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Kevlar-Alumina Composite as An Alternative Substrate for 5G Antenna Application

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***Abstract*— This paper introduces a millimetre-wave antenna design for 5G application using an alternative substrate called Kevlar-Alumina Composite. Kevlar-Alumina Composite had been researched and measured comprehensively by Indonesian Institute of Science (LIPI) Bandung showing dielectric value of 9.2. The application of the antenna geometry is based on Vivaldi Coplanar antenna with L shaped feeding on the ground plane. Vivaldi Antenna is chosen as it has relatively small size with various structures. An antenna of 3.75 GHz for 5G application using Kevlar-Alumina Composite is proposed. The simulated results of single element 5G antenna has return loss value of -21.949 dB, 1.173 VSWR, directive radiation pattern at E-Plane and H-plane, and surface current. The use of Kevlar-Alumina Composite performed good results.**

***Keywords*— 5G, 5G antenna, Kevlar, Alumina, Kevlar-Alumina Composite.**

I. INTRODUCTION

As the technology advancing into more sustainable material used, the needs of an alternative substance for antenna fabrication are significantly essential. One of the fabrics that has widely used is Kevlar KM2 fibre. Kevlar KM2 character of transversely isotropic when implement in small strain. However, this research mentioned that there are large energy absorbtion[1]. Another alternative material for substrate has been demonstrated on the previous research, Kevlar fabric composites shows better properties on high modulus and tensile strength compare to glass fibre and carbon while the mutual interaction of the fiber with another substance are negligible [2]. Kevlar/Polytetraflureothylene (PTFE) has been introduced as it has properties of wear and tensile resistance. In Addition, this study is also mentioned that nano-alumina may improve the formation of transfer current on the surface [3]. Another study about the composite material substrate presents the good performance of scattering parameter. However this study not stated what kind of composide used [4]. From those previous researches, the use of Kevlar and Alumina substance could increase the performance of materials purposedly for the use of microstrip antenna substrate will be investigated on this paper.

On the previous study [5], has been mentioned that the standard alumina substrate permittivity is 9.9 used for C-band frequency. Global System for Mobile Communication Association (GSMA) has been published a public policy position on 5G spectrum on March 2021 explaining that 5G requires spectrum in low, middle and high spectrum band in order to provide the large coverage and facilitate wide range of use. Low bands use 1500-1800 MHz, middle bands use 3.3-4.2 GHz while high bands utilize 4.8 GHz and 6GHz spectrums. A study about 5G antenna wireless application using inkjet-printed millimeter-wave PET-based flexible [6] has been exhibited in wideband frequency of 26-40 GHz resulting in consistent omnidirectional radiation pattern with 7.44 dBi as the peak gain. This research also suggests that potential wearable devices in 5G future application.

Microstip patch antenna has been widely used for 5G application. 4.8GHz H-Shaped slot rectangular microstrip patch antenna has been implemented and studied. However, this study has defect on the ground plane regarding the respon of the antenna [7]. Planar microstrip also had been investigated on the application of 5G application regarding the beamforming capabilities [8]. This study shows that 28GHz of the antenna implementation but limited on the performance of the array antenna [9].

Vivaldi antenna is a well-known antenna that has wideband operational bandwidth. Vivaldi antenna has geometry of tapered (curve) slot. This type of antenna commonly acknowledged as compact wideband antenna. The first study about this antenna was introduced as Tapered Slot Antenna (TSA), an exponential curve design proceeding from thin metal material [10]. On the recent research [11] investigating the influence of feeding structure toward antenna parameter performance shows the L shaped of feeding can work optimal in the targeted parameters. Vivaldi antenna has been implemented for 5G base station [12]. However, this study using radial stub and circular cavity. This kind of patch is complex to be implemented. On another study [13] 60-GHz antenna vivaldi had been implemented on the on-chip. Nevertheless, this research not mentioning the substrate used. Multiple strips of Vivaldi antenna for high-speed 5G communication also had been studied [14], this study is limited on the use of double slotted with few corrugations and grating elements.

In this paper, a simulation of 3.75 GHz 5G antenna is conducted based on Vivaldi antenna geometry. In addition, this paper will introduce Kevlar-Alumina Composite as a substitute of FR-4 (Epoxy), a material commonly used in microstrip antenna design. The results of this study are expected to provide benefit in the form of sustainable material applied in technology of communication in the future.

In section II, the antenna design including geometry of the antenna are presented. In section III, the simulation result and analysis of the results are explained methodically. The conclusion of this study is discussed in Section IV.

II. ANTENNA DESIGN

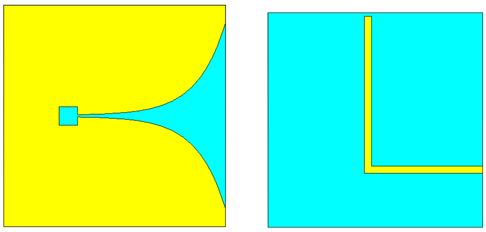
In this section, will be elaborated the antenna Vivaldi design for 5G application. There are several structures of the tapered plane in Vivaldi. On this study, the only structure used is a tapered formed by the following exponential formula [15].

$$y = c_1 e^{RX} + c_2 \quad (1)$$

$$c_1 = \frac{y_2 - y_1}{e^{Rx_1} - e^{Rx_2}} \quad (2)$$

$$c_2 = \frac{y_2 e^{Rx_1} - y_1 e^{Rx_2}}{e^{Rx_1} - e^{Rx_2}} \quad (3)$$

where R is the exponential taper rate, (x_1, y_1) and (x_2, y_2) are the nitial and end points of the tapered curve.

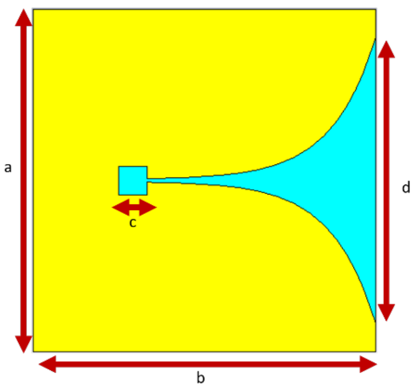


(a) (b)

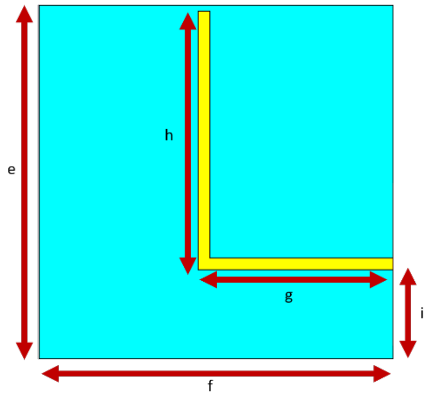
Figure 1. proposed antenna model (a). front view (b). bottom view

TABLE I
TARGETTED ANTENNA PARAMETERS

Specification	Value
Antenna Patch Type	Rectangular
Return Loss	< -10 dB
Working Frequency	3.75 GHz
VSWR	< 2
Feeding Method	Probe
Input Impedance	± 50 Ω
Radiation Pattern	Directional



(A)



(B)

Figure 2. The geometry of the antenna (a). forepart (b). back part.

TABLE II
PROPOSED ANTENNA GEOMETRY

Geometry	Name	Value (mm)
A	Forepart Length	60
B	Forepart Width	60
C	Reactangular Balun	5
D	Tapered rate	40
e	Ground Plane Length	60
f	Ground Plane Width	60
g	Feedring Strip Horizontal	33
h	Feeding strip vertical	44
i	Feeding Probe	15

Figure 1 shows the proposed antenna model of Vivaldi Antenna in front and bottom views. The specific tapered curve patch is the specialty of this type of this particular antenna. Table I presents the targetted antenna parameters on this study while Table II elaborate the detail geometry of the proposed antenna. Figure 2 illustrates the 5G antenna design based on the Vivaldi geometry. Every part of the antenna is essentials. However, until this paper publised there are no specific method or formula used in order to deternine each part of the antenna. On this paper, the geometries of the antenna are obtain by iterations of each part in the simulation software CST Microwave Studio apart from the tapered curve. The tapered curve dimension is obtained by using formula mentioned above.

TABLE III
SUBSTRATES SPECIFICATIONS

Specification	FR-4	Kevlar-Alumina Composite
Dielectric Coefficient	4.3	9.2
Permeability Coefficient	1	Under further research
Tangent Loss	0.025	Under further research
Optimal Frequency	1.109 – 9. 109 Hz	Under further research
Mass Density	1900 Kg/m	N/A
Thickness	1.6mm	2 mm

Table III presents the comparison of Kevlar-Alumina Composite versus FR-4. Despite still being under further research, this study chose Kevlar-Alumina Composite as substrate due to the effort of the investigation on how optimal this substrate will be when implemented into various types of antenna applications. Kevlar-Alumina Composite has been locally researched under antenna propagation laboratory in Politeknik Negeri Semarang and examine carefully until it ready to be used and measured professionally by the Indonesian Institute of Science (LIPI) Bandung resulting in discover of dielectric value of 9.2. This result indicates that this new alternative substrate has potential in the future sustainable material in communication technology. However, further study is profoundly required to observe this new material comprehensively.

III. RESULTS AND DISCUSSION

The proposed 5G antenna using Kevlar-Alumina Composite has been simulated. Several parameters namely return loss, VSWR, radiation pattern and surface current are discussed and analysed on this section.

A. Return Loss

The simulated return loss result of the proposed 3.75 5G antenna using new alternative substrate is shown in the Figure 3. After many iterations conducted on the CST Microwave Studio 2019, the antenna achieved the targeted parameter less than -10dB. A single element of the antenna work on the frequency of 3.75 GHz has value of return loss -21.949 dB. However, the antenna is designed supposedly to work on the designated frequency only, yet the result shows the antenna has frequency bandwidth of 78 MHz, 3.7027 GHz to 3.7816 GHz.

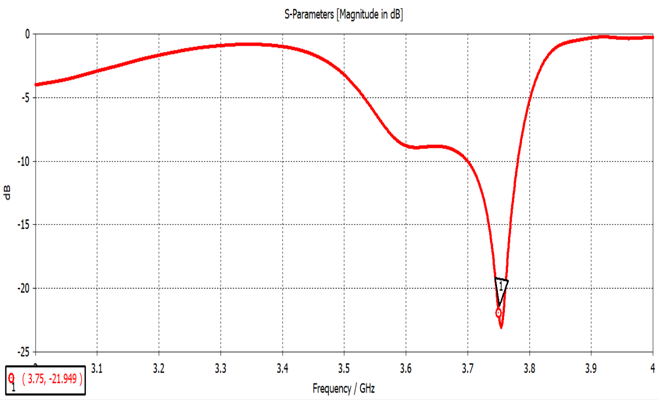


Figure 3. Return loss simulated result

B. Voltage Standing Wave Ratio (VSWR)

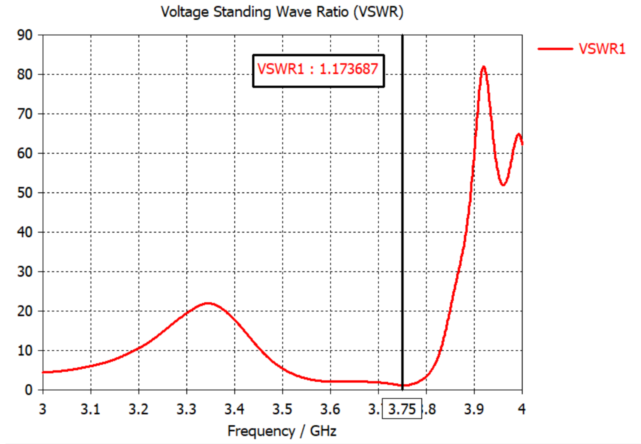


Figure 4. VSWR simulated result

The simulated result of VSWR is presented on the Figure 4. The proposed 5G antenna design utilized the dielectric coefficient of 9.2 shows positive result. The targeted parameter of VSWR is less than 2 whereas the simulation result demonstrates the value of 1.173687 in the frequency of 3.75 GHz, as shown on the Figure 4.

C. Radiation Pattern

As presented in the Figure 5, radiation pattern of the antenna shows the main lobe direction at -11^0 with the magnitude value around 0.889, while the angular width has value of 45.6^0 with side lobe level -0.5 dB. Figure 6 displays the 3D model of the radiation pattern. It is clearly seen that the pattern not directionally up front as it supposedly to be. This could be the side effect occurred due to the substrate that use. However, this is will be a topic to be discussed on the future. The gain of the antenna at the main lobe shows the value of 1.896.

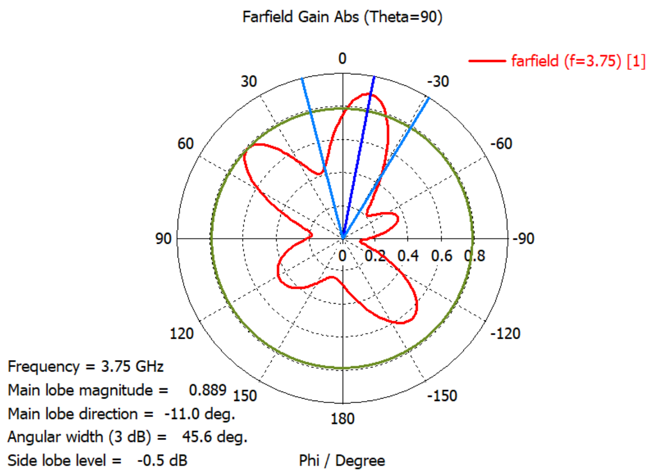
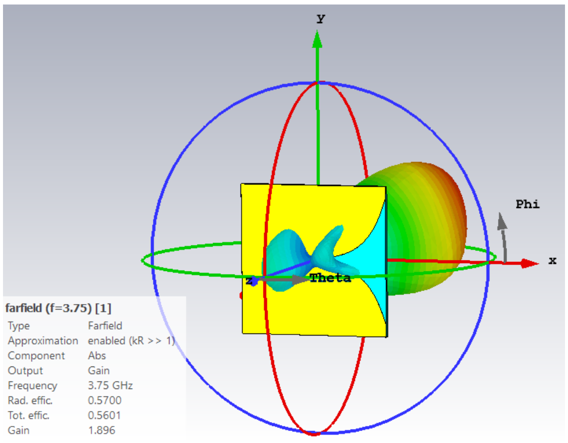
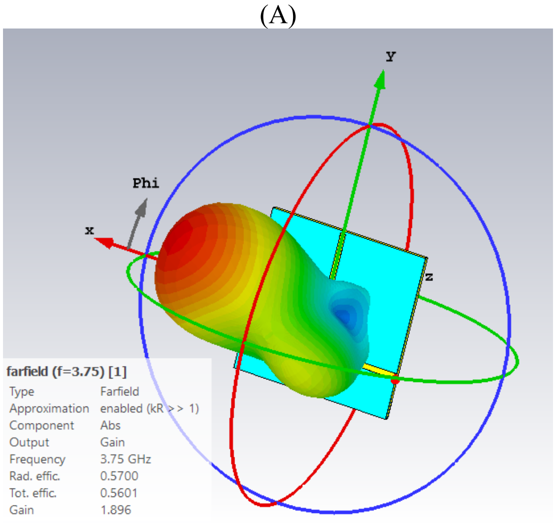


Figure 5. Radiation Pattern of 3.75 GHz 5G Antenna using Kevlar-Alumina Composite on polar coordinate.



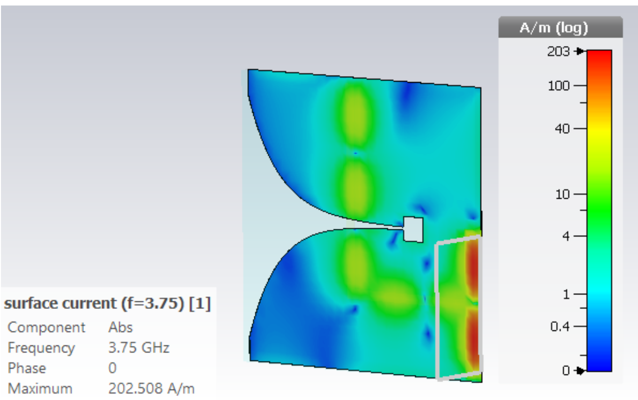
(A)



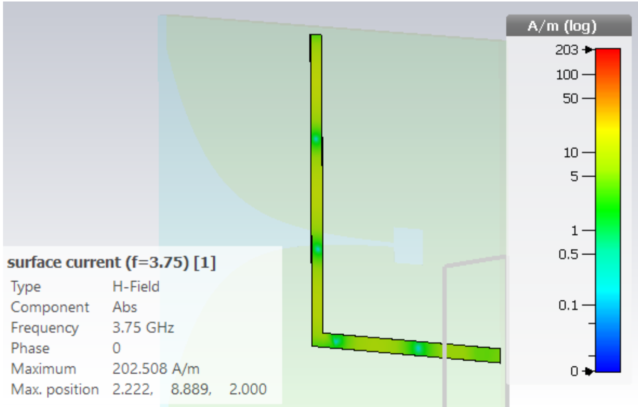
(B)

Figure 6. Radiation pattern of the proposed antenna in 3D models. (A) forepart (B) back part

D. Surface Current



(A)



(B)

Figure 7. Surface current distribution

The surface current distribution of the antenna has been shown in the Figure 7. The maximum surface current concentrate on the area around the probe and radiated on the patch in front. The current density on the ground plane displays the small number of current flows. This incident could affect the power radiated and direction of the radiation from the antenna.

IV. CONCLUSION

The 3.75 GHz 5G antenna using Kevlar-Alumina composite has successfully designed, simulated and analyzed. The proposed antenna has met the criteria of the targeted parameters. The new alternative substrate has achieved the improvement on a new material introduced. The simulated result has accomplished of working frequency 3.75 GHz, return loss value of -21.949 dB, and 1.173 VSWR. Subsequently, the antenna collected 1.896 gain on the main lobe.

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