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DESIGN, DEVELOPMENT AND CONTROL OF LONG RANGE QUADCOPTER

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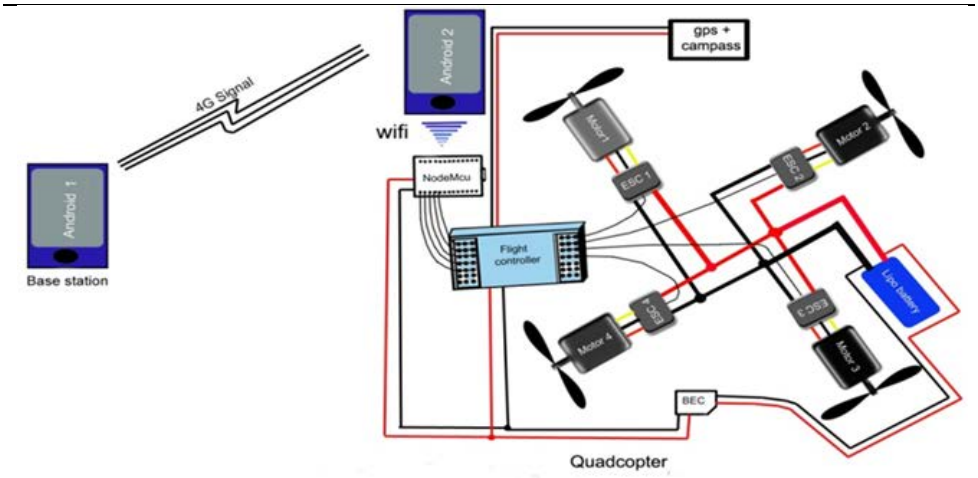
HIGHLIGHTS

- Designing and developing of all mechanical parts of Quadcopter.
- Developed and designed our own 4G communication module that is compatible to interface with Quadcopter design.
- Replace remote control (RC) communication module with our own made 4G communication module.
- We get freedom to control the Quadcopter from any location of the world where 4G network is available.
- Automatic mission is accomplished with Quadcopter by using GPS base navigation system.

GRAPHICAL ABSTRACT



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ABSTRACT

This research is based on the design, development and control of long range quadcopter using 4G network. The developed Quadcopter has capability to be controlled from any location where 4G network is available. The Quadcopter consist of mainly 4 components including: flight controller, motors and propellers, electronic speed controller and communication module. The first three components are same as used in conventional Quadcopter where as the long range is achieved with the help of unique communication system. The communication module of this Quadcopter consists of Nodemcu with 4G wifi module and android based mobile phone. A graphical user interface is developed in blynk software through which Nodemcu is control which results to control Quadcopter from distant place. 4G based quadcopter has an advantage over conventional RF module based quadcopter which has limited coverage area. Automatic mission is accomplished with Quadcopter using GPS based navigation system.

1. INTRODUCTION

Multi-rotor drone is an unmanned aerial vehicle (UAV), which is to be controlled from the ground station, without pilot on the board using communication module. Multirotor drone has wide range of indoor and outdoor application such as surveillance, aerial photography, agriculture monitoring purposes etc. Multirotor drone is the most prominent drone due to its vertical take-off and landing (VTOL) capability [1-3]. Quadcopter is a type of Multirotor drone consisting of 4 high speed brushless motors, 4 Electronic speed controllers(ESC), 4 propellers, Flight controller, communication module and lipo battery. Quadcopter has two frame configuration, that is '+' and '×' configuration [4]. This paper belongs to '×'configuration of quadcopter frame. Two motors on opposite arms of the

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quadcopter frame rotating clockwise (CW) direction, whereas the two motors on the other two opposite arms rotating counter-clockwise (CCW) direction, which compensate the action and reaction effect (Newton's third law), then quadcopter will take-off without producing any torque in the body frame [1-7]. Flight controller is a main controlling board, is a type of MIMO (multiple input, multiple output) system) which takes multiple input control signal from the communication module (i-e thrust, pitch, roll and yaw signals) and perform some necessary action and give control signal to the output of flight controller [8]. The outputs of the flight controller work as a input to the ESC's and the output of ESC's are connected to the four brushless motors. The ESC's takes control signal in the form of PWM from flight controller and then precisely control the speed of the brushless motors. Propeller connected with brushless motors produce thrust in the upward direction depending on the shape and size of the propellers. Communication module is a transceiver that controls the quadcopter from ground station [9]. Dedicated Radio frequency (RF) module has limited coverage area according to their transmitter and receiver range. If such quadcopter is to be used for long distance then these dedicated RF module does not work. This paper introduce unique 4G communication module in the quadcopter, which comprises of Nodemcu having wifi capability and android cell phone connected with the flight controller and another android cell phone with graphical user interface developed in blynk software is on the ground station control the attitude of the quadcopter. Camera of an android cell phone connected with flight controller has been used for live video streaming and dynamics of quadcopter can be seen on another android cell phone on the base station from unlimited range using 4G network and automatic mission has also been accomplished with Quadcopter using GPS based navigation system.

2. QUADCOPTER DYNAMICS

The quadcopter has four arms with "×" configuration frame as shown in Figure 1.

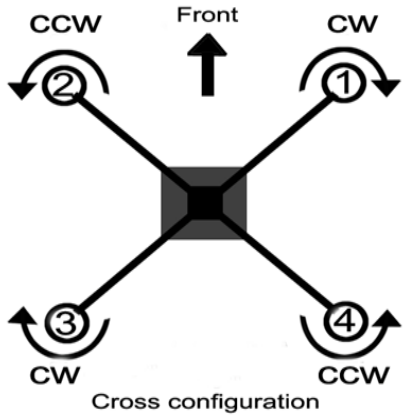

Fig.1. *Show the "×" configuration*

As we explained previously that the quadcopter has four brushless motors on which propellers are mounted, which make the quadcopter has four input forces. Propeller '1' and propeller '3' are moving in clockwise direction, whereas propeller '2' and propeller '4' are moving in counter-clockwise direction. The reason is because when propeller '1' and '3' are moving in clockwise direction, then due to reactive effect the whole body frame of the quadcopter should be moving in counter-clockwise direction (according to Newton's third law) [9-11]. In the same way when propeller '2' and '4' are moving in counter-clockwise direction, then due to reactive effect the whole body frame of the quadcopter should be moving in clockwise direction. If all of the propellers are rotating with the same speed rate, then these two reactive effects will compensate each other and the quadcopter will take-off and landing without producing any torque. If w_1, w_2, w_3 and w_4 represents the rotational speed of the four propellers T_1, T_2, T_3 and T_4, then force 'F' (thrust) is directly proportional to w^2 (Force α w^2) [12-14].

3. EXPERIMENTAL WORK

The schematic diagram of quadcopter system has shown in Figure. 2. Which consists of mechanical part, flight controller, electronics speed controller and 4G communication module.

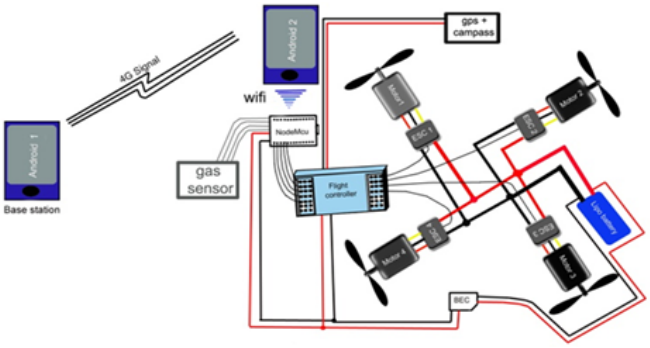

Fig.2. *Show the schematic diagram of quadcopter*

Designing and developing of all mechanical parts of Quadcopter in which F450 Quadcopter frame has been used in this project which has four arms on which 1000KV brushless motor is connected. Where KV is constant that is equal to rpm/volt. 1045 propeller is mounted with each motor which convert rotation of the brushless motor into an upward thrust. The upward thrust is directly proportional to the rotation of the motors. The speeds of brushless motors are controlled by 30A Electronic speed controller (ESC) according to the command received from the APM 2.8 flight controller. Neo-7m GPS+COMPASS module has also been used with flight controller to introduce different modes of function during the flight such as return to launch (RTL), acro, auto mode and position hold mode etc. A 11.1V, 5.2A Lithium Polymer battery has been used to power to all the circuitry, and motors of the quadcopter. A 4G based communication module has been introduced in this quadcopter which gives freedom to control quadcopter from any location where 4G network is available. An android cell phone has been used in Quadcopter for

providing video streaming, and communication between flight controller and base station. This cell phone is connected with flight controller via Nodemcu using wifi network. In base station another cell phone is utilized to provide control which has graphical user interface in blynk software. Base station cell phone works in same manner as that of wireless remote act as 4G transmitter. 4G recevier designed consisting of Nodemcu, output pins and a USB port/mobile internet. USB port has an alternative way of connecting internet connection with Nodemcu by using USB 3G/4G dongle as shown in Figure. 3. 4G transmitter having different types of control options such as thrust, pitch, yaw, roll and modes of flight.

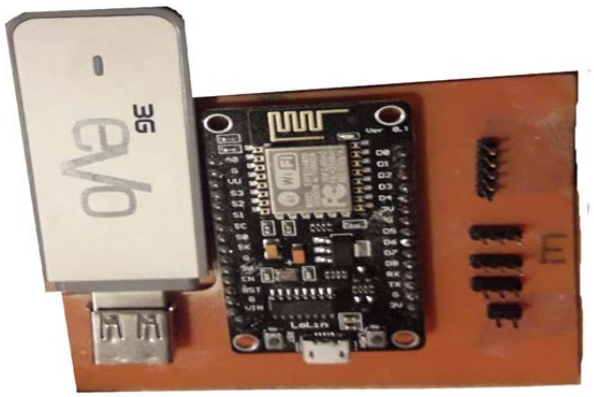

Fig.3. PCB designed of Nodemcu with USB port works as 4G receiver module

4G Communication Module

In this research two android mobile phones have been used as a transceiver communication module in which one android phone is connected with flight controller via Nodemcu and another android cell phone is on the base station which is connected through 4G to establish communication between flight controller and base station. The graphical user interface (GUI) of quadcopter control is developed in blynk software as shown in Figure. 4.

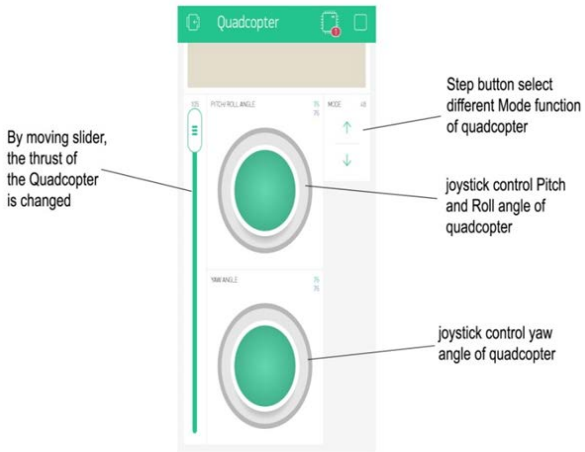

Fig.4. *Shows android mobile with blynk software*

In GUI widgets are used for different function such as slider is used for thrust control, joystick for pitch, roll and yaw angle and step button is used to select different modes of function for quadcopter. Each widget has a parameter that can be changed to set the desired PWM signal on the output of Nodemcu. Nodemcu is also known as Node microcontroller that supports wifi connectivity and is programmed by using standard computer programming. Nodemcu has several general purpose input/output pins in which 5 pins (D0-D4) are connected with the corresponding input of the flight controller for different function where D0 is assigned for Pitch angle control, D1 is assigned for Roll angle control, D2 is assigned for thrust (upward force), D3 for Yaw angle and D4 is assigned for different mode function of the quadcopter. As we found in the oscilloscope that the desired PWM signal for input of the flight controller has frequency of 50Htz and Duty cycle is to be from 20% to 25%. 20% Duty cycle represents minimum value whereas 25% Duty cycle represents maximum value as shown in Fig. 5,which means that if the slider widget is at minimum state, then pulse width of the signal is 20% and the rotation of the four brushless motors has minimum or zero speed which provide zero or minimum thrust (upward force) to the quadcopter. As the slider is moved toward maximum value, then pulse width of duty cycle will be increasing from 20% and thrust of the quadcopter will also be increasing by increasing the speed of the motors. When the slider reaches to its maximum state then duty cycle of PWM signal is 25% and provides full thrust (upward force) to the quadcopter to takeoff. Similarly same parameters are set for pitch angle, roll angle and yaw angle of the quadcopter. Android mobile with blynk application and duty cycle of PWM signal has shown in Figure. 5.

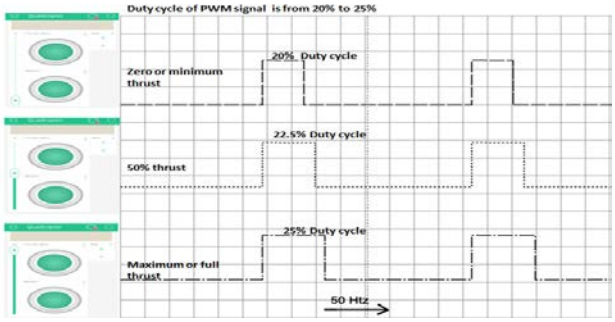

Fig.5. *Graph shows pulse width of the signal change from 20% to 25% by moving the slider*

4. RESULT AND DISCUSSION

Implementation of 4G communication in quadcopter has been done through which we can control the quadcopter from any location where 4G network is available. One android cell phone is the handheld user's mobile in which blynk software is installed and acts as a base station controller whereas another android cell phone is connected with the quadcopter frame that has two functions first function is to provide 4G communication between base station and flight controller and second function is to utilize its camera for live video streaming through which we can see the dynamics of the

quadcopter on the base station. Figure. 6 shows the quadcopter is to be controlled from the ground station.

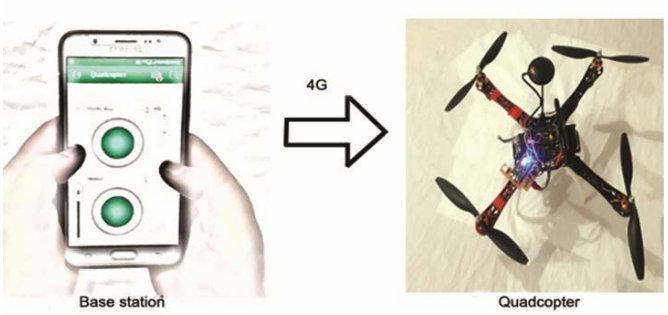

Fig.6. *Shows quadcopter controlled from base station*

Mission Planned

During experiment automatic mission has successfully been performed by selecting an AUTO mode in different flight modes then quadcopter has followed the preplanned path by using GPS module and servo gripper has also been connected with the flight controller for deliver and drop application. The path is defined and loaded from the mission planner software into the flight controller via personal computer. The following path has been followed by the quadcopter.

- Initially the quadcopter grabbed the ball with the help of servo gripper and took off vertically from the home position until attained 10 meter height.
- When the quadcopter attained its maximum height then it faced and moved toward the preplanned path (waypoint).
- When it reached to the maximum horizontal distance that is 500m from home position and reached to position 1 and then it produced yaw angle and moved toward position 2 and stayed over there for 6 second defined in the preplanned mission.
- After 6 second it landed and then dropped the ball at position 2.
- After dropping the ball at position 2 then it's taken off again and return to home position and landed at the same position from where it has been taken off at the beginning.

Path followed by quadcopter defined in mission planned has shown in the following Figure. 7.

Fig.7. *Show the path defined for quadcopter mission in mission planner software*

5. CONCLUSION

The development in the quadcopter facilitates the people that they can control the quadcopter from any region without fears of range limitation and it also help to send the quadcopter to those area where there is a security threat for human being and the events occurring in those areas can be seen through mobile or laptop screen using 4G network. It also helps to accomplish the auto mission with the help of GPS module from any region of the world just by changing the flight mode from stabilized to AUTO mode via GUI. It also helps the people to delivers and drop material application with the help of servo gripper.

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