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SHORT COMMUNICATION

Study and assembly of Quadrotor UAV for telecommunication applications

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Summary

UAVs are defined to be aerial vehicles controlled without humans onboard and are used in a large array of missions where tasks automation and human user protection are necessary. The use of UAVs is growing quickly increasing in many application domains as military surveillance, military fight, and frameworks monitoring...etc. UAVs can carry multiple devices in order to execute these functions like cameras, weapons, and equipment of chemical and biological detection. Nowadays, the development of UAVs became the centre of interest of many research workers who are looking to explore its fields of application. There is currently a large array of projects and research subjects emerging in this field. Our work revolves around an assembly and configuration of Quadrotor Drones in telecommunication inspections operations of transmission networks because of their easiest construction and their rapidly services. The user of the realized UAV can control and schedule the operation so intuitive thanks to its graphic control interface.

KEYWORDS:
UAVS, Assembly, Quadrator, Configuration, Flight.

1 | INTRODUCTION

Unmanned Aerial Vehicle (UAV), known as also Drone, is an aircraft controlled remotely by a human in the field or autonomously via an onboard computer[1]. UAVs have become a mass-market technology and increasingly common part of a variety of applications[2], also the centre of interest of researchers[3]. Preliminary research has shown that the most versatile UAV and the easiest to build is the quadrotor Helicopter[4]. This is due to the fact that the aerial quadrotor robot is a VTOL (Vertical Take-Off and Landing) system. Quadrotors are controlled by varying the speed of the four propellers without requiring any mechanical link to vary the propellers pitch angle like for a conventional helicopter[4].

In recent years, UAV development has attracted the attention of many sectors and researchers because of its large range of applications domains[3] as trade, environment[5], transportation[6], telecommunications[5]...etc. UAVs are a convenient choice for commercial applications[7] due to their easiness employment, low maintenance cost, high-mobility and capacity to hover[1]. Also, UAVs are used in environmental management[3] as natural disaster monitoring[5], border surveillance[7], emergency assistance[6], search and rescue missions[8], delivery of merchandises[9], the use of UAVs transportation applications encompass traffic monitoring[6], security surveillance, inspection of road projects[7], and survey of traffic[9]...etc. In addition, the use of UAVs is of particular

[0]**Abbreviations:** UAV, unmanned aerial vehicle ; VTOL , vertical take-off and landing ; 4G, 4 generation ; LTE, long term evolution ; 5G, 5 generation ; RPM, revolutions per minute ; ESC, Electronic speed controller ; IMU, Inertial Measurement Unit ; GPS, global positioning system ; AH, amp hours ; USB, Universal Serial Bus ; IMU, inertial measurement unit.

interest in mobile networking applications [3] due to their fast deployment and large coverage capabilities [8], UAVs are being utilized to provide wide-area [10], high-quality connectivity ensuring safe and secure operations [3]. UAVs are becoming more attractive as aerial base stations or communication relay nodes [1] flying in the sky to supply wireless connectivity between two or more distant wireless devices [3]. The next generation 5G networks will have a high capacity to provide connectivity services and mobile broadband coverage to optimize mobile connectivity [11], network coverage and reduce the inter-cell interference [1]. 4G LTE and the forthcoming 5G networks support a diversity of capacities that appropriate greatly with drone requirements [10]. UAVs offer a number of advantages for the application domains mentioned above because of their sizes, capabilities, they provide unique viewing angles that can not be achieved from piloted aircraft [12]. They can also cover different height levels. In addition, drone technology is highly deployable and economical [13].

Our work describes the assembly and configuration of an autonomous quadrotor UAV in telecommunication applications, with the ability to operate complex inspection operations of transmission networks in zones and at heights that are hard to reach out.

The remainder of the article is structured as follows. Sections 2 and 3 define the different standard components of UAV Quadrotor and its characteristics. In Section 4 presents the Quadrotor Assembling methodology. In the last section, we conclude and discuss further perspectives of the UAVs Quadrotor.

2 | CONCEPT OF QUADROTOR UAVS

The quadrotor consists of a main frame with four arms connected centrally and four brushless motors attached to each arm, four propellers are attached to each motor whose rotation of the propellers is controlled by radio remote control, all these motors are connected to controllers to control the speed of each one. These controllers are connected together in parallel with the power distribution board. Also, a battery is used as a source of energy. The figure 1 shows the Quadrotor UAV synoptic diagram assembly [14] :

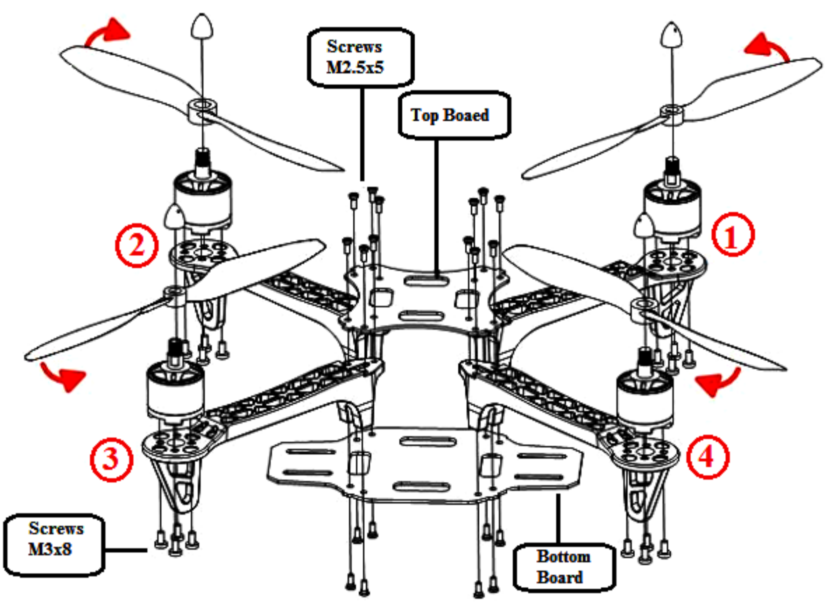

FIGURE 1 UAV Assembly diagram [14]

The power distribution motors are powered by the battery. Thus, the card distributes the power equally to the four electronic speed controllers and finally arrives on each engine. The accelerometers will measure the angle of the quadrotor on the X, Y and Z axes, and then adjust the number of revolutions per minute (RPM) of each motor to stabilize [14 15].

In the next section we will describe the components we have chosen for the realization of our drone.

3 | FRAME DESIGN AND BUILDING

The first approach for building the frame is to assemble each arm to the central crossing point to obtain convenient assembly points and good support for each frame component [16].

There are two arms attached perpendicularly to the centre and tightened by two boards, these boards are the base support for the flight controller, the battery, and the power distribution board. The motors are mounted at the end of each arm [14 17]. The components used to assemble our Quadrotor UAV are described below:

Quadrotor SK450 frame . The frame is made of resistant fibreglass, as to the arms which are made of a light nylon polyamide, This frame of 450 millimetre and 80 millimetre height.

Carbon fiber propellers 12 inches . Propellers are used to generate aerodynamic thrust force. The first pair of propellers are clockwise (Pusher) and the other pair is counter-clockwise (Puller) [18]. The thrust produced by a propeller depends on the density of the air, on the propeller's RPM, on its diameter, on the shape and area of the blades and on its pitch.

Turnigy Multistar 980Kv motor . The motors have a huge impact on the payload which the vehicle can support, as well as the flight time. It is mandatory to use the same motor everywhere on the same vehicle as if a pair of motors are the same brand and model, and from the same production run, their speeds may vary slightly, which is something the flight controller will take care of [18].

Electronic speed controller (QBrain ESC) . The electronic speed controller (ESC) controls the speed and direction of a motor by signal input from the flight controller. The ESC must handle the maximum current which the motor consumes.

Pixhawk flight controller . The flight controller is an autopilot programmable microcontroller Pixhawk Mini made by 3dr which includes an IMU (Inertial Measurement Unit) with ameliorated sensors (Accelerometer, Gyroscope, etc.) which guarantee good flight stability and navigation to specific GPS coordinates.

Radio remote control Turnigy 9X . The Radio Control receiver sends inputs to the vehicle wirelessly to control all the vehicle movements with a minimum of four channels associated to :

1. Pitch (Translates the vehicle to forward / backward motion).
2. Roll (Strafe the vehicle left and right).
3. Yaw (Rotating clockwise or counter-clockwise).
4. Throttle (Elevating the vehicle farther away or closer to the ground).

2200 mAh Lithium Battery . The battery offers high capacity with low weight and high discharge rates. The battery pack's capacity is measured in amp-hours (Ah) and the higher the capacity, the longer the flight time.

4 | ASSEMBLY AND CONFIGURATION METHODOLOGY

The quadrotor assembly is done in several steps from the assembly of the chassis to the assembly of the electronic components, their calibration and final vehicle configuration, before explain any of this, we will present the tools used in this assembly.

4.1 | Tools used

The tools used to assemble our quadrotor UAV are :

1. Hexagonal screwdriver 2.0 millimetre.
2. Phillips screwdriver 3.0 millimetre.
3. Wire stripper.
4. Soldering iron and tin.
5. Precision pliers.
6. Plastic cable clamp and pliers.

4.2 | Outer frame assembly

In this part, we are going to describe the connexion of electronic components with each other, and the frame assembling without electronic components[15].

4.2.1 | Connection and wiring of components electronic

Standard quadrotor wiring for pixhawk mini uses a four-output power distribution board in order to power the ESC (The electronic speed controller) and the flight controller, the figure 2 shows the wiring diagram of electronic components of quadrotor.

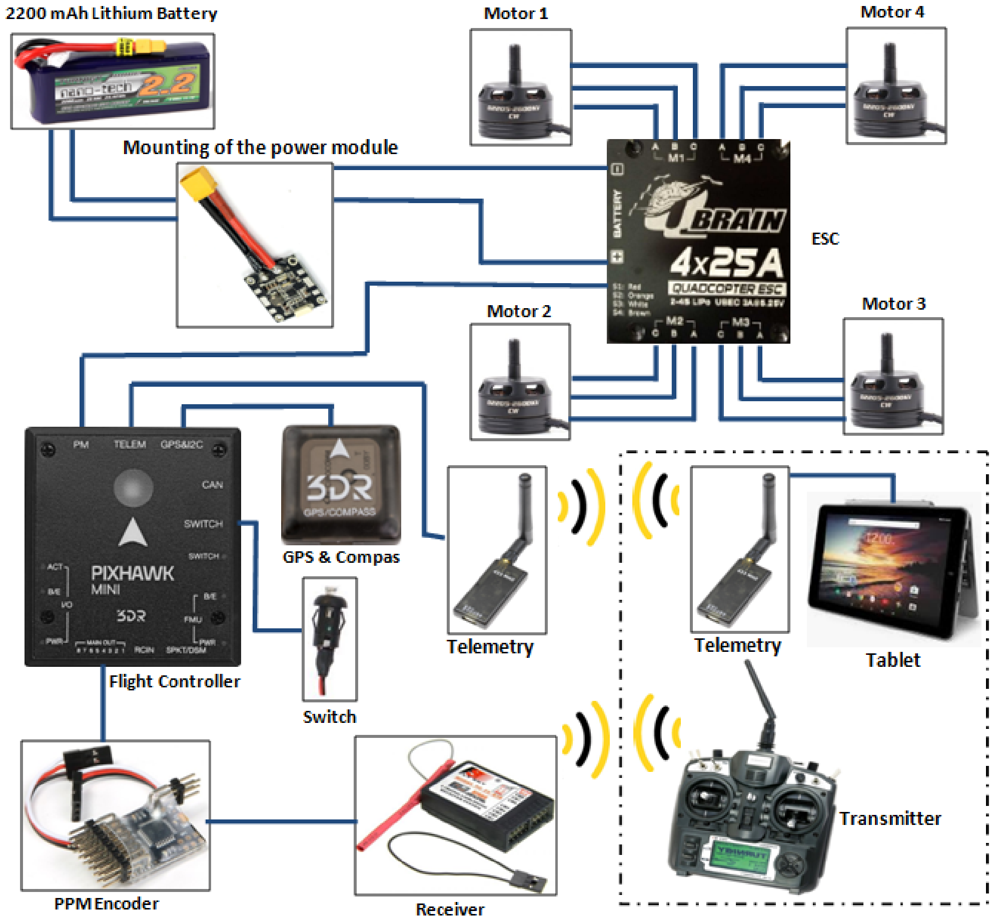

FIGURE 2 The wiring diagram of electronic components of quadrotor

4.2.2 | The assembly frame alone

In order to assemble the frame of the vehicle we are going to follow the steps below:

- Assemble the four arms with the main board using screws.
- Mount the skids at the end of each arm.
- Mount the motors plates at the end of each arm.
- Mount the upper board.

The figure 3 below describes the assembly frame alone :

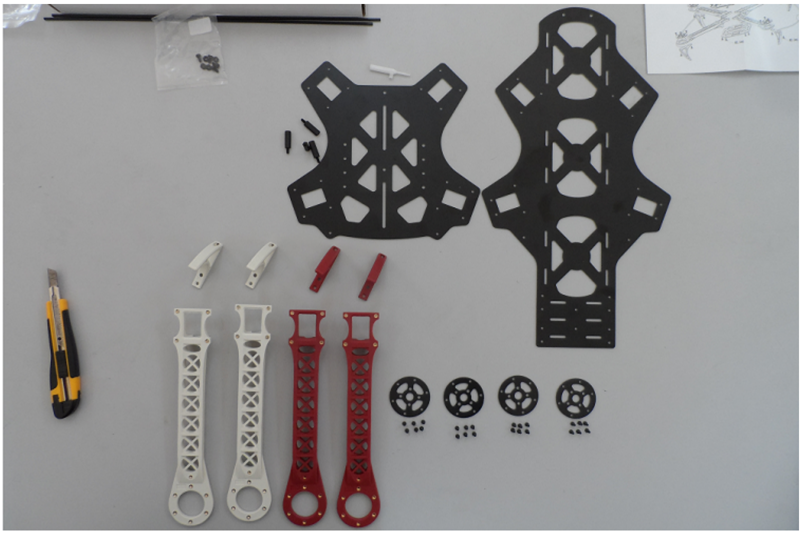

FIGURE 3 Quadrotor frame 450 millimetre

4.3 | Complete assembly with electronic components

In this part, we are going to describe the complete assembly of the Quadrotor sk450 frame including the flight controller mounting and the electronics wiring.

4.3.1 | Motors mounting

We mount the motors respecting the right order at the end of each arm using the motor plates. The motors rotation change following the user desire to give the vehicle a specific motion (Take off, landing, Throttle, yaw, pitch, roll, etc.).

4.3.2 | ESC mounting

The ESC is mounted on the main board then wired to each motor respecting the right order. The signal input goes from the flight controller to the ESC which in his turn adjusts the motor speed. The figure 4 shows the ESC assembly :

FIGURE 4 ESC assembly

4.3.3 | The power module mounting

The power module with four outputs is fixed on the central plate by means of a cable clamp and connected to the electronic flight controller (ESC) as it shown in the figure 5:

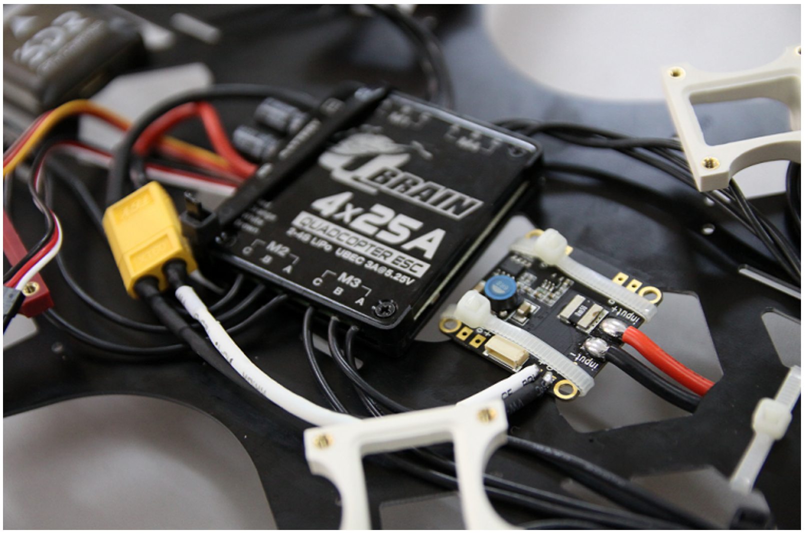

FIGURE 5 Mounting of the power module

4.3.4 | The flight controller mounting

After mounting the frame's upper board, we are going to use the mounting foams to stick the Pixhawk Mini right in the centre of gravity of the vehicle frame. Thee foams are going to be used as vibration dampeners to allow the flight controller to operate correctly. The flight controller should also be oriented to the front of the vehicle. The figure 6 shows Pixhawk Mini Flight Controller mounting:

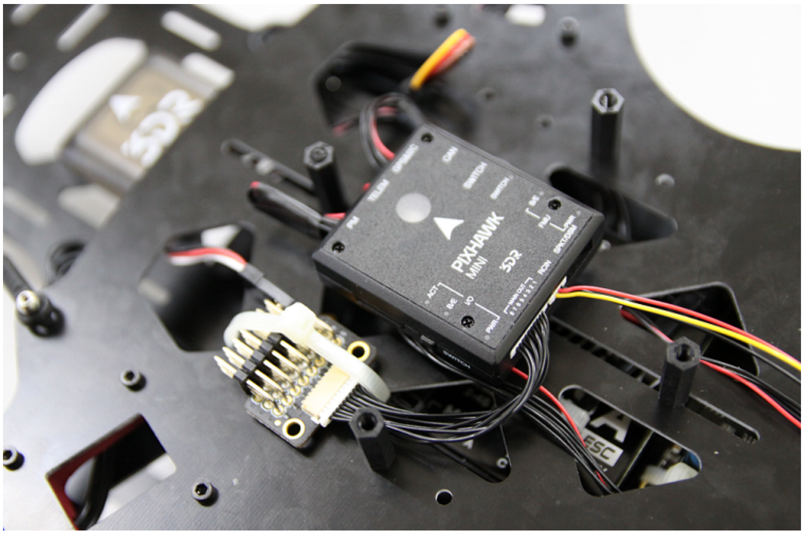

FIGURE 6 Pixhawk Mini Flight Controller mounting

4.3.5 | Wiring the power module to the flight controller

We connect the quad power module to the flight controller using a six pin cable in order to power it when connected to the battery.

4.3.6 | The GPS module and radio telemetry mounting

The GPS module is mounted and oriented to the front of the vehicle. We mount then the radio telemetry in order to communicate with the vehicle wirelessly as it shown in the figure 7 below:

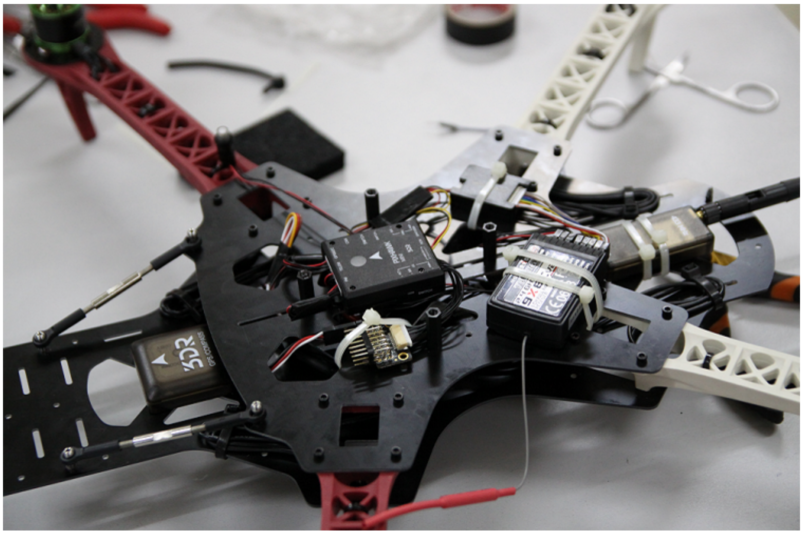

FIGURE 7 Assembly of GPS module and radio telemetry

4.4 | Base station installation / Configuration

In order to control our vehicle and configure the electronics, we used the QGroundControl that helps us visually edit and configure the necessary parameters. It is open source software that allows us also to modify the code to suit our specific needs. It also allows us to change the drone light modes (Characteristics), including how it reacts to our inputs, how well and how quickly it stabilizes and more. The Ground control station is also used in order to plan missions and give specific paths to navigate following GPS coordinates. The following steps describe the basic configuration of a quadrotor UAV:

4.4.1 | PX4 Firmware implementation

We launch the program QGroundControl after downloading and installing it on our computer by selecting "Firmware" on the sidebar, then we connect the flight controller to our computer via a USB cable.

4.4.2 | Frame selection

The airframe tab shows the multiple frames configurations that the autopilot can manage. We choose the appropriate frame configuration. The flight controller will reboot after we validate our choice.

4.4.3 | Sensors calibration

The embedded IMU (Inertial Measurement Unit) includes a gyroscope, compass, accelerometer that needs to be calibrated in order for the flight controller to stabilize its flight. We calibrate the sensors by manually moving the vehicle in the indicated directions (figure 8).

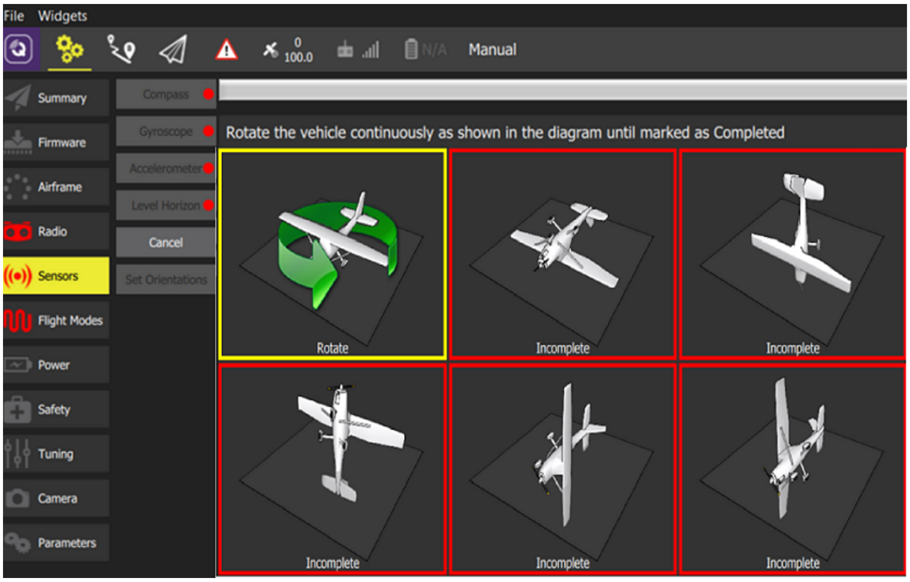

FIGURE 8 Sensors calibration with QGround control software

4.4.4 | Radio calibration

After switching on the transmitter, we select the appropriate mode and we start moving the joysticks in the indicated directions. We can monitor our transmitter channels in order to assign a specific channel to a specific input. The radio calibration with QGround control software is shown in the figure 9.

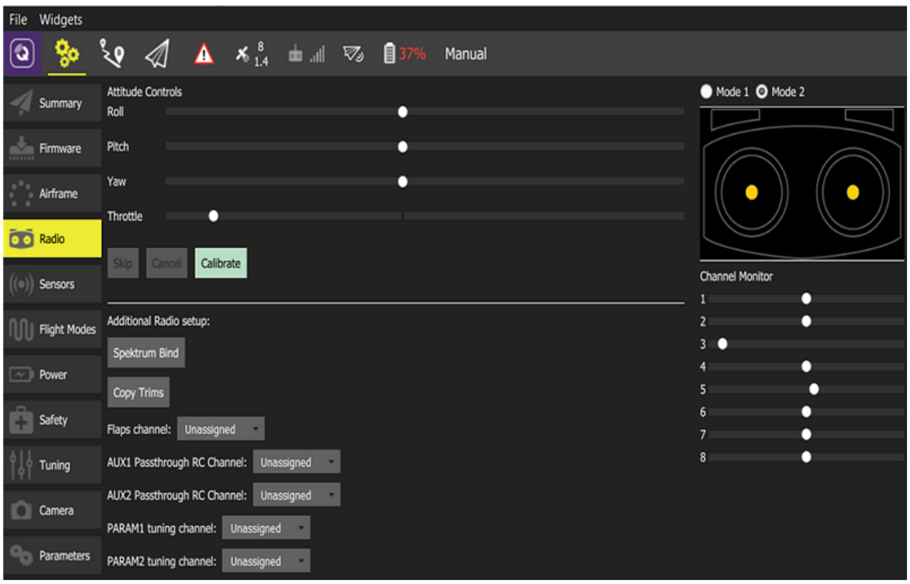

FIGURE 9 Radio calibration with QGround control software

4.4.5 | Flight modes selection

Flight modes allow us to operate autopilot assisted flights and also manual ones. We configure the receiver in order to control the following main flight modes:

- **Stabilized**: The vehicle flips difficulty and stabilizes itself automatically when the sticks are released.
- **Altitude**: Takeoff and landing are controlled to have a maximum rate.
- **Position**: When sticks are released the quadrotor will stop and hold a stationary position.

4.5 | Flight

At the moment of flying the UAV, we must before check the following conditions :

- **Choosing the right environment**: UAV test flights are operated in two distinguished environments, first indoor (Controlled environment) and outdoor (Real environment), however, the UAV test flights is subject to weather conditions (wind, rain, etc.) which may affect the handling of the drone.
- **The neighborhood**: In order to define the path and the flight plan of the drone, we must take note of the dwellings, objects, trees and surrounding roads. However, avoid flying near an airport or in advance.
- **Study the flight modes**: Different modes and parameters can influence our flight and our ability to control the drone. Before the flight, we must set the settings of the drone according to the chosen environment.
- **Checking the battery**: It must be ensured that the battery is properly recharged to avoid emergency landing.

After following the predefined steps of assembling and configuration of quadrotor UAV, who wears a 4K camera to inspect the transmission part of telecommunications networks as shown in figure 10:

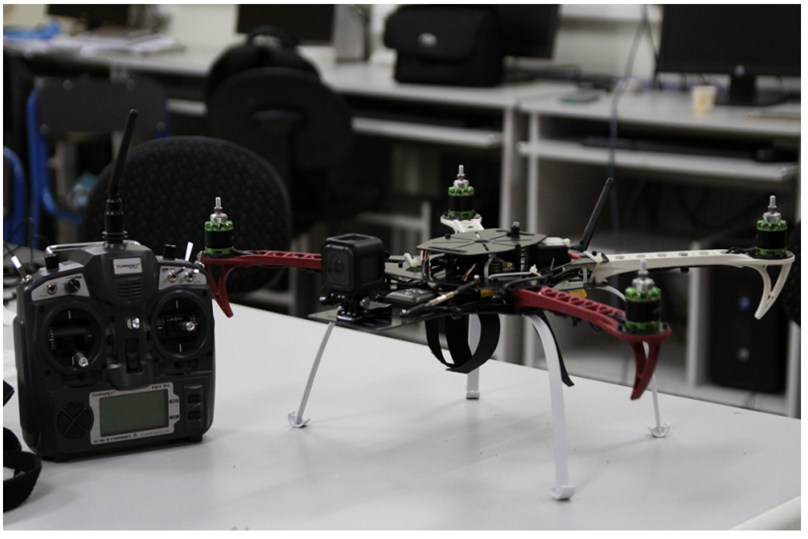

FIGURE 10 Quadrotor UAV released

5 | RESULTS

After having spread out the configuration and assembly process of our aerial vehicle, and describe the components that we chose for its realization. We have considered a telecommunication infrastructures inspection operation in order to highlight the introduction of our technique which is the use of a UAV during such operations.

Inspections of telecommunications infrastructure are done to ensure conditions of operability, and security to regulate communication services offered by telecommunication operators. In general, the inspection of telecommunication sites requires climbing and visual control of the structures. Each structural part is subject to inspection and verification. The structures inspected are generally steel masts, steel towers and concrete towers, antennas parabolic, sectoral antenna and rooftop telecommunications structures,..etc.

These inspections of telecommunications infrastructure are done exclusively by humans, and are a costly business for infrastructure companies, and create problems for operators and subscribers, and such inspections are time-consuming. In order to achieve this, we've developed a technique for auditing sites using our quadrotor UAV, which can carry out inspections for any telecommunication site thanks to the integrated tools such as the 4K camera, measurement sensors...etc. In combination, these techniques provide the means to measure and monitor the condition and operation of critical equipment in depth. However, the risk of breakdowns due to poor or faulty equipment can be significantly reduced when the state of the infrastructure is closely monitored and tracked on an ongoing basis.

Our developed quadrotor type UAV has the ability to perform complex inspection operations in regions and at heights difficult to reach in order to solve possible problems, such as telecommunications site failures, climbing falls, burns and non-accurate measurements of physical parameters...etc.It is in this context, we carried out an audit operation to make measurements on the heights of telecommunication towers.

The radio team of telecommunication operator Mobilis-ALGERIA has launched a human based operation for a pylon 20 meters height. The field engineer measures the time required to complete this operation for this pylon by making the different measurements of the physical parameters of the relay (azimuth, tilts, heights, type of antennas,..etc), in order to generate reports of the results obtained. Likewise, we have launched an inspection operation based on our Quadrotor UAV for the same pylon already mentioned, once the drone has finished its mission, the results obtained are compared with a table representing the execution time of the two operations as shown in the table 1 below:

TABLE 1 The execution duration of the 20 meter tower.

Tower inspection steps	**Human based inspection (minutes)**	**UAV inspection (minutes)**
Tower climbing and Checking the feeders	8	2
Determination of pylon altitude	2	/
Taking photos of the orientation and type of the parabolic antenna	1	1
Measurement of the azimuth and GPS points	2	/
Measurement of parabolic antenna tilt	1	1
General site photo	1	1
Tower descending	5	1
Total duration	20	6

The table shows in detail the duration of each step of the inspection process performed by the human or UAV for a telecommunication tower with a height of 20 meters. We notice that the execution time of the step « tower climbing and checking the feeders » human based is very large compared to that made by the UAV, the same remark for the « tower descending ». Determining the tower altitude, GPS point and the azimuth of the antenna did not take long, because it is measured when the UAV starts to take the orientation picture and determining the type of parabolic antenna. Thanks to the better sensitivity of the GPS&Compass sensor integrated in the UAV, we had more accurate measurements compared to those of human inspection that using a classic compass. The total duration of all human inspection steps is 20 minutes, unlike the UAV-based inspection times which equals to six minutes, which means that the UAV saves more time and thus avoid all probable risks during this operation.

The radio team has launched another audit operation, for two other pylons with heights of 40 metres and 70 metres, to check whether the height of the tower can influence the execution time of all steps of the inspection based human or UAV, the results obtained are compared with a histogram representing the execution time of the two operations as shown in the figure 11 below:

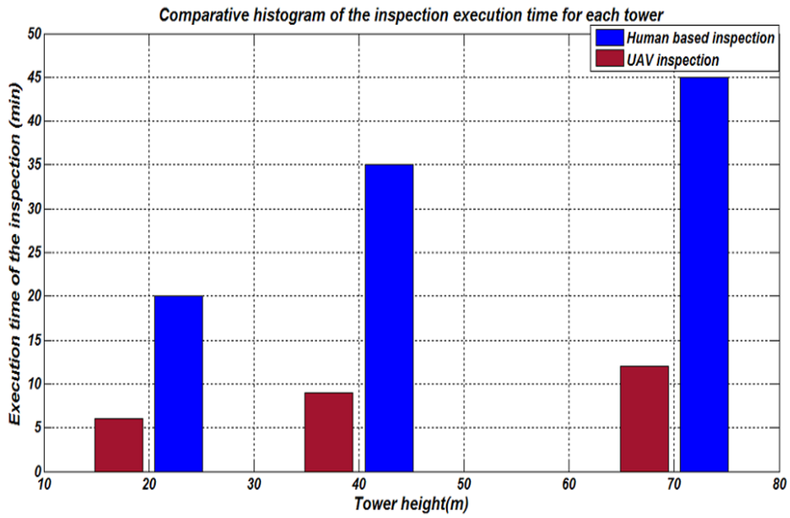

FIGURE 11 Comparative histogram of the inspection execution time for each tower

According to the comparison between the two inspection operations, we notice that for the human based operation the 20 meter pylon took 20 minutes of time, and the 70 meter tower took 45 minutes of time, and about the UAV based operation, the 20 meter tower took six minutes to complete, and 14 minutes for the 70 meter one, we find whereas that for all pylon heights for all pylon heights the execution time for the UAV-based inspection operation is still less than the human based one, which means that the inspection operation does the UAV always saves more time in such operations.

The main difference between the two types of inspections is that is the degree of accuracy and reliability of the information. In addition, the operation based on our quadrotor UAV gives an accuracy of the measured physical parameters, and offers a better quality of panoramic photos thanks to the stability of the UAV, as it has eliminated all the likely problems that can occur in such operations (falls, burns, human error...).

6 | CONCLUSION AND FUTURE SCOPE

During this study, we started by presenting the aim of the UAV and its applications domains. Afterwards, we described the concept of Quadrotor UAV, also the frame assembly and its components electronic. We then presented Quadrotor UAV configuring and assembling methodology. We chose this type of UAV thanks to its stability, great autonomy, reliability, efficiency of execution and its important flight time compared to other types of UAVs.

Therefore, the future scope of the UAV Quadrotor realized with precision presents various possibilities of continuation of this project, by integrating different sensors for precise measurements, and the integration of a machine learning algorithms to make it completely autonomous for more complex telecommunications operations.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

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