255 km Aircraft Scatter QSO on 24 GHz

First crossing of Bass Strait on 24 GHz

By Rex Moncur VK7MO and David Smith VK3HZ

On 13 March 2012, VK3HZ at Mt Liptrap near Wilson's Promontory in Victoria worked VK7MO, assisted by Joe VK7JG, near Georgetown in Tasmania using JT65c via Aircraft Scatter over a 255 km non-line-of-sight path on 24 GHz. There was no evidence of signals when we beamed direct. The idea behind this work was that by using Aircraft Scatter, the majority of the path is at high altitude were the levels of water vapour are lower and thus absorption is decreased. We have calculated the absorption loss for this path at the surface at 65 dB compared to 9 dB for the Aircraft Scatter path.

Radio Path (Green) and Aircraft Path (Pink)

QSO

The following is an abbreviated version of VK3HZ's WSJT ALL.TXT file showing only those files where there is an indication of an aircraft. It is seen that of six aircraft three gave decodes with the best giving -21 dB.

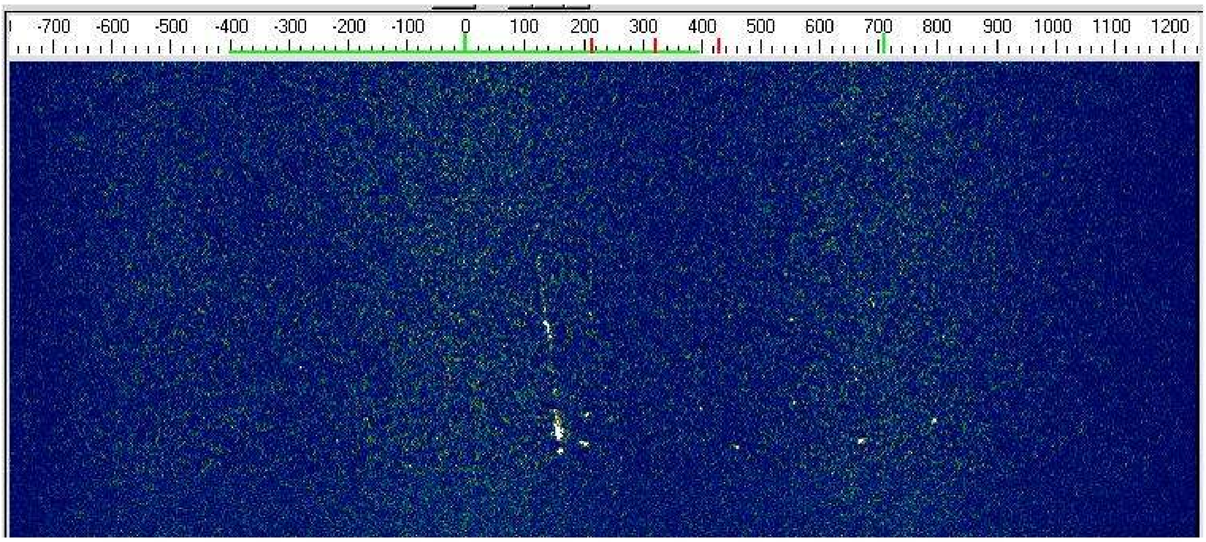
```
221700  Transmitting: JT65C   VK7MO VK3HZ QF21

233200  0  -30 -0.1  129  7 *
233400  0  -29  9.4    0  3 #

005800  2  -21 -0.3  167  7 *      VK3HZ VK7MO QE38          0  10

005905  Transmitting: JT65C   VK7MO VK3HZ -21

010000  0  -28  3.0   16  6 *
010200  0  -32  5.8 -159  5 #

025400  0  -32 -0.0  226 33 *
025600  0  -30 -0.2   94  5 *
025800  2  -27 -0.2   -3 10 *      VK3HZ VK7MO R-28          0  10
```

```
025904  Transmitting: JT65C   RRR                           (Shorthand)
031400  0  -33  1.1 -167 41
031600  0  -32 -0.1  -13 16 *
040400  0  -33  0.1  194 18
040600  0  -28 -0.2 -108  6 *      VK3HZ VK7MO R-28          0  10
```

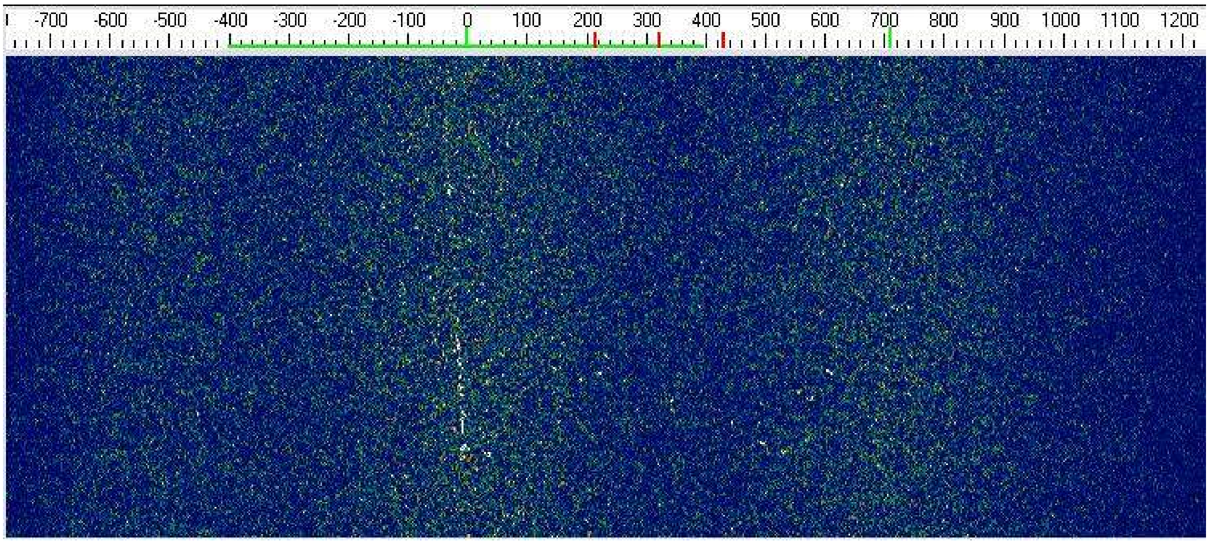
The following is abbreviated from VK7MO's WSJT ALL.TXT file. While there were indications of other aircraft, only one gave a decode and the two tone RRR was received twice visually on the waterfall . The difference in decoding possibly relates to a difference in power (1.5 watts TX from VK3HZ and 4 watts from VK7MO)

```
005900  0  -33 -0.4   73 12
010100  0  -28 -0.2  -30  4 *      VK7MO VK3HZ -21       ?   0   3
010206  Transmitting: JT65C   VK3HZ VK7MO R-28
010300  0  -33  4.0 -105 26
```

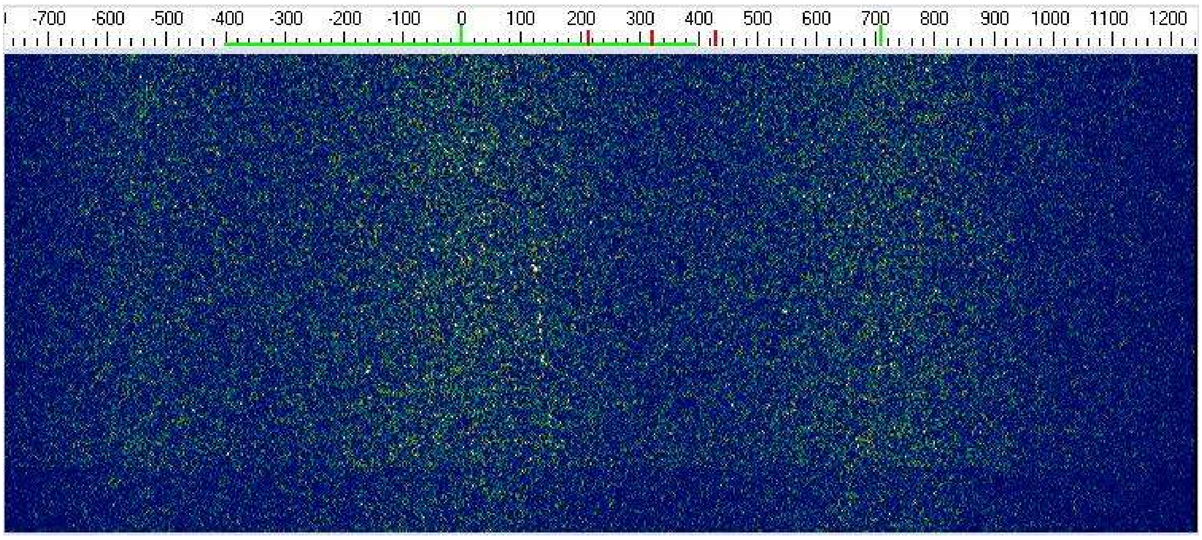
The following are examples of signals that gave decodes and one that did not decode



Decoded as: `005800  2  -21 -0.3  167  7 *     VK3HZ VK7MO QE38     0  10`



Decoded as: `025800  2  -27 -0.2   -3 10 *      VK3HZ VK7MO R-28      0  10`



Did not decode

From the above examples, it is seen that there tends to be a weak background signal that lasts for several seconds or longer and stronger glints for short periods. This is similar to Aircraft Scatter on 10 GHz but the glints are shorter in duration on 24 GHz. One interesting point is that VK3HZ decoded at 0058 while VK7MO did not decode this same aircraft until 0101, some three minutes later and neither station decoded it at 0059 and 0100. Thus it seems that two separate reflecting surfaces at slightly different angles could have been responsible for the signals. As the aircraft may have been at the margins of out beamwidth over this longer period, this suggests there may be advantage in attempting to track the aircraft in Azimuth during each aircraft pass.

Another point to note is that there is very little frequency spreading on the 24 GHz signal which means one can take advantage of narrow bandwidth modes such as JT65c.

Equipment Used

All systems are GPS locked and use the digital mode JT65c

24 GHz

VK3HZ: Thales module and 38 cm dish (37 dBi) – estimated 1.5 watt TX and 1.5 dB sun noise on RX

VK7MO: DB6NT transverter, pre-amp and 3 watt PA to 47 cm (39 dBi) offset dish – estimated output 3 watts to feed and 3.8 dB sun noise on RX

10 GHz

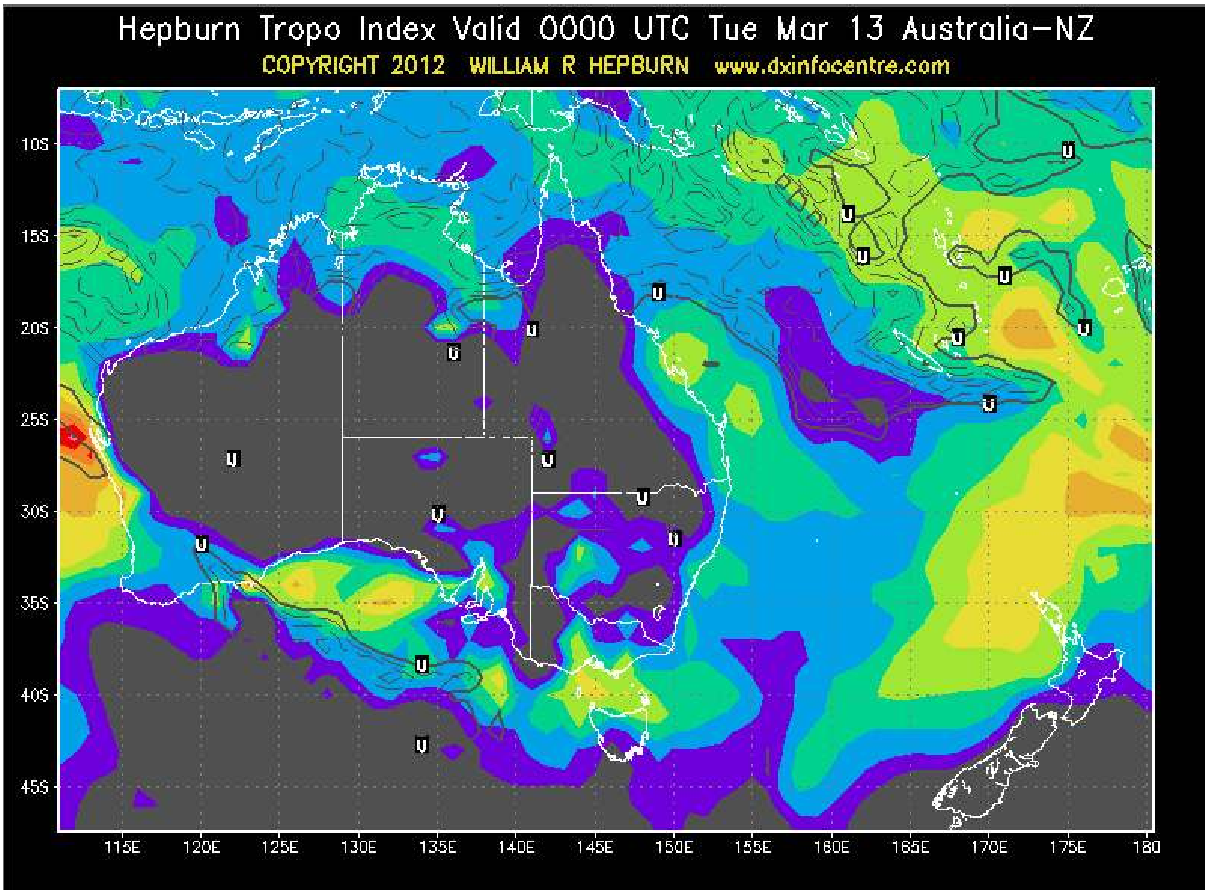
VK3HZ: Qualcomm transverter, DEMI PA with 7 watts to the feed 60 cm (34 dBi) dish DB6NT pre-amp.

VK7MO: DB6NT transverter, pre-amp and 10 watt PA to 64 cm (34 dBi) offset dish – 7 watts to feed and 3 dB sun noise

A key issue is alignment of the antennas on the aircraft as the 24 GHz antennas have a 3 dB beamwidth of only around +/- 1 degrees in Azimuth and Elevation – such that an error at either end in Azimuth or Elevation of 1 degree puts one 3 dB down. The technique used, which has been developed on 10 GHz, is to beam directly at the other station with dish slightly raised and wait for the aircraft to cross the path. Azimuth angles are set against a known reference that is determined either by GPS or from Google Earth. The elevation angle is determined on the basis of the aircraft height, which is established from the ADS-B data transmitted by the aircraft on 1090 MHz. The Elevation angle is determined taking account of the 4/3rds Earth Curvature rule for radio propagation and the height and distance of the aircraft using the spread sheet at http://www.vk3hz.net/ .

A second important issue is that the aircraft must cross the path at a small angle so that the Doppler shift can be coped with by WSJT's AFC system. We have found that 15 degrees is the maximum for 10 GHz, which equates to around 5 degrees on 24 GHz. Thus it is necessary to select a path that is aligned with the aircraft route to within 5 degrees.

Non-Aircraft Scatter Tests



The Hepburn Chart above indicates the possibility of ducting on the day in question. Accordingly, tests were also conducted with both stations beaming direct at the horizon. Nothing at all was seen on 24 GHz, while 10 GHz gave strong signals at the same time at around 40 dB above the detectable limit on the water fall. The mode of propagation was not obvious as signal levels on 10 GHz were too strong for tropo-scatter and too weak to be a good duct. The 10 GHz signals showed spreading of around 30 Hz which is typical of tropo-scatter - perhaps a combination of a duct and tropo-scatter. The lack of signals on 24 GHz is likely to be explained by the additional losses due to high absorption on a low level path as discussed below.

Absorption Loss

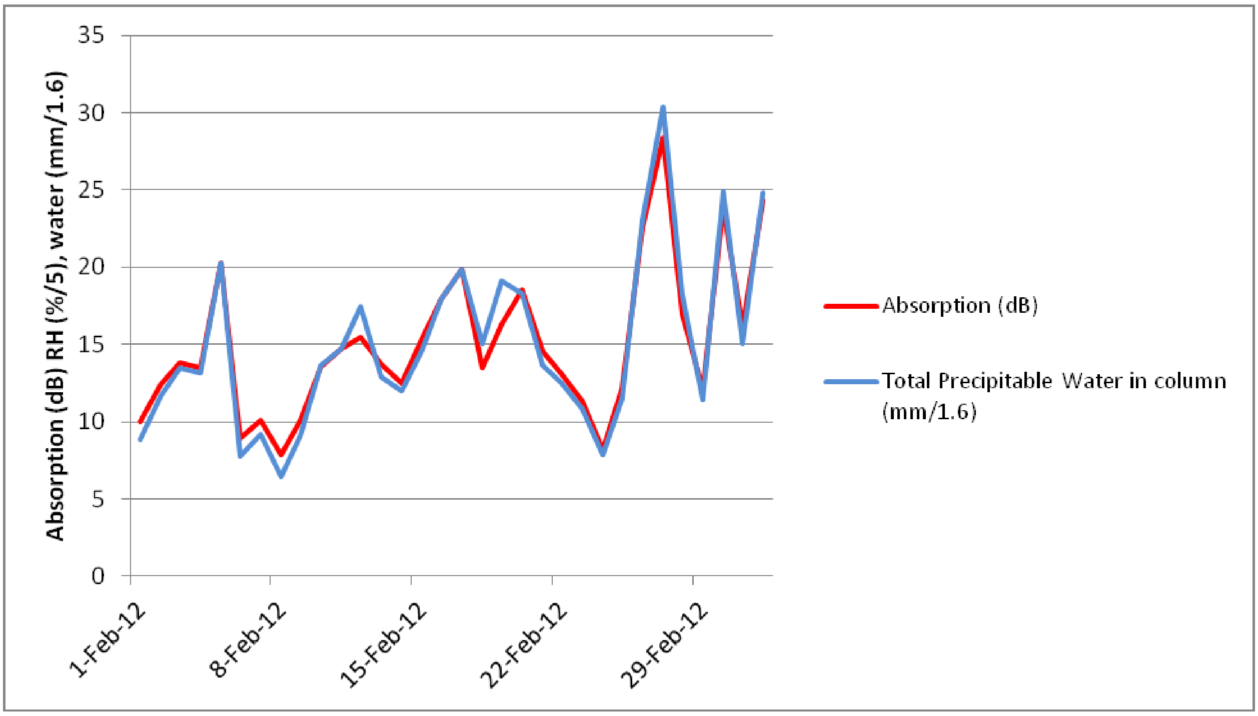
Assuming the direct signals were propagated near the surface, the absorption loss can be calculated from Humidity (60%), Temperature (21.8 degC) and Pressure (1005 hPa) data using the first row of the Melbourne radiosonde data (Appendix A) and VK7MO's Absorption Loss calculator available at http://www.vk3hz.net/ . The losses come out at 65 dB for 24 GHz and 5 dB for 10 GHz giving a 60 dB difference and thus a key factor in the lack of direct signals at 24 GHz.

For the Aircraft Scatter path, the losses can be calculated using the Melbourne radiosonde data at Appendix A (available at http://weather.uwyo.edu/upperair/sounding.html) and VK7MO's Absorption Loss Calculator for an Aircraft Enhancement path at http://www.vk3hz.net/. The calculator gives a loss of 9.5 dB for an aircraft at 10,000 metres at 24 GHz and 1.2 dB at 10 GHz.

Thus in terms of absorption loss the 24 GHz Aircraft Scatter path has the advantage of being only 8 dB worse than 10 GHz compared to 60 dB worse for propagation at the surface.

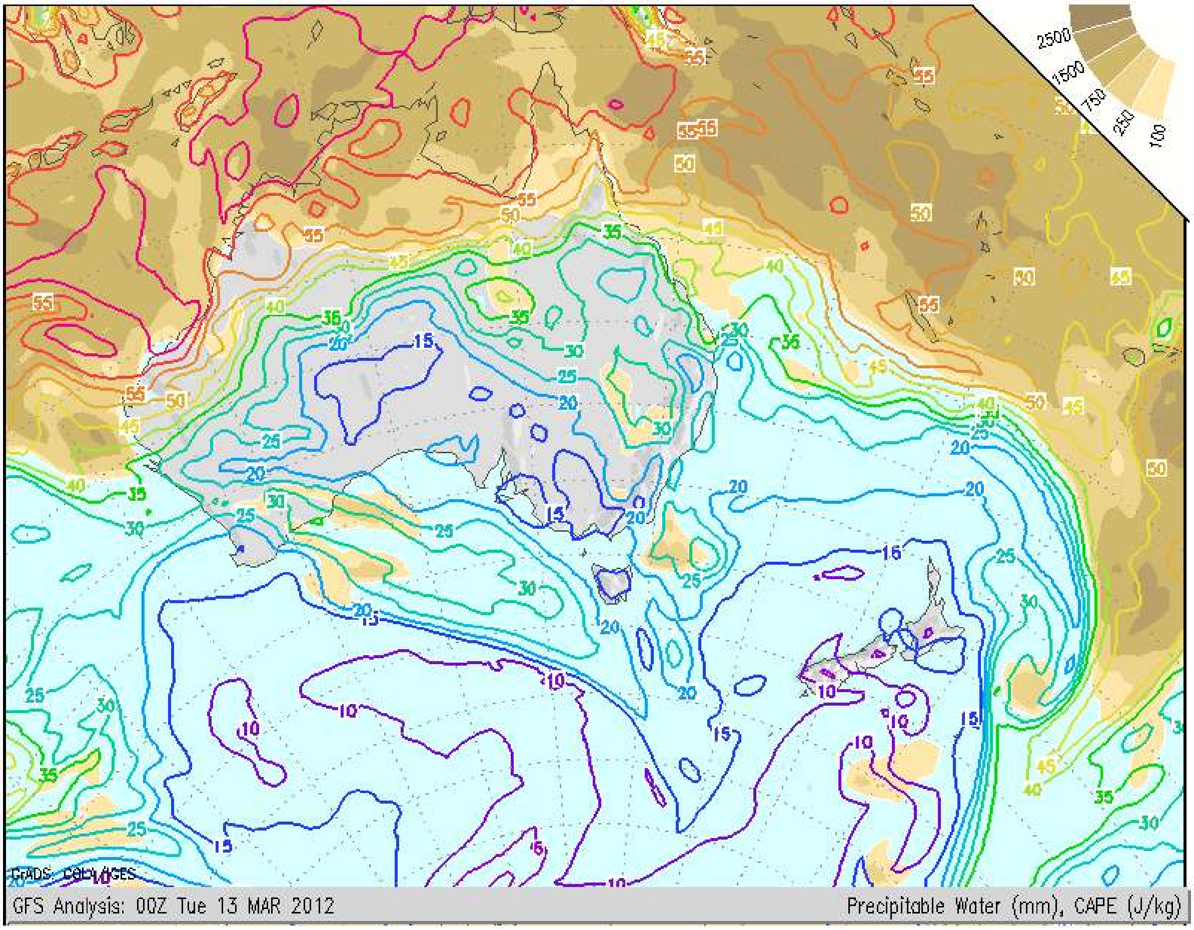
Forecasting Absorption Loss

The radiosonde data at Appendix A includes summary information at the end with the last item being the amount of precipitable water in the entire sounding. We have compared the absorption loss over a one month period with the amount of precipitable water and found a very good correlation as below:



The above comparison was made for a 221 km path and one would expect that the losses would be proportionally larger for a longer path so the scaling factor for the 255 km path in this case would be around 1.4, giving an absorption loss of around 10 dB which is very close to that calculated by the layer by layer method of 9.5 dB.

The advantage of using precipitable water is that there is, for the Australian region, a model that forecasts precipitable water up to 6 days ahead (available at http://australiasevereweather.com/links/ozcharts.htm). The following is an example of the precipitable water chart for the time. These forecasts of precipitable water are thus a very useful tool for planning 24 GHz Aircraft Scatter at a time when the absorption losses are low.



The precipitable water chart gives a figure of 15 mm at both ends of the path, which is close to the 14.02 measured with the Melbourne radiosonde.

The graphs at Appendix B show the number of days in each month that the amount of precipitable water (proportional to absorption loss) is below a given value. This information was derived from radio-sonde data for each month over the year 2011. The graphs have been separated between the first and second six months of the year so that the trends are visible. It is seen that the summer months of Jan and February are worst and that the winter months are the best times for low amounts of precipitable water. Nevertheless, there are examples, even in the summer, were the losses are moderate.

Future Possibilities

The aircraft in this case were small domestic aircraft such as 737s and experience on 10 GHz indicates that larger International aircraft such as the A380 can produce signals around 10 dB greater.

At this early stage we cannot be sure that both stations were accurately aligned on the aircraft and thus there is the possibility of improvements. It may also be that careful tracking of the aircraft in Azimuth will increase the number of useful bursts of signal.

At least in one case the signal level reached -21 dB giving some 7 dB to spare.

The precipitable water level for this test was around 14 mm whereas on the best days in winter this can be as low as 7 mm. It is possible to further reduce the absorption by locating both stations on high mountains.

The basic Aircraft Scatter equation results in an increase in propagation loss of 12 dB for each doubling of the distance (i.e. inverse square law) or 6 dB both to and from the aircraft.

If the absorption losses can be reduced to the same level by choosing a time of low absorption and a large aircraft such as an A380, there is the prospect of doubling the distance to around 500 km for Aircraft Scatter on 24 GHz.

Conclusions

- This first test has demonstrated the viability of Aircraft Scatter at 24 GHz over a 255 km path.
- There is the prospect of increasing the distance to around 500 km through the use of large international aircraft at a time of low absorption.
- Forecasts of precipitable water are a useful tool for planning 24 GHz Aircraft Scatter tests

APPENDIX A

94866 YMML Melbourne Airport Observations at 00Z 13 Mar 2012

PRES hPa	HGHT m	TEMP C	DWPT C	RELH %	MIXR g/kg	DRCT deg	SKNT knot	THTA K	THTE K	THTV K
1005.0	119	21.8	13.8	60	9.96	5	15	294.5	323.4	296.3
1000.0	154	20.4	12.4	60	9.12	0	16	293.6	319.9	295.2
979.0	337	18.9	11.8	64	8.97	345	17	293.8	319.8	295.4
978.0	346	18.8	11.8	64	8.96	345	17	293.8	319.8	295.4
968.0	434	19.4	9.4	52	7.70	345	17	295.3	317.8	296.6
927.0	805	16.7	5.8	48	6.27	345	17	296.2	314.8	297.4
925.0	823	16.6	5.6	48	6.20	340	17	296.3	314.7	297.4
889.0	1160	14.2	0.2	38	4.39	318	11	297.2	310.5	298.0
885.0	1198	14.2	-1.4	34	3.92	315	10	297.5	309.5	298.2
859.0	1449	14.0	-12.0	15	1.78	319	10	299.9	305.6	300.2
850.0	1538	13.4	-10.6	18	2.02	320	10	300.2	306.6	300.5
821.0	1828	12.4	-13.2	15	1.69	325	11	302.1	307.6	302.4
782.0	2235	10.9	-16.8	13	1.32	295	15	304.8	309.2	305.0
778.0	2278	10.8	-17.2	12	1.28	295	15	305.1	309.4	305.3
754.0	2538	9.0	-11.0	23	2.20	297	15	305.9	313.0	306.3
700.0	3147	4.4	-15.6	22	1.63	300	16	307.3	312.8	307.6
686.0	3311	3.2	-15.8	23	1.64	300	16	307.8	313.2	308.1
675.0	3442	2.7	-17.9	20	1.39	300	16	308.6	313.3	308.9
640.0	3871	1.0	-25.0	12	0.79	290	17	311.4	314.2	311.6
621.0	4109	-0.9	-26.3	13	0.72	285	17	311.9	314.5	312.1
598.0	4407	-3.3	-27.9	13	0.65	300	17	312.5	314.9	312.7
551.0	5053	-8.5	-31.5	14	0.50	293	18	313.8	315.6	313.9
505.0	5724	-12.6	-43.7	6	0.16	285	20	316.7	317.3	316.7
500.0	5800	-13.1	-45.1	5	0.14	285	20	317.0	317.6	317.0
488.0	5985	-13.5	-51.5	2	0.07	271	16	318.7	319.0	318.7
487.0	6000	-13.6	-51.5	2	0.07	270	16	318.8	319.1	318.8
445.0	6680	-16.7	-49.7	4	0.09	287	18	323.2	323.6	323.2
438.0	6798	-17.6	-50.2	4	0.09	290	18	323.5	323.9	323.5
428.0	6969	-19.0	-50.9	4	0.08	280	17	323.9	324.3	323.9
420.0	7109	-20.1	-51.4	4	0.08	265	19	324.3	324.6	324.3
400.0	7470	-22.9	-52.9	5	0.07	275	23	325.1	325.4	325.1
385.0	7749	-25.1	-54.1	5	0.06	277	26	325.8	326.1	325.8
370.0	8033	-27.5	-50.5	9	0.10	280	30	326.4	326.8	326.4
350.0	8429	-30.8	-45.5	22	0.19	285	26	327.1	327.9	327.1
328.0	8892	-34.7	-39.7	60	0.37	265	29	327.9	329.3	328.0
300.0	9510	-39.5	-47.5	42	0.18	270	28	329.6	330.3	329.6
278.0	10025	-44.4	-51.5	45	0.12	280	29	329.8	330.3	329.8
274.0	10123	-45.3	-52.3	45	0.11	280	29	329.8	330.3	329.9
250.0	10730	-49.7	-61.7	23	0.04	280	28	332.1	332.2	332.1
228.0	11318	-54.5	-65.6	24	0.02	265	34	333.5	333.6	333.5
208.0	11905	-59.4	-69.5	26	0.02	255	31	334.8	334.9	334.8
206.0	11966	-59.9	-69.9	26	0.02	258	31	334.9	335.0	334.9

Station information and sounding indices

Station identifier: YMML
Station number: 94866
Observation time: 120313/0000
Station latitude: -37.66
Station longitude: 144.85
Station elevation: 119.0
Showalter index: 11.42
Lifted index: 4.11
LIFT computed using virtual temperature: 3.82
SWEAT index: 40.02
K index: -4.10
Cross totals index: 2.50
Vertical totals index: 26.50
Totals totals index: 29.00
Convective Available Potential Energy: 0.00
CAPE using virtual temperature: 0.00
Convective Inhibition: 0.00
CINS using virtual temperature: 0.00

Bulk Richardson Number: 0.00
Bulk Richardson Number using CAPV: 0.00
Temp [K] of the Lifted Condensation Level: 281.84
Pres [hPa] of the Lifted Condensation Level: 857.42
Mean mixed layer potential temperature: 294.52
Mean mixed layer mixing ratio: 8.35
1000 hPa to 500 hPa thickness: 5646.00
Precipitable water [mm] for entire sounding: 14.02

APPENDIX B

The following graphs show the number of days in which the amount of Precipitable Water (proportional to absorption loss) is below a given level in each month in 2011