Gain (dB)	Tuning Range
GT3-24002	$\varepsilon_{\perp}$=2.5	2.443	-13.08	9.92	4.09%
	$\varepsilon_{\parallel}$ =3.3	2.343	-15.49	9.73	
BL037	$\varepsilon_{\perp}$=2.35	2.468	-12.60	9.95	1.70%
	$\varepsilon_{\parallel}$ =2.61	2.426	-13.43	9.89	
BL006	$\varepsilon_{\perp}$=2.62	2.425	-13.47	9.89	2.56%
	$\varepsilon_{\parallel}$ =3.11	2.363	-15.03	9.76	
E7	$\varepsilon_{\perp}$=2.72	2.411	-13.78	9.87	2.28%
	$\varepsilon_{\parallel}$ =3.17	2.356	-15.12	9.75	

5. Conclusion

In this paper, an effort has been made to deal with the comparative investigation of the patch antenna substrate with different LC materials. Fundamentals of LC material, its characteristics with bias voltage and its application for reconfigurable micro strip patch antenna is shown. Antenna design is simulated using HFSS software. Tuning range achieved with BL037, BL006, E7 and GT3-24002 is 1.70%, 2.56%, 2.28% and 4.09% respectively with reduced return loss as compared to the antenna without LC material. It has been concluded that the proper selection of LC material is the key features in achieving desired reconfigurability. It would also be possible to make antenna reconfigurable using other tunable material like Graphene which is one of the most promisable material for high frequency applications.

6. References

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