External Command Study of the Phase Shifter for Applications to Array Antenna with Nematic Liquid Crystal

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Abstract
This article is devoted to characterization by finite difference method in simulation software HFSS of Coplanar microwave phase shifter based on liquid crystal for array antenna printed electronic scanning. In this paper we propose a new external Phase Shifter command. The structure consists of three parts of liquid crystal placed between the ground plane and transmission line. The simulation results concerning the losses in reflection of phase shifter and the influence of the static magnetic bias field of liquid crystal on these parameters are shown in detail.
Keywords: COPLANAR LC PHASE-SHIFTER, LIQUID CRYSTAL, ARRAY ANTENNA, EXTERNAL COMMAND, FINITE DIFFERENCE METHOD

Introduction

Beam-steering antennas are the ideal solution for a variety of system applications including traffic control,[1] regulation and collision avoidance radars installed on most ocean going ships to provide better detection of ships in rough sea and heavy rain condition. Beam-steering antennas also used in smart base station antennas for WLAN and cellular communication [1][2]. Beam-steering is most commonly achieved through phased arrays, where phase shifters are used to control the relative main-beam of the antenna array. Many antenna system applications require that the direction of the beam's main lobe was changed with time, or scanned.

In the last decade, liquid crystals (LC) have been investigated as active dielectric for tunable microwave devices [3]. This represents a new application of these materials largely used in visualization displays. Liquid crystals were used to realize tunable phase shifters, planar antennas and filters [3][4]. LC present good potentialities among them, low driving electric field(typical 0.2V/μm) and relatively low.

Operation of these phase shifters is based on controlling the orientation of LCs anisotropy of dielectric permittivity with an applied electric field, which allows for external control of the phase of microwave signal. It is well known that when the relative phases of the feeding RF signals to the array antenna are changed, the direction of a main beam can be controlled [4]. Thus in our experiment, a LC loaded phase shifter which we had fabricated is used to control electrically the phase of the feeding RF signal.

This is usually done by mechanically rotating a single antenna or an array with fixed phase to the element. However, mechanical scanning requires a positioning system that can be costly and scan too slowly. For this reason, electronic scanning antennas, which are known as phased array antennas, are used. It can

sweep the direction of the beam by varying electronically the phase of the radiating element, thereby pro producing a moving pattern with no moving parts. Phased array antennas are the fundamental function of a phase shifter circuit is to produce a replica of the signal applied at its input [1], but with a modified phase. The general structure of an antenna network with electronic scanning is shown schematically in Figure 1. The use of the liquid crystal allows integrating the phase shifter and the change in phase of the signal is obtained by the action of the static magnetic field applied to the liquid crystal.

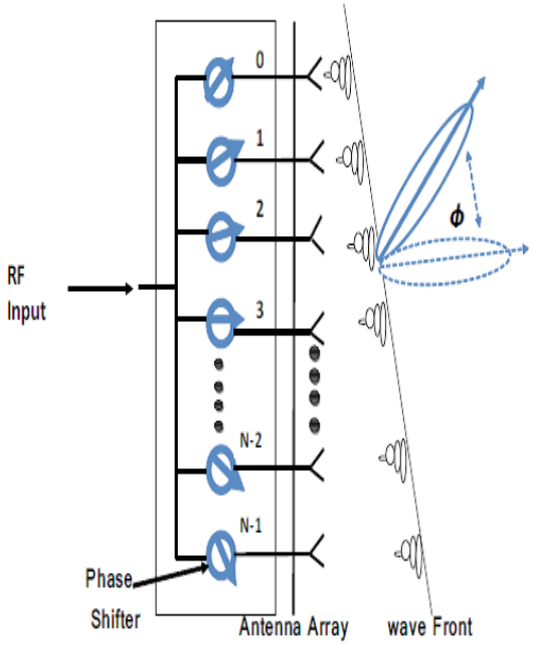

Figure 1. Phased array antenna

Nematic Liquid Crystal

Here we present LC. Under the applications we use the LC nematic phase in an ambient temperature [2][5]. The nematic LCs are characterized by their center of gravity, the molecules showing no order of position. However, molecules procure an orientation order in case of long distance [6]. Their long-distance and long axes are parallel to an average direction defined by the vector director n (Figure 2). In this phase the LCs are anisotropic materials with complex permittivity presented in the form of a tightening (equation 1)[1][5].

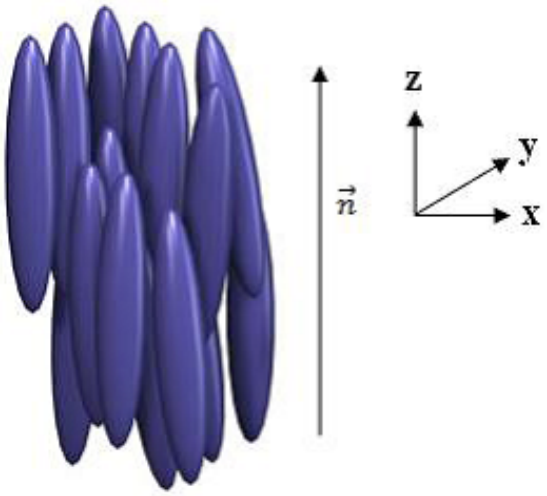

Figure 2. Representation of molecules CL in phase Nematic

$$\varepsilon^* = \begin{bmatrix} \varepsilon^*_{\square} & 0 & 0 \\ 0 & \varepsilon^*_{\perp} & 0 \\ 0 & 0 & \varepsilon^*_{\perp} \end{bmatrix} \quad (1)$$

It then defines the dielectric anisotropy by the equation2.

$$\Delta\varepsilon = \varepsilon'_{\square} - \varepsilon'_{\perp} \quad (2)$$

Δε: Dielectric anisotropy

$\varepsilon_{\square}^{'}$: LC permittivity with DC voltage

$\varepsilon_{\perp}^{'}$: LC permittivity without DC voltage

Measures in two different directions of the material are needed to determine each of its parameters [2],[6]. It is possible to orient the liquid crystal by applying an outside magnetic field of typical 0.4 Tesla. Therefore the molecules align their long axis in its direction.

The permittivity analyzed by the microwave field E_{HF} measure amends following this trend.

Here we will choose two configurations in the measurement of permittivity $\varepsilon_{\square}^{'}$ and $\varepsilon_{\perp}^{'}$

Studied Materials

The LC is the simulated K15 (5cb) (pentylcyanobiphnyl) which exhibits only nematic phase between 22.5^0 and 35^0. This figure shows the dielectric characterization of K15 at room temperature [7].

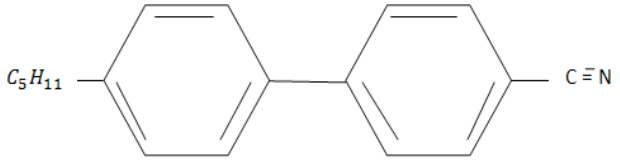

Figure 3. Chemical formula of liquid crystal K 15

The characteristics of liquid crystals are summarized in Table 1.

Table 1. Characteristics of liquid crystal

CL	sequence phase	$\varepsilon_{\perp}^{'}$	$\tan\delta_{\perp}$	$\varepsilon_{\square}^{'}$	$\tan\delta_{\square}$	$\square\varepsilon^{'}$
5CB	C 22.5^0	2.64	0.031	2.98	0.014	0.34
	CN 35^0CI					

Phase Shifter agile Frequency Liquid Crystal Substrate

Order of liquid crystal within a microwave substrate In the case of a line micro strip classic, the gap reached between input and output is fixed at a given frequency [2]. This phase shift depends on effective permittivity and the line length of the following:

$$Q = \frac{360.L.F.\sqrt{\varepsilon_{reff}}}{c} \quad (3)$$

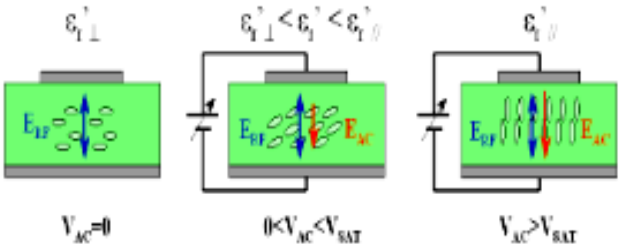

Figure 4. Influence of an electric field command on the orientation of liquid crystal

The electrodes by treating surface (planar orientation) [2]. The permittivity seen by the microwave signal is noted $\varepsilon_{reff(0)}$.

This permittivity is related mainly to the permittivity LC $\varepsilon_{r\perp}$.

As a result of the electric field command, the molecules of LC will gradually move perpendicular to the electrodes (n//E) to saturation permittivity. The east view $\varepsilon_{reff(E)}$.

The saturation permittivity $\varepsilon_{reff(E)}$ is related mainly to the liquid crystal permittivity $\varepsilon_{r\square}$.

This variation of permittivity will induce a change in the wavelength guided; [2] therefore a change in phase is given by:

$$\Delta Q = \frac{-360.L.F.(\sqrt{\varepsilon_{reff(E)}} - \varepsilon_{reff(0)}}{c} \quad (4)$$

Phase Shifter Design

In a first step, the HFSS (High frequency structure simulator), designed phase shifter.

The structure of the phase shift is shown in figure 5. The two illustrations (figure 6, and 7) show the two parts of the circuit component. The figure 6 a coplanar line is a structure in which all the conductors supporting wave propagation are located on the same plane.

The figure 7 consists of a brass plate in which a cavity, which serves to confine the LC, is grave. This cavity is positioned at the active portion of the circuit. The assembly of these two parts provides the final structure for coplanar phase shifter illustrated in Figure5.

Results and discussions

The simulation results are created by the simulator HFSS, for the applicability of the 3 crystal liquid parts proposed.

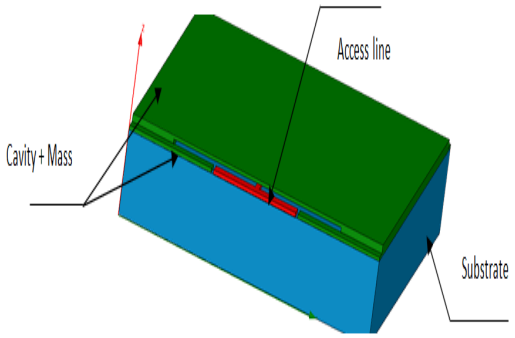

Figure 5. Structure of coplanar phase shifter

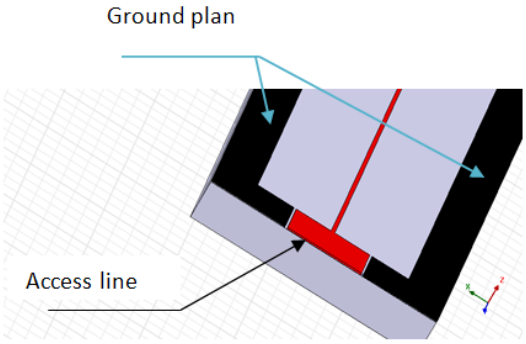

Figure 6. (CPW)

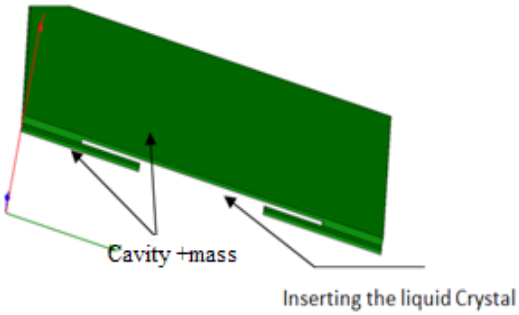

Figure 7. Cavity +mass

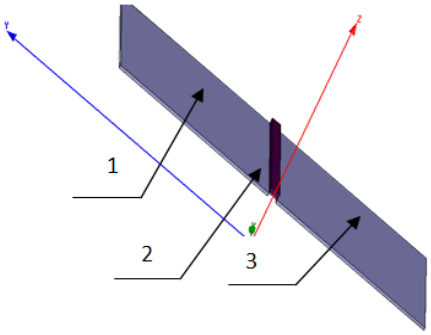

Figure 8. The 3 LC parts

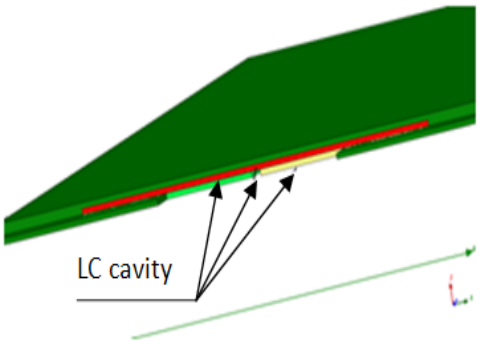

Figure 9. LC cavity position

The simulation is performed in the frequency range (10 − 50GHz) to obtain the phase-shifter characteristics. The substrate is realized by DUROID 4003. The dimensions of the phase shifters active part are the following: (X size 3.06 mm, Y size 15 mm, and Z size 0.05 mm). The liquid crystal is introduced between the ground plane and the transmission lines with dimensions are the following: parte 1 and 3 (X size 1 mm, Y size 14 mm, and Z size 0.025 mm) and part 2 (X size 0.05 mm, Y size 14 mm, and Z size 0.025 mm) The amplitude of the reflation coefficients versus frequency of the phase shifter is given in Figures 10. Without driving, a good matching of the device is observed (S11 < -30 dB). The phase of (S21) for different excitations is shown in figures: 11, 12 and 13.

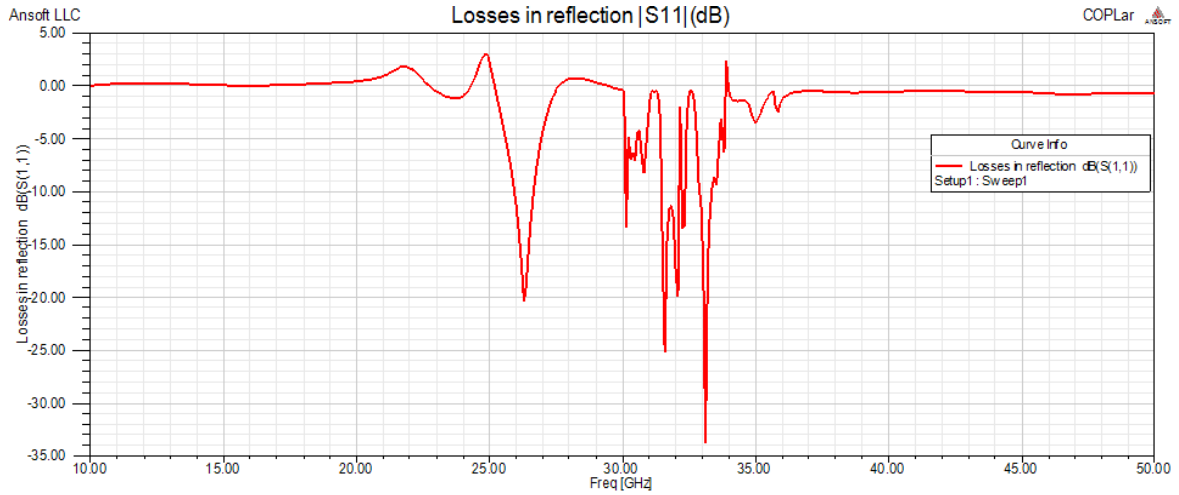

Figure 10. The reflection coefficients S11 (dB) of the phase shifter

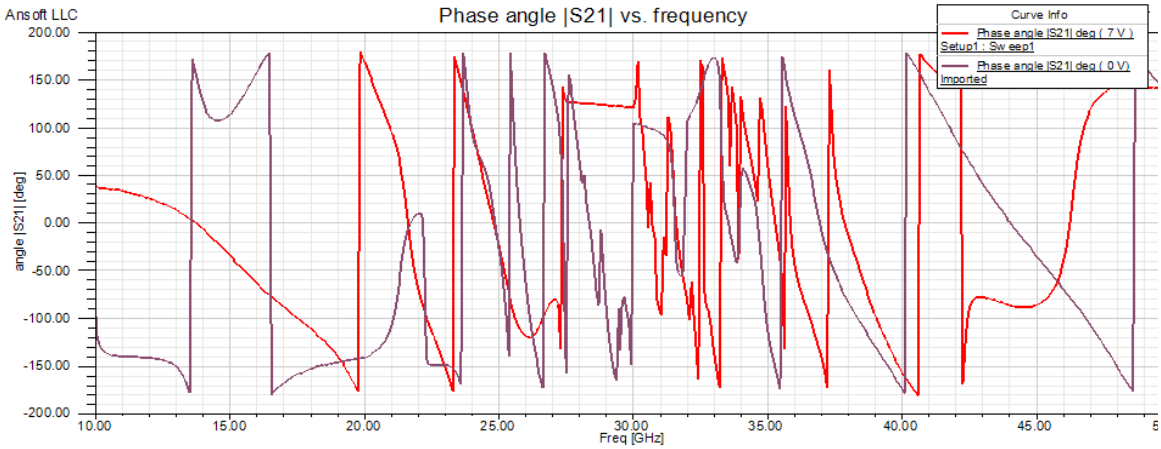

Figure 11. Phase angle |S11| (degree) of phase shifter, with and without control voltage

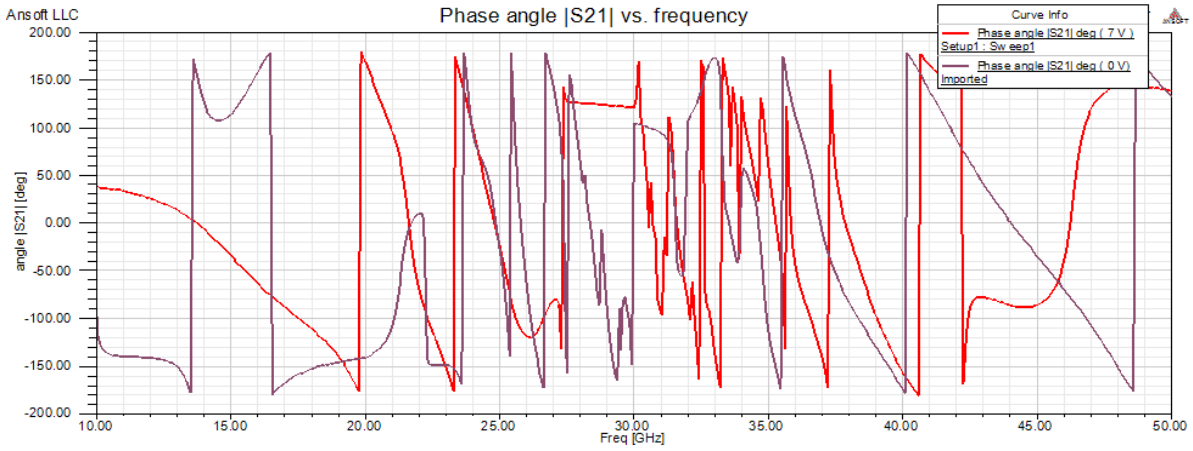

Figure 12. Change phase S (21) (degree) of phase shifter depending on the frequency, with and without Control voltage

The (S21) phase variations as a function of frequency are given in Figures 11. The (S21) phase variation is calculated from the difference between the (S21) phase measured with and without driving voltage (0 V and 7 V). The (S21) phase evolves linearity with frequency. At 30 GHz, the value of the phase angle |S11| variation is approximately 20◦

Figure 13, shows the phase shift obtained from the excitations positions we give the (S21) phase variation evolution versus excitation position. The structure is composed of three parts of liquid crystal placed between the ground plane and the transmission line (part 1, 2 and 3).

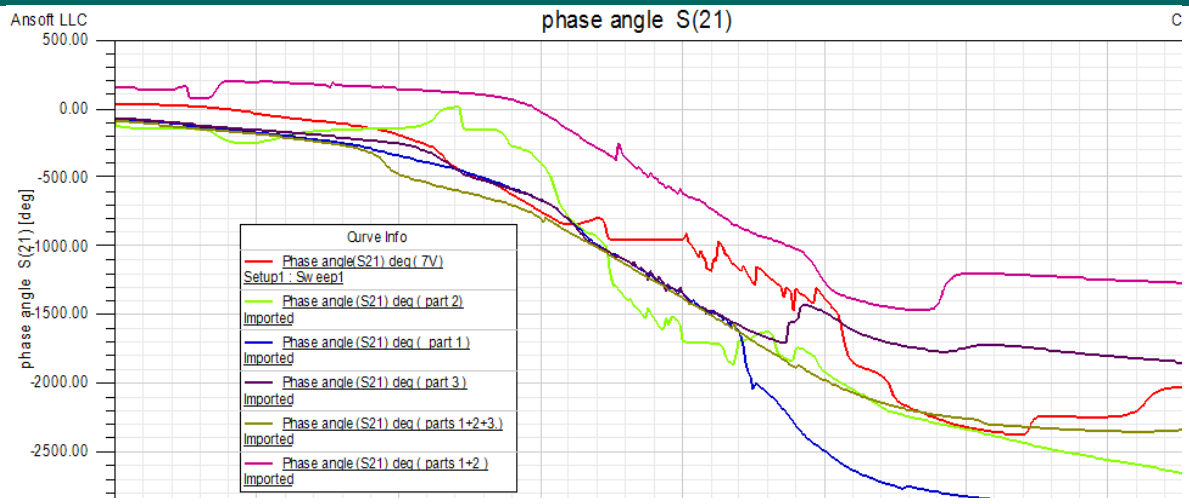

Figure 13. Change phase (S21) (degree) of phase shifter depending on the frequency, taking part 1, 2, and 3

This figure show a comparison between the phases results obtained of (S21) for different excitations parts ((degree) of phase shifter).

The approximate values of the phase variation obtained at 35 GHz taking parts 1, 2, and 3, shown in table 2

Table 2. Phase shift obtained at 35 GHz taking part1, 2, and 3

comparison	|part1|	|part3|	|part1 + 2 + 3|
|part1|	24	100^0	50^0
|part2|	60^0	40^0	10^0
|part1 + 2 |	120^0	20^0	70^0

Conclusion

In this paper we describe a study on phase shifter based on liquid crystal. The proposed method was based on two influences (voltage and position) on the phase of the transmission coefficient (S21) with HFSS software. Obtained results reveal that we can control the phase shift with the excitation voltage and in addition the position of excitation. In the present work, we proved that is possible to control phase shifter with a new standard that is the position of excitation.

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Wellbore Temperature Distribution in Hydraulic-Fracturing Horizontal Wells for Gas

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Abstract
Use of distributed temperature sensors (DTS) to monitor the productive zones of horizontal wellbores by real-time temperature profile measurement is becoming an industry standard. Well completion method, skin factor and non-Darcy flow phenomenon are among operating parameters potentially related to DTS data. In order to study on the above-mentioned relationship, this paper establishes temperature models which consider skin factor and non-Darcy flow, in turn whose foundation are mass-, momentum-, and energy-balance equations. The models presented here account for heat convection, fluid expansion, heat conduction and viscous dissipative heating. Once configured, these models were applied to predict wellbore temperature distribution and analyze factors influencing the wellbore temperature profile. Arriving temperature and wellbore temperature curves are plotted by