Triple Band Tunable SIW Cavity Antenna with Cristal Liquid Materials for Wireless Applications

1st Fakher Sboui
Department of Physics, Microwave electronics Research Laboratory, Faculty of Siences of Tunis, University of Tunis El Manar 2092, Tunis, Tunisia
Fakher.sb@gmail.com

2nd Jan Machac
Departmenet of Electromagnetic Field, Faculty of Electrical Eengineering, Czech Technical University in Prague, Technicka, 16627 Prague 6, Czech Republic
machac@fel.cvut.cv

3st Lassaad Latrach
Department of Physics, Microwave electronics Research Laboratory, Faculty of Siences of Tunis, University of Tunis El Manar 2092, Tunis, Tunisia
Latrach.lassaad@gmail.com

4st Ali Gharsallah
Department of Physics, Microwave electronics Research Laboratory, Faculty of Siences of Tunis, University of Tunis El Manar 2092, Tunis, Tunisia
Ali.gharsallah@fst.utm.tn

***Abstract*—This communication was developed with the purpose of presenting a frequency reconfigurable rectangular cavity backed antenna based substrate integrated waveguide, using for wireless applications. The frequency agility is obtained by the integration of a crystal liquid material between the upper face and the substrate of the proposed SIW antenna, this material maintains the proprieties of changing the permittivity and the permeability by applying a DC voltage. This is leads to the variation of the resonance frequency. Simulated results obtained by CST simulator show that the first band is tuned from 27 GHz to 28 GHz, the second one is varied from 27.85 to 29 GHz. and the frequency in the third band is changing from 29.45 GHz to 30.89 GHz. Those results are obtained when the permittivity of the CL is varying from 2.7 to 3.4. The maximum gain is around 7.92 dB and a high radiation efficiency is obtained. The proposed antenna is required for wireless applications**.

Keywords*— *Cristal liquid, substrate integrated waveguide, frequency reconfigurable, wireless applications

I. Introduction

The emergence of wireless network and its diverse range of applications from medical and household appliances, to mobile communications and safety, introducing a new class of advanced antenna solutions to fulfill the corresponding massive traffic volume and substantial data rate demands seems necessary[1-4]

Frequency reconfigurable antennas appears as one of those solutions where they are commonly known by their capability of operating frequency variation Hence, compared to other terminals antenna and wireless components, they occupy less area and simplest integration with other devices. Various techniques were recently presented that ability of frequency agility, such as in [5-11]. In [12], a frequency tunable SIW antenna with bowtie shaped radiation slot is investigated, the agility is obtained by applying a bias magnetic field that changes the permeability of two the ferrite slabs inserting in the antenna. In [13], a tunable dual band patch antenna was reported where with a loading of a varactor diode in the radiating slot.

In this communication, a novel dual band frequency tunable antenna base on SIW resonator cavity backed and usage of integrated CL layer is suggested. This design is able to tune the resonant frequency in three bands by changing the proprieties of the CL layer inserted between the top face of the SIW cavity and the substrate. Simulated results are achieved by the commercial software CST.

II. Design of the CL SIW cavity backed antenna

The configuration of the proposed antenna comprises for layers as presented in Fig. 1, the top face of the SIW cavity, the bottom face with a radiating spiral slot that allows obtaining a dual band radiation behavior. The Rogers 5880 substrate with permittivity 2.2 and the layer of CL with permittivity 3.2 [14]. The antenna is alimented by a 50 Ω GCPW transition characterized by a width of 1.56 mm. The design of the SIW cavity is presented in relations proposed in reference [15] with adding a wall of vias in the terminal of SIW. The number of half wave field variations in the z-direction is now limited. By exploiting the TE_{101} mode, a dominant resonance is produced.

$$f_{mnl} = \frac{c}{2\sqrt{\mu_r \varepsilon_r}} \sqrt{\left(\frac{m\pi}{w_{eff}}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{l\pi}{l_{eff}}\right)^2} \qquad (1)$$

The inserted CL layer has the same dimensions of the patch and a thickness of 0.508 mm. The finale optimized dimensions parameters are listed in Table I.

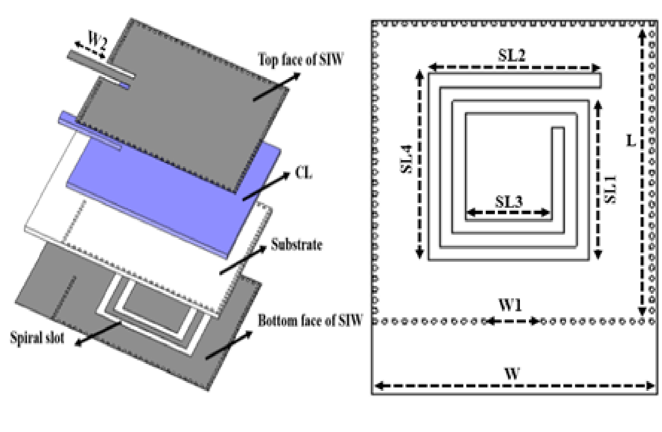

Fig. 1. Layout of the proposed design (exploded view)

TABLE I. DIMENSIONS OF THE PROPOSED ANTENNA (MM)

Parameters	**L**	**W**	**W1**	**W2**
Value(mm)	22.8	23.15	3.2	5
Parameters	**SL1**	**SL2**	**SL3**	**SL4**
Value(mm)	12	14	7	14

III. SIMULATION RESULTS AND DISCUSSION

Numerical simulation was carried out to obtain the results of the proposed CL SIW frequency tunable cavity antenna with the commercial software CST Microwave Studio 2017.

A. Without Cristal Liquid Layer

At the first stage, the proposed SIW cavity antenna radiating with the spiral slot without the CL materials was studied. Fig. 2 displays the results of the return loss S11. It can be noticed that the antenna functions in two frequency bands, the first resonance frequency is given at 27 GHz and the second one is obtained at 29.5 GHz with an impedance matching of 14 dB and 23 dB, respectively.

Fig. 3 shows the results of the gain and directivity over the frequency. As observed, high radiation efficiency is achieved in both radiating bands. The gain value of the first resonance frequency 27 GHz is around 7.25 dB and 7 dB at the second one 29.5 GHz.Besides,2-D radiation patterns are presented in Fig.4. Results display a broadside radiation characteristic with good cross polarization levels.

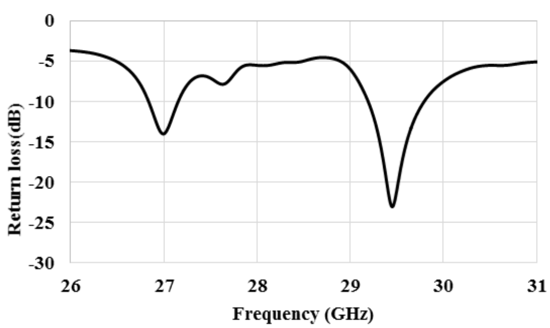

Fig. 2. Scattering S-parameters of the proposed Spiral SIW cavity backed antenna without CL materials

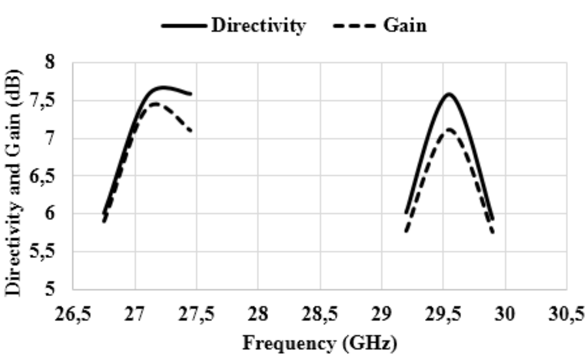

Fig. 3. Simulated gain and directivity over the frequency of the dual band SIW cavity antenna

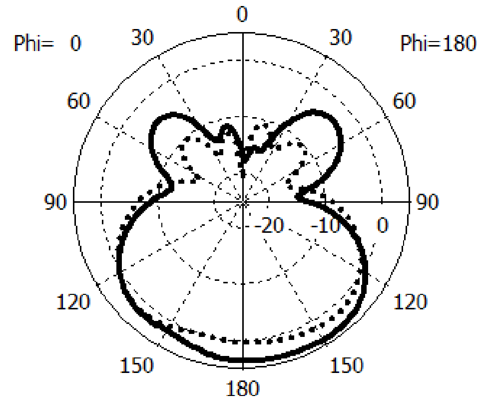

Fig. 4. 3-D radiation patterns of the proposed SIW cavity backed antenna at 27 GHz (solid line) and 29.5 GHz (dotted line)

B. With Cristal Liquid Layer

In this work, we used as tunability technique the CL materials, this type characterized by its nematic phase where it can provide a varied permittivity and permeability in function of the static external electric fields. Table II shows the propriety of the Polymer CL we have used at the frequency 30 GHz. simulated results of return loss are presented in Fig. 5. It can be noticed that by integrating the CL layer, the appearance of a third resonance band is visualized.

TABLE II. THE CHARACTERISTICS OF THE POLYMER CL (23°C, 30 GHz)

$\varepsilon\perp$	2.47	**tan $\delta\perp$**	0.0151
$\varepsilon\parallel$	3.16	**tan $\delta\parallel$**	0.0033

Results shows that a wide range of frequency variation in three frequency bands is achieved when the permittivity of the substrate was set to be 2.9, 3, 3.1, 3.2, 3.3 and 3.4. The tuning frequency ranges are equal to 1000 MHz, 1150 MHz and 1450 MHz for the first, second and the third bands, respectively. Table III summarize the obtained results of returns loss and gain in all cases, it can noticed that high gain value is achieved around 7 dB ±1 dB.

TABLE III. SIMULATED RESULTS OF THE PROPOSED ANTENNA ACCORDING TO THE FIRST, SECOND AND THIRD FREQUENCY BANDS

Permittivity	**First band**		
	Frequency (GHz)	**Matching (dB)**	**Realized Gain (dB)**
2.9	28	-15	7.3
3	27.849	-19.78	7.92
3.1	27.647	-31.15	7.14
3.2	27.499	-27.60	7.09
3.3	27.334	-19.73	6.94
3.4	27.163	-16.15	6.04
Without CL	27	-14	7.25

Permittivity	Second band		
	Frequency (GHz)	Matching (dB)	Realized Gain (dB)
2.9	29	-14	6.9
3	28.75	-13	7.1
3.1	28.55	-12.2	7.12
3.2	28.3	-11.5	6.8
3.3	28.1	-10.3	6.88
3.4	27.8	-8	7.15
Without CL	-	-	-

Permittivity	Third band		
	Frequency (GHz)	Matching (dB)	Realized Gain (dB)
2.9	30.894	-18	7.02
3	30.612	-19.26	6.98
3.1	30.356	-20.34	6.88
3.2	30.113	-21.20	6.24
3.3	29.879	-21.98	6.84
3.4	29.662	-22.65	7.08
Without CL	29.452	-23.04	7

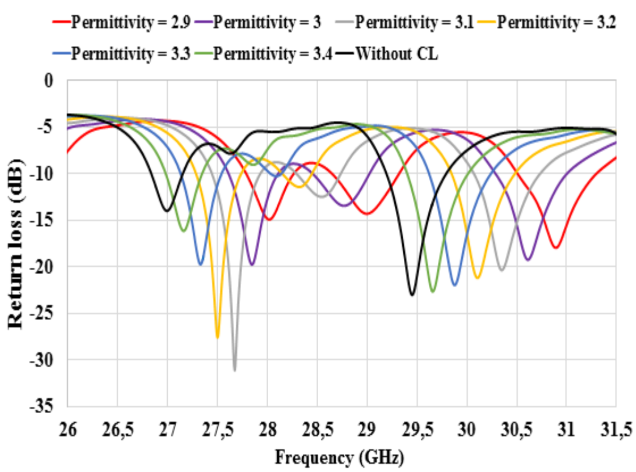

Fig. 5. Simulated return loss for different LC permittivities

The comparison between the triple band frequency tunable SIW antenna presented in this work and the references are displayed in Table IV. The comparison of the antenna type is shown, the frequency agility range and the maximum gain value of the proposed antenna and those presented in the references. It is very obvious that the antenna proposed in this article has the largest frequency range of agility and the highest gain value. This means that better radiation performances are guarantees by the proposed work.

TABLE IV. COMPARISON BETWEEN SUGGESTED AND REPORTED FREQUENCY AGILE ANTENNAS

Ref	Antenna type	Agility technique	Tuning range (MHz)	Maximum gain (dB)
Ref [16]	SIW cavity backed	Ferrite slab	380MHz	6.85
Ref [17]	Dual band square patch loaded with a hexagonal slot	Varactor diodes	First band: 357 MHz	2.1
			Second band : 126 MHz	1.2
Ref [13]	Patch antenna for dual band operation	Varactor diodes	First band: 400 MHz Second band: 1100 MHz	7 6.8
This work	5G Dual band SIW cavity backed	Cristal liquid	First band:1000 MHz Second band:1150 MHz Third band:1450 MHz	7.92 7.15 7.08

IV. CONCLUSION

In this communication, a triple band frequency agile antenna based on polymer LC material is presented. The simulated results demonstrate that the triple band frequency tunability can be provided by inserting a Polymer Cristal Liquid layer in the design with a wide range of agility and a high gain value. This antenna can be considered as a good candidate for wireless and 5G applications systems.

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