Ku-band Liquid-crystal-based Frequency reconfigurable Comb SIW slot Leaky-wave antenna

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Abstract: In this paper, based on liquid crystal anisotropy characteristics, a kind of frequency reconfigurable comb substrate integrate waveguide slot leaky-wave antenna use liquid-crystal-based is proposed at Ku band. It adopt comb shape and defected ground structure to compose comb SIW's top and bottom. The slots are etched at top and bottom surface. The resonant point of propose antenna move from 15.85GHz to 14.37GHz, the tunable range is 1.5GHz by changing liquid crystal's permittivity. Return loss less than -30dB at resonant point and the maximum gain is 8.79dB. The bandwidth of proposed antenna is 1 GHz. All the results show the reconfigurable of proposed antenna is good.

Keywords: liquid crystal, comb substrate integrate waveguide, reconfigurable, leaky-wave antenna

I. INTRODUCTION

With the modern wireless communication system becoming complicated, the demand of antenna is enhanced. So, Antenna's design required by scarce band and interference source increased. Modern wireless system needs a adaptable antenna which can changed index by users' need. Therefore, the definition of reconfigurable antenna is proposed. The reconfigurable antenna are mainly including: pattern reconfigurable antenna, frequency reconfigurable antenna and polarizable reconfigurable antenna. Frequency reconfigurable antenna can remain others index invariant and changed antenna's working frequency band to match user need. It have good adaptability and the use of channels' transform. The design of reconfigurable antenna has the following methods: by controlling antenna's resonance units open or short to change antenna's working frequency by switch; by controlling antenna medium's permittivity or permeability to change electric field or magnetic field through the constitutive relation. It is commonly that use liquid crystal (LC) and ferrite, and so on.

The comb substrate integrate waveguide (CSIW) is a kind of variation of SIW. This shape prevent the electric field loss off and simplify the metal vias[1]. The same theory as the traditional waveguide slot antenna design, slot at CSIW surface, truncate the surface current lead surface emerge to the displacement current, excite the slots and emerge the electromagnetic field which is radiate outward. Literature [2] shown that SIW antenna have both advantages of waveguide slot antenna of high efficiency, low sidelobe level and microstrip of low profile, integration conveniently. Because of these advantages and the small loss of tunable medium, in recent years, many researchers focus on the design of SIW slot reconfigurable leaky-wave antenna using tunable medium control, such as literature[3] use ferrite into SIW structure ,but the bandwidth of literature propose is narrow(1.82% relative bandwidth). Besides, the literature [4] presented a kind of new left-right hand reconfigurable leaky wave antenna using LC in PCB, the tunable range is 0.5GHz (12.25-12.75GHz).

In this paper, a new frequency reconfigurable CSIW slot antenna is proposed. Comparing to the above literatures, this antenna have wider bandwidth about 1GHz and larger tunable range about 1.5GHz. Antenna adopt the CSIW structure which loaded LC in it, radiated by slots at top and bottom. The top slots and bottom slots are quadrature 90 degrees.

II. ANTENNA DESIGN

A、antenna structure description

The wide of CSIW designed 1~2 wavelength to make electromagnetic working at TE10 mode. The top side use CSIW structure, etch slots at top and bottom surface of CSIW .The bottom side adopt defected ground structure to keep circuit balance. The structure is the same as top side but slots have quadrature 90 degrees, and the center of slots are coincident[5]. This article using this slotting method designed 1×4 slots array, the distance of slot unit is half wavelength.

Antenna use microstrip feed. There is a impedance excessive line between the CSIW line and microstrip to achieve impedance match. Impedance excessive line's length is one wavelength. The CSIW's top and bottom surfaces are etched at a couple of rogers 5880 substrates ($\varepsilon = 2.2$，$\tan\delta=0.0009$) to prevent the LC leak. The thickness of substrates and LC layer are both 0.762mm. The purpose of using Rogers 5880 that have low loss and similarly permittivity with LC. When mircostirp fed, the impendence transform is slightly. Fig.1 portray the concrete structure about antenna.

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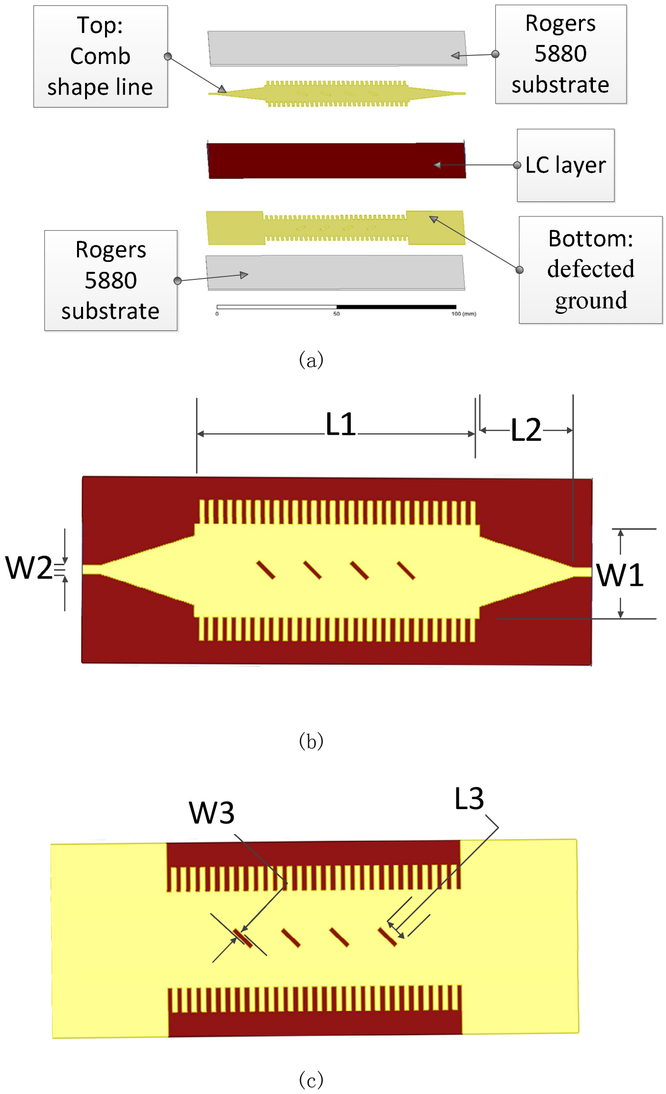


Fig.1 The structure of antenna
(a)General structure (b)top side structure (c)bottom side structure
Dimensionsare:L1=61mm,L2=20mm,L3=5mm,W1=20mm,W2=2mm,W3=0.9mm

B、*Antenna design theory*

As a kind of anisotropy media, LC's constitutive relation can shown by:

$$D = \varepsilon E \qquad (1)$$

Because LC's permittivity ε is a tensor, the electric current density D is no longer parallel with electric field. Therefore, when LC permittivity change, the internal electric field will changed. This changing bring about the resonant point move. However, LC is mixture, so different kinds of LC have different equivalent permittivity. This paper adopt the type BOE-F028B produced by BaYi Space company, which permittivity band can changed from $\epsilon_{\perp}$=2.6 to $\epsilon_{//}$=3.2 by bias voltage at Ku band.

The purpose of make slots quadrature 90 degrees at top and bottom side that to generate strong coupling at two sides slots. The transmission of electric field is stable and it avoid the unnecessary electric field chaos because of the slotting method and the balance of two surfaces.

The electric field about compare between bottom side within slots and without slots is shown in Fig2. The insertion loss of antenna slots at bottom with side or without slots at bottom side is shown in Fig3.

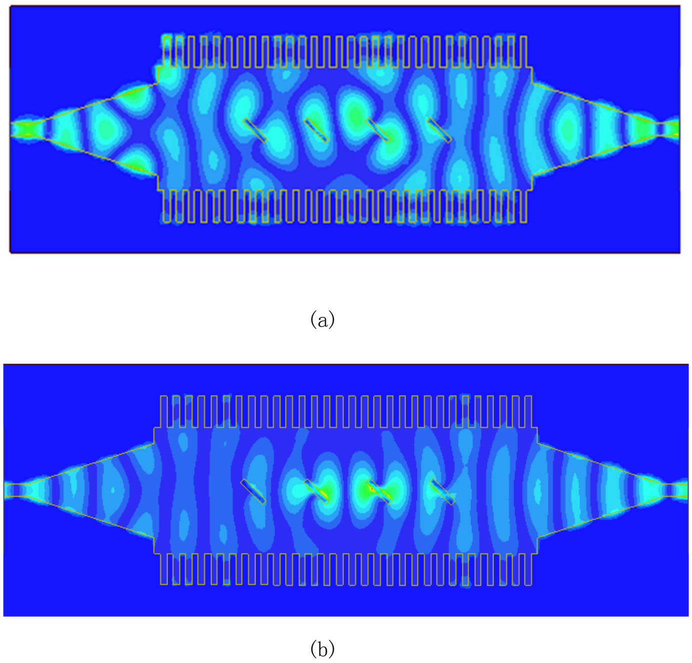


Fig2 The electric field of antenna
(a)bottom without slot (b)bottom with slot

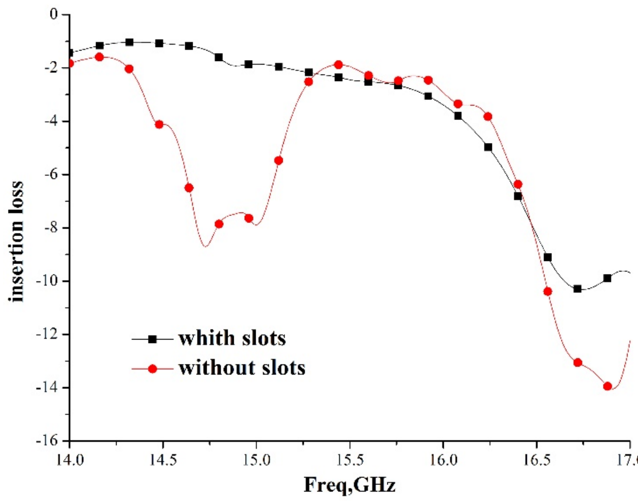


Fig3 Insertion loss of antenna

As Fig2 (a) shown, electric field is chaos even generate the backflow when bottom without the slots, Fig2(b) shown the bottom side with slots, the Electric field become regular obviously. At the center of the comb line, electric field is converged. The strongest place of electric field is center. Therefore, the gain of the antenna will not deteriorate due the double-sided slot generation of the gate lobe. While the electric field passing the slots, it back to the original. Fig3 shown the insertion loss also become lesser.

III. RESULT AND DISCUSSION

This model use HFSS15.0 electromagnetic simulation software to simulated and verified.

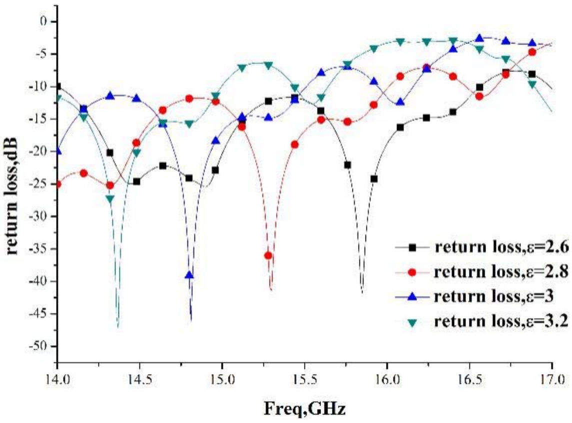


Fig4 Antenna’s resonance point influenced by permittivity changing

As is shown in Fig4. Return loss is less than -40dB at resonance point. The resonant point of antenna moved by changing LC’s permittivity. When permittivity changed from 2.6 to 3.2, the resonant point have changed 1.5GHz (15.85GHz~14.37GHz).

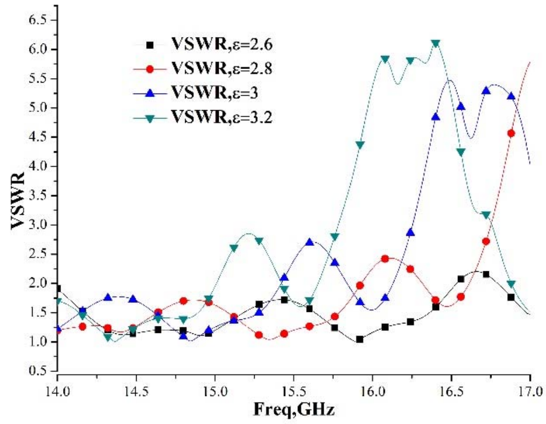
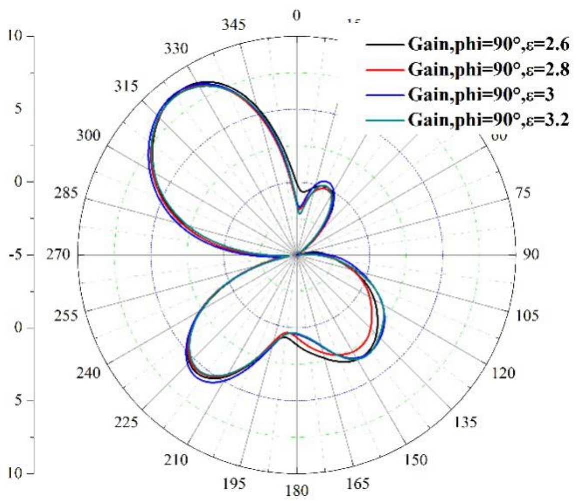
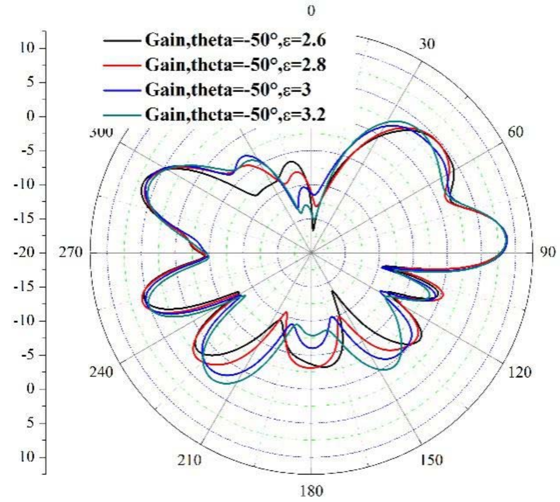


Fig5 VSWR influenced by permittivity change

According to Fig5 portrayed, antenna’s VSWR less than 2 at CSIW’s single modearea the bandwidth of this antenna is 1GHz (VSWR＜1.5). It demonstrate that microstrip-SIW impedance excessive is matched. Antenna is working at Ku band, it can used at satellite communications.



(a) φ=90°



(b)θ=-50°

Fig6 Antenna’s pattern at every resonance point

The Fig6 shown the pattern at all resonant points about e-plane and h-plane. Antenna’s radiation pattern unchanged at all resonant points by permittivity changing. Antenna have 4 side lobes because the slots etched at two sides and quadrature 90 degrees. By changing LC’s permittivity, the resonant point of antenna is: 15.85GHz, 15.3GHz, 14.81GHz and 14.37GHz corresponding to ε=2.6, 2.8, 3 and 3.2. The maximum gain is 8.79dB.

IV. CONCLUSION

In this paper, a new frequency reconfigurable CSIW slot leaky-wave antenna is presented. It use liquid crystal as medium and adopt CSIW structure. The 4 couples slots etched at top and bottom, which are put quadrature 90 degrees to control electric field balance. By changing LC’s permittivity, the resonant point moved 1.5GHz, antenna’s return loss and gain after reconfiguration is invariant. With the development of reconfigurable antenna, the SIW slot reconfigurable antenna could be used in more applications.

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