WI-FI COMMUNICATION SYSTEM FOR A FIXED-WING TWIN-ENGINE AIRPLANE UAV

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Abstract: *Unmanned Aerial Vehicle (UAV) systems have automated pilots that can be configured to suit various mission requirements. In this study, we assess, develop, and evaluate a bidirectional Wi-Fi communication link for an automated piloting system, utilizing the Cube Orange architecture that is mounted on a fixed-wing twin-engine airplane UAV. This Wi-Fi link enables seamless data exchange between the UAV and the ground control station. Using this bidirectional communication link, the user gains access to telemetry data, providing real-time insights into the UAV's flight parameters. Additionally, the user can send commands to the UAV, ensuring dynamic mission control and adaptability, while, the Wi-Fi link facilitates the retrieval of live video data from the UAV's onboard camera, enabling display on the command station screen or recording for future analysis and utilization. This comprehensive Wi-Fi communication system enhances the overall functionality and efficiency of the UAV's automated piloting, enabling smooth and reliable operations for various mission scenarios.*

Keywords: *Aerospace, Fixed-wing UAV, Automated Pilot, UAV Mission Planning, Additive manufacture*

1. INTRODUCTION

Unmanned Aerial Vehicle (UAV) systems have witnessed a decline in cost, making them more accessible to build. However, their successful development still requires meticulous planning, thoughtful design, and precise implementation. Current research in this field is concentrated on several key areas: advancements in quad-copter UAV technology, focusing on enhancing their capabilities, efficiency, and performance [1,2,4,5,7], development of fixed-wing UAVs, aiming to improve their design, stability, and operational characteristics [6,10,11,12], integration of automated systems seeking to create seamless and intelligent UAV operations for various applications [1,2,3,4,5,6,10,11,12], communication interfaces to ensure reliable and efficient data transmission between UAVs and ground control systems [3,8,9,10,11,12], developing sophisticated simulations, refining navigation algorithms, enhancing stability during flight, and exploring diverse mission types for UAVs[1,2,3,4,5,6,7,10,11,12]. As the technology continues to evolve, these research directions pave the way for more capable and versatile UAV systems in various industries and applications.

The UAV community is continuously expanding, with an array of products and solutions spanning across underwater, ground, and air vehicles. As prices decrease in the near future, the number of UAVs is expected to rise, resulting in a more crowded sky and less communication band.

To address this, the development of an onboard autopilot capable of achieving its mission without relying on ground guidance becomes crucial. This paper presents such an autonomous flying vehicle with a bidirectional Wi-Fi communication system to relay data and video info to a ground station.

The establishment of an autonomous flying vehicle hinges on a crucial element - the precise determination of the aircraft's flight path. Adaptations to the flight path may be necessary based on the mission profile, and these adjustments might occur even while the vehicle is in flight. For our study, we employed a 3D printed airplane with 3D printed engines, incorporating an automated control system centered around a CubePro Orange processor. This processor is interconnected with a ground control station via a bidirectional Wi-Fi system, enabling the seamless transmission of flight path corrections, flight data, and a live video feed during the mission.

The airplane was fabricated utilizing additive manufacturing technologies. Specifically, for the fuselage and wings, we employed Fused Deposition Modeling and as fabrication material we used reinforced composite with short fiberglass for the fuselage and short carbon fiber for the wings. The parts were produced using a Zortrax M300 Dual for composites with fiberglass, and an Ultimaker S5 for composites with carbon fibers.

To power the aircraft, we installed two brushless motors, manufactured using the Selective Laser Sintering method, using A6 steel on a 3D System SPRO 60 SD. Each of these motors generates a thrust of 10 kgf and comes equipped with 15-inch counter-rotating blades for enhanced efficiency.

FIG. 1 Fixed-wing twin-engine aircraft made from 3D printed composite materials [10]

The CubePro Orange controller was integrated into the airplane using a PixHawk motherboard as interface. This controller serves a dual purpose: commanding the servos responsible for controlling various flight components such as engines, flaps, ailerons, stabilizer, and direction, while also facilitating the transmission of telemetry data to the ground control station via a wireless 868 MHz transmitter (Fig. 2).

Additionally, we setup a live video feed from a Tau 2 Longwave Infrared Thermal Camera Module using a 2.4 GHz analog video transmitter. To ensure efficient data transfer, the video signal is overlaid with the telemetry information gathered during flight, providing real-time feedback and crucial data during the mission (Fig. 3).

The CubePro Orange controller is an onboard device specially designed for unmanned aerial vehicles (UAVs). Its primary function is to act as the central processing unit, efficiently managing the aircraft's flight operations and automation. The controller comes equipped with a diverse range of input/output (I/O) ports, enabling communication with various components and peripherals, as:

• 14 PWM servo outputs (8 from IO, 6 from FMU) to control multiple servo motors responsible for maneuvering the UAV.

• Radio control receiver (R/C) inputs, supporting different signal types such as CPPM (Combinatorial Pulse Position Modulation), Spektrum / DSM (Digital Spectrum Modulation), and Serial Bus for flexible control options.

• Analogue / PWM (Pulse Width Modulation) RSSI (Received Signal Strength Indicator) input to monitor signal strength.

• Serial Bus servo output for interfacing with compatible devices.

• 5 general-purpose serial ports, with 2 featuring full flow control for data communication.

• Two I2C ports, providing connectivity to compatible sensors and peripherals.

• One SPI port (un-buffered) suitable for short cable connections, though not recommended for extensive use.

• Two CAN Bus interfaces for communication with devices using the Controller Area Network protocol.

• 3 analogue inputs for reading analog signals from sensors or other devices.

• High-powered piezo buzzer driver for audio feedback and alerts.

• High-power RGB LED for visual indications and status updates.

• Safety switch / LED for added safety and control.

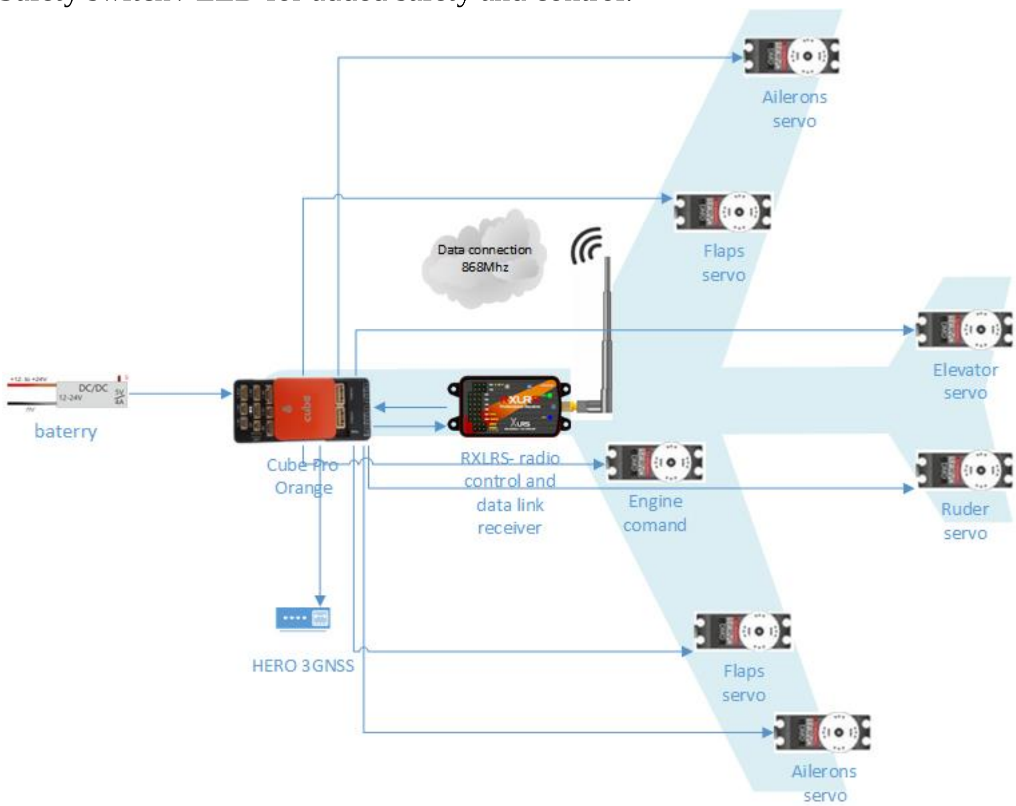

FIG. 2 CubePro Orange controller integrated on the airplane. Linkage configuration of the controller

This powerful controller offers robust connectivity options, enabling it to interface with a wide array of devices, including servos, sensors, cameras, and other electronic modules. It plays a crucial role in interpreting flight instructions, adjusting control surfaces such as ailerons, flaps, rudder, and elevator, ensuring precise maneuverability during flight. The chosen configuration for our UAV airplane, depicted in Fig. 2, consists of the following components:

- one CubePro Orange controller;
- one RXLRS- radio control and data link receiver;
- one HERO 3 RTK GNSS (Global Navigation Satellite System);
- two servos for flaps;
- two servos for ailerons;
- one servo for elevator;
- one servo for ruder;
- one ESC (Electronic Speed Controller) for engine control;
- and a 5V Lipo battery.

With its compact and lightweight design, the CubePro Orange controller optimizes the UAV's weight distribution and stability, contributing to enhanced performance. It is also designed to handle real-time telemetry data, allowing for efficient communication between the UAV and the ground control station.

The HERO 3 RTK GNSS (Global Navigation Satellite System) system is a high-precision positioning solution that enhances the capabilities of the CubePro Orange controller for unmanned aerial vehicles (UAVs). With RTK technology, it significantly improves the UAV's positioning data accuracy and reliability.

By integrating the HERO 3 RTK GNSS system with the CubePro Orange controller, the UAV gains access to highly precise location information, ensuring stable and accurate flight trajectories, even in challenging environments. This enables the UAV to execute complex missions with utmost precision. The system's robust signal reception supports multiple satellite constellations, including GPS, GLONASS, Galileo, and BeiDou, providing comprehensive global coverage for navigation, and increasing the reliability and availability of satellite signals, making the UAV less susceptible to signal obstructions or interference.

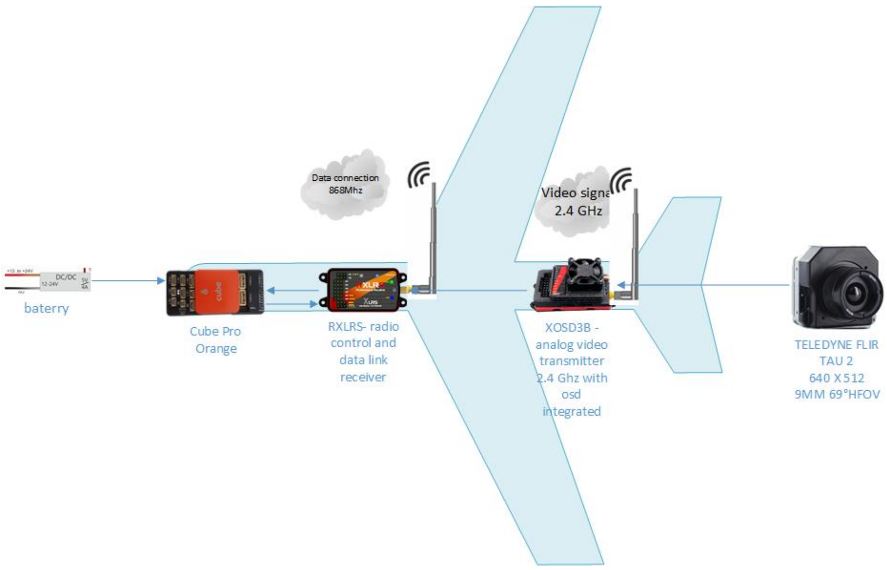

FIG. 3 UAV airplane Wi-Fi communication system configuration

The RXLRS- Radio Control and Data Link Receiver is a device crafted for unmanned aerial vehicles (UAVs) and other remote-controlled applications, serving as a communication link between the UAV and the ground control station. With a god range, it supports long-distance operations, making it perfect for applications requiring expansive coverage.

Its robust radio communication capabilities ensure real-time transmission of control commands, enabling instantaneous response and control during flight. Additionally, acting as a data link, the RXLRS- receiver facilitates the transmission of telemetry data and flight information back to the ground control station, enhancing situational awareness and enabling real-time monitoring of vital flight parameters like altitude, speed, battery status, and GPS coordinates.

We have enhanced the Wi-Fi communication system by integrating the XOSD3B with a built-in On-Screen Display (OSD) capability Fig. 3. This feature allows flight data and telemetry information to be overlaid directly onto the transmitted video feed in real-time. Key flight parameters such as battery status, altitude, speed, and GPS coordinates are displayed, improving situational awareness for the operator without the need for additional displays or telemetry equipment. Furthermore, the XOSD3B's analog video transmission technology ensures a stable and low-latency video feed, essential for real-time monitoring and precise control of the UAV during flight. Operating on the 2.4 GHz frequency, this setup provides a reliable connection, reducing signal interference and ensuring a smooth and uninterrupted video transmission experience.

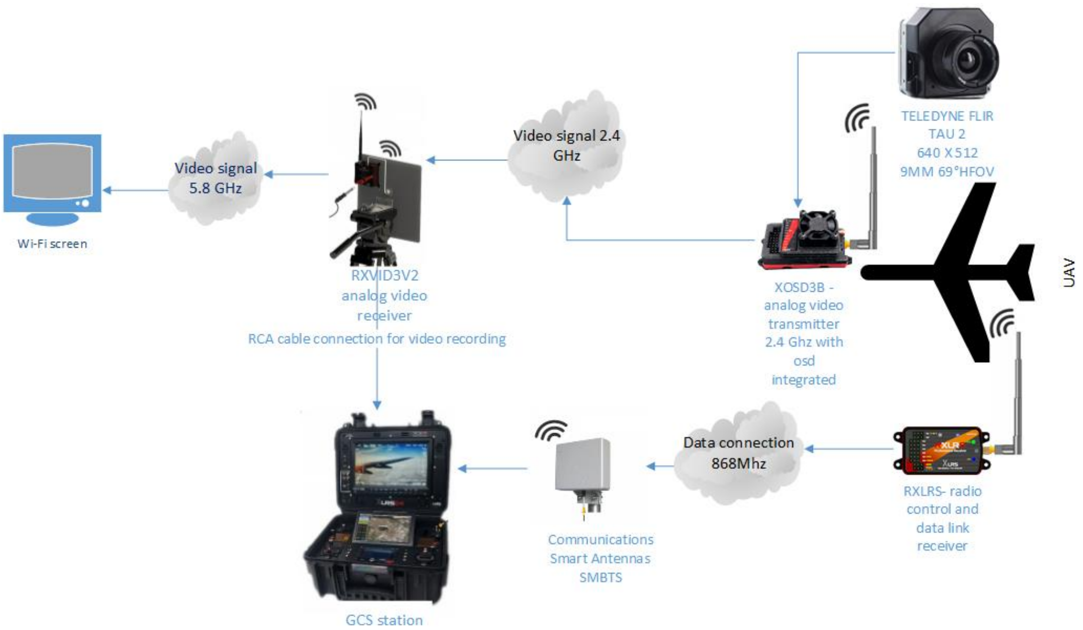

FIG. 4 Complete Wi-Fi communication system

Using the XOSD3B, we transmitted a real-time video feed from the Teledyne FLIR TAU 2 640 x 512 9mm 69°HFOV - LWIR Thermal Imaging Camera Core (Fig. 3). This camera core operates in the long-wave infrared (LWIR) spectrum, enabling detailed thermal imagery even in challenging environmental conditions like low light or adverse weather. Its wide 69° horizontal field of view (HFOV) ensures comprehensive scene coverage, making it suitable for monitoring and reconnaissance tasks. Equipped with image processing capabilities, the Teledyne FLIR TAU 2 camera core provides precise temperature measurement and radiometric data. Additionally, it offers various imaging modes, allowing users to customize settings according to specific applications and requirements.

To finalize the communication system, we integrated the GCSD4 ground control station from Digital Micro Device, alongside two ground antennas: Communications Smart Antennas SMBTS and the RXVID3V2 analog video receiver, as depicted in Fig 4.

This setup ensures communication between the ground control station and the unmanned aerial vehicle (UAV), enabling real-time monitoring, data transmission, and video reception for the UAV operation.

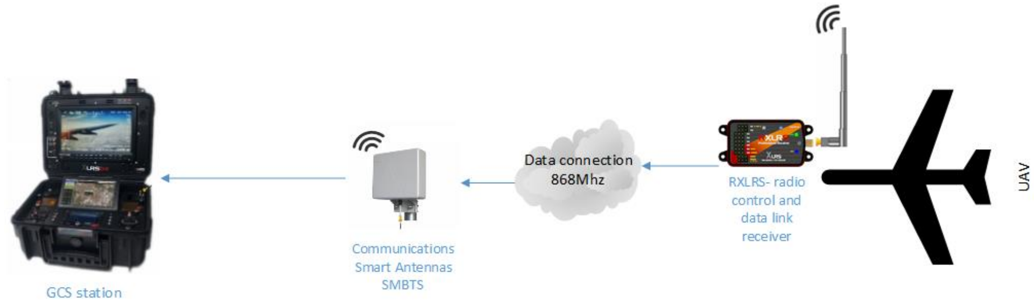

FIG. 5 Data link Wi-fi communication system

The entire Wi-Fi system can be divided into two distinct components: the video feed, depicted in Fig. 5, and the data link communication, illustrated in Fig. 6. These two essential elements work together to ensure transmission of video and data, enabling real-time monitoring, control, and communication between the ground control station and the unmanned aerial vehicle (UAV).

The data link communication channel is form from tree main components, as seen in Fig.5:

- the RXLRS- radio control and data link receiver, operating on the 868 MHz band, serves to transmit and receive data between the ground control station (GCS) and the UAV;
- the Smart Antenna SMBTS facilitates bidirectional data transmission between the GCS and the UAV, also utilizing the 868 MHz frequency;
- and the GCS station that acts as the central hub, receiving data from the UAV through the data link, visualizing the information, and sending commands to update the flight path as needed.

This communication loop ensures data exchange and real-time control over the UAV's operations during flight.

FIG. 6 Wi-fi VIDEO feed system

The video feed channel if formed from five components, as illustrated in Fig. 6, that ensure data transmission and real-time control over the UAV's operations during flight. The components are as follows:

- The Teledyne Flir Tau 2 640 x 512 9mm 69°hfov - LWIR thermal imaging camera core captures infrared imaging data, providing thermal imagery during the UAV's missions.
- The XOSD3B analog video transmission technology with built-in On-Screen Display (OSD) capability ensures a stable and low-latency video feed. This feature is crucial for real-time monitoring and control of the UAV throughout its flight. The XOSD3B operates on the 2.4 GHz frequency range, ensuring reliable video transmission.
- The RXVID3V2 Analog Video Receiver plays a crucial role in the video feed channel, receiving data on the 2.4 GHz band from the XOSD3B and retransmitting it on the 5.8 GHz band. This enables display of the video feed on the GCS. Additionally, the receiver has an RCA connector output, allowing the video signal to be displayed or recorded on a secondary device.
- As an optional component, a second device can be utilized to record the video feed from the analog receiver. This secondary recording device can be a laptop or any other compatible recording equipment.
- The GCS station serves as the central hub for the video feed channel, receiving, and visualizing the transmitted video data. This enables the operator to have real-time access to the UAV's thermal imagery and make informed decisions during the mission.

The integration of these components ensures a robust video feed channel, providing critical thermal imaging data and enabling effective control and monitoring of the UAV's operations from the ground control station.

CONCLUSIONS

Creating a bidirectional Wi-Fi communication system with video feed capabilities for a fixed-wing twin-engine airplane UAV, along with a ground control station, is a challenging task that requires specialized equipment and careful planning. However, such a system offers numerous advantages:

- Information Telemetry: The system provides real-time telemetry data about the UAV's flight to the ground control station, enabling the monitoring of flight parameters.
- Real-Time Flight Path Updates: The bidirectional communication allows for updating the UAV's flight path in real-time and sending new commands to the autopilot, enhancing mission flexibility and adaptability.
- Real-Time Video Feed: The system facilitates the transmission of live video information about the flight, providing visual feedback to the operator and enhancing situational awareness during operations.
- In the case of a Search and Rescue Missions: Coupling the system with a thermal core allows real-time tracking of a person's whereabouts, enhancing the effectiveness and efficiency of such operations.

When designing the communication system, careful consideration must be given to the selection of the communication band. RF 868MHz is a public bandwidth in European Low Power Networks (LPWAN) and regulated in Europe by ERC-REC-70-3E, while the 2.4 GHz band is also available but can be crowded with Wi-Fi, Bluetooth, and other radio devices, especially in urban areas. Therefore, selecting the appropriate frequency band is crucial to avoid interference and ensure reliable communication.

As the main mission involves search and rescue tasks, incorporating a thermal module is essential. However, it's vital to take precautions to protect the expensive thermal module during landing or in the event of a crash. This requirement necessitates the transmission of thermal imagery, adding complexity to the system. By using two separate frequency bands and employing separate compression and transmitting devices for video and data, the challenges associated with the complex communication system can be effectively addressed, ensuring efficient and reliable operation.

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