An Interesting Night on 40-Meters and 160-Meters
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Earlier this year I received an e-mail from Jim KR9U, who is one of the locals here in Fort Wayne and a fellow 160-Meter aficionado. He commented that his weekly Tuesday evening sked at 9 PM local (0200 UTC on February 18) with Bill NE9Z (a former Fort Wayne resident now living near Jackson, WY) on 40-Meters was rather unusual. Initially they could barely hear each other, but as the QSO progressed Bill's signal went to 40 dB over S9 – the strongest he has ever heard Bill.

Later that evening around midnight he checked 160-Meters, and said it was the best he had heard it in years. He said it was hard to tell the EU stations from the stateside stations. So what happened on 40-Meters? What happened on 160-Meters? And were these two observations related? Let's take a look at some space weather data to see if we can figure this out. With respect to the great conditions on 160-Meters, I was already in bed at midnight – so the old saying "you snooze, you lose" was very applicable to me.

Figure 1 shows the planetary K index (Kp) for the period in question.

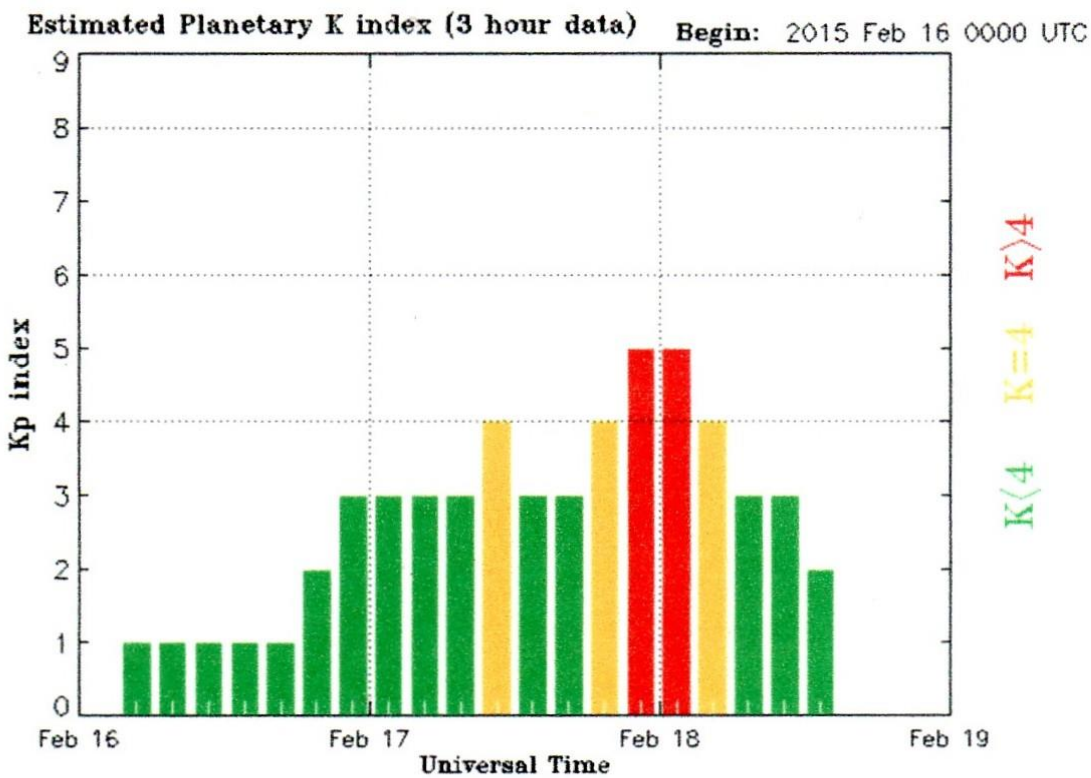

Figure 1 – Kp During the KR9U-NE9Z Sked

Around the time of KR9U's sked (0200 UTC on the 18th), the K index spiked up to 5 for two three-hour periods. It wasn't a major geomagnetic disturbance, as it settled back down rather quickly. This short-lived spike is a clue for the great propagation seen by

KR9U on 160-Meters. In fact, many other topbanders have reported similar enhancements concurrent with a spike in the K index.

I believe the mechanism for this enhancement is ducting becoming the dominant mode, as opposed to multi-hop. When the K index increases, the electric field in the ionosphere (in terms of mV/meter) increases. And when the electric field increases, the electron density valley in the nighttime ionosphere just above the E region peak becomes better developed – in other words, the valley is more conducive to ducting. Figure 2 shows this concept.

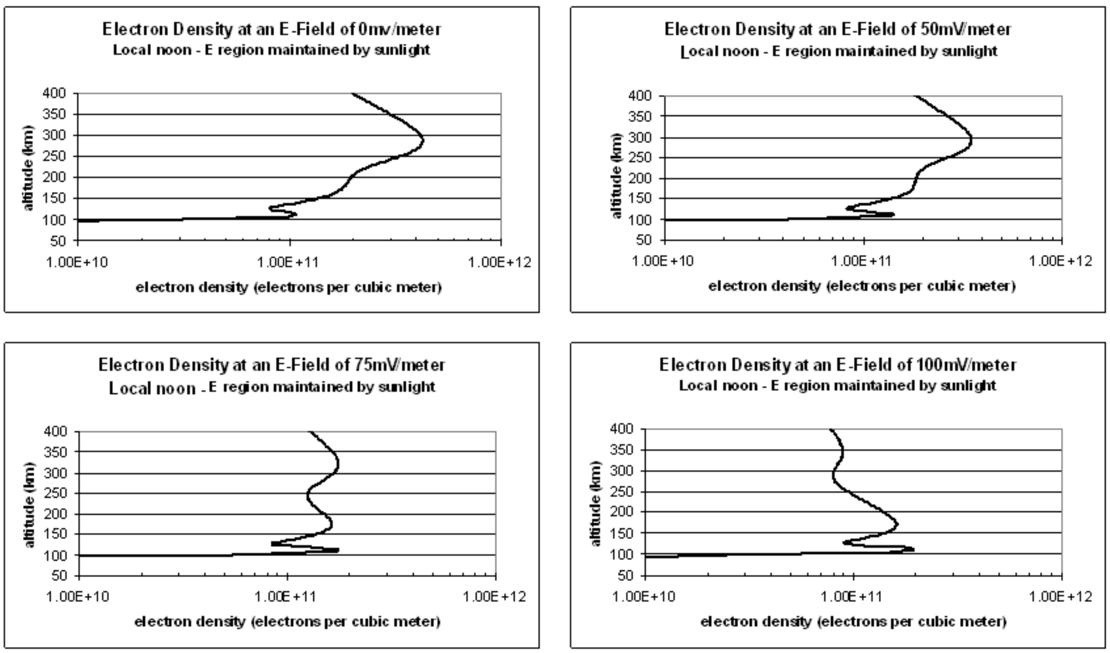

Figure 2 – Development of the Valley When the K Index Increases

These results are from Zhang, et al (*A modeling study of ionospheric conductivities in the high-latitude electrojet regions*, **Journal of Geophysical Research**, Vol 109, 2004), and they are simulated results for daytime conditions. Note that the valley is not well developed at 0 mV/meter (upper left) when the K index is low, but becomes nice and deep with a good lower and upper boundary at 50 and 75 mV/meter (upper right and lower left, respectively) as the K index elevates. At 100 mV/meter (lower right) the upper boundary is beginning to go away due to electron depletion in the F region from an even higher K index. Thus there appears to be a sweet spot in the K index for enhanced propagation for ducting on 160-Meters. Although these results are for daytime conditions, I would expect similar trends for nighttime conditions.

This certainly is a plausible explanation for what KR9U observed (and what others have observed) on 160-Meters, but does it have anything to do with KR9U's 40-Meter observation with NE9Z? My first reaction is "no" as the KR9U-NE9Z path is about 2080 km and could be covered with one hop – so why would ducting offer an advantage? I think we're going to have to dig a bit deeper for the 40-Meter observation.

So let's take a look at the possible modes between KR9U and NE9Z using ray tracing with Proplab Pro V3 (Solar Terrestrial Dispatch, Canada). We'll look at both the ordinary wave and the extraordinary wave, as they both propagate similarly on 7 MHz in terms of elevation angle and absorption (and they are both circularly polarized). Table 1 summarizes the important parameters for this path at 0215 UTC on February 18, 2015. The signal powers and S-meter readings at the receiver include the antenna gains at KR9U (2-element shorty-40 at 120 feet) and at NE9Z (rotatable dipole at 70 feet) with both stations running 1 kW.

Table 1 – Ray Tracing Results at 0215 UTC on 18 February 2015

	mode	elevation angle (degrees)	absorption (dB)	signal power at receiver (dBm)	S-meter reading at receiver
o-wave	1F	5.1	1.4	-54.4	S9 + 18.6 dB
o-wave	2F	22.3	1.3	-52.9	S9 + 20.1 dB
x-wave	1F	5.1	1.6	-57.3	S9 + 15.7 dB
x-wave	2F	22.1	1.6	-53.1	S9 + 19.9 dB

As can be seen, ray tracing confirms that the ordinary wave and the extraordinary wave propagate very similarly. The 2F waves arrive a bit stronger than the 1F waves. It's interesting why this happens. The 1F waves at 5.1 degrees do not incur a ground reflection, but 5.1 degrees is down quite a way in the antenna elevation pattern. The 2F waves at 22.3 degrees incur a ground reflection, but this is more than made up for by 22.3 degrees being nearer the peak gain of the antennas.

As for an explanation of the 40-Meter observation, several hypotheses come to mind.

1) Early on in the sked, the waves were arriving so that they cancelled each other, but later in the sked one of them dominated.
2) Early on in the sked, the lower strength 1F waves were the only ones propagating because the ionosphere couldn't support the higher angle 2F waves due to a lack of enough ionization.
3) Early on in the sked, none of the waves were supported via pure refraction – a weak scatter mode gave some signal early on and transitioned to pure refraction (with less loss) later in the sked.

To try to sort out the three hypotheses, I took a look at ionosonde data. The midpoint of the KR9U-NE9Z path is in southeast South Dakota, and the nearest ionosonde to this midpoint is in Boulder, CO (about 600 km southwest of the midpoint). Unfortunately there is no data on February 18, so we're out of luck with Boulder.

The next nearest ionosonde is at the Idaho National Lab in east central Idaho (about 1100 km west-northwest of the midpoint). Figure 3 is the ionogram at 0215 UTC on February 18.

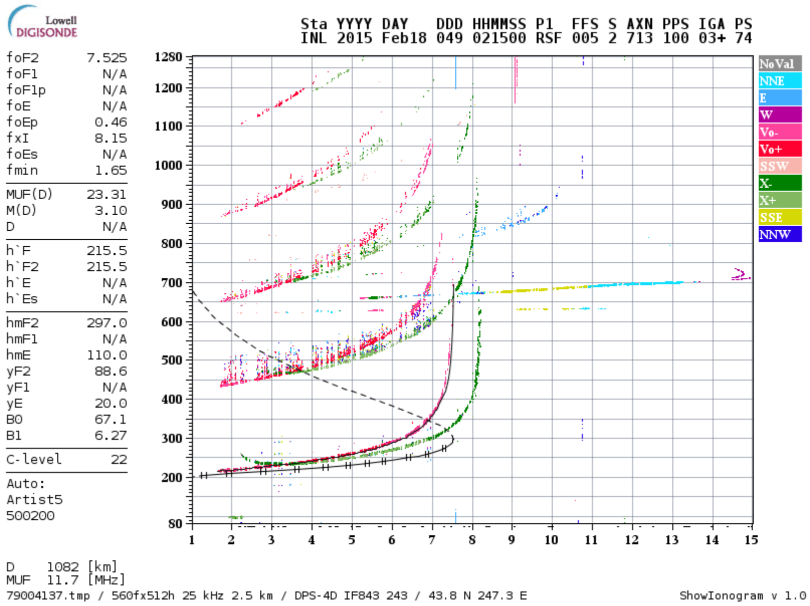

Figure 3 – Ionogram from Idaho National Lab

The lowest red trace is the ordinary wave, and the F2 region ordinary wave critical frequency (foF2 in the tabular data) is reported to be 7.525 MHz. The lowest green trace is the extraordinary wave, and the F2 region extraordinary wave critical frequency (fxI in the tabular data) is reported to be 8.15 MHz. The red and green traces up higher are simply multiple reflections between the ionosphere and the ground – they are not higher layers – and they do indicate that ionospheric absorption was low (also confirmed by f_{min} being down at 1.65 MHz). The low amount of absorption is not surprising since this is in the northern hemisphere in February when the Sun is low on the southern horizon.

The MUF for the one-hop mode at 5.1 degrees calculates to around 18 MHz. The MUF for the two-hop mode at 22.3 degrees calculates to around 11.5 MHz. So both the one-hop and two-hop modes would be supported. But these values are for the Idaho National Lab ionosonde, which is 1100 km farther west than the actual midpoint of the path – and the actual midpoint is more in darkness since it is farther east. Even taking this into account suggests both modes could still be supported.

There's another problem, too – the discrepancy between KR9U's reported S-meter reading later in the sked (S9 + 40 dB) and the ray trace S-meter reading (S9 + 20 dB). A decrease in absorption isn't likely as there's not much absorption to start with. Perhaps the 2F waves were dominant, and they incurred less loss in the ground reflection than Proplab predicted. Perhaps there's an enhancement at the NE9Z end resulting in more antenna gain than reported by my flat-ground model. Or perhaps something else is going on that we're not aware of. Of course Proplab could be erring on the low side, too.

In summary, I feel confident in the explanation for the 160-Meter observation. But any explanation at the moment for the 40-Meter observation is pure conjecture. And I don't know if the 160-Meter and 40-Meter observations were related – it's plausible to believe that they were, but an explanation in terms of ionospheric physics is needed.