# Electric Duct Fan Uav With Telemetry System Using Yagi-Uda Antenna

**Muhammad Agung Bramantya, Ariefa Yusabih**

**Abstract**:Rasayana Racing Plane was designed to fly at high speeds with an Electric Ducted Fan (EDF) motor as the main driver. The manufacturing process of Rasayana Racing Plane was carried out to make a UAV as light as possible using composite materials through the vacuum bagging method for fuselage and hand lay-up for the wings and stabilizer by adding core material in several points as reinforcement. The main focus of the research is on the air duct in the form of nozzle and diffuser to maximize the speed. The UAV uses electronic components such as ESC, battery, receiver, transmitter, servo, power module, etc. Whereas the UAV that is supposed to fly auto requires additional electronic components, i.e. flight controller, GPS, and telemetry system uses a Yagi-Uda antenna. The analysis was conducted for the wing such as aspect ratio and wing load, then the testing of air duct, flight controller parameters, and Yagi-Uda antenna were carried out by direct flight test.

**Index Terms**:Electric Ducted Fan (EDF) Motor , Unmanned Aerial Vehicle (UAV), Yagi-Uda Antenna..

## 1 INTRODUCTION

Rasayana Racing Plane was designed to resemble a commercial fighter jet with flight characteristics that are suitable to the high-speed application. The UAV manufacturing process is made to be as light as possible by using composite materials through a vacuum bagging method and added core material at some points as a reinforcement. The main focus of this research is on the air duct which is in the form of a nozzle and diffuser to maximize the UAV speed. Unmanned aerial vehicle requires electronic components so that it can fly. Electronic components that must be used to make aeromodelling UAV are motor, ESC, battery, receiver, transmitter, servo, power module, etc. The UAV that is supposed to fly in auto mode requires additional electronic components, i.e. flight controller, GPS, and telemetry. The antenna that is developed for the ground control system (GCS) is a Yagi-Uda antenna. The consideration in choosing an antenna to be developed is the radio wave radiation pattern. The radiation pattern of an antenna is a mathematical function or graphical representation of the radiation properties of the antenna as a function of coordinate space (Agnihotri, Prabhu, and Mishra, 2013)

## 2 DESIGN MODEL AND IMPLEMENTATION

### 2.1 Vehicle Design

The design of Rasayana Racing Plane uses Electric Ducted Fan (EDF) as the main driver.

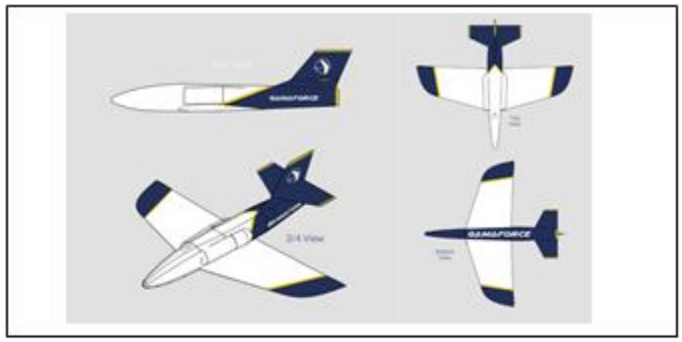

***Fig. 1***. *Rasayana Racing Plane Design*

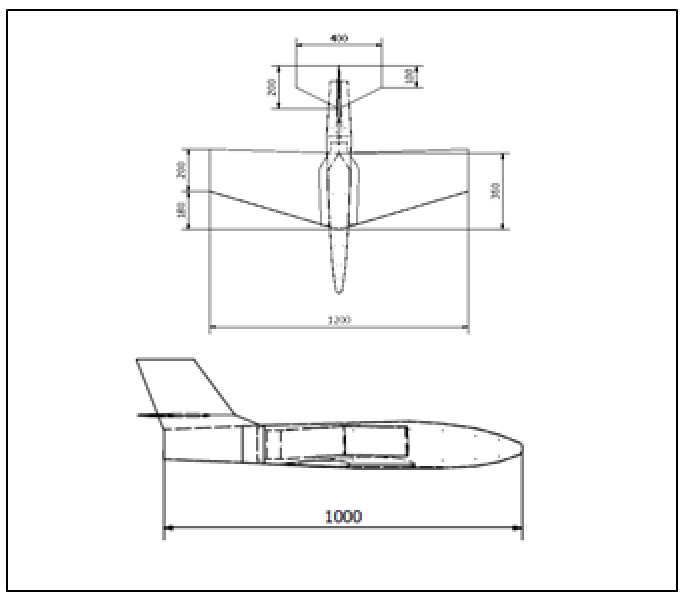


***Fig. 2.*** *The Engineering Drawing of Rasayana Racing Plane*

### 2.2 Air Duct Design

The design of Rasayana Racing Plane uses Electric Ducted Fan (EDF) as the main driver. The design of Rasayana Racing Plane uses Electric Ducted Fan (EDF) as the main driver. The design of Rasayana Racing Plane uses Electric Ducted Fan (EDF) as the main driver. The placement of air duct that consists of inlet and outlet is important because its shape that resembles a diffuser and nozzle helps maximize the incoming air so that the resulting speed is optimal.


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***Fig. 3**. The Engineering Drawing of Rasayana Racing Plane Outlet Tube*

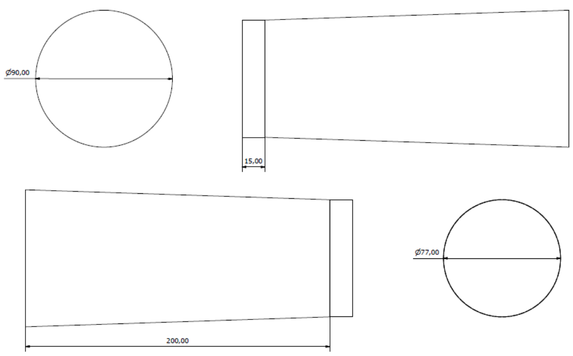
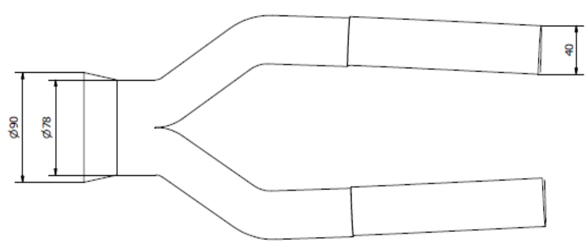



***Fig. 4.** The Engineering Drawing of Rasayana Racing Plane Inlet*



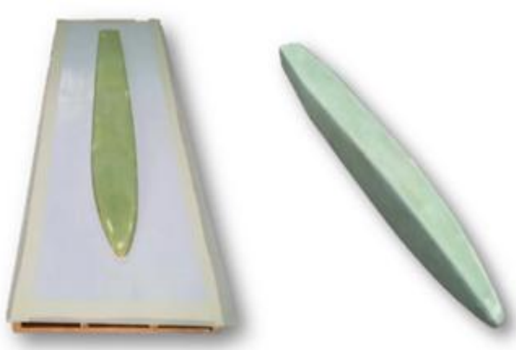

### 2.3 Manufacturing of UAV Molding

The positive mold is composed of foam coated with fiber that has been stuck by resin, and then for the finer results, putty was added as a finishing.

#### 2.3.1. Positive Mold

The positive mold is composed of foam coated with fiber that has been stuck by resin, and then for the finer results, putty was added as a finishing.

***Fig. 5.** Positive Mold of UAV Fuselage*



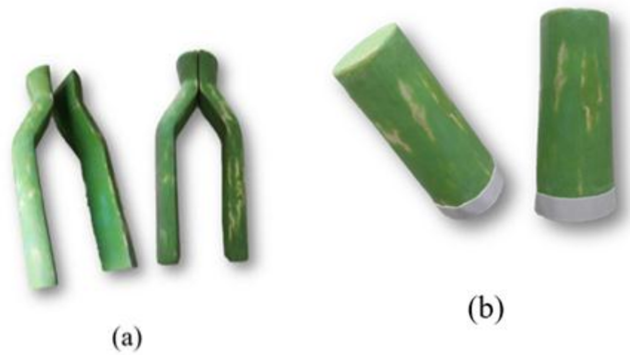



***Fig. 6.** Positive Mold of Air Duct (a) Inlet Tube (b) Outlet Tube*

#### 2.3.2. Negative Mold

The negative mold is composed of fiber that has been stuck by red resin and gel coat mixture. Negative mold can be made after the positive mold

***Fig. 7.** Negative Mold of UAV Fuselage.*

#### 2.3.3. UAV Manufacturing

#### 2.3.3.1. Fuselage

UAV fuselage manufacturing uses vacuum bagging method because it is considered more effective, efficient, and economical than vacuum infusion method. Furthermore, the product of the vacuum bagging method will be lighter than the product of hand lay-up method.

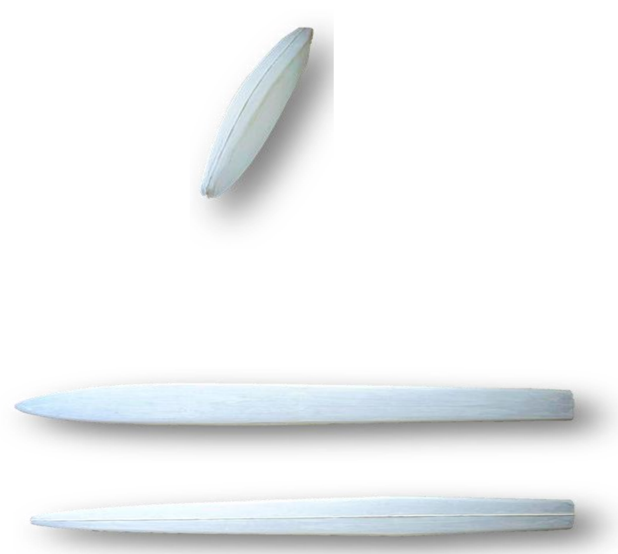


***Fig. 8.** Fuselage Composite*

**2.3.3.2. Thrust Tube Tube**

Thrust tube manufacturing does not use negative mold so that the air that hits the tube is more fluent and smooth, moreover, it can reduce the drag on the surface.

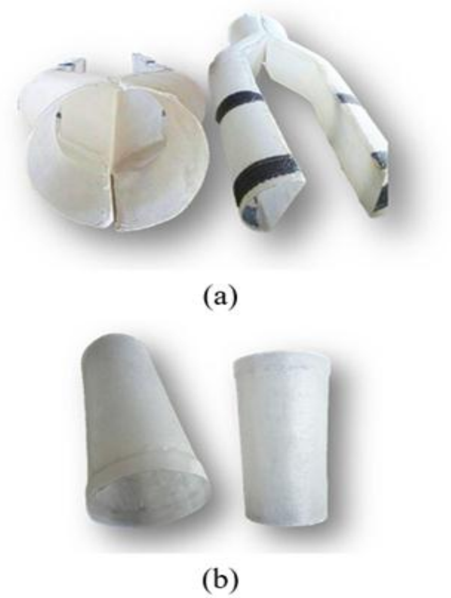



***Fig. 9.*** *Thrust Tube Composite (a) Inlet Tube (b) Outlet Tube*

**2.3.3.3. Wing and Stabilizer**

Wing and stabilizer are made of foam coated with fiber to increase hardness and strength.

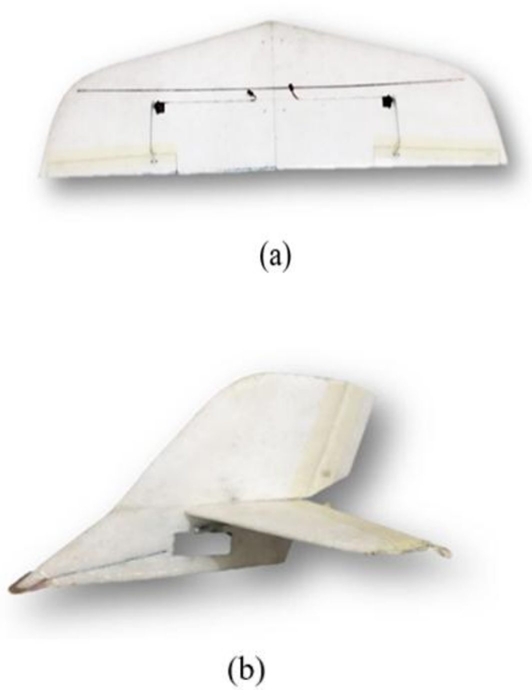



***Fig. 10.*** *Wing and Stabilizer (a) Wing (b) Stabilizer*

**2.4 Electronic Circuit**

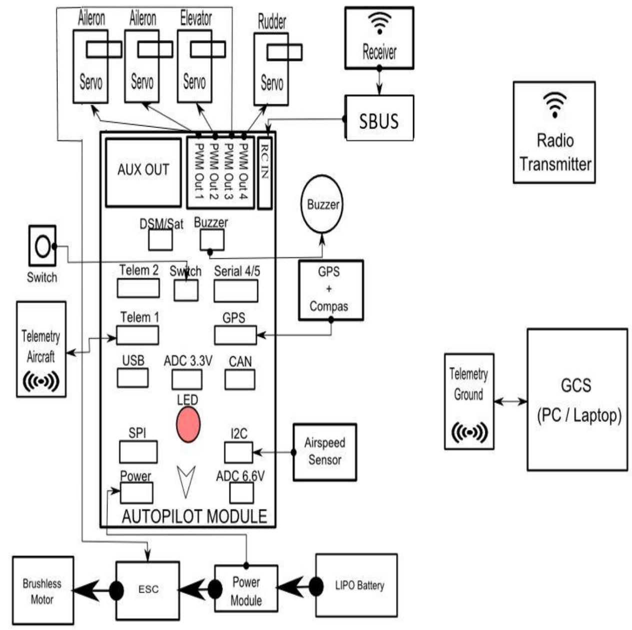



***Fig. 11.*** *Electronic Circuit*

UAV require electronic components so that they can fly. The electronic components are motor, ESC, battery, receiver, transmitter, servo, power module, etc. If the UAV is supposed to fly automatically, it requires additional electronic components, namely flight controller, GPS, and telemetry. The motor that will be discussed is Electric Ducted Fan (EDF). Here are the functions of each component: *Electric Ducted Fan (EDF)* Electric Ducted Fan (EDF) is the actuator that will make the UAV has the ability to fly. We use EDF 90mm. EDF motor has several disadvantages compared to BDC motor and induction motor, including: Better speed than torque characteristics High dynamic response Wider speed range Etc.*Electronic Speed Controller (ESC)* Electronic Speed Controller (ESC) is a power controller that will be used by the motor. We use ESC 150A. *Battery* The battery is a power supply for UAV. The battery that commonly used is Lithium Polymer (LiPo) battery. LiPo battery 6S 3700 MAh is used as power supply for EDF motor. *Transmitter* Transmitter or remote control is a component used by a pilot to control UAV by transmitting signals to the receiver. In general, transmitter works using radio wave. *Receiver* The receiver is a component that receives signals from the transmitter. *Flight Controller* Flight controller reads data from the sensor and performs calculations to order the drone to move according to the order. We use Pixhawk 1 as the flight controller in our UAV. *GPS (Global Positioning System)* GPS module measures the location of the UAV by measuring how long the signal moves from the satellite. *Telemetry* The telemetry module is a device that transmits and receive data through radio signals. There are two modules that used in UAV, one is in the ground station and the other is mounted on the UAV.

***TABLE 1***

*DATA OF SPEED TESTING RESULTS.*

| No. | Inlet Tube (%) | Outlet tube (%) | Results |
|---|---|---|---|
| 1 | 95% | 95% | Speed is not optimal |
| 2 | 95% | 92,5% | Optimal speed |
| 3 | 95% | 90% | Very high pressure causes failure on the EDF motor |

## 3 TESTING AND ANALYSIS

*Aspect Ratio* Aspect ratio can be calculated by wing span squared divided by wing chord, or 120cm² divided by 3360cm² and the result is 4,29. So the aspect ratio is 4,29. *Wing Load Calculation* Basically, the wing load relates to the weight of the UAV when taking off or being above the ground level. Wing load calculation can be done by dividing the UAV total mass by the surface area of the wing. UAV total mass is measured using a digital scale and the result is 2,9kg, while the surface area of the wing is calculated using *Aircraft Center of Gravity Calculator* and the result is 3360cm$^2$, so the wing load result is 8,63kg/cm$^2$. *Air Duct Result by Flight Test* This step discusses the effect of the percentage of inlet tube diameter and outlet tube diameter to Fan Swept Area (FSA) on the EDF motor using FSA calculator. The test results are then analyzed by doing the flight test in the field using the same parameter and we get the optimal inlet tube is 95% of FSA and the optimal outlet tube is 92,5% of FSA. *System Analysis*

When the UAV carries out the mission relying on Autonomous Flight, Ground Control Station has to put in the waypoint coordinates in the form of latitude, longitude, and altitude which will be executed by flight controller. The data during the flight will be received in real time by GCS via telemetry that connected to the Flight Control Board. The data received are ground speed, roll, pitch, yaw, and altitude of the UAV when carrying out autonomous flying missions.

The flight controller parameters have been adjusted to support the UAV for high-speed cruising. When the UAV flying autonomously the cruising speed can be observed through GCS and the top speed data obtained is 200 km/hr. Top speed is obtained by increasing the throttling parameter during autonomous flight so that the UAV is at its best performance. However, that must be supported by the UAV condition that is capable to fly stable at high speeds, besides the UAV also must be easy to be controlled so that the UAV can fly safely. *Yagi-Uda Analysis with Numerical Simulation Method* We use MMANA-GAL to design and analyze the characteristics of the Yagi-Uda antenna. The radio wave frequency used in wireless communication between GCS and the UAV is 433MHz. The material used for the antenna is a copper cable with a diameter of 2.5mm. The length of each element is 34.37cm for the reflector, 32.75cm for the driven element, 30.46cm for the director 1, 30.12cm for the director 2, and 29.77cm for the director 3. Based on the simulation results, the distance between elements that can generate a Standing Wave Ratio value close to 1 and the resistance value close to 50Ω are shown below

***TABLE 2***

*DATA OF DISTANCE AND ELEMENT*

| Element | Distance |
|---|---|
| Reflector - driven element | 19cm |
| Driven element - director 1 | 15,9cm |
| Director 1 – director 2 | 18.7cm |
| Director 2 – director 3 | 21.8cm |

| F (MHz) | R (Ohm) | jX (Ohm) | SWR 50 | Gh dBd | Ga dBi |
|---|---|---|---|---|---|
| 433.0 | 50.3 | 0.1201 | 1.01 | 9.06 | 11.21 |

| F/B dB | Elev. | Ground | Add H. | Polar. |
|---|---|---|---|---|
| -605.61 | 90.0 | Free | --- | hori. |

***Fig. 12.*** *Data Close to Target*

The radiation pattern obtained from the simulation results is as shown below.

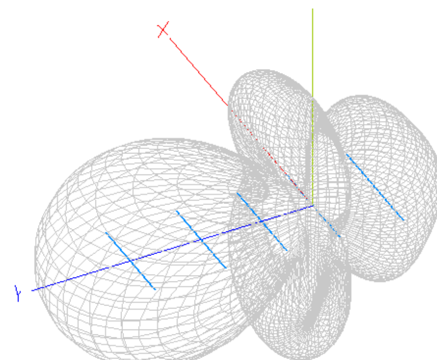


***Fig 13.****Radiation Pattern*

*Experimental Testing of Yagi-Uda* The experimental testing is conducted to determine the characteristics of the antenna directly. An experimental test was carried out using measuring instruments, namely Rig Expert, and the UAV connected to GCS. Measuring using Rig Expert is carried out by connecting the Rig Expert to the antenna that has been made. The characteristics of the antenna in the form of SWR and resistance will be obtained through measurements using the Rig Expert. Measuring the distance of the radiant wave range and signal strength is carried out using the UAV and GCS. The UAV is wirelessly connected to GCS via the Yagi-Uda antenna. Measurements are conducted by moving the UAV away from the GCS until they are disconnected. The distance measurement is carried out at an elevation of ± 1m from the ground level, while the signal strength measurement is carried out at an elevation of ± 100m and at distance of 700m from the GCS. The distance between the UAV and GCS is known through GPS (Global Positioning System) and signal strength is known directly from the GCS. The data from GPS is transmitted from the UAV to the GCS. The test results using Rig Expert show that the SWR value obtained is 1.4 and the resistance value is 55Ω. The farthest radiation range in conditions where the UAV is at an altitude of ± 1m from the ground level is 1km. The signal strength can be caught by the antenna at a distance of 700m is 99%.

## 4 CONCLUSION

Rasayana Racing Plane has a wing aspect ratio of 4.29, a wing loading of 8.63kg/cm$^2$ with an inlet diameter configuration of 95% and an outlet diameter configuration of 92.5% on EDF Fan Swept Area, which makes it up to 202km/hr.
Yagi-Uda antenna keeps the UAV connected to Ground Control Station at a distance of up to 1km on the ground with a signal strength of 99% at a distance of 700m in the air.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