Dual-Band Frequency Antenna for Drone Application

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Abstract. Dual-band antenna is the main element for this project of unmanned aerial vehicle application. Previously, a frequency of 2.45 GHz is informed of linear polarization while the frequency of 1.575 GHz informed of circular polarization. Global Positioning System (GPS) applied towards the UAV use circular polarization with the antenna facing up for satellite connection and for Industrial Scientific and medical (ISM), the UAV use linear polarization where the antenna is facing down towards the ground to establish a connection with others electronic devices. Integrating both antennas into single antenna unit is challenging as it involves the characteristics of dual-band of frequencies and dual types of polarization where all the characteristics need to be fulfilled as a whole in order to be functioned as dual-band dual polarization antenna. Computer simulation software (CST) is used to design and optimize the antennas. Comparison is done among four designs of antennas designs which use microstrip feed line and proximity coupled feed to obtain the most efficient design to be applied at UAV for full operation. The best technique covered in order to fulfill all the requirements needed is proximity coupled feed. Design four is the best design because of the wide axial ratio bandwidth and efficiency is high.

1. Introduction

An unmanned aerial vehicle (UAV) known as the vehicle that is able to fly remotely either by the controller or autonomously while unmanned aircraft system (UAS) includes UAV as well as the system that connects between the personnel and the UAV. UAV comes with various types in term of weight and size which ranges from the size of vehicles until a few inches to aircraft with wingspans of up to 400 feet [1–3]. Apart from size and weight, UAV also could be categorized in term of maximum altitude and general operating characteristics. There is six major purposes of UAV which are target and decoy, reconnaissance, combat, logistics, research and development (R&D), civil, and commercial. Target and decoy UAVs are typically used for military training purposes. Reconnaissance and combat UAVs are used on the battlefield for intelligence attack capability in high-risk missions. As the name suggests, logistics UAVs are used for cargo and logistics operations. Likewise, R&D UAVs are used to further develop UAV technologies [4–7].

Currently, UAV technology is rapid growing due to its efficiency in completing the operations. The defense sector will remain as the primary market for UAV at the moment. Apart from the defense sector,
manufacturers also focusing on developing UAV for the uses of border enforcement, humanitarian relief, search and rescue, scientific research, meteorology, firefighting, precision agriculture, infrastructure surveying, police surveillance, freight delivery and communication signals relaying [8–12].

The manufacturing of UAVs requires a significant amount of electronic components for data recording and transmission purposes, as well as for avionics functions [13]. Antennas are among the most important electronic components of any UAV or UAS, for they allow the vehicle to transmit information to and receive information from other systems, as well as the people on the ground [14]. The UAV antennas existed in various form factors and frequency ranges. The antennas can be used in ground-to-ground, ground-to-air, and air-to-ground communications systems. Increase the loitering capability and persistence of unmanned aerial vehicles (UAVs) with a lightweight, aerodynamic antenna that can go wherever needed. Through careful design and extensive testing and evaluation, reliable UAV antennas that conform to the non-planar surfaces of a drone’s fuselage has been realized [15]. The unique wideband blade antennas support VHF through C-band frequencies, reducing the number of required apertures on an airframe, and aiding in minimizing aerodynamic drag. Octane Wireless’ drone antennas offer greater flight range and increased link performance over traditional airborne antennas, enabling tactical teams to maximize their operational footprint during mission-critical aerial operations [14,16].

Unmanned Aerial Vehicles (UAV) currently uses separate antennas for Wireless Local Area Network (WLAN) 802.11b/g and Global Positioning System (GPS) as they are operating in different frequencies and using different polarization [18]. Frequency of 2.45 GHz with linear polarization will be used for Wireless Local Area Network while the frequency of 1.575 GHz with circular polarization will be used for Global Positioning System. Industrial Scientific and medical (ISM)/ Wireless Local Area Network will be facing down towards ground for connection while antenna for Global Positioning System will facing up towards the sky for connection with satellites.

2. Antenna Design
The first antenna design would be the combination of two different designs of the single antenna to become dual-band combo antenna with back-to-back attached facing opposite towards each other consist of optimized design of single rectangular patch antenna and single truncated patch antenna. Double sided antenna realized by both single antenna is combined with the front and the back side and the ground in the middle. The substrate and the of the antenna ground have the same dimension of measurement while the dimension of the rectangular patch needs to be optimized to achieve the target frequency and miniaturize purpose [17]. The design has two ports which are for the front side and back side of the antenna respectively. Front side antenna operated at 1.575 GHz while the back side antenna operated for 2.45 GHz. where both ports are used the discrete port [19] as shown in Figure 1.

Figure 1. Double-sided combo antenna; (a) front view and (b) back view
Proximity coupled feed technique would be the second design of the antenna. This kind of technique is the other technique for the feed line which is known as proximity coupled feed. The technique is used to improve the antenna performance for fulfilling the requirement of the specification of the antenna. This technique has five different layers to form complete antenna structure which is layer one is a patch, layer two is a substrate, layer three is feed line, layer four is a substrate and the last layer is patch as well as shown in Fig. 2. Layer 3 which is feed line is not attached with patch layer. CST software is used to create proximity coupled feed where the material for this feed line is copper.

![Figure 2](image1.png)  
**Figure 2.** (a) Proximity coupled feed at the front side for 1.575 GHz and (b) at backside for 2.45 GHz

3. Result and Discussion

Reflection Coefficient (S11) is the parameter that indicated how much amount of a signal is transmitted and reflected from the antenna. A good performance antenna indicated by having the S11 below -10dB where 90% of the signal being transmitted than reflected [20]. This antenna can operate at the best performance. Figure 3 demonstrated the S11 for truncated patch antenna design that operates at frequency 1.575 GHz. The graphs in Figure 3 show the results of the four optimized designs operated at 1.575 GHz. The S11 for design two and four are lower compared to design one and three. Hence, optimized design four has been selected as the final design for antenna operated at 1.575 GHz since it has the lowest reflection coefficient compared with 3 others which are -30.76 dB [21].
On the other hand, Figure 4 displays the S11 for rectangular patch antenna which is operated at the frequency of 2.45 GHz. The graphs in Figure 4 shows the optimized designs for 2.45 GHz. All four optimized designs are good designs since all the S11 at 2.45 GHz is below than -10dB. Design two for the optimized steps is the lowest S11 compared with others design it recorded S11 of -27.343877 dB.

Truncated antenna operated at 1.575 has the bandwidth of 49.6 MHz meanwhile rectangular antenna operated at 2.45 GHz recorded bandwidth of 48.4 MHz. Table 1 summarizes the bandwidth recorded for an optimized design for both the frequency of 1.575 GHz and 2.4 GHz.

| Designs       | Bandwidth (1.575 GHz) MHz | Bandwidth (2.45 GHz) MHz |
|---------------|---------------------------|--------------------------|
| 1st Optimized | 28.1                      | 28.1                     |
| 2nd Optimized | 24                        | 28.8                     |
| 3rd Optimized | 27.7                      | 48.4                     |
| 4th Optimized | 49.6                      | 28.2                     |

This project used the L1 band for GPS within the frequencies range of 1.563 MHz to 1.587 MHz. Circular polarization applied towards the GPS antenna due to retaining the connection between the drone and the controller or personnel where circular polarization able to retain the connection between transmitter and receiver eventhough both parts is not in the line of sight [22-23]. For circular polarize, the axial ratio must be below than 3 dB to ensure the antenna is circularly polarized [24]. Figure 5 shows the...
result of axial ratio for four optimized antenna designs operated at 1.575 GHz. From the graph, the axial ratio for design four is the best which is nearly approach 0dB (0.59 dB) compared to the 3 others. Proximity coupled technique is the better approach to obtain good axial ratio compare with double sided feed line antenna [25]. Figure 5 demonstrates the axial ratio for four optimized antenna design for proximity coupled antenna.

![Graph showing axial ratio for four optimized antenna designs](image)

**Figure 5.** The axial ratio for optimized proximity coupled the antenna

Table 2 shows the gain and efficiency of the four optimized double-sided antenna at the frequency of 1.575 GHz and 2.45 GHz. Every optimized design has their own gain and efficiency value where the higher the gain, the wider the operated area covered by the antenna [26]. The highest gain and efficiency recorded by forth optimized design which is 5.08 dB and 68.29% respectively compared to other optimized design for 1.575 GHz. On the other hand, for 2.45 GHz, the best gain and efficiency recorded by third optimized design at the gain of 6.35 dB and efficiency of 79.91%. The antenna could be considered as a well-operated antenna if the efficiency recorded is above 50% [20].
Table 2. Gain and efficiency of optimized double-sided feed line antenna

| Designs | Gain | Efficiency | Gain | Efficiency |
|---------|------|------------|------|------------|
|         | 1.575 GHz | 2.45 GHz |      |            |
| 1       | Gain: 3.6 dB | 46.83 | Gain: 5.46 dB | 64.05 |
| 2       | Gain: 5.07 dB | 68.01 | Gain: 5.34 dB | 63.81 |
| 3       | Gain: 3.45 dB | 46.51 | Gain: 6.35 dB | 79.91 |
| 4       | Gain: 5.08 dB | 68.29 | Gain: 5.96 dB | 74.06 |

4. Conclusion
As a conclusion, Dual-band combo antenna for unmanned aerial vehicle application has been realized. The combo antenna consists of the operated frequency of 2.45 GHz formed in linear polarization while the frequency of 1.575 GHz formed in circular polarization functioned as dual-band dual polarization antenna. The technique applied for 2.45 GHz of linear polarization is side feed antenna design while technique for
1.575 GHz of linear polarization is proximity coupled feed antenna design. The antenna recorded S11 of -30.76 dB and -27.34877 dB for 1.575 GHz and 2.45 GHz respectively. In term of bandwidth, truncated antenna operated at 1.575 has the bandwidth of 49.6 MHz meanwhile rectangular antenna operated at 2.45 GHz recorded bandwidth of 48.4 MHz. The gain and efficiency recorded for 1.575 GHz are 5.08 dB and 68.29% respectively meanwhile for 2.45 GHz, the gain and efficiency recorded are 6.35 dB 79.91% respectively.

References

[1] Theuav.com 2013 The UAV - Unmanned Aerial Vehicle. UAV

[2] Ng T S 2018 Unmanned Aerial Vehicle System pp 109–18

[3] Li M and Tang L 2017 Unmanned Aerial Vehicle (UAV) International Encyclopedia of Geography: People, the Earth, Environment and Technology pp 1–7

[4] Tse Z T H, Box J, Hovet S, Lewis D, Kirsche K, Perry J, Moore J and Jordan S 2017 State-of-the-art technologies for UAV inspections IET Radar, Sonar Navig. 12 151–64

[5] Jordan S, Moore J, Hovet S, Box J, Perry J, Kirsche K, Lewis D and Tse Z T H 2018 State-of-the-art technologies for UAV inspections IET Radar, Sonar Navig. 12 151–64

[6] Marques P 2013 Emerging Technologies in UAV Aerodynamics Int. J. Unmanned Syst. Eng. 1 3–4

[7] Bäumker M, Przybilla H-J and Zurhorst A 2013 Enhancements In Uav Flight Control And Sensor Orientation ISPRS - Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. XL-1/W2 33–8

[8] Iqbal L U and Sullivan J P 2008 Application of an Integrated Approach to the UAV 46th AIAA Aerospace Sciences Meeting

[9] Perz R and Wronowski K 2019 UAV application for precision agriculture Aircr. Eng. Aerosp. Technol. 91 257–63

[10] Li D, Wang H and Gai W 2011 Application of a feedforward controller with a disturbance observer for UAV during missile launch 2011 2nd International Conference on Artificial Intelligence, Management Science and Electronic Commerce, AIMSEC 2011 - Proceedings pp 2811–5

[11] Samad A M, Kamarulzaman N, Hamdani M A, Mastor T A and Hashim K A 2013 The potential of Unmanned Aerial Vehicle (UAV) for civilian and mapping application Proceedings - 2013 IEEE 3rd International Conference on System Engineering and Technology. ICSET 2013 pp 313–8

[12] Zeng Y, Zhang R and Lim T J 2016 Wireless communications with unmanned aerial vehicles: Opportunities and challenges IEEE Commun. Mag. 54 36–42

[13] A. Paz-Perez, M. Castillo-Morales and T P B-S 2015 Design and Manufacturing of Unmanned Aerial Vehicle Soc. Ind. Syst. Eng. 2015

[14] Ali W A E and Ibrahim A A 2017 A compact double-sided MIMO antenna with an improved isolation for UWB applications AEU - Int. J. Electron. Commun. 82 7–13

[15] Tefiku F and Yamashita E 2002 Double-sided printed strip antenna for dual frequency operation pp 50–3

[16] Syed A and Aldhaheri R W 2015 A compact ultra-wideband MIMO antenna with improved isolation IEEE Antennas and Propagation Society, AP-S International Symposium (Digest) vol 2015-October pp 2311–2

[17] Rahman, N.A.A., Jamlos, M.F., Lago, H., Jamlos, M.A., Soh, P.J., Al-Hadi, A.A., "Reduced size of slotted-fractal Koch log-periodic antenna for 802.11af TVWS application", (2015) Microwave and Optical Technology Letters, 57 (12), pp. 2732-2737.

[18] Moradi K and Nikmehr S 2012 A Dual-Band Dual-Polarized Microstrip Array Antenna For Base Stations Prog. Electromagn. Res. 123 527–41
[19] Jamlos, M.A., Jamlos, M.F., Khatun, S., Ismail, A.H., "An optimum quarter-wave impedance matching feedline for circular UWB array antenna with high gain performance", (2014) IEEE Symposium on Wireless Technology and Applications, ISWTA, art. no. 6981180, pp. 165-169.

[20] Islam I, Jamlos M F and Jamlos M A 2015 Nonuniform inverted-L slot double-sided array antenna for LTE and WLAN application Microw. Opt. Technol. Lett. 57 1915–9

[21] Matolak D W and Sun R 2014 Antenna and frequency diversity in the unmanned aircraft systems bands for the over-sea setting AIAA/IEEE Digital Avionics Systems Conference - Proceedings pp 6A41–6A410

[22] Singh, Gurmeet; Solanki L S 2015 Design and Analysis of Dual Band Printed Microstrip Dipole Antenna for WLAN IJCA Proceedings on International Conference on Advancements in Engineering and Technology pp 9–11

[23] Nayan, M.K.A., Jamlos, M.F., Jamlos, M.A., "Mimo circular polarization array antenna with dual coupled 90° phased shift for point-to-point application", (2015) Microwave and Optical Technology Letters, 57 (4), pp. 809-814. Cited 7 times.

[24] Ali M, Khawaja B A, Tarar M A and Mustaquin M 2013 A dual band u-slot printed antenna array for LTE and WiMAX applications Microw. Opt. Technol. Lett. 55 2879–83

[25] Jusoh, M., Jamlos, M.F., Kamarudin, M.R., Subapathy, T., Jais, M.I., Jamlos, M.A., "A fabrication of intelligent spiral reconfigurable beam forming antenna for 2.35 2.39GHz applications and path loss measurements (2013) Progress in Electromagnetics Research, 138, pp. 115-131.

[26] Katie, M.O., Jamlos, M.F., Mohsen Alqadami, A.S., Jamlos, M.A., "Isolation enhancement of compact dual-wideband MIMO antenna using flag-shaped stub", (2017) Microwave and Optical Technology Letters, 59 (5), pp. 1028-1032. Cited 5 times.