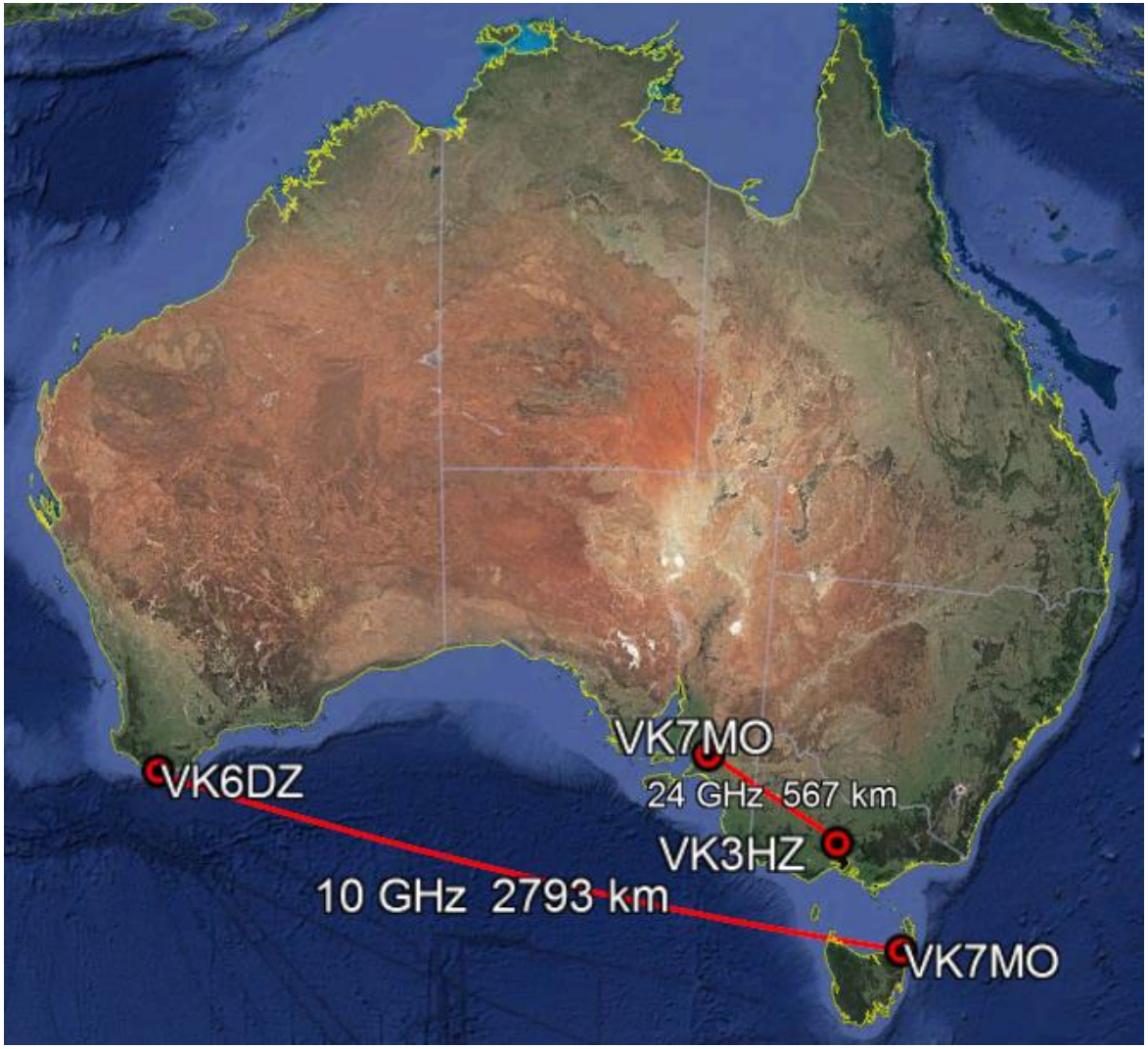
10 and 24 GHz Terrestrial DX

By VK7MO



Portable EME >> Terrestrial DX

- Pointing
- GPSDO Locking
- Dishes and Power
- Digital modes
- Single tone integration
- Absorption
- System reliability and preparation.

10 & 24 GHz Terrestrial DX

Propagation	10 GHz	24 GHz
Tropo-scatter Always available	650 km Est	250 km Est
Aircraft-scatter A few times a day	905 km VK7MO-VK3HZ	566 km VK7MO-VK3HZ
Rain-scatter A few times a month	1129 km DK3SE-IK7UXW	710 km LX1DB-F2CT
Tropo-ducting A few times a year	2793 km VK7MO-VK6DZ	581 km DL7QY-F6DKW

Pointing

- Weak tropo-scatter is difficult to peak due to short and long term QSB.
- Aircraft Scatter: Only a second or so & does not allow peaking.
- Rain-scatter: Both stations beaming accurately at each other to minimize Doppler and Doppler spreading and waiting for the rain to cross.
- One can wait for hours for a tropo-duct to open and both stations must be pointed accurately to detect an opening.

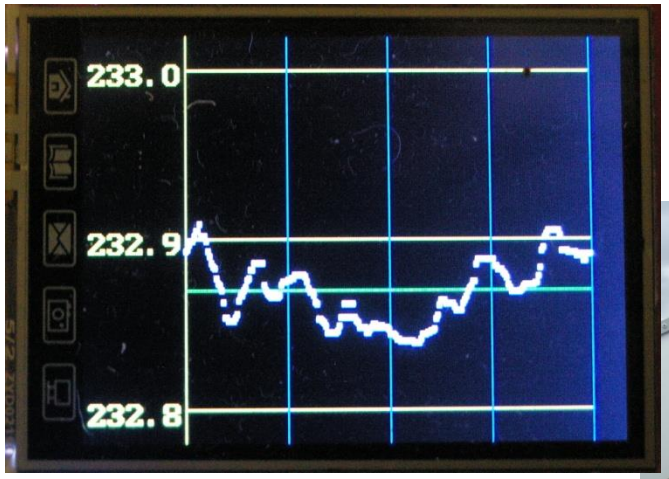
Pointing Methods

Rifle-scope aligned to the dish:

- Use something that can be identified on Google Earth as a bearing reference.
- Place or find a marker out several hundred metres and use handheld GPS Lat and Long plus spreadsheet.
- Use differential GPS.

Differential GPS – see Paper in Proceedings

- Within 0.1 degree on a 5 metre baseline



GPSDO Locking

- If you are tuning around for a weak signal to rise out of the noise you have little hope.
- You can use more sensitive digital modes.
- Single tone integration facility on WSJT - gives about 6 dB advantage.
- Much more confidence in a single tone that is within a few Hz.

Use a good quality Double Oven GPSDO.

Digital Modes

- Tropo-scatter : Signal spread up to 20 Hz – use QRA64D.
- Aircraft Scatter: Signal comes in short bursts with Doppler up to 1000 Hz – use ISCAT-A or B.
- Rain-scatter: Signal spread up to 20 Hz or more use QRA64D or E if your Passband is up to it.
- Ducting: Signal is spread less than 1 Hz but can involve wider tropo-scatter extensions. QRA64D but might use QRA64A.

Single Tone Integration

- When waiting for a duct to open use 1000 Hz single tone and the WSJT-X integration facility to detect the presence of a signal.
- TX 1250 Hz single tone when you want the other station to send messages.

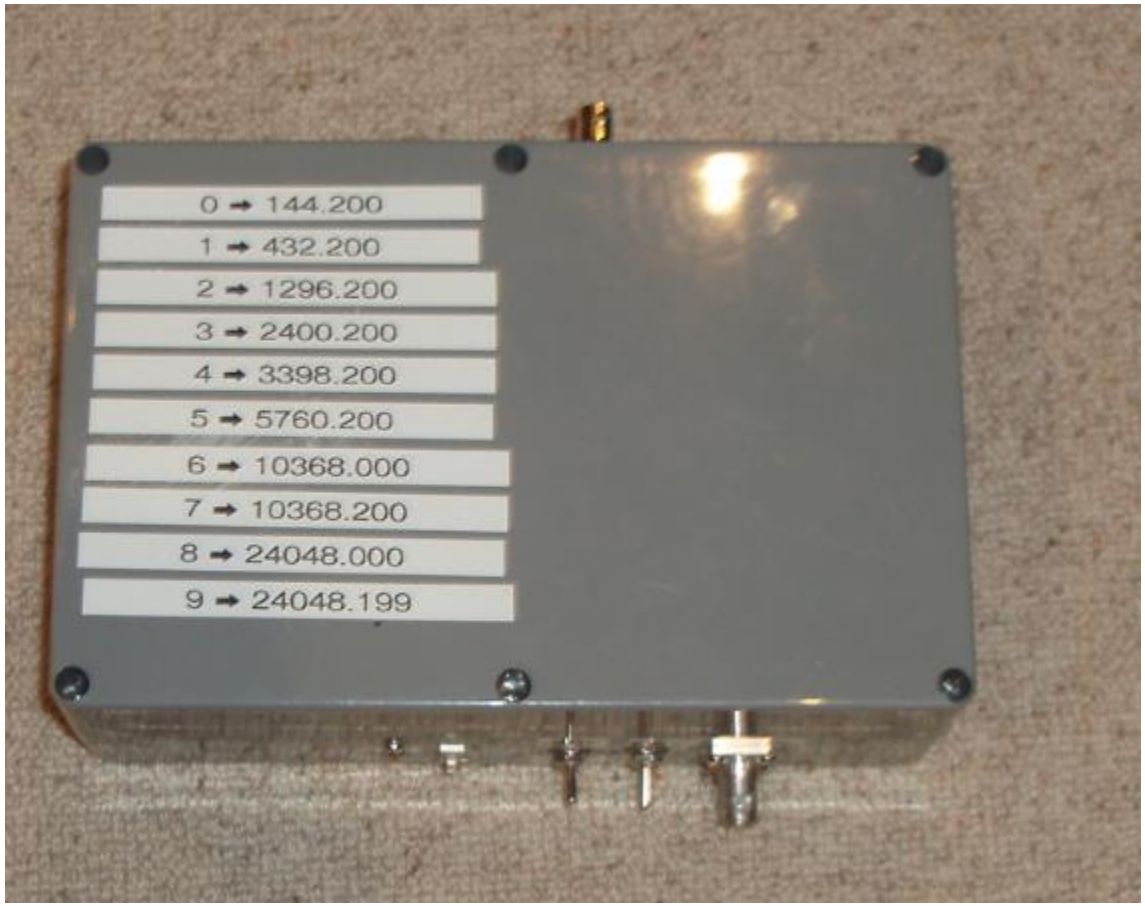
Dishes, Power and Digital Modes

- In 1994 VK6KZ & VK5NY set 10 GHz terrestrial World Record at 1912 km. They used 40 cm dishes, 100 mW and SSB with drifting oscillators and used VHF signals to align their antennas.
- With today's EME capable portable stations we can use 60 watts (+28 dB), 4 foot dishes at both ends (+16 dB), and digital modes (+ 30 dB) -- improvement of over 70 dB.

System Reliability and Preparation

- Lots of proving, improving and experience.
- Both stations to be set up and tested at the agreed time.
- Agreement on Frequency, Mode & sub-mode and first/second period.
- For ducting both stations available to travel to sites when Hepburn shows promise.
- Check RX with ground noise to cold sky.
- Check TX with PA current.
- Check frequency with an independent GPSDO locked Weak Signal Source

GPSDO locked Weak Signal Source



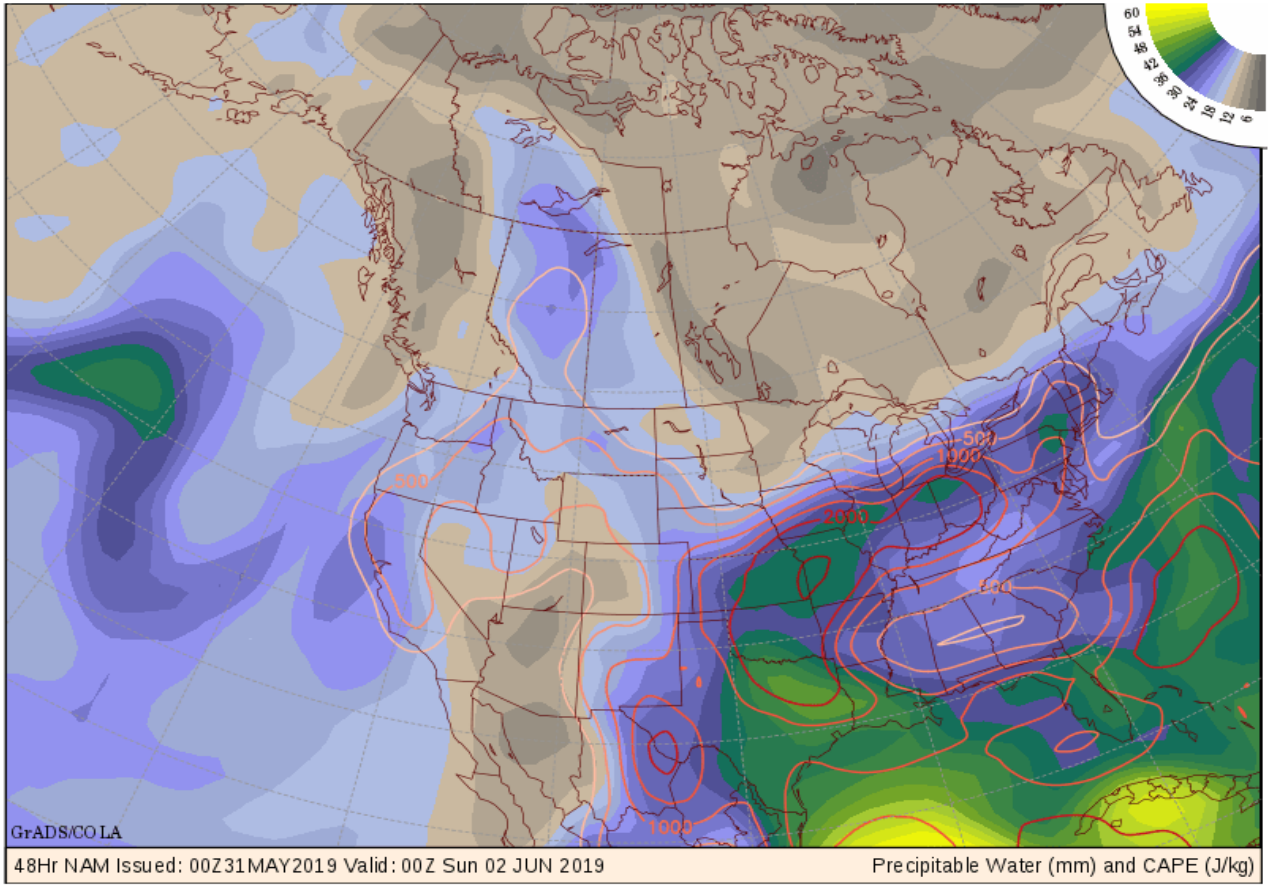
Absorption: 500 km path

Temperature and Relative Humidity	1.296 GHz (dB)	10.368 GHz (dB)	24.048 GHz (dB)
0 Deg C, 20%	3.4	5.1	18.9
0 Deg C, 50%	3.4	5.9	34.9
0 Deg C, 80%	3.5	6.6	50.8
15 Deg C, 20%	3.0	5.2	35.0
15 Deg C, 50%	3.0	7.1	76.4
15 Deg C, 80%	3.1	9.0	117.1
30 Deg C, 20%	2.7	6.2	71.0
30 Deg C, 50%	2.7	10.4	164.0
30 Deg C, 80%	2.8	14.8	254.6

Absorption at sea level, over a 500 km path based on International Telecommunications method which has been applied with a Spreadsheet.

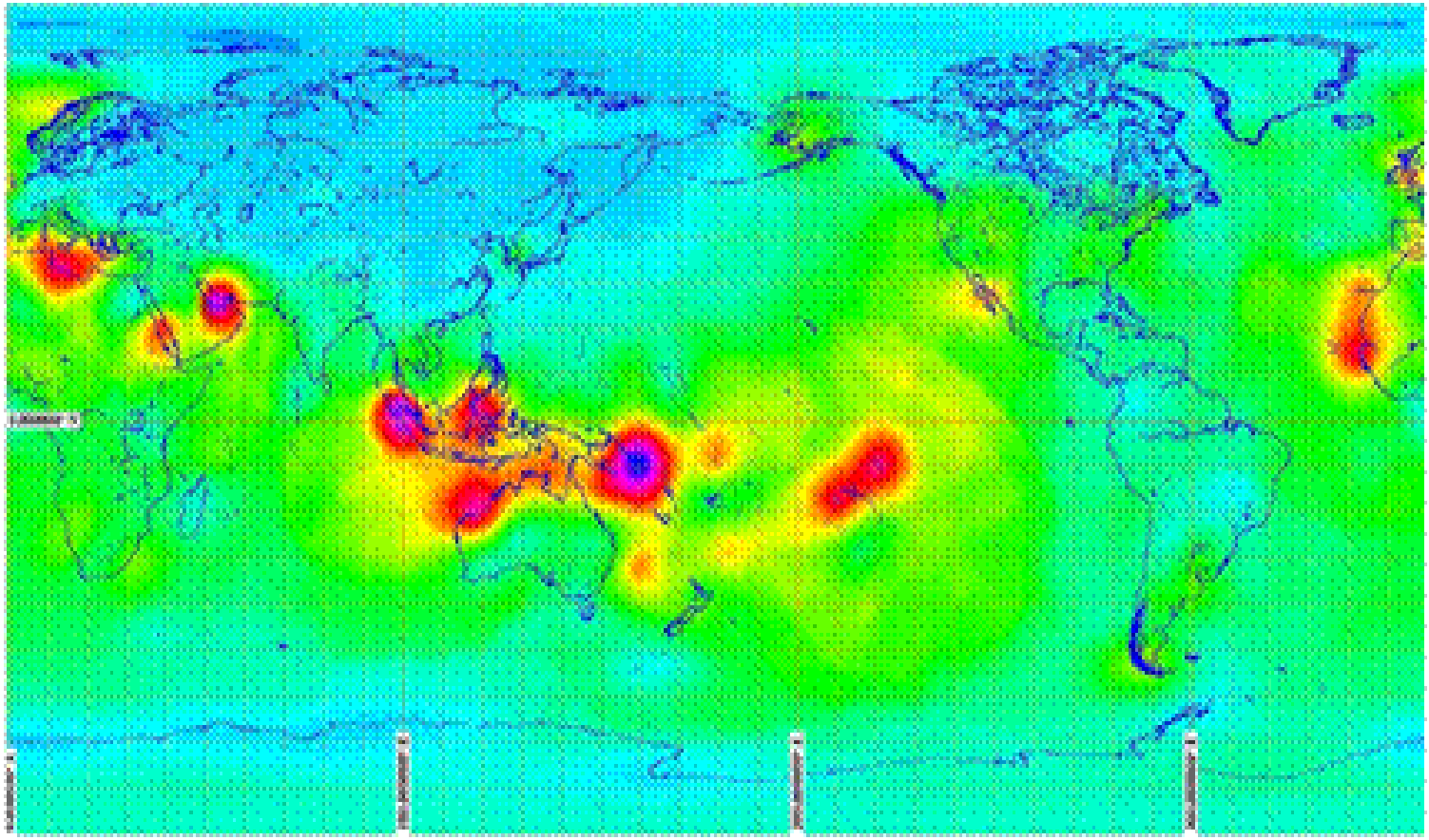
Ducts usually occur with high temperatures on 10 GHz a 4000 km path may have 40 to 100 dB absorption

Precipitable Water as an indicator of Absorption



5 mm in Canada and 50 mm in Dallas

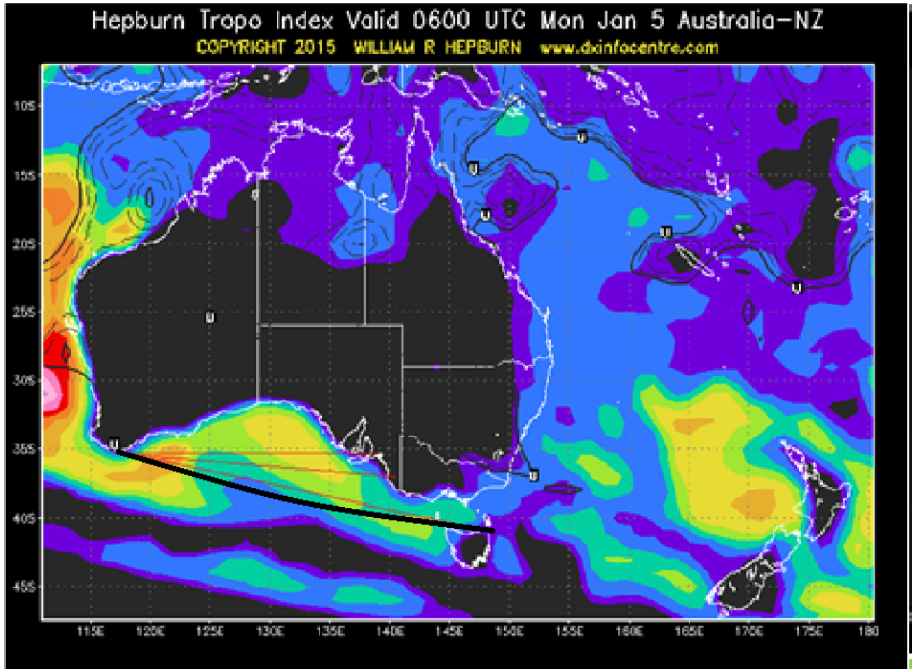
Ducting – nothing to do with EME



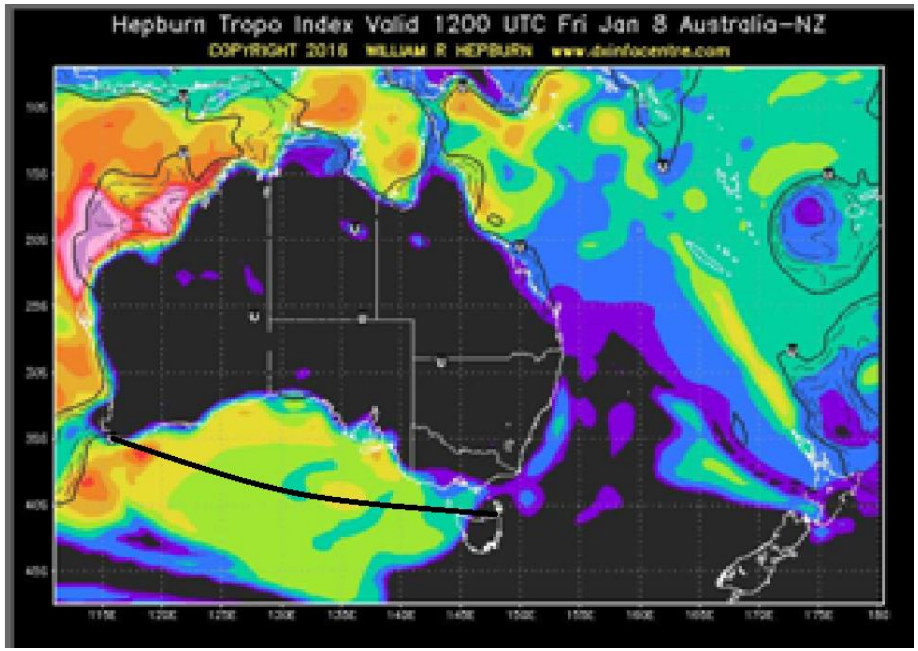
ITU Map on the Global Incidence of Ducting

Hepburn Charts

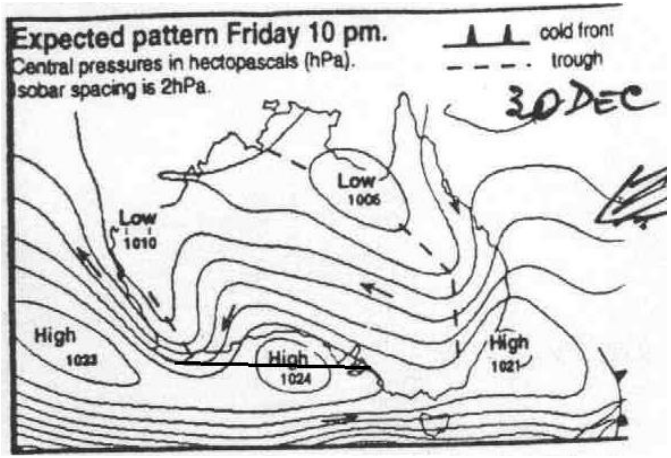
2732 km
5 Jan 2015
Digital and SSB



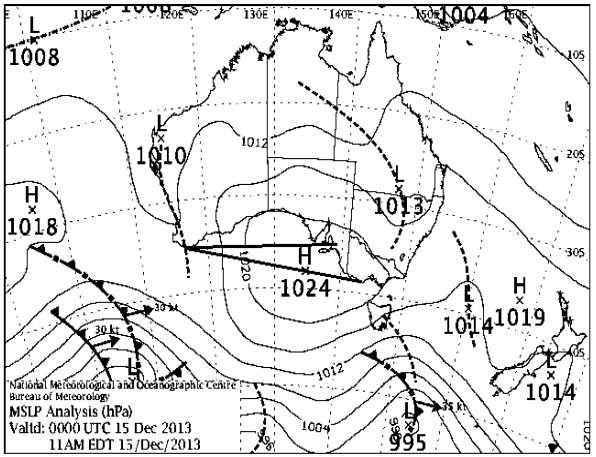
2793 km
8 Jan 2016
Digital only



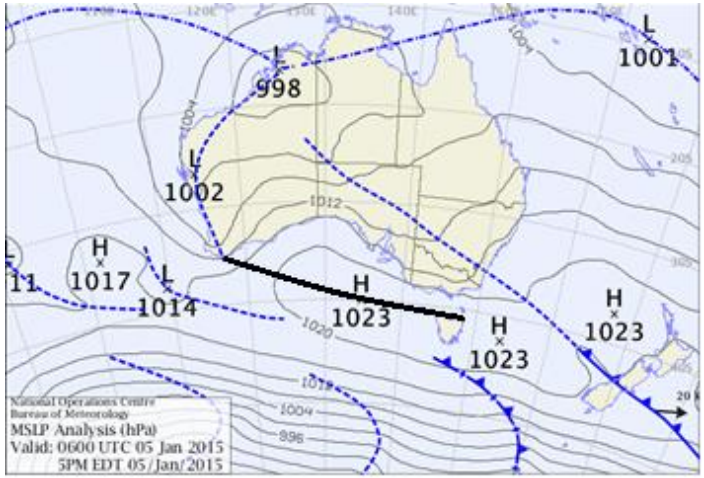
Mean Sea Level Charts



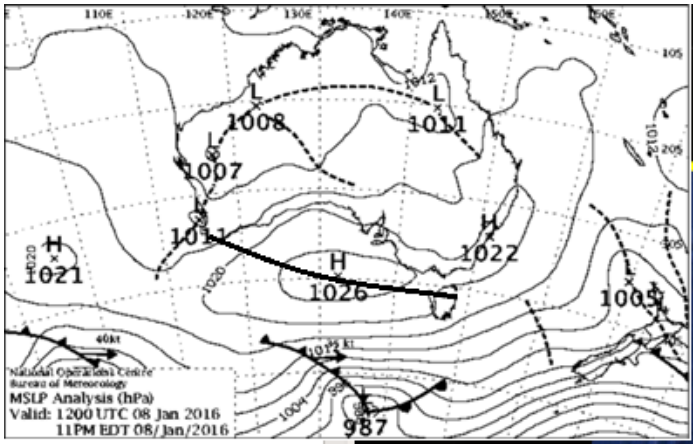
30 Dec 1994 1912 km VK6KZ-VK5NY



14 Dec 2013 2293 km VK7MO-VK6DZ



5 Jan 2015 2732 km VK7MO-VK6DZ



8 Jan 2016 2793 km VK7MO-VK6DZ

Upper Air Data

University of Wyoming
College of Engineering
Department of Atmospheric Science

Region	Type of plot	Year	Month	From	To	Station Number
North America	Text: List	2019	Jul	22/00Z	22/00Z	72672

Click on the image to request a sounding at that location or enter the station number above.

University of Wyoming
College of Engineering
Department of Atmospheric Science

Region	Type of plot	Year	Month	From	To	Station Number
South Pacific	Text: List	2019	Jul	22/00Z	22/00Z	72672

Click on the image to request a sounding at that location or enter the station number above.

94802 YPAL Albany Airport Observations at 00Z 05 Jan 2015

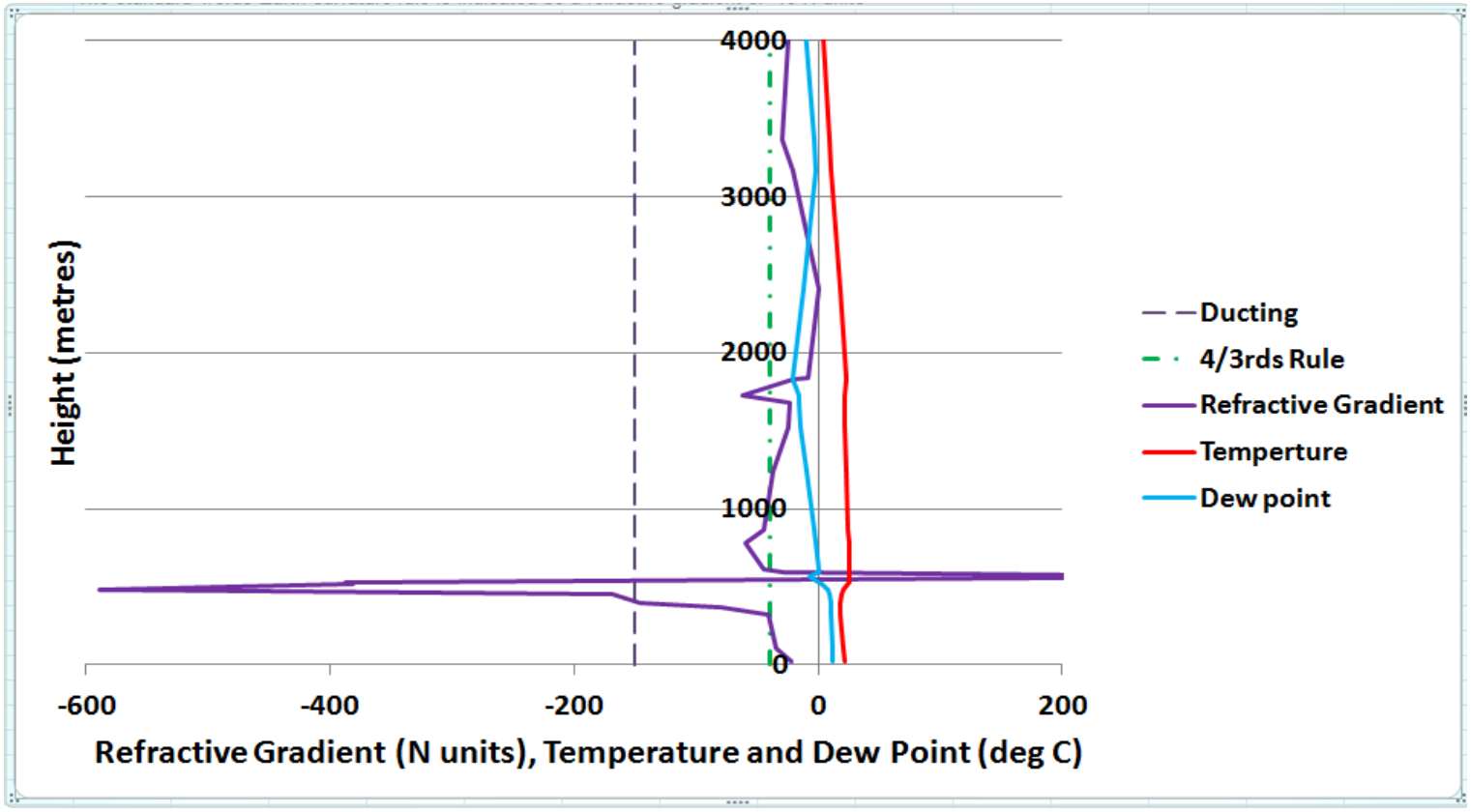
PRES hPa	HGHT m	TEMP C	DWPT C	RELH %	MIXR g/kg	DRCT deg	SKNT knot	THTA K	THTE K	THTV K
1007.0	68	20.0	16.2	79	11.63	75	10	292.6	325.8	294.6
1000.0	129	18.0	14.8	82	10.69	95	12	291.1	321.6	293.0
982.0	284	16.6	14.7	89	10.82	85	15	291.3	322.0	293.1
974.0	354	16.2	13.6	85	10.14	80	17	291.5	320.5	293.3
962.0	461	21.0	7.0	40	6.57	73	19	297.4	317.0	298.6
950.0	570	22.4	6.4	35	6.38	65	21	299.9	319.1	301.1
925.0	801	22.0	3.0	29	5.16	50	26	301.8	317.6	302.7
913.0	914	22.2	-0.5	22	4.06	55	21	303.1	315.8	303.9
912.0	924	22.2	-0.8	22	3.97	54	21	303.2	315.6	304.0
881.3	1219	20.4	0.4	26	4.48	15	20	304.4	318.4	305.2
850.0	1531	18.6	1.6	32	5.08	10	17	305.6	321.4	306.6
791.7	2134	13.6	1.4	44	5.39	0	12	306.6	323.4	307.6
778.0	2282	12.4	1.4	47	5.47	353	12	306.8	323.8	307.8
763.5	2438	11.3	-1.0	42	4.67	345	11	307.3	322.0	308.2
736.1	2743	9.3	-5.8	34	3.39	290	17	308.3	319.2	308.9
727.0	2847	8.6	-7.4	31	3.03	287	17	308.6	318.4	309.2
720.0	2927	8.8	-22.2	9	0.90	284	17	309.7	312.8	309.9
709.5	3048	8.3	-31.1	4	0.41	280	17	310.4	311.9	310.5
700.0	3159	7.8	-39.2	2	0.18	300	19	311.1	311.8	311.1
683.7	3353	6.9	-41.7	2	0.15	305	21	312.2	312.7	312.2
679.0	3409	6.6	-42.4	2	0.14	308	20	312.5	313.0	312.5
658.6	3658	5.5	-33.5	4	0.35	320	18	314.0	315.3	314.0
635.0	3956	4.2	-22.8	12	0.97	315	20	315.8	319.2	316.0
611.1	4267	3.3	-31.1	6	0.47	310	23	318.2	320.0	318.3

Spreadsheet 1: Ducting

Spreadsheet 2: Atmospheric absorption

https://drive.google.com/open?id=1ctR-ptUrW_6ZBmOlSkxy2NpUrM1Su_Gz

Duct for 2732 km 10 GHz QSO



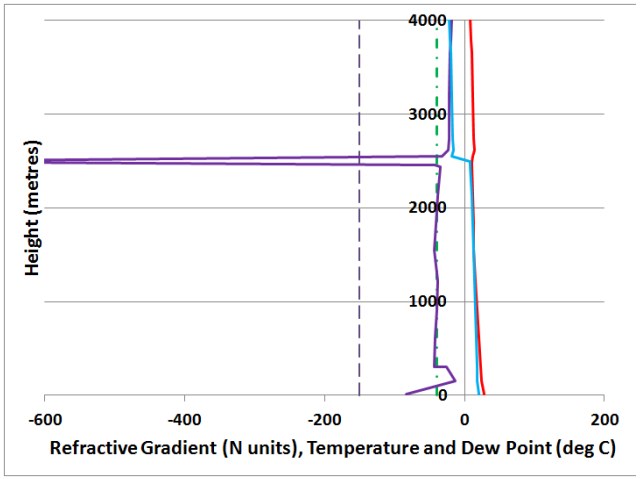
Absorption Loss Calculator

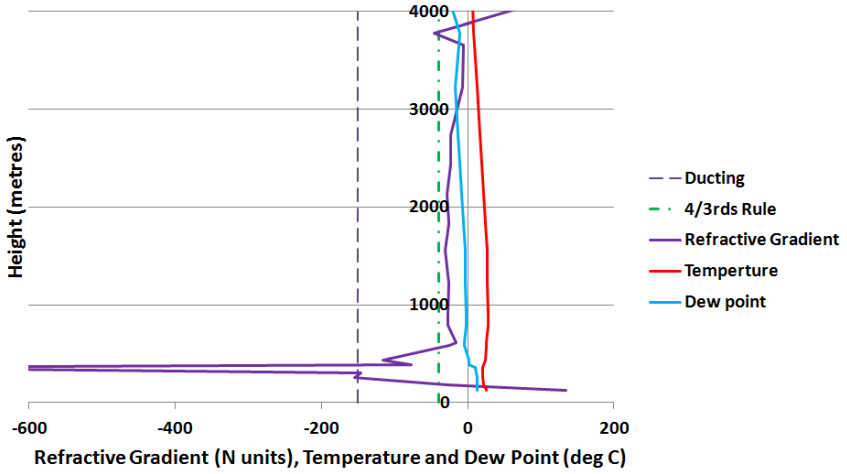
From International Telecommunications Union ITU-R P676-8

10.368 GHz
2732 km

Pressure	Height	TEMP	DWPT	RELH	Mixing ratio	Wind Direction	Wind Speed	THTA	THTE	THTV	Total Loss
hpa	m	C	C	%	g/kg	deg	Knots	K	K	K	(dB)
1010	27	21.2	12.2	56	8.91	20	9	293.5	319.3	295.1	47.2
1000	109	19.8	11.8	60	8.76	15	10	292.9	318.2	294.5	46.8
975	326	17.8	10.8	64	8.41	27	14	293.1	317.4	294.6	44.8
970	370	17.6	10.6	64	8.31	30	15	293.2	317.3	294.7	44.3
967	397	17.4	10.4	63	8.25	27	17	293.4	317.2	294.8	43.5
960	459	18.8	8.8	52	7.45	21	20	295.4	317.2	296.7	40.3
957	486	20	8	46	7.08	19	22	296.9	317.8	298.1	38.7
953	522	23.8	2.2	24	4.74	15	24	301.1	315.7	302	30.5
952	531	24.8	0.8	21	4.28	14	24	302.2	315.4	302.9	29.3
948	568	25	-7	11	2.4	10	24	302.7	310.4	303.2	23.6
945	596	25.2	0.2	19	4.13	7	23	303.2	316.1	304	28.0
943	614	25.2	0	19	4.06	5	23	303.4	316	304.1	28.0
925	783	24.8	-2.2	17	3.53	10	19	304.7	315.8	305.3	26.0
916	868	24.5	-3.7	15	3.19	20	20	305.2	315.4	305.8	24.4
878	1237	23.1	-10.1	10	2.03	15	19	307.4	314.1	307.8	20.2
850	1519	22	-15	7	1.41	45	15	309.2	314	309.4	17.6
834	1683	21.4	-15.6	7	1.36	55	13	310.2	314.8	310.4	17.1
830	1725	21.2	-15.8	7	1.35	63	12	310.4	315.1	310.7	16.9
820	1830	22.4	-20.6	4	0.91	83	10	312.8	316	313	15.2
819	1840	22.3	-20.5	4	0.92	85	10	312.8	316.1	313	15.2
766	2409	17.4	-12.7	12	1.89	75	2	313.6	320	313.9	16.4
700	3175	10.8	-2.2	40	4.67	235	8	314.4	329.5	315.3	20.3
684	3367	9	-3	43	4.51	261	7	314.5	329.1	315.4	19.6
608	4330	1	-13	34	2.32	31	1	316	323.9	316.5	13.3
606	4356	0.8	-13.3	34	2.27	35	1	316.1	323.7	316.5	13.2
565	4912	-3.9	-20.9	25	1.29	285	10	317	321.5	317.2	10.5
553	5082	-5.3	-23.1	23	1.08	260	13	317.3	321.1	317.5	9.9

29 July 1991





Off the scale at -842 N units at 2500 meters

Off the scale at -867 N units at only 400 meters

29 July 1991

- KH6HME to N6CA 3983 km on 5.7 GHz
- Hawaii to California

Summary of 29 July 1991 QSO

Frequency	Absorption Hawaii (dB)	Absorption California (dB)
10 GHz	22-21	46-36
5.7 GHz	18-17	30-25

Height of Duct

Hawaii 2500 metres

California 400 metres

Some Questions

- Should absorption be measured at the bottom of the duct?
- Is absorption the only difference with frequency?
- Implications of the intensity of the duct?
- The benefits of being at the height of the duct?
- Why are all 10 GHz ducting records over water?

A task for clever young people

- Automate the reading of the University of Wyoming upper air data.
- Run statistics on the intensity and height of ducts and absorption.
- See how often the July 1991 conditions occur and the best locations around the World.

For retired people who have time and a portable EME station plan on extending the 10 GHz Terrestrial Record.

CONCLUSIONS

- EME capable digital and GPSDO locked portable stations offer good prospects for extending the 10 and 24 GHz records with Modes such as QRA64.
- Ducting is the best prospect for 10 GHz but as distance increases absorption losses become significant – it may be better to operate in temperate areas even if openings are less frequent.
- Forward rain scatter appears the best prospect at 24 GHz and digital modes should significantly enhance capability.

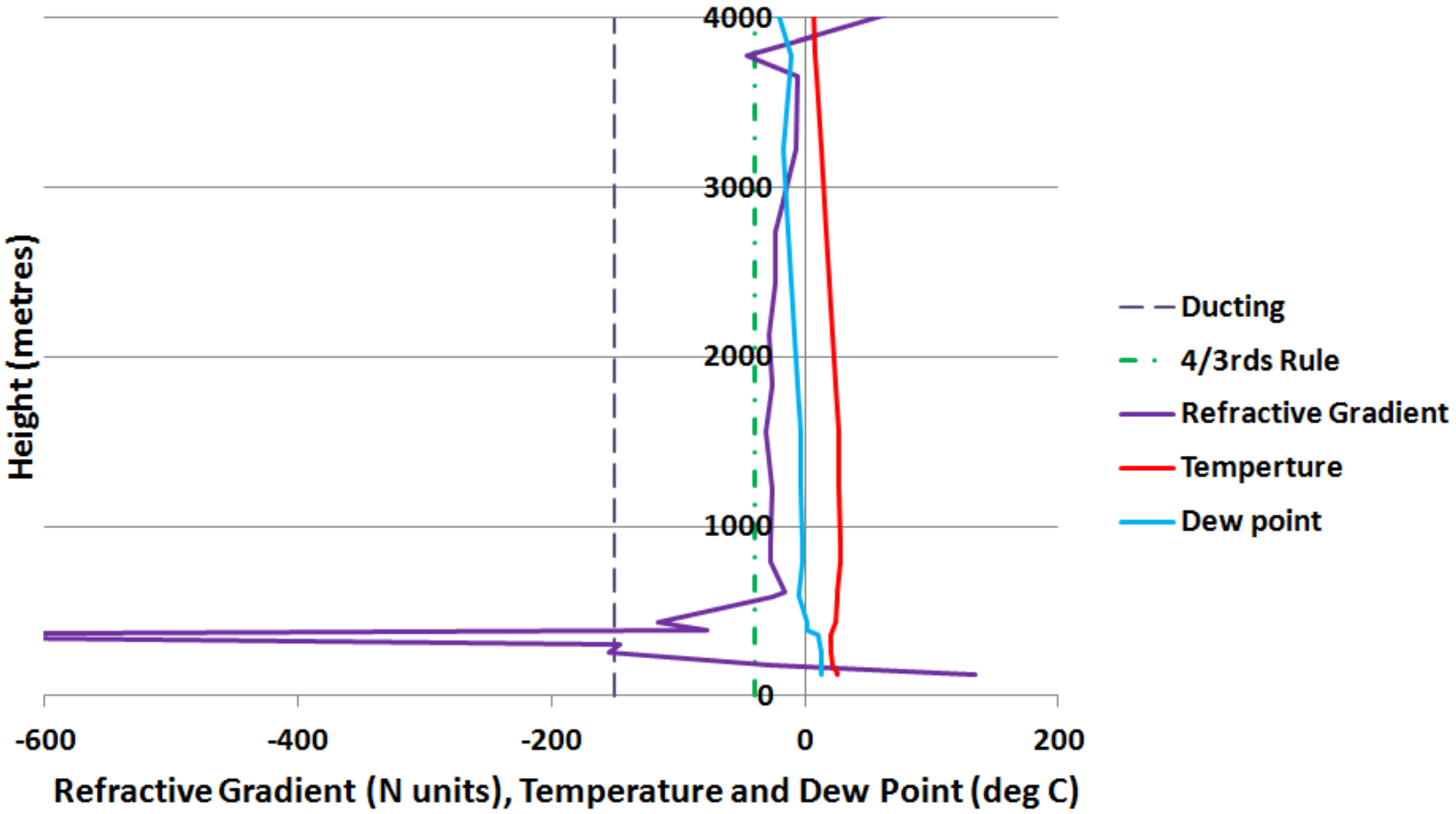
Absorption at Hawaii -- 5.7 GHz

Pressure	Height	TEMP	DWPT	RELH	Mixing ratio	Wind Direction	Wind Speed	THTA	THTE	THTV	Total Loss
hpa	m	C	C	%	g/kg	deg	Knots	K	K	K	(dB)
1017	11	27.3	20.3	66	14.98	40	9	299	342.9	301.7	43.1
1000	156	24.4	18.4	69	13.5	35	9	297.6	336.9	300	41.2
983.2	304	22.5	18.3	77	13.65	35	10	297.1	336.8	299.5	40.9
983	306	22.5	18.3	77	13.65	35	10	297.1	336.8	299.5	40.9
949	609	20.3	16.9	81	12.94	45	9	297.9	335.6	300.2	38.5
915.9	914	18.1	15.5	85	12.26	40	8	298.6	334.5	300.8	36.2
883.9	1219	15.8	14.1	90	11.6	20	7	299.4	333.5	301.5	34.1
850	1555	13.4	12.6	95	10.9	20	6	300.2	332.4	302.1	31.9
822.8	1828	12.4	11.3	93	10.33	35	8	301.9	332.7	303.8	29.8
793.5	2133	11.4	9.9	90	9.71	50	11	303.9	333.2	305.7	27.7
765.2	2438	10.3	8.4	88	9.13	65	14	306	333.7	307.6	25.7
763	2462	10.2	8.3	88	9.08	66	14	306.1	333.8	307.8	25.6
760	2495	10.2	8.1	87	8.99	68	13	306.5	333.9	308.1	25.4
755	2550	11.8	-18.2	11	1.21	71	12	308.8	312.9	309	18.0
749	2617	13.8	-16.2	11	1.45	74	10	311.6	316.6	311.9	17.5
737.8	2743	13.3	-16.7	11	1.41	80	8	312.5	317.3	312.7	17.1
700	3184	11.6	-18.4	11	1.29	70	7	315.3	319.8	315.5	15.6
661.3	3657	10	-20	10	1.19	90	3	318.7	322.9	318.9	14.1
651	3787	9.6	-20.4	10	1.17	94	4	319.6	323.8	319.9	13.7
613.3	4267	6	-24	9	0.9	110	7	320.9	324.2	321.1	12.4
568.6	4876	1.3	-28.7	9	0.64	90	14	322.5	324.9	322.7	11.1
507.4	5791	-5.6	-35.6	7	0.36	75	12	324.8	326.2	324.9	9.3
500	5910	-6.5	-36.5	7	0.34	75	13	325.1	326.4	325.1	9.1
488.1	6096	-7.9	-37.9	7	0.3	80	13	325.6	326.8	325.6	8.8

Absorption at Hawaii --10.3 GHz

Pressure	Height	TEMP	DWPT	RELH	Mixing ratio	Wind Direction	Wind Speed	THTA	THTE	THTV	Total Loss
hpa	m	C	C	%	g/kg	deg	Knots	K	K	K	(dB)
1017	11	27.3	20.3	66	14.98	40	9	299	342.9	301.7	92.7
1000	156	24.4	18.4	69	13.5	35	9	297.6	336.9	300	85.6
983.2	304	22.5	18.3	77	13.65	35	10	297.1	336.8	299.5	85.4
983	306	22.5	18.3	77	13.65	35	10	297.1	336.8	299.5	85.4
949	609	20.3	16.9	81	12.94	45	9	297.9	335.6	300.2	79.6
915.9	914	18.1	15.5	85	12.26	40	8	298.6	334.5	300.8	74.0
883.9	1219	15.8	14.1	90	11.6	20	7	299.4	333.5	301.5	68.9
850	1555	13.4	12.6	95	10.9	20	6	300.2	332.4	302.1	63.5
822.8	1828	12.4	11.3	93	10.33	35	8	301.9	332.7	303.8	58.7
793.5	2133	11.4	9.9	90	9.71	50	11	303.9	333.2	305.7	53.7
765.2	2438	10.3	8.4	88	9.13	65	14	306	333.7	307.6	49.4
763	2462	10.2	8.3	88	9.08	66	14	306.1	333.8	307.8	49.1
760	2495	10.2	8.1	87	8.99	68	13	306.5	333.9	308.1	48.5
755	2550	11.8	-18.2	11	1.21	71	12	308.8	312.9	309	22.4
749	2617	13.8	-16.2	11	1.45	74	10	311.6	316.6	311.9	22.2
737.8	2743	13.3	-16.7	11	1.41	80	8	312.5	317.3	312.7	21.6
700	3184	11.6	-18.4	11	1.29	70	7	315.3	319.8	315.5	19.7
661.3	3657	10	-20	10	1.19	90	3	318.7	322.9	318.9	17.5
651	3787	9.6	-20.4	10	1.17	94	4	319.6	323.8	319.9	17.0
613.3	4267	6	-24	9	0.9	110	7	320.9	324.2	321.1	15.0

California



Off the scale at -867 N units at only 386 meters

California End – 5.7 GHz

5.7 GHz
3983 km

Pressure	Height	TEMP	DWPT	RELH	Mixing ratio	Wind Direction	Wind Speed	THTA	THTE	THTV	Total Loss
hpa	m	C	C	%	g/kg	deg	Knots	K	K	K	(dB)
999	128	25.6	12.6	44	9.25	320	10	298.8	326.2	300.5	35.9
998.5	132	25.3	12.6	45	9.28	320	10	298.6	326	300.3	36.0
993	181	22	13	57	9.56	321	11	295.7	323.6	297.4	37.2
984	261	20.8	12.8	60	9.52	324	12	295.3	323	297	36.9
979.1	304	20.8	11.5	55	8.76	325	13	295.7	321.3	297.3	35.7
973	359	20.8	9.8	49	7.87	324	13	296.3	319.4	297.7	34.3
970	386	22	2	27	4.58	324	13	297.7	311.6	298.6	30.2
965	431	23.8	1.8	24	4.54	323	13	300	313.9	300.8	29.4
948	587	25.3	-4.7	13	2.86	320	12	303	312.1	303.6	26.1
945.7	609	25.6	-4.4	13	2.93	320	12	303.6	312.9	304.1	26.0
926	795	28.1	-1.9	14	3.61	317	11	307.9	319.5	308.6	25.2
913.7	914	27.8	-2.2	14	3.59	315	11	308.9	320.4	309.5	24.6
882.9	1219	27.1	-2.9	14	3.53	315	11	311.2	322.6	311.9	23.2
850	1556	26.4	-3.6	14	3.46	315	8	313.8	325.2	314.4	21.7
824	1828	24.6	-5.4	13	3.11	325	6	314.6	325	315.2	20.4
823	1839	24.5	-5.5	13	3.1	326	6	314.7	324.9	315.3	20.4
795.3	2133	22.1	-7.9	13	2.67	345	7	315.2	324.1	315.7	19.2
767.5	2438	19.6	-10.4	12	2.27	360	6	315.8	323.5	316.2	18.0
740.6	2743	17.1	-12.9	12	1.93	75	3	316.3	322.9	316.7	17.0
700	3227	13.2	-16.8	11	1.47	110	8	317.1	322.2	317.4	15.5

California End – 10.3 GHz

10.368 GHz
3983 km

Pressure	Height	TEMP	DWPT	RELH	Mixing ratio	Wind Direction	Wind Speed	THTA	THTE	THTV	Total Loss
hpa	m	C	C	%	g/kg	deg	Knots	K	K	K	(dB)
999	128	25.6	12.6	44	9.25	320	10	298.8	326.2	300.5	66.4
998.5	132	25.3	12.6	45	9.28	320	10	298.6	326	300.3	66.7
993	181	22	13	57	9.56	321	11	295.7	323.6	297.4	69.8
984	261	20.8	12.8	60	9.52	324	12	295.3	323	297	69.0
979.1	304	20.8	11.5	55	8.76	325	13	295.7	321.3	297.3	65.2
973	359	20.8	9.8	49	7.87	324	13	296.3	319.4	297.7	60.6
970	386	22	2	27	4.58	324	13	297.7	311.6	298.6	46.4
965	431	23.8	1.8	24	4.54	323	13	300	313.9	300.8	45.2
948	587	25.3	-4.7	13	2.86	320	12	303	312.1	303.6	36.1
945.7	609	25.6	-4.4	13	2.93	320	12	303.6	312.9	304.1	36.1
926	795	28.1	-1.9	14	3.61	317	11	307.9	319.5	308.6	36.8
913.7	914	27.8	-2.2	14	3.59	315	11	308.9	320.4	309.5	36.0
882.9	1219	27.1	-2.9	14	3.53	315	11	311.2	322.6	311.9	34.0
850	1556	26.4	-3.6	14	3.46	315	8	313.8	325.2	314.4	32.0
824	1828	24.6	-5.4	13	3.11	325	6	314.6	325	315.2	29.2
823	1839	24.5	-5.5	13	3.1	326	6	314.7	324.9	315.3	29.1
795.3	2133	22.1	-7.9	13	2.67	345	7	315.2	324.1	315.7	27.0
767.5	2438	19.6	-10.4	12	2.27	360	6	315.8	323.5	316.2	24.4
740.6	2743	17.1	-12.9	12	1.93	75	3	316.3	322.9	316.7	22.7
700	3227	13.2	-16.8	11	1.47	110	8	317.1	322.2	317.4	19.8