Dancing with The D-Layer:

Recording WWV's Skip-Path Doppler Shift

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John Gibbons, N8OBJ
and the
Case Amateur Radio Club, W8EDU

First, a word from our sponsors:

The Case Amateur Radio Club

Radio Station W8EDU

Rachel Boedicker, AC8XY, President
Kristina Collins, KD8OXT, Vice-President
Nathaniel Vishner, KB1QHX, Sec/Treas.
and the rest…

What problem are we addressing?

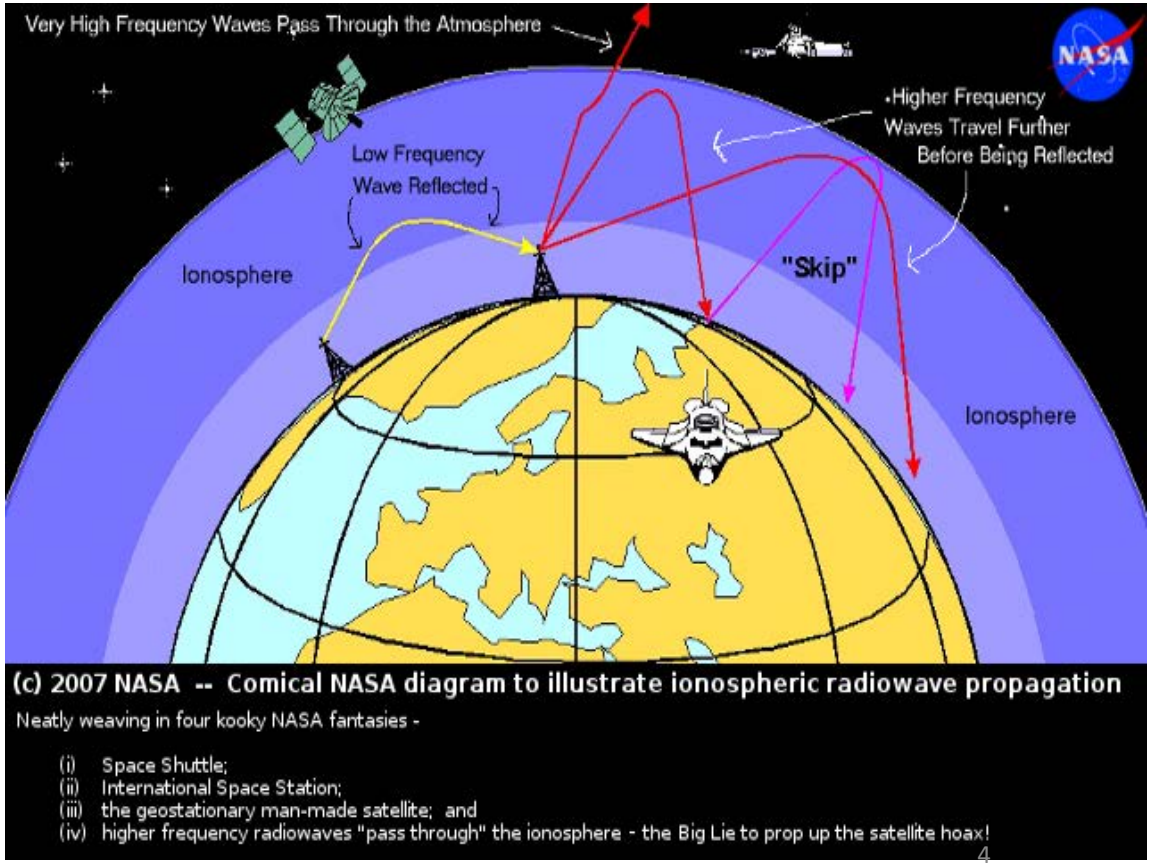
- Expansion of Eclipse Mob: Distributed HF monitoring. The great natural experiment is RF monitoring during solar eclipses.
  - (they're hard to schedule, so *semper paratus*)
- As the average reflection height changes, beacon signal path lengths change and produce a Doppler shift.
- HF Doppler provides surrogate ionosphere measurement.
- We're paying good money already for excellent beacons in Colorado! Yay, NIST! (don't defund the NIST!)

Why examine high-frequency signals?
SKIP!

In 1912, amateur radio operators were limited to frequencies above 1.5 MHz (200 meters on down). The government thought those frequencies were useless.

This led to the discovery of

HF radio propagation via the ionosphere in 1923.



NIST provides physical measurement standards.

You thought EE was so special? Food science labs have to be calibrated, too.
[nist.gov on standard peanut butter (smooth)]

WWV is the NIST's time and frequency standard

"The heartbeat of shortwave radio," broadcasting time, RF/AF frequency, and technical ephemera on 2.5, 5, 10, 15, 20, and sometimes 25MHz.

100th anniversary
1 October 2019!
Party in Fort Collins!
Be there or be R^2!

We do not forget our northern friends:

But note that 7335 kc. moved to 7.850 MHz.

Times and allocations change.

April 2019 Frequency Measuring Test

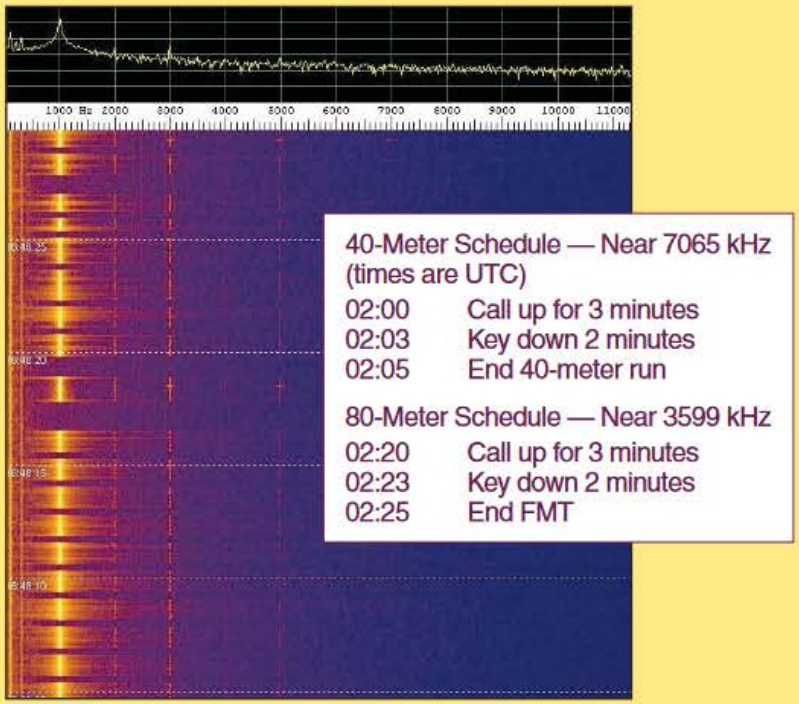
0200 – 0225 UTC, April 12

The format of the April Frequency Measuring Test (FMT) will be to measure a single-frequency signal transmitted first on 40 meters then on 80 meters from one station in eastern Oklahoma: K5CM.

The FMT will begin at 0200 UTC, April 12 (Thursday evening in North America). Measure the transmitted frequency and report your results at the new ARRL FMT page, **fmt.arrl.org**. Results must be submitted by 0200 UTC on April 15, at which time the results will be published on the website.

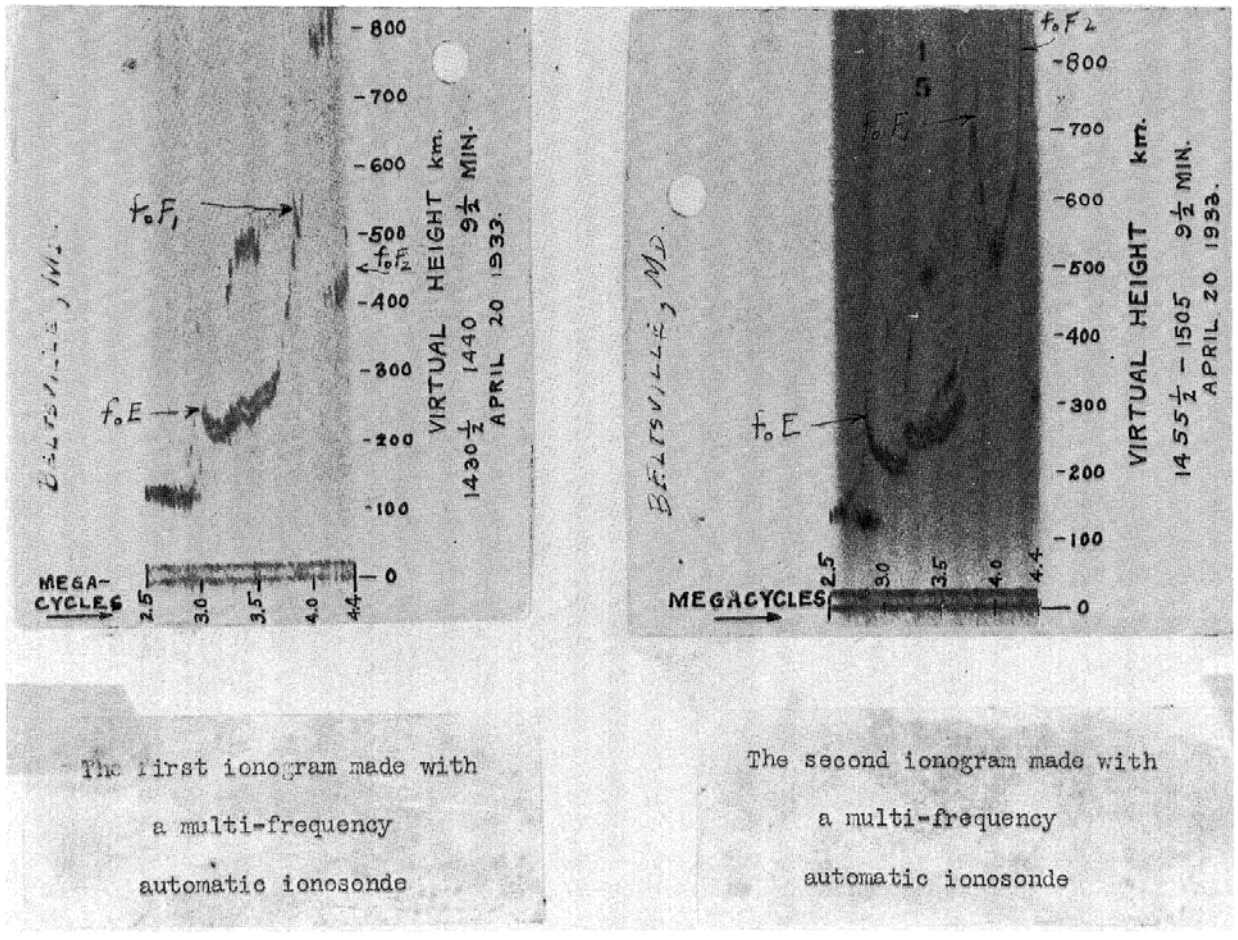
To be listed in the "Green Box" of the results, submit a measurement with an accuracy of better than 1 Hz.

Although the "call up" is scheduled to start at a very specific time, K5CM will try to start earlier. Every effort will be made to start the key-down measurement period at the published time.



Measuring audio frequencies with *Spectrum Lab*.

By 1927, ionospheric sounding was established, providing data for shortwave communication.



The first ionogram made with a multi-frequency automatic ionosonde

The second ionogram made with a multi-frequency automatic ionosonde

1933, first multifrequency swept ionosonde recordings.

"Ice pick" recording straight up, here from Beltsville, Maryland.

[NOAA on ionosondes]

Ham mentors are all “Elmer.”
Perhaps ham ionosphere measurers are “Lou”:

Skip, skip, skip to my Lou,
Skip, skip, skip to my Lou,
Skip, skip, skip to my Lou,
Skip to my Lou, my darlin’.

(old squaredance caller’s song)

Beacon measurement: Was WWV's first Sputnik monitoring? (*amplitude,* not freq.)

1958, WWV's 20 MHz signal: tracked the disintegration of Sputnik.

Dr. John Kraus at OSU figured that what was left of Sputnik would exhibit "meteor scatter," writ large. His prediction was correct. WWV's strengthened for durations lasting over a minute. In addition, the strengthening came from a direction and at a time of day that agreed with predictions of the paths of Sputnik's last orbits. Kraus was able to draw up a complete timeline of Sputnik's disintegration.

[New York Times 1958 on Krause and WWV]

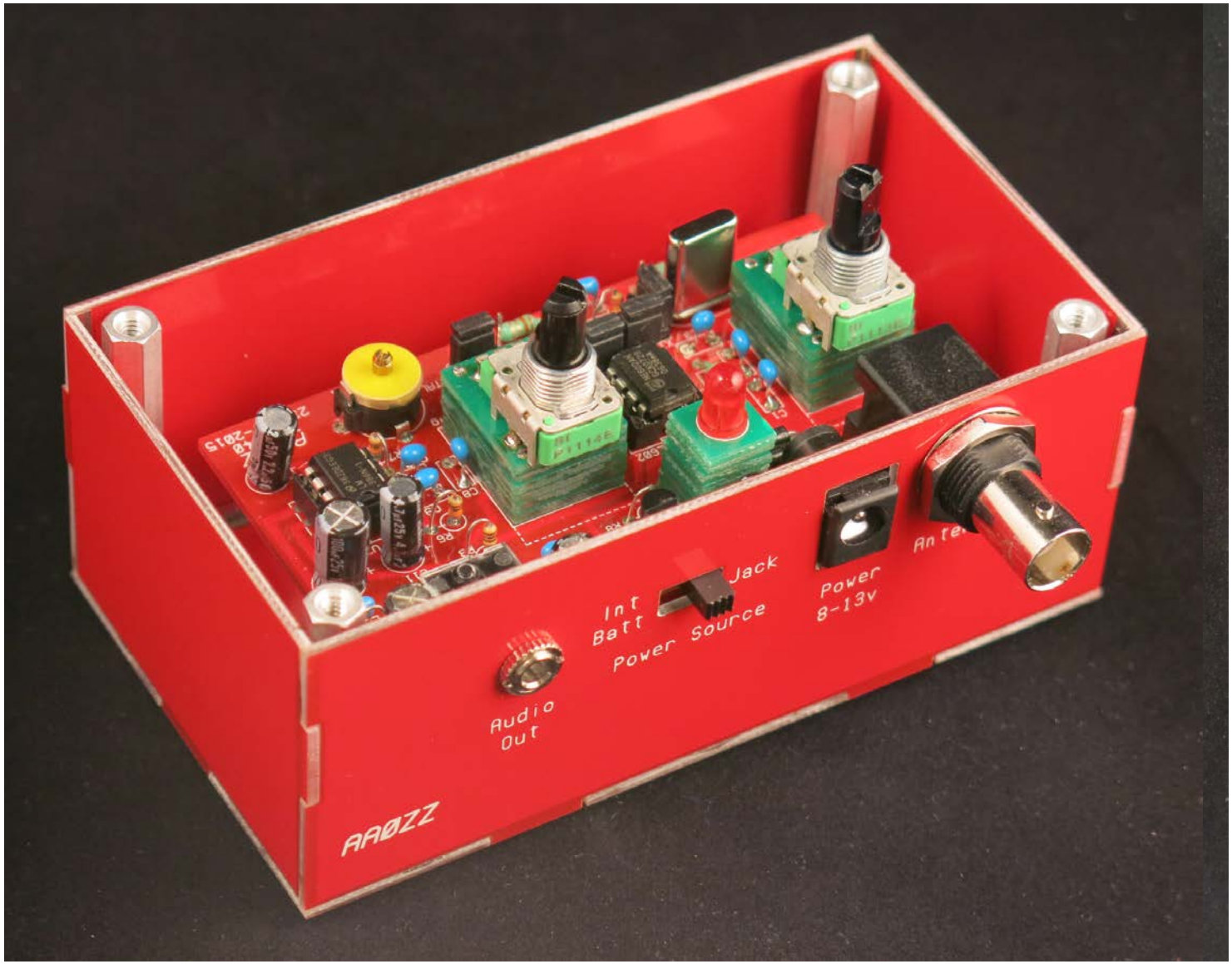
What has changed? The availability of highly stable beacons such as WWV…

- WWV is maintained at ~$3x10^{-18}$ through the NIST-F2 cesium fountain
  - (don't quote me on this. WWV isn't directly controlled by that clock)

<<and>>

The GPS constellation distribution of ~$3x10^{-13}$ stable frequencies worldwide, cheaply and compactly.

[Bodnar Mini GPS, £99.99]

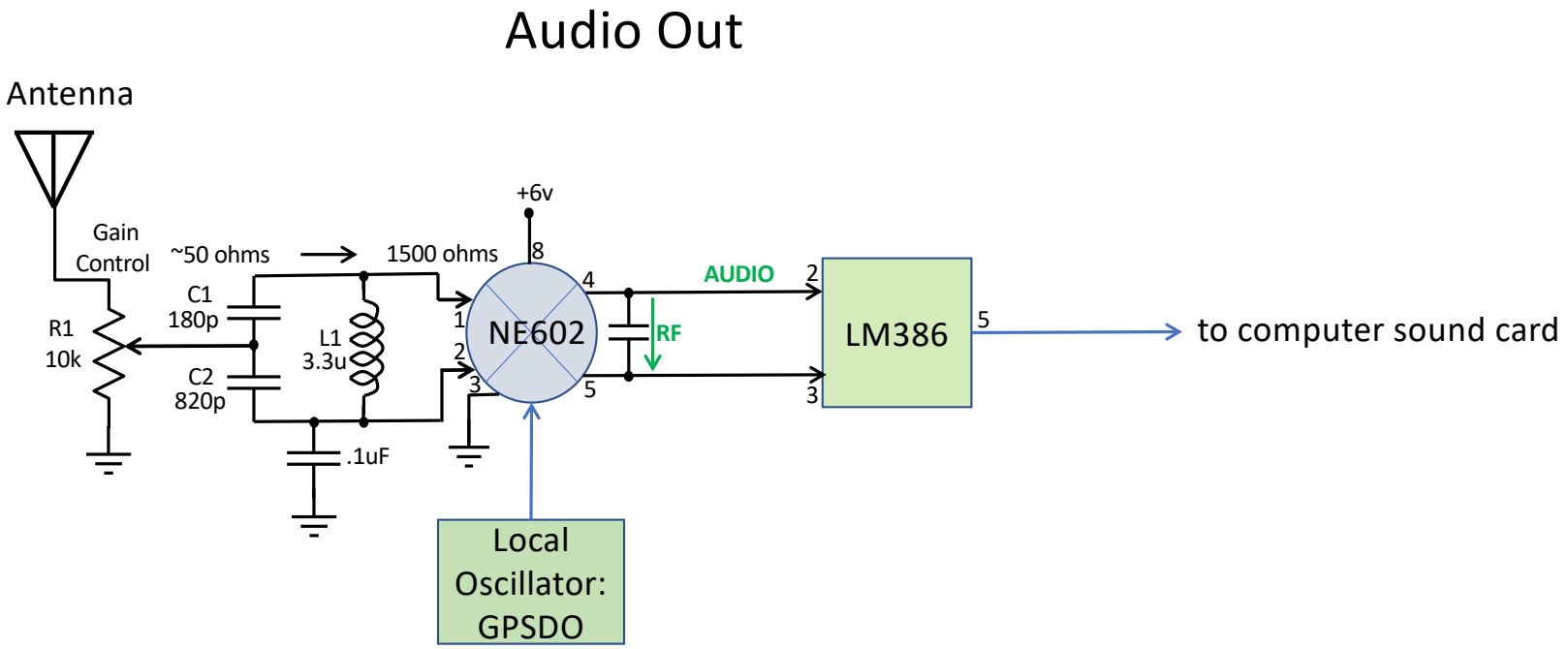


Frequency estimation on the cheap: Low-IF receiver.

Nice one from AA0ZZ.

Use 1000 Hz IF for analysis.

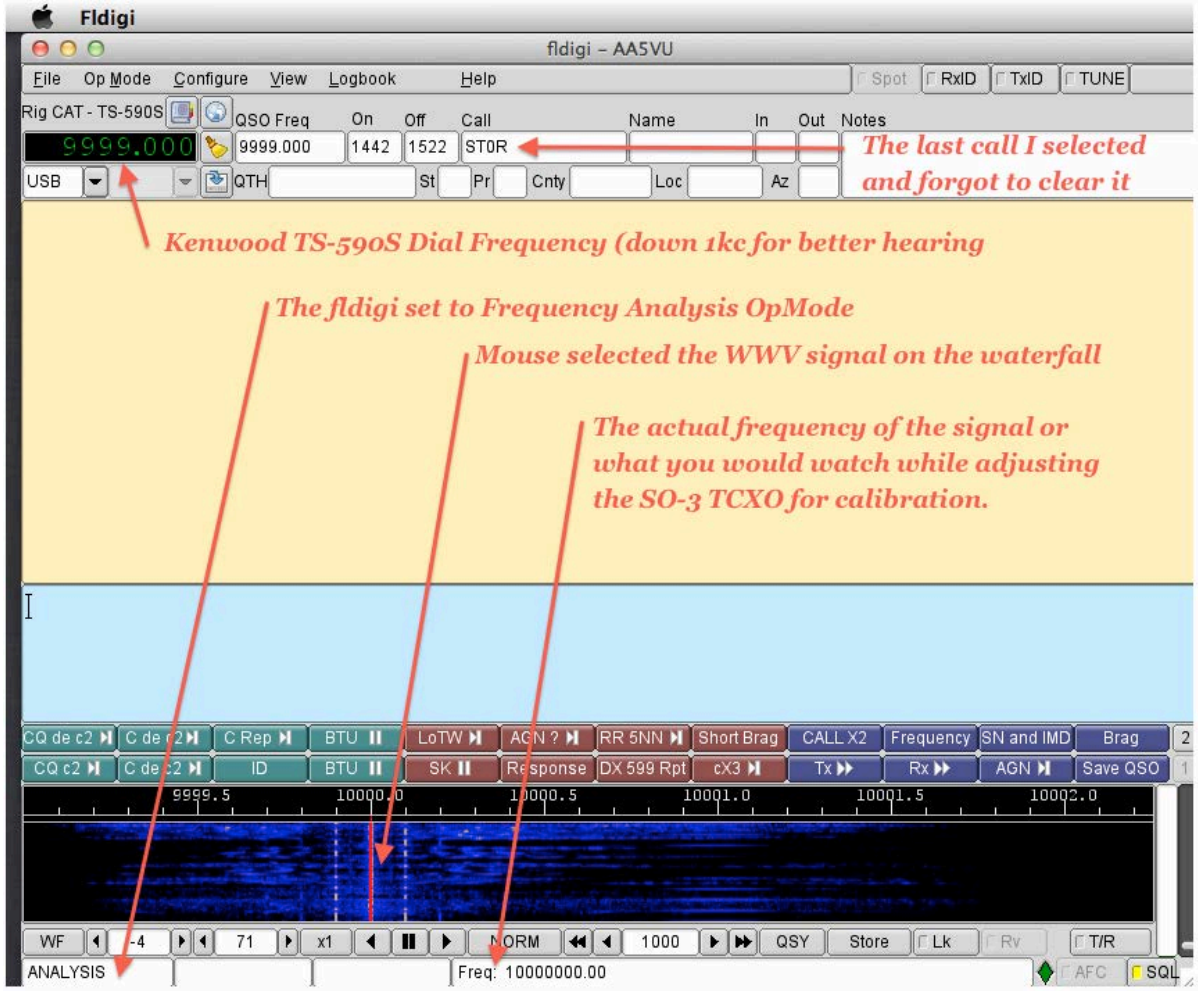
ZZRX-40: “Nothing groundbreaking here.” –*AA0ZZ in* QST *article*



modified from AAØZZ

August 18, 2016

fldigi analysis mode for frequency estimation

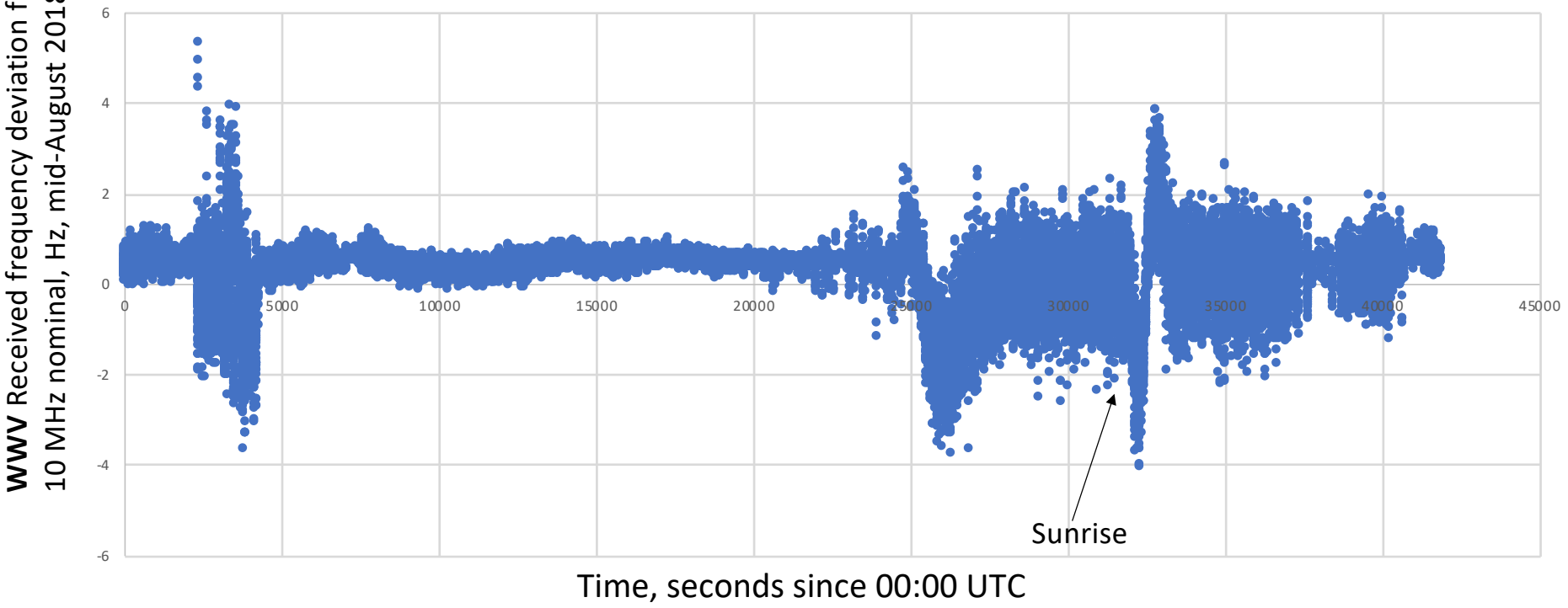


Underlying math:

Jeffrey Tsui and Sam Reisenfeld, **"A highly accurate DFT-based parameter estimator for complex exponentials,"**

Journal of Telecommunications and Information Technology Jan 2006

WWV Doppler measurement: ?disturbances around dawn from solar storm activity



Doppler Data Plots

Observations, Conjectures, and Future Directions

No radio operator is an island.
Each station going “SK” diminishes us, [“silent key”]
For we are involved in radio
And physics and IEEE.
Therefore, send not to know
For whom the cesium clock tolls,
It tolls for thee.

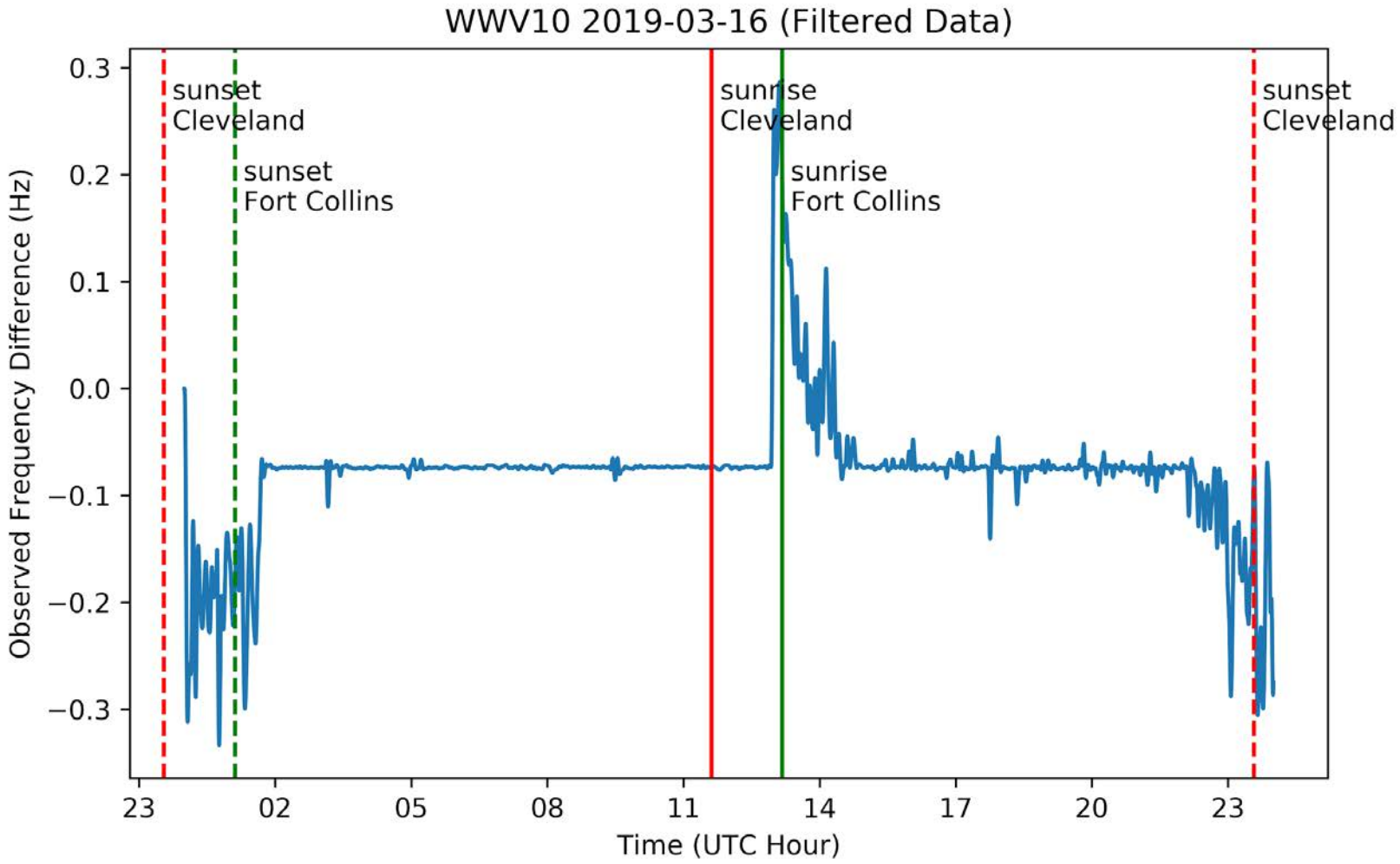
John, WD0NNE

W8EDU on saving WWV

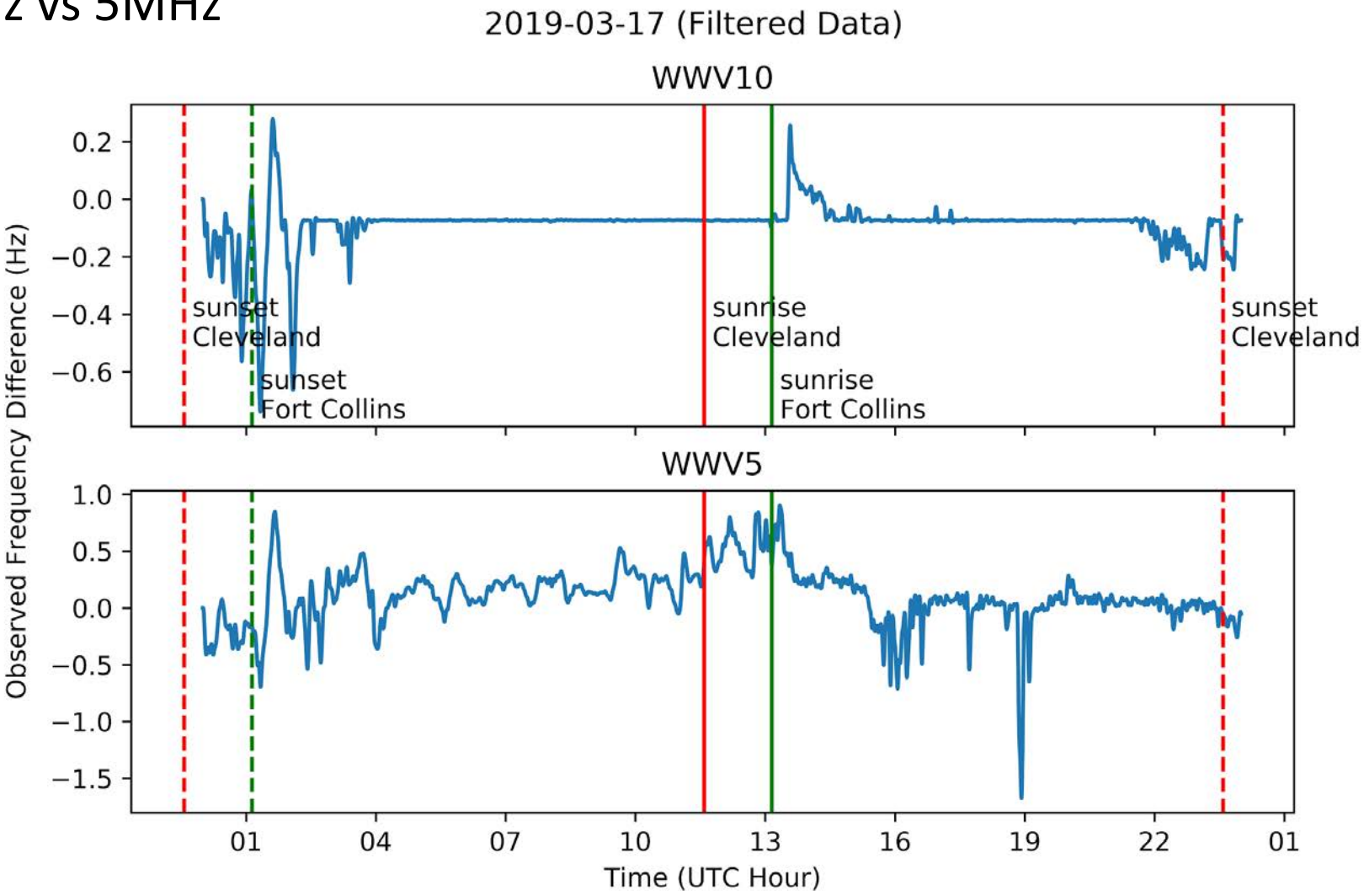
M Hi hi

(yes, we know: John Donne,
Meditation 17
Devotions upon Emergent Occasions)

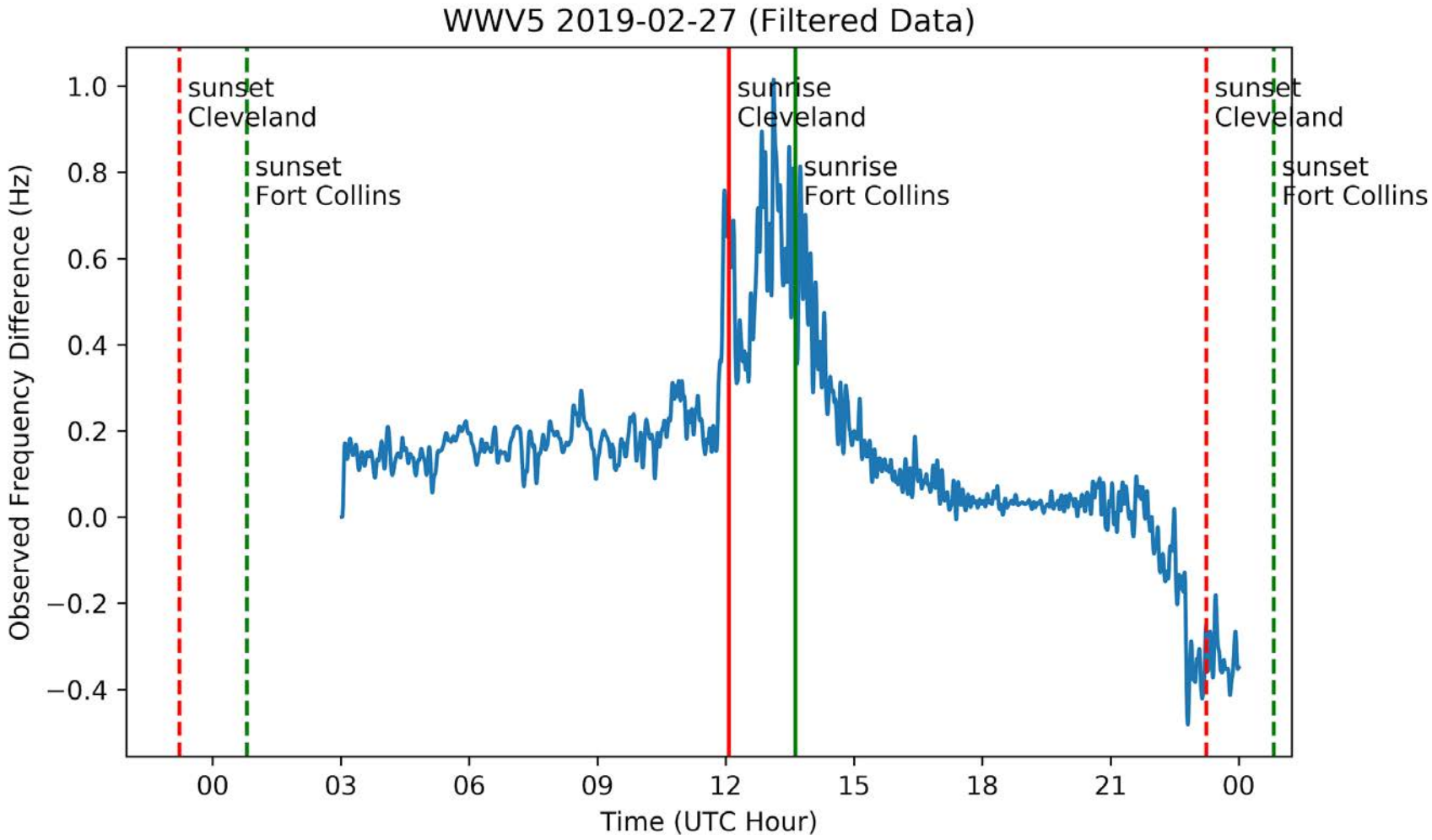
Sunrise and Sunset Observations



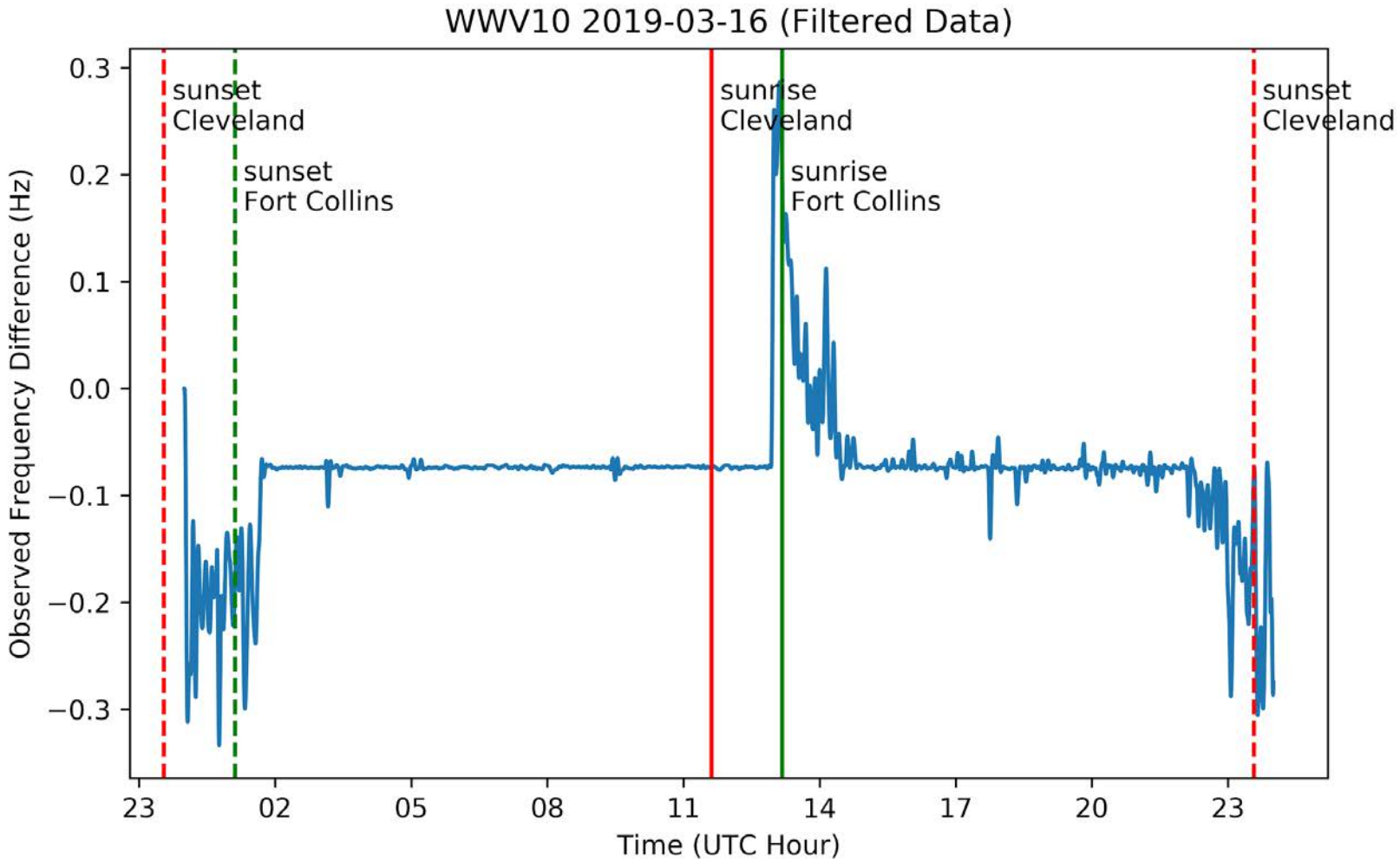
10MHz vs 5MHz



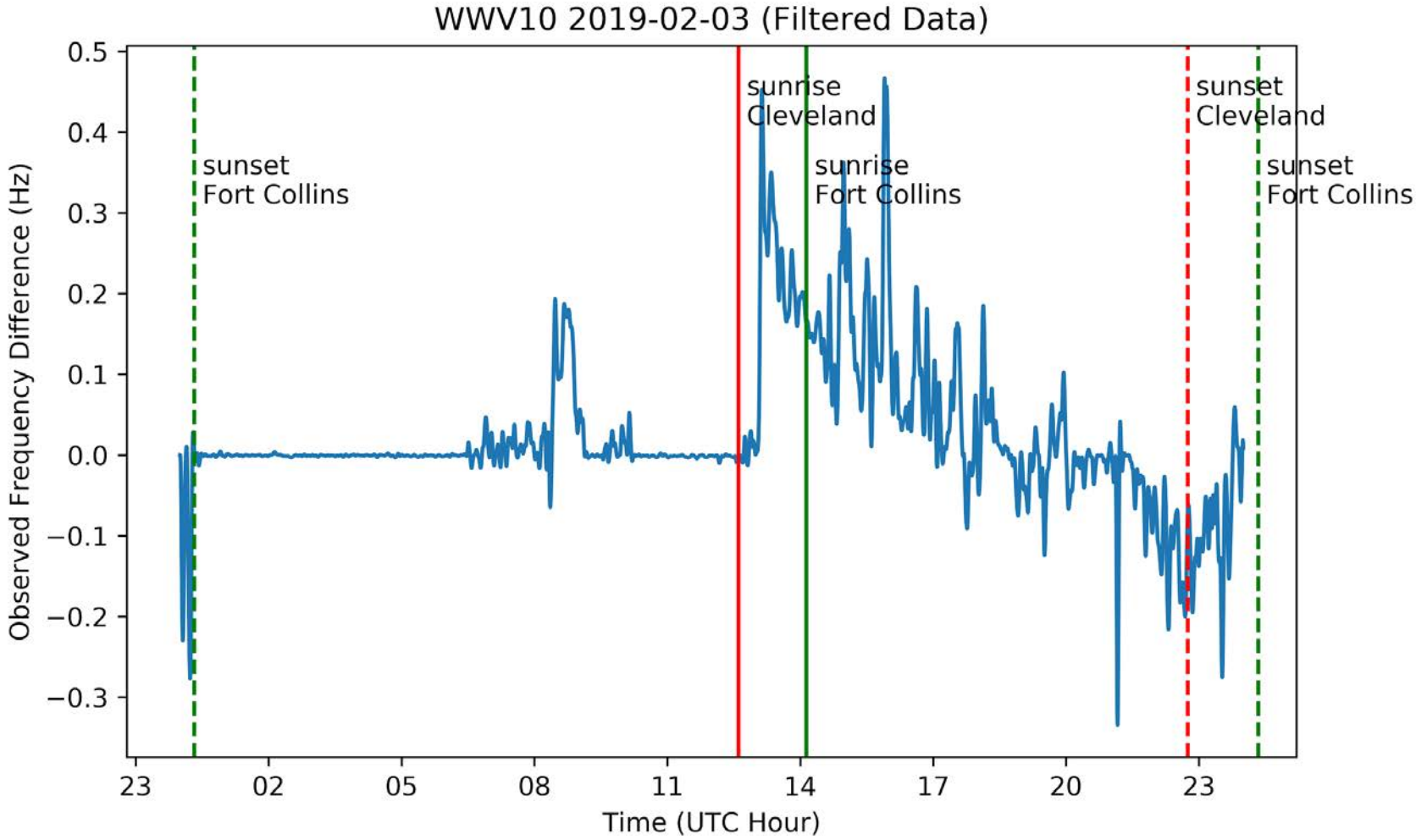
Possible Travelling Ionospheric Disturbances (TIDs)



Back to our typical day that we first showed



Strange occurrences in the Night



Simultaneous WWV Frequency Measurements