# October 2023 Annular Eclipse Propagation Anomalies at HF: Preview of FST4W Observations

## Part 6: Doppler shift - Comparison of FST4W and Grape Personal Space Weather Station measurements

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### The Grape Personal Space Weather Station

The Grape PSWS is major initiative of HamSci [1]. Specifically designed for Doppler sounding of the ionosphere, Grape 1 receivers are user-built, single-channel devices, most operate at 10 MHz listening to WWV. Early versions process data locally using highly modified fldigi software [2]. Later versions collect data in digital_rf format [3]. All upload data to central servers. Several peer-reviewed papers describing, and drawing upon, Grape Doppler data have been published [e.g. 4,5].

Digital_rf Grape data can be obtained by clicking on Central-Control System green icons [6] and selecting a one-day file from station data page. Here, we use the Grape at St George (DM37fc, UT, 92% obscured) as the midpoint of its path from WWV ( DN70lq, CO, 83% obscured ) was only 112 km from path midpoint KA7OEI (DM39ce,UT, annular at 16:24 UTC) to KV6X (DM75aq, NM, annular at 16:36 UTC), Figure 1.

### Calculating Doppler shift from Grape IQ data

The Python 'read' example at [3] was used to read in the 10 samples/s digital_rf format IQ data from the St George Grape. The Doppler shift was calculated using the complex autocorrelation at one lag algorithm [7] for baseband signal $x(t)=r(t)+i\,q(t)$:

$$f = \frac{1}{2\pi\tau}.Arg(\overline{x(t).x^*(t+\tau)})$$

where * denotes complex conjugate, $\tau$ the lag, here 100 ms, and the average taken over 600 samples, that is one minute.

### Comparison of Grape and FST4W Doppler

Figure 2 shows the Doppler shift time series measured at 10.14 MHz using FST4W on the KA7OEI to KV6X path and that from 10 MHz WWV at the St George Grape from the complex autocorrelation algorithm. Immediately obvious is the inadequate FST4W 0.1 Hz resolution. While broad features match, e.g. the step after 16:30 UTC followed by a tail to lower Doppler, and some subtle variations are captured, e.g. the periodic variations around 16:00 UTC, the low FST4W resolution loses much of the detail. There is a ~0.1 Hz offset in the Grape data. While the Grape uses a GPSDO it is also dependent on the clock accuracy of a low-cost USB audio dongle. Nevertheless, the scatterplot, Figure 3, shows that 73% of the variation was explained by a linear relationship ($R^2$=0.73). The scale factor should be 1.014 (ratio of frequencies) rather than the measured 0.967. For the WO7I to ND7M path, midpoint 636 km to the west of WWV to Grape path, $R^2$ was, as expected, lower, at 0.467. These are encouraging results; but, for the 2024 total eclipse, it would be advantageous for FST4W frequency resolution to be 0.01 Hz.

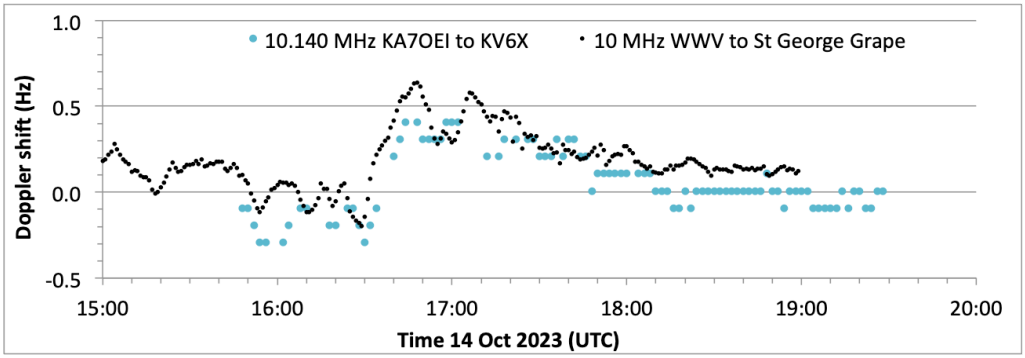


*Figure 2. Time series of the Doppler shift measured using FST4W on 10.14 MHz on the KA7OEI to KV6X path and that from 10 MHz WWV to the St. George Grape receiver obtained using the complex autocorrelation algorithm.*

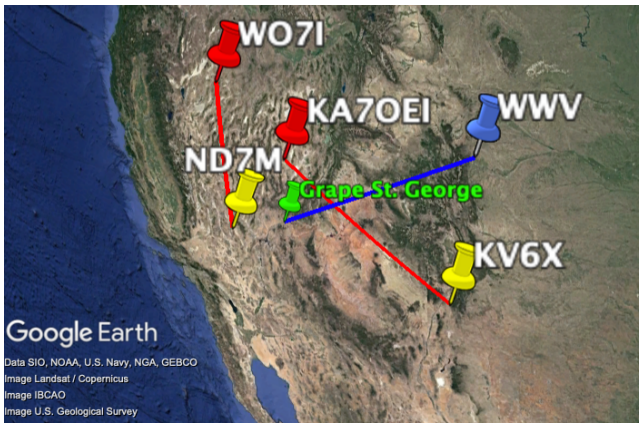


*Figure 1. Map showing the paths discussed in this summary. The mid point of the path from WWV to the Grape at St George, UT, was 112 km from the mid point of the path from KA7OEI to KV6X.*

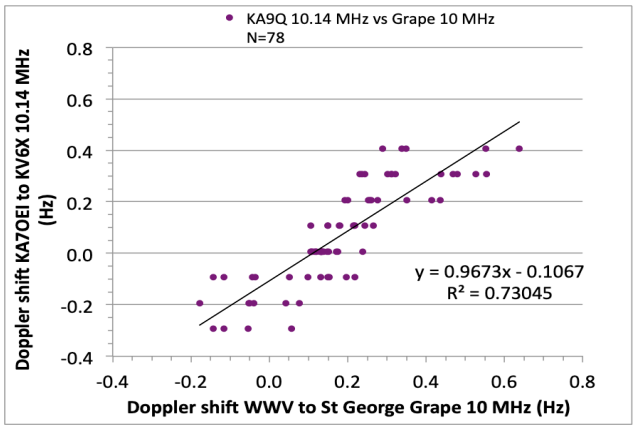


*Figure 3. Scatterplot of the KA7OEI to KV6X path Doppler against that on the WWV to Grape path with linear best fit and $R^2$.*

### Data availability

Grape data is available via http://psws.hamsci.org. For WsprDaemon data a guide is available [8], with an Annex on access methods. Sites wspr.rocks and wspr.live provide access and graphical outputs. Please acknowledge Rob Robinett AI6VN and data contributors as below.

### References

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3. https://github.com/MITHaystack/digital_rf
4. Collins, K. et al. 2023. Crowdsourced Doppler... *Earth Syst. Sci. Data*, 15, 1403–1418, doi.org/10.5194/essd-15-1403-2023.
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6. https://pswsnetwork.caps.ua.edu/analysis/analysis
7. Passarelli Jr, R.E. and Siggia, A.D., 1983. The autocorrelation function... *J. App. Meteorology and Climatology*, *22*(10), pp.1776-1787.
8. http://wsprdaemon.org - see guide on the Timescale page.

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