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Design of 1x5 Planar Array Microstrip Antenna with Edge Weighting to Increase Gain

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Abstract—**Research on improving the performance of microstrip antennas is continuously developing the following technology; this is due to its light dimensions, cheap and easy fabrication, and performance that is not inferior to other dimension antennas. Especially in telecommunications, microstrip antennas are constantly being studied to increase bandwidth and gain according to current cellular technology. Based on the problem of antenna performance limitations, optimization research is always carried out to increase the gain to become the antenna standard required by 5G applications. This research aims to increase the gain by designing a 5-element microstrip planar array antenna arrangement at a uniform distance (lamda/2) with edge weights at a frequency of 2.6 GHz, Through the 1x5 antenna design with parasitic patch, without parasitic, and using proximity coupling.This study hypothesizes that by designing an N-element microstrip planar array antenna arrangement at uniform spacing (lamda/2) with edge weights, a multi-beam radiation pattern character will be obtained so that to increase gain, parasitic patches contribute to antenna performance. This research contributes to improving the main lobe to increase the gain performance of the 1x5 planar array antenna. Based on the simulation results of a 1x5 microstrip planar array antenna using a parasitic patch and edge weighting, a gain value of 7.34 dB is obtained; without a parasitic patch, a gain value of 7.03 dB is received, using a parasitic patch and proximity coupling, a gain value of 2.29 dB is obtained. The antenna configuration with the addition of a parasitic patch, even though it is only supplied at the end (edge weighting), is enough to contribute to the parameters impedance, return loss, VSWR, and total gain based on the resulting antenna radiation pattern. The performance of the 1x5 microstrip planar array antenna with parasitic patch and double substrate (proximity coupling), which is expected to contribute even more to the gain side and antenna performance, has yet to be achieved. The 1x5 planar array antenna design meets the 5G gain requirement of 6 dB.**

Keywords—**microstrip antenna; edge weighting; parasitic patch; proximity coupling; 5G antenna gain**

I. INTRODUCTION

MICROSTRIP patch is a type of antenna widely used in mobile electronic devices. The main characteristic advantages of this antenna are its low profile, low cost, and simple fabrication but it has the disadvantage of low gain and bandwidth compared to other antennas [1]. Many techniques have been studied to improve performance through patch modification, adding reflectors, adding patches, providing multilevel substrates, etc. One of the easiest ways to enhance antenna performance is to amplify using resonators or parasitic elements. Parasitic patches can be placed around the patch antenna, designed to maximize the return loss, VSWR and radiation pattern parameters ([2]–[11]). Here are some studies on microstrip antennas using parasitic patches to increase the bandwidth or total gain of the antenna[12]–[20], and proximity coupling[21]–[23].

Based on some of the references above, adding a parasitic patch will increase the bandwidth or gain. This study wants to see whether using edge-weighted parasitic patches on a 1x5 planar array antenna will increase bandwidth or gain, increasing total gain and directivity with return loss below -20 dB and a resonant frequency of 2.6 GHz.

The novelty of this study is how the effect of edge weighting contributes to the increase in gain or bandwidth in planar array microstrip antennas with or without parasitic patches. Therefore, the antenna needs to be upgraded with a slightly wider bandwidth and higher gain to ensure that the antenna can receive better signal strength and quality. The research partner, BRIN, contributed to antenna measurements after fabrication, discussion discussions, and making journals until publication. Some of the points that form the formulation of this research problem are: What is the gain value obtained on a 1x5 planar array antenna with edge weights using a parasitic patch, without a parasitic patch, using a parasitic patch and proximity coupling, and a comparison of the performance of the three antennas based on the gain value obtained.

This research aims to design an N-element planar array microstrip antenna arrangement in uniform spacing (lamda/2) with edge weighting to facilitate a channel capacity increase design by increasing the throughput of each sharp, multiple, and narrow beam. The proposed antenna operates at a frequency of 2.6 GHz.

II. RESEARCH METHOD

Flowchart of Antenna Design and Manufacturing of Microstrip Antennas The research methodology used in designing and implementing microstrip antennas requires steps that describe the initial stages of the antenna design process to obtain the final results before proceeding to the production

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process. These steps are presented as a flowchart shown in Figure 1.

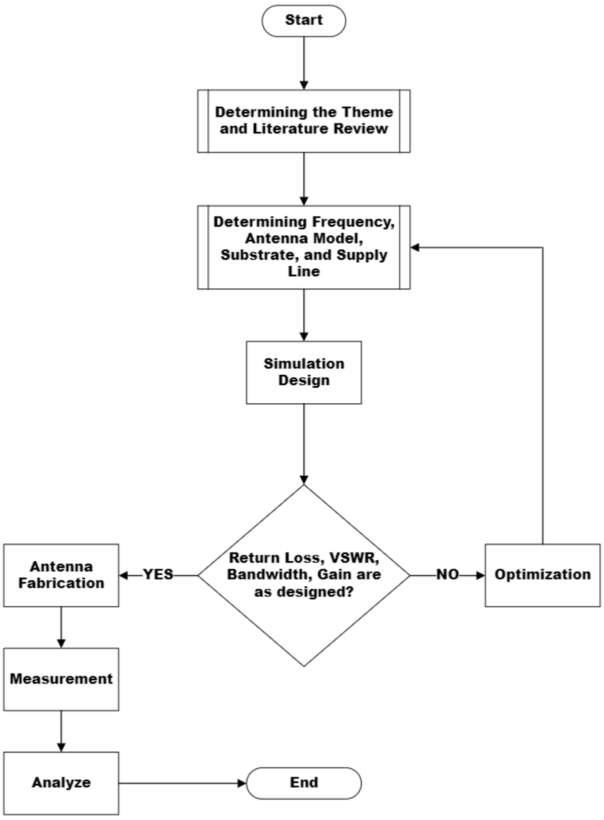


Fig. 1. Antenna design and manufacture flowchart

After the design and design calculations have been completed through simulation, the following process is making the antenna. FR-4 material is used in the manufacture of microstrip antennas. Then, the manufacturing results are measured so that the parameter values of the antenna are obtained. The measurement and simulation results are then compared to see how far the parameter values have been obtained.

A. 1x5 Antenna Design

The microstrip planar array antenna in a 1x5 configuration was modified to the antenna design using parasitic and non-parasitic patches with edge weights at uniform distances. Standard antenna parameters are return loss below -20 dB with a working frequency of 2.6 GHz. Each patch element is equally spaced λ/2, weighted only at the right and left ends. Furthermore, with the same scenario, it is also simulated with proximity coupling, whether or not it provides better gain performance. Performance is compared by comparing the value of the parameter return loss, VSWR, and the accuracy of the operating frequency in the design using parasites and without parasites.

After getting the best design, it is continued with fabrication and measurement. To find out how far the antenna's performance is designed to give the best gain contribution.

B. Planar array antenna 1x5 – with parasitic patch

Figure 2 is a proposed antenna design with five patches; 3 of the five patches are parasitic patches, and two ends in the supply with edge weighting. All of them are given a uniform distance of λ/2.

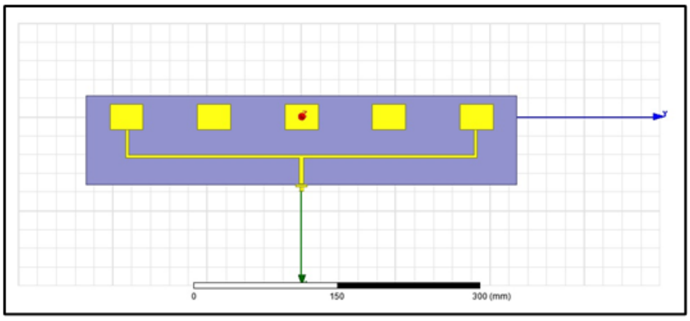


Fig. 2. Planar array antenna 1x5 with parasitic patch

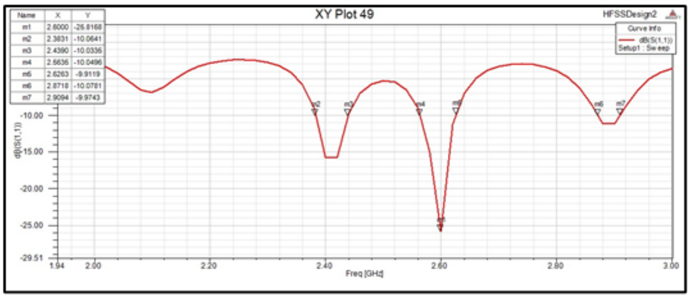


Fig. 3. Return loss value of 1x5 planar array antenna with parasitic patch

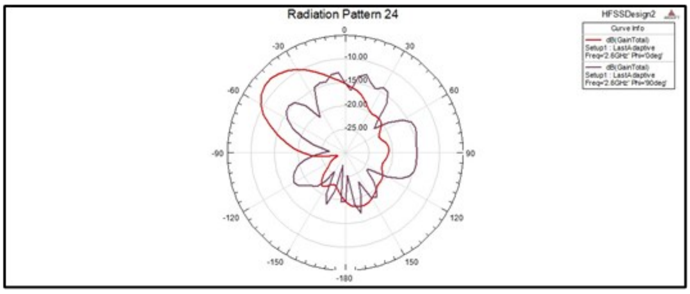


Fig. 4. Radiation pattern of a 1x5 planar array antenna with parasitic patches

From the simulation, the dimensions and width of the antenna feeder were changed until they met the return loss requirement of < - 20 dB and were at a working frequency of 2.6 GHz.

1) Return Loss 1x5 planar array antenna design with parasitic patch

Figure 3., it is clear that the best return loss value is at a working frequency of 2.6 GHz with a value of -25.628 dB. Bandwidth width can be measured from the lowest and highest frequencies at return loss below -10 dB of approximately 60 Mhz.

2) Radiation pattern based on total antenna gain

The radiation pattern of the 1x5 planar array antenna with parasitic patches in Figure 4. is described at phi 0° and 90°. The beam range is more varied at a 90 phi angle and gives a smaller side lobe level. The number of beams corresponds to the number of radiating patches.

C. Planar array antenna 1x5 without parasitic patch

Figure 5. is a proposed antenna design with two patches fed on both ends with edge weighting. They are all given a uniform distance of λ/2*5.

From the simulation, the size and width of the feeder antenna are varied to meet a return loss of < - 20 dB and at a working frequency of 2.6 GHz.

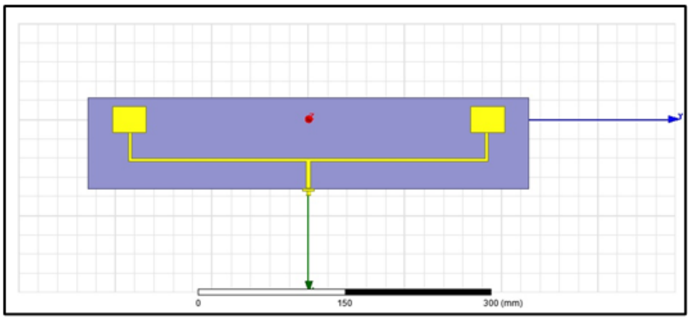
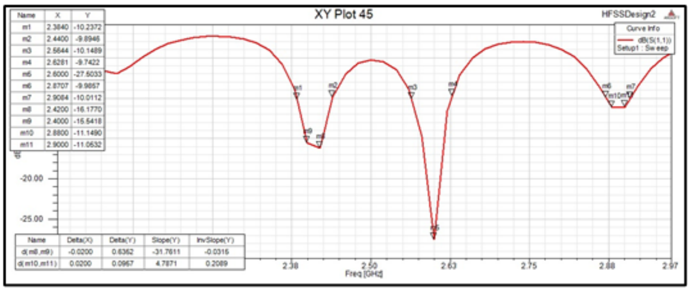


Fig. 5. Planar array antenna 1x5 without parasitic patch



Name	X	Y
m1	2.3840	-10.2372
m2	2.4400	-9.8946
m3	2.5644	-10.1489
m4	2.6281	-9.7422
m5	2.6000	-27.5033
m6	2.8707	-9.9857
m7	2.9084	-10.0112
m8	2.4200	-16.1770
m9	2.4000	-15.5418
m10	2.8800	-11.1490
m11	2.9000	-11.0632

Name	Delta(X)	Delta(Y)	Slope(Y)	InvSlope(Y)
d(m8,m9)	-0.0200	0.6362	-31.7611	-0.0315
d(m10,m11)	0.0200	0.0967	4.7871	0.2089

Fig. 6. Return loss of 1x5 planar array antenna without parasitic patch

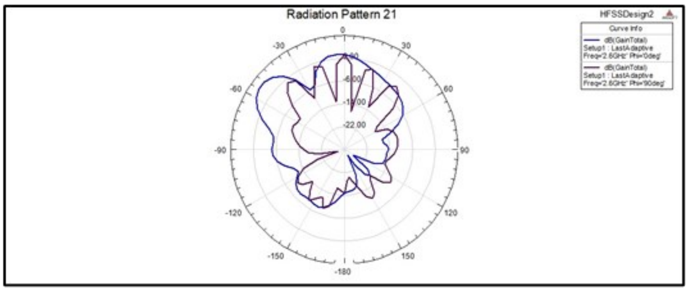


Fig. 7. Radiation pattern of a 1x5 planar array antenna without parasitic patches

1) Return Loss Antenna Design

Figure 6., it is clear that the best return loss value is at a working frequency of 2.6 GHz with a value of -27.5 dB. Bandwidth width can be measured from the lowest and highest frequencies at return loss below -10 dB of approximately 40 Mhz.

2) Radiation pattern based on total antenna gain

The radiation pattern of the 1x5 planar array antenna without the parasitic patch in Figure 7. is described at phi 0° and 90°. The beam range is more varied at a 90 phi angle and gives a smaller side lobe level. The number of beams becomes more than the number of patches and narrower. Judging from the more significant beam and the SLL, it is similar.

D. Planar array antenna 1x5 with parasitic patch and proximity coupling

Figure 8. is a proposed antenna design with five patches and 2 in both end supplies with edge weighting. The feeder system is different from the two previous antenna designs. In this design, the feeder does not directly contact the patch, and substrates of the same type are added. They are all given a uniform distance of λ/2*5.

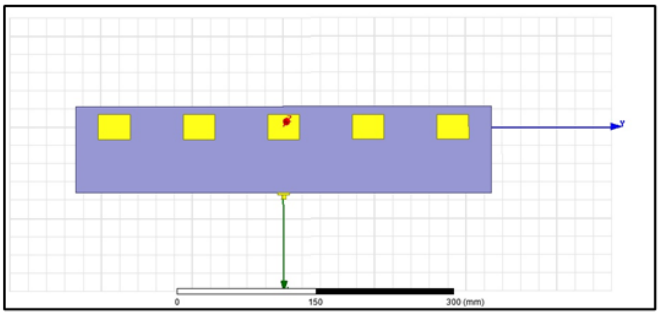
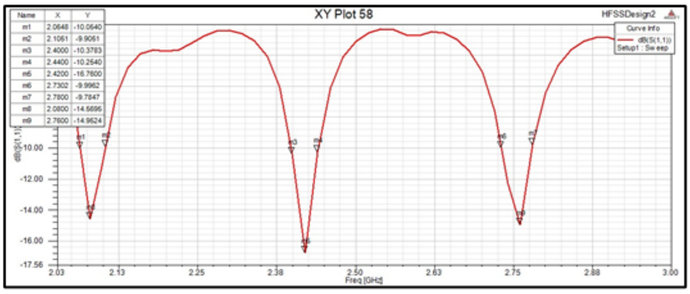


Fig. 8. Planar array antenna 1x5 with parasitic patch and proximity coupling



Name	X	Y
m1	2.0648	-10.0640
m2	2.1061	-9.9061
m3	2.4000	-10.3783
m4	2.4400	-10.2540
m5	2.4200	-16.7600
m6	2.7302	-9.9962
m7	2.7800	-9.7847
m8	2.0800	-14.5695
m9	2.7600	-14.9624

Fig. 9. Return loss of 1x5 planar array antenna with parasitic patch and proximity coupling

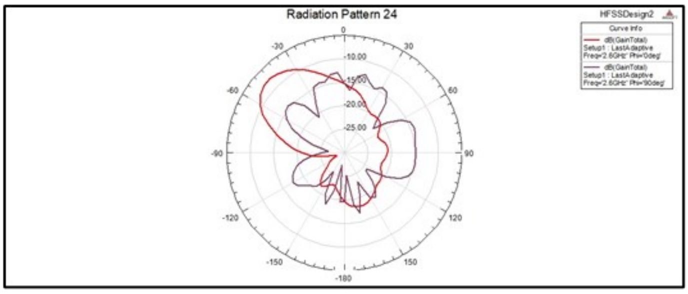


Fig. 10. Radiation pattern of 1x5 planar array antenna with parasitic patch and proximity coupling

From the simulation, the dimensions and width of the antenna feeder were changed until they met the return loss requirement of < - 20 dB and were at a working frequency of 2.6 GHz.

Figure 9., it is clear that the best return loss value is at a working frequency of 2.42 GHz with a value of -16.76 dB. Bandwidth width can be measured from the lowest and highest frequencies at return loss below -10 dB of approximately 40 Mhz. The same valley is obtained at 3 (three) surrounding frequencies but does not fit at the working frequency of 2.6 GHz. Therefore, optimization is still needed in terms of antenna performance.

The radiation pattern of the 1x5 planar array antenna with parasitic patches and proximity coupling in Figure 10. is described at phi 0° and 90°. The beam range is more varied at a 90 phi angle and gives a smaller side lobe level. The number of beams corresponds to the number of radiating patches, but the HPBW width is wider than the single substrate antenna design.

III. RESULT AND DISCUSSION

A. Fabrication Results of Planar Array Microstrip Antenna 1x5 With Edge Weighting

Antenna fabrication is carried out after conducting a simulation test using HFSS software with close to ideal parameter values. A third party, a PCB printing service provider, manufactures the antenna. Before printing, the file must be provided to the research partner to be printed in Gerber format and opened in CorelDraw software to prepare the antenna print size. Then, it is printed as a photographic film, as shown in Figure 11., which is then converted into a 1x5 microstrip planar array antenna using the substrate type FR-4.

The physical form of the 1x5 planar array microstrip antenna after fabrication can be seen in Figure 12. The SMA female connector has been installed.

B. *Measurement of 1x5 Microstrip Antenna without parasitic patches*

After simulating, optimizing, and fabricating microstrip antennas, the fabrication results were measured on Radar Telecommunication Indonesia. That is to determine the characteristics of the antenna being produced and to ensure the success of the design process according to the desired specifications. The first measurement uses a network analyzer (VNA) operating at a frequency of 2.6 GHz. The microstrip antenna is measured to obtain impedance, return loss, VSWR, and radiation pattern parameters in this measurement. Fabrication of a 1x5 microstrip antenna without a parasitic patch is shown in Figure 13.

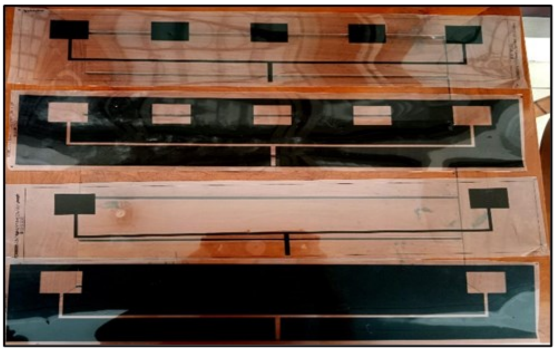


Fig. 11. Negative film in the photo etching process

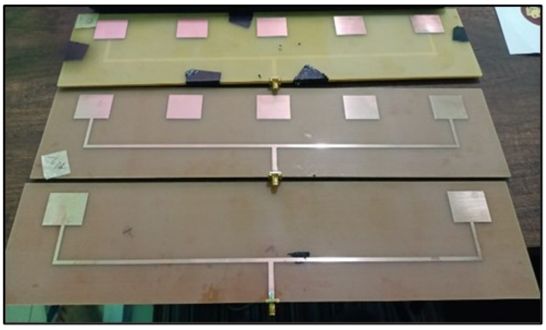


Fig. 12. Manufacturing of a 1x5 Planar Array Microstrip Antenna

Fig. 13. 1x5 microstrips without parasitic patches

In Figure 13., compares the fabricated antenna with A4 paper 30 cm long. The resulting antenna's dimensions are more significant because the working frequency is below 6 GHz. That is following the resulting wavelength, which is also longer than other 5G frequencies in the millimeter and centimeter range.

1) *Return Loss (S_{11})*

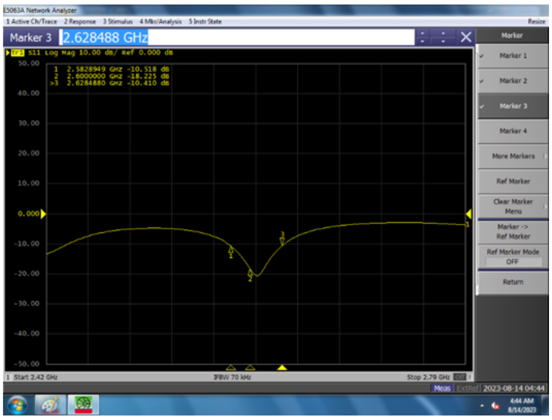
Measurement of reflected losses is carried out to compare the reflected wave and the transmitted wave to determine whether the antenna is following the expected parameters. Reflection loss is also a parameter that shows how well the antenna is designed and simulated.

The return loss measurement results are in Figure 6.4 at a frequency of 2.62 GHz with a value of -20 dB. This value is excellent because the ideal return loss is <-10dB. Although the antenna simulation results get the best results at a working frequency of 2.6 GHz and a return loss of -25 dB. The frequency shift occurs slightly, so the return loss from -25 dB becomes -20 dB. However, these results can still be said to be good because they are still following the ideal return loss value.

2) *Impedance*

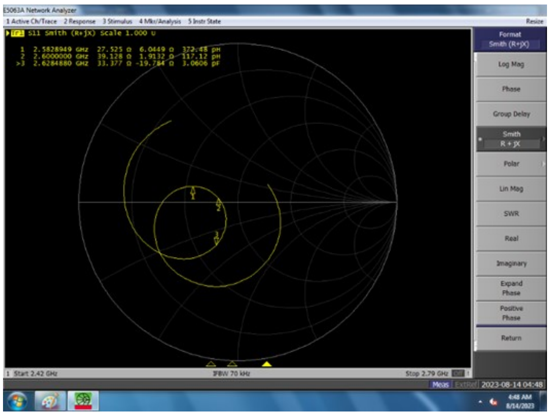
Impedance is the ratio of voltage to current. The unequal current and voltage values along the conductor will cause unequal impedance values along the antenna, while the impedance must be the same as the line impedance.

In Figure 15., the antenna impedance at a frequency of 2.6 GHz is 39,128 ohms, which is the closest to the total impedance of 50 Ohms. The 50 Ohm value is obtained using a 50 Ohm line impedance.



```
Tr1 S11 Log Mag 10.00 dB/ Ref 0.000 dB
  1  2.5828949 GHz -10.518 dB
  2  2.6000000 GHz -18.225 dB
 >3  2.6284880 GHz -10.410 dB
```

Fig. 14. Return loss measurement results of 1x5 microstrip antenna without parasitic patches



```
Tr1 S11 Smith (R+jX) Scale 1.000 U
  1  2.5828949 GHz  27.525 Ω  6.0449 Ω  372.48 pH
  2  2.6000000 GHz  39.128 Ω  1.9132 Ω  117.12 pH
 >3  2.6284880 GHz  33.377 Ω -19.784 Ω  3.0606 pF
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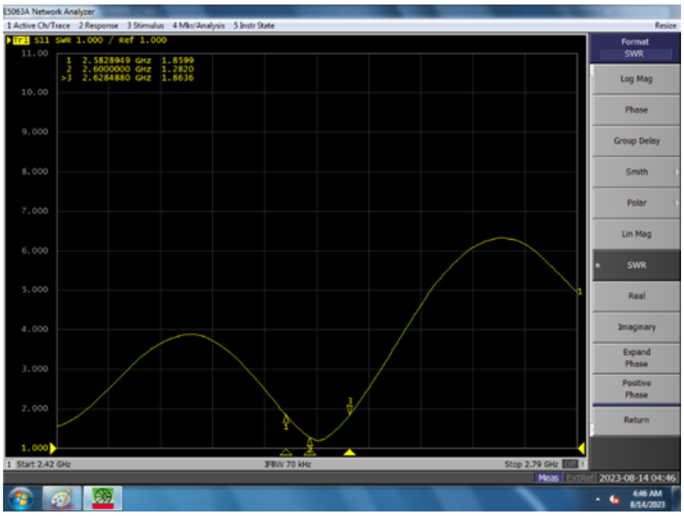
Fig. 15. Impedance measurement results of 1x5 microstrip antenna without parasitic patches



```
Tr1 S11 SWR 1.000 / Ref 1.000
  1  2.5828949 GHz  1.8599
  2  2.6000000 GHz  1.2820
 >3  2.6284880 GHz  1.8636
```

Fig. 16. VSWR measurement results for 1x5 microstrip antenna without parasitic patches

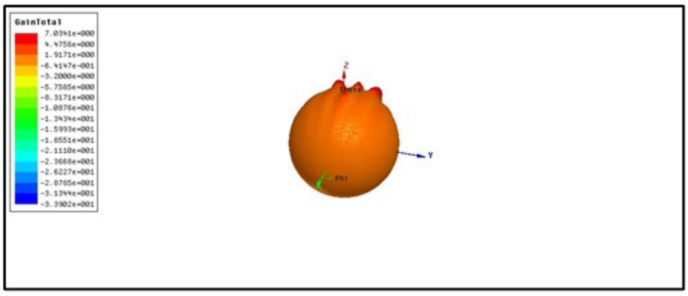


Fig. 17. Total gain of 1x5 microstrip antenna without parasitic patches

3) *VSWR*

Figure 16. is the measurement of the VSWR antenna with a working frequency of 2.6 GHz at 1.28; this value is considered ideal because it meets the requirements, namely < 2. This value is synchronous with the small return loss value; the impedance is close to the line impedance value, so it can be said that the 1x5 microstrip array antenna design has matched based on the simulation and fabrication values.

4) *Total Gain by Radiation Pattern*

After measuring the parameters of return loss, impedance, and VSWR, it can be concluded that the antenna being measured has matched. Therefore, the total gain obtained based on the radiation pattern produced by the antenna can be seen in Figure 17. In the picture, the highest total gain value is 7.034 dB at a certain point. For more details, see the 3D image above. For 5G, the standard minimum gain value is 6 dB. In other words, this antenna meets the requirements because it is above 6 dB.

C. *Measurement Results in Antenna 1x5 with patch parasitic*

Furthermore, measurements of the 1x5 microstrip antenna fabrication with parasitic patches are shown in Figure 18. The meter operates at a frequency of 2.6 GHz.

Measurements include impedance, return loss, VSWR, and total gain based on the resulting antenna radiation pattern. This measurement is intended to determine whether the antenna with a parasitic patch has a significant effect on the total gain of the antenna or not.

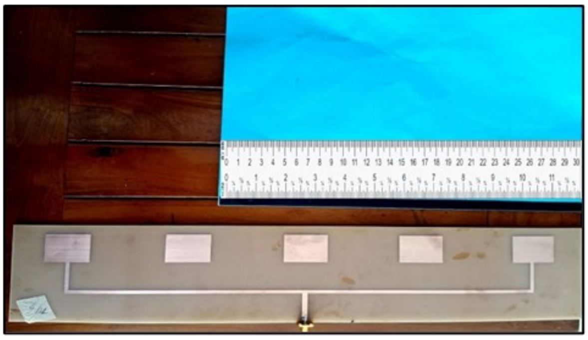
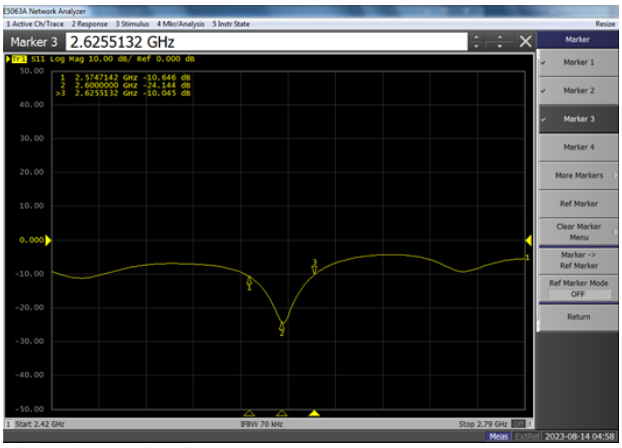


Fig. 18. 1x5 microstrips with parasitic patches



```
Marker 3  2.6255132 GHz
Tr1 S11 Log Mag 10.00 dB/ Ref 0.000 dB
  1  2.5747142 GHz -10.646 dB
  2  2.6000000 GHz -24.144 dB
 >3  2.6255132 GHz -10.045 dB
```

Fig. 19. Return loss measurement results of a 1x5 microstrip antenna with a parasitic patch

1) *Return Loss (S_{11})*

The return loss measurement results are in Figure 19 at a frequency of 2.6 GHz with a value of -24 dB. This value is excellent because the ideal return loss is <-10 dB. Although the antenna simulation results get the best results at a working frequency of 2.6 GHz and a return loss of -25 dB. The frequency shift occurs slightly, so the return loss from -25 dB becomes -24 dB. However, these results can still be good because they are still following the ideal return loss value.

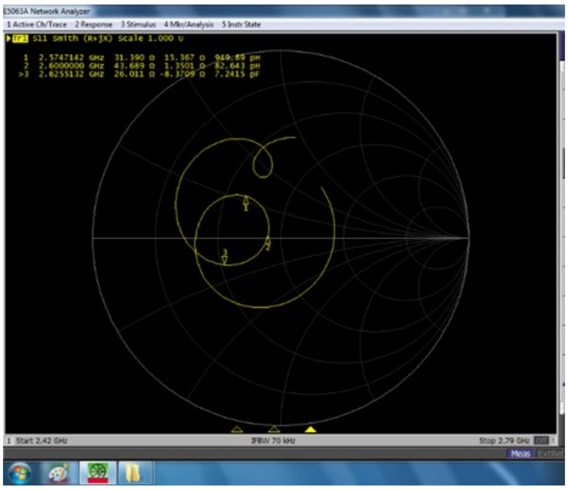
The return loss measurement results on a 1x5 microstrip antenna with a parasitic patch give a better value than without a parasitic patch. Based on the results obtained, the next thing to compare is the 1x5 microstrip antenna with a parasitic patch with one substrate and two substrates (proximity coupling).

2) *Impedance*

In Figure 20, the antenna impedance at a frequency of 2.6 GHz is 39,128 ohms, which is the closest to the total impedance of 50 Ohms. Then, on a 1x5 microstrip antenna with a parasitic patch in Figure 20, the impedance is 43.689 ohms. The configuration with ptach also contributes to the channel matching of 50 Ohms.

3) *VSWR*

The VSWR measurement for the 2.6 GHz antenna in Figure 21 is 1.13, which is ideal because it meets the requirements, namely < 2. Compared to the previous VSWR value, this design increases the value to become even better. This value is synchronous with a small reflection loss value. The impedance is close to the line impedance value, so the 1x5 microstrip array antenna design with a parasitic patch has been adjusted based on simulation and fabrication values.



```
 1  2.5747142 GHz  31.390 Ω  15.367 Ω  949.89 pH
 2  2.6000000 GHz  43.689 Ω  1.3501 Ω  82.643 pH
>3  2.6255132 GHz  26.011 Ω -8.3709 Ω  7.2415 pF
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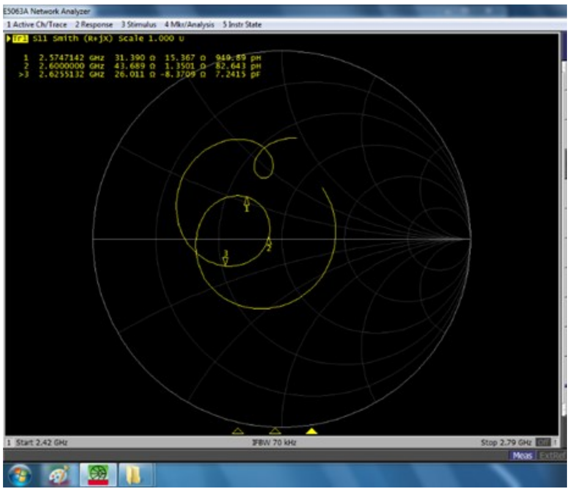
Fig. 20. Impedance Measurement Results of a 1x5 Microstrip Antenna with a parasitic patch



```
 1  2.5747142 GHz  31.390 Ω  15.367 Ω  949.89 pH
 2  2.6000000 GHz  43.689 Ω  1.3501 Ω  82.643 pH
>3  2.6255132 GHz  26.011 Ω -8.3709 Ω  7.2415 pF
```

Fig. 21. VSWR measurement results for 1x5 microstrip antenna without parasitic patches

4) *Radiation Pattern (Total Gain)*

After measuring the return loss, impedance, and VSWR parameters on a 1x5 microstrip antenna with a parasitic patch, it can be concluded that the total gain of the antenna based on the radiation pattern is 7.34 dB; details can be seen in Figure 22. The total value of this gain increases slightly compared to the antenna without a patch, which is 7.03 dB.

The increase in the total gain value also shows that the antenna with the patch also provides a gain contribution value besides the return loss, impedance, and VSWR parameters. For 5G, the standard minimum gain value is 6 dB. In other words, the antenna with this parasitic patch also meets the requirements because it is above 6 dB.

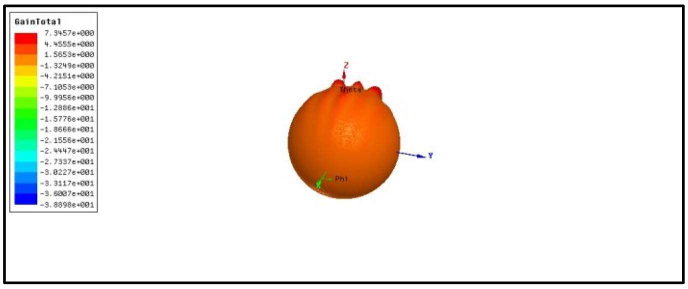
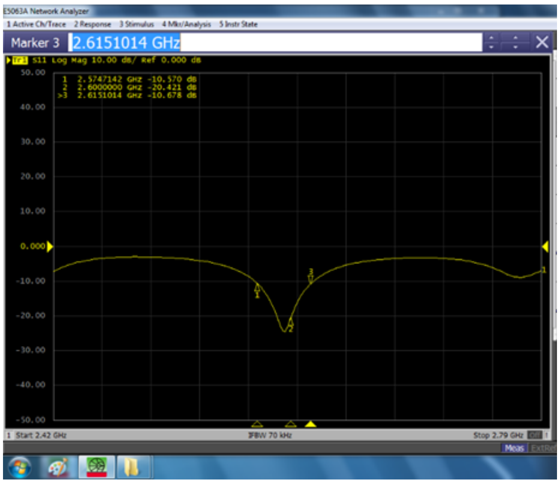


Fig. 22. Total gain values of a 1x5 microstrip antenna with a parasitic patch

Fig. 23. 1x5 microstrips with parasitic patches



```
 1  2.5747142 GHz -10.570 dB
 2  2.6000000 GHz -20.421 dB
>3  2.6151014 GHz -10.678 dB
```

Fig. 24. Return loss measurement results for a 1x5 microstrip antenna with a parasitic patch and proximity coupling

D. *Measurement Results in Antenna 1x5 with patch parasitic and proximity coupling*

The subsequent measurement is a 1x5 microstrip fabricated antenna with a parasitic patch using a proximity coupling shown in Figure 23. The meter operates at a frequency of 2.6 GHz.

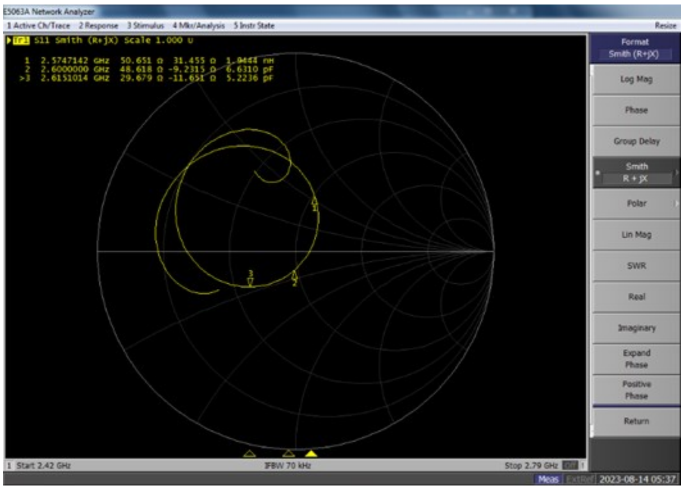
Measurements include impedance, return loss, VSWR, and total gain based on the resulting antenna radiation pattern. This measurement is intended to determine whether an antenna with a single substrate parasitic patch with a double substrate significantly affects the antenna's total gain.

1) *Return Loss (S11)*

The results of the return loss measurement of the 1x5 microstrip antenna with parasitic patches and adjacent proximity couplings are shown in Figure 24 at a frequency of 2.6 GHz with a value of -20.4 dB. This value is excellent because the ideal return loss is < -10 dB. Although the previous antenna simulation results (single substrate) get the best results at a working frequency of 2.6 GHz and a return loss of -24 dB. The addition of substrate does not contribute to a better return loss value. However, these results can still be good because they are still following the ideal return loss value, which is < - 10dB.

2) *Impedance*

In Figure 25, the antenna impedance at a frequency of 2.6 GHz is 48.618 ohms, which is the closest to the total impedance of 50 Ohms. Then, on a 1x5 microstrip antenna with a parasitic patch in Figure 6.10, the antenna impedance is 43.689 ohms. The configuration with the patch also contributes to the channel matching of 50 Ohms.



```
Tr1 S11 Smith (R+jX) Scale 1.000 U
  1  2.5747142 GHz  50.651 Ω  31.455 Ω  1.9444 nH
  2  2.6000000 GHz  48.618 Ω -9.2315 Ω  6.6310 pF
 >3  2.6151014 GHz  29.679 Ω -11.651 Ω  5.2236 pF
```

Fig. 25. Impedance measurement results of a 1x5 microstrip antenna with a parasitic patch and proximity coupling

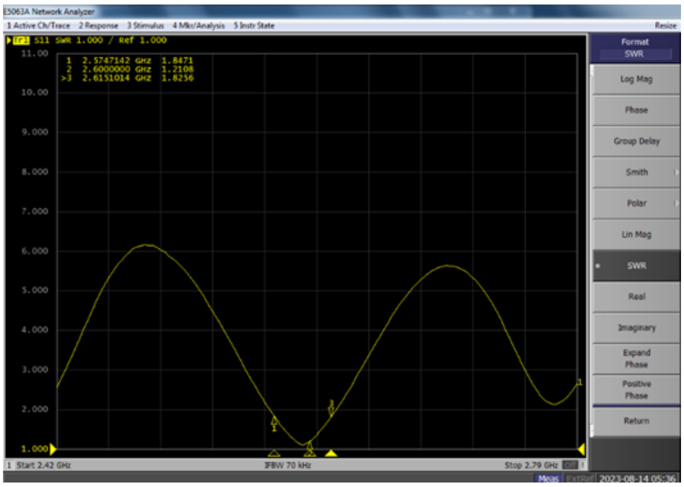
3) VSWR

The VSWR measurement for the 2.6 GHz antenna in Figure 26 is 1.21, which is still within the ideal value range because it meets the requirements < 2. Compared to the previous VSWR value of 1.13, this design has decreased. However, the 1x5 microstrip array antenna design with parasitic coupling and proximity has been refined based on simulation, fabrication, and measurement values.

4) Radiation Pattern (Total Gain)

After measuring the return loss, impedance, and VSWR parameters on a 1x5 microstrip antenna with a parasitic patch, it can be concluded that the total gain of the antenna based on the radiation pattern is 2.29 dB; details can be seen in Figure 27. The total gain value decreased drastically compared to the patch antenna (single substrate), which is 7.34 dB.

This decrease in total gain value also shows that antennas with double substrates do not contribute gain but bandwidth. For 5G, the standard minimum gain value is 6 dB. In other words, an antenna with a parasitic patch and proximity coupling does not meet the requirements because the value is below 6 dB. Optimization needs to be done from the other side.



```
Tr1 S11 SWR 1.000 / Ref 1.000
  1  2.5747142 GHz  1.8471
  2  2.6000000 GHz  1.2108
 >3  2.6151014 GHz  1.8256
```

Fig. 26. VSWR measurement results for a 1x5 microstrip antenna with a parasitic patch and proximity coupling

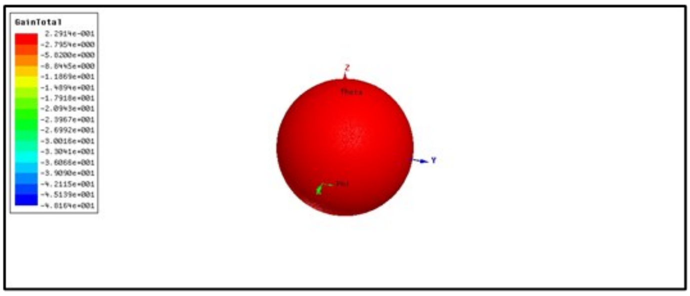


Fig. 27. Total gain values of 1x5 microstrip antenna with parasitic patch and proximity coupling

E. Antenna performance analysis results based on simulations and measurements

After simulation, fabrication, and measurement, it was found that the antenna with the addition of a parasitic patch configuration, even though it was only supplied at the end (edge weighting), was sufficient to contribute to the parameters of impedance, return loss, VSWR, and total gain based on the resulting antenna radiation pattern.

Furthermore, the 1x5 microstrip planar array antenna results with parasitic patches and double substrates, which are expected to contribute even more to the gain and antenna performance side, have yet to be achieved. Therefore, it is necessary to examine again in terms of patch size dimensions, weighting, and mutual coupling calculations apart from separating feeds and adding similar substrates.

Of the three antennas proposed so far, an antenna with a single layer and a feed connected directly to the patch provides better performance than one that does not use a parasitic patch and the addition of substrate (mutual coupling).

CONCLUSION

Several conclusions were obtained from the design, simulation, realization, and measurement of the triangular array microstrip patch antenna for 5G antennas. The simulation results of a 1x5 microstrip planar array antenna using parasitic patches and edge weighting obtained a gain value of 7.34 dB. The simulation results of a 1x5 planar array microstrip antenna with no parasitic patches and edge weighting obtained a gain value of 7.03 dB. The simulation results of a 1x5 microstrip planar array antenna using parasitic patches and edge weighting with proximity coupling, a gain value of 2.29 dB, is obtained. The antenna configuration with the addition of a parasitic patch, even though it is only supplied at the end (edge weighting), is enough to contribute to impedance, return loss, VSWR and total gain based on the resulting antenna radiation pattern. The performance of the 1x5 microstrip planar array antenna with parasitic patch and double substrate (proximity coupling), which is expected to contribute more to the gain and antenna performance, has yet to be achieved. Therefore, it is necessary to examine again in terms of patch size dimensions, weighting, and mutual coupling calculations apart from separating feeds and adding similar substrates. Of the three antennas proposed so far, an antenna with a single layer and a feed connected directly to the patch provides better performance than one that does not use a parasitic patch and the addition of substrate (proximity coupling).

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