Dual Bands of Substrate Integrated Waveguide Antennas for 5G Applications

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Abstract: For K-band applications, this article presents a dual band circular slot fixed on a substrate integrated waveguide (SIW) antenna. The simulation result of the antenna includes of a micro strip probe with two rounded slots put in on the top of the radiation plane and located one on top of another for increased bandwidth. This probe was intended with a “dielectric constant” of 2.2 as well as a thickness of 1.5 mm on a Roger layer. Better antenna vibrates at 23.43 GHZ and 30.16 GHZ with a fractional bandwidth of 2.9 GHZ and 1.1 GHZ, consequently. The peak gain attained is about (6.63 and 6.09 dB) above the working frequencies, united. This makes it perfect for K and Ka applications with strong corresponding and returns loss features. The analysis and construction assessment of the proposed probe was led by the EM simulator, CST Microwave Studio

Keywords: dual bands, Micro-strip, substrate integrated waveguide SIW, K and Ka –band.

1. Introduction

By way of the first 1G network development, cellular networks have grown exponentially since 1980. Up now, broadband networks have achieved the level of a 5G network built to meet the specifications of telecommunications standards such as LTE-Advanced Requirements and IEEE 802.16 m. [1]. Broadband networks and cell phones can be seen everywhere today. The speed of data delivery in digital networking has raised the need for wireless networks. Consequently, the major issues for engineers to design future wireless networks are the rising need for higher connectivity speeds and an increasing users' number. For instance, in the case of wireless communication, uncompressed high-definition video and images demand a very high data transmission rate (more than 1 Gbps).

That this next generation of microwave guidance components often used Microwave Integrated Circuits are published transmission lines (MICs). The advantage of the (MICs) are low-profile systems, however the downside is the lack of high transport capacity and the high Q factor of the traditional waveguides. SICs have been constructed to fix these issues between (MIC) structures and standard waveguides which have the small planar structures advantage like MIC structures with high load capacity and high Q factor, along with waveguides. [3]. One of the techniques of SIC is the optimized waveguide substrate (SIW). Microwave modules, including antennas, active circuits and passive parts, have been very well implemented to SIW technology [4]. The feasibility of the definition for microstrip transformations has been shown in [5]. Coplanar waveguide transformation, also developed in[6][7], Basic waveguide filter and slot antennas were presented in[8],[9],[10]. The lack of radiation caused between the vias was defined in [11]. Inserting a rectangular waveguide through a micro-strip substrate lowers the Q-factor waveguide due to reduced volume and dielectric loading. [6]. SIW suggested a successful finding when it was included in the antenna structure as we can see next.

In this article, the substrate integrated waveguide (SIW) model was developed to the conservative micro-strip to create circular SIW distributions and three circular slots are formed on the upper metallic substrate of the antenna.

2. Microstrip Design Procedure

The measurements of the micro-strip reinforcement probe as shown in Fig.1. They are determined by taking into account the patch size and thickness [12].

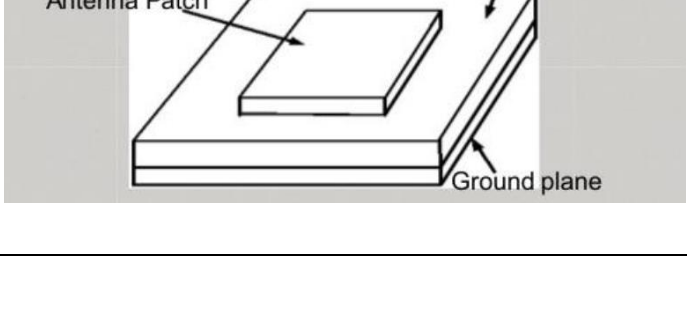


Fig. (1) General configuration of the micro-strip area

Where:

$$w_p = \frac{c}{2f_0\sqrt{\frac{(\epsilon_r + 1)}{2}}} \quad (1)$$

$$L_p = L - 2\Delta L \quad (2)$$

Where:

$$\mathrm{L} = \frac{c}{2f_0\sqrt{\epsilon_{reff}}} \quad (3)$$

C: The speed of light in free space.

f_0: Frequency resonates.

$\in r$: The substrate dielectric constant.

$\in reff$: The effective permeability.

ΔL: duration of the expanded incremental patch.

The effective dielectric constant can be determined as:

$$\epsilon_{reff} = \frac{\in r+1}{2} + \frac{\in r-1}{2} + \left[1 + 12\frac{h}{wp}\right]^{\frac{1}{2}} \quad (4)$$

h: Dielectric substrate thickness.

Wp: the patch width;

3. SIW Configuration And Design Procedure

The substrate integrated waveguide antenna (SIW) can be signified by metallic rods rows that are inserted between two metallic plates into the dielectric substrate and excited with inset feed as shown in Fig.2.

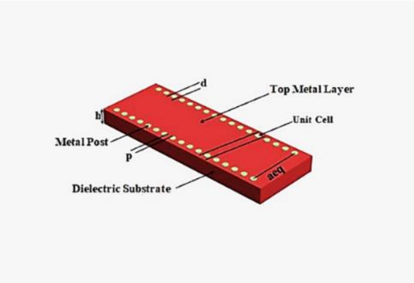


Fig.2 The substrate integrated waveguide (SIW) antenna [15].

In frequently to secure a low leakage between the vias gap (d<λ g/5) and (p≤2d) the p (pitch: distance between the two vias) and d (diameter of the hole) and the λ g (waveguide length) were investigated [14]. The SIW was performed to allow minimized leakage between the vias by using these parameters. [13]. In the configuration of the SIW antenna, two essential parameters must be estimated (equivalent width a eq) and (equivalent length leff) as in the following equations:

$$a_{eq} = a_{siw} - \frac{d^2}{0.95\,p} \quad (5)$$

$$l_{eff} = l_{siw} - \frac{d^2}{0.95\,p} \quad (6)$$

Where

a_{siw}: Width between two rows of vias.

l_{siw} : Length between two rows of vias.

3.1 Proposed Antenna Configuration

The first recommended antenna was built without (SIW) antenna which can be seen in Fig. (3). Measuring and comparing the findings. The simulation results prove that it has a single band with a resonant frequency of 25.81 GHz and a bandwidth of 0.8 GHz and a return loss of (-13.6 dB) as shown in Fig. (4).

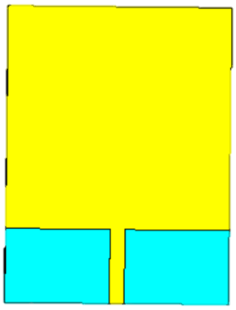


Fig. (3) designed antenna without (SIW)

The s11 the parameter shown in the following figure

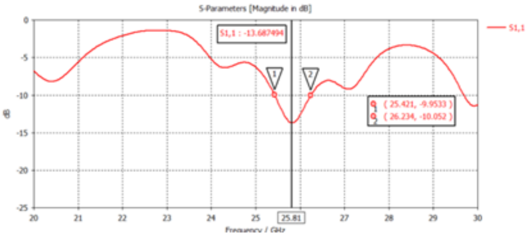


Fig. (4): S11 Parameter of the planned antenna without SIW.

The planned SIW antenna structure with a whole measurement (15 mm x 20 mm) was demonstrated on the Roger substrate as a single row with a relative allow ability of = 2.2, a loss of Δ = 0.0013 and a thickness of h = 1.5 mm. The diameter of the metallic via is fixed at 0.6mm and the pitch between the two vias is 1.2mm. In Fig (5), the geometry of planned SIW antenna is shown. The total measurements of the antenna are listed in the table (1).

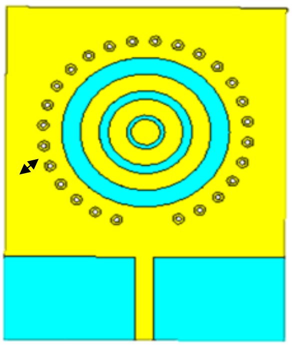


Fig. 5 The geometry of planned SIW antenna

Table (1) Antenna Dimensions Of Proposed Model

Symbol	Value	Description
W	15	Total width
L	20	Total length
P	1.2	Pitch between vias
D	0.6	Via diameter

Lf	5	Length of microstrip feed
Wf	1	Width of microstrip feed
Wp	15	Patch width
Lp	15	Patch length
h	1.5	Thickness of substrate
S1	1	Width of slot 1
S2	0.5	Width of slot 2
S3	0.4	Width of slot 3

4. Results And Discussion

The Coefficient Reflection consequence (S11) response was shown in Fig. (6). The antenna has dual-band resonant activity at 23.43 GHz and 30.16 GHz bandwidth (2.9 GHz) for the lower band, and 1.1 GHZ for the upper band for return losses-40.0 dB and-17.49 dB accordingly. This indicates that the new SIW antenna acceptable for the 5G mobile connectivity requirement, radar and satellite systems.

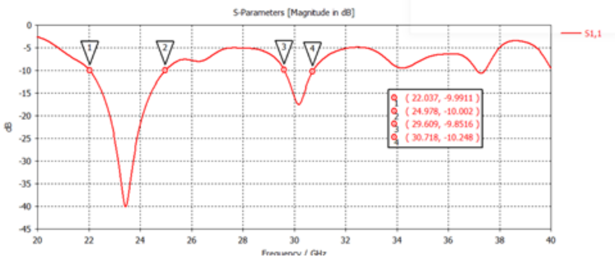
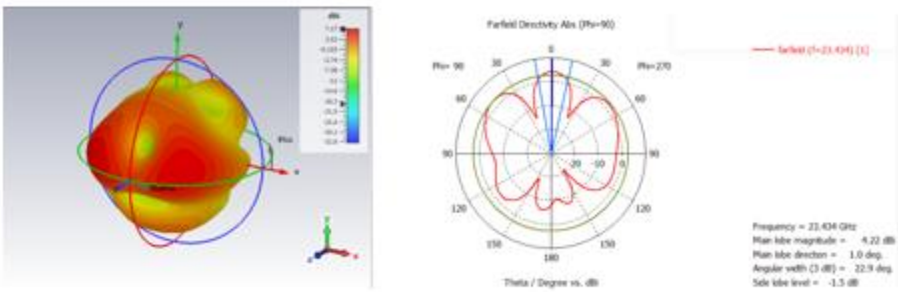
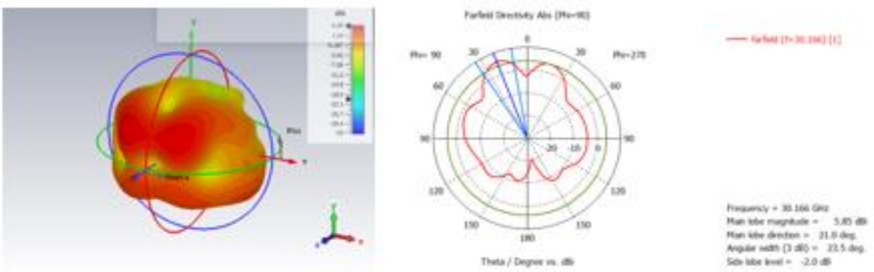


Fig. (6): The S11 parameter of the SIW antenna.

As shown in fig. (7) .Below, the directivity of the first resonant frequency is (7.1 dB and 6.99 dBi).



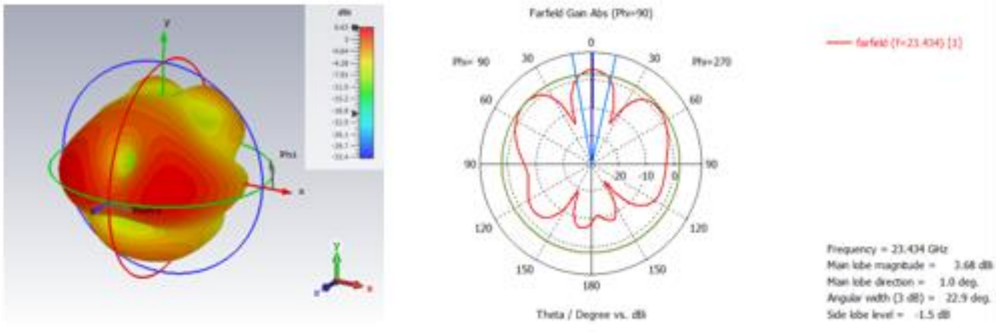
(a) F=23.43 GHz



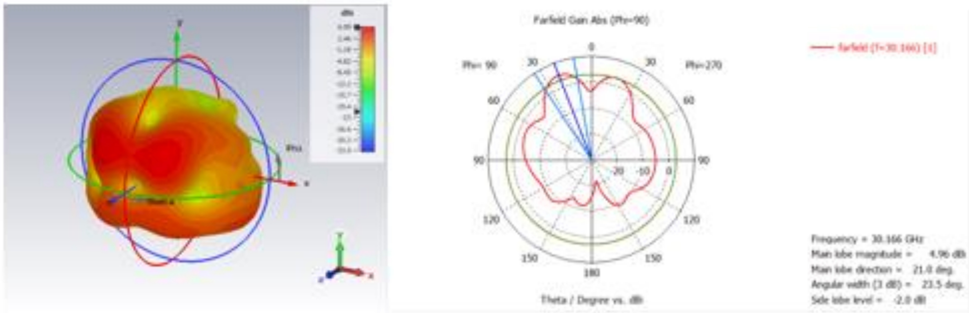
(b) F=30.16 GHz

fig. (7) The directivity

The resonant frequency gain 23.43 GHz and 30.16 GHz is (6.63 dB and 6.09 dB), receptivity. As shown in fig. (8)



(a) F=23.43 GHz



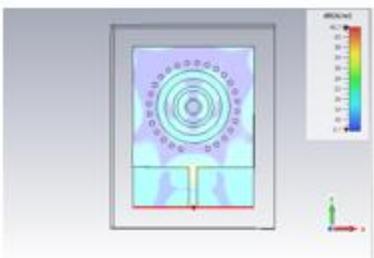
(b) F=30.16 GHz

Fig. (8) The gain

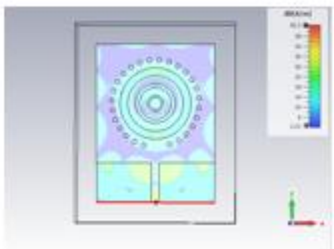
Table (2) : Characteristic parameters of proposed model (SIW)

Resonance Frequency (GHz)	Return Loss (dB)	Gain (dB)	Directivity (dBi)	Bandwidth (GH)	Efficienc y (%)
43.23	-40.0	6.63	7.1	2.9	93.3
30.16	-17.49	6.09	6.99	1.1	87.12

Again from above SIW technology, the probe effectiveness is improved during the matching time and this leads to bigger directivity and gain so as to make the antenna appropriate for K-band and Ka-band implementations. The actual distribution of the slot antenna at two frequencies is shown in fig. (9) below:



(a)



(b)

Fig. (9): (a) current distributions at F=23.43 GHZ. (b) current distributions at F=30.16 GHZ.

5. Conclusion

In recent years, multimedia connectivity has practiced a great deal of transition, in other words, the tremendous growth of the mobile device sector, which has contributed to the requirement to offer broadband for these networks. But the spectrum available has become saturated, and this involves an extension of the spectra band and a decrease of its duration. In comparison, the increase in probe gain and presentation is compensated by a greater loss of spread at high frequencies, which means that the obtained signal frequency has to be higher. In this article, a rounded hole patch antenna is gained depended on the SIW structure and introduced as a substitute for dual-band K-band and Ka-band applications. The result displays that the planned antenna shows the ability to include the SIW technique to the model antenna, which will increase the performance on a feasible alternative. The consequence of this antenna meets the principles for 5G mobile connectivity, radar and satellite networks

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