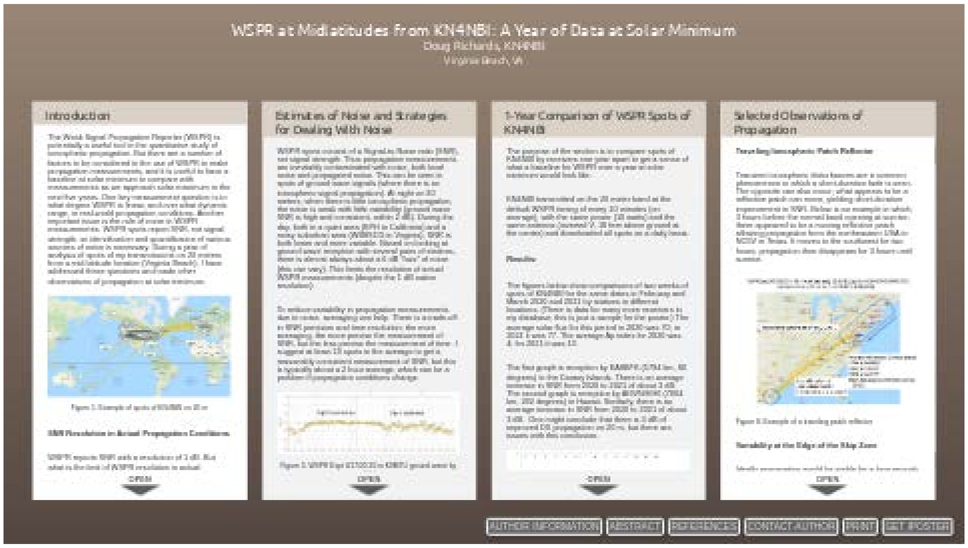
WSPR at Midlatitudes from KN4NBI: A Year of Data at Solar Minimum



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PRESENTED AT:

INTRODUCTION

The Weak Signal Propagation Reporter (WSPR) is potentially a useful tool in the quantitative study of ionospheric propagation. But there are a number of factors to be considered in the use of WSPR to make propagation measurements, and it is useful to have a baseline at solar minimum to compare with measurements as we approach solar maximum in the next five years. One key measurement question is to what degree WSPR is linear, and over what dynamic range, in real-world propagation conditions. Another important issue is the role of noise in WSPR measurements. WSPR spots report SNR, not signal strength, so identification and quantification of various sources of noise is necessary. During a year of analysis of spots of my transmissions on 20 meters from a mid-latitude location (Virginia Beach), I have addressed these questions and made other observations of propagation at solar minimum.

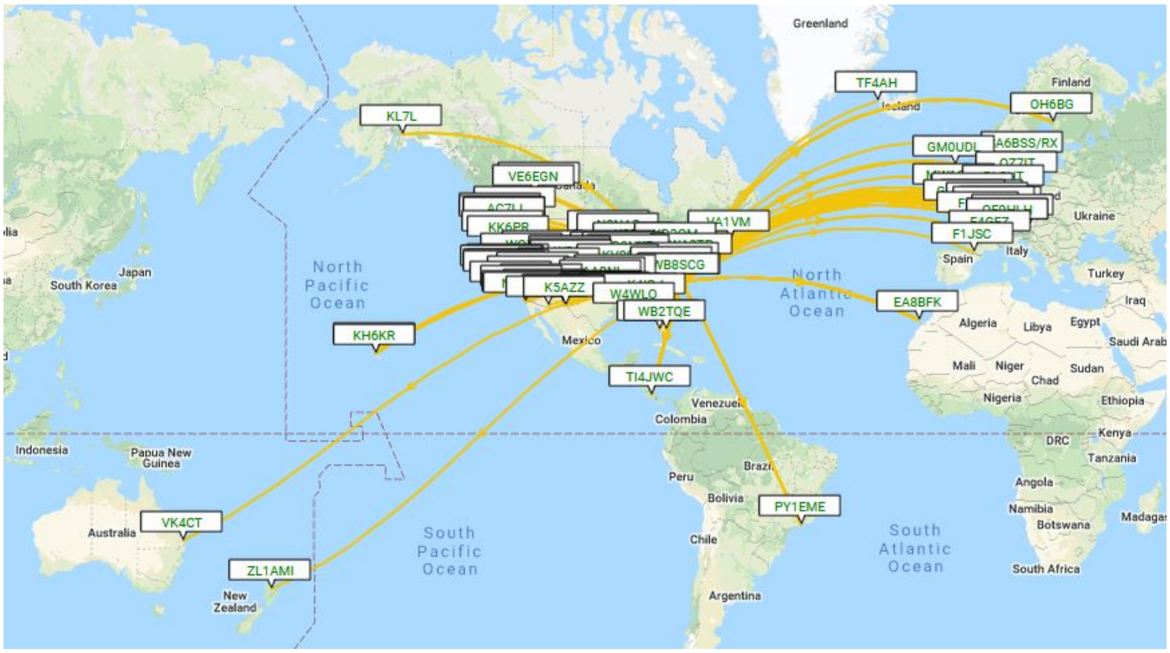

Figure 1. Example of spots of KN4NBI on 20 m

SNR Resolution in Actual Propagation Conditions

WSPR reports SNR with a resolution of 1 dB. But what is the limit of WSPR resolution in actual propagation conditions? For ionospheric propagation, there is usually so much variability that it is not possible to tell. However, on ground wave at night, when there is little propagated noise, my signals can often be heard by local stations for several hours with an unvarying SNR, or, at worst, +- 1dB. Thus any variability in long-distance measurements is not due to limitations in WSPR, but rather to variability in noise and propagation. That is, in real-world conditions, the SNR resolution of WSPR spots is confirmed to be 1 dB.

Linearity and Dynamic Range Measurements

What is the dynamic range of WSPR in actual propagation conditions, and is it linear? On 40 meters, I did transmissions at 0.1 watt, 1 watt and 10 watts (a 20 dB range). As expected, there was substantial variability in SNRs of received spots due to noise and propagation conditions, so averaging was necessary. Below is an example of the results: the difference in power measured at the transmitter (by a calibrated SDRPlay RSP2) was 19.5 dB; the difference in average SNR at the receiver (WA2ZKD) was 18.6 dB, a difference of less than 1 dB. These results were consistent for several different receivers, although it can be challenging to find sufficiently stable propgation conditions to make the measurements.

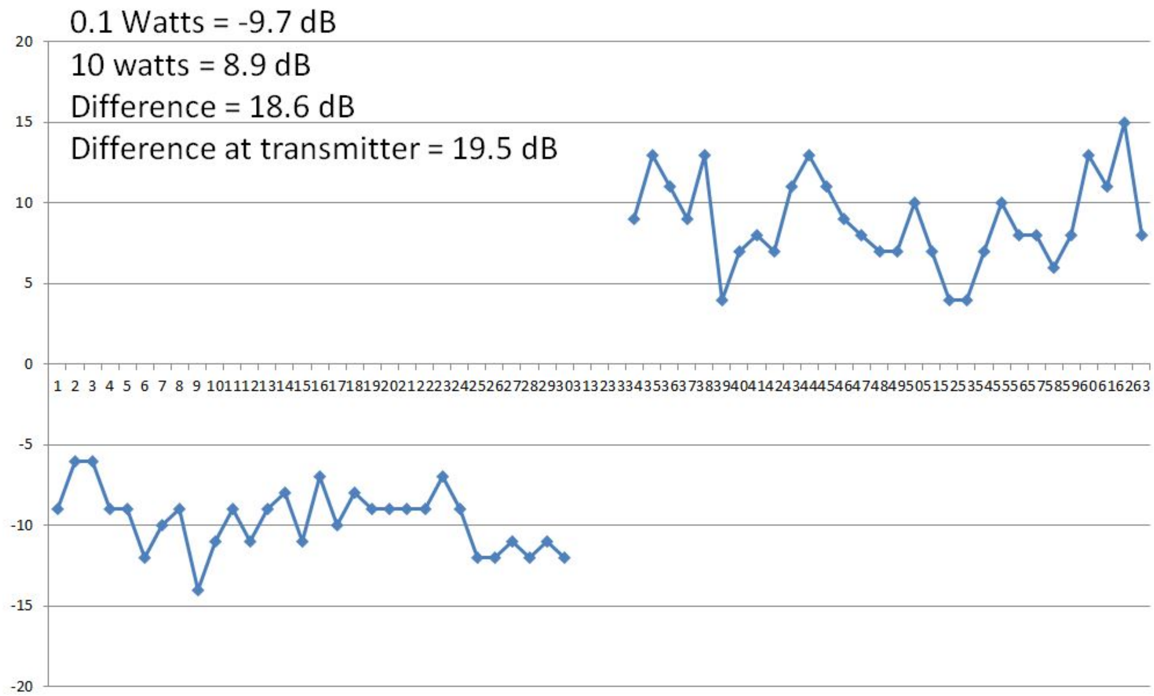

Figure 2. Comparison of received SNR at 0.1 and 10 watts

As discussed later in this poster, however, the low end of the SNR range can be tricky to interpret. Although WSPR can decode signals at -31 dB, variability makes it difficult to use spots below about -25 dB for consistent measurement; missed spots below -31 dB make averaging yield artificially high estimates of SNR. On the high end, WSPR appears to be linear to at least +15 dB; however, I have found that signals above +15 dB can overload the dynamic range of some receivers, not allowing low level signals (e.g., below -25 dB) to be simultaneously decoded.

ESTIMATES OF NOISE AND STRATEGIES FOR DEALING WITH NOISE

WSPR spots consist of a Signal-to-Noise ratio (SNR), not signal strength. Thus propagation measurements are inevitably contaminated with noise, both local noise and propagated noise. This can be seen in spots of ground wave signals (where there is no ionospheric signal propagation). At night on 20 meters, when there is little ionospheric propagation, the noise is weak with little variability (ground wave SNR is high and consistent, within 2 dB). During the day, both in a quiet area (KPH in California) and a noisy suburban area (WB8SCG in Virginia), SNR is both lower and more variable. Based on looking at ground wave reception with several pairs of stations, there is almost always about a 6 dB “fuzz” of noise (this can vary). This limits the resolution of actual WSPR measurements (despite the 1 dB native resolution).

To reduce variability in propagation measurements due to noise, averaging can help. There is a trade-off in SNR precision and time resolution; the more averaging, the more precise the measurement of SNR, but the less precise the measurement of time. I suggest at least 10 spots in the average to get a reasonably consistent measurement of SNR, but this is typically about a 2 hour average, which can be a problem if propagation conditions change.

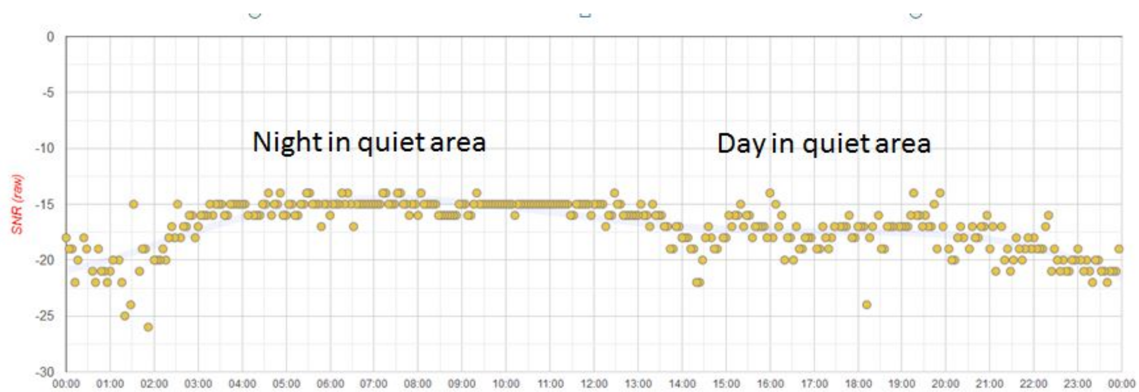

Figure 3. WSPR Expt 3/17/20 20 m K6MTU ground wave by KPH

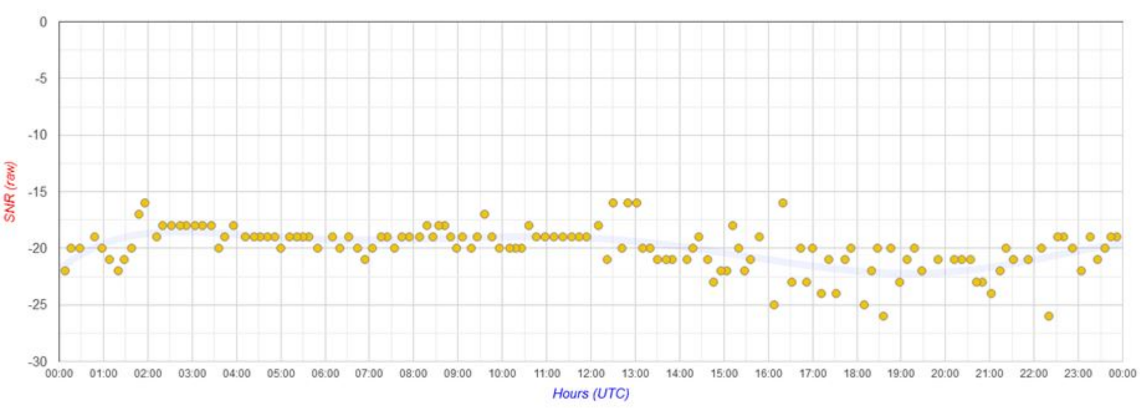

Figure 4. WSPR Expt 2/27/21 20 m KN4NBI ground wave by WB8SCG

While averaging can mitigate the problem of noise *variability*, WSPR spots do not give the absolute level of the noise (e.g., the absolute noise level at quiet KPH and noisy KN4NBI is likely quite different, but this cannot be determined from the spots). Griffiths et al. (2020) have explored a way to estimate absolute noise levels, addressing calibration, using *wsprdaemon*. Their method may prove useful in correcting for noise to obtain measurements of propagation.

1-YEAR COMPARISON OF WSPR SPOTS OF KN4NBI

The purpose of the section is to compare spots of KN4NBI by receivers one year apart to get a sense of what a baseline for WSPR over a year at solar minimum would look like.

KN4NBI transmitted on the 20 meter band at the default WSPR timing of every 10 minutes (on average), with the same power (10 watts) and the same antenna (inverted V, 18 feet above ground at the center) and downloaded all spots on a daily basis.

Results:

The figures below show comparisons of two weeks of spots of KN4NBI for the same dates in February and March 2020 and 2021 by stations in different locations. (There is data for many more receivers in my database; this is just a sample for the poster.) The average solar flux for this period in 2020 was 70; in 2021 it was 77. The average Ap index for 2020 was 4; for 2021 it was 13.

The first graph is reception by EA8BFK (5794 km, 80 degrees) in the Canary Islands. There is an average increase in SNR from 2020 to 2021 of about 3 dB. The second graph is reception by AI6VN/KH6 (7804 km, 282 degrees) in Hawaii. Similarly, there is an average increase in SNR from 2020 to 2021 of about 3 dB. One might conclude that there is 3 dB of improved DX propagation on 20 m, but there are issues with this conclusion.

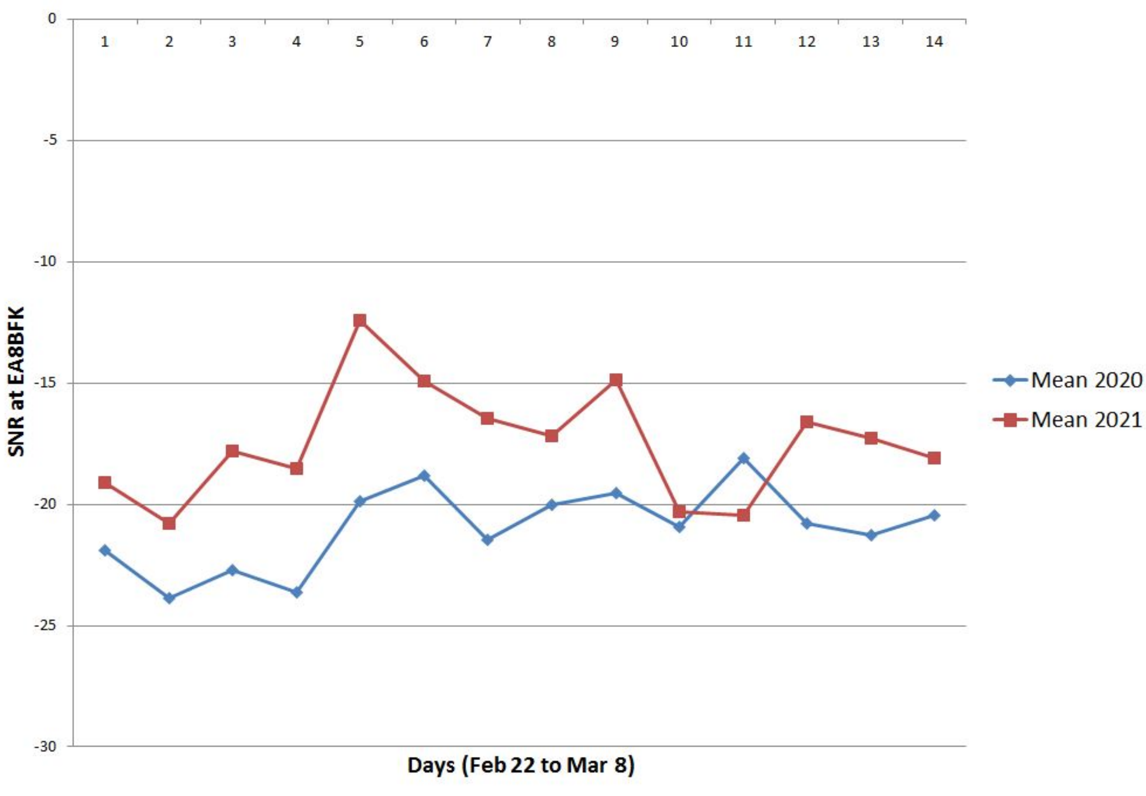

Figure 5. Comparison of Mean SNRs of spots of KN5NBI by EA8BFK, Feb-Mar, 2020 and 2021

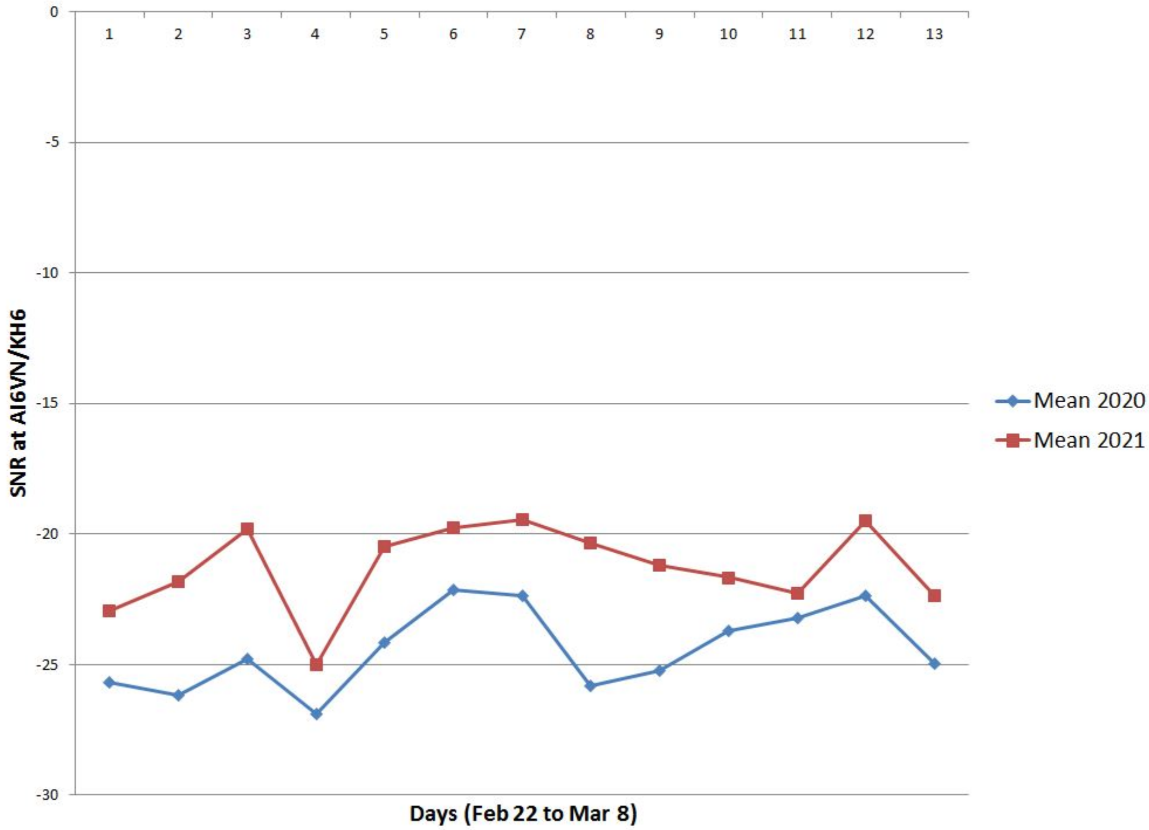

Figure 6. Comparison of Mean SNRs of spots of KN5NBI by AI6VN/KH6, Feb-Mar, 2020 and 2021

Issues: 1) A significant issue arises in dynamic range. Figure 7 is a scatterplot of the AI6VN/KH6 data, comparing the mean SNR to the standard deviation of the SNRs. It is clear that for low mean SNRs (especially below about -23 dB), the standard deviations are much lower. This is likely due to missing spots below the -31 dB WSPR threshold, resulting in an artificially high mean. Thus quantitative comparisons may be misleading if the mean SNR is too low – the actual mean should be even lower.

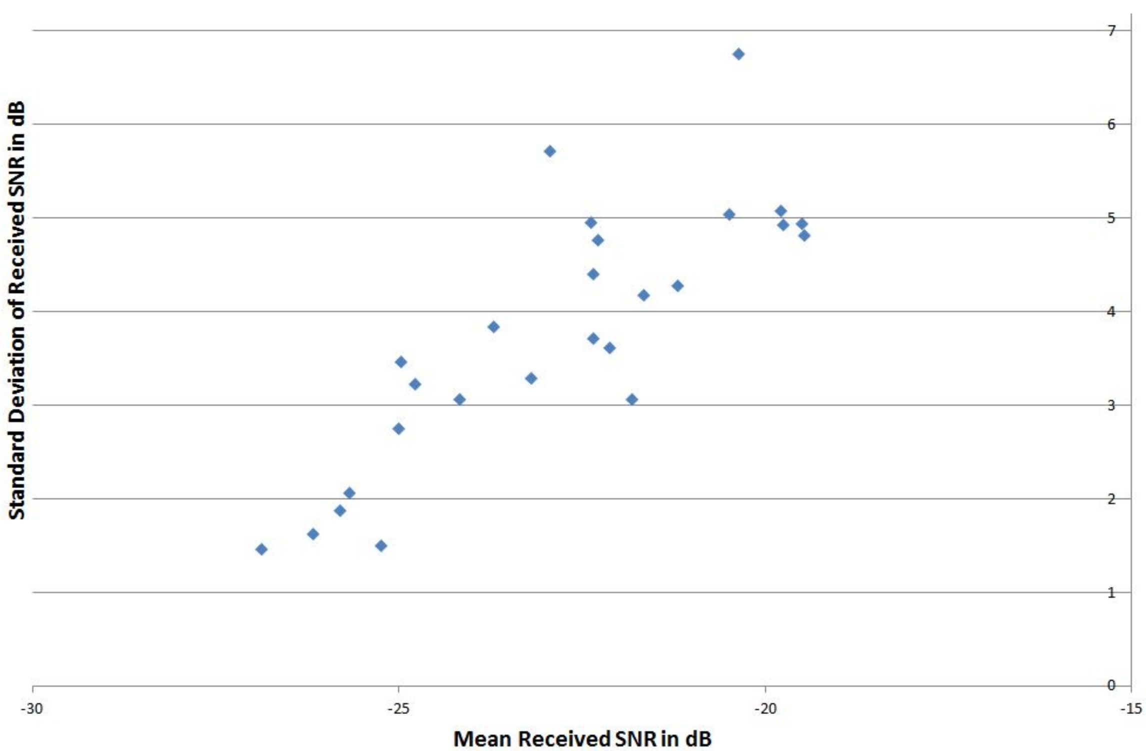

Figure 7. Scatterplot of Standard Deviations of Mean SNRs vs. Mean SNRs for KN4NBI received by AI6VN/KH6

2) Although the measurement year (2/22/20 – 3/8/21) began during solar minimum (sunspots = 0, flux = 69-71), solar cycle 25 had begun by the end (sunspots = 0-33, flux = 71-81). This is still very near the minimum (expected high around 2025 at perhaps sunspots = 150 and flux = 150), but is important to note for its possible effects on WSPR spots.

3) The most serious uncontrollable variable over a year is changes in the receiving stations. Though this is generally not an issue with short-term comparisons, it is possible over a year that changes will have been made in either the receiver or the antenna (or in the local background noise). One solution to this is to examine data for several receivers, looking for consistencies and inconsistencies. An alternative for the future would be to prearrange with receivers to make no changes in their configuration (or to ask them in retrospect what changes they have made on what dates over the past year).

SELECTED OBSERVATIONS OF PROPAGATION

Traveling Ionospheric Patch Reflector

Transient ionospheric disturbances are a common phenomenon in which a short-duration fade is seen. The opposite can also occur; what appears to be a reflective patch can move, yielding short-duration improvement in SNR. Below is an example in which, 3 hours before the normal band opening at sunrise, there appeared to be a moving reflective patch allowing propagation from the northeastern USA to NO5V in Texas. It moves to the southwest for two hours; propagation then disappears for 3 hours until sunrise.

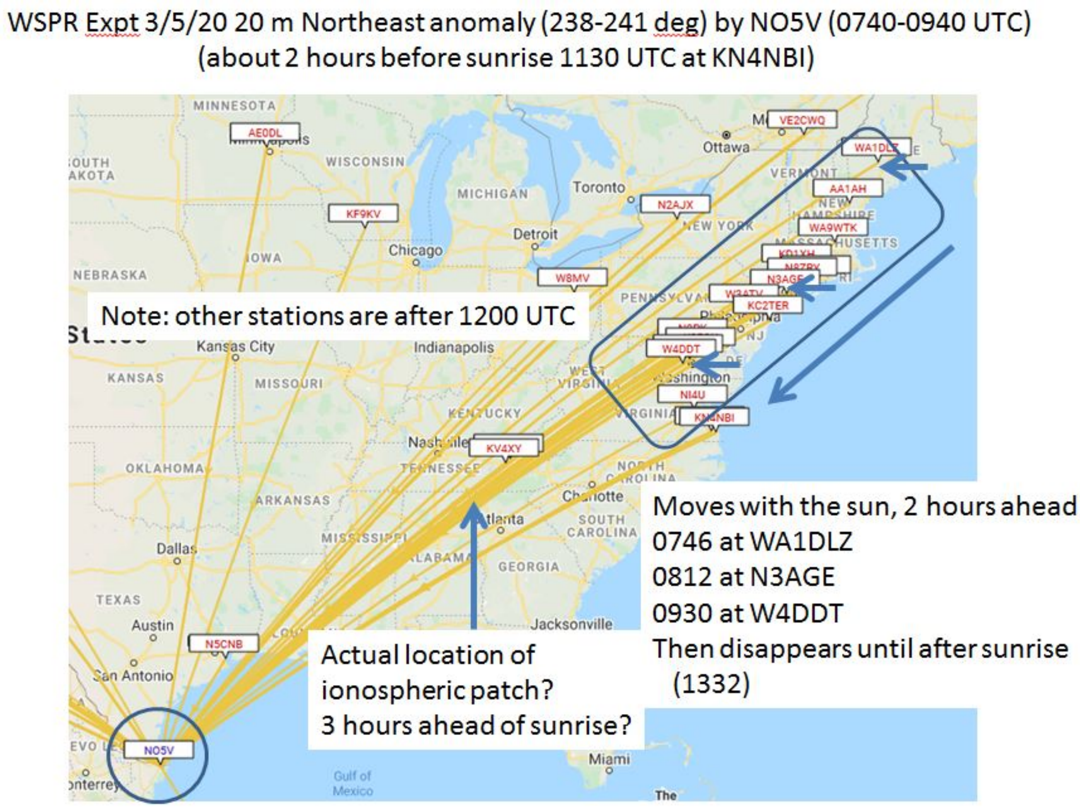

Figure 8. Example of a traveling patch reflector

Variability at the Edge of the Skip Zone

Ideally propagation would be stable for a long enough time to allowing some averaging to eliminate noise variability, e.g., to compare antennas. One might think that long distance propagation involving several hops would be less stable than shorter distance propagation. However, my observations suggest that the most variable area is at the edge of the skip zone. It often varies within a few minutes from very high SNR spots to very low. On 20 meters I have found that the skip distance can vary from about 500 km to over 1000 km. For applications like antenna measurements, my recommendation on the 20 meter band is to not use any spots closer than 1500 km, and not use any spots near sunrise or sunset (over the path to the spotting station), when propagation changes rapidly. On 20 meters there is usually a several hour period between sunrise and sunset when propagation is relatively stable.

AUTHOR INFORMATION

Doug Richards (KN4NBI) holds an Amateur Extra Class license and has been a ham since 1967. He is a retired biology teacher (Ph.D. in Zoology from the University of North Carolina at Chapel Hill). He lives in Virginia Beach, Virginia. His email address is doug.richards@cox.net.

ABSTRACT

The Weak Signal Propagation Reporter (WSPR) is potentially a useful tool in the quantitative study of ionospheric propagation. But there are a number of factors to be considered in the use of WSPR to make propagation measurements, and it is useful to have a baseline at solar minimum to compare with measurements as we approach solar maximum in the next five years. One key measurement question is to what degree WSPR is linear, and over what dynamic range, in real-world propagation conditions. Another important issue is the role of noise in WSPR measurements. WSPR spots report SNR, not signal strength, so identification and quantification of various sources of noise is necessary. During a year of analysis of spots of my transmissions on 20 meters from a mid-latitude location (Virginia Beach), I have addressed these questions and made other observations of propagation at solar minimum. My results include:

- a determination that WSPR spots are linear with respect to transmit power from around -25 dB SNR to over +10 dB SNR;

- that the dynamic range may extend to more than 60 dB; however, a particular receiver's dynamic range for simultaneous spots may be substantially less than this;

- there is an approximately 6 dB noise “fuzz” measured from ground wave reception, that can be averaged out, but a cost of time resolution;

- there is especially large variability in propagation at sunrise, sunset, and at the edge of the skip zone; on the other hand, long-distance propagation (e.g., to Hawaii or the Canary Islands) can have surprisingly low variability;

- even with zero sunspots and low K indices, there is substantial short-term variability in propagation which I have attempted to characterize. Very small changes in the K-index can have major effects on the distance of the skip zone and on nighttime propagation.

REFERENCES

Griffiths, G, Robinett, R., & Elmore, G. (2020). Estimating LF-HF Band Noise While Acquiring WSPR Spots. QEX, September/October 2020, 25-33.