

Explore one of the technology used in a wireless remote control aircraft

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Abstract—Radio Controlled or (RC) aircrafts have been around for decades and no doubt the technology has evolved over the years. A typical RC aircraft system consists of an aircraft with an embedded receiver connected to several servos to actuate the flight controlled surfaces of the aircraft namely aileron, elevator and rudder. The speed controller for the aircraft and landing gears, where applicable, are also connected to the receiver. The aircraft operator or pilot on the ground uses a transmitter, to fly and control the aircraft, which is tuned to the receiver over a Radio Frequency or RF link.

In this paper, we investigated the protocol used for a typical RC aircraft system; Guanli Skysport 4 and implemented both the transmitter and receiver in National Instrument's USRP using Labview Integrated Development Environment (IDE).

Index Terms—Radio Controlled, Radio Frequency, Integrated Development Environment, USRP, FM, PPM, LabView

I. INTRODUCTION

RADIO Controlled aircraft price ranges from a few hundred of dollars to thousands depending on the make model and the type of technology used in the Radio Frequency link. The cheaper models are usually constructed of foam material to reduce the weight of the aircraft to balsa wood in the larger and more expensive models. The engines can be electric motors in less expensive models to petrol powered engines in the more high-end models. Due to budget constraint we were forced to purchase one of the less expensive models. The Guanli Skysport 4 is described as a four channel Digital Proportional Radio Control System which means that the speed, aileron, rudder and elevator will vary proportionally to the movement of the joysticks on the transmitter. A complete system consisting of transmitter, receiver, servos and accessories is shown below.



After acquiring the RC system we tried to obtain documentation on the wireless protocol that was used on the RF link but the information for our specific system was non-existent and information in general on the wireless protocol used in RC aircraft was scarce. In order to achieve our goal of implementing both the transmitter and receiver using a NI USRP and LabView to develop a process of reverse engineering.

II. RESEARCH WORK

In our research we have found that there are several technologies employed in wireless radio controlled aircraft industry namely Pulse Position Modulation PPM, Pulse Code Modulation PCM, Direct Sequence Spread Spectrum DSSS and Frequency Hopping Spread Spectrum FHSS. DSSS and FHSS are more advanced technologies and are used at the higher end of the industry. PPM and PCM are more common and in our case we examined PPM technology.

A. PPM

In PPM the position of the potentiometer is encoded to correspond with the width of the channel pulses. The pulses are then modulated using Frequency Modulation (FM) at a frequency of 72.430 MHz. The signal is then transmitted using a Frequency Shift Keying transmitter (FSK) which means it only sends two frequencies. The frequencies are 1.5 kHz above and below the center frequency. A PPM frame is shown below. The frame consists of a synchronizing pulse followed by a set of smaller pulses representing the channels. The frame length is 20 ms long with a 0.05 ms buffer between each channel. The width of the pulse varies from 1ms to 2ms with the midway point of the potentiometer being 1.5ms. In fig. 1 is a PPM Frame example [1].

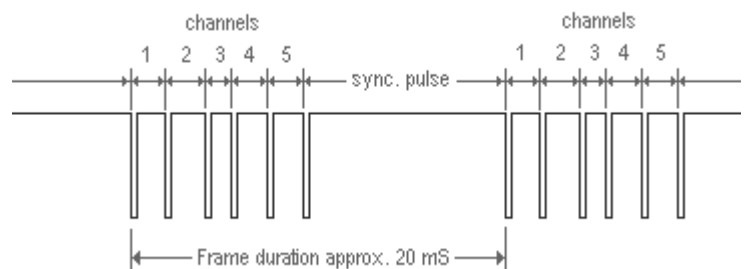


Fig.1 PPM Frame

The receiver is often based upon the super heterodyne principles. Double conversion super heterodyne is typically used in order to guard against harmonic problems found in the single conversion method.

III. EXPERIMENTATION

In order to validate the little theory we had researched we used a spectrum analyzer to examine the frequency profile of the transmitter signal. The spectrum analyzer showed that magnitude of the carrier frequency was high at 72.430 with half power side-lobes at (+/-) 1.5 KHz. Based on the frame description found in our research we proceeded to design a receiver that would produce a proportional output to the pulse widths.

A. The Receiver

The step taken in creating the receiver was to first pass the received signal through a FM demodulator. The picture below shows the FM demodulator VI in Labview.

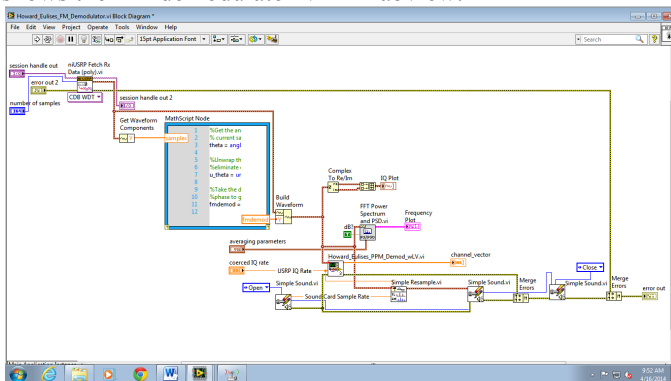


Fig. 2 FM Demodulator VI

The picture below shows the demodulated FM signal; notice that the waveform can be made out but it is shrouded in high frequency interference from the transmission channel. To remove the noise from the demodulated signal the output of the FM demodulator was passed through a low pass filter.

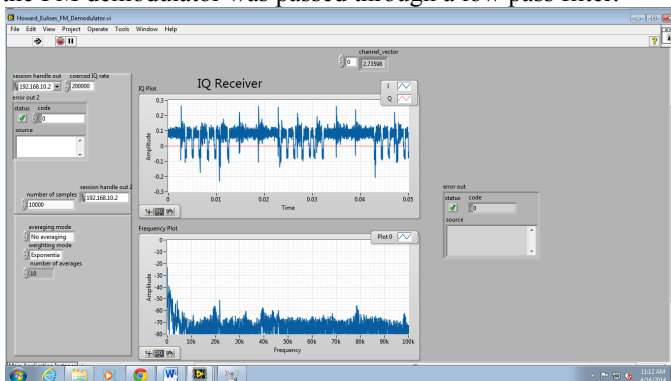


Fig. 3 Demodulated FM signal

After the signal is filtered it is then passed to the PPM demodulator. The PPM demodulator was first realized with a mathematical model in Matlab. Using an exported signal from LabView the demodulator was designed offline in order to be able to find accurate timings for the channel pulse

widths. Using this mathematical method we were able to successfully demodulate the PPM signal but the response was very slow; when we move the joystick there was a lag in the output. The Matlab code was imported to a LabView Mathscript and it is shown below.

```
% This Funtion Demodulates the PPM Signal
%Students: Eulises Ulloa, Howard Harris
%Lab Instructor: Karthik Vasudeva
%Date: 04/04/2013

%Remove spuriuos samples
FM_Dem_Signal=FM_Dem_Signal(500:end);
%Find maximun and minumun for amplitudes thresholds
max_amp=max(FM_Dem_Signal);
min_amp=min(FM_Dem_Signal);
%After correcting the signal for capture delays
mid_reference_level=min_amp+(max_amp-min_amp)/2;
%Initialize vectors that store the pulses width and the channel voltages
pulse_vector=[];
channel_vector=[];
%Finde the Star Pulse (Need a Pulse of 10ms or (fs*10ms) samples in length)
%initialize Counters
start_count=0;
pulse_count=0;
pulse_number=1;
n=1;
%Loop through the signal
while (n<=length(FM_Dem_Signal))
%Find the first negative pulse
if (FM_Dem_Signal(n)<=mid_reference_level)
%Wait for the signal to go high again
while (FM_Dem_Signal(n)<=mid_reference_level) &&
(n<length(FM_Dem_Signal))
n=n+1;
end
%While the signal is high count the number of samples
while (FM_Dem_Signal(n)>=mid_reference_level) &&
(n<length(FM_Dem_Signal))
pulse_count=pulse_count+1;
n=n+1;
end
%Store the pulse width in the pulse vector
pulse_vector(pulse_number)=pulse_count;
%Increment pulse vector index
pulse_number=pulse_number+1;
%Reset pulse count
pulse_count=0;
%correct for the last n increment
n=n-1;
end
n=n+1;
end
%map the pulse widths to the channels using an output vector
k=1;
while k<=length(pulse_vector)
%Find the start pulse
if pulse_vector(k)>=2000;
k=k+1;
%index for channel vector
ch_index=1;
while ((k<=length(pulse_vector)) && (pulse_vector(k)<=2000))
channel_vector(ch_index)=(pulse_vector(k)*0.025)-5;
k=k+1;
ch_index=ch_index+1;
end
end
```

```

%correct the increment
k=k-1;
end
k=k+1;
end
    
```

To overcome the slow responsiveness of the system we changed the configuration of the PPM demodulator by converting most of mathematical model to functional/logical blocks within the VI as shown below in Fig. 4, Fig. 5 and Fig. 6.

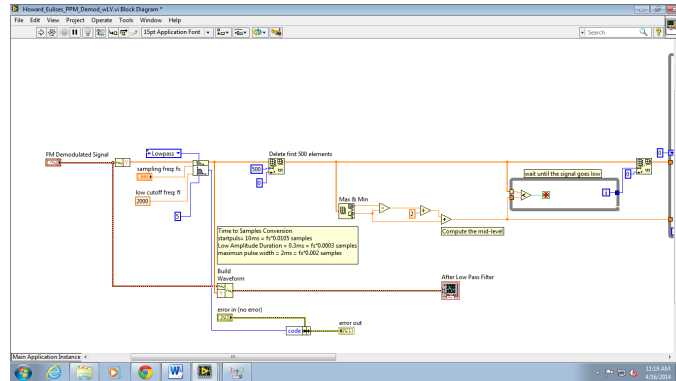


Fig. 4 PPM Demodulator

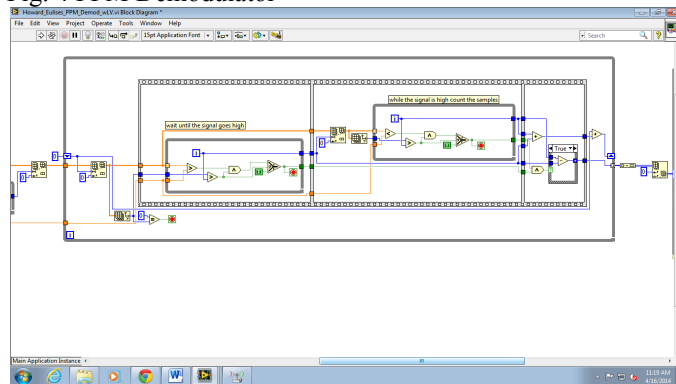


Fig. 5 PPM Demodulator continued

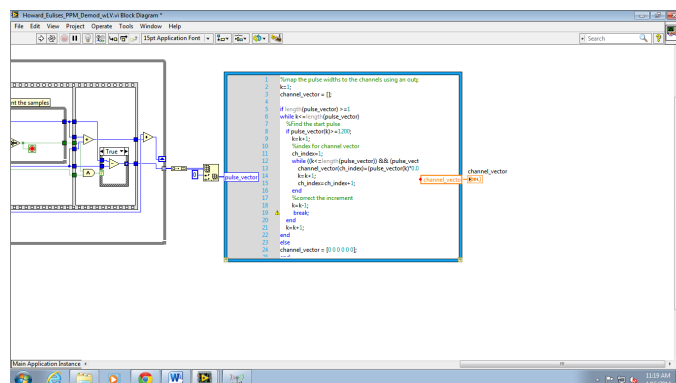


Fig. 6 PPM Demodulator continued

When the output of the PPM demodulator was examined it showed that the transmitter was transmitting six pulses. Each of the pulses corresponds to a channel on the receiver however, the first four channels were proportional to the movement of the joystick and the other two were to switch a relay on or off. The top level VI of the entire receiver is shown below in Fig. 7

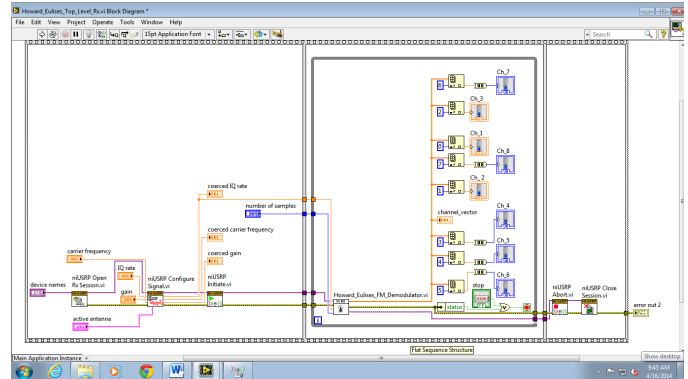


Fig. 7

B. The Transmitter

After having the receiver operating properly we proceeded to implement the transmitter in the USRP. We constructed the transmitter to generate a PPM frame containing 4 pulses, which would convey the voltage information to be transmitted to the servos, and a start pulse which indicates to the receiver the beginning of a frame. The PPM signal was modulated using FM and transmitted over the wireless link.

It can be seen that for different voltage levels generated by the AIL, ELE, THR, and RUD sliders the generated frame shown in the waveform plot will contain the sliders value as a function of the width of the pulses. The first pulse is a start pulse with a minimum value of 10 ms and a maximum value that will vary depending of the width of the pulses; this is implemented in order to keep the length of the frame fixed. The rest of the frame will contain four channels, each of them containing the information of the voltage from the sliders and represented as pulse width using the linear function that was developed when designing the transmitter. A value of 5 V at the slider will suggest a maximum pulse width in the corresponding channel (208 samples / IQ rate). Similarly, a value of 0V at the sliders will suggest a minimum pulse width at the corresponding channel (60 samples / IQ rate.) Additionally, 3ms pulse width was used for the low amplitude pulses.

The transmitter VI will take the PPM signal and modulate it using FM. It is necessary to create a waveform from the generated frame in order to do this we use a build waveform VI and input the PPM signal and the coerced IQ rated generated by the USRP. For the PPM modulation we use a frequency deviation of 2.5 times our signal bandwidth. Finally, the USRP will transmit the FM signal continuously using a while loop controlled by user. Fig. 8 and Fig. 9 show the block diagram for the transmitter.

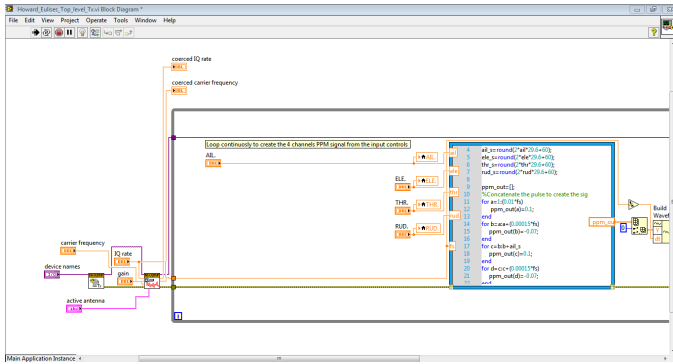


Fig. 8

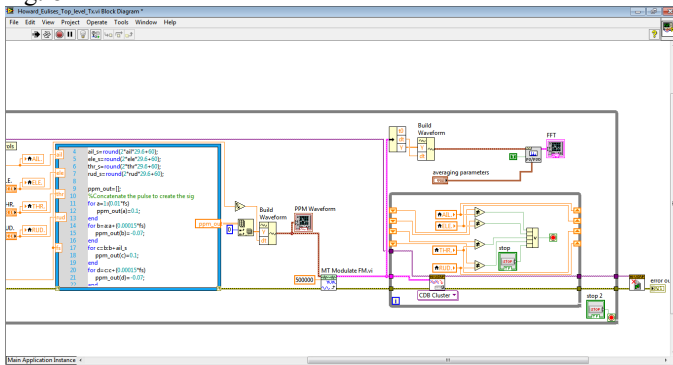


Fig. 9

IV. RESULTS

Fig. 10 shows the receiver output for the Guanli Skysport 4 transmitter. It shows the training pulse and the four proportional pulses and the two on and off pulses.

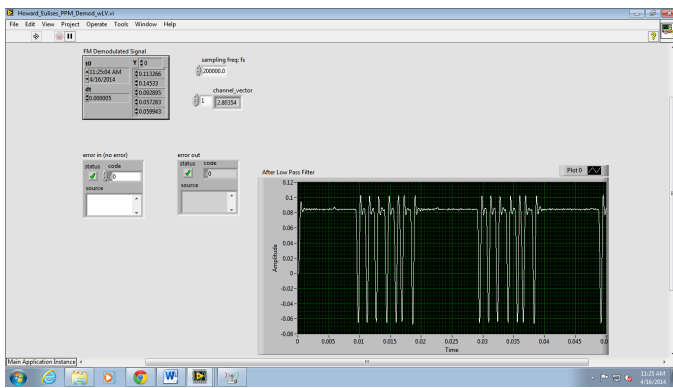


Fig. 10

Fig. 11 and Fig. 12 show the front panel of the top-level transmitter VI. The Figures also show how the frame changes for different sliders' values; this will give an intuitive idea of how the PPM signal is generated

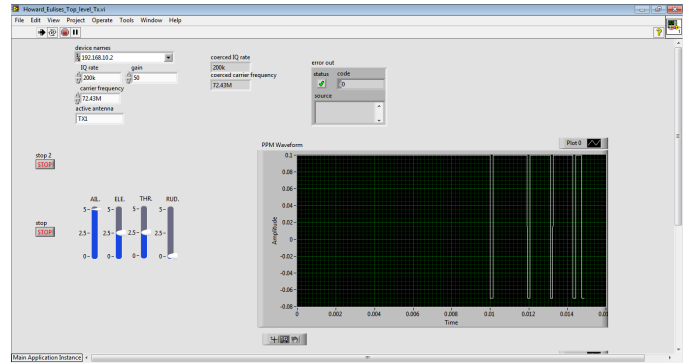


Fig. 11

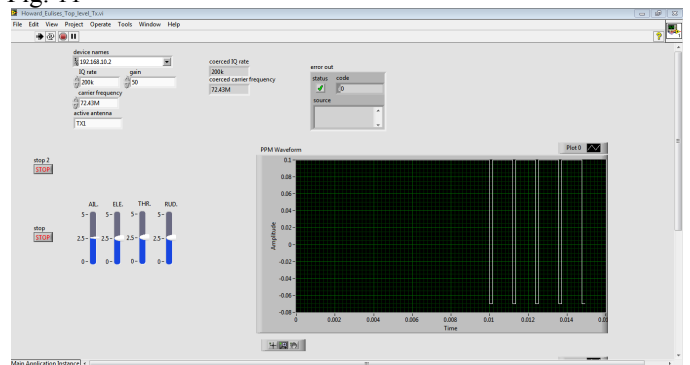


Fig. 12

Fig. 13 shows the PPM signal at the receiver for the transmitter implemented using USRP. We clearly can see the start pulse and the four consecutive channels. This signal is successfully decoded at the receiver side and can be use to control the servos' voltage levels.

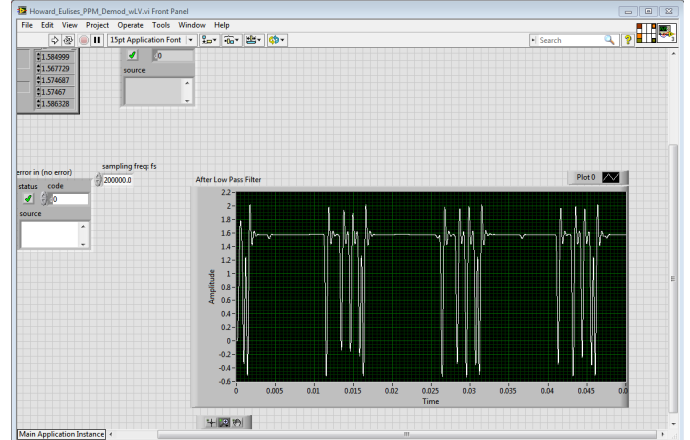


Fig. 13

V. CONCLUSION

This project has demonstrated the versatility of the USRP and its ability to implement a modulation/demodulation scheme to be use in RC aircrafts. Using the NI USRP and Labview we were able to implement a receiver/transmitter system. It will help others seeking to implement the communication system of RC Helicopter as a start point since the results in this paper can be use as a protocol for channel mapping, timing estimations and frame develop.

VI. REFERENCES

[1] Model Aircraft [**Online Source**] Available:
<http://adamone.rchomepage.com/guide1.htm>