Extended Distance Cloudbounce Tests

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On 22 November, Ken, VK7DY went portable using the 35 photo-diode receiver to determine the distance he could copy Rex's 60 Luxeon transmitter via cloud bunce. It was found that voice could be copied at 36 km and WSJT at 48 km.

Portable Equipment

The following shows the 35 photo-diode receiver mounted in the back of Ken's van which provides a stable platform and allows a useful amount of Azimuth and Elevation adjustment.

Ken used a Laptop and external battery pack to provide several hours operation without any hum problems as occur with switch mode power supplies. The Receiver was aligned by transmitting a tone and peaking azimuth and elevation on Spectran in a bandwidth of 0.084 Hz.

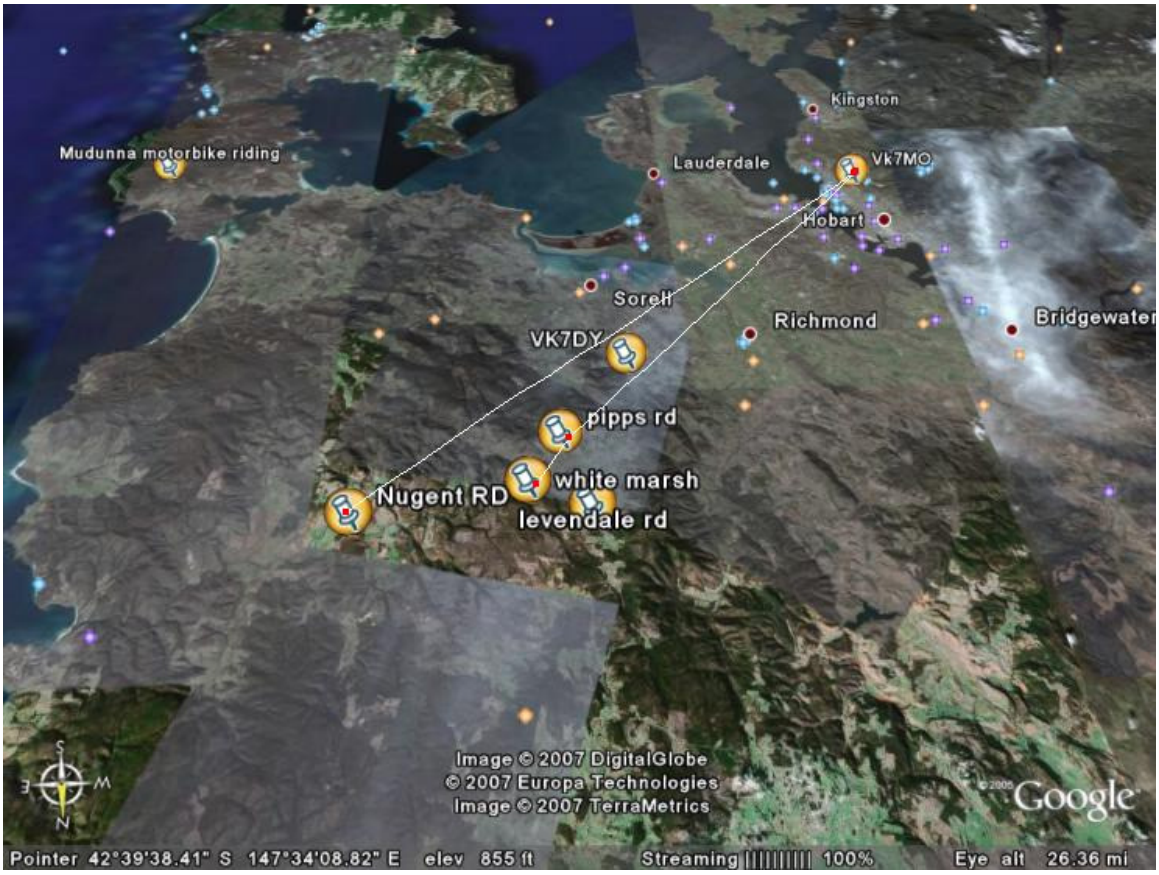
Locations

The following diagram shows the locations for the tests to Rex VK7MO's QTH from:

Pipps Rd 36 km

White March 42 km
Nugent Rd 48 km

Pipps Road is a high location around 300 meters and while out of line of sight would give a very low angle horizion – around 1 degree. White Marsh and Nugent Rd are much lower with an horizon angle of a few degrees.



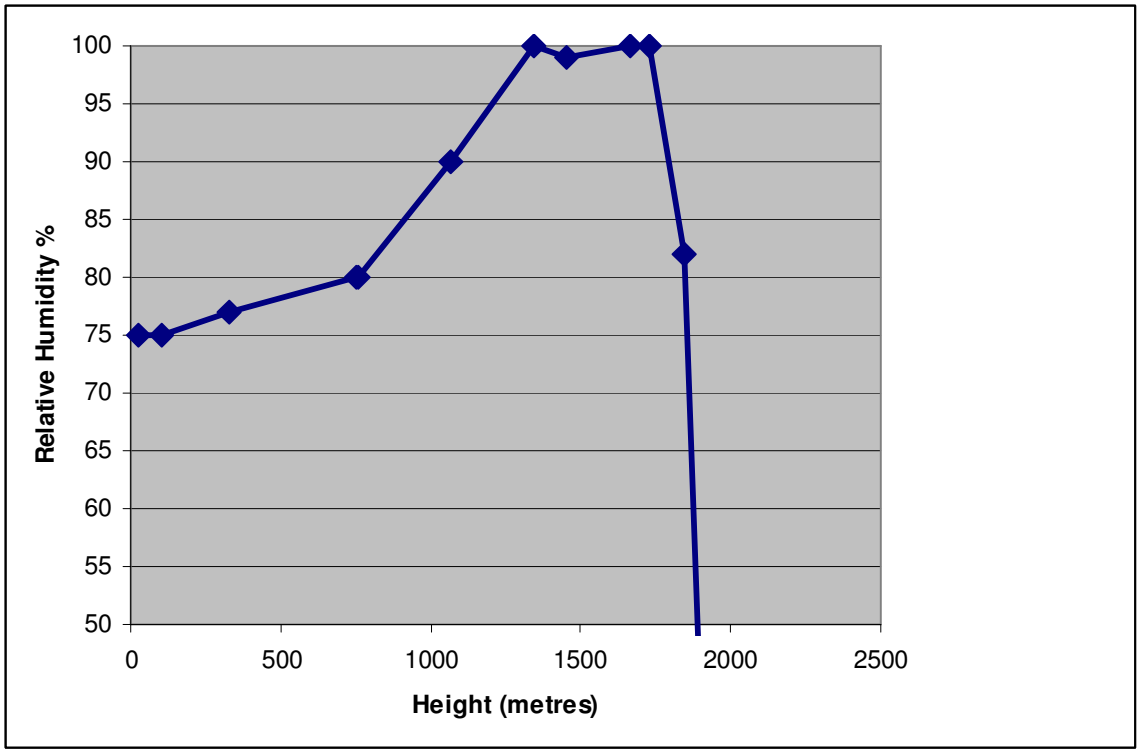
Meteorology

The airport meteorological reports, which is roughly in the middle of the paths, were as follows compared to signal strength at each location.

Date Time UTC		Temp Deg F	Dew Point Deg F	Relative Humidity	Wind Direction	Wind Speed knots	Visibility Miles	Lower Cloud report	Cloud height feet	Cloud height metres	Next Cloud Report		Distance km
22/1300	29.88	59	39	48	290	9	6.2	FEW045	4500	1372		Nugent Rd	48
22/1230	29.88	59	41	51	310	9	6.2	FEW044	4400	1341	BKN053		
22/1200	29.88	61	45	55	240	6	6.2	FEW040	4000	1219	BKN048	White Marsh	42
22/1130	29.88	59	50	72	190	6	6.2	BKN045	4500	1372			
22/1100	29.88	61	50	68	130	5	6.2	BKN050	5000	1524		Pipps Rd	36
22/1030	29.88	61	48	63	170	9	6.2	FEW040	4000	1219			
22/1000	29.85	61	50	68	190	10	6.2	FEW045	4500	1372	SCT250		
22/0930	29.83	63	41	45	270	11	6.2	FEW045	4500	1372			
22/0900	29.85	64	41	42	260	15	6.2	FEW045	4500	1372	SCT240		

The cloud reports of FEW and BKN are consistent with the visual observation at each end of the path that is was mainly a clear sky with stars showing through. However on these relatively long paths the horizon shows the total cloud and tends to give a more continuous cloud band for cloudbounce.

A radiosonde is released at the airport at 1200 z (Yellow above) and the humidity profile was as below:



It is seen that the Relative Humidity reached 100% at around 1350 meters consistent with the cloud height given by the airport reports. 1350 meters provides a useful window to transmit light over the Meehan range at 300 to 350 metres around 10 km from Rex's QTH.

Results

Pipps Road, 36 km: WSJT full copy at -8 dB and weak voice but sufficient to copy an unknown word.

White March, 42 km: WSJT full copy at -13 dB to 14 dB but too weak for voice

Nugent Rd, 48 km: WSJT full copy at -21 dB

Signals at all locations were very consistent varying by no more than one dB which suggests to us that for these long paths the variability of clouds averages out given the relatively wide beamwidth we are using.

It is seen that the signal level is dropping quite rapidly with distance at around 1 db per km suggesting that under these conditions signal levels would drop to the WSJT limit of around -28 dB at around 55 km. Of course we do not know if signals might vary considerable under other conditions although compared to our best results of -4 dB at 27 km it would appear that conditions were in fact very good on this night.

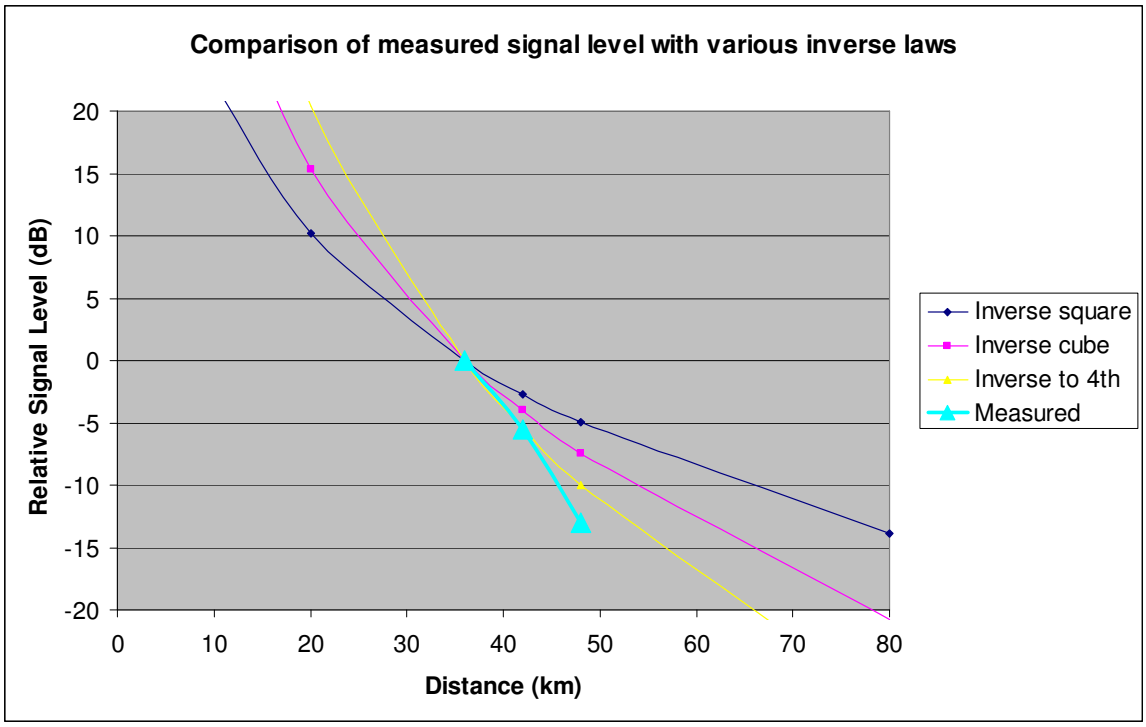
Discussion

(Note: This discussion raises some issues with the measurement of signal levels in optical systems and at this stage is put forward more as speculation to encourage further discussion)

As pointed out by Yves F1AVY the wide beamwidths we are using means that signal levels will tend to fall as the inverse the 4^{th} power of distance as signal is lost around the reflecting target at long distance. This compares to the 2^{nd} power for narrow beamwidth laser systems.

We tend to agree with Yves as the angular window between the mountains and the clouds will reduce as the distance increases although this may not be directly proportional to distance and some more geometry is need to investigate this. The horizontal dimension is more problematic as at long distances the full beamwidth tends to be intercepted by clouds. However the clouds at wider angles may not scatter significant energy to the receiver and thus this component of the signal is also likely to exhibit a reduction at increased range such that the inverse to the 4^{th} power would apply as proposed by Yves.

We have found that an increase in transmitter power of 3 dB produces a 6 dB improvement in output signal to noise ratio. This sounds like something for nothing but the explanation seems to be that for light receivers the received signal is a voltage proportional to the number of photons and as the number of photons increases with a doubling of input power the signal increases by 3 dB in terms of voltage giving a 6 db gain in power. Now while this is great for improving system performance this characteristic of light receivers works in reverse as one increases the distance and thus reduces the photons at the receiver. In effect this means that the received voltage reduces by the 4^{th} power as proposed by Yves but he received signal to noise ratio reduces by the square second power so signals reduce by the sixth power. This results in an extremely rapid drop in received signal to noise ratio with distance as shown in the following diagram. The something for nothing principle seems to apply also to our use of multiple phot-diodes.



Note that the graphs are marked at the second, third and 4th power based on the reduction of photons, but include the additional affect due to the fact that we are measuring voltage to show the effect in terms of signal to noise ratio. We have included our actual measured results that compare reasonably with the 4th power reduction as proposed by Yves (which in practice is a 6th power reduction in signal to noise ratio for an optical receiver. It is seen that in fact the signal is dropping even faster than the inverse 4th power for photons (ie inverse 6th power for signal to noise ratio) which would be expected due to atmospheric absorption. We see this as early days in understanding light propagation as this was not what we would call a carefully controlled experiment and equipment set up and cloud conditions and path geometry could all be important factors.

CONCLUSION

Our results show that with our system of 60 Luxeons and 35 photo-diodes it is possible to achieve voice transmission over 36 km and digital transmission with WSJT over 48 km. We note, however that the signal levels are dropping extremely rapidly which suggests we are very close to the limiting distance for this sort of system.