Design and Analysis of Substrate Integrated Waveguide at K-band for Emerging Radar Application

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Abstract : In terms of the radar system, several industry products have used the millimeter wave band, the broadband waveform, and the multi-antenna to make the radar smaller in size and more accurate in parameter estimation. Substrate integrated waveguide (SIW) is a new form of transmission line that has been popularized in the past few years by some researchers. This paper proposed the substrate integrated waveguide (SIW) using RO3003 substrate material at k-band. Simulated results show that the optimized bandwidth is approx 10GHz with -74.05 dB return loss. The resonant frequency is 26.51 GHz.

***IndexTerms* – SIW, RO, K-band, Radar, Antenna.**

I. INTRODUCTION

The classical rectangular waveguide devices still serve as the mainstream for microwave and millimeter wave systems. However, the bulky size and inability of these devices to integrate with planar technology, i.e. PCB, prevent them to be used in the new generation wireless devices. In addition, the waveguide technique cannot be used to reduce the weight and volume. Hence, it is not appropriate for low-cost and bulk production. Further, its post fabrication processing, like tuning and assembling becomes a real problem for manufacturers. The realization of the planar rectangular waveguide is now possible by a newly promising technology called Substrate Integrated Waveguide technique (SIW). This technology has earned much attention over the recent years, in the area of high density integration of microwave and millimeter wave subsystems. The SIW allows us to create Substrate Integrated Circuits (SICs), as it provides the platform to integrate all microwave and millimeter wave active and passive components on the same substrate, such as the oscillators, amplifiers, filters, couplers, antennas and many more [2,3]. In this technique, rows of narrowly spaced metallic vias between two planes emulate the adjacent walls of a thin rectangular-type waveguide filled with dielectric [4]. The properties of SIW include low loss, low profile, high power capacity, easy integration and fabrication with planar technology, and mass production.

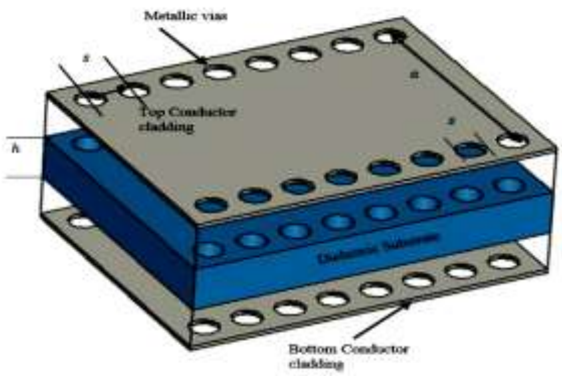


Figure 1: Configuration of SIW

Generally, due to the presence of the dielectric substrate, the width of SIW is narrower than that of the conventional waveguide. Owing to the limited thickness of the dielectric substrate, the electromagnetic field, along the height of SIW remains constant. Hence, the propagation and non-propagation of modes get excited inside its cavity [8].

II. BACKGROUND

E. Massoni, et al.,[1] presents an expansion of antenna radiation productivity, as less force is dispersed by the voyaging wave. So as to demonstrate this idea, two antennas have been planned with similar qualities (focal recurrence of 28 GHz, pointing edge of 50°, and beamwidth of 10°), one dependent on SIW and the other dependent on SISW. Our exploratory confirmation yields 64% radiation productivity for the SIW LWA and 80% radiation proficiency for the SISW LWA, in this way demonstrating the hypothetical and mimicked forecasts.

Z. Qi, et al.,[2] presents HSIW H-plane horn antenna shows a greatest acknowledged gain of 11.2 dBi with 77.6% radiation proficiency and 32.9% bandwidth (27.7-38.6 GHz). In view of the antenna component, a 1 × 4 HSIW H-plane horn antenna exhibit is proposed. The exhibit shows a most extreme acknowledged gain of 17.2 dBi with 66.5% radiation effectiveness and 31.9% bandwidth (27.6-38.1 GHz). Great understandings of the deliberate and reproduced results are accomplished for the two structures. The proposed antenna and exhibit can be acceptable contender for ease millimeter-wave remote correspondence frameworks.

W.El-Halwagy et al.,[3] presents dipole is created utilizing vias in a standard PCB procedure to fit at the telephone or tablet edges including wideband activity with expansive half-power beamwidth in the height plane (HPBWELEV), high gain and high front-to-back radiation proportion (F/B). For improved gain, parasitic-vias are included front of the dipole as chiefs. To improve

HPBW without giving up gain, the chiefs are executed as Angular cut parasitic-vias. A through fence encompasses the dipole structure to stifle back radiation and upgrade F/B. The dipole is associated with a parallel-strip line (PS) which is interfaced to the principle SIW feed through a novel SIW-to-PS change. Careful examination, improvement, and parametric investigation are accommodated each plan parameter of the proposed structure.

E. Massoni et al.,[4] presents the usage of a broadband substrate integrated waveguide (SIW) by an added substance fabricating procedure. A 3-D printed material dependent on Ninjaflex fiber has been acknowledged by melded statement displaying. By changing the infill rate, printed materials with various dielectric properties have been manufactured and tentatively portrayed. Two materials got from a similar fiber with various infill rates have been utilized for the usage of a substrate integrated slab waveguide (SISW), which permits expanding the single-mode bandwidth contrasted and that of a standard SIW.

R. Tiwari et al., [5] Microstrip Patch Antenna (MPA) is array design is also very emerging research area for 5th generation communication application. This paper proposed a novel design of dumbbell shape microstrip antenna array with defected ground structure for wi-fi communication applications under 5G network.

A. Mukhopadhyay et al., [6] presents world leader in telecommunications, Bose was a significant figure behind the creation of modern radio and sonic technology. In 1896 his work was commemorated by IEEE as the oldest "milestone achievement" from Asia. In 1997 the Institute of Electrical and Electronic Engineers of America named Bose as a "Father of Radio Science." Royal Society of England was impressed by a research paper of Bose on electro-magnetic waves.

R. Tiwari et al., [7] presents on antenna design and simulation is an emerging area among researchers. Antenna is a basic element for wireless communication. There are various shapes and types of antenna, which uses in different application. Now a day's Microstrip antenna is very useful in advance electronics devices applications.

S.Pandit, et al.,[8] presents displays a novel low-profile high-gain antenna with cross-polarization (x-pol) concealment utilizing cross circular loop resonator (CCLR) metamaterial (MTM) slab in substrate-integrated waveguide-bolstered space antenna (SIW-SA). The SIW-SA antenna, which is the reference antenna, works at 9.73 GHz. The CCLR MTM slab goes about as a low-impedance slab, which is put in the superstrate of the reference antenna at the stature of just λ0/10, where λ0 is the free-space wavelength at the reverberation recurrence of the antenna.

III. PROPOSED DESIGN METHODOLOGY

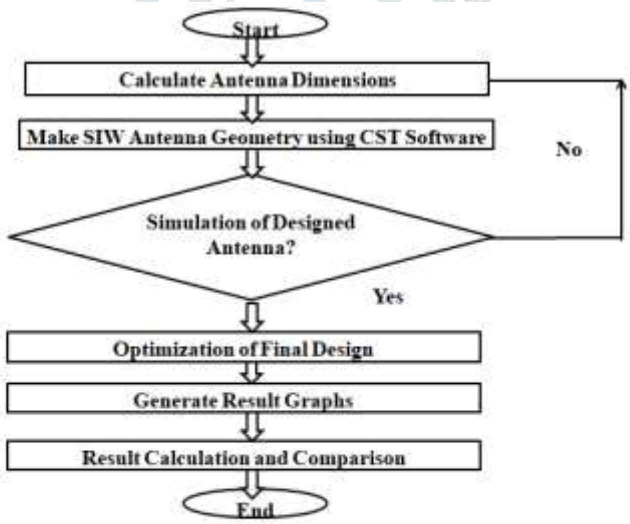


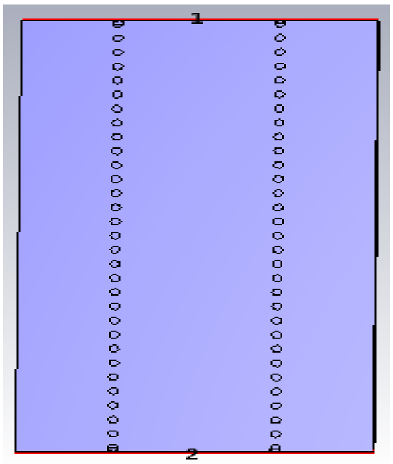
Figure 2: Flow Chart

The flow chart work as following steps-

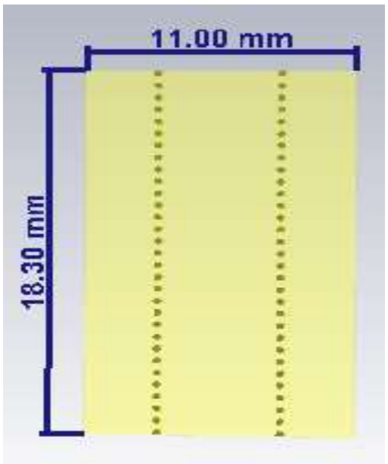
1. First find application and define requirement.
2. Next steps is finding out major specification of antenna
3. Resonating Frequency of antenna (according to application define in initial step of CST).
4. Choose a suitable substrate, it may depend upon various factor like availability of material, integration of antenna with other circuit components on board. Dielectric constant and height of substrate are important for SIW antenna parameter calculation.
5. Calculate SIW antenna dimension. Most of the time antenna used in wireless communication is not simple antenna, these are customized structure.
6. Calculate antenna width and length using standard formula.
7. Antenna height (Its define in substrate material already for microstrip antenna its usually 1.5mm-1.6 mm). It can be selected using CST.
8. Draw antenna geometry and define materials.
9. Run simulation and check performance parameters values.

Now the use of CST microwave studio software, make the design using calculated dimensions.

Figure 3, showing top perspective on proposed SIW antenna, the RO3003dielectric material is used for substrate layer and copper material is used for design of SIW overall structure. The dimension of proposed SIW antenna is 11 mm X 18.30 mm.



(a)



(b)

Figure 3: (a) Top view of proposed design (b) Antenna Dimension

(a)

(b)

Figure 4: (a) Metal view (b) Substrate View

Figure 4 is showing the metal view which made from copper material and substrate material which made from RO dielectric material.

IV. SIMULATIONS RESULTS

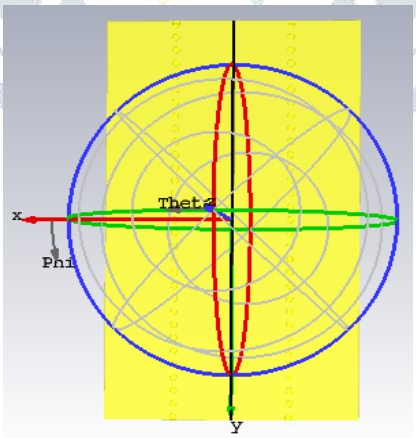


Figure 5: Simulation and fields of proposed antenna

CST microwave studio used to recreate the proposed plan. Figure 5 is demonstrating reenacted electric and attractive field in round organize framework.

Table 1: Design parameters for proposed Antenna

Sr No.	Parameter	Value
1	Frequency(f_r)	20-30 GHz
2	Dielectric constant(ε_r)	3.6 / Rogers RO3003
3	Metal Height	0.035mm

4	Substrate Height(h)	1.57 mm
5	Line Impedance	50 Ω
6	Antenna Length	18.3 mm
7	Antenna Width	11 mm
8	Tangent Loss	0.06

Return loss

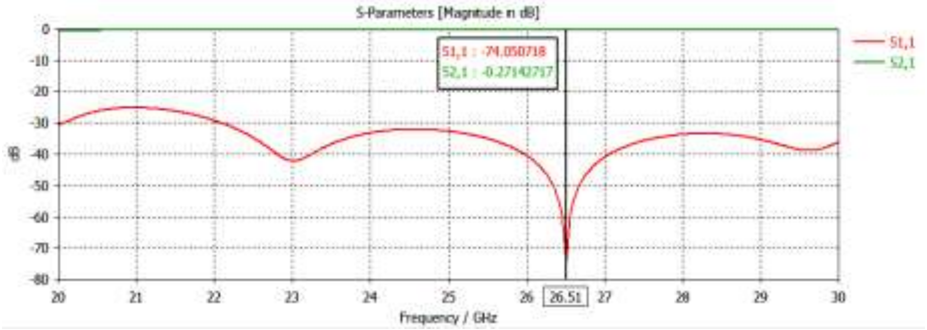


Figure 6: Return loss

Figure 6 is showing the obtained value of S11 or return loss that is -74.05 dB for 26.51 GHz resonant frequency, where antenna efficiency is higher.

Bandwidth

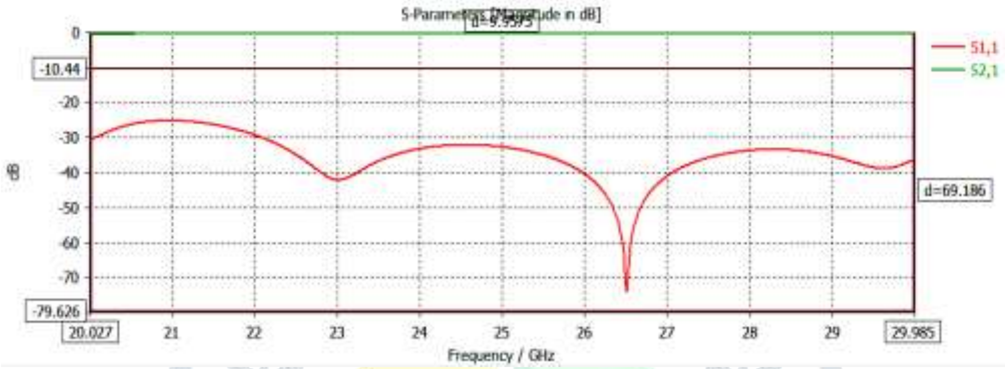


Figure 7: Bandwidth

For broadband antennas, the bandwidth is expressed as a percentage of the frequency difference (upper minus lower) over the center frequency of the bandwidth. The bandwidth of proposed antenna is 9.9575 GHz, (29.98GHz – 20.02GHz).

Voltage Standing Wave Ratio (VSWR)

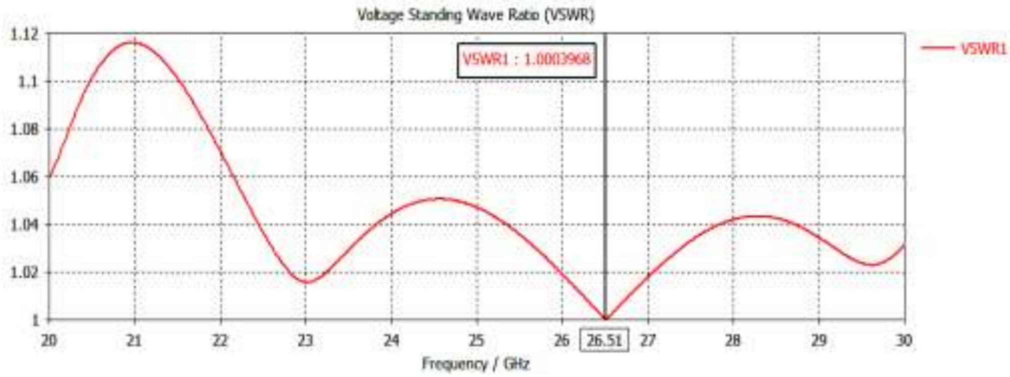


Figure 8: VSWR

Figure 8 shows VSWR esteem, it is voltage standing wave proportion; VSWR must lie in the range of 1-2, which has been achieved for the frequencies 26.5GHz. The value for VSWR is 1.0003.

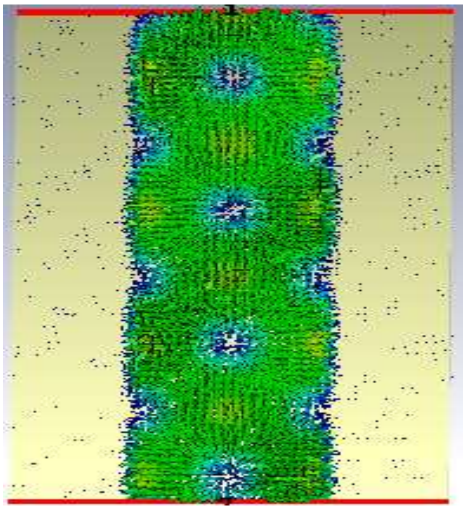


Figure 9: Surface Current

Figure 9 shows the surface current which is an actual electric current that is induced by an applied electromagnetic field. The electric field pushes charges around.

Table 2: Simulated Results of Proposed Antenna

Sr No.	Parameter	Optimized Band
1	S11 or Return Loss	-74.05 dB
2	Band Width	9.95 GHz
3	VSWR	1.0003
4	Resonant Frequency	26.51 GHz

Table 2 shows performance parameters like return loss, bandwidth, VSWR and resounding recurrence. It is clear by observing reenacted values from table 2, proposed antenna accomplish siginificant improved outcome.

Table 3: Comparison of proposed design result with previous design result

Sr No.	Parameter	Previous work	Proposed work
1	S11 or Return loss	-29 dB	-74.05 dB
2	Band Width	Approx 175 MHz	9951 MHz
3	VSWR	1.0714	1.0003
4	Resonant Frequency	28 GHz	26.51 GHz
5	Dimension	95.5X13X1.64	18.3X 11X 1.64

Table 3 is showing comparison between previous design and proposed design. It is clear from this table and results the proposed SIW antenna design have significant good and improved result than previous results.

V. CONCLUSION

The proposed design of SIW antenna characteristics on a Roger Substrate Integrated Waveguide antenna for radar and satellite applications has been investigated. Different parameters like VSWR values are 1.003 for the respective frequencies 26.5 GHz. In the last, the new types of proposed antenna (SIW antenna), which are more appropriate for 5G communication applications like radar communication at K band are presented. .

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