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Developing and Verifying A 3.5ghz Smart Antenna for Wideband 5G Communication

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Abstract: Nowadays, 5G technology plays a crucial role in various aspects of human life, such as communication, business, education, and transportation. The 5G technology utilizes frequency bandwidths that can be categorized into low, medium, and high bandwidths. This study aims to design a 3.5GHz smart antenna using FR-4 substrate and microstrip feeding line for wideband 5G communication in large open areas. The designed antenna is suitable for 5G applications in the 3.5GHz frequency range. The output of the fabrication is measured using a Vector Network Analyzer, which is connected to the microstrip feeding line through a subminiature version A connector. The FR-4 substrate used in this project has a dimension of 40mm x 32mm and a thickness of 1.6mm. Initially, the antenna is simulated using CST software, and then it is fabricated for measurement to validate the simulation result. The simulation result shows a return loss of -42.287dB and a VSWR of 1.016, which is approximately equal to 1.00 of the VSWR

Keywords: Smart antenna, 5G communication, wideband, 3.5GHz

1. Introduction

According to a study [1], Long Term Evolution (LTE) technology, commonly known as 4G, is widely utilized in various sectors but faces several challenges such as latency, frequency spectrum limitations, and data bandwidth constraints. In response to these technological limitations, the development and implementation of 5G technology have emerged, offering enhanced capacity, expanded coverage connectivity, improved energy efficiency, and reduced costs compared to 4G technology. However, one limitation of 5G technology is its shorter range [2]. Many countries have prioritized the allocation of wave propagation and bandwidth resources for 5G services, with China leading in the deployment of the highest frequency bandwidth for cellular and Internet of Things (IoT) applications [3]. The frequency bandwidth of 5G technology can be categorized into three main bands: low, medium, and high bandwidths, with each serving different purposes. To elaborate, the low frequency bandwidth of 5G, operating around 700 MHz, offers high download speeds similar to the frequency range of 4G. This band is commonly utilized in rural areas or villages. The medium frequency bandwidth of 5G, approximately 3.5 GHz, is typically employed in large open areas. Conversely, the high frequency bandwidth of 5G, around 26/28 GHz, is utilized in densely populated areas such as cities [4-6]. The objective of this project is to design a wideband 3.5 GHz antenna for 5G communication. Various

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antenna structures, including low-profile wideband antennas, compact wideband circularly polarized antenna arrays, wideband MIMO antennas, and meta-material-based antennas, will be explored. The design of the wideband antenna will be facilitated using the CST Studio Suite software, a powerful electromagnetic and multi-physics simulation software known for its accessibility and user-friendly components [7, 12-15]. By utilizing a 3.5 GHz antenna for wideband 5G communication, several advantages can be achieved, including increased capacity, improved coverage, reduced power consumption, and enhanced security [4]. The main objectives of this project are as follows: first, to design and develop a 3.5 GHz smart antenna that fulfills the performance standards of a wideband 5G communication system; second, to evaluate the performance of the designed 3.5 GHz smart antenna using the CST software tool; and third, to validate the simulated results by constructing the developed antenna and conducting real-world measurements. The research for this project focuses on investigating microstrip antennas suitable for 5G communication systems, specifically aiming to design and simulate a Multiple-Port Antenna (MPA) with a frequency range of 3.5 GHz for wideband 5G communication. The CST software will serve as the simulation tool for the design and analysis of the project antenna.

Table 1 - Summarization of literature review comparison

Ref	Project	F(GHz)	Area (mm^2)	BW (GHz)	Return loss
[8]	Millimeter Wave Microstrip Patch Antenna for 5G Mobile Communication	38,58	6x6	1.94	-12, -15.5
[9]	Design of 2.4GHz patch antenna for WLAN application	2.4	29.2x29.2	0.5	-39.008
[10]	Low return loss slotted rectangular microstrip patch antenna at 2.4GHz	2.4	52.31x62.04	0.16	-40
[11]	Bandwidth Enhanced Rectangular Patch Antenna Using Partial Ground Plane Method for WLAN Application	2.4	40x50	0.057	-41.38

Table 1 shows that the previous work researcher of designed the microstrip patch antenna. Microstrip patch antenna has been gaining great approach by research as it has the capability of compactness and low-cost fabrication in communication devices.

2. Methodology

There are 4 phases involved in this project. Fig. 1 shows the flowchart of the project in CST and fabrication work.

- Phase 1: Review research related literature review.
- Phase 2: Design a microstrip patch antenna for 5G application by using CST software.
- Phase 3: Fabrication and measurement carry out to validate simulated results.
- Phase 4: Write thesis report.

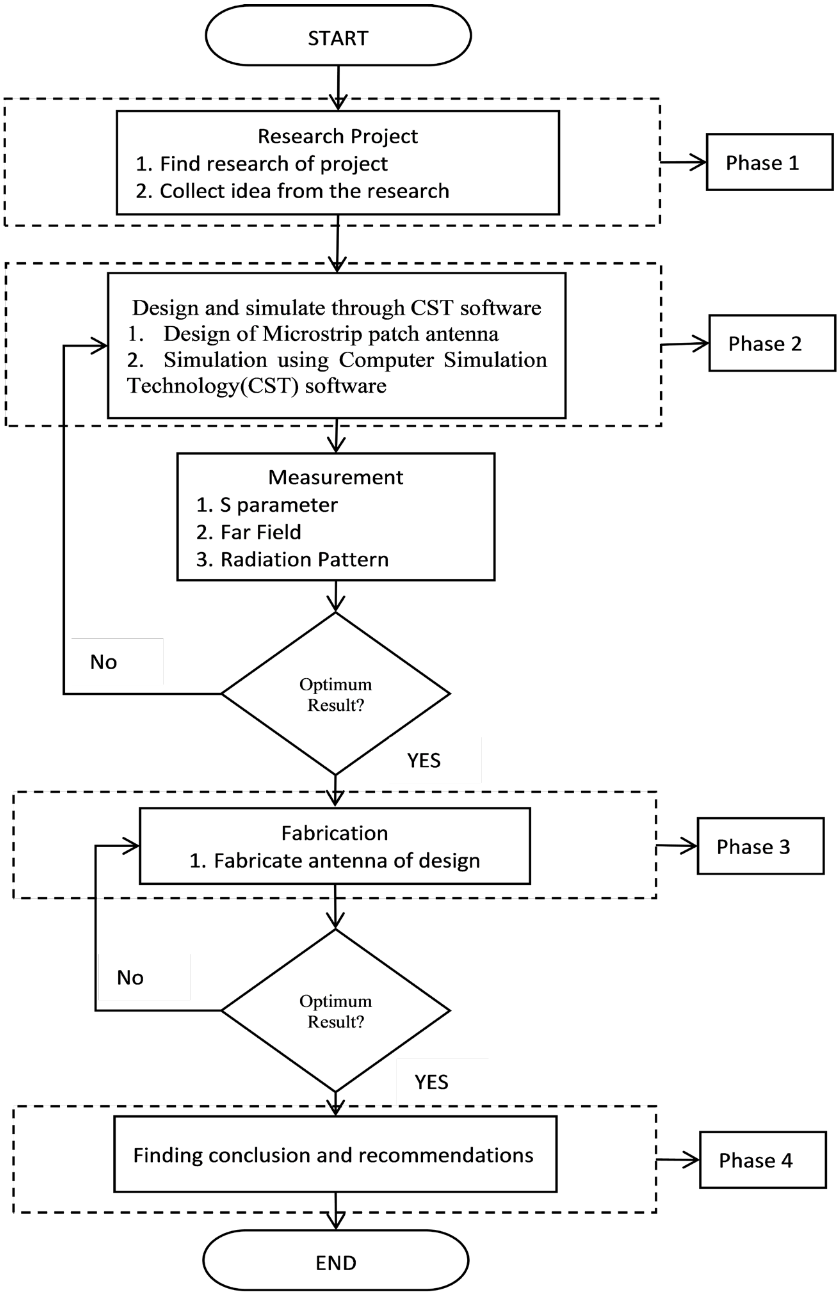
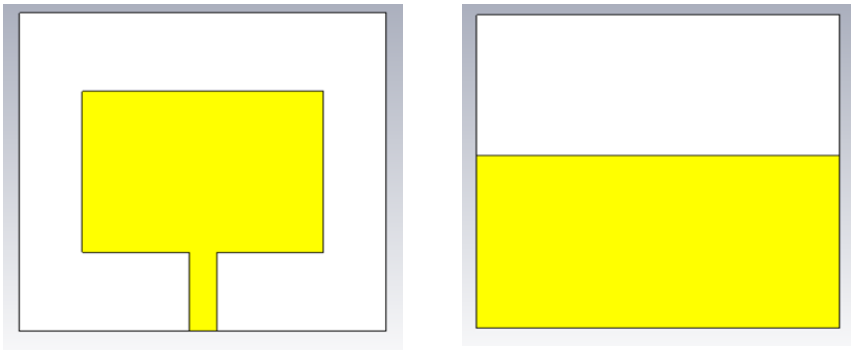


Fig. 1 - Flow chart of project

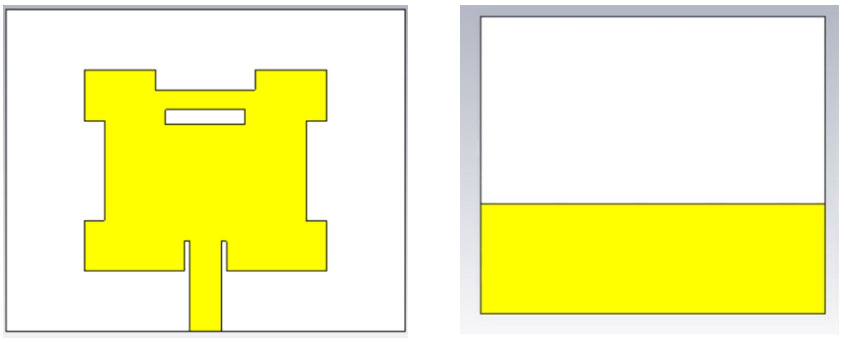
2.1 Simulation and Parametric Study

A dielectric material, FR-4 is used as antenna substrate. The dimension and properties of FR-4 is listed in table 2. A patch of copper is pasted at top of the FR-4 substrate. The ground plane of the antenna is partially covered by copper. This patch antenna consists of partial with other shape pattern ground, some slot made at the patch The patch is fed by a 50-ohm microstrip line. The resonant frequency for the patch is fixed at the frequency 3.5GHz. From the dimension and properties in Table 2, there are few steps to design proposed antenna and shows at the below. Initially, the design process will start with create a FR-4 substrate with dimension as in the Table 2. Then, create a partially ground which dimension is 56.2538x44.0332x0.035mm on the back of the substrate. A patch also created with dimension 52.6539x40.4330x0.035mm on the front of the substrate. After created patch at top, a dimension 3x24x0.035mm of microstrip feeding line is created. A port created and connected with the bottom faces so can be measured values. Fig. 2 shows proposed patch antenna and ground plane. The proposed antenna design was simulated by using CST and the results shows in Fig. 2 below.



Top view Botton view

Fig. 2 - Proposed patch antenna and ground plane



Top view Bottom view

Fig. 3 - Modified patch antenna and ground plane

Table 2 shows the parameter and dimension of modified antenna. There are some changes in dimension of substrate, ground, patch, feed line. Dimension of slots also recorded in Table 2.

Table 2 - Parameter and dimension of modified antenna

Parameter	Dimension of proposed antenna	Dimension of modified antenna	Description
w	40	40	Width of FR-4 substrate
l	40	32	Length of FR-4 substrate
h	1.6	1.6	Height of FR-4 substrate
gw	56.2538	40	Width of ground
gl	44.0332	24	Length of ground
gh	0.035	0.035	Height of ground
pw	52.539	24	Width of patch
pl	40.4330	20.3	Length of patch
ph	0.035	0.035	Height of patch
fw	3	3.2	Width of feed line
fl	24	24	Length of feed line
fh	0.035	0.035	Height of feed line
sw	-	5	Width of first slot
sl	-	4	Length of first slot
sw2	-	4	Width of second slot
sl2	-	5	Length of second slot
sw3	-	0.5	Width of third slot
sl3	-	3	Length of third slot
sw4	-	8	Width of fourth slot
sl4	-	1.5	Length of fourth slot

2.2 Fabrication Process

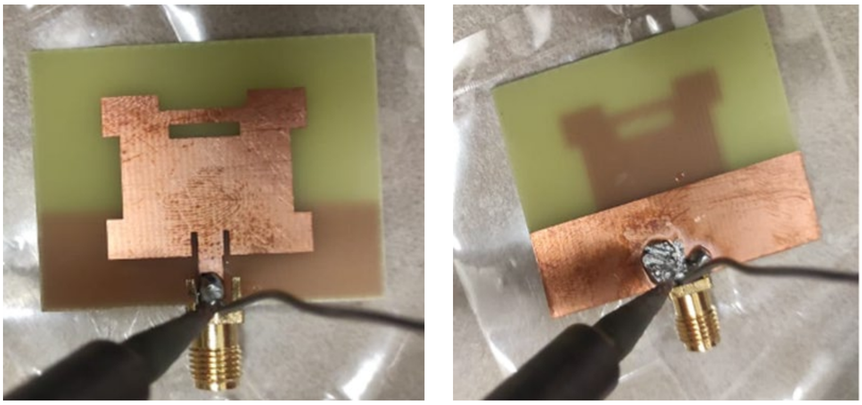


Fig. 4 - Modified antenna solder with subminiature version

Fig. 4 shows the modified antenna solder with subminiature version A (SMA) connector. The product connects with the SMA by soldering to carry out measurement. The measurement will carry out with connect between SMA connector and VNA to observe the result.

3. Result and Discussion

3.1 Simulation Result

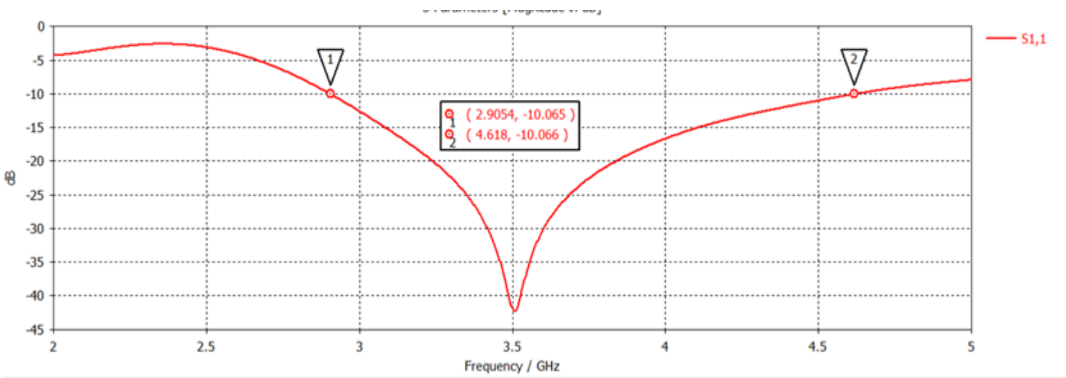


Fig. 5 - S11 parameter of modified antenna

Fig. 5 shows the s11 parameter of modified antenna. From Fig. 5 the above, the modified antenna achieves 3.5GHz as the project objective. Bandwidth of modified antenna is 1.713GHz and the return loss is -42.287dB. The frequency, bandwidth and return loss are similar with the objective of this project.

3.2 Measurement

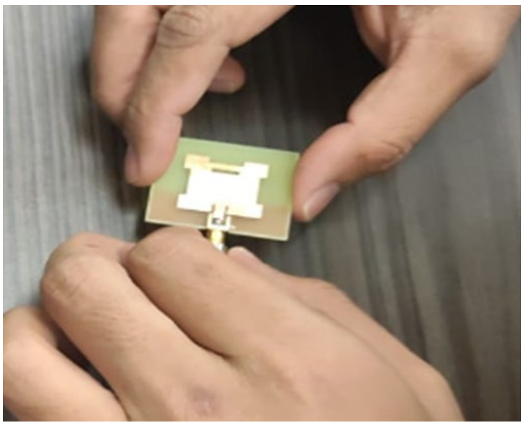


Fig. 6 - Modified antenna connect with VNA

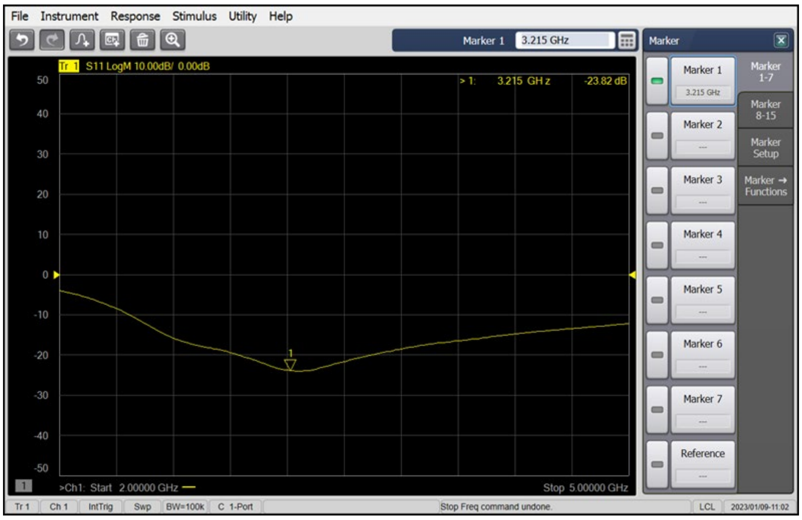


Fig. 7 - Measurement S11 parameter of modified antenna

Fig. 6 shows the modified antenna connect with. After finish calibration of VNA, connect antenna with VNA to measure s11 parameter and the result shows at screen. Fig. 7 shows the measurement s11 parameter of modified antenna. Measurement result of s11 parameter of modified antenna is observed and recorded. From the Fig. 7, the measurement frequency is about 3.215GHz as the deep return loss of the s11 parameter. Measurement return loss is about -23.82dB and the bandwidth is observed but there is no clear and good.

3.3 Comparison Between Simulation Results and Measurements

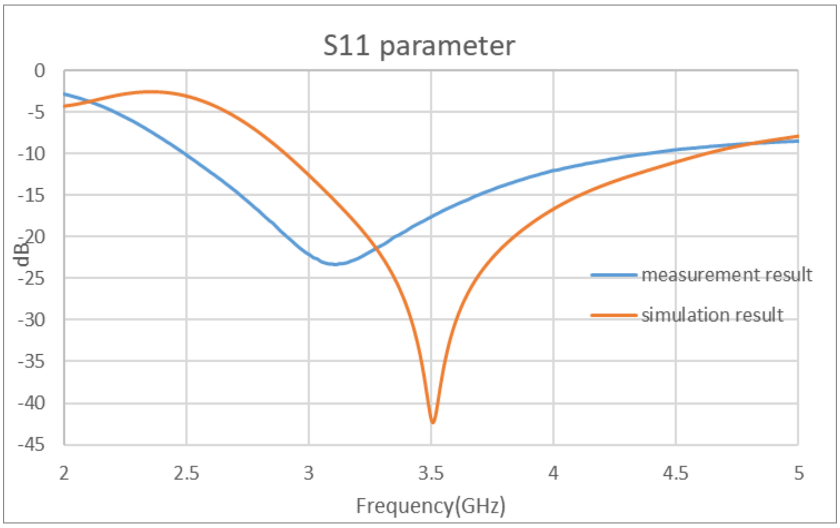


Fig. 8 - Comparison of s11 parameter

Fig. 8 shows the comparison s11 parameter between simulation and measurement results. From the Fig 8., simulation result and measurement result are recorded in csv file. The data in csv file imported to excel and plot graph. From the above Fig. 8, frequency achieved by simulation and measurement are different. Simulation frequency result is 3.5GHz while measurement frequency result is 3.215GHz that is lower than simulation frequency. Return loss of measurement result from the Fig.8 above is obviously lower than return loss of simulation result. Both simulation and measurement results are wide bandwidth as the Fig. 8 shown. Bandwidth of simulation result is 1.713GHz while the measurement result is 1.825GHz. There is very similar result of both. Table 3 recorded the results of simulation and measurement results.

Table 3 - Comparison result between simulation and measurement

Parameter	Simulation Result	Measurement Result
Frequency	3.5GHz	3.215GHz
Return loss	-42.287dB	-23.82dB
Bandwidth	1.713GHz	1.825GHz

4. Conclusion

This project is work for design a compact wideband antenna for 5G application. 3.5 GHz is selected as the optimal frequency in this project and need to design an antenna that achieve with 3.5GHz frequency. 3.5GHz is suitable in a large open area and is a popular frequency used. In this project, FR-4 substrate, inset fed microstrip line feed technique, partial ground, slots added at patch are used. The dimension of the substrate, patch and ground decreased to get a higher frequency and a wideband antenna. As a result, modified antenna design had achieved that as the objective of this project. The modified antenna has the feature as compact, wideband, and suitable for the 5G application. Decreasing in dimension of antenna to become a compact size antenna. The frequency of modified antenna is 3.5GHz, 1.713GHz bandwidth range and return loss is about -42.287dB which are good results as a wideband antenna. Measurement results of frequency of modified antenna is 3.215GHz, 1.825GHz for bandwidth range and return loss is about -23.82dB which are similar results as simulated results. There are some recommendations for future research. Firstly, change using fed method, shapes, dimension to achieve other frequency and wider bandwidth. Make sure the substrate thickness is available in laboratory before start design an antenna. If not, wasting time to adjust and re-design again. Next, try to modify wider bandwidth of antenna.

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