Simulating a Novel SIW Bow-Tie Antenna and Comparing Return Loss and Gain Performance with SIW Slot Antenna for X Band Applications

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Keywords: Novel SIW Bow-Tie Antenna, SIW Slot Antenna, Gain, HFSS, Return Loss, Communication Technology.

Abstract: To compare the performance of Bow-Tie shaped SIW antenna with the SIW Slot antenna in terms of return loss and gain running at 10 GHz on 50-ohm characteristics impedance. Return loss and gain on 50 Ω characteristic impedance for SIW Bow-Tie antenna (n=27) and SIW Slot antenna (n=27). SIW Bow-Tie antenna (Return loss: -31.9265 dB, Gain: 4.57 dBi) outperforms SIW Slot antenna (Return loss: -27.0050 dB, VSWR: 2.0 dBi). SIW Bow-Tie antenna and SIW slot antenna have ideal proportions of 19.8mm x 16.8mm. The Independent sample test between both groups (SIW Bow-Tie antenna and SIW Slot antenna) achieved a significance value p=0.036 ($p<0.05$) for return loss and p =0.000 ($p< 0.05$) for gain, indicating a significant dissimilarity amongst the two antennas. The gain and return loss of the novel Bow-Tie shaped SIW Antenna are higher than that of the SIW Slot Antenna.

1 INTRODUCTION

The intention of the analysis study is to simulate using HFSS software and assess the return loss and gain performance of a SIW Bow-Tie antenna and SIW slot antenna running at 10 GHz on 50-ohm characteristics impedance. Bow-Tie antennas were employed to increase performance by providing a lower return loss, a flatter input impedance, and a steadier radiation pattern. Bow-tie slot antennas are suitable choices for larger bandwidth and easy planar antenna construction (Kaur and Solanki 2012). Bow tie shaped antenna provide several of positive aspects, notably slim profile, ease in layout and manufacture, better radiation symmetry, planar construction, and condensed dimensions than others (L. Liu et al. 2018). SIW technology was created as a replacement for large metallic waveguides. Using this method, a hollow space may be built on flat plane surfaces. As a result, microwave circuits, which previously required a massive metallic waveguide, shrank significantly in size. Despite having a larger loss than typical metal-containing waveguides, these provide adequate functionality for an extensive variety of antenna operations and tiny filter types (Varnoosfaderani, Lu, and Zhu 2014). One potential contender for extended-range spatial coverage is the Antenna with a bow tie built around SIW technique. At 24 GHz, the antenna is ideal for limited range vehicle radar-related uses (Abhay Kumar and Srivastava 2021). Applied to the KU and X bands (Maruti, Maruti, and Naga Kishore 2022). Ground-penetrating radar (GPR) Applications (Nayak and Maiti 2019). Tri-Band Applications (H. Liu et al. 2013) and UWB (ultra-wideband) applications (Sayidmarie and Fadhel 2013). For broadband applications, the BTCRS (Bow-tie-complementary-ring-slot) antenna replaces the conventional wire bowtie antenna (Arvind Kumar and Raghavan 2018). Point-to-point interfaces, which are similar to local area networks (LAN), are one of the MMW spectrum's applications. Broadband and high-definition TV in the Ka (MMW) band have been employed to provide people with high-quality government services. In addition, radars with excellent precision and resolution are utilised in this frequency spectrum for uses in sensing. These kinds of uses can be realised with the use of an appropriate antenna, such as the SIW Antenna (Oliaei and Abrishamian 2020).

Cited Articles and Their Findings

Several academic articles on SIW Bow-Tie antennas were published during the previous five-year period. IEEE Xplore published 9 papers on research, but Google Scholar released 15,100. A redesigned bow-tie antenna (Dadgarpour et al. 2015) configuration is presented for good gain performance at frequencies

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ranging from 57 to 64 GHz. The antenna is made up of two tilted bow-tie radiators, one on each end of a shared dielectric base, and is supplied by a SIW feedline. The bow-tie emitters are crossed symmetrically to maximise the gain of the antenna and achieve the desired emission distribution. Over the frequency band of 57-64 GHz, the antenna has a calculated gain of 11.5- 12 dBi and an apparent reflection factor of less than -11 dB. The suggested antenna is easy to develop and cheap to build. The properties of the antenna make it appropriate for usage in 60 GHz interior wirelessly communication technology systems. The intent of the current study (Althuwayb 2021) is to develop a novel slot bowtie antenna design working from 30 GHz to 37 GHz that is suitable for the lower frequency range of the 5G millimeter-wave region. A bowtie arrangement was formed by creating two trapezius-shaped slots in sequence. It is proved that a wide frequency bandwidth with good radiation performances may be achieved utilising the MTM (metamaterial) and SIW (substrate integrated waveguide) concepts with no loss of the material properties. A revolutionary approach for generating dual bands in technology of SIW is provided and thoroughly examined in (Nandi and Mohan 2016). The architecture is versatile since each of these mixed-mode frequency resonances may be modified independently. To create the second band, both the second and the third combined resonating frequencies of this dual-band antenna were adjusted moved nearer together. To keep the antenna low profile, it is built on a single substrate layer and fed by a basic GCPW (grounded coplanar waveguide) approach. Furthermore, the suggested antenna has a modest gain and a broadband response in both bands, making it suitable for a variety of dual-band practical applications in the X-band. The designed SCPBTA's (self-complementary planar bow-tie antenna) experimental and numerical performance parameters in both the time and frequency domains have been given and discussed in (Sayidmarie and Fadhel 2013). In comparison to a variety of recent designs disclosed in the open literature, the suggested antenna is simpler in construction and manufacturing, while providing a broader bandwidth and a lower footprint. The results suggest that the SCPBTA is a capable choice for usage in UWB (ultra-wideband) communication or phased array systems. According to the results of the studies (Tan et al. 2014), the highest frequency tuning range of ferrite-loaded the SIW cavity-backed bowtie slot antennas is 1460 MHz. In the meantime, the antenna's pattern of radiation and gain fluctuate slightly with tuning, showing robust radiation performance for practical applications. The antenna's design has the advantages of affordability, slim profile, ease in integration with planar circuits, and ease of manufacture, and it may be utilised in wireless transmission platforms such as radar and communications via satellites. The primary disadvantage of the antenna with SIW Slot is that it has a lower gain and return loss than the novel SIW Bow-Tie Antenna. Many studies have been carried out in order to improvise the gain and return loss of the SIW antennas. An antenna's return loss and gain characteristics can be enhanced by adjusting the patch design's location and pattern. At 10 GHz input frequency, this article analyzes the gain and return loss characteristics of a unique SIW Bow-Tie antenna with a SIW Slot antenna.

2 MATERIALS AND METHODS

The analysis is being conducted in the VLSI Laboratory at Saveetha School of Engineering's Department of Electronics and Communication Engineering. A total of two groups were formed. Each category has a total of 27 samples. The overall count of participants is 54. When doing evaluations and with one as the enrollment ratio, the pre-test power for continuous testing is 80%. The alpha and beta values in the proposed study are 0.05 and 0.2 respectively (Rosner 2015).

For this study, two different preparation procedures were implemented. In Group 1, SIW Bow Tie Antennas were created and simulated using HFSS software. A Bow Tie Antenna has been designed and built using Substrate Integrated Waveguide (SIW) technology. The dimensions and specifications of the Ground, a Substrate on the top, with a Patch, and a Feed with a Feedline, and dimensions of the Patch were modified according to the parameters in Table 1.

Group 2 followed the same preparation procedures as Group 1. In Group 2, SIW Slot antenna was constructed and analyzed using HFSS software. A SIW Slot Antenna has been designed and built using Substrate Integrated Waveguide (SIW) technology. The measurements of Ground, a Substrate on the top, with a Patch, and a Feed with a Feedline, and dimensions of the Patch were modified according to the parameters in Table 1.

HFSS is a highly effective full-wave EM field emulator 3D geometric inert equipment modelling programme that runs on Windows by Microsoft. It combines modelling, representation, structural modelling, and automation into a simple user interface. Package modelling, PCB board modelling, EMC/EMI, and antenna mobile communications are all common applications. Through the evaluation technique, Return Loss and Gain of the innovative SIW Bow-Tie and SIW Slot antennas are computed. While testing both the return loss and gain, keep the frequency at 10 GHz. Combine the values from the results data together. SPSS, which stands for statistical package for the social sciences is a grouping of software products. The principal use of this programme is to analyse scientific data related to social science. The results of this analysis might be used in market analysis, polls, information extraction, and other ways. SPSS saves and classifies the data entered before synthesising the data collection to generate suitable output. SPSS is designed in such a manner that it can handle a wide range of variable data types.

To complete the project, Windows 11, an i5 8th edition CPU, and HFSS modelling and evaluation technologies were employed. To obtain the findings, start Ansys HFSS and create an entirely novel layout as shown in (Madhav et al. 2011). Create a substrate over the ground, a patch above it, and a Bow-Tie design in the patch using the specifications in Table 1. Construct a patch feed. Choose the material of the substrate as Rogers RT/duroid 5880. Make a shield for radiation around the antenna. Give the spacing and diameter of the holes. Set the excitement to the feed. Start the analysis. Examine the results and the model. The mentioned procedure is utilised to make Group 2’s samples by just changing the patch’s pattern as of Table 2 results.

3 RESULTS AND DISCUSSION

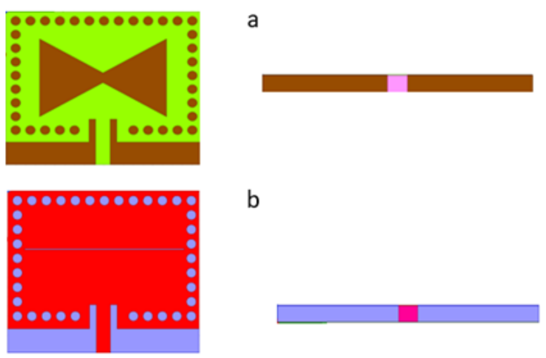

Figure 1: (a) Proposed Bow-Tie shaped SIW Antenna; (b) SIW Slot Antenna.

The novel SIW Bow-Tie antenna and the SIW Slot antenna's Return Loss and Gain were effectively tested and explored on 50 Ω various impedance characteristics at 10 GHz. The settings direct the input testing procedure. The outcome is produced by the allocation of boundary and excitation. The output of the graph has been saved to an Excel spreadsheet.

This file is then opened in SPSS for evaluation of the data. Work components and procedures that have been suggested leads to improved worker efficiency.

Tables 2 and 3 compare the Gain and Return Loss of the novel SIW Bow-Tie and SIW Slot antennas at 10 GHz. Through the comparison from the tables, the SIW Bow-Tie antenna has a better Return Loss (-31.9265) and gain (4.57). The SIW Slot antenna has a less return loss (-27.0050) and gain (2.0) than the SIW Bow-Tie antenna. As a result, the novel SIW Bow-Tie antenna is well established for X band applications. The Table 4 shows that the SIW Bow-Tie antenna has a higher mean (9.6115) than the SIW Slot antenna (7.5996) for Return Loss. When compared to the SIW Bow-Tie antenna (4.5700), the SIW Slot antenna (2.0000) has a low mean gain. Compared to the SIW Bow-Tie antenna (7.75448), SIW slot antenna (8.32783) has higher standard deviation for return loss. SIW slot antenna (1.60269) has higher standard error mean than the SIW Bow-Tie antenna (1.49235) for return loss. Both the mean deviation and the average mean of SIW Bow-Tie antenna and SIW slot antenna is .00000 for return loss and gain. The Table 5 uses T-test of independent samples to compare the SIW Bow-Tie antenna to the SIW Slot antenna at 10 GHz frequency. The difference of mean for Return Loss is 2.01189, whereas the difference of standard error is 2.18992. While gain has a difference of mean 2.57000 and difference of standard error of .00000, with most significant in return loss p value is 0.036 and Gain’s p-value is 0.000 ($p<0.05$). Hence this article is beneficial.

Fig. 1 and Fig. 2 shows the top and front views of the SIW Bow-Tie and SIW Slot antennas, respectively. Fig. 3 and Fig. 4 show the return loss and gain of Bow-Tie shaped SIW antenna. Fig. 5 and Fig. 6 show the SIW Slot antenna's return loss and gain. Fig. 7 shows the comparison between Return Loss of the SIW Bow-Tie and SIW Slot antenna. In the forms of gain and return loss, Fig. 8 compares the Bow-Tie shaped SIW antenna to the SIW Slot antenna. As a result, the Bow-Tie shaped SIW Antenna has a higher return loss and larger gain than the SIW Slot Antenna.

3.1 Discussion

The SIW Bow-Tie and SIW Slot antennas' return loss and gain performance are implemented and evaluated. According to several experiments, the novel SIW Bow-Tie antenna beats the SIW Slot antenna in regards of Gain and Return Loss. This data is recorded in an excel file and will be analyzed further with SPSS software.

Table 1: Bow-Tie shaped SIW antenna's dimensions and SIW Slot antenna. (Inner patch's length and width of Bow-Tie shaped SIW antenna: 12.95 x 8.57 mm^2).

Parameters	SIW Bow-Tie values	SIW slot values
Resonance frequency	10 GHz	10 GHz
Substrate material	Rogers RT/duroid 5880	Rogers RT/duroid 5880
Substrate length (L_{sub})	19.8 mm	19.8 mm
Substrate width (W_{sub})	16.35 mm	16.35 mm
Thickness of Substrate	0.5 mm	0.5 mm
Ground plane Length (L_g)	19.8 mm	19.8 mm
Ground plane Width (W_g)	14.3 mm	14.3 mm
Patch width (W_p)	14.3 mm	14.3 mm
Patch length (Lp)	19.8 mm	19.8 mm
Feed Length	1.45 mm	1.45 mm
Feed width	0.5 mm	0.5 mm
Feedline length	1.45 mm	1.45 mm
Feedline width	5 mm	5 mm
Gap of feedline	0.7 mm	0.7 mm
Inner Patch Length	12.95 mm	16.5 mm
Inner patch Width	8.57 mm	0.1 mm
Hole Diameter	1 mm	1 mm
Gap between Hole	1 mm	1 mm
Technique of Feed	Line Feed	Line Feed

Table 2: Antenna Performance of SIW Bow-Tie antenna (Return Loss: -31.9265 dB).

Feeding Technique	Return loss (dB)	Gain (dBi)	VSWR
Microstrip Line Feed	-31.9265	4.57	1.05

Table 3: Antenna Performance of SIW Slot antenna (Return Loss: -27.0050 dB).

Feeding Technique	Return loss (dB)	Gain (dBi)	VSWR
Microstrip Line Feed	-27.0050	2.0	1.09

This paper compares and analyzes the SIW Bow-Tie Antenna and SIW Slot Antenna into 50-ohm characteristic impedance at 10 gigaherrtz. To support my results this paper by (Barik et al. 2020) depicts that return loss of the bowtie antenna is -28.58 dB and a gain of 5.77 dB with an input frequency of 6.62 GHz. The study that opposes my article is (Gan, Tu, and Xie 2018) which states that to achieve a better return loss there needs to be a high frequency, The results according to the article published have a Return Loss value of -26.47 dB and Gain value of 5 dBi with a frequency of 45.5 GHz. The proposed work has a reduced Return Loss value of -31.9265 dB and a Gain performance of 4.57, that is superior to (Fernández-Bolaños et al. 2010), (Chen et al. 2022), (Robbins and Bowers 1978; Zabow, Dodd, and Koretsky 2021).

Biconical antennas, particularly bowtie antennas, have low transmission efficiency at low frequencies. In RF sniffing or RF signal detection, a bowtie antenna is not as effective as a complete biconical antenna. Traditional bow-tie antennas have problems such as end-fire evaluations, limited connectivity, scattering properties, inefficient performance, and effectiveness. The introduction of numerous types of metamaterials into the antenna patch may aid biological applications in the future.

Table 4: Descriptive analysis of SIW Bow-Tie antenna (N=27, Mean: 9.6115) and SIW Slot antenna (N=27, Mean: 7.5996).

Parameters	Type	N	Mean	Std.Deviation	Std. Error Mean
RETURN LOSS	Bow tie Antenna	27	9.6115	7.75448	1.49235
	SIW slot antenna	27	7.5996	8.32783	1.60269
Gain	Bow tie Antenna	27	4.5700	.00000	.00000
	SIW slot antenna	27	2.0000	.00000	.00000

Table 5: Independent sample test between both groups (SIW Bow-Tie antenna and SIW Slot antenna). Analysis of groups in detail the most significant in return loss p value is 0.036 and Gain p value is 0.000 (p<0.05).

Independent sample test between both groups (SIW Bow-Tie antenna and SIW Slot antenna)		Levene test of equality for variables		Equality of Mean's T-test						
		F	Sig	t	df	Sig (2-tailed)	Mean difference	Std. Error difference	95% confidence difference of interval	
									Lower	Upper
RETURN LOSS	Equal variance assumed	0.015	.049	.919	52	.036	2.01189	2.18992	-2.38250	6.40628
	Equal variances not assumed			.919	51.738	.036	2.01189	2.18992	-2.38303	6.40681
GAIN	Equal variance assumed		.000	1.155E+16	52	.000	2.57000	.00000	2.57000	2.57000
	Equal variances not assumed		.000	1.155E+16	26.000	.000	2.57000	.00000	2.57000	2.57000

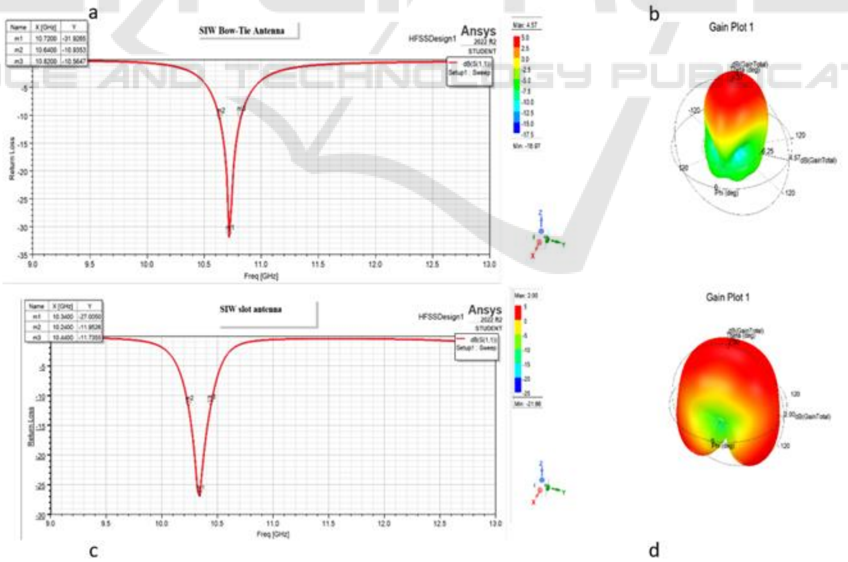

Figure 2: SIW Bow Tie antenna (a) Return loss (b) Gain; (c) & (d) is the Return loss and Gain for the SIW slot antenna.

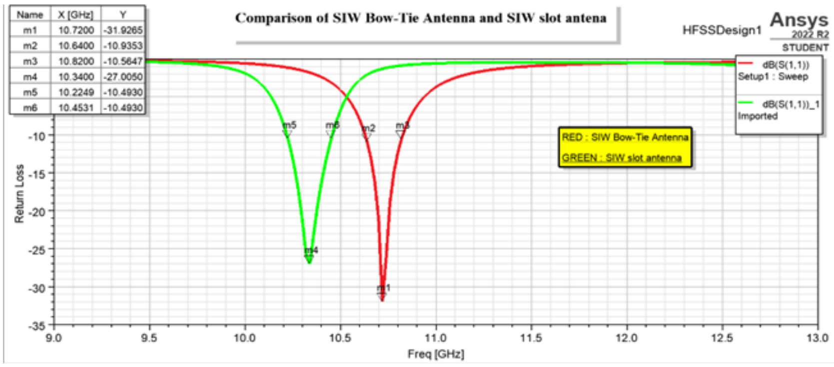

Figure 3: SIW Bow-Tie Antenna (-31.9265 dB) and SIW slot antenna (-27.0050 dB) comparison by its Return Loss performance.

4 CONCLUSION

This research looks at and improves the Return Loss and Gain of SIW Bow-Tie and SIW Slot antennas at 10 gigahertz. As an outcome, the suggestion was made SIW Bow-Tie antenna (Return Loss: -31.9265, Gain: 4.57) outperforms the SIW Slot antenna (Return Loss: -27.0050, Gain: 1.09). According to this, the SIW Bow-Tie antenna is best usable for X band network applications.

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