78 GHz DX'ing in the Desert Southwest

By Barry Malowanchuk VE4MA

As a winter resident of Arizona for a number of years now, I have heard many stories of the great long distance 10 GHz QSOs from Arizona Mountain tops. The only regular activity on 10 GHz has occurred during the ARRL "10 GHz & Up" Contest in the late summer, when the temperatures are very high and with high humidity that severely affects the bands above 10 GHz. During the winter months the Arizona temperatures are much lower and the atmosphere very dry and thus more supportive of long distance QSOs at 24, 47 and 75 GHz. This paper will discuss efforts to explore the possibilities for real DX on 75 GHz.

Distance Records

The records for microwave frequencies are kept by the ARRL at www.arrl.org and for early 2019 the records for 47 and 75 GHz are shown in Figure 1.

47 GHz			
Tropo (C)	344.8	AD6FP /6 (DM07as) - W6QIW/6 (DM04ms)	19-Sep-15
Tropo (C)	343	W6QI/6 (DM04ms) - AD6FP/6 (DM07bs)	30-Oct-05
Tropo (C)	246	W0EOM/6 (CM97ei) - KF6KVG/6 (DM06ms)	9-Feb-03
Tropo (C)	232	KB8VAO/6 (CM96qi) - AD6FP/6 (DM04ms)	18-Sep-04
Tropo (C)	215	KT1J/N1JEZ (FN34bi) - VE2UG/VE3FN (FN26rf)	30-Jun-16
Tropo (C)	205	N1JEZ/1 (FN44ig) - WA1MBA/1 (FN42bl)	3-Jul-05
Tropo (C)	174	W3IY/4 (FN10ff) - W4SW/4 (FM08us)	14-Nov-01
Tropo (C)	120	NU7Z (CN87ms) - KD7TS (CN96aw)	4-Oct-03
75 GHz			
LOS	289	AD6IW (CN90fl) - KF6KVG (CM97av)	23-Jun-14
LOS	289	AD6IW (CN90fl) - K6GZA (CM97av)	23-Jun-14
LOS	205	N1JEZ/1 (FN44ig) - WA1MBA/1 (FN42bl)	19-Sep-14
LOS	177	AD6FP/6 (CM88qp) - KF6KVG/6 (CM97ad)	1-Mar-02
LOS	177	W0EOM/6 (CM88qp) - KF6KVG/6 (CM97ad)	1-Mar-02
LOS	110	K2AD (EM96ur) - W2SZ (FM07fm)	20-May-99

Figure 1 ARRL 47 & 75 GHz Distance Records March 2019

Notably the distances for both bands are similar in spite of the fact that 47 GHz equipment has enjoyed the benefit of possibly having receiver and transmitter amplifiers for a number of years now. Amplified equipment has only become available recently for 75 GHz. The distance limitation is mostly imposed by the requirement for Line of Sight (LOS) visibility between

stations. Of course with low powers and poor receivers the option of going beyond the horizon has not been an option.

75 GHz Propagation

On Line of Sight paths the path loss is defined as 20 log (4πd/λ), which can be calculated. At frequencies above 10 GHz there are atmospheric absorptions caused by Oxygen and Water Vapor in the air. Brian WA1ZMS has generated a convenient set of curves for the microwave bands from 24 to 411 GHz and are available at www.wa1mba.org . The curve for 76 GHz is shown in Figure 2 below.

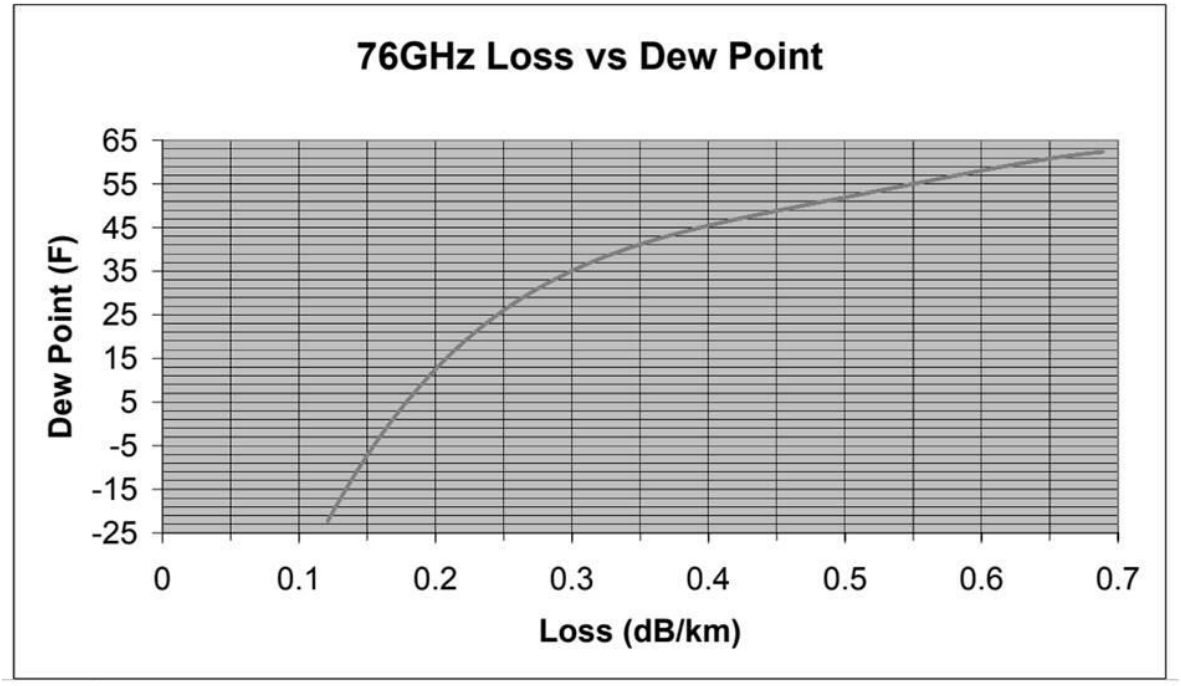

Figure 2 WA1ZMS Atmospheric Loss Chart for 75 GHz

It can be seen that even at very low "dew point" temperatures, the additional path loss due to atmospherics is greater than 0.1 dB / km. Thus on a 200km path that is an additional 20 dB of loss. This loss increases dramatically as the temperature increases above freezing (32 deg. F) to 55 dB! Fortunately as the altitude increases in order to gain a longer LOS distance, the temperature normally drops as well as atmospheric pressure, so this tends to lower the calculated atmospheric losses. So a good Line of Sight and a very low Dew Point temperature over the length of the path are essential for very long distance QSOs.

Path Selection

The two (2) most important aspects of planning 78 GHz path tests are of course “Locations” (the LOS path) and the weather forecast. I was indeed fortunate to have some veteran Arizona 10 GHz operators available to provide advice on locations that could be used for long distance tests. Unfortunately 10 GHz is very much like a VHF band in that it propagates very well over the horizon (non-LOS paths) and stations generally have a much higher ERP than is possible on the mmWave microwave bands.

Once a list of possible paths was developed it was necessary to evaluate each path with software to see if the paths were LOS or obstructed. We know that at 10 GHz obstructed or knife edge paths can work, but we have NO experience for anything like this at 24, 47 or 78 GHz. Several software packages were used including freeware like “Radio Mobile” and “Hey Whats That” and a commercial product. The freeware products provided conflicting results for marginal LOS paths and so they were evaluated with the commercial software thanks to Brian WA1ZMS. “Hey Whats That” does provide good results however and the learning curve is not so steep on its use. It provides a list of all points visible with the bearing and distance.

Initially we wanted a short hop, just something to check out the equipment on locally and then at a short distance (~60 km) . There are mountains that ring around the City of Phoenix, with many hiking trails and good access, so that if was not a problem to find a 60 km hop.

Of course I was looking for the ultimate DX path…one that would break the existing record of 289 km but I was disappointed. There are many hops in the 265 km range and some that are close to 280 km but are subject to the uncertainty of the LOS.

There is a hop in Southern Arizona from Mt. Lemmon (near Tucson) to White Tanks (Just west of Phoenix and the distance is 207 km (120 mi). This hop is covered on 1.2 and 2.4 GHz for linking digital ATV repeaters, using a 2.4 m (8ft) dish. The path profile is shown in Figure 3.

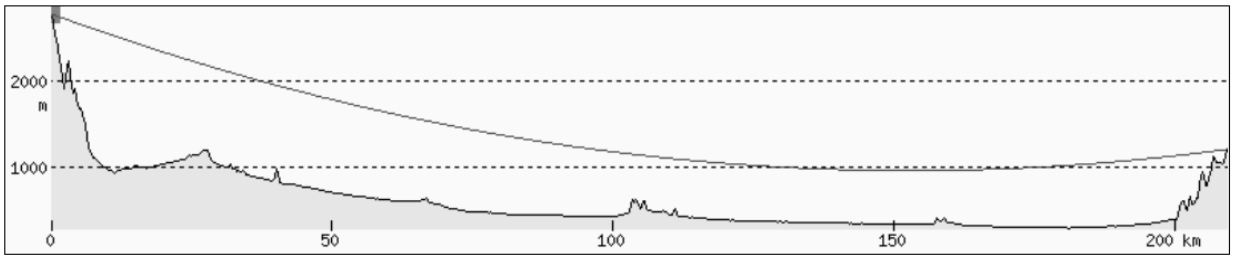

Figure 3 Mt Lemmon to White Tanks 207 km Path Profile

A longer 265 km hop exists from Mt Lemmon to Mt Union (NW of Phoenix near Prescott) and the path profile is shown in Figure 4.

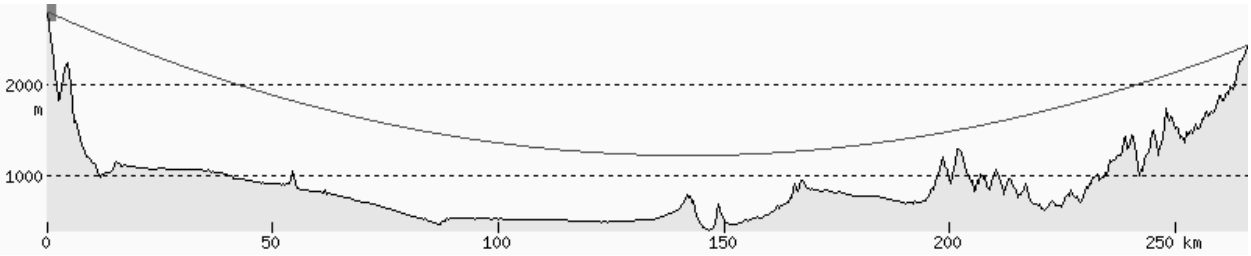

Figure 4 Mt Lemmon to Mt Union 265km Path Profile

As mentioned earlier the ability to knife edge or go over the horizon is unknown as yet. A 280km hop exists from Mt Lemmon to Mt Harquahala which has some obstruction (~ 10 m or 35 ft). This hop was studied closely and the most optimistic path profile used the commercial software and is shown in Figure 5. Other similar slightly obstructed hops exist elsewhere that could be record breakers.

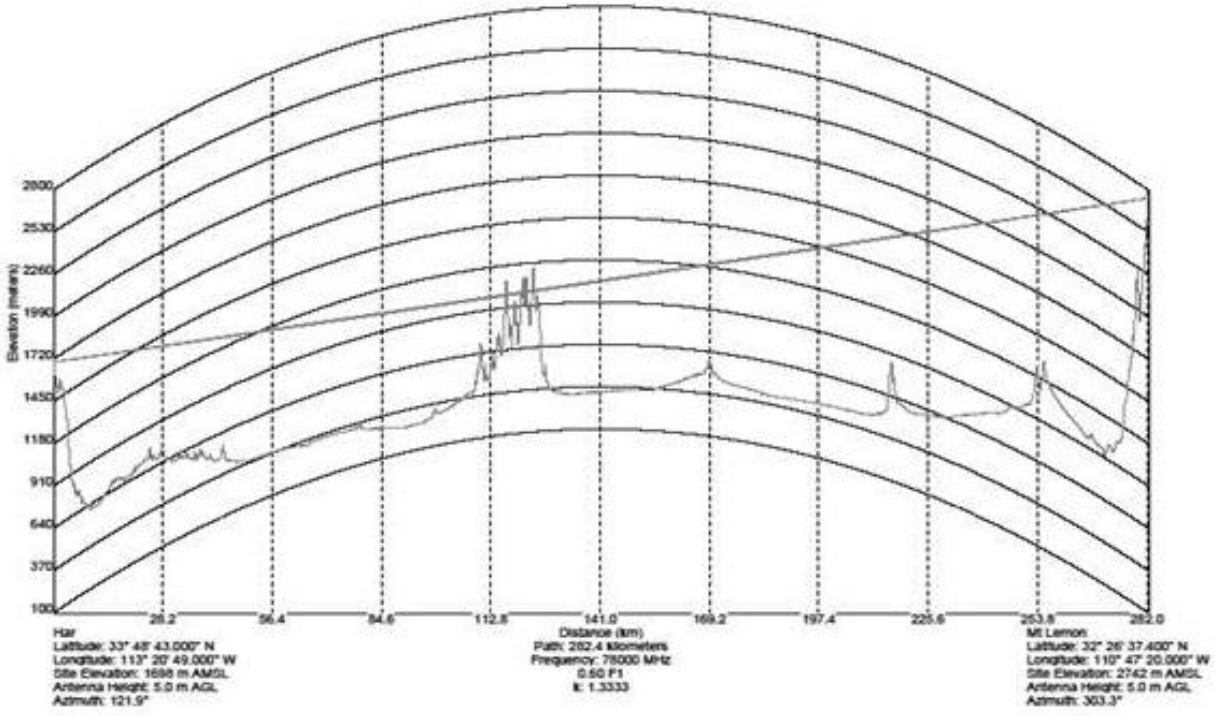

Figure 5 Mt Harquahala to Mt Lemmon 280 km

Arizona Weather

Of course we know "It Never Rains in Arizona"….at least that is the way IT WAS BEFORE 2019. Usually weeks would go by with sunny dry weather. In the winter of 2018/2019 The amount of rain was twice (2X) the normal amount and it seemed like it rained about every third day. The Historical Annual

Humidity levels for Phoenix are shown in Figure 6. It shows that the weather should be dry from December until near the end of May.

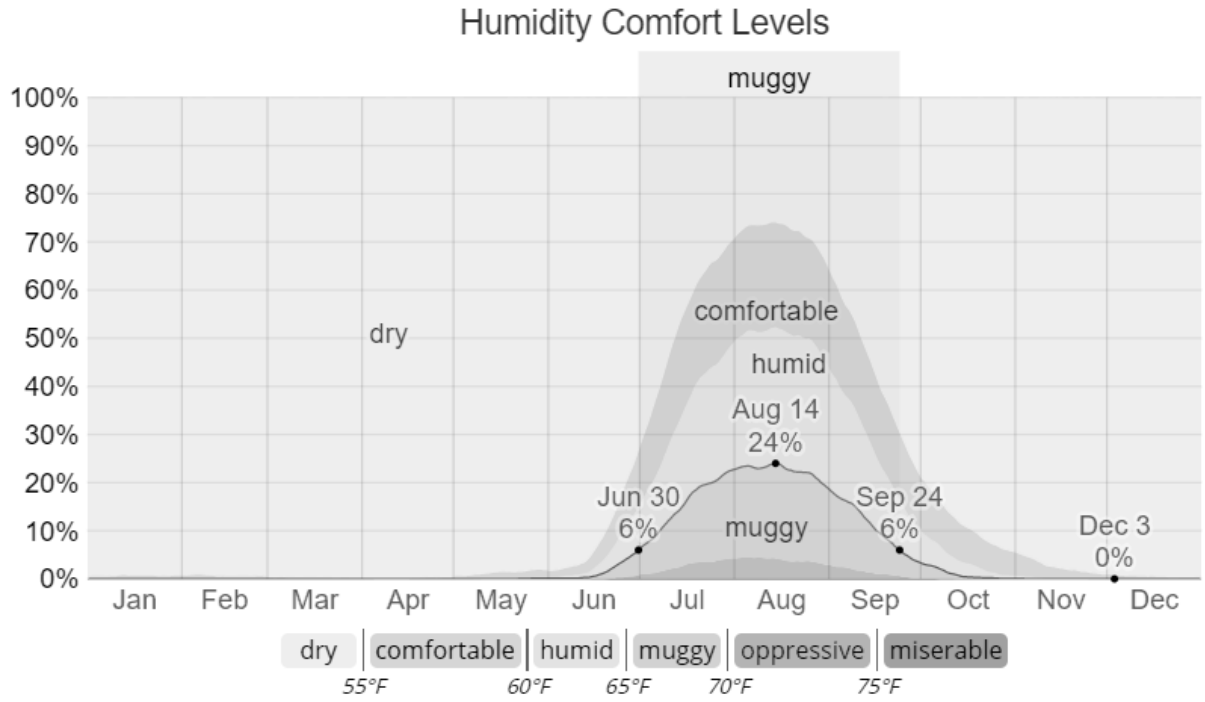

Figure 6 Historical Annual Humidity Levels for Phoenix

The weather was so unsettled in January & February and not looking very good at the beginning of March. The Dew Point temperatures were just not coming down below 30 degrees F. I began looking at the forecasts from "Weather Underground" and they were showing a period of 3 days with very low (20 deg. F) Dew points for Phoenix (see Figure 7). The average Dew Point temperature for a hop has to be "guess-timated" since the information is not available for all locations. Phoenix being the approximate low point in the hop should have the greatest influence, but the end points at high altitude should have values much lower.

It is notable that the Dew Point was shown to be lowest on March 8, 9 & 10 with a return to the rainy weather pattern starting on Monday March 11. It also showed a period of very high winds on Friday March 8. Notably this weather forecast remained unchanged as the days approached. These dates fit in well with the availability of other stations and me. The group was scheduled for these dates.

The Operating Groups & Equipment

With the short notice of this activity not everyone was able to attend. Two groups were assembled, the first one with Mark N0IO from Colorado, Bill W7QQ from New Mexico and who were escorted by Kevin AD7OI & Tammy KI7GVT. The second group included Barry VE4MA, Al W5LUA from Texas, Tony K8ZR from Ohio, Jim K0KFC from Wisconsin and who were escorted by Steve KJ7OG and Ron K7RJ and his wife Clare.

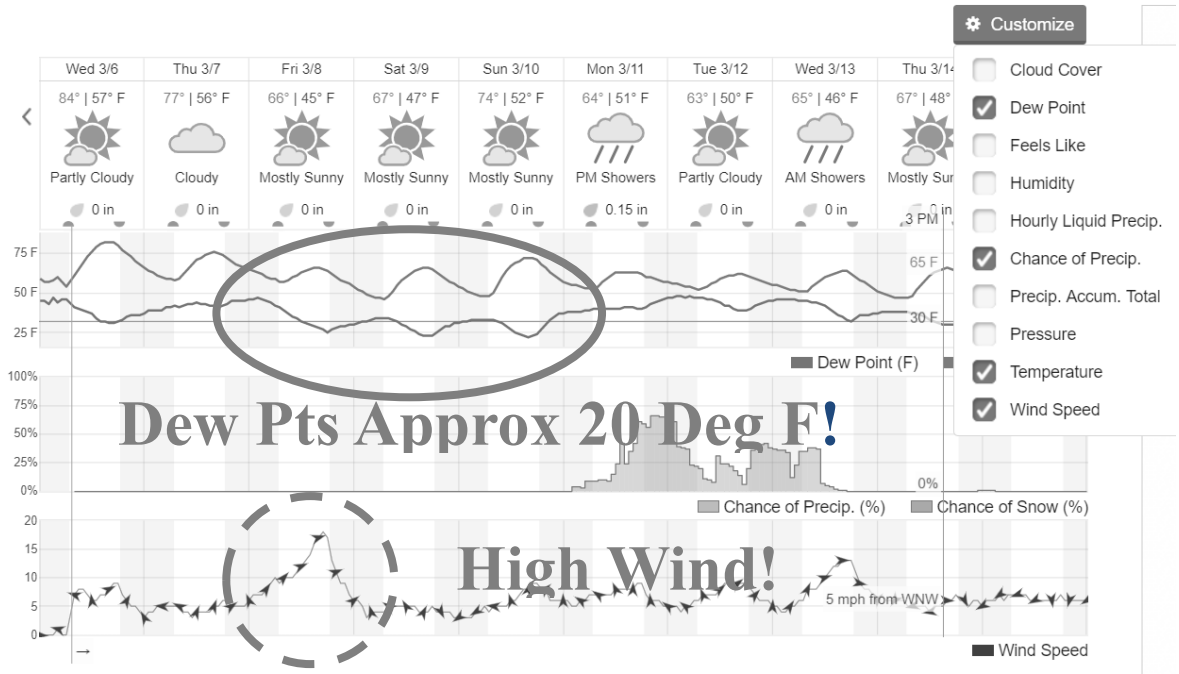

Figure 7 Phoenix Weather Forecast for Early March 2019

The organization of the groups was so that all bands from 10 to 78 GHz were available at both ends. We also were able to make use of a linked 2m repeater for liaison although 10 GHz would prove valuable in this regard as well as for optimizing antenna pointing.

The "75 GHz" amateur band was expanded in 2017 to include the spectrum from 76 to 81 GHz, which is the spectrum used by vehicular radar system. For this event we chose to operate at 78192 MHz since 3 of the rigs did not have frequency agility and had been configured for this. The path loss is actually lower at 78 GHz than at 76 GHz where most of the world operates. The equipment for 78 GHz was very important since we were expecting the most difficulty to cross long paths at this frequency. Four of the Five Stations incorporated WA1MBA receive preamplifiers giving an approximate 5 dB noise figure. All stations were capable of high power (0.25 to 1 W) but by the 2017 license restriction we adjusted our TX powers to produce the allowed 55 dBm (315 W) ERP. Three of the stations used 30 cm (12 in) dishes with 10 mW of power while the fourth station uses a lower gain long horn and correspondingly more TX power for the same ERP.

Operating Results Day #1 Friday March 8, 2019

We began the day by reconfiguring K8ZR's station to operate on 78 GHz. Tony's earlier work in Ohio and Michigan was on 76032 MHz. This was easy to do with his programmable Kuhne PLL Lo and Image Rejection Kuhne transverter. We then did a basic check to ensure that all rigs were operating before we moved to our first operating position near the San Tan Mountain. The second group moved to Shaw Butte in North Central Phoenix, which gave us an LOS path of 63 km (39 mi). See the path profile in Figure 8. Signals were very strong with SSB used on all bands through 78 GHz. As forecast in the weather shown in Figure 7, we suffered from strong winds which unfortunately toppled the 10/24 GHz rig at one point. The setups are shown in Figures 9, 10 & 11. The two groups met for dinner in Phoenix that night,

as it was the only chance to get together. Unfortunately Jim K0KFC had to return to Wisconsin due to a family emergency, but was able to leave his 10/ 24 GHz rig for liaison purposes.

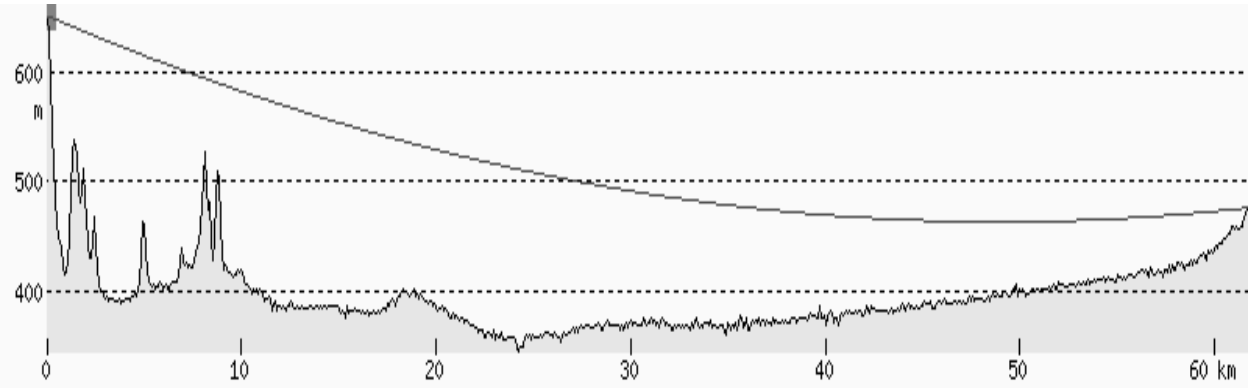

Figure 8 Shaw Butte to San Tan Mountain Park Path Profile

Figure 9 W5LUA's 47/78 GHz & K8ZR's 78 GHz Setup at San Tan Mountain Park

Figure 10 VE4MA with K0KFC's 10/ 24 GHz Liaison Rig at San Tan Mountain Park

Figure 11 N0IO & W7QQ 24, 47 & 78 GHz Setup on Shaw Butte

Operating Results Day #2 Saturday March 9, 2019

The drive from my winter home in Apache Junction, to the summit of Mt Lemmon was nearly 3 hours. We met with Steve KJ7OG, his wife Clare and Ron K7RJ for lunch in Tucson and afterwards proceeded up a fully paved road to the astronomical observatory at the summit where Steve, who is an alumnus of the University of Arizona, had arranged for access. The ground was snow covered but firm and the winds light with a temperature of about 30°F or -1°C (see Figure 12 & 13).

Figure 12 W5LUA, K8ZR, & VE4MA with 78 GHz on Mt Lemmon

The second team again met up with Kevin AD7OI and Tammy KI7GVT and made the journey up the rough road to the White Tanks Mountain site, which with the lower altitude was considerably more comfortable than mount Lemmon with no snow (see Figure 14).

A 10 GHz beacon exists atop White Tanks and this was used to provide initial antenna alignment from Mt Lemmon and after shutting off the beacon, 10 GHz became the means of liaison. 78 GHz signals from N0IO were quickly established at Mt Lemmon, but there was difficulty in the opposite direction. After some chatter to allow system optimization, an intermittent coaxial cable connection was found and solid S7-8 QSOS were concluded. The" trouble shooting" process at White Tanks was videoed and is available on YouTube by searching for 78 GHz W7QQ-VE4MA. This strength of signals is clearly apparent on this video. Notably the smaller 47/78 N0IO rig with Horn antennas was just as strong as the dish rig as it had the same ERP (see Figure 15). In additional QSOs were made by W5LUA, K8ZR, N0IO and W7QQ on 47 GHz.

Figure 13 The View from Mt Lemmon towards White Tanks

Figure 14 Aerial Drone View of N0IO, W7QQ & AD7OI on White Tanks

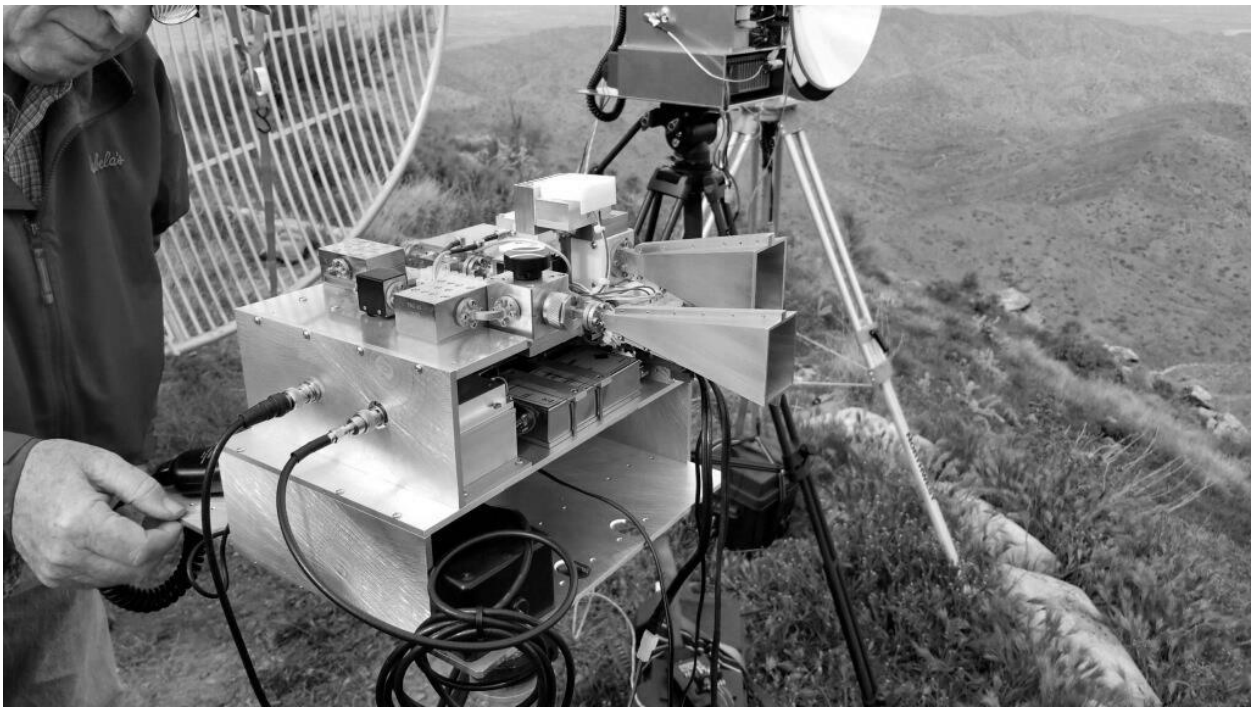

Figure 15 W7QQ with N0IO's Rover Rig for 47 & 78 GHz

Operating Results Day #3 Sunday March 10, 2019

We had originally intended to try the Mt Lemmon to Mt Union 164 mi (265km) path, however Mt Union was not accessible do to over 3ft (1m) of snow that had fallen in the previous week. But buoyed by the outstanding signals on Saturday we were quite optimistic with our chances to make it on the 173 mi (280 km) Mt Lemmon to Mt Harquahala path (see Figure 5). We expected however that the obstruction loss might make it difficult. We assembled in Tucson about 10 am and the weather was marvelous, sunny and about 70°F or 21°C, however as we got within a few thousand feet (1 km) of the summit the weather started to change with cloud rolling in and very high winds causing the pine trees to move violently ! We got set up at the same location; however it took 3 people to mount the 30 in 10/24 liaison dish and 2 people to hold it up! W5LUA and K8ZR set up their equipment downwind of their vehicles. The VE4MA 78 GHz rig was held down with a large cement block and tethered to a guyed street light standard (see Figure 16). Operating the FT817 Radio in the cold wind required headphones and bare hands.

The team at Harquahala drove on another difficult mountain road but did not get any of the bad weather conditions and had a spectacular view (see Figures 17 & 18).

We were able to establish contact on 10 GHz but the signals were very poor. No signals were found on 47 or 78 GHz in spite of numerous attempts! This was truly disappointing and we looked for an explanation. We later obtained the weather data (see Figure 19) and found that the sustained winds on Lemmon were 50 mph (80 km/h) with gusts to 64 mph (104 km/h). More significantly for 47 & 78 GHz was that the Dew point temperature had climbed dramatically to about 30°F or -1°C. This is a significant

increase from 0°F or -18°C on Day 2 and would have given an addition loss of ~ 28 dB, which is certainly enough to kill any signals on this path.

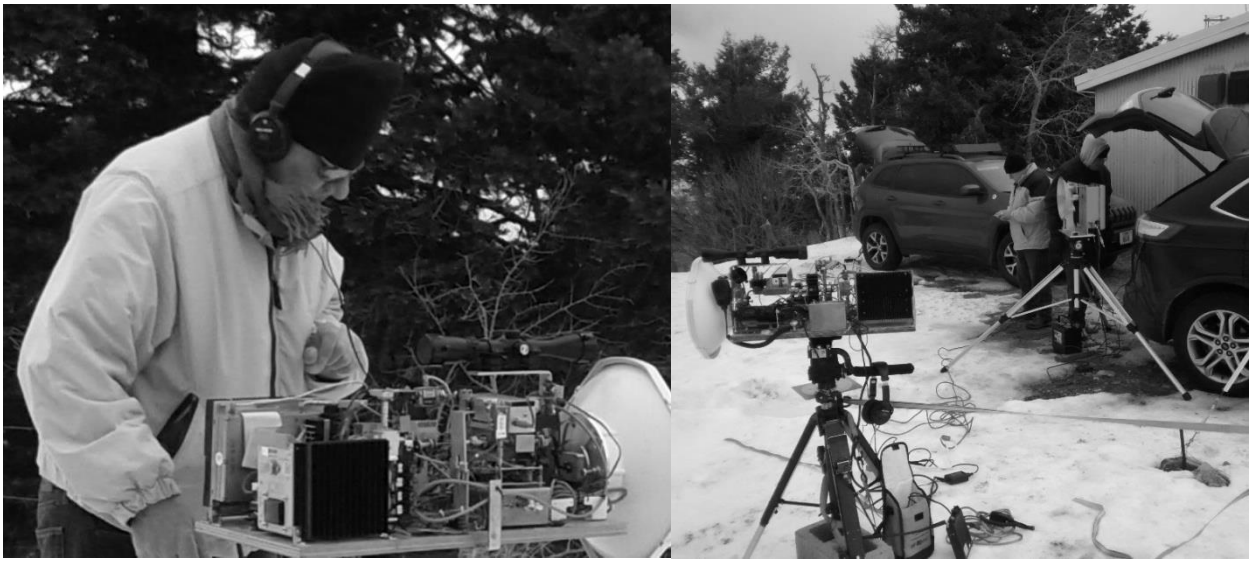

Figure 16 Miserable Windy & Cold Operating Conditions on Mt Lemmon

Figure 17 View from Mt Harquahala

Summary

We certainly were able to show that Arizona can provide some excellent mmWave paths when the weather cooperates! We look forward to going back to test Mt Lemmon to Mt Union and further trying to break the 289 km world record. We also want to test on 122 & 241 GHz and optical frequencies.

On behalf of the team members I would like to extend our appreciation to Steve KJ7OG, his wife Clare, Ron K7RJ, Kevin AD7OI, Tammy KI7GVT and Jim K0KFC for their support in planning, executing and documenting this adventure.

Figure 18 Second Group Operating at Mt Harquahala

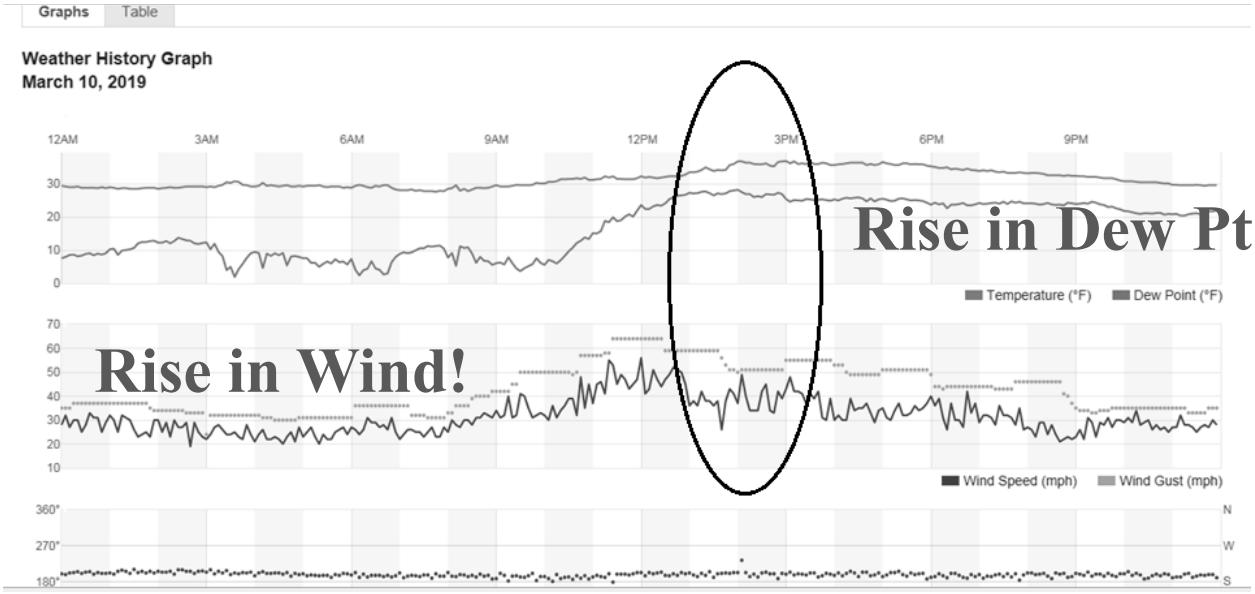

Figure 19 Mt Lemmon Weather Information for Day 3 Tests