

Transcription Method used for P-3C AQH4 Tapes

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**Maritime Operations Division
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ABSTRACT

Sonobuoy data is regularly obtained using the RAAF P-3C aircraft during DSTO trials. This data is recorded on the aircraft using 28 track AQH4 tapes and needs to be transcribed onto CDs for storage and analysis. The method used to transcribe analogue sonobuoy data was recently upgraded. This document describes the equipment used and the steps involved in transcribing this data.

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Executive Summary

During trials with the RAAF P-3C aircraft, sonobuoy data is stored on the aircraft using 28 track AQH4 Tapes. This data needs to be transcribed onto CDs for storage and analysis. This transcription method for analogue sonobuoys has been improved. The previous method required moving large data files between a number of different computers before it was ready to be copied onto CD and had limited quality control checking. The improvement required the purchase of an analogue to digital (A/D) converter card and a number of FM cards for the AQH4 tape recorder.

Transcription of data from the AQH4 tapes onto CDs now involves the following steps:

- Replay of the AQH4 Tape
- Anti-alias filtering of the analogue signal
- Digitisation of the analogue signal
- Quality checking the data files
- Writing the data onto CD for storage and analysis

This new method now has the digitisation, validation, and storage processes in one PC, thus simplifying the transcription process. In addition, a commercial off the shelf (COTS) software program called Cool Edit was purchased to check the data files. This has improved the validation process, since it is user friendly, fast, and has a good Graphic User Interface (GUI) to check the data quality.

This document describes the new transcription process, the required filter settings, and the techniques for using the A/D card software.

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List of abbreviations

A/D	Analogue to Digital
BNC	Bayonet Nut Connector
CD	Compact Disk
COTS	Commercial off-the-shelf
DIFAR	Directional Frequency Analysis and Recording
DICASS	Directional Command Active Sonobuoy System
DIG	Digital
EEPROM	Electrically Erasable Programmable Read Only Memory
ESM	Electronic Support Warfare Measures
FM	Frequency Modulated
GUI	Graphical User Interface
ICS	Internal Countermeasure Set
PC	Personal Computer
PCI	Peripheral Component Interconnect
RAAF	Royal Australian Air Force
RTC	rooftop checker
SS1	Sensor Station 1
SS2	Sensor Station 2
SSQ	Sonobuoy
TCG	Time Code Generator

1. Introduction

Sonobuoy data obtained using the RAAF P-3C aircraft is recorded onto AQH4 tapes during a trial. This data then needs to be transcribed to CD, so it can be analysed and archived. The method of transcribing analogue sonobuoy signals has been updated, improving the ability to digitise multiple channels at the same time, and at a higher sampling frequency.

The upgrade also reduced the time taken to transcribe the data to CD and improved the ability to validate the data. This was done by combining the A to D card and CD writer in one PC, so time is not wasted transferring the data between machines and off the shelf software could be used to check the data.

As part of the upgrade, a Graphical User Interface (GUI) was written to simplify the digitisation process. This report describes the new method used to transcribe and validate the data.

2. The Transcription Process

The transcription of FM data from AQH4 tape to CD has a number of steps:

1. The FM tracks of the AQH4 tapes are replayed using a RACAL STOREHORSE recorder. Each FM track produces an analogue data channel.
2. The analogue data is then low pass filtered, using a multi channel programmable filter, to remove aliasing during the digitisation. The current filter has eight channels, so a maximum of eight channels can be digitised at the current time.
3. The data is digitised and saved as a separate file for each AQH4 track of interest on the PC's hard disk.
4. These files are then checked for errors by audio replay and displaying the data graphically using 'Cool Edit'.
5. The data is written onto CD's for analysis and storage.

The RACAL recorder, filter, and PC have been installed in racks and connected to a number of BNC connector panels (see Figure 1). This enables the different AQH4 tracks to be easily digitised. A second RACAL recorder also has been placed in the racks, to enable duplication of tapes, but this is only possible for the FM tracks (see Table 1).



Figure 1: Digitisation Equipment Set up

2.1 Replay of AQH4 Tapes

Data recorded during trials, by the RAAF P-3C aircraft, are stored on 28 track AQH4 tapes. SSQ-57A, SSQ-36 bathythermograph, SSQ-53D DIFAR, and SSQ-62B DICASS sonobuoys all have analogue electronics and are recorded on AQH4 tapes as FM signals on specific tracks during the RAAF trials (see Table 1). A RACAL recorder has been set up at MOD Salisbury to replay the AQH4 tape's FM tracks. Each FM track used by the RAAF has a FM card installed in the RACAL recorder. This simplifies the replay of AQH4 tapes since the cards do not have to be moved around in the back of the RACAL recorder to change the tracks. These FM cards are connected to the back of a BNC panel, displaying the AQH4 track numbers. The data can be replayed off the tapes, with an analogue signal being produced for each FM track. Changing tracks just requires changing the cables connected to the front of the BNC connector panels (see Figure 1). These signals then need to be low pass filtered before digitisation to stop aliasing.

Table 1: AQH4 Track Allocation

AQH4 Track	Function	Sensor Station Number	Receiver Module Number	AQH4 Track	Function	Sensor Station Number	Receiver Module Number
1	Pilot Headset or ICS			15	DIG	SS1	5 & 6
2	FM	SS1	2	16	FM	SS1	5
3	FM	SS1	3	17	DIG	SS1	7 & 8
4	FM	SS1	4	18	FM	SS1	5
5	FM	SS1	6	19	DIG	SS1	1 & 2
6	FM	SS1	7	20	FM	SS1	6
7	DIG	SS1	1 & 2	21	DIG	SS1	3 & 4
8	SERVO			22	FM	SS1	7
9	FM	SS1	8	23	DIG	SS1	5 & 6
10	FM	SS1	2	24	SERVO		
11	FM	SS1	3	25	DIG	SS1	7 & 8
12	FM	SS1	1	26	FM	SS1	8
13	DIG	SS1	3 & 4	27	TCG		
14	FM	ESM or SS2	4	28	FM	SS1	1

2.2 Anti-Aliasing Filter

Since the data replayed from the RACAL recorder is analogue, it has to be filtered before digitisation to stop aliasing. An IOtech 488 eight channel programmable analogue filter bank is used as the aliasing filter. The filters are 8-pole Chebyshev low pass filters with programmable cut off frequencies from 1 Hz to 50 kHz. The cut-off frequencies are the same for all of the eight filters and are specified using a Windows based program called Filter488. The input and output lines for the filter are connected to the BNC panels.

2.2.1 Using the Filter488 program

Launch the Filter488 program by double clicking on the **Filter488 shortcut** that appears on the window's desktop. Figure 2 will then appear.

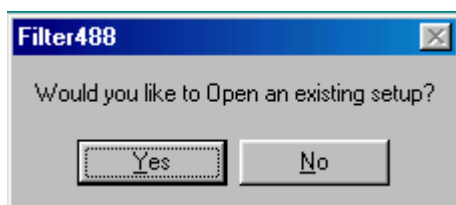


Figure 2: Start up window for Filter488

Click on the **yes** button and select an appropriate set-up from ambient.ftr, bathy.ftr, dicass.ftr, strum.ftr, or sus.ftr.

Figure 3 displays the filter settings after selecting sus.ftr.

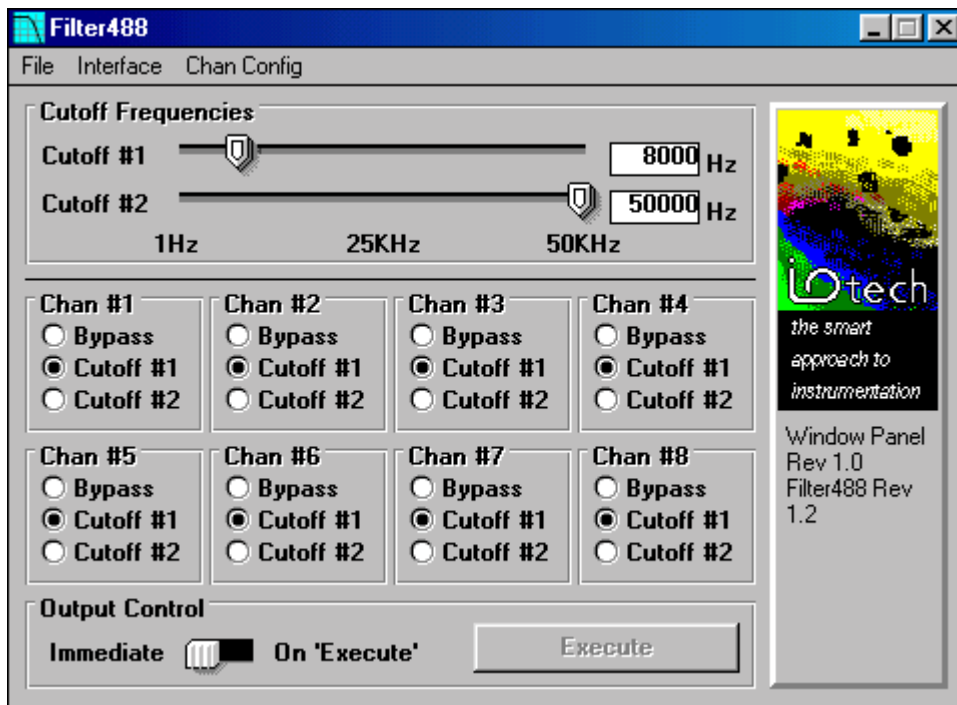


Figure 3: Filter488 setting window

To transmit these setting commands to the programmable filter, the **Output Control** button has been selected in the immediate position (see Figure 3). After selecting the output control to immediate, the filter settings will be set and the filter is ready for use.

To change the filter set-up, select **File** then **Open** and choose a new set-up from the list. Select the **Output Control** to immediate to set the filter to the new set-up parameters.

2.2.2 Selecting the cut off frequency

When selecting an anti-aliasing filter for use in a data acquisition application, the cut off or corner frequency f_c of the filter is normally the highest frequency of interest in the signal being acquired (see Figure 4). The attenuation of the filter at the Nyquist frequency f_N is what determines the level of any aliasing that appears in the signal being acquired. As the upper frequency of interest is f_c , some aliasing in the region f_c to f_N can be tolerated as long as there is sufficient attenuation in the band $f_s - f_c$ to f_s , where f_s denotes the sampling frequency in the data acquisition process. Signals in the band $f_s - f_c$ to f_s are aliased to frequencies below f_c , so these must be attenuated by a minimum of 50 dB.

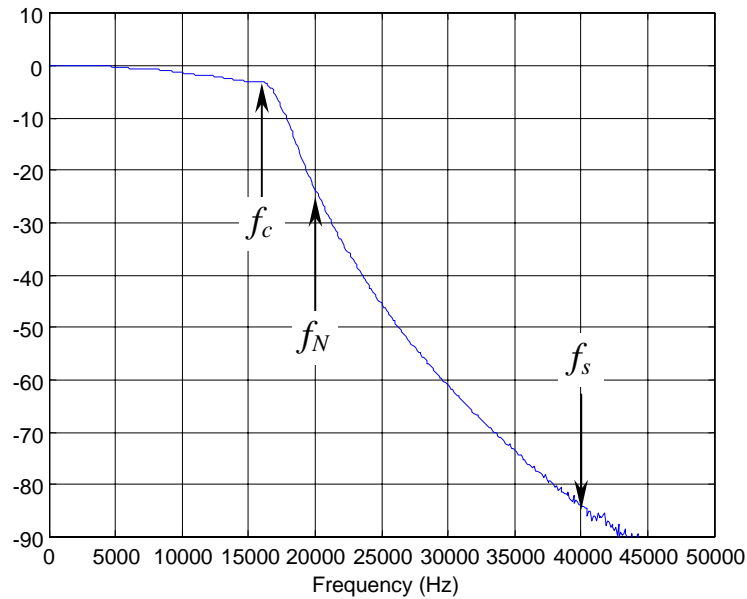


Figure 4: Typical Filter Response Curve, with $f_s = 40\text{kHz}$, $f_N = 20\text{kHz}$, and $f_c = 16\text{kHz}$.

The Chebyshev filters used in the programmable filter module specify an attenuation rate of 80 dB per octave. The simple rule of selecting the filter cut off frequency to be 80% of the Nyquist frequency (ie. $f_c = 0.4f_s$) would result in any aliased signals in the band $0 \rightarrow 0.4f_s$ being attenuated by a minimum of $80(\log_2(0.6) - \log_2(0.4)) \approx 47\text{ dB}$, which is an acceptable level of attenuation.

Since data obtained from SSQ-57A, SSQ-36 bathythermograph, SSQ-53D DIFAR, and SSQ-62B DICASS sonobuoys are normally digitised at set rates (see Table 2), the anti-aliasing filter was characterised for each required sampling rate using the set up described in Appendix A.1. This enabled correct settings for each desired sampling frequency to be determined and applied during on-going data transcription work, instead of relying on the 80 dB per octave as being correct.

The results obtained from the measurements showed that the filters do not achieve this level of attenuation (see Appendix A.2). The actual attenuation rate was approximately 66 dB per octave from f_c to $2f_c$, with an attenuation of about 42 dB at $0.6f_s$. This would normally not be sufficient attenuation, but since pre-whitened sonobuoy data is being digitised with a dynamic range of about 30 dB, this level of attenuation is satisfactory. Table 2 shows the standard digitisation rates and filter settings used for digitising sonobuoy data.

Table 2: Recommended Filter Settings for Digitisation of Sonobuoy Signals

Sampling Rate (Hz)	Filter cut off frequency (Hz)	Signal type and application
10000	4000	Bathythermograph buoy
20000	8000	SSQ-57A & SSQ-57B sonobuoys for SUS runs and ambient noise
40000	16000	SSQ-57A & SSQ-57B sonobuoys for ambient noise analysis
50000	22500	SSQ-57A & SSQ-57B sonobuoys for DICASS analysis
50000	22500	DICASS, DIFAR, and STRUM sonobuoys

Table 2 has the standard $f_c = 0.4f_s$ for all sampling rates except 50 kHz. At the 50 kHz sampling rate the filter is set to 22.5 kHz, which is $0.45f_s$, this is used since the SSQ-57A, DICASS, DIFAR, and STRUM sonobuoys already have a designed roll-off below this frequency. The SSQ-57B sonobuoy signal does not contain this roll-off, but is filtered at the same rate for convenience. The SSQ-57B sonobuoy data should only be used up to 20 kHz; any higher data could have aliased data in it (see Figure 24).

2.3 Digitisation of AQH4 FM Tracks

The digitisation is done using a National Instruments PCI-MIO-16E-1, 16 channel, 1.25 MHz, 12 bit, A/D card installed in the PC and a BNC-2090 panel next to the other BNC panels. Since there are 16 FM tracks on an AQH4 tape and only eight filter channels, the channel numbers on the A/D card do not match the track numbers on the AQH4 tape. The BNC panels are used to change which AQH4 track is recorded on which digitisation channel. A 16 channel A/D card was chosen so a future update to the anti-aliasing filter will enable all FM tracks to be digitised simultaneously.

A GUI program called NI_Card_dll was written in Visual Basic to control the A/D card. The main window is displayed when starting the program (see Figure 5). This has the 16 channels in a frame in the top left, the operation buttons in the top right, a frame for the type of digitisation in the bottom right, and a progress bar and text box in the bottom left. The text box displays the process that is occurring or that has just occurred. At start up the text box should display either 'Calibration constants obtained from EEPROM factory defaults' or 'Calibration constants obtained from EEPROM self calibration' (see Figure 5). If neither of these is displayed the calibration constants were not obtained from the A/D cards EEPROM, so any data obtained is not calibrated and the card should be either re-calibrated or repaired.

First, choose the channels required and the names of files in which data is to be saved. Each channel has a tick box, which tells the program which channels you want digitised. When a channel is chosen you can add the file name by either clicking the '...' button or the file name display area. This will open a standard 'save file name' window. The file name chosen will be displayed after **OK** is pressed (see Figure 6).

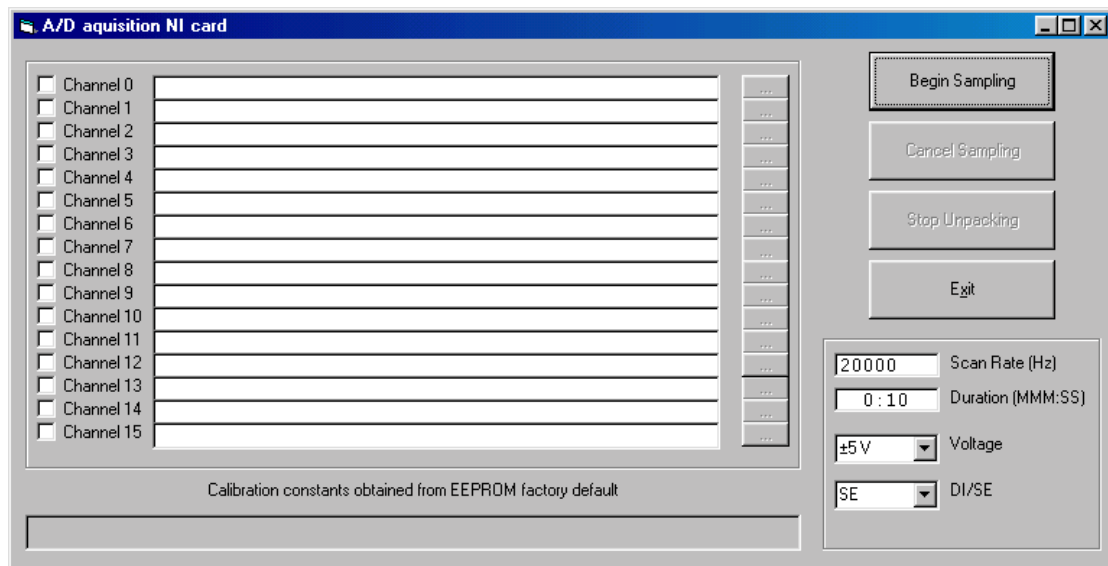


Figure 5: NI_Card_dll.exe main form

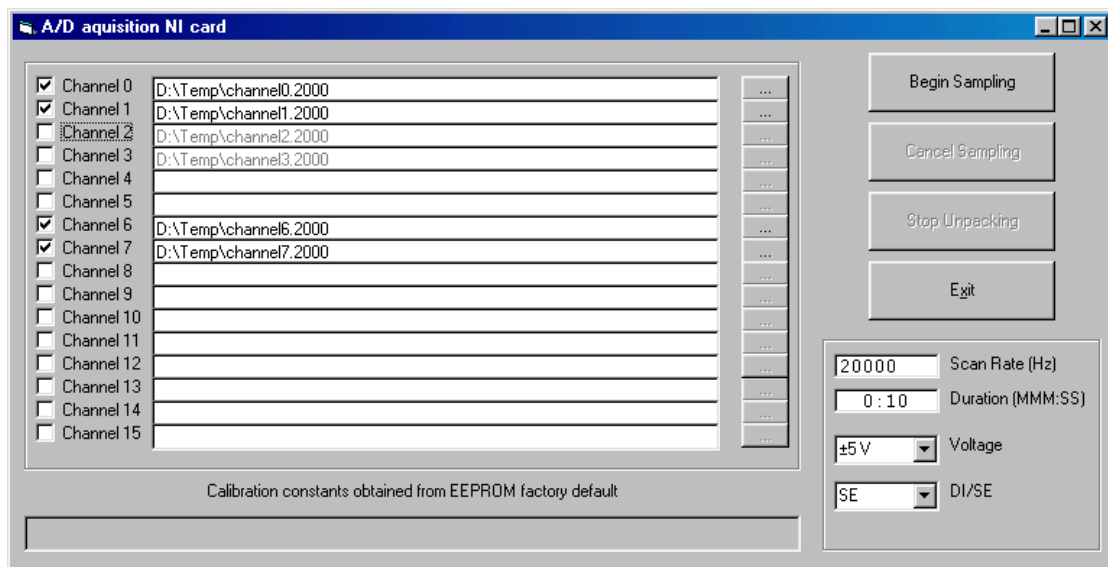


Figure 6: Loading the file names

A tick box can be unselected, if you no longer want that channel digitised. If the file name has already been chosen, it will be greyed out and not used (see Figure 6).

Next, the **Scan Rate** should be chosen. The **Scan Rate** is the digitisation rate for each channel, not the combined rate (ie. if you want 4 channels digitised at 20kHz each, the **Scan Rate** is 20000, while the combined rate would be 80000). The A/D card is only capable of handling a combined digitisation rate of 1.25 MHz, but this high speed can quickly overflow the card buffer, so a max speed of 1.0 MHz has been set in the program.

The A/D card can digitise only at set rates, depending on the internal clocks in the card. These set rates have been put in the program, so if you select a rate the program will select the closest rate possible and display it in the scan rate text box.

The **Duration** of the digitisation can now be set. This has set intervals that can be used due to the buffer sizes used. If the time duration does not match the buffer length, it will be increased to fill the last buffer.

There is a pre-digitisation amplifier in the A/D card that is set by the program. The default setting is 5 volts, which is the normal level required for digitising SSQ-57A sonobuoys. If a different input voltage is required, it can be set between 0.05 and 10 volts using the **Voltage** put down window.

The only other setting required before digitisation is the **DI/SE** (differential or single ended) setting. The anti-aliasing filter used has a common earth so single ended is used. When a number of channels are being digitised without a common earth, the differential setting can be used, but this reduces the number of channels to eight (ref PCI E Series User Manual, July 1997).

The settings mentioned above could be set in any order, but the **Scan Rate** and **Duration** could change if other settings are altered.

When all the settings are correct the AQH4 tape should be positioned to start at the section to be digitised and played. When the tape is playing the **Begin Sampling** button should be pressed. This will start the A/D card going with about a one-second delay. The GUI will be disabled except for the **Cancel Sampling** button (see Figure 7).

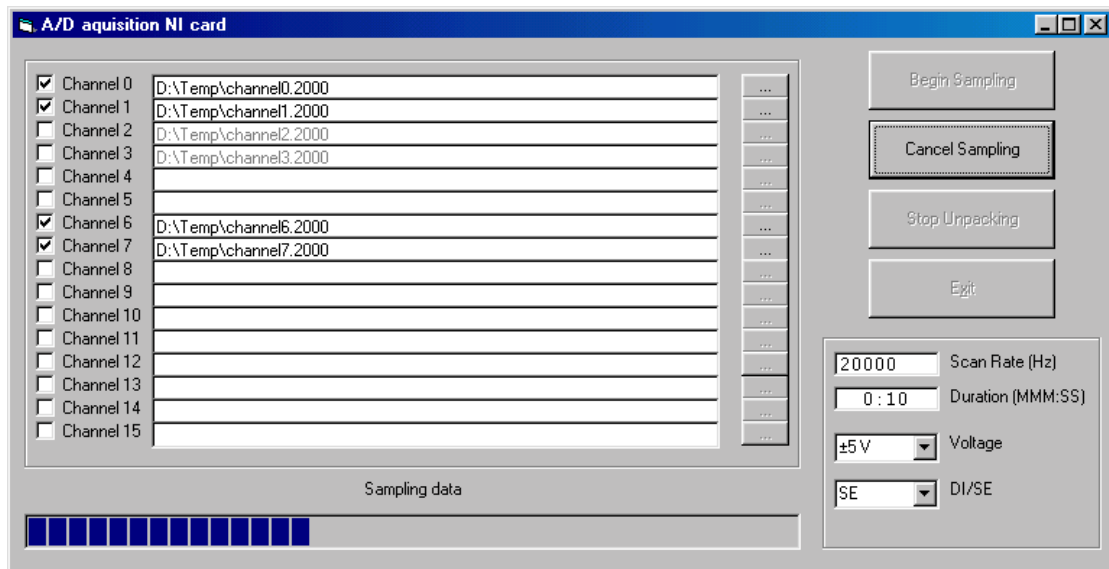


Figure 7: Sampling data

During sampling, the program can be stopped by pressing the **Cancel Sampling** button. The sampling process requires a large amount of computer resources to save the data when it digitises. For this reason the screen saver or other programs that could use up computer time should be stopped. The progress bar will display how much longer the sampling has to go. During sampling, the data is recorded in a temporary file, with all the channels in one file.

When the sampling has finished the data needs to be unpacked from the temporary file and into the file names selected for each channel (see Figure 8). This is done using a dll written in C giving a major speed improvement over Visual Basic.

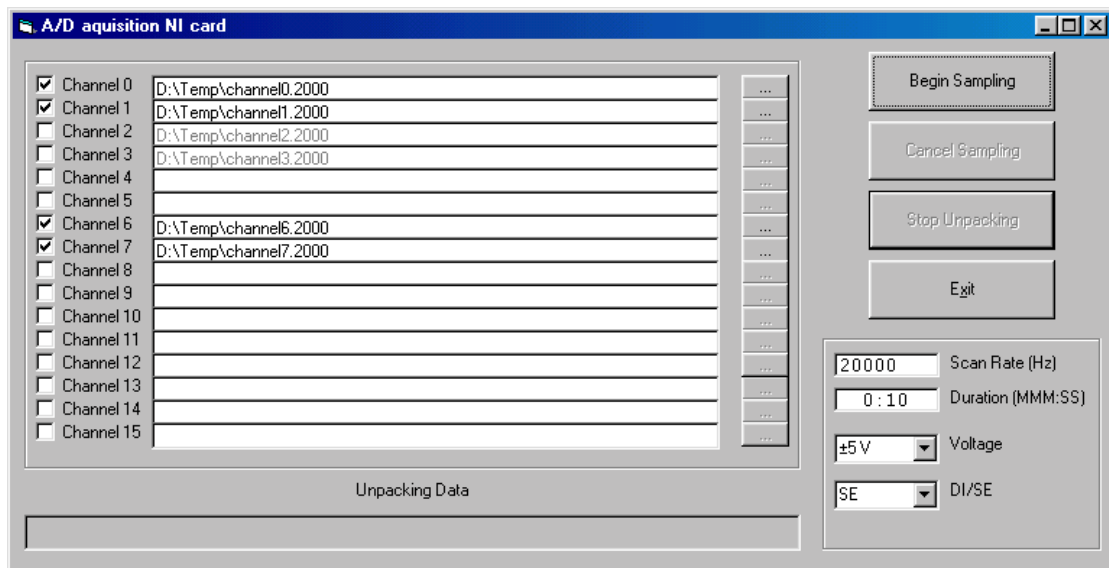


Figure 8: Unpacking Data

After the data has been unpacked, it is saved into the file names displayed as 16 bit little endian binary data. The A/D card only digitises at 12 bit, but the data files are saved as 16 bit since this is a more commonly used format. The text box then displays 'Data Unpacked and Saved' and the files saved are displayed in green (see Figure 9). These files can not be over written until some change is made to the settings. This stops you accidentally pressing the ***Begin Sampling*** button, clearing the data already obtained.

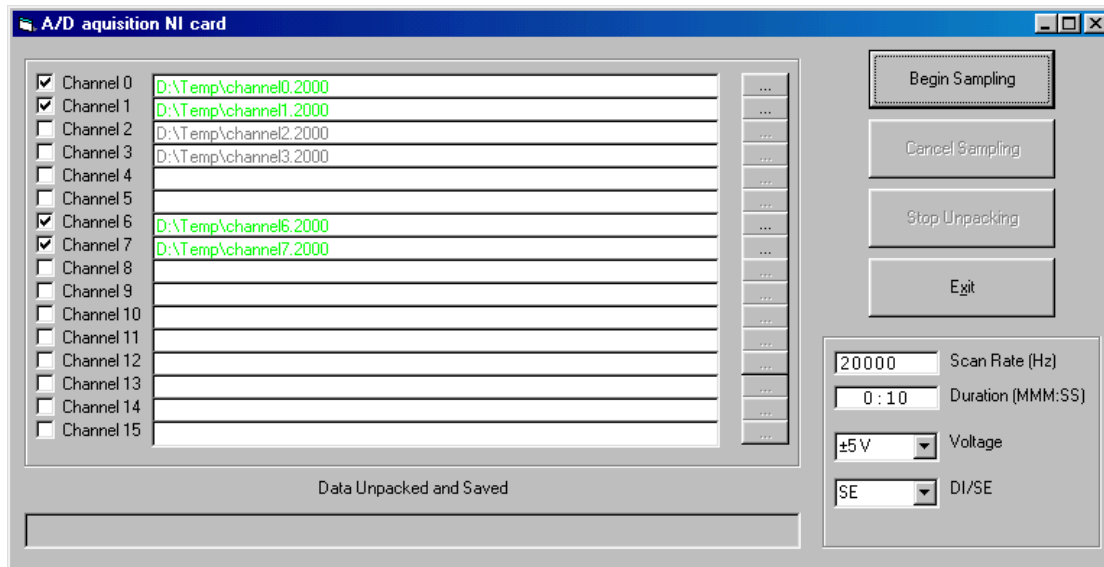


Figure 9: Data saved

2.4 Validation of Data Digitised

The digitised data is validated using Cool Edit. Cool Edit enables the data to be viewed as a time series or spectrogram, with an ability to zoom in on specific sections of the data. The data can also be listened to on speakers connected to the PC. These combined features enable the data to be quickly checked.

The different types of sonobuoys have specific features, which can be used to verify if the sonobuoy was functioning correctly. Some examples are:

- The DIFAR and DICASS sonobuoys have two tones in the recorded signal, at 7.5 kHz and 15 kHz (ref. J. Savage 1991). These can be seen on a spectrogram (see Figure 10).
- The SSQ-36 bathythermograph returns a tone that is dependent on the temperature in the water (see Figure 11).
- The SSQ-57 sonobuoy is omnidirectional, so the signal looks similar to white noise (see Figure 12). The standard SSQ-57 and 20 dB attenuated SSQ-57A sonobuoy data can have some structure, due to shrimp, fish, and shipping noise. Listening to these sonobuoys can quickly verify if the sonobuoy is working. 40,

60, and 80 dB attenuated SSQ-57A sonobuoys tend to contain mostly electrical noise, unless there is a strong signal source in the water.

- Any SUS or DICASS signals in the data can also be used verify if the sonobuoy is working (see Figure 13).

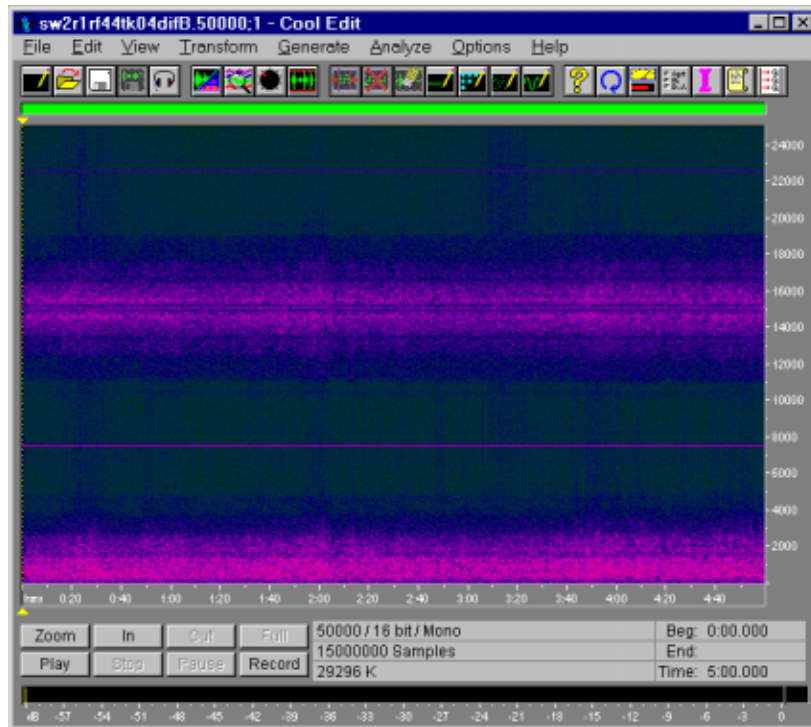


Figure 10: Spectrogram of a DIFAR signal using Cool Edit.

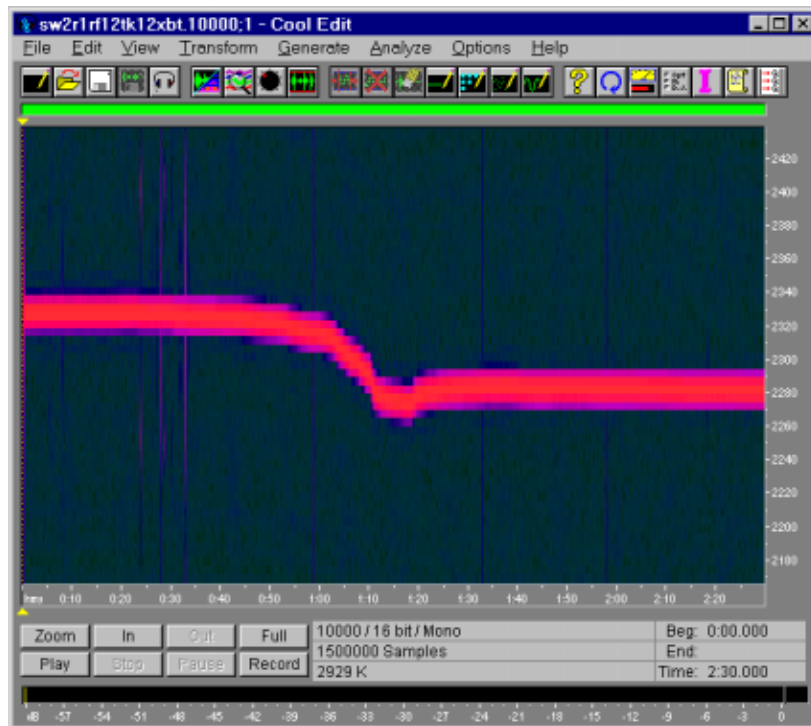


Figure 11: Spectrogram of a Bathythermograph sonobuoy, zoomed in on the frequency scale.

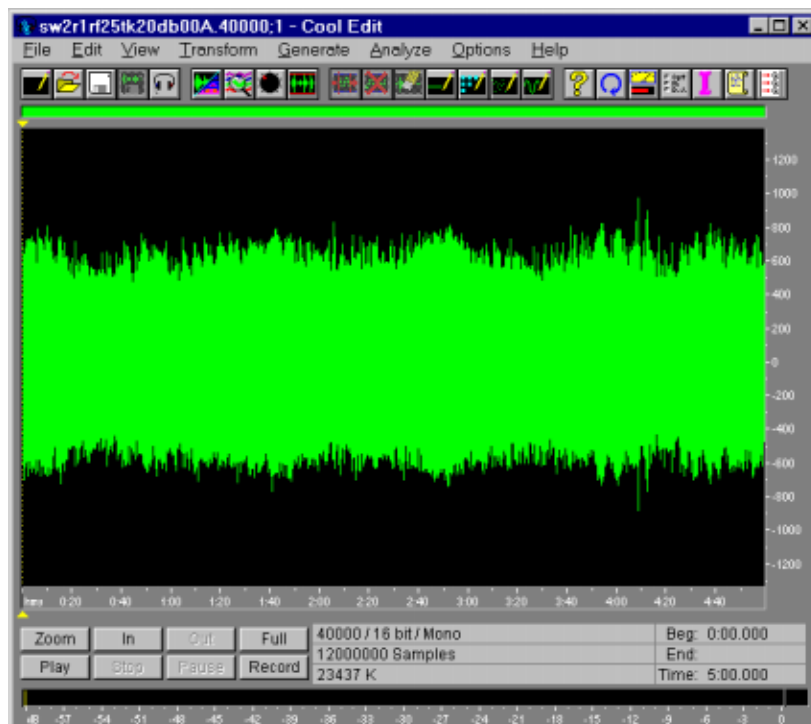


Figure 12: Time series of ambient noise from an SSQ-57A sonobuoy, zoomed in on the amplitude scale.

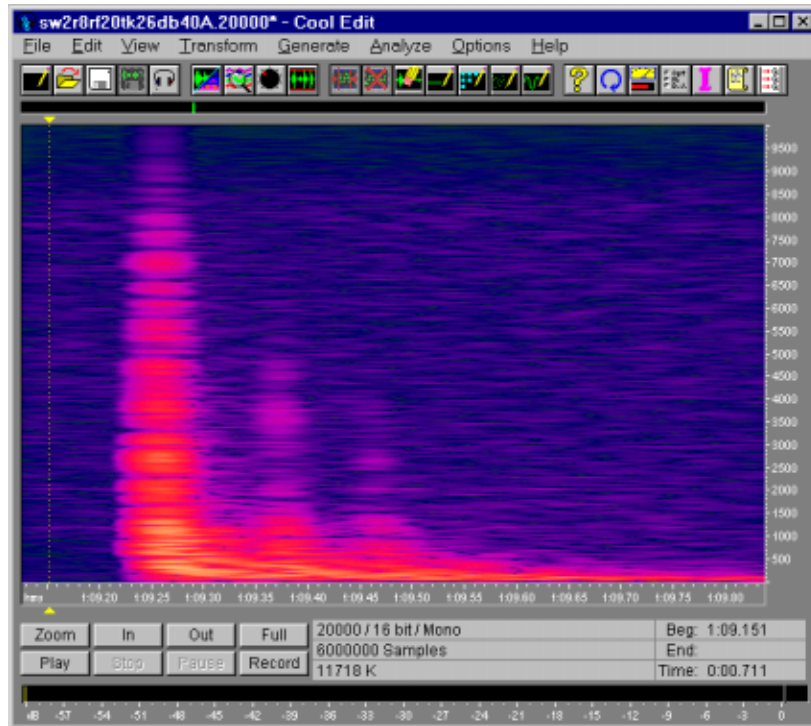


Figure 13: Spectrogram of a SUS charge recorded using a 40 dB attenuated SSQ-57A. Three spikes can be seen showing the shock wave and two bubble pulses.

To calibrate the SSQ-57 sonobuoys a rooftop checker (RTC) signal is recorded onto the AQH4 tapes and digitised using the same equipment. This signal is a 100 Hz sine wave (see Figure 14), so is easily checked to see if it was digitised correctly.

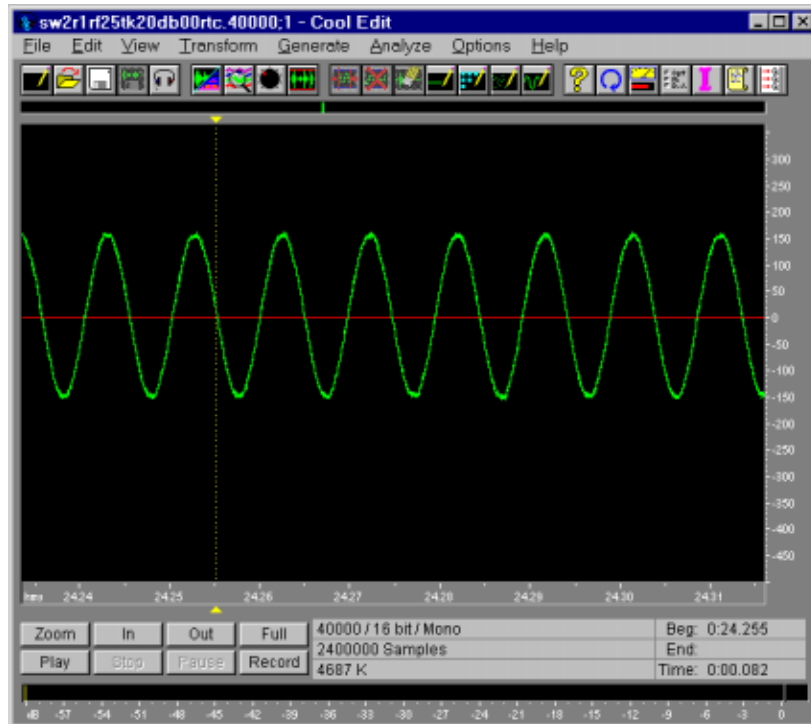


Figure 14: Rooftop checker signal, zoomed in on the time scale. A spectrogram would show a dominant line at 100 Hz.

2.5 Storage of Digitised Data

Since most of the digitised data files are large, the PC has a 650 MByte CD writer and 100 MByte zip drive installed. This enables the data to be easily stored onto CD for later processing and archiving or copied to another PC using the zip drive.

The data files produced contain 16 bit little endian binary data. The A/D card only digitises at 12 bit, but the data files are saved as 16 bit since this is a more commonly used format.

3. Conclusions

This set-up enables simplified digitisation of the FM tracks on AQH4 tapes, by combining the digitisation, validation, and storage process into one PC. Also digitising many channels at once reduces the time used to digitise the required tracks and gives synchronous data.

Testing of the anti-aliasing filter showed that the filter was not working at the level expected but was good enough for the settings used (see Table 2). This filter is only an eight-channel filter, which could be upgraded to include another eight channels enabling all 16 FM channels to be digitised simultaneously.

The validation of the digitised data files has also improved, by using a COTS program called Cool Edit. Cool Edit enables the data to be viewed as a time series or spectrogram, with the ability to zoom in on segments of data and listen to it.

4. References

John E. Savage, (1991-1992), Basic Introduction to Air ASW Acoustic Systems, Mission Avionics Technology Department, Naval Air Development Center, Warminster, PA, USA.

PCI E Series User Manual, (July 1997), National Instruments Corporation, Austin, TX 78730 - 5039, USA. Part Number 320945C-01.

SR785 Dynamic Signal Analyser (January 1998), Operating Manual and Programming Reference, Stanford Research Systems, Sunnyvale, California 94098, USA.

Appendix.A Testing of Anti-Aliasing Filter

A.1. Experimental Set up for the Anti-Aliasing Filter Test

To test the performance of the anti aliasing filters the Stanford Research Systems SR 785 Dynamic Signal Analyser was used to generate a test signal, which was fed through the programmable filter. The generated test signal and the filter output were both monitored by the signal analyser, and the filter response was obtained by process of direct comparison of the filter input and output. Figure 15 shows the experimental set up.

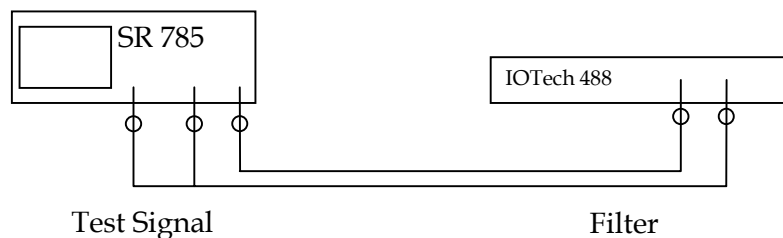


Figure 15: Experimental set up used to test the anti-aliasing filter

The analyser was set up to perform a swept sine measurement. In this configuration, the analyser provided a sweeping sine wave source that swept a sine wave between specified start and stop frequencies. This swept sine signal was fed from the analyser source output into the input of the filter. The analyser also monitored this input signal by connecting it to the analyser Ch 1 A input. The output of the filter was monitored by connecting it to the analyser Ch 2 A input.

The measurement process was conducted as per the swept sine measurement process specified on pages 1-45 - 1-46 of the SR785 Dynamic Signal Analyser Operating Manual. Table 3 specifies the start and stop frequencies used for the measurement process, along with the specified filter cut off frequencies.

Table 3: Settings used during the Anti-Aliasing Filter Measurement

Start frequency (Hz)	Stop frequency (Hz)	Filter cut-off frequency (Hz)
10	10000	3000
10	16000	5600
10	20000	7100
10	40000	14000
10	40000	15000
10	50000	16000
10	50000	18000
10	50000	20000
10	50000	22500

A.2. Anti-Aliasing Filter Responses

The following figures are the results obtained from the swept sine measurements for the configurations listed in the Table 3.

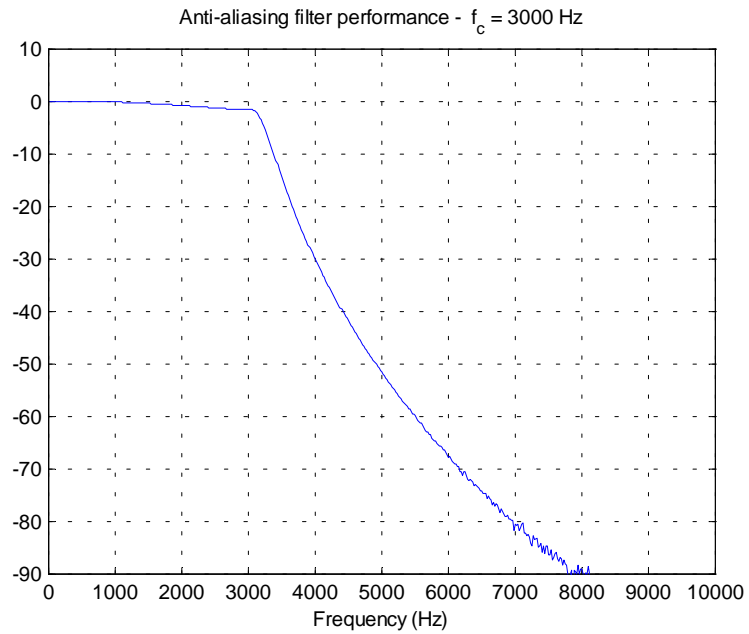


Figure 16: Filter response for a filter cut-off frequency of 3000 Hz

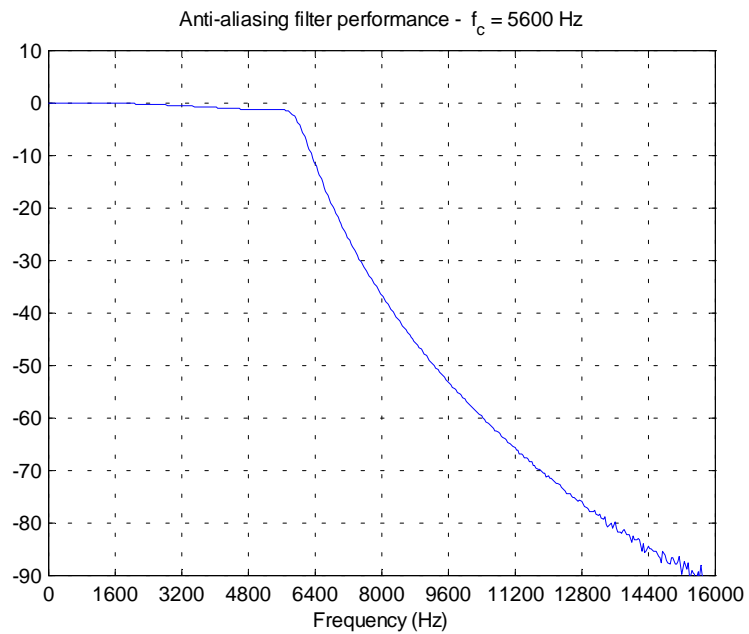


Figure 17: Filter response for a filter cut-off frequency of 5600 Hz

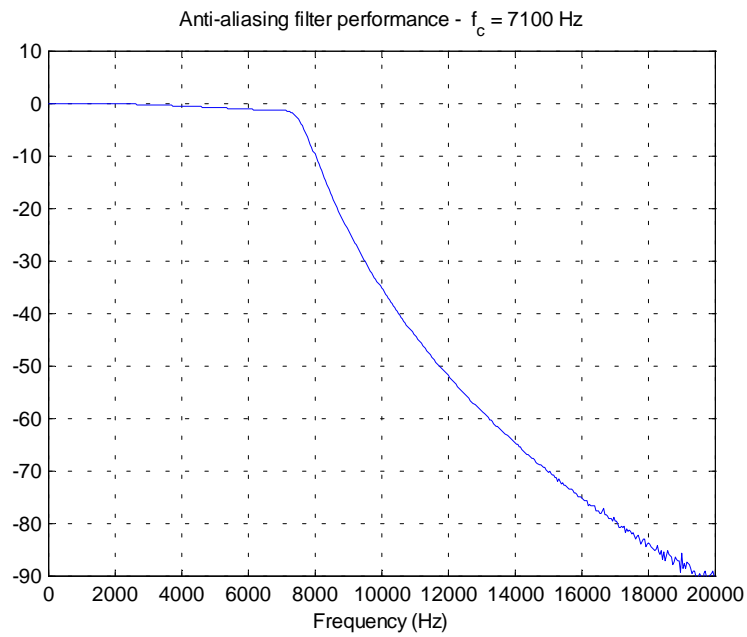


Figure 18: Filter response for a filter cut-off frequency of 7100 Hz

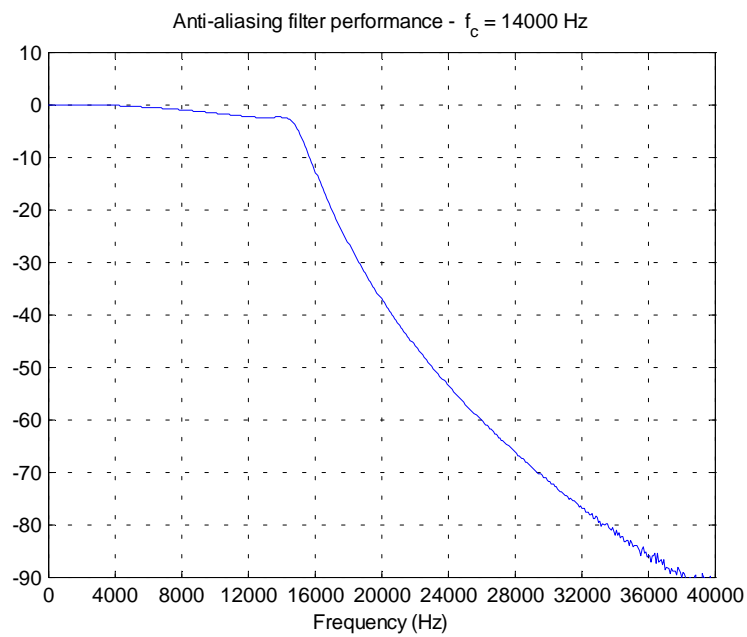


Figure 19: Filter response for a filter cut-off frequency of 14000 Hz

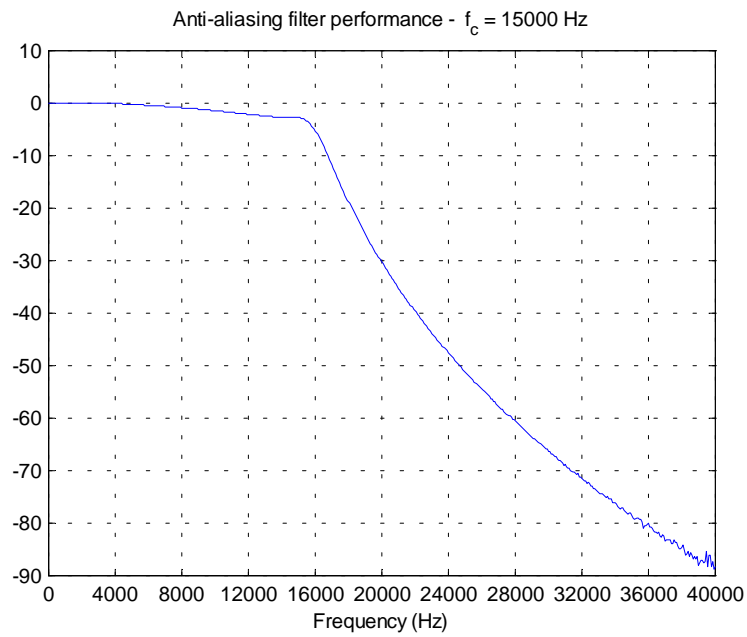


Figure 20: Filter response for a filter cut-off frequency of 15000 Hz

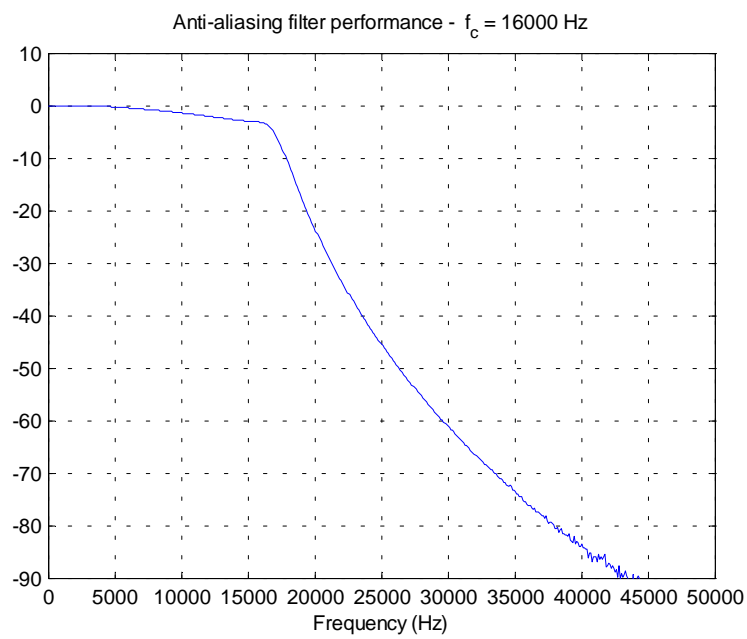


Figure 21: Filter response for a filter cut-off frequency of 16000 Hz

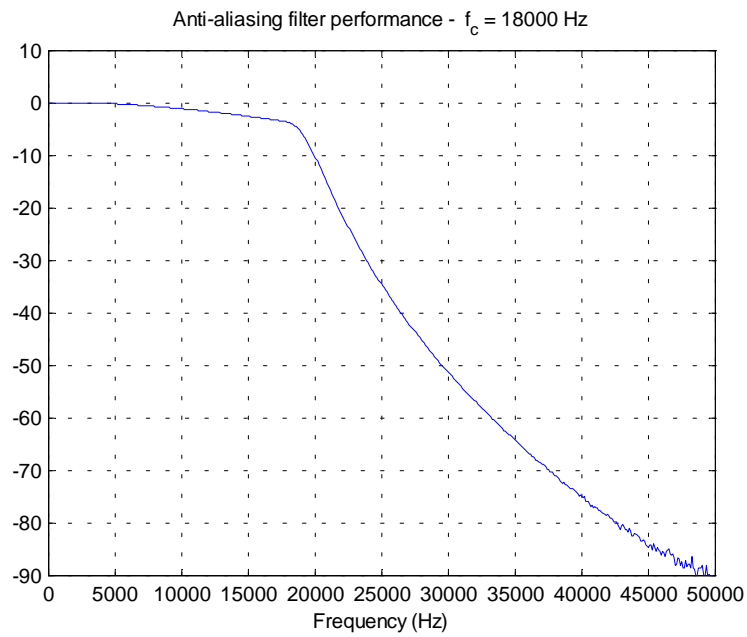


Figure 22: Filter response for a filter cut-off frequency of 18000 Hz

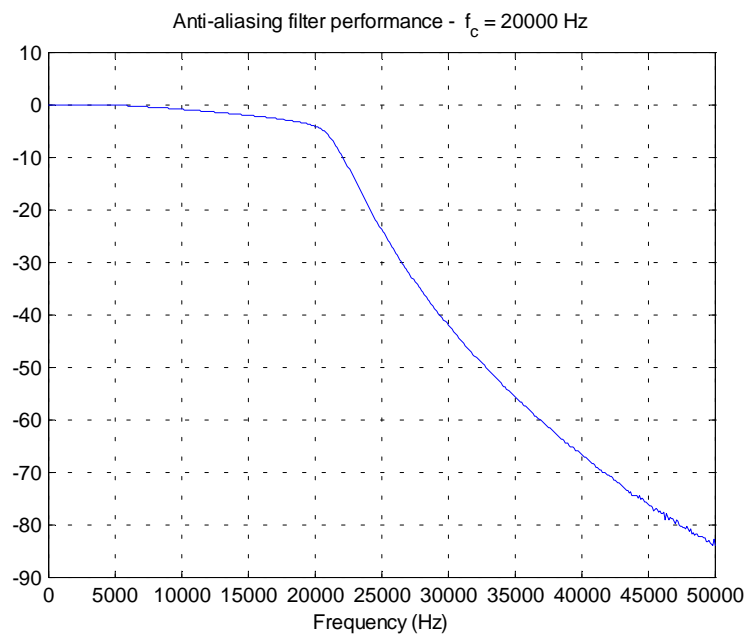


Figure 23: Filter response for a filter cut-off frequency of 20000 Hz

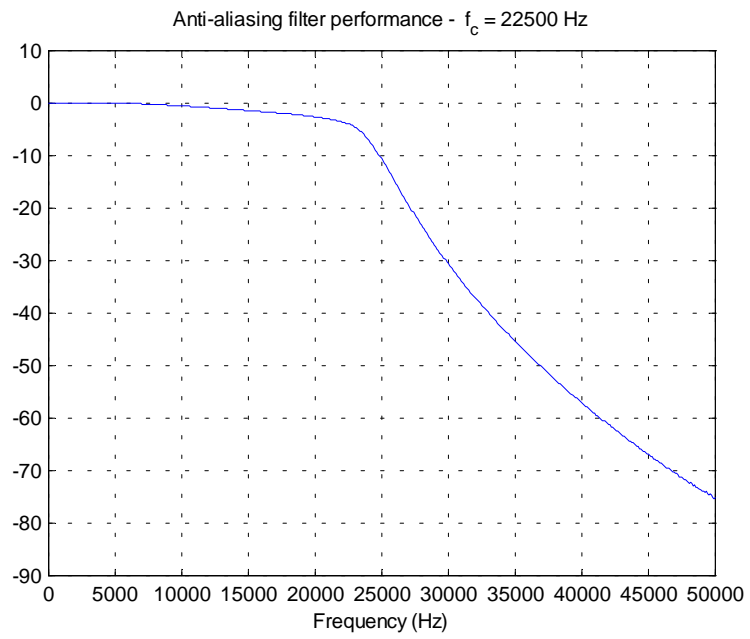


Figure 24: Filter response for a filter cut-off frequency of 22500 Hz

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19. ABSTRACT Sonobuoy data is regularly obtained using the RAAF P-3C aircraft during DSTO trials. This data is recorded on the aircraft using 28 track AQH4 tapes and needs to be transcribed onto CDs for storage and analysis. The method used to transcribe analogue sonobuoy data was recently upgraded. This document describes the equipment used and the steps involved in transcribing this data.					