GAIN ENHANCEMENT IN DOUBLE C-SHAPED SLOT MULTIPLE INPUT MULTIPLE OUTPUT ANTENNA COMPARING WITH SINGLE C-SLOTTED ANTENNA FOR ULTRA WIDEBAND APPLICATIONS

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ABSTRACT:

Aim: The main aim of this work is to design a double C-shaped slot Multiple Input Multiple Output Antenna using FR4 epoxy substrate at a frequency range of 2.5 GHz to 8 GHz to improve the gain (dB) in comparison with the single C-shaped slot Multiple Input Multiple Output antenna. Materials and Methods: The gain and frequency of double C-shaped slot Multiple Input Multiple Output antenna (Group 1 Sample size n = 10) was compared with the gain and frequency of single slotted antenna (Group 2 Sample size n = 10) in frequency range of 2.5 GHz to 8 GHz range. The G power value is 80% and threshold is 0.05% with the confidence interval of 95%.

Results: The double C-shaped slot Multiple Input Multiple Output Antenna has significantly higher gain 9.653 dB than the single C-shaped slot antenna having gain 6.092 dB. The optimal frequency for maximum gain in double C-shaped slot Multiple Input Multiple Output Antenna was at 4.5 GHz and for single C-shaped slot antenna the maximum gain was at a frequency range at 6.4 GHz. The significance value is 0.046 (p<0.05).

Conclusion: Within the limits of the novel antenna design the double C - shaped slot MIMO Antenna has the better enhancement of gain at 8 GHz range.

KEYWORDS: Gain, Multiple Input Multiple Output Antenna, wireless communication, High Frequency Structure Simulator, C-shaped slot, Ultra Wideband applications, FR4 epoxy substrate, Novel antenna design.

1. INTRODUCTION:

The Multiple Input Multiple Output Antenna was used rapidly in the recent technology for various wireless standards. The double slot reconfigurable Multiple Input Multiple Output antenna having the planar structure based on microstripfeedline was designed in the frequency range of 1.3 GHz to 2.6 GHz to enhance the isolation upto 12 dB for wireless communication and Ultra Wideband applications to enhance the gain and bandwidth (Zhao and Riaz 2018). The design and analysis of Multiple Input Multiple Output antenna was designed on FR4 epoxy substrate having 1.6 mm thickness consists of four identical rectangular elements with 4.1 GHz and 5.3 GHz frequencies for obtaining the bandwidth upto 200 MHz to 450 MHz for next generation wireless communication networks (Shiddanagouda, Vani, and Hunagund 2018). The proposed antenna was designed with four element dual band antenna with a frequency range of 6 GHz using microstrip - fed square slot 5G MIMO antenna and is used for wide range applications with very low latency and high speed delivers for enhancing the gain (Sarkar and Srivastava 2018). The Multiple Input Multiple Output Antenna was designed using the dual band frequency reconfigurable patch - slot based on a reconfigurable microstripfeedline having the frequency range of 1.3 GHz to 2.6 GHz for Ultra Wideband applications (Zhao and Riaz 2018).

The articles published related to this work are more than 110 journals in Google Scholar and around 25 journals in IEEE. The Multiple Input Multiple Output novel antenna design of dual band coplanar waveguide fed slot antenna operating at 5G frequency band at 28 GHz to 38 GHz range using High Frequency Structure Simulator for return loss and gain with better results (Omar et al. 2021). The dual band slot antenna for wireless
applications with circular polarization operating at a frequency range of 2 GHz to 4.8 GHz to obtain a gain of 5 dB to 6 dB using the FR4 epoxy substrate along with the Rogers5800 Substrate having the isolation (> 11 dB) and having the total efficiency (> 52 %) (Pirooj et al. 2017). The Multiple Input Multiple Output antenna using pentagon slot resonator to enhance the bandwidth using 1.5 GHz to 2.4 GHz frequency range for obtaining the high bandwidth and isolation (-28 dB) mostly used for multimode applications such as GPS, Wi-Fi applications (Borakhade and Pokle 2018). The antenna proposed with a multiband monopole multiple input multiple output antenna containing a C-shaped slot with ground plane containing double U- slots which acts a indicator for altering the antenna characteristics similar to that of the short circuit transmission line (Priya et al. 2014). Dual C-slot MIMO antenna containing the microstrip patch for multiband wireless applications along with Mobile network and Ultra Wideband applications using the Rogers5800 substrate having the frequency range of 3.3 GHz to 21.3 GHz to enhance the gain and directivity (Gupta, Shanmuganantham, and Kiruthika 2017). Our team has extensive knowledge and research experience that has translate into high quality publications (Patturaja and Pradeep 2016; Ramesh Kumar et al. 2011; Krishnan, Pandian, and Kumar S 2015; Felicita 2017b, [a] 2017; Kumar 2017; Sivamurthy and Sundari 2016; Sathivel et al. 2008; Sekar et al. 2019) Based on the existing research analysis it is important to know that the optimization of gain in the antenna is an important parameter that needs to be taken into consideration while designing an antenna. Comparison of double C-shaped slot and single C-shaped slot Multiple Input Multiple Output antenna was carried out to explore the characteristics of antenna parameters for Ultra Wideband applications and wireless communication networks. Hence, the main aim of this study is to enhance the gain in double C-shaped slot Multiple Input Multiple Output antennas as compared with the single C-shaped slot antenna for Ultra Wideband applications.

2. MATERIALS AND METHODS:

This study was conducted at Antenna and wave propagation lab, Departments of Electronics and Communication Engineering, Saveetha School of Engineering, Saveetha Institute of Medical And Technical Sciences. This study was based on the novel antenna design in gain enhancement of Multiple Input Multiple Output antenna using Double C-shaped slot in comparison with Single C-shaped slot MIMO antenna. The sample size was calculated by using previous study results (Rao et al. 2019). Present analysis was carried out by using the clinicalcalc.com by keeping the G - power at 80% threshold at 0.05% confidence interval at 95%. Sample size of each group is 10 and total sample size is 20. Ansoft High Frequency Structure Simulator is a tool for designing high frequency antennas (Omar et al. 2021)

In the current research there are two groups in designing a novel antenna. Group 1 refers to a single C-shaped slot antenna with 10 samples. The antenna can be constructed by defining the variables (Length, Width, Height, Frequency) and assigning the boundaries and lumped ports of the antenna.

Group 2 refers to a double C-shaped slot MIMO antenna with 10 samples. The antenna is designed at a frequency range of 2.5 GHz to 8 GHz and is used as the testing input. The antenna can be constructed by defining the variables (Length, Width, Height, Frequency) and assigning the boundaries and lumped ports of the antenna.

C-Shaped Slot Mimo Antenna Design

In the novel antenna design of C - shaped slot Multiple Input Multiple Output antenna using FR4 epoxy dielectric Substrate with a frequency range of 2.5 GHz to 8 GHz is created at first and then in between the substrate two C-shaped slots are inserted with specific dimensions of length (L), width (W) and height (H) were analysed based on the frequency range. The dimensions of the patch are designed using the below given Equation. (1) and Equation. (2).

Length (L) of the patch is used in the novel antenna design based on the multiple input and multiple output was calculated using the following Equation. (1) based on the frequency (Fr) and lambda (λο).

\[ \lambda_o = \frac{c_0}{F_r} \]  \hspace{1cm} [1]

\[ l = \frac{\lambda_o}{2} \]  \hspace{1cm} [2]

Where c0 is the velocity of light in free space, Fr is the operating frequency, λo is the wavelength and L is the length of the patch. Similarly, the width (W) of the patch can be calculated by using the below Equation. (3).
where \( c_0 \) is the velocity of light in free space, \( Fr \) is the frequency and \( \varepsilon_r \) is the dielectric constant of the substrate. Similarly, the height \( (h) \) of the substrate will be in the range of 1.2 mm to 1.6 mm thickness based on the shape of the C-slot used for novel antenna design of MIMO antenna in enhancing the gain.

The novel antenna design of Multiple Input Multiple Output C-shaped slot dual band is based on the resonating fed microstrip patch antenna for 5G network and WIMAX applications having the frequency range of about 3.5 GHz (Li et al. 2020). Ground was designed to dielectric substrate and assigned with perfect E-Plane. Source was created and assigned with a lumped port. Radiation boundaries, Operating Frequency and frequency sweep were assigned for developing a novel antenna structure. Save the model and validate it. Performance of double C-shaped slot and single C-shaped slot antenna were analysed by calculating antenna parameters such as gain and return loss. The multiple input multiple output antenna dimensions are adjusted along with frequency ranges in the design to enhance the gain with high data rate (2 Mbps), low profile and low data loss for Ultra Wideband applications used in wireless communication networks.

Ansoft High Frequency Structure Simulator (HFSS) is a simulation tool for designing high frequency antennas. The testing setup is used to design the MIMO antenna in Ansoft High Frequency Structure Simulator (HFSS). The system configuration used to set up the testing procedure in intel core i3 gen processor. The novel antenna is designed at a frequency range of 2.5 GHz to 8 GHz and is used as the testing input. The antenna can be constructed by defining the variables \( (l, w, h, f) \) and assigning the boundaries and lumped ports of the antenna using High Frequency Structure Simulator software (HFSS). The frequency sweep is applied to the configuration, after which the antenna is validated to determine the errors, and the antenna is simulated to determine the gain (dB).

**Statiscal Analysis**

SPSS version 21 was used for statistical analysis of collected data for parameters by gain (dB) and frequency (GHz) (Raeva, Mihova, and Nikolaev 2019). The independent sample t-test and group statistics are calculated using the SPSS software. The length \( (L) \) of the substrate, width \( (W) \) of the substrate and height \( (H) \) of the antenna are independent variables, while gain (dB) and frequency (GHz) are dependent variables (Ibrahim 2019).

### 3. RESULTS

The results of MIMO antenna design with a double C-shaped slot are plotted. Frequency is assigned to the modelled MIMO antenna double C-shaped slot antenna and single C-shaped slot antenna using FR4 epoxy substrate. Corresponding changes in gain due to frequency range of 2.5 GHz to 8 GHz were measured. Based on frequency, the design of a single C-shaped slot antenna to calculate the gain is shown in Fig. 1. Similarly, the design of a double C-shaped slot MIMO antenna using FR4 epoxy substrate is shown in Fig. 2. The design corresponding to gain values of single C-shaped slot antenna and double C-shaped slot MIMO antenna using FR4 epoxy substrate are calculated and tabulated Table 1. It has been observed that the gain Vs frequency graph is plotted and the maximum gain for MIMO antenna using double C-shaped slot is at 4.5 GHz range. It has also been observed that the gain Vs frequency graph is plotted and it is shown in Fig. 3 as the maximum gain for MIMO antenna using single C-shaped slot is at 6.4 GHz. Comparison graph of gain in single C-shaped slot MIMO antenna and double C-shaped slot MIMO antenna is shown in Fig. 4.

The gain of single C-shaped slot MIMO antenna is constant with small variation whereas double C-shaped slot MIMO antenna is proportional to frequency. The t-test comparison of gain in both single C-shaped slot and double C-shaped slot MIMO antenna using FR4 epoxy substrate is tabulated in Table 2. Single C-shaped slot MIMO antenna has highest gain of 6.092 dB and double C shaped slot MIMO antenna has a high gain of 9.653 dB. The mean, standard deviation and significant difference of gain in single C-shaped slot and double C-shaped slot MIMO antenna is tabulated in Table 3 which shows there is a significant difference between two groups \( p<0.05 \) (Independent Sample t-test). When compared with the performance of the proposed MIMO antenna with a double C-shaped slot is achieved better gain (dB) of performance than MIMO antenna with single C-shaped slot.

### 4. DISCUSSION

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Double C-shaped slot MIMO antenna has more gain as compared to single C-shaped slot MIMO antenna using FR4 epoxy substrate as a dielectric in the frequency range of 2.5 GHz to 8 GHz using independent sample t-test (Bambarkar and Kulkarni 2017). The MIMO antenna is designed using a rectangular patch with FR4 epoxy dielectric substrate at a frequency range of 2.83 GHz to 10.18 GHz to enhance the gain (dB) with high data rate and low data loss. The results obtained in the current research are having higher gain as compared to the previous studies.

The total gain obtained for MIMO antenna with double C-shaped slot is 8 dB and for MIMO antenna with single C-shaped slot is 3 dB. Gain improvement of 5 dB is achieved. The proposed antenna values of gain appear to be better compared to the MIMO antenna with a single C-shaped slot in which the gain is 0 dB to 3 dB. (Kadir 2017) proposed Multiple Input Multiple Output antenna design the C-shaped slot at a frequency range of 2.5 GHz to 8 GHz for enhancing the gain up to 10.053 dB can be used in ultra wideband applications and wireless communication networks. In the future, the MIMO antenna gain can be compared with the microstrip antenna having parameters like gain and bandwidth. The various factors like thickness of the substrate, impedance matching and antenna dimensions such as length of the substrate, width and height of the antenna affect the performance of the antenna. (Wang et al. 2017) Gain can be replaced by maximizing the substrate dimensions between the ground and radiating patch. Spacing between the slots also influences the gain obtained by the antenna. (El Misilmani and El-Hajj 2017) designed MIMO antenna using a millimeter wave design for 5G communication at 38 GHz band for obtaining the peak gain value of >8 dBi with the increased network flexibility and efficiency used in wireless communication networks.

In the current study, the height of the dielectric substrate is constant (1.3 mm) which can be changed up to 5 mm and in analysing the characteristics of the antenna. The current study was carried out only in the frequency range of 2.5 GHz to 8 GHz (Kahng et al. 2017). The gain of MIMO antenna can be enhanced more by designing with various shapes of slots like L-shape, C-shape and U-shape on patch by using different dielectric substrate materials based on various frequency ranges to identify the antenna performance. (Moradi et al. 2017) The MIMO antenna with double C-shaped slot structure has better isolation than -15.4 dB for the low band and -20 dB for the high band. As the self-isolated multiple input multiple output antenna utilizes ground elements in enhancing the isolation and gain of the antenna, they can obtain a better gain of 18 dBi (Sharawi, Ikram, and Shamim 2017).

The limitations of this work is the time taken for executing the novel antenna design will be more because in the substrate design the presence of radiation boxes in the simulation environment. The design of the Multiple Input Multiple Output antenna using the FR4 epoxy dielectric substrate will have more complexity in design because of the shape of the slot. The proposed work includes the C-slot MIMO antenna designed at frequency of 2.5 GHz to 8 GHz to enhance the gain. In further studies, the antenna can be designed with innovative techniques which can be used for WIMAX applications and in medical applications with multiple shapes of the substrate slots.

5. CONCLUSION

The novel antenna design includes the Multiple Input Multiple Output with C-shaped slot at a frequency range of 2.5 GHz to 8 GHz to enhance the gain of 10.053 dB. The double C-shaped slot MIMO antenna offers better gain of 10.053 dB as compared with the single C-shaped slot having 4.892 dB. The standard deviation obtained for the single C-shaped slot Multiple Input Multiple Output antenna was 0.684 and the standard deviation obtained for the double C-shaped slot was 0.0167.

6. DECLARATIONS

Conflicts of Interests
No Conflict of interest in this manuscript.

Author Contribution
Author GM was involved in the data collection, data analysis, and manuscript writing. Author PK was involved in Conceptualization, guidance and critical review of manuscript.

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2. Saveetha University
3. Saveetha Institute of Medical and Technical Sciences.
4. Saveetha School of Engineering.

7. REFERENCES


**TABLES AND FIGURES**

**Table 1** Data collection of Gain in Single C - shaped slot Multiple Input Multiple Output antenna and Double C - shaped slot Multiple Input Multiple Output antenna using FR4 Epoxy substrate at the frequency range of 2.5 GHz to 8 GHz. For Single C- shaped slot MIMO antenna, the Gain is varying from 2.0019 to 6.092. Double C- shaped slot MIMO antenna with FR4 substrate the Gain is varying from 2.0791 to 9.653. Frequency range is 2.5 GHz - 8 GHz.

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Single C - shaped slot MIMO Antenna (dB)</th>
<th>Double C - shaped slot MIMO Antenna (dB)</th>
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<table>
<thead>
<tr>
<th>Gain</th>
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<th>N</th>
<th>Mean</th>
<th>Std.deviation</th>
<th>Std.Error Mean</th>
</tr>
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<tbody>
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<td></td>
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<td>1.802</td>
<td>0.6845</td>
<td>0.318</td>
</tr>
</tbody>
</table>

Table 2 Comparative means of Single C - shaped slot MIMO antenna and Double C - shaped slot MIMO antenna using FR4 Epoxy substrate. Single C - shaped slot MIMO antenna has mean gain (dB). Double C - shaped slot MIMO antenna with FR4 Epoxy Substrate has mean gain (dB). The mean and standard deviation for Single C - shaped slot and Double C - shaped slot are 1.802, 0.6845 and 2.8913, 0.067.
Table 3 Comparison of gain in single C-shaped slot MIMO antenna and Double C-shaped slot MIMO antenna. There is a statistical significant difference in Gain of single C-shaped slot and double C-shaped slot MIMO antennas. In the t-test, the observed significance value is 0.046. (p<0.05)

<table>
<thead>
<tr>
<th></th>
<th>Gain</th>
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<tbody>
<tr>
<td>Leven’s test for equality of variance</td>
<td>t - test for Equality of Means</td>
</tr>
<tr>
<td>F</td>
<td>Sig</td>
</tr>
<tr>
<td>Equal Variances assumed</td>
<td>30.4</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
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</table>

Fig. 1. Representative Model of the Single C-shaped slot Multiple Input Multiple Output antenna using the HFSS tool at a frequency range of 2.5 GHz to 8 GHz. The antenna is defined by constructing the variables of Length (L) in X-axis, Height (H) in Y-axis and Width (W) in Z-axis.
Fig. 2. Representative Model of the Double C - shaped slot Multiple Input Multiple Output antenna using the HFSS tool at a frequency range of 2.5 GHz to 8 GHz. The antenna is defined by constructing the variables Length (L) in X - axis, Height (H) in Y - axis and Width (W) in Z - axis.

Fig. 3. The gain in the Double C - shaped slot Multiple Input Multiple Output antenna using High Frequency Structure Simulator (HFSS) a) 2.5 GHz b) 4 GHz c) 5.8 GHz d) 8GHz. Red curve represents the Gain and it will vary according to frequency ranges. Red curve represents the Gain and it will vary according to frequency ranges.
ranges. From this, it is inferred that for the Double C - shaped slot MIMO antenna, the Gain Vs Frequency plot is almost the same for the frequencies 2.5 GHz, 4 GHz, 5.8 GHz, 8 GHz and the gain varies drastically at the frequency of 8 GHz.

Fig. 4. Comparison graph of gain in both Single C - shaped slot and Double C - shaped slot Multiple Input Multiple Output antenna using FR4 Epoxy dielectric Substrate. The gain of the Single C- shaped slot Multiple Input Multiple Output antenna is ranging from 2.0019 dB to 6.092 dB. The gain of the Double C - Shaped slot Multiple Input Multiple Output antenna is ranging from 2.0791 dB to 9.653 dB. Hence, the Double C - shaped slot Multiple Input Multiple Output antenna offers better performance than Single C - shaped slot Multiple Input Multiple Output antenna.

Fig. 5. Bar graph represents the comparison of mean gain of the Single C - shaped slot Multiple Input Multiple Output antenna and the Double C - shaped slot Multiple Input Multiple Output antenna. The Mean Gain of Double C - shaped slot Multiple Input Multiple Output antenna is better than the Single C - shaped slot MIMO antenna. X-Axis: Double C - shaped slot MIMO antenna vs Single C - shaped slot MIMO antenna. Y- Axis: Mean deviation is ± SD.

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