Security Surveillance UAV using Analog System

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Abstract - Unmanned Aerial Vehicles (UAVs) have revolutionized surveillance presented various applications across domains. In this research paper, we explore an unconventional approach by leveraging analog systems for security surveillance UAVs drones. While digital systems dominate the UAV landscape, analog technology offers unique advantages in terms of simplicity, robustness, and real-time responsiveness. Our study investigates the design, implementation, and performance evaluation of an analog-based UAV system tailored for security applications. We delve into the intricacies of analog signal processing, sensor integration, and communication protocols to create a reliable and efficient surveillance platform. By bridging the gap between traditional analog techniques and modern security needs, our proposed system succeeds at enhance situational awareness, minimize latency, and ensure seamless operation in challenging environments for real-time tracking and monitoring.

***Key Words*:** Analog System, Drone, GPS Telemetry, Real-Time Surveillance, UAV, Wireless Communication

1.INTRODUCTION

The escalating global security landscape demands innovative solutions for surveillance and intelligence gathering. High-speed, long-range surveillance capabilities are critical for monitoring vast territories, identifying threats, and safeguarding national interests. Additionally, the ability to carry important payloads enhances the versatility of surveillance UAVs, allowing them to perform a wide range of tasks beyond mere reconnaissance.

In recent years, the use of kamikaze drones has gained prominence, especially in conflict zones. These drones, also known as loitering munitions or suicide drones, blur the lines between reconnaissance and offensive capabilities. Their unique design enables them to loiter in the vicinity of a target, gather real-time intelligence, and, if necessary, execute a precision strike by diving directly into the target.

The ongoing Russia-Ukraine war serves as a stark example of how security surveillance UAVs, including kamikaze drones, play a pivotal role. Both sides have deployed UAVs extensively for reconnaissance, target acquisition, and even offensive operations. The Ukrainian forces have utilized Bayraktar TB2 drones, equipped with high-resolution cameras and laser-guided munitions, to counter Russian advances. On the other hand, Russia's use of the Orion-E surveillance UAVs has provided critical intelligence on Ukrainian troop movements and infrastructure.

In this paper, we delve into the integration of analog systems within security surveillance UAVs. We explore the benefits of analog signal processing, the challenges associated with long-range communication, and the trade-offs between digital and analog approaches. Our research aims to contribute to the advancement of UAV technology, ensuring that security forces have reliable, efficient, and adaptable tools at their disposal.

The proposed research investigates the aspects of analog signal processing by analyzing the advantages of analog signal processing for UAVs. Analog systems offer inherent noise resilience, reduced latency, and simplified hardware requirements. By harnessing analog components, we enhance the real-time capabilities of surveillance systems. Secondly, high-speed surveillance necessitates robust links which guarantee long-range communication. Analog communication protocols, such as frequency modulation (FM), provide extended range and reliability. We explore methods to optimize communication channels for seamless data transmission over vast distances.

More importantly, payload capacity directly impacts mission effectiveness. Analog systems allow for efficient power distribution and lightweight payloads. We discuss payload options, including high-resolution cameras, thermal sensors, and even kamikaze modules. These specialized UAVs combine surveillance capabilities with offensive potential. We delve into their design, deployment strategies, and ethical implications.

2. LITERAURE REVIEW

For architecture selection [1] provides detailed documentation of parametric to be considered when building a UAV, it reveals a significant gap in scientific research regarding the design and performance of racing drones, despite substantial advancements in drone control techniques and their broad applications. Historically, research has concentrated on simplified dynamic models and control techniques, enabling strides in autonomous flight, agility, and maneuverability, especially for civilian uses. Recent trends, however, have moved towards more complex models that consider rotor dynamics and aerodynamic forces, particularly for high-performance and aggressive maneuvers. Despite these advancements, there's a noticeable scarcity in studies focused on the geometric design's impact on racing drone performance. The review underscores the importance of addressing this gap by integrating pilot know-how with empirical data from experimental flight tests to enhance understanding of how geometric characteristics influence racing drones' agility, stability, and overall performance.

[2] emphasizes upon the different types of drones differentiated in terms of the type (fixed-wing, multirotor, etc.), the degree of autonomy, the size and weight, and the power source. These specifications enabled us to understand the importance for the drone's cruising range, the maximum flight duration, and the loading capacity. Aside from the drone itself (i.e., the 'platform') various types of payloads can be distinguished, including freight (e.g.,mail parcels, medicines, fire extinguishing material, flyers, etc.) and different types of sensors (e.g.,cameras, sniffers, meteorological sensors, etc.). In order to perform a flight, drones have a need for (a certain

amount of) wireless communications with pilot on the ground. In addition, in most cases there is a need for communication with a payload, like camera or a sensor. To allow this communication to take place a frequency spectrum is required. The requirements for frequency spectrum depend on the type of drone, the flight characteristics, and the payload. Legal issues on frequency spectrum usage and electronic equipment(national and international legal matters on frequency spectrum an equipment requirements) are discussed, as well as frequency spectrum and vulnerability (an insight in available frequency spectrum and associated risks in using the frequency spectrum) and surveillance and compliance (enforcement of frequency spectrum use, and equipment requirement. Finally, future developments in drone technology are discussed. The trend is for drones to become smaller, lighter, more efficient, and cheaper. Drones have become increasingly autonomous.

For understanding the flow of architecture and integration of drone technologies, [3] provides advanced and sustainable solutions for surveillance holding significance in the smart cities, surpassing conventional methods in efficiency and effectiveness. Unmanned Aerial Vehicle (UAV)-based methodologies for diverse surveillance tasks categorizes surveillance drone applications into seven areas, explores their integration with other technologies like the Internet of Things (IoT), Wireless Sensor Networks (WSNs), Convolutional Neural Networks (CNNs), Artificial Intelligence (AI), Machine Learning (ML), Cooperative Intelligent Transport Systems (C-ITS), Computer Vision (CV), Web Real-Time Communication (WebRTC), and cloud computing, and identifies aerial sensors used. Despite its early-stage status in research. Drones, either standalone or combined with these advanced technologies, provide real-time data and efficient solutions, overcoming conventional methods' limitations. Most studies relied on simulations for validation, with real-world implementations being rare. Rotary-wing UAVs, primarily equipped with cameras, are the predominant type for surveillance, although some models utilize laser scanners.

An SSDS [4] was successfully developed to detect and track the objects concerned in case of intrusion and fire accidents with the support of AI models and IoT communication. Computer vision models, YOLOv8 and Cascade Classifier, were trained and implemented in the workstation for object classification. Furthermore, three algorithms for drone control were implemented for the automation optimization of drone functions like target following and dangerous object avoidance. The entire system is capable of collecting the alerts from IoT sensors and manipulating the drone for acquiring the data, monitoring the stream to store the data, and transmitting the data to other responsible electronic devices via Wi-Fi. In the future, the developed system will be applied to more circumstances, such as particular factories, for further experiments to collect more information about the system’s pros and cons. From this stage, more drone control algorithms and AI models can be employed in the smart flight system.

Despite limitations in satellite communication and costs, UAVs have advanced significantly[5]. Recent developments include drones operated via 2.4 GHz RF controllers and capable of live audio-visual feedback, with control systems simulated in MATLAB/Simulink for stability. Microcontroller-based systems enhance remote operation, while integration with Android devices and GPS provides live position tracking initially deployed for military surveillance, UAV applications now extend to policing, firefighting, flood monitoring, video recording in inaccessible areas, and security tasks.

3. METHODOLOGY

Our methodology for developing the security surveillance UAV using analog systems involves a systematic approach to design, implementation, and testing.

i. Requirements Analysis:

- Definition and identification of specific requirements for the security surveillance UAV, including high-speed, long-range surveillance capabilities, and payload capacity. Adressing the need for analog systems to enhance real-time responsiveness and robustness is crucial.

ii. System Architecture Design:

- A high-level architecture considering the specified dimensions: 235mm x 230mm x 90mm (without propellers) and 300mm x 310mm x 90mm (with propellers).
- Allocate tasks between analog and digital subsystems based on the specified motor and propeller details.

iii. Analog/Radio Signal Processing:

- Developing analog signal processing modules, considering the 2306 1750 kV motors with a temperature rating up to 200°C.
- Radio controller commands are executed by the ELRS reciever which is mounted on UART-2 of the flight controller. These commands are then executed by flight controller by signalling the ESC.

iv. Sensor Integration:

- Ensure seamless communication between analog sensors and the flight controller (Speedybee F405 V3 which consists of STM32F405 Microcontroller).
- Options to integrate analog sensors (gyroscopes, barometer, accelerometers, altimeters) into the UAV system.

v. Communication Protocols:

- Implement analog communication protocols (e.g., frequency modulation) for long-range communication, considering the specified 2.0 km range.
- Address noise, interference, and reliability challenges.

vi. Motor and Propeller Selection:

- Choosing motors and 5-inch propellers on the specified motor model (2306 1750 kV) and torque requirements to cater to proposed architecture.
- Optimize motor control for stability and speed (180 km/h).

vii. Power Supply Design:

- Designing power distribution systems for analog components, considering the specified 6S LiPo(22.2V) battery configuration.
- Balance power requirements with weight constraints.

viii. Payload Integration:

- Evaluation of payload options within analog constraints (up to 650 grams).
- Accommodate high-resolution cameras (1200 TVL).

ix. Drone Implementation:

- Developing a specialized UAV variant for offensive operations, considering the specified payload capacity.
- Address ethical implications and safety protocols(Black box).

x. Testing and Validation:

- Rigorously test the analog-based UAV system and validate real-time responsiveness and robustness.

xi. Deployment and Field Trials:

- Deploy the security surveillance UAV in relevant scenarios, considering the specified altitude (300 feet) and geofenced areas.
- Monitor performance and refine the system based on practical insights.

By following this methodology, we aim to create a reliable and efficient security surveillance UAV that leverages analog systems to enhance situational awareness and operational effectiveness.

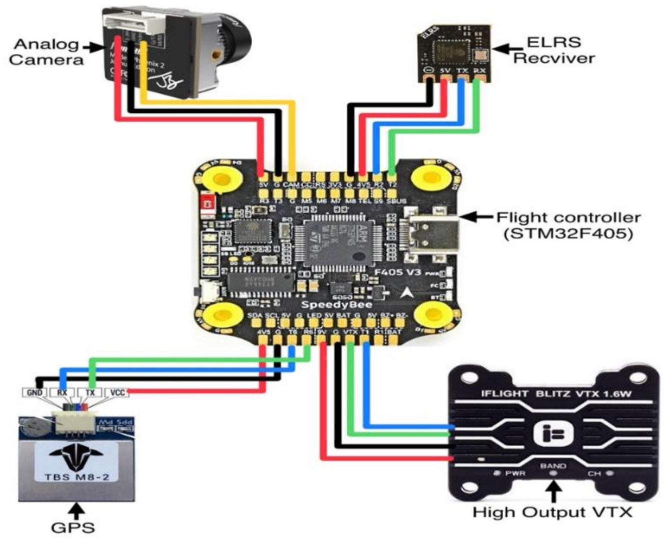

Fig-1: Proposed System Architecture

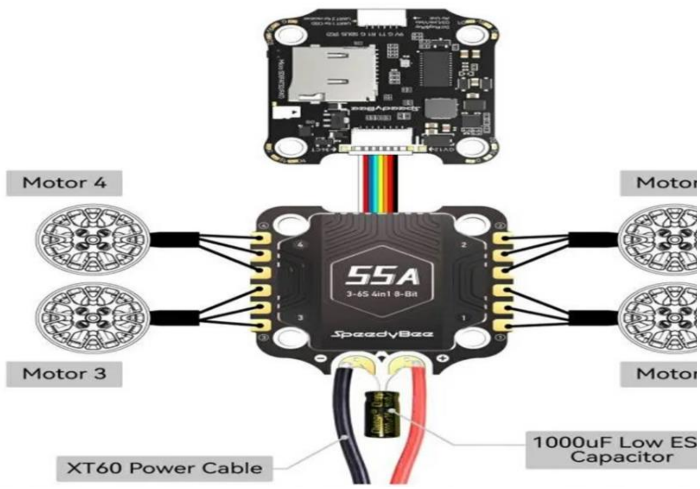

Fig -2: UAV Architecture

The central component in this schematic is the SpeedyBee SSA electronic speed controller (ESC). It serves as the nerve center for motor control and power distribution. Here's a breakdown of the key elements:

1. **Motors (Motor 1 to Motor 4):**
- Each motor is connected to the ESC. These motors drive the drone's propellers, enabling lift and movement.
- Proper motor placement and orientation are crucial for balanced flight.

2. **XT60 Power Cable:**
- The XT60 connector ensures efficient power transfer from the battery to the ESC.
- It's essential for stable performance during flight.

3. **1000uF Low ESR Capacitor:**
- This capacitor plays a vital role in voltage stabilization.
- It minimizes voltage spikes, ensuring smooth power delivery to the ESC and motors.

Assembling a drone involves connecting motors to the ESC, ensuring proper power supply, and incorporating voltage-stabilizing components. This ensures reliable flight performance and longevity.

The envisioned drone boasts impressive capabilities, designed for high-performance aerial missions with parametric like remarkable top speed of 180 km/h, this drone can swiftly cover vast distances. Its aerodynamic frame and powerful brushless motors ensure efficient propulsion. The drone operates on a 6S LiPo battery, delivering ample power for extended flights. This battery configuration strikes a balance between energy density and weight. It is equipped with a robust communication system; the drone achieves a commendable range of 2.5 km. High-gain antennas and reliable radio frequencies facilitate seamless control even at extended distances.

The drone can carry payloads weighing up to 600 grams, making it suitable for various applications, from aerial photography to scientific research.

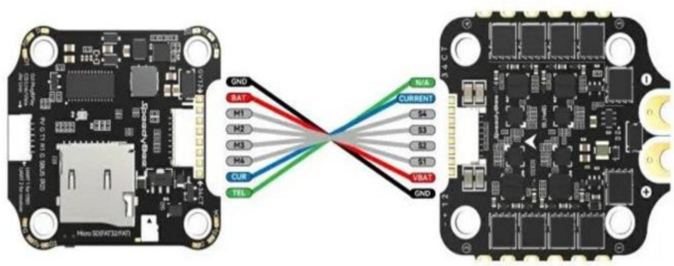

Fig-3: FC-ESC Configuration

Fig-4: Complete UAV Implementation

4. CONCLUSION

Our research paper has outlined a comprehensive methodology for the development of a security surveillance UAV utilizing analog systems. By bridging the gap between traditional analog techniques and modern security needs, we have demonstrated the potential of analog technology to revolutionize surveillance and reconnaissance applications. Through the integration of analog signal processing, sensor integration, communication protocols, and payload options, we have proposed a robust and efficient UAV platform tailored for security applications.
The advantages offered by analog systems, including simplicity, robustness, and real-time responsiveness, have been highlighted throughout our study. Analog signal processing

modules, optimized for sensor inputs and motor control, provide inherent noise resilience and reduced latency, enhancing the real-time capabilities of surveillance systems. Furthermore, analog communication protocols such as frequency modulation (FM) offer extended range and reliability, addressing the challenges associated with long-range communication.
The implementation of a specialized UAV variant for offensive operations, such as kamikaze drones, underscores the versatility and adaptability of our proposed system. By accommodating high-resolution cameras, thermal sensors, and other surveillance equipment within analog constraints, we enable security forces to enhance their situational awareness and operational effectiveness.

5. FUTURE SCOPE

While our research lays the groundwork for the development of analog-based security surveillance UAVs, there are several avenues for future exploration and refinement.
Advanced Sensor Integration: Investigating advanced sensor technologies and their integration into the UAV system can further enhance its capabilities. Emerging sensors such as LiDAR, hyperspectral imaging, and synthetic aperture radar (SAR) could provide additional layers of intelligence for surveillance missions.
Autonomous Navigation capabilities using artificial intelligence and machine learning algorithms can enable UAVs to operate more independently, navigating complex environments and optimizing mission efficiency.
As UAVs become increasingly connected and reliant on digital systems for communication and control, cybersecurity becomes a paramount concern. Future research should focus on developing robust cybersecurity measures to protect UAVs from cyber threats and ensure the integrity of data transmission.
Ethical and Legal Implications: As surveillance UAVs become more pervasive, it is essential to consider the ethical and legal implications of their use. Future studies should delve into the ethical frameworks and regulatory guidelines governing UAV operations, ensuring responsible and accountable deployment in various scenarios.
Furthermore, exploring ways to minimize the environmental impact of UAV operations, such as optimizing energy efficiency and reducing carbon emissions, is crucial for long-term sustainability.
We can continue to advance the field of security surveillance UAVs, ensuring that security forces have access to reliable, efficient, and adaptable tools for safeguarding national interests and maintaining situational awareness in dynamic environments.

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