HAMSCI: HAM Science Citizen Investigation

Rogue Valley ARC

April 7, 2022

Tom McDermott, N5EG

Life Senior Member, IEEE

HamSCI

The **H**am radio **S**cience **C**itizen **I**nvestigation is:

hamsci.org/dayton2017

Founder/Lead HamSCI Organizer:
Dr. Nathaniel A. Frissell, W2NAF
The University of Scranton

An organization that allows university researchers to collaborate with the amateur radio community in scientific investigations.

Objectives:

1. **Advance** scientific research and understanding through amateur radio activities.
2. **Encourage** the development of new technologies to support this research.
3. **Provide** educational opportunities for the amateur community and the general public.

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Participants

- HAMSCI – A group that does citizen science.
  - Will deploy many low-cost Space Weather Stations, conduct observations, submit data.
    - Universities, Researchers, Individuals - You can participate.

- TAPR – Tucson Amateur Packet Radio
  - Designing Tangerine Space Weather Station hardware.
  - Modular platform. 1st implementation:
    - Data Engine (DE) + HF Receiver + GPSDO + 3-axis Magnetometer + Local Host computer.

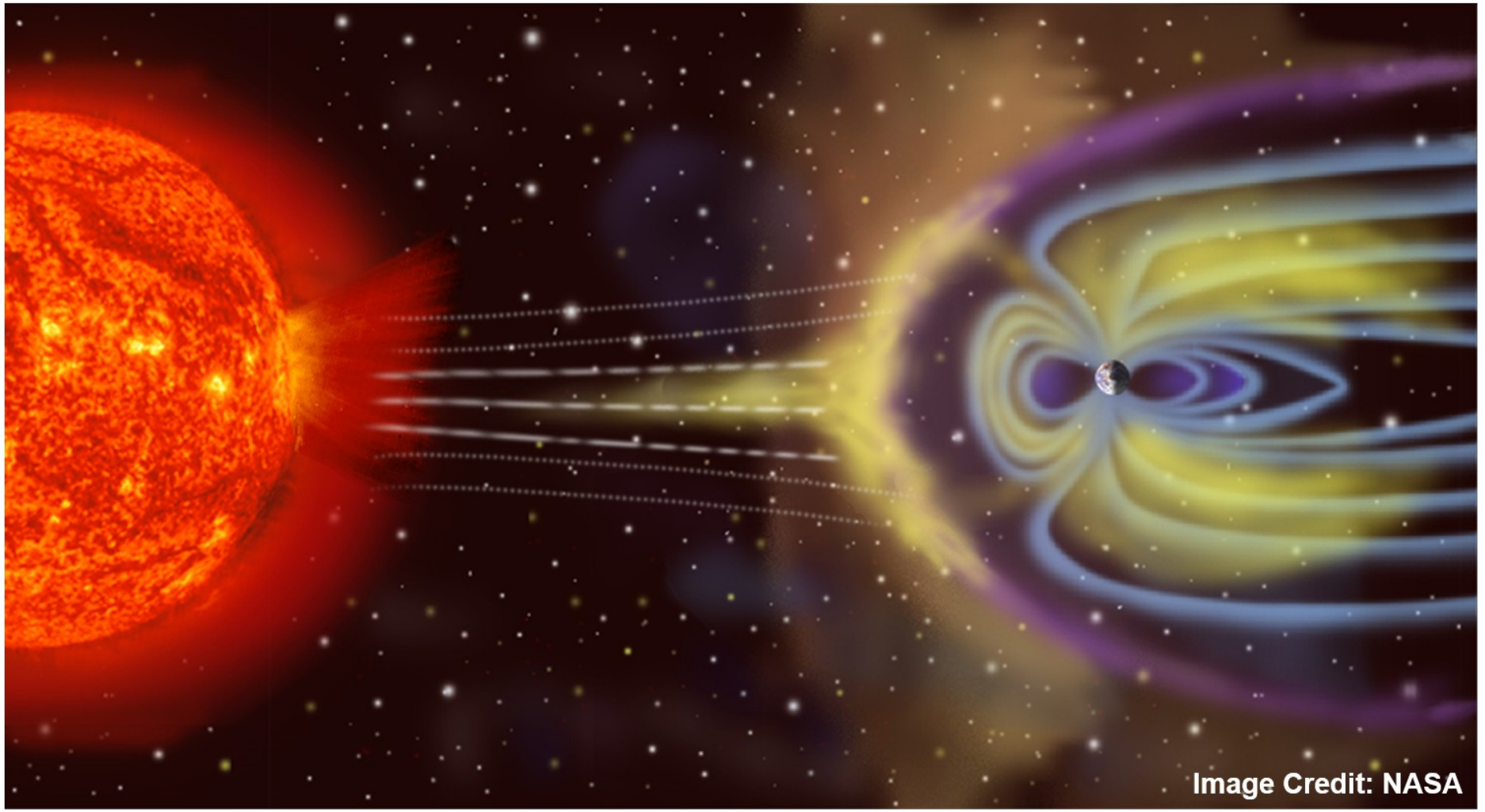
- Principle Investigators (PI)
  - Devise the investigation, determine what data to collect, determine equipment requirements.
  - Central data server, Curation policies, Storage, Metadata definition. System control.

What is Space Weather?

- Space weather is *broad* field, covering solar, heliospheric, magnetospheric, ionospheric physics, meteorology, aerospace engineering, etc...
- Definition: “Space weather refers to conditions on the Sun and in the space environment that can influence the performance and reliability of space-borne and ground- based technological systems, and can endanger human life or health.”

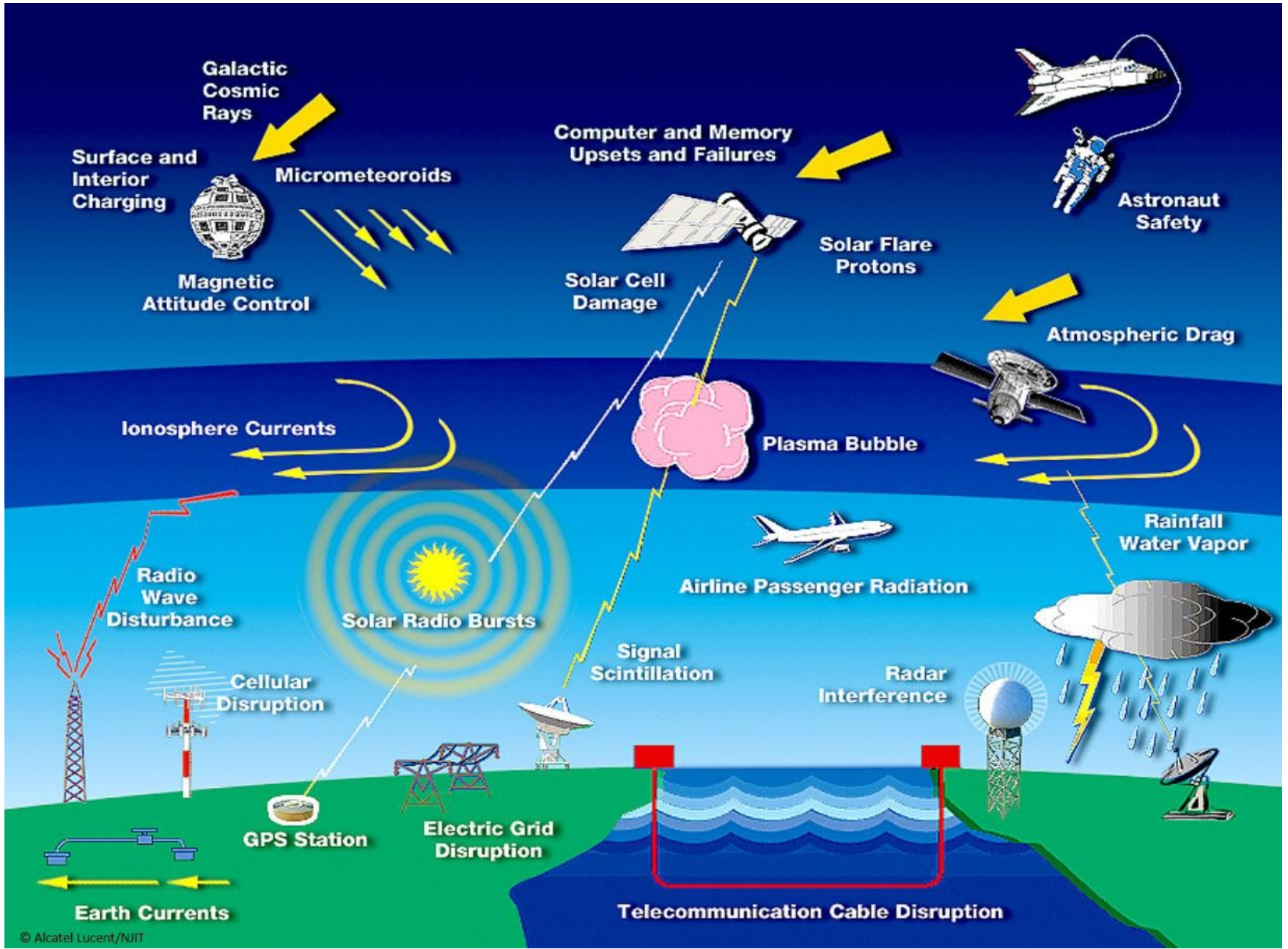
[National Space Weather Program]

Where is Space Weather?

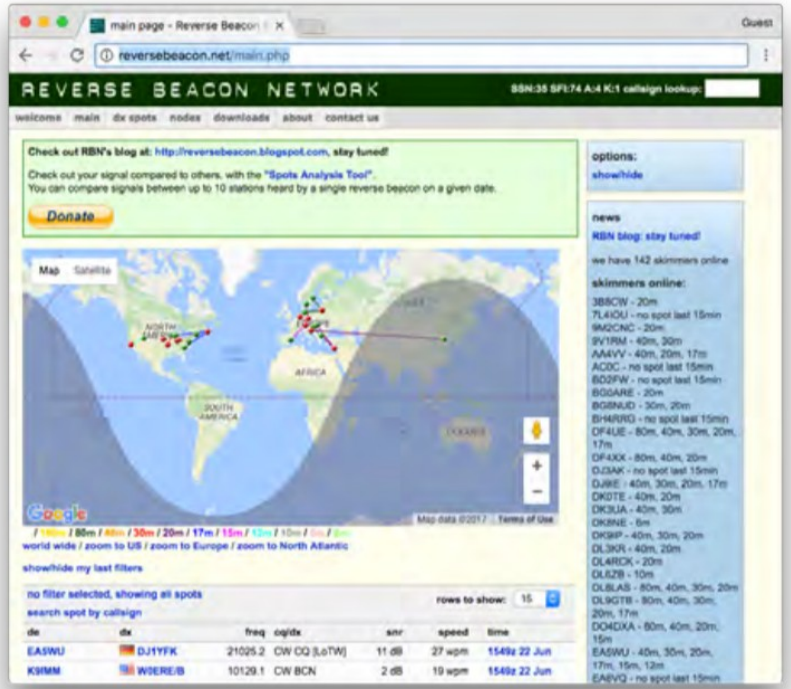


- Sun (Heliosphere)
- Solar Wind
- Magnetosphere
- Ionosphere

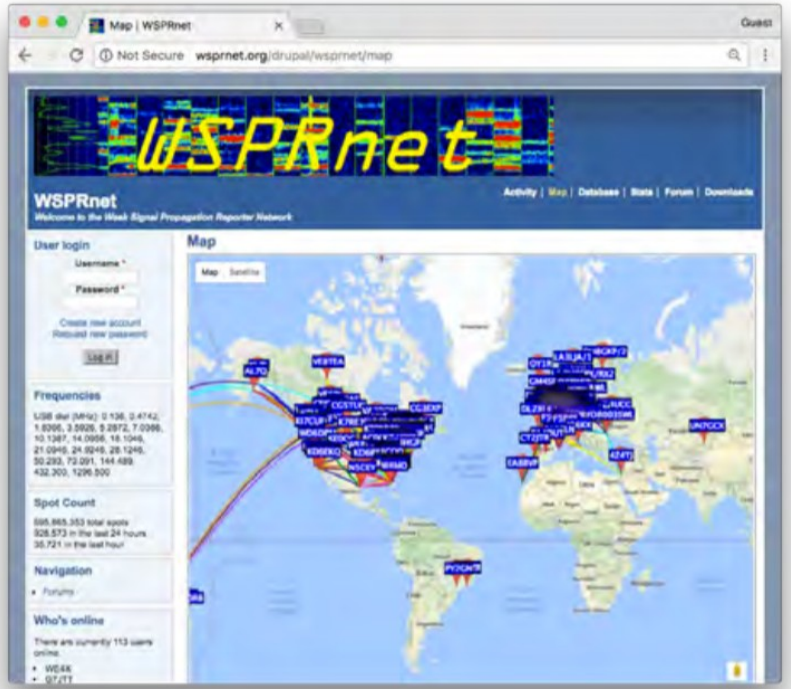
What does Space Weather affect?



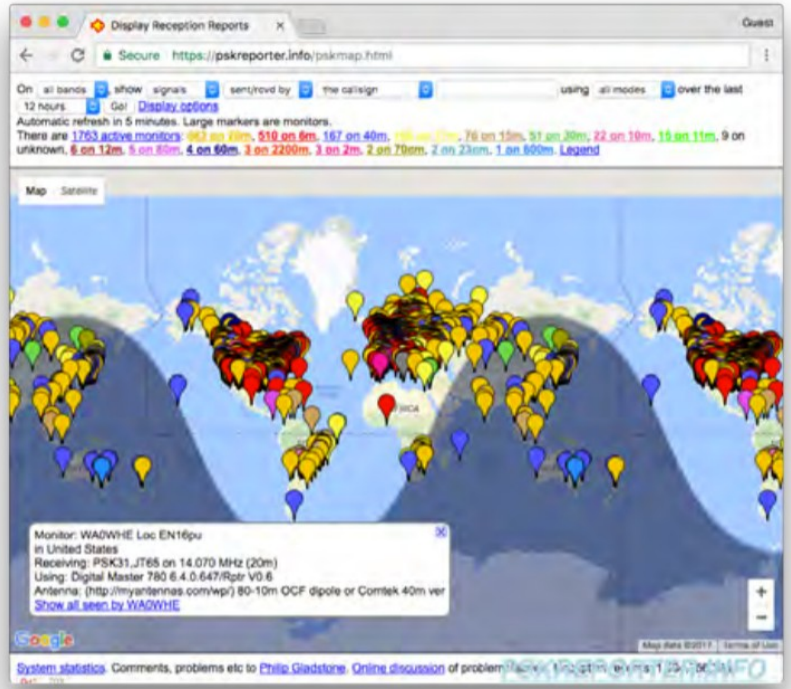
Ham Radio Observation Networks



Reverse Beacon Network (RBN)
reversebeacon.net



WSPRNet
wsprnet.org



PSKReporter
pskreporter.info

- Quasi-Global
- Organic/Community Run
- Unique & Quasi-random geospatial sampling

- Data back to 2008 (A whole Solar Cycle!)
- Available in real-time!

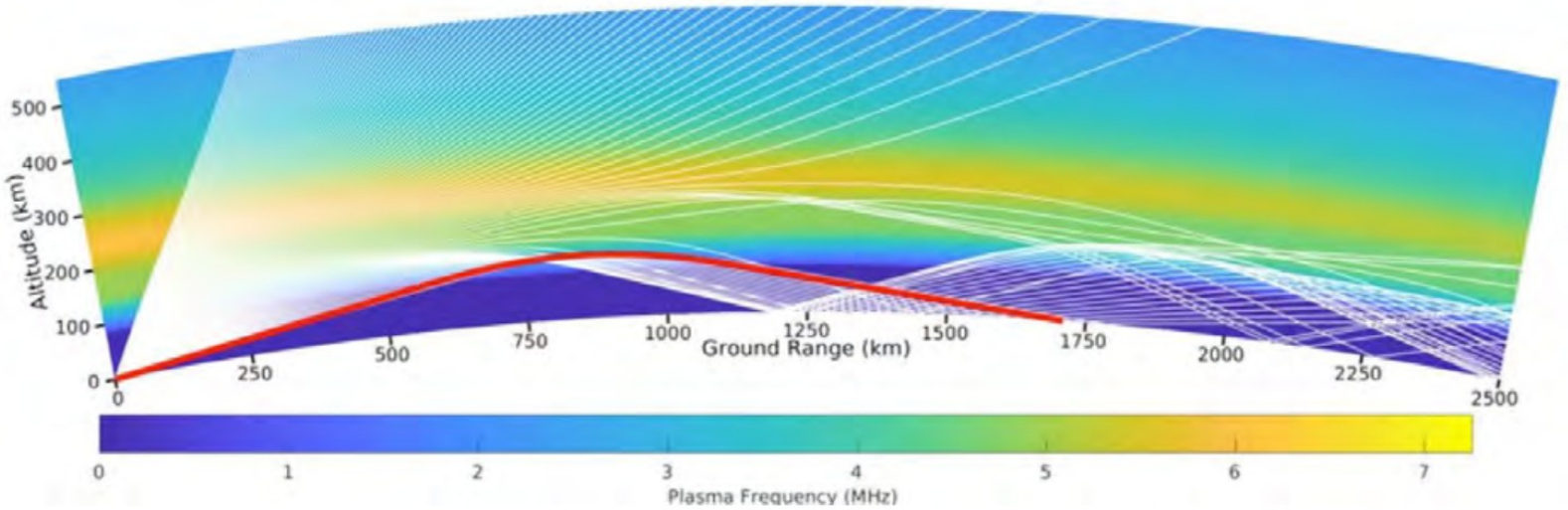
Ham Radio Frequencies and Modes

	Frequency	Wavelength
LF	135 kHz	2,200 m
MF	473 kHz	630 m
	1.8 MHz	160 m
HF	3.5 MHz	80 m
	7 MHz	40 m
	10 MHz	30 m
	14 MHz	20 m
	18 MHz	17 m
	21 MHz	15 m
	24 MHz	12 m
	28 MHz	10 m
VHF+	50 MHz	6 m
	And more…	

PHaRLAP Raytrace

1600 UT 21 Aug 2017 14.03 MHz - Eclipsed SAMI3

TX: AA2MF (Florida) RX: WE9V (Wisconsin)



- Hams routinely use HF-VHF transionospheric links.
- Often ~100 W into dipole antennas.
- Common HF Modes
  - Digital: FT8, PSK31, WSPRNet, RTTY
  - Morse Code / Continuous Wave (CW)
  - Phone: Single Side Band (SSB)

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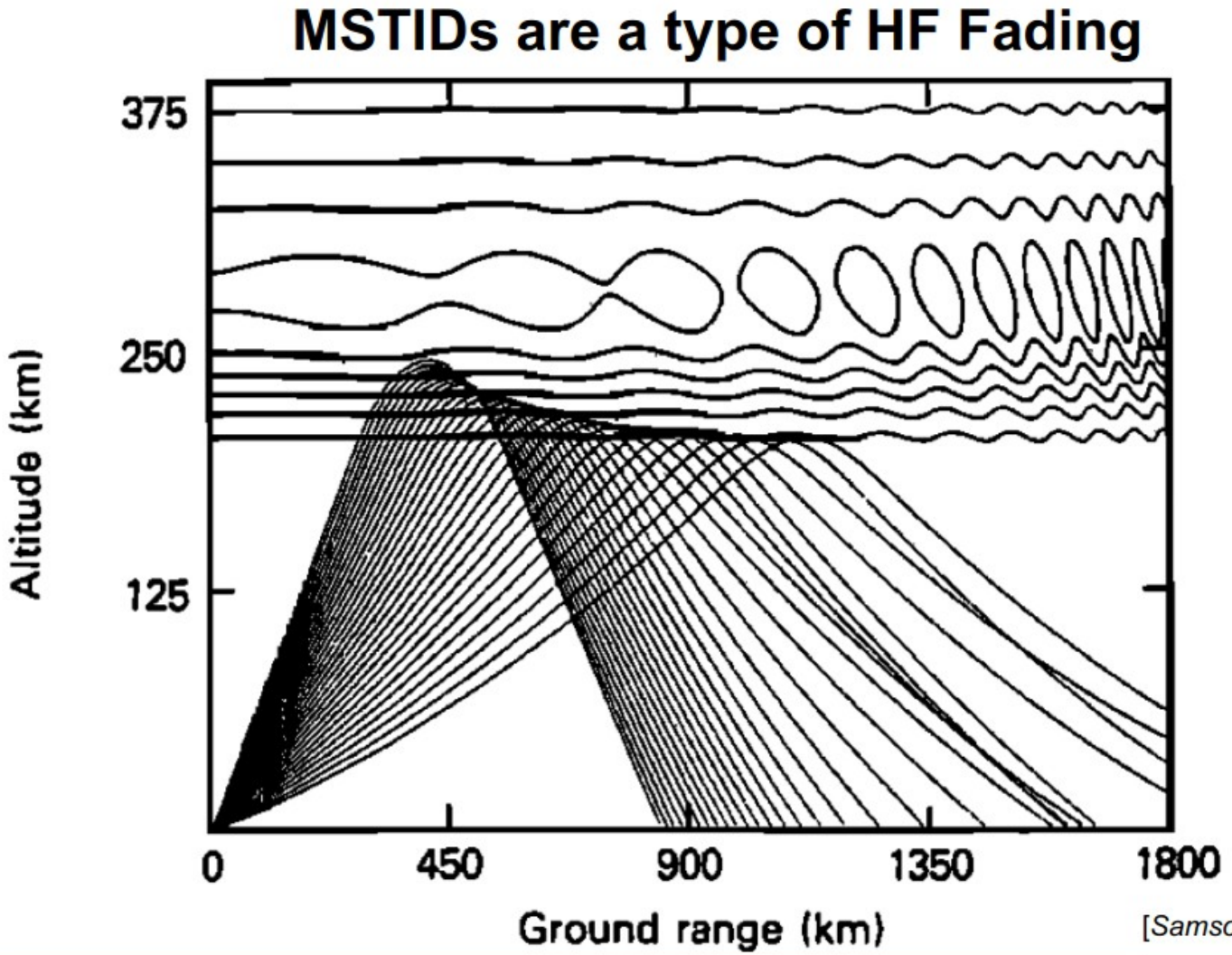
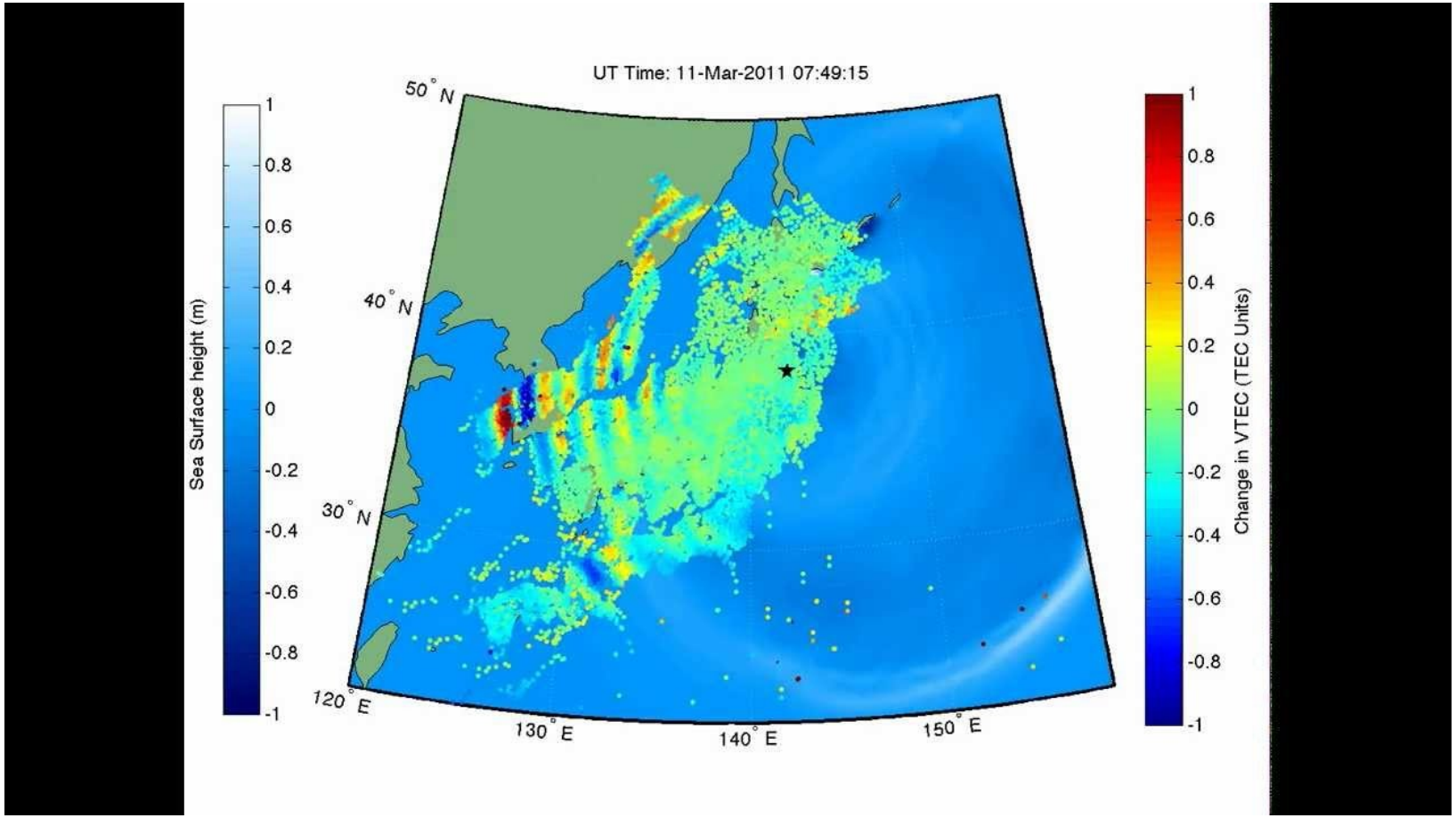
Traveling Ionospheric Disturbances



[*Samson et al.*, 1990]

TID Example



https://www.youtube.com/watch?v=Fd__wlhkZ1M

Space Weather Station Goals

As hams building a Personal SW Station, what do we want to do?

Operations

Hams:

- Know the best frequencies for working DX
- Understand the RFI Environment
- Communicate better during emergencies

Research

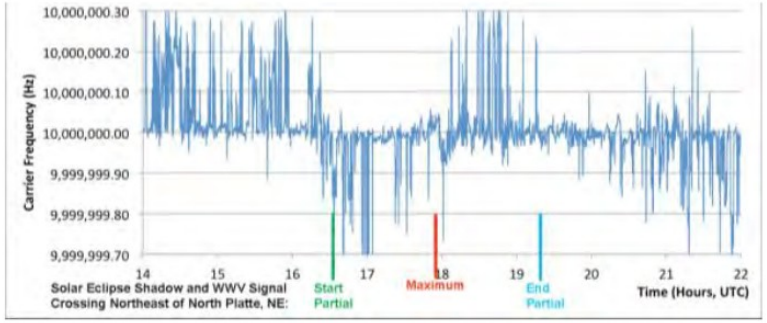
Scientists:

- Better sample the environment
- Better understand near-Earth Space

Low-Cost “Grape” PSWS

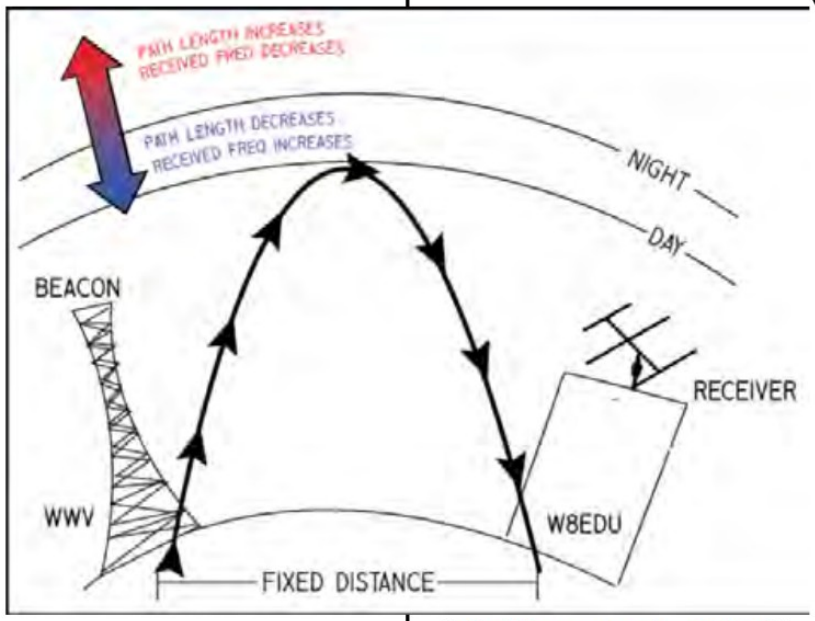
- HF “Doppler Shift” Monitoring
- Main components: Raspberry PI, GPSDO, Custom Direct-conversion receiver board
- Cost: ~$100 to $200
- Developed by Case Western

10 MHz Doppler During 2017 Eclipse
TX: WWV RX: WA9VNJ (Milwaukee)



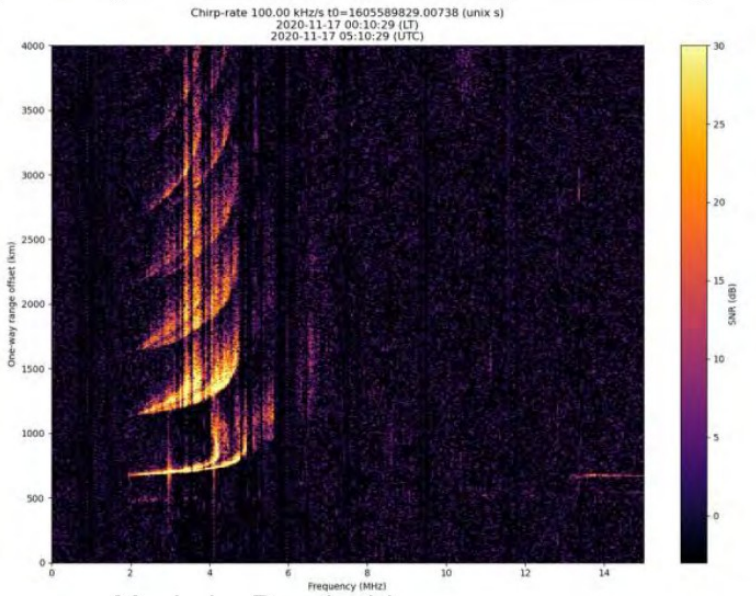
SDR-Based “Tangerine”

- HF FPGA-based Software Defined Radio
- Precision timing and frequency measurement
- 2 to 4 coherent, phase-locked receive channels
- Cost ~$500 to $1000
- Developed by Amateur Radio Group TAPR



[Collins et al., 2021]

Oblique Ionograms
(Currently on Ettus N200 but will be ported to Tangerine)



Movie by Dev Joshi
GNUChirpsounder2 by Juha Vierinen

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What's In a Name?

TangerineSDR

IT'S

- Summertime Snack
- Fruity
- Delicious
- Orange!
- Not trademarked

Orange is the new black!

(And yes, Virginia, we *can* get orange solder mask)

Key PSWS Performance Needs

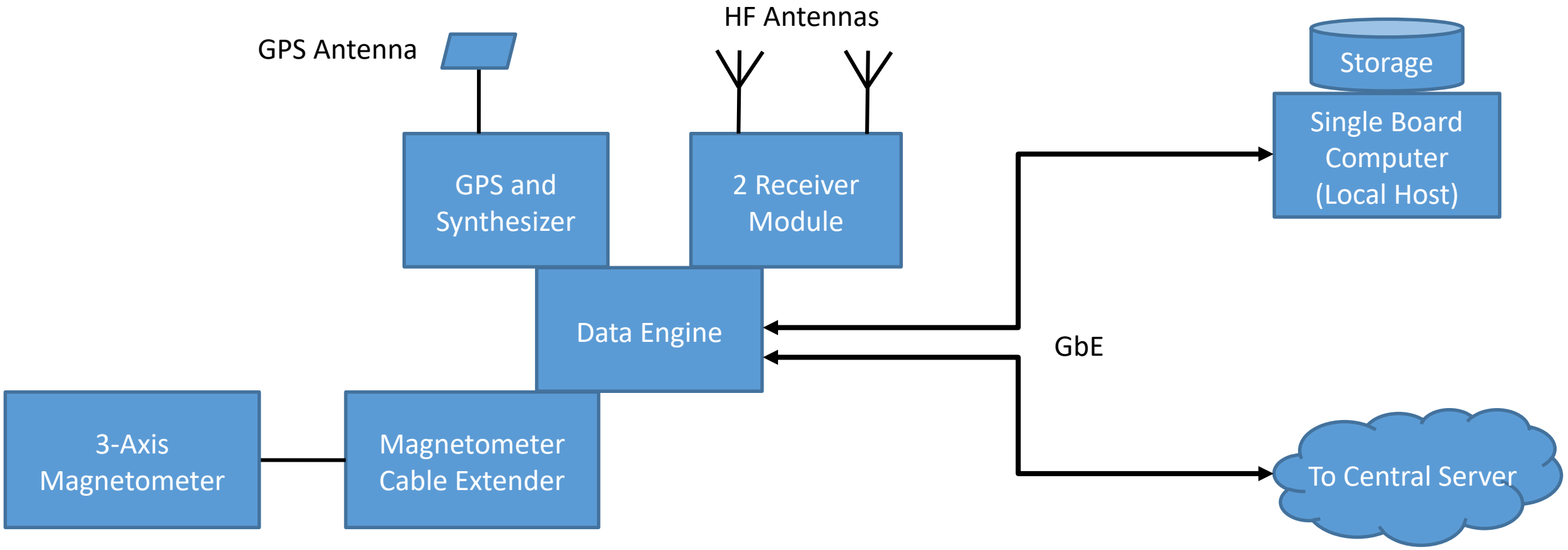
- Low Cost
- Two HF (0.1 – 30 MHz) receivers with reasonable dynamic range.
  - Up to 8 bands per receiver.
  - NF <= 10 dB.
- Low receiver phase noise.
- Ability to calibrate receiver amplitude.
- Tight phase coherence between receiver channels
  - Ability to do interferometry.
- High accuracy time-stamping of samples & high frequency accuracy.
  - Objective: ±50 nanoseconds during normal GPS reception.
- 3-axis magnetic field measurements:
  - 13 nT resolution / 1 second update rate.

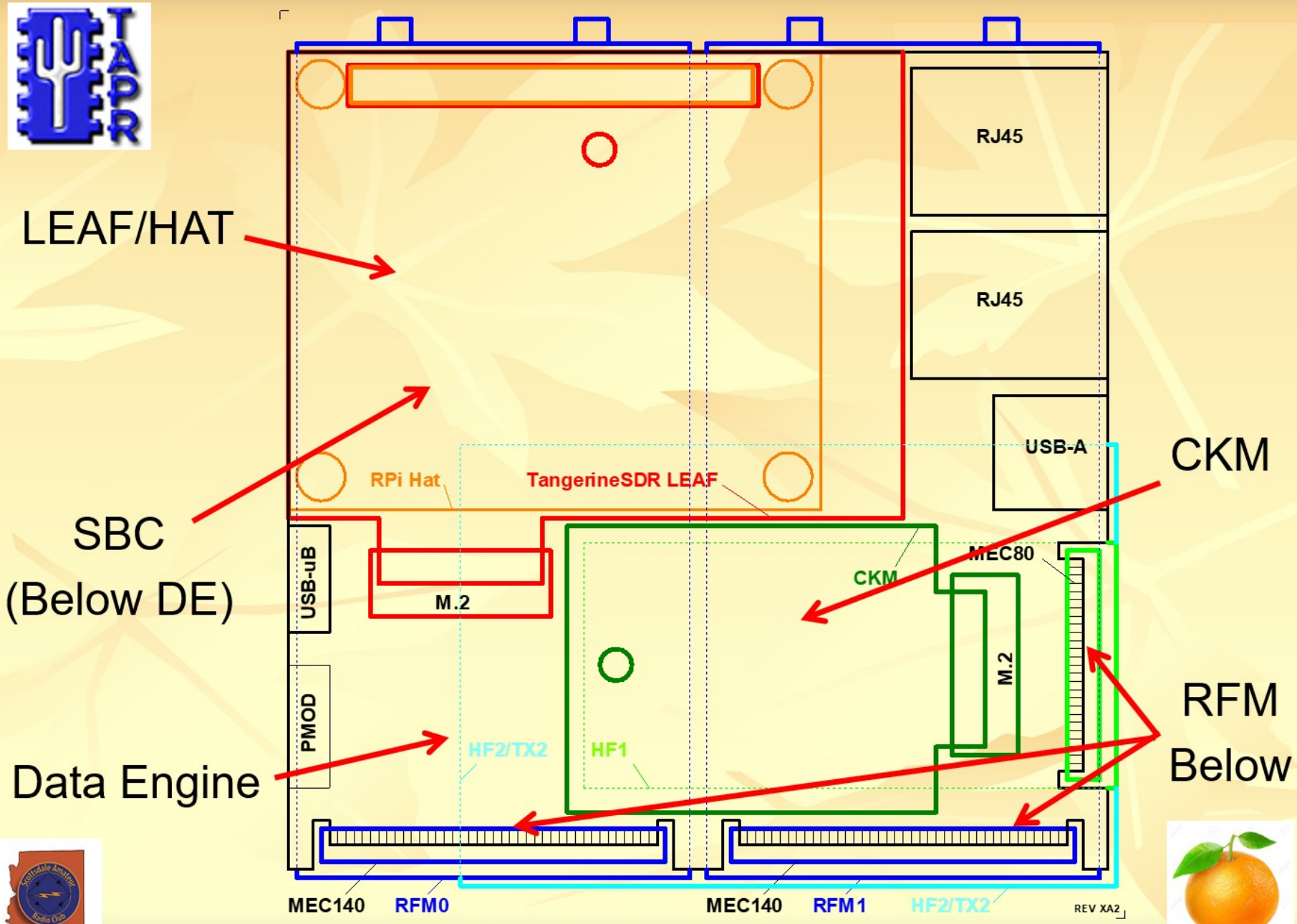
System Requirements

- Low cost. Fully open source.
- Ability to store received data, annotate with Meta-data (data describing the data).
  - Local host computer (SBC, i.e. Odroid or maybe R-Pi 4).
- Ability to trigger and upload previously recorded data.
  - Internet connection to central server.
- Positive control of the network (passwords, tokens, etc. on the Internet-facing interface).
- Local GUI Display.
  - May use some SATNOGS infrastructure / software.

PSWS Block Diagram

(Using TangerineSDR Modules)



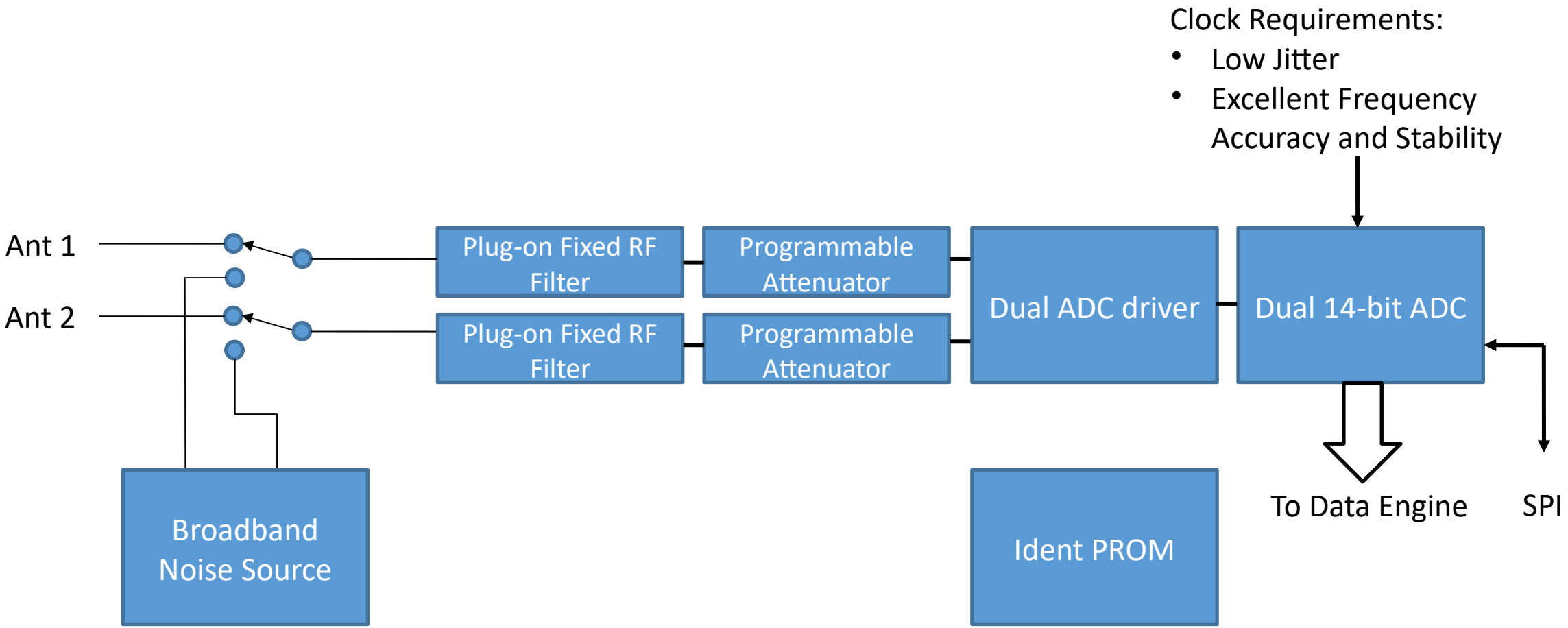


Video of TangerineSDR mockup

- Shown by Scotty, WA2DFI at the 2019 DCC in Detroit.
- https://youtu.be/81MlpIpB7Mo

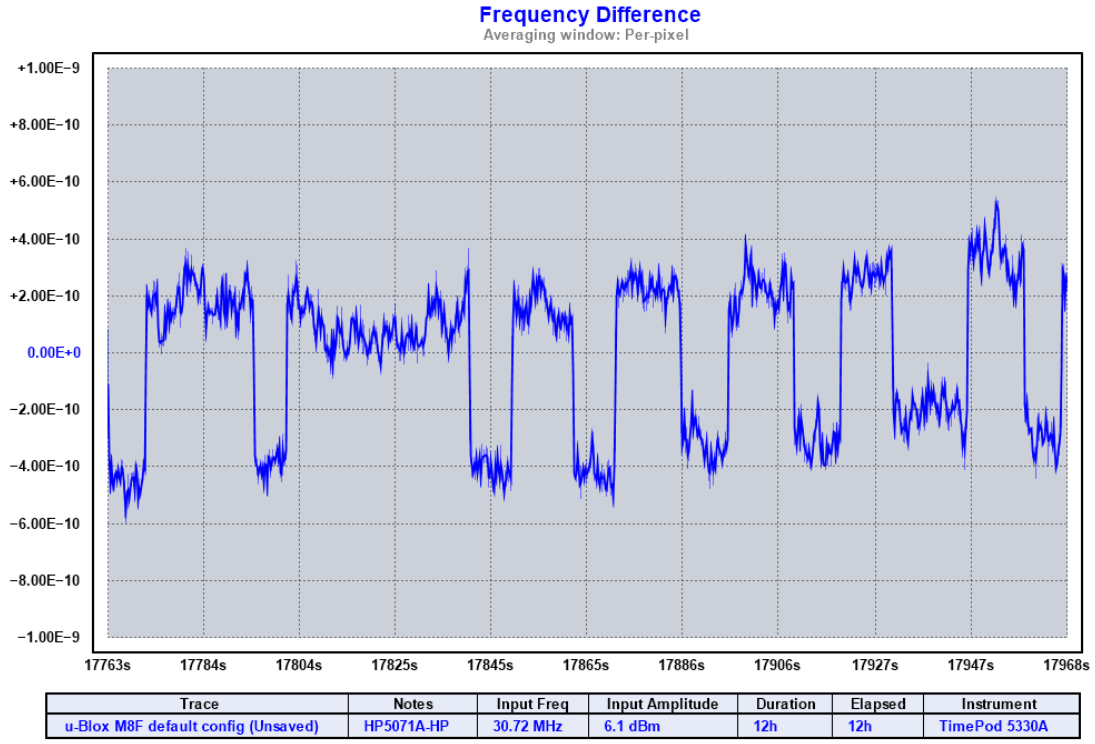
HF Dual Receiver Block Diagram

TSDR-RXM-5001D variant for PSWS Use



GPS Implementation Issues

- Off-the-Shelf GPS module with internal crystal oscillator.
  - Unusual frequency variation. Not usable for PSWS.
  - Hope to improve with external higher-performance TCVCXO



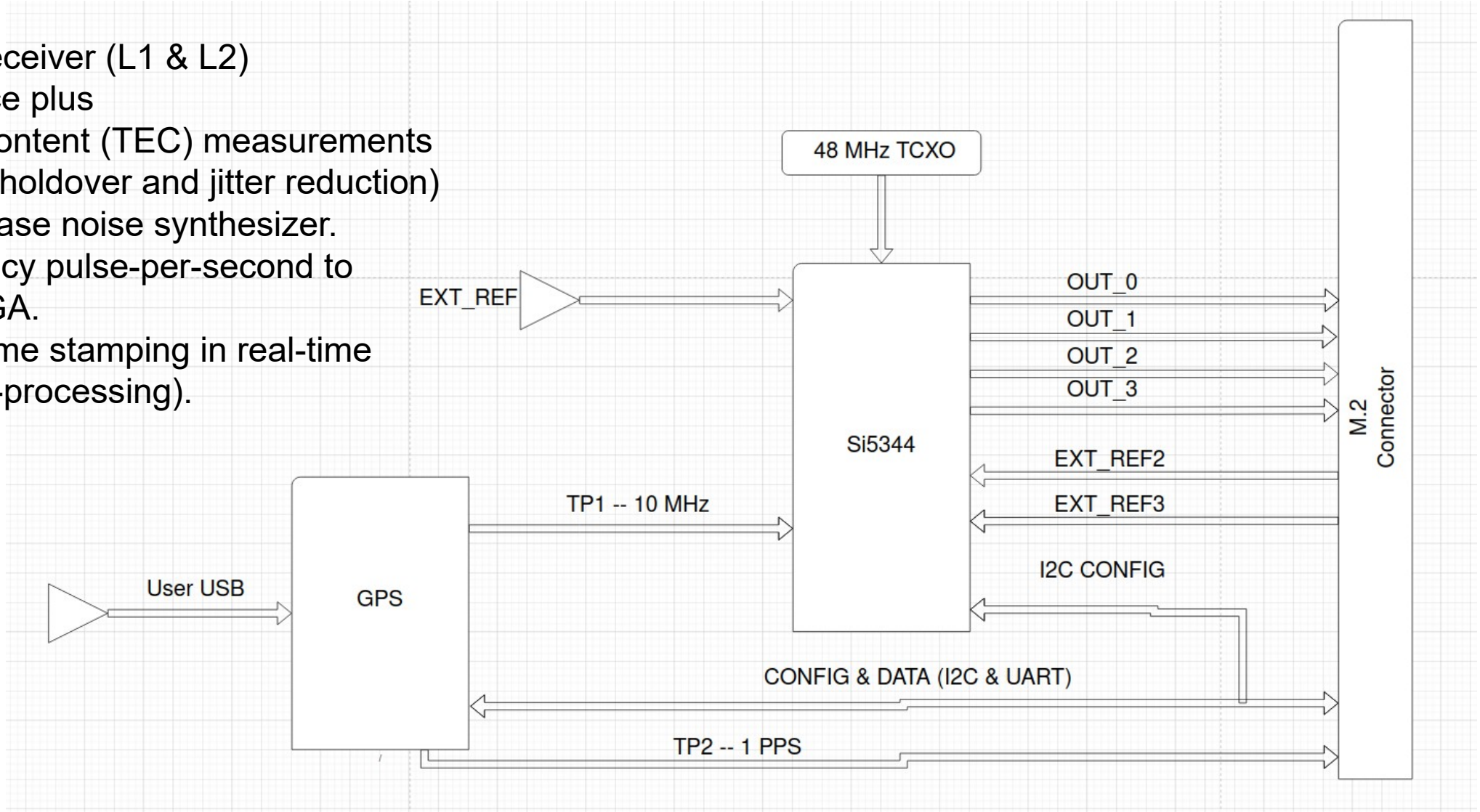
N8UR Measurement vs. Cesium Reference

- Average Frequency Correct.
- Instantaneous Frequency dither is too large.
  - Approximately 60 ppb dither.

Tangerine Clock module

High Performance variant:

Dual-channel GPS receiver (L1 & L2)
    High performance plus
    Total-Electron-Content (TEC) measurements
High stability TCXO (holdover and jitter reduction)
Low-jitter and low-phase noise synthesizer.
Provides high-accuracy pulse-per-second to
    data engine FPGA.
Expect +/- 50 nsec time stamping in real-time
    (better with post-processing).



Magnetometer Block Diagram

TSDR-MAG-8000 (Magnetometer Module) variant for PSWS Use

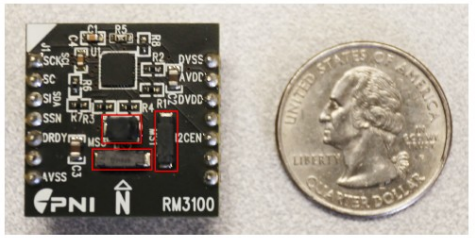


Fig. 3 – PNI RM3100 magnetometer.

3-Axis Magnetometer Sensor Module

Magnetometer Remote Cable Extender + Power Extractor

Up to 100 meters Cat 5 or 6 Shielded Cable w/ RJ45 (I2C differential, 5V power)

Magnetometer Local Cable Extender + Power Injector

PMOD I2C Interface

Data Engine or Local Host Interface

+5 VDC

Other Uses for TangerineSDR

- HF directional antenna beamforming.
  - Widely spaced receivers with accurate time stamp could form a synthetic antenna with narrow angular resolution.
  - Real-time time-stamping accuracy likely not good enough (probably require post-processing of time).
- TDOA – Time difference of arrival.
  - HF direction finding based on time-of-arrival at co-located receivers.
- Multichannel WSPR, FT-8, other signals.
- Future modules possible:
  - Transmitter module
  - Microwave module.

Documentation
(@ TangerineSDR.com)

- Interface Control Documents
  - Clock
  - Magnetometer
  - 2-Chan Receiver
  - Data Engine (in process)
- Requirements
  - Clock
  - Magnetometer
  - 2-Chan Receiver
  - Data Engine (in process)
- Objectives

References

- HAMSCI Home Page
  - https://hamsci.org
- TangerineSDR is Open Source.
  - https://tangerinesdr.com
  - Documents, Specifications, Email List transcripts, meeting recordings and notes available on-line.
  - Public Git repository planned when appropriate content becomes available.
- Tangerine SDR Zoom session:
  - Monday Nights - 6:00 PM Pacific Time / 9:00 PM Eastern Time
    - Tuesdays 0100 UTC during USA Daylight Saving Time
    - Tuesdays 0200 UTC during USA Standard Time
    - Meeting ID: 914 3224 7420
    - Passcode: tangerine