Multimode Communication for Unmanned Aircraft Vehicle

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Abstract: This paper focuses on current research on a flexible communication system for a battery operated Mini UAV. This is a three year implementation program with a main focus on advanced signal processing algorithms implementation for low power transmission systems. The implementation covers statistical based image compression, adaptive coding and modulation schemes, feed forward synchronization methods, COFDM and SISO and MIMO RF front ends.

**Keywords**: UAV , LDPC, OFDM

1. Introduction

The heart of the low power communication system is the high performance flexible Forward Error corrector. The LDPC is selected due to its good code rate flexibility for adaptable frame and modulation schemes. The UAV communication covers SISO (Single input Single Output) for command and control and MIMO (Multiple Input Multiple Output) for down link pay load. The system needs to function in built-up areas as well as open space environment. The first part of the implementation focuses on high performance algorithms using low power electronics. These are met by LDPC and binary and modular arithmetic (Residue Number Arithmetic) for signal processing.

A conceptual view of the UAV transmission system is shown below :
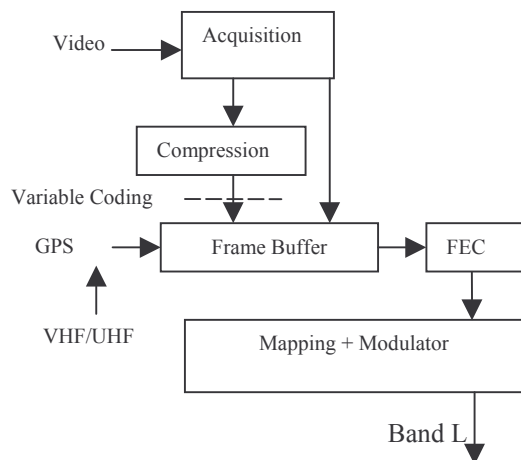
A possible antenna configuration is given below
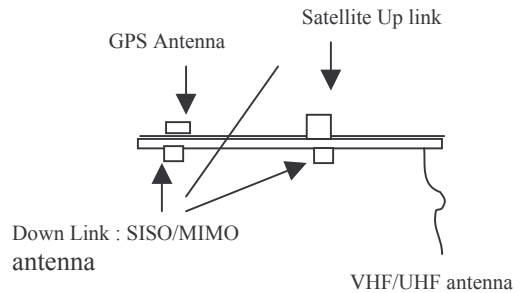
## 2. Presentation of the UAV Communication System

The UAV communication system is made of 4 functional blocks:
- Acquisition
- Forward Error Correction
- Transmission
- Command and Control

The first three functional blocks are presented below.

2.1 Source coding

The Video system is able to handle multi-video stream with a possibility to add wavelet compression. The wavelet transform recursively decomposes the signal into approximation and details at the lower next resolution. The compression ratio can be changed on-the-fly according to the application. This feature allows to reduce the power consumption. The algorithm is validated using a Virtex – II FPGA from Xilinx the prototype is shown below.
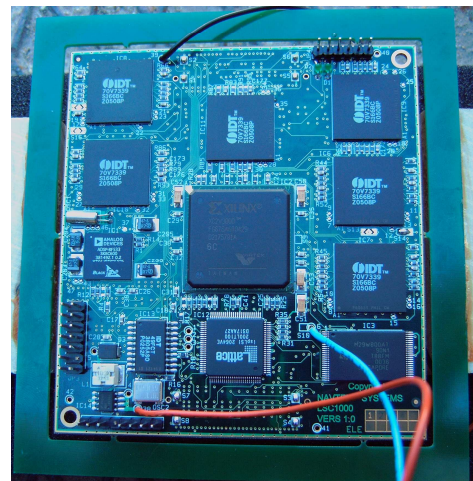
The compression prototype handles feature extraction. The validated algorithms needs to be transferred to low power electronics.

The compression algorithm allows for soft degradation in case of transmission errors. The BER should be kept lower than 10^{-5}.

2.2 Forward error corrector

The LDPC is selected as the forward error corrector for the UAV to ground segment communication link.

The codes belong to the class of linear block codes (n,k). The k information bits are mapped to n-bit codeword. While source coding is aimed at removing as much redundancy as possible for a given distortion, the channel code introduces redundancy to minimize the transmission error rate in order to allow for faithful reconstruction of the source data at the receiver end.
The down link uses four frame sizes according to the SNR and application requirements. These are 512, 1K, 4K and 16K.

LDPC basis:

An LDPC code is described by its (sparse) parity check matrix **H**. Such a matrix can be efficiently represented by a bipartite graph. A bipartite graph $G = (V, C, E)$ consists of a set of variable nodes V, a set of check nodes C and a set of edges E. Each edge $e \in V$ connects a variable node $v_e \in V$ to a check node $c_e \in C$. The variable nodes correspond to the set of codeword. We say that a LDPC code is (λ, ρ) regular when each variable has a degree λ and each check node has a degree ρ. Regular LDPC codes have an advantage in hardware implementation because the regular structure can be exploited to simplify the decoder. Further, for short block length, irregular codes may have a smaller minimum distance and regular code may be preferable to avoid the error curve flattening effect. Since the required BER lies around 10^{-5}, it should not be necessary to concatenate the selected LDPC code with some other codes.

Encoder characteristics:

The LDPC encoder is generally complex when compared to other forward error corrector encoders. In the UAV application, the FEC needs to handle various code rates with low power. For this reason, only two LDPC families are investigated :
 - Cyclic or quasi-cyclic codes from finite geometry,
 - IRA (Irregular Repeat and Accumulate) codes such as the code normalized for DVBS2
 Both families can be encoded straightforwardly and we look forward to the possibility of drawing the different codes we need from one single code family in order to minimize on-board complexity.

Decoder characteristics:

The standard iterative decoding algorithm, known as belief propagation algorithm (BPA) is used. It passes messages along the edges of the bipartite graph associated to the code. Each variable node is initialised with channel information. Decoded messages (check-to-variable and variable-to-check), referred as extrinsic information, are iteratively updated on each node and exchanged through the edges between neighbouring nodes. As the decoder is ground based, complexity requirements are not stringent. As already mentioned, on the FEC side, the challenge is rather on the code design.

2.3 Modulation schemes

The communication system functions under a burst mode: it will be extended to continuous mode in the final phase of the programme. The conceptual view of the transmitter structure is given below.
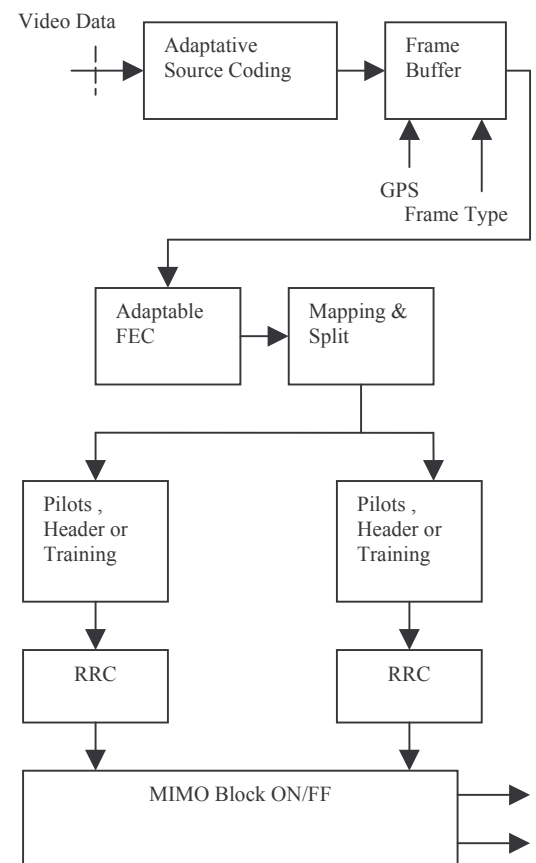
An example of a data frame is given below

Header : SynWord + GPS Data	Data : Clear/Crypted with pilots/non pilots

The selected modulation schemes for the first phase are BPSK and QPSK but higher order modulation will be evaluated in the 2nd phase.

The down link depends on the mode of transmission as illustrated below:

TX1	Modulation Type A	OFDM		SISO - Mode

TX1	Spread Spectrum	OFF		MIMO
TX2		QPSK		

The operating SNRs for the considered modulation schemes are given below

| MODULATION	EB/N0
BPSK	-1 dB
QPSK	1.5 dB

The use of OFDM provides a better performance for multipath interference, flat fading, and frequency selective fading. In OFDM, the data is sent using multi carriers, each modulated with a portion of the data at a lower rate. As the number of carriers increases, it results in an increase of the Peak to Average Power Ratio (PAPR). This is a major draw-back for low power transmission due to the high power consumption in the linear power amplifier. If no PAPR reduction technique is used, the power amplifier for OFDM requires a much higher power than simple QPSK (in the range of 60 –70%).
Various PAPR reduction methods have been studied [1].

Navtel Systems focuses on two avenues: one based on coding and the 2nd is the selected mapping.
In the use of coding techniques, selecting the code produces OFDM symbols for which the PAPR needs to be below some desired level. In this method, the higher the PAPR reduction, the smaller the coding rate. We choose a code that provides necessary error-correcting properties and reduces the PAPR of the OFDM transmission.

For the mapping selection, the basis is to take advantage of the fact that the PAPR of an OFDM signal is very sensitive to phase shifts in the frequency-domain data. The PAPR reduction is achieved by multiplying independent phase sequences with the original data and determining the PAPR of each phase/data combination [2]. These two methods as well as various algorithms for the UAV communication will be evaluated using simulation and validated on an FPGA platform shown hereafter.
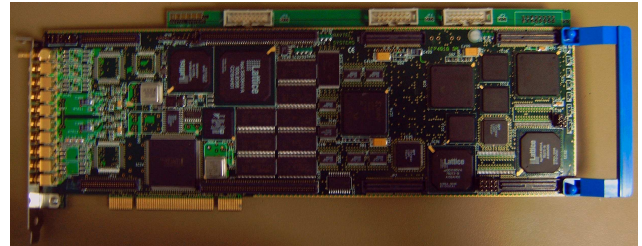
At the present stage, various simulation modes are under definition.

3. References

[1]   Muller, S.H, Huber, J.B, "A comparison of Peak Power Reduction schemes for OFDM", GLOBECOM97, Phoenix, AZ, USA, Nov.3-8,1997, vol.1.3,pp.1-5]. [2]   Authors: "*Title of Paper*", Name of the Journal, Volume, Issue, Publisher, and Year of publication.

[2]   G.T. Zhou, R.Baxley and N.Chen, "Selective mapping with monomial phase rotations for peak-to-average power ratio reduction in OFDM". Proc. intl. Conf. On communications, Circuits and Systems, June 2004].

4. Glossary

UAV   Unmanned Aircraft Vehicle