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Design of a wireless communication system among Unmanned Aerial Vehicles UAVs

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Abstract

The lightweight Unmanned Aerial Vehicle (UAV) flight operations are limited, especially in the UAV range or action radius and endurance, by the mission essential communication link capabilities. Presented paper addresses Design of a wireless communication system among small Unmanned Aerial Vehicles UAVs (Mini or Micro). The existing wireless communication system is designed to allow a UAV to securely send video footage and other information to its ground-based operator at the highest possible speed, even when it is out of direct range. As there are several functional subsystems in UAV, it is important to delimit the scope of the work. To create communication from UAV to UAV, and transmit data from one to another, a communication protocol and device are needed.

Keywords: *communication; Unmanned Aerial Vehicles; mission; endurance; COT; wireless.*

INTRODUCTION

UAV, which is the abbreviation for "unmanned aerial vehicle", is an aircraft that flies without a human on-board the aircraft. It is also defined as a reusable, unmanned vehicle capable of controlled, sustained, level flight and powered by a jet or reciprocating engine. One UAV can do a lot of things for human beings. The greatest uses of UAV are in military applications. It is also used in a small but growing number of civil applications. The lightweight Unmanned Aerial Vehicle (UAV) flight operations are limited, especially in the UAV range or action radius and endurance, by the mission essential communication link capabilities. The Unmanned Aerial Vehicle (UAV) communication links requirements are defined by the mission objectives and the flight environment. The UAV Data–Link connections are summarized in figure 1.

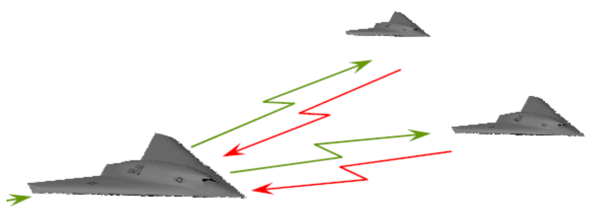

Figure 1

APPLICATION OF UAVS AND ITS COMMUNICATION SYSTEM

a. UAVs applications

UAVs are usually deployed for military and special operation applications, but also used in a small but growing number of civil applications, such as Localization of radars, Wildfire management, Polar climatology, Agricultural monitoring, Reconnaissance, Meteorological monitoring, Aerial photography, Search and rescue tasks and nonmilitary security work, such as inspection of power or pipelines. UAVs are often preferred for missions that are too "dull, dirty or dangerous "for manned aircraft.

b. UAV Communication systems applications

Communication among the UAVs enhances, Formation Flying, Navigation and collision avoidance, Co-operative missions and Path Planning Strategies for Networked Unmanned Aerial Vehicles.

UAV COMMUNICATION SYSTEM DESIGN

There are several protocols which can be used in wireless communication. The following groups of protocols can be considered:

- IEEE 802.11 a/b/g/n wireless LAN and Mesh (Wi-Fi certification)
- IEEE 802.15 wireless PAN
- IEEE 802.16 broadband EC wireless access (Wi MAX certification)

Based on the requirements, there are two main categories protocols to be focused on:

a. Wireless local area networks (WLANs)

WLAN is a replacement or extension for wired local area networks (LANs) such as Ethernet (IEEE 802.3). A WLAN device can be integrated with a wired LAN network, and once the WLAN device becomes part of the network, the network treats the wireless device the same as any other device within the network. The goal of a WLAN is to maximize the range and data rate.

b. Wireless personal area networks (WPANs)

WPANs, in contrast, are not developed to replace any existing wired LANs. WPANs are created to provide the means for power-efficient wireless communication within the personal operating space (POS) without the need for any infrastructure. POS is the spherical region that surrounds a wireless device and has a radius of 10 meters.

Also WPANs are divided into three common classes by the data rate:

(1) HR (high-rate) WPANs

The high data rate helps in applications such as real-time wireless video transmission from a camera to a nearby TV; for instance, IEEE 802.15.3 with a data rate of 11 to 55Mbps.

(2) MR (medium-rate) WPANs

The medium data rate can be used in high quality voice transmission in wireless headsets; for example, Bluetooth, with a data rate of 1 to 3Mbps.

(3) LR (low-rate) WPANs

The low data rate can be used in some common low quality application, like Zig Bee with a maximum data rate of 250Kbps.

The two of most important subjects of a UAV communication system are data–link protection and data security. The provision of sufficient communication exchange between the UAVs influenced by environmental or self implied conditions and above all by hostile jamming is secured by complex and expensive protection features like: (a) error robust coding techniques with error detection and correction capabilities, (b) error robust protocols, (c) minimization of the electromagnetic exposure of jammers with by for example directed or narrow beam antennas, (d) frequency hopping methods, (e) spread spectrum techniques, and (f) intelligent signal processing to eliminate selectively known jamming patterns

c. CONCEPTUAL DESIGN OF UAV COMMUNICATION SYSTEM

One of a desired feature of a design is that UAV is equipped with the commercial–off–the–shelf (COTS) sub–systems. The COTS communication systems market is offering a variety of light–weight mobile UAV to stationary GCS radio link options in a wide spectrum of frequency bands available. However, each frequency band has its own advantages as well as disadvantages [1], and those are briefly summarized in the table 1.

The use of COTS communication systems guideline is defining not only the communication frequency range, but the airborne UAV transmitter transmitting power, its line–off–sight operations requirements, achievable communication range, expected severity of interferences on a frequency band used as well. Clearly the communication system between the UAVs influences the UAVs system operational performances directly.

Table 1: Advantages and disadvantages of different frequency band communication systems.

Frequency	Advantage	Disadvantages
430 MHz	Multiple channels at one location Minor multipath distortion range less	does not support broadcast of quality video

Frequency	Advantage	Disadvantages
	susceptible to weather Signals in VSB modulation can be received by the TV set	legally transmitted power inside band 433,050 - 434,79 MHz restricted to 10mW e.r.p.
900 MHz	Enables video broadcast Low cost due to the mass produc-tion	EU dedicates for GSM consequently legal transmitting power restricted to 10mW e.r.p expected interfere- -nce in populated areas due to the wide use: spectrum wireless LAN
2.4 GHz	Enables video broadcast Low cost system	expected interference in populated areas due to the wide use: microwave ovens, cordless phones, wireless LAN line–off–sight operational requirements range affected by humidity in the air legal transmitting power restrictions (100mW e.r.p.) for the 802.11.b/g technology
5.8 GHz	Enables video broadcast Small transmitting antennas low multi-path distortions in spread spectrum OFDM modulation	severe multipath distortion causes very poor performance in FM mode line–off–sight operational requirements range affected by humidity in the air equipment expensiveness

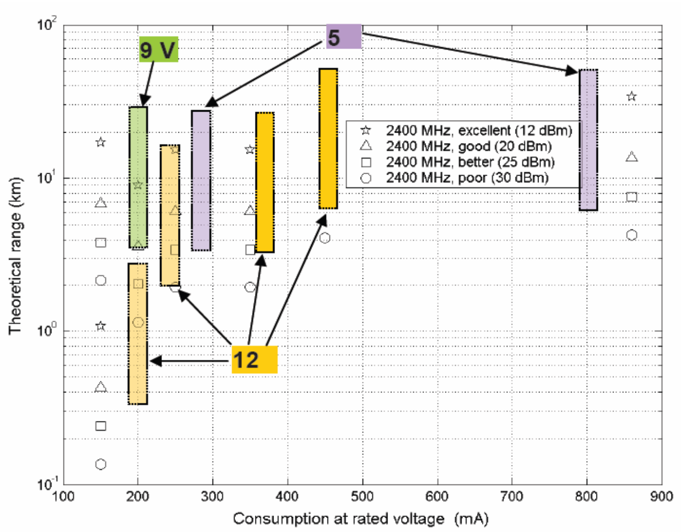

Figure 2: Some of 2400 MHz UAV-UAV COTS links basic characteristic: range as a function of current consumption at the operational battery voltage and a reserve power budget.

The set of seven 2400 MHz transceivers applicable for a lightweight hand–launched UAV is represented in figure 3, the range of a transceiver link is presented as a function of a power consumption required. According to the specified demands of each device three different battery voltages were applied: 5, 9 and 12 V.

Some manufacturers provide a whole set of parameters for their links on certain frequency (f in MHz) consisting of: ERP (effective radiated power also e.r.p.) of the transmitter, gains of both antennas (G in dBi, i for virtual isotropic antenna, each real antenna has a lower gain), sensitivity of the receiver (S in dBm). By inserting the distance (D in km) between transmitter and receiver the reserve levels could be calculated or vice versa.

d. Equations

As a model of large scale effects, a free space field between transmitter and receiver is selected. A model includes important limit of use: type of link is a pure line-of-sight. Eventually multi-path fading has a small scale effect. Calculation of the reserve levels Pr (in dBm) by the formula [2] for the loss calculations gives the equation:

$$Pr_{dBm}=ERP_{dBm}+G_{TdBi}+Sr_{dBm}+Gr_{RdBi}-20\log(f(MHz))-20\log(D(km))-3.6\ 73 \quad (1)$$

The large scale effects determine a power level averaged over an area of tens or hundreds of meters and therefore called area-mean power. Shadowing also has an important effect since it introduces additional changes and that is the reason why received local-mean power varies around the area-mean power. When the UAV-UAV link gets shadowed a simple diffraction model could be used to give an estimate of path loss.

By using Equation (1) and taking into account only two selected COTS, one for the 430 MHz and the other for 2400 MHz it is simulated (figure 3) how attenuation of the transmitted e.r.p. (in mW) affects the range of the link. A principle of attenuation could be used to decrease the e.r.p. and thus meet the legal restrictions for the selected frequency at the certain area of operation.

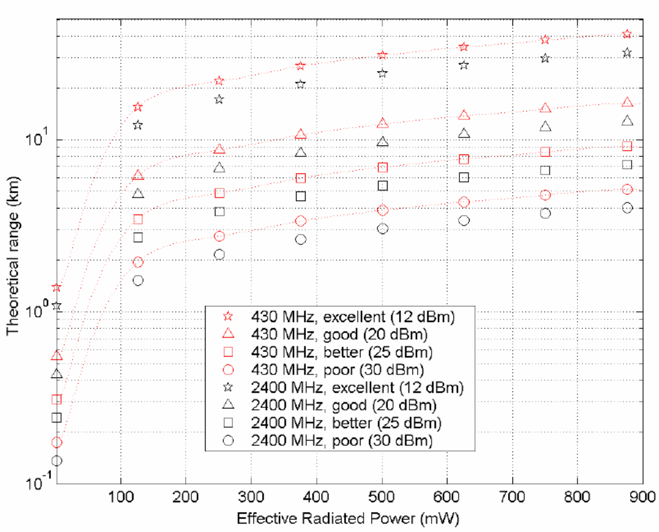

Figure 3: COTS communication systems basics characteristics for two frequencies: range as a function of radiated power and a reserve power budget.

Theoretical conclusions would be corrected by the results of practical experiments (figure 5).

All the major effects were taken into account at the selection of the COTS combinations. If a legislation of the operation area has to be fully incorporated into frequency selection and e.r.p. setting a very narrow set of COTS (if any) would be found. An airborne telemetry in the band of 2.30-2.33 GHz according to the CEPT/ERC recommendation 62-02 could possibly be used for the data exchange for flight control but the channel is occasionally used for the distant mobile camera control. Airborne radio–navigation bands 2.70-2.90 GHz or 4.40-5.00 GHz could also be possible solutions in the cooperation with the concerned authorities.

The mission task would be accomplished after getting the appropriate combination of airborne and terrestrial systems which would pass the practical tests and be proven for operation with certain reserve budget of most parameters we discussed in theoretical part of work.

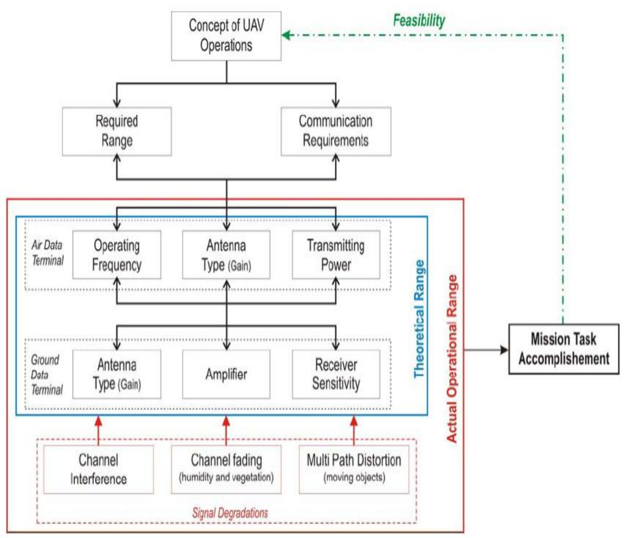

Figure 5: Structured plan of the UAV project

CONCLUSIONS

To conclude, a lightweight UAV action radius or operational range is limited by the feasible range of reliable two–way communication stream (figure 6).

By using COTS communication systems will always have some signal interference and interruptions. The Proposed methods communication protocols can be used to reduce the interference. Multi–path distortion of a communication signal can be reduced to a point by installing the antennas far from the UAV propeller and by employment of carbon–fiber propeller.

For signal degradations compensation a variety of diversity technology [9] can be employed: (a) the frequency diversity (the same signal is transmitted over multiple channels at different carrier frequencies), (b) the time diversity (the same signal is transmitted multiple times), and (c) the space diversity (the receiver is listening with multiple antennas all tuned to the same transmitter). The diversity technology is still a COTS technology but it's a complex and costly.

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