Wireless Communication System for the transmission of thermal images from a UAV

Jorge A. Pardo
UGT. Universidad de las Fuerzas Armadas ESPE
Pontificia Universidad Católica del Ecuador
Sangolquí, Ecuador
japardo@espe.edu.ec

Wilbert G. Aguilar
DSD. Universidad de las Fuerzas Armadas ESPE
GREC, Universitat Politècnica de Catalunya
Sangolquí, Ecuador
wgaguilar@espe.edu.ec

Theofilos Toulkeridis
DSD. Universidad de las Fuerzas Armadas ESPE
Sangolquí, Ecuador
ttoulkeridis@espe.edu.ec

***Abstract*— Unmanned aerial vehicles (UAVs) have gained interest in different areas due to their versatility and multiple applications. In this case study, a wireless communication system is analyzed between the UAV and its earth station, for the transmission of thermal images in real time and application in fire control. Considering different types of UAVs capable of transporting a high performance thermal camera, a wireless video transmission system was designed for 5.8 GHz frequency. Finally, prototype performance tests were carried out, in which it defined configurations of height, flight conditions, color palettes and types of antennas.**

Keywords*— *Wireless Communication, fire control, thermal imaging, video streaming, UAVs

I. Introduction

One of the biggest technological trends in the world is the development of unmanned aerial vehicles (UAV) and their applications in the civil and military spheres. In Latin America, the development and commercialization of this type of vehicle has also grown considerably, and due to its potential applications in specific problems in the region, several research groups have focused their efforts on the improvement of these platforms [1].

According to data released by the organization UVS International (www.uvs-international.org) in its publication "The Global Perspective 2012/2013", there are about 50 countries with manufacturers of this type of UAS systems in the world and around 1600 Types of referenced platforms. In Ecuador one of the first jobs in unmanned aircraft was the "RPV Cotopaxi" project [2] of 1997 as a requirement of the Ecuadorian National Security Armed Forces. This project was developed by the Ecuadorian Air Force, through the FAE Research and Development Center (CIDFAE), for surveillance applications. In the Ecuadorean agricultural field, UAVs are also being applied, such as [3] flying over 180 meters above a 200-hectare banana plantation located in the Baba canton in the south of the province of Los Ríos.

With the use of UAVs, the negative impacts of wildfires can be reduced significantly. Through research conducted by the Croatian Society Electronics in the sea-ELMAR it shows how UAVs can help reduce the likelihood of errors committed by tactics on the ground and in the air, reaction time, accuracy decision-making, charging people and equipment on peak days or saturated. [4]

School of Automation and Electrical Engineering, University of Science and Technology Beijing China, developed software that provides functions in processing aerial imagery obtained from UAVs in real time, helping users quickly determine the number and location of fire points. The monitoring software covers functions including detection module sources of fire, the fire location module, the module fires range estimate and report generation module. [5]

The Department of Conservation and research fire Rotorua in New Zealand, calculated the benefits of aircraft piloted remotely and infrared images, aimed at reducing the cost compared with the use of helicopters, and were estimated as an average of $ 548 fire (where the average cost was $ 1767 fire) showing cost savings of 31% on total costs. Incorporating remotely piloted aircraft and infrared if implemented and managed properly in the future, could improve the profitability of current efforts to combat forest fires. [6].

As evidence, the use of remotely piloted aircraft and the use of infrared images provide great advantages in detecting and fighting forest fires. The Department of Mechanical and Industrial Engineering at Concordia University in Canada, in

978-1-5386-3123-2/17/$31.00 ©2017 IEEE

Authorized licensed use limited to: Chungbuk National Univ. Downloaded on October 10,2020 at 01:12:22 UTC from IEEE Xplore. Restrictions apply.

conjunction with the Department of Control Engineering and Information Technology University of Xian, developed an algorithm to match unmanned aerial vehicles (UAVs) with ground vehicles unmanned (UGVs) to enhance firefighting. First, the UGVs are used to transport UAVs to your nearest search area assigned location. UAVs take off and begin the monitoring mission and search. When one of the UAVs detected the fire, sends coordinates from the fire to the leader UGV and fire management personnel on the ground. Then, the UGV leader has powerful capabilities image processing computer, generate the reference path for the UAV continue to detect and continuously monitor the spread of fire. [7]

The Research Center on Software Technologies and Multimedia Systems for Sustainability (CITSEM) of the Universidad Politécnica de Madrid, proposes a novel method for detecting forest fires, through the use of a new color index, called the Forest Fire Detection Index (FFDI). [8] The method could be used in real-time in Unmanned Aerial Systems (UASs), with the aim of monitoring a wider area than through fixed surveillance systems. On-going work includes implementation into a commercially available drone.

Similarly the Pablo de Olavide University and the Center for Advanced Aerospace Technology (CATEC), Andalusian Technological and Aeronautical Park, presents an Unmanned Aircraft System (UAS), consisting of several aerial vehicles and a central station, for forest fire monitoring [9]. Shows how an UAS can automatically obtain this information by means of on-board infrared or visual cameras. Moreover, it is shown how multiple aerial vehicles can collaborate in this application, allowing to cover bigger areas or to obtain complementary views of a fire.

The UAV are those aircraft that are based on the air by the lift force generated by the rotation of the propeller in air, are known as multirrotores or helicopters [10].

II. THERMAL IMAGING CAMERAS FOR UAS

In the world of UAS / S there are several manufacturers and models of thermal imaging cameras. Analysis performed considering technical, practical parameters such as weight, size and resolution; It follows that the thermal imaging camera with excellent performance and a relatively affordable price is the FLIR Vue Pro since it is an instrument of thermal measurement which is designed for professional use with the ability to record data adding immense value to operations and services UAS [11].

A. Application of thermal cameras in fire fighting

The thermal image transmitted by a spatially distributed UAV provides temperature of the soil surface. Unlike satellite-based measurements or on land, the use of a UAV allows us to obtain spatially resolved and geometrically distributed on the temperature of the soil surface information without access to the ground. [12]

Wildfires are appropriate scenarios to demonstrate the performance and capabilities of multi-UAV. Wildfires are highly complex, unstructured, where the use of multiple sources of information in different locations is essential. [13]

Additional applications such as inspection of mobile phone towers, monitoring fiber optic networks, topography, energy audits, search and rescue among others that over time will develop. As verified, the world of thermography with UAS is constantly evolving.

III. WIRELESS COMMUNICATION SYSTEM BETWEEN A UAV AND BASE STATION FOR DISPLAYING THERMAL IMAGES

A. Telemetry

The UAS has built its telemetry equipment is formed by two radio TX / RX working at 433MHz or 915MHz, omnidirectional antennas 2dbi gain with a coverage range of about 500 m depending on the conditions environmental and noise sources.

B. Wireless communication system for transmitting video

Whereas the payload is critical when executing a mission parameter, it is important that the communication equipment is installed in the UAV is light, you must have a power of large transmission and antennas must be high gain.

The transmission system analog video that has been implemented has a downlink (downlink) video, in Figure 1 a simplified diagram shown:

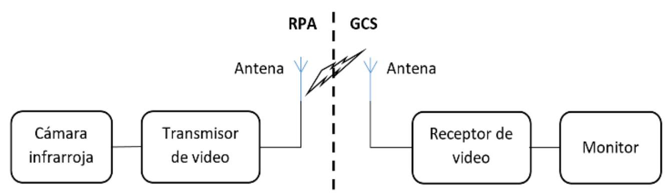


Fig. 1. Link for streaming video from the UAV at the earth station

With the selected equipment, the system schematic wireless video transmission is as follows:

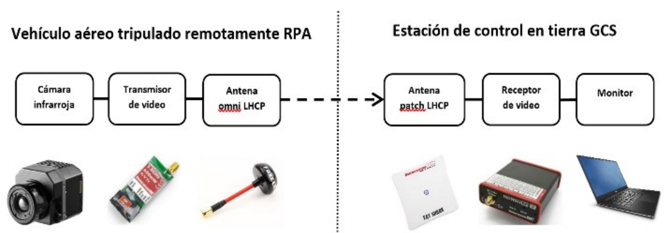


Fig. 2. Transmission system realtime video

C. Calculating the link power budget

After making a suitable selection of equipment to use for transmission of video, it is important to ensure propagation or signal transmission from the GPR to the earth station.

This must be done for the power budget point to point link consisting of calculating all gains and losses from the transmitter, through the cables, connectors, free space to receiver. The estimate of this calculation is done to get a better communication system design and use better equipment purchased.

Initially it considered a transmission distance of 1 Km and the frequency band of operation of the equipment is of 5860 MHz.

Authorized licensed use limited to: Chungbuk National Univ. Downloaded on October 10,2020 at 01:12:22 UTC from IEEE Xplore. Restrictions apply.

To determine the viability of the link the following expression is used:

SRx(dBm)=PTx(dBm)-Pérdida Cable Tx(dB)+Ganancia antena Tx(dBi)-PEL(dB)+Ganancia antena Rx(dBi)-Pérdida Cable Rx(dB) (1)

SRx (dBm) is the sensitivity of the receiver PTx (dBm) is the power of the transmitter. The gain of each antenna in Tx and Rx is measured in dBi. Loss in free space PEL (dB) is the attenuation of the signal from the transmitter to the receiver.

TABLE I. DATA TO DETERMINE VIABILITY OF THE LINK IN THE FREQUENCY OF 5860 MHZ

PARAMETER	UAV (TRANSMITTER)	GCS (RECEIVER)
PTx (dBm)	28	-
SRx (dBm)	-	-90
Antenna (dBi)	5,14	13
Attenuation Cable and Connectors	0.25	0.25

Considering the equipment used, the data are summarized in the table below for the link budget.

The value of cable attenuation is not considered since both the transmitter and receiver are connected directly to the antennas and is considered attenuation for connectors 0.25 dB connector. On the side of the UAV (transmitter) an omnidirectional antenna was selected and the GCS (receiver) a directional antenna.

They should be estimated losses in free space at the frequency of 5860 MHz according to the distance between the UAV and the GCS. Loss in free space in dB is determined by the expression:

TABLE II. LOSS OF FREE SPACE TO 5860 MHZ FOR DIFFERENT DISTANCES

Distance (Km)	PEL Loss (dB)
0.1	88
0.3	97
0.5	102
1	108
3	117
5	122
7	125
8	126
10	128

$$PEL(dB)=32{,}4+20.\log f(MHz)+20.\log d(Km) \qquad (2)$$

If f=5860 MHz and d=1Km so: PEL(dB)=107,76≈108

Then, the total antenna gain is calculated by adding the individual gain values of each antenna used (in dBi):

TABLE III. TOTAL GAIN ANTENNAS

Transmitter antenna (UAV) dBi	Receiver antenna (GCS) dBi	Total gain (dBi)
5,14	13	18,4

Then, total losses are have been estimated considering the losses of cables, connectors and loss in free space:

TABLE IV. CONSIDERING TOTAL LOSS OF LINK CABLES, CONNECTORS AND PEL

cable and connector losses in the transmitter (UAV) dB	cable and connector losses in the receiver (GCS) dB	Free space loss (dB)	Total Loss (dB)
0.25	0.25	108	108.5

With data from the communication link budget is calculated from the UAV (transmitter) to the ground control station (receiver).

TABLE V. LINK BUDGET

Tx Power (dBm)	(+) Total Gain antenna (dBi)	(-) Total Loss (dB)	(=) Received signal intensity (dB)	Receiver sensitivity (dBm)
28	18.14	108.5	-62.36	-90

The received signal strength is better than the receiver sensitivity. The link margin, -90 - (-62.36) is about -28 dB which is sufficient to adverse weather conditions.

However, if you consider a distance of 5 km, the free space loss is 14 dB and increase the intensity of the received signal would be -76.36 dB. In this case the link margin is about -14 dB in practice would be the distance limit for video in the earth station.

For a distance of 8 km, the free space loss is 18 dB and increase the intensity of the received signal would be -80.36 dB. In this case the link margin is about -10 dB. With the above it follows that the video transmission system theoretically would operate until 8 Km.

IV. FUNCTIONAL PROTOTYPE TESTING TO VERIFY TRANSMISSION OF THERMAL IMAGES IN REAL TIME FROM THE UAV TO THE EARTH STATION.

It was considered take four parameters: the height of UAV (20 m - 50 m), palettes camera (WhiteHot - Fusion), antenna (omni - patch) and the time of day (9:00 a.m. - 7pm) for raise several test scenarios and to conclude the best options for operation of the prototype.

A. Test 1.

Test description. - The test involves transmitting thermal images of people and animals from the UAV at the earth station (GCS), to differentiate their silhouettes or profiles. Tests were

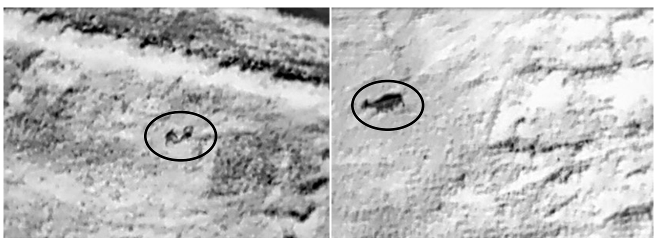
Authorized licensed use limited to: Chungbuk National Univ. Downloaded on October 10,2020 at 01:12:22 UTC from IEEE Xplore. Restrictions apply.

conducted outdoors in the city of Latacunga, in a place called Hacienda Tilipulo, it has a runway model airplane and provides the necessary facilities for overflights with UAVs since it is a large area and depopulated. The parameters used were:

TABLE VI. PARAMETERS FOR TEST 1

Antenna tx / rx	Height	Palette	Hour
dipole	20 m	BlackHot	17:00

Result. - They receptaron on the screen earth station several images of people and animals, it was observed that the use of dipole antennas and BlackHot palette camera, image transmission varied, the quality of the images was not appropriate since people were not readily differentiated the coverage area (Fig 3a); however, animals such as cows could be distinguished (Fig 3b).



(a) (b)

Fig. 3. Images of people (a) and cow (b) obtained at the earth station

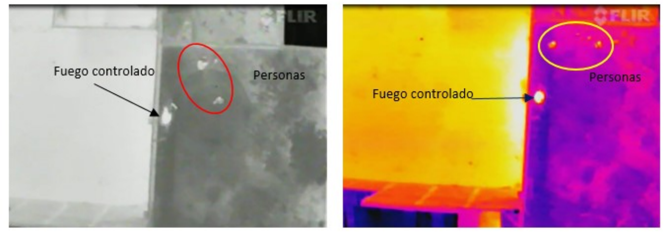
B. *Test 2.*

Test description. - The test involves transmitting thermal images from the UAV at the earth station (GCS), people and a small controlled fire, to differentiate the temperatures of the bodies and silhouettes, using two different color palettes and to verify quality video at the earth station. Tests were performed outdoors with the particularity that was held in the evening hours. The parameters used were:

TABLE VII. PARAMETERS FOR TEST 2

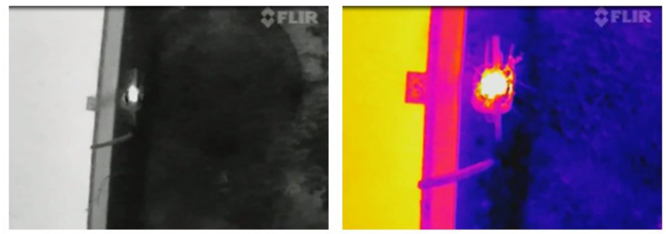
Antenna tx / rx	Height	Palette	Hour
Omni / Patch	20 m	WhiteHot / Fusion	19:00

Result. - By using the palette WhiteHot, was observed on the screen of the earth station silhouettes fire in white and color people lead (Fig 4a). Fusion with paddle, fire has a white-yellow and people are shown in orange-yellow (Fig 4b). This test clearly shows the differences in temperature of the bodies; however, the silhouettes are not very obvious. A height of about 10 meters, clearly shows the differences in temperature of the fire with respect to other objects with WhiteHot palette (Fig 5a) with the Fusion palette (Fig 5b).



(a) (b)

Fig. 4. Thermal images of people and fire controlled to 20 m high at night



(a) (b)

Fig. 5. Thermal Imaging fire controlled to 10 m high

V. CONCLUSIONS

This case study has implemented a wireless communication system in order to transmit thermal images in real time from a UAV to an earth station, for which we have studied a wide range of drones enabling installing a thermal camera excellent performance and light weight, as well as equipment suitable commercial wireless communication for UAVs has selected the appropriate equipment for testing and implementation phase.

As a result of analysis of the main characteristics of the UAV has been suggested the use of drone Phantom 3 Professional, since it has the best cost / benefit ratio more than having transmitting wireless video from a 4k camera to a theoretical distance of 5 km; however, the technology of UAV is developing rapidly now offering new models with collision avoidance systems, greater autonomy, recognition and object tracking; allowing further develop new applications.

The fact that all bodies emit heat makes thermography has almost endless applications. For technical personnel, aerial thermographic inspection is very useful and important, since it allows for viewing angles and a new point of view, in addition to inspections faster assuming a significant cost savings of working hours and monitoring all areas of interest; It is precisely where the camera Flir Vue Pro meets the requirements for use in various applications such as fire control.

Transmitting data from a UAV to an earth station, it becomes more important when you want to observe real-time information such as video or images; for that reason based on testing of wireless communication system with teams Immersion brand, type SpiroNet and patch antennas in the frequency band of 5.8 GHz, it is concluded that the wireless communication system is reliable, since allowed to view video in real time without interruptions with thermal images of good quality.

Authorized licensed use limited to: Chungbuk National Univ. Downloaded on October 10,2020 at 01:12:22 UTC from IEEE Xplore. Restrictions apply.

To validate a prototype, it is important to perform various functional tests, so that functional tests performed allowed us to verify the work of each individual part and the system as a whole. From the evidence it is concluded that the system for optimal performance consist of: antenna SpiroNet in the transmitter, antenna type patch on the receiver, height of UAV around 20 meters and pallets WhiteHot, BlackHot, Fusion and GreenHot to identify different shapes and colors of objects; necessary information for example in controlling fires.

Based on the analysis performed in the calculation of the link budget we can conclude that in practice the distance limit for infrared video in real time at the earth station is approximately 5 km and in theory the 8 Km since in the latter distance, the link margin is around -10 dB

VI. REFERENCES

[1] GS Jimenez, "http://www.infodefensa.com/," 12 February 2015. [Online]. Available: http://www.infodefensa.com/wp-content/uploads/Vehiculos_aereos_no_tripulados_en_Latam.pdf.

[2] PA Rodriguez, "http://repositorio.espe.edu.ec/," 10 July 2015. [Online]. Available: http://repositorio.espe.edu.ec/bitstream/21000/289/6/T-ESPE-014364.pdf.

[3] W. Paspuel, "http://www.elcomercio.com/," 6 December 2014. [Online]. Available: http://www.elcomercio.com/app_public.php/actualidad/tecnologia-drones-plantaciones-agricultura-ecuador.html.

[4] PMS &. VH Skorput, "The use of unmanned aerial vehicles for forest fire monitoring," Elmar Proceedings - International Symposium Electronics in Marine, pp. 93-96, 2016.

[5] LWBPWLCLZ &. GY Zhang, "Forest fire detection solution based on UAV aerial data," International Journal of Smart Home, pp. 239-250, 2015.

[6] BR Christensen, "Use of UAVs or remotely piloted aircraft and forward-looking infrared in forest, rural and wildland fire management: Evaluation using a simple economic analysis," New Zealand Journal of Forestry Science, p. 45 (1), 2015.

[7] Kakma &. ZY Ghamry, "Cooperative forest fire detection and monitoring using a team of UAVs-UGVs," International Conference on Unmanned Aircraft Systems, ICUAS 2016 ,, Key Bridge MarriottArlington, United States, 2016.

[8] M. E. J. M. a. J.-F. M. Henry Cruz *, «Efficient Forest Fire Detection Index for Application,» sensors, pp. 1-16, 2016.

[9] J. M.-d.-D. ·. I. M. A. O. Luis Merino · Fernando Caballero, «An Unmanned Aircraft System for Automatic Forest Fire Monitoring and Measurement,» Journal of Intelligent and Robotic Systems, vol. 65, nº 1, p. 21, 2012.

[10] JJ Diaz Garcia-Cervigón, "http://eprints.ucm.es/,» November 2015. [Online]. Available: http://eprints.ucm.es/31423/1/TFM_Juan_Diaz_Cervignon.pdf.

[11] FLIR® Systems, "http://www.flir.com.mx/," 20 May 2016. [Online]. Available: http://www.flir.com.mx/suas/content/?id=70728.

[12] UM Margarete Vasterling, "Challenges and Opportunities for UAV-Borne Thermal Imaging," Thermal Infrared Remote Sensing, Netherlands, Springer, 2013, pp. 69-92.

[13] LMAOLMRXVJR Martínez-of-God, "Multi-UAV Experiments: Application to Forest Fires," of Multiple Heterogeneous Unmanned Aerial Vehicles, Berlin Heidelberg, Springer, 2007, pp. 207-228.

Authorized licensed use limited to: Chungbuk National Univ. Downloaded on October 10,2020 at 01:12:22 UTC from IEEE Xplore. Restrictions apply.