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Electrically tunable liquid crystal coplanar waveguide stepped-impedance resonator

Key words: Tunable stepped-impedance resonator (SIR); Liquid crystal; Coplanar waveguide (CPW)

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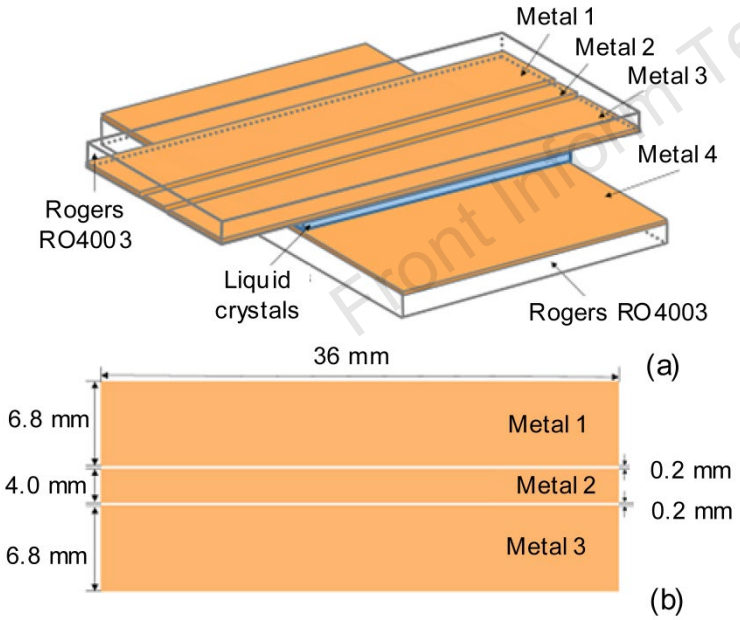
Motivation

- Resonator is one of the key elements for broadband, multi-frequency, frequency modulational radio frequency (RF) devices. It is still challenging to realize light weight, low cost, no moving part, and low power consumption continuous tunable resonators.
- Liquid crystal with significant electrical tunable permittivity has emerged as a promising technological advancement for tunable and reconfigurable microwave devices.
- A simple structure of tunable coplanar waveguide (CPW) stepped-impedance resonator (SIR) would further promote the functionalities of the electrically tunable devices.

Method

- The liquid crystal layer is sandwiched between two substrates with a thickness of 0.1 mm.
- The patterned copper patch is a CPW transmission line with a high impedance Z_2 of 50 Ω at both ends, and a low impedance Z_1 of 6.010 Ω for the middle part.



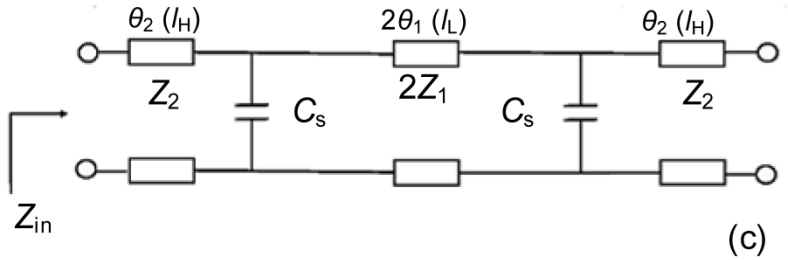


Fig. 1 Schematic of the proposed liquid-crystal-based CPW SIR (a), structure of the transmission line (b), and configuration of the SIR (c)

Method (Cont'd)

- At the voltage off state, the equivalent dielectric constant of liquid crystal is $(\varepsilon_{//}+2\varepsilon_{\perp})/3$ as a random distribution of the liquid crystal molecules.
- The equivalent dielectric constant of liquid crystal can be tuned as the liquid crystal molecules trend to be arranged in the direction of the applied field, resulting in the modulation of the resonant frequency of the proposed SIR.

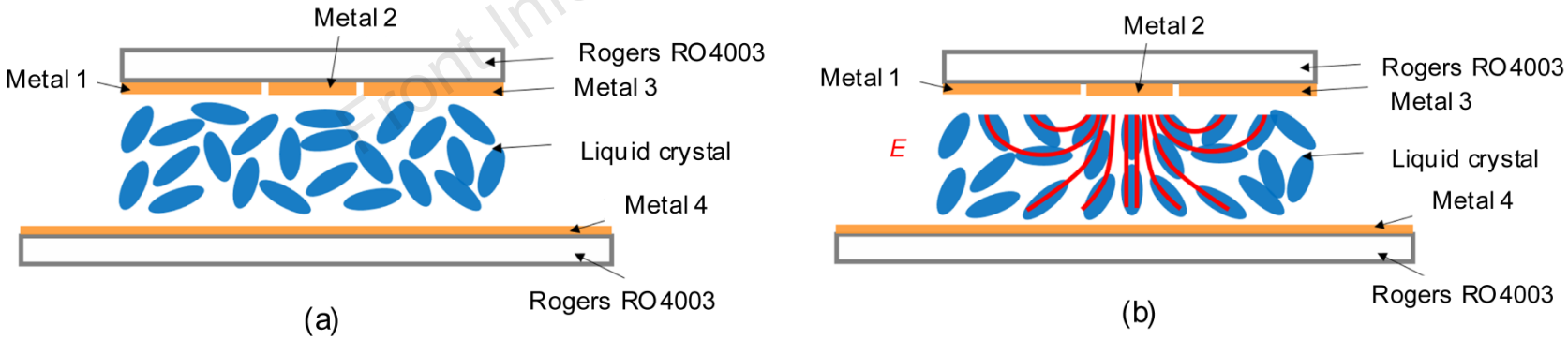


Fig. 2 Liquid crystal molecule distribution of SIR: (a) voltage off state; (b) voltage on state

Major results

Simulation results of SIR

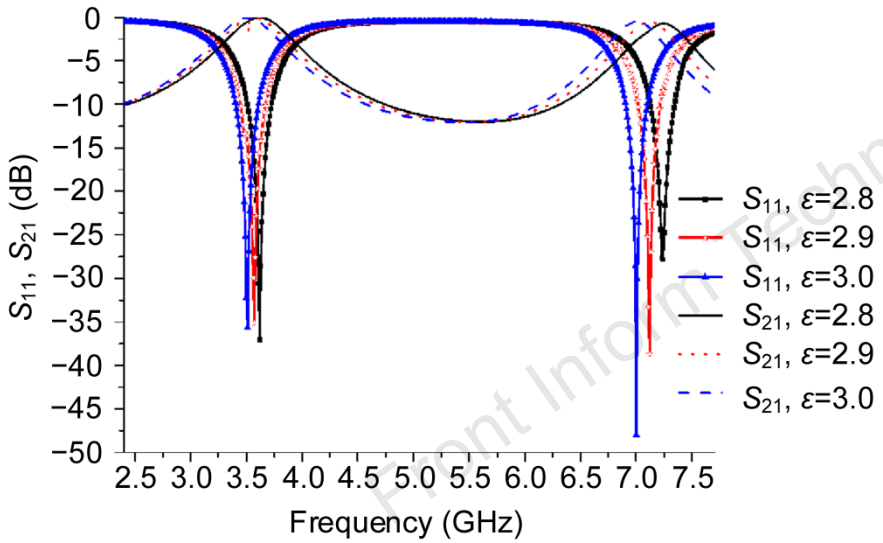


Fig. 3 Simulation results of S_{11} and S_{21} spectra of SIR when the liquid crystal dielectric constant varies from 2.8 to 3.0

- Two resonant frequencies are formed within the frequency range from 2.4 to 7.7 GHz
- Both the resonant frequencies shift to a lower band with the increase of the dielectric constant of liquid crystal

Major results (Cont'd)

Experimental results of SIR

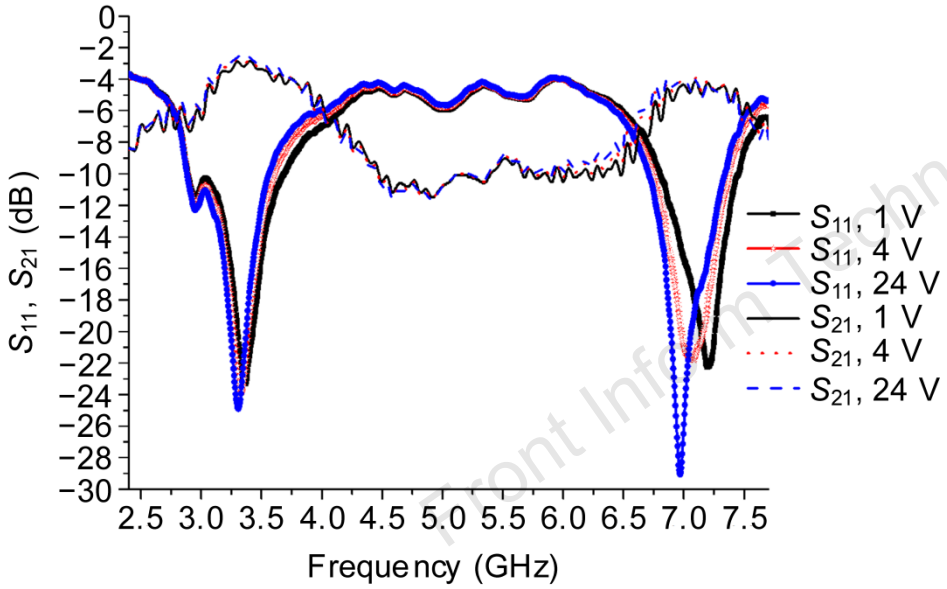


Fig. 4 Experimental results of S_{11} and S_{21} spectra of SIR when the applied voltage is 1, 4, or 24 V

- Well agree with the simulation results
- The low resonant frequency f_1 changes from 3.367 to 3.311 GHz
- The high resonant frequency f_2 shifts by 221 MHz from 7.198 to 6.977 GHz
- The insertion loss is −2.9 dB for f_1 and −4 dB for f_2
- The return loss is less than −21.5 dB

Major results (Cont'd)

Experimental results of SIR

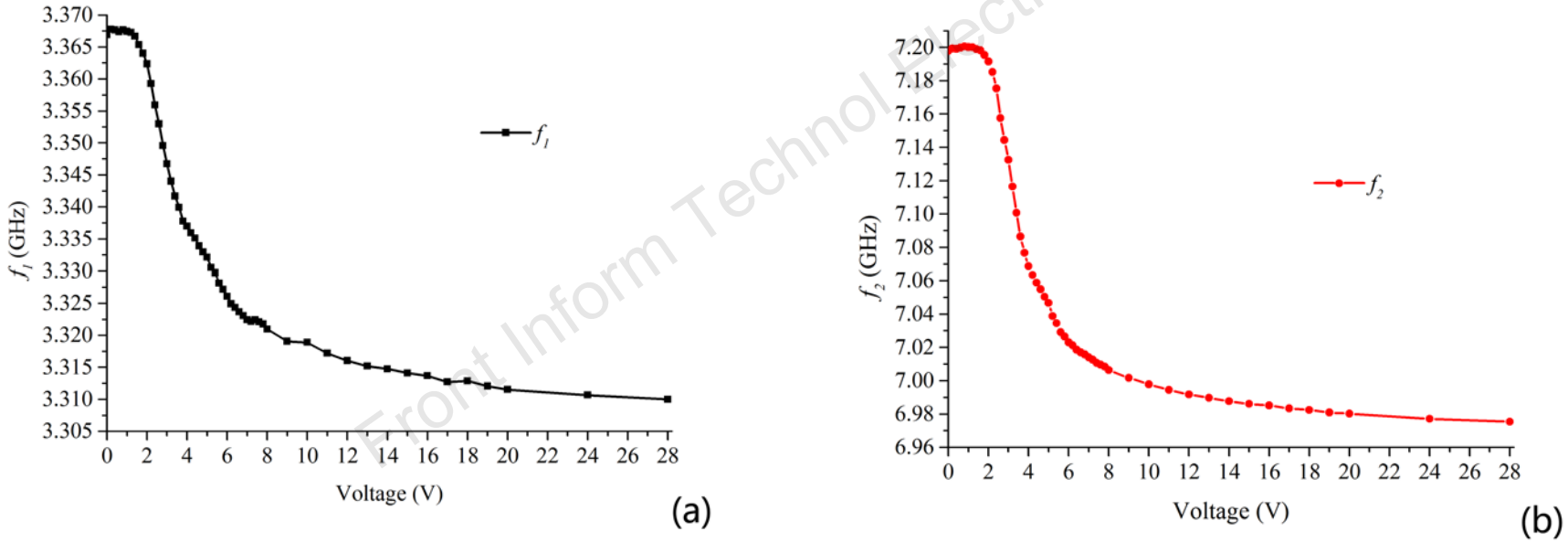


Fig. 5 Experimental results of the resonant frequency as a function of the applied voltage: (a) low resonant frequency f_1; (b) high resonant frequency f_2

Major results (Cont'd)

Experimental results of SIR

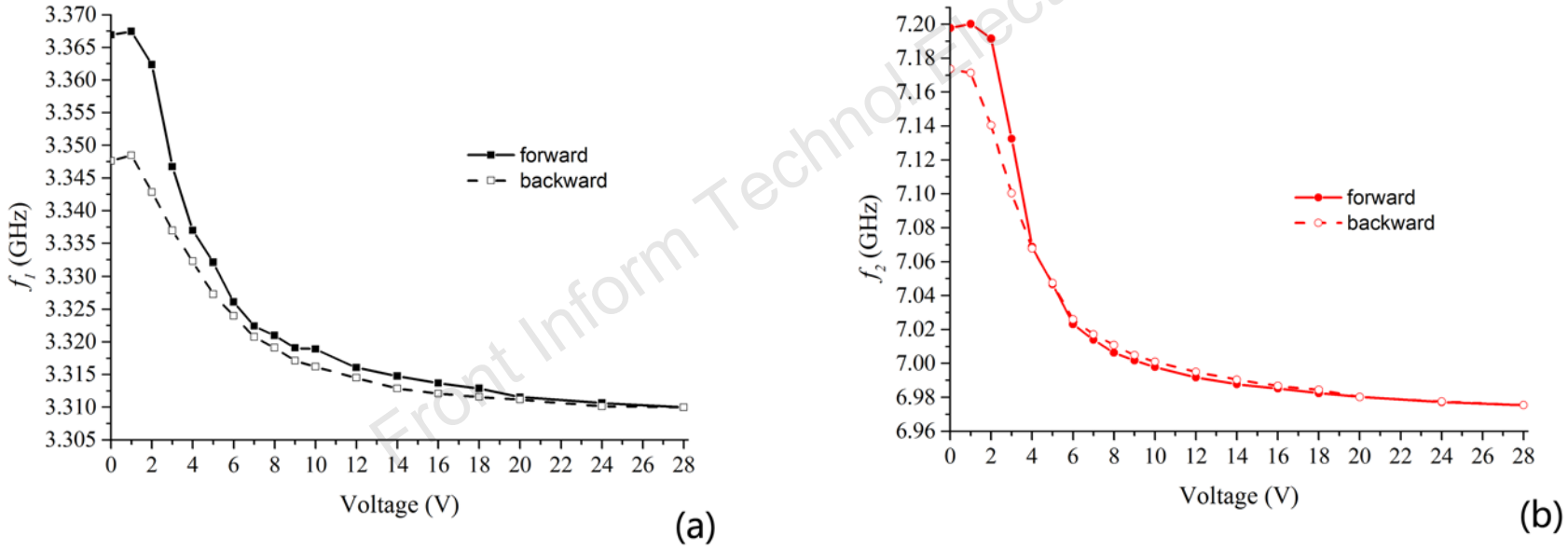


Fig. 6 Measured hysteresis loops of the resonant frequency under different electric fields: (a) low resonant frequency f_1; (b) high resonant frequency f_2

Conclusions

- An electrically tunable liquid crystal CPW SIR is proposed and experimentally realized.
- Continuous tunable frequency ranges of 52 and 210 MHz are obtained at the resonant frequencies of 3.367 and 7.198 GHz, respectively, at a particularly low driving voltage of 14 V.
- The tunable resonator possesses the characteristic of low insertion loss of −2.9 and −4 dB for the two resonant frequencies, and the return losses are less than −21.5 dB.
- The phenomenon of voltage-induced hysteresis is investigated.