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STUDY OF DIELECTRIC PARAMETERS OF LIQUID CRYSTAL MIXTURES USEFUL AS A DIELECTRIC SUBSTRATE IN DESIGN OF TUNABLE PATCH ANTENNA

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Abstract

The principal dielectric permittivity (ε') and dielectric loss (ε'') components were measured as a function of temperature and the D. C. bias voltages for a nematic liquid crystal mixtures (E-47). The relaxation frequency (f_r), dielectric strength $(\delta\varepsilon)$, and distribution parameters (α) have been calculated. The result of substrate to influence for propose the use of liquid crystal mixtures as a dielectric substrate for a tunable patch antenna whose frequency can be tuned by changing the temperature and biasing voltage across the substrate due to dielectric parameters has been changed also, reported in this paper.

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1. Introduction

Today liquid crystals (LCs) have become important because of their applications in modern technology. The anisotropic properties and characteristics of the mesophases help to understand the applicability of the mesogens in different devices. These are studied in terms of many physical properties such as conductivity, dielectric anisotropy, dielectric strength and distribution parameter etc. [1]. Recently, it has been created much interest in developing patch antenna for tunable of microwave frequency using dielectric material. Thus, the much attention has been moved towards the liquid crystal (LC) material having dielectric properties and frequencies can be varied along with the phase of reflection. A better option is to use electronic beam scanning since this tends itself to faster beam steering and because no moving parts are required. From the previous 20 years, to prepare tunable microwave components, considerable interest in exploiting anisotropy property of nematic liquid crystal (NLC) has been reported [2, 3].

Recently, the attempted work on phase angle reflect array antenna using LC has been reported to control the reflected signal using D. C. voltage, still difficulties were observed in the devices.

In the present work, tunable patch antennas with LC substrate are proposed and the paper is organized as follows: The section 2 describes the dielectric theory of LCs with field. In section 3, the patch antenna description with LC dielectric substrate are described. In section 4, study of dielectric parameter of substrate are discussed. Section 5 gives the results and discussion of the circular patch antenna and dielectric parameter of substrate. Section 6 gives the conclusion of work and important applications.

2. Dielectric Theory of Liquid Crystals

The NLC is a non-linear dielectric material with two dielectric permittivity values ε_1 and $\varepsilon_\perp$, which are the two extreme states of the LC orientation i.e., parallel and perpendicular to the excited field, respectively. The dielectric strength is related to the average induced polarization as given.

$$\varepsilon_0 \Delta\, \varepsilon(T) \simeq \lim_{\varepsilon \to 0} \frac{(p)}{\varepsilon}.$$

Where E is the magnitude of a static applied electric field. Here it has been assumed that the field acts in the X-direction, which originates in the dielectric anisotropy of molecules. The anisotropy is defined as the dependence of the dielectric constant on the orientation of the applied electric field. To obtain desired electrical and mechanical properties in a substrate, suitable filler materials are generally added during the process of substrate manufacturing. These fillers have a tendency to assume preferred orientations. This may lead to anisotropic effects in some of the substrates used in practice. Mathematically the effective dielectric anisotropy is defined as:

$$\delta\varepsilon \approx \varepsilon_1 - \varepsilon_\perp \quad (1)$$

$\delta\varepsilon$ = Dielectric anisotropy of substrate

ε_1 = LC permittivity with D. C. voltage.

$\varepsilon_\perp$ = LC permittivity without D. C. voltage.

It has been shown by different researchers that dielectric anisotropy plays an important role in adjusting the resonant frequency of an antenna element. This describes the tendency of electric field to align the molecules with their axis of the largest dielectric susceptibility in the direction of field [4-6]. The applied voltage between the patch element and the ground plane control to the permittivity and electrical size of the patches. Consequently, the alignment layers exerted the torque on the molecular dipoles, which can also be controlled by the applied electric field.

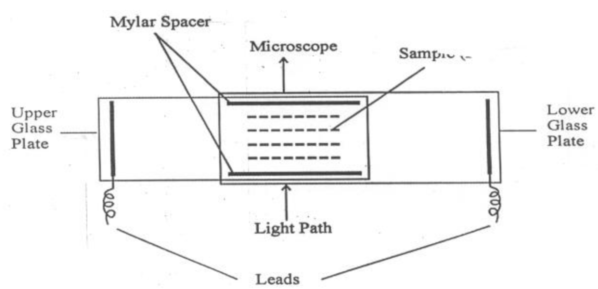

Figure (1). Shows electrical connection profile of the cell.

3. Antenna Description for Design

The low dielectric constant substrates are preferred for higher radiation efficiency and the impedance bandwidth can be increased using thicker substrate. The circular metallization radius 'a' is determined by the resonance condition, that is $-j_n(k \cdot a\sqrt{\varepsilon_r})$.

For the lowest order mode $n = 1$ and the first root of J_1 occurs at 1.841. The resonance frequency $\{f_r\}$ of a circular patch antenna can be measured by [7-9].

$$f_r = \left(\frac{1.941c}{2\pi a\sqrt{\varepsilon}}\right). \quad (2)$$

Where c {velocity of light} $= 3 \times 10^8$ m/s, a $\to$ is the patch radius and $\varepsilon \to$ is the dielectric of substrate. The tunability of the resonance frequency was achieved by preferring a suitable LC as the dielectric substrate material. The varying temperature and D. C. bias voltage across the dielectric substrate, the change in dielectric constant (ε) was observed with applied bias voltage [5]. As a result, dielectric change leads to alteration in resonance frequency of tunable patch antenna. Figure (1) shows an electrical connection profile, to calculate the relative permittivity for a patch antenna with a LC substrate with certain bias voltages [10]. In the proposed tunable patch antenna with LC substrate, bias voltage is applied to tune the resonance frequency whereas in the traditional patch antennas resonance frequency is fixed.

4. Study Model of Dielectric Parameter of Substrate

The prepared dielectric cell is an assembly of a parallel plate capacitor connected with relatively short leads. When condenser was filled with the air as a medium (Cair), it has a contribution from the capacitance of the active area of the plates. The non-homogeneities of the field lines at the edge of the active area are shown in figure (1) and contribution of the leads to arise the stray capacitance (Cs). The spacer does not contribute to the capacitance because they are placed outside the active area. In this case, Cair can be written as:

$$C_{air} = C_{eff} + C_s \quad (3)$$

Where C_{eff} is the live capacitance of the empty cell.

To determine the C_{eff}, standard liquids (pure benzene) with known dielectric permittivity has been used. When filling the cell with a liquid (pure benzene), which has known dielectric permittivity $(\varepsilon'_B)C_B$ the capacitance filled with benzene is:

$$C_B = \varepsilon'_B C_{eff} + C_s \tag{4}$$

from Equation (3) and Equation (4) C_{eff} can be calculated.

$$C_{eff} = \frac{(C_B - C_{air})}{(\varepsilon'_B - 1)}. \tag{5}$$

We have calculated estimated C_{eff} from the geometry of the (cell) parallel capacitor. The experimentally measured applied voltage dependent values of the capacitance of the NLC is directly related to permittivity of the LC cell as given in equation (6) and (7).

$$C = \frac{\varepsilon - \varepsilon A}{d}. \tag{6}$$

The permittivity value of the LC filled parallel plate capacitor as a function of the bias voltage (V_{bias}) is approximately Gaussian. Thus, we can write:

$$\varepsilon(V_{bias}) = \varepsilon_{dc} e^{-\left(\frac{V_{bias}^2}{2\sigma^2}\right)}. \tag{7}$$

Where, ε is the dielectric constant of substrate at zero bias voltage and σ^2 is the variance.

5. Result and Discussion

This section has been devoted to the results measurements of nematic mixtures E-47 at different temperature and frequencies with varying bias in planar alignment. The measured range of frequency was 50 Hz to 1 MHz and theoretically range extended up to 10 GHz as shown in figure 2. Dielectric strength of NLC has been studied as a function of bias voltage as shown in figure 3.

It was observed that below 1 kHz, change in dielectric values due to the ionic conductance and electrode polarization effect, however, above 100 kHz, combined effect of lead inductances and electrode surface resistance affected to the dielectric values. Further, using these dielectric parameters the resonance frequency values for tunable patch antenna with LC substrate are calculated, as listed in table 2.

6. Conclusion

We have proposed a tunable patch antenna using LC substrate having technologically wide importance. The biasing voltage across the dielectric substrates adjust to the operating frequency of tunable patch antenna with LC substrate. Further, the resonance frequency of the tunable antenna showed the exponential behavior with the applied bias voltage. The permittivity values of NLC substrate has been measured experimentally and corresponding resonance frequency of patch antenna has been calculated, theoretically. The proposed technique has the significance in the area of wireless communication, antenna based modulator and can be used to mitigate fading using frequency diversity [11, 12].

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E-47 [BDH]

Table 1. Preliminary data of NLC mixture at 20oC.

Materials	Birefringence and refractive index	Dielectric permittivity
E-47	$\Delta n = 0.2081$ $n_e = 1.7314$ $n_0 = 1.5233$	$\varepsilon_{II} = 18.5$ $\varepsilon_{\perp} = 5.2$

Table 2. Theoretical Calculated Resonance frequency values for tunable circular patch antenna for different bias voltages at different temperatures.

Serial No.	Dielectric measurement		Theoretical calculated resonance frequency {GHz}
	Bias Voltage {*V*}	Dielectric Constant	
At 30°C			
1.	0	3.33	4.819
2.	3	3.70	4.570
3.	5	3.85	4.481
4.	7	3.90	4.452
5.	10	4.17	4.306
At 34°C			
1.	0	3.57	4.654
2.	3	3.57	4.654
3.	5	3.93	4.435
4.	7	4.10	4.343
5.	10	4.20	4.291
At 37°C			
1.	0	3.60	4.634
2.	3	3.92	4.442
3.	5	3.95	4.424
4.	7	4.15	4.317
5.	10	4.30	4.240

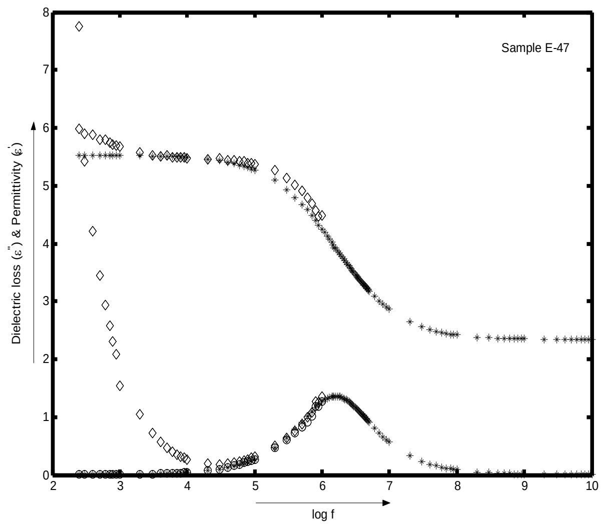

Figure 2. Frequency dependence of measured permittivity $(\varepsilon') - \lozenge$ and loss $(\varepsilon'') - \lozenge$ for E-47 at 30°C. Theoretically calculated values of $\varepsilon' - *$ and $\varepsilon'' - *$ are also shown.

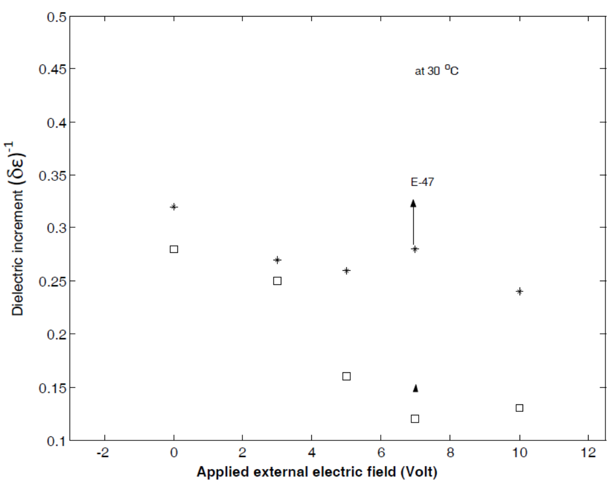

Figure 3. Dielectric increment $(\delta\varepsilon) - 1$ as a function of applied external electric field.