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Development and Operation of UAVs for Military and Civil Applications

(Développement et utilisation des avions sans pilote (UAV) pour des applications civiles et militaires)

This report is a compilation of the edited proceedings of the "Development and Operation of UAVs for Military and Civil Applications" course held at the von Kármán Institute for Fluid Dynamics (VKI) in Rhode-Saint-Genèse, Belgium, 13-17 September 1999.

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signal is changed pseudo-randomly according to the FHSS code between a given number of frequencies. By FHSS the effectiveness of a jammer, which can overcome DSSS is reduced proportionally to the number of frequencies used, so that the remaining interference effects can be corrected by channel-coding.
As for the DSSS code the FHSS code can be selected from a database and loaded into the data-link equipment prior to the mission.

Data Link Design Summary (viewgraph 39)

As a consequence of the previous discussions the following design features should be selected for a wide band microwave data-link.

- Use of Ku-Band

  In addition to the fact that this band is recommended for UAV use by NATO the Ku-Band has the following advantages

  - allows very small antennas at sizes, which can still be accommodated in a tactical UAV
  - a wide frequency range is allocated for data-links, which allows very wide-band transmission. Very high bandwidth together with frequency hopping and direct sequence spread spectrum is very difficult to implement in the other microwave bands due to congestion.

- Directional antennas should be used to limit transmitter power and to make the link jam-resistant and difficult to intercept. Additionally narrow-beam antennas can reduce multi-path effects and allow angle-tracking of the UAV.

- Direct Sequence Spread Spectrum (DSSS) improves the jamming resistance of the link and allows a precise measurement of the distance to the UAV.

- Frequency Hopping Spread Spectrum further improves the links jamming resistance and is a very effective way to minimize the influence of multi-path effects.

- Channel Coding allows to minimize the Bit Error Rate (BER) for a given signal to noise ratio and allows to correct errors. Interleaving is an effective counter-measure against pulse jammers.

UAV DATA-LINK EXAMPLES

UAV Satellite Link – Example: Global Hawk (viewgraphs 41, 42)

Global Hawk is a high-altitude, long endurance UAV equipped with SAR and EO sensors. With a range of ca. 25,000, a maximum altitude of 20,000 m and a mission time of up to 40 h it is a truly impressive UAV.

The UAV has a size, which comes close to manned aircraft of the business-jet class. This size allows some flexibility in the selection of on-board equipment.

As a result military off-the-shelf (MOTS) equipment could to be used for the SATCOM Data-Link. By combining a number of standard 1.5 MBit/s SATCOM channels an overall data-rate in excess of 45 MBit/s can be achieved.

This size of aircraft allows to accommodate the very sizeable antenna, which is necessary for this type of SATCOM Link. With an antenna diameter of 1.25 m and a volume of ca. 1 m^3 the space taken up by the antenna unit would be sufficient to accommodate a complete tactical UAV.

To keep the pencil beam of this antenna (~ 1.5°) focussed on the satellite high precision antenna control and a very accurate long term measurement of the UAV's orientation in space are necessary.

In a UAV of this class the choice of SATCOM is a feasible way to avoid many of the problems that tactical UAVs are facing.

HF UAV Data-Link – Example: Mücke Jamming UAV System (viewgraphs 43 to 46)

The Mücke UAV System is used for jamming of enemy communication systems at VHF and above using jamming equipment developed by Dasa in Ulm. As a consequence a microwave Data-Link cannot be used for EMI reasons.

The tasks of the Data-Link in the Mücke System are confined to data transfer for Jammer Control, Status and Position Request and Reporting and updating of the Mission Plan.

This results in an overall data rate of ~ 1 kb/s, which can well be accommodated by an HF Link.

The requirements to the link allow to base it on military-of-the-shelf equipment (MOTS). In this case components of the HRU 7000 system, developed by Dasa in Ulm for long-range reconnaissance forces of the army, were used:

- The HRU 7000 digital transceiver, which covers the HF spectrum with an output power of 30 watt. This transceiver also includes a link processor to control frequency hopping and co-ordination of the semi-duplex communication with its counter part. A digital HF modem is also included.
- The ATU 7000 Antenna Tuning Unit allows to match whip antennas, random wires and dipoles over the whole HF spectrum.

As the Mücke UAV is a relatively small A/V with a wingspan of ca. 3.5 m and a length of ca. 2.5 m integration of an efficient HF antenna is a challenge. Full-size dipole antennas covering 2 MHz to 12 MHz would have a length between 80 m or ca. 12 m respectively.

A shortened horizontal dipole antenna with capacitive loading was integrated into the wing-edge of the UAV and is matched by a modified ATU 7000 to the HRU 7000. Ranges of more than 400 km can be achieved with this configuration

As can be seen from this example even small UAVs can be equipped with an HF-Link for long-range non-line-of-sight communication using COTS hardware if low data rate can be tolerated.

Microwave UAV Data-Link – Example: BREVEL Reconnaissance UAV System (viewgraphs 47 to 59)

A high-sophisticated data-link has been developed in a co-operation of **DaimlerChrysler Aerospace** and **MATRA Systemes & Information** for the **BREVEL RECONNAISSANCE UAV System**. This system has been jointly developed by Germany and France between 1992 and 1998.
The BREVEL System is a highly mobile UAV System for deployment in close proximity to the battlefield. Consequently the exposure to ECM is very high and the data link equipment has to withstand extreme environmental conditions.

BREVEL Operational Tasks (viewgraph 48)

The BREVEL System is used for reconnaissance missions over the battlefield area using an IR camera. In addition to that targets detected in the footprint of the UAV sensor shall be located with a precision, that allows engagement of that target by weapons like MLRS or SMArt 155 to their maximum engagement range.

Design Drivers for the BREVEL Data-Link (viewgraph 49)

Concerning the data-link this mission requires

- an extremely high resistance to jamming
- low detectability
- the ability to correct errors
- flexibility in the anti-jamming characteristics from mission to mission
- precise localization of the UAV
- survivability to battlefield conditions like NEMP

BREVEL Data-Link Design Choices (viewgraph 50)

For the above requirements a digital Data Link is the logic choice.

Due to the digital nature of the Radio Frequency signals a digital link allows powerful information- and signal processing, that is not possible to the same extent with the analog data-links still deployed in most UAV systems today.

A digital link is the basis, on which the most performant spread spectrum techniques and error correction techniques can be applied. Together with an uplink and a downlink, which exist at the same time on different frequencies, a so-called full-duplex solution the anti-jamming performance is further improved and propagation delay between UAV and ground can be measured very precisely.

The link becomes even less vulnerable through the use of highly directional antennas, which also improve the link budget and are the basis for tracking of the UAV and measurement of the UAVs direction.

Localization Function (viewgraph 51)

The localization function is a special design feature of the BREVEL Data-Link, which allows to determine A/V localization with sufficient accuracy for engagement of ground targets in the footprint of the imaging sensor. This makes the system independent of the GPS P/Y code.
The localization function requires knowledge of AV direction and AV slant range relative to the Data Link Vehicle (DLV) and the height of the AV. Together with accurate knowledge of the DLV location this information allows precise location of the Air Vehicle.