A "Nearly QSO" on 24 GHz over a 421 km Path using JT65c

By Rex Moncur VK7MO and David Smith VK3HZ

Introduction

On 24 February 2012, David VK3HZ and Rex VK7MO carried out tests on 24 GHz over a 421 km path between John's Hill lookout, Victoria and Mt Barrow, Tasmania over a non-line-of-sight path as shown in Fig 1. The path of propagation is in white and the pink lines show domestic aircraft routes.

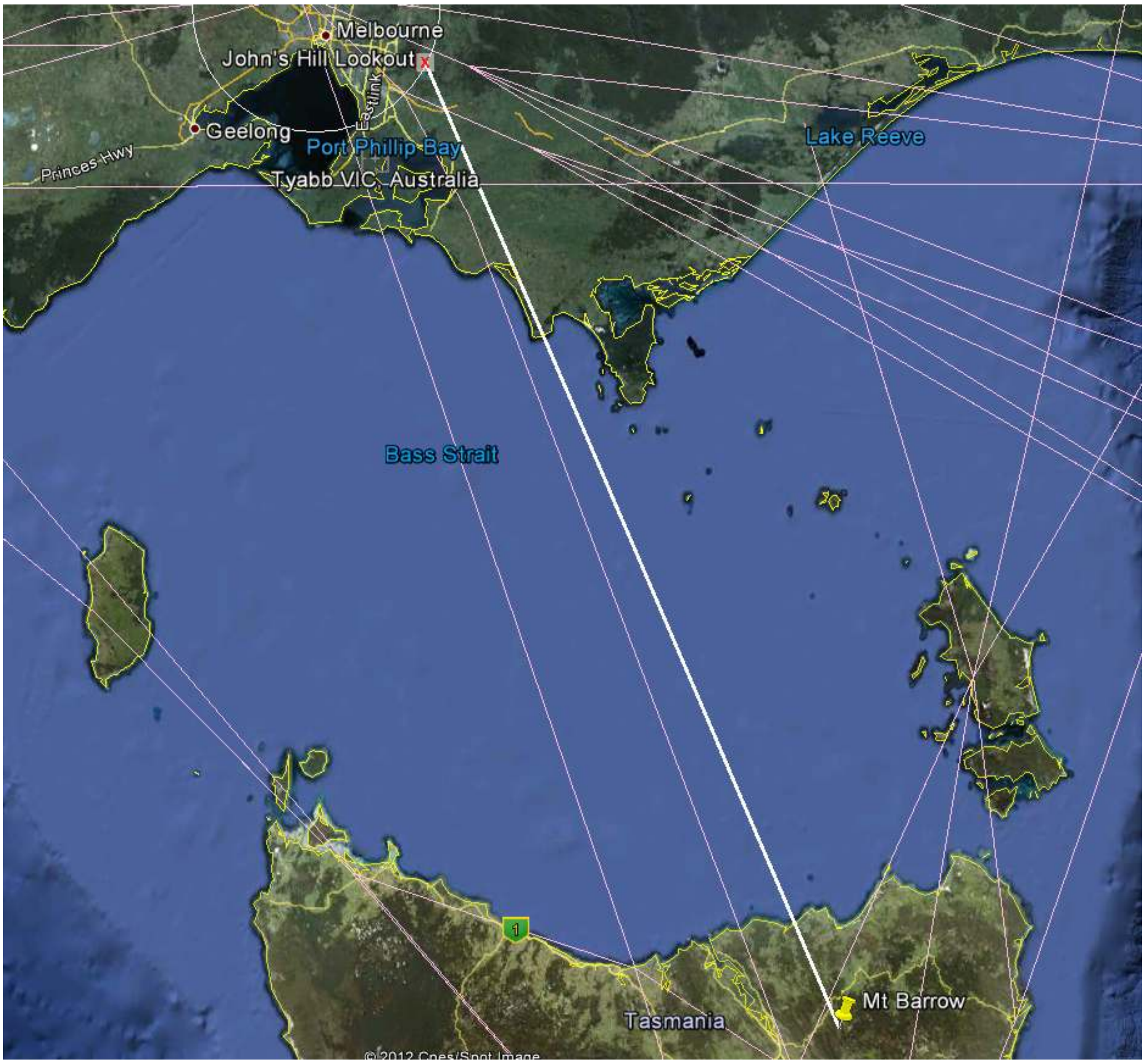

Figure 1: Locations for Tests between John's Hill lookout (VK3HZ) and Mt Barrow (VK7MO)

The tests were undertaken with JT65c and also test tones on 1270 Hz. They were undertaken at a time when the Hepburn tropo index (Fig 2) indicated that tropospheric ducting should be present.

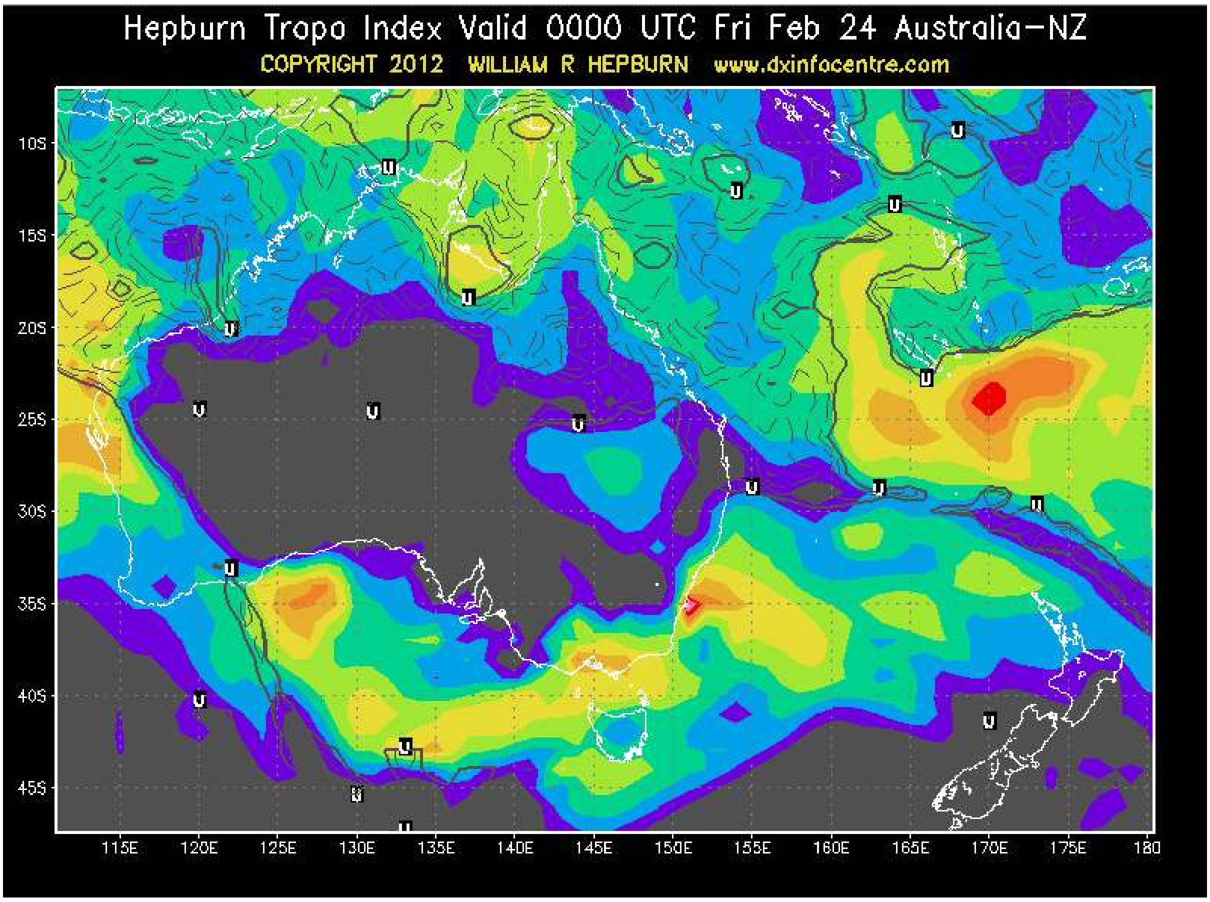

Figure 2: The Hepburn Tropo Index chart at 0000 on Friday 24 February coincides closely with the time the tests were run and shows a good yellow patch between Mt Barrow and John's Hill lookout, which suggests there should be enhanced signals.

While a QSO was not completed, three full decodes were exchanged suggesting that such a path is possible on 24 GHz. The means of propagation is not entirely certain but it is likely to be due to high level tropospheric ducting - the duct producing low propagation loss for a non-line of sight path and the high level duct ensuring low absorption losses as a result of lower densities of water vapour and oxygen. Comparisons were made with 10 GHz which gave peak signals around 45 dB greater.

Results of Tests

The 24 GHz tests started at 2257 UTC on 23 February with both stations transmitting a 1270 Hz tone representing the reference frequency of JT65c. Nothing at all was seen.

At 2349 we moved to 10 GHz where signals were very strong varying from -1 to +4 dB on the WSJT scale. At 2357 we moved back to 24 GHz and VK7MO noticed a difference in heading between the 10 GHz system and 24 GHz system of about 2 degrees. Almost as soon as this was corrected signals were detected as 1270 Hz tones and we moved to sending callsigns. There was then evidence of signals for about 11 minutes with two decodes at -27 and -26 dB at the VK7MO end and one at -26 dB at the VK3HZ end. After this period nothing at all was seen in a further almost 2 hours testing when we again checked 10 GHz and found the signal levels had dropped to around -6 dB.

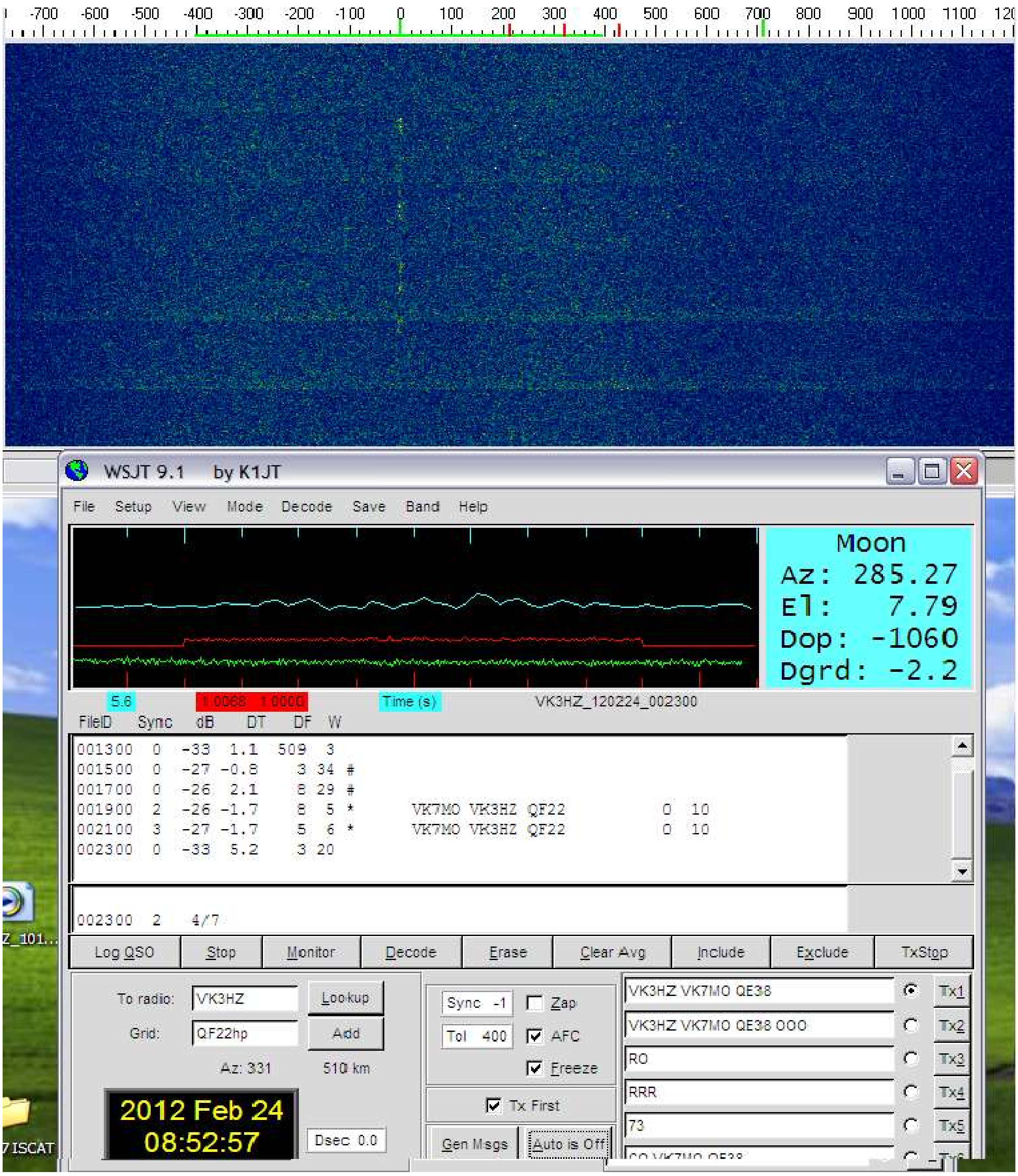

Figure 3: Results Received by VK7MO

As shown in Figure 3, VK7MO received two good decodes at -26 (0019) and -27 dB (0021) with DF plus 8 and plus 5 Hz. There is evidence of the signal at 0015 Hz with 3 Hz DF and 0017 with 8 Hz DF when David was transmitting a 1270 Hz single tone. While these signals are typical of aircraft scatter there is no evidence of significant Doppler on the DF and in fact David VK3HZ's signal always decodes at 8 Hz DF on 10 GHz on tropo so this made us think it was unlikely to be aircraft. Also as shown on Figure 1 no domestic aircraft cross the route and in any case as we were looking for tropo we were beaming too low for domestic aircraft.

At VK3HZ's end the signals decoded were as shown in figure 4.

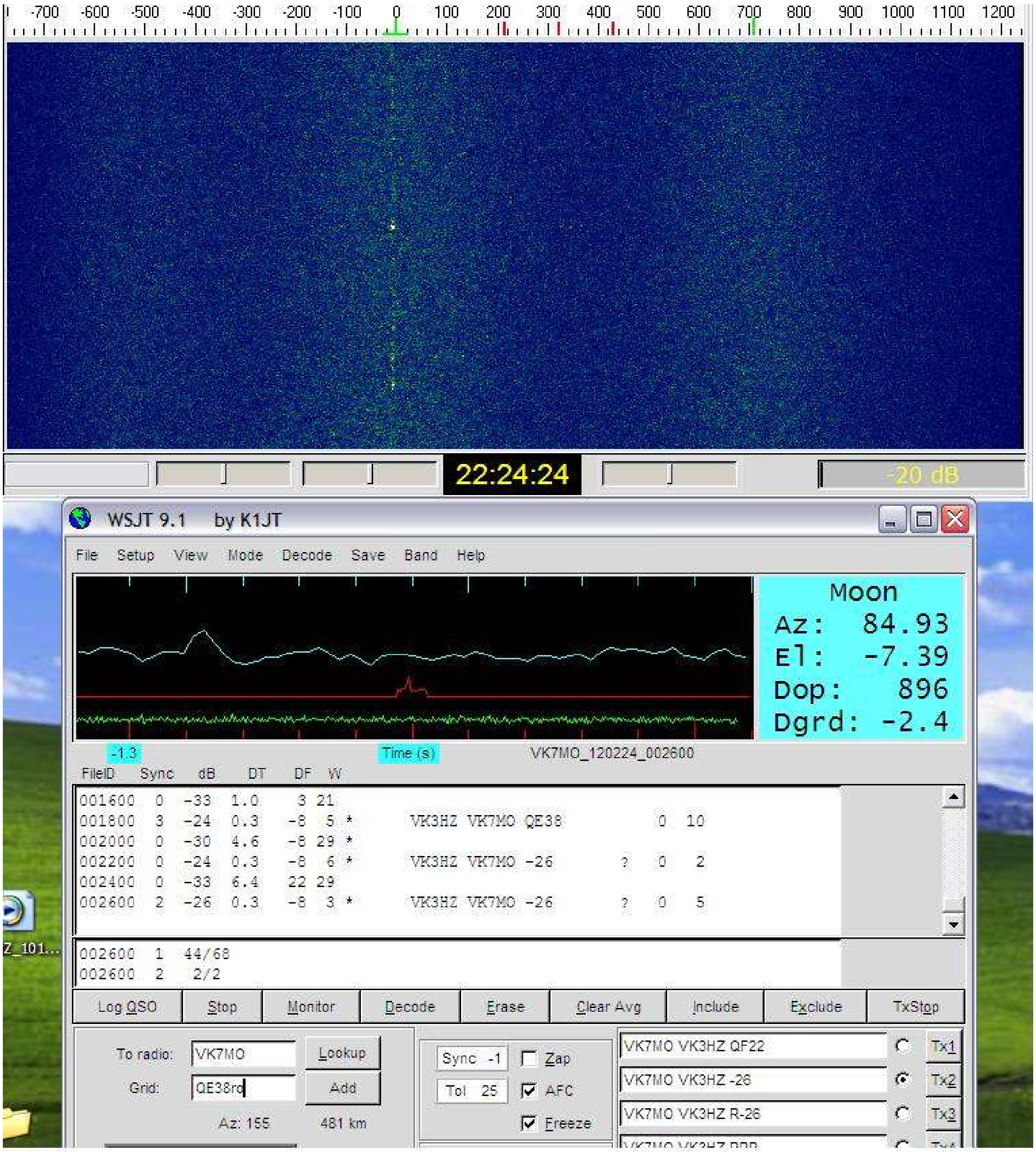

Figure 4: Shows decodes obtained from files recorded by VK3HZ

During the actual test VK3HZ decoded only the file at 0026 as he had not set the grid square in which VK7MO was operating at time 0018 and the Rate In parameter needed to be adjusted to 1.000 to decode the file at 0022. Thus potentially VK3HZ could have achieved 3 decodes.

There is evidence of the signal from 0015 as RXed by VK7MO to 0026 as RXed by VK3HZ or for a total on 11 minutes. The DF is essentially stable over this period, which tends to rule out aircraft scatter.

It is also noted that the JT65c signals are well constrained to within a few Hz with WSJT reporting widths of 3 to 6 Hz. From our tests on 10 GHz we have seen spreading on tropo-scatter of 10 to 20 Hz with ducting producing very narrow signals – thus the narrow signals on 24 GHz are consistent with ducting.

10 GHz Comparison

Tests on 10 GHz showed a consistent tropo path with signals varying between +4 dB and -6 dB on the WSJT scale. As WSJT tends to compress above -10 dB these signals are in fact much stronger and by ear were estimated at 5/9 plus. Figure 5 which derives from Spectrum Lab using the WSJT wave files shows the peak signal reached around 60 dB above the noise in 2.7 Hz bandwidth, equivalent to around +30 dB on the WSJT scale.

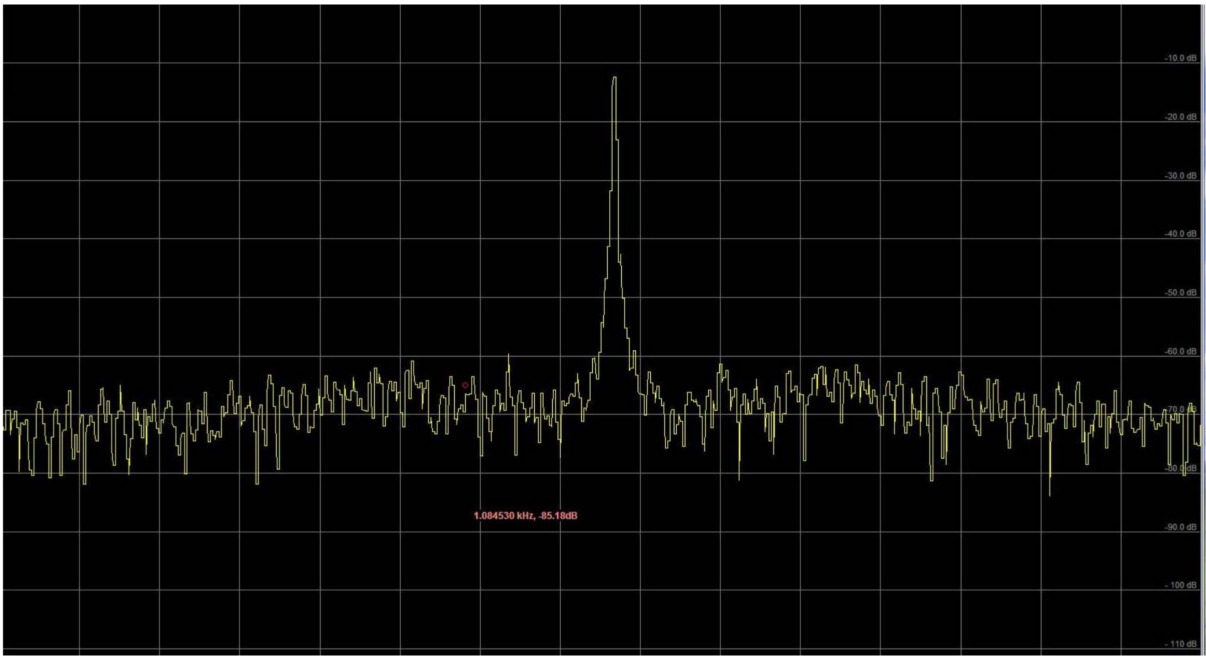

Figure 5: 10 GHz Signal to Noise ratio

As WSJT can detect signals down to around -30 dB by eye, the peak 10 GHz signal was some 60 dB above the detectable limit. This level is stronger than for previous 10 GHz tests over similar paths and suggests some tropo enhancement. Given the good conditions forecast by Hepburn these tests were arranged on the basis of the possibility of tropo-ducting at 24 GHz. However, despite 10 GHz showing signal levels some 60 dB above the detectable limit there was no evidence of consistent tropo on 24 GHz. In fact over a period of around 2 hours there was evidence of 24 GHz signals for only 11 minutes. The best signal seen on JT65c on 24 GHz was -24 dB and by eye the peak would have perhaps reached -15 dB still some 45 dB less than the peak seen on 10 GHz. Given that the 24 GHz system is around 5 dB lower in performance than 10 GHz (see section on equipment below) this implies that there was around 40 dB difference in propagation.

The fact that the 24 GHz signal rose from the noise for a short period and that there was no evidence of the signal at all at other times did make us think that it could have been due to aircraft scatter. However, the signal was essentially stable in frequency to within a few Hz for the 11 minutes that a signal was detected and this is very unlikely based on our experience of aircraft scatter at 10 GHz. In addition the path of propagation is not in line with any domestic aircraft paths and we would have been both beaming too low for aircraft. We also later realised that the beginning of the signal coincided closely with the realignment of the antenna at the VK7MO end. Thus our conclusion is that the signal was most likely the result of tropo-ducting which dropped below the noise a mere 11 minutes after this antenna shift.

The best tropo-ducts have been measured to produce signal levels approaching line-of-sight propagation. A calculation of the line-of-sight losses indicates that the peak signal levels on 10 GHz were about 40 dB below line-of-sight so it is still possible that much better paths might be obtained.

Equipment Used

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 4 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

The basic free space propagation loss is 20 log10(24048/10368) or 7.3 dB greater at 24 GHz.

RX system noise will be similar on all systems as it is basically limited by ground noise when beaming at the horizon

TX power is up on 10 GHz by around 4 to 7 dB say 6 dB.

Antenna gain is up on 24 GHz by 8 dB

Thus system performance should be around –7-6+8 dB or around 5 dB down on 24 GHz. As the peak signals on 24 GHz were around 45 dB below those on 10 GHz this suggests that the additional propagation losses (probably due to absorption on 24 GHz) were around 40 dB.

Absorption Losses

We can get some idea of the absorption losses using the ITU methods by using the accompanying Absorption Loss Calculator. In the table below we have used the pressure, temperature and relative humidities from Figure 7 for heights of 400 metres representing the height of VK3HZ and 1300 metres the height of VK7MO and 3200 meters the duct that was most likely being used.

Height (metres)	Pressure hpa	Temp (deg C)	RH (%)	Loss/Km (dB)	Total Absorption Loss (dB)
400	960	22	40	0.18	76
1300	840	21	18	0.08	36
3200	700	9.2	6	0.02	8

Table 1: Absorption losses at 24 GHz

Height (metres)	Pressure hpa	Temp (deg C)	RH (%)	Loss/Km (dB)	Total Absorption Loss (dB)
400	960	22	40	0.013	5.8
1300	840	21	18	0.008	3.4
3200	700	9.2	6	0.0045	1.9

Table 2: Absorption losses at 10 GHz

The absorption losses have a small impact on 10 GHz. The additional absorption loss at 24 GHz would be around 70 dB if the path was in a duct at 400 metres and around 32 dB if the path was around 1300 meters falling to only 6 dB if the full path was around 3200 metres.

Height of Ducts

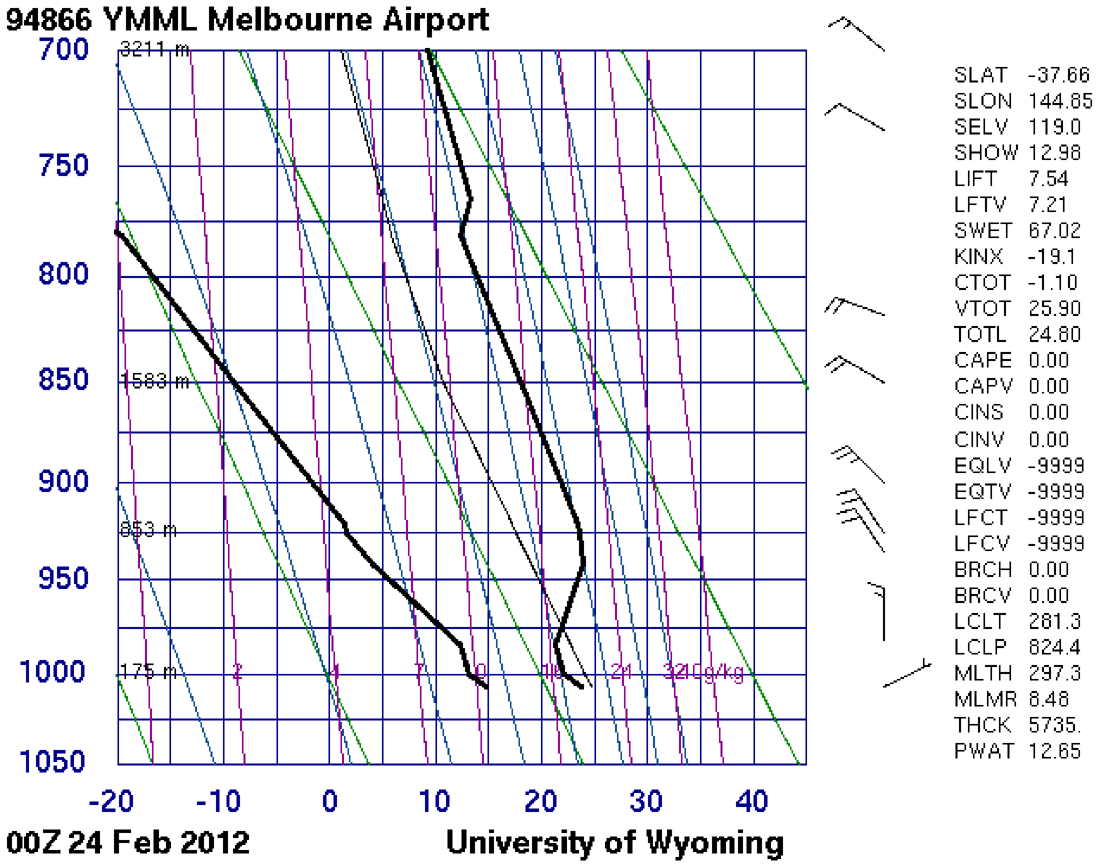

Figure 6a: Radiosonde Data at the time of the tests from near Melbourne (the VK3HZ end of the Path) as provided by the Bureau of Meteorology via the University of Wyoming.

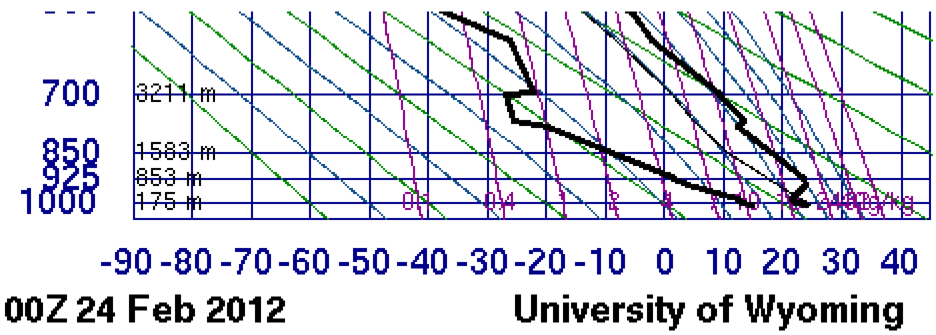

Figure 6b: Same data on an expanded scale with evidence of a sharp change in Humidity at 700 Hpa

94866 YMML Melbourne Airport Observations at 00Z 24 Feb 2012

PRES hPa	HGHT m	TEMP C	DWPT C	RELH %	MIXR g/kg	DRCT deg	SKNT knot	THTA K	THTE K	THTV K
1007.0	119	23.8	14.8	57	10.61	65	5	296.4	327.3	298.2
1000.0	175	22.2	13.2	57	9.62	45	9	295.4	323.3	297.1
984.0	315	21.4	12.4	56	9.27	5	16	295.9	323.0	297.6
982.0	333	21.5	12.0	55	9.06	0	17	296.2	322.7	297.8
941.0	704	24.0	4.0	27	5.44	330	20	302.4	319.0	303.4
935.0	759	23.9	3.1	26	5.14	325	21	302.8	318.6	303.7
925.0	853	23.6	1.6	24	4.67	325	22	303.4	317.9	304.3
921.0	891	23.4	1.4	24	4.62	323	22	303.6	317.9	304.4
900.0	1090	21.9	-1.6	21	3.80	315	23	304.0	315.9	304.7
850.0	1583	18.0	-9.0	15	2.29	300	20	305.0	312.4	305.4
818.0	1907	15.5	-13.8	12	1.62	290	19	305.7	311.0	306.0
781.0	2298	12.4	-19.6	9	1.04	294	16	306.4	310.0	306.6
765.0	2472	13.4	-25.6	5	0.63	296	14	309.3	311.6	309.5
734.0	2816	11.4	-26.2	5	0.62	300	11	310.9	313.1	311.0
700.0	3211	9.2	-26.8	6	0.61	310	13	312.6	314.9	312.8
696.0	3258	9.0	-23.0	8	0.87	310	13	313.0	316.1	313.1
695.0	3270	9.0	-22.0	9	0.95	309	13	313.1	316.4	313.2
647.0	3851	4.8	-23.6	11	0.89	260	14	314.8	317.9	314.9
595.0	4531	-0.1	-25.4	13	0.82	255	17	316.7	319.7	316.9
575.0	4809	-2.1	-26.1	14	0.80	258	19	317.5	320.4	317.6
521.0	5588	-5.3	-36.3	7	0.33	266	25	322.7	324.0	322.8

Figure 7: Raw Radiosonde Data – inversions highlighted in green

Analysis by Andrew Martin VK3OE

Note: We have discussed the results with Andrew VK3OE who undertook an analyis to derive a Refractivity Profile. Andrew provided the diagram at Fig 8 and text for this section rests heavily on discussions with him. (A copy of VK3OE's spreadsheet that allows the calculation of the Refractivity Profile accompanies this paper and can be applied to other situations using upper air data available from the University of Wyoming web site.)

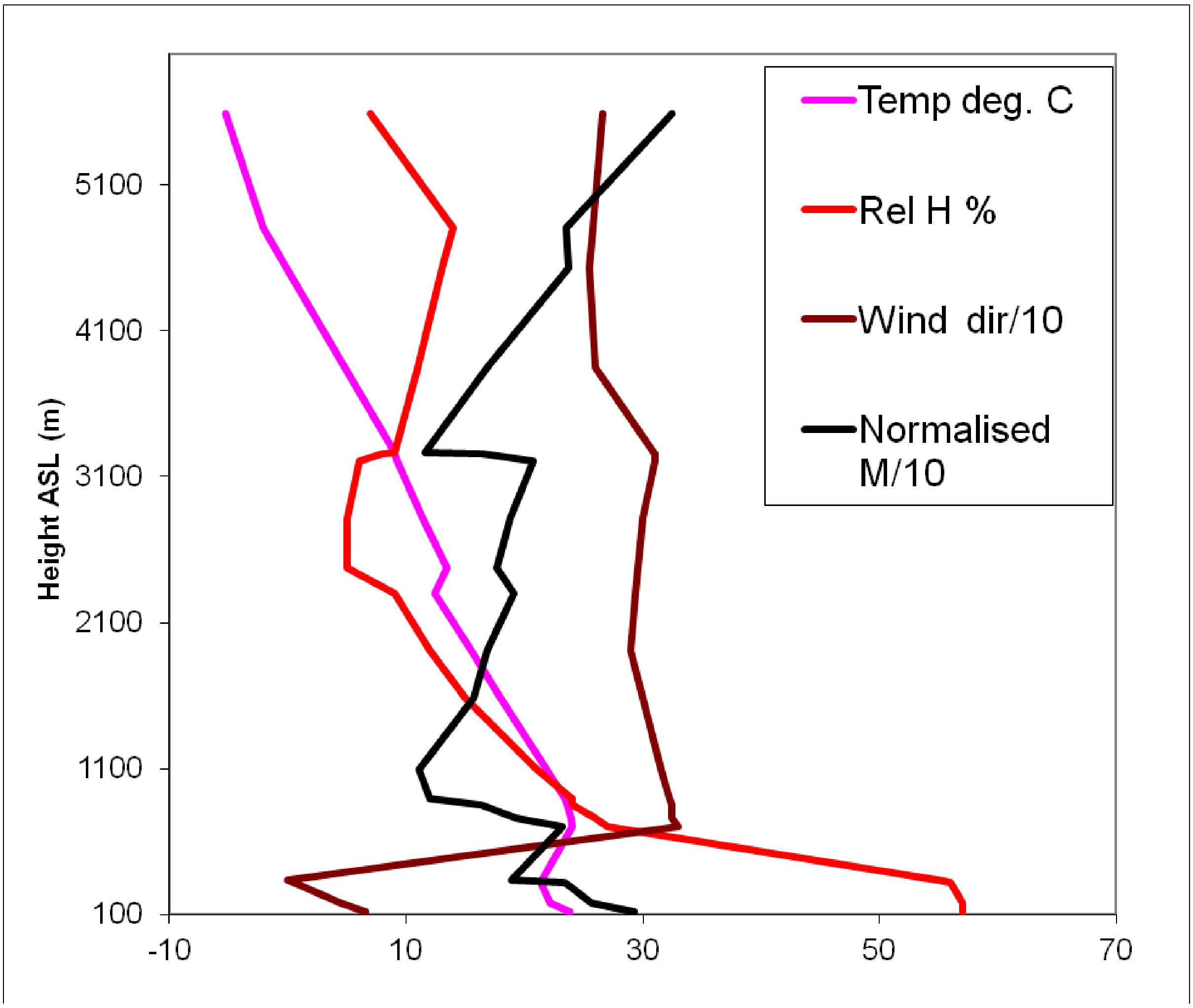

Figure 8: Refractivity M profile (normalised/10) calculated from the data of Fig. 7. Also shown are the temperature, relative humidity and wind direction.

Fig 8 shows a number of areas with negative Refractivity gradients (Black line), but only two at around 2300 and 3200 metres are above the height of Mt Barrow and thus likely to be useful for propagation in this case. VK3OE advises that as frequency is increased it becomes necessary to use stronger inversions to maintain ducting propagation (Refer also his GippsTech 2004 paper). The 3200 metre duct has a very significant negative gradient indicating a very strong duct and thus VK3OE considers it is likely to mechanism for propagation.

As the 3200 metre duct is significantly higher than both locations and as both stations were beaming at the horizon with narrow beamwidth antennas (about +/- 1 degree) it would not be possible to access this duct until near the centre of the path. Thus it seems likely that the duct was used for perhaps only a short distance near the middle of the path and the majority of the path was at lower levels with higher absorption. Depending on the actual length within the duct the absorption will be some combination of the losses calculated in Table 1 above and thus is broadly consistent with the 40 dB higher attenuation between 24 GHz and 10 GHz.

Conclusions

- It seems likely that the 24 GHz propagation was via high level tropo-ducting at around 3200 metres.
- Comparisons between 10 GHz and 24 GHz together with calculations of absorption loss support the fact that a high level duct was involved.
- Calculations of absorption loss are consistent with the 40 dB weaker signals at 24 GHz compared to 10 GHz.
- The ducting signals are stable in frequency and constrained within a few Hz and thus JT65c is useful for tropo-ducting at 24 GHz.
- It seems that for planning purposes it will be necessary to use high ducts to avoid excessive absorption and that it will be preferable also to have elevated TX and RX locations to reduce absorption losses.
- While a QSO was not completed in this case (due mainly to minor stuff-ups at both ends) there is evidence that such a path is possible given that this was our first attempt and we have both been operational on 24 GHz for only a few days.

Accompanying Spread Sheets

Absorption Loss Calculator by VK7MO :
http://www.vk3hz.net/microwave/Absorption_Loss_Calculator_by_VK7MO.xls

Refractive Gradient Plotter by VK3OE :
http://www.vk3hz.net/microwave/Refractive_Gradient_Plotter_by_VK3OE.xls