Petr Makula

DATA LINK CONCEPTION FOR JOINT TACTICAL UNMANNED AERIAL VEHICLES BASED ON STDMA PROTOCOL

INTRODUCTION

Any information about theater of operations has the strategic sense. Acquisition of that information by using Joint tactical unmanned aerial vehicles has become common in few last years. In this paper, I present the basic approaches of modern data link conception for unmanned aerial vehicles (UAV) operating in environment causing a lot of errors and interference.

Effective utilization of UAV needs reliable and precise control of that vehicle and design of dependable crash-proof secure data links between UAV and control station (CS). Communication system must ensure transmissions of TV signal, and telemetric information from onboard sensors to control station and command control from CS to UAV. Generally, there are two separate data links with different data transfer rate.

If several UAVs operate together and one of them works as relay station, the conception of the data links is getting more complicated and it must fit following requirements:

- Basic of the system is multiple access protocol.
- Entire data throughput of the system allows transmission of image signal from at least three sources simultaneously.
- Each UAV is able to transmit and receive data containers of equal size (relay function).
- All UAVs are completely replaceable by each other.

Satisfaction of all above-defined requirements is not elementary. The most important parameter of the system is data throughput in arbitrary spatial configuration of the system.

RECEIVER AND TRANSMITTER FUNCTIONS

Modern sophisticated radio communication devices are designed with respecting to software oriented radio conception with an open architecture and modular

components, which has a lot of advantages. One of the motivating factors behind developing them is that they have the potential to provide enhanced performance, growth and flexibility. Figure 1 illustrates the functional diagram and the basic elements of a spread spectrum digital communication system, with which we can mainly meet in data link conceptions.
The functions of the particular elements will be discussed in next chapters. Discussion will be limited only on the transmitter functions because of the receiver functions are generally inverse.

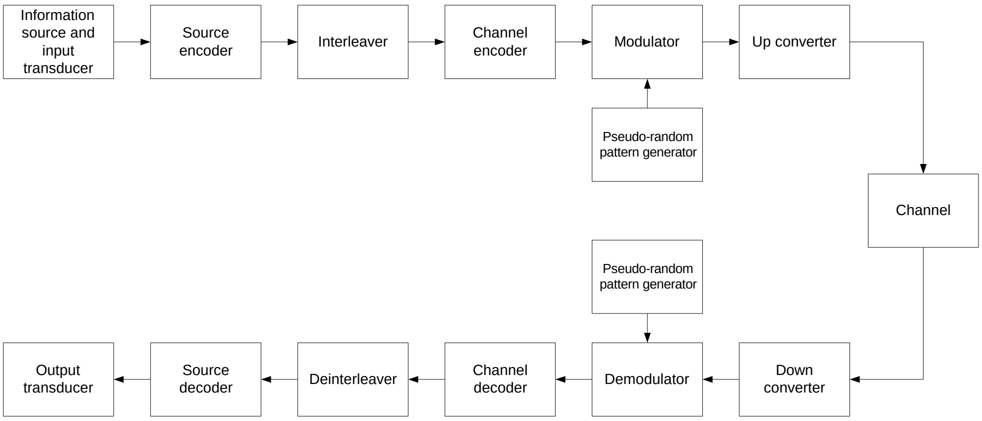

Fig. 1: Basic elements of a spread spectrum digital communication system

Source coding

Because command control and information messages don't have high redundancy, we don't have to use source coding and therefore this chapter will describe source coding of image information.
Image modulation signals of analog TV systems share wide frequency band, approximately from 4 to 6MHz. After conversion, the bit rate of a PCM formatted digital signal is higher than $200Mb.s^{-1}$ and the bit rate of HDTV systems is even higher. If the system cannot supply such a high bit rate, it's necessary to implement an effective source coding in a transmitter.
Digital communication systems for transmissions of video signals, whose have suppressed the redundancy, mustn't have the bit error rate (BER) worse than 10^{-10}. Generally, there are two types of the redundancy in TV signals: spatial and time redundancy.

Only modern video source encoders based on the MPEG-2 standard can sufficiently suppress bit rate from 200Mb.s^{-} to 5-10Mb.s^{-1}.

Channel coding and interleaving

If a system cannot ensure a required BER by using optimal methods of modulation and detection of the signal we have to use channel codes that make it possible to achieve reliable communication, with as small an error probability as desired. The channel capacity requirements will rise by using the channel coding. In particular, we treat two classes of codes, namely, block codes and convolutional codes. The block codes are widely used in wireless applications, because they are simply feasible, sufficiently effective and can be used for high bit rates. The Reed-Solomon code seems to be suitable for data link concept, because it is much faster than convolutional code.
Most of the well-known codes that have been devised for increasing the reliability in the transmission of the information are effective when the errors caused by the channel are statistically independent. This is the case of AVGN channel. However, there are channels that exhibit bursty error characteristic. An effective method for dealing with burst error channels is to interleave the coded data in such a way that the bursty channel is transformed into a channel having independent errors. The interleaver can take one of two forms: a block structure or a convolutional structure. A block interleaver formats the encoded data in a rectangular array of m rows and n columns. The bits are read out column-wise and transmitted over the channel. Convolutional interleavers are better matched for use with the class of convolutional codes.
Unfortunately, the complicated digital communication systems cannot achieve reliable communication with a simple channel coding. Therefore they use concatenated codes and the forward error correction (FEC).

Spread spectrum and digital modulator

The concept of data link using the spread spectrum (SS) with applied method of direct sequence (DS-SS) is the most perspective for the military applications. The advantage of DS method of spreading the frequency spectrum is that the unauthorized receiving of the transmitted signal is disallowed or at least embarrassed. Next benefit of the DS concept is his reliability during the operating in the environment with a lot of errors and interference due to jamming, multipath propagation and noise. The basic of the robustness of this method is caused by spectral expansion of the spurious signal in input

demodulator in contrast to desired signal. Only fractional part of the spurious signal energy appears on the output of following narrow band filter.
The input data are spreaded by pseudorandom sequence with several times higher bit rate than is the bit rate of original input data. Spreading is accomplished by logical XOR. Output data flow is at the next time processed by digital modulator.
Current systems of data transmission most of the time use the methods of quadrature phase shift keying (QPSK) and its varieties. They are the most effective under the condition of jamming.
The offset QPSK (O-QPSK) modulation, instate of classical QPSK is widely used in data link concepts due to its less spurious amplitude modulation.

Up convertor

Up-convertor converts modulation signal and interfrequency (IF) into required frequency band, which is wide enough to realize reliable transmission of signal with high bit rate. The transmission of image information is accomplished in the X or Ku bands.

Methods of encryption

According to the text above the SS transmission concept contains certain degree of encryption itself, which is defined and characterized by used algorithm of pseudorandom sequence generation. The principal of frequency spectrum expansion also hides the present of signal behind noise. When higher demands of the encryption are requested, there can be added an encryptor into the communication system. In the military applications are common the standard encryptors COMSEC devices KG-68 and KG-135.

PROPOSAL OF THE DATA LINK BASED ON STDMA PROTOCOL

The STDMA protokol can be charakterized like a TDMA protocol with the dynamic slot allocation. A unique feature of the STDMA system is the way that the available transmission time is divided into a large number of short time-slots synchronized to a global time base. Each time slot may be used by a radio transponder (mounted on aircraft, ground vehicles or at fixed ground stations) for transmission of data. The exact timing of the slots and planned use of them for transmissions are known to all users, so that efficient use of the data link can be made and users do not transmit simultaneously. As a result of this ‘self-organizing’ protocol, the STDMA system does not require any ground infrastructure to operate and can therefore support air-air as well as ground-air communications and applications.

Communication system architecture

Each user of the system is equipped (UAV, surface station) with a transponder for determining the position and time, managing transmissions on the data link and for transmitting and receiving data. Figure 2 shows one of the principle architecture of a communication system. This principle architecture is the same for airborne and ground users.

The GNSS receiver provides position and time information via its one pulse per second time signal. This pulse is synchronized to UTC. The communication processor co-ordinates the use of the communication channel and holds a virtual image of the time-slot frame in its memory. Further, it controls the slot allocation for the station own transmissions and continuously updates its own slot map.

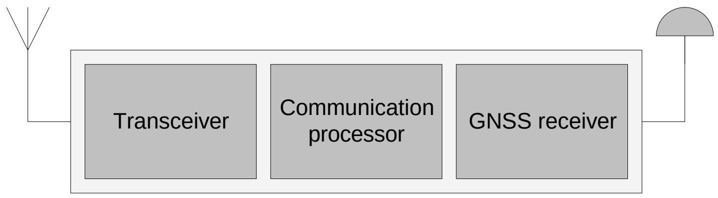

Fig. 2. Communication system architecture

The communication processor controls the transceiver functions. The internal structure of the transceiver was discussed in chapters above.

Slot selection

An important feature of the STDMA protocol is the method used to select the slots for a new transmisson or for placing reservation for future transmission. When a channel is not busy, slot selection is straightforward since a slot that has not been previously reserved by another station can be easily found. When a channel becomes busier such that unreserved slots are harder to find, the system must ensure slot selection according to the priority of transmitted data. For example the transmission of the command control has higher priority than the transmision of the ISR sensor data. The slot selection proces is described in next bullets:

— An application wishing to send data or to place a reservation to send data in the future first specifies a range of candidate slots from which a slot will be chosen.
— The station then derives a list of available slots. The available slots are a subset of the candidate slots
— A slot is selected randomly from the available slots.

Channel capacity

In a TDMA system, each user transmits for 1/K of the time through the channel of bandwitch W, with average power KP. Therefore, the capacity per user is

$$C_K = \left(\frac{1}{K}\right) W \log_2 \left(1 + \frac{KP}{WN_0}\right)$$

The channel capacity per user in STDMA system will be changing according to slot allocation requests. It means that there will not be requested extremely high channel capacity for transmission of control signals – only small number of allocated slots. On the other hand the image transmission requires incomparable higher number of allocated slots caused by desired bit rate about 20 MB.s-1. The average channel capacity per user is then lower compared to protocol TDMA.

CONCLUSION

As mentioned above, the data link transmissions among several users based on STDMA protocol achieve much better results than standard TDMA protocol. The main advantage is that surface control infrastructure is not required. Its self-organizing feature is divided from the synchronization by UTC time of GNSS receiver. Slot allocation seems to be complicated but the benefit is reduction of entire channel capacity.