ISSN 2744-1741
Original Research

Defense and Security Studies
Vol. 3, January 2022, pp.74-82
https://doi.org/10.37868/dss.v3.id203

The Concept of Stealth Unmanned Combat Aerial Vehicle (UCAV) to Support Air Defense Systems

Opa Mustopa[1*], Romie Oktovianus Bura[2]
[1,2] Faculty of Defense Technology, Indonesia Defense University, Indonesia

*Corresponding author E-mail: opa.mustopa@tp.idu.ac.id

Received Oct. 27, 2022
Revised Nov. 13, 2022
Accepted Nov. 14, 2022

Abstract

One platform that is currently highly developed as an air defense technology is the Unmanned Combat Aerial Vehicle (UCAV) which is a UAV system equipped with a weapon system or has combat capabilities. In this study, the UCAV concept was developed with the aim of having a stealth or low observability aspect by being shown to have a low Radar Cross Section (RCS) value. And in this paper the UCAV model developed is a generic UCAV configuration developed by the NATO STO/AVT-161 task group, namely SACCON UCAV. The SACCON UCAV is also goal-oriented typical of low observability with a combination of high agility and high Angle of Attack (AoA) capabilities. The results of the SACCON UCAV design were then analyzed by the RCS value using the SBR method using the Ansys HFSS software. And the results of the RCS calculation show that the SACCON UCAV model has a low RCS value and the RCS value can be reduced again by shaping the UCAV configuration.

Keywords: Unmanned Combat Aerial Vehicle (UCAV), Stealth Technology, Radar Cross Section (RCS), SACCON UCAV

1. Introduction

Talking about a country's defense system, one of the most important aspects to study is the air defense system. Due to the development of the times, defense technology, especially aircraft technology, is also developing. Now every country in the world is competing to create a concept of fighter aircraft as a means of national defense in airspace. And one of the air defense technologies that is currently highly developed is the Unmanned Aerial Vehicle (UAV). The UAV system is an unmanned aircraft flight system that is not manned by humans, which is controlled remotely, either manually or automatically, which consists of unmanned aircraft, payloads, human resources, control systems, data networks, and supporting elements [2]. Utilization of the UAV system basically can be an appropriate alternative to overcome existing problems, as well as a response to the influence of rapid technological advances, and in line with the implementation of Revolution in Military Affairs (RMA), which is aimed at achieving Network Centric Operation or Network CentricWarfare [7]. The ability of the UAV system to carry out surveillance of the national territory by air with its characteristics and advantages, including in terms of flexibility and range, minimized operational risks, and the ability to fly for a relatively long period of time, is a significant consideration for the unmanned aerial vehicle to be able to empowered as a reliable defense equipment to support national defense [8]. The development of the UAV system is currently very widely used and is used for various missions such as intelligence, surveillance, reconnaissance and even including UAV for attack missions or commonly called

Unmanned Combat Aerial Vehicle (UCAV) [4]. In carrying out these various missions, the UAV/UCAV also requires a supporting technology, one of which is stealth technology .technology stealth aims to avoid detection by enemy defense radars, so that the UAV/UCAV can more freely carry out its mission [9].

1.1. Concept of Stealth Technology

The emergence of stealth is caused by the emergence of major changes in the scope of warfare that bring the application of technological inventions combined with fundamental changes in doctrine, operations and concepts of military organization, which are fundamentally related to the character and way of conducting military operations. This change is generally known as Revolution in Military Affairs (RMA) [6]. Therefore, major countries are trying to develop weapons as a product of their defense industry by prioritizing the application of advanced technology. In general, the purpose of using this technology is to launch attacks using aircraft in enemy areas without being detected by the air defense radar [1].

To meet the stealth of the aircraft, there are three things that can be minimized, namely:

1. Visual aspects, such as eliminating smoke trails, repainting or repainting the aircraft to resemble environment in which the mission is carried out.
2. Infrared aspect which reduces the use of after burner.
3. Radar aspect, namely reducing the radar cross section (RCS) of the aircraft. Low surveillance is felt to be able to increase the probability of a fighter aircraft's success in carrying out its mission because it is able to provide an element of surprise in the opponent's area. In addition, with the existence of low surveillance combat aircraft, it is hoped that the aircraft will be able to have a better life cycle than combat aircraft that have a higher RCS [3].

Radar Cross Section (RCS) is the ability of an object to reflect the radar signal back to the transmitter source. The smaller the RCS value of an object, the more difficult it is for the object to be detected by enemy radar. The advantages of reducing RCS are as follows:

1. Reduction of the detection distance from the target or aircraft.
2. A reduction in the search area or search volume of enemy radar will take longer to scan than for the same amount of space .
3. The enemy defense radar will not be able to detect what objects are approaching [5].

Therefore, stealth in aircraft is currently being developed with various methods, one of which is by modifying the shape of the aircraft (shaping) and with material technology that can absorb and deflect radar electromagnetic waves or commonly known as the Radar Absorbing Material (RAM) method [10]. The following is a graphic illustration of the difference in RCS values on conventional aircraft with aircraft that have stealth.

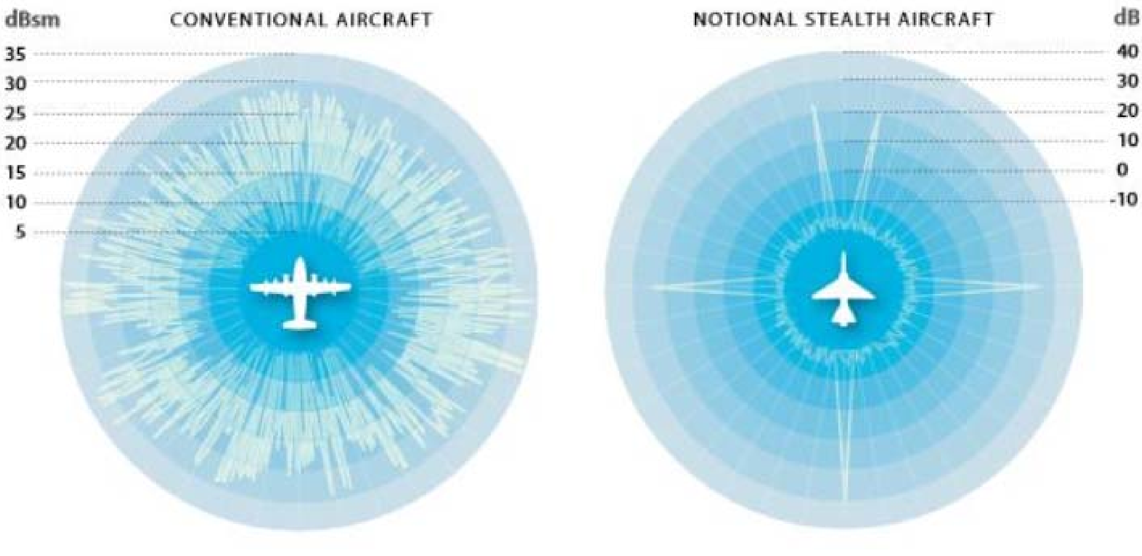


Figure 1. Graph of comparison of RCS values between conventional aircraft (20 dB) and stealth (-10 dB) [1].

It can be seen in the image above that by modifying the shape of the aircraft using stealth technology, the RCS value is much smaller than ordinary conventional aircraft, meaning that the aircraft with stealth technology is able to provide superiority to the effect of enemy radar monitoring range so that it is suitable for use on UAV for military missions or in this case for surveillance missions, reconnaissance and even attacks in the new state capital area.

1.2. Radar Cross Section (RCS)

Radar Cross Section is the ability of a target to reflect back the radar signal towards the source from the radar transmitter. RCS has units of square meters because RCS shows signature of a target, especially fighter aircraft, because it can be said that RCS also shows the projected area of a metal sphere that will emit a certain amount power towards a target [3, 11]. In the usual RCS analysis, there are two types of cases as shown in Figure 2, namely the monostatic where the radar transmitter-receiver is located in one place, or the bistatic where the radar transmitter and receiver are separated at different locations.

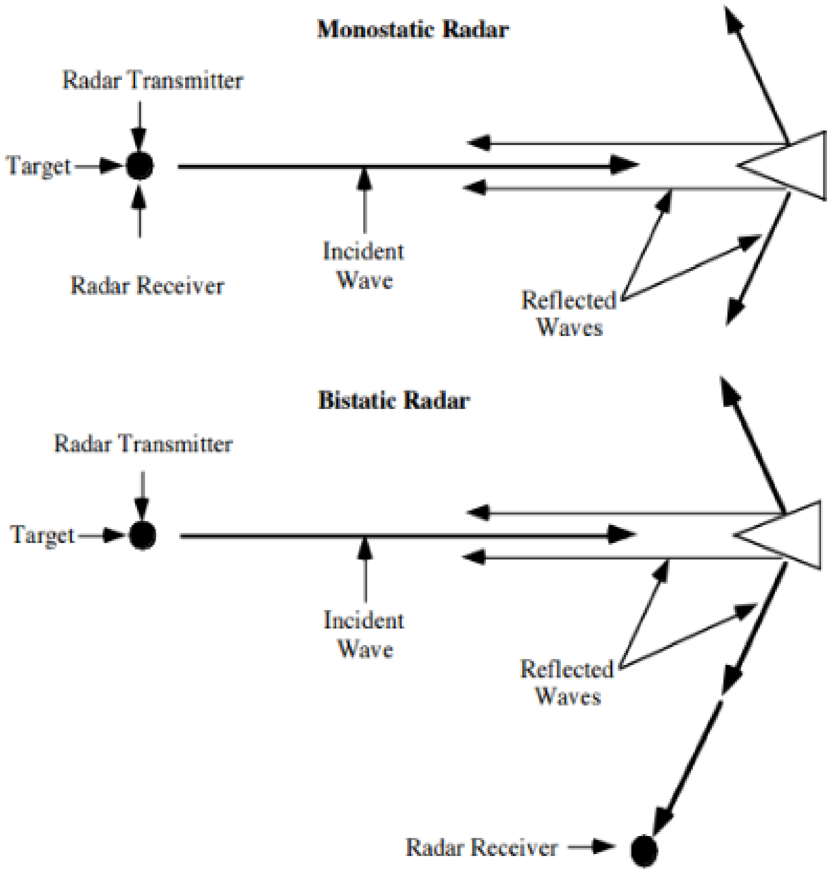


Figure 2. Reference RCS concept [11]

2. Research method

In predicting the RCS value, there are several techniques or methods which are broadly divided into two, namely the exact method and numerical approximation. In this research, the method used is numerical approximate with the help of ANSYS HFSS software. Shooting and Bouncing Ray (SBR) method is an approximation method to calculate the RCS value with high frequency, so that predicting the RCS value on large objects will be more effective because great accuracy can be achieved in high frequency analysis [13, 14]. This SBR method is the latest method in analyzing RCS values based on ray tracing and combines Geometric Optics (GO) and Physical Optics (PO) approaches. The advantage of the SBR method is that it can consider several reflection effects and shadow effects. Use of the SBR method requires a Scattering Analysis (SA) process which is carried out in 3 stages.

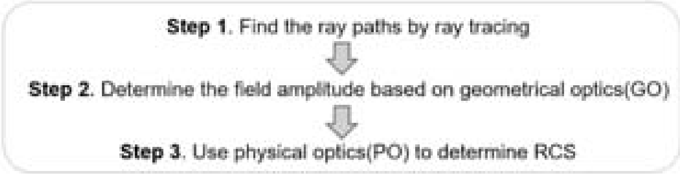


Figure 3. Process of SBR Method [12]

For analysis, the SBR method still has a weakness because it has not considered the diffraction field at the edges. Therefore, ANSYS HFSS v193 software is used. In HFSS, SBR is available with advanced diffraction and wave creep physics for increased accuracy. The following is the flow of analysis in predicting the RCS value with the SBR method in the ANSYS HFSS software.

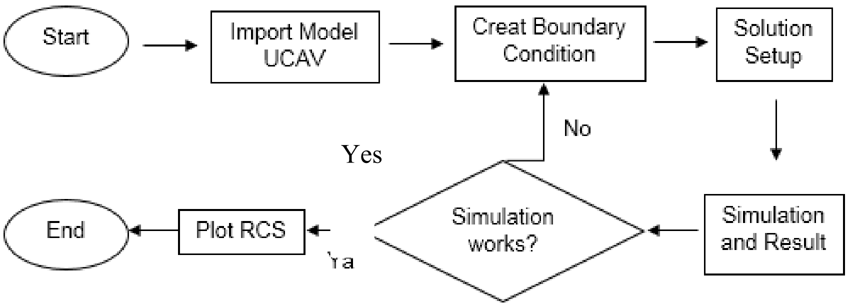


Figure 4. Flowchart of RCS analysis with the SBR method in the Ansys HFSS software.

3. Results and Discussion

3.1 Unmanned Combat Aerial Vehicle (UCAV) Design

The Unmanned Combat Aerial Vehicle (UCAV) model used is a generic UCAV configuration developed by the NATO STO/AVT-161 task group, namely SACCON UCAV. The main reason for choosing this UCAV platform is because the geometry of the SACCON UCAV platform has been designed with stealth requirements which lead the UCAV design to the flying wing concept. The basic lambda-shaped geometry of the SACCON UCAV configuration is also oriented towards the typical goal of low observability with a combination of high agility and high Angle of Attack (AoA) capabilities, so that in addition to considering low capabilities detected by enemy defense radars, this SACCON UCAV model was also developed as a realistic UCAV concept. The mission parameters and boundary conditions applied to the SACCON UCAV design are given in table 1 and figure 5 below.

Table 1. Mission parameters and boundary conditions

Parameter	Value
Outer shape	Scaled SACCON geometry
Propulsion	1 or 2 turbofan engines
Engine integration	buried (due to signature reasons)
Payload storage	Internal (due to signature reasons)
Payload mass	1 × 2000 kg or 2 × 1000 kg
Design range	3000 km (without refueling)
Fuel reserve	≈45 min
Cruise altitude	11 km
Cruise Mach number	0.8 (all altitudes)
Stability margin	2–8 %

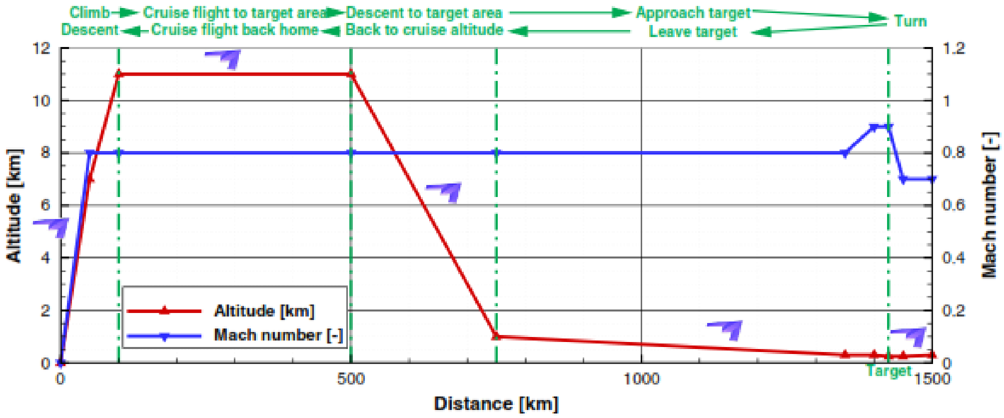


Figure 5. Design Mission of SACCON UCAV

The total payload mass for the UCAV is 2000 kg. Due to signature requirements, the internal storage must be in one or two payload space. A design range of 3000 km without aerial refueling is considered sufficient as an additional spare time of about 45. With this assumption, an operational radius of 1500 km can be achieved. Cruising flights to the target area were carried out at an altitude of 11 km with a rate of Mach 0.8. In the target area, the UCAV must descend to an altitude of 300 m while maintaining a Mach figure of 0.8. During the last kilometers it can even descend to 250m and accelerate to Mach 0.9 but due to its fixed outer shape, this is only an optional requirement. To maintain good maneuverability for this UCAV flying wing without making it laterally unstable, a stability margin of 2–8% was chosen. Furthermore, the typical mission of SACCON UCAV is given in Figure 6 below.

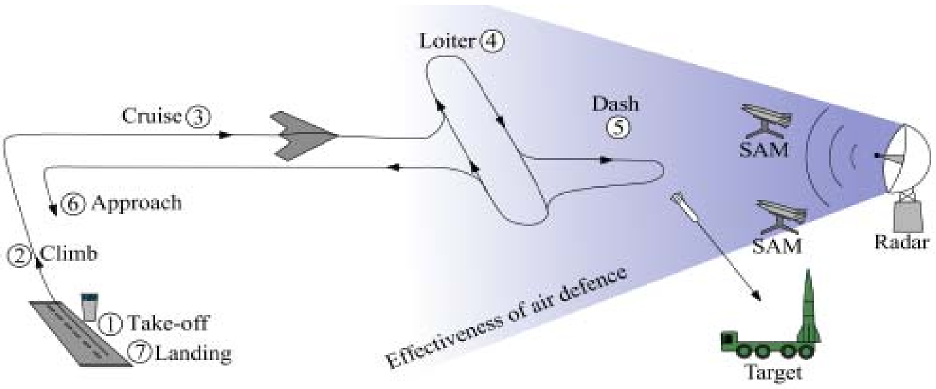
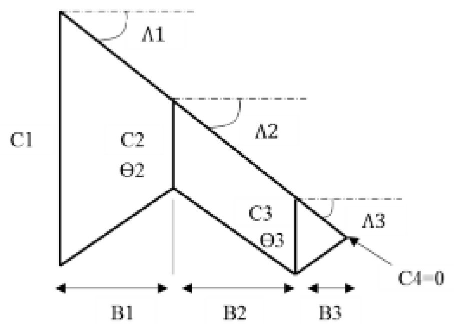


Figure 6. Typical Mission of SACCON UCAV

The following is an explanation of the typical SACCON UCAV Mission as follows

1) Take-off - the aircraft will operate outside the airfield in several friendly areas. The length and distance of the runway to some threshold heights will be limited. This is very important for aircraft carrier operations.
2) Climb - the aircraft will rise to its cruising altitude, precisely at the edge of the stratosphere (~11,000 m). A high climb rate and low fuel requirement would be desirable.
3) Cruise - the plane will sail to a roaming location. With speeds just below the Mach drag increase rate then long distances and fast sailings are desirable.
4) Loiter - The aircraft will roam, perhaps at a lower altitude, in an area that can use sensors and possibly use weapons. Here long endurance is very important.
5) Dash - The aircraft will fly towards its target as quickly as possible to deploy weapons and/or gather intelligence. Maximum speed here is very important.
6) Approach - During approach, the aircraft will lose altitude to land.
7) Landing - The aircraft must be able to slow itself down to landing speed. After landing, he must stop before the end of the runway.

Furthermore, to design the SACCON UCAV platform, it is necessary to determine the design variables and the geometry of the aircraft to be parameterized first. Figure 7 below is given the design variables with some assumptions or limitations.



Variable	Information	Geometry Parameters
C	Chord lengths	C1 = 10.5 m C2 = 5 m C3 = 4.5 m C4 = 0 m
B	Span Sweep	B1 = 2.5 m B2 = 3.5 m B3 = 1.5 m
Λ	Sweep Angles	Λ = 53°
C*	Airfoils	C1* : NACA 64012 C2* & C3* : NACA 64008

Figure 7. SACCON UCAV Geometry Parameterization

Then with the help of CATIA software, a SACCON UCAV platform design was made based on the variables and parameters that have been previously determined in figure 7 so that the SACCON UCAV design was obtained as follows

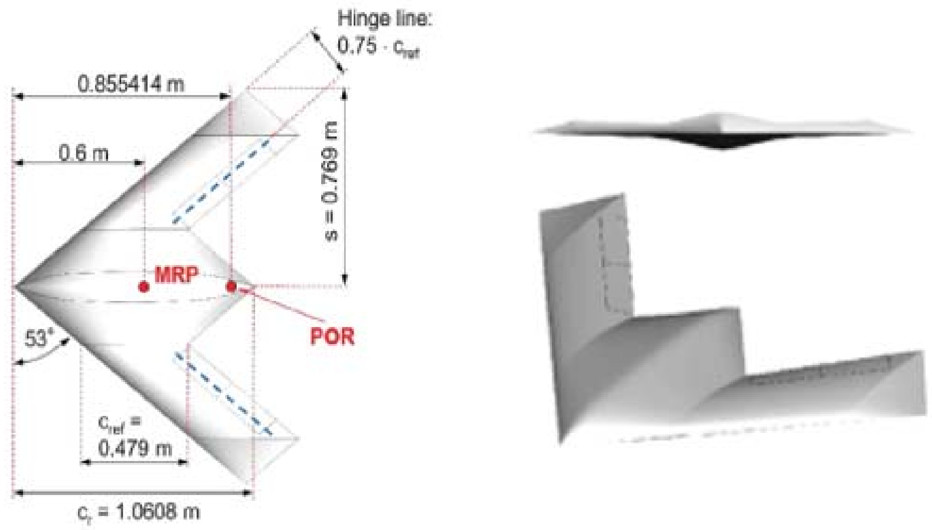


Figure 8. Design of SACCON UCAV

The coordinate system in SACCON UCAV are given in Figure 9 below.

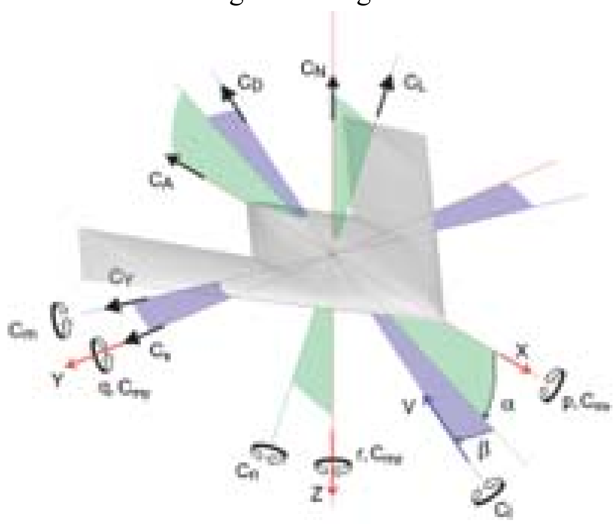


Figure 9. Coordinate System of SACCON UCAV

3.2 Radar Cross Section (RCS) Analysis of SACCON UCAV

In conducting the Radar Cross Section (RCS) analysis to calculate the value approach, it is carried out numerically with the help of the Ansys HFSS (High Frequency Structure Simulator) 2019 R3 software. To perform the Radar Cross Section (RCS) simulation, the assumption used is that the material used is in the form of Perfect Electric Conductor (PEC) which is an ideal material that can restore electromagnetic wave energy perfectly so that it is suitable for simulation of Radar Cross Section (RCS) calculations. Then the frequency used is 10 GHz, which includes high-frequency X-band radar with a frequency range of 8-12 GHz. This X-band radar is a type of radar commonly used in the military world to detect military aircraft, including aircraft with stealth technology that are still within the range of this radar. Then the threat area used is 90° on the elevation plane and 0° to 360° on the azimuth plane. After these assumptions are inputted, then a setup simulation is carried out using the SBR+ method approach with the type of radar receiver used is a monostatic radar. The following are pictures of the simulation results of the Radar Cross Section (RCS) on the UCAV SACCON model.

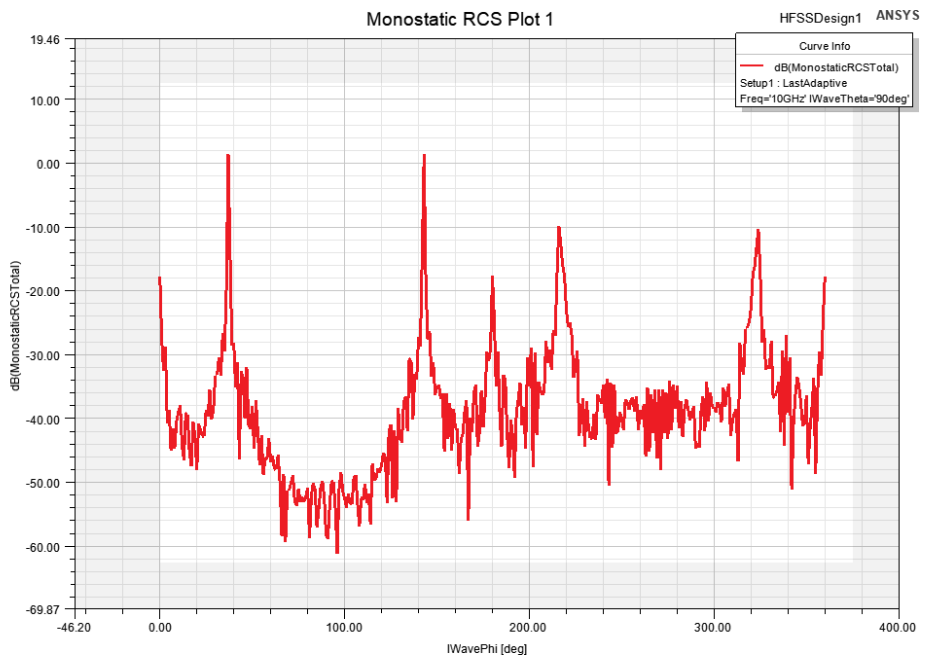


Figure 10. Simulation of RCS Linear Plot

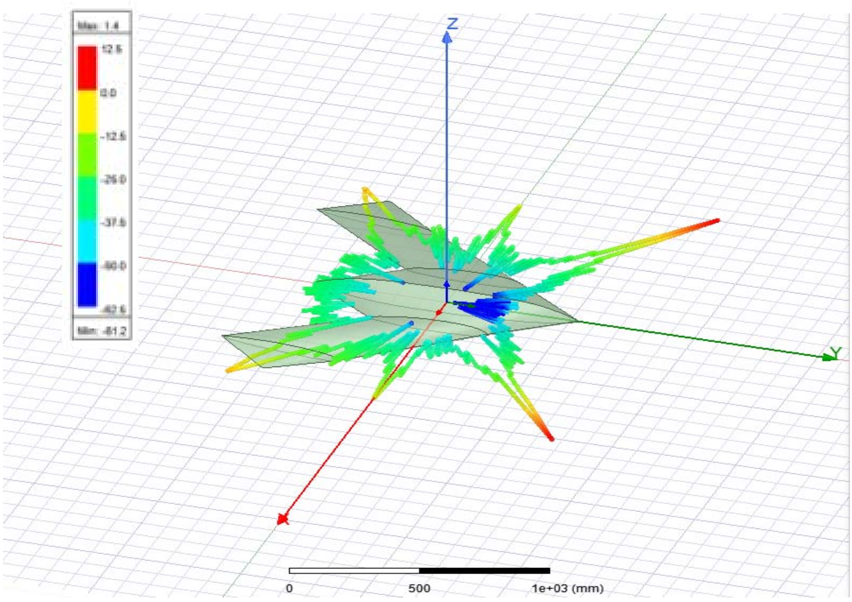


Figure 11. 3D RCS Plots over the entire surface of the UCAV Geometry

Then from the simulation results above, the calculation of the RCS value can be generated as a result of entering the input in the RCS simulation in the Ansys HFSS software as follows.

Tabel 2. Calculation of the RCS on the UCAV SACCON Model

Freq [GHz]	I Wave Theta [deg]	I Wave Phi [deg]	Monostatic RCS Total [dB]
10	90	0	-17.8039
10	90	15	-39.4049
10	90	30	-33.3534
10	90	45	-33.5918
10	90	60	-46.8229
10	90	90	-58.5062
10	90	120	-47.3148
10	90	150	-35.1005
10	90	180	-17.7782
10	90	270	-35.4863
10	90	360	-17.8039

From the simulation results and the calculation of the Radar Cross Section (RCS) value above, the average RCS value is -38.9633 dB or equivalent to 0,0039 m^2. This RCS value is quite small for the UCAV class in general, so for reconnaissance missions or air defense security this platform is very suitable for use as a defense tool. From the results of the RCS simulation in Figure 10 which is a linear plot related to the effect of the incident wave on the azimuth plane to the RCS value, it shows that the RCS value experienced a spike in the graph at several points. These points cause a spike in the RCS value at approximately -5° to 5°, 30° to 45°, 145° to 150°, 210° to 215° and 315° up to 320°. These points are in the azimuth plane which is the point that has the highest RCS value where when viewed on the UCAV platform these points are located on the front of the UCAV platform or nose, the side of the UCAV and on the tail of the UCAV. This is what needs to be analyzed in more depth for the shaping technique at the time of the UCAV design that in order to reduce the RCS value the things that must be considered and prioritized in shaping are the nose of the UCAV, the wings and tail of the UCAV.

4. Conclusions

The Unmanned Combat Aerial Vehicle (UCAV) model used is a generic UCAV configuration developed by the NATO STO/AVT-161 task group, which is named SACCON UCAV. The main reason for choosing this UCAV platform is because the geometry of the SACCON UCAV platform has been designed with stealth requirements which lead the UCAV design to the flying wing concept. The basic lambda-shaped geometry of the SACCON UCAV configuration is also oriented towards the typical goal of low observability with a combination of high agility and high Angle of Attack (AoA) capabilities, so that in addition to considering low capabilities detected by enemy defense radars, this SACCON UCAV model was also developed as a realistic UCAV concept.

The results of the SACCON UCAV design were then analyzed by the RCS value using the SBR method using the Ansys HFSS software. From the simulation results and the calculation of the Radar Cross Section (RCS) value above, the average RCS value is -38.9633 dB or equivalent to 0,0039 m^2. From the results of the RCS simulation in Figure 10 which is a linear plot related to the effect of the incident wave on the azimuth plane to the RCS value, it shows that the RCS value experienced a spike in the graph at several points. These points cause a spike in the RCS value at approximately -5° to 5°, 30° to 45°, 145° to 150°, 210° to 215° and 315° up to 320°. These points are in the azimuth plane which is the point that has the highest RCS value where when viewed on the UCAV platform these points are located on the front of the UCAV platform or nose, the side or side of the UCAV and on the tail of the UCAV. This is what needs to be analyzed in more depth for the shaping technique at the time of the UCAV design that in order to reduce the RCS value the things that must be considered and prioritized in shaping are the nose of the UCAV, the wings and tail of the UCAV.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

Funding information

No funding was received from any financial organization to conduct this research.

References

[1] N. Pramadi, Radar and Stealth, Jakarta: Pena Nusantara, 2019.
[2] F. Noor, "Historiography Drone: From military to cinema," *ProTVF*, vol. 4 (02): p. 185-205, 2020.
[3] F. Purnomo, R. Bura, "Aerodynamics-Radar Cross Section (RCS) Optimization on the Cropped Delta Wing with Design of Experiments (DOE) and Multi Objective Genetic Algorithm (MOGA) methods," *Journal of Defense and Security Innovation*, vol. 01 (01): p. 38-48, 2018.
[4] E. Sloan, Military Transformation and Modern Warfare, Westport: Preager Security International, 2018.
[5] C. M. Liersch, K. C. Huber, "Conceptual Design and Aerodynamic Analyses of a Generic UCAV Configuration," *AIAA Aviation*, p. 1-17, 2014.
[6] L. Gupta et al., "Survey of Important Issues in UAV Communication Networks" *IEEE Commun*, vol. 18 (01): 1123–1152, 2015.
[7] D. Lesmana, "Military Drone Application With Indonesian Alutsista Products for Over the Horizon Operations," *Proceedings of the Indonesian National Seminar on Science, Technology and Innovation - Air Force Academy*, vol. 3, p. 1–10, 2021.
[8] A. Utama et al., "Sejarah Penggunaan Pesawat Terbang Tanpa Awak (PTTA) Dalam Perang Modern dan Persiapan Militer Indonesia," *Jurnal Pertahanan dan Bela Negara*, vol. 11 (3): p. 167-181, 2021.
[9] Salunkhe and Naikwade, "Stealth Aircraft Technology" *International Journal of Engineering Science and Computing*, vol. 8 (6): p. 18268-18271, 2018.
[10] Zikidis K., "Low Observable Principles, Stealth Aircraft and Anti-Stealth Technology," *Journal of Computations and Modelling*, vol. 4, no.1, pp. 129-165, 2014.
[11] F. Knott, Eugene, T. Tuley, F. Shaeffer, Radar Cross Section, 2nd Edition, SciTech Publishing: USA, 2004.
[12] J. Coppin, Aerodynamics-Stability and Shape Optimisation of Unmanned Combat Air Vehicle, Thesis, University of Sheffield, Southern Yorksire, England, 2014.
[13] C. M. Liersch et al. "Multidisciplinary design and aerodynamic assessment of an agile and highly swept aircraft configuration" *CEAS Aeronaut*, p- 677–694, 2016.
[14] D. Vicroy et al., "Low-speed dynamic wind tunnel test analysis of a generic 53 swept UCAV configuration with controls," *AIAA Applied Aerodynamics Conference*, 2014.