MODEL OF THE TRANSMISSION SYSTEM OF THE RECONNAISSANCE SYSTEM ORPHEUS

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Abstract

The robotic platform Orpheus is a top-class reconnaissance system being developed at ÚAMT (FEEC, BUT). The system is controlled by an innovative technology called telepresence: an operator is controlling the robot in real-time using HOTAS interface while watching situation grabbed by robot's cameras and other sensoric data. The transmission system of the robot is very critical part of the system, because it must provide short robot response time, while serving wide band video signal to the operator. Standard Wi-Fi technology can handle both there parameters, but it struggles with poor reliability in situations without line of sight between the robot and the operator's transmitter antenna. Unfortunately, these situations are very typical for reconnaissance systems. Since the Wi-Fi technology is widespread, we decided to keep it and its successors as a base for a new proprietary digital transmission system. The reliability problems can be overcome by the use of suitable modulation and equalization techniques. This article deals with a model of the transmission system in Matlab environment.

1 Introduction

The robotic platform Orpheus is a top-class reconnaissance system being developed at ÚAMT (FEEC, BUT). The system is controlled by an innovative technology called telepresence: an operator is controlling the robot in real-time using HOTAS interface while watching situation grabbed by robot's cameras and other sensoric data. The transmission system of the robot is very critical part of the system, because it must provide short robot response time, while serving wide band video signal to the operator. The typical working environment is indoor environment which is characterized, from the communication point of view, mainly by the Non Line of Sight (NLOS) wireless channel with high multi-path distortion. This means that the channel is frequency selective fading.

For that reason, the control data between operator and robot are send by separate wireless modem on the lower frequency (869MHz) where these effects are not so crucial. This enables the robot to be under control in relatively long distances. On the other hand, the video-sensoric data can not be send in this frequency band, because the available the band is not wide enough. Recently, for video-sensoric data the Wi-Fi technology in 2.4GHz frequency band is used, namely the 802.11g. However, the Wi-Fi technology provides significantly higher attenuation at long distances for NLOS environment, which significantly limits the use of the robot. Moreover, Wi-Fi is multiuser packet system, where the delay between the transmitter and receiver and the bit rate are not guaranteed.

Following these conditions and requirements, we had to choose the way of proprietary solution of communication system in 2.4GHz (ISM unlicensed frequency band) based on Wi-Fi technology and its successors (IEEE 802.11, IEEE 802.15 and IEEE 802.16). This proprietary system, compared to 802.11, has a couple of simplifying properties . First, from the system point of view, the communication is only broadcasting of video stream, thus it is one way traffic and there is no need to confirm packet reception. Any data losses are treat on the base of the data coding. Second simplifying property profits from only one receiving user of transmitted stream, which means that there is not multiuser environment. Finally, to combat the effect of frequency selective fading caused by NLOS and multi-path, we have decided to use Multiple Input Multiple Output (MIMO) OFDM system.

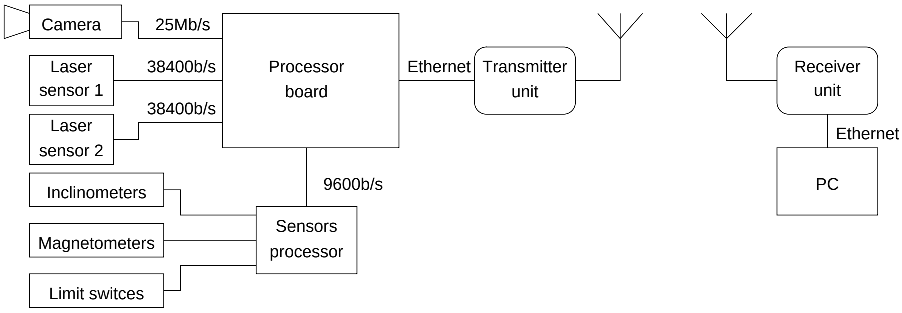

Figure 1: Block diagram of a communication system of rescue robot.

2 System overview

As can be seen on Figure 1, transmitted data are consist of three main sources: one camera and two lasers. The most amount of data stream is taken by video camera signal, which can reach up to 25Mb/s for color video sequence. Other two sources are lasers for temperature and space distance measurements. They require about 75kb/s of bit rate. The processor unit (industrial PC) at the robot encapsulates all the data in Ethernet frames and handles datagram protocol (UDP), so the transmitter unit is fed by 100Mbit Ethernet and doesn't need to care about error detection, data compression or other overheads. Transmitting unit connects opposite receiving side by 2x4 MIMO wireless channel (i.e. two transmit antennas and four receive antennas). At the receiver, after decoding, the data are send to the standard PC, which treats (using the UDP) and displays the data.

The system requirements on the communication channel are summarized as follows:

- Minimum bit rate: 17.28Mbit/s (27.6Mbit/s for fully featured solution)
- Minimum delay: 50ms (25ms fully featured)
- Minimum indoor range: 100m (includes reinforced concrete buildings)
- Minimum outdoor range: 200m

To minimize the amount of data to be transmitted, some effective compression of video stream is provided. The compression method is based on Motion JPEG method and is out of interest of this article.

3 Communication system

Digital communication device which operates under difficult conditions has to be based on more robust technology. One of the questions is a proper choice of digital modulation. We picked orthogonal frequency division modulation (OFDM). The main reason for this choice is narrow band behavior of individual subcarriers, which eliminates the effect of frequency selective fading of wideband channel and transform it to the set of flat fading narrowband channels. To effectively combat the effect of NLOS environment, it has been proven that MIMO technique is the proper choice. MIMO techniques also enables us to increase the maximal data rate using some multiplexing method and increase the maximal space distance by the use of modern equalization techniques. We assume that up to two transmitting and four receiving will be used.

Transmitter unit (fig. 2) stands of an encoding and interleaving blocks theirs output is quadrature modulated by QAM mapper. After inverse Fourier transformation the cyclic prefix is added to each symbol. An analogue processing and amplifier follow at the end of chain.

Receiving unit at opposite side does basically same as transmitter in reverse order, except that there has to be done a frame detection and synchronization of received symbols. Obviously these blocks will extend to more complex computations in case of multiple antennas. This block is entitled as time and frequency synchronization on receiver diagram on figure 3.

To profit form the MIMO, we have decided to test the following space time coding methods: Alamouti block codes, space time trellis codes, space time turbo codes and spatial multiplexing methods (V-BLAST and Turbo BLAST). Systems with spatial multiplexing coding will be supplemented by the equalization and beamforming methods for OFDM.

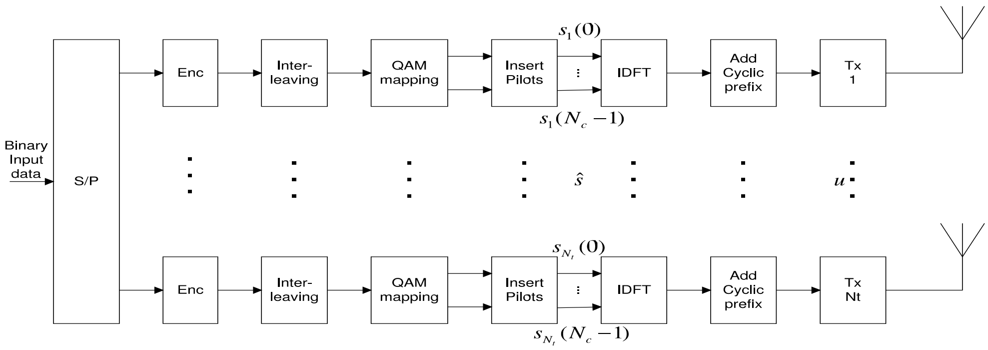

Figure 2: Simplified diagram of transmitting unit

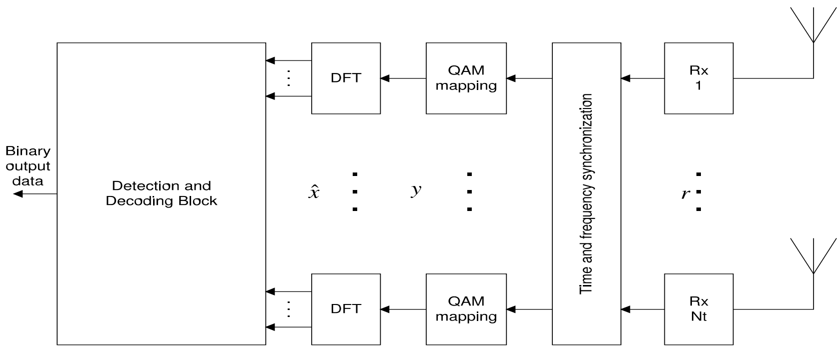

Figure 3: Simplified diagram of receiving unit

The overall system is prototyped in Matlab environment. Recently we have implemented the following basic blocks. First of all, we have implemented frequency selective MIMO channel model using finite impulse response filter with random coefficients. Time variations of the channel coefficients based on a random walk algorithm. QAM modulator/demodulator has been also implemented. Next, we have implemented OFDM modulator/demodulator with variable size of the OFDM symbol and of the cyclic prefix. Several frame detection and coarse time synchronization algorithms for SISO systems (single input single output channel) are recently tested (see Figure 4). For decoding only Alamouti space time block coder/decoder has been implemented yet. Some basic equalizer design methods in time (TEQ) or frequency (FEQ) has been done as well (see Figure 5).

4 Conclusions and future work

On the platform of a rescue robot we are designing a proprietary communication system based on the MIMO OFDM. This enables us to increase both the maximum data rate as well as the maximum space distance between the operator and the robot. For system prototyping we have chosen the Matlab environment, which enables fast development of the modern DSP algorithms.

Recently we have implemented some basic blocks of the system such as MIMO channel model, QAM coder/decoder. Development of the other subsystems such as Time and frequency synchronization and space time block coders are in the phase of testing and comparison of several methods.

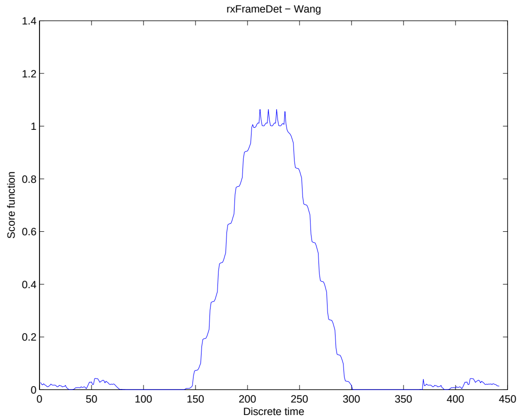

Figure 4: Output of the frame detection and coarse time synchronization function

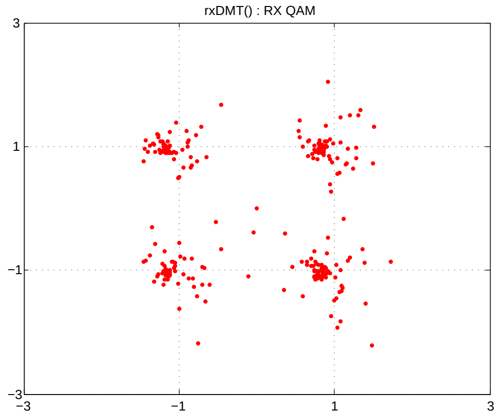

Figure 5: Output of the TEQ equalizer for 4-QAM signal constalation

From the space time coders we have implemented only Alamouti block coder/decoder. We plan to investigate more design work in space time trellis codes and Turbo space time codes. Finally, all the system will be implemented on FPGA platform. For that stage of development, we plan to: make numerical analysis of individual blocks, use developed Matlab blocks functional models and create final FPGA system design using Mathworks/Xilinx System Generator

5 Acknowledgements

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