VH-MDX Communications

Analysis aiding the search for missing aircraft VH-MDX

3rd Edition, November 2017
(1st Edition: May 2014)

Glenn Strkalj

Distribution: Public

Copyright and distribution of this document

Document purpose

The contents of this document are purely intended to clarify accident events to the best of the author's ability to offer a solid base in determining the location of VH-MDX.

The information and data presented in this document may be inaccurate or subject to interpretation errors by the author so should not be used as evidence in legal matters

This document must not be used for any purpose other than to provide guidance in locating VH-MDX

Acknowledgement

Many people have provided significant assistance to the author in producing this and other VH-MDX research documents. Many individuals have requested anonymity and the author would like to thank these people for their important input.

Special thanks go to the National Archives of Australia and the Airways Museum and Civil Aviation Historical Society for their fantastic support.

Thanks to Compton Allen of WICEN NSW who liaised with Airservices Australia on behalf of he author to attempt confirmation of the FIS-5 outlet location in 1981.

This reference paper will be subject to change as new information and data is found or errors are corrected: it is a

Amendments

2nd Edition July 2014

- Addition of post final VH-MDX transmission attempts at communications
- Updated general ‘tracking direction vs. signal strength’ map to clarify suggestion
- Table added for all VHF ATS agencies VH-MDX communicated with
- Clarification of weather attenuation south of ranges: ‘middle to lower’ descriptors with respect to the river systems flowing from the Barrington/Gloucester ranges.
- Error in weather attenuation regarding areas south of the main ranges fixed
- Grammatical errors fixed

3rd Edition November 2017

- New styling
- Grammatical amendments
- Addition of ‘Barrington General’ FIS-5 VHF area radio propagation analysis to treetop level.

Abbreviations

AACC	Area Approach Control Centre
AM	Amplitude Modulation
ACMA	Australian Communications and Media Authority
ARC	Aircraft Radio and Control
ASIB	Air Safety Investigation Branch
ATC	Air Traffic Control
ATS	Air Traffic Service(s)
AVR	Automatic Voice Recorder
BASI	Bureau of Air Safety
dB	Decibels
dBi	Decibel Isotropic
dBm	Decibel milliwatts
dBW	Decibel Watts
EIRP	Equivalent Isotropically Radiated Power
FIS	Flight Information Service
FM	Frequency Modulation
FS	Flight Service
FSC	Flight Service Centre
FSU	Flight Service Unit
GS	Ground Speed
IAS	Indicated Air Speed
ITU	International Telecommunication Union
kHz	Kilohertz
km	Kilometer
ºM	Degrees Magnetic
NDB	Non-Directional Beacon
MHz	Megahertz
NM	Nautical Mile
PEP	Peak Envelope Power
SRTM	Shuttle Radar Topography Mission
ºT	Degrees True
TAS	True Air Speed
UTC	Universal Time Coordinated
VHF	Very High Frequency
VOR	VHF Omni Directional Range
W	Watts
WGS	World Geodetic System

Executive Summary

The purpose of this document was to overview *radio communications* aspects of the VH-MDX accident and to utilise this information and data in order to assist in the location of VH-MDX.

Various equipment specifications were found or reasonably assumed. It was shown the *only* ground based civilian ATS unit to communicate with VH-MDX after Taree was Sydney FIS-5 on 121.6MHz. This is important as significant events unfolded after Taree.

VHF communications propagation was described as predominately *line of sight* with a diffraction propagation mode enabling some 'bending' of signals around terrain and objects.

It was confirmed that the Sydney FIS-5 121.6MHz ground transceiver was located on Mt Berrico to the east of the Gloucester Tops in 1981.

BASI spectrographic analysis findings were used in an alternate way to show that increased received VHF communications *signal strength* at the 0938:29UTC point compared to 0923:52UTC could indicate an approximate tracking direction considering distance and weather attenuation effects. Specifically, signal strength was *lower* at approximately the Polblue Camping Area position (determined by dead reckoning back from the initial Sydney radar position) than at the 0938:29UTC position.

This can indicate a *general* track of VH-MDX between east and south *from* the Polblue area. This was based on *lower* signal attenuation at the 0938:29UTC area resulting from:

- Tracking away from likely weather over the main Barrington ranges or reduced weather between VH-MDX and Mt Berrico and,
- Decreased distance to the Mt Berrico FIS-5 outlet.

Area and link type propagation analysis in the Barrington Tops and Gloucester Tops area was performed indicating communications was only *generally* possible at treetop level in the following broad areas:

- Mt Berrico
- Around 5NM west to north-west of Craven waypoint
- Gloucester Tops area.

Specific propagation 'link' type analysis was also conducted between Mt Berrico and *specific* geographical spot sample points of historical and contemporary interest where VH-MDX is thought to be located near. These can be used in flight path concepts to assist in verifying or disproving assumptions or findings.

Communications was shown to be at a '*definite'* probability at 5000'AMSL VH-MDX altitude at all sample points except at the Upper Allyn River sample point which was '*likely*'. Propagation results are shown on the next page.

These results form only a *limited* snapshot of propagation probability and are not exhaustive. Further propagation analysis should be carried out.

VH-MDX Position	VH-MDX Altitude	Communications Possibility
5NM West Craven Waypoint	Tree Level	Definite
The Pinnacle	Tree Level	Definite
Upper Gloucester River Valley	3000’ AMSL 3500’ AMSL	Unlikely Definite
Upper Chichester River Valley	3500’ AMSL 4000’ AMSL 4500’ AMSL	Not Possible Unlikely Definite
Upper Kerripit River Valley	3000’ AMSL 3500’ AMSL	Unlikely Definite
Upper Williams River Valley	4000’ AMSL 4500’ AMSL 5000’ AMSL	Unlikely Likely Definite
Upper Allyn River Valley	4000’ AMSL 4500’ AMSL 5000’ AMSL	Not Possible Unlikely Likely
Polblue Camping Area	8000’ AMSL	Definite

Communication possibility between Sydney FIS-5 at Mt Berrico and various geographic positions. The key VH-MDX altitude of interest is 5000’AMSL as this was the likely and approximate altitude at which the final received call from VH-MDX was made. Communications between FIS-5 at Mt Berrico and VH-MDX at 5000’AMSL was found ‘definitely’ possible at all sample points except the Upper Allyn River sample point although Communications would have still been *likely* but perhaps scratchy. The Polblue sample point only accounts for a VH-MDX altitude of 8000’AMSL as it was unlikely the aircraft was below this altitude at this phase of flight.

Analysis of VHF communications has yielded some indication of where VH-MDX may or may not have been at various times. Further analysis is likely to result in more positive outcomes to locating VH-MDX.

Table of Contents

Amendments 3

Abbreviations 4

Executive Summary 5

Table of Contents 7

1. Introduction 9
1.1. Background 9
1.2. What can be determined with such information? 9
1.3. What are the outcomes for VH-MDX? 9
1.4. Document aim 9

2. Very High Frequency (VHF) communications 9
2.1. VH-MDX Radio communications 9
2.2. VHF aviation band (voice communications) 10
2.3. Propagation characteristics 10
2.4. Communications range 10

3. VH-MDX VHF communication equipment 11
3.1. VHF transceiver 11
3.2. VHF antenna 11
3.3. Transceiver specifications 12

4. ATS VHF communication equipment 12
4.1. Sydney Flight Information Service (FIS)-5 12
4.2. FIS VHF transceiver positions 13
4.3. FIS-5 121.6MHz transceiver location 14
4.3.1. Importance 14
4.3.2. Defensible sources 14
4.3.3. Sources causing confusion 15
4.3.4. Confirmed location 15
4.4. Polling/voting /simulcast 16
4.5. Ground transceiver power output 17
4.6. Antenna height and gain 17
4.7. Known coverage 17

5. Automatic Voice Recording (AVR) 17
5.1. Sources of AVR 17
5.1.1. VHF communications AVR 17
5.1.2. Intercom AVR 18
5.2. Sydney AACC and FSC AVR equipment 18
5.3. Timing accuracy 18
5.4. Use of AVR by ASIB/BASI 18
5.5. Available communications recordings 19
5.6. Validation of compact cassette recordings 19
5.6.1. Modified recordings 19
5.6.2. Cross referencing transmissions 19
5.6.3. Timing 19
5.6.4. UTC reference 20
5.6.5. Summary of findings 20

6. ASIB communications transcripts 20
6.1. Overview 20
6.2. Validation 21
6.3. Findings 21

7. Analysis of radio calls **21**
7.1. Final transmission from VH-MDX 21
7.2. Communications after VH-MDX's final transmission 21
7.2.1. Overview 21
7.2.2. FIS-5 22
7.2.3. Qantas 26 22
7.2.4. VH-CNW 22
7.3. Outcomes 23

8. ASIB communications analysis **23**
8.1. Overview 23
8.2. ASIB findings 24
8.3. Use of signal strength differences 24
8.3.1. Overview 24
8.3.2. Position of VH-MDX at lower signal strength 25
8.3.3. Distance attenuation 25
8.3.4. Weather attenuation 26
8.3.5. Findings: VHF communications signal strength 27

9. Propagation analysis of 121.6MHz FIS-5 .... **28**
9.1. Methodology 28
9.2. Variables 29
9.3. Barrington Tops general 30
9.4. 5NM west Craven waypoint 30
9.5. The Pinnacle 31
9.6. Upper Gloucester River Valley 32
9.7. Upper Chichester River Valley 33
9.8. Upper Kerripit River Valley 35
9.9. Upper Williams River Valley (ASIB/RCC final fix) 36
9.10. Upper Allyn River Valley 37
9.11. Polblue Camping Area 39
9.12. Findings: Radio propagation 39

10. Conclusion **41**

References **42**

ANNEX A: ASIB VH-MDX avionics equipment list **44**

ANNEX B: ACMA site details Mt Berrico **45**

ANNEX C: ACMA Assignment details: 120.55MHz (Current frequency servicing existing 121.6MHz area) **46**

ANNEX D: ASIB communications spectrographic report **47**

ANNEX E: ASIB communications spectrographs **48**

1. Introduction

1.1. Background

Overview of communications between VH-MDX and Air Traffic Service (ATS) units on the ground may reveal additional clues as to the *general* whereabouts of VH-MDX whilst prorogation analysis may confirm if communications was possible at certain times when developing flight path predictions.

Sources of information include:

- Bureau of Air Safety Investigation (BASI) communications transcripts
- BASI spectrographic analysis of communications
- Audio voice recordings (AVR) of the accident
- Relevant equipment specifications of the time
- Current equipment specifications
- Aeronautical charts and publications
- Spectrum licensing.

1.2. What can be determined with such information?

- Confirmation of ground outlet location
- Signal strength comparison
- Propagation analysis to determine likeliness of communications links
- Determining timings of transmissions to assist flight path analysis

1.3. What are the outcomes for VH-MDX?

- *Broad* conclusions of *general* tracking directions of VH-MDX
- Assessment of communications ability at certain times and locations to support flight path concepts
- Developing ‘end of flight’ times from the timings of attempted communications to VH-MDX

1.4. Document aim

To overview radio communications aspects of the VH-MDX accident.

2. Very High Frequency (VHF) communications

2.1. VH-MDX Radio communications

VH-MDX was fitted with shorter range VHF (Very High Frequency) radio communications and longer range HF (High Frequency) radio communications equipment[5].

There was no reason for the pilot of VH-MDX to use the HF system as the aircraft was in range of VHF ground stations along the entire route from Coolangatta to Bankstown. Communications transcripts show that all communications with VH-MDX were using VHF[5][20][22].

Accordingly only VHF communications will be analysed.

VHF communications are predominately line of sight (LOS) with some predictable diffraction modes so, analysing VHF communications relating to VH-MDX can offer clues to aircraft position.

2.2. VHF aviation band (voice communications)

C*ivil* aircraft voice communication both in 1981 and presently, is carried out primarily on the VHF Aviation Band (Airband)[1] within the following frequency range and emission characteristics:

- 118.00MHz-135.975MHz[2]
- Single channel simplex[2]
- ITU 6K00A3E signal: (6kHz bandwidth, double sideband with full carrier, single channel analogue, telephony (voice))[3], Amplitude Modulated{2}.

The VHF band is less much less affected by natural and man-made radio 'noise' than bands with lower frequencies. Consequently, VHF offers *clear* and *reliable* communications over short ranges; exactly what is required for an aviation application[1].

2.3. Propagation characteristics

VHF transmissions travel predominately line-of-sight (i.e. in straight lines)[1] with some diffraction (bending) around blocking objects[4]. Thus, VHF signals are capable of being received at the normal line of sight horizon and somewhat 'around' terrain and Earth curvature.

For example, a receiver positioned slightly on the lee side of a mountain range outside line-of-sight from a VHF transmitter would receive signals to some extent dependent on position.

Despite this diffraction capability, line-of-sight is preferred for *reliable* and *consistent* communications. VHF propagation offers good performance for the short range communications required for *most* domestic aviation applications.

A phenomenon known as *ducting* also occurs from time to time whereby temperature inversions in the lower atmosphere 'trap' and 'duct' VHF transmissions over much longer distances than line of sight. This generally happens at or near ground level over flatter areas such as the sea but can also occur in an elevated sense. Given the terrain and temperature apparent, ducting is viewed as being not particularly relevant to VH-MDX.

2.4. Communications range

The primary factors affecting VHF *range* are:

- Power output
- Receiver sensitivity
- Antenna gain
- Signal attenuation in free space and
- Establishment of line of sight (perhaps the most crucial).

These translate into the following *practical variables* affecting VHF communications *range*:

- Transceiver *specifications*
- Transceiver *serviceability*
- *Altitude* of both transceivers
- *Terrain* in between both transceivers
- *Signal attenuation* by weather, particularly precipitation
- *Antenna icing attenuation* of signal
- *Shielding* of aircraft VHF antenna by aircraft (e.g. wings, fuselage etc.)
- *Squelch* setting
- *Modulation* (speech input) *levels* (i.e. loud voice input = higher transmitter power output and vice-versa)
- *Equipment serviceability* (ground and airborne equipment).

3. VH-MDX VHF communication equipment

3.1. VHF transceiver

In 1977 VH-MDX was fitted with a single ARC RT328T VHF transceiver[5] ('VHF Comm') that also incorporated a VHF Omni-directional Range (VOR) *navigation aid* receiver. It is believed this equipment was still fitted during the accident[5].

Annex A contains the ASIB's (Air Safety Investigation Branch) notes regarding VH-MDX equipment. Figure 1 displays a photo of an ARC RT328T VHF transceiver unit and figure 2 in Section 3.2 is a photo of VH-MDX in the late 1970's showing a single VHF comms antenna, alluding to a single VHF Comm.

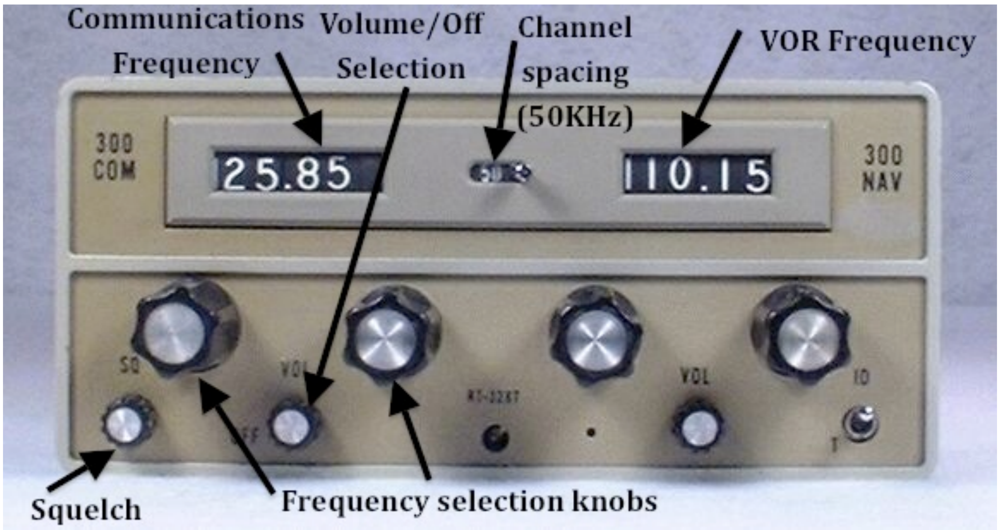


Figure 1: ARC RT-328T VHF Communications/Navigation Unit. This model VHF Comm./Nav was originally installed on VH-MDX and is believed to have been the unit onboard during the accident[5].

The ARC RT-328T has the ability to select and use only a *single* communications frequency at a time.

3.2. VHF antenna

Section 3.1 identified that VH-MDX was fitted with a single VHF communications transceiver. A single VHF antenna has been identified from the photo below of VH-MDX taken sometime prior to the accident.

Figure 2: VH-MDX VHF Communication antennae position. Also visible are the VHF Nav antennas, HF Comm antenna and ELT(Electronic Location Beacon) antenna (Photo: I. Boyd c.late 1970's obtained by G. Strkalj 2017).

3.3. Transceiver specifications

At the time of radio installation in VH-MDX, airband VHF communications *transmitters* were defined in Technical Standard Order (TSO) C-37b by three classes based on *minimum* transmit *carrier* power and standard useable range[15]:

- Class 1: 200NM not less than 16W output
- Class 2: 100NM not less than 4W output
- Class 3: 50NM not less than 1W output

Airborne transceivers generally were Class 2 typically having a power output of 25W *Peak Envelope Power* (PEP) or approximately 6W-8W *carrier* power with 'normal' speech input. VH-MDX's RT-328T was certified as Class 2[16].

4. ATS VHF communication equipment

4.1. Sydney Flight Information Service (FIS)-5

Based on ASIB communications transcripts and the *Accident Preliminary Report* of 21st August 1981[5], Sydney FIS-5 operating on 121.6MHz was the only Air Traffic Service (ATS) outlet to communicate with VH-MDX from Taree until the final transmission at approximately 0939:26UTC.

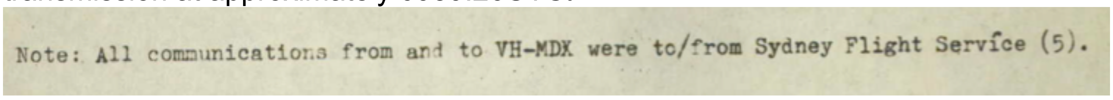

Note: All communications from and to VH-MDX were to/from Sydney Flight Service (5).

Figure 3: Extract from Accident Preliminary Report 21st August 1981. (Image: Australian Government (Air Safety Investigation Branch) 1981).

FIS-5 was *not* Air Traffic Control (ATC) as FIS-5 only offered a *Flight Information Service* (FIS) rather than *control* and *separation* from other aircraft as ATC does. FIS assists pilots in maintaining their *own* separation from other aircraft whilst also providing services such as weather information and liaison between aircraft and ATC to obtain airspace clearances[1][6].

In 1972, FIS-5 was described as being responsible for an area including Sydney- Bankstown – Quirindi – Crowdy Head (near Taree) – Sydney and at this stage it is assumed that the boundary was the same for 1981[19].

An official map from 1972 shows the boundaries of the 121.6MHz FIS frequency which includes the areas described above and further north to Moree (Figure 4).

Accordingly, Sydney FIS-5 was the Sydney FIS agency responsible for the Barrington Tops area and more broadly from Taree to Bankstown.

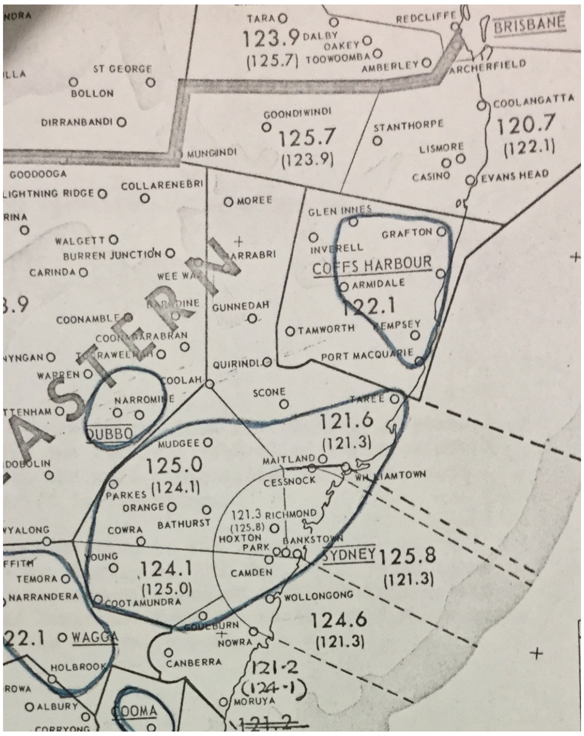


Figure 4: FIS area frequencies c.1972. (Image: National Archives Australia (NAA), 1969-1976, Department of Civil Aviation).

4.2. FIS VHF transceiver positions

Ground based ATS operated VHF radio transceivers are located at spacings to ensure near continuous coverage to aircraft in medium to high-density traffic locations.

These transceivers are generally positioned on points of high terrain to maximise range and coverage to the area. Aircraft can select or be instructed to transfer to the next frequency based on proximity to the closest ground station to achieve the most reliable communications.

Figure 5 shows a basic map depicting Flightwatch ground stations during 2005[7] being the earliest map based depiction of FIS type frequencies available to the author *at present*.

Note: Flightwatch offers a FIS[6] so, despite the difference in name, is effectively the same as a FIS.

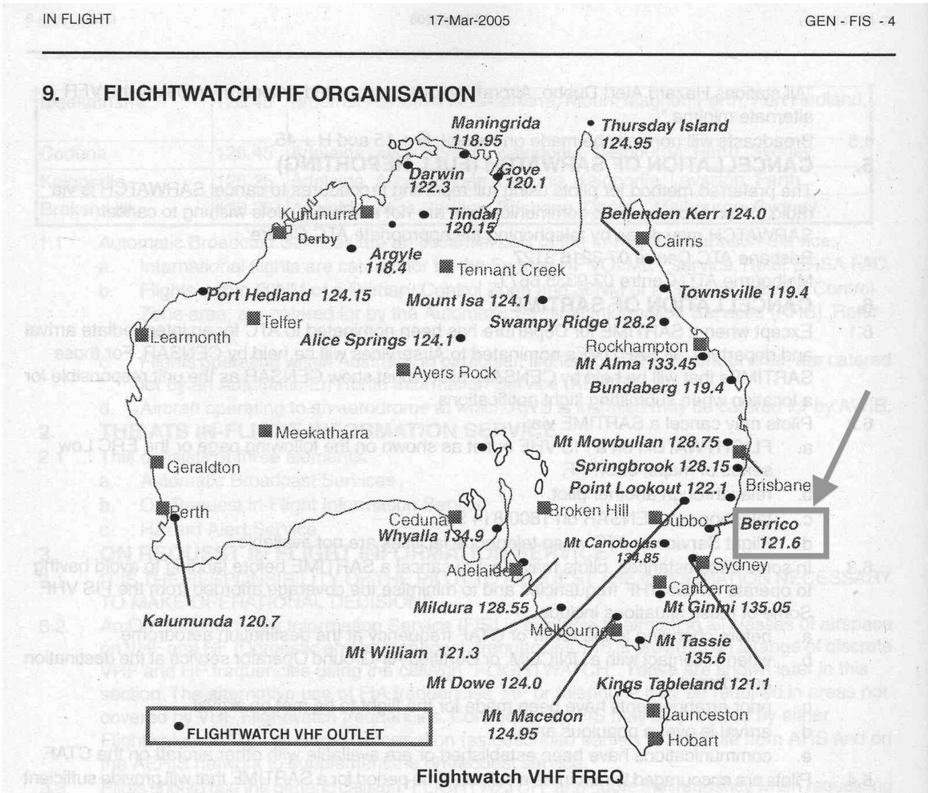


Figure 5: Flightwatch VHF Ground stations 2005[7]. As can be seen, 121.6MHz is located at 'Berrico' (Image: Airservices Australia 2005).

Communication transcripts[5] of the accident flight reveal the following progression of ATS communications:

Agency	Frequency (MHz)	Start Time (UTC)	End Time (UTC)
Coolangatta	Various Freq	0654	0702
Brisbane Control (AACC)	123.0	0702	0724
Brisbane FS-4	120.7	0724	0739
Coffs Harbour	122.1/ 124.6	0739	0851
Sydney FIS-5	121.6	0851	Last transmission (0939:26)

Figure 6: Frequencies and ATS agencies VH-MDX communicated with.

Note: Brisbane instructed VH-MDX to contact Coffs Harbour on 122.1MHz however transcripts record 124.6 as the Coffs frequency[5].

As can be seen from figure 5, VH-MDX's tracking from Coolangatta towards Bankstown is proximate to the Point Lookout Flightwatch (Coffs Harbour) 122.1MHz station and then the Berrico 121.6MHz Flightwatch (Sydney FIS-5) station. This shows part of the logical progression of changes to selected VHF ground stations.

4.3. FIS-5 121.6MHz transceiver location

4.3.1. Importance

A number of VH-MDX researchers have nominated incorrect locations for the FIS-5 121.6MHz transceiver. In particular, some have suggested the transceiver was located at the locality of Berrico. As will be shown, without adequate industry and technical knowledge, it is easy to be lead astray when overviewing information relating to the transceiver's location.

Utilising the incorrect location for radio propagation analysis and other applications will result in inaccurate results and conclusions. Accordingly, it is important to verify and publish the actual location for this transceiver.

4.3.2. Defensible sources

The ACMA (Australian Communications and Media Authority) licence resister in 2014 identify an Airservices VHF site as 'Airservices Site Mt Berrico new Gloucester' specifying coordinates as shown in Annex B and C. Of note is that the 121.6MHz frequency has since been changed to the current Flightwatch frequency servicing the area of 120.55MHz at the same site.

An Airservices Australia Frequency Planner confirmed the location as the Mt Berrico location described in the previous paragraph although it was suggested that Sydney FIS-3 utilised the 121.6MHz frequency[8] rather than FIS-5. Despite this, it is the location of the frequency outlet that is more important. It was stated by the ASIB that Sydney FIS-5 operating on 121.6MHz was the only Air Traffic Service (ATS) outlet to communicate with VH-MDX from Taree until the final transmission at approximately

0939:26UTC. Accordingly the naming of FIS-3 in this case is classed as an error and as will be shown, the callsign for the121.6MHz outlet changed with time.

Department of Civil Aviation (DCA) correspondence of the mid 1970's[21] discusses the coverage limitations at 5000' to the west or north-west of the 'Berrico' located 121.6MHz FIS 'repeater' due to this transceiver location being some 2000' lower than the Barrington Tops. Mt Berrico is just over 1800' lower than Mt Barrington whilst Berrico Locality is approximately 4550' below Mt Barrington. This largely eliminates the town of Berrico as the transceiver location in addition to common sense in not having the repeater located in a valley.

4.3.3. Sources causing confusion
Aviation information publications dating 2001 to 2005 identify the location of the 121.6MHz ground station generally in the Eastern Barrington Tops area. Various aeronautical publications of more recent times depict the 121.6MHz frequency as 'Flightwatch' which is a callsign for a FIS and identify 121.6MHz as being located at 'Berrico'[7][9].

A chart dated November 2001 has a star symbol indicating the *approximate* location in the Mt Berrico NSW area although not directly over Mt Berrico[9]. This practice of offsetting the exact position of the star is often done to prevent obscuring critical navigation information such as bearings or leg distances that, in this case would have obstructed track information from the Craven waypoint.

This chart is shown on the following page as figure 7.

4.3.4. Confirmed location
The 121.6MHz ground station during 1981 has been confirmed as being located on Mt Berrico[8] approximately 21km/11NM south-west of Gloucester NSW and approximately 5km/ 3NM south-west of Berrico locality (Annex B and C refers) at:

AGD66: S32˚ 06' 29", E151˚ 45' 55"
WGS84: S32° 06' 23.3", E151°45' 59.0".

Mt Berrico is not to be confused with Berrico Locality some 5km/3NM to the north-east of Mt Berrico in a valley

Figure 7: Enroute Chart Low 3, November 2001[9]. The star indicates the approximate position of the Flightwatch 121.6MHz ground based transceiver. These stars are often offset from the actual ground station position to allow clarity in reading other more important information that in this case is the CRAVN position and associated bearing information. This chart confirms 121.6MHz as being used for FIS purposes in the Barrington area during 2001. It was unlikely the frequency was changed since 1981 to 2001 despite the callsign having changed (Chart: Airservices Australia 2001, additions: Glenn Strkalj 2014).

4.4. Polling/voting /simulcast

To achieve expanded coverage and/or better quality reception from a single VHF frequency, techniques such as polling, voting or simulcast may be used. Such techniques involve the use of multiple ground-based transceivers on a single frequency with automatic selection or ‘voting’ of the ground transceiver with the best signal strength or synchronised transmissions from multiple ground stations.

If any of these techniques were used, multiple ground station transceivers would be involved in any analysis leading to complications and questions of which transceiver was active at a particular time.

VHF Airband both in 1981 to the present day is a highly simplistic technology that does not use any of the described techniques but rather, one ground-based transceiver per frequency.

The fact that aircraft had to change frequencies with change of location and that a map as displayed in figure 4 was provided to indicate where to change frequencies also suggests that polling was not used in 1981.

Additionally, it was also stated by a former Sydney ATS Radio Technical Officer[10] that polling was *not* utilised in aviation VHF ground stations during the early 1980's.

4.5. Ground transceiver power output

The actual transmitter power of the FIS-5 Berrico outlet in 1981 has not been confirmed.

Contemporary aviation ground-based transceivers for ATS outlets typically have a power output of 50W PEP (approximately 17W carrier power with normal speech) thus fitting in TSO Class 1[15].

The current transmitter (2014) at Mt Berrico servicing the same area as 121.6MHz has a transmission output capability of 50W *mean* power[17] as shown in Annex C. Note that Equivalent Isotropically Radiated Power (EIRP) and mean power have been swapped in error on the ACMA Register.

It is unlikely that transmitter power output would have been changed over the years thus it is accepted the Mt Berrico FIS-5 outlet in 1981 had a 50W *mean* power transmitter.

4.6. Antenna height and gain

The current antenna height of the 120.55MHz transceiver on Mt Berrico servicing a similar area to 121.6MHz in 1981 has an antenna height above *ground level* of 35m and a gain of 2.2dBi[17]. It is assumed the FIS-5 outlet in 1981 had the same antenna height and a rounded off gain of 2dBi.

4.7. Known coverage

Around 1974, the Department of Civil Aviation reported that there was no 121.6MHz coverage to the west or north-west of Mt Berrico at 5000' and below '*due to the Barrington Tops ranges which are some 2000ft higher than Berrico and completely shield all transmissions'*[21].

5. Automatic Voice Recording (AVR)

5.1. Sources of AVR

AVR of the VHF frequencies in use by ATC or FS (Flight Service) and also of the intercoms of ATC or FS workstations was normally performed to allow capture of critical communications during aviation safety events.

5.1.1. VHF communications AVR

Continual AVR of the VHF communications frequencies *used* by civilian ATC centres, Flight Service Centres (FSC) and Flight Service Units (FSU) was carried out at those locations during the 1981. RAAF Williamtown ATC also carried out AVR in 1981. In the case of VH-MDX, the following ATS units recorded transmissions from the VH-MDX:

- Coolangatta ATC
- Brisbane AACC (Area Approach Control Centre)
- Coffs Harbour
- Sydney FSC
- RAAF Williamtown ATC.

The ASIB appear to have obtained actual AVR of VH-MDX VHF communications from all the above units except RAAF Williamtown. The author has searched for RAAF Williamtown AVR tape and AVR transcripts but is unable to locate these.

5.1.2. Intercom AVR

In the case of VH-MDX, the following units would have AVR of intercom communications at the following positions:

- Coolangatta ATC
- Brisbane AACC
- Coffs Harbour
- Sydney FSC (FIS-5, FIS-5 Assist and SFS (Supervisor Flight Service))
- Sydney ATC (Sector 1 and STAC (Senior Terminal Approach Controller) and SOC (Senior Operations Controller))
- RAAF Williamtown ATC (Williamtown Tower).

The ASIB appear to have obtained AVR of VH-MDX related intercom communications from all the above units except RAAF Williamtown. Despite the latter, RAAF Williamtown intercom communications and many Williamtown Tower VHF communications were recorded by AVR at the various Sydney ATS units that were talking to Williamtown Tower via the intercom.

5.2. Sydney AACC and FSC AVR equipment

Sydney AACC and FSC AVR are the most important AVR to the VH-MDX accident because:

- Sydney FIS-5 (located at Sydney FSC) communicated with VH-MDX from Taree to the final received VHF transmission from VH-MDX
- Sydney Sector 1 (located in Sydney AACC) communicated with FIS-5 and RAAF Williamtown Tower during the VH-MDX accident.

VHF communications frequencies used by ATC and FS, and intercom communications at workstations, were recorded on a multi-channel reel type recorder. The reel recorder used one-inch width magnetic tape and was likely to be a Electrodata branded unit.

5.3. Timing accuracy

It would be unlikely that timings of the *original* recordings were inaccurate by very much at all given the tight controls that would have been in place with such equipment. Nolan in *Operation Wittenoom VH-MDX Research*[18] does present a reasonable case suggesting the timings of recordings should be taken as accurate.

The ASIB *Spectrographic Unit* derived transcript timings are down to individual seconds whilst the Williamtown-Sydney transcript timings for the most part are to 10-second intervals.It is accepted that the timings on transcripts are accurate with a tolerance indicated by the resolution of the recorded times (eg 1 sec for ASIB transcripts and 10 sec for Williamtown-Sydney transcripts).

5.4. Use of AVR by ASIB/BASI

It has been found that after an accident the recordings on the original one-inch reels were transferred to quarter-inch tape reels that were then kept inside the ASIB/ BASI accident investigation folio. Following this transfer process, the original one-inch tape reels were then returned to service.

The author has found that a number of aircraft accident investigations during the VH-MDX era have quarter-inch tape reels within their accident investigation folios.

In VH-MDX's case, it was stated by ASIB that the '*transmissions from the aircraft for the period 0857 GMT to 0939 GMT were re-recorded on ¼ inch tape for analysis on the Sound Spectrographic Unit*'[5][20].

Despite this, the author has found that neither the Main Office nor Sydney Branch VH-MDX ASIB/BASI accident investigation folios contain the quarter inch tape relating to VH-MDX. Although transcripts of various VH-MDX related communications were made, access to the original recordings could allow further or different types of analysis.

Generation of transcripts take time and are an iterative process. Errors are naturally made in the early versions where the demand for information by the Rescue Coordination Centre (RCC) is great and time pressure is significant.

As time progresses, the tapes are reviewed in more detail by additional personnel resulting in a more accurate transcribed representation of the recorded audio. Such outcomes are obvious in the case of VH-MDX. Communications transcripts will be discussed in Section 6.

5.5. Available communications recordings

Available recordings of VH-MDX communication transmissions and of ATS intercom communications is presently limited to commonly available recordings on compact audio cassette.

These recordings have been altered by people in various ways thus do not completely represent the actual communications characteristics of the accident.These compact audio cassette recordings have been transferred to digital format for portability and ease of analysis.

5.6. Validation of compact cassette recordings

5.6.1. Modified recordings

Presently obtainable recordings on compact audio cassette have significant modifications including cropping resulting in altered time lines and lost content.

Another VH-MDX researcher, Chessor[13],exposes the problems associated with using compact cassette versions of audio recordings in determining timings of calls highlighting the timing variability possible.

5.6.2. Cross referencing transmissions

Some confidence could be gained from comparison of the same transmission between multiple transcripts or audio recordings from different ATS positions or agencies. Unfortunately, multiple audio recordings of the same transmissions from *different* agencies or positions have not yet been located by the author and communications transcripts have many gaps for cross-referenced timing checks.

5.6.3. Timing

According to the most accurate communications transcript available, the ASIB Spectrographic Unit generated transcript, at 0936:07UTC the pilot of VH-MDX makes the transmission: '*MDX we're squawking 3000 ident and we're up and down like a yo yo*' and the final transmission of '*Five thousand*' at 0939:26UTC. This gives a total time interval of 3 minutes 19 seconds.

Timing the same transmissions by stopwatch of an available digital version of the audio recording by the author yields a time interval of 3 minutes 5 seconds; a difference of 14 seconds to the previously mentioned transcript.

The audio recording used appeared not to have any breaks in continuity during the period analysed unlike sections of the recording beforehand.

This *coarsely* validates the time interval of the last 3 minutes 19 seconds of recorded flight although not verifying the actual UTC values. This interval is important as the 0936:00UTC Williamtown radar fix occurred around the beginning of the time interval overviewed.

The difference of 14 seconds could easily be attributed to variations in cassette recording and playback speeds which are known to vary, or perhaps to modifications to the recording conducted by individuals. 14 seconds is not insignificant but is well within the *general* industry time-keeping standard of +/-30 seconds[6]. It would be expected that industry tolerances for *recordings* were much, much less than this, in the order of seconds. +/-5 seconds is suggested as the maximum tolerance for the audio recordings themselves but, transcripts can be out more than this value.

5.6.4. UTC reference

In the audio recordings available to the author, a person who is obviously transferring the audio recording to a compact cassette, is heard verbalising the UTC times at regular intervals.

UTC time verification can loosely be confirmed by these ‘time stamps’. These appear to be within about 15 seconds of what is expected but generally much less than this. In particular, the 0939UTC time stamp is within seconds of that expected.

The recording appears to have been made by placing the compact cassette recorder closer to but not plugged into the source recording. This means that background noise not associated with the VH-MDX accident is likely included in the recording.

5.6.5. Summary of findings

Presently available audio recordings of ATS related to the VH-MDX accident:

- Have been significantly modified resulting in lost content and inaccurate time lines in particular sections
- Likely include additional ambient noise from the transfer recording process
- The section between 0936:07UTC (‘*MDX we’re squawking 3000 ident and we’re up and down like a yo yo*’) and the final transmission of ‘*Five thousand*’ at 0939:26UTC is 14 seconds faster than transcript timings.

6. ASIB communications transcripts

6.1. Overview

The ASIB overviewed automatic voice recordings from various ATS agencies and positions then transcribed their *interpretations* of these recordings[5].

Typed ‘final’ versions of communication transcripts as well as what appears to be original *hand written* transcripts exist in the Central and Sydney Branch VH-MDX BASI accident investigation folios.

Transcripts for the following ATS positions have been located:

- Coolangatta ATC
- Brisbane AACC
- Coffs Harbour
- Sydney FSC (FIS-5, FIS-5 Assist and SFS (Supervisor Flight Service))
- Sydney ATC (Sector 1 and STAC (Senior Terminal Approach Controller) and SOC (Senior Operations Controller))
- RAAF Williamtown ATC (Williamtown Tower).

This covers most of the time VH-MDX was airborne and a short time after the last radio call received from VH-MDX.

6.2.Validation

Minor differences between the transcripts have been found, mostly typo errors but also timing and timing resolution related differences. Other than such minor differences the transcripts are generally aligned.

As the original AVR's nor accurate recordings of the original AVR's have been located, no accurate cross-check between transcripts and AVR can be conducted.

Transcripts were also crosschecked with logbooks entries which showed general alignment between the sources again with the odd misalignment.

It is accepted that the transcripts are accurate based on the expectation that appropriate standards, procedures and equipment were in place to ensure accuracy and that cross checks between transcripts and logs generally indicate alignment.

Tolerance for timings should be based on consideration of the transcript type and finesse in values depicted. For example, the ASIB *Spectrographic Unit* derived transcript is down to individual seconds but the Williamtown-Sydney transcript is finessed for the most part to 10-second intervals.

6.3.Findings

VH-MDX transcripts:

- Exist as draft and final versions
- Cover most of the time VH-MDX was airborne and a short time after the last radio call received from VH-MDX
- Have been cross-checked between transcripts and logs and are generally aligned with some miss-alignment
- Are accepted as accurate with tolerances based on the transcript resolution.

7. Analysis of radio calls

7.1. Final transmission from VH-MDX

The time of VH-MDX's final *received* transmission ('*five thousand*') from various written sources within the BASI accident investigation archives are[5]:

- Just after 0939:23UTC; from '*FIS-5 tape*', both typed and written communications transcripts
- From 0939UTC; (probably not based on a recording but rather placed in the transcript for reference also this timing is out of sequence with other entries) '*Transcripts of Sydney and Williamtown Tapes Accident Involving VH-MDX 9/8/81*'.
- 0939:26UTC; from the communications transcript associated with the Spectrographic Unit's analysis.

Timings would have been determined precisely during the spectrographic analysis so 0939:26UTC will be used as the time of the final received call from VH-MDX.

7.2. Communications after VH-MDX's final transmission

7.2.1.Overview

Scrutinising *attempted* communications *to* VH-MDX following the final transmission may reveal additional clues to maximum VH-MDX fly on time. Despite this, the pilot of VH-MDX may not have had the ability (considering workload) to *initiate* or respond to a communications call. Nevertheless some conclusions can be made.

In particular, other airborne aircraft at high altitude being almost uninhibited by terrain shielding effects to radio communications can yield such clues with reasonable confidence.

7.2.2. FIS-5

Following acknowledgement of the '*Five thousand*' call, FIS-5 next attempted communications with VH-MDX at:

- 0940:38UTC
- 0941:39UTC
- 0944:28UTC
- 0954:33UTC

No response from VH-MDX was *received*. It cannot be *completely* concluded that VH-MDX had impacted terrain by 0940:38UTC as pilot workload or terrain masking of communications may have prevented communications.

Regardless, considering pilot communications tempo leading up to the final call, it is reasonable to assume VH-MDX was no longer airborne at 0940:38UTC if the aircraft was in an area of good VHF signal strength from FIS-5.

7.2.3. Qantas 26

Qantas 26 (QF26) flying at FL210 (21 000'), was the first *airborne aircraft* to attempt communications with VH-MDX. Attempted transmissions to VH-MDX were at the following times:

- 0951:32UTC
- 0951:54UTC
- 0954:47UTC
- 1000:00UTC

QF26 did conduct a right turn to track 'back' over the Barrington area around 0956:47UTC attempting further communications with VH-MDX to no avail. The QF26 pilot stating *'….and proceed back over the area'* suggests QF26 had already flown over the Barrington Tops area and being an even flight number, QF26 was likely inbound to Sydney.

Accordingly, it can be seen QF26 was to the south of the Barrington area at the initial call to VH-MDX at 0951:32UTC before turning back to overfly the area again. From the high altitude QF26 was initially at and, considering QF26 was between the Barrington Tops and Sydney, most probably much closer to the Barrington Tops given altitude, QF26 would have had an excellent ability to transmit into valleys over a wide area around the greater Barrington Tops area and beyond. This ability would likely have exceeded FIS-5's to communicate with VH-MDX.

Notwithstanding that the pilot of VH-MDX was unable to respond to communications from QF26 due to workload and anxiousness, it can be seen unlikely that VH-MDX was airborne at 0951:32UTC.

7.2.4. VH-CNW

VH-CNW attempted communications with VH-MDX at:

- 0954:56UTC

VH-CNW was a Piper-28 (PA-28) conducting Night Visual Flight Rules (NVFR) training from Cessnock. The intended route was Cessnock-Scone-Merriwa-Cessnock but when abeam Lake Liddel the Pilot In Command (PIC) elected to track back towards Cessnock via Singleton NDB as a perceived widespread 'wall of cloud' was observed ahead on the planned route.

VH-CNW reported departing Cessnock at 0912UTC, tracking 334˚(?) and was climbing to 6500'. This appears to be the Cessnock to Singleton NDB track. Somewhere between 0920:00UTC and 0921:21 CNW calls in a flight plan amendment for an amended 3 POB.

Just after 0927:00UTC VH-CNW advises FIS-5 of a Singleton Actual Time of Arrival (ATA) of 0923UTC, maintaining 6500', estimating Scone 0943UTC.

VH-CNW was operated at 7500' AMSL for at least some of the legs and was located generally south of the Barrington Tops. Potential communications with VH-MDX would have likely been possible if VH-MDX did continue to fly on towards the south of the Barrington Range but, communications may have been terrain blocked if VH-MDX proceeded to the north-east of the Barrington and Gloucester Tops ranges.

Accordingly, it is unlikely VH-MDX was airborne beyond 0954:56UTC that in any case is some 3.5 minutes after QF26 attempted communications with VH-MDX.

Additionally, during the VH-MDX final call of '*Five thousand*' VH-CNW would have been located between Lake Liddell and Singleton, likely much closer to Lake Liddell and was likely maintaining or close to maintaining 7500'AMSL by this stage. This means terrain shielding of communications would be possible if VH-MDX was on the north side of the main Barrington range when VH-CNW attempted communications with VH-MDX.\

7.3. Outcomes

If one accepts that the pilot of VH-MDX *would* have been expected to keep making transmissions after the 5000' call then:

- It is *almost certain* that VH-MDX impacted terrain *by* 0951:32UTC (+12 minutes 06 seconds after the final call)
- Provided radio propagation between the FIS-5 Mt Berrico outlet and various terrain areas of interest was possible and notwithstanding pilot workload, it is *likely* that VH-MDX impacted terrain by 0940:38UTC (+1 minute 12 seconds after the final call).

These suggestions do not mean VH-MDX flew as long as the intervals specified as VH-MDX could have impacted terrain much, much earlier. These intervals are maximums for consideration in flight path analysis.

8. ASIB communications analysis

8.1. Overview

Annex D and Annex E contains extracts from the BASI archived accident investigation files relating to this section. ASIB requested a spectrographic analysis of ATS automatic voice recordings of VH-MDX communications in an attempt to '*determine whether any additional information could be gained concerning the operation of the aircraft during the final 15 minutes of flight.*'[5]. Of particular interest was an attempt to detect[5]:

- Warning sounds from the aircraft (e.g. stall warning horn)
- Aerodynamic noises that may indicate increasing airspeed or similar.

Two periods of communications were analysed[5]:

- VH-MDX transmission commencing 0923:52UTC ('…*in the clag in turbulence*….')
- VH-MDX transmission commencing 0938:29UTC (<open microphone for some time> and '*we're down to six and a half*')

In particular the periods of no speech with open microphone were analysed[5] thus to a large extent removing the issue of transmission power variability with modulation as mentioned in section 2.4.

8.2. ASIB findings

The *conclusion* of the automatic voice recording analysis was that:
'*There were no recordings containing audio warnings or significant sounds emanating from the aircraft*'[5].

What was also suggested from the examination of the recordings was that the *signal strength* of the transmission commencing 0938:29UTC was *greater* than the signal strength of the transmission commencing at 0923:52UTC[5].

8.3. Use of signal strength differences

8.3.1. Overview

Provided near line-of sight is maintained, signal strength differences can be indicative of VH-MDX's *distance* from the Mt Berrico ground transceiver station although, other variable factors may cause variation in signal strength such as:

- Precipitation over the aircraft or ground station, or between the aircraft and ground station
- Icing on aircraft antenna
- Fuselage/wing blanking of aircraft antenna (e.g. in a turn, more likely *away* from the ground station with top mounted antennae on the C-210)
- Ground transceiver gain control limits/ automatic gain control
- Aircraft transmissions with polarisation away from the vertical in a turn
- Modulation levels.

Of these factors, *precipitation* and *blanking* would be the most significant factors in the case of VH-MDX.

Modulation levels would have some effect as demonstrated by the noticeable change in inflection and perhaps volume of the pilot's voice at the second call (as is evident in the actual audio recording). Despite this, it was stated that the periods of *no voice transmission* with open microphone were analysed thus removing to a large extent the effects of modulation on output power[5]. The only modulation effect would be that of possible increased background noise perhaps due to increased aircraft speed.

It cannot be concluded that attenuation from antenna icing affected signal strength. Of note is that the second transmission was of higher signal strength despite the pilot having reported a second bout of ice accumulation by this stage. Assuming that *signal strength* was indicative of aircraft *distance* to the ground transceiver, one can *very broadly* suggest that VH-MDX was *closer* to Mt Berrico at 0938:33UTC at approximately 6500' than at 0923:52UTC when at approximately 8000'-8500' AMSL.

Additionally, a very important consideration is the significant cloud and precipitation along the mountain-tops particularly in the areas of highest terrain near the Barrington Tops and Gloucester Tops.

This weather would likely have contributed to readily discernible radio communications attenuation. Accordingly, signal strength would be expected to increase if VH-MDX tracked roughly south or south-east to the Mt Berrico side of the weather (i.e. avoiding having the bulk of the weather between the aircraft and Mt Berrico).

Equally if VH-MDX tracked east back along the Gloucester River area a similar result would manifest. Obviously tracking generally north or west would result in decreased signal strength at 0938:33UTC due to the increased distance.

8.3.2. Position of VH-MDX at lower signal strength

The time interval from the second spectrographic analysis time of 0923:52UTC to the first radar fix by Sydney ATC at approximately 36NM north of Singleton NDB just after 0928:28 UTC, to is 4 minutes and 36 seconds: approximately 4.5 minutes. Assuming:

- A course of 265°T to the initial Sydney radar fix
- A reported and reliable sighting (to the author) of VH-MDX heading west at a position approximately 3km south of Mount Mooney Station, to the initial radar fix position described,
- Considering forecast winds of 250°T at 45 knots and,
- A pilot reported wind of 250°T at 70 knots,
- Climb Indicated Air Speed (IAS) of 110 knots (faster end of standard climb speeds for turbulence buffer and unaware of the ensuing prolonged inability to climb)
- True Air Speed (TAS) of 120 knots based on a climb IAS of 110 knots and ISA-4° conditions;

A Ground Speed (GS) of 76 knots and 51 knots results from the slowest and fastest winds respectively. This equates to a distance from the initial radar fix of 3.8NM and 5.7NM back towards the east, which results in VH-MDX being in the vicinity of Polblue swamp and camping area.

This agrees very broadly with Chessor's suggestion[13] of VH-MDX being in the Polblue area at a similar time.

8.3.3. Distance attenuation

As stated in section 8.3.1, as a general rule, increased distances between the ground transceiver and VH-MDX decreases signal strength.

Approximate distances from Mt Berrico FIS-5 ground transceiver to various areas of interests based on reported radar positions and dead reckoning considering Cessna 210 climb type speeds and forecast winds are[11]:

Position	Distance to Mt Berrico
Approximate 0923:52UTC position (IVO PolBlue)	18-20NM
Upper Allyn River	17NM
BASI final Williamtown radar position (Upper Williams River)	15NM
Upper Kerripit River	15NM
Upper Chichester River	12NM
Upper Gloucester River	8NM
The Pinnacle 56H3729 64471	6NM
Final Sydney ATC radar position (5NM west of Craven Waypoint)	5NM

Figure 8: Distances from Mt Berrico to areas of interest. The geographical positions in this figure represent areas of interest in relation to possible positions VH-MDX may have transited or impacted terrain near. Although it is not defensible to draw *hard* conclusions from the findings in this section, it is possible to use such information as a complement to other analysis methods.

It would be indefensible to draw a hard boundary in terms of the above distances where the signal strength would be stronger given the possible variables. Regardless, a *general trend* can possibly be used and complement other forms of analysis.
For instance, at the point of 'lower' signal strength, VH-MDX was approximately 18-20NM from Mt Berrico.

Accordingly, and not withstanding other factors mentioned in the first paragraph of this section, one would *not* expect *stronger* signal strength at *similar* distances to this such as the Upper Allyn, Williams and Kerripit Rivers but would expect increased signal strength at the final Sydney radar position 5NM west of Craven waypoint.

Terrain masking must also be considered as signal blanking may occur. Generally speaking, VH-MDX was likely to be at or above 7500'AMSL up to approximately the Williamtown 0936:00UTC fix and reported being at 6500'AMSL at 0938:33UTC with these altitudes being above the 5171' elevation of the highest terrain[12] in the immediate area.

These VH-MDX altitudes above the interleaving terrain coupled with the relatively short distance of VH-MDX to Mt Berrico (approximately ≤20NM) that minimise the effects of Earth curvature suggest that *terrain masking* to the 6500' reported altitude is not a factor. Propagation analysis that will be conducted in the following sections will consider this crucial factor but also of communications possibilities below the highest terrain in the area.

8.3.4. Weather attenuation

Other than *distance*, another likely and significant contributor to decreased VHF communications signal strength in the Polblue area would be attenuation due to *clouds and precipitation*. When VH-MDX was in the Polblue area:

- The pilot had reported entering cloud at an earlier time[5]
- Given the wind direction and strength coupled with terrain elevation, formation of clouds and precipitation from orographic uplifting would be apparent over the higher areas of terrain in the area between Polblue and Mt Berrico[23].

Furthermore, some time after being in the Polblue area the pilot of VH-MDX reports having picked up significant ice[5]. These clues confirm the formation of cloud on and in vicinity of the main Barrington range. Cloud was isolated and limited to mountaintops and windward terrain[23]. Some cloud was also possibly located on the lee side of mountains[23]. The Barrington ranges likely had cumulus/ strato-cumulus and lenticular clouds apparent during the VH-MDX accident with tops around 7500'AMSL to 8000'AMSL[23].

Indeed, the higher points of terrain that would have resulted in generating the largest orographic uplift hence cloud and precipitation, would have been generally between Mt Berrico, Mt Barrington, Mt Brumlow and north to the Polblue area. This is shown in figure 9 on the next page. There is some evidence suggesting clear skies from some point east of the Gloucester Tops and that the main range from and generally west of the Gloucester Tops experienced the cloud and precipitation[23].

Signal attenuation from weather effects such as cloud and precipitation would likely have decreased the VHF communications signal strength when VH-MDX was in the Polblue area, over the main range or if/ when VH-MDX was *close* to the southern upper sections of the main range. If VH-MDX was *well south* of the range or east of the Gloucester Tops then much less weather based attenuation would be expected.

These suggestions do support the ASIB Spectrographic unit findings of:

- Decreased signal strength at 0923:52UTC when VH-MDX was in the Polblue area resulting in the signal path passing through significant cloud and precipitation and;
- Increased signal strength at 0938:29UTC at which point VH-MDX was likely in vicinity of the Gloucester Tops and clear of most of the cloud,

but more importantly give reasons to why the signal strength differences occurred.

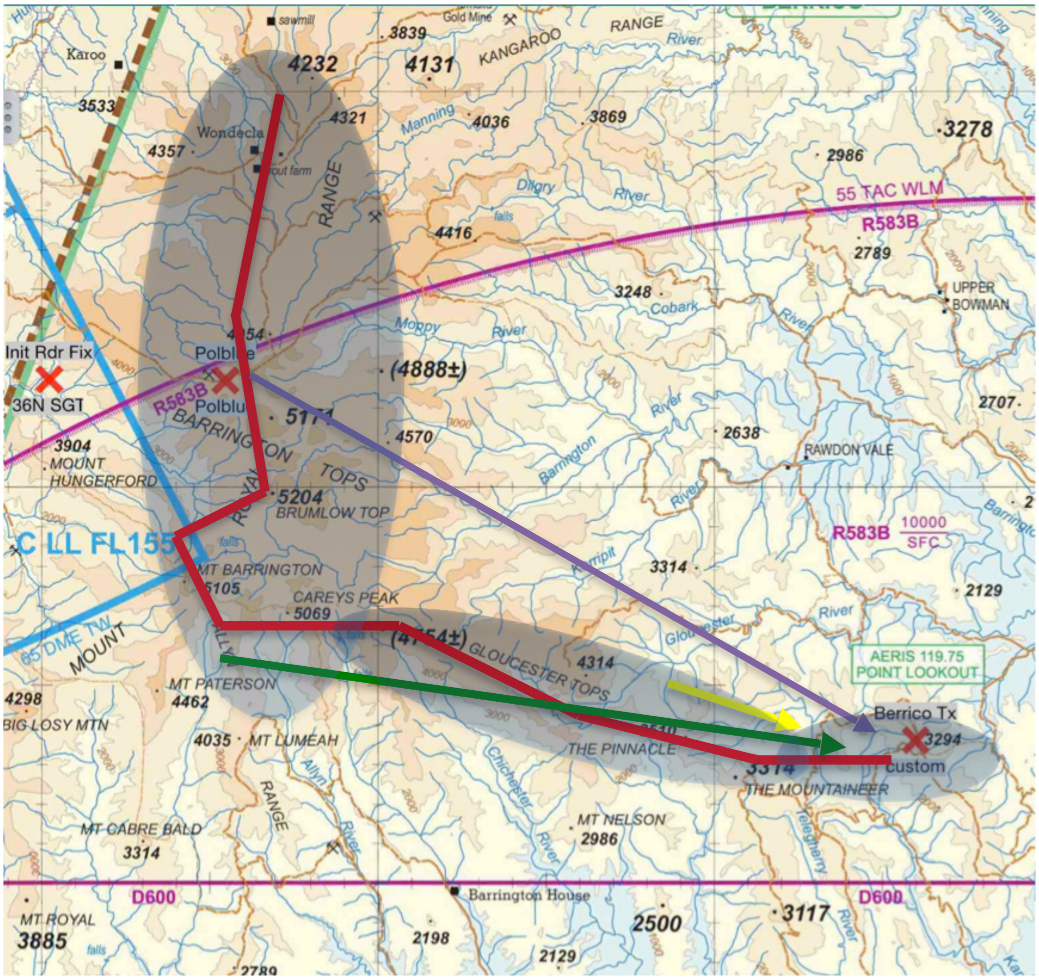


Figure 9: Communications paths through likely cloud and precipitation. According to the ARFOR, a strong south-westerly wind was apparent causing orographic uplifting that generated unstable cloud along much of the main range mountain tops. Likely areas of precipitation and clouds is highly approximated with a blue shading. Significant points of orographic uplifting are marked with a red line. The purple line marks the approximate communications path between VH-MDX to Mt Berrico FIS-5 outlet at the time of lower signal strength and can be seen to pass through likely areas of significant weather. The green line marks a communications path from just south of the main range to FIS-5 and it can be seen that the signal would also pass through orgographic weather resulting in signal attenuation. The yellow line represents 5NM west of Craven intersection to FIS-5 and is subject to much less weather related attenuation. In conjunction with distance between transceivers, this may give some general guidance on approximate *broad* tracking of VH-MDX, isolating quadrants or hemispheres of likely tracking direction. (Chart: Ozrunways 2014, Additions: Glenn Strkalj 2014).

8.3.5. Findings: VHF communications signal strength

1. VHF communications signal strength can offer an alternative method to suggesting the *general* position of VH-MDX at different times.
2. Considering signal attenuation from cloud and precipitation and due to the distance between the two radios, VHF communications signal strength comparison suggests VH-MDX tracking generally between *east through to south* from the initial Sydney radar fix of approximately 36NM north of Singleton NDB.
3. Finding 2 corroborates with radar fix information.

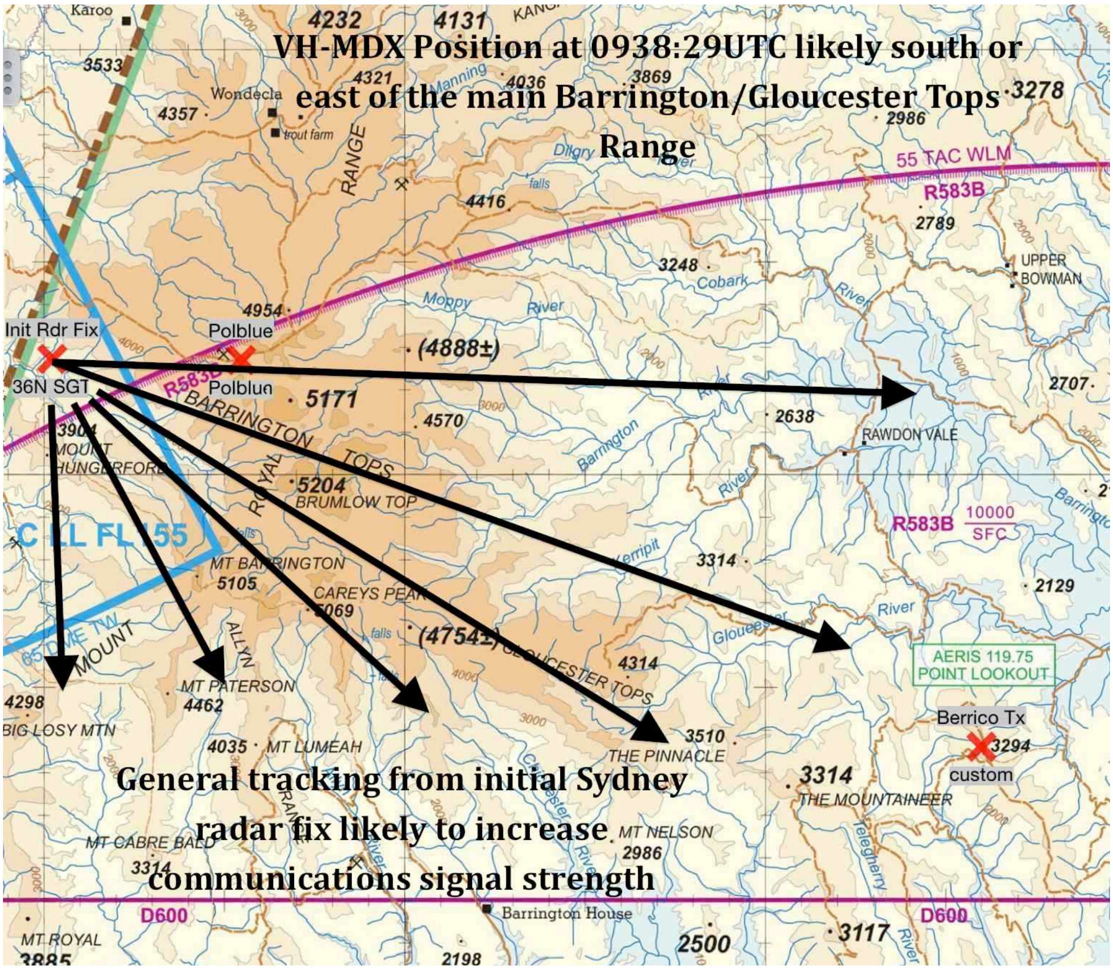


Figure 10: VH-MDX general direction vs. signal strength. It is assumed that received signal strength reduces with range between transceivers and that increased attenuation from moisture in clouds and falling precipitation was more apparent at the higher parts of the Barrington Ranges. Only a very broad conclusion of the general tracking of VH-MDX can be made from these assumptions. It can be seen from this figure that a generally easterly through to southerly course from the initial Sydney radar fix would be expected of VH-MDX with VH-MDX likely being located south or east of the Mount Barrington area at 0938:29UTC (southern or eastern sections of the Barrington and Gloucester Tops). This coarsely verifies the validity of the Williamtown 0936:00UTC radar fix (Chart: Ozrunways 2014, additions: Glenn Strkalj 2014).

9. Propagation analysis of 121.6MHz FIS-5

9.1. Methodology

Specific geographical areas of interest as identified in Section 8 and a general overview of the Barrington and Gloucester Tops will be focused on for propagation analysis using *Radio Mobile On-Line* propagation analysis software[14].

Radio Mobile On-Line offers a number of variables that can be adjusted and considers Earth curvature and terrain effects[14]. As Radio Mobile On-Line is a tool for Amateur Radio operators[14], the precise radio frequencies of the radio equipment in interest is not able to be analysed.

The author strongly believes that selecting the closest Amateur frequency to the radio frequency of interest will provide a result that has negligible deviation. Information on the Mt Berrico and VH-MDX transceivers is not completely accurate or available to such an extent that *precise* population of all variables in the Radio Mobile On-Line software is possible.

Despite this, in the author's opinion there is sufficient information and data currently available to achieve highly *accurate* and *defensible* results.

Two approaches will be taken:
- A general *tree top level* area propagation analysis
- A link (boresight) analysis between the Mt Berrico FIS-5 outlet and *specific* geographic locations where VH-MDX may have been at various altitudes.

Regarding the latter, the specific locations chosen are *not* exhaustive and represent only a *very small* sample of the area in question. Additional specific propagation analysis as required to analyse sub theories and concepts should be carried out.

9.2. Variables

The following variables are used for propagation analysis.

Airborne VHF Communications Transceiver	
Receiver Sensitivity	3 microvolts (assumed based on an airborne transceiver of a similar era S+N/N 6dB or more)[2]
Transmitter Power	25W PEP (based on TSO class)[16]
Antenna Gain	0dBi (assumed due omni-directional antenna)
System Losses	3dB (assumed)

Figure 11: Airborne VHF communications receiver specifications. Not all specifications can be confirmed however, reasonable assumptions are made based on likely and known technical characteristics.

Ground VHF Communications Transceiver	
Receiver Sensitivity	3 microvolts (assumed based on airborne transceiver)
Transmitter Power	50W mean power[17]
Antenna Gain	2dBi (assumed based on current station antenna gain)[17]
System Losses	3dB (assumed)
Antenna height	35m (assumed based on current station antenna gain)[17]

Figure 12: **Ground based VHF communications receiver specifications.** Again, not all specifications are known and reasonable assumptions are made based on current installed equipment and known technical characteristics of similar equipment.

9.3. Barrington Tops general

<u>**At approximate tree-top level**</u>

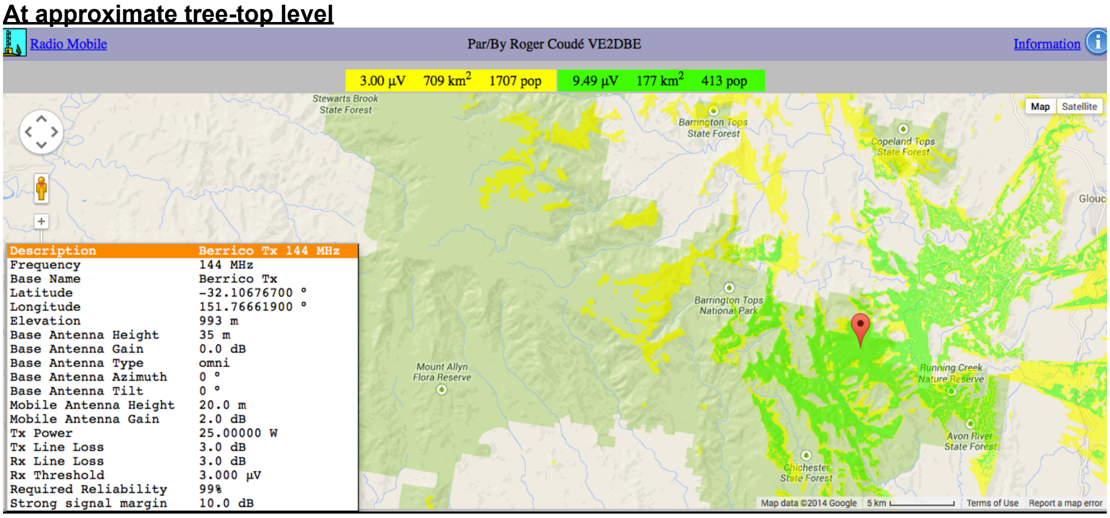
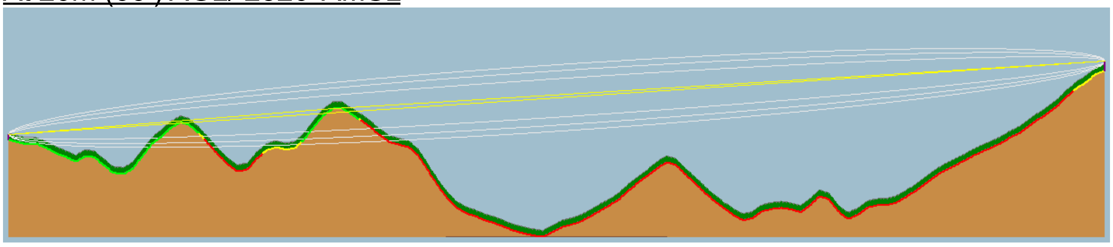


Figure 13: FIS-5 coverage at approximate tree-top level. Yellow areas represent a signal of 3.00µV which is the expected approximate signal level expected for reception. Green is 10dB higher signal strength. It is readily apparent that communications near the Upper Allyn, Williams and Chichester River Valleys is dependent on aircraft altitude whilst coverage generally exists in the vicinity of the Sydney ATC final radar fix[14].

9.4. 5NM west Craven waypoint

<u>At 20m (66') AGL/ 2520' AMSL</u>



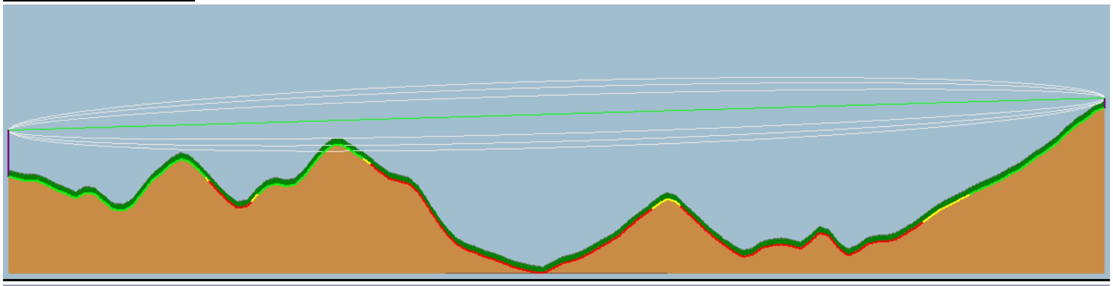
Radio Mobile — Par/By Roger Coudé VE2DBE — Information

5NM West Craven (1)		(2) Berrico Tx	
Latitude	-32.109055 °	Latitude	-32.106767 °
Longitude	151.670832 °	Longitude	151.766619 °
Ground elevation	748.0 m	Ground elevation	993.0 m
Antenna height	20.0 m	Antenna height	35.0 m
Azimuth	88.41 °	Azimuth	268.36 °
Tilt	1.61 °	Tilt	-1.69 °
Radio system		**Propagation**	
TX power	43.98 dBm	Free space loss	94.68 dB
TX line loss	3.00 dB	Obstuction loss	10.45 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.89 dB
RX sensitivity	-97.46 dBm	Total path loss	137.01 dB

Performance	
Distance	**9.026 km**
Precision	10.0 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-97.04 dBm
Received Signal	3.15 µV
Fade Margin	**0.42 dB**

Figure 14: Communications possibility at tree-top level 5NM west of Craven waypoint[14].

At 3000’ AMSL



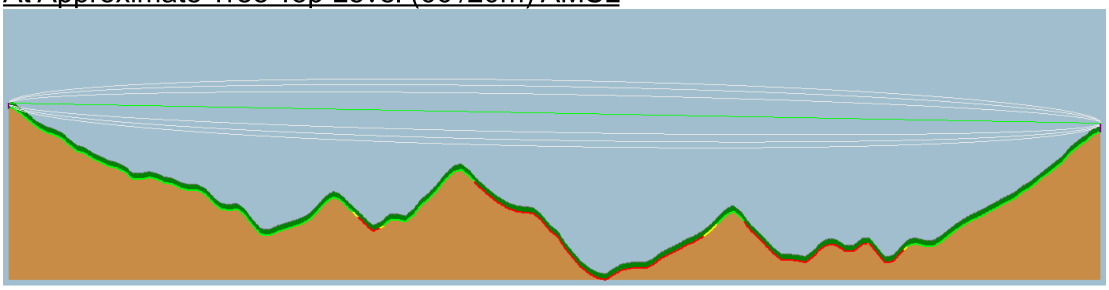
Radio Mobile	Par/By Roger Coudé VE2DBE		Information
5NM West Craven (1)			(2) Berrico Tx
Latitude	-32.109055 °	Latitude	-32.106767 °
Longitude	151.670832 °	Longitude	151.766619 °
Ground elevation	748.0 m	Ground elevation	993.0 m
Antenna height	166.0 m	Antenna height	35.0 m
Azimuth	88.41 °	Azimuth	268.36 °
Tilt	0.68 °	Tilt	-0.76 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	94.68 dB
TX line loss	3.00 dB	Obstuction loss	0.90 dB
TX antenna gain	0.00 dBi	Forest loss	0.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.95 dB
RX sensitivity	-97.46 dBm	Total path loss	126.53 dB

Performance	
Distance	**9.026 km**
Precision	10.0 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-86.55 dBm
Received Signal	10.53 µV
Fade Margin	**10.91 dB**

Figure 15: Communications possibility at 3000’AMSL 5NM west of Craven waypoint[14].

9.5. The Pinnacle

At Approximate Tree Top Level (66’/20m) AMSL



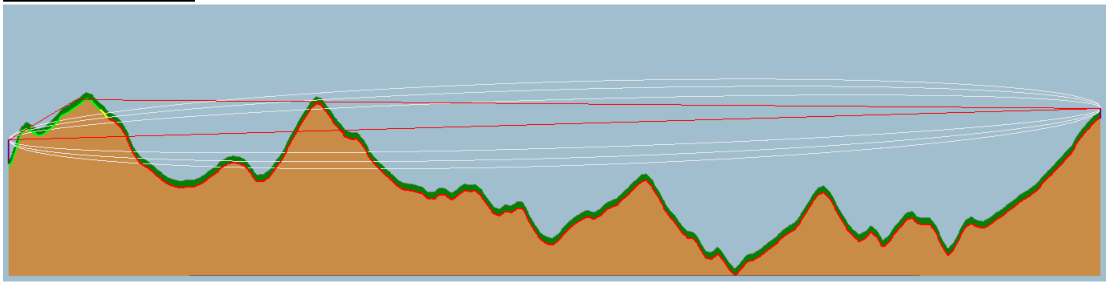
The Pinnacle-Mt Berrico 20m			
The Pinnacle (1)			(2) Berrico Tx
Latitude	-32.105612 °	Latitude	-32.106767 °
Longitude	151.652856 °	Longitude	151.766619 °
Ground elevation	1085.0 m	Ground elevation	993.0 m
Antenna height	20.0 m	Antenna height	35.0 m
Azimuth	90.72 °	Azimuth	270.66 °
Tilt	-0.46 °	Tilt	0.36 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	96.17 dB
TX line loss	3.00 dB	Obstuction loss	0.22 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.93 dB
RX sensitivity	-97.46 dBm	Total path loss	128.32 dB

Performance	
Distance	**10.716 km**
Precision	10.0 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-88.34 dBm
Received Signal	8.57 µV
Fade Margin	**9.12 dB**

Figure 16: Communications possibility at tree-top level at The Pinnacle[14].

9.6. Upper Gloucester River Valley

At 3000' AMSL

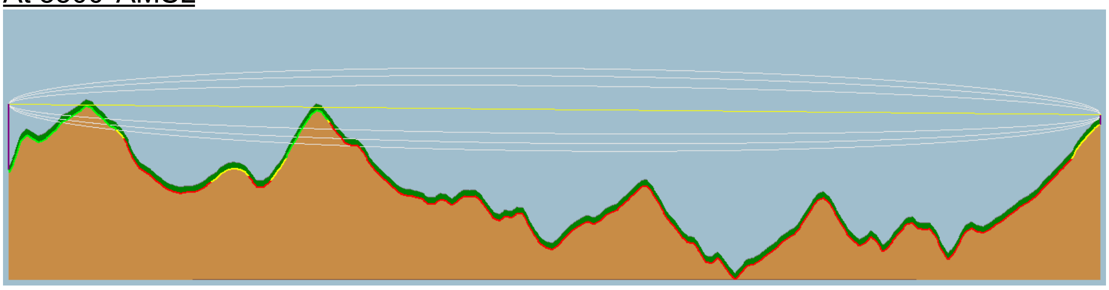


UGR-Mt Berrico 3000'			
320-Wing (X UGR) (1)			(2) Berrico Tx
Latitude	-32.093197 °	Latitude	-32.106767 °
Longitude	151.612442 °	Longitude	151.766619 °
Ground elevation	827.0 m	Ground elevation	993.0 m
Antenna height	87.0 m	Antenna height	35.0 m
Azimuth	95.97 °	Azimuth	275.89 °
Tilt	0.38 °	Tilt	-0.51 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	98.86 dB
TX line loss	3.00 dB	Obstuction loss	27.64 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.75 dB
RX sensitivity	-97.46 dBm	Total path loss	158.24 dB

Performance	
Distance	**14.601 km**
Precision	10.0 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-118.27 dBm
Received Signal	0.27 µV
Fade Margin	**-20.81 dB**

Figure 17: Communications possibility at 3000' AMSL in the Upper Gloucester River Valley[14].

At 3500' AMSL



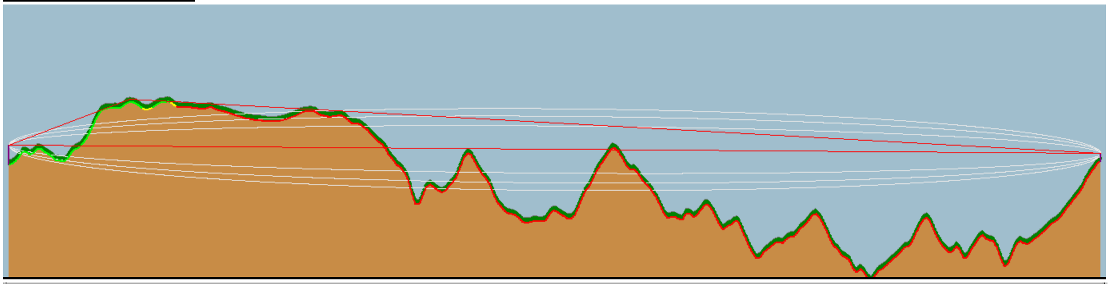
UGR-Mt Berrico 3500'			
320-Wing (X UGR) (1)			(2) Berrico Tx
Latitude	-32.093197 °	Latitude	-32.106767 °
Longitude	151.612442 °	Longitude	151.766619 °
Ground elevation	827.0 m	Ground elevation	993.0 m
Antenna height	240.0 m	Antenna height	35.0 m
Azimuth	95.97 °	Azimuth	275.89 °
Tilt	-0.22 °	Tilt	0.09 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	98.85 dB
TX line loss	3.00 dB	Obstuction loss	5.47 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.78 dB
RX sensitivity	-97.46 dBm	Total path loss	136.10 dB

Performance	
Distance	**14.601 km**
Precision	10.0 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-96.12 dBm
Received Signal	3.50 µV
Fade Margin	**1.34 dB**

Figure 18: Communications possibility at 3500' AMSL in the Upper Gloucester River Valley[14].

9.7. Upper Chichester River Valley

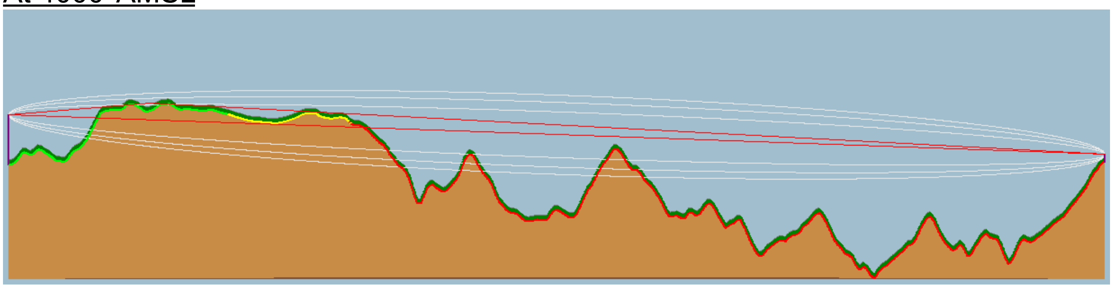
At 3500’ AMSL



UCR-Mt Berrico 3500'			
UCR (1)			(2) Berrico Tx
Latitude	-32.082274 °	Latitude	-32.106767 °
Longitude	151.521038 °	Longitude	151.766619 °
Ground elevation	978.0 m	Ground elevation	993.0 m
Antenna height	89.0 m	Antenna height	35.0 m
Azimuth	96.78 °	Azimuth	276.65 °
Tilt	-0.20 °	Tilt	-0.01 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	102.91 dB
TX line loss	3.00 dB	Obstuction loss	26.59 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.57 dB
RX sensitivity	-97.46 dBm	Total path loss	161.07 dB
Performance			
Distance			**23.294 km**
Precision			11.6 m
Frequency			144.000 MHz
Equivalent Isotropically Radiated Power			12.530 W
System gain			137.44 dB
Required reliability			99.000 %
Received Signal			-121.09 dBm
Received Signal			0.20 µV
Fade Margin			**-23.63 dB**

Figure 19: Communications possibility at 3500’ AMSL in the Upper Chichester River Valley[14].

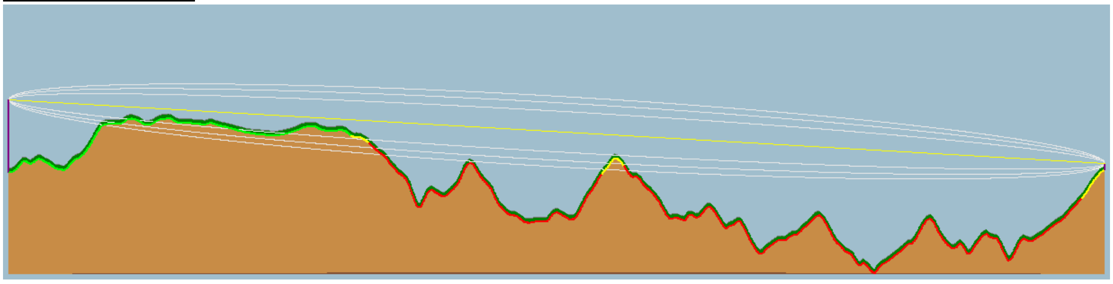
At 4000’ AMSL



UCR-Mt Berrico 4000'*			
UCR (1)			(2) Berrico Tx
Latitude	-32.082274 °	Latitude	-32.106767 °
Longitude	151.521038 °	Longitude	151.766619 °
Ground elevation	978.0 m	Ground elevation	993.0 m
Antenna height	241.0 m	Antenna height	35.0 m
Azimuth	96.78 °	Azimuth	276.65 °
Tilt	-0.57 °	Tilt	0.36 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	102.91 dB
TX line loss	3.00 dB	Obstuction loss	14.27 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.65 dB
RX sensitivity	-97.46 dBm	Total path loss	148.83 dB
Performance			
Distance			**23.294 km**
Precision			11.6 m
Frequency			144.000 MHz
Equivalent Isotropically Radiated Power			12.530 W
System gain			137.44 dB
Required reliability			99.000 %
Received Signal			-108.85 dBm
Received Signal			0.81 µV
Fade Margin			**-11.39 dB**

Figure 20: Communications possibility at 4000’ AMSL in the Upper Chichester River Valley[14].

At 4500’ AMSL

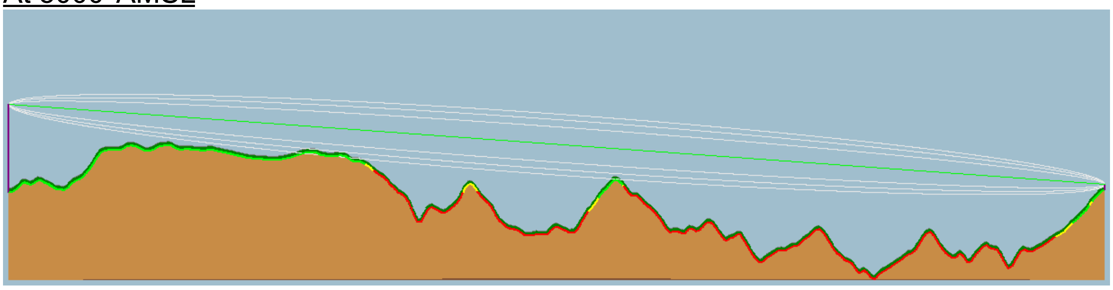


UCR-Mt Berrico 4500'			
UCR (1)			(2) Berrico Tx
Latitude	-32.082274 °	Latitude	-32.106767 °
Longitude	151.521038 °	Longitude	151.766619 °
Ground elevation	978.0 m	Ground elevation	993.0 m
Antenna height	394.0 m	Antenna height	35.0 m
Azimuth	96.78 °	Azimuth	276.65 °
Tilt	-0.95 °	Tilt	0.74 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	102.91 dB
TX line loss	3.00 dB	Obstuction loss	1.01 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.60 dB
RX sensitivity	-97.46 dBm	Total path loss	135.52 dB

Performance	
Distance	**23.294 km**
Precision	11.6 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-95.54 dBm
Received Signal	3.74 µV
Fade Margin	**1.92 dB**

Figure 21: Communications possibility at 4500’ AMSL in the Upper Chichester River Valley[14].

At 5000’ AMSL



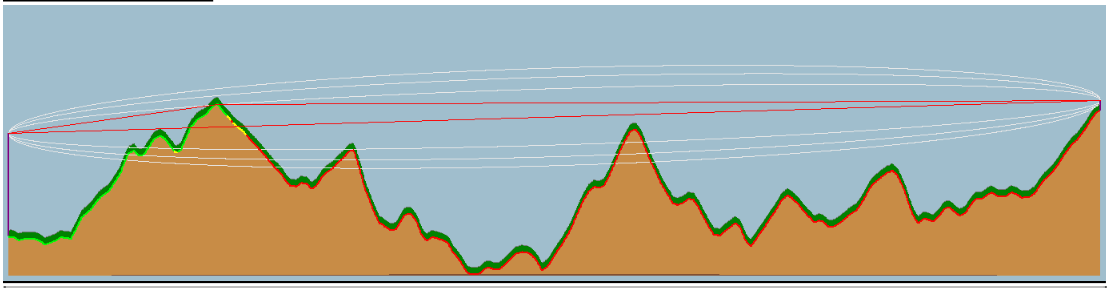
UCR-Mt Berrico 5000'			
UCR (1)			(2) Berrico Tx
Latitude	-32.082274 °	Latitude	-32.106767 °
Longitude	151.521038 °	Longitude	151.766619 °
Ground elevation	978.0 m	Ground elevation	993.0 m
Antenna height	546.0 m	Antenna height	35.0 m
Azimuth	96.78 °	Azimuth	276.65 °
Tilt	-1.32 °	Tilt	1.11 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	102.91 dB
TX line loss	3.00 dB	Obstuction loss	-0.43 dB
TX antenna gain	0.00 dBi	Forest loss	0.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.65 dB
RX sensitivity	-97.46 dBm	Total path loss	133.14 dB

Performance	
Distance	**23.294 km**
Precision	11.6 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-93.16 dBm
Received Signal	4.92 µV
Fade Margin	**4.30 dB**

Figure 22: Communications possibility at 5000’ AMSL in the Upper Chichester River Valley[14].

9.8. Upper Kerripit River Valley

At 3000’ AMSL



UKR-Mt Berrico 3000'

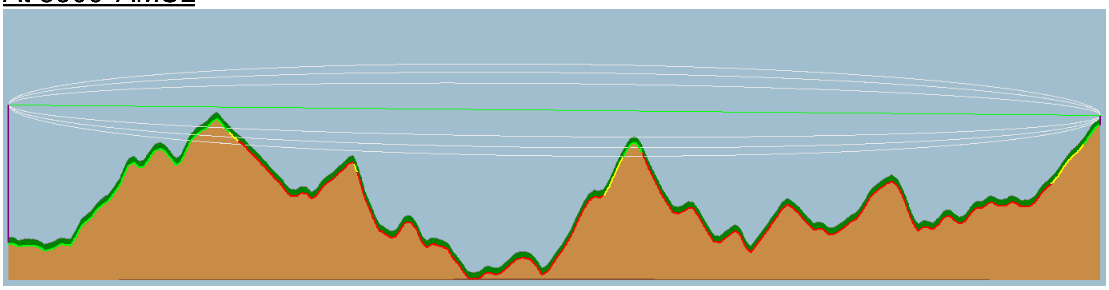
UKR (1)		(2) Berrico Tx	
Latitude	-32.036017 °	Latitude	-32.106767 °
Longitude	151.592523 °	Longitude	151.766619 °
Ground elevation	560.0 m	Ground elevation	993.0 m
Antenna height	354.0 m	Antenna height	35.0 m
Azimuth	115.67 °	Azimuth	295.57 °
Tilt	0.28 °	Tilt	-0.44 °

Radio system		Propagation	
TX power	43.98 dBm	Free space loss	100.77 dB
TX line loss	3.00 dB	Obstuction loss	14.54 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.77 dB
RX sensitivity	-97.46 dBm	Total path loss	147.08 dB

Performance	
Distance	**18.193 km**
Precision	10.0 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-107.10 dBm
Received Signal	0.99 µV
Fade Margin	**-9.64 dB**

Figure 23: Communications possibility at 3000’ AMSL in the Upper Kerripit River Valley[14].

At 3500’ AMSL



UKR-Mt Berrico 3500'

UKR (1)		(2) Berrico Tx	
Latitude	-32.036017 °	Latitude	-32.106767 °
Longitude	151.592523 °	Longitude	151.766619 °
Ground elevation	560.0 m	Ground elevation	993.0 m
Antenna height	507.0 m	Antenna height	35.0 m
Azimuth	115.67 °	Azimuth	295.57 °
Tilt	-0.20 °	Tilt	0.04 °

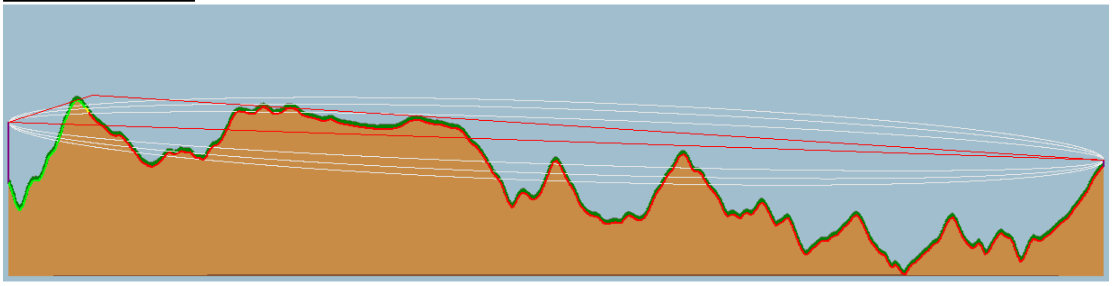
Radio system		Propagation	
TX power	43.98 dBm	Free space loss	100.77 dB
TX line loss	3.00 dB	Obstuction loss	0.26 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.77 dB
RX sensitivity	-97.46 dBm	Total path loss	132.79 dB

Performance	
Distance	**18.193 km**
Precision	10.0 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-92.81 dBm
Received Signal	5.12 µV
Fade Margin	**4.65 dB**

Figure 24: Communications possibility at 3500’ AMSL in the Upper Kerripit River Valley[14].

9.9. Upper Williams River Valley (ASIB/RCC final fix)

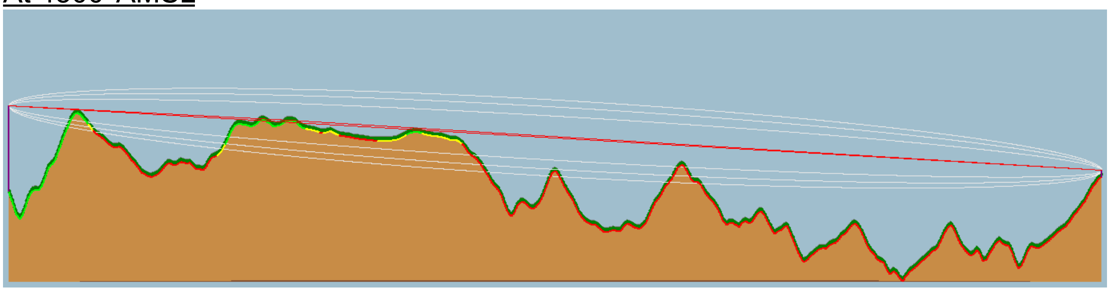
At 4000’ AMSL



BASI-Mt Berrico 4000'			
BASI Last RDR Converted (1)			(2) Berrico Tx
Latitude	-32.077583 °	Latitude	-32.106767 °
Longitude	151.483056 °	Longitude	151.766619 °
Ground elevation	912.0 m	Ground elevation	993.0 m
Antenna height	307.0 m	Antenna height	35.0 m
Azimuth	97.00 °	Azimuth	276.85 °
Tilt	-0.53 °	Tilt	0.29 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	104.17 dB
TX line loss	3.00 dB	Obstuction loss	19.74 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.65 dB
RX sensitivity	-97.46 dBm	Total path loss	155.55 dB
Performance			
Distance			**26.909 km**
Precision			13.5 m
Frequency			144.000 MHz
Equivalent Isotropically Radiated Power			12.530 W
System gain			137.44 dB
Required reliability			99.000 %
Received Signal			-115.57 dBm
Received Signal			0.37 µV
Fade Margin			**-18.12 dB**

Figure 25: Communications possibility at 4000’ AMSL in the Upper Williams River Valley[14].

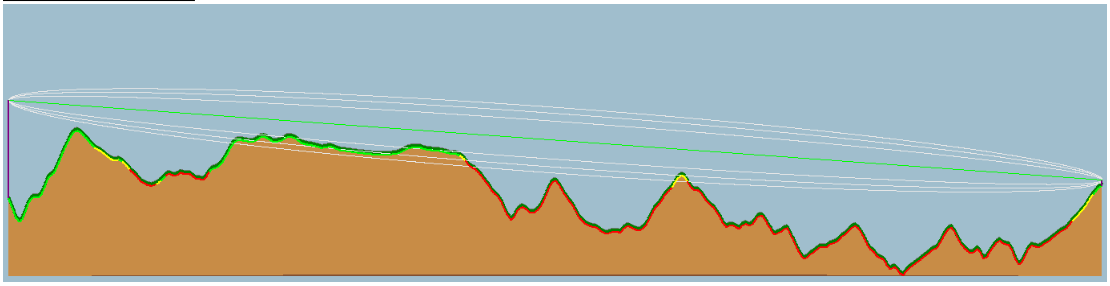
At 4500’ AMSL



BASI-Mt Berrico 4500'			
BASI Last RDR Converted (1)			(2) Berrico Tx
Latitude	-32.077583 °	Latitude	-32.106767 °
Longitude	151.483056 °	Longitude	151.766619 °
Ground elevation	912.0 m	Ground elevation	993.0 m
Antenna height	460.0 m	Antenna height	35.0 m
Azimuth	97.00 °	Azimuth	276.85 °
Tilt	-0.85 °	Tilt	0.61 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	104.17 dB
TX line loss	3.00 dB	Obstuction loss	7.64 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.62 dB
RX sensitivity	-97.46 dBm	Total path loss	143.43 dB
Performance			
Distance			**26.909 km**
Precision			13.5 m
Frequency			144.000 MHz
Equivalent Isotropically Radiated Power			12.530 W
System gain			137.44 dB
Required reliability			99.000 %
Received Signal			-103.45 dBm
Received Signal			1.51 µV
Fade Margin			**-5.99 dB**

Figure 26: Communications possibility at 4500’ AMSL in the Upper Williams River Valley[14].

At 5000’ AMSL



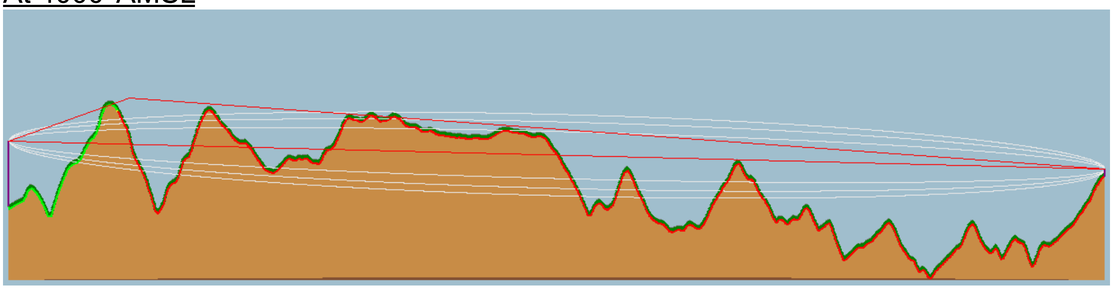
BASI-Mt Berrico 5000			
BASI Last RDR Converted (1)			(2) Berrico Tx
Latitude	-32.077583 °	Latitude	-32.106767 °
Longitude	151.483056 °	Longitude	151.766619 °
Ground elevation	912.0 m	Ground elevation	993.0 m
Antenna height	612.0 m	Antenna height	35.0 m
Azimuth	97.00 °	Azimuth	276.85 °
Tilt	-1.18 °	Tilt	0.93 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	104.17 dB
TX line loss	3.00 dB	Obstuction loss	-0.78 dB
TX antenna gain	0.00 dBi	Forest loss	0.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.58 dB
RX sensitivity	-97.46 dBm	Total path loss	133.97 dB

Performance	
Distance	**26.909 km**
Precision	13.5 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-93.99 dBm
Received Signal	4.47 µV
Fade Margin	**3.47 dB**

Figure 27: Communications possibility at 5000’ AMSL in the Upper Williams River Valley[14].

9.10.Upper Allyn River Valley

At 4000’ AMSL

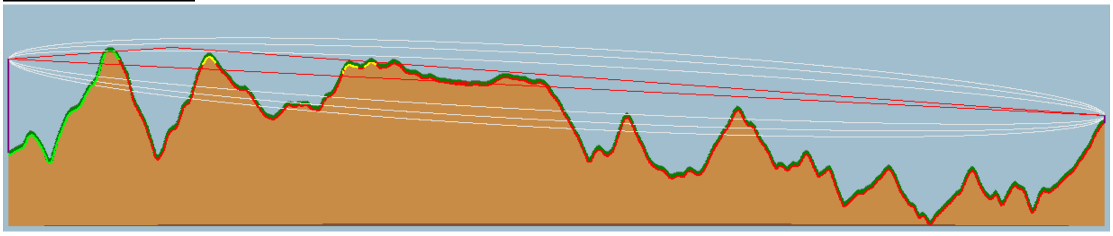


Radio Mobile		Par/By Roger Coudé VE2DBE	Information
UAR (1)			(2) Berrico Tx
Latitude	-32.072633 °	Latitude	-32.106767 °
Longitude	151.441560 °	Longitude	151.766619 °
Ground elevation	825.0 m	Ground elevation	993.0 m
Antenna height	357.0 m	Antenna height	35.0 m
Azimuth	97.15 °	Azimuth	276.98 °
Tilt	-0.42 °	Tilt	0.15 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	105.35 dB
TX line loss	3.00 dB	Obstuction loss	23.40 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.60 dB
RX sensitivity	-97.46 dBm	Total path loss	160.36 dB

Performance	
Distance	**30.857 km**
Precision	15.4 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-120.38 dBm
Received Signal	0.21 µV
Fade Margin	**-22.92 dB**

Figure 28: Communications possibility at 4000’ AMSL in the Upper Allyn River Valley[14].

At 4500’ AMSL

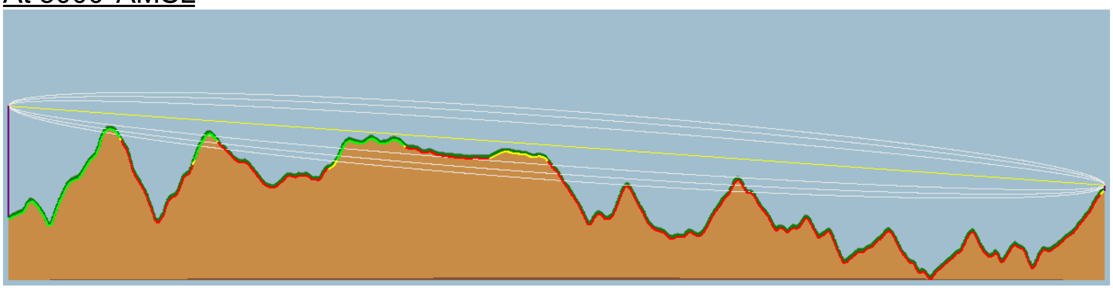


Radio Mobile	Par/By Roger Coudé VE2DBE		Information
UAR (1)			(2) Berrico Tx
Latitude	-32.072633 °	Latitude	-32.106767 °
Longitude	151.441560 °	Longitude	151.766619 °
Ground elevation	825.0 m	Ground elevation	993.0 m
Antenna height	510.0 m	Antenna height	35.0 m
Azimuth	97.15 °	Azimuth	276.98 °
Tilt	-0.71 °	Tilt	0.43 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	105.35 dB
TX line loss	3.00 dB	Obstuction loss	14.15 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.63 dB
RX sensitivity	-97.46 dBm	Total path loss	151.13 dB

Performance	
Distance	**30.857 km**
Precision	15.4 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-111.15 dBm
Received Signal	0.62 µV
Fade Margin	**-13.70 dB**

Figure 29: Communications possibility at 4500’ AMSL in the Upper Allyn River Valley[14].

At 5000’ AMSL

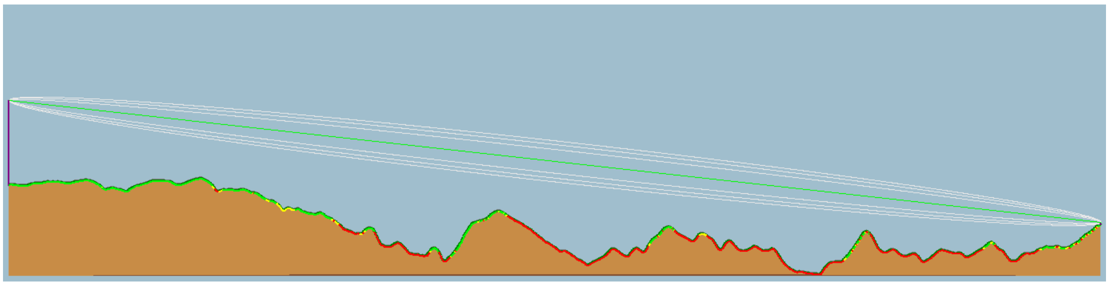


UAR-Mt Berrico 5000'			
UAR (1)			(2) Berrico Tx
Latitude	-32.072633 °	Latitude	-32.106767 °
Longitude	151.441560 °	Longitude	151.766619 °
Ground elevation	825.0 m	Ground elevation	993.0 m
Antenna height	699.0 m	Antenna height	35.0 m
Azimuth	97.15 °	Azimuth	276.98 °
Tilt	-1.06 °	Tilt	0.78 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	105.36 dB
TX line loss	3.00 dB	Obstuction loss	2.97 dB
TX antenna gain	0.00 dBi	Forest loss	1.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.53 dB
RX sensitivity	-97.46 dBm	Total path loss	139.85 dB

Performance	
Distance	**30.857 km**
Precision	15.4 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-99.87 dBm
Received Signal	2.27 µV
Fade Margin	**-2.41 dB**

Figure 30: Communications possibility at 5000’ AMSL in the Upper Allyn River Valley[14].

9.11.Polblue Camping Area



Polblue-Mt Berrico 8000'			
Polblue (1)			(2) Berrico Tx
Latitude	-31.953889 °	Latitude	-32.106767 °
Longitude	151.425232 °	Longitude	151.766619 °
Ground elevation	1456.0 m	Ground elevation	993.0 m
Antenna height	982.0 m	Antenna height	35.0 m
Azimuth	117.93 °	Azimuth	297.75 °
Tilt	-2.38 °	Tilt	2.05 °
Radio system			**Propagation**
TX power	43.98 dBm	Free space loss	106.79 dB
TX line loss	3.00 dB	Obstuction loss	-5.10 dB
TX antenna gain	0.00 dBi	Forest loss	0.00 dB
RX antenna gain	2.00 dBi	Urban loss	0.00 dB
RX line loss	3.00 dB	Statistical loss	30.65 dB
RX sensitivity	-97.46 dBm	Total path loss	132.34 dB

Performance	
Distance	**36.396 km**
Precision	18.2 m
Frequency	144.000 MHz
Equivalent Isotropically Radiated Power	12.530 W
System gain	137.44 dB
Required reliability	99.000 %
Received Signal	-92.36 dBm
Received Signal	5.40 µV
Fade Margin	**5.10 dB**

Figure 31: Communications possibility at 8000' AMSL over the Polblue Camping Area[14].

9.12.Findings: Radio propagation

Radio propagation software was used to analyse communications probability between VH-MDX and the Mt Berrico FIS-5 outlet. Specifically, the following areas were focused on using likely or actual transceiver specifications of both the airborne and ground stations:

- *General* coverage at 20 meters above terrain level across the general Barrington Tops area (approximating tree-top level) and,
- *Specific link* (boresight) analysis between locations where VH-MDX may have been and Mt Berrico FIS-5 outlet at various altitudes.

Four categories will be used to represent communications possibility between VH-MDX in the various locations and the FIS-5 outlet at Mt Berrico. These four categories are defined by *Determining conditions*. Only simple line of sight, Fresnel zones and basic receiver sensitivity (known and likely) are considered.
Factors such as selectivity, Signal to Noise and Distortion Ratio (SINAD) and noise factor are not known for both transceivers thus are *not* considered in sensitivity discussions.

Where line of sight or Fresnel propagation is apparent, results are broken down into three categories of likeness of a communications link based on known or likely aviation receiver sensitivity values.

0.25µV represents the receiver floor of a typical VHF receiver, 1.50µV the sensitivity of contemporary aviation VHF receivers and 3.00µV representing a receiver of the time of VH-MDX. (note: different SINAD/(S+N)/N values in applicable standards at the differing times result in different minimum sensitivity levels).

Other than lacking line of sight and Fresnel propagation, the remaining divisions are only *indicative* of communications possibilities.

Communications Possibility	Determining Conditions
Not possible	Not in line of sight or Fresnel zone <u>or</u> < 0.25µV
Unlikely	0.25µV to <1.50µV received signal
Likely	1.50µV to <3.00µV received signal
Definite	3.00µV or greater received signal

Figure 32: Definition of communications likeliness.

VH-MDX Position	VH-MDX Altitude	Communications Possibility
5NM West Craven Waypoint	Tree Level	Definite
The Pinnacle	Tree Level	Definite
Upper Gloucester River Valley	3000’ AMSL 3500’ AMSL	Unlikely Definite
Upper Chichester River Valley	3500’ AMSL 4000’ AMSL 4500’ AMSL	Not Possible Unlikely Definitely
Upper Kerripit River Valley	3000’ AMSL 3500’ AMSL	Unlikely Definitely
Upper Williams River Valley	4000’ AMSL 4500’ AMSL 5000’ AMSL	Unlikely Likely Definitely
Upper Allyn River Valley	4000’ AMSL 4500’ AMSL 5000’ AMSL	Not Possible Unlikely Likely
Polblue Camping Area	8000’ AMSL	Definitely

Figure 33: Communications likeliness of VH-MDX at certain spot locations.

The findings above can be used in different ways depending on assumptions made in a particular theory. For example, if it assumed that the pilot of VH-MDX *was* expected to make further radio calls below 5000’ then one could suggest eliminating the Upper Allyn and Upper Williams Valleys as likely impact areas.

If further communications after the 5000’ call was *not* expected, then the results can be used to confirm areas of *likeliness* for the 5000’ call (All areas ‘definite’ except Upper Allyn where it was ‘likely’).

Limited extrapolation of position from those above can be used to provide a rough indicator of communications likeliness at lower altitudes. This can then be followed up with further propagation analysis in specific locations.

The findings above offer only an initial very limited insight into communications possibilities at specific geographic locations. Additional radio propagation analysis will be carried out.

Free-space weather attenuation adjustments could be made in the analysis to reflect propagation paths through likely weather. This may yield added insight into the general position of VH-MDX.

10. Conclusion

An overview of VHF communications regarding the VH-MDX event was carried out. A number of suggestions were made based on VHF communications propagation and comparison of received signal strength.

References

[1] Aviation Theory Centre, 1990, *Introduction to Flight Radio and Air Legisla*tion, *Guide for the Student Pilot,* Williamstown.

[2] Powell. J, 1981, *Aircraft Radio Systems*, Aircraft Technical Book Company, LLC.

[3] American Radio Relay League, 1984, *The ARRL 1985 Handbook for the Radio Amateur*, American Radio Relay League, Newington.

[4] Miller. G.M, 1996, *Modern Electronic Communication*, Fifth Edition, Prentice-Hall Inc, Englewood Cliffs.

[5] National Archives Australia (NAA): Bureau of Air Safety Investigation (BASI); C1789, SI/812/1036, 1981 onwards, Aircraft Accident, VH-MDX C-210, 75km North of Singleton 9th August 1981.

[6] Airservices Australia, 2014, Aeronautical Information Publication Australia, Canberra.

[7] Airservices Australia, 2005, Enroute Supplement Australia, Canberra.

[8] Airservices Australia, e-mail correspondence with Compton Allen (WICEN), 4th June 2014.

[9] Airservices Australia, 2001, Enroute Chart Low 3 (ERC-L3), Canberra.

[10] Radio Technical Officer B, Personal Communications, e-mail, May 2014.

[11] Europa Technologies 2014, Google Earth 2014, Sinclair, Knight, Merz, 2014, Google Earth.

[12] OzRunways 2014, OzRunways Version 4, Castle Hill.

[13] Chessor. D, 1990, Research into Probable Crash Sites in Barrington Tops of Cessna 210 VH-MDX, Sunday 19:40 HRS, 9th August 1981, Draft, 25th September 1990.

[14] Coude. R, 2014, Radio Mobile On-line, Radio Propagation Software for the Radio Amateur, (http://www.cplus.org/rmw/english1.html).

[15] Federal Aviation Agency, 1962, *Technical Standard Order, VHF Radio Communications Transmitting Equipment Operating within the Radio Frequency Range of 118-136 Megacycles*, TSO-C37b, 22 October 1962.

[16] Cessna Aircraft Company, 1975, Service/Parts Manual 300 NAV/COM Type RT-328T, 1 August 1975, Wichita, Kansas.

[17] Australian Government, 2014, Register of Radio Communications Licences, (http://web.acma.gov.au/pls/radcom/assignment_search.lookup?pACCESS_ID=1252751&pDEVICE_ID=1252269), Device ID 1252269, Australian Communications and Media Authority.

[18] Nolan. M, c.2013, *Operation Wittenoom VH-MDX Research*.

[19] Australian Government, 1972, Radionavigation Chart AUS-RNC 3, 6 January 1972, Department of Civil Aviation Australia.

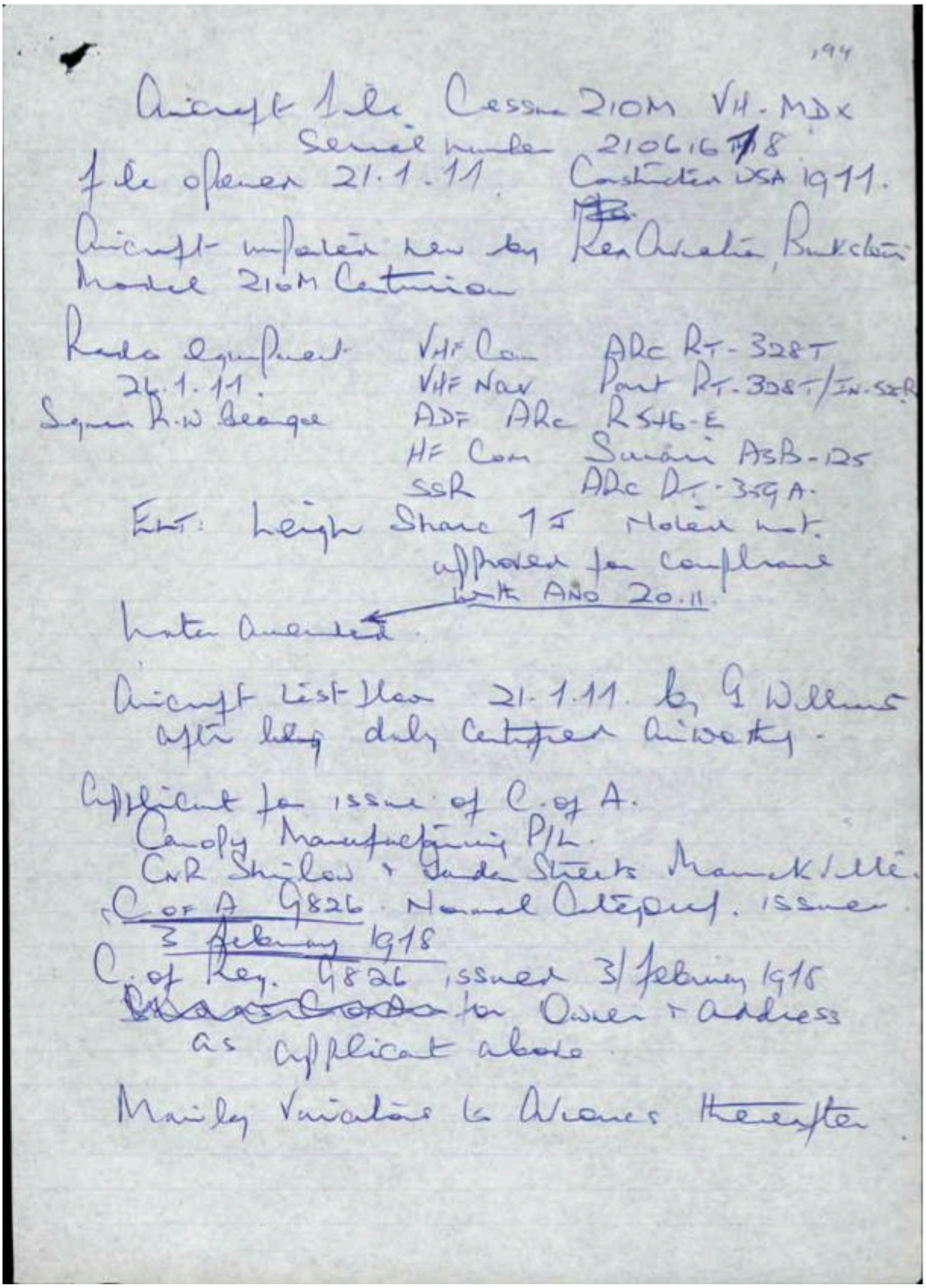
[20] National Archives Australia (NAA), 1981 onwards, Bureau of Air Safety Investigation (BASI), Series no: B638, Control Symbol: 116/812/1036, Barcode: 31885425, *Photocopy of Central Office version of air accident file titled: Registration number VH/MDX Cessna 210, 75 kilometres north of Singleton [Barrington Tops, NSW], 9 August 1981.*

[21] National Archives Australia (NAA), 1969-1976, Department of Civil Aviation, Series no: C273/201, Control Symbol: 69/260, Barcode: 13784004, *Airways Operations: Aeronautical Information Service Flight Information Zone Boundaries.*

[22] Australian Government, 1981*, various VH-MDX Air Traffic Services transcripts, Sydney ATS.*

[23] Strkalj.G, 2015, VH-MDX Meteorological Conditions, Background Data, Information and Investigative Findings Volunteered in the Search of Aircraft VH-MDX, 2nd Edition, October 2015.

ANNEX A: ASIB VH-MDX avionics equipment list



194

Aircraft file Cessna 210M VH-MDX
Serial number 21061678
File opened 21.1.77. Construction USA 1977.
Aircraft imported new by Ren Aviation, Bankstown
Model 210M Centurion

Radio equipment 21.1.77. Signed R.W. Beague

VHF Com	ARC	RT-328T
VHF Nav	ARC	RT-328T/IN-5xR
ADF	ARC	R546-E
HF Com	Sunair	ASB-125
SSR	ARC	RT-359A

ELT: Leigh Share 1J Noted not approved for compliance with ANO 20.11.
Later amended

Aircraft List [illegible] 21.1.77. by G Williams after being duly certified airworthy.

Applicant for issue of C of A.
Canopy Manufacturing P/L.
Cnr Shirlow & [illegible] Streets Marrickville.
C of A G826. Normal Category. issued 3 February 1978
C of Reg. G826 issued 3 February 1978 ~~[illegible]~~ for Owner & address as applicant above.

Mainly variations to Avionics thereafter.

(Image: Australian Government (Air Safety Investigation Branch) 1981).

ANNEX B: ACMA site details Mt Berrico

Australian Communications and Media Authority: Register of Radiocommunication Licences

acma.gov.au

Register of Radiocommunications Licences

Site Details

Site ID	7452
Name	Airservices Site Mt Berrico near GLOUCESTER
Location	NSW 2422
AMG Zone	56
AMG Easting	383512
AMG Northing	6446895
Precision	Within 10 metres
Latitude (AGD66)	-32 06 29
Longitude (AGD66)	151 45 55 [KML]
Licence Fee Density	Low Density Areas

[Nearby Sites Map] [Nearby Sites List] [Site Location Map] [Google Maps] [New Site Search]

Assignments at this Site

Results **1 - 4** of **4** assignments.

ID	Frequency	Emission Designator	Client	Licence No
1252751-1252269	120.55 MHz	6K00A3E	Airservices Australia (391222)	1252186
133325-126065	123.4 MHz	6K00A3E	Airservices Australia (391222)	420154
133519-126711	130.1 MHz	6K00A3E	Airservices Australia (391222)	420345
133625-126066	132.35 MHz	6K00A3E	Airservices Australia (391222)	420484

http://web.acma.gov.au/pls/radcom/site_search.site_lookup?pSITE_ID=7452 [4/06/2014 10:51:06]

(Image: Australian Government (Australian Communications and Media Authority) 2014).

ANNEX C: ACMA Assignment details: 120.55MHz (Current frequency servicing existing 121.6MHz area)

Register of Radiocommunications Licences

Assignment Details

General Details

Licence Number	1252186	Access ID	1252751
Client	Airservices Australia		
Site	Airservices Site Mt Berrico near GLOUCESTER		
Operating Mode	Transmit/Receive		
Access Status		Date Approved	24-MAY-99
Coverage	Local	Hours of Operation	

[New Search]

Frequencies

Assigned	120.55 MHz	Lower	120.5375 MHz
Carrier		Upper	120.5625 MHz

Device and Antenna details

Device ID	1252269	Emission Designator	6K00A3E
EIRP	50	Transmitter Power	83.00 pY
Antenna ID	60216		
Antenna Height (AGL)	35 m	Antenna Polarity	Vertical
Antenna Azimuth	ND	Antenna Tilt	0 °

acma.gov.au

Register of Radiocommunications Licences

Antenna Details

Antenna ID	60216
Gain	2.200 dB
Beamwidth	.000 degrees
Front-to-back	0 dB
Band	VHF/UHF
Size	
Type	Dipole
Type-code	D
Manufacturer	SCALAR
Model	B42

[New Search]

(Images: Australian Government (Australian Communications and Media Authority) 2014).

ANNEX D: ASIB communications spectrographic report

CONTINUATION SHEET | Section No. | Title | File M116/812/1036 | Page 2

SUBJECT

3.5 The Spectrographs for the first period show very little background noise with no significant signals (Figures 1, 2 & 3).

The Spectrographs for the second period (Figure 4 and 5) have a band of "noise" between the frequencies 600 to 1000 Hz. This may be indicative of increased aerodynamic noise within the aircraft. However the overall signal strength of this transmission was greater than the first which may have brought up the background noise to a discernible level.

3.6 There were no signals recorded during these two transmissions, nor during any of the other transmissions examined, which indicated any cockpit audio warnings or significant background sounds.

3.7 The aircraft reported at 7500 feet at 0937:40, 6500 feet at 0938:33 and 5000 feet at 0939:26. Assuming constant rates of descent between these reports the average rates of descent were approximately

(i) 1130 feet per minute from 7500 to 6500 ft

(ii) 1700 feet per minute from 6500 to 5000 ft.

4. CONCLUSIONS

4.1 The AVR tape concerning transmissions between Cessna VH-MDX and Sydney Flight Service position five was examined.

4.2 There were no recordings containing audio warnings or significant sounds emanating from the aircraft.

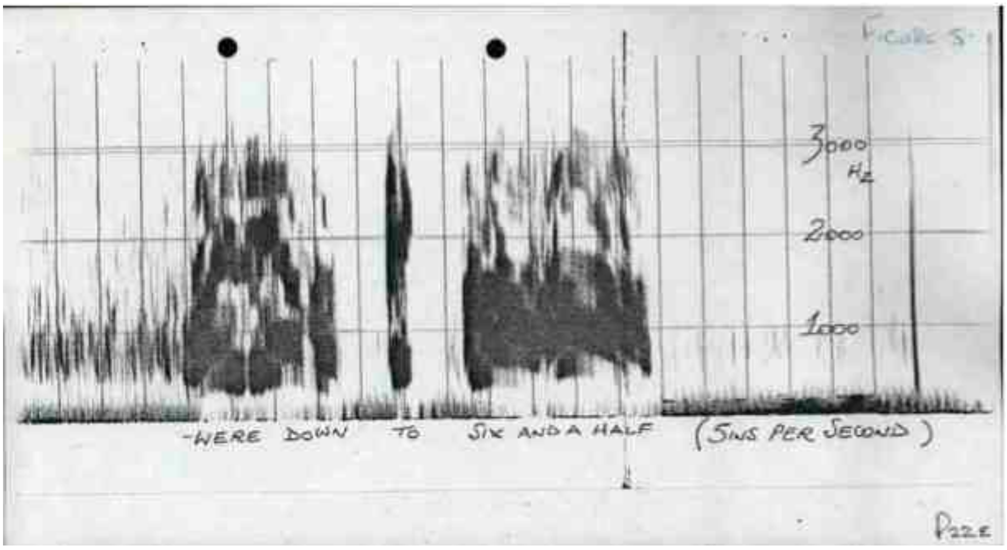
SIRS

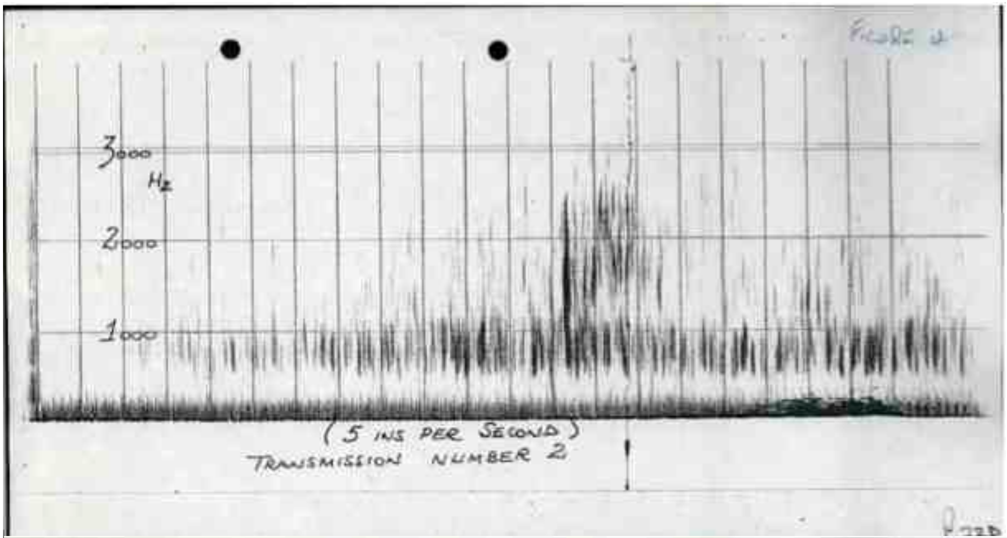
14 September 1981

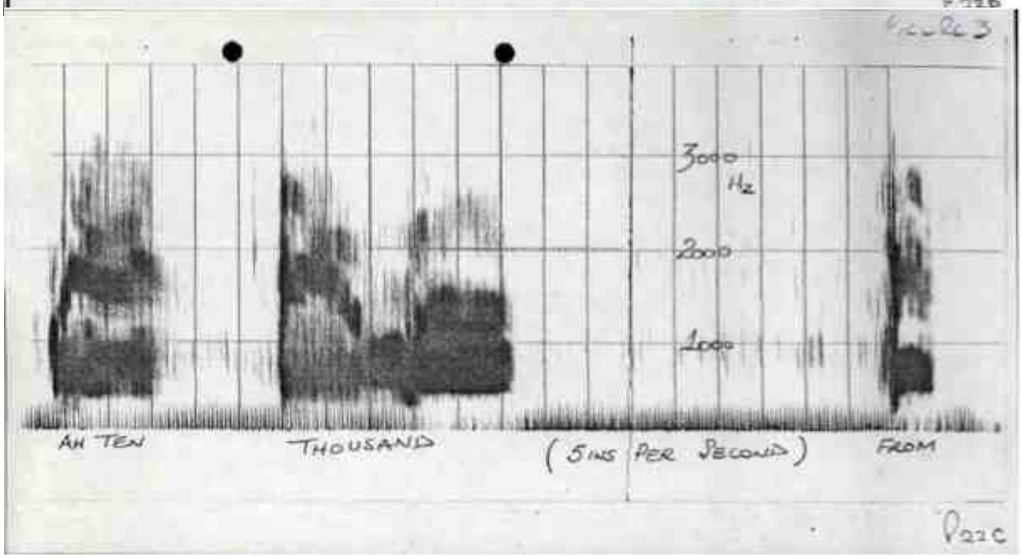
16

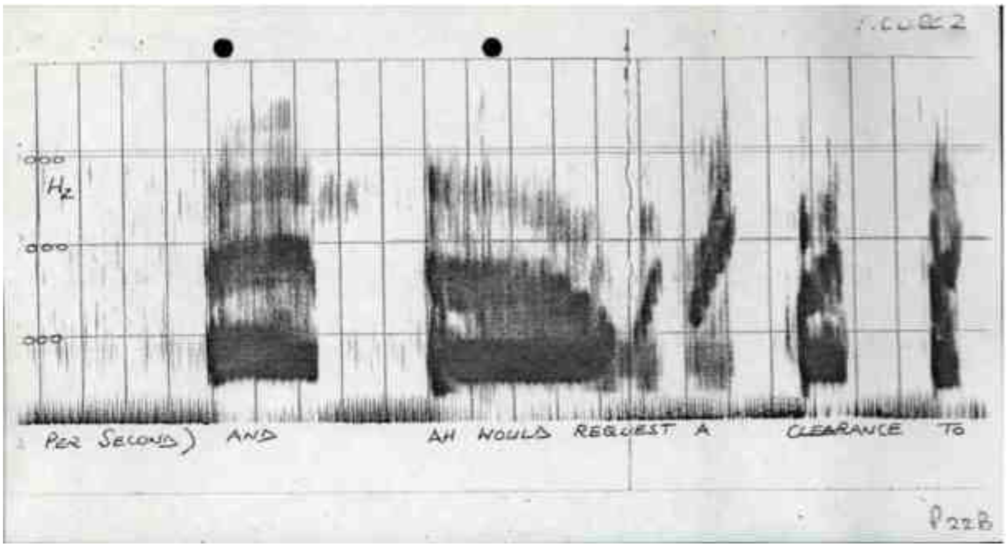
(Image: Australian Government (Air Safety Investigation Branch) 1981).

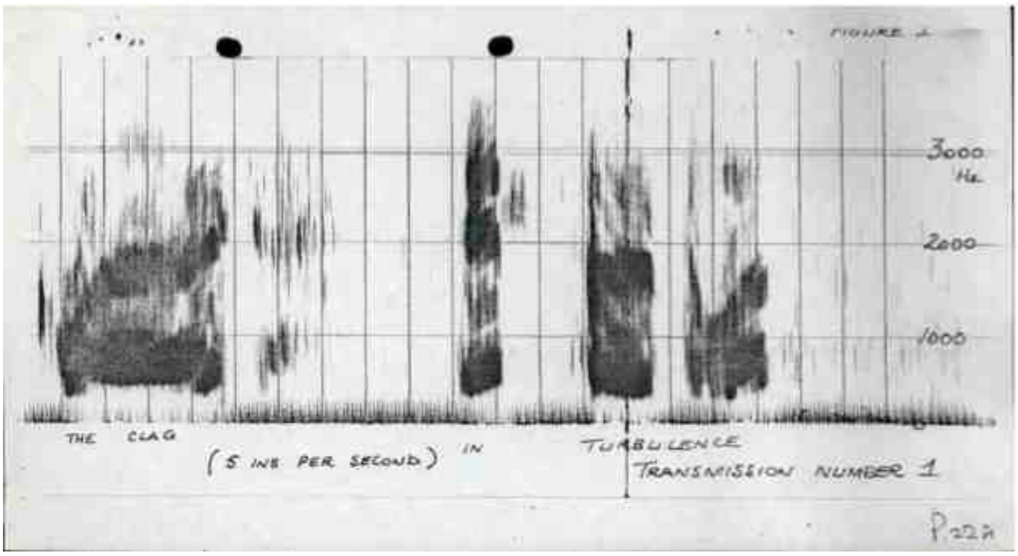
ANNEX E: ASIB communications spectrographs











(Images: Australian Government (Air Safety Investigation Branch) 1981).