Analysis of an FT8 6-Meter QSO

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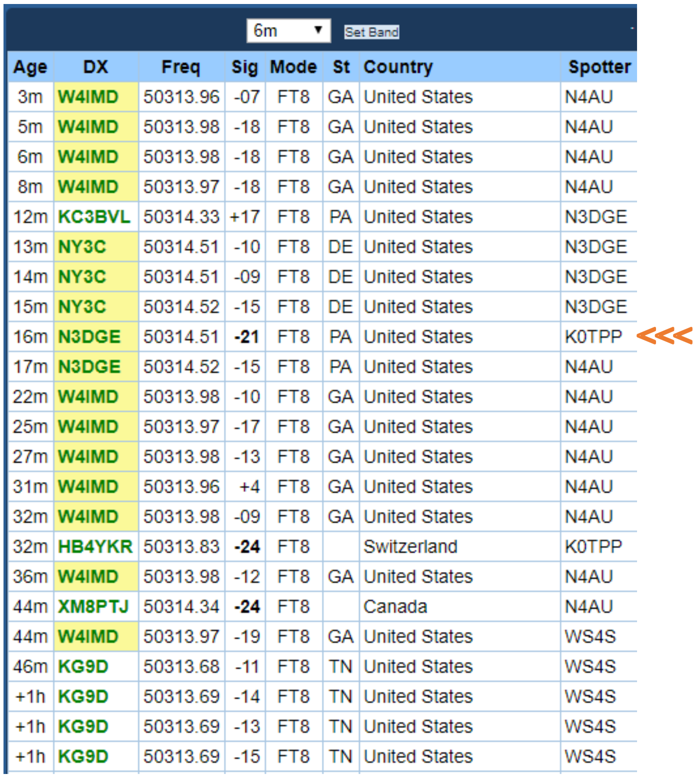
On February 28, 2018 around 1502 UTC, Larry K0TPP in Missouri (38.45° N / 90.57° W) worked Mike N3DGE in Pennsylvania (40.00° N / 75.20° W) on 6-Meters using FT8. K0TPP reported that N3DGE was at an SNR (signal-to-noise ratio) of -21 dB. Here's the screen capture of this QSO (from hamspots.net):



Age	DX	Freq	Sig	Mode	St	Country	Spotter
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 K0TPP 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 Ohio, southern Indiana and southern Illinois. K0TPP'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 K0TPP'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 know this is a fictional assumption since we're nearing solar minimum between Cycles 24 and 25 and February is for all intents and purposes in a non-Es month. 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 being a one-hop path.

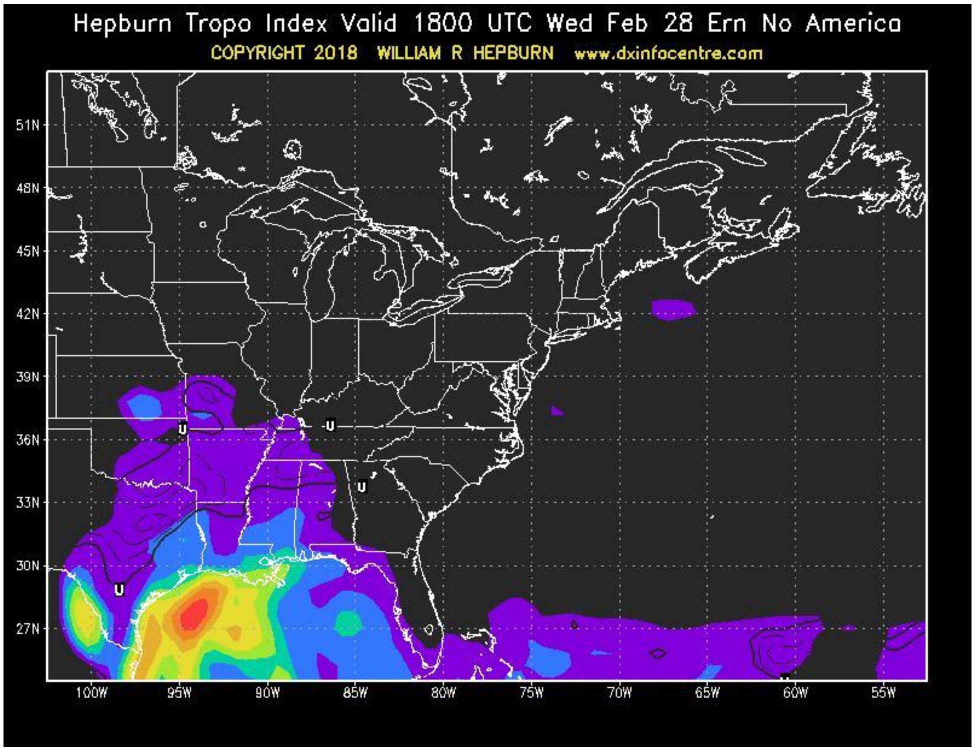
The -53 dBm signal power is about S9 + 20 dB – a reasonable value for this path if the MUF was high enough for pure refraction. Since FT8 reports SNR, let's go one step farther and add in KØTPP's noise to get an SNR for this condition. From pictures on his www.qrz.com page, I'll assume that he is in 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 at 50 MHz is well below this value. 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 confirms 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.



From the legend on the home page of the web site, there was no chance of tropospheric ducting on this path across southern Illinois, southern Indiana and southern Ohio on February 28.

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, this is not feasible as there is a null on the horizon. A 5° elevation angle is more reasonable, which requires the 6-Meter antenna to be at 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.

It does not appear that tropospheric scattering was the mechanism for this QSO.

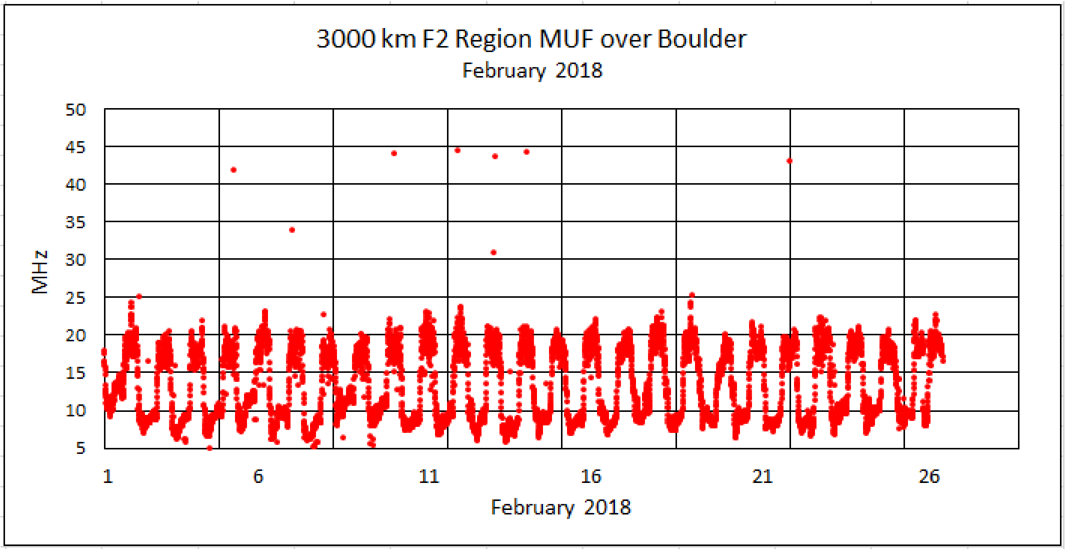
Ionospheric Scatter

We know that ionospheric scatter occurs because of actual observations, and VOACAP includes an above-the-MUF mode that accounts for 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 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 note 4].

For our analysis of the N3DGE-to-KØTPP path, the SNR degraded from +68 dB at maximum signal power under pure refraction to -21 dB as reported by FT8. This is a loss of 89 dB, which suggests from the graph 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?

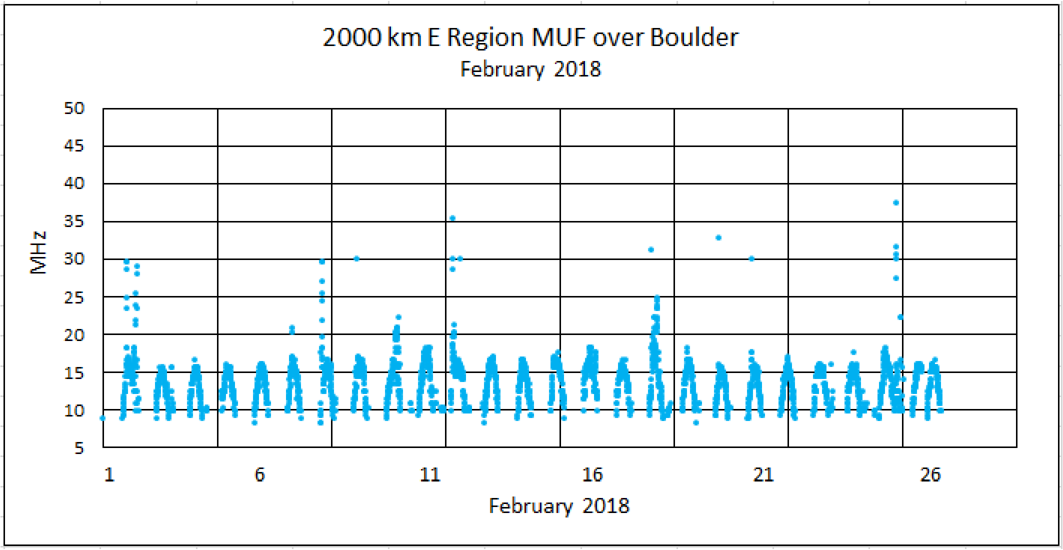
Let's take a look at data from the Boulder ionosonde for the month of February 2018. It takes data every 5 minutes. Here's the MUF data for the F2 region.



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 ‘normal’ MUF would be reported to be around 20 MHz during the best time of the day – a reasonable value for being near solar minimum at this mid-latitude observing station.

What’s more important here are the short-term high MUFs. Yes, there aren’t that many, but the Boulder ionosonde only takes data every 5 minutes – 12 times an hour. Thus there likely are a lot more unseen short-term high MUFs.

These short-term high MUFs are not limited to the F2 region. Here’s Boulder data for February 2018 for the E region.



Again, the diurnal variation of the E region is easily seen. After looking at the individual ionograms at the times of the short-term high MUFs, it appears that these high MUFs in the E region are associated with sporadic E. That’s an interesting observation – that sporadic E can occur at a low level in February – but not high enough to allow CW/SSB/RTTY contacts.

These short-term high MUFs from the F2 region 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 5]. 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.

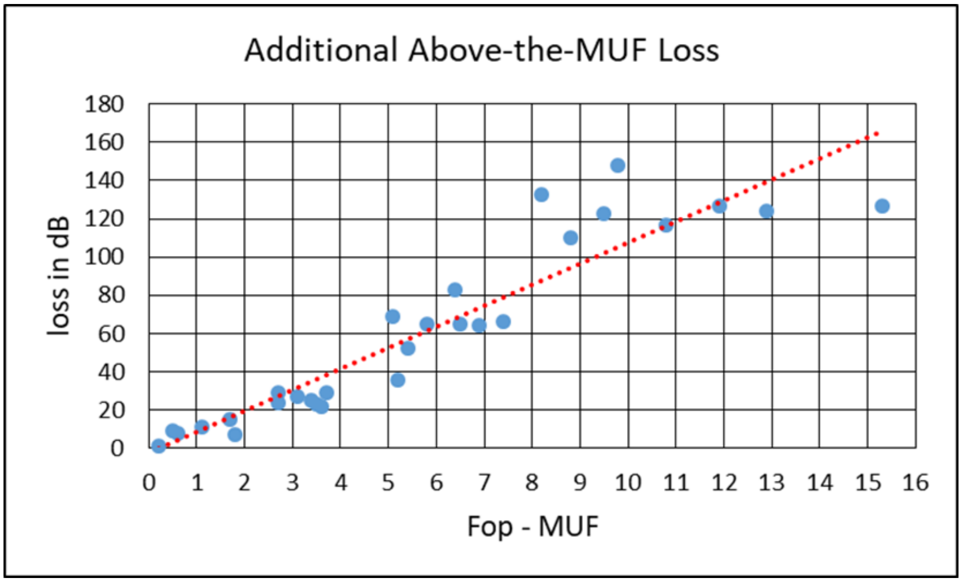
Also, I personally believe that there are many ionospheric irregularities that could be conducive to scattering – but are not ‘visible’ to an ionosonde. In other words, the ionosphere is not a smooth and homogeneous medium.

Summary

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 large 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. 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