Observations of HF sporadic E SNR, frequency spread and Doppler shift with FST4W

UK to Austria opening of 26-27 December 2023

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Method

Combining the frequency spread measurement of FST4W, a beacon mode within WSJT-X, and WsprDaemon's 0.1 Hz resolution frequency reporting [1] with GPSDO transmitters and receivers allows useful sporadic E (Es) observations at HF. These observations were made at 14 MHz on the 906 km path from G3ZIL (IO90hw, QRP Labs QDX tx) to OE9GHV (JN47wk, KiwiSDRs x 4). Es critical frequency (foEs) values are from the Dourbes ionosonde (JO20hc, 83 km bearing 041° from the path mid point), code DB049 at https://giro.uml.edu/ionoweb/#.

SNR and spread

Figure 1 shows time series of SNR, frequency spread and Doppler shift of G3ZIL's FST4W 14 MHz signals at OE9GHV with foEs from ARTIST-5 autoscaling [2]. Main points are:

- Daytime propagation was *primarily* via F2 one-hop (I1), with SNR of 10-20 dB, median 13 dB (in 2.5 kHz bandwidth) and median frequency spread of 54 mHz.
- Prior to and after F2 one-hop, propagation was via two-hop sidescatter (I3), median SNR -17 dB, median frequency spread 533 mHz.
- It is *possible* that frequency spread outliers during F2 one-hop propagation, i.e. those >200 mHz, coinciding with highest daytime foEs, may have been due to similar signal level multipath via F2 and E layers.
- Nighttime propagation (I6) is attributed to sporadic E because it coincided with E layer reflections at the Dourbes ionosonde and presence of high confidence autoscaled foEs values.
- In previous work [1] F2 one-hop and sidescatter propagation modes formed distinctive and separate clusters in spread vs. SNR scatter plots. That is also the case with this data set, I1 and I3 in Figure 2 (bottom).
- When we add the data for the sporadic E period, Figure 2 (top), there are two new clusters, I6. One, with median SNR ~ -20 dB and median spread ~ 140 mHz, occurred during the opening's decay, i.e. after 00:14 UTC. The other cluster, during the near-constant SNR period, was adjacent to, and to a degree overlapping with, I1 extending to lower SNR and higher spread. This cluster had median SNR 2 dB and median spread 75 mHz.
- Es does not appear to form simple, single-peak spread vs. SNR clusters.
- The first two spots of the Es opening (20:32 and 20:38 UTC) had very low spread, 15 mHz and 16 mHz respectively. It is our working assumption, yet to be tested, that such low values are when the extraordinary (X) ray alone is received. This assumption is compatible with a) seen at the start of an opening given its higher critical frequency, by half the electron gyro frequency, over the ordinary (O) ray and b) the absence of multipath spreading from co-propagating X and O rays.

Doppler shift

Figure 1 (bottom) shows the difference between the precisely known GPSDO-controlled transmit frequency and the frequency measured at four co-sited GPSDO receivers. The difference is attributed to Doppler shift. While there is variability in this 0.1 Hz resolution data set the overall picture is clear:

- From the start of the data until ~09:00 UTC the positive, decreasing Doppler was compatible with decreasing height of refraction within the F2 layer.

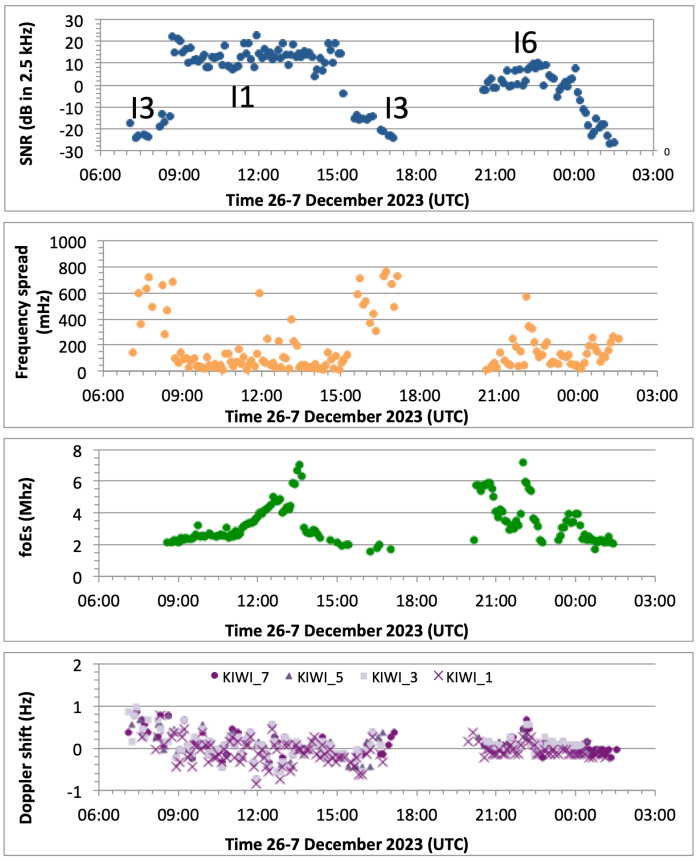

Figure 1. Time series of (from top) SNR, frequency spread, Es layer critical frequency (foEs) from the Dourbes ionosonde and Doppler shift with measurements from each of the four GPSDO-clocked KiwiSDRs at OE9GHV.

- During nighttime Es Doppler was essentially zero.
- The foEs step rise from 3.9 to 7.15 MHz between 21:55 and 22:00 coincided with steps in spread, 50 to 574 mHz, and Doppler, 0.06 to 0.39 Hz.

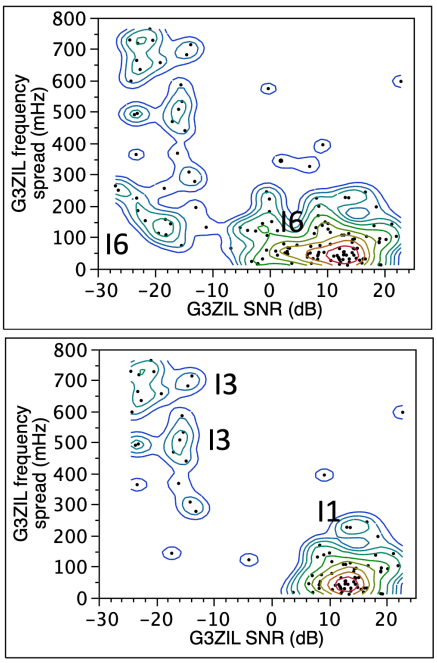

Figure 2. Scatterplots of frequency spread against SNR with non-parametric density contours for (top) entire data set of Figure 1 and (bottom) without the sporadic E period.

Data availability

For a WsprDaemon data guide with notes on access methods see [1]. Please acknowledge as below.

Acknowledgment

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References

1. http://wsprdaemon.org/ and the presentations and technical tabs
2. http://www.digisonde.com/IGF/pdf/Day4/Galkin-ARTIST5.pdf

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