DESIGN OF A NOVEL RECTANGULAR CPW DUAL-BAND ANTENNA BY OPTIMIZING THE GAIN IN COMPARISON WITH THE W-SHAPED ANTENNA

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Article History: Received: 12.12.2022 **Revised:** 29.01.2023 **Accepted:** 15.03.2023

Abstract

Aim: - To design a novel rectangular CPW dual-band Antenna by optimizing the gain in comparison with the W-shaped antenna in Military applications.
Materials & Methods: - The no. of groups for the work are 2 and the no. of samples per group is 18. The total sample size is 36. Group 1 in this work is a novel rectangular CPW dual-band Antenna and Group 2 is the W-shaped Antenna. The sample size is calculated using the G-Power calculator in which the G-Power is 80 percent. The significant value of frequency is 0.007 and is 0.014 for gain ($p<0.05$) .
Results: - The rectangular Co-Planar Waveguide dual-band antenna is having a gain of 23 dB and the gain of the W-shaped antenna is 4.9 dB.
Conclusion: - In this work, the novel rectangular CPW dual-band antenna has a significantly better performance when compared to the W-shaped antenna.

Keywords: FR4 Epoxy, Novel Rectangular CPW Dual-Band Antenna, W-shaped Antenna, Frequency, Gain, Antenna design.

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1. Introduction

The subject of this work is about designing a novel rectangular CPW dual-band antenna (Li, Li, and Ye 2013; Yu 2011) by optimizing the gain in comparison with a W-shaped antenna (Choi and Sarabandi 2018) in the Military applications which is in the range of 0-15 GHz. In this work, by increasing the gain, the effective transmission power is going to have a raise which further improves the signal strength. In this work, FR4 Epoxy is used as the dielectric material. In FR4 Epoxy 'FR' stands for flame retardant. There are applications of antennas such as WLAN applications, Radar applications, Ultra-band applications, marine applications, and Wi-Max applications where cpw antenna is used.

There are several publications on co-planar waveguide antenna and W-shaped antenna in the last 5 years. In IEEE Xplore, there are about 20 publications. In google scholar, the no. of research articles published are 20. Bandwidth Enhancement of CPW-fed circle-like slot antenna with dual band-notched characteristics (Emadian et al. 2012). A dual-band CPW-fed inductive slot monopole hybrid antenna (Lin and Yu 2008). A compact-planar and CPW-fed metamaterials inspired a dual-band antenna (Si, Zhu, and Sun 2013). The best-cited work is "A compact-planar and CPW-fed metamaterials inspired dual-band antenna. "

Our institution is keen on working on latest research trends and has extensive knowledge and research experience which resulted in quality publications (Rinesh et al. 2022; Sundararaman et al. 2022; Mohanavel et al. 2022; Ram et al. 2022; Dinesh Kumar et al. 2022; Vijayalakshmi et al. 2022; Sudhan et al. 2022; J. A. Kumar et al. 2022; Sathish et al. 2022; Mahesh et al. 2022; Yaashikaa et al. 2022). The existing W-shaped antenna has less gain and is considered as the main drawback of the system. The proposed novel rectangular CPW dual-band Antenna has a relatively high gain compared to the existing square antenna for radar applications.

2. Materials and Methods

The research is carried out in the Department of Electronics and Communication Engineering, Saveetha School of Engineering, Chennai. The total no. of groups in this work is 2. The no. of samples per group is 18. The total sample size is 36. Group 1 is a novel rectangular CPW dual-band antenna and Group 2 is a W-shaped antenna. The Sample-size is calculated using 80% G-power (Yan and Zhang 2022).

The software tools which are used in this work are HFSS version.15 and SPSS software. The HFSS antenna design software is used to design, analyze and simulate. The SPSS tool is utilized to analyze the results and give the desired graph.

In the HFSS tool, the antenna is designed with the length, width, and height dimensions of the ground, patch, and substrate with FR4 Epoxy of the antenna. The design is analyzed by giving the solution setup and give the frequency sweep. The results will be shown in HFSS. This procedure will be done for both the sample groups. The produced results in HFSS are compared in the SPSS software.

CPW Dual-Band Antenna

The novel rectangular CPW dual-band antenna (Si, Zhu, and Sun 2013; Kirtania et al. 2021; P. Kumar, Urooj, and Alrowais 2020; Abdulkarim et al. 2019; de Cos Gómez et al. 2019) is designed with the data available in the existing system and is executed using HfSS antenna design software, the simulation of the antenna, execution, and analysis of the required parameters are done. The design of the novel rectangular CPW dual-band antenna has a substrate with FR4 Epoxy, which is ungrounded CPW. The substrate which has FR4 Epoxy dielectric material has the dimensions 15mm,20mm,1.6mm. The patch dimensions are 1.5mm,-3.5mm on the X-Y plane. The dimensions of the antenna are obtained by some basic formulas which are represented here. The antenna dimensions are wavelength dependent. This can be determined from Equation 1.

$$\lambda g = \lambda / f\sqrt{\varepsilon eff} \quad \ldots(1)$$

Where,

$\lambda = c/f$

$\varepsilon eff \approx (\varepsilon r + 1)/2$

$\varepsilon eff =$ effective constant;

The software tools which are used in this work are the HFSS version.15 (Cendes 2016) (Satheesh et al. 2008)and SPSS software (Pallant 2020a; Tausendpfund 2019; McCormick and Salcedo 2017). The HFSS antenna design software is used to design, analyze and simulate. The SPSS tool is

used to compare the results and give the desired graph.
In the HFSS tool, The antenna is designed with the length, width, and height dimensions of the ground, patch, and substrate with FR4 Epoxy of the antenna. The design needs to be analyzed by giving the solution setup and giving the frequency sweep.

Statistical Analysis
The statistical analysis of this work was performed using the IBM SPSS statistical tool(Cleophas and Zwinderman 2010; Pallant 2020b). The independent samples t-test was performed for the dependent variables and independent variables. In this research, frequency and dielectric constant are independent variables since they both are inputs and cannot be changed. Gain is a dependent variable because it is dependent on the input. Analysis for the gain of the novel rectangular CPW dual-band antenna was done using the HFSS antenna design software.

3. Results

The performance of the novel rectangular Coplanar waveguide (CPW) dual-band antenna and the W-shaped antenna is investigated. Table 1. gives the comparison values of Gain between novel rectangular CPW dual-band antenna and W-shaped antenna. The mean Gain of the novel rectangular CPW dual-band antenna is 9.7472 and the W-shaped antenna is -7.8961. The mean frequency of the novel rectangular CPW dual-band antenna and the W-shaped antenna is 7.8056.
From Table 2. we see that the significant value of frequency is 0.007 and is 0.014 for gain. The mean difference of Frequency is 0.00000 and the mean difference of the gain is 17.64333. The Std. Error Difference of frequency is 1.59158 and the Std. Error Difference of the gain is 1.79540.
Figure. 1. represents the design of CPW dual-band antenna with the substrate length of 15mm, the width of 20mm, and the height of 1.6mm. The substrate dielectric material is FR4 Epoxy. The Gain of the novel rectangular coplanar waveguide (CPW) dual-band antenna is shown in Fig.2. The results shown in Fig. 3. can be obtained with the help of SPSS software. The gain values of the antenna are calculated. The bar graph represents the performance of the antenna by varying the frequency. The bar graphs are comparing the mean of gain (+/-2 SD). The X-axis has Groups that contain the antennas named CPW and W-shaped and the Y-axis contains Mean gain. The value of the Standard deviation is (+/-2 SD).

4. Discussions

In this analysis, the independent sample t-test is done for a novel rectangular CPW dual-band antenna in comparison to the W-shaped antenna. From the simulation curve, it has been observed that the proposed novel rectangular CPW dual-band antenna has a gain of 23 dB at 5 GHz, which is better than the W-shaped antenna.
The proposed antenna novel rectangular CPW dual-band antenna is used for military applications. In (Mantash et al. 2010) the gain is between 2 dB to 4 dB at 5 GHz whereas in the proposed antenna the gain is 23 dB at 5 GHz. In (Pandit and Harish 2016) it has a directional radiation pattern with peak gains of 6.64 dB, 7.84 dB at 2.4 GHz and 5.5 GHz respectively. In (Kovacs 2007) the obtained gain is 10 dB at 4 GHz for a microstrip antenna. Microwave antennas waves have distinct advantages over other military solutions. Using the Ansoft HFSS antenna design software version 15.0, the schematic antenna design of a novel rectangular CPW dual-band antenna is done with the dimensions of 15mm length, 20mm width, and 1.6mm height. The gain of novel rectangular CPW dual-band antenna i.e. 23 dB at 5 GHz. From the analysis of antenna in the HFSS antenna design software, it is observed that the novel rectangular CPW dual-band antenna is better in terms of Gain than the W-shaped antenna.
The proposed method focused on the optimization of gain by comparing two separate antennas named novel rectangular CPW dual-band antenna and W-shaped antenna. The limitation of the novel rectangular CPW dual dual-band antenna is its thick substrates. In future work, the gain can be optimized furthermore to improve the performance of the antenna.

5. Conclusion

In this work, the novel rectangular CPW dual-band antenna has been proposed and designed using HFSS antenna design software. The gain of the novel rectangular CPW dual-band antenna is 23 dB at the frequency of 5 GHz and the gain of the W-shaped antenna is -4.9 dB at the frequency of 5 GHz. The proposed antenna has significantly better performance ($p<0.05$) than the W-shaped antenna.

Declarations
Conflicts of interests
No conflict of interest in this Manuscript.

Author contribution
Author UV was involved in data collection, data analysis, and manuscript writing. Author MS was involved in conceptualization, data validation, and critical review of manuscripts.

Acknowledgment
The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical

Sciences(Formerly known as Saveetha University) for providing the necessary infrastructure to carry out this work successfully.

Funding

We thank the following organizations for providing financial support that enabled us to complete the work.

1. QBEC INFOSOL Pvt. Ltd.
2. Saveetha university
3. Saveetha Institute of Medical and Technical Sciences.
4. Saveetha School of Engineering.

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Tables and Figures

Table 1. The comparison values of Gain between novel rectangular CPW dual-band antenna and W-shaped antenna. The mean Gain of the novel rectangular CPW dual-band antenna is 9.7472 and the W-shaped antenna is -7.8961. The mean frequency of the novel rectangular CPW dual-band antenna and the W-shaped antenna is 7.8056.

	GROUP	N	Mean	Std. Deviation	Std. Error Mean
FREQUENCY	CPW	18	7.8056	4.77475	1.12542
	W-SHAPED	18	7.8056	4.77475	1.12542
GAIN	CPW	18	9.7472	6.86743	1.61867
	W-SHAPED	18	-7.8961	3.29554	0.77677

Table 2. The values of Leven's Test for Equality of Variances are 0.000 and 0.007 for frequency. The values of Leven's Test for Equality of Variances are 6.676 and 0.014 for the gain. The mean difference of Frequency is 0.00000 and the mean difference of the gain is 17.64333. The Std. Error Difference of frequency is 1.59158 and the Std. Error Difference of the gain is 1.79540.

Independent Samples test										
		Levene's Test Equality of Variances		t-test for Equality of Means						
		F	Sig	t	df	Sig. (2-tailed)Mean difference	Mean Difference	Std. Error Difference	95% Confidence interval of the Difference	
									Lower	Upper
Frequency	Equal variances assumed	0.000	0.007	0.000	34	1.000	0.00000	1.59158	-3.23448	3.23448
	Equal variances not assumed			0.000	34.000	1.000	0.00000	1.59158	-3.23448	3.23448
Gain	Equal variances assumed	6.676	0.014	9.827	34	0.000	17.64333	1.79540	13.99465	21.29202
	Equal variance			9.827	24.435	0.000	17.64333	1.79540	13.94131	21.34536

	s not assumed									

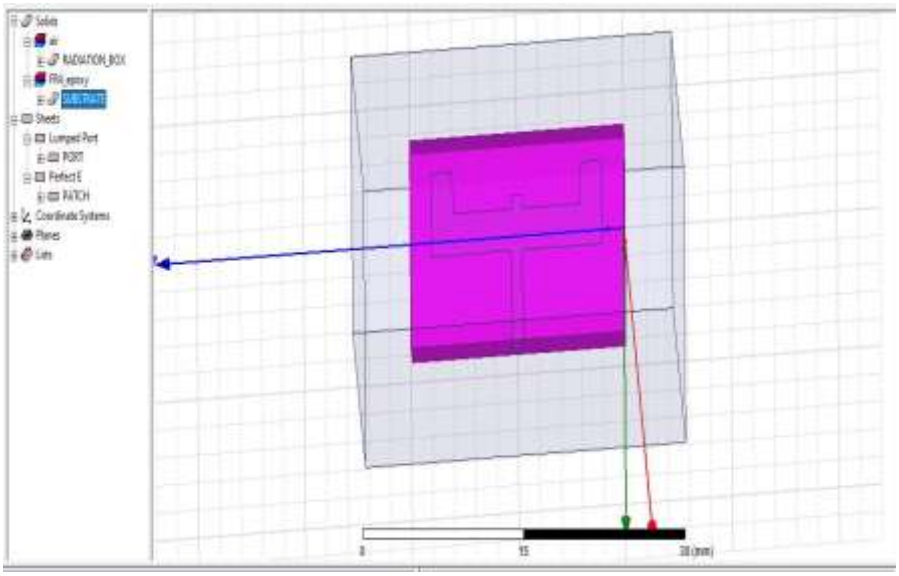

Fig. 1. The novel rectangular CPW dual-band antenna design with a substrate length of 15mm, a width of 20mm, and a height of 1.6mm. The substrate dielectric material is FR4 Epoxy.

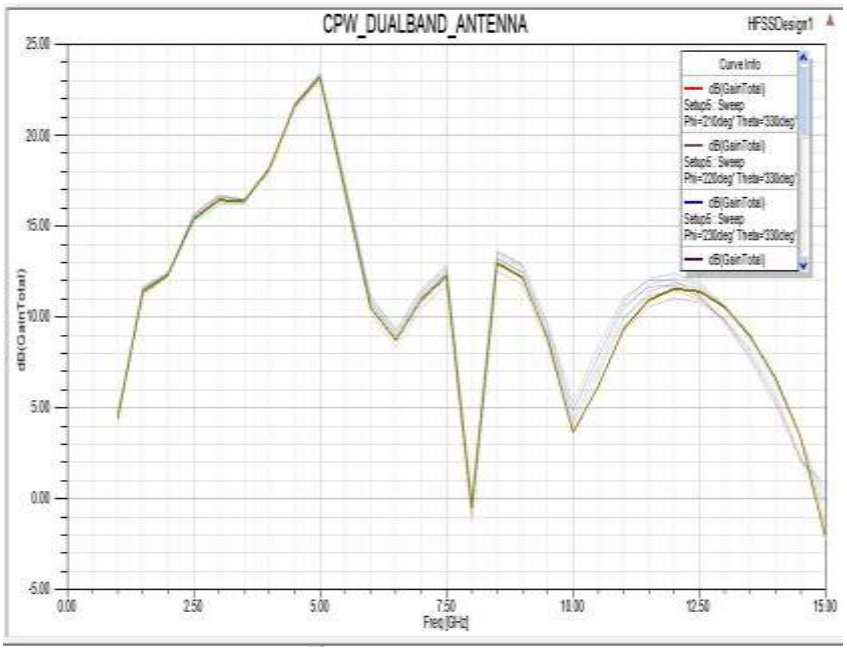

Fig. 2. The X-axis is the Frequency and the Y-axis is the Gain of the novel rectangular CPW dual-band antenna. It resonates at two frequencies 6.5 GHz and 10 GHz with the Gain of 9 dB and 4 dB respectively.

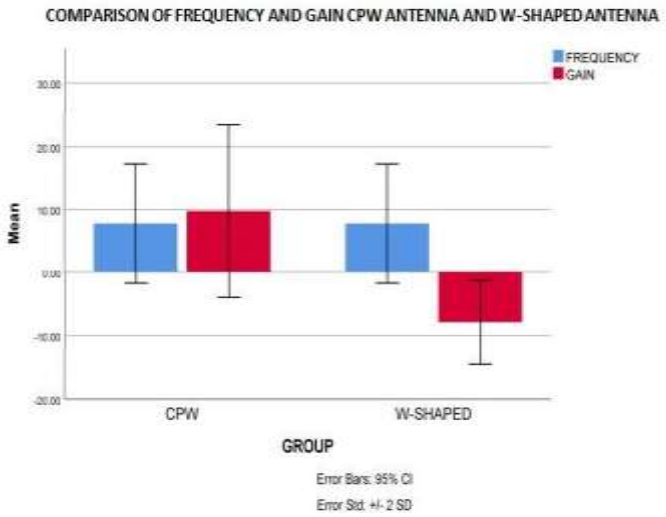

Fig. 3. The Bargraph of the comparison of Mean gain and frequency of novel rectangular CPW dual-band antenna and W-shaped antenna. The X-axis has Groups that contain the antennas named CPW and W-shaped and the Y-axis contains Mean frequency and gain. The value of Standard deviation is (+/-2 SD).