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Development of a Helical and Pigtail- Based Range Extension System for Campus Surveilance Quadcopter

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***Abstract*— A Quadcopter commonly known as a drone is a type of Unmanned Aerial Vehicle (UAV) that is lifted and propelled by four (4) rotors. They usually come with a control pad and LCD screen receiver that receives videos and photographs from the quadcopter while aloft. The major problem faced by UAVs is the communication range limitation between the drone and its ground control station. Generally, the longer the range the lager the UAV coverage and in turn, the more productive. In this work a range extender system was constructed and used to extend the communication and control range of a campus surveillance drone. To achieve this, the quadcopter was coupled and many field trials were conducted for the purpose of understanding its flight mechanism and to empirically measure its range. However the average communications range between the quadcopter and its control pad was 108 meters. In order to increase this range, range extender system was constructed. It consists of a pigtail antenna for extending the control and video transmission range, and a helical motorized antenna for extension of the flight range. Flight trails and empirical measurements at the Federal University of Technology Minna campus showed that the communication range of the UAV was extended by 200 meters.**

Keywords; Surveillance quadcopter, Communication range, Control station, pigtail antenna, helical antenna, range extender.

I. INTRODUCTION

An Unmanned Aerial Vehicle (UAV), known commonly as a drone is an airplane without a human pilot on board. Its flight is controlled either autonomously by computers in the vehicle, or under the remote control of a pilot on ground or in another vehicle [1]. The vehicles are developed purposely to operate in regions where the presence of an on-board human pilots is either unnecessary or too dangerous. UAVs have prospective applications in military for recognition, environmental observation, and maritime surveillance. Other non-military applications of UAVs are environmental and infrastructure surveillance among others [2]. A quadcopter is a type of UAV with four (4) rotors which pushes air downwards, thus, creating a thrust force keeping the vehicle on air. It usually has a control pad with LCD screen which is used to control its speed, direction, and flip motion. The LCD screen receiver receives aerial videos and photographs which were taken by the camera mounted on the Quadcopter. This camera has a pigtail antenna mounted on it which transmits videos and photographs captured to the LCD screen receiver at the ground control station.

One of the serious challenges of any UAV, especially in surveillance applications, is the short communication range between the Quadcopter (transmitter) and the LCD screen (receiver). The longer the communication range between devices and their controls, the more efficient the output and also more conveniently they can be remotely operated [3]. This challenge can be overcome by a variety of techniques, which include the use of a Wi-Fi repeater, and increment of the strength of the transmitter antenna among others. Wi-Fi repeater, which could also be called a wireless range extender/booster, is a wireless repeater that extracts signal that already exist from a wireless router and rebroadcasts it to create a second network. On the other hand an antenna is an electrical device that converts electric power to radio waves and coverts radio waves back to electrical power. Helical antenna is a passive radio frequency signal booster that uses the principle of convergence of RF signals at the focal point of reflective parabolic object, which increases the transmission and reception signal range. Pigtail antenna usually has a high frequency coupling device called PIGTAIL that enables the antenna to be mounted to the circuit [4].

In this work, we used both helical and pigtail antennas to extend the communication range between the quadcopter and its control pad at the ground station. Firstly, various parts of the quadcopter were coupled together and tested several times in the field to understand its principle of operation and also to determine its maximum average communication range. The antenna inside the control pad and the LCD screen of the quadcopter were then extended using a pigtail antenna. Helical antenna was also constructed and the cable from the antenna was then connected to the pigtail antennas on the control pad and the LCD with the aid of connectors.

The rest of the paper is organized as follows: Literature review is presented in section 2. Methodology of the work is described in section 3. Test and Result is presented in section 4, while, section 5 concludes the paper.

II. LITERATURE REVIEW

In recent years, development of UAVs has become a significant growing segment of global aviation industry. These vehicles are purposely developed to operate in various applications where human intervention is dangerous or considered difficult [3]. The first flying quadcopter was invented by Etienne Oehmichen in 1922 in order to run "Wireless Control Quadcopter with Stereo Camera and Self Balancing System" research. Several theory and techniques were reviewed from previous related research report. The reviews includes the technological development and control methods used in the development of the quadcopter. The inputs are usually the desired values of the height, roll, pitch and yaw. While the outputs are the power of each of the four rotors that is necessary to reach the specifications. The first recorded construction of a quadcopter was in the same year when Georges De Bothezat and Ivan Jerome fabricated and flew the Quadcopter. The quadcopter was to a certain extent large and used variable-pitch propellers for control. This project sponsored by the United State army was cancelled when the quadcopter proved difficult to fly and the military became more interested in autogiros. Later in 1956, another more successful quadcopter was built and flown by designer D. H. Kaplan [4][5].

Quadcopter exists in different sizes ranging from as small as size of a compact disc (CD) up to something big as one (1) meter in width. Larger quadcopters need larger motors which, in turn, have larger inertias and cannot be controlled as quickly as smaller motors. As the size increases to a certain level, the quadcopter can no longer be stabilized through RPM control alone because the torque required to quickly change the rotational velocity of the motor exceeds the capacity of the motor. Therefore, variable-pitch blades become essential for larger quadcopters merely for stabilization purposes

The longer the communication range between devices and their controls, the more efficient the output and also the more conveniently it can be remotely operated. The communication range between quadcopter and its control pad could be extended through the use of Wi-Fi repeater and increment of the length of the transmitter antenna [6]. A Wi-Fi repeater which could also be called a wireless range extender or wireless range booster is a wireless repeater that extracts signal that already exists from a wireless router and rebroadcasts it to create a second network. When two or more hosts have to be connected with one another and the distance is too long for a direct connection to be established, a wireless repeater is used to bridge the gap. Wi-Fi repeater has been used to extend the range of communication between the quadcopter and its control station by taking a signal that already exists and rebroadcasting that same signal thereby creating a second network. [6].

Radio repeater is a type of wireless repeater used to extend the range of coverage of a radio signal. It usually consists of a radio receiver connected to a radio transmitter. The received signal is amplified and retransmitted, often on another frequency to provide coverage beyond the initial range, without any alteration to the signal.

An antenna or an aerial is an electrical device that converts electric power to radio waves and from radio waves back to electrical power. Radio waves are electromagnetic waves which carry signals at the speed of light through the air or space with almost no transmission loss before getting to its destination (the receiver). They are commonly used with radio transmitters and radio receiver. In order to transmit signal using an antenna, a radio transmitter supplies an electric current oscillating at radio frequency (RF) to the terminal of the antenna. The energy from the current supplied by the radio transmitter is radiated as electromagnetic waves/radio waves by the antenna and during reception, an antenna intercepts some of the power of an electromagnetic wave thereby produce a tiny voltage at its terminals. This voltage produced at the terminal of the intercepting antenna is applied to a receiver to amplify it. Antennas can be used for a large variety of equipment that uses radio such as radio broadcasting, television broadcasting, telephones, radar, communications receivers, satellite communications, wireless microphones, and Bluetooth enabled devices among others. [7][8]

The focus of this work is extension of communication and flight range of a campus surveillance UAV. A range extension system consisting of pigtail antennas, and motorized helical antennas was developed to achieve this purpose. The methodology used in doing this is discussed in the next section.

III. METHODOLOGY

The methodology employed in this work is in three fold, which is described in three (3) subsections, which are; coupling of the quadcopter parts, extension of the UAV control and video transmission range with pigtail antennas and the construction of the motorized helical antenna for extension of the UAV flight range

A. Coupling of the Quadcopter Parts.

The drone used in this work came as experimental chassis parts, which were then assembled together to give a complete quadcopter system. The snap-shot of the assembled system is shown in plate 1. These parts include camera, propeller guide, propeller and Quadcopter stand among others. The control pad and LCD screen constituted the control system at the ground station. The assembled system was taken to the field and tested several times with the aim of understudying the principle of its flight operation and also to understand the control mechanism. The maximum average communication range between the quadcopter and its control system at the ground station was also determined empirically during these field.

B. Extension of the UAV Control and Video Transmission Range with Pigtail Antenna.

In other to extend the communication range between the quadcopter and its control pad, the length of the antenna in both the control pad and LCD screen pad of the system were increased. We opened both the control board and the LCD screen and soldered 2cm of a 2.4 GHz Pigtail antenna to the length of the antennas found inside the two components. This antenna is described as pigtail because it has a high frequency coupling device called PIGTAIL, which enabled us to mount the antenna to the circuit. The end of the pigtail antenna in both the LCD screen and the control pad were connected to a female connector, the snapshot of this connection is shown in plate 2 and 3 respectively.

Plate 1: The assembled Quadcopter

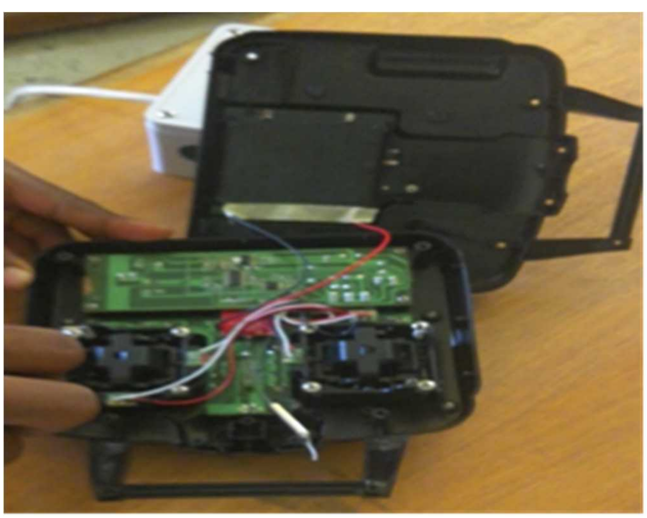

Plate 2: Pigtail antenna on the control board

Plate 3: Pigtail antenna on LCD screen receiver.

C. Construction of the Helical Antenna for extension of the UAV Flight Range.

A helical antenna is a spring with N turns made up of a conducting wire wound in the form of a helix with a reflector. Helix dimensions is determined by the wavelength (*λ)* which also depend on the frequency (F) of the radio wave used as shown in the following equations.

$\lambda = 0.3/F$ ………………………………. (1)

$D = \lambda/\pi$ ………………………………… (2)

$C = D\pi$ …………………………………. (3)

$d = C/4$ ……………………………….... (4)

Where 'F' is the operating frequency (2.4 GHz), D is the diameter of a turn, 'C' is the circumference of a turn and'd' is the approximated space distance between the turns. To obtain a circular polarization around the axis, the circumference (C) of a turn must be approximately one wavelength (λ) and size of the reflector (R) is equal to C or λ.[11][12]

The materials we used in the construction of the helical antenna based on the values obtained from the equations are shown in plate 4. Two 40 cm PVC pipes were used and the wires of a coaxial cable were wounded around the pipes making use of 12 numbers of turns at a distance of 3.3cm to produce the helical antenna. The wire has a colorized PVC isolation and the slight difference in D of 42 mm as against the calculated 39.3 mm is due to the thickness of the isolation. The calculated 132 mm of C obtained is 1.07 of λ. The two helical antennas constructed were placed on an RC reflector which was curved in order to focus the energy in one direction.

The Helical antenna was then placed on a Dual axis motorized stand, which is connected to a gear box used in controlling the direction of the Dual axis motorized stand. The stand is powered by a 12 V D.C battery by connecting the cable from both motors on the stand to it. The snapshot of the constructed helical antenna on dual axis motorized stand is shown in plate 5, while, the snapshot of the entire UAV extender system is shown in plate 6. This antenna extends the flight range of the quadcopter in a given direction.

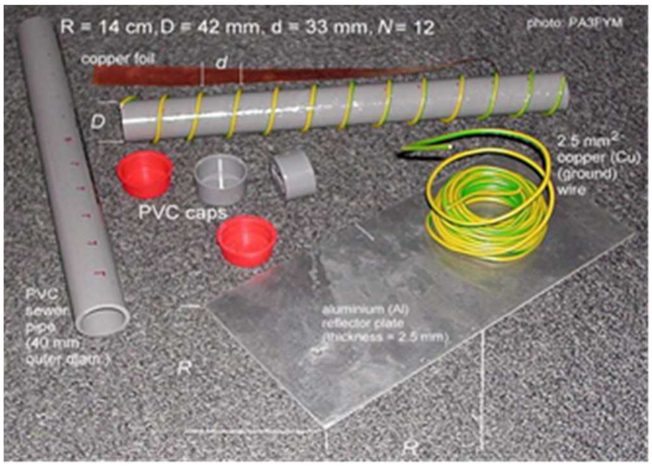

Plate 4: Materials for Helical Antenna

Plate 5: The helical antenna mounted on the Dual axis motorized stand

Plate 6: UAV extender system

IV. RESULT AND DISCUSSION

The complete project work shown in plate 6 was taken to a field in campus for test and evaluation. The quadcopter crash landed several times at the early stage of the test. However, after several trails, all the commands sent to the quadcopter from control pad, such as flipping, trimming, hopping, taking aerial video and photographs were well executed. Since the flight extender is a directional antenna, while the Quadcopter is on flight, the helical antenna points in the direction in which it flies by using the buttons on the gear box connected to the antenna to control the Dual axis motorized stand in the up or down, left or right directions.

Plates 7 (a), (b), (c) and (d) show some of the aerial photographs taken by the quadcopter while aloft in campus.

Plate 7 (a); FUT Minna, Senate Building Road

Plate 7 (c): FUT Minna, Academic Publishing Center

Plate 7 (b) FUT Minna, Research Farm

Plate 7 (d): FUT Minna, Back of Senate Building

The initial average communication range between the quadcopter and its control pad was measured after several field trails to be 108 meters. However, with the introduction of the Pigtail/Helical Antennas, the new average communication range was measured after several field trails to be 308 meters line of sight. It was observed that while a great distance was achieved, the battery capacity reduced from 5 minutes to 3 minutes due to the amount of power being consumed by the antennas.

V. CONCLUSION

In this work an experimental chassis parts of a UAV quadcopter was assembled. Knowing that one of the challenges of most UAVs is inadequate communication range between the vehicles and their control pad, field trials were conducted for the purpose of studying the operating principle and to empirically determining the range. The average communication range of the UAV was measured after several field trials to be 108 meters. A range extension system, consisting of pigtail antennas and motorized helical antenna was developed to extend the communication and flight range of the UAV quadcopter. Field tests with the developed system at the Federal University of Technology (FUT) Minna air space showed that the communication range was successfully extended by 200 meters. This means that the new communication range was measured to be averagely 308 meters line of sight. The vehicle was therefore able to gain wider coverage aloft and videoed and transmitted very clear aerial images of the areas covered. This shows that campus surveillance can be better achieved with the UAV. However, considering the size of this campus, multiple UAVs may be employed for complete surveillance.

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