Hexagonal Triangular Fractal Antenna with Tapered Feedline and Reflector for 5G and UWB Applications

B. Pratiknyo Adi Mahatmanto[1], Catur Apriono[2], Fitri Yuli Zulkifli[3], Eko Tjipto Rahardjo[4]
Department of Electrical Engineering, Faculty of Engineering
Universitas Indonesia
Depok, West Java, Indonesia
[1)]b.pratiknyo@ui.ac.id, [2)]catur@eng.ui.ac.id, [3)]yuli@eng.ui.ac.id, [4)]eko@eng.ui.ac.id

Abstract—**5G technology would provide high data rates and high-quality multimedia applications. This technology needs a broad bandwidth antenna. Among various antenna types, the hexagonal-triangular fractal antenna has advantages of compact design, low-profile material, wide-bandwidth of frequency work, and low-cost material for the antenna. This paper proposes a modified Hexagonal-triangular fractal antenna for 5G at 28 GHz and ultrawideband (UWB) application. The modification consists of a tapered feedline section, a smooth notch on the ground plane, slit on the ground plane, gap-filling on patch section, and adding a reflector. The dimension is 35 x 52 mm. From simulation and measurement, the proposed antenna design can work from in a range frequency of 2.4 GHz until more than 30 GHz. By combining with a planar reflector element, the obtained gain is 7.65 dB at frequency 6 GHz. The proposed antenna fulfills the frequency requirements for UWB application and 5G Application.**

Keywords—fractal, hexagonal-triangular, tapered feedline, reflector

I. INTRODUCTION

Nowadays, wireless communication has undergone rapid evolutions from analog voice communication to the short upcoming 5G mobile communications. The 5G is expected to work at frequency 28 GHz as the candidate for its frequency band allocation. This technology would provide high data rates and high-quality multimedia applications, i.e., audio, video, and data services. These systems also demand highly efficient, compact, and wide bandwidth wireless antennas.

A hexagonal-triangular fractal antenna has advantages characteristics of compact design, low-profile material, wide-bandwidth of frequency work, and low-cost material for the antenna. The hexagonal-triangular fractal pattern antenna consists of two primary initiators, i.e., hexagonal and triangular. Combination of the initiator with several smaller shape elements as generators produces several resonance frequencies bands [1] [2]. Hexagonal-triangular antennas have had a potential also for receiving antennas in ultrawideband (UWB) applications that work from 3.1-10.6 GHz [3] [4] [5]. The hexagonal-triangular fractal antenna is also promising for 5G applications at frequency 28 GHz [6] [7]. Some modifications, such as feed line [8] [9], notch [10] [11], slit [12], fill-gap [13], substrate thickness [5], and reflector [14], can provide an antenna that can work for both 5G and UWB applications.

This paper proposes a modified design of hexagonal-triangular fractal antenna for UWB applications in a range of 3.1-10.6 GHz and 5G applications at the frequency of 28 GHz. The modification consists of a tapered feedline section, a smooth notch on the ground plane, slit on the ground plane, gap-filling on patch section, and adding a reflector.

II. ANTENNA DESIGN

This research objective is to design, simulate, and fabricate a hexagonal-triangular fractal antenna that can work on UWB and 5G applications. This study uses CST Microwave Studio to design and simulate the proposed antenna design. The optimum antenna design is then fabricated and measured to verify the simulation results.

A. Hexagonal Triangular Fractal Antenna

Figure 1 shows the initial design of a hexagonal-triangular fractal antenna, which consists of the hexagonal and triangular element. The hexagonal ringside length (a) is 10 mm. The antenna consists of three triangular, which the upper side length of b, c, and d are 3.95 mm, 2.76 mm, and 2.6 mm, respectively. The feedline length (e) and width (f) are 10.18 mm and 2.5 mm, respectively. The considered ground plane dimension (g x h) is 25 mm x 10 mm. The overall antenna dimension width is 32 x 25 mm. The design is then modified in some parts, such as feed line, notch, slit, fill-gap, substrate thickness, and reflector.

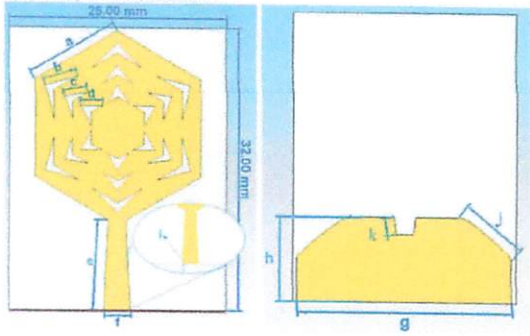

Fig. 1. The initial design of hexagonal-triangular fractal antenna (a) front and (b) rear point of view

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B. *Feedline Modification*

Figure 2 shows the return loss simulation results from the feedline parameterization conducted at the additional edge width (*i*) in a range from 0.1 to 1 mm. It shows that most of the return loss is lower than -10 dB, which indicates a wideband antenna characteristic. The critical frequencies are at 4 GHz, 8 GHz, 15 GHz, and 21 GHz. The additional feedline width of 0.5 mm shows the most obtained matching condition.

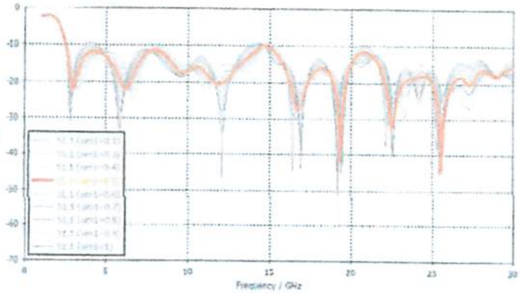


Fig. 2. Return loss (S_{11}) of the feedline parameterization

C. *Ground Plane Modification*

Figure 3 is the return loss simulation results from the notch parameterization conducted at the ground plane width (*j*) in a range from 0.1 to 1 mm. The notch size of 0.2 mm shows the most obtained matching condition, which improves the result lost, especially at the frequency of 6 GHz.

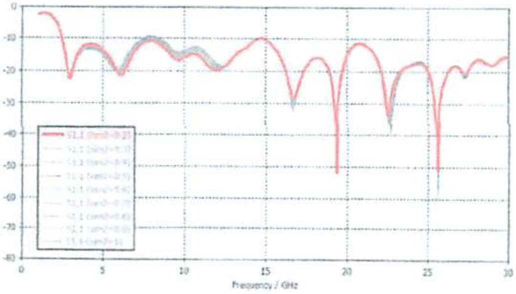


Fig. 3. Return loss (S_{11}) of the notch parameterization

D. *Slit Modification*

Figure 4 shows the return loss simulation results from the slit parameterization conducted at the ground plane width (*k*) in a range from 0.1 to 1 mm. The critical frequencies at 21 GHz. The most obtained matching condition is at the size of 0.2 mm.

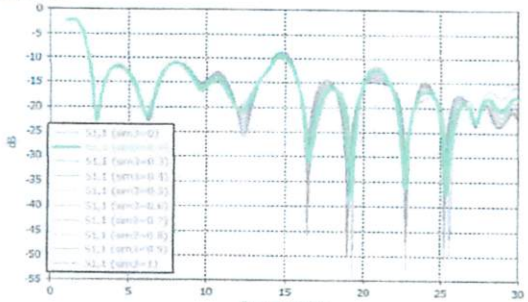
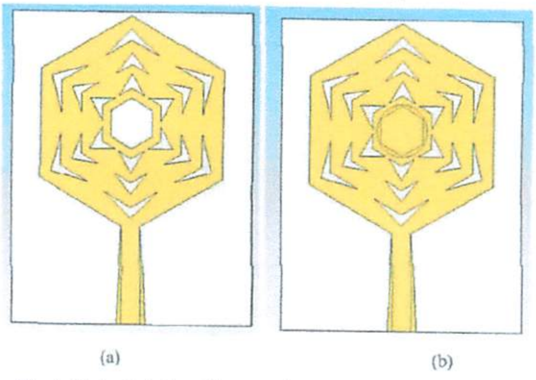


Fig. 4. Return loss (S_{11}) of the slit parameterization

E. *Patch Modification*

Basic Hexagonal-triangular fractal antenna has an empty part in the center of the patch. In this paper, the circle part fills the center part, as shown in Figure 5. The advantage of the modification is to reduce the return loss at a frequency of 15 GHz and more than 30 GHz, as shown in Figure 6.



(a) (b)

Fig. 5. The basic design of hexagonal-triangular fractal antenna with (a) empty and (b) filled circle in the center part

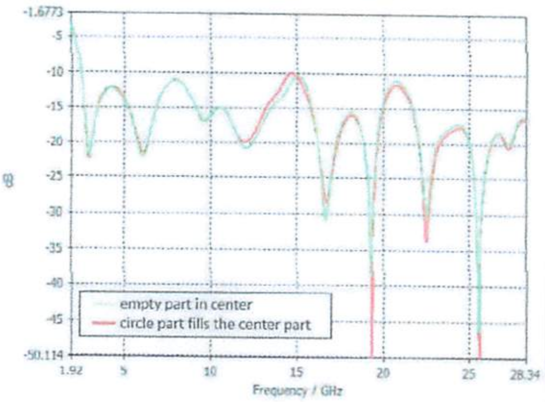


Fig. 6. Return loss (S_{11}) of the fill gap parameterization

F. *Substrate Thickness parameterization*

Figure 7 shows the return loss simulation results from the substrate thickness (l) parameterization conducted in a range from 0.1 to 2 mm. The most obtained matching condition is at the size of 1.6 mm. Figure 7 shows that the substrate thickness changes give more effect to the return loss pattern.

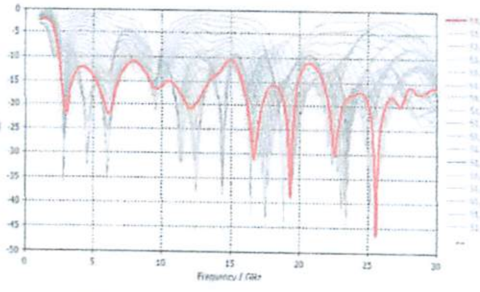


Fig. 7. Return loss (S_{11}) of thickness parameterization

G. *Reflector*

Figure 8 shows return loss simulation results from the antenna with a reflector element conducted in a separate distance from 1 to 10 mm. The critical frequencies at 15 GHz. The most obtained matching condition is at the size of 10 mm.

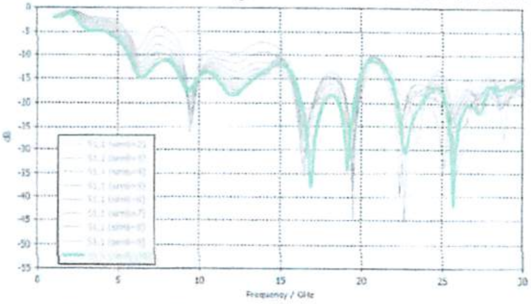


Fig. 8. Return loss (S_{11}) antenna after adding a reflector

The modified reflector size is from 1 to 10 mm of the size of the antenna. Figure 9 shows the return loss simulation results of the reflector element, which shows a critical frequency at a frequency of 18 GHz. The most obtained matching condition is at a size of 5 mm, and the total dimension of the reflector antenna is 52 x 35 mm.

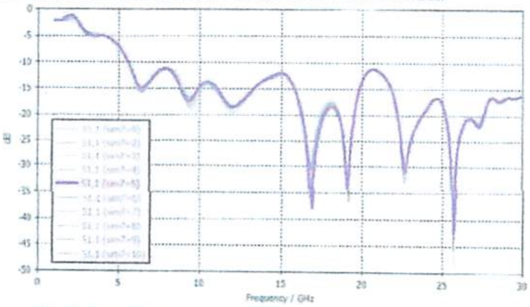


Fig. 9. Return loss (S_{11}) parameterization antenna with reflector

III. RESULTS AND DISCUSSION

Figure 10 and Figure 11 show fabricated hexagonal-triangular fractal antenna without and with reflector element, respectively. Due to the limited frequency range of measuring instruments, return loss and antenna impedance in a range frequency of 1 to 9 GHz are measured by using Network Analyzer Rohde & Schwarz ZVL 9kHz-13.6 GHz. Gain measurement is carried out in a range frequency of 2 to 6 GHz using Network Analyzer Hewlett Packard 8753E 32kHz-6GHz and Schwarzbeck BBHA 9120 A as a reference antenna. Radiation patterns measurement is carried out in the anechoic chamber at frequency 4 GHz by using Network Analyzer Hewlett Packard 8753E 32kHz-6GHz.

Fig. 10. Fabricated Hexagonal Triangular Fractal Antenna without reflector

Fig. 11. Fabricated Hexagonal Triangular Fractal Antenna with Reflector

TABLE I. ANTENNA DIMENSION

Measurement	Dimension
Antenna	32 x 25 mm
Reflector	52 x 35 mm
Distance between antenna and reflector	10 mm

A. Return Loss measurement

Figure 12 shows a return loss comparison between simulation and measurement data. It shows that there are shifting frequencies of the measurement results compared to the simulation results. There is a possibility that the fabricated antenna is not precise from the actual size. The FR4 substrate material used for manufacturing is possibly not the same characteristics in the dielectric constant and the tangent loss. Poor soldering of the grounding connector and the patch can provide additional losses. Although there is a different working frequency of the fabricated antenna, the ultrawideband characteristic is remaining. Although there is a different results in the working frequency of the fabricated antenna, the ultrawideband feature is remaining.

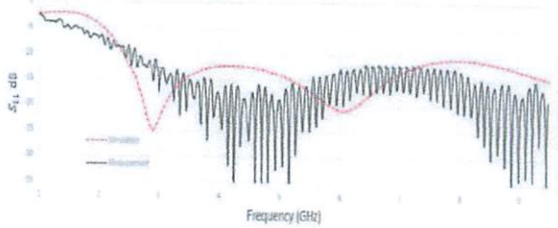


Fig. 12. Return loss (S_{11}) comparison between simulation and measurement

B. Gain Measurement

After simulating the distance between the antenna and the reflector, and the most reflector optimum dimensions, we measure and compare the antenna gain between without and with the reflector element. The distance between the antenna and the reflector element is 10 mm. The reflector dimension is 35 x 52 mm. Figure 13 shows the antennas gain measurement between the hexagonal-triangular fractal antenna without and with reflector. The obtained maximum gain is 7.65 dB at 6 GHz for the antenna with reflector. Improvement gain of the hexagonal-triangular fractal antenna with reflector is around 3.5 dB at all frequencies.

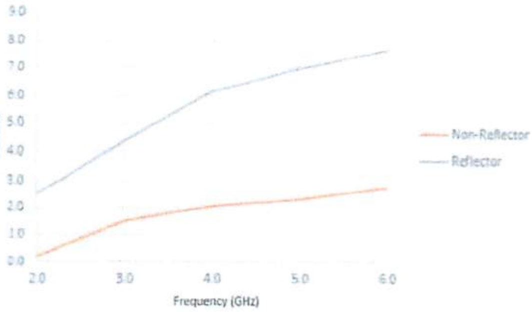


Fig. 13. Antenna gain measurement without and with reflector

C. Radiation Pattern measurement

Figure 14 and 15 show comparisons of simulated and measured radiation pattern at frequency 4 GHz for E-plane and H-plane, respectively. The radiation pattern indicates an omnidirectional. In general, the radiation pattern from measurement data shows a similar result compared to the simulation.

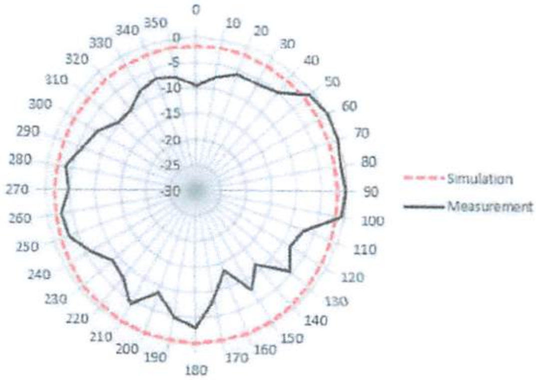


Fig. 14. Radiation Pattern (dB) for E-plane at frequency 4 GHz

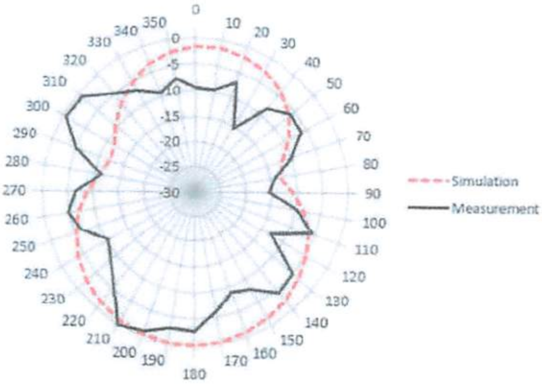


Fig. 15. Radiation Pattern (dB) for H-plane at frequency 4 GHz

IV. CONCLUSION

Hexagonal-Triangular Fractal Antenna with modification on tapered feedline section, a smooth notch on the ground plane, slit on the ground plane, gap-filling on patch section, and adding a reflector has been designed and fabricated for 5G and UWB applications. This proposed antenna can work at frequency 2.4 GHz until more than 30 GHz. Hexagonal-Triangular Fractal Antenna with a planar reflector antenna has obtained gain value from 2.5 dB to 7.65 dB at frequency 2-6 GHz. The modified design of Hexagonal-Triangular Fractal Antenna is potential for 5G and UWB applications.

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