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NEW ZEALAND

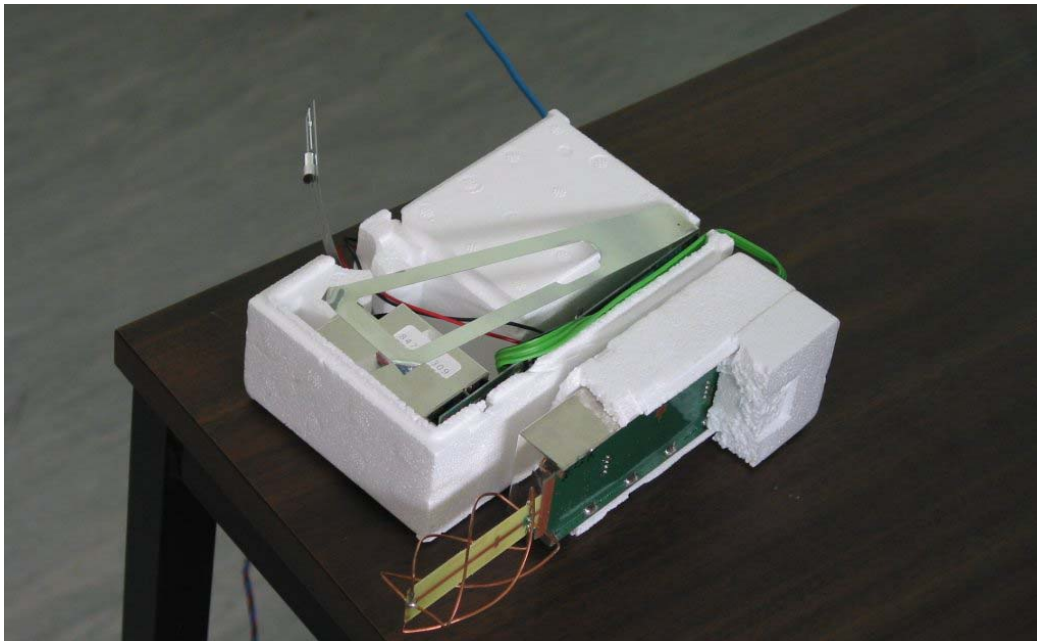
DTA 
DEFENCE TECHNOLOGY AGENCY

Part IV Project 2003

Final Report

Department of Electrical & Electronic Engineering

Implementation of an Atmospheric Data Receiver for Use in a Military Environment (118)



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ABSTRACT

The Defence Technology Agency (DTA) has a number of uses for a portable meteorological information gathering system. This system is required to gather information for predicting changes on the electromagnetic spectrum by weather conditions, and to model the dispersion characteristics of an airborne agent. A device such as a radiosonde is ideally suited to this task, except for the limitations imposed by the operations of the commercially available receiver.

This report begins with an overview of the justification behind the project, then meteorological data gathering techniques are investigated with a focus on the RS-80 radiosonde. The methods of research are then explained with a few key findings highlighted. The dismantling of a RS-80 and an investigation into the internal workings follows leading to a summary of the capabilities of the RS-80 radiosonde. Finally the projects findings are outlined and recommendations made to DTA, along with the possibility of continuing this research in specific areas.

DECLARATION OF ORIGINALITY

This report is my own unaided work and was not copied from
nor written in collaboration with any other person.

Signed: _____

Name: Jonathan N. Stirling.

Date: 14 September 2003.

ACKNOWLEDGMENTS

There are six key people whose assistance requires acknowledgement, for without them, this project would not have been the success that it was.

- Dr. B.J. Guillemain, our project supervisor, who accepted the role of administrating this project in addition to the three other projects he is overseeing.
- Miss S. Garrett, the scientist at DTA who suggested this project, and has supported us with resources.
- Mr. N. Easton, who has freely given his time and technical knowledge about many aspects of this project
- Mrs. S. Stirling, my wife, for all the support and encouragement she has given me.
- Miss K. Day, Warren's fiancée, for the support she has been to Warren.
- Mr. Sebastian Zettle, a German whose willingness to share his technical knowledge has aided this project immensely.

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1 INTRODUCTION

Due to amount of background knowledge required for a complete understanding of this project, this section has been divided into five sub-sections. The first two sub-sections cover the direction that the report and the project have taken, to illustrate the big picture. The following sub-section covers the initial aim, and the refinements made as the project progressed. Next, the three ways that meteorological data is collected are examined, prior to the final sub-section, which explains the Defence Technology Agency's (DTA) need for meteorological data.

1.1 OVERVIEW OF THE REPORT

This report has been broken into three major sections. The first section is an introduction that gives the background knowledge required to appreciate the complications in satisfying the requirements of the aim. The second section identifies the various methods used in researching the characteristics of the RS-80 radiosonde, before the final section summarises the way that a RS-80 operates.

1.2 OVERVIEW OF THE PROJECT DIRECTION

This project can be broken into two major stages, research and development. The research stage began with an investigation of meteorological systems, which focused on Vaisala instruments with a final in-depth examination of the RS-80. Following the research stage, hardware and software were developed to analyse the RS-80 and obtain an understanding of the data transmitted, with the aim of constructing a unit to convert the signal into meaningful data.

1.3 THE AIM OF THE PROJECT

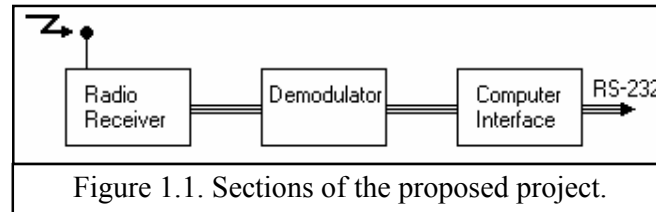
Due to the lack of knowledge about radiosondes, the aim of this project has been refined as research was conducted. The original aim was to design a data receiver for all radiosondes, but this was later limited to a feasibility investigation for designing a decoder for a RS-80 15G.

1.3.1 Original Project Direction

The original aim of this project was to construct a data receiver so that atmospheric information transmitted from Vaisala meteorological probes could be gathered from a Royal New Zealand Air Force (RNZAF) P3 Orion aircraft. If this worked well, the project was to be expanded to encompass receiving the data transmitted from Vaisala meteorological probes onboard Royal New Zealand Navy (RNZN) ANZAC class frigates. This would rectify the current inability of the DTA, and the other New Zealand Defence Force (NZDF) departments to receive raw data from Vaisala atmospheric data transmitters.

The project is primarily for the DTA, which is the research and development section of the NZDF. As the DTA has the greatest scientific knowledge within the NZDF, it is called upon to provide scientific and technological support for a variety of defence projects. The DTA has an aim to provide advice, knowledge and expertise on research and development, updating equipment and maintenance, amongst other things.

At the beginning of this project, the envisaged solution was broken into a block diagram, as shown in figure 1.1. The radio receiver must be designed to receive data transmitted between 400-406 megahertz (MHz). The demodulators' function is to take the electrical signal from the radio receiver, convert it to a digital signal then relay it to the interface. The computer interface includes data packet recognition, buffering, and translates the information to serial output for database use and display.



For an appreciation of the intended project, the proposal is attached in Appendix (A).

1.3.2 Refinements to the Aim

This project has had two major refinements in its direction. The first was to narrow the scope to just the RS-80, and the second was to focus on the feasibility of decoding the signal from a RS-80 into meaningful data.

The first investigation that was carried out focused on the difference between the various probes in the Vaisala radiosonde range. From the findings of this research, the decision was made to narrow the scope of the project to the Vaisala RS-80 15G radiosonde, for the following reasons:

- Different radiosondes operated in different ways.
- The DTA had a number of RS-80 15G's radiosondes in stock.
- The only technical information found was about the RS-80.
- The only radiosonde in production at the time was the RS-80.

The aim was modified a second time to being a feasibility study into the design of a decoder because commercially available radio receivers are cost efficient and satisfactory for the requirements of this project. A small amount of research went into identifying a radio receiver to use, but the focus of the project became interpreting the signal from the receiver into meaningful data.

1.4 HOW METEOROLOGICAL INFORMATION IS COLLECTED

There are many methods for collecting meteorological information, depending on the location and the type of data that is required. The different ways that the information can be collected is divided into three classes based on the area that the systems are used in, being surface systems, atmospheric systems, and extra terrestrial systems.

1.4.1 Surface Systems

Surface systems can be further divided into units that are attached to the ground, and free-floating buoys in the oceans.

The ground units are fixed to semi-permanent structures attached to the earth's surface. Since there is no size constraint, any number of probes can be attached to these units depending on the information required. The more common readings taken are the volume of rain, air temperature, atmospheric pressure, relative humidity, solar radiation, and wind velocity. An example of this type of unit is shown in photo 1.2.



Photo 1.2. A semi-permanent weather station.

The ocean-deployed systems can be either fixed or free floating, but are very similar in nature to the ground units. The only additional probe that is added to the free-floating units is a positional sensor, so the location the readings are taken at is known.

1.4.2 Atmospheric Systems

The second class is atmospheric systems. These probes are launched into the atmosphere and the information is sent back to a base station via a radio signal. The methods of deployment are varied. These methods include being launched up into the sky underneath helium balloons, as shown in photo 1.3; attached to rockets; or dropped out of aircraft. These probes take similar readings to fixed stations, with the exception of volume of rain and solar radiation. These units can be modified to carry specialised probes for sensing atmospheric elements e.g. the concentration of ozone in the ozone layer.

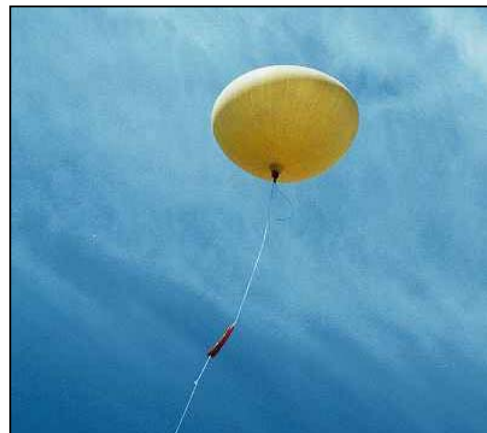


Photo 1.3. A weather balloon.

1.4.3 Extra Terrestrial Systems

There are two different types of satellites used in meteorological information gathering, Geostationary Operational Environmental Satellites (GOES) and Polar-Orbiting Environmental Satellites (POES). The GOES and POES collect similar data, but the GOES is used for short term forecasting, and the POES for long term forecasting. These satellites gather data on cloud images, water vapour images, surface temperatures, and thermal energy radiating from earth. From the cloud images, wind speed can be calculated and estimations made about the levels of precipitation.

1.5 VALUE OF METEOROLOGICAL INFORMATION TO DTA

The DTA has a number of uses for accurate meteorological information. The desired method for collecting this data would be an inexpensive effortless system that is portable. A system such as the RS-80 radiosonde is ideal, apart for the restrictions inherent with the commercially available receiver.

1.5.1 Uses For The Data

There are a number of uses for accurate meteorological data. Two areas have been identified that are currently of interest to the DTA and are explained below. Other uses of this data could be for reasons as simple as weather forecasting or for the safety of aeronautical operations.

The first is for the Advanced Refractive Effects Prediction System (AREPS). AREPS uses meteorological information to predict the effects that the weather conditions have on the electromagnetic spectrum. This is of great importance as the electromagnetic spectrum alters the probability of detection by radar, the vulnerability to electronic surveillance, and the range of radio communications. All of these characteristics are of high importance for the NZDF, and therefore to the DTA.

The second use is to design an accurate model of the dispersion characteristics of an airborne agent such as radioactive fallout, chemical weapons, and biological weapons. Airborne agents are an area of high military concern. The greatest influence on dispersion characteristics is the weather, which highlights the need to accurately record the meteorological conditions in any locations of interest.

1.5.2 Limitations of the Commercial System.

There is a commercially available receiver system for the RS-80 radiosonde, but the internal processing of the data restricts the utility of the system. The cost of \$250 000 is also a factor in finding another method of receiving and decoding the data from RS-80.

The commercial system takes a number of readings to synchronise itself with the radiosonde, and does not give the user any data for the synchronisation period. This means that data from the low level atmosphere, which the DTA needs in order to construct an accurate dispersion mode, is not available.

The DTA would like to modify a radiosonde to be deployed on a kite. The kite could then be towed behind a vehicle and its altitude varied. This system could be used to build a three dimensional image of the low level atmosphere in an area of interest. The commercial receiver only records data from a single ascent meaning that this data gathering method will not work.

2 DETERMINING THE CAPABILITIES OF THE RS-80 RADIOSONDE

As the only units available for this project were the RS-80 15G, it is this unit that has been investigated, although it is believed that this unit is very similar to the others of the RS-80 family. This unit, pictured below in photo 2.1, uses the 7 – 10 kilohertz (kHz) frequency range for the Pressure, Temperature and Humidity (PTU) data, and the Doppler shift of the global positioning system (GPS) signals to determine the wind velocity.



Photo 2.1. A Vaisala RS-80 15G Radiosonde

2.1 COMPANY PROVIDED DATA

Our first point of investigation was the company that manufactures the RS-80 radiosonde. From their website, we examined the datasheets of the RS-80 and other related radiosonde devices. We also made contact with the Vaisala representative in Australia via e-mail in an effort to gather more information.

2.1.1 Datasheets

The datasheet, which is attached in Appendix B, for the RS-80 radiosonde has vague technical information about its operation. This information provided a starting point to examine frequency and the methods of data transfer. The datasheet explained that two separate systems were used; one to determine the PTU of the atmosphere, and the

other to determine the wind velocity. This data was combined onto a single signal of 403 MHz for transmission to the base station.

The PTU data is transmitted using an analogue system, with an update rate of 7 samples every 10 seconds. There is also a high and a low reference signal transmitted with this data, however no information as to the signal type is given.

The wind velocity is calculated using the shift in the L1 carrier from the GPS satellites. The data has 24-bit resolution, and is transmitted using 1200-baud frequency shift keying (FSK) modulation. This information is updated every 500 milliseconds (ms), with new independent data from up to eight GPS satellites.

2.1.2 E-mails

Communication with Vaisala was not very productive. The only information that they were willing to divulge was the pricing of the various systems, and the fact that the same receiver could be used with the entire range of radiosondes. The company policy is to not reveal any information about systems under production so no technical information was obtained.

2.2 INTERNET DOCUMENTATION

The Internet was full of data about radiosondes; unfortunately there is a lack of technical information available.

2.2.1 General information

The Internet provided a lot of information about what a radiosonde is and does, and the locations of regular launch sites throughout the world. Examples of the types of information provided are listed below:

- Radiosonde is both a product name and a family name. The product is the device that is launched beneath a weather balloon, but as a family name it also includes rocketsondes and dropsondes.
- The name radiosonde is a combination of radio, for the onboard 'radio' transmitter and 'sonde', which is messenger from old English.
- The GPS signal from the radiosonde is corrected at the base station to give a value relative to earth, as apposed to relative to the GPS satellite's orbits.

2.2.2 Technical information

There was very little in the way of technical information about radiosondes to be found on the Internet. The most useful page that was found was in German. An initial translation by Google, an Internet search engine, revealed a wealth of knowledge about the technical side of the RS-80. The website gave us information about the PTU system, the wind velocity system, and the way both systems are combined together.

The PTU data is time division multiplexed (TDM) onto the carrier using a repeating sequence of six tones. These tones are in one of two frequency ranges, depending on the model of radiosonde, either 700 Hertz (Hz) to 1 kHz for the more advanced

model, or 7 kHz to 10 kHz for the simpler model. This sequence lasts 1.5 seconds, and is comprised of tones representing:

- A high reference
- The capsule temperature
- The atmosphere pressure
- A low reference
- The air temperature
- The atmospheric humidity

Following the data structure, a method of decoding the PTU data is explained. Suggested methods are using either software on a signal direct from a soundcard, or a hardware device that converts frequency to voltage.

The wind velocity system uses two frequencies, 3050 Hz and 4250 Hz, for transmitting the data. The data is modulated using FSK, and has a refresh rate of 500 ms. Since the only data transmitted is the velocity of the radiosonde, the position is near impossible to calculate accurately.

The data from the two sensor systems are combined onto the radio signal using frequency modulation (FM). The carrier frequency can be varied from 400.15 MHz through to 406 MHz, allowing for multiple radiosondes to operate within radio range of one another.

2.3 COMMUNICATION WITH A RADIOSONDE EXPERT

While searching the Internet for technical information, a RS-80 decoder was discovered. This device translated the PTU tone signal into a 19200-baud signal that can be read by a computer serial port. Due to our interest in this device, contact was established with the manufacturer. This turned out to be a private German citizen, Sebastian Zettle, with interests in a number of fields, including radiosondes.

Sebastian Zettle was also trying to produce a system capable of receiving a radiosonde signal and translating it into meaningful data. He had already developed the PTU decoding system mentioned above, and was prototyping a wind velocity decoding system, but was facing a number of errors.

He sent us information about the technical operation of the RS-80, allowing us to further our own investigations. This information included the data structure for the wind velocity signal, and the output pins on the wind velocity module within the radiosonde.

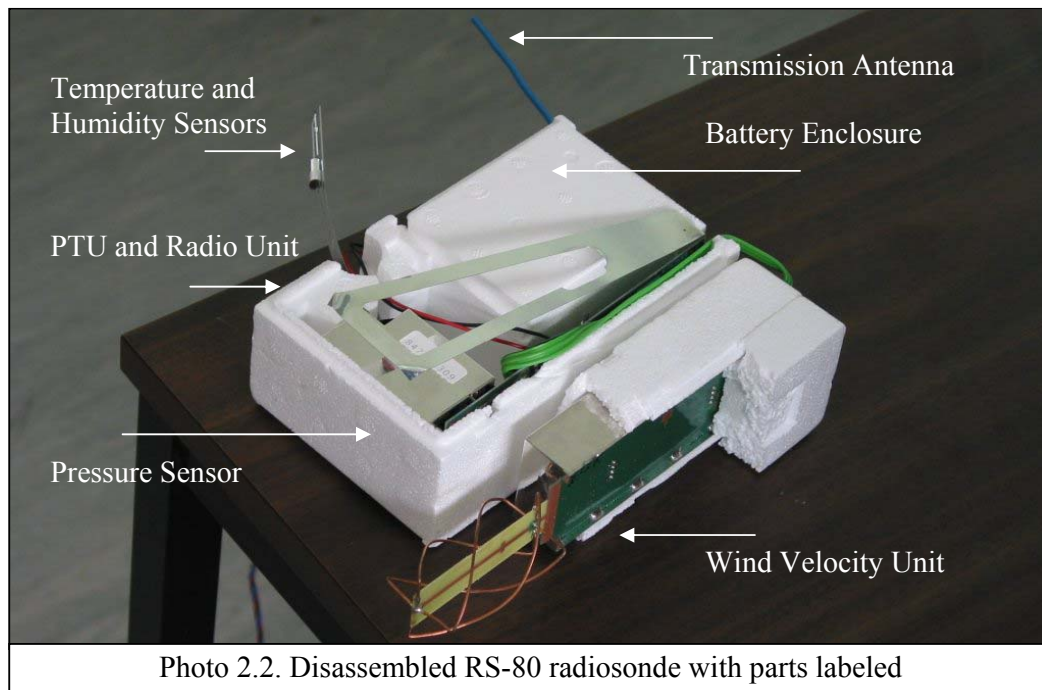
2.4 EXAMINATION OF RS-80

Once the initial paper investigation had been conducted, the research focused on the RS-80 15G units. The first procedure was to remove the cardboard and polystyrene housing, enabling us to examine the electrical components inside. Following this, the unit was divided into two, the wind velocity module, and the PTU and radio module.

Then each module was examined, and the systems were reverse engineered as much as possible to aid in the understanding.

2.4.1 Dismantling

The first stage of dismantling was to remove the housing. This was an outer shell of cardboard, with polystyrene used to pack the different modules together. There are three separate modules within the RS-80, these being the battery, the wind velocity system, and the PTU and radio transmitter system, as shown in photo 2.2.



The PTU and radio system are combined together on a single printed circuit board (PCB). The temperature and humidity sensors are attached to an arm, while the pressure sensor is in its own metal housing at the base of the PCB. At the top of this PCB is the transmission antenna, with two metal wings on either side that fold back towards the PCB to create a ground plane for the radio transmissions.

The wind velocity system is very complex. It is comprised of a right hand polarised spiral antenna and two layers of surface mounted electronic devices within a metal-shielded housing, as shown in photo 2.3. At the base of the PCB are four pins with wires attached to three of these; this has been modified in photo 2.3 so that signals can be extracted from all the pins.

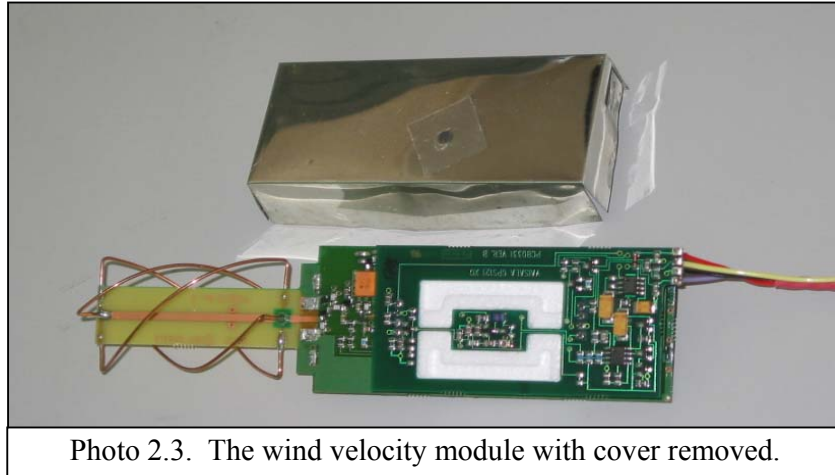


Photo 2.3. The wind velocity module with cover removed.

The power source is a single 19V water activated battery. It comes sealed in a foil package, to prevent inadvertent activation by moisture, and is attached to the PTU and radio transmitter PCB via a 9 volt battery clip.

The modules were split to enable more detailed examination. Removing the battery was simple, as it does not come connected, and then wires connecting the PCBs together were desoldered at one end. Tracing the solder paths back along the PTU and radio transmitter PCB, the signal and power wires were identifiable.

2.5 HARDWARE ANALYSIS OF RS-80 OUTPUTS

To gain an understanding of the signals at different stages within the RS-80, two pieces of equipment were used, a spectrum analyser and an oscilloscope. Using a spectrum analyser, the transmission frequency could be identified. Then using a FM demodulator, one of the functions of the spectrum analyser, the six tones could be heard. Finally an oscilloscope was used to view the FSK signal output of the wind velocity system.

2.5.1 Design of computer interface

Two interfaces were required to enable the signals from a RS-80 to be analysed using a computer. As the wind velocity unit's signal was accessible before it was modulated using FM onto the carrier, a simple FSK demodulator was constructed, and connected through a RS-232 driver to a computer serial port. The PTU signal, however, required a radio receiver to remove the FM carrier. The radio receiver output was connected directly to a computer soundcard.

The FSK demodulator that was used is an XR-2211 tone decoder chip. By selecting various resistors and capacitors, the chip was tuned to the two frequencies used in the FSK modulation. As the output of this chip gave transistor-transistor logic (TTL) level outputs, a RS-232 driver was required. The device used was a MAX-232 chip, which converts TTL level signals into signals of appropriate voltage levels that can be recognised by a computer serial port.

A commercial radio receiver was acquired that could receive the 403 MHz signal, and demodulate the PTU tones from the carrier. The radio obtained was an AOR-5000, which is a wide band, all mode base receiver. A lead was then used to connect the external speaker socket to the line-in socket on the sound card of a computer.

2.6 SOFTWARE ANALYSIS OF RS-80 OUTPUTS

Existing programs were used to analyse the signals so they could be viewed on a computer. But as these programs could not perform the tasks required, we wrote our own programs using Matlab. Matlab is a high-performance language for technical computing with advanced linear algebra processing abilities, proving to be ideal for use with this project.

2.6.1 Existing Programs

The PTU signal was read from the soundcard at the highest available resolution, 44 100 bits per second, and then examined using Goldwave. Goldwave is a professional digital audio editor that allowed the signal to be easily manipulated and viewed. Using Goldwave, the different tones could be isolated, and their frequencies identified using a fast Fourier transform (FFT) subroutine. The problem with Goldwave is that it gives a graphical representation of the frequency when the desired output is a single discrete frequency per tone.

HyperTerminal, which is the default Microsoft Windows application that enables a computer to communicate directly with a modem or serial port, was used to view the wind velocity signal. This enabled the characters to be viewed on screen, but there were a number of limitations.

The wind velocity signal is a continual stream of numbers, which HyperTerminal reads as American Standard Code for Information Interchange (ASCII). ASCII assigns characters to numerical values. But as there are 32 non-printing characters, HyperTerminal carried out the commands of these characters, which includes backspaces and sounding the bell. These non-printing characters cause data to be lost, meaning the HyperTerminal could not be used for this task.

2.6.2 Data analysis

The two programs mentioned in the previous section, although not giving the desired results, produced data that could be analysed. The Goldwave program gave a small graphical spectrum analysis, that was used to identify frequency bands of interest, and to compare the output of our self authored code against.

An example of the data output by HyperTerminal is shown in figure 2.4. This shows a repeating pattern, starting with four asterisks (*), then followed by a plus (+). There are also a number of characters that increase or decrease through the ASCII tables over regular intervals, and non-printing characters that create line breaks and spaces. The repeating pattern was identified here, and used later with the numerical display to locate the headers.

```

_i_L6ê°*****"BmZê*Té K•^_(Ò<c&±ár_g·_i |GM¯;Kp
'd*****+“š>Z_ÁîS%èg^<Èac5ô; r_6é,,_*
s *ðTKD †*****•__Z#¨·Sô pS^6Â&c>`ŠrD_3__P ç>_i rØJÅ ès*****+-}œY÷
:¨S_Z→¼]ø }_cVÉ
Vró ö¼_ö «6_ü "xJ_°m*****+—¶_Yû "kSO~]:Kçbi.r_{__Ð_Å _ JÝ
+I*****~ fXá à RÝ` , ]

```

Figure 2.4. HyperTerminal Output showing ASCII characters

2.6.3 Self written code

A number of programs were written in order to analyse the captured data. These identified the frequencies of the PTU signal, and manipulated the wind velocity data into the appropriate form.

Matlab was used to analyse the PTU data, using the FFT function from the signal processing toolbox. This enabled the exact frequencies to be identified, and a numerical output given. Prior to this program being executed, the PTU signal was recorded as a sound file, and then edited using Goldwave to give a discrete number of tones. The code is attached in Appendix D and is discussed in more detail in a later section of this report

To enable the wind velocity data to be easily viewed, and to prevent the issues of non-printing characters in ASCII format, numeric representation was used as shown in figure 2.5. Three programs were written for this process using Matlab. The first configured the serial port(s) to receive the data and format it as a matrix. Then a second program was used to convert the matrix into a text file with appropriate breaks so the information could be viewed using Microsoft Excel. Once the data was understood, another program was written that manipulated the data into the various groups, and discarded the irrelevant data.

```

16619950121814917942424242431670240521851077157011492117
01140909262117017924923079079123445023952079862501271052
18665013058465995021981331864242424243168024046861070219

```

Figure 2.5. Numerical data format.

3 SUMMARY OF RS-80 CAPABILITIES

This section is divided into three areas. The first is an overview of the RS-80 as a complete unit. The second is a focused examination of the PTU system and the method of calculating meaningful data from the tones received. The final area is concentrated on the wind velocity system, including the required base station reference system.

3.1 RS-80 RADIOSONDE

The RS-80 is one of the many meteorological data gathering instruments produced by Vaisala. Released in the early 1980s, the RS-80 has gone through a number of modifications. This includes various wind-finding techniques and the fitting of other sensors e.g. for the measurement of radioactivity and ozone levels.

The design is small and lightweight, allowing small weather balloons to be used, and enabling deployment by a single operator. Vaisala have also introduced automatic launch systems, removing the need for an operator to be present at the launches.

3.1.1 How they work

The RS-80 combines the signals from the various sensors, and transmits this data using either one of two meteorological aids bands, 400.15 - 406 MHz or 1668-1700 MHz. The data can take different forms; with the PTU data in the form of a TDM repeating six-tone analogue system, and the wind velocity system using a FSK modulation of the Doppler shifts from the GPS satellites.

3.1.2 Overview of the different systems on board

There are two measurement systems used by the RS-80. An analogue system that measures PTU, and a digital GPS system that measures wind velocity.

The first is the PTU system, which uses capacitive sensors to measure the environment. The output of these sensors alters the frequency of independent oscillators, which produce tones relative to the values sensed. These tones are sampled before being modulated onto the radio carrier in a repeating six-tone cycle.

The wind velocity system creates an internal signal, which is compared with the received signals from up to eight GPS satellites. The difference between the internally generated and GPS satellite signals creates a Doppler shift signal, which gives the RS-80's velocity relative to the GPS satellites. This Doppler signal is modulated onto the radio carrier using FSK for transmission. Once the signal has been received at a terrestrial base station, it is compared with a reference Doppler shift signal, between the base station and the GPS satellites, so that the RS-80's velocity can be calculated using ground as a reference.

3.2 PTU SYSTEM

The PTU system measures the pressure, humidity and temperature, and has remained relatively unchanged over the lifespan of the RS-80 radiosondes. Each of the individual sensors are variable capacitors, which change capacitance relative to the environmental parameters that they are measuring. This signal is easily received, and the data can be observed visually or aurally once it is demodulated from the radio carrier. Using a software based FFT, the individual frequencies can be identified. The problem we encountered was that these frequencies are coded and this caused the halt in progress for this system. Within the packaging for the RS-80 is a punched hole tape, as shown in photo 3.1, which contains a number of variables required to decode the tones into meaningful data.

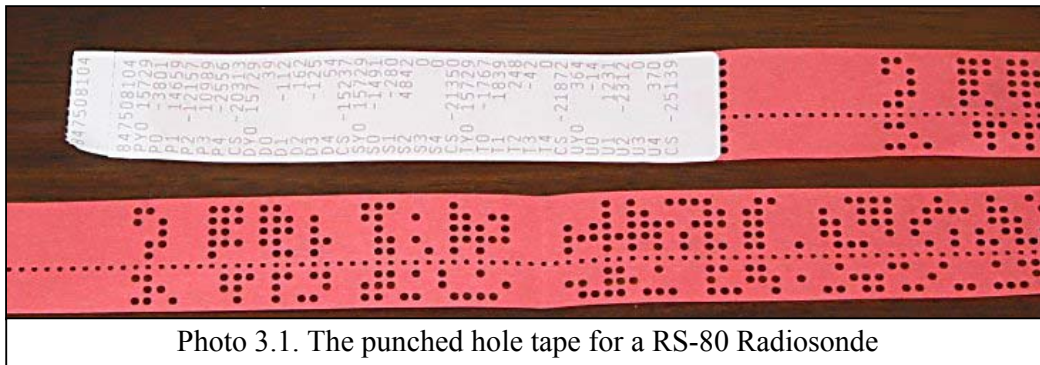


Photo 3.1. The punched hole tape for a RS-80 Radiosonde

3.2.1 Hardware used

Using a standard commercial wide band FM radio receiver and the correct sized antenna, the PTU signal can be easily received. If the RS-80 has other systems onboard, then a band pass filter is required to isolate the PTU signal. This signal is then fed directly into a computer sound card, and all the translation is completed using software. The only requirements for the computer is the capability to run Matlab, which requires a Pentium processor with 90 megabytes free hard disk space and 128 megabytes random access memory.

3.2.2 Software code

The software code used for the PTU data requires the two types of data. The audio signal recorded from the sound card, and the numbers read from the punched hole tape. The software operates in two stages, first reading the data and identifying the frequencies, and then the converting the frequencies into meaningful data. This code is attached in Appendix D.

As only one RS-80 unit was being used, the numbers from the punched hole tape are hard coded into the program. If the system worked, the code could then be altered to prompt the user to input the variables.

The software program initially reads the sound file, and then loops through each tone, identifying and logging the frequency for use by the second part of the program. This program cannot deal with partial tones, so Goldwave is used to edit the sound wave file to remove the incomplete tones and the beginning and end of the recordings.

The second part of the program locates the high reference signal, therefore identifying all the other signals due to the ordering. Using the known frequencies of the tones, an attempt was made to calculate the meaningful data. This is explained further in the following section titled conversion of tones to meaningful data.

3.2.3 PTU Data format

Once the PTU signal is isolated, it can be easily observed either aurally or visually. The signal is comprised of six tones, each lasting 250 milliseconds, repeating in sequence, giving a 1.5 second frame rate. The order of the tones is as follows:

- High Reference
- Capsule Temperature
- Pressure
- Low Reference
- Air Temperature
- Humidity

The two reference tones are used in the calculation of the atmospheric data, as this removes the effect of any fluctuations in the transmission frequency, and the capsule temperature is transmitted because the pressure sensor is temperature dependant.

3.2.4 Conversion of Tones to Meaningful Data

Once the six tones are identified, they require conversion to produce meaningful data. The tone frequencies are one of the variables in fourth order polynomial equations, which are used to calculate the atmospheric parameters. The other variables used in the equations are the calibration information provided with each individual RS-80 in the form of a punch hole tape. This gives high accuracy floating point results for the pressure, temperature and humidity. As shown in figure 3.2, the air temperature is calculated by initially using the reference tones to calculate Y, then V is calculated with the use of a variable from the punched hole tape. Finally, the temperature (T) is calculated using variables from the punched hole tape and V.

$$Y = \frac{1 / \text{Low Reference} - 1 / \text{Air Temperature}}{1 / \text{Low Reference} - 1 / \text{High Reference}}$$

$$V = \frac{1}{Y_0 - Y}$$

$$T = T_0 + T_1(V / 4) + T_2(V^2 / 4^2) + T_3(V^3 / 4^3) + T_4(V^4 / 4^4)$$

Where the Variables Y_0 and $T_0 - T_4$ are from the punched hole tape.

Figure 3.2 Formulas required to convert tones into temperature data

3.2.5 Reasons for halt in progress

The values read from the punched hole tape are too large to give reasonable results directly. With consultation with Sebastian Zettle, we discovered that the numbers on the punch hole tape required scaling. The only scalar known is that T_0 has to be divided by 2^{14} . This scalar was used to scale the other numbers from the punched-hole tape, but this did not give realistic results. Other methods were tried, with each number from the punched-hole tape divided by 2^n when n is varied from 1 to 16. This also gave unrealistic results and lead to a halt in progress, as the scalars could not be determined.

3.3 WIND VELOCITY SYSTEM

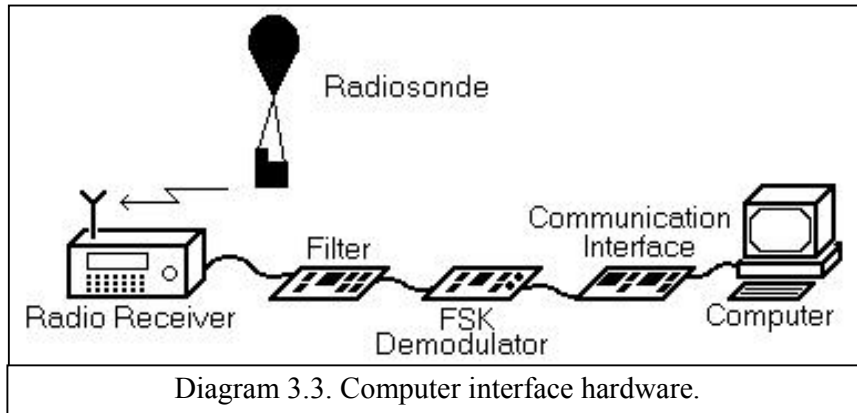
The wind velocity is calculated using Doppler shifts generated between an internally generated frequency, and the signals received from the GPS satellites. When compared to the Doppler shift of the base station, the velocity of the RS-80 relative to ground can be determined. Using the same radio receiver as the PTU system uses, but a different filter, the FSK frequencies used for the wind velocity system can be isolated. This signal requires hardware for demodulation and a communication interface to convert the TTL signal into a RS-232 signal. This enabled the signal to be fed into a computer via a serial port, and manipulated with software until the expected signal was derived, and the byte meanings established.

3.3.1 Base Station Reference System

As the Doppler shift calculated by the RS-80 is the relative motion between the GPS satellites and the RS-80, a reference system is required at the base station. For this, a wind finding unit was removed from a second RS-80, and the data from this unit used to determine the motion of the GPS satellites. But subtracting the signals from the RS-80 and this base station unit, it was assumed that the velocity of the RS-80 relative to earth could be calculated. This assumption turned out to be false, as when the RS-80 and base unit were powered simultaneously while sitting side by side, there was a substantial difference in the signals. This is further discussed in two following sections, the software code and the reasons for halt in progress.

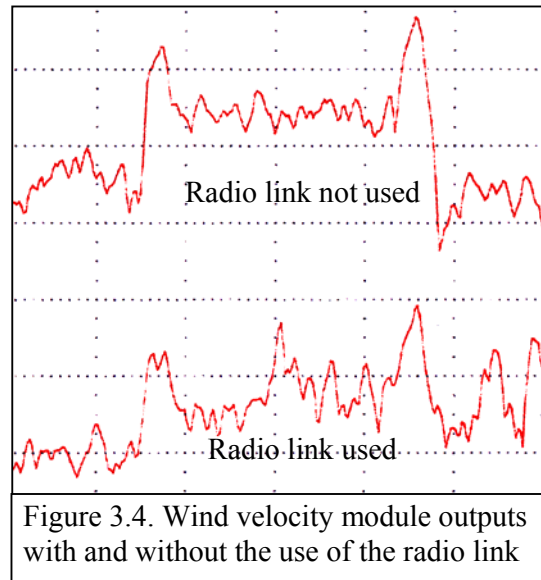
3.3.2 Hardware design

Five different hardware systems are required to convert the wind velocity component of the radio signal into a format that can be analysed using software, as shown in diagram 3.3. The same radio receiver as used for the PTU system can be used, but a different filter is required. This filter must pass the two frequencies used for the FSK, being 3050 Hz and 4250 Hz. Once filtered, the signal requires demodulation, prior to converting the TTL signal into a RS-232 signal. The final stage is feeding the signal onto a computer via a serial port. This computer can be the same one as used for the PTU system, or an independent one.



In an attempt to demodulate the FSK signal, two methods were used. The first was using an XR-2211 FSK demodulator chip, and the second was to use a LM-567 tone recognition chip.

The XR-2211 worked when the wind velocity signal was acquired prior to being modulated onto the radio carrier, but did not produce the correct signal when fed from the radio receiver via the filter. This was due to the operation of the chip, as it creates a reference frequency, between the two tones of interest, and then uses logic to determine which side of the reference frequency the received signal is. When the radio receiver was used, an excessive noise was present between the two tones as shown in figure 3.4. The chip confused the noise with the signal and therefore gave a garbled output.



To overcome the noise problem, a LM-567 tone recognition chip was used. This chip was set up to identify one for the two frequencies used, and from there create a TTL signal. This method did not work, as the 1200-baud signal was too fast for the chip, and the output would drop out whenever the signal was high for more than one pulse.

A communication interface was required to transform the TTL signals output from the XR-2211, LM-567, or the base station reference unit, into the RS-232 level signals required for serial communication with a computer. A MAX-232 RS-232 driver/receiver chip was used for this purpose. The MAX-232 chip can convert two signals simultaneously from a 5-volt TTL signal to a ± 10 -volt signal used in serial communication. This enabled the one chip to convert both the RS-80 signal and the base station reference signal, so the signals could be compared.

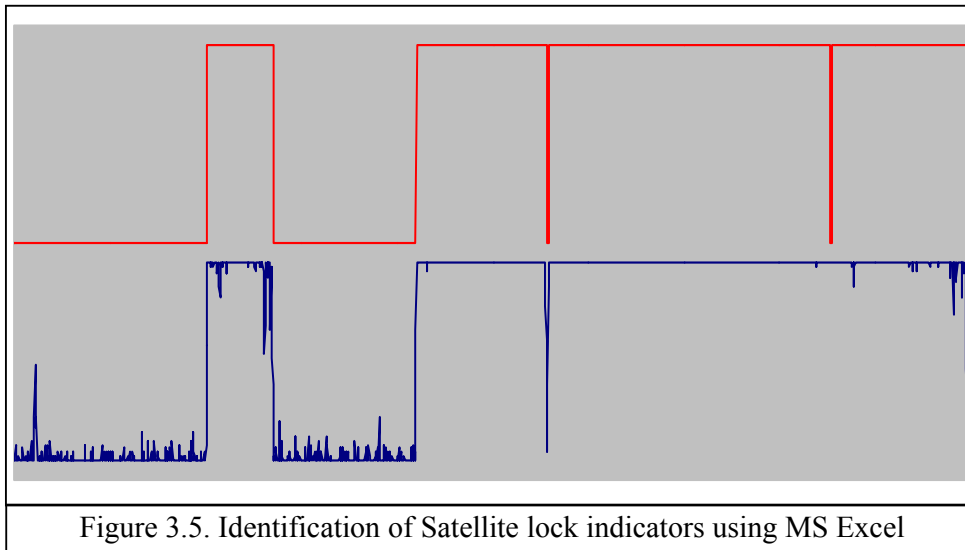
3.3.3 Software code

Once the data was available at the serial port, a program was required to display this data as numerical code, to prevent the non-printing characters in ASCII from corrupting the information. As all the programs that were found for serial port interface used ASCII, a self-authored code was required.

Matlab was used, as it is designed for numerical manipulation, and has serial port communication subroutines. After a number of iterations of the code, four individual programs were written. The first two handled the data reception and formatting, the third is an exporting routine that saves data to text files, and the final program was used to compare the wind velocity data from two different units. The code used can be found in Appendix E.

The first program configures the serial port, and then formats the data as matrices. This program can read from two serial ports simultaneously so that a RS-80 and the base station are using the same signals from the GPS satellites. The second program takes the data from the matrices and divides it into the required segments. For example, the synchronisation pulse is ignored, and the three bytes that make the Doppler information are combined together.

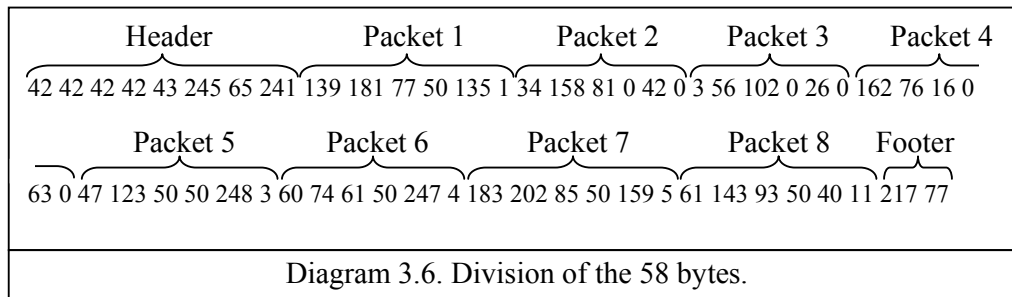
The third program exports the data from a given matrix into a text file. This text file can be examined as is, but is also formatted so that Microsoft Excel can import the data. Using Excel the data can be graphed allowing for easy analysis as shown below in figure 3.5, where two bytes are compared against one another to see if they both indicate satellite locks.



The final program was used to synchronise the wind velocity signals from the RS-80 and base station. It was intended to use this as the starting point for calculating the movement of the RS-80. When this program was run with the Radiosonde positioned next to the base station, there were only 19 identical Doppler shifts from 12 000 readings. This highlighted a lack in understanding about the operation of these units, which lead to a halt in progress.

3.3.4 Data Format and Byte Meanings

The transmission from the wind velocity unit is a 1200-baud FSK signal, using two frequencies of 3050 Hz and 4250 Hz. As the data is sent in packets 500 milliseconds long, that is what the format is based around. In that time, 600 bits are received. The first 20 of these are a synchronization pulse, followed by 580 bits of data. These bits convert to 58 bytes, with each byte containing 8 bits plus a start and stop bit. The 58 bytes can be broken down into an eight-byte header, eight six-byte data packets from up to eight GPS satellites, and finally a two-byte footer, as shown in diagram 3.6.



The header contains a four-byte synchronization pulse, then a single-byte identifying the firmware version. The sixth and seventh bytes are a counter for identification of missed signals. The eighth byte is an indicator of which of the six-byte data packets have locked onto a GPS satellite, in the order of least significant bit being the first packet, and the most significant bit being the last packet.

Each of the eight six-byte packets have the same format. The first three bytes are the Doppler information, with the third byte the most significant. The fourth byte ranges from 0 to 50, and gives an indication of the lock status of the packet, with any value above 36 being a lock. The meaning of the fifth byte could not be established. The sixth byte is a GPS signal received strength indicator, which varies from 255 through 0 to 15. Values of 255 and 0 indicate zero or minimal signal received, and any value above 3 indicates a reliable and usable signal.

The final two bytes meanings have not been established, but are believed to be a type of error checking system.

3.3.5 Reasons for halt in progress

There are two reasons for the halt in progress in relation to the wind velocity system. The first is the inability to demodulate the FSK signal when the radio link is used, and the second is the difference in data between a RS-80 unit and the base station unit.

As mentioned earlier in the hardware design section, once the wind velocity data has been transmitted across the radio link, no method of demodulating the FSK has been successful. Two methods have been attempted, using a FSK demodulating chip, and using a tone recognition chip tuned to one of the frequencies used by the FSK. Due to the time constraints of this project, other solutions have not been investigated.

When a wind velocity unit is removed from the radiosonde and used to create a base station reference, the signal is different to that from a radiosonde operated in an

identical manner. This highlighted an error in previous assumptions, as well as a lack of understanding about the operation of the wind velocity unit.

4 SUMMARY

The RS-80 is a complex meteorological instrument package, despite being originally released in the early 1980's. The manufacturing company, Vaisala, has designed the RS-80 in such a way that the complex routines involved with converting the transmissions into meaningful data are only possible by purchasing the commercial receiver. Although much of the RS-80 system operation has been deciphered, there are a few major hurdles yet to be overcome. An overview of this is contained in the following sub-sections, with more detailed information in the body of this report.

4.1 FINDINGS OF THE PROJECT

The RS-80 radiosonde is comprised of three major systems, a power supply, a PTU system and a wind velocity system. The power supply is a water-activated battery, and due to its trivial nature is not discussed in detail. The other two systems are outlined in the following paragraphs.

The PTU system is an analogue unit, which samples the pressure, temperature and humidity, and transmits the data using tones. These tones are combined with two reference tones and an internal temperature tone, as the pressure sensor is temperature dependant. Using TDM the tones are combined onto the radio carrier using FM. The sequence lasts 1.5 seconds with each tone lasting for 250 milliseconds in the following order:

- A high reference
- The capsule temperature
- The atmosphere pressure
- A low reference
- The air temperature
- The atmospheric humidity

The frequency of the tones is converted back into meaningful data using fourth order polynomial equations and the calibration variables that come with the RS-80 on a punched hole tape. The problem with the variables is that they require scaling, but only one of the scalars is known.

The wind velocity system determines the movement of the RS-80 by measuring the Doppler shift with the L1 radio signal transmitted from the GPS satellites. This Doppler information is transmitted on the same radio carrier as the PTU system, but uses a digital FSK modulation. A second set of Doppler shift information is required at the base station so that the RS-80 movement can be calculated with reference to earth. This FSK transmission contains 58 bytes of information and is updated every 500 milliseconds. The 58 bytes contain an eight-byte header, eight six-byte Doppler shifts from up to eight independent GPS satellites, and finally a two-byte footer. There is a difference between the wind velocity data from two RS-80s operated in the same location under identical conditions. This proved an initial assumption wrong, and inhibited the continuation of this line of investigation. Due to time constraints, no other lines of investigation could be explored.

4.2 RECOMMENDATIONS TO DTA

As this project was unsuccessful in designing a system that can receive and convert the RS-80 radio signal into meaningful data, the following recommendations are made to the DTA.

If the requirement exists for measuring the wind velocity, then there are two options. The first is contact the manufacturer and explain the limitations with the current system, and see if there is another system that would fulfill the tasks required. The other is to modify the sampling regime so that the limitations of the commercial receiver are not breached.

If the wind velocity is not required, then an additional option exists. This is to continue this project but only focus on determining the scalars involved with converting the numbers on the punched hole tape. Once these scalars are found, then the RS-80 without the wind velocity unit can be used.

4.3 FUTURE DIRECTION OF THIS PROJECT

There are three major areas where further investigations into the RS-80 would be of use. These are:

- Investigate systems to enable the wind velocity data to be demodulated from the FSK modulation once transmitted over the radio link.
- Identify the coding used in the variables on the punched hole tape.
- Investigate the operation of the wind velocity unit; determine the way the GPS satellite signals are selected, and the base internal frequency used to calculate the Doppler shift information.

If solutions were found in these three areas, then a receiver unit could be produced.

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APPENDIX (A) INITIAL PROJECT PROPOSAL



Fourth Year Electrical and Electronic Engineering Project Proposal

To Implement an Atmospheric Data Receiver for use in a Military Environment.

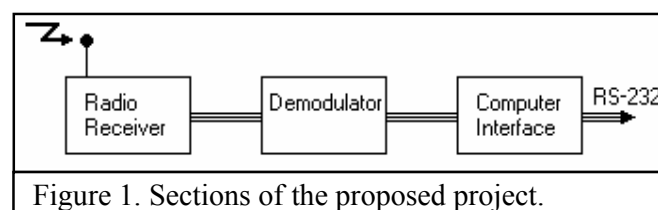
The Defence Technology Agency (DTA) has a number of atmospheric data transmitters (radiosondes) produced by Vaisala. These measure temperature, humidity, barometric pressure, and wind velocity. Wind velocity is calculated using Global Positioning System (GPS) information. This information is relayed via a Radio Signal, however currently the New Zealand Defence Force (NZDF) has no means of decoding these signals. The proposed system would be capable of interpreting data from all variations of radiosondes.

The primary objective is to enable an atmospheric information data basing capability onboard the Royal New Zealand Air Force (RNZAF) P3 Orion Aircraft using the dropwindsonde. This information would enable DTA to accurately model RADAR and Infrared (IR) propagation through the atmosphere, which is not always constant due to the effects of humidity and temperature gradients.

As well as the RNZAF capabilities the system could be used as a base station or modified to be fitted to the ANZAC class frigates of the Royal New Zealand Navy (RNZN). These systems would collate low-level atmospheric data to allow a better understanding of surface skimming missiles and dispersion of airborne agents.

The commercially available radio receiver designed for the transmitter is not suitable for our application for a number of reasons. The receiver, at a cost of NZ\$500 000, requires a number of readings to calibrate resulting in the loss of initial data. The information that is received is automatically processed consequently data is not relevant. The cost alone prohibits the purchase of this receiver, but the irrelevant functionality means it is not a viable solution.

This project can be broken down into a three main sections, as shown in the diagram figure 1. The receiver must be designed to receive data transmitted at 400-406 MHz. Power output of the transmitter and received signal strength will be considered. The demodulators' purpose is to take the electrical signal from the radio and pass a digital signal to the interface. The computer interface includes data packet recognition, buffering, and translates the information to serial output for databasing and display.



There are a number of constraints on this project. The first is the inability to carry out any modifications to the airframe of the P3 Orion's to fit the finalised device. This also means that the receiver antenna is restricted to one currently fitted to the P3 Orion's. The final constraint is the price of purchasing the receiver designed for this system.

In conclusion, the reason for undertaking this project is to rectify the current inability for DTA, and the other NZDF departments to receive raw data from the Vaisala atmospheric data transmitters.

Proposed by students:

Warren G McLuckie	ID: 2497452
Jonathan N Stirling	ID: 2498527

APPENDIX (B) RS-80 DATASHEET



RS80 Series GPS Radiosondes

VAISALA GPS WINDFINDING - UNSURPASSED PERFORMANCE

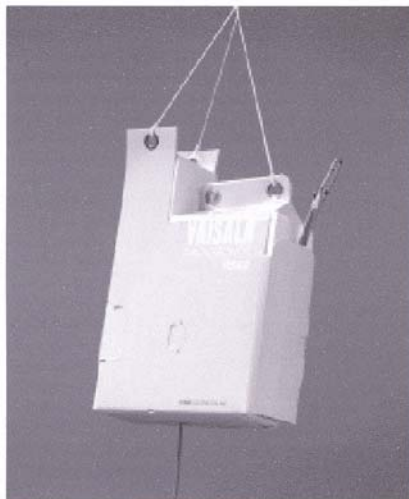
- High accuracy
- Good vertical resolution
- Ease of use

The Vaisala GPS system offers high-resolution windfinding for general and scientific sounding applications.

The GPS windfinding system is available as an upgrade to existing DigiCORA and MARWIN Systems.

GPS RADIOSONDE MODELS

- RS80-15G** Complete 403 MHz radiosonde with GPS windfinding
- RS80-15GH** 403 MHz radiosonde with H-HUMICAP
- RS80-30G** Complete crystal controlled 403 MHz radiosonde with GPS windfinding, 1kHz PTU
- RS80-30GE** Complete crystal-controlled 403 MHz radiosonde with GPS windfinding, 1kHz PTU, equipped with special sensor interface



An RS80-15G Radiosonde

GPS WINDFINDING

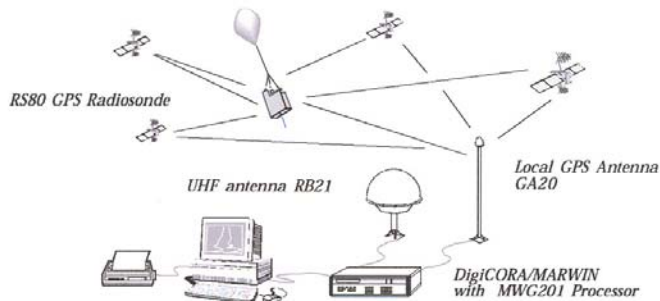
- Codeless, 8-channel digital GPS receiver in radiosonde.
- GPS signal from all visible satellites is used automatically.
- Down transmission of the GPS data is done with 1200-baud FSK modulation.
- Wind vector update rate 2 Hz for raw and 2 s or 10 s for filtered data.
- Wind computation is done in ground equipment.

The GPS receiver of GPS-radiosonde measures L1 carrier shift frequencies (=Doppler's) using a unique codeless detection and measurement technique. The measured Doppler shifts are a combination of satellite and radiosonde motion and contain the pertinent information for wind speed and direction computation. Doppler frequency measurements of up to 8 satellites are sent to the ground equipment using a low bandwidth (1200 baud) digital link. New independent GPS Doppler measurements from the GPS-sonde are provided every 0.5 s for up to 8 channels with 24-bit resolution.

The ground equipment computes the wind speed and direction using the differential GPS concept. Local carrier phase Doppler shift measurements to satellites are obtained from a high-quality 12-channel GPS engine. The remote and local Doppler measurements along with GPS time and satellite ephemerides form the basic raw data for wind computation.

New independent unfiltered velocity components and filtered wind vectors are provided with an update rate of 2 Hz. The filtering is required for pendulum removal which is the dominant feature at the 0.5-second raw velocity vector level.

The windfinding accuracy is very good even in the case where a mobile sounding station is used. The slight degradation in accuracy is mainly due to SA (Selective Availability).



CODELESS GPS RECEIVER

Number of channels	Digital, 8 channels
Radiosonde downlink	Digital, 1200 baud
Temporal resolution	0.5 s

Fixed station (with SA on, PDOP < 4)

Wind measurement accuracy	0.2 m/s RMS
---------------------------	-------------

Mobile sounding station, without RTCM differential correction (with SA on PDOP < 4)

Wind measurement accuracy	0.5 m/s RMS
---------------------------	-------------

PTU TRANSDUCER

Sampling rate	7 samples/10 s for each parameter
Calibration data content	Polynomial for each sensor with checksum

Calibration data format	8-channel paper tape
Sensor references	Low and high range

Battery	Water-activated
Voltag:	19 V

DIMENSIONS AND WEIGHT

Dimensions excl. antenna	55 mm by 155 mm by 125 mm
Weight, battery activated	approximately 330 g

METEOROLOGICAL SENSORS

PTU sensors are individually factory-calibrated.

Pressure	BAROCAP [®] Capacitive aneroid
Measuring range	1060 hPa to 3 hPa (mb)
Resolution	0.1 hPa

Accuracy	
Reproducibility ¹⁾	0.5 hPa
Repeatability ²⁾	0.5 hPa

Temperature	THERMOCAP [®] Capacitive bead
Measuring range	+60 °C to -90 °C
Resolution	0.1 °C

Accuracy	
Reproducibility ¹⁾	0.2 °C up to 50 hPa, 0.3 °C for 50-15 hPa, 0.4 °C above 15 hPa level
Repeatability ²⁾	0.2 °C

Lag	< 2.5 s (6 m/s flow at 1000 hPa)
-----	----------------------------------

Humidity	HUMICAP [®] thin film capacitor
Measuring range	0 to 100 % RH
Resolution	1 % RH

Lag	1 s (6 m/s flow at 1000 hPa, +20 °C)
Accuracy	
Reproducibility ¹⁾	<3 % RH
Repeatability ²⁾	2 % RH

1) Data based on WMO International Radiosonde Comparison Phases I, II, and III (WMO/TD no 195 and 451)

2) Standard deviation of differences between two successful calibrations



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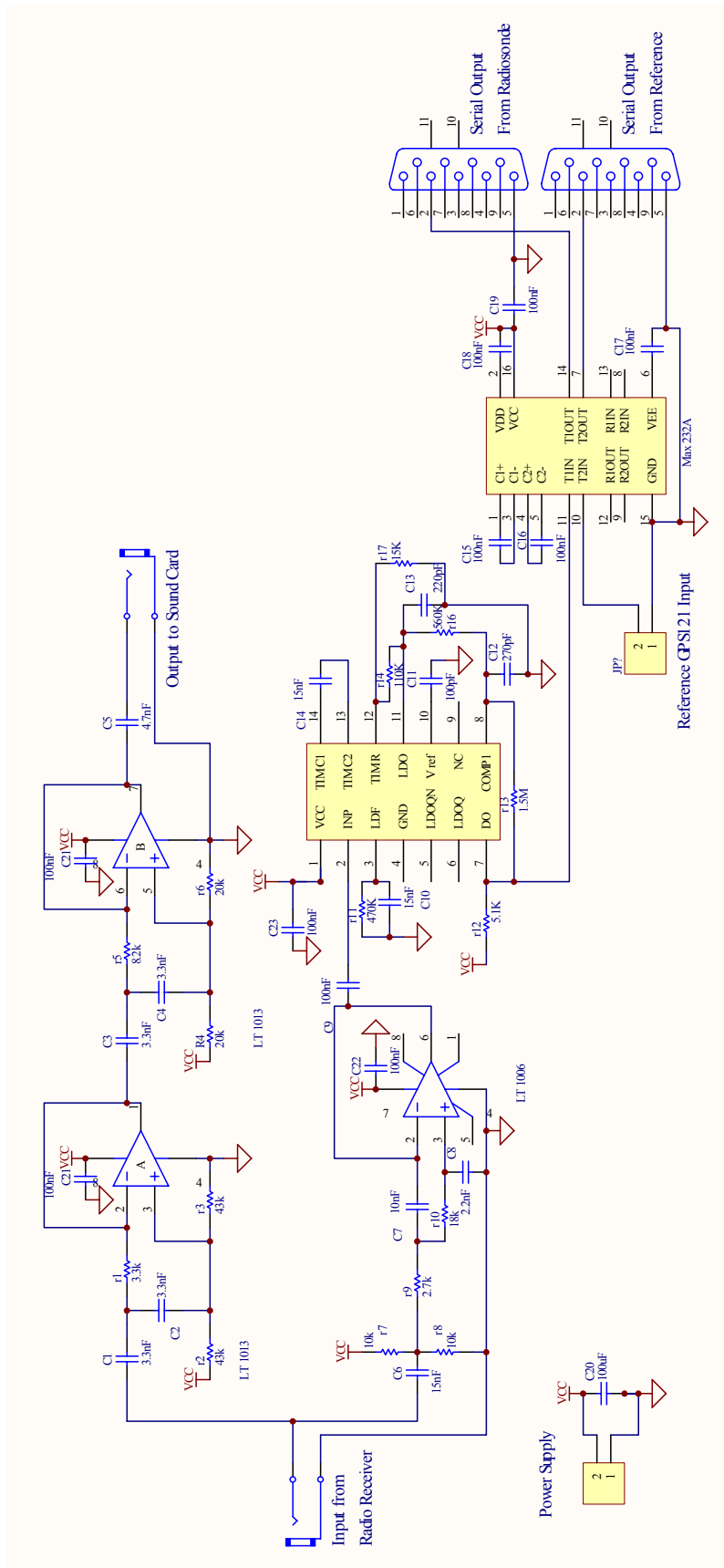
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APPENDIX (C) HARDWARE DIAGRAM



APPENDIX (D) SOFTWARE CODE FOR PTU ANALYSIS

```
% Filename: Spectro3.m
% Author: Warren G McLuckie
% Purpose: Translate wave files into meaning meterological data.

% Spectro 2 takes the designated input file and performs an FFT on
individual tones. Power is calculated and the frequency at which the max
power occured is stored in a matrix. This matrix is then synchronised and
translated using the appropriate formula and calibration data into
meaningful pressure, temperature and humidity values.

% Initialisation of counters and variables
counter = 1;
sync = 1;
tonefreq = [];
Pc = [];
Ts= 25;
pref = 1015;

% Calibration Data (Later to be input by the user)
pyo=15729/2^14; % Calibration data is coded by binary reference
dyo=pyo;
syo=dyo;
tyo=syo;
uyo=364;
p=[-4876;17054;-15143;12701;-2948];
d=[31;24;-110;89;1];
s=[-1410;-619;5316;0;0];
%t = [-1810;2321;216;19;0];%309
t=[-1772;2139;348;-45;0];% 306
u=[21;1054;-2156;0;370];
Ts=25

filename = input('Enter filename: ','s');
[y, fs, bits]=wavread(filename);
samplelen=length(y);

% Establish the length of each tone for individual tone analysis. An
estimate number of samples per tone is shortened to reduce the risk of
incorporating other frequencies. (Not very accurate but works)

if fs == 44100
    tonelen = 10440;
elseif fs ==22050;
    tonelen = 5050;
else
    tonelen = fs/4;
end

numtone=samplelen/tonelen;
numtone=ceil(numtone);
n1 = 300;
n2 = tonelen - 300;

% Each tone is windowed and the spectral power calculated.

while (n2 <= samplelen) & (counter <= numtone)
    [y, fs, bits] = wavread(filename, [n1 n2]);
    len=length(y);
    window = hann(len);
    y = y.*window;
    Y = fft(y,len);
    P=Y.*conj(Y)/len;
    rounded = floor(len/2); % Rounds to lowest integer
    f = fs*(0:(rounded))/len; % Creates frequency vector
```

```

% Following function creates a verticle matrix of spectral power and
Frequency. The max power is found and the associated frequency stored in a
matrix (tonefreq).

```

```

matrix = [P(1:rounded +1) f']; % Creates power frequency vector
maxpwr = max(matrix);          % Finds max power value
flag = 0;
i = 1;

```

```

% The while loop locates the frequency at which the maximum power occurred.

```

```

while flag == 0
    value = matrix(i);
    if value == maxpwr(1)
        flag = 1;
    else
        i = (i + 1);
    end
end

```

```

tonefreq = [tonefreq ; matrix(i,2)];

```

```

counter = counter +1;          % Move on to next tone
n1 = n1 + tonelen;            % Read samples for next tone.
n2 = n2 + tonelen;

```

```

end

```

```

disp('The number of tones is:');
disp(length(tonefreq));
disp('The frequency sequence is:');
disp(tonefreq);

```

```

% The following is used to convert the frequency data into meaningful
values. The data is first synchronised by finding the high or low reference
and assigning it a pointer value.

```

```

maxt = max(tonefreq);
mint = min (tonefreq);

```

```

while sync == 1
    if tonefreq(sync) == maxt
        pointer = 1;
        sync = 2;
    else if tonefreq(sync) == mint
        pointer = 4;
        sync = 2;
    else
        tonefreq = (tonefreq(2:length(tonefreq)));
    end
end

```

```

end

```

```

% Cycles through frequency matrix converting data using formulas and
calibration data.

```

```

while flag == 1
    switch pointer
    case 1
        pointer = pointer + 1;          % High reference
    case 2
        pointer = pointer + 1;
    case 3
        for i = 1:5
            Pc(i)=p(i)+d(i)*Ts;
        end
        y = ((1/mint)-(1/tonefreq(pointer)))/((1/mint)-(1/maxt));
        v = 1/(pyo-y);
    end
end

```

```

        psonde=Pc(1) + Pc(2)*(v/4) + Pc(3)*(v^2/4^2) + Pc(4)*(v^3/4^3)
+Pc(5)*(v^4/4^4);
        k = pref/psonde;
        P = k*sum(Pc);
        pointer = pointer + 1;

    case 4
        pointer = pointer + 1;          % Low reference

    case 5
        y = ((1/mint)-(1/tonefreq(pointer)))/((1/mint)-(1/maxt));
        %y = (tonefreq(pointer)-mint)/(maxt-mint);
        v = 1/(tyo-y);
        T = (t(1)) + (t(2))*(v/4) + (t(3))*(v/4)^2 + (t(4))*(v/3)^3;
%+(t(5)/2)*(v/4)^4;
        %T = (90*t(1)/(90+t(1))) + (1 + (t(1)/(t(1)+90))*tsamp;
        disp('The temperature was: ');
        disp(T);
        pointer = pointer + 1;

    case 6
        pointer = pointer + 1;
    otherwise
        pointer = 1;          % Resets synchronisation
        flag = 2;
    end
end
end

```

APPENDIX (E) SOFTWARE CODE FOR WIND VELOCITY SYSTEM

DATA RECORDER

```
% J. Stirling - Final Year Project
% 14 July 2003

% Record data from the Serial port(s) and sync it together.

% Prompt the user for the number of ports to be used.
p = 1;
while p == 1
    ports = input('How many ports? [1]:');
    % Default setting of 1.
    if isempty (ports)
        ports = 1;
    end

    % Ensure either 1 or 2 is selected
    if (ports == 1 | ports == 2)
        p = 0;
    else
        disp ('Select either 1 or 2.')
    end
end

% Prompt the user for the samples required.
samples = input('How many samples? [10]:');
if isempty(samples)
    samples = 10;
end

% Set the serial port to 1200 8N1 if it does not already exist.
p = exist ('s1');
if p == 0
    s1 = serial('COM1','BaudRate',1200,'DataBits',8);
    s1.Timeout=5;
end

% Open the serial port if it is not already open
status = s1.status;
if status(1,1) ~= 'o'
    % Due to problems occuring when opening the serial port,
    % ensure that nothing is connected before attempting to
    % open the port.
    disp 'Please disconnect from serial port 1.'
    pause;
    % Open the port.
    fopen(s1)
end

% Same as above, except for port 2.
if ports == 2
    p = exist ('s2');
    if p == 0
        s2 = serial('COM2','BaudRate',1200,'DataBits',8);
        s2.Timeout=5;
    end
    status = s2.status;
    if status(1,1) ~= 'o'
        disp ('Please disconnect from serial port 2.')
        pause;
        fopen(s2)
    end
end

end
```

```

% As the buffer can hold 8 seconds of data, inform the user.
disp('You have 8 seconds once connected to begin recording')
if ports == 1
    disp('Please connect to port 1.')
else
    disp('Please connect to ports 1 and 2.')
end

disp('Press any key to begin recording')
pause;

% Inform the user of the time required to sample.
b = clock;
b(6) = b(6) + samples * 0.5;

% Format the time into hours, minutes and seconds.
while b(6) > 60
    b(6) = b(6) - 60;
    b(5) = b(5) + 1;
end
while b(5) > 60
    b(5) = b(5) - 60;
    b(4) = b(4) + 1;
end
while b(4) > 12
    b(4) = b(4) - 12;
    b(3) = b(3) + 1;
end

disp('')
a =sprintf('Approx time sampling complete = %.0f:%2.0f:%2.0f', b(4), b(5),
b(6));
disp(a)

% Set flag values.
flag(1) = 1;
flag(2) = 0;

% Reset error flags
errorport(1) = 0;
errorport(2) = 0;

% Sync the first port to **** or 42 42 42 42
while flag(1) == 1
    % read one character at a time.
    [p,count,msg1] = fread (s1,1);

    % Check for an error when port is read.
    if count == 0
        flag(1) = 0;
        errorport(1) = 1;
    end

    % Increment flag2 if character is a *
    if p == 42
        flag(2) = flag(2) + 1;
    % or reset flag2 if a false alarm.
    else
        flag(2) = 0;
    end

    % If 4 *'s break out of while loop
    if flag(2) == 4
        flag(1) = 0;
    % Read the remaining 54 characters
    [a] = fread (s1,54);
    % Avoid wasting the first read.

```

```

        result1 = [ 42; 42; 42; 42; a];
    end
end

% Set flag values.
flag(1) = 1;
flag(2) = 0;

% When both ports are used, Sync the second port to **** or 42 42 42 42
if ports == 2
    while flag(1) == 1
        % read one character at a time.
        [p,count,msg2] = fread (s2,1);
        % Check for an error when port is read.
        if count == 0
            flag(1) = 0;
            errorport(2) = 1;
        end
        % Increment flag2 if character is a *
        if p == 42
            flag(2) = flag(2) + 1;
        % or reset flag2 if a false alarm.
        else
            flag(2) = 0;
        end
        % If 4 *'s break out of while loop
        if flag(2) == 4
            flag(1) = 0;
        % Read the remaining 54 characters
        [a] = fread (s2,54);
        % Avoid wasting the first read.
        result2 = [ 42; 42; 42; 42; a];
    end
end
end

% Sample both ports, to prevent filling the second
% buffer while reading from the first port.
if errorport(1) == 0
    % Sample for the required number
    for w = 2 : samples
        [a] = fread (s1,58);
        % Combine into one matrix
        result1 = [result1 a];
        if errorport(2) == 0 & ports == 2
            % Sample for the required number
            [a] = fread (s2,58);
            % Combine into one matrix
            result2 = [result2 a];
        end
    end
end

% Display any error messages
if ~isempty(msg1) == 1
    disp('Error with port 1.')
    disp(msg1)
end

if ports == 2
    if ~isempty(msg2) == 1
        disp('Error with port 2.')
        disp(msg2)
    end
end

% Prompt the user with default as no.
i = input('Have you finished? Y/N [N]: ','s');
```



```

if isempty(i)
    i = 'N';
end

% Close the port if it is finished with.
if i ~= 'N'
    fclose(s1)
    if ports == 2
        fclose(s2)
    end
end

% Clear the workspace of unmeaningful variables.
clear('a','b','count','flag','i','p','status','samples')

```

DATA FORMATTER

```

% J. Stirling - Final Year Project
% 8 August 2003

% Format the data, using known structure.
% Gives the result in lockdata1 or lockdata2 depending on channel selected.

result = input ('Format channel 1 or 2? (1/2) [1]:');
if isempty (result)
    result = 1;
end

% create a copy as not to corrupt the original.
chan = 0;
if result == 1 & exist('result1') == 1
    chan = 1;
    result = result1;
end
if result == 2 & exist('result2') == 1
    chan = 2;
    result = result2;
end

if chan == 0
    disp('Error. Data does not exist.');
```

```

else
    [len wid] = size (result);
    for b = 1:wid
        % result(1) .. result(4) = 42 - Sync pulse - not meaningful data
        % result(5) = 43 - not meaningful data

        % result(6) .. result(7) = Counter
        counter = result(6,b) + result(7,b) * 256;

        % result1(8) = Lock indicator
        str = dec2bin(result(8,b),8);
        for a = 1 : 8
            % result1(a*6+3) .. result1(a*6+5) = GPS Doppler Shift Data
            % result1(a*6+6) is 0 - 50
            % result1(a*6+7) = Unknown
            % result1(a*6+8) is 0 - 15 Signal Strength??

            if str(9 - a) == dec2bin(1)
                locked(a) = result(a*6 + 3,b) + result(a*6 + 4,b) * 256 +
result(a*6 + 5,b) * 65536;
                strength(a) = result(a*6 + 8,b);
            else
                locked(a) = 0;
                strength(a) = 0;
            end
        end
    end
end

```

```

        % Compile the locked data with a counter reference
        if chan == 1
            lockdata1(b,1:17) = [counter locked strength];
        else
            lockdata2(b,1:17) = [counter locked strength];
        end

        % result(57) = Unknown
        % result(58) = Unknown

    end
end

% Clear memory of variables used.
clear('a','b','counter','len','wid','str','locked','chan','result','strength
');

```

DATA EXPORTER

```

% J. Stirling - Final Year Project
% 15 August 2003

% This program exports any matrix into a text file, formatted for viewing
with Excel.

% Prompt the user for the matrix.
matrix = input('Please enter the name of the matrix to export: ');

% Prompt the user for the filename.
filename = input('Please enter the name of the file: ','s');

% Use default if no input selected.
if isempty(filename)
    filename = 'default';
end

% Extend filename with '.txt' extension and open file for writing.
filename = strcat(filename,'.txt');
file = fopen(filename,'w');

% Measure the size of the matrix
[len wid] = size (matrix);

% Rotate matrix if its too wide, but not too long to view in Excel.
if wid > 255
    disp('This matrix is too wide for viewing with MS Excel. ');
    if len < 255
        disp('This problem may be overcome by rotating the matrix. ')
    end
end

rotate = input('Do you want to rotate the Matrix? (Y/N) [Y]: ','s');
if isempty(rotate)
    rotate = 'Y';
end

if rotate == 'Y' | rotate == 'y'
    matrix = matrix';
    [len wid] = size (matrix);
end
else
    disp('The matrix is too long to rotate. Program is continuing. ')
end
end

% Export the data
for a = 1:len
    for b = 1:wid
        fprintf(file, '%3.0f\t',matrix(a,b));
    end
end

```

```

    fprintf(file, '\n');
end

% Clear the workspace of unmeaningful variables and close the file.
fclose(file);
clear('matrix','filename','a','b','len','wid','file','rotate');

```

SIMILARITY LOCATOR

```

% J. Stirling - Final Year Project
% 12 August 2003

% Find the occasions when the doppler signals are identical.
% The first stage to synchronising GPS units when powered up at different
% times.

% N.B. This process is very processor intensive

[a,b] = size(lockdata1);
[c,d] = size(lockdata2);
count = 0;

for e = 1:a
    for f = 2:b
        for g = 1:c
            for h = 2:d
                if lockdata1(e,f) == lockdata2(g,h) & lockdata1(e,f) ~= 0
                    count = count + 1;
                    match(count, 1:3) = [count lockdata1(e,1)
lockdata2(g,1)];
                end
            end
        end
    end
end

% Clear the variables used.
clear('a','b','c','d','e','f','g','h','count');

```