Design and Development of a Multiple Sensor Vision Based Man-Machine Interface for an Unmanned Rescue Helicopter

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Copyright Statement

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Dedicated to my mother for always loving and tolerating me and in loving memory of my father whom I miss everyday

Abstract

Streaming videos from multiple cameras mounted on an unmanned aerial vehicle is desirable for applications such as rescue and search, remote sensing, aerial mapping and disaster response. In this research, the goal is to develop a real time system that can help in flying an unmanned aerial vehicle using vision and other telemetry sensors to estimate the states of vehicle. Using this system, a combined view from multiple cameras will be displayed on a single screen. Moreover, this is a GPS based vision system that will gather all the necessary telemetry information from onboard sensors. Further this telemetry sensor data is overlapped on the video, to be sent to the display screen on receiver end.

H.264 multi view video coding has been proposed to transmit all videos efficiently using LS 3000/5 long range audio video 2.4GHz transmitter. The video footage is digitally recorded at H.264 compression rate and processed. This scheme encodes video frames along with telemetry sensor data and then transmits each description using a single transmission path.VRX-24L Video and Audio receiver is used to receive and send flight data to Ground Control Station. Using such multiple vision sensors on an unmanned aerial vehicle is quite challenging since it adds more number of video data that has to be monitored simultaneously on a single screen. However, in multi-view videos, users will have a choice to watch any preferred viewpoint. This digital video recorder also has an advantage of permanent storage of video footage while maintaining excellent video quality for many useful applications. The developed system provides real time feedback from multiple cameras to control and maneuver an UV when it is operated beyond the visual range. The experimental testing is done from long range 15km LOS and data is transmitted with high SNR.

Keywords: DVR Digital Video Recorder, UV Unmanned Aerial Vehicle, LOS Line of Sight, SNR Signal-to-Noise ratio

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List of Abbreviations

UAV	Unmanned Aerial Vehicle
SWP	Size, Weight and Power
VSWR	Voltage Standing Wave Ratio
ERP	Effective Radiated Power
L_{FS}	Loss in Free Space
RMS	Root Mean Square
RF	Radio Frequency
LOS	Line of Site
FPV	First Person View
AHI	Artificial Horizon Indicator
MPH	Meter per Hour
RSSI	Received Signal Strength Indicator
OSD	Onscreen Display
CCD	Charge Coupled Device
PAL	Phase Alternating Line
NTSC	National TV System Committee

Chapter 1: Introduction

Pakistan is one of most seismically active country, since it lies in center of tectonic plates, so it has been vulnerable to deadly earthquakes and land sliding. In the past ten years alone, there had been seven major floods and one major earthquake in Pakistan, in which thousands of precious lives were lost. In the past few years, there had been major floods and one major earthquake in Pakistan, in which thousands of precious lives were lost. Whether the disaster hits in the form of earthquakes, land sliding and floods there is always a big number of affectees. In these situations, there is a nee d of advanced surveillance to detect human life so it can be rescued.

Despite the fact, that many government and non-government organizations are involved in disaster management and rescue operations, they however, do not possess adequate facilities and equipment to survey the disaster struck areas in order to rescue the precious lives. The surveillance of the disaster struck areas and to gather the survey data consume major part of the time and money leaving a small portion for the rescue operations. This delay in rescue operations fails to save many precious lives. To develop unmanned helicopters indigenously, which provide a very quick and low cost solution for the initial disaster surveying and a small scale relief package drops. In order to cover wider area through aerial surveillance, multiple vision sensors data along with telemetry sensors data is required, unmanned aerial vehicles cannot go beyond a few hundred meters of visible range without the help of a vision system. A vision system is based on electro-optical sensors involves a variety of areas like long range signal propagation, wireless video transmission, overlaying telemetry data on the video stream and telemetry data acquisition, and further post video processing for locating and identifying targets [1]. Each area of vision system involves its respective challenges in which multi-view videos signal transmission are more significant. These challenges become more critical in the environment in which they are being installed. RC UAV helicopters are highly vibrational platforms with limited payload capacity. So, weight, size and power (SWP) are the real constraints of the environment for multi-view videos transmission. SWP are inversely proportional to its endurance and hence, its area of work. Endurance, obviously, depends on fuel quantity, charging time and payload on a UAV. Optimization in fuel carrying capacity, battery timings and payload capacity are required to make such UAVs appropriate for the surveillance of disaster areas and dropping of small and instant relief package.

In all situations in which wide area has to be monitored a practice emerging in recent years consists in using Unmanned Aerial Vehicle (UAV). Though there is much advancement in fully autonomous control of UAV's, but usually a human pilot is in charge of controlling the aerial robot. Teleporating UAV's become a hard task when it comes to multiple visual feedbacks. In order to find an acceptable approach to the problem above these fundamental issues should be particularly taken into account i.e. quality and typology of the visual feedbacks.

A GPS based vision system is developed that gathers all the necessary telemetry information through onboard sensors and multiple video cameras then encrypt and send them back in form of one signal from long range to the Ground Control Station. The data is received, filtered and amplified and then decrypted and displayed on monitor.

To operate an UAV beyond visual range by a human operator an increase field of view is required, horizon and first person view (FPV) is utmost needed. The development of multi-view video technology has spurred the appearance of immersive video content such as three-dimensional video and free viewpoint video [2]. The superimposed GPS coordinates are extracted from the video stream and given to the GCS. A data logger is used onboard to take input from fully compatible sensors at the rate of 10 values per second. The On Screen Display hardware is used to communicate with the data logger and overlay the information on the video stream. Analog video stream comes from a high resolution camera used in the vision system [3].

There are many existing technologies of multiple video streaming on ground(wired) but it is rare to find a platform where multiple video sensors are integrated and transmitted wirelessly from an RC helicopter [4]. Sensor multi-tasking is employed to switch the field of view periodically with camera switcher between two (or more) target areas that are being monitored. World over, there were a few platforms where several cameras provide multiple video feedback simultaneously but are very expensive, larger in size and weight is more than payload capacity of RC helicopter [5]. Existing technologies for multi-view video transmission are Successive Motion Model [6] and Random Access Model [7]. Random Access model uses following three schemes: Request and Response, Simulcast and H.264/AVC MVC.

1.1 Purpose

The purpose here is to develop a vision system for an unmanned helicopter that provides multi-view video streaming simultaneously from long range distance of 15km from the ground control station. The vision system sends the required telemetry data to the ground station from a very long distance. The live video stream of the horizon enables the vehicle to be controlled remotely beyond the visible range. The wider and multi-view area surveillance of disaster struck areas with the help of UAV can provide guidance on where exactly rescue efforts are needed. . It can also gather the survey data very quickly and then this survey data can be shared with other rescue teams. It can guide the other rescuers for where their exactly efforts are needed. The relief package drop can save the lives of the disaster affectees. The relief package may contain high energy tablets, pure water, medicines and other eatables.

1.2 Benefits and Limitations of UAVs

UAVs are beneficial along with some limitations. One implicit benefit of UAVs is that they could assist in hard to reach area by providing surveillance of the disaster areas with multi-view coverage and in time approach. In comparison to the earthly relief programs, coverage, range and reach time of UAVs are significant assets, they quickly reach areas like battlefield, land sliding and floods. Despite the beneficial edge of using UAVs for disaster management, complications occurred in the past that limit unmanned air vehicle implementation on the projects. Major concern of UAVS is the high accidental rate which has been multiplied in the recent years and it is far above than that of manned aircrafts. The severe and disastrous weather can also confine the UAV's surveillance capabilities. The CBP Inspector General is of the view that operating a UAV is much costlier than operating a manned aircraft.

The work done so far in the field of UAVs is still in evolutionary stages. In US, from border security to the detection of potential nuclear reactor accidents are surveyed by the UAVs. These have also been used by other organizations at commercial level. The NASA-sponsored Environmental Research Aircraft and Sensor Technology (ERAST) program has made use of UAVs to monitor environmental pollution and measure ozone level. The Massachusetts

Institute of Technology (MIT) has involved in developing GPS and video camera based navigation systems for UAVs to identify and locate the toxic substances.

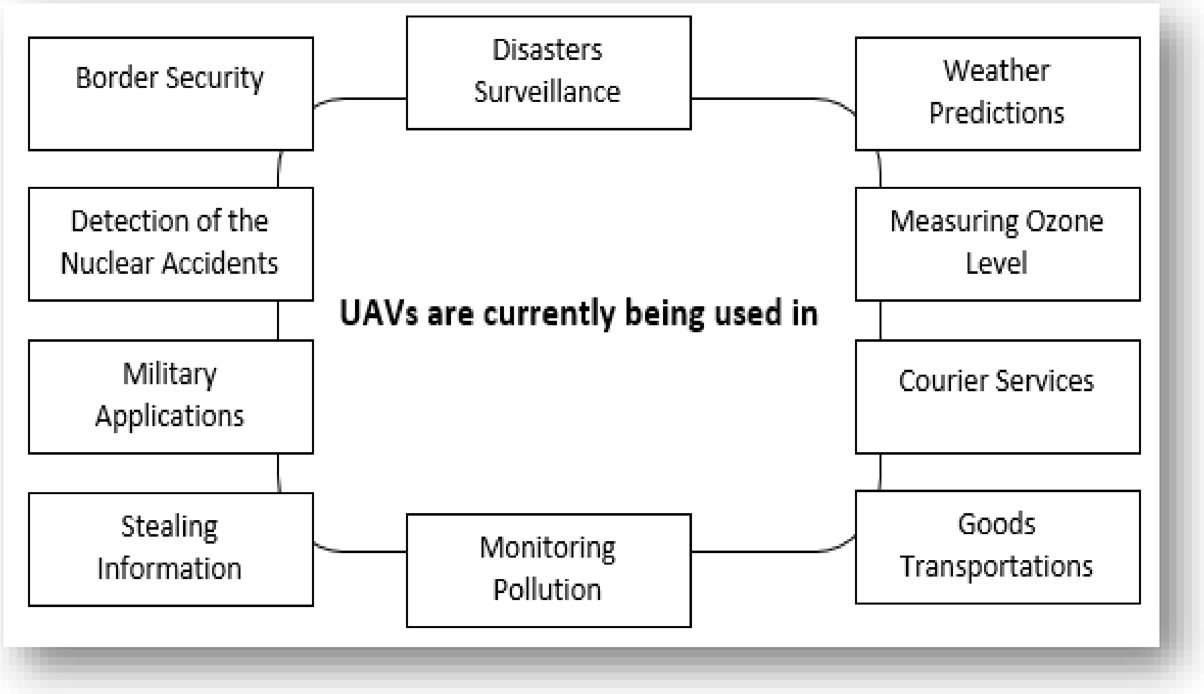

Figure 1.1: Areas of the Application of UAVs.

Shows the fields in which the helicopters, fixed wing air craft and quadcopters are being used. The developed vision system enables the UAV helicopter to work in disaster surveillance.

Pakistan, with the help of China, is developing unmanned aerial vehicles indigenously of about 500 Km range basically for the peaceful purposes but these vehicles are being upgraded to carry lethal weapons. Integrated Defense Systems (IDS) displayed its tactical fixed wing aircraft "Huma-1" in ideas 2006. Multiple remote sensing tasks can be performed by it. Its range is five hundred kilometers. Its payload capacity is 20Kg and it has a real time video transmission based vision system. Huma-1 has been flying since 2003 through a truck mounted ground station. Pakistan also has tactical and strategic versions of "Uqab" fixed wings unmanned aircrafts. Both versions have capabilities to undertake pre-programmed tasks up to 350Km range. They can be piloted and controlled by Ground Control Station. New missions can be adapted by the both UAVs during flight.

1.3 Overview

The first chapter provides a brief introduction about the development of the vision system and the purpose to develop the UAVs indigenously. The benefits and the limitations of UAVs are also discussed. There is an overview of the chapters and my contributions in the development of the multiple vision sensors system are written in this chapter. In the second chapter, the basic parameters that are involved in the development of the vision system are discussed i.e. LOS/NON-LOS signals propagation in free space and an estimation of the free space loss of the 15 kilometer wireless link. Then there is estimation of the antenna gain and the calculation of the effective radiated power and the field strength of the telemetry data transmission system. The third chapter focuses on the challenges in wireless signals transmission and the sources involved in the signals attenuation. Then accumulative system gains and losses are estimated which cause the attenuation in the signals propagation. The fourth chapter includes the development of the onboard system. There is a description about each component used in the development of the onboard vision system. The figures of each individual component and the installation instructions of each component are covered in this chapter. The fifth chapter discusses about the development of the ground control station and individual components used in the development of the ground control station. System design and the connection diagrams of the onboard system and ground control station are included in sixth chapter. The seventh chapter highlights the test results and their analysis. The eights chapter concludes the overall vision system. It includes the summary and features of multiple vision sensor long range system and recommendations for the future work. The reference section covers all the references. Three appendices are also added at the end of thesis which covers step by step procedure to develop the onboard vision system and the ground control station with the help of the actual pictures and the installation of the software and the important instructions to be followed.

1.4 Contributions of This Work

In this work, the following Journal Paper is submitted in the International Journal of Aero space engineering which is under review process on 10 august 2015.

- Fazal-e-Umer, Dr. Irtiza Ali Shah "*Estimation of the basic factors involve in the development of long range vision system of a UAV helicopter" 2015,* International Journal of Aerospace Engineering, Hindawi Publishing Corporation.

The following conference paper is published in the 1st Applied Mechanical Engineering Conference AMEC organized by the Society of Mechanical Engineers of Pakistan (SMEP).

- Fazal-e-Umer, Dr. Irtiza Ali Shah, Umair Iqbal, "*Design of Long Range Video and Telemetry Data Transmission System for a UAV Helicopter" 2014,* 1st Applied Mechanical Engineering Conference AMEC

The following research paper is submitted for the publication in 1st Multi-disciplinary Students Research Conference (MDSRC-2015) organized by University of Wah, Pakistan.

- Fazal-e-Umer, Dr. Irtiza Ali Shah, "Telemetry *Data Transmission System over a Live Video Stream for a Flood Relief Unmanned Helicopter" 2015,* 1st Multi-disciplinary Students Research Conference (MDSRC-2015).

Chapter 2: Basic Parameters Involved in Telemetry System

For the wireless systems operating at frequency below than 10 GHz, atmospheric precipitation and absorption become secondary considerations and can be neglected. For the frequency above 10 GHz, excessive signal attenuation due to rain fall and loss due to atmospheric effect become the major issues. This chapter covers the basic parameters used in the long range signal propagation. The vision system under consideration is based on a line-of-sight signals transmission.

2.1 LOS / Non-LOS Signals Propagation

In telemetry systems radio signals are important parameter need to address firstly. The radio signals of low frequencies (below 2 MHz) move along the curvature of the earth, due to diffraction of the waves from the atmospheric layers. The signals of up to 30 MHz frequencies reflect from the ionosphere layers. In both of the above cases the signals reach the receiver along multiple deflected straight lines.

Horizon determines an observer's maximum range of vision and thus of communication. On the other hand, LOS signal propagations imply a terrestrial connectivity. For the propagation of the LOS link, sufficient clearance is needed such that the emitted signal should fall within the beam width of the receiver's antenna. To enhance the range of the transmitted telemetry data up to 15 Km, it becomes very difficult to maintain the LOS link when the transmitting source is in motion. The simple model to calculate the altitude of the helicopter at 15 Km given by the formula [8];

$$D_{km} \approx 3.57. \sqrt{H(meters)} \quad (1)$$

Where

D= Horizon in kilometers

H= Height of the helicopter above the ground in meters

R= Radius of earth

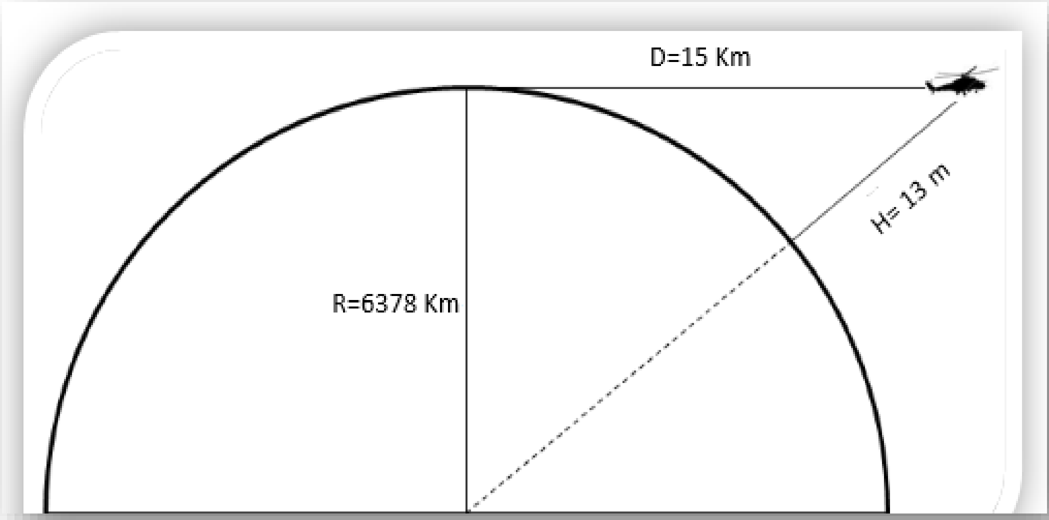

Figure 2.1: Illustration of the calculation of the Minimum Height of the Helicopter.

It shows the minimum height of the helicopter should be at least 13m above the ground when it goes 15 Km away from the GCS. R is the radius of the Earth.

Considering the atmospheric effects on the signal propagation and refractive effects of the atmospheric layer, signals are somewhat curvy so the maximum horizon distance is not equal to the geometric line of site distance. Hence for the actual service range, the altitude of helicopter at 15km is calculated by expression **(2)**;

$$D_{km} \approx 4.12.\ \sqrt{H(meters)} \quad \textbf{(2)}$$

Eq. (2) implies, in order to maintain **15 Km LOS range** for the receiving antenna on the ground station, the helicopter should be at least **13 meters above the surface** of the earth.

2.2 Free Space Loss in Signals Transmission

Path loss calculations are made in according to different terrains, atmosphere and weather conditions to approximate the distance to a helicopter can go safely. Free space path loss considers frequency and distance only.

Free space path loss is the most varying quantity in wireless signal propagation, it depends upon frequency of the signals, heights of the antennas of both transmitter and receiver and distance between.

$$L_{FS} = 32.45 + 20Log\ (D_{km}) + 20Log\ (f_{MHz}) \qquad (3)$$

The above expression gives the optimistic value of free space loss without taking into account any type of reflection and distortion [9]. For **2.4 GHz** frequency link, the above expression gives path loss of **123.5 dB** for **15 Km** long communication path.

2.3 Antenna Gain

Antenna gain is the ratio of the power required at the input of the antenna to the power supplied at the input to produce the same field strength in a given direction for the same distance. The positive value of the antenna gain increases the radiated power in a given direction and negative decibels shows the decrease in radiated power. There are different types of antennas used in project are Omni directional antenna, patch antenna an. Effective aperture of the receiving antenna is also contributing to the gain positively. One should not confuse directivity with gain of an antenna [10]. Directivity neglects the losses like polarization, dielectric, resistance, and VSWR (Voltage Standing Wave Ratio) losses. When the losses are very small, the directivity can be approximated with antenna gain.

Antenna gain with losses can be given as;

$$G = 4\pi.\eta.A/\lambda^2 \qquad (4)$$

Where;

η = Efficiency

A= Physical aperture area

λ = Wavelength

Solving equation (4) for the circular antenna gives the gain in logarithmic form as follows;

$$10 \, Log \, G = 20 \, Log \, (D/\lambda) + 10 \, Log \, (\eta) + 9.94 \, dB \quad (5)$$

Where

D= diameter of the circular (dish) antenna

2.4 Field Strength and The Effective Radiated Power

The power that is supplied to an isotropic antenna to have same field strength as is measured in direction of maximum antenna gain is effective radiated power [12].

The mean field strength is given by the equation;

$$E = 173\sqrt{\frac{P(kw)}{D(km)}} \quad (6)$$

Where

E = RMS field strength in volts/meter

P = Isotropic radiated power of transmitter in Watts

D = Distance in Km between the transmitter antenna (A) to the receiver antenna (B) in space.

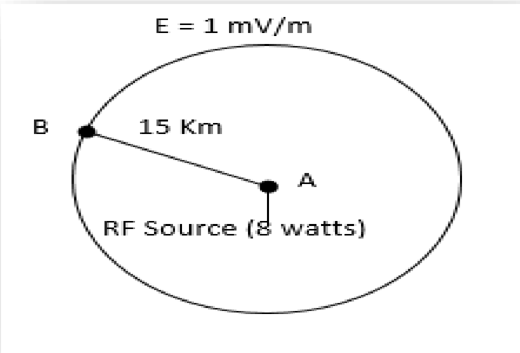

Figure 2.2: Illustration of the Calculation of the Field Strength.

The above figure shows point A is transmitter antenna and point B is receiver antenna and the link distance is 15Km. The vision system has RF source of 8 watts and E is the field strength calculated as 1mV/m for the vision system.

The field strength, for the linear polarized transmitter of 8 watts' power at a distance of 15 Km neglecting all other losses has calculated from the above expression (6) as 1 mV/m. The effective radiated power can also be estimated as;

Power of the transmitter = 5 watts

Duplexing loss of the transmitter = 3 dB

Power reaching the feed line = 2.5 watts

Loss of the feed line = 1 dB

Power reaching the antenna = 1.98 watts

Gain of the transmitter antenna = 6 dBi

ERP = 8 watt.

The power of transmitter used in the said project is 5 watts. It has duplexing loss of 3 dB means 2.5 watts' power is reaching the feed line input. Taking into consideration the 1 dB loss of feed line means 1.98 watts of power is reaching the antenna input. If the antenna has gain of 6 dB, the mean ERP of the transmitter is 8 watt.

Chapter 3: Factors Affecting the Vision System

Long range multiple vision sensors system involves different types of areas which can be affected by the respective challenges. Long range wireless communication is an area of signals propagation and maintenance of the long range LOS link with negligible time delay. It involves the challenges like attenuation produced by multiple sources, signal fading, and atmospheric effect on propagation, diffraction effects and interference. Similarly, wireless transmission has to face the problems like transmission losses, strict timing constraints, high bandwidth demand, and system noise and data compression error. System mobility and GPS based antenna tracking are kind of situational problems which can lead to sever accidents.

3.1 Challenges in Wireless Signal Communication

There are different challenges involve in the long range signal communication. The major effect of these challenges is the decrease in the signal strength at the receiving end than the desired value or no signals for limited time or completely absence of the signals. It occurs mainly due to increase in either the distance of the wireless link or the frequency of signal. Signal fading is the reduction in signal power due to various factors including line of site interference, Fresnel zone interference, multiple path reception, RF interference, and weather condition. Similarly, shadowing is another effect in which the received signal power fluctuates due to object obstructing the propagation path between transmitter and receiver. Our system works on LOS based propagation where shadowing has the least effect on the signal. However, the onboard system is a mobile source of the signal propagation, therefore the chances of the signal shadowing cannot be neglected.

3.1.1 Sources of Signal Attenuation

The major reasons of the attenuation are both signal frequency and range between the end points of the medium. These end up in reducing the amount of signal power. With the increase in range, the attenuation increases. Smaller frequencies have lower attenuation. Defective parts used in the system can also contribute to the signal attenuation.

3.1.2 Estimation of Accumulative Attenuation

Every meter increase in the link budget attenuates the signal strength and attenuation is also directly proportional to the frequency. It is just opposite of signal amplification. Attenuation is usually measured in dB/Km. Attenuation of the microwave signals is directly proportional to the selected frequency of the system and the link length.

$$\textit{Attenuation} \propto \textit{Frequency}$$

$$\textit{Attenuation} \propto \textit{Link length} \quad (7)$$

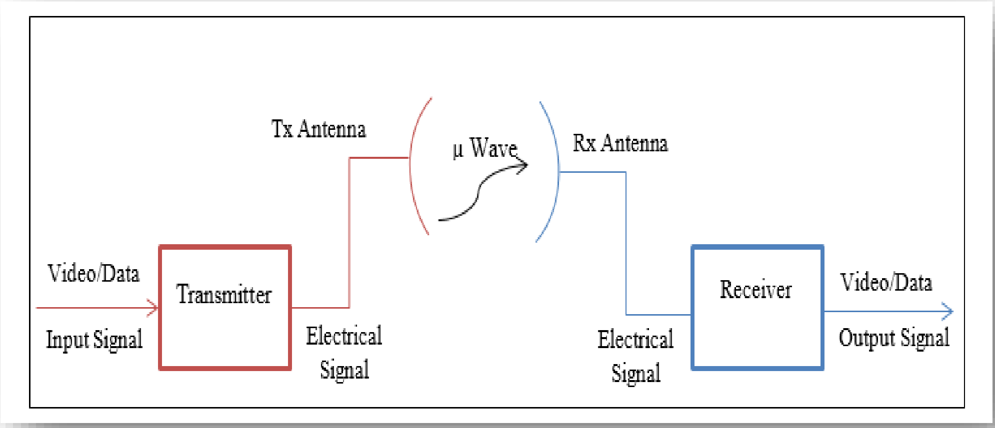

Figure 3.1: Block Diagram of a Video Transmission System.

Figure shows a transmitter takes video signal as input and converts it to an electrical signal and the transmitter antenna transduces the electrical signal into the micro wave signal. The micro wave signal travels with the speed of light and hits the receiver antenna. The receiver antenna transduces it back to electrical signal. The receiver reconstructs the video signal.

It is obvious that there is some attenuation in transmitter (At) and receiver (Ar) blocks but the major portion of signal loss occurs in microwave link (LFS) [8]. The microwave signals propagation formula is given as;

$$Pr = Pt + Gt + Gr + Ga - L_{FS} - Lt - Lr - Lc \quad (8)$$

Where;

Pr = Received Power (dBm) =?

Pt = Power of the transmitter = 5 watts

Gt = Gain of the Transmitter antenna = 6 dBi

Lt = Transmitter loss = 3 dB

L_{FS} = Free Space Path Loss = 123 dB

Lc = Connections losses = 6 dB

Gr = Gain of the Receiver antenna = 14 dBi

Ga = Gain of the amplifier = 18 dBi

Lr = Receiver loss = 6 dB

d = Distance = 15 Km

f = Frequency = 2400 MHz

The term L_{FS} is the main constituent of the attenuation of the microwave signal and Ga is the main contribution in system gain.

For 10 km Long link budget calculations are;

$$L_{FS}\ (dB) = 20Log\ (f\ MHz) + 20Log\ (d\ Km) + 32.45 \qquad (9)$$

$$L_{FS}\ (dB) = 32.45 + 20\ Log\ (2400) + 20Log\ (15)$$

$$= 32.45 + 67.6 + 23.5$$

$$L_{FS}\ (dB) = 123.5\ dB$$

So, the eq. (8) becomes,

$$Pr = Pt + Gt + Gr + Ga - 123.5 - Lt - Lr - Lc \qquad (10)$$

The received signal power calculated is -63 dBm which is above the sensitivity threshold of the receiver which is -92 dBm, it is sufficient power to establish a wireless link.

Chapter 4: Development of Onboard System

The experimental setup of this work focuses on a Video Stream Generation Unit, Data Logging Unit, Flight Sensor Unit, Multiplexing Unit and a Transmission unit. The system design is chosen so that it can support events like video surveillance, agriculture, environment inspection and other contexts from utilization of multiple cameras and other sensors. Hardware is designed in such a way that image processing and flight control calculations are performed on Onboard System teleported by a Ground Control Station.

The onboard vision system comprises of multiple video cameras, sensors information unit, data logging unit, on screen displays, video transmitter, video multiplexer and a power unit. Still images from two HD Go Pro Hero3 cameras are recorded and sent to On Screen Display. Sensors data is logged into Eagle Tree eLogger which is then communicates with On Screen Display. On Screen Display then overlaid all the telemetry sensor data on to video stream for further processing. Videos are then further processed through a video multiplexer at H.264 video compression standard, and then encrypted videos are transmitted into air with the help of a transmitter and transmitter high gain antenna.

All the onboard system units are selected which are compact in size and light weight and power efficient. The heaviest among them all is video transmission unit that weighs 270g and Power unit that weighs 260g. Rest of the equipment used in onboard vision system weighs 200g approximately. So, the overall vision system is very compact in size, lightweight and power efficient. It is a complete system and installed on AF25B helicopter and it can be installed in any unmanned air vehicle.

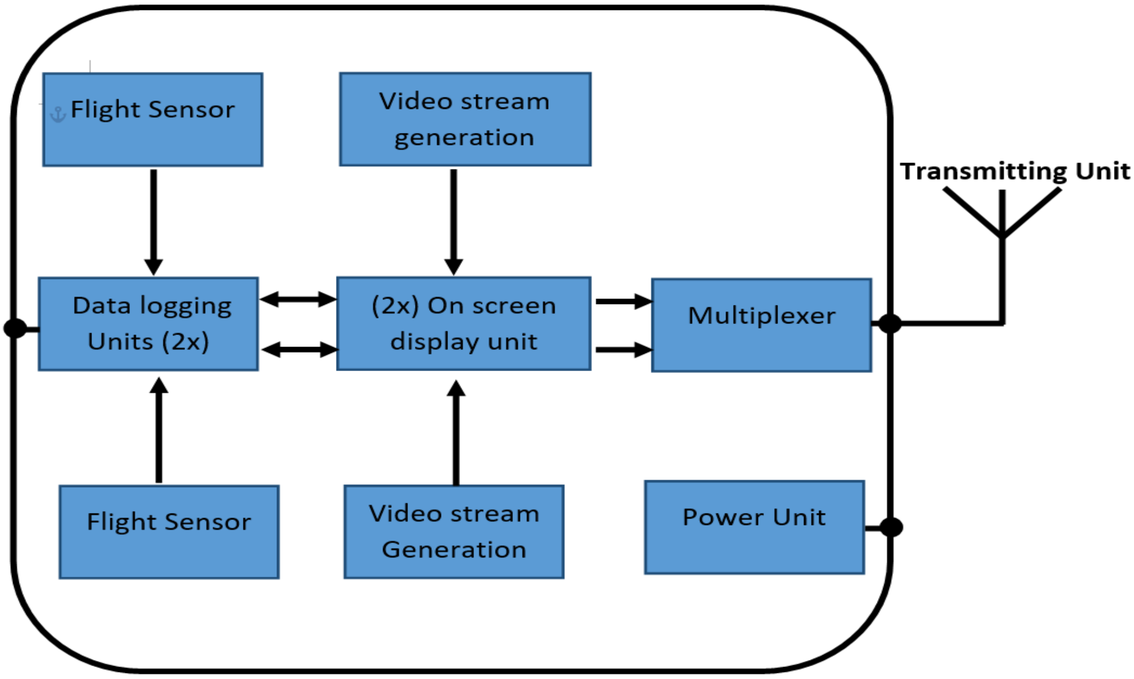

Figure 4.1: Block Diagram of the Onboard Vision System.

The above figure shows the block diagram of the onboard system in which the Flight Sensors Unit (contains all the sensors) gives output to the Data Logging Unit. The Data Logging unit communicates with the On Screen Display Unit. The On Screen Display Units take a live videos stream generated as input by the two Video Stream Generation Unit and overlays all the telemetry information on the videos and send it to the Video Multiplexing Unit. Multiplexing Unit synchronize videos with a code. The Transmission Unit transmits the video signal to air to be received by GCS. Power unit powers up all the onboard vision system.

4.1 Flight Sensors Unit

This unit contains all the sensors used in the vision system i.e. air speed sensor, altimeter, accelerometer, GPS sensor, Optical RPM sensor, temperature sensor and stabilization sensor.

4.1.1 Air Speed Sensor

It provides the measurement of the speed of air by measuring the pressure difference between a static sensor not in the air stream and the sensor in air stream through the pitot-tube. It measures airspeed from approximately 2MPH to 350MPH

The live value of the air speed can be logged in the data logger at the rate of 10 values per sec and then transmitted with the video stream to the ground control station. The air speed information extracted from the video stream is displayed on monitor.

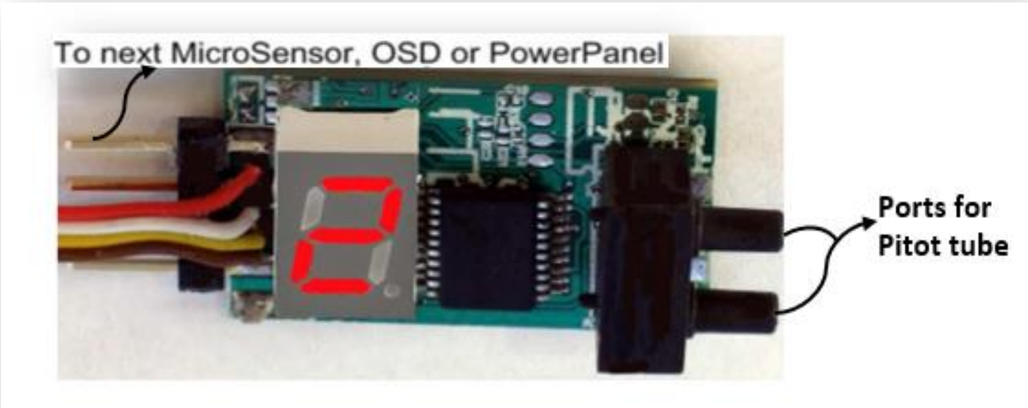

Figure 4.2: Port Description of the Eagle Tree Air Speed Micro Sensor[12].

This figure shows air speed sensor used in the vision system for the measurement of the air speed of the helicopter. Two black ports are connected to the Pitot tube through rubber tubing. The pins are used to connect the next micro sensor, OSD or power panel.

4.1.2 Altimeter

It gives the approximate value of the altitude of the onboard system. By using Barometric formula (z=cT log (Po/P)) the relative pressure difference between atmospheric pressures at sea level and at specific altitude. The data logger logs 10 values of altitude in a second and the OSD overlays the altitude information on the video stream [13].

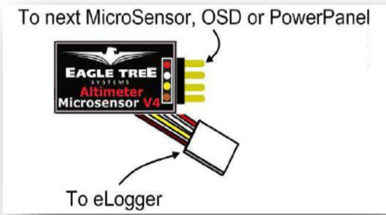

Figure 4.3: Ports description of the Eagle Tree Altimeter Micro sensor V4[13].

The pins port can be used for the next Micro Sensor, OSD or Power Panel and the plug port goes to the eLogger.

The micro sensor Altimeter can be mounted anywhere in the helicopter. To read the LED displaying the maximum altitude in digital numbers a small hole can be cut at the mounting location of the sensor. It should not be mounted near surfaces where temperature changes rapidly during the flight.

4.1.3 Accelerometer (G-Sensor)

This micro sensor has three axis accelerometer which constantly measures the change in acceleration along X-axis, Y-axis and Z-axis. It measures in the unit 'g' which is acceleration of gravity (9.81m/s2). The maximum measurement it can give is +/- 38g. The acceleration values in all axes can be displayed and graphed. The data logger takes 10 values per second of the accelerations from the sensor. It has built in 7- segment LED to display the maximum values achieved by the sensor in each axes one by one. It has nonvolatile memory feature, so when power is removed the stored values must be are retained.

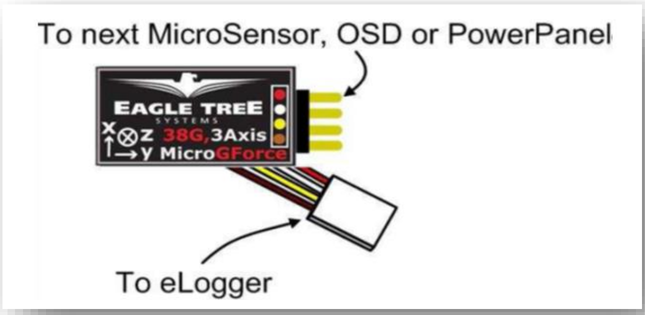

Figure 4.4: Port Description of the Eagle Tree Micro GForce-38 Sensor[14].

It shows the accelerometer used to measure acceleration in X, Y and Z coordinates simultaneously. The pins port can be used for the next Micro Sensor, OSD or Power Panel and the plug port goes to the eLogger.

The micro sensor can be mounted on a horizontal surface of the helicopter in such a way that the "Y-axis" arrow points the direction of the travel. The "Z-axis" arrow points the direction towards the sky. The "X-axis" is horizontally perpendicular to heading of the helicopter. With this mounting configuration, the forward and up directions show the positive values of the acceleration and backward and down directions indicate the negative values of the acceleration.

4.1.4 GPS Sensor

Global Positioning System provides the most critical information about position and speed of the onboard system. It gives the accurate value of position and velocity anywhere in the world depending upon the accuracy of the GPS sensor used. The GPS coordinates are also used to determine the “Distance to Home” and following the waypoints which are given in the form of Longitude, Latitude and Altitude.

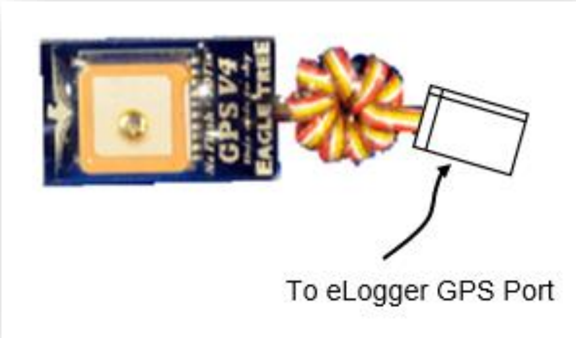

Figure 4.5: Port Description of the Eagle Tree GPS V4 Module[15].

It shows the GPS module used in the Vision System for the GPS navigation. The plug goes to the eLogger GPS port.

The upper side of the sensor (with the label) while installing on UAV helicopters is exposed to the sky. After powering up the helicopter place the idle side up under the sky to automatically receive the GPS signals from the satellite [9]. It is usually not recommended to mount it inside the vehicle but for a very thin surface vehicle it can be mounted inside. Due to its own built-in antenna to receive the GPS signals, it must be mounted away as it can be from the other on-board antennas.

4.1.5 Optical RPM Sensor

The Optical RPM sensor has built-in IR emitter source and a detector to detect and counts the light pulses received from the black and white surface of the rotating object. This contactless type RPM measuring sensor used logs the rotating speed of the main rotor shaft of the helicopter

The optical RPM sensor can be mounted in such a way that it is facing the main rotor shaft of the helicopter. The shaft should be painted black and white in halves. It must not be shiny or reflective. Its face should be mounted so that it is about 1-4 mm from the spinning object. In most cases, closer is better. The RPM sensor should be firmly fastened so it could not be displaced with the vibrations.

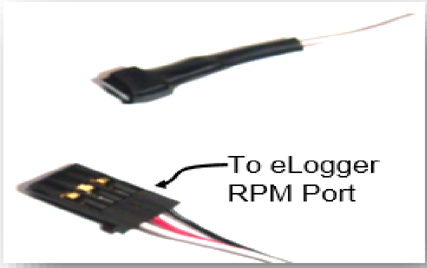

Figure 4.6: Port Description of the Eagle Tree OPT-RPM Sensor[16].

It shows the contactless RPM sensor used in the Vision System. The plug directly goes to the eLogger RPM Port.

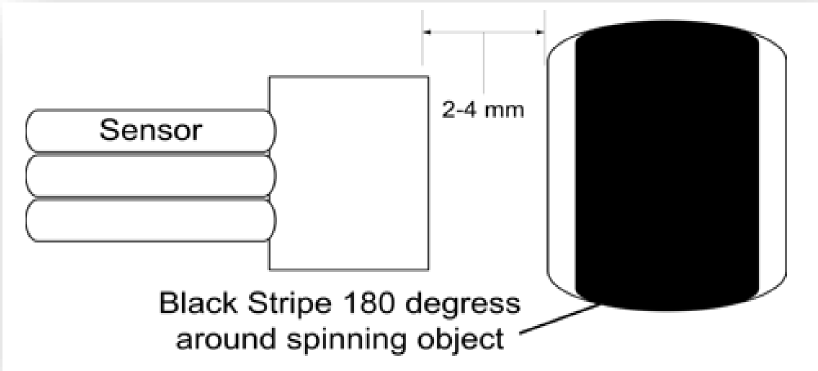

Figure 4.7: Installation Guide for the Optical RPM Sensor[17].

It shows the sensor should not be more than 4 mm away from the spinning shaft of the helicopter and the shaft should be striped in halves non reflective black and white patches.

4.1.6 Temperature Sensor

Temperature sensor records the temperature variation. More than one temperature sensor is used at different places like to measure the temperature variation at engine exhaust, to log the variation in temperature at video transmitter and the temperature variation of the environment.

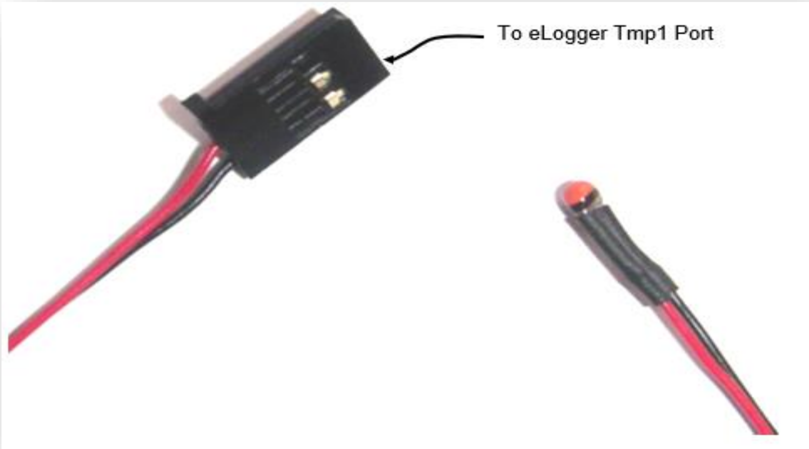

Figure 4.8: Port Description of the Eagle Tree TEMP-Micro Sensor [18].

It shows the temperature sensor used in the Vision System to measure the temperature variations of the specific part of the onboard system. The plug directly goes to the eLogger TMP1, 2 or 3 port. Three different temperature sensors can also be used.

4.1.7 Stabilization Sensor (Guardian)

Three-axis gyroscope provides full featured inertial stabilization by giving an artificial horizon indicator on the live video stream which helps to perform aerobatic maneuvering and immediately return to stabilized position.

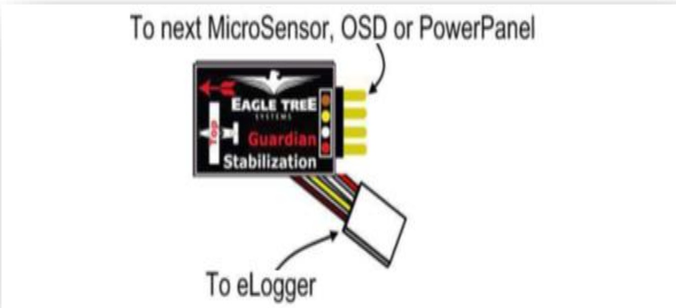

Figure 4.9: Port Description of the Eagle Tree Guardian Stabilization Expander Sensor[19]**.**

It shows the 3 axis gyroscope used the in the Vision System. It is used to stabilize the helicopter and show Artificial Horizon Indicator in the video. The pins port can be used for the next Micro Sensor, OSD or Power Panel and the plug port goes to the eLogger.

To mount the Guardian micro sensor in helicopter, the label side of the sensor should be faced upward to the sky. Care should be taken about orientation of sensor and the front of the sensor should be pointing the direction of flight. It should be firmly installed in the helicopter on a horizontal surface with comparatively less vibrations.

4.2 Data Logging Unit

Data logger the black box of helicopter records data from sensors with adjustable logging rate. It logs current, voltage and data from all other available sensors for about 4 hours at 10 Hz logging rate and stores data to built-in permanent memory. All flight data can be retrieved via USB port and then graphed the whole flight. It has full support for English and Metric units.

Figure 4.10: Eagle Tree eLogger V4 module[20].

It shows the data logger used in the Vision System to log all the telemetry information coming from sensors. The data logger is available in dean connectors and in leads also.

The board system can be programmed, in case of failure of the communication system it can follow the way points and return to home position. The GPS sensor used in the vision system can receive UTC time from the satellite and use to calculate the total length of the operation [14]. The GPS coordinates can be logged in a Google Earth's compatible file in live mode. So the onboard system can be traced from the Google Earth's software.

The data logger can be mounted anywhere in the helicopter to log all flight data is logged to the eLogger. The battery pack is connected to the leads marked “Batt”. The engine based helicopter has no need to use the leads marked “ESC”. The temperature sensors, RPM sensor, GPS sensor, and OSD are directly connected to the eLogger.

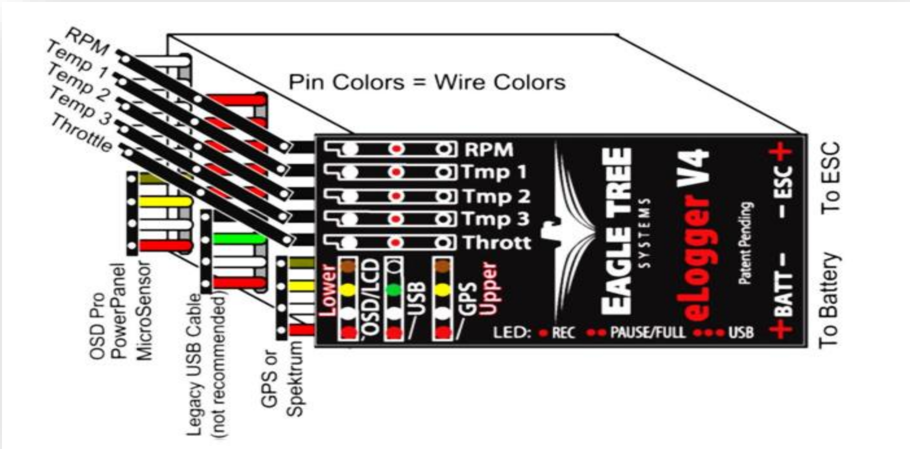

Figure 4.11: Pin Configuration of the Eagle Tree Data Logger V4**.** The figure is taken from the manual of the eLogger [21].

It shows pin configuration of the eLogger. The RPM, Temp1, 2, 3 and throttle ports are 3 pin, with color code White, Red and Black, should be used vertically and the OSD, USB, and GPS ports are 4 pins, with color code Brown, Yellow, White and Red, should be used horizontally. In electric helicopter, port" ESC" is used for the main motor and the port "BATT" is for the battery.

In order to configure the flight path, the OSD settings and to update the firmware of the other sensors it has a USB port to be connected with the computer. It has nonvolatile memory for keeping the flight information safe. The USB port can also be used to retrieve all flight data after the flight.

4.3 Onscreen Display Unit(OSD)

On Screen Display communicates in real time with the data logger and takes the sensors information. Live analog video stream from the cameras is input to OSD. The OSD overlaid the flight sensors information on the video stream in the form of numeric values, artificial horizon bar, home indicator, direction of travel, battery status, speed and altitude ladders. It also overlay the positions of throttle, aileron and rudder. With the help of Gyroscope and the GPS information, OSD can take the control of the helicopter and make it follow the way points and return to home when engaged the RTH function or in case of failure of the communication system. OSD output goes to DVR/Multiplexer. It is synchronized with data logging rate of the eLogger.

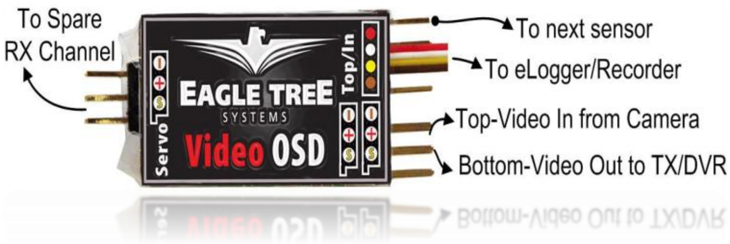

Figure 4.12: Pins Description of the Eagle Tree OSD (On Screen Display) Pro module. The picture is taken from the manual of the OSD [22].

In this figure, the OSD is used in the Vision System to overlay the telemetry information from sensors and eLogger on the video Stream. The Micro Sensor port, eLogger, Video In, and Video Out ports are shown here. The Rx Channel I/O ports are for Radio receiver.

The OSD has "Video In" and "Video Out" ports in order to route the video stream into and out of the OSD. The servos of the helicopter can also be routed through the OSD to use the auto pilot function of the helicopter. The other sensors such as Air speed sensor, Altimeter, Guardian stabilizer and Accelerometer are directly connected with the OSD.

4.4 Video Stream Generation

A high resolution multiple video cameras GoPro Hero3 with wide dynamic range is used to generate the aerial view of the horizon. The video stream generated by the camera can be routed from the OSD to get the information overlaid and is then multiplexed by video multiplexer and then sent to video transmitter.

Figure 17: GoPro Hero 3 Video Camera. Shows the camera used in the Vision System to generate the live video stream. It is wide angle self-powered video camera [23].

4.5 Video Multiplexing Unit

Multiplexer is a device that selects one of several analog or digital input signals and forwards the selected input into a single line. These are mainly used to increase the amount of data that can be sent over the network within a certain amount of time and bandwidth.

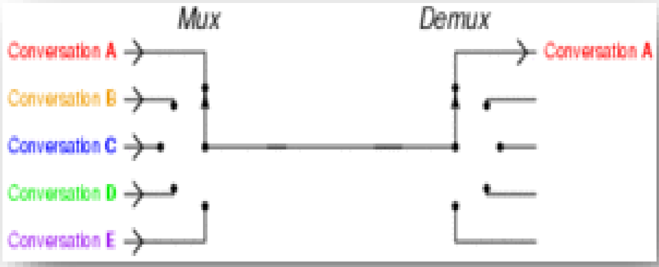

Figure 4.13: The basic function of a multiplexer,

The above figure shows multiple inputs into a single data stream. On the receiving side, a de-multiplexer splits the single data stream into the original multiple signals.

For Multiplexing the video feeds from multiple cameras. Camera signals are synchronized with a code.JPEG is used. Digitized video is compressed at H.264 Compression standard .SPS (Sequence Parameter Set) is set to 30fps (frames per second)

4.6 Video Transmission Unit

A very compact in size (LX-3000/5), weighs 350g, powerful video transmitter is used to transmit the encrypted video at 2.4 GHz frequency. For range enhancement of the transmitter, RF power of the transmitter is increased to 5W and high gain antennas on both transmitting and receiving ends are used. It has eight selectable built-in frequency channels to select frequency from 2.3 GHz to 2.5 GHz. It has video/audio in ports and it can support the power source from 9-16 V DC. The OSD video and audio out ports come directly in the video/audio in ports.

Though the unit is provided with the built-in heat sink within the box but it should not be covered with any plastic material. Let the air keep it cool.

The gain of the transmitting Omni-directional antenna is 6.5 dBi. It has the following specifications;

POWER	**Max. 5W**
RANGE	Over 15 km from the Air
CURRENT CONSUMPTION	3A / 12V
WEIGHT:	350 grams
Dimensions	6" X 3 " X2"
Modulation	WFM
Antenna Gain	6 dBi

4.7 On Board Power Unit

Two 2-cells LiFe batteries of 6.6 V (3000 mAh) are serially connected to power up the complete onboard vision system. The total time of flight with this power system is extended to 90 minutes. The weight of the complete power pack is about 200g. The batteries must be fully recharged before going to test or flight.

Chapter 5: Development of Ground Control Station

The Ground Control Station has the basic setup of Video Receiving System, Video Decoding and Information Extraction System, Antenna Tracking System, Graphing and Displaying system.

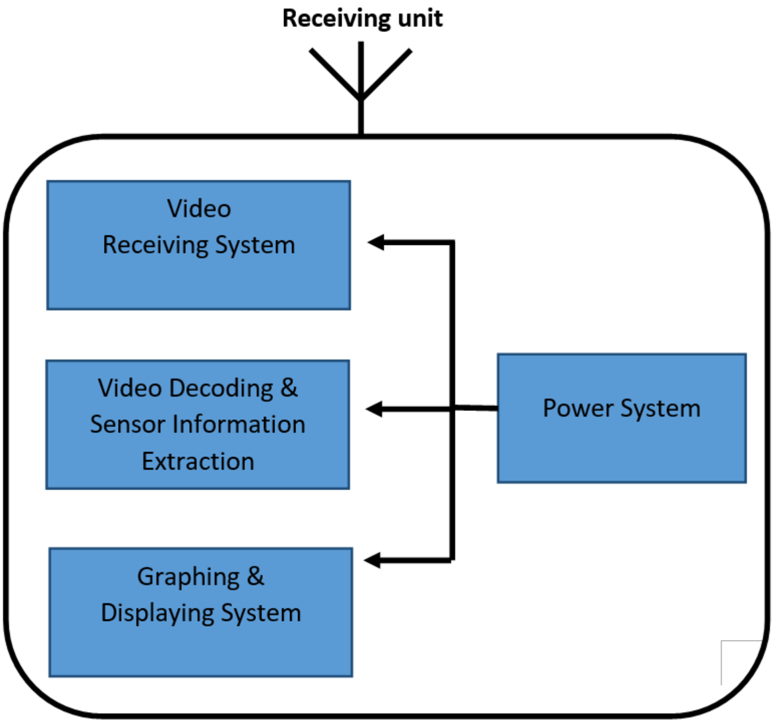

Figure 5.1: Block Diagram of the Ground Control Station.

It shows the Video Receiving system in which the receiver antenna mounted on a Pan Tilt Kit receives the video signal, amplify it and send it to the video receiver. The receiver sends it to the Video Decoding and Information Extraction System. It extracts the telemetry information the sends the video signal to the Graphing and Displaying System. The GPS coordinates are sent to the Antenna Tracking System. Different power sources are there to power up the whole ground control station.

5.1 Video Receiving System

This system has three main components. One is high gain directional antenna that is directly exposed the microwave signals coming from the transmitter. Second component is the amplifier. It amplifies the signal after transducing by the antenna. The gain of the amplifier used is 18dBi. The third and the main component is highly sensitive receiver with sensitivity -92dBm.

5.1.1 High Gain Receiver's Antenna

The receiver's antenna PN-24S has a major role in increasing the range of the UAV helicopter. In receiving system, high gain directional antenna has 14 dBi gain in 2400-2500 MHz frequency range. The antenna has 30-degree beam width in both horizontal and vertical axes.

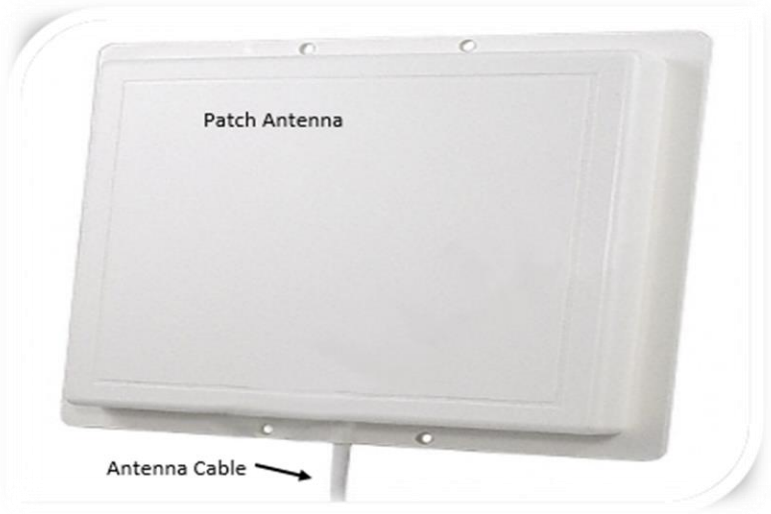

Figure 5.2: High Gain Patch Antenna (PN-24).

The figure shows the high gain patch antenna used in the Vision system to receive the video signal. It has gain of 14 dBi.

The height of the receiver's antenna contributes much in the range of the link. In order to avoid interference, shadowing and signal fading the antenna should be above all the nearby buildings. The higher the antenna, the better the reception of the signals and hence, the better quality of the video images.

5.1.2 Amplifier

It is the most efficient amplifier of 2.4 GHz range has low noise and high gain. Antenna gives direct input to the amplifier, it enhances the signals and passes on to the eagle eyed FPV station further actions. It has gain of 18 dB in 2.4 GHz band. It can be separately powered up from an external 9V battery.

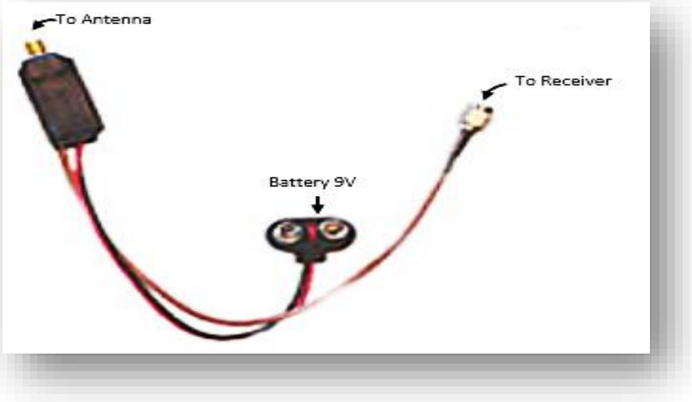

Figure 5.3: Ports Description of the Amplifier AMP-18/24M[24].

It shows the 2.4 GHz amplifier has gain of 18 dBi. It is used in the Vision System to amplify the received video signals.

5.1.3 Video Receiver

VRX-24LTM is a very powerful 2.4 GHz Audio/Video receiver used in our project. It is perfectly compatible with the transmitter. It has a built-in sound and encryption demodulator as well. The power supply required is 9-12 V/200 mA. It has an SMA type antenna connector. This receiver has 8 selectable channels. Video out is 1 V / 75 ohm that is a standard for all TV systems. It has 8 selectable frequency channels from 2.3 GHz to 2.5GHz. The frequency used for the transmitter must be the used for the receiver. It has the following specifications:

Sensitivity:	**-92 dBm**
Video Format:	PAL, NTSC
Current Consumption:	280 mA / 9 V
Impedance:	50 ohms
Video Impedance:	75 ohms
Video distortion:	3%
Modulation	WFM

5.2 Video Decoding and Information Extraction System

An OSD compatible FPV station is used to decrypt the amplified video signals. Telemetry information from video signal are decoded and sent to graphing and displaying system for live mode display of the flight data in numerical and graphical display on the laptop screen. The video signal is displayed on a separate/same laptop screen.

EagleEyes FPV station has the following built-in functions;

- *Diversity Controller*

EagleEyes FPV station supports multiple receiver. When two receivers are connected with FPV station, it automatically picks the better signal at any given time, which can greatly reduce video fades and improve connectivity.

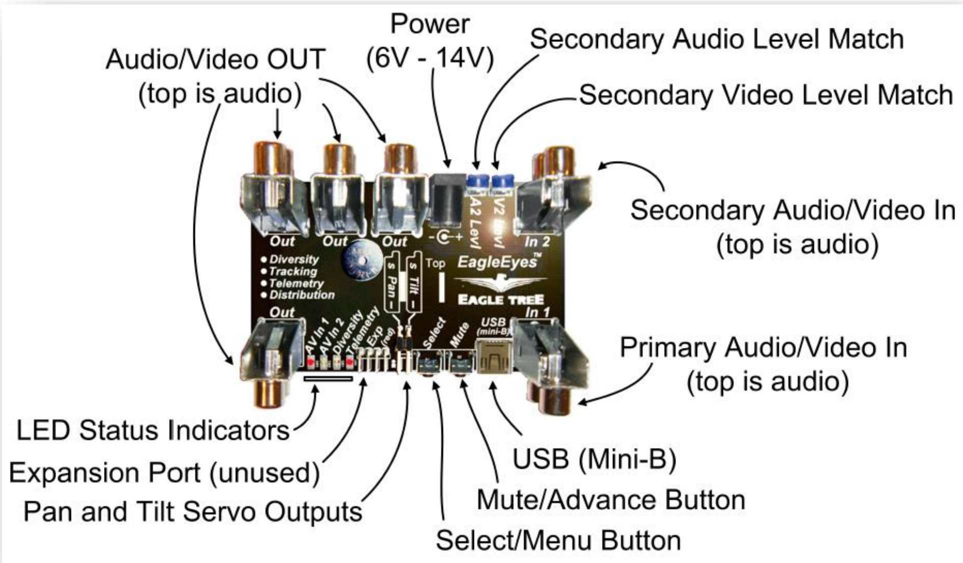

Figure 5.4: Ports Description of the Eagle Eyes FPV Station (EE-FPV-GND Module).

It is used to decode the video signal and extract the telemetry information. It has 2 "Audio / Video In" Ports and 4 "" Audio / Video Out" Ports. It has "Pan and Tilt Servo Output Ports", a "USB Port" and push buttons for menu selections. It works from 6V -14V DC. The Picture is taken from the manual of the Eagle Eyes FPV station. Source: [25].

- *Antennal Tracking*

EagleEyes FPV station has built in ports for pan-tilt kit and has regulator to support large servos. It gives the GPS coordinates to the pan-tilt kit to track down the position of the on-board system. It is fully compatible with OSD airborne system.

- *Telemetry Data Extraction*

EagleEyes FPV station when coupled with our OSD Pro airborne system, all Eagle Tree data (not just GPS position) [10] are transmitted to the laptop, via the video transmitter and the FPV station's USB port. The flight can then be graphed and displayed, or visualized (either in real time or after flight session) with Google Earth.

- *Multiple A/V Ports*

EagleEyes FPV station has two A/V input ports and four output ports. The input ports are for connecting the multiple receivers and the output ports are for the multiple monitor screens.

- *Alarms*

EagleEyes FPV station has programmable low voltage alarm and loss of telemetry alarm. When the battery of the station is below the set voltage, it gives two beep alarm. When the telemetry data is not receiving, four beeps alarm is triggered.

5.3 Graphing and Displaying System

Data recorder software is used to display and log the live mode information. The live video stream is actually used to control and fly the helicopter beyond visual range. It has all the important information written on it. A log file of GPS coordinates is created, Google Earth uses this file to track down the helicopter in a live mode and marks its path. At any time, the location of helicopter can be seen on the Google Earth [11].

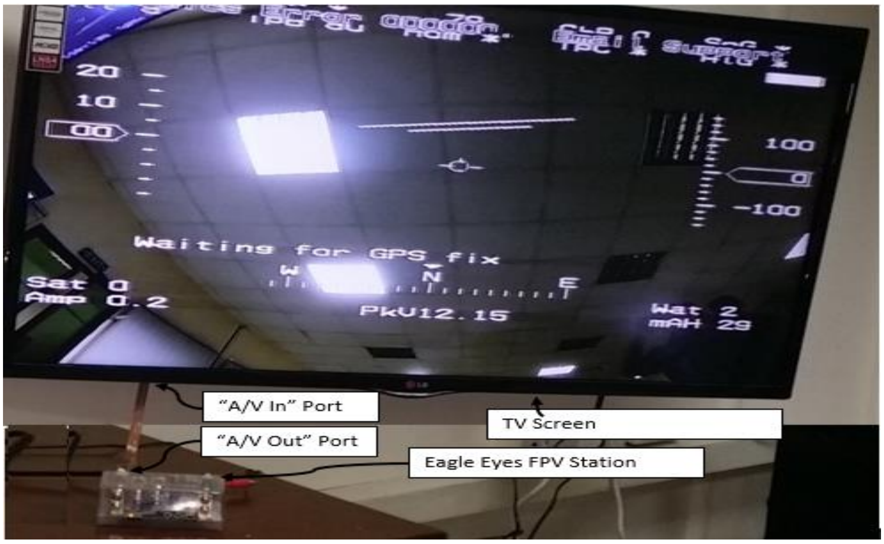

Figure 5.5: The Laptop Used in the Vision System. A plasma TV screen used for displaying videos and telemetry data in digital form.

Chapter 6: System Design

The following connection diagrams and instructions must be followed to get the precise operation. Though the most of the components used are reverse polarity protected, yet it should be made sure the connection are made according to the connection diagrams in order to get the desired operation.

6.1 System Design of the On-Board Vision System

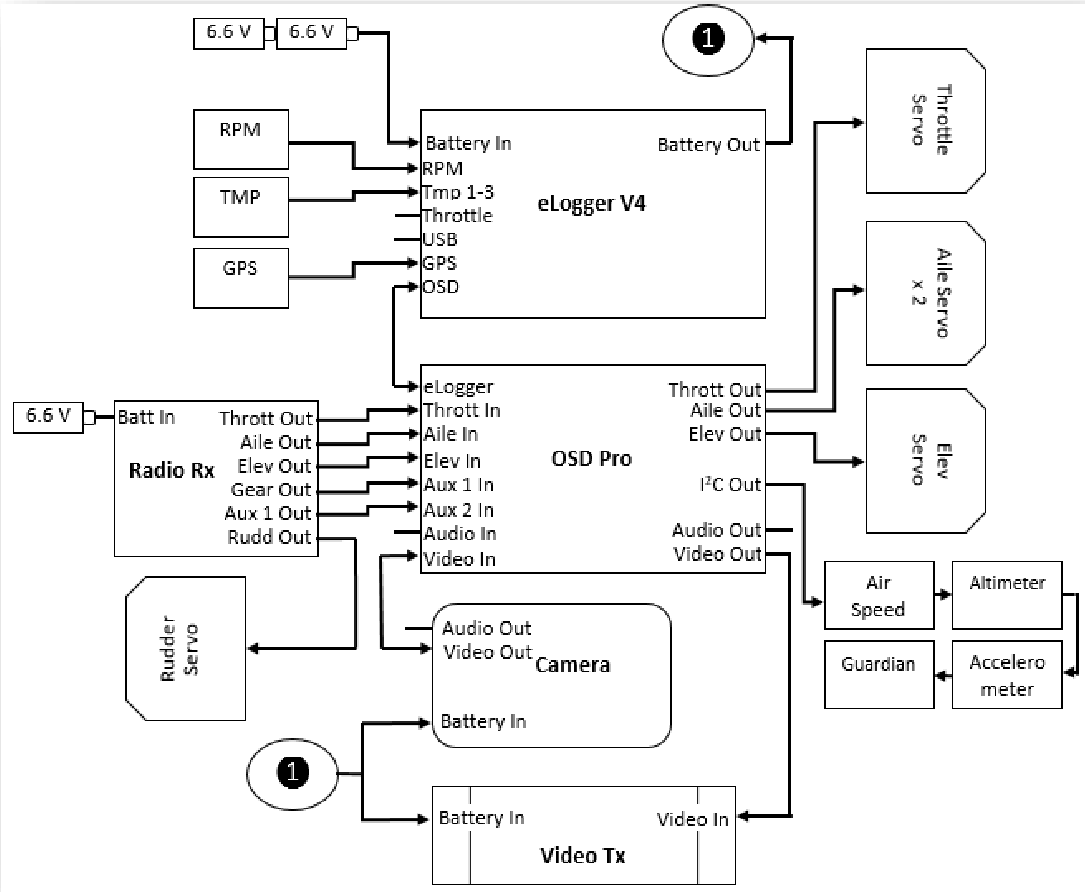

Figure 6.1: Connection Diagram of the Onboard Vision System.

Figure shows a complete onboard vision system. The ports used in the onboard vision system are shown here. The vision system is developed according to the diagram.

All the onboard components used are of the range of 10 to 14 Volts or 12 to 16 Volts range. So, it is workable that we use two 6.6 Volts batteries in series to get 13.2 Volt for all the onboard vision components.

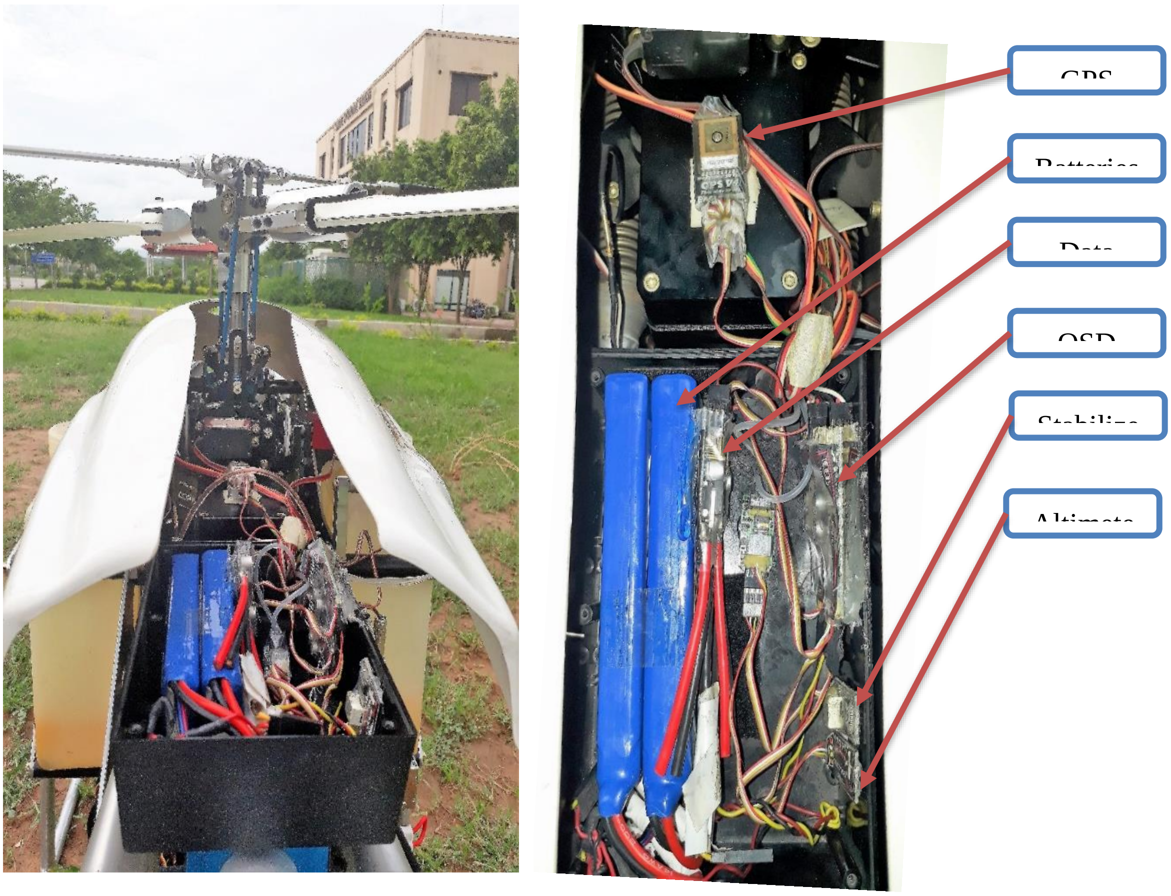

Figure 6.2: Onboard Vision System.

A complete onboard system showing battery pack, Guardian stabilization sensor, Accelerometer, Air Speed sensor, Altimeter, OSD module, GPS module, Optical RPM sensor, Data Logger, Video Camera, Temperature sensor, Video Transmitter, Pitot-tube, and Transmitter antenna. The picture is taken in the Aerial Robotics Lab, SMME, NUST

6.2 System Design of the Ground Control Station

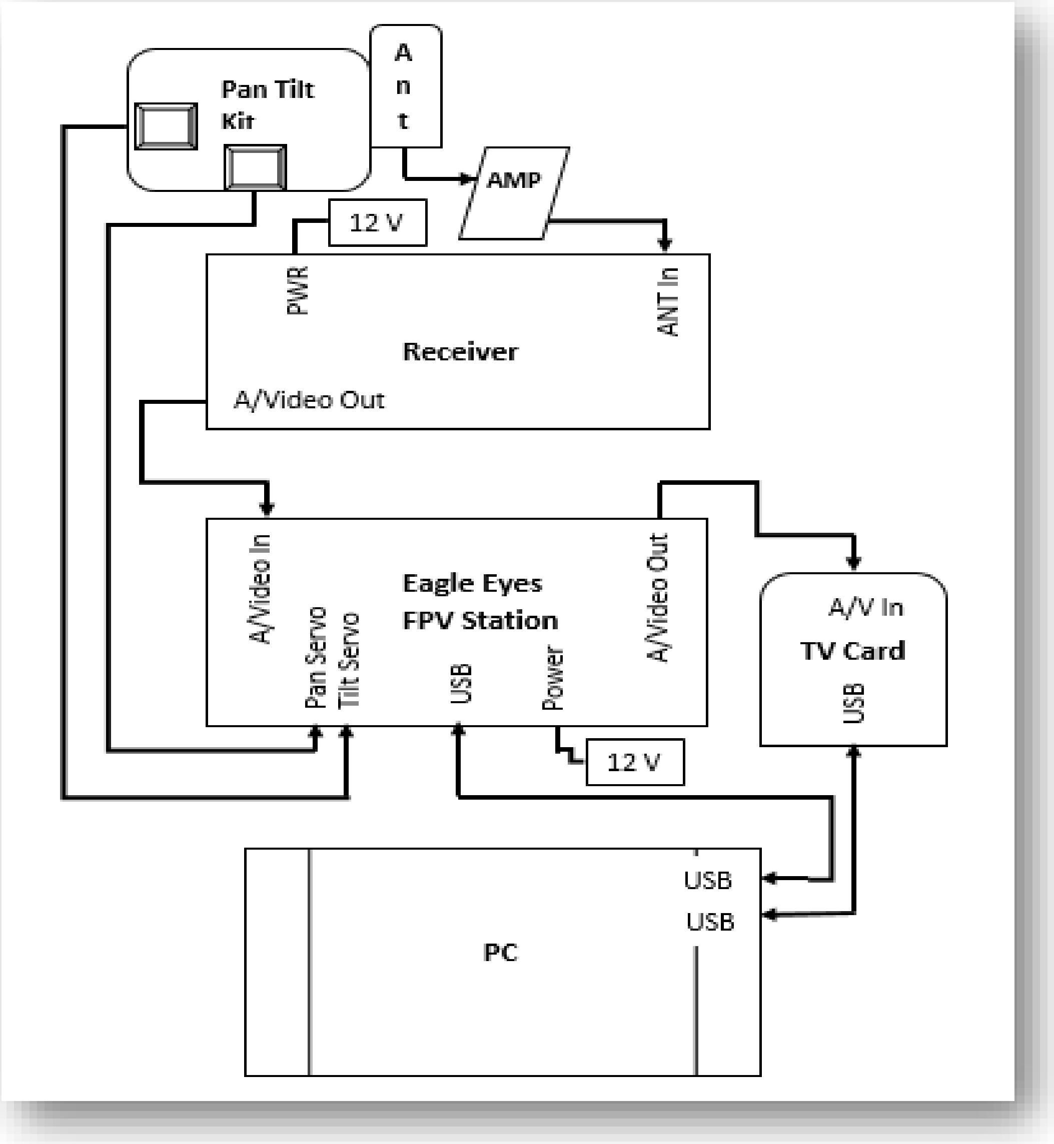

Figure 6.3: Connection Diagram of the Ground Control Station.

It shows the connection diagram according to which the ground station is developed. The ports of the components used in the ground station are shown in the diagram.

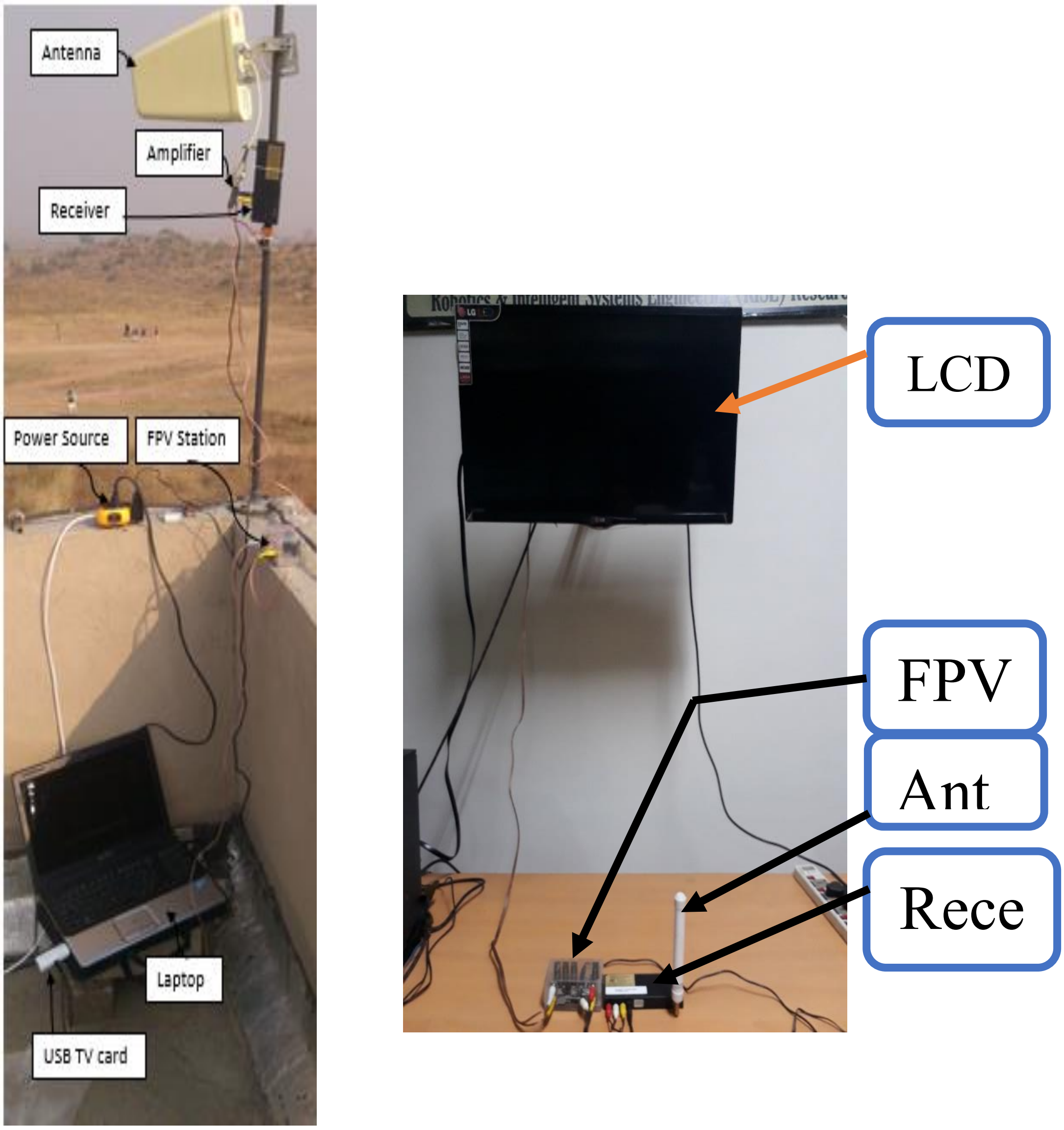

Figure 6.4: Ground Station.

The figure shows the outdoor and indoor setup of ground receiving station made during the vision system testing. The picture is taken from the SMME building NUST.

Chapter 7: Test Results and Analysis

After complete development, the Vision system was subjected to standalone testing before it was installed in the helicopter. Multiple tests were conducted in indoor and outdoor environment. A finer quality of multiple view videos from multiple cameras is achieved video quality was lost up to some extent because of unavoidable multiple sources of interference. Multiple vision sensor video was successful. In the complete testing, that lasted 70 minutes, multi view videos and a huge amount of flight data was collected.

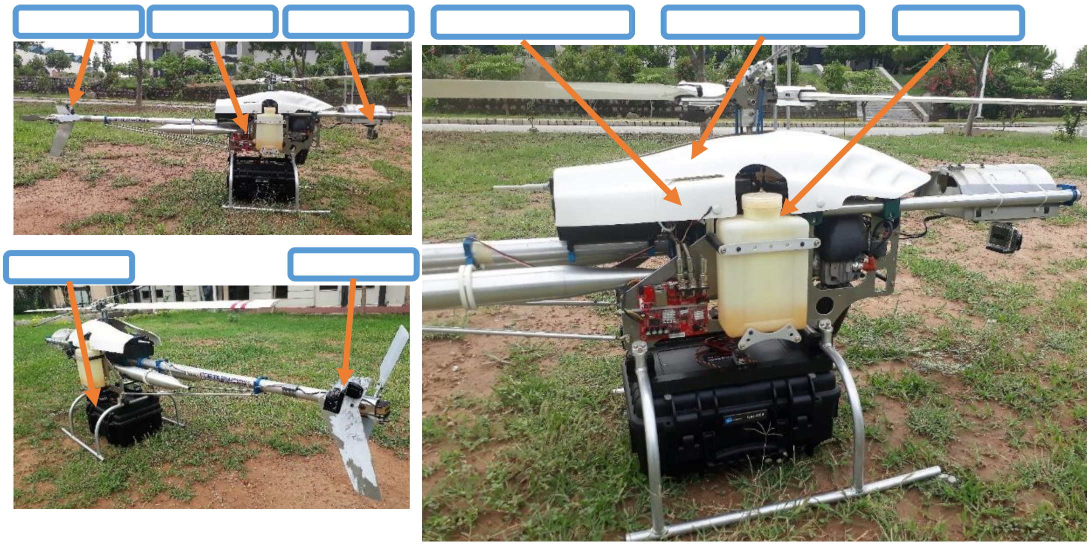

Figure 7.1: Engine Based AF25B with Vision System.

The couple of pictures taken during the payload testing of the velocity 90 helicopter with the extended skid and the vision system installed on it. It was successfully flown in the air. The test was performed in the SMME, NUST ground.

Figure 7.2: The Couple of Snapshots Taken from the Multiple Live Video Stream Receiving, showing multiple cameras videos with Telemetry Information.

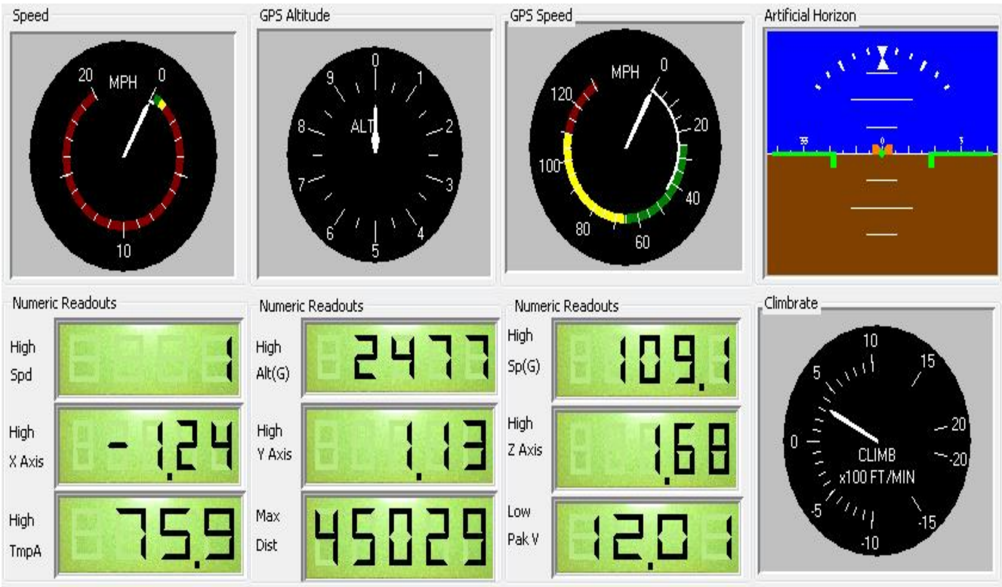

Figure 7.3: Telemetry Information Display.

It shows the telemetry information are extracted from the video signal showing Speed (air speed), GPS altitude, GPS Speed and Climb rate on the dial gauges and Air Speed (Spd), GPS Speed (Sp(G)), Acceleration along (X-axis, Y-axis & Z-axis), temperature (TmpA), Distance (Dist), Altitude (Alt(G)) , Voltage (Pak V) on the numeric readouts. It shows the maximum distance from site of the test “Daman-e-Koh” to SMME, NUST is 45029 ft. and the maximum altitude achieved during the test is 2477ft. above sea level.

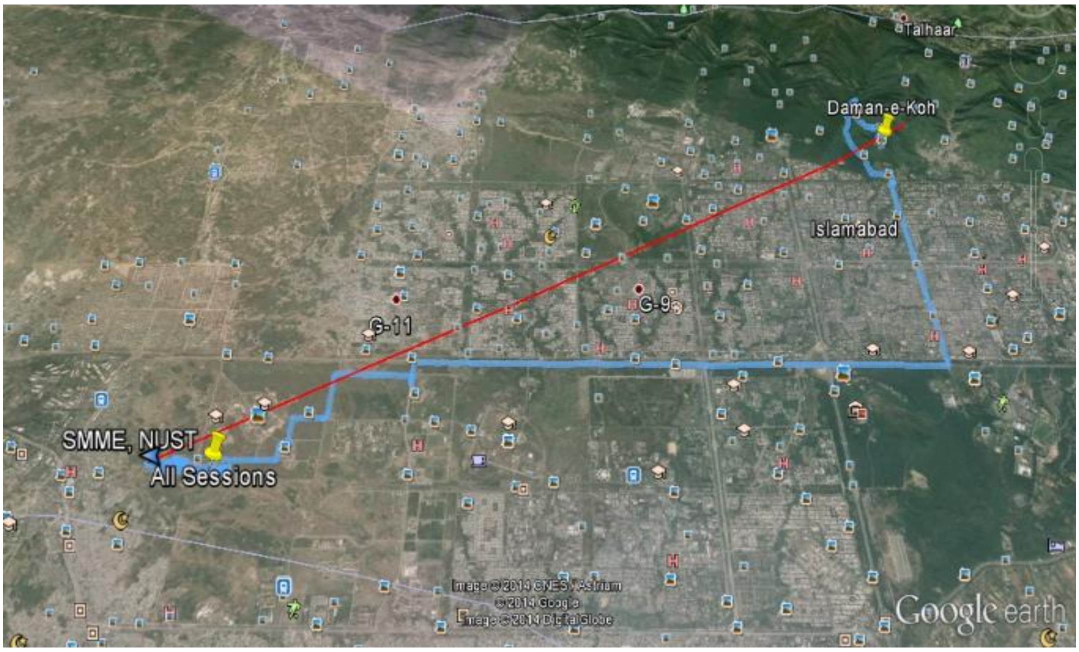

Figure 7.4: GPS Course Followed by the Onboard is tracked by the Google Earth**.**

Picture taken from the Google Earth in Live Mode displaying in blue the GPS path followed by the onboard vision system from SMME, NUST, Islamabad to “Daman-e-Koh, Islamabad” during the range test. The red straight line shows the LOS distance from the test site to the ground control station is 14.3 Km.

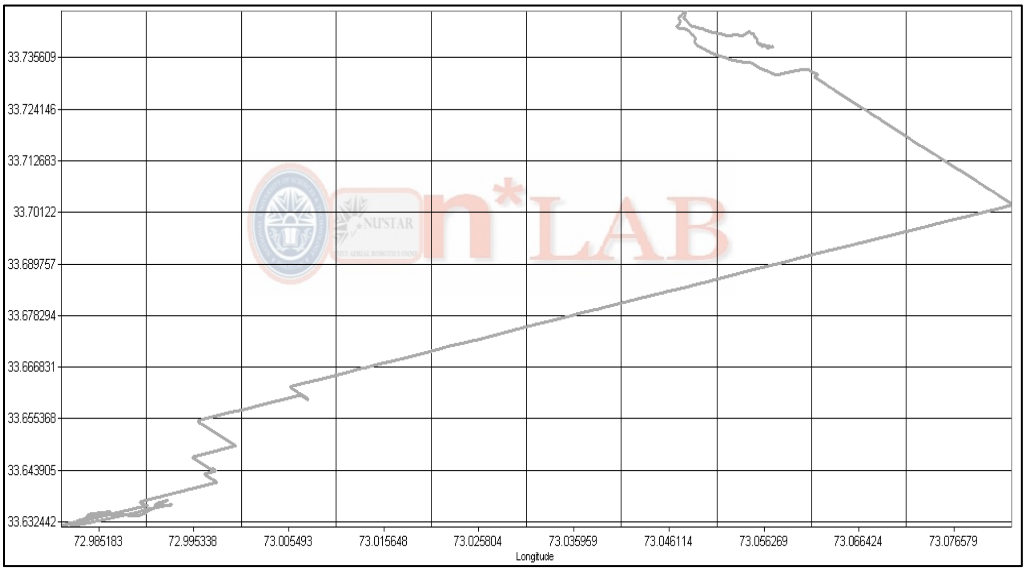

Figure 7.5: GPS Course Plotted from the GPS Coordinates.

The graph plotted between the Longitudes and the Latitudes of the GPS coordinates recorded by the Data Logger during long range test from "Daman-e-Koh" site to SMME, NUST shows the GPS Course followed by the vehicle on which the onboard vision system is taken to the site. This GPS course drawn here is similar to the GPS course drawn by the Google Earth in Fig. 7.3.

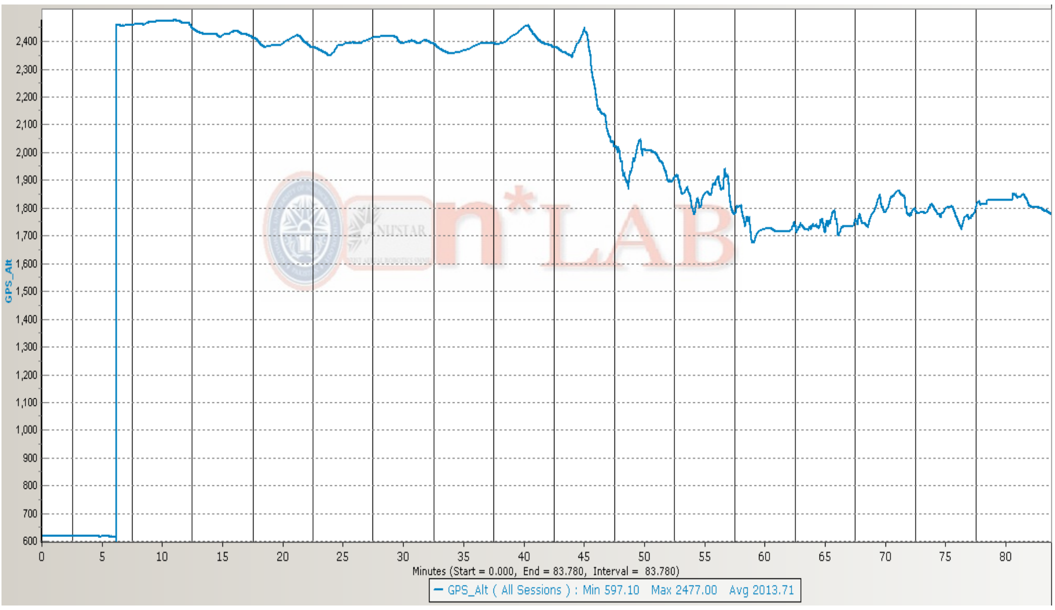

Figure 7.6: Graph plotted Between GPS Altitude and Time.

The figure shows the graph plotted between GPS Altitude vs Time in which the total time duration of the range test from "Daman-e-Koh" site to SMME, NUST is 83.7 minutes. The graph shows the maximum height achieved during the test is 2477ft. above the sea level.

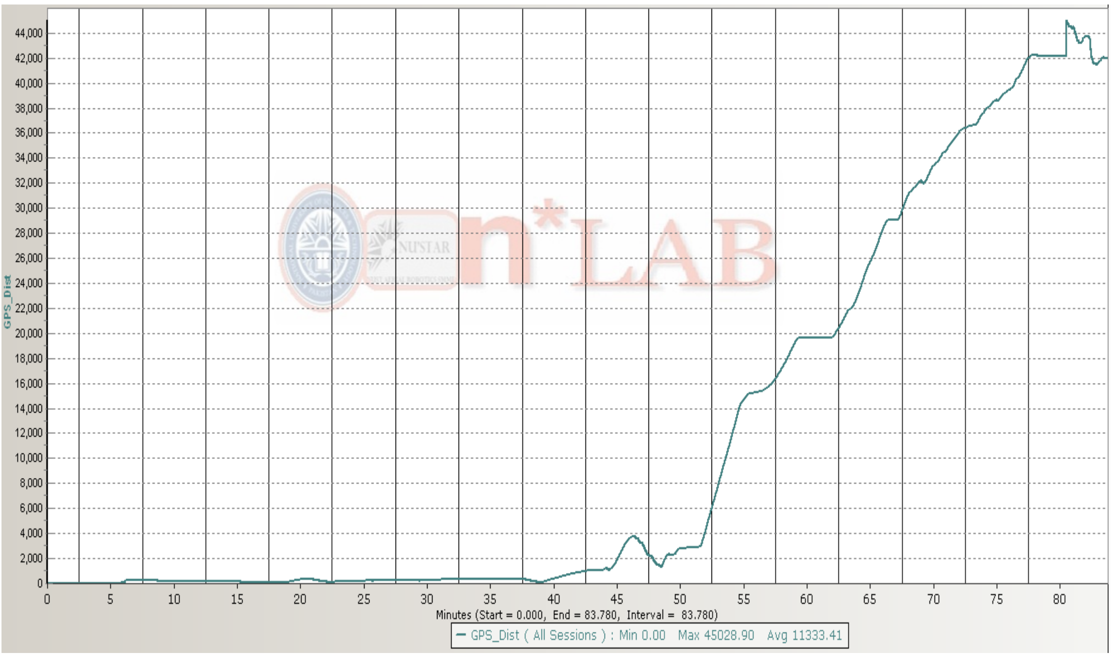

Figure 7.7: Graph Plotted Between GPS Distance and Time.

The figure shows the graph plotted between GPS Distance and Time in which the LOS distance from the home position covered by the onboard vision system is 45029 ft.

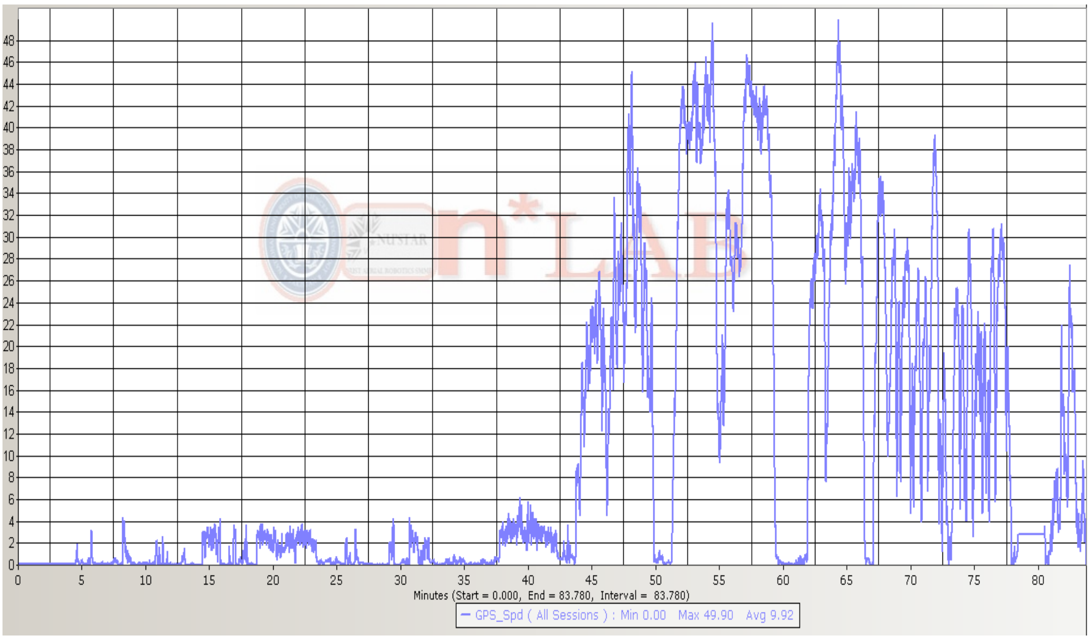

Figure 7.8: Graph Plotted Between GPS Speed and Time.

The figure shows GPS Speed of the vehicle on which the on board system was manually taken to the site “Daman-e-Koh” for long range test. The duration of the test is 83.7 Minutes. The maximum speed is 49.9 m/s. The speed data collected is 10 values per second for 83.7 minutes.

In figure 28, multiple cameras vision system is installed on helicopter. The test is successfully conducted and the onboard vision system falls completely under limits of the pay load capacity of the AF25B helicopter. In figure 29, live multi-view video stream is displayed on the TV screen. Figure 30, shows the telemetry information are extracted from the video signal showing Speed (air speed), GPS altitude, GPS Speed and Climb rate on the dial gauges and Air Speed (Spd), GPS Speed (Sp(G)), Acceleration along (X-axis, Y-axis & Z-axis), temperature (TmpA), Distance (Dist), Altitude (Alt(G)) , Voltage (Pak V) on the numeric readouts. It shows the maximum distance from site of the test “Daman-e-Koh” to SMME, NUST is 45029 ft. and the maximum altitude achieved during the test is 2477ft. above sea level. The figure 28, shows the GPS course followed by the onboard is tracked by the Google Earth in blue line. The red straight line shows the LOS distance from the test site to the ground control station is 14.3 Km. The above graphs show the telemetry data logged in the data logger is plotted against time. A large amount of data is collected during the test from all the sensors.

Chapter 8: Conclusion

The multiple cameras vision system is basically developed for a UAV helicopter platform to make it fly worthy beyond visual range to provide a low cost, power and weight efficient system. With the help of this vision system, A UAV helicopter can go beyond the visual site up to 14.3 Km but the transmitter along with sensor is tested for 48 Km range.The most difficult part in this testing is to maintain the line of site between the onboard system and the ground control station. This vision system is a stand alone,small,easy to handle in hard to reach area. System can be installed in any UAV upto payload capacity of 3.5 Kg. helcopter. It is a low cost, compact in size and power efficent solution for the disaster management. It has been tested and it completely falls under the under the payload capacity of 3.0 Kg of AF25B helicopter. Multiple tests are performed to check the video transmission from different outdoor sites with different light intensity. The transmission remained successful. It was harder to maintain the LOS because of trees. Full remote access (receiving and transmitting systems are both portable).No IP based and external power is required to cameras. Cameras are directly attached to on-screen display. Multiple Sensors integration like GPS, Temperature, altimeter, stabilizer, air-speed, accelerometer are integrated.Long range transmission is possible with the wireless cost efficient system. System can transmit and receive independently even if no other internet server is available.

Depending upon LOS of site, a better quality multi view video is achieved because of clearance. The selected components are fully competible with each other. The recorder’s rate of logging is set as 10 values per second. A huge telemetry data is collected from each sensor.

The constraints of developed vision system are to maintain Line of sight for continuous communication. Cameras cannot work at night (lack of flash light). Heating issue on prolong surveillance. Transmitter is not tested in disastrous conditions.Cannot zoom in/out video during receiving from air.. It can only be installed in the unmanned aerial vehicle with atleast payload capacity of 3 Kg. The unmanned aerial vehicle should have a communication system of range at least 15 Km line of site. The UAV also required to have endurance of atleas 30 minutes. The video quality is lost upto some extent due to vibration of the helicopter platform. In order to maintain the LOS between the Onboard vision system and the ground control station a GPS based antenna trancker is requied. There are also some unavoidable sources of signals atteneuation like nearby buildings, atmospheric conditions, absorption, distortion and interference. This vision system is designed for open band frequancy, so the video can be received other receiver matches the same specifications.

It is recommended that a pan-tilt kit can also be used with the camera to increase the view of the camera. The height of the receiver antenna above the building can impart very important role in the maintenance of the LOS link. Solar batteries for onboard system can be used in order to make it work for 24 hours. By using received signals from aerial platform deep learning algorithm can be applied to provide path and trajectory to flying vehicle. Air to Ground Video Receiving station should be make portable with steered antennas**.**

The proposed helicopter when developed indigenously will be provided for disaster survey and search for rescue requirements and small scale relief operations. The further advancement in this field will make these UAVs used in border security, surveillance of crowds and disasters, the prediction of weather conditions, Goods transport and courier services, monitor pollution, detection of nuclear accidents and so many other civil and military applications.

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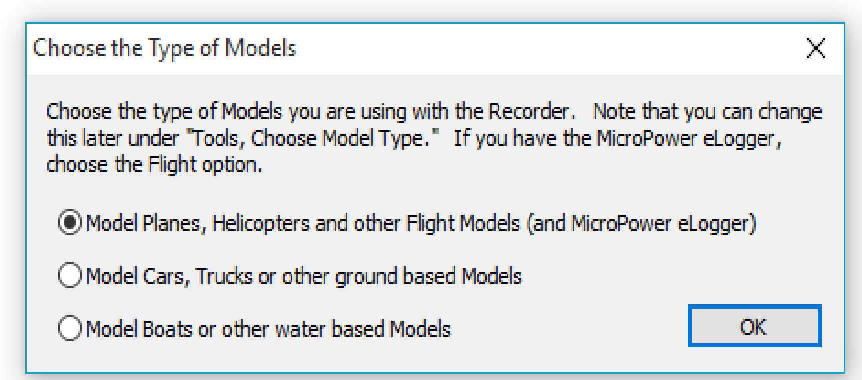
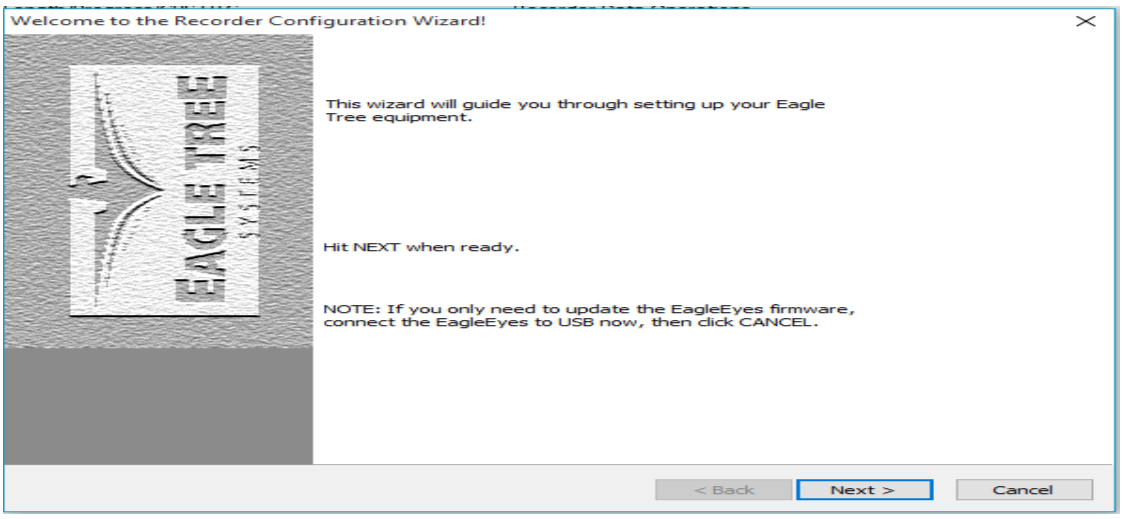
Chapter 10: Appendix A: Installing Software

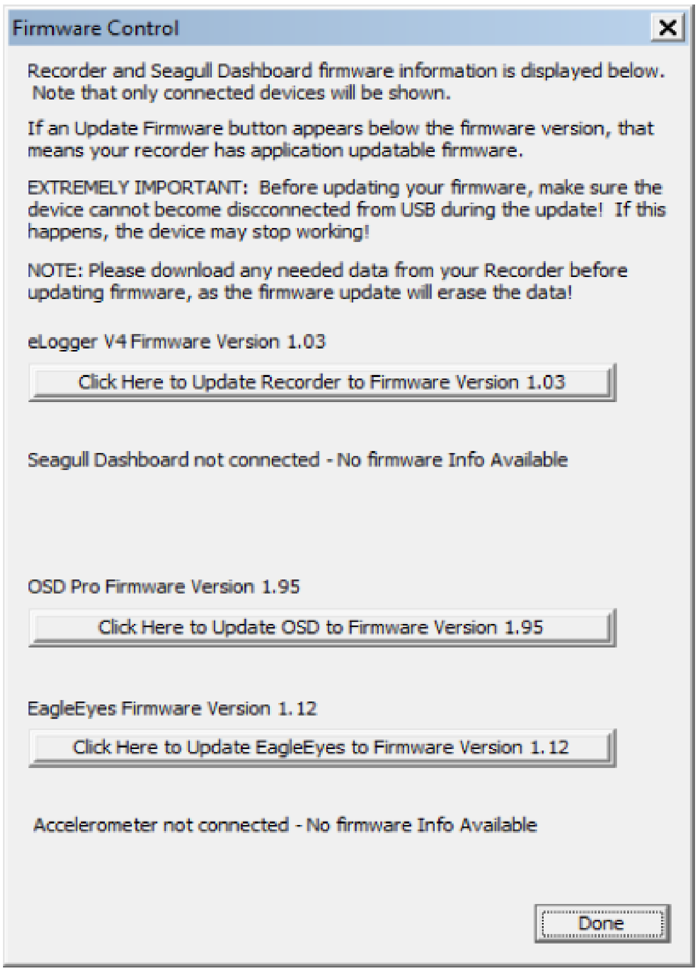
To install the software, form the CD available with the eLogger, insert CD into the CD Rom and run the setup.exe file and follow the instruction. The setup will install the software of the eLogger. When the setup is successfully installed, run the data logger application short cut on the desktop. The following screen will appear.



Choose the first option “Model Planes, Helicopters and Other Flight Models (and MicroPower eLogger)” if using helicopter. Then click OK. The following window will open. This configuration wizard will guide you through setting up your Eagle Tree equipment. Click Next.

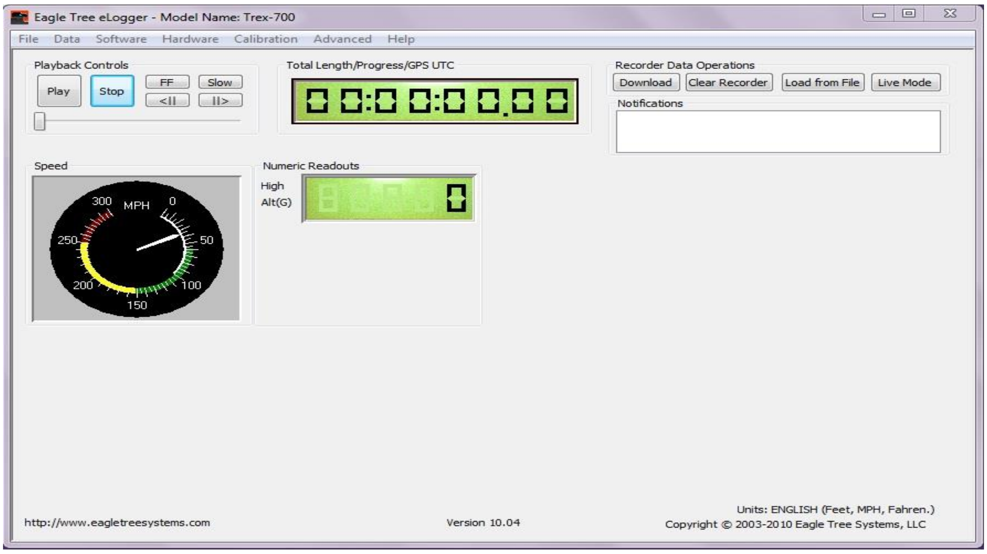


This window will ask to connect all the sensors with OSD and eLogger, Click next when Ready. After following the instruction, it will get you to the firmware update windows.

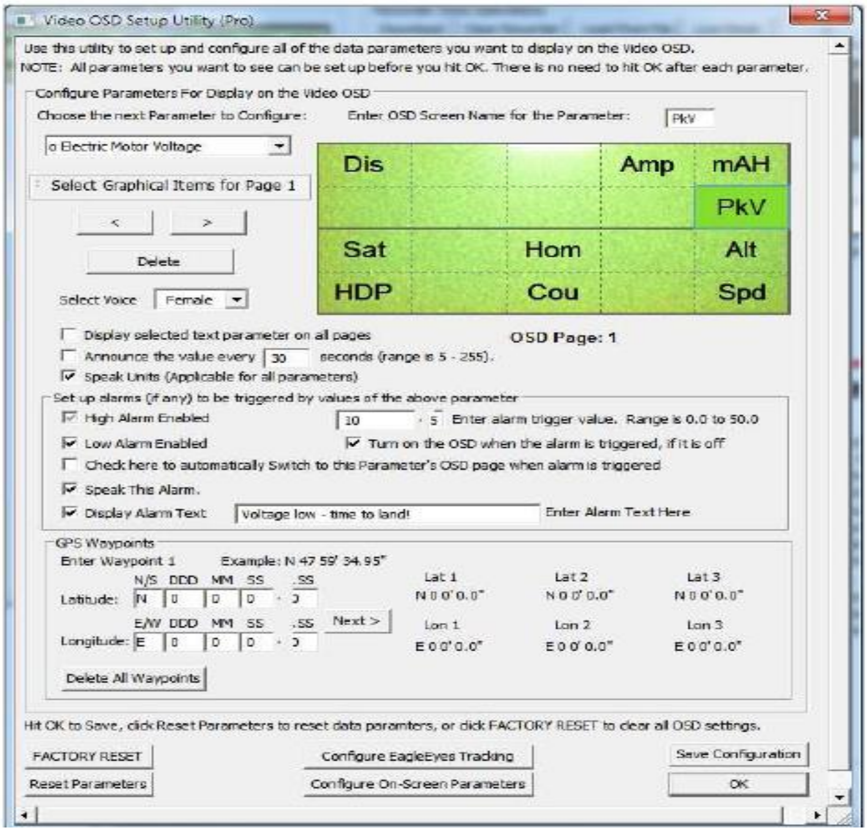


All the sensors attached will be displayed here. If any of attached sensors doesn't appear, please reconnect the sensor. Update one by one every sensor to the latest firmware version. A working internet connection is required to update sensors.

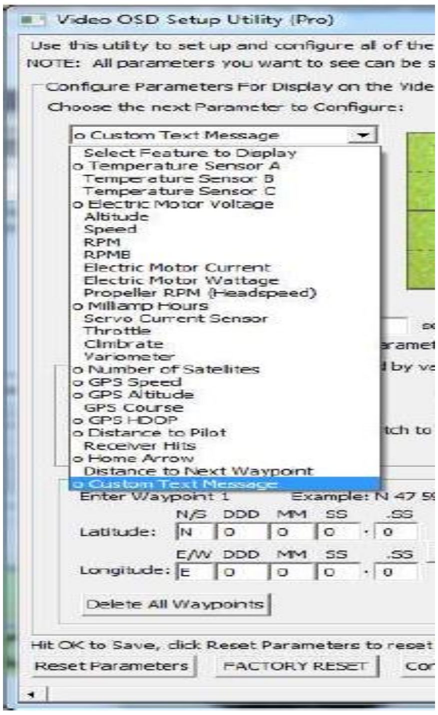
After completing the firmware update, the following main screen and is ready to configure the OSD and eLogger.

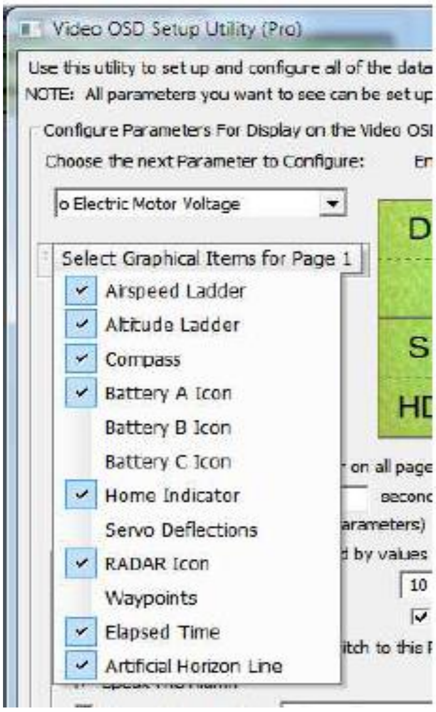


Now click “Hardware” tab and select “Choose Parameters to Display on the Video OSD” from the popup menu. This further get you to the following windows.



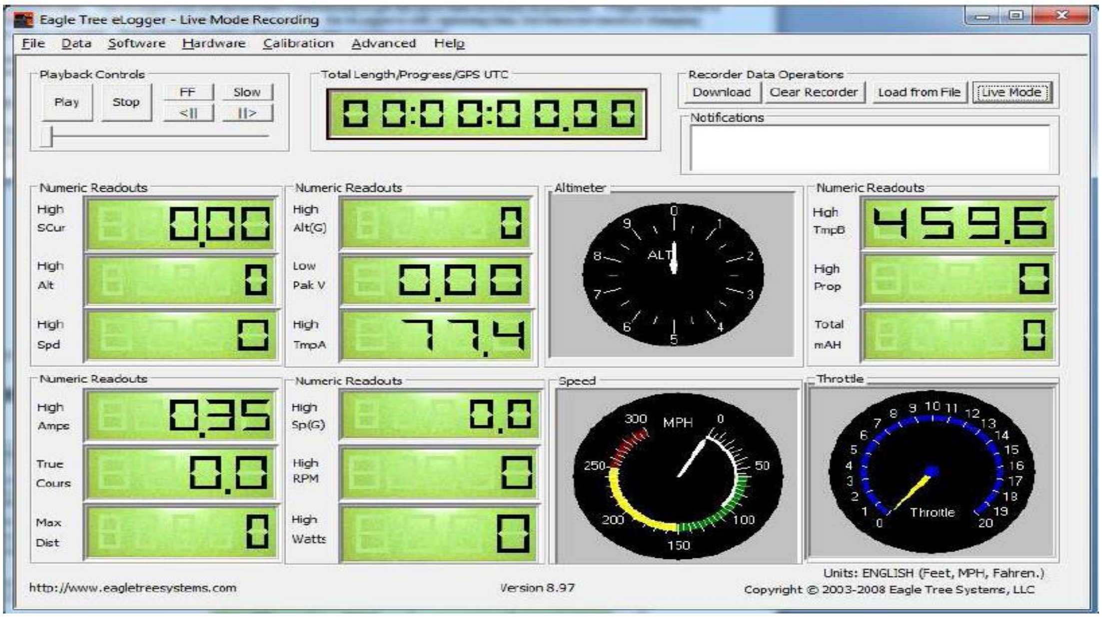
By clicking the red circled menues, The following pop up menus will be displyed.





Choose the parameter that you want to display on the video screen and to appear on the main screen of the software. Select the sensors you want i.e. Air speed Ladder, Altitude Ladder, Compass, Battery icons, Home Indicator, Radar icon, Elapsed Time, and artificial Horizon Line. Click OK when you are done. The following video will be displayed on the TV screen.

For the windows software the following main screen will be appeared when connected to the EagleEyes FPV station.



From this main screen you can choose the “Live Mode” when your vision system is powered up and ready to transmit the telemetry data. The “Download” tab is to retrieve data from the eLogger after the flight. You can display the data file later by clicking the “Load from File” tab. Load the file and click “Play” tab.

Chapter 11: Appendix B: System Buildup

Onboard System Buildup

Here is a step by step guide to develop the hardware of the onboard system as well as the ground control station. In order to use the sensors in onboard system, the following figure will be helpful. All the sensors are connected serially with each other. The sensors can be used in any sequence.

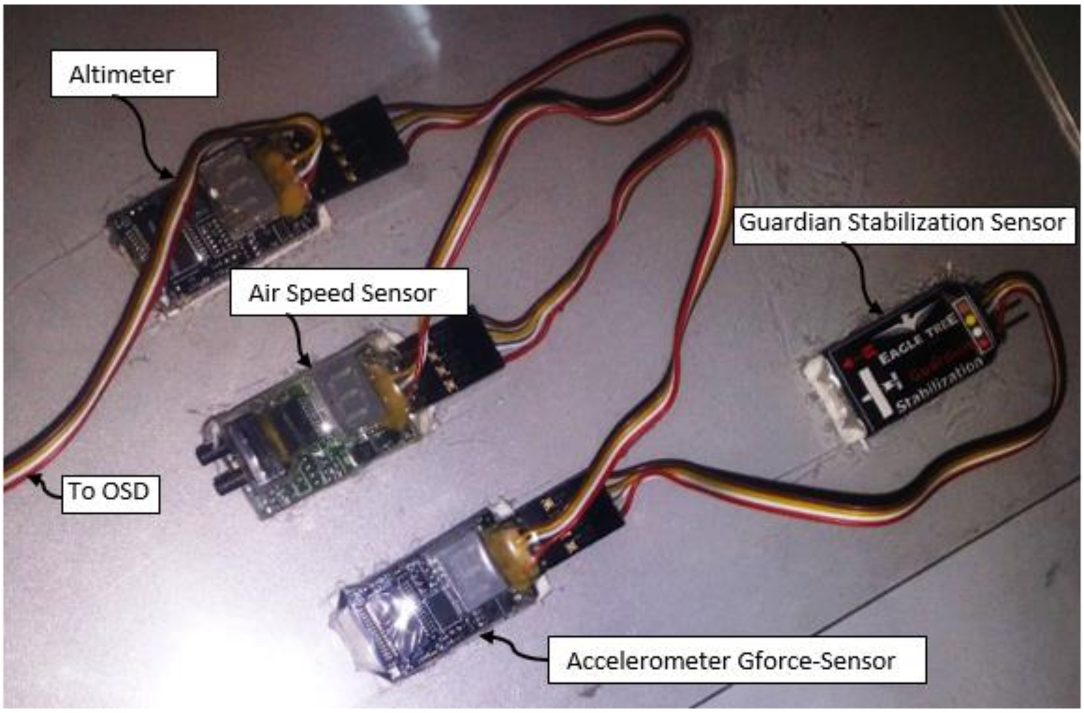


Figure 11.1: Connecting Sensors used in the Onboard Vision System.

The figure shows the sensors Altimeter, Air Speed Sensor, Guardian Stabilization Sensor Accelerometer G-force Sensor are serially connected with each other as used in the vision system. The picture is captured at the Aerial Robotics Lab SMME, NUST.

The sensors are connected with the OSD module as shown in the following figure. The wires of the sensors and the OSD module have a color coding Red, White, Yellow and Brown. All the sensors should be connected according to the color coding.

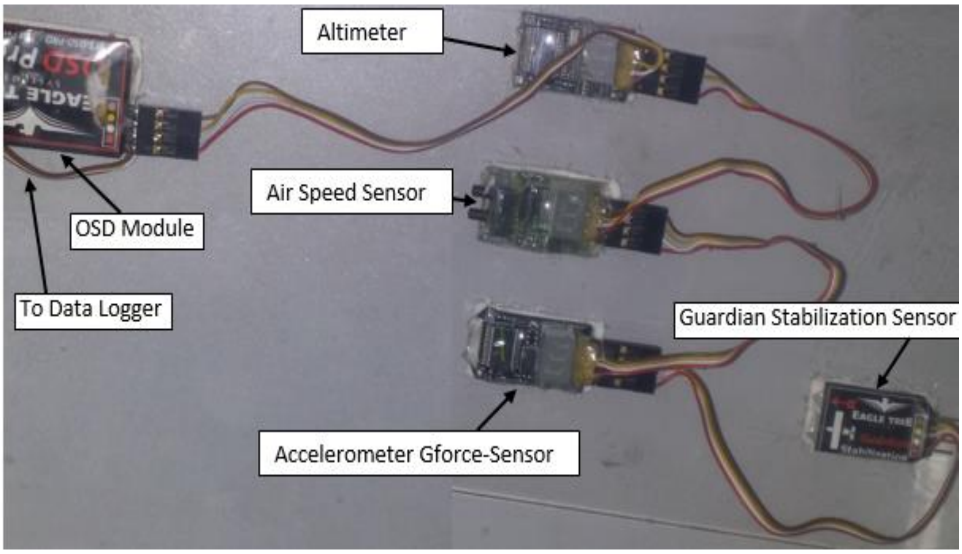


Figure 11.2: Connecting Sensors used in the Onboard Vision System with OSD Module.

The figure shows the sensors Altimeter, Air Speed Sensor, Guardian Stabilization Sensor Accelerometer G-force Sensor are serially connected with each other and the Altimeter is connected with the OSD Module as used in the vision system. The picture is captured at the Aerial Robotics Lab SMME, NUST.

The OSD wire is connected to the "OSD In" port of the Data Logger according to the following figure.

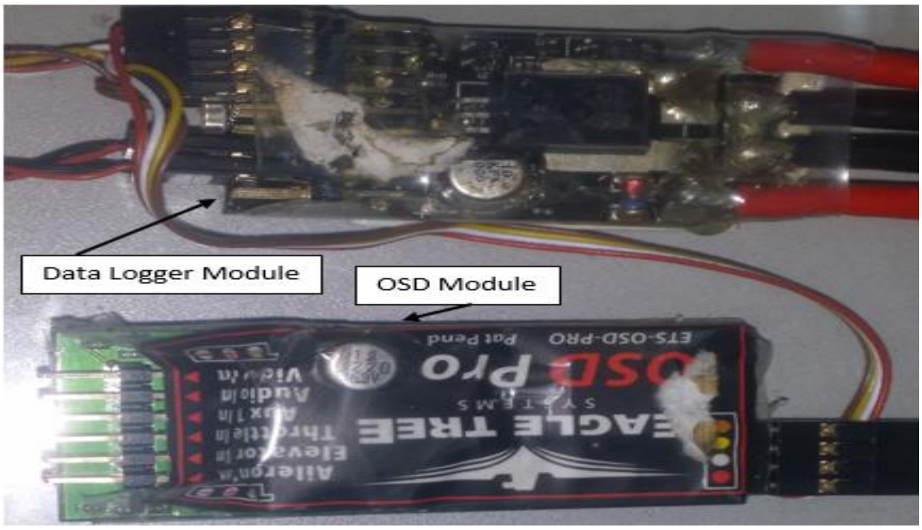


Figure 11.3: Connecting OSD module with the Data Logger Module.

The figure shows the OSD Module wire is connected to the "OSD In" port of the Data Logger. The picture is captured at the Aerial Robotics Lab SMME, NUST.

The GPS module, the Optical RPM sensor and the Temperature sensor are connected with Data Logger Module as shown in the following figure.

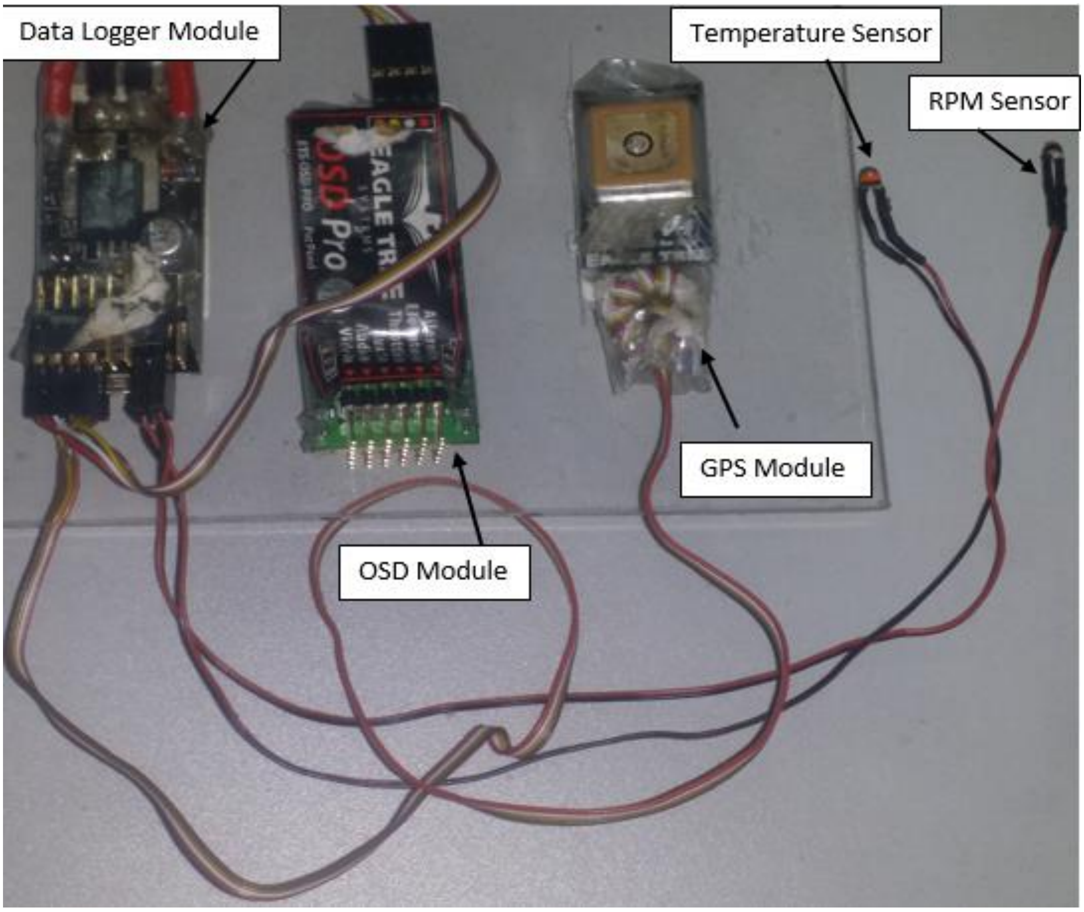


Figure 11.4: Connecting OSD Module, GPS Module, Temperature Sensor and RPM Sensor with the Data Logger Module.

The figure shows the connections of OSD Module, GPS Module, Temperature Sensor and RPM Sensor with the Data Logger Module in “OSD In”, “GPS”, “Tmp1” and “RPM” ports of the data logger respectively. The picture is captured at the Aerial Robotics Lab SMME, NUST.

Connecting the camera with the OSD module is shown in the figure. The video output (Yellow Pin) should be connected to the “Video In” port of the OSD Module. Here a connecting cable is needed to be made which should be compatible with the Video pin of the camera at the one end and with OSD port at the other end.

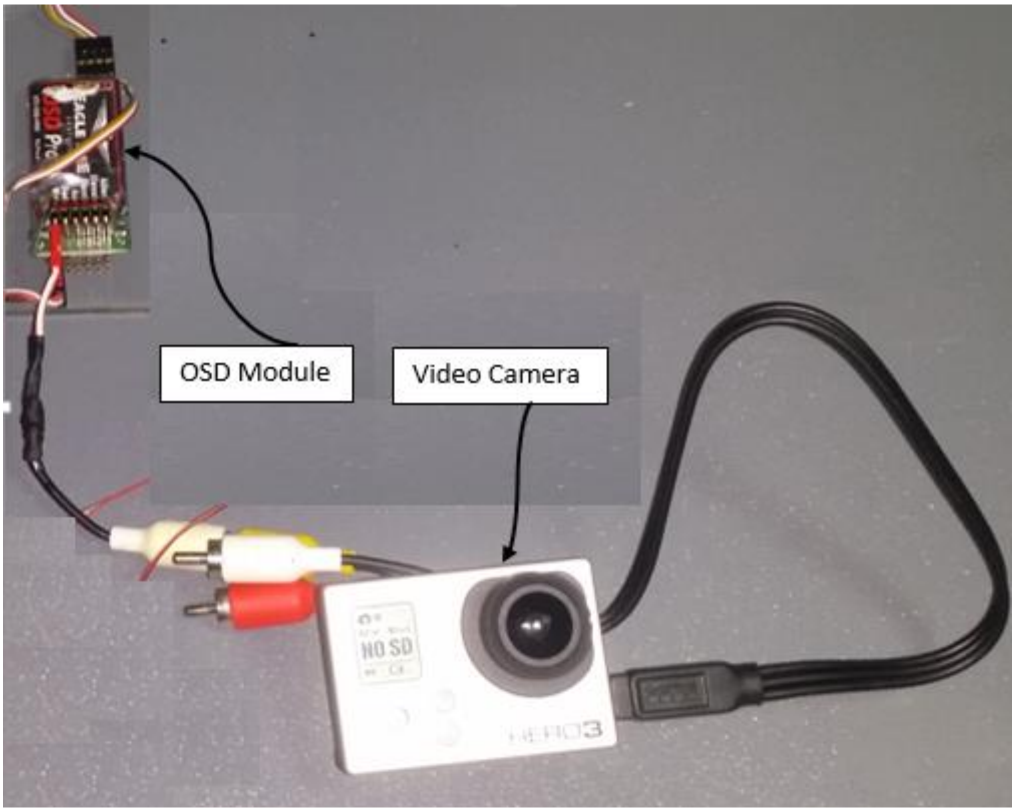


Figure 11.5: Connecting Camera with the OSD.

The figure shows the video output of the camera is connected with “Video In” port of the OSD. The picture is captured at the Aerial Robotics Lab SMME, NUST.

In order to connect the OSD with the video transmitter, the following figure will be helpful. The “Video Out” port should be connected with “Video In” port of the Video Transmitter. Here a connecting cable is needed to be made which should be compatible with the “Video In” port of the Video Transmitter at the one end and with OSD port at the other end.

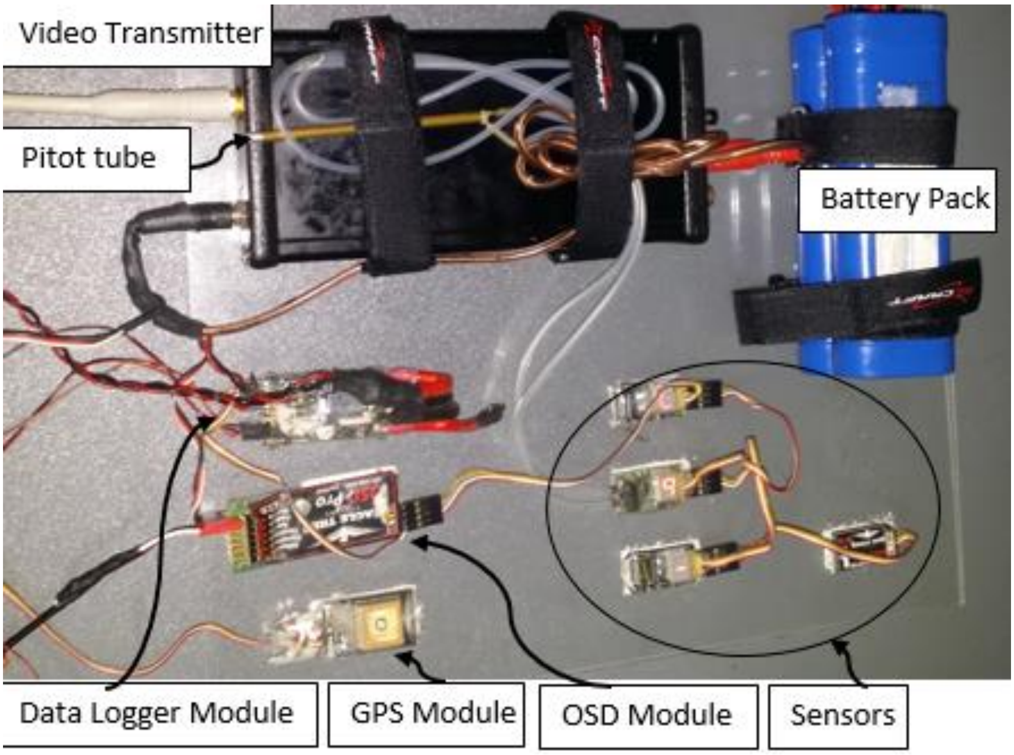


Figure 11.6: Connecting OSD module with the Video Transmitter.

In the above figure, the OSD connected with the video transmitter is shown. The picture is captured at the Aerial Robotics Lab SMME, NUST.

The power pack of the onboard system can be connected to the according to the following diagram. The connector cable is needed to connect the power pack to the rest of the components that can be made according to the following scheme.

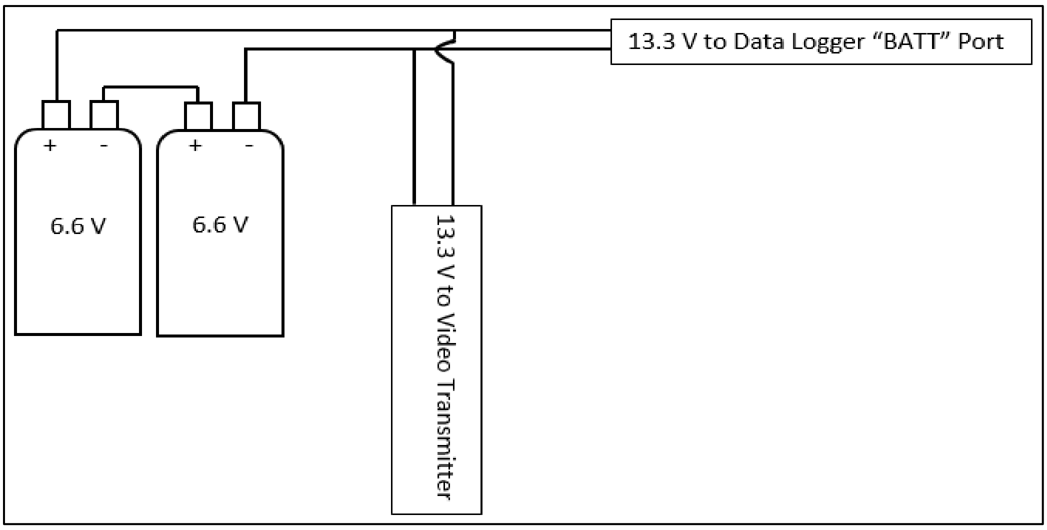


Figure 11.7: On board Power schematic diagram.

The figure shows the power connection of the onboard system.

Ground Station System Buildup

Connecting antenna and amplifier with the receiver can be seen in the following figure. An N5 to SMA type connector is required to connect the antenna to the amplifier as the antenna has N5 type end connector and the Amplifier has SMA type end connector. The Amplifier is further connected with the "Ant In" port of the Receiver.

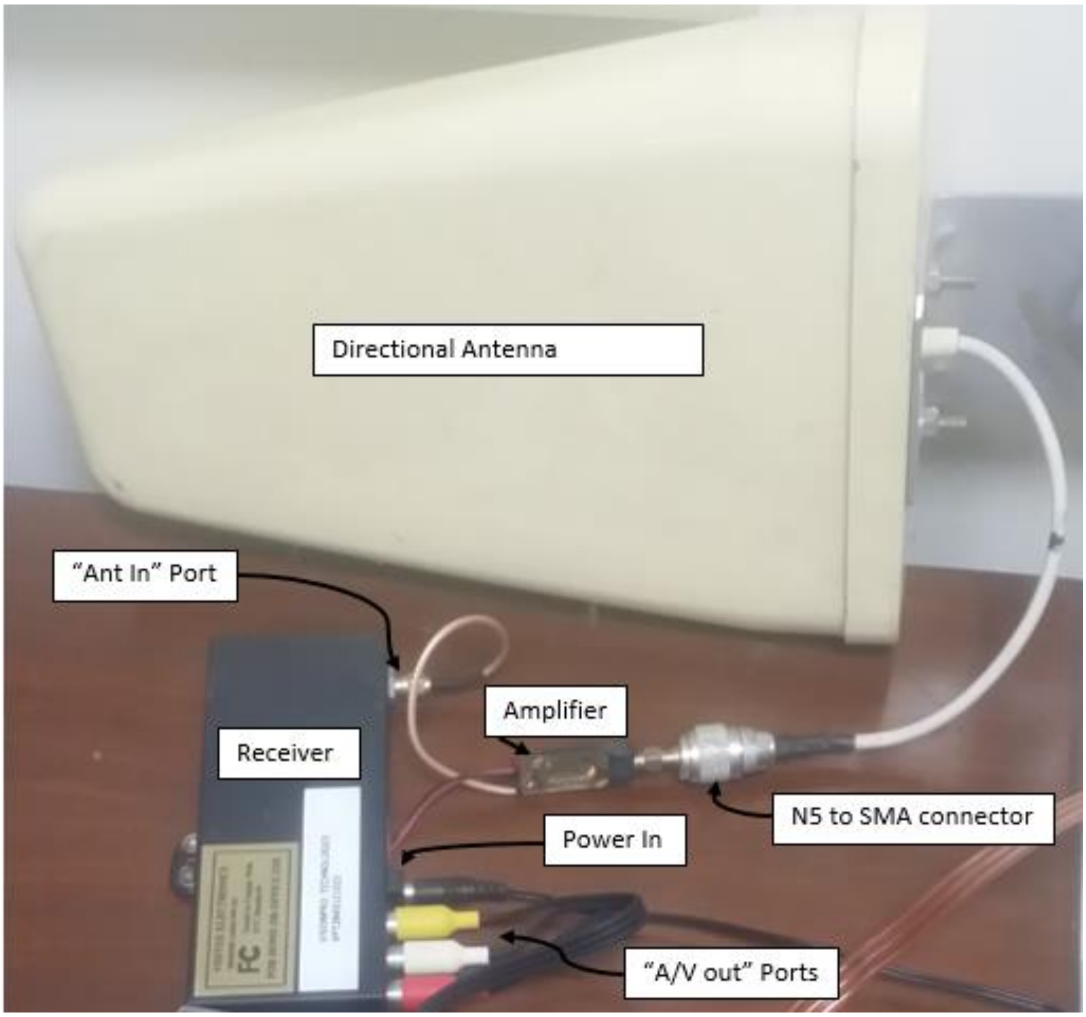


Figure 11.8: Connecting Antenna with the Amplifier and the Receiver.

It shows the connection of the antenna with the amplifier and the receiver. The figure is capture in Aerial Robotics Lab, SMME, NUST.

Connecting the receiver with Eagle Tree FPV Station through AV cable is shown in the following figure.

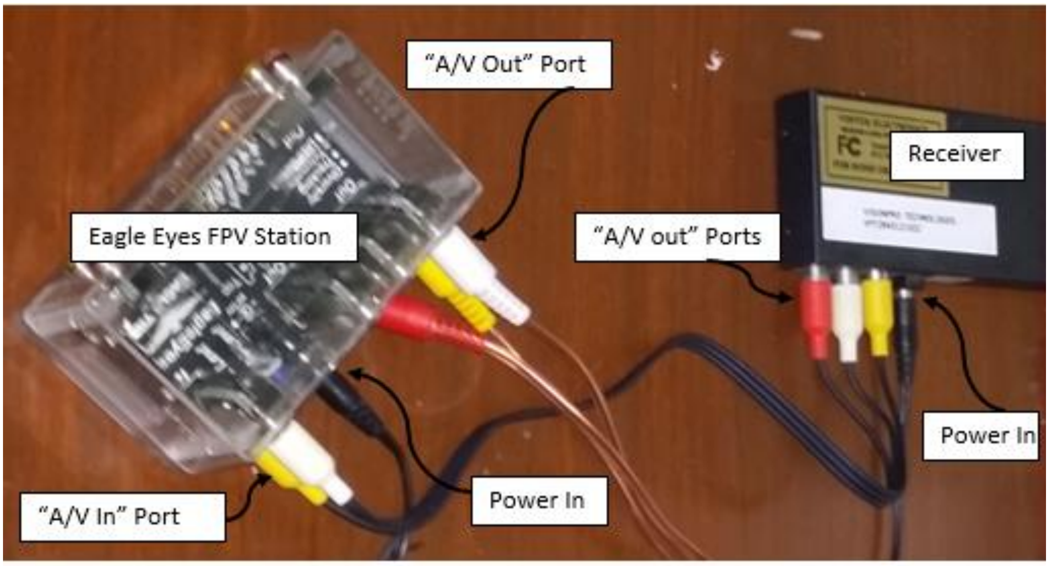


Figure 11.9: Connecting the Receiver with the Eagle Eyes FPV Station.

The figure shows "A/V out" port is connected to the "A/V In" port of the Eagle Eyes FPV station. The picture is captured at the Aerial Robotics Lab SMME, NUST.

The following figure shows the connection between the Eagle Eyes FPV station to the TV screen or the lap top screen. The figure shows the "A/V Out" port of the Eagle Eyes FPV station is connected with "A/V In" port of the TV and the USB port can be connected to the Laptop.

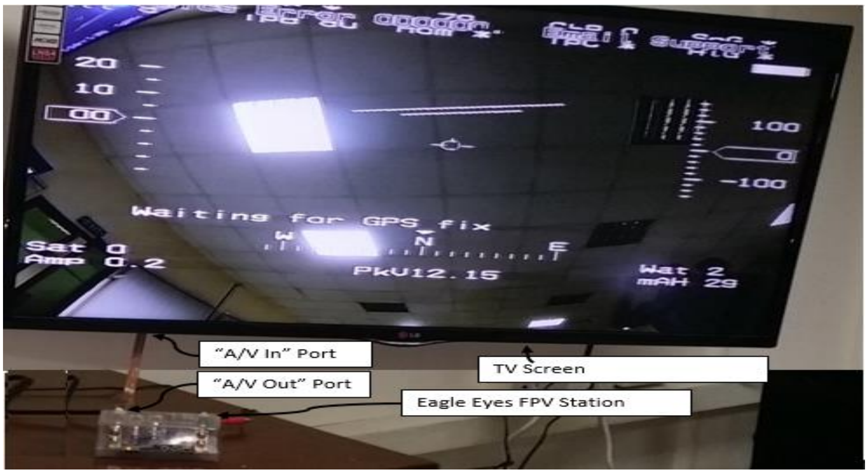


Figure 11.10: Connecting Eagle Eyes FPV Station with TV Screen.

It shows the "A/V Out" port of the Eagle Eyes FPV station is connected with "A/V In" port of the TV. The picture is captured at the Aerial Robotics Lab SMME, NUST.

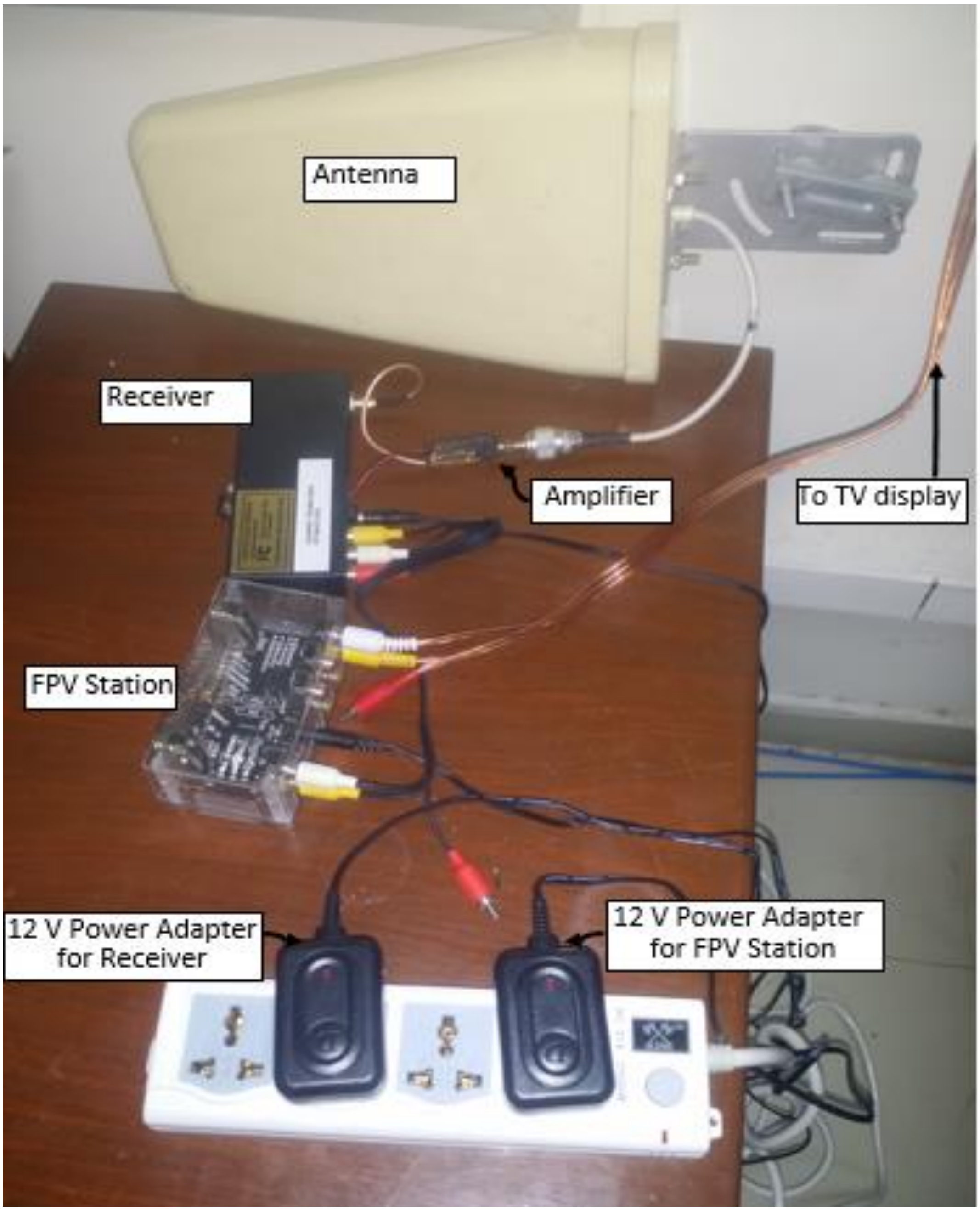


Figure 11.11: Connecting Power Source with Ground Station Components.

The figure shows the 12 V adapters are needed to power up the Receiver and the FPV station. The picture is captured at the Aerial Robotics Lab SMME, NUST.

12 V DC power adapter is required to power up the Receiver and another 12 V Power adapter is needed for the FPV station. The Amplifier should be powered up by a 9 V DC battery. TV can have direct supply of 220 V AC.

Chapter 12: Appendix C: Instructions

- Batteries must be fully charged before flying or testing.
- The connection should be made according to the connection diagrams.
- Most of the components are reverse polarity protected. But even then polarity must be taken into consideration.
- In OSD, the pins close to the board are ground, middle is positive and the farthest from the board are for the signals.
- On the Data Logger, each component should be inserted in its respective port and in the right direction as mentioned on the cover.
- Power up the onboard system and leave it for few minutes to let the GPS receive the signal and connect with the satellite.
- Try to mount the onboard antennas as far from each other as you can to avoid the interference.
- Firmly hold all the parts of the onboard system and double check the connections.
- Connections must well fix. There should be no loose connection in the system.
- The entire components should be in a safe position away from engine exhaust.
- The metallic tube of the air speed sensor must be exposed to the air. The rubber tubes should not be pressed and block the air.
- All the sensors are factory calibrated. No need to calibrate them.
- Learn the software of the eLogger completely before get to the flying.
- GPS sensor must be exposed to the sky.
- Video transmitter radiates heat. So let the air cool it down. It should not be covered.
- Cameras should be fixed in such a way that the vibrations have the least effect on it.
- The guardian stabilization sensor must be fixed in the right orientation and it should be on a flat horizontal surface.
- Consult the manual of the components used for any inconvenience.

- The receiver antenna should be away from the obstacles and must be at least 3m higher than the buildings nearby.
- Use low loss coaxial cable from antenna to the receiver or cut short the length of the cable.
- Set up antenna tracker for its North position every time before flying.
- Avoid any extra load on the servos of the pan-tilt kit.
- It is necessary to have a working internet connection for the Google Earth to work.
- Only expert flyer should operate the helicopter.

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