

## CIRCULARLY POLARIZED TUNABLE PATCH ANTENNA USING LIQUID CRYSTAL

Kazuhiro Kitatani, Tomoshi Tsuji and Yasuyuki Okamura  
 Graduate School of Engineering Science, Osaka University  
 1-3 Machikaneyama-cho, Toyonaka, Osaka 560-8531, Japan  
 E-mail : kitatani@ee.es.osaka-u.ac.jp

## 1. Introduction

Microstrip antennas [1] have a planer structure composed of a compact and lightweight substrate. A service of radio communications systems will become increasingly prominent in microwave and millimeterwave band regions. Functional microstrip antennas which operate at various frequencies and polarizations of interest and scan beams are desired. Microwave and millimeterwave devices using liquid crystals are developed for controllability of the dielectric anisotropy by applying an electric field. There are reported various types of circuit devices such as variable phase shifters [2], [3] and variable delay lines [4] in which the liquid crystals were used as a dielectric layer of a microstrip line. In addition, a lens [5], a beam former [6] and a wavelength selector [7] using a stacked liquid crystal cell were studied. Moreover, the microstrip patch antenna using the liquid crystal as the dielectric substance layer was able to adjust resonant frequencies [8], [9]. We are advancing research on the linearly polarized planar antenna using the liquid crystal, and reported the phased array antenna [10] and the variable frequency patch antenna [8] until now.

This paper describes a circularly polarized tunable microstrip patch antenna using a liquid crystal. We confirmed the fundamental operation of the proposed antenna, where operating frequencies ranged from 20.45GHz to 21.84GHz. The characteristics of the impedance and the radiation patterns were experimentally investigated.

## 2. Operation and structure of an antenna

Figure 1 shows a schematic configuration of the proposed antenna. Opposite two corners of a squared conducting patch were partially cut for use of a single feeding technique to generate circular polarization. The element was fed with a microstrip line printed on the same board as the patch. The plane printed the patch was placed on the grounded substrate. A liquid crystal was inserted into the gap prepared between the patch and the ground plane. The design for the antennas was referred to [11].

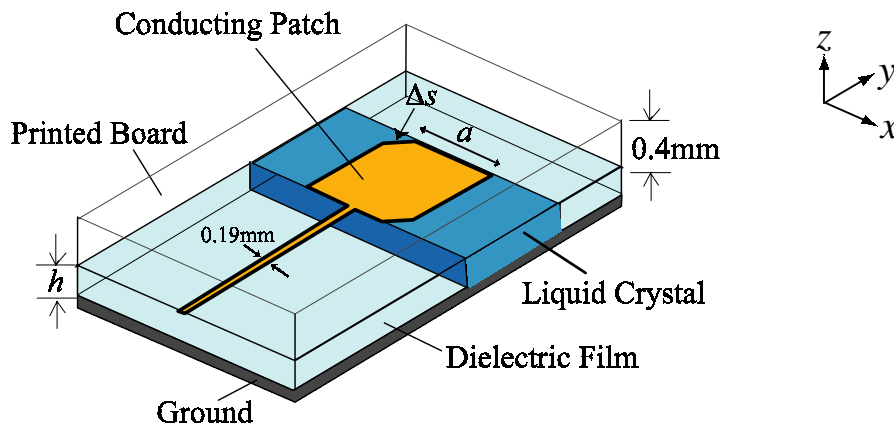


Fig.1. Structure of the proposed antenna.

The substrate dielectric film was a fluoroc resin including a glass whose relative permittivity was 2.6. The printed board had a relative permittivity of 2.2. The patch shape was square except for cut edges. The square size was  $4 \times 4$ mm. The area  $\Delta s$  of each cut edge was  $0.26 \text{ mm}^2$ . The microstrip line for the feed had a width of 0.19mm and a characteristic impedance of  $50\Omega$ . The input impedance of the conventional microstrip patch antenna fed by the edge is high, allowing the transformer between the antenna and the feed line. However, the input impedance of the tested antenna using a liquid crystal substrate was reduced to a lower one for a high loss tangent  $\tan\delta$  ( $\sim 0.01$ ) and a small thickness  $h$  of the liquid crystal. It became possible to connect the patch with the microstrip line of  $50\Omega$ . A liquid crystal was nematic liquid crystal RDP-85475 (made by Dainippon Ink and Chemicals Co. LTD.). The long axis of the liquid crystal molecule had a relative permittivity of 3.24 and  $\tan\delta$  was 0.01. On the other hand, the short axis of the liquid crystal molecule had a relative permittivity of 2.63 and  $\tan\delta$  was 0.03. The liquid crystal molecule was aligned in the direction of  $y$  by the rubbing method.

The operation of the proposed antenna is as follows. When the voltage is applied between the patch and the ground, the liquid crystal molecule aligns in the electric field direction. The long axis of the liquid crystal molecule turns in the direction of  $z$ . The microwave field senses the large permittivity of the long axis changing from the small one of the short axis. The operating frequency of the antenna can be controlled electrically. Thus, the continuous tuning of the operating frequency is achieved.

### 3. Experiment results

Frequency characteristics of the return loss for the tested antenna was measured by using a conventional network-analyzer (HP8510C). A measured frequency range was 18-24GHz. Figure 2 shows the measured result when applying voltage to the liquid crystal. The resonant frequency was 22GHz when applying no voltage to the liquid crystal. As an increase of the applied voltage the resonant frequency decreased. When applying 20V, the resonant frequency changed to 20.5GHz. The return loss at the resonant frequency has consistency with -10dB or less. The variation of the frequency response was fairly agreement in the computer simulation based on the FDTD method.

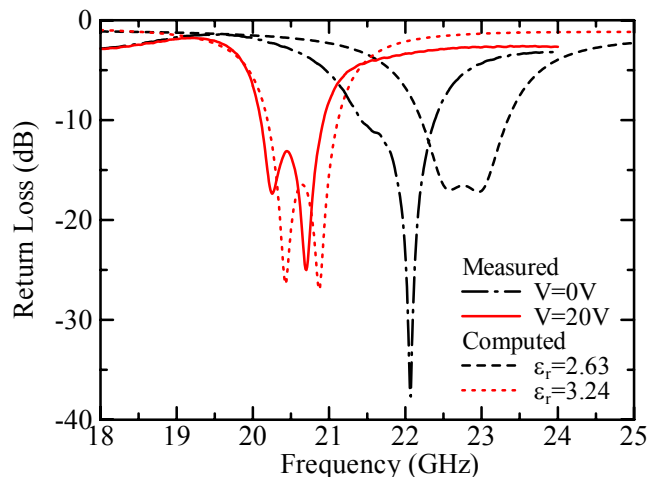


Fig.2. Frequency characteristics of return loss for the tested antenna with and without applying voltage.

The measured radiation pattern of an antenna is shown in Fig. 3 at the operating frequency of 21.15GHz. This is the pattern for the applied voltage of 2V. Although it was an unevenness pattern, the axial ratio in the direction of the front was as good as 0.6dB. The small axial ratio indicated the circularly polarized generation from the antenna. Improvement of the axial ratio is needed except the direction of the front.

Next, the frequency characteristics of the axial ratio in the direction of the front was measured. Figure 4 shows the measured results for three voltages : 0V, 2V and 20V. The frequency characteristics of the axial ratio had a narrow bandwidth when applying a constant voltage. The operating frequency of the antenna with the axial ratio less than 3dB changed 20.45GHz form to 21.84GHz. The return losses at the resonant frequency obtaining the minimum axial ratio were -11.47dB, -18.55dB, and -13.09dB for the applied voltages 0V, 2V, and 20V, respectively

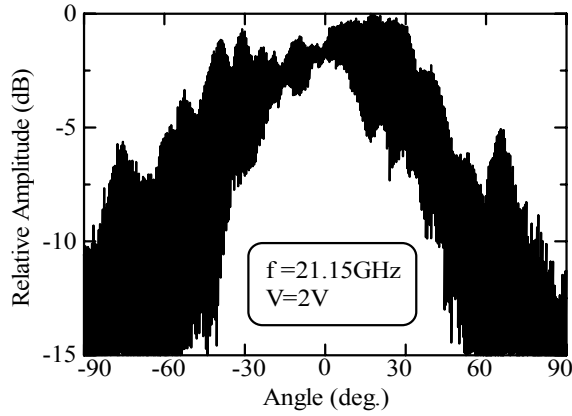


Fig.3. Radiation pattern of the proposed antenna.

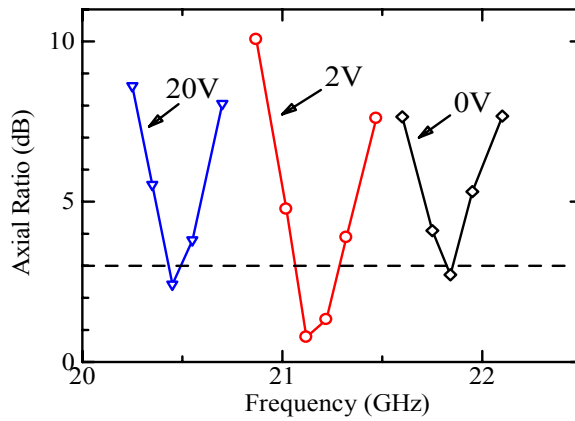


Fig.4. Frequency characteristics of the axial ratio.

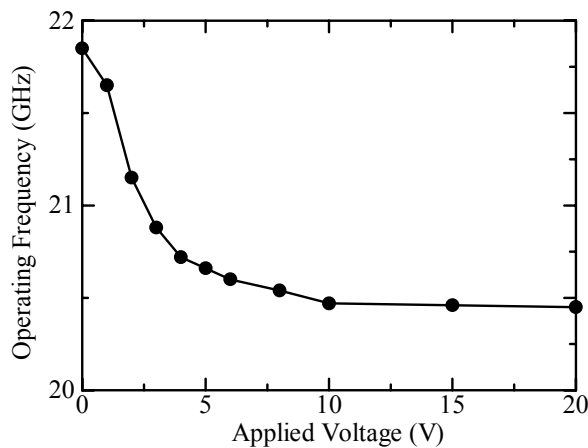


Fig.5. Operating frequency versus applied voltage.

Figure 5 shows the measured operating frequency at the minimum axial ratio against the applied voltage. The operating frequency is controllable by a relatively low voltage of 10V. Thus, the operating frequency of the antenna is controllable by the applying voltage to liquid crystal. The variable width of frequency was 1.39GHz (6.3%).

#### 4. Conclusion

Circularly polarized microstrip tunable patch antennas using a liquid crystal with a simple structure have been proposed. We have experimentally confirmed the operating frequency agility of 6 % in the K-band.

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