Thickness Dependence of Liquid Crystal Reflectarray on Reflection Phase

Xiaotong Li †1 Hiroyasu Sato †1 Yosei Shibata †2 Takahiro Ishinabe †2 Hideo Fujikake †2 Qiang Chen †1

†1 Department of Communications Engineering, Graduate School of Engineering, Tohoku University

†2 Department of Electronic Engineering, Graduate School of Engineering, Tohoku University

1. Introduction This report presents an experiment of a reconfigurable reflectarray (RA) with liquid crystal (LC), which is capable of phase changing by bias voltage. As the unit cell, 4-finger is designed, two 21×19 elements LC-RAs with bias voltage controlling of different thickness are manufactured and compared.

2. Reflectarray Design and Experiment Validation A RA unit of 4-finger is shown in Fig.1. LC was poured into the interface of a pair of quartz glasses coated with metal layer face to face. By changing the bias voltage, the dielectric constant and loss tangent of the liquid crystal also change, causing the phase of the reflected wave steered. In the LC RA model, by optimization method[1] provided by software HFSS, proper parameters were obtained, the sizes marked in Fig.1 were as follows: h_G=0.6mm, W=W_0=0.4mm, L_{x1}=2.2mm, L_{x2}=2.3mm, L_{x3}=2.4mm, L_{x4}= 2.5mm. Voltage changing procedure is imitated by defining material of LC from none bias state($\varepsilon_{r,\perp}$=2.6, tan$\delta_\perp$=0.031) to full bias state ($\varepsilon_{r,\parallel}$=3.2, tan$\delta_\parallel$=0.023), the maximum phase variation frequency near 37.5 GHz was achieved.

The experimental scene of the RA phase measurement was shown in the Fig.2: the LC RA is placed on the plastic foam(ε_r=1.0) with radio absorbing material at the bottom, A horn antenna working at Ka band is placed above the RA with F=1050mm which can guarantee the far field region for RA. With labview controlling wave function generator, different voltages are output through amplifier and connected to the electrodes of LC RA, in this way the LC RA is controlled by voltage. The reflected wave from LC RA were collected by PNA, thus the phase changing data of LC RA is measured. Two sets of 21×19 elements LC-RAs of 4-finger unit were fabricated with parameters shown previously. The thickness of LC layers were set h_{LC}=0.05 mm and h_{LC} =0.10 mm as a comparison. The results show that the model h_{LC}=0.10 mm can achieve larger maximum phase shift of Δϕ =223° rather than Δϕ =75° when h_{LC} =0.05 mm. So thick LC layer has larger phase changing scale, while thinner LC layer the LC RA also causes the phase of reflected wave with a smooth phase curve.

3. Conclusion In this report, the phase changing ability of LC-RA with changing the thickness of LC was investigated. Two LC-RAs with different thickness of LC layer were manufactured and measured to compare the phase steering condition. From the comparison of two models, it is concluded that the thicker LC layer causes the LC RA change phase with larger scale, and the thinner LC layer has smooth phase curve through bias voltage changing.

ACKNOWLEDGMENT

This research is supported by the Ministry of Internal Affairs and Communications in Japan (JPJ000254).

Reference

[1] Kim, Jaehoon, et al. "Liquid-Crystal-Embedded Aperture-Coupled Microstrip Antenna for 5G Applications," IEEE Antennas and Wireless Propagation Letters 19.11: 1958-1962. Nov, 2020

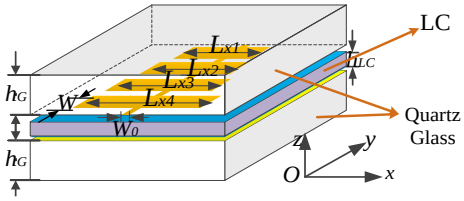

Fig. 1. Structure of unit-cell 4-finger LC-RA.

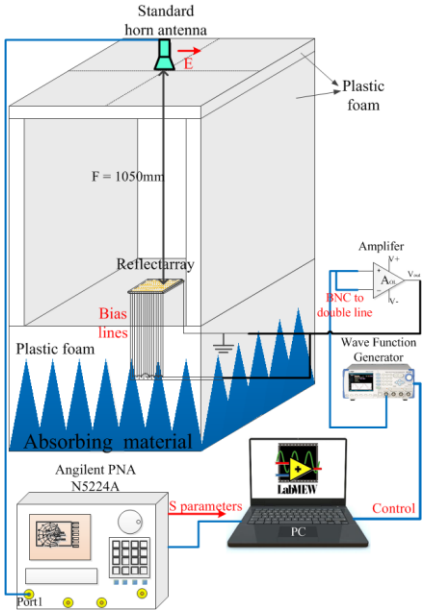

Fig. 2. Experiment system to measure the phase steering condition by bias voltage

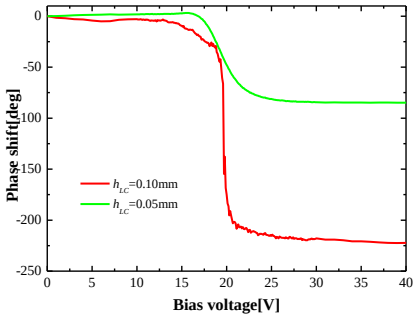

Fig. 3. Comparison of phase steering at frequency 37.5 GHz