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Performance Improvement of a Quadcopter as a Surveillance Robot

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***Abstract*: -- The quadcopter is an unmanned four-rotor helicopter, which works on the principle of aviation, Newton's Third Law, Faraday's Law of electromagnetic induction and Modern Power Electronics. This paper deals with the design, hardware implementation, control technique and programming for a quadcopter. It is observed that with modifications in the aerodynamic design of the frame, electrical circuits and electronic speed controllers, the quadcopter performance has been improved. The quadcopter is able to travel at higher speed with more accuracy and gives better video transmission resulting in a better surveillance robot.**

***Keywords*— Introduction, Working Principle, Design Hardware, Programing, Conclusion, Appendix, Acknowledgement, Reference.**

I. INTRODUCTION

QUADCOPTER is a unmanned aerial vehicle also called as quadrotor helicopter or quadrotor which is classified as rotorcraft as lift is generated by a set of rotors (vertically oriented propellers).It works on Principle of Aviation, Newton's Third Law, Faraday's Law of Electromagnetic Induction, Modern Power Electronics. A quadcopter is added with a video camera and video transmitter to transmit live video footage to a grounding station is used as surveillance robot. the use of small and mini drones in a network is capable of further improving the performance and the coverage area of these UAVs. Discussing the use of Quadcopter based network surveillance system is the base of this paper. These small drones will be modified with the existing system of Surveillance technology. The vehicle is constructed such that it can carry a play load of around 3 kg which could be any required instrument as well as any special surveillance system which could enhance its primary video system to increase its ability and functionality to a greater extent. Also it is been modified and equipped with latest more power full machines to give higher speed and greater stability to decrease the time of reach to location. [4]

II. WORKING PRINCIPLE

Quadcopter has two pairs of fixed pitch propellers, two rotating in clockwise and two rotating in anticlockwise direction. It has motors with pitch of the propeller placed such that it produces a downward thrust to generate upward lift. To control the quadcopter there is a sensing unit placed at the center of frame to give feedback of the orientation. The received feedback is processed by a flight controller to generate control signals which are sent to the electronics speed controllers (esc's) which thereby controls the speed of motor to adjust the thrust. The speed of each motor is controlled separately to achieve control and to shift the center of thrust, which create turning force to move it in different directions. [2][5]

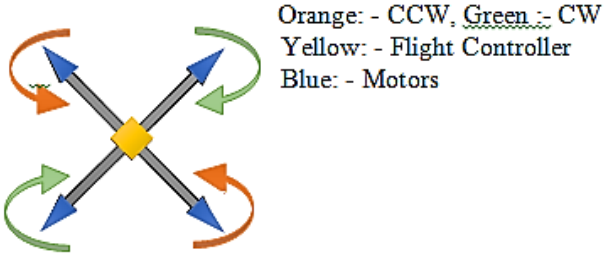

Fig- Schematic of quadcopter

III. HARDWARE

List of hardware required-

Sr. No	NAME OF HARDWARE	SPAECIFICATIONS	QTY
1.	Frame	210mm wheel base	1
2.	Motors	2205, 2300KV	4
3.	Flight controller	STM32F4 ARM BASED FLIGHT CONTROLLER	1
4.	Electronic speed controller	40 Amps, PWM to Dshot1200 compatible	4
5.	Receiver	2.4 GHz band with PWM, PPM and IBUS	1

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6.	Transmitter	2.4 GHz freq. band 10 channel	1
7.	Camera	2.5mm lens, 16:9 ratio, 800 TVL, CMOS sensor with 0.01 LUX illumination	1
8.	Video transmitter (VTx)	5.8 GHz 40 channel	1
9.	Video Antenna 1	Circular polarized 4dbi	2
10.	Video antenna 2	14dbi panel polarized	1
11.	Video receiver (VRx)	5.8 GHz 40 channel diversity receiver	1
12.	Battery	1500mAh, 110c, 4 s	1
13.	Propellers	Cyclone 5045	4

III. DESIGN OF FRAME

A predesigned Rasvelg feather light carbon fiber has been used with 210 mm wheel based, 5/6 mm thickness arms with 2 mm top and bottom plate with 2 mm arm support plate and 1 mm camera holding plates with titanium hex screws with nylocs, the modifications done are as follows:

• Thickness of arm was changed from 5X6 mm to 5X12 mm with stepped carbon fiber layering to get thick and curved arm to increase strength and reduce drag by proper aerodynamics.

• Added with aluminum brackets between the spacers which join top and bottom plate to make space and mounting arrangement for regular esc's eliminating need of 4 in 1 esc which are less durable, sophisticated and costly.

• A carbon fiber bracket was added to top plate for mounting video transmitter with upward direction antenna for better range.

Fig.- Rasvelg Frame

IV. MOTORS

The motors used are BLDC motors with stator diameter of 22 mm with stator height of 5 mm (2205) with multi-strand, silver cored windings in delta configuration, 3 phase windings with steel shaft and high-speed ceramic stainless-steel ball bearings with neodymium magnet.[3] Which was then replaced by new motor with following specifications-

Modifications-

• The new bell housing to adjust new more powerful curved N-52 neodymium magnets.

• Replaced the stainless-steel shaft with titanium hollow shaft.

Fig- New Modified Bell Housing

V. ELECTRONIC SPEED CONTROLLERS

There are no such modifications that can be made but the choice of esc's can add to better control and performance due to their advanced protocols and their updates. Old esc worked on PWM signals (hardware) whereas new updated esc's works on D-shot 1200 for better and faster loop times. For our motors ratings we used better 40 Amp One-shot 125 esc's with higher burst rating MOSFETs and microprocessor-controlled operation of esc. [3][5]

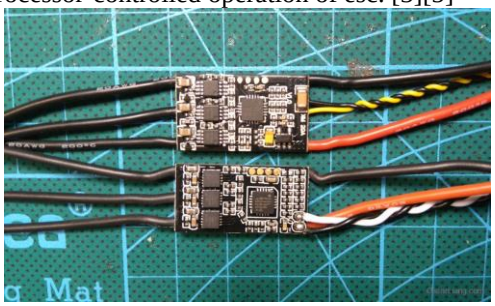

Fig.- 40 Amp esc

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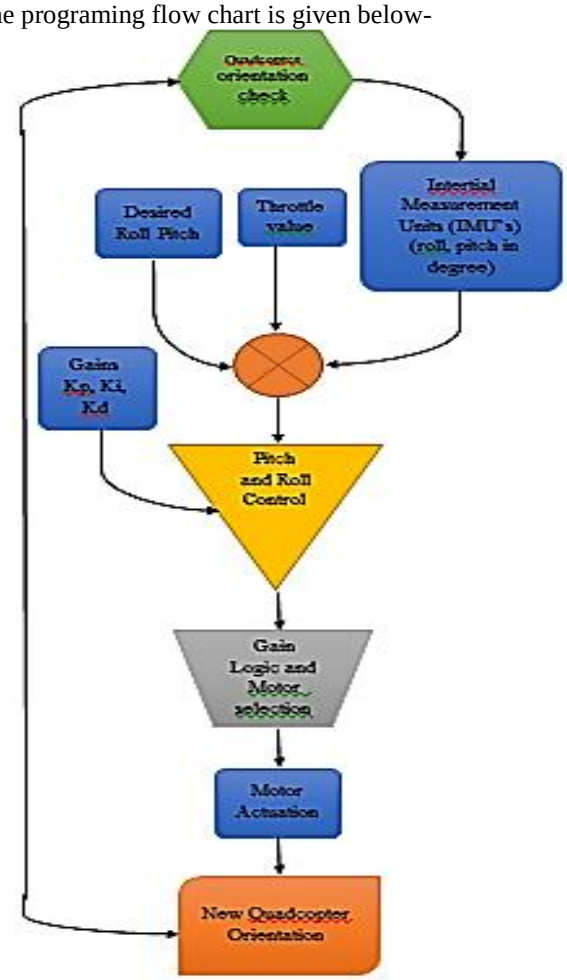
VI. PROGRAMMING

Programing is done on an open source software "Beta Flight Configurator" with its latest update and version. [1][3][4][5] The beta flight configurator is a app which works under google apps and is compatible with windows/iOS/android. It's a open source software we used to program our flight controller which was beta flight compatible. Basically, the programing or the control system works by taking data from the IMU's which could be a gyroscope, accelerometer, it gives data for orientation of quadcopter in angle's in degree which are then taken by CPU where they are processed with the PID gains and error is eliminated. The new gain is send to selected motor to actuate it and achieve new orientation and the process is repeated in cycle to achieve desired orientation.

The programing flow chart is given below-



VII. VIDEO SYSTEM

The video system is divided into three main parts-

A. Camera-

The camera used is a compact camera with inbuilt on Screen Display (OSD) which is useful to show technical parameters such as amp draw in quadcopter, battery voltage etc. It is a 16:9 / 4:3 switchable aspect ratio which it does by simply chopping off end part of 16:9 ratio. It can deliver resolution of 800 television lines (TVL) with 0.0001 lux of illumination power which makes it able to give better video transmission at low light in night condition. The camera weighs only 15g. It also has a 2.5 mm lens with 170 degree wide angle view. With features such as selectable format NTSC and PAL, WDR support and latency reduced to 25 milliseconds.

B. Video Transmitter- [6]

The video transmitter used is a 40 channel 5.8 GHz frequency band and switchable output power – 13dBm (25mW), 23dBm (200mW), 27dBm (500mW), 29dBm (800mW). It also supports smart audio (6.5Ghz) that is it can also transmit audio with video transmission. It features a robust RF amplifier which allows it to work for hours without antenna. It has wide operating range of 7.4V to 26V such that it can support any kind of battery. After having so many features still weigh only 7g.

C. Video receiver- [7]

Video receiver plays an important role in the transmission range and quality so we preferred to use a Diversity receiver or antenna diversity, also known as space diversity or spatial diversity, is any one of several wireless diversity schemes that uses two or more antennas to improve the quality and reliability of a wireless link. We have used a open source developed diversity receiver called as Open pilot RX5808 Pro receiver. It's a atmega 32 8bit microcontroller designed by atmel company-based diversity receiver.

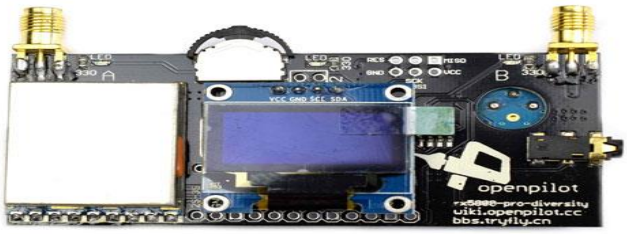


Fig- Open pilot RX5808 Pro

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VIII. RESULT

• Outcomes for frame- The original frame was weighing 78 gm, with modification it added extra 40 gm which increased its strength significantly 1.5 times that of original frame with better aerodynamics which reduced the forward drag offered while cruising resulting in higher forward velocity and the extra bracket mounted on the frame to adjust alignment of antenna increased transmission power 3 times. With 14 dbi panel antenna it can give 14 km of range in open space (condition applied)

• Outcomes for motors- The changes resulted in reduction of weight . The performance was increased as shown in table.[8]

	Before modification			
Supply	RPM	Amp	V	W
100%	26233	29.50	16.55	422
75%	21976	15.57	15.33	239
50%	16244	5.78	16.11	93
25%	9838	2.96	16.40	48
idle	5084	1.75	6.50	28.81

	After modification			
Supply	RPM	Amp	V	W
100%	28275	27.53	16.09	427
75%	22851	14.95	15.77	236
50%	16525	6.80	15.95	108
25%	9868	2.81	16.04	50
idle	5028	1.60	16.06	36

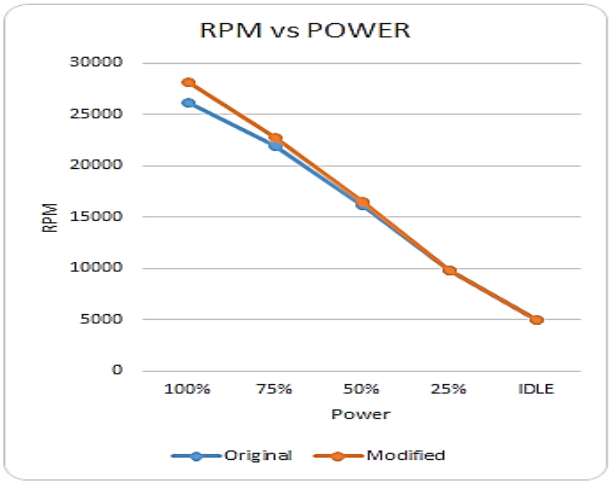

Fig.- graph showing original and modified-power with respect to RPM.

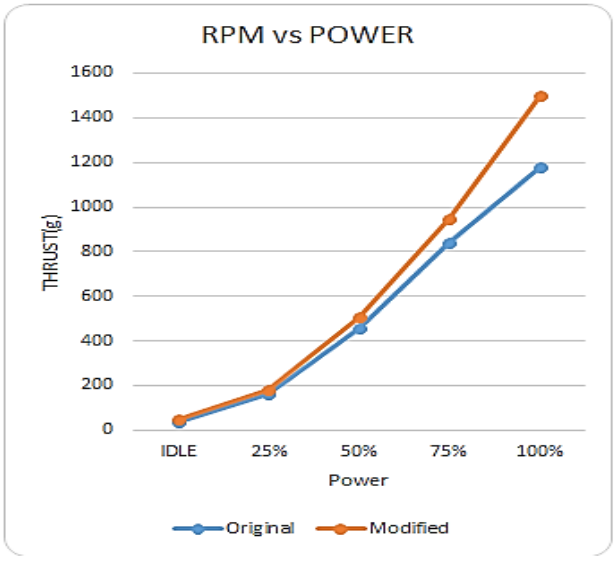

Fig.- graph showing original and modified -power with respect to thrustin grams.

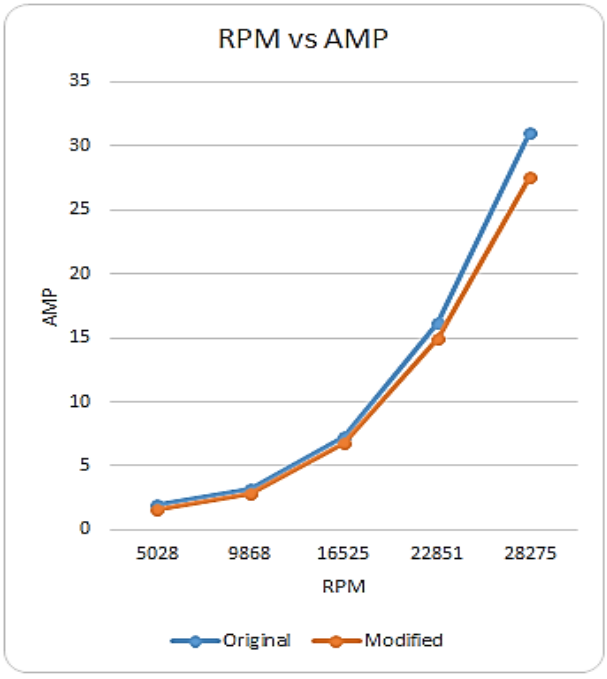

Fig.- graph showing original and modified- RPM with respect to Amp draw.

At 100% with modification the thrust obtained was 1201 gm which was 779 gm earlier.

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- Outcome for video system – For the given configuration coupled with a pair of 4dbi clover leaf circular polarized and a high gain 14dbi polarized antenna can give a live video and audio transmitting range upto 20 km in open space (condition's applied).

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