IonTV: Using WWV Timing Reference Signals to Observe Ionospheric Variation

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HamSCI

2019 Meeting
22 March 2019 CWRU

python™

MIT HAYSTACK OBSERVATORY

JOHNS HOPKINS APPLIED PHYSICS LABORATORY

UMASS BOSTON

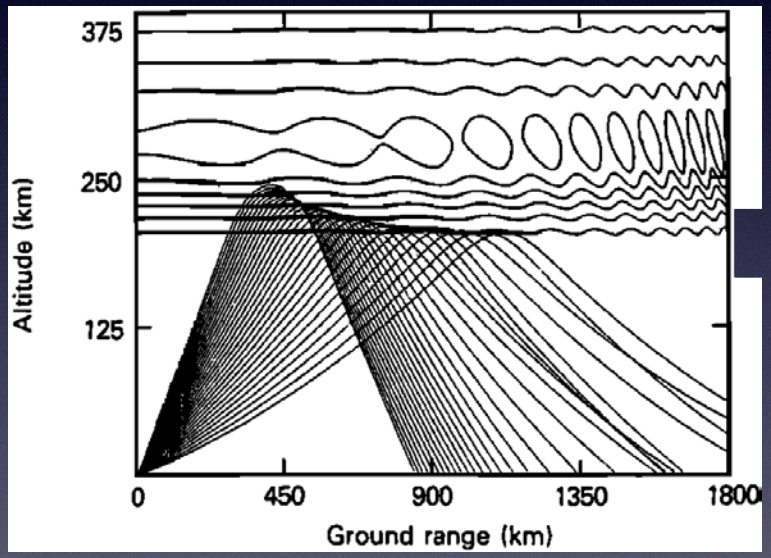
UNIVERSITY OF BATH

NIST National Institute of Standards and Technology U.S. Department of Commerce

Central question in this presentation:

[Bill Liles]:
"Can reception of WWV time ticks be used as a low cost distributed ionospheric / space weather sensor?"

First:
- What is WWV?
- What do its time signals look like?
- Are they useful for remote sensing?
- How hard is it to process them?



[*Samson et al.*, 1990]

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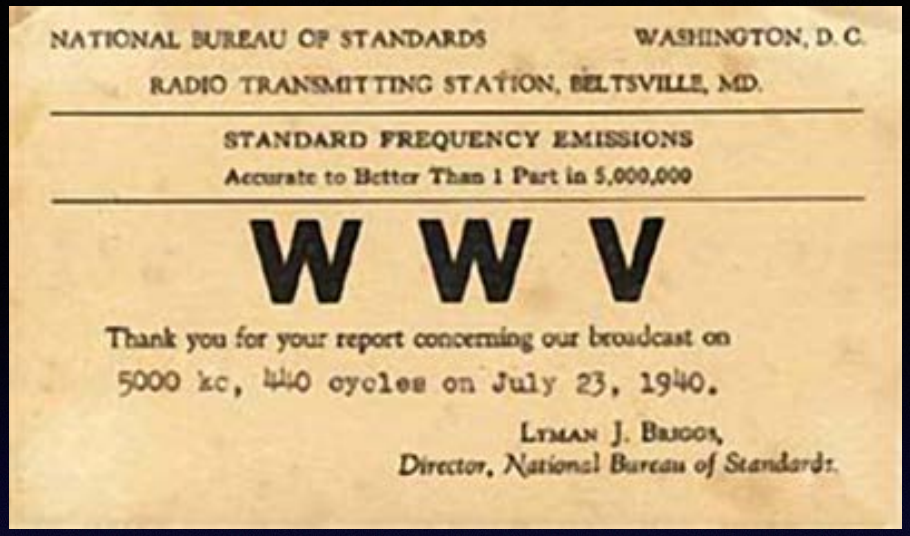


NATIONAL BUREAU OF STANDARDS WASHINGTON, D. C.

RADIO TRANSMITTING STATION, BELTSVILLE, MD.

STANDARD FREQUENCY EMISSIONS

Accurate to Better Than 1 Part in 5,000,000

W W V

Thank you for your report concerning our broadcast on 5000 kc, 440 cycles on July 23, 1940.

LYMAN J. BRIGGS,
Director, National Bureau of Standards.

NIST

Physical Measurement Laboratory / Time and Frequency Division

TIME AND FREQUENCY SERVICES

(NB: also WWVH from Hawaii, WWVB at VLF frequencies)

https://www.nist.gov/pml/time-and-frequency-division/radio-stations/wwv

"NIST radio station WWV broadcasts time and frequency information 24 hours per day, 7 days per week to millions of listeners worldwide. WWV is located near Fort Collins, Colorado, about 100 kilometers north of Denver. The broadcast information includes time announcements, standard time intervals, standard frequencies, UT1 time corrections, a BCD time code, geophysical alerts and marine storm warnings."

MIT HAYSTACK OBSERVATORY

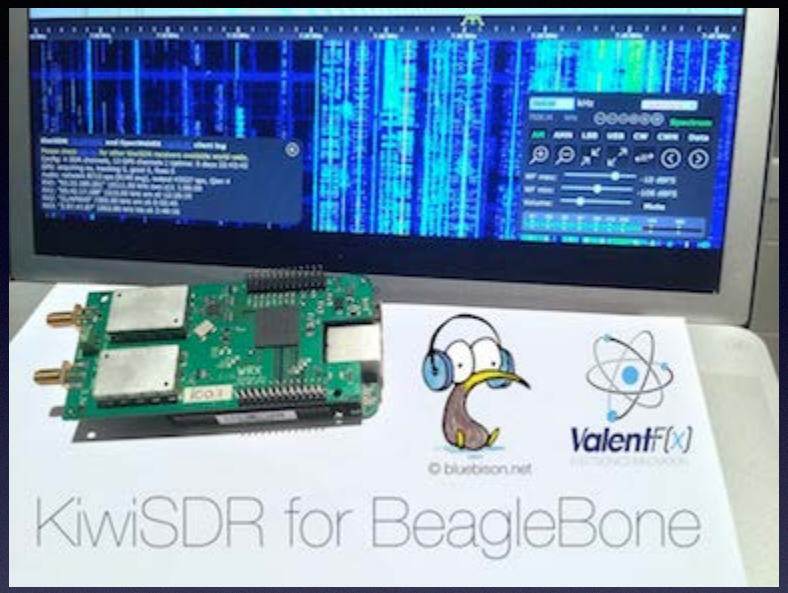
2.5, 5*, 10*, 15*, 20, [25] MHz
* = 10 kW power

Synchronized to NIST time standards

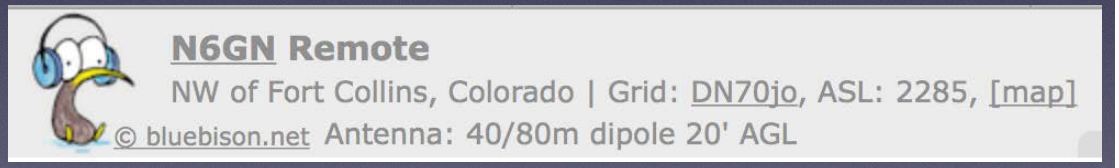
HamSCI
Erickson IonTV

What does WWV sound like?

Then
(Hallicrafters SX-110)

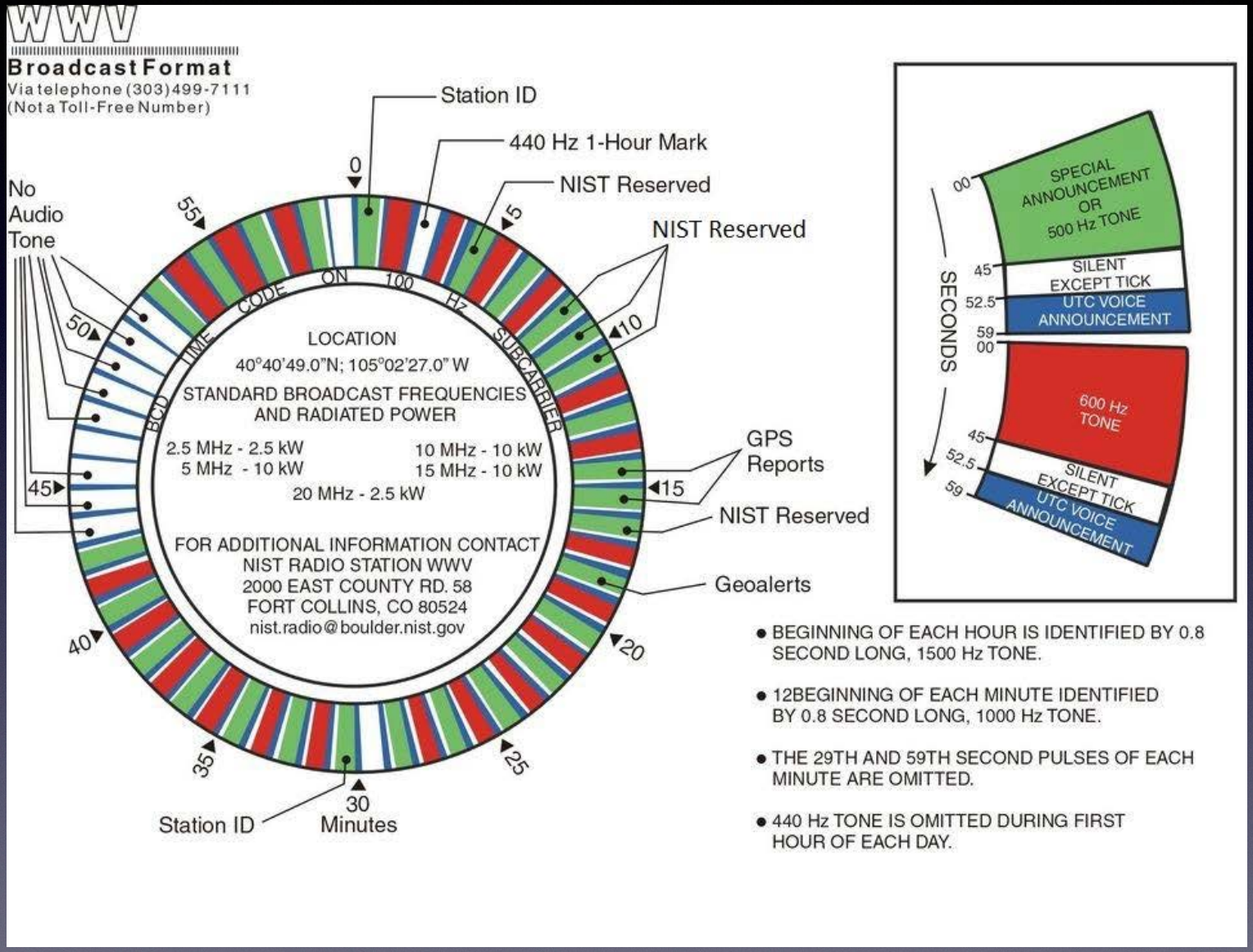


Now
(e.g. KiwiSDR)

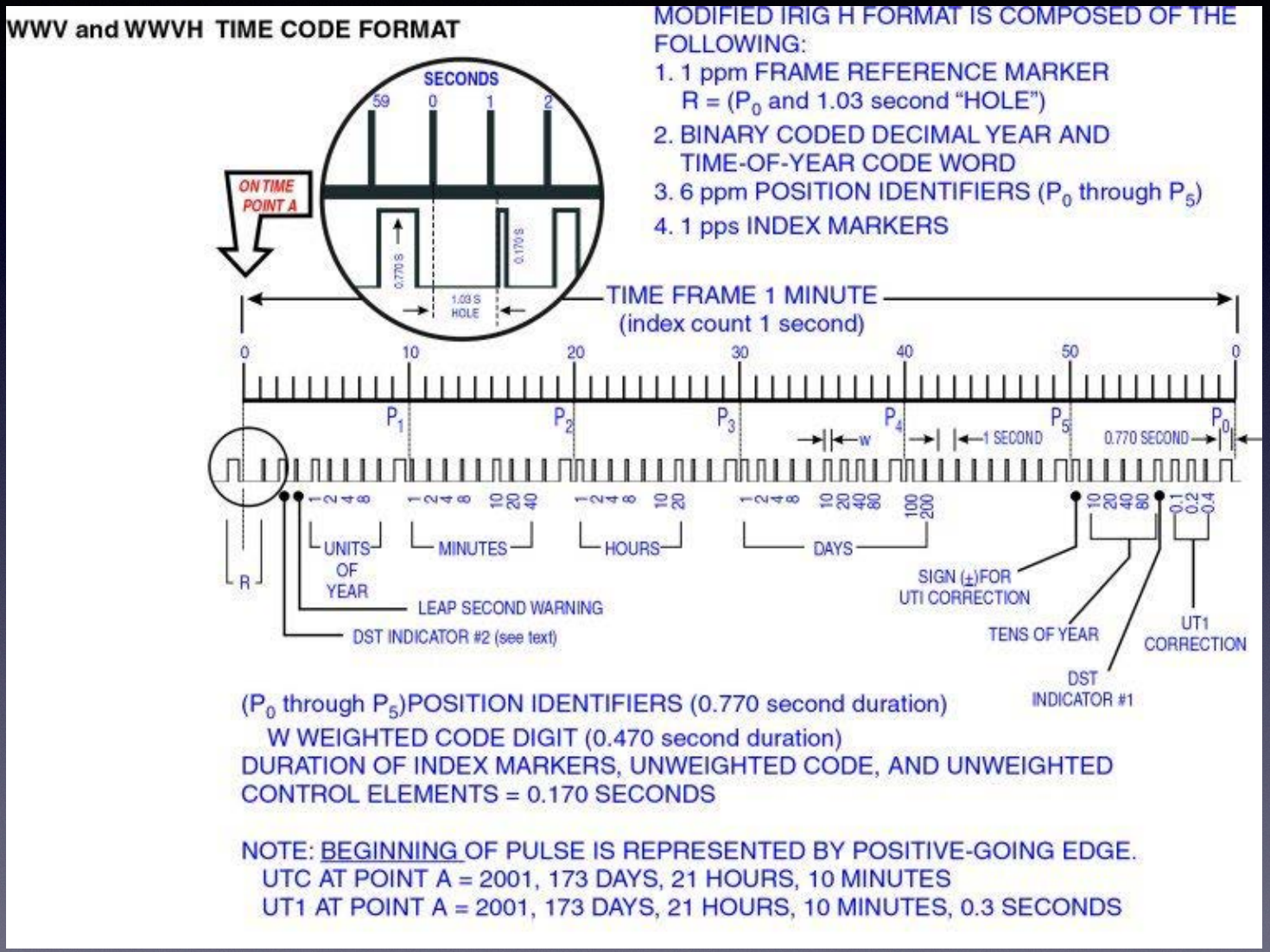


Very familiar to hams, SWLs

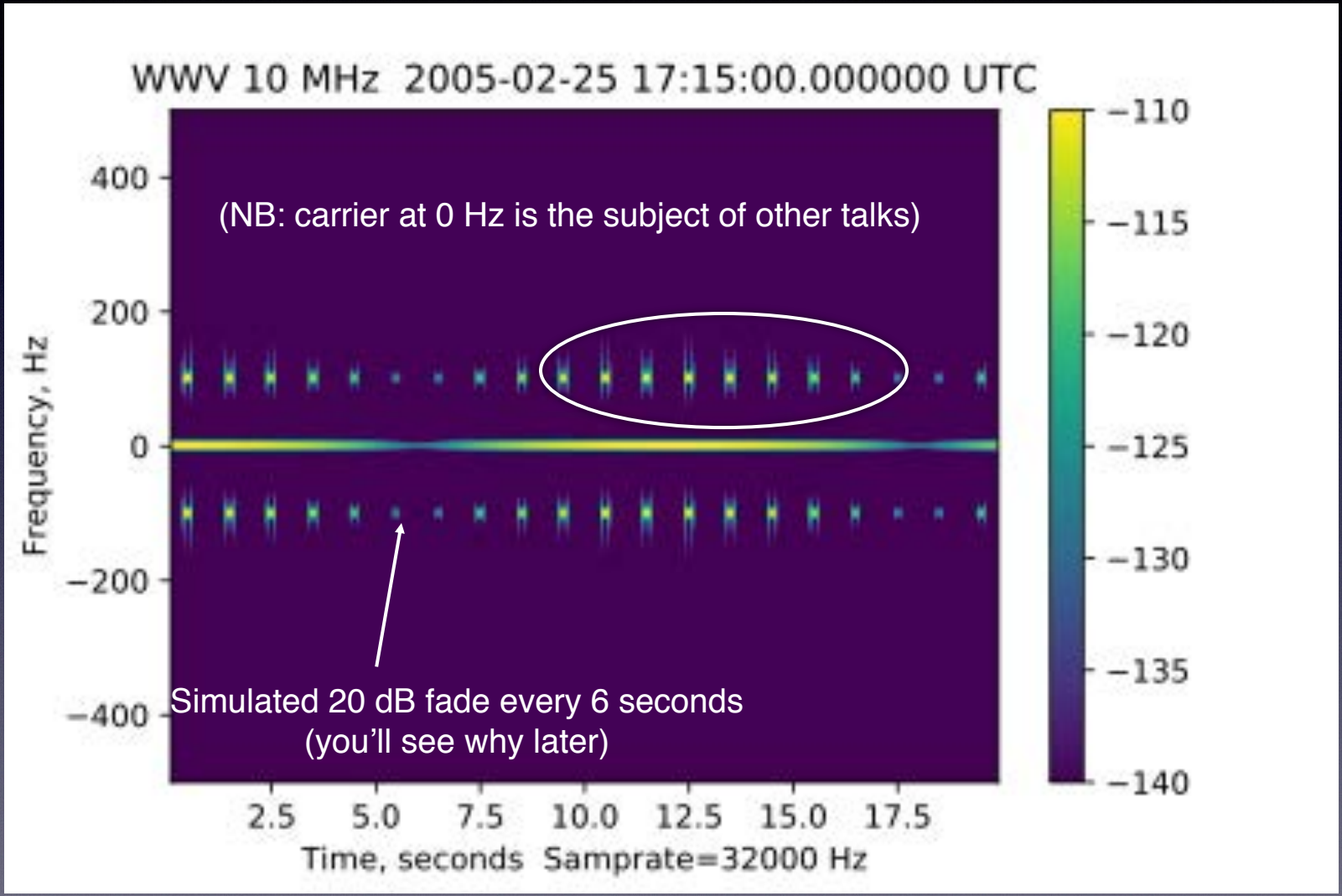
WWV Time and Information on HF Frequencies



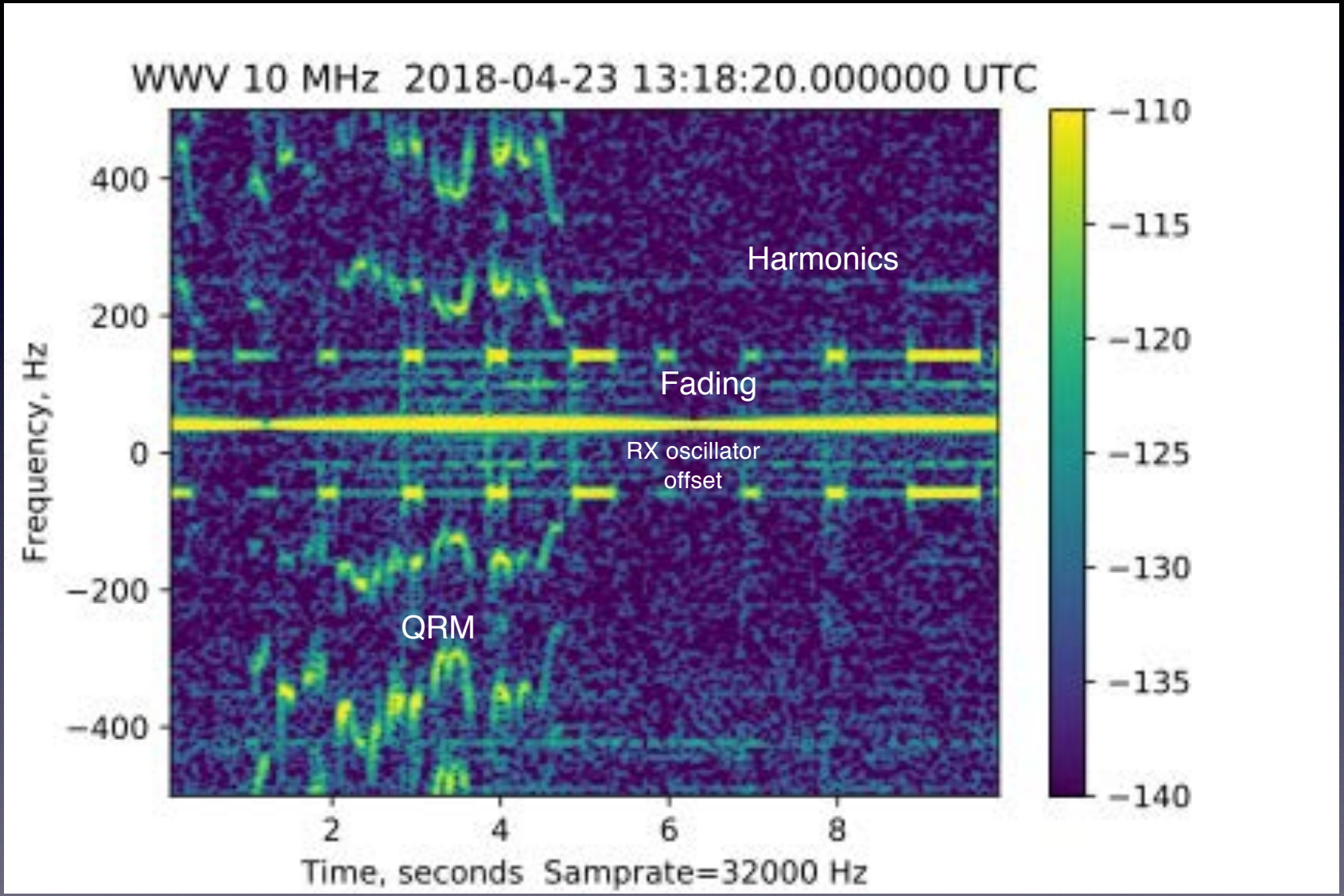
WWV Time and Information on HF Frequencies: 100 Hz subcarrier (Binary coded decimal) Pulses always there, once per second



Simulated WWV signal with 100 Hz subcarrier

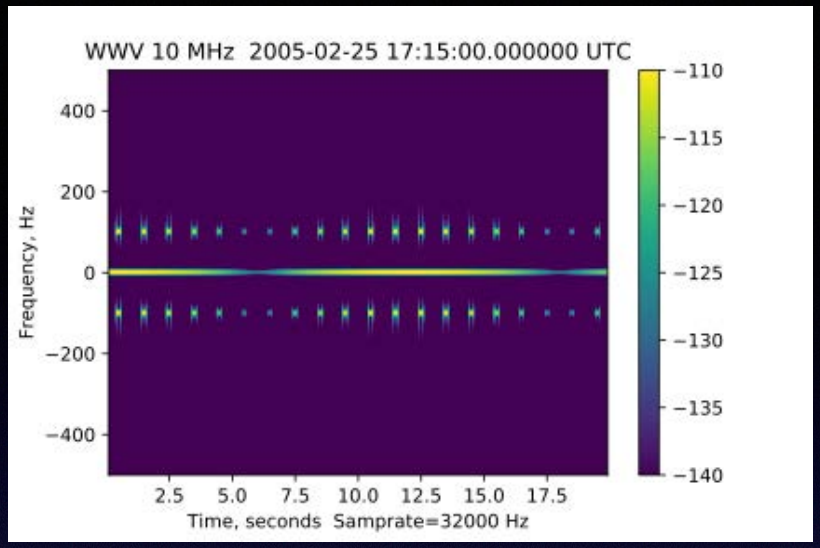


The real world



Fan dipole in W1PJE backyard

Time tick detection algorithm



SDR

DIGITAL RF https://github.com/MITHaystack/digital_rf

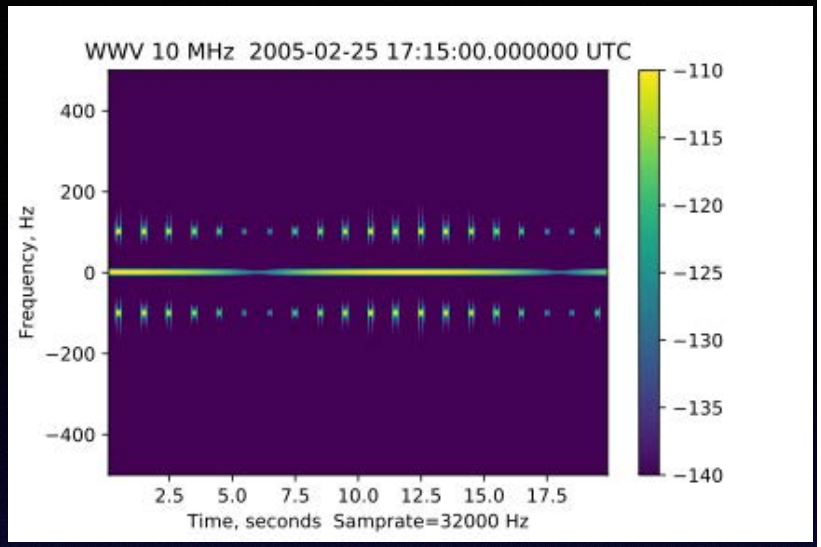
WWV recording → Heterodyne -100 Hz → LP filter 10 Hz → Threshold detect → Matched filter → Edge location

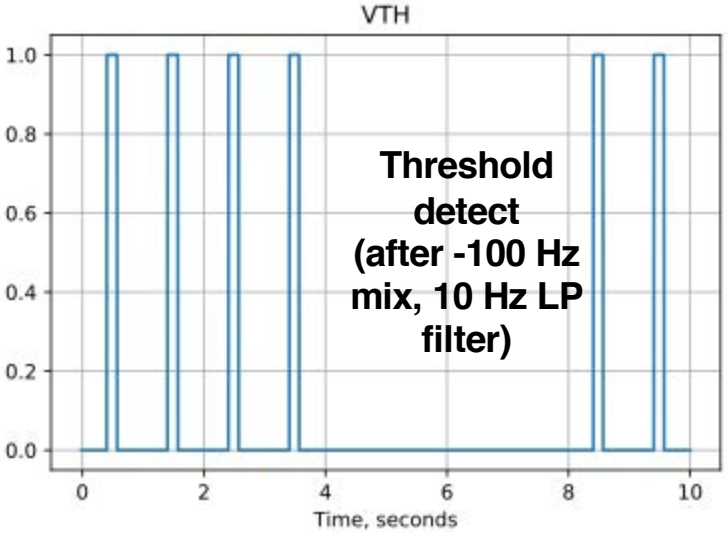
Remove carrier offset using locked PLL (Dusenbury, Kerby-Patel) cf. 2019 URSI talk

Pulse length >= WWV baud = 0.17 sec

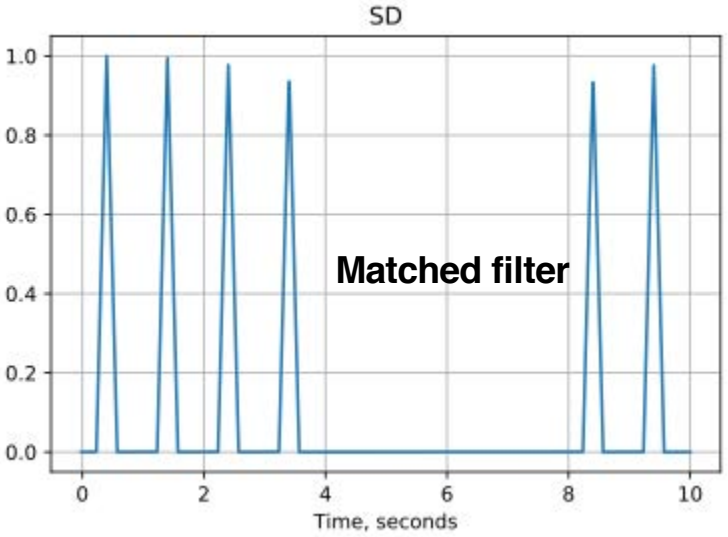
WWV recording → BP filter center=100 Hz → Locate first few 100 Hz zero crossings after edge location → HDF5 file

Time tick detection algorithm

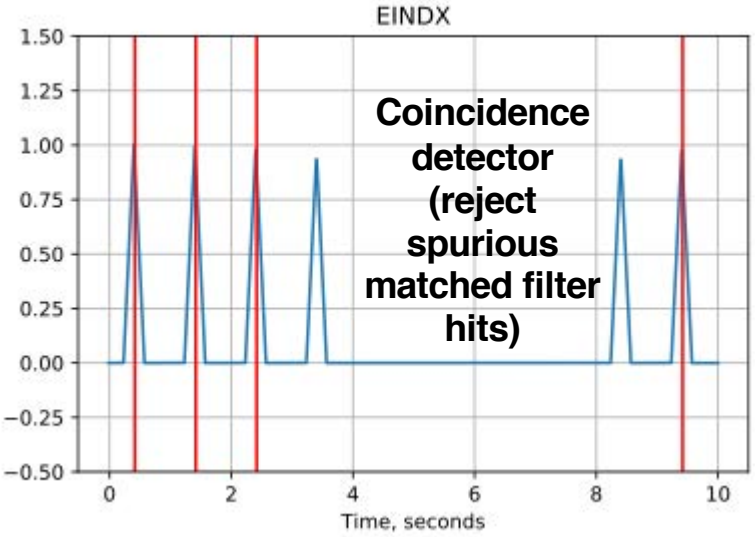




Threshold detect (after -100 Hz mix, 10 Hz LP filter)

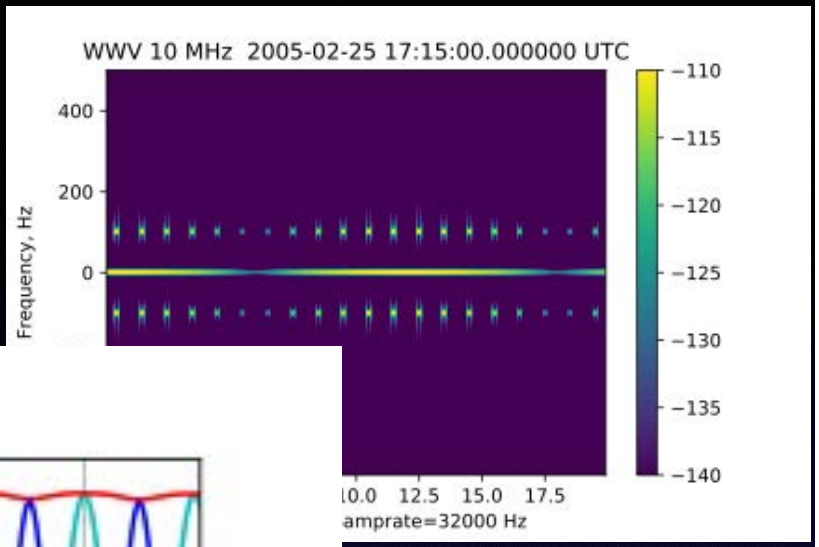


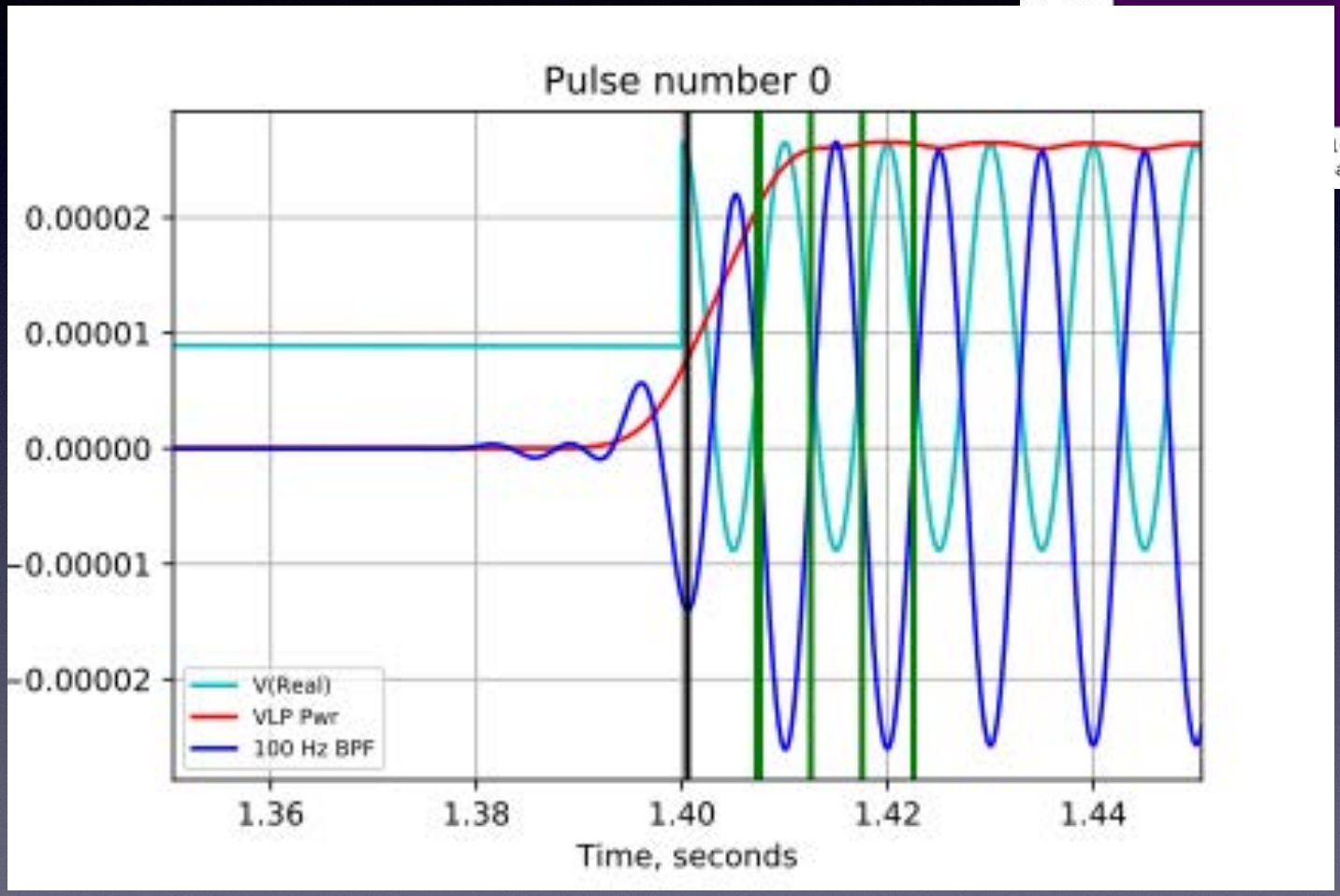
Matched filter



Coincidence detector (reject spurious matched filter hits)

Pulse detect example

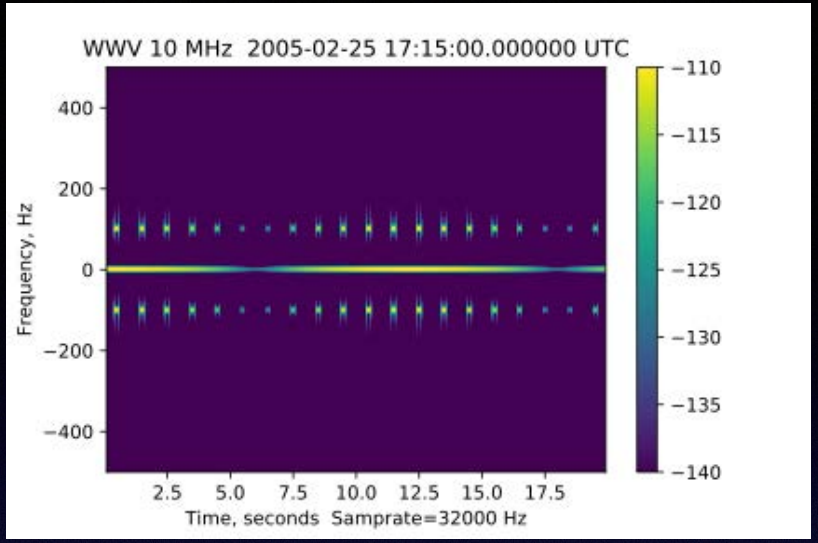


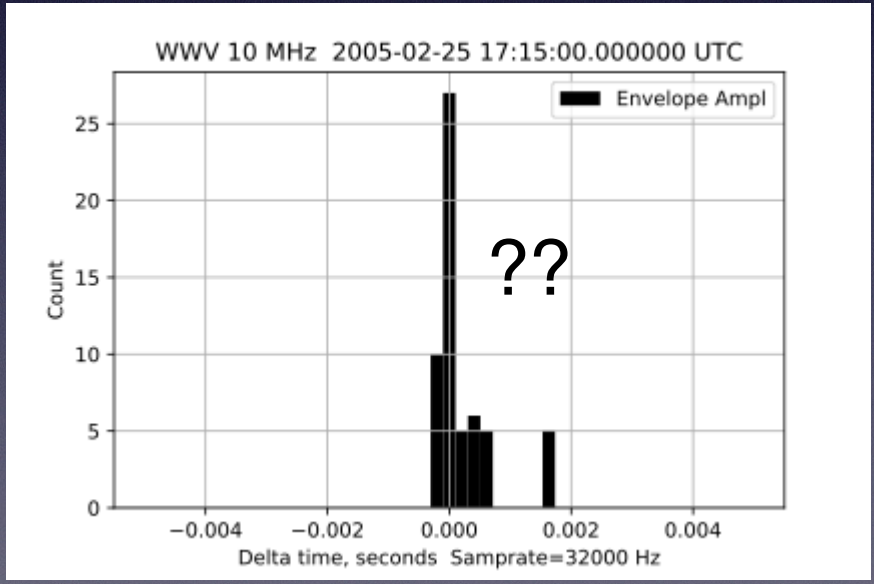


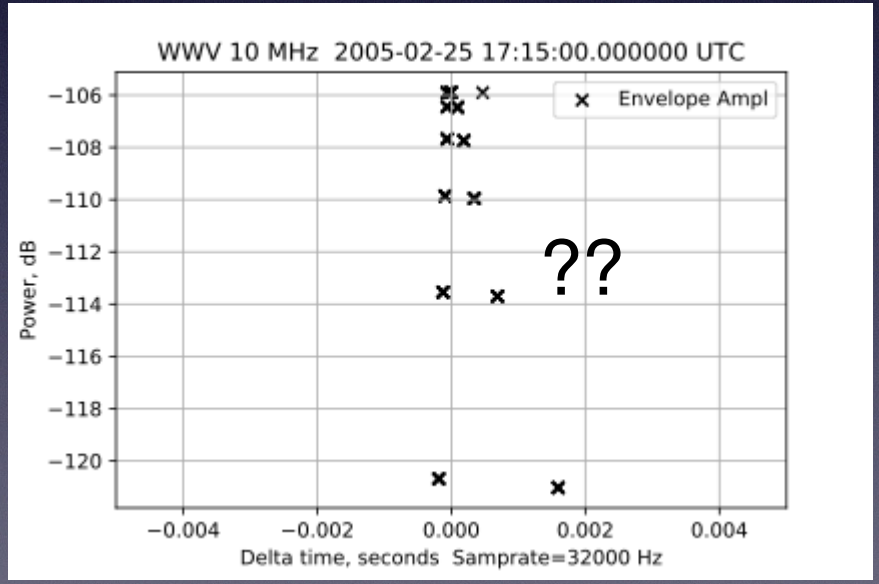
Statistical Results: Simulated WWV

Matched filter detect

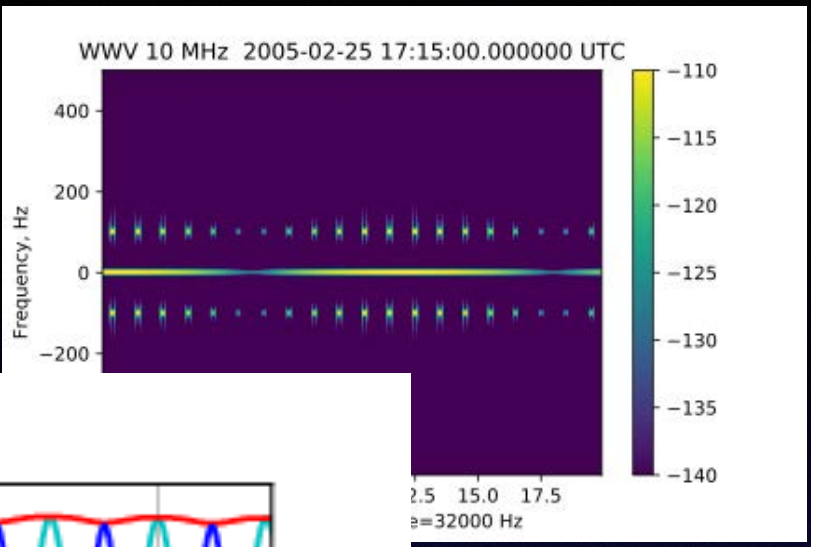
1 second edge variations

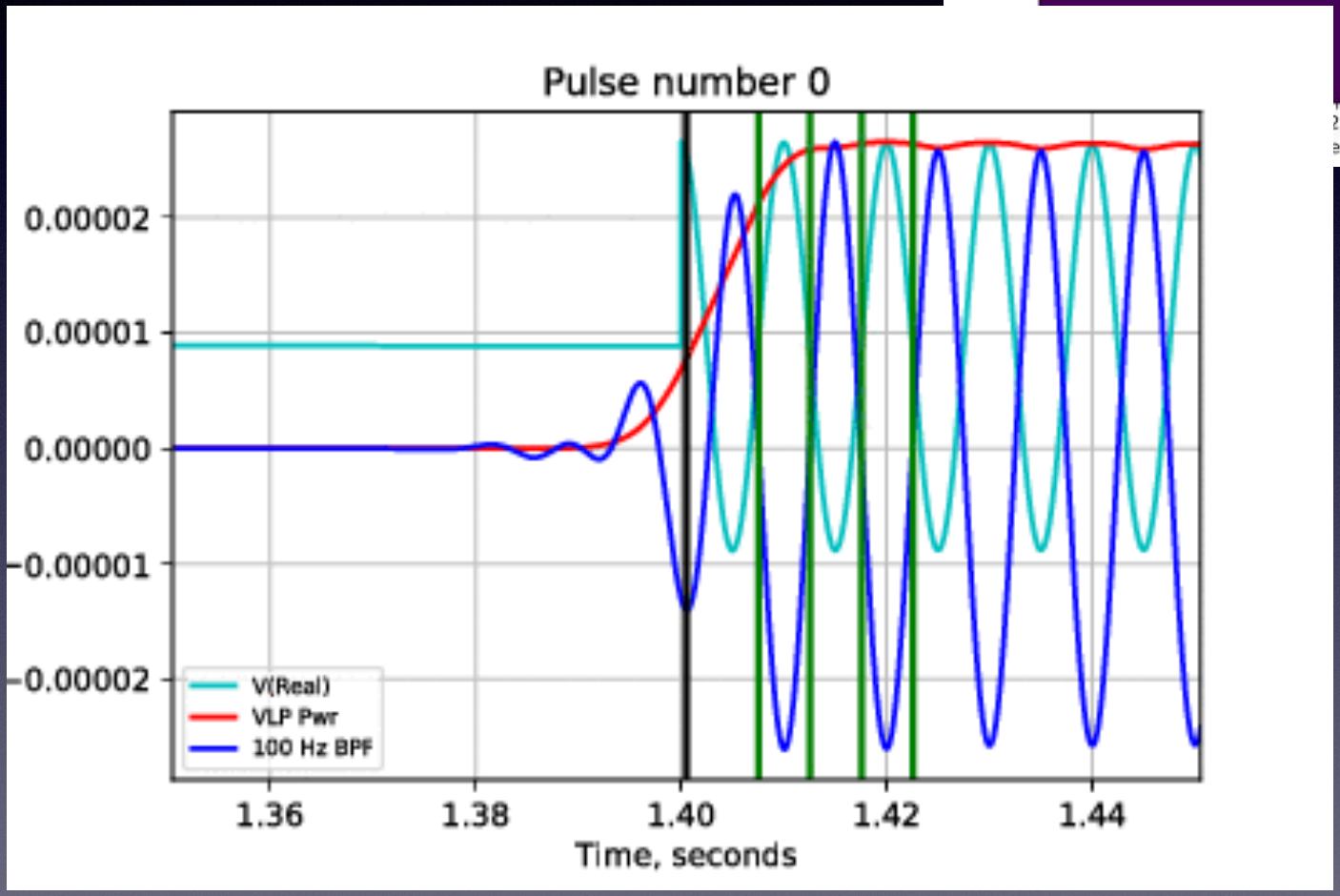






Fading effects on edge location

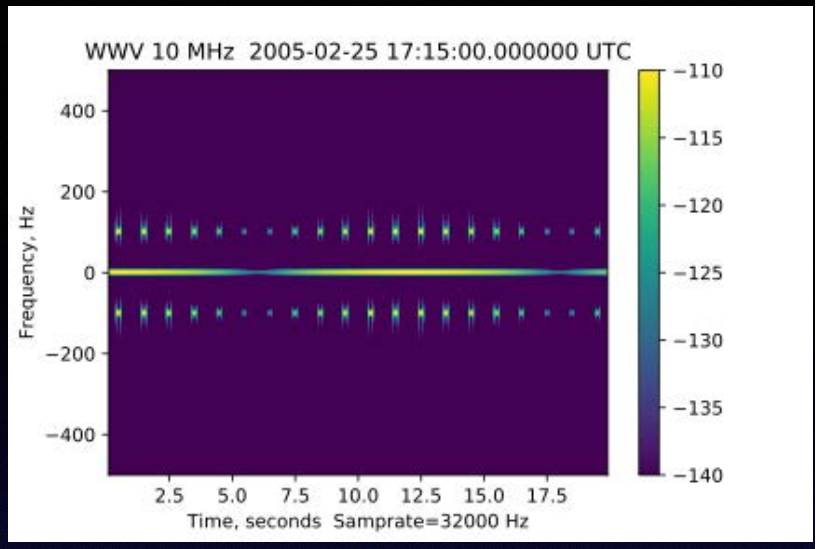


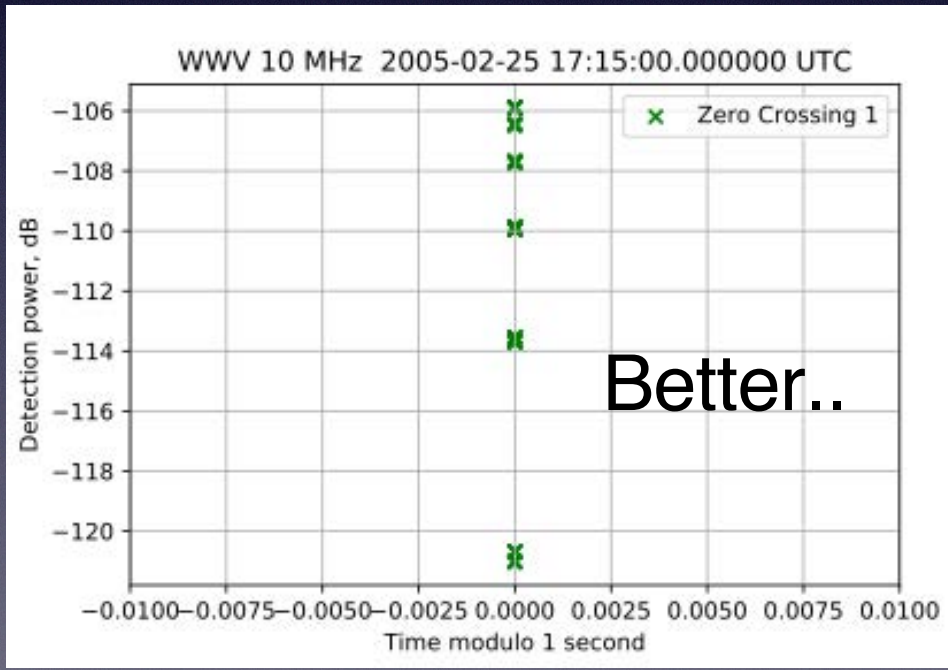


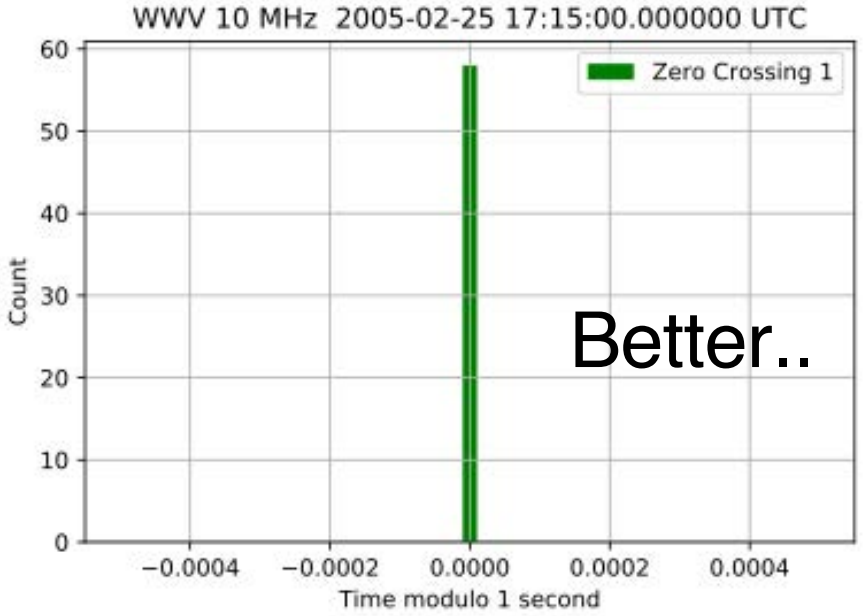
Statistical Results: Simulated WWV

2nd zero crossing after matched filter edge detect

1 second variations



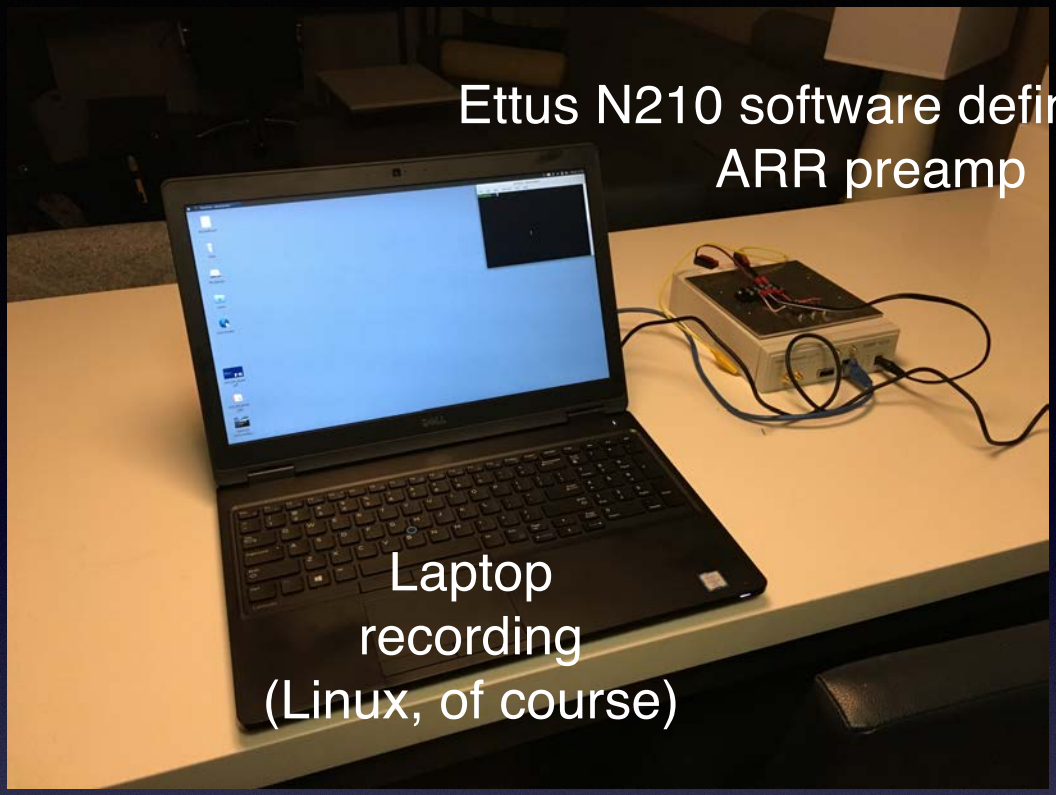




Obtain some ground wave WWV transmissions

E. Miller, G. Bust [JHU/APL] field campaign
near Ft. Collins, CO during January 2019 URSI meeting

"Liles errand"

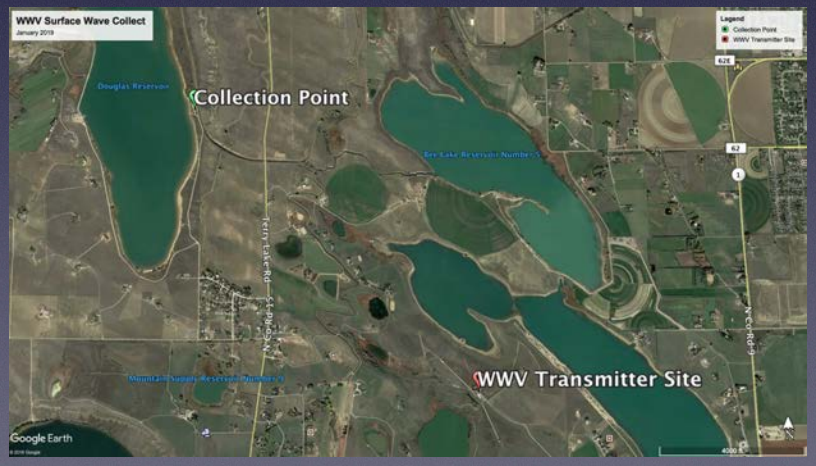


Ettus N210 software defined radio,
ARR preamp

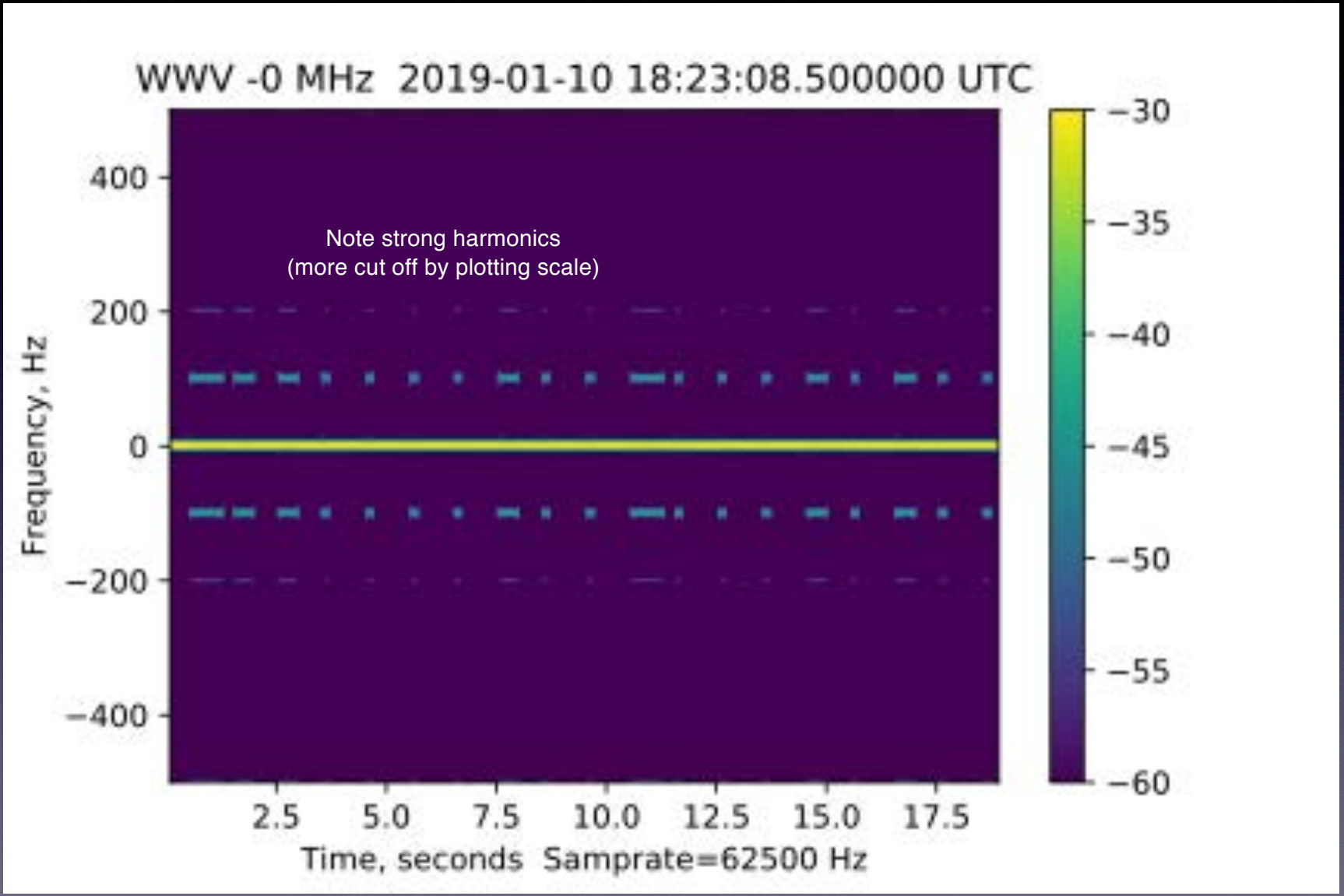
Power conditioning
(mobile op)

Laptop
recording
(Linux, of course)

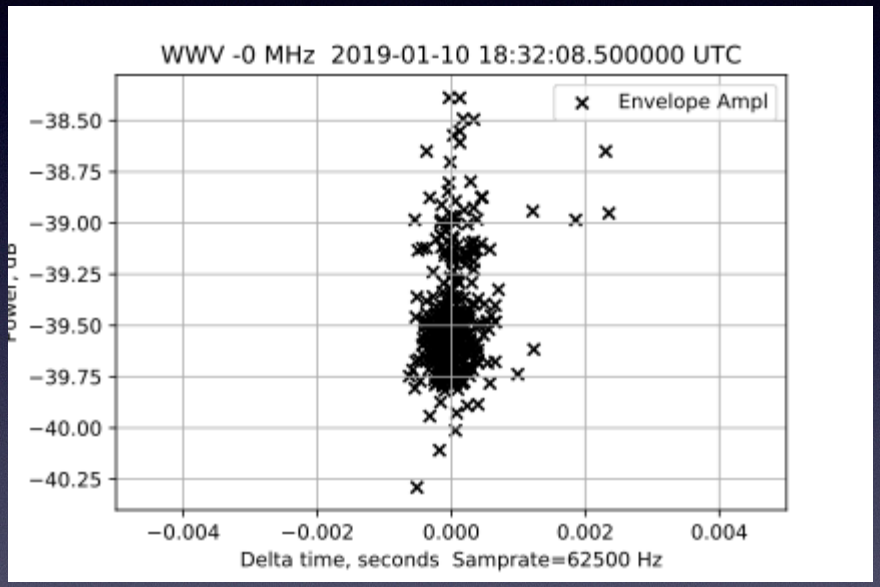
WWV transmitting towers

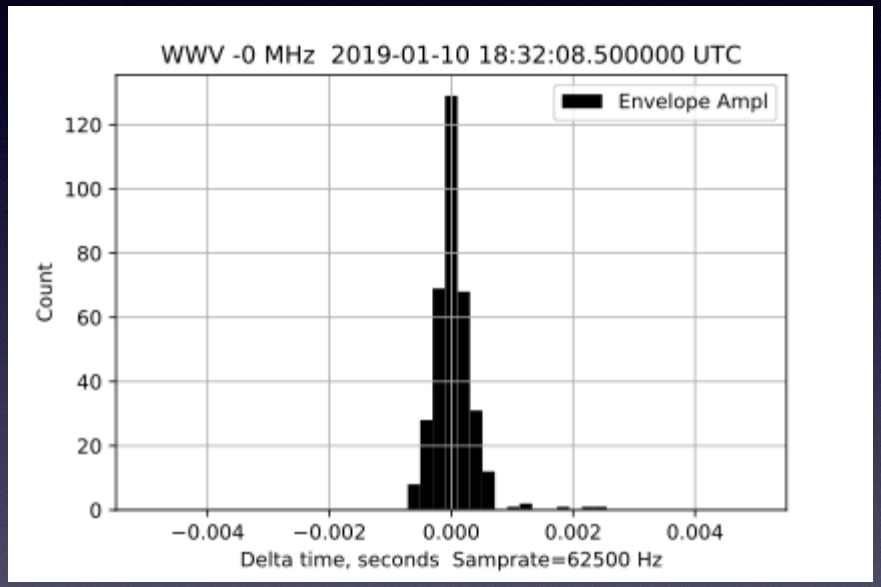


WWV Ground Wave: Clean signal at TX



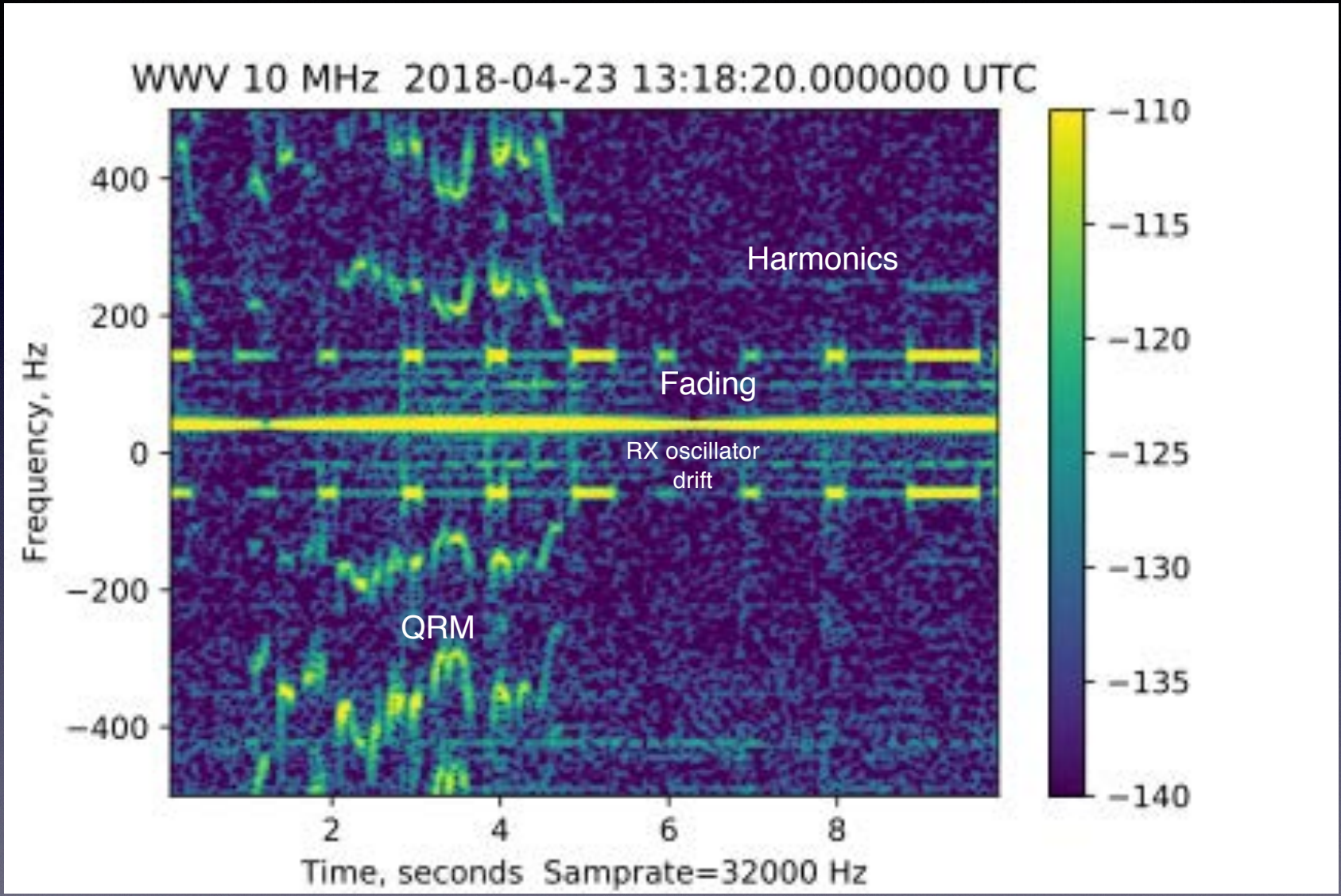
WWV Ground Wave Signal Statistics





(only envelope edge detections shown;
remember they are ‘blurry’ if any fades occur)

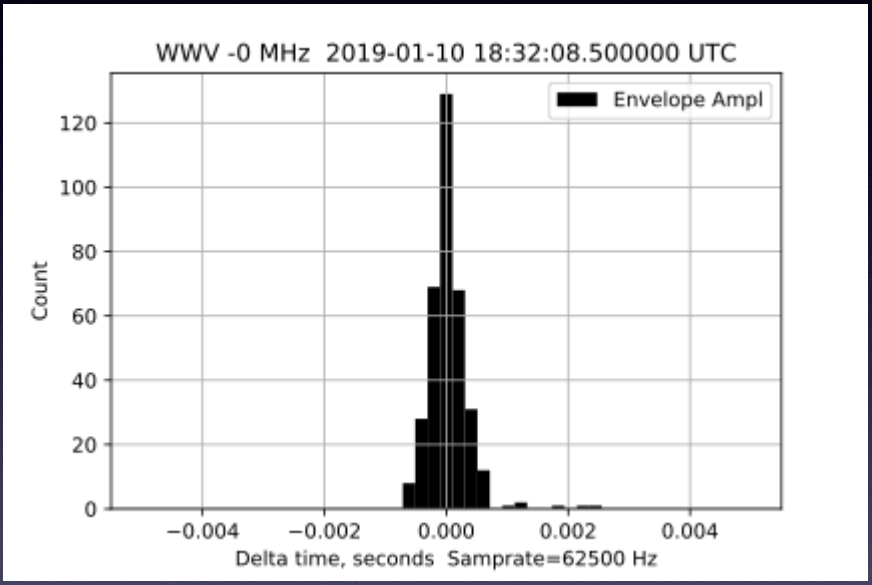
Remember W1PJE's back yard?



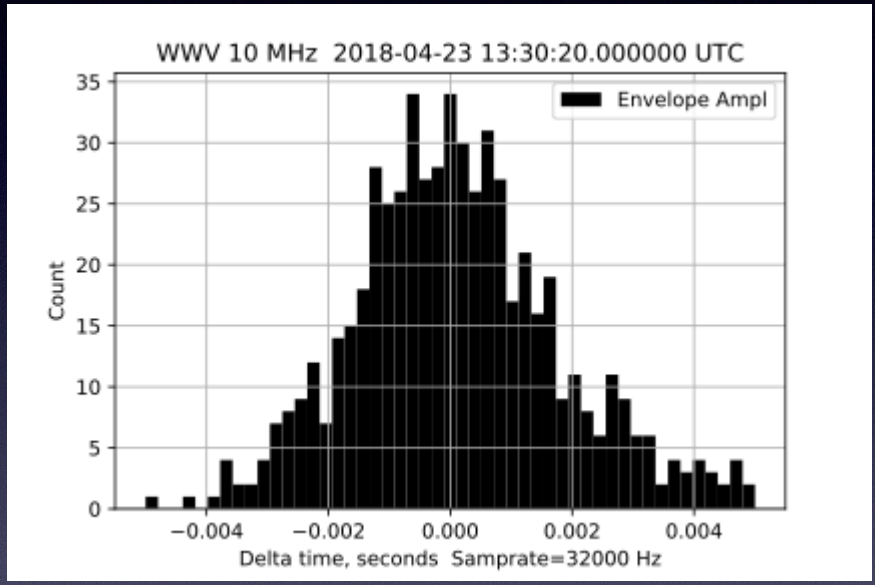
(Note: not the same time as WWV local collect)

Ionospheric effects on time tick variance?

NB: not the same collect time…



Typical ground wave (Colorado)



Ionospheric path (Massachusetts)

Ionosphere is having some kind of impact.
Now all we have to do is figure out what it means!

Summary

- WWV has potential as a simple ionospheric remote sensor
- Interesting signal detection problem
- But what do the results mean?
- Much more work needed…

John Cameron Swayze says..

Thanks for listening.

NOTE: This is a collective effort.