Analysis of an FT8 6-Meter QSO
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On February 28, 2018 around 1502 UTC, Larry KØTPP in Missouri (38.45º N / 90.57º W) worked Mike N3DGE in Pennsylvania (40.00º N / 75.20º W) on 6-Meters using FT8. KØTPP reported that N3DGE was at an SNR (signal-to-noise ratio) of -21 dB. Here's the screen capture of this QSO (from hamspots.net):

Age	DX	Freq	Sig	Mode	St	Country	Spotter	
		6m ▼	Set Band					
3m	W4IMD	50313.96	-07	FT8	GA	United States	N4AU	
5m	W4IMD	50313.98	-18	FT8	GA	United States	N4AU	
6m	W4IMD	50313.98	-18	FT8	GA	United States	N4AU	
8m	W4IMD	50313.97	-18	FT8	GA	United States	N4AU	
12m	KC3BVL	50314.33	+17	FT8	PA	United States	N3DGE	
13m	NY3C	50314.51	-10	FT8	DE	United States	N3DGE	
14m	NY3C	50314.51	-09	FT8	DE	United States	N3DGE	
15m	NY3C	50314.52	-15	FT8	DE	United States	N3DGE	
16m	N3DGE	50314.51	-21	FT8	PA	United States	K0TPP	<<<
17m	N3DGE	50314.52	-15	FT8	PA	United States	N4AU	
22m	W4IMD	50313.98	-10	FT8	GA	United States	N4AU	
25m	W4IMD	50313.97	-17	FT8	GA	United States	N4AU	
27m	W4IMD	50313.98	-13	FT8	GA	United States	N4AU	
31m	W4IMD	50313.96	+4	FT8	GA	United States	N4AU	
32m	W4IMD	50313.98	-09	FT8	GA	United States	N4AU	
32m	HB4YKR	50313.83	-24	FT8		Switzerland	K0TPP	
36m	W4IMD	50313.98	-12	FT8	GA	United States	N4AU	
44m	XM8PTJ	50314.34	-24	FT8		Canada	N4AU	
44m	W4IMD	50313.97	-19	FT8	GA	United States	WS4S	
46m	KG9D	50313.68	-11	FT8	TN	United States	WS4S	
+1h	KG9D	50313.69	-14	FT8	TN	United States	WS4S	
+1h	KG9D	50313.69	-13	FT8	TN	United States	WS4S	
+1h	KG9D	50313.69	-15	FT8	TN	United States	WS4S	

I confirmed this QSO with both KØTPP and N3DGE to make sure the decoding of the calls was correct. This is an East-West path of 1333 km (829 miles), passing over southern Pennsylvania, northern West Virginia, southern Ohio, southern Indiana and southern Illinois. KØTPP's antenna is a 10-element LFA (Loop Fed Array) on a 60-foot boom [note 1]. N3DGE's antenna is a 4-element Yagi, and he was running 75 Watts.

The first order of business is to estimate N3DGE's signal strength at KØTPP's QTH assuming the MUF (maximum useable frequency) is sufficiently high (around 50.3 MHz) to allow refraction via either the E region (including sporadic E) or the F2 region. Of course we think this is a fictional assumption since February is for all intents and purposes a non-Es month and we're nearing solar minimum between Cycles 24 and 25. But it's a good starting point for further analysis.

Using Prx = Ptx + tx ant gain + rx ant gain – free space path loss – absorption – gnd refl loss, we can estimate the maximum signal strength (actually signal power). The result of this calculation is a received signal power of -53 dbm. I also added some cable loss to get from the rigs to the

antennas, I've assumed ionospheric absorption is minimal due to it being inversely proportional to the square of the frequency and I've assumed there are no ground reflection losses due to this likely being a one-hop path.

The -53 dBm signal power is about S9 + 20 dB – a reasonable value for this path <u>if</u> the MUF was high enough for pure refraction. Since FT8 reports SNR (signal-to-noise ratio), let's go one step farther and add in KØTPP's noise to get an SNR for this condition. From pictures on his www.qrz.com page, I'll assume that he is in a rural noise environment.

Using the ITU (International Telecommunication Union) document Recommendation ITU-R P.372, the man-made noise at 50 MHz is -121 dBm in 2500 Hz (2500 Hz is the bandwidth in which FT8 SNR is reported). Atmospheric noise (lightning discharges) at 50 MHz is well below this value in February. Thus the maximum signal power under ideal ionospheric conditions gives an SNR of +68 dB (the difference between -53 dBm and -121 dBm). Obviously KØTPP's reported SNR of -21 dB suggests that the MUF was not high enough to give pure refraction.

So how was this QSO made? Let's look at three possibilities: tropospheric ducting, tropospheric scatter and ionospheric scatter.

Tropospheric Ducting

Here's the Hepburn Tropo Index (http://www.dxinfocentre.com/tropo.html) for February 28.
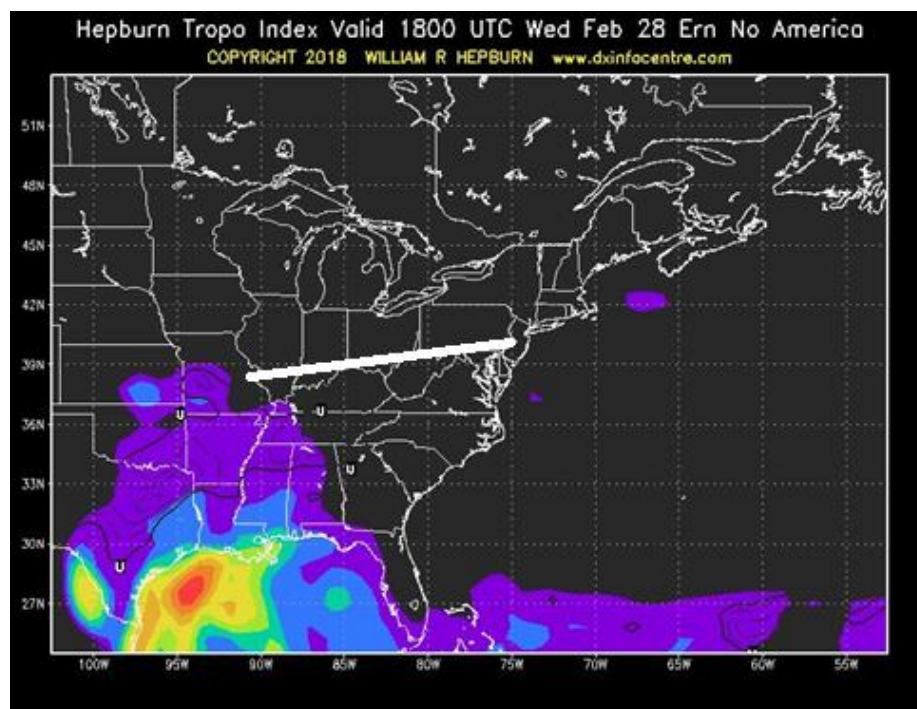
The N3DGE-to-KØTPP path is the thick white line added to the map. From the legend on the home page of the web site, it does not appear that tropospheric ducting was the mechanism on

this path across southern Pennsylvania, northern West Virginia, southern Ohio, southern Indiana and southern Illinois on February 28, 2018.

Tropospheric Scatter

The distance over which tropospheric scatter is effective is limited by the height of the tropospheric scattering area. The height of the tropospheric scattering area is roughly 10 km, which puts the maximum distance at 713 km assuming a zero degree radiation angle.

With horizontal antennas, a 0° elevation angle is not feasible as there is a null in the elevation pattern on the horizon. A 5° elevation angle is more reasonable, which requires the 6-Meter antenna to be about 60 feet. The maximum distance for this condition is 210 km. An antenna height of 100 feet would put the peak of the main lobe at 3°, which gives a maximum distance of 310 km.

Due to the short distances involved (remember that the N3DGE-to-KØTPP path is 1333 km), it does not appear that tropospheric scattering was the mechanism for this QSO.

Ionospheric Scatter

We know that ionospheric scatter occurs because of actual observations, and VOACAP includes an above-the-MUF mode that may account for some of these observations. This above-the-MUF mode was the focus of my October 2017 QST article [note 2], and is based on Phillips-Abel theory [note 3].

When the operating frequency is above the MUF, refraction does not occur. But some form of scatter (forward, side, back) may occur to allow the QSO to still be completed. Additional loss is incurred with scatter [see the plot in note 4], so the ability to decode signals below the noise may be necessary. JT65 and FT8 offer this, and appear to offer a decided advantage over CW [see the text in the article referenced in note 4].

For our analysis of the N3DGE-to-KØTPP path, the SNR degraded from +68 dB at 75 Watts transmit power for pure refraction to -21 dB as reported by FT8. This is a loss of 89 dB, which suggests from the plot in note 4 that the MUF was down around 50 MHz – 8.5 MHz = 41.5 MHz. Could the ionosphere have briefly provided a MUF this high so near solar minimum? One way to possibly find out is to look at ionosonde data.

But there isn't an ionosonde near the midpoint of the N3DGE-to-KØTPP path (which would be southern Ohio). The best we can do is look at data from the closest ionosondes – which are Alpena, MI (about 500 km away from the midpoint), Wallops Island, VA (about 600 km away) and Eglin AFB, FL (about 1000 km away).

Unfortunately Alpena only has individual ionogram data, not tabular data that can be imported into Excel. Wallops Island only has tabular data through 0415 UTC on February 17 – and there are even significant gaps in this limited data. I also looked at Boulder, CO ionosonde (extremely

far away from the midpoint) but the F2 region data is contaminated with interference that gives bogus results.

That leaves the Eglin AFB data for a full set of data. Here is the plot of the F2 region MUF for a 3000 km path for Eglin AFB for the 28 days of February 2018.

3000 km F2 Region MUF over Eglin AFB
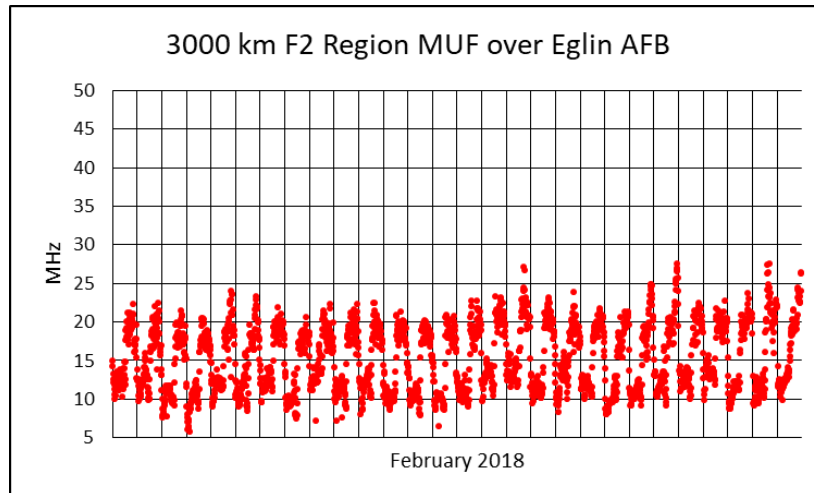
It's easy to see the diurnal variation of the F2 region – it's highest during the day and lowest during the night. And the monthly median MUF would be reported to be around 23 MHz during the best time of the day – a reasonable value for being near solar minimum at this low-latitude observing station. So there's nothing unusual going on here in the F2 region to move the MUF anywhere near 41.5 MHz.

As a side note, the data from the Alpena ionosonde around the time of the QSO is similar to the Eglin AFB data. And the limited Wallops Island data is in general agreement with the Eglin AFB data. The bottom line from all the ionosonde data is that there aren't any unusual higher F2 region MUFs. Now let's look at the E region – specifically the sporadic E layer (Es).

Here's the Eglin AFB sporadic E critical frequency (foEs) data for the 28 days of February 2018.

foEs over Eglin AFB
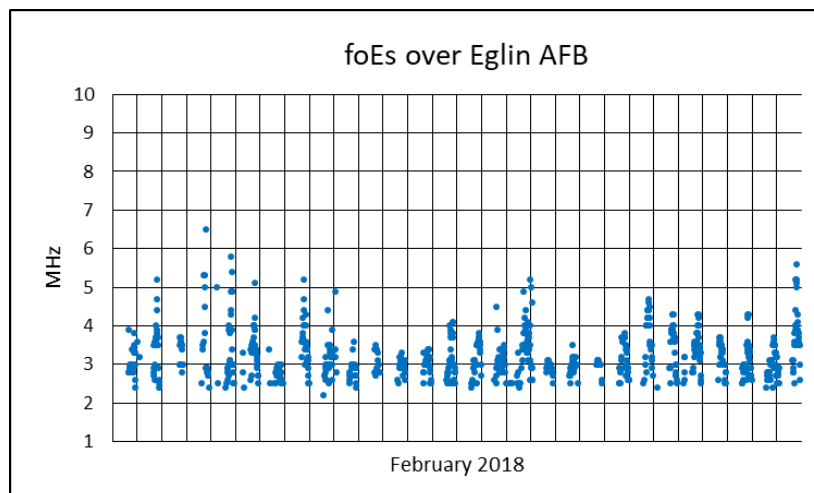
Since the M-factor [note 5] for the E region is around 5, the MUF for a 2000 km path via the E region would be in the neighborhood of 25 to 35 MHz.

I should point out the cadence of the Eglin AFB ionosonde is 15 minutes – in other words, data is taken every 15 minutes. Thus there easily could be more echoes of foEs above 6 MHz. It is interesting that sporadic E occurs at a low occurrence rate in February.

This also says higher F2 region echoes could have been missed, too. Although we didn't see any short-term high MUFs from the F2 region, they have shown up in the scientific literature. For example, single-day dayside electron density enhancements in the F2 region have been observed over Europe [note 6]. Similarly, we should all be aware of short-term pings on 10-Meters and 6-Meters, which are likely due to either Es or meteor trails.

The bottom line here is that the ionosphere is much more dynamic than what our monthly median model of it suggests. Short-term events appear to occur on a regular basis that aren't captured in the monthly median model.

And I personally believe that there are many ionospheric irregularities that could be conducive to scattering – but are not 'visible' to an ionosonde. In other words, the ionosphere is not a smooth and homogeneous medium.

<u>Summary</u>

I believe ionospheric scatter is a plausible explanation for this FT8 QSO on 6-Meters and others on 6-Meters – even when the 'normal' MUF is well below 50 MHz. Since additional loss is incurred, JT65 and FT8 with their ability to decode at negative SNRs may still allow the QSO to be completed.

Notes

1. http://www.innovantennas.com/our-antennas/view/category/virtuemart_category_id/3.html

2. Carl Luetzelschwab K9LA, *Understanding Propagation with JT65, JT9 and FT8*, **QST**, October 2017, pages 45-47

3. J. L. Wheeler, *Transmission Loss of Ionospheric Propagation Above the Standard MUF*, **Radio Science**, Vol. 1, No. 11, November 1966

4. Here's the plot on the first page of *Above-the-MUF Propagation and JT65/FT8 Advantages Over CW*, Carl Luetzelschwab K9LA, March 2018 Monthly Feature, **https://k9la.us**
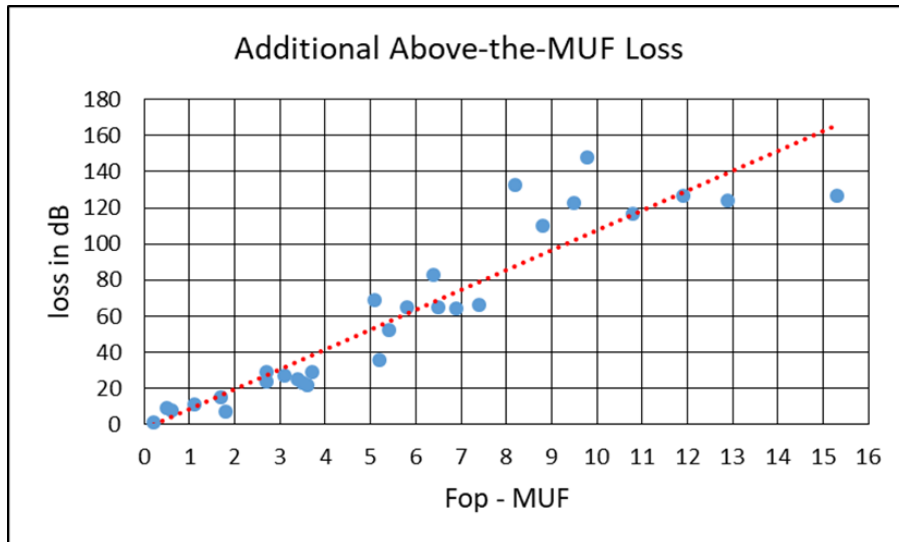
5. The M-factor is the value that the critical frequency of a region is multiplied by to determine the MUF. The M-factor is inversely proportional to the height of the peak electron density, and is around 3 for the F2 region and around 5 for the E region.

6. Michael David and Jan J. Sojka, *Single-day dayside density enhancements over Europe: A survey of a half-century of ionosonde data*, **Journal of Geophysical Research**, Vol 115, A12311, 2010