

On a solution for converting radio-controlled drones into fiber-optic-controlled drones: News & Views

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ABSTRACT

The paper presents a solution for converting the system of control channels, data channels, and status channels from the commonly used radio transmission channels in current drones to optical fiber transmission channels. Drones controlled via fiber-optic cables offer significant advantages, such as immunity to electronic warfare countermeasures from the adversary, the ability to transmit high-definition reconnaissance images with large bandwidth, real-time operation, low latency, and strong information security. Additionally, fiber-optic technology effectively supports the processing of control algorithms and complex recognition tasks due to its ability to transmit large amounts of data and provide high-speed processing back to the central control station.

Keywords: Drone; Fiber-optic controlled.

1. INTRODUCTION

In recent conflicts, drones have not only served as reconnaissance tools but have also become primary offensive weapons. Thousands of low-cost FPV drones are used to destroy tanks, artillery, and enemy positions, with common flight ranges of 5-20 km [1]. This widespread use has driven the need for improved communication to avoid being neutralized by the adversary's electronic jamming systems. Most commercial drones use 2.4 GHz and 5.8 GHz frequency bands for control and video channels, which are easily jammed, interfered with, or detected. On the battlefield, the rate of signal loss or drone crashes due to jamming is very high, especially for analog video transmission systems without encryption [2]. The fiber-optic control solution fully overcomes these drawbacks. Optical fibers do not emit electromagnetic radiation, are immune to jamming, offer low latency, and provide large bandwidth, enabling simultaneous transmission of control commands, status data, and high-definition real-time video. Many units in Ukraine and Russia have begun deploying FPV drones connected to control stations via optical fibers, indicating that this conversion trend is necessary and feasible in modern electronic warfare environments.

2. SOLUTION FOR CONVERTING RADIO-CONTROLLED DRONES TO FIBER-OPTIC-CONTROLLED DRONES

2.1. Structure and drone control protocols

The current radio-controlled (RC) drone system fundamentally comprises two main parts: the Ground Control Station (GCS) and the Drone Air Unit.

The GCS contains the handheld controller, video receiver, and radio transmission/reception equipment, typically operating on the 2.4 GHz and 5.8 GHz bands with a maximum range of approximately 10 km.

The drone air unit integrates key components:

- Radio transceiver module (air unit): Manages bidirectional radio data transmission.
- Flight controller: The central unit that receives control commands (via protocols like SBUS,

PPM, or PWM) to stabilize flight and command the motors (via ESCs). It is connected to IMU sensors and GPS.

- Video channel: Transmits video (Analog PAL/NTSC on 5.8 GHz or Digital IP/HD on 2.4/5.8 GHz) from the camera back to the GCS via the air unit.

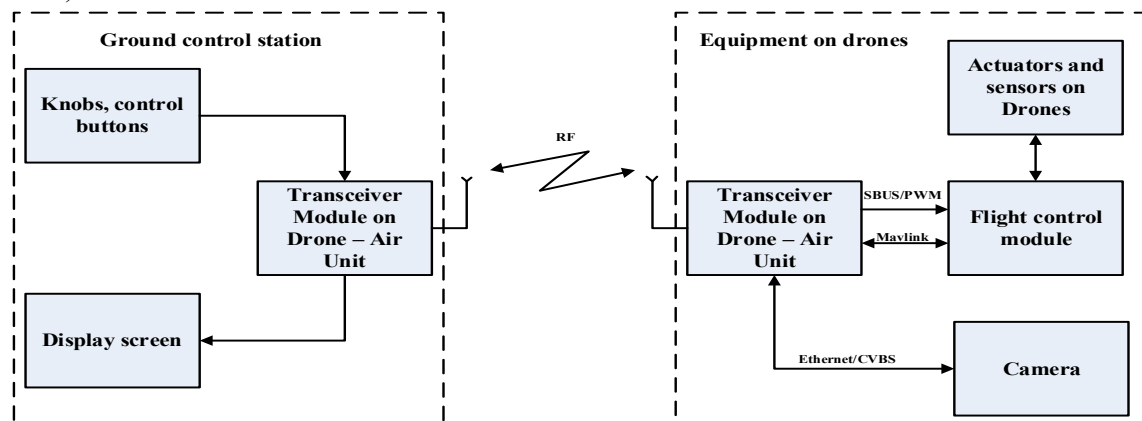


Figure 1. Structure of the radio control information channel on the drone.

The entire communication process involves three primary signal transmission channels: Operational Control Channel (GCS \rightarrow Drone): Transmits commands from the controller to the flight controller. Modern systems often utilize SBUS, a fast, low-latency serial digital bus protocol that can carry 16–18 data channels over a single wire, ideal for real-time response. The radio link uses various proprietary and open protocols (e.g., ExpressLRS, TBS Crossfire). Status Information Channel (Drone \rightarrow GCS): Provides essential feedback (position, velocity, battery, sensor status) from the drone. The common standard is MAVLink (Micro Air Vehicle Link), a lightweight binary protocol optimized for embedded systems. Image Transmission Channel (Drone \rightarrow GCS): Uses either Analog Video (low latency, common in FPV) or Digital Video (high-definition, higher latency). These protocols define the data structure that must be maintained when converting to a fiber-optic link.

2.2. Solution for converting radio-controlled drones to fiber-optic-controlled drones

The conventional radio-controlled (RC) system relies on the Air Unit module, mounted on the drone, to manage all radio communication with the Ground Control Station (GCS) on 2.4/5.8 GHz bands. This radio link is a critical weakness, being highly susceptible to detection and jamming in electronic warfare environments.

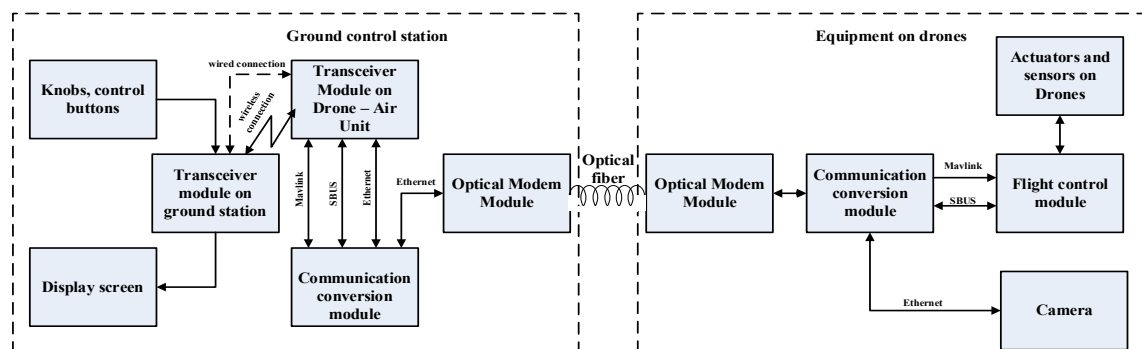


Figure 2. Solution for building an optical fiber transmission channel to replace the radio channel on the drone.

The proposed solution is to relocate the entire Air Unit module from the drone to the Ground

Control Station, while maintaining the original signal flows and control protocols (SBUS, MAVLink, IP Video).

Instead of using radio waves, these signals are aggregated, converted to optical form, and transmitted via a single-mode optical fiber using a pair of bidirectional optical modems (TX/RX).

- At the GCS: The controller connects directly to the Air Unit. The resulting electrical control, status, and video signals (SBUS, MAVLink, IP Video) are fed into the Optical Transmitter Modem, which converts them into optical signals.

- On the drone: The optical receiver modem demodulates and separates the optical signal back into the original electrical forms (SBUS to the flight controller, MAVLink to telemetry, IP Video to the camera/encoder).

This method creates a "transparent extension" between the Air Unit and the drone, where the optical fiber acts purely as a physical intermediary. By replacing the entire radio link with a bidirectional optical transmission path, the system completely eliminates RF emissions, achieves absolute jamming resistance, and offers extremely low latency and high bandwidth without requiring changes to the drone's internal software or control structure.

For implementation, the research team selected the 1x9 BiDi (bidirectional) optical module pair from Optcore due to their low cost, small size, and support for bidirectional transmission over a single-mode fiber [5].

3. IMPLEMENTATION RESULTS OF THE SOLUTION

During the testing phase, the author team built the model as described by using a commercial FPV drone and removing the radio Air Unit from the drone. The handheld remote control to the original Air Unit at the ground station. SBUS and camera signals are separated, amplified, and passed through the optical module pair. The Experimental Results show that the drone transmits and receives signals stably with a 500 m optical fiber coil, video latency is negligible compared to a direct connection, status information is fully transmitted and received, and control information from the controller to the drone is stable. The Experimental Results and technical specifications of the drone system using the fiber-optic cable control solution to replace the radio control channel are presented in figure 3.



Specifications:

- Weight before and after installation is 2.5 kg and 2.9 kg;

- FSPL (Free-Space Path Loss) for 500 m (0.5 km)

- 2.4 GHz (2400 MHz): $20 \cdot \log_{10}(0.5) + 20 \cdot \log_{10}(2400) + 32.44 \approx 94.0$ dB

- 5 GHz (5000 MHz): ≈ 100.4 dB

Signal losses approximately 94–100 dB due to free-space propagation alone (excluding antenna gains, connector losses, and fading).

fiber attenuation:

- Single-mode fiber: ≈ 0.35 dB/km $\Rightarrow 0.35 \times 0.5 = 0.175$ dB

- Input voltage 7.4 (V) \div 24 (V).

Figure 3. Drone using the solution for building an optical fiber transmission channel.

4. CONCLUSIONS

Using optical cables as control channels for drones is a feasible solution and has been tested by many parties on the battlefield. The drone control solution via optical cables leverages superior advantages such as immunity to suppression by the adversary's electronic warfare systems, the ability to transmit high-definition reconnaissance images in real-time, and the destruction of heavily protected targets such as missile complexes, tanks, armored vehicles, and self-propelled artillery of the adversary. However, the optical cable solution also has limitations: the cable coil increases weight, limits flight range and maneuverability, optical fibers are prone to breaking or tangling, requiring skilled pilots, and distance is limited by the cable length. Therefore, converting from radio drones to optical cable drones should be considered as a supplementary solution for situations requiring absolute anti-jamming and not a complete replacement for radio systems.

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TÓM TẮT

Giải pháp chuyển đổi drone điều khiển bằng sóng vô tuyến thành drone điều khiển bằng cáp quang

Bài báo trình bày một giải pháp chuyển đổi hệ thống các kênh điều khiển, kênh dữ liệu, kênh trạng thái từ kênh truyền dẫn vô tuyến đang được sử dụng phổ biến trên Drone hiện nay thành kênh truyền dẫn qua sợi quang. Các Drone điều khiển bằng cáp quang phát huy những ưu điểm vượt trội như không bị chế áp bởi hệ thống tác chiến điện tử của đối phương, có khả năng truyền hình ảnh trinh sát độ nét cao, băng thông lớn, thời gian thực, độ trễ thấp, bảo mật thông tin tốt. Bên cạnh đó, công nghệ sợi quang cũng hỗ trợ hiệu quả cho việc xử lý các thuật toán điều khiển, các bài toán nhận dạng phức tạp nhờ khả năng truyền tải lượng dữ liệu lớn và tốc độ xử lý nhanh về trạm điều khiển trung tâm.

Từ khoá: Drone; Điều khiển qua sợi quang.