https://doi.org/10.31891/csit-2024-1-4
UDC 004.89: 004.3

Olga PAVLOVA, Oleksandr HALYTSKYI
Khmelnytskyi National University

VIDEO REPEATER DESIGN CONCEPT FOR UAV CONTROL

This study is aimed at the utilization of a video repeater for unmanned aerial vehicle (UAV) control, involving a comparative analysis of existing scientific literature, methodologies, and available solutions. Through comparative analysis, the method of using an external repeater emerged as the most promising, offering flexibility in selecting repeaters with superior performance and advanced capabilities. Notably, this approach allows for the utilization of a single repeater across multiple UAVs and facilitates convenient modification or upgrade of the repeater without necessitating alterations to the UAV itself. Following component selection, an experimental prototype was designed to facilitate empirical investigations. Additionally, a frequency transmission scheme was devised for quadcopter control employing the repeater. This research represents a significant advancement in the realm of UAV control systems, introducing a novel approach to video repeater integration that is poised to revolutionize operational efficiency and adaptability across diverse operational settings. This approach offers unparalleled flexibility in the selection of repeaters boasting superior performance and advanced capabilities. The insights gleaned from this study are poised to catalyze further advancements in UAV technology, particularly in the realm of optimizing video transmission for enhanced situational awareness and mission effectiveness. By shedding light on the efficacy of video repeater integration, this study lays the groundwork for future innovations aimed at pushing the boundaries of UAV capabilities and enhancing their utility across a myriad of applications. The findings from this study are anticipated to inform further developments in UAV technology, particularly in optimizing video transmission for improved situational awareness and mission effectiveness.
Keywords: unmanned aerial vehicle (UAV), video repeater

Ольга ПАВЛОВА, Олександр ГАЛИЦЬКИЙ
Хмельницький національний університет

КОНЦЕПЦІЯ ПРОЕКТУВАННЯ РЕТРАНСЛЯТОРА ВІДЕО ДЛЯ КЕРУВАННЯ БПЛА

У статті розглянуто використання ретранслятора відео для управління безпілотним літальним апаратом (БПЛА), що включає порівняльний аналіз існуючої наукової літератури, методик і доступних рішень. Завдяки порівняльному аналізу метод використання зовнішнього ретранслятора виявився найбільш перспективним, пропонуючи гнучкість у виборі ретрансляторів із чудовою продуктивністю та розширеними можливостями. Примітно, що цей підхід дозволяє використовувати один ретранслятор для кількох БПЛА та полегшує зручну модифікацію або модернізацію ретранслятора без необхідності внесення змін до самого БПЛА. Після вибору компонентів був розроблений експериментальний прототип для полегшення емпіричних досліджень. Додатково розроблена схема частотної передачі для управління квадрокоптером за допомогою ретранслятора. Це дослідження є значним прогресом у царині систем керування БПЛА, запроваджуючи новий підхід до інтеграції відеоретрансляторів, який готовий революціонізувати операційну ефективність та адаптивність у різних робочих налаштуваннях. Цей підхід забезпечує неперевершену гнучкість у виборі ретрансляторів, що відрізняються чудовою продуктивністю та розширеними можливостями. Уявлення, отримані в результаті цього дослідження, мають намір стати каталізатором подальшого прогресу в технології БПЛА, зокрема в області оптимізації передачі відео для покращення ситуаційної обізнаності та ефективності місії. Висвітлюючи ефективність інтеграції відеоретрансляторів, це дослідження закладає основу для майбутніх інновацій, спрямованих на розширення можливостей БПЛА та підвищення їхньої користі в безлічі програм. Очікується, що результати цього дослідження сприятимуть подальшому розвитку технології БПЛА, зокрема щодо оптимізації передачі відео для покращення обізнаності про ситуацію та ефективності місії.
Ключові слова: безпілотний літальний апарат (БПЛА), ретранслятор відео

Introduction

In the conditions of training and combat missions when working with a drone, sometimes other teams that are nearby turn on the drone and work on the same frequency of the video signal. Due to this, the video signals of both teams are superimposed on each other and interfere with work. Pilot 1 instead of the image from drone 1 sees a picture of drone 2, or vice versa pilot 2 sees a picture of drone 1.

There are two possible solutions of this problem:

1) Summarize the general notification system, who works at which frequency and at what time.

Implementation difficulties: this system must be introduced to the entire front line, which is a long and bureaucratic process. In the realities of hostilities, this decision is not expedient and requires much more urgent options.

2) Create an individual system for the pilot, so that in the event of a frequency match, the pilot can quickly switch the video communication channel.

In the Crossfire protocol, it is possible to switch the video channel from the remote control. For this, the IRCTramp (Zeus pro) or Tbs smart audio (rush solo tank) protocol to the VTX port in the drone needs to be installed.

This task is solvable, but to switch the channel, the pilot needs to take off his glasses and go to the remote-control menu to perform the operation. The reception channel on the glasses also needs to be changed. This operation is quite slow and will take up to a minute. During this period, the drone will most likely intervene.

The following proposals follow from the idea: to speed up the channel switching time on the receiver and transmitter to a few seconds.

This task is easily implemented on FC quadcopters with the help of fine settings of the video transmitter and remote control. Simply speaking, on one of the analog channels of the remote control, for example, aux4 (3-position stream), set the switching between 3 video channels.

Switching channels on the glasses remains a problem, because there is no direct connection between the glasses and the remote control.

A solution option is to take out the video signal receiver separately and use a repeater.

State-of-the-Art

Examination of contemporary technological advancements in Unmanned Aerial Vehicles (UAVs) development and deployment [1-1] reveals the critical necessity for dependable and efficient video relay systems within this domain.

Notably, researchers [1] investigate the optimization of resource allocation and the design of dynamic adaptive streaming over HTTP (DASH)-enabled services in a UAV communication framework, utilizing UAVs as base stations for multiuser video streaming.

In another study [2], the application of fixed-wing VTOL UAVs for real-time low-latency monitoring systems is explored, showcasing the practical benefits of such video surveillance systems. Utilizing simulation via Robot Operating System (ROS) and subsequent validation through hardware and software, this research underscores the tangible advantages of employing UAVs for surveillance purposes.

Additionally, authors of [3] examine UAV-to-UAV (U2U) communication scenarios, where high-altitude UAVs serve as mobile base stations to facilitate video streaming from other UAV-users, promoting collaborative video transmission capabilities.

In a distinct approach, research [4] focuses on enhancing wide-area surveillance capabilities through UAV-borne repeat-pass circular stripmap (CSM) VideoSAR observation, employing innovative algorithms to optimize imaging demonstration.

Furthermore, efforts [5] aim to detect objects from real-time video streams transmitted by low-altitude long-endurance (LALE) fixed-wing hybrid VTOL UAVs, emphasizing the potential of employing multiple UAVs to enhance coverage and resolution. However, concurrent operation of multiple UAVs poses challenges such as limited coverage and co-channel interference in conventional communication systems [6]. Addressing these issues, researchers propose a multi-UAV full-duplex system to facilitate high-specification video transmission and stable flight control.

Additionally, advancements in UAV technology include the development of a fully-integrated transceiver for high-definition video transmission [7] and a systematic approach to drone detection mechanisms using RF control signals [8]. In [9] the expansion of the capabilities of digital devices for three-pulse suppression of aircraft transponder requests by side lobes in terms of increasing the accuracy of aircraft flight azimuth measurement is discussed. The work [10] is devoted to the justification of the choice of the basic methodology for assessing the efficiency of the optoelectronic surveillance system, which could be taken as a basic model of this system for the distribution of forces and means to ensure a sufficient level of efficiency of border protection in the area of application of the system, as well as to determine those provisions that need to be taken into account in the specified basic methodology for assessing the effectiveness of the system. The paper [11] presents an intellectualized control system for unmanned aerial vehicles. It is based on the use of a fuzzy logic device, the implementation of which in the controller of an unmanned aerial vehicle made it possible to track and control the trajectory of its movement. Despite these advancements, existing studies do not explore the utilization of repeaters for data transmission using drones.

Moreover, an analysis of existing solutions [12-17] underscores the absence of readily available options that meet specific requirements, necessitating the urgent development of a video repeater for FPV drone control.

Analysis of the ready-to-use solutions and technologies

Throughout the research, the authors conducted a comparison of current technical solutions and advancements concerning the utilization of a video repeater for unmanned aerial vehicle (UAV) control. The outcomes of this comparative analysis are detailed in Table 1.

After evaluating existing systems, the authors suggest the development of their own device, based on the removal of the video signal receiver separately, and the use of a repeater, which will speed up the channel switching time on the receiver and transmitter to a few seconds.

Table 1

Comparative analysis of existing technical solutions and developments regarding the use of a video repeater for controlling unmanned aerial vehicles (UAVs)

Solution	Advantages	Disadvantages
A system with a built-in repeater	Ease of installation and use, as the repeater is built directly into the UAV. Weight and volume reduction as no excessive equipment is required. Minimization of delays in video transmission, as it occurs in real time.	Limited ability to upgrade or expand functionality without replacing the entire UAV.
Using an external repeater	Flexibility to choose a repeater with higher performance or advanced capabilities. The possibility of using one repeater for several UAVs. Convenience in modifying or updating the repeater without changing the UAV itself.	Additional weight and volume of equipment that may affect performance or flight range. Increased costs and more complex installation due to the need for external equipment.
Integrated relay systems	Optimizing performance and weight through optimization of UAV and repeater interoperability. Ensuring high-quality video transmission in real time thanks to optimized internal communication. Flexibility in the choice of functionality and the possibility of expansion through software updates.	High costs of acquisition and maintenance of such integrated systems. Limited options for choosing a repeater and its compatibility with other equipment.

The principle of the video repeater operation for UAV control

Components whose characteristics and description are given in Table 2 were used to develop the quadcopter control system shown in Figure 1.

Fig.1. Quadrocopter designed as part of the study

The operation scheme of the proposed device is as follows: the pilot has a control panel with a 2.4 GHz channel. There is a 2.4GHz control receiver on a Mavik-type quadcopter or on the mast of any UAV. This receiver transmits the signal to 2 objects: the 900MHz transmitter, which already receives the 900MHz copter, and the control board of the 5.8GHz video receiver. On the 2.4GHz receiver, one of the outputs can be programmed to work with the same analog signal of the aux4 remote. On the video receiver, program a change in the aux4 parameter, which is responsible for changing the receiving channel.

The video receiver via a cable or using another video transmitter with a lower signal, say 1.2 GHz, transmits the signal to the pilot's glasses.

As a result, we will get a switch on the remote control, which simultaneously switches the channel on the transmitter of the video signal of the drone and on the receiver of the video signal on the repeater.

Among the disadvantages is that channel switching is limited by the number of switches in the analog toggle switch of the remote control, namely 3 channels on tx12. But for emergency situations, this scheme is effective and can save the drone and continue the mission.

Table 1

List of components that were used to design a quadcopter control system using a repeater

Component name	Characteristic	Quantity
Remote control	Size: 170 * 159 * 108mm Weight: 363g Frequency: 2.400 Ghz-2.480 Ghz RF Chip Option: ExpressLRS (ELRS) TX power: 20 dBm Antenna Gain: 2db Working Current: 320mA@8.4V Voltage Range: 6.6-8.4V DC Range: > 2km (depending on receiver) Firmware: EdgeTX (Transmitter) / ExpressLRS (RF module)Number of channels: up to 16 (depending on receiver) Display: 128*64 USB Charging: QC3 USB-C SD Card: Included	1
2.4 GHz Receiver	Happymodel EPW6 TCXO 2.4GHz PWM Receiver ESP8285, SX1280/1281Antenna Connector: IPEX MHF 1/U.FL6x PWM RF Outputs Frequency: 2.4GHz (2400~2480MHz) Telemetry power: 12 dBm Receiver Protocol: PWM or CRSF Input voltage: +5v ~ 8.4v PCB size: 19mm x 17.5mm Vaga: 1.49g / antenna	1
Receiver	Model: ELRs-915m-Nano Назва: Express LRS RX Frequency: 915 MHz Antena: T-type Чіп: SX 1276+ESP 8285 Feedback power: 100 MW Input Voltage: 3.6V-5.5V Antenna Connector: IPEX1 Weight: 0.6g (receiver only) Size: 11mm*1.8mm	1
Transmitter 915	Firmware download Passage of the beta flight Beta Flight Pass or Wi-Fi SD card or configurator, Wi-Fi or configurator ES900TX and ES900RX modules are a set of Long Range 915 MHz/868 MHz (optional) wireless transmission equipment designed and developed based on ExpressLRS open source software. This set of modules is characterized by ultra-long range, stable operation and low latency. The module is compatible with most Opentx remote controls.	1
Transmitter & Receiver 433	433MHz wireless transceiver based on SX1278. Connection interfaces: UART. Supports protocol: LoRa. Supports data encryption and compression. Transmitter power: 21-30dBm (standard 30dBm about 1W), receiver sensitivity: -147dBm (0.3kbps over-the-air transmission), transmission distance: ~8km in open space with antenna. Antenna connector: SMA-K. Power supply: 3.3 . 5,2 VDC. Dimensions: 43x23 mm. Manufacturer: Ebyte. Dimensions: 43x23 mm|Power supply, V: 3,3.5,2 V|T°C: -40.+85°C|Communication type: RF|Frequency: 410.441 MHz|Interface: UART	2
Flight Controller	Firmware BLHeli_S JH50 Wireless Network Configuration Full configuration is supported in the SpeedyBee app DC 50A*4 Serial current 55A(5C) 1500uF Low ESR Capacitor (Packed) ESC DSHOT300/600 protocol Input Power 3-6S LiPo VBAT Output Power Dimension: 45.6 (L) * 44 (W) * 6.1 mm (H) Вага 13.8г	2
Protocol Converter	Module size: 2.5cm*1.2cm (PCB)	1

Experiments and Results

To carry out the experiment, a repeater holder for a mavik was made of textolite (Fig.2). The following components were also purchased:

1) RushFPV TANK SOLO VTX video transmitter
2) Skyzone steadyview x receiver with IPS screen (STVX) video receiver
3) TrueRC 5.8 MK II SMA RHCP antenna
4) Control receiver with additional pwm outputs HappyModel ExpressLRS ELRS EPW6 TCXO 2.4GHz
5) BETAFPV ELRS Micro TX Module 915MHZ control transmitter
6) DC-DC voltage converters

18650 type elements are used to universalize the power supply

Fig.2. The slingshot platform made of textolite is made for attachment to the Mavik-3 UAV

Figure 3 shows the frequency transmission scheme when controlling a quadcopter using a repeater.

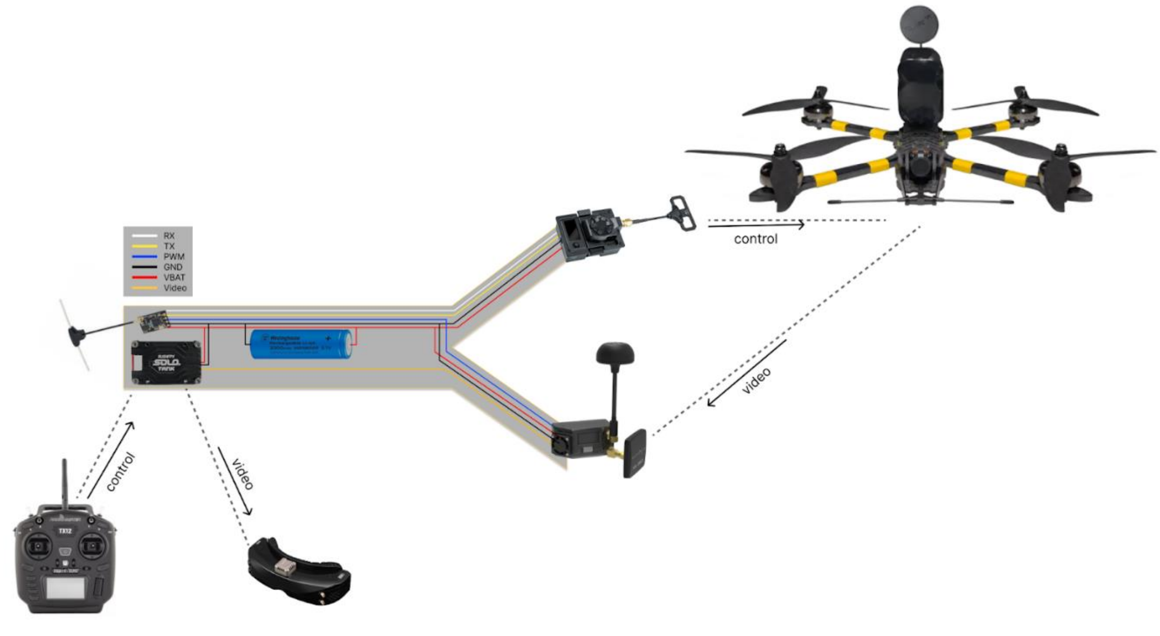

Fig. 3. Frequency transmission scheme when controlling a quadcopter using a repeater

Further efforts of the authors will be directed to the assembly and testing of the prototype and obtaining statistical data on the performance of the prototype.

Conclusions

In the course of the study, an analysis of existing scientific publications and known methods and ready-made solutions for the use of a video repeater for controlling unmanned aerial vehicles (UAVs) was carried out. As a result of the comparative analysis, the method of using an external repeater was chosen, which has such advantages as flexibility in choosing a repeater with higher performance or advanced capabilities, as well as the ability to use one repeater for several UAVs, convenience in modifying or updating the repeater without changing the UAV itself.

Components were also selected and an experimental prototype was designed for conducting experiments. A frequency transmission scheme was also designed when controlling a quadcopter using a repeater.

The authors will focus their future endeavors on assembling and testing the prototype, as well as gathering statistical data on its performance.

References

1. Zhan, Cheng, et al. "Joint resource allocation and 3D aerial trajectory design for video streaming in UAV communication systems." IEEE Transactions on Circuits and Systems for Video Technology 31.8 (2020): 3227-3241.
2. Sonkar, Sarvesh, et al. "Low-cost smart surveillance and reconnaissance using VTOL fixed wing UAV." 2020 IEEE Aerospace Conference. IEEE, 2020.
3. binti Burhanuddin, Liyana Adilla, et al. "QoE optimization for live video streaming in UAV-to-UAV communications via deep reinforcement learning." IEEE Transactions on Vehicular Technology 71.5 (2022): 5358-5370.
4. Zhang, Ying, et al. "Multirotor UAV-borne repeat-pass CSM-VideoSAR." IEEE Transactions on Aerospace and Electronic Systems 58.3 (2021): 2601-2605.
5. Sonkar, Sarvesh, et al. "Real-time object detection and recognition using fixed-wing Lale VTOL UAV." IEEE Sensors Journal 22.21 (2022): 20738-20747.
6. Yu, T., Imada, S., Araki, K., & Sakaguchi, K. (2021, January). Multi-UAV full-duplex communication systems for joint video transmission and flight control. In 2021 IEEE 11th Annual Computing and Communication Workshop and Conference (CCWC) (pp. 1423-1428). IEEE.
7. Huang, S., Lin, M., Wang, R., Chen, Z., & Dong, Y. (2020). A 400MHz Single-Chip CMOS Transceiver for Long Range High Definition Video Transmission in UAV Application. Chinese Journal of Electronics, 29(3), 554-562.
8. Abunada, Abdularahman Hasan, et al. "Design and implementation of a RF based anti-drone system." 2020 IEEE International Conference on Informatics, IoT, and Enabling Technologies (ICIoT). IEEE, 2020.
9. Hovorushchenko, T., Pavlova, O., Avsiyevych, V. Method of Assessing the Impact of External Factors on Geopositioning System Operation Using Android GPS API. International Scientific and Technical Conference on Computer Sciences and Information Technologies, 2021, 1, pp. 295–298
10. Hovorushchenko T., & Yanovytskyi O. (2022). Improvement of the Digital Device for Suppression of False Request by Side Lobes of the Air Traffic Control Systems Antenna. Computer Systems and Information Technologies, (1), 32–35. https://doi.org/10.31891/CSIT-2022-1-4
11. Borovyk O.V, Borovyk D.O., & Tsymbryk D. I. (2020). The main provisions that need to be taken into account when creating a decision support system for the distribution of forces and means to ensure a sufficient level of effectiveness of border protection in the area of application of the optoelectronic surveillance system. Computer Systems and Information Technologies, (1), 80–90. https://doi.org/10.31891/CSIT-2020-1-11
12. Lysenko S., & Rumiantsev S. (2020). Intelligent control system for unmanned aerial vehicles. Computer Systems and Information Technologies, (1), 22–27. https://doi.org/10.31891/CSIT-2020-1-3
13. BetaFPV official website. URL: https://betafpv.com/ (last accessed January 10,2024)
14. High Performance Open Source Radio Control Link. URL: https://www.expresslrs.org (last accessed January 10,2024)
15. SkyZone official website. URL: https://www.skyzonefpv.com/ (last accessed January 10,2024)
16. RadioMaster official website. URL: https://www.radiomasterrc.com/ (last accessed January 10,2024)
17. RushFPV official website. URL: https://rushfpv.net/ (last accessed January 10,2024)

Olga PAVLOVA **Ольга ПАВЛОВА**	PhD, Associated professor of Computer Engineering & Information Systems Department, Khmelnytskyi National University, Khmelnytskyi, Ukraine, e-mail: olya1607pavlova@gmail.com https://orcid.org/0000-0001-7019-0354 Scopus Author ID: 57218181382	доктор філософії, доцент кафедри комп'ютерної інженерії та інформаційних систем, Хмельницький національний університет, Хмельницький, Україна.
Oleksandr HALYTSKYI **Олександр ГАЛИЦЬКИЙ**	Postgraduate student of Computer Engineering & Information Systems Department, Khmelnytskyi National University, Khmelnytskyi, Ukraine, e-mail: kniazgal@gmail.com	аспірант спеціальності «Інформаційні системи та технології», Хмельницький національний університет, Хмельницький, Україна.