



Active HF Dipole Balun

Candidate Active Antenna for HamSCI's PSWS

rx_freq: 3.925M if_attn: 40 rx_gain: 30 lna_attn: 0
Candidate Active Anten fine freq 53

Relative Gain (dB)

Frequency (kHz)

lpf_cutoff: 1.2k

delay_rate

Fast Medium Slow

USB LSB

uned Freq: 3.91764M

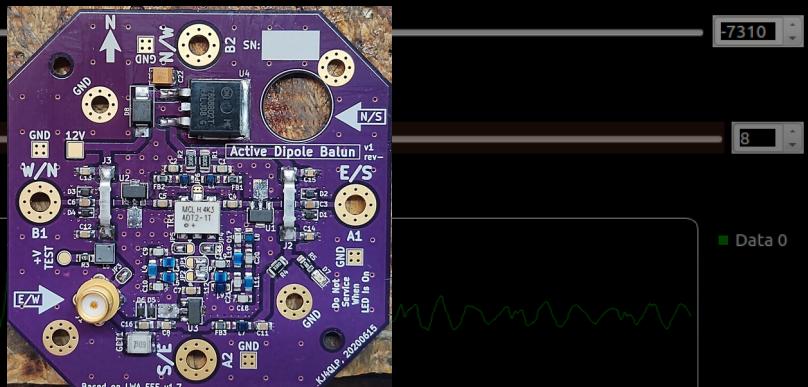
$\nabla \cdot D = \rho$

$\nabla \cdot B = 0$

$\nabla \times E = -\frac{\partial B}{\partial t}$

$\nabla \times H = J + \frac{\partial D}{\partial t}$

pole Balun



23 July 2020

Active HF Dipole Balun, KJ4QLP

Zach Leffke, KJ4QLP

zleffke@vt.edu

www.github.com/zleffke



$$\nabla \cdot D = \rho$$

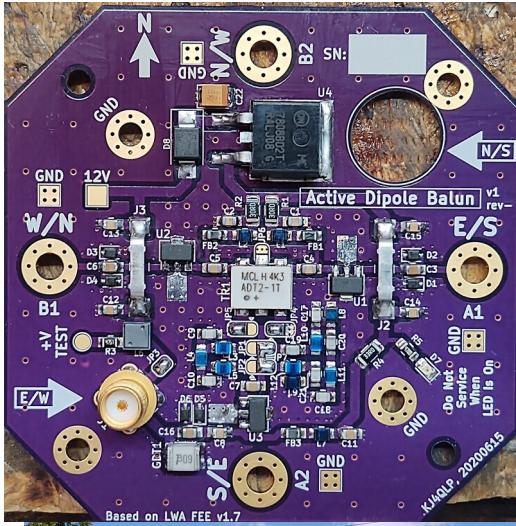
$$\nabla \cdot B = 0$$

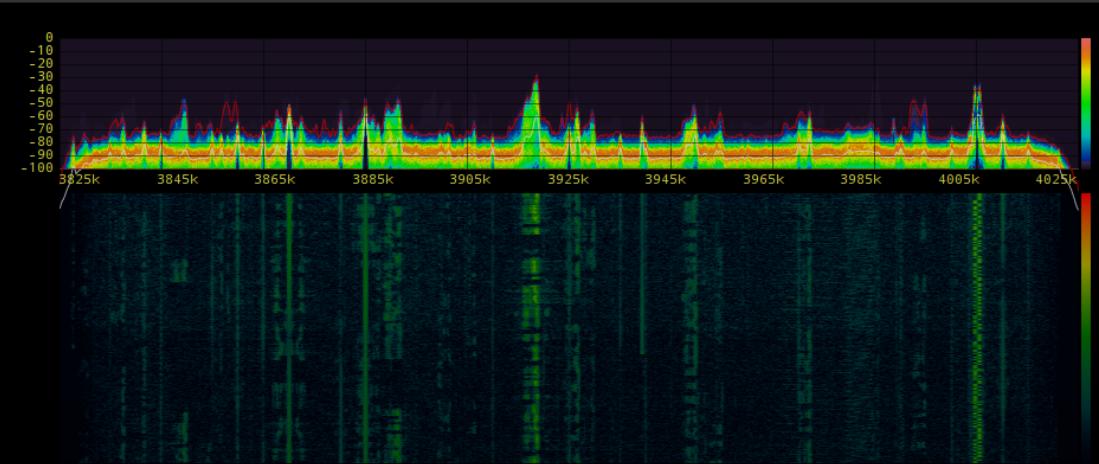
$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Agenda

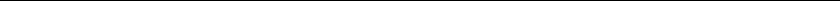
- Introduction & Overview
- Schematic & PCB
- Bench RF Measurements
- On Air Comparisons
- Selected Screengrabs
 - T2FD
 - DXE-RF-PRO-1B





rx_freq: 3.925M if_attn: 40 rx_gain: 30 lna_attn: 0 agc

Introduction & Overview

coarse_freq  -7310

A horizontal slider control for volume, consisting of a dark brown track with a light gray slider knob and a small orange segment indicating the current volume level.

23 July 2020

Active HF Dipole Balun, KJ4QLP



Frequency (kHz)

lpf cutoff: 1.2k

decay_rate

Frequency (kHz)

$$\begin{aligned}\nabla \cdot D &= \rho \\ \nabla \cdot B &= 0 \\ \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \times H &= J + \frac{\partial D}{\partial t}\end{aligned}$$

Introduction, References, & Links

- Long Wavelength Array
 - Memo Series: www.faculty.ece.vt.edu/swe/lwa/
 - Collected Engineering Memos for LWA-FEE (used heavily):
 - www.faculty.ece.vt.edu/swe/lwa/memo/lwa0190.pdf
- AHFDB Github
 - www.github.com/zleffke/kicad_active_balun (current design, might rearrange a bit)
 - kj4qlp.wordpress.com (coming soon...definition of 'soon' TBD...)

Item	Cost	Note
3 PCBs	\$37.85	Osh Park (x3 rule)
1 PCB	\$12.62	Per PCB
Single Balun BOM	\$36.03	Mouser/Digikey
Dual Balun BOM	\$71.17	Dual Pol

Estimating **~\$150-\$200** for complete Dual Polarization system (everything in picture, not coax or backend systems)



LWA-FEEv1.7	AHFDB, v1, rev-
Freq: 10-88 MHz	Freq: 1.5-50 MHz
180° Hybrid	MC RF Transformer
Low Pass Filter	LPF, BPF, Bypass
12V Vreg	8V Vreg
LWA-FEEv1.7 size	More Compact

$$\begin{aligned}\nabla \cdot D &= \rho \\ \nabla \cdot B &= 0 \\ \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \times H &= J + \frac{\partial D}{\partial t}\end{aligned}$$

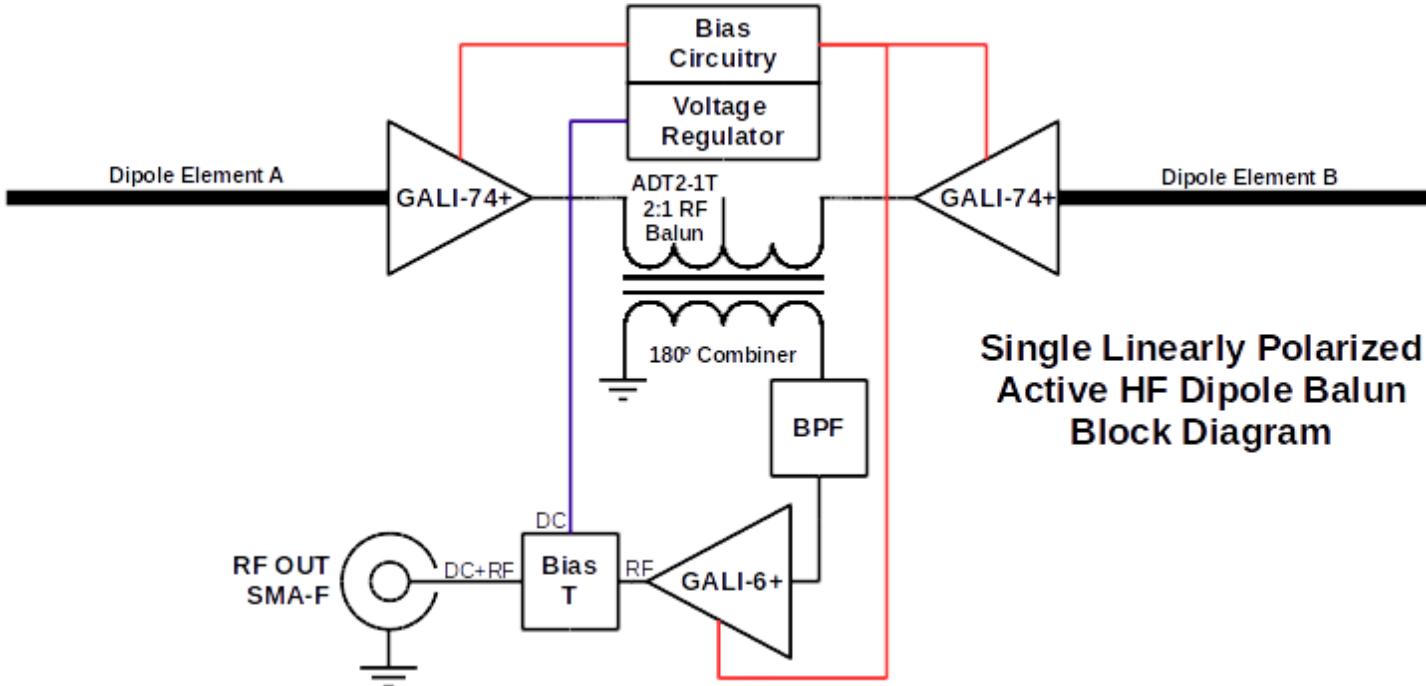
RF Performance Summary

Parameter	Unit	Value
Design Frequency of Operation (-3dB)	MHz	1.5 to 50
Realized Frequency of Operation (-3dB)	MHz	4.0 to 47.5
Average Gain (passband)	dB	36.1
Average Noise Figure (passband)	dB	3.87
Input 1dB Compression Point (P1dB)*	dBm	-18.41
Input Third Order Intercept Point (IIP3)*	dBm	-2.5 to -3.0
DC Input Voltage Range	V	10.0 to 35.0
DC Input Voltage, Nominal	V	13.8
DC Supply Current, Nominal	mA	0.250
DC Supply Method, Nominal	n/a	Bias-T via coax
DC Supply Method, Alternate	n/a	external

Note *: Linearity numbers *without* output protection diodes installed

$$\begin{aligned}\nabla \cdot D &= \rho \\ \nabla \cdot B &= 0 \\ \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \times H &= J + \frac{\partial D}{\partial t}\end{aligned}$$

Active Dipole Balun - Simplified Block Diagram



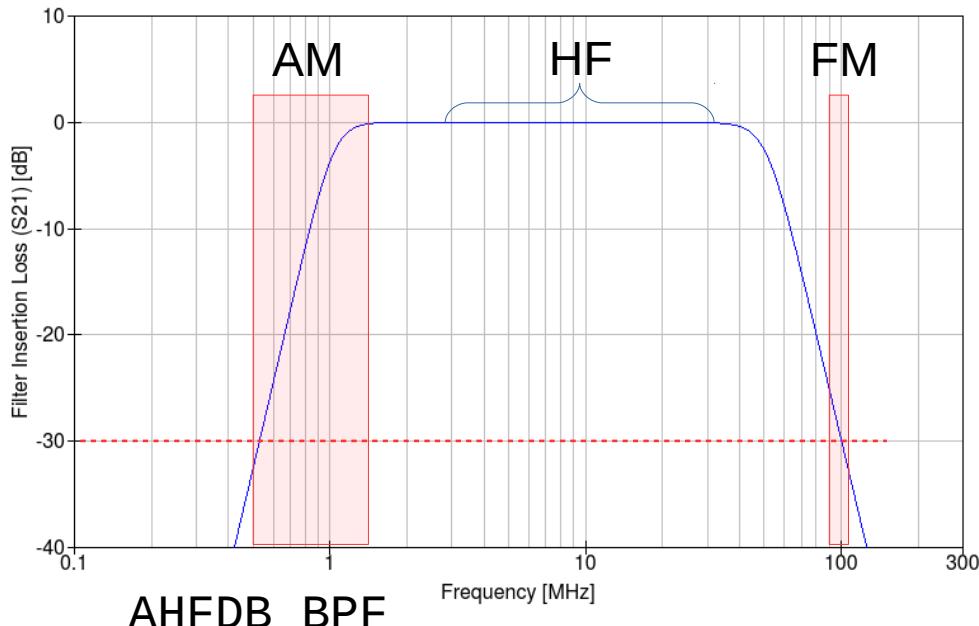
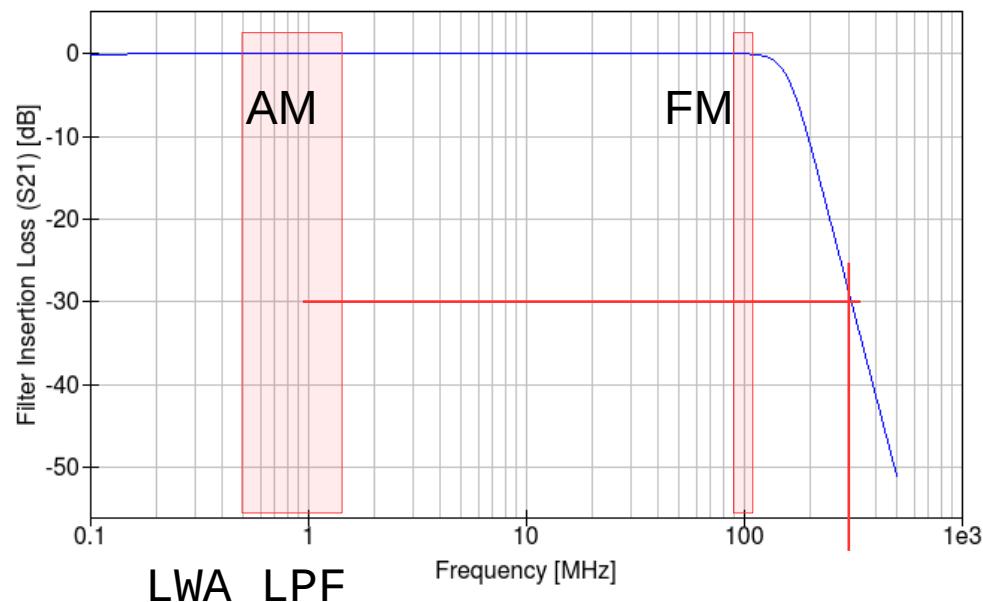
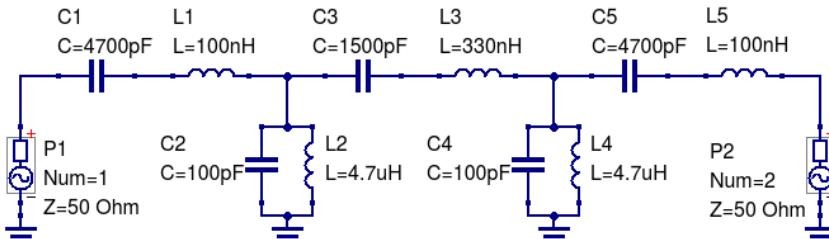
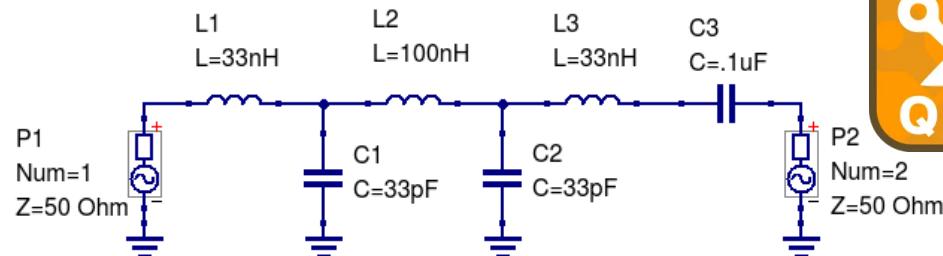
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

LWA-FEEv1.7 LPF vs AHFDB BPF - Simulated



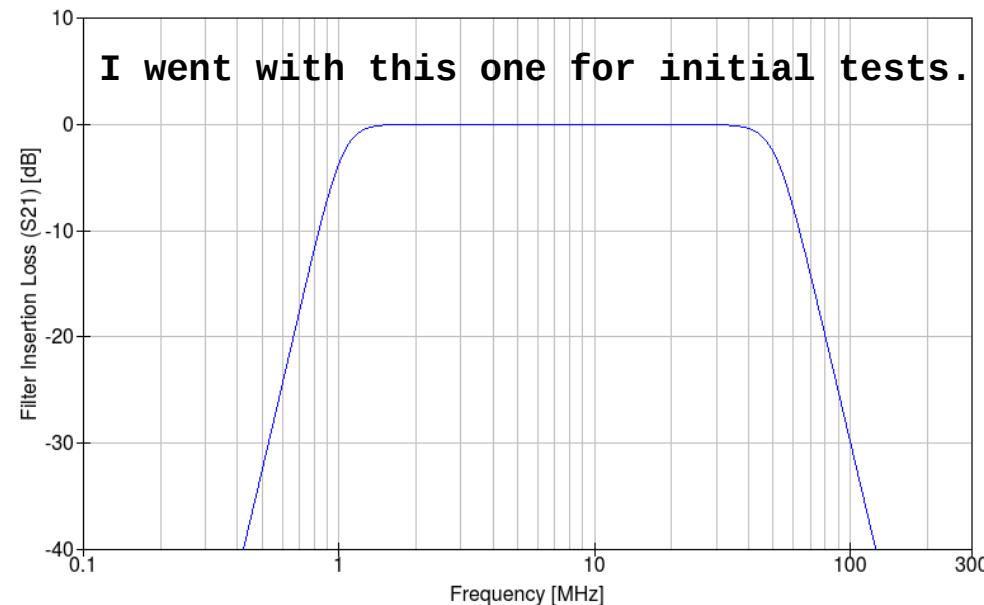
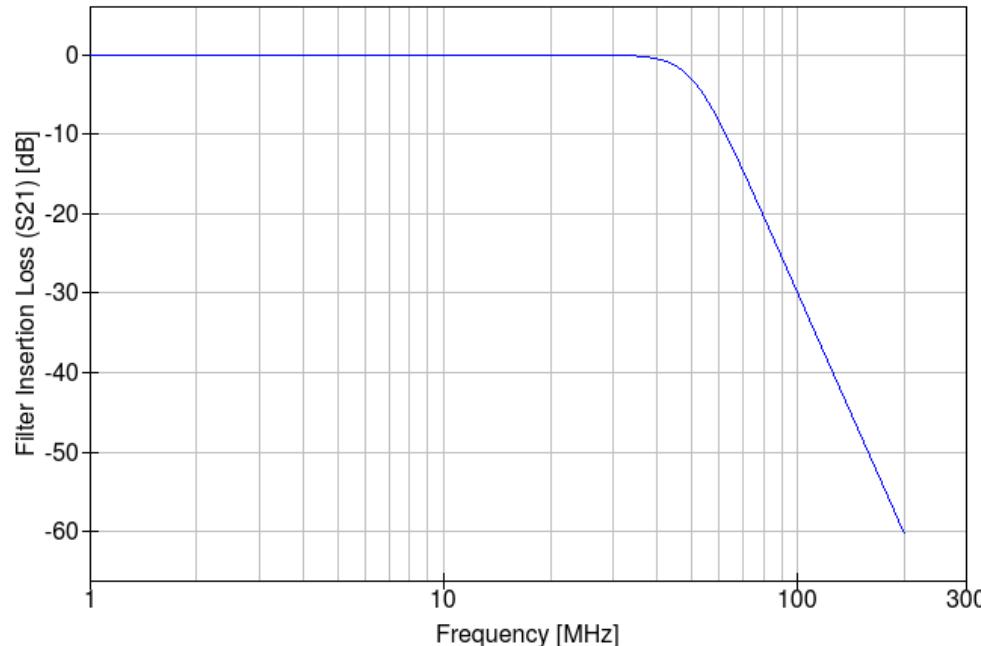
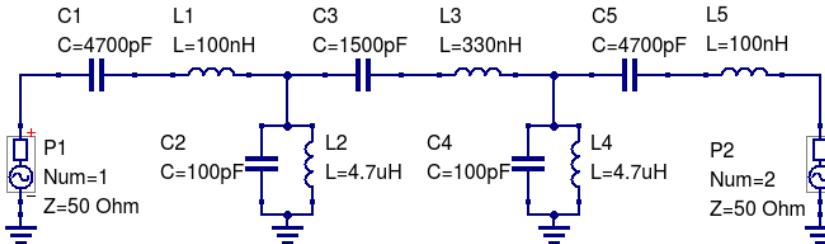
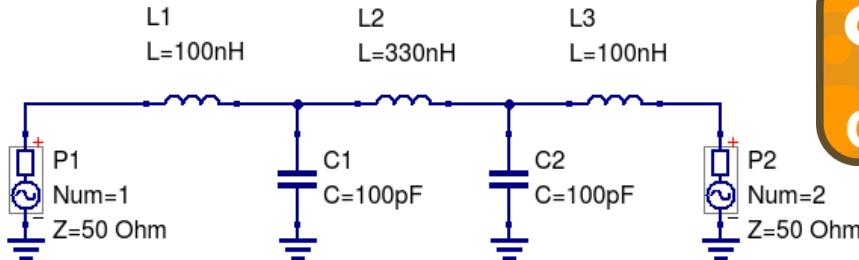
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

AHFDB Filter Simulations - QUCS



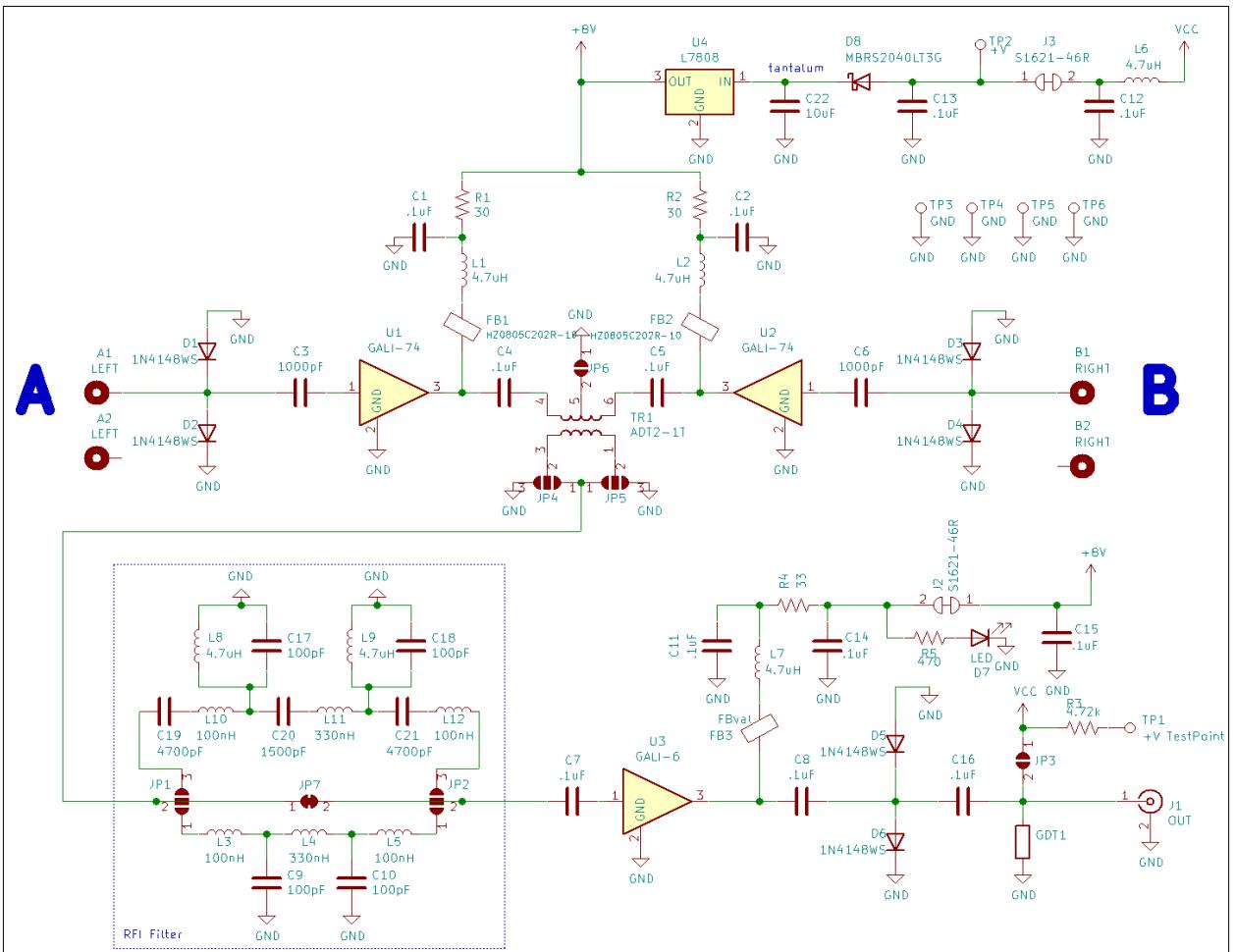
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Schematic



NOTES:

- Amp bias resistors R1, R2, & R4 Have been updated to 39Ω
- This is to match datasheet recommended values

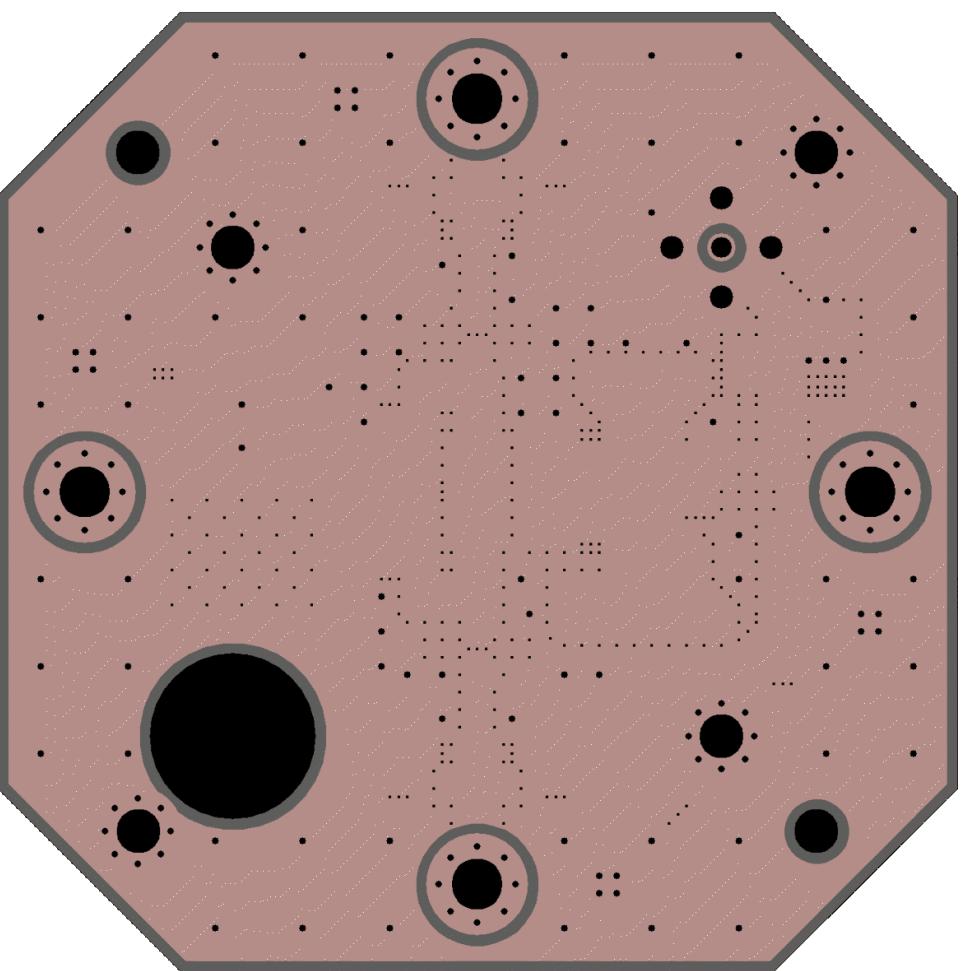
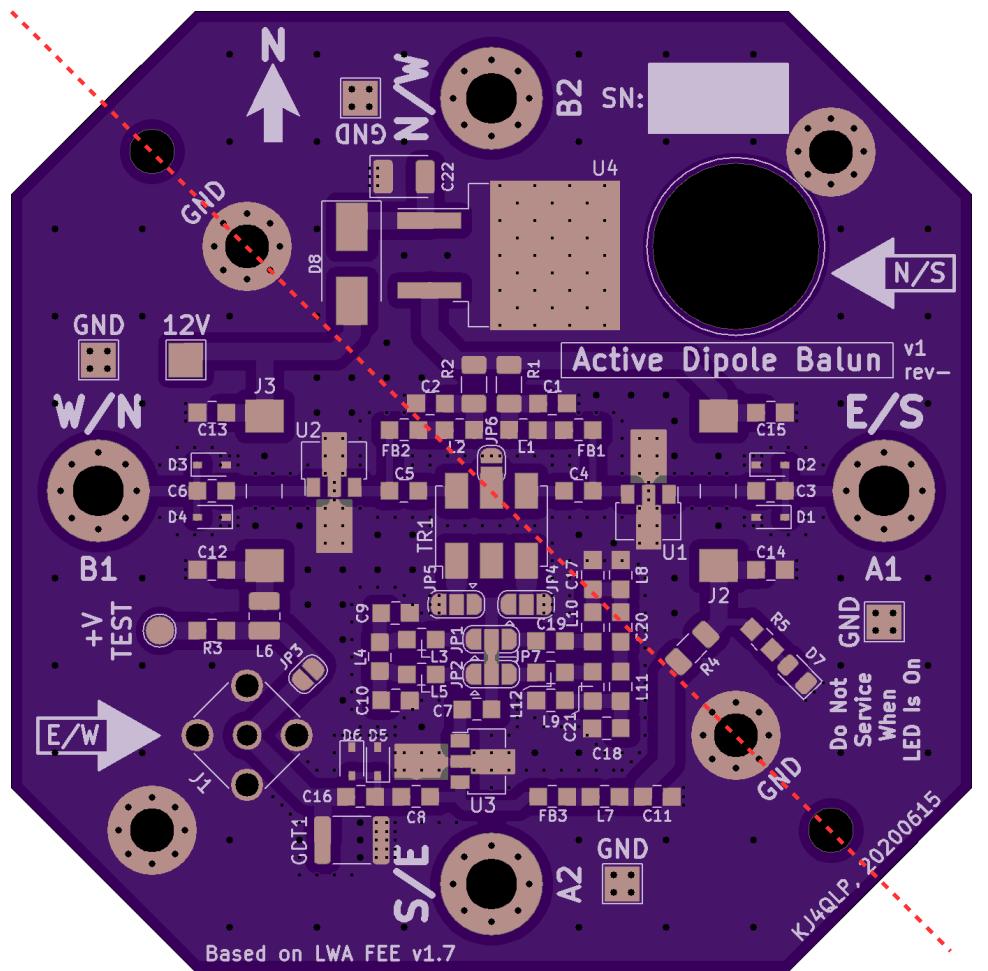
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

PCB Layout - 0sh Park Images



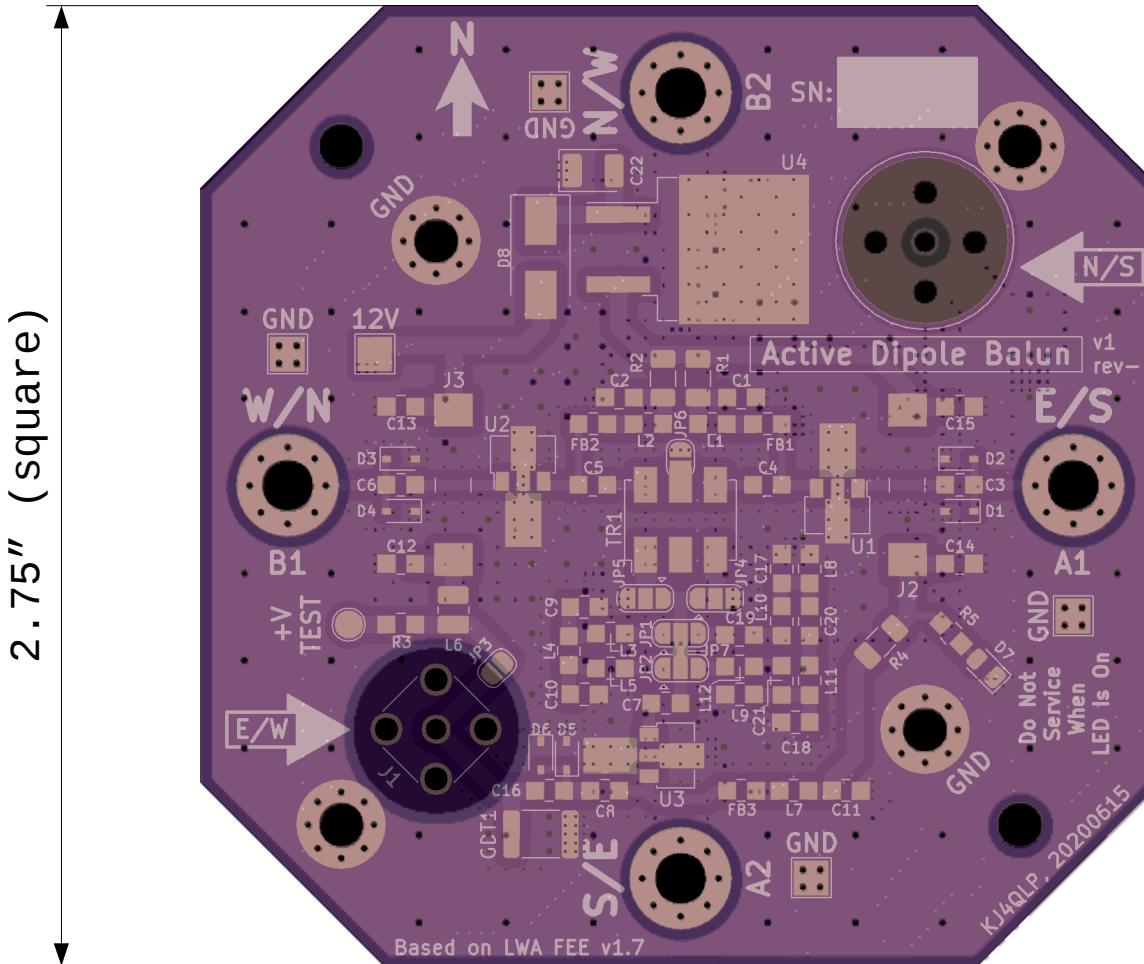
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Back to Back PCBs - Dual Polarization



Populated PCBs

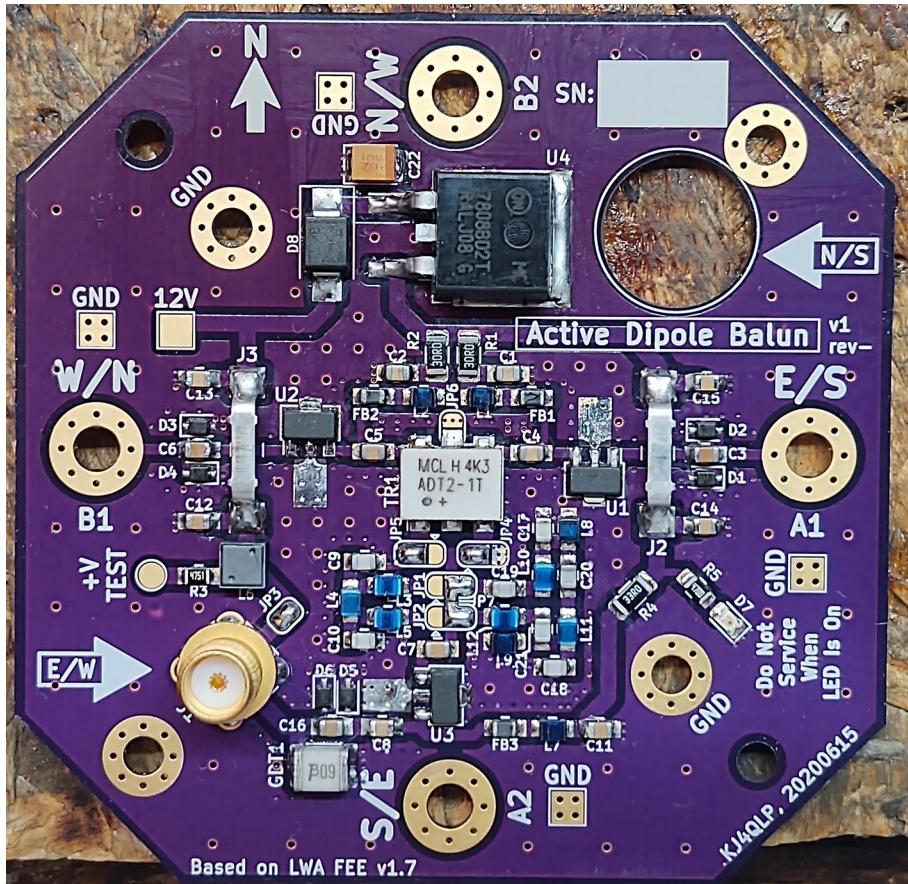
$$\nabla \cdot D =$$

$$\nabla \cdot B =$$

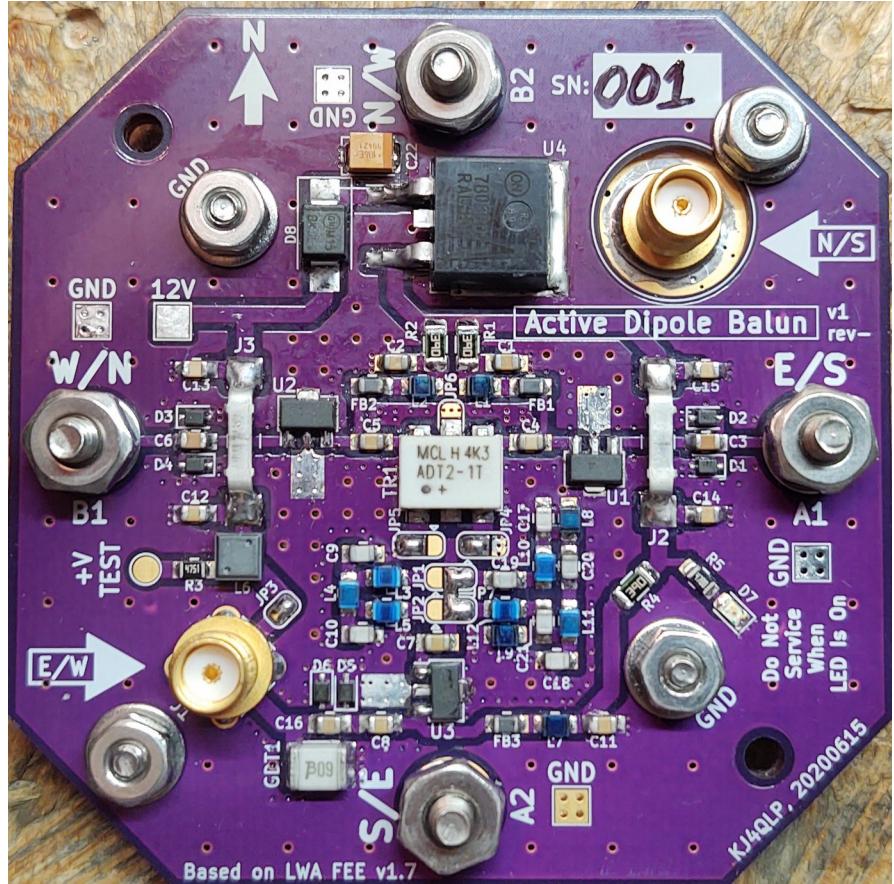
$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Single Balun



Double Balun



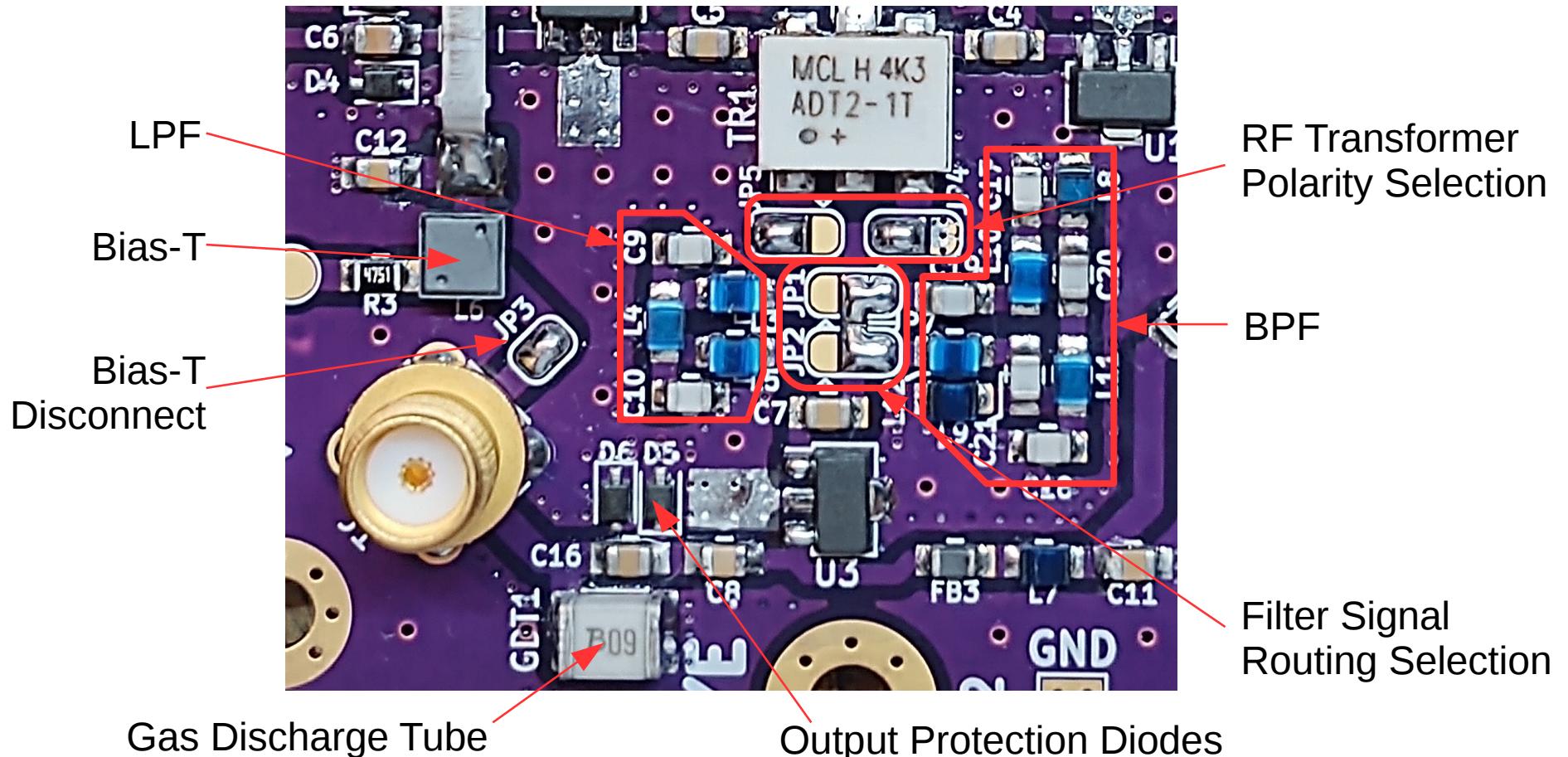
$$\nabla \cdot D = \rho$$

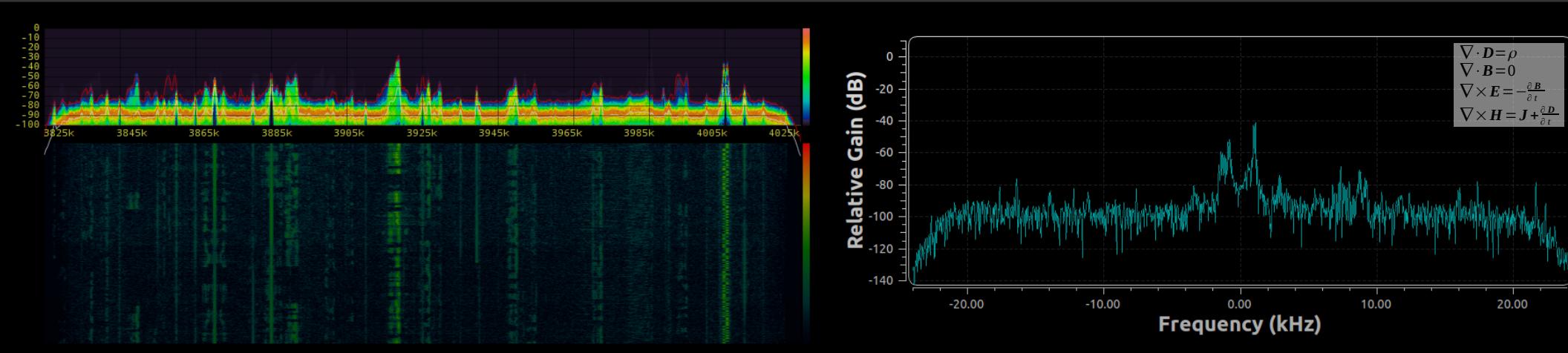
$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Solder Jumpers & some other details

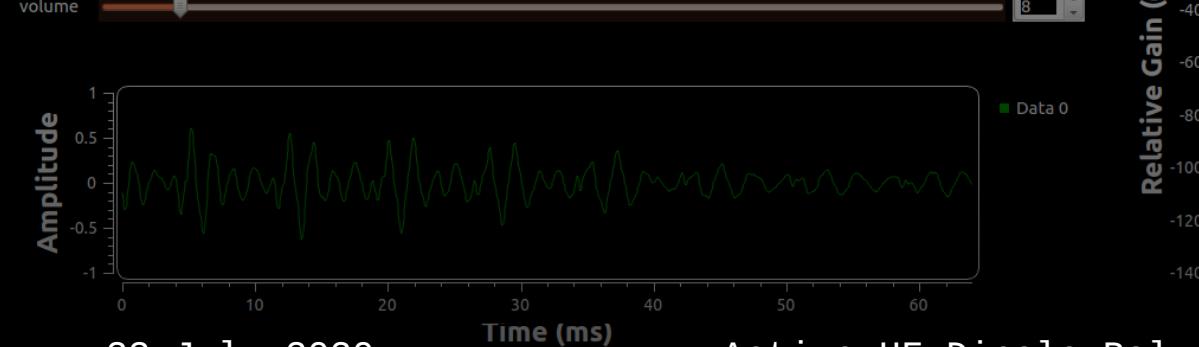




rx_freq: 3.925M if_attn: 40 rx_gain: 30 lna_attn: 0 agc

fine_freq
coarse_freq

volume



23 July 2020

Active HF Dipole Balun, KJ4QLP



lpf_cutoff: 1.2k decay_rate
Fast Medium Slow



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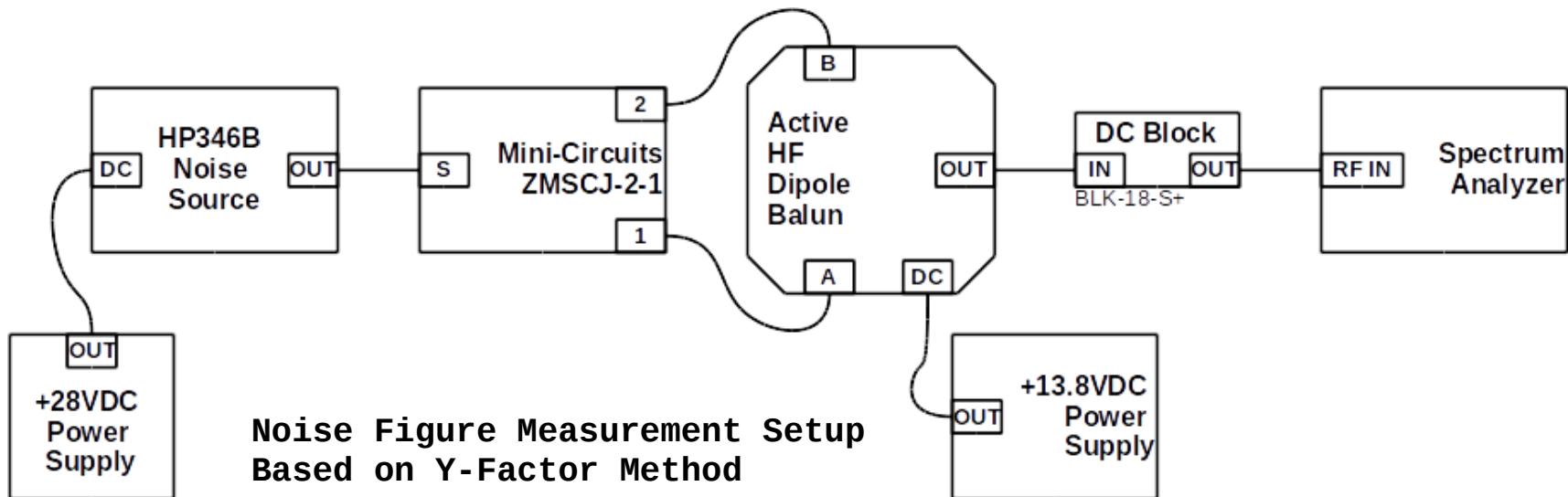
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Noise Figure Measurement Setup



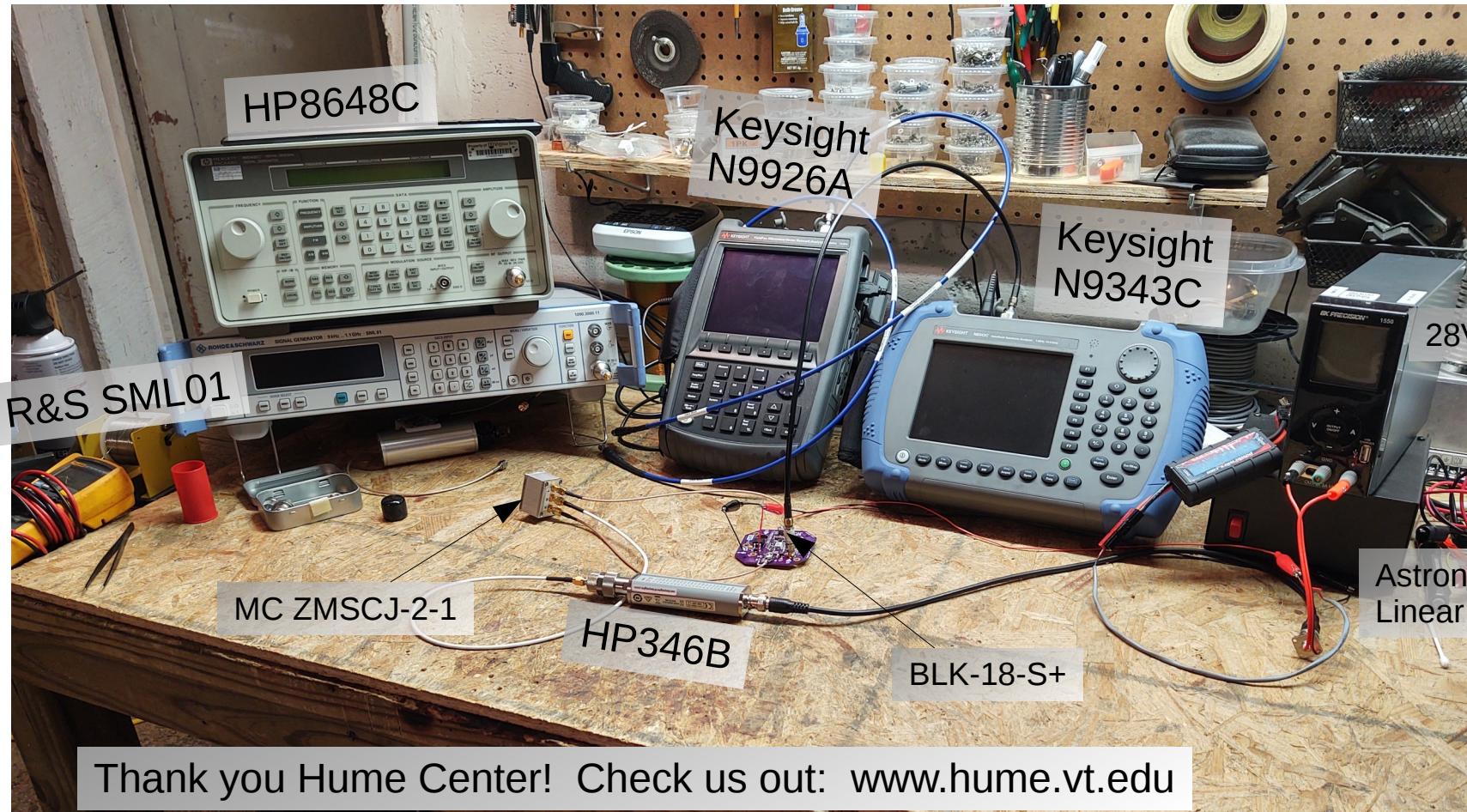
- I don't have time to present each configuration for each measurement type.
- All measurements included component calibration, which are factored into the results presented.
- More details may be presented in future documentation focused on the measurement process.

$$\begin{aligned}\nabla \cdot D &= \rho \\ \nabla \cdot B &= 0 \\ \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \times H &= J + \frac{\partial D}{\partial t}\end{aligned}$$

The Test Equipment



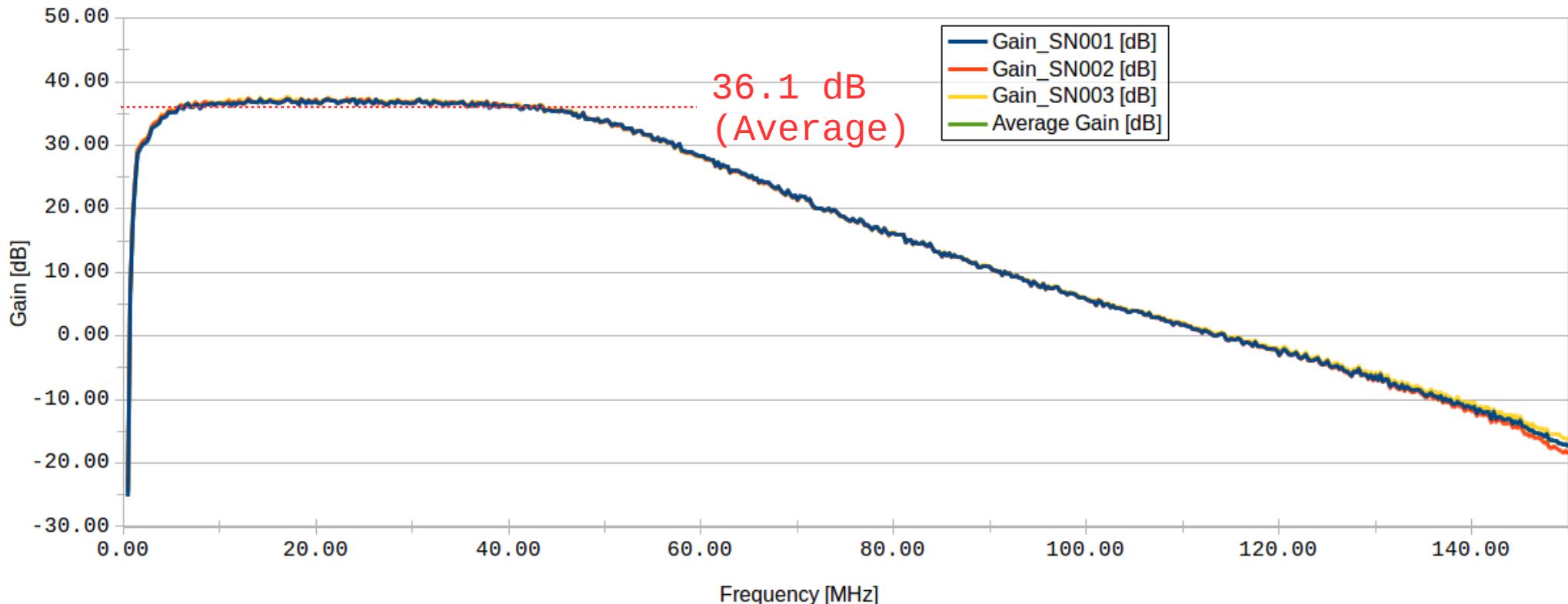
HUME CENTER FOR NATIONAL
SECURITY AND TECHNOLOGY
VIRGINIA TECH™



$$\begin{aligned}\nabla \cdot D &= \rho \\ \nabla \cdot B &= 0 \\ \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \times H &= J + \frac{\partial D}{\partial t}\end{aligned}$$

Active HF Dipole Balun, Gain (S21) Measurements

Version 1, Revision-; SN001, SN002, SN003



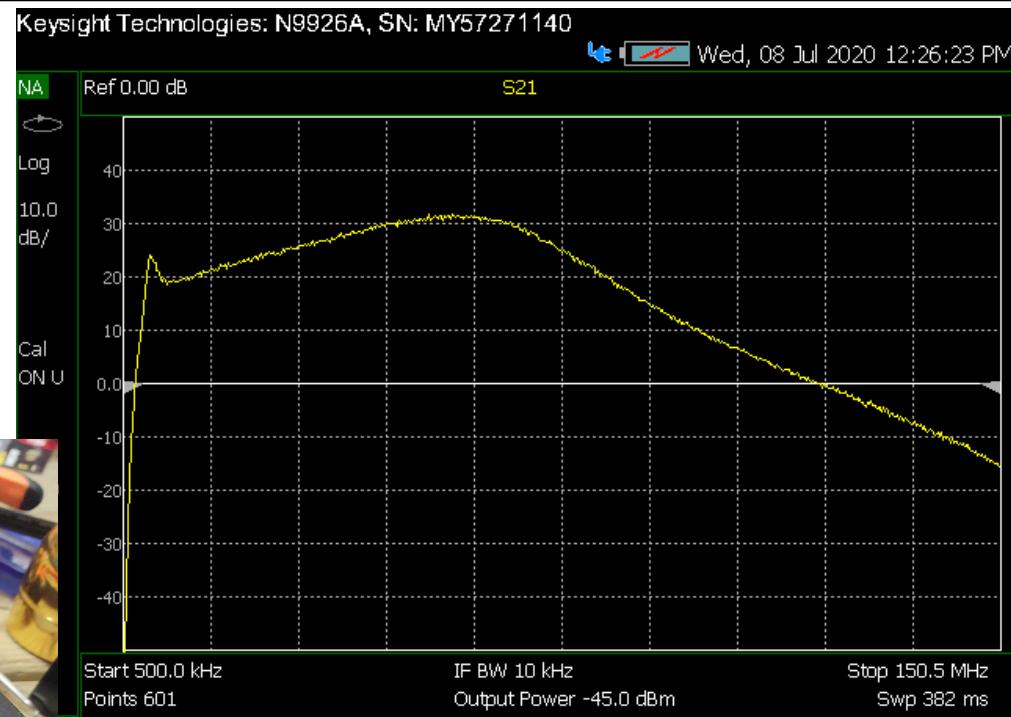
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Bad SMT Solder Job = Bad Filter Response



With surface mount
soldering by hand (no
stencil)...**Less is More!**

$$\nabla \cdot D = \rho$$

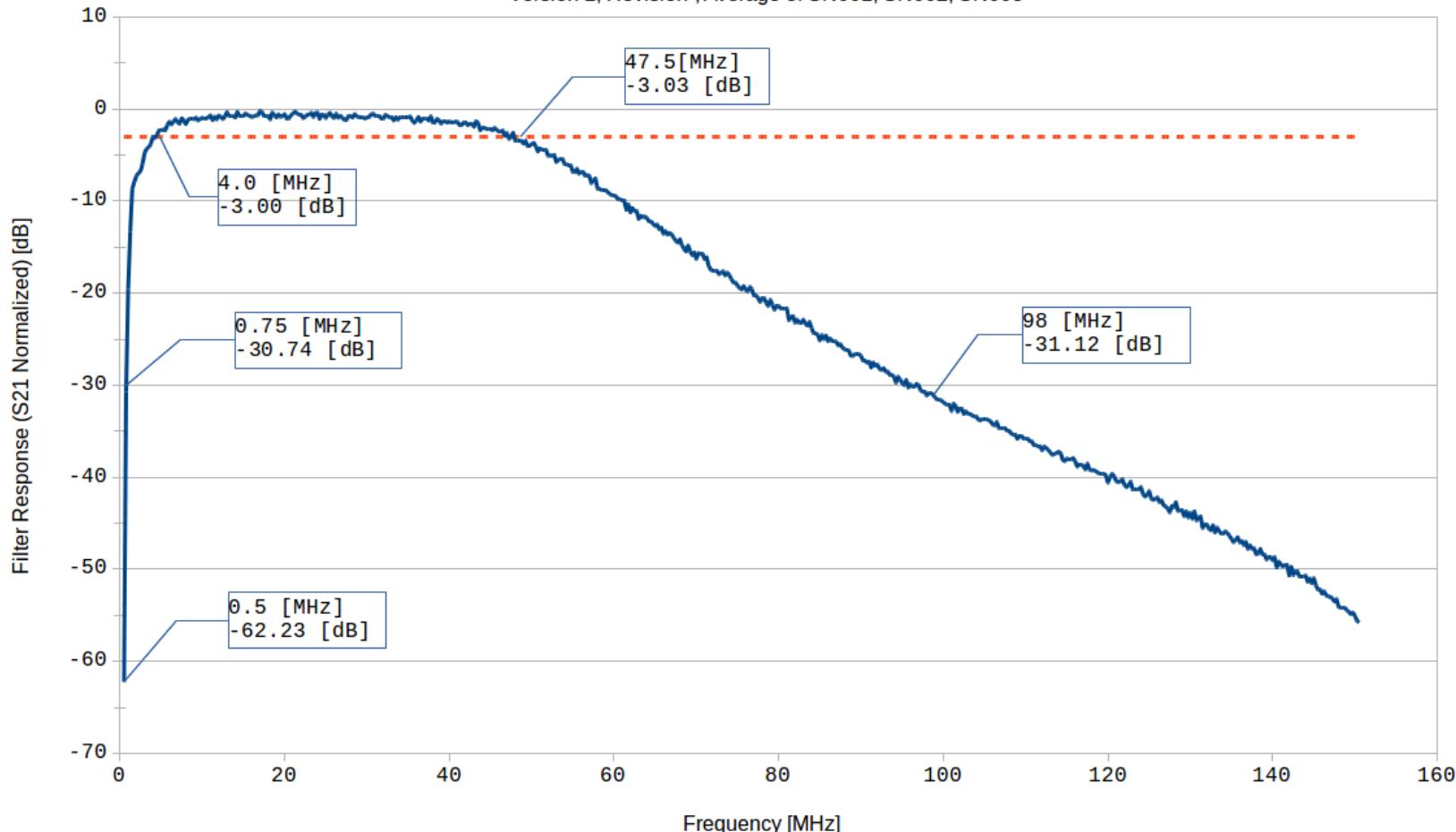
$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Integrated Band Pass Filter Response

Active HF Balun Board, Measured Filter Response
Version 1, Revision-; Average of SN001, SN002, SN003



$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

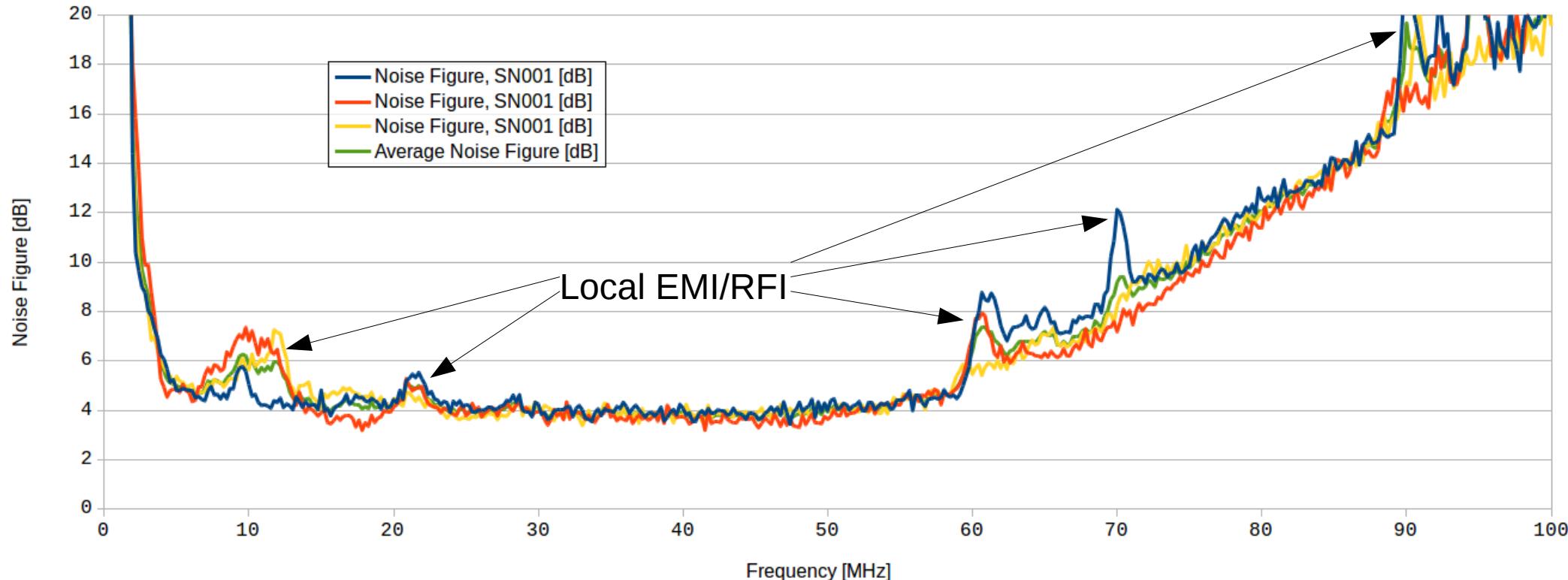
$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Noise Figure

Active HF Dipole Balun, Noise Figure Measurements

Version 1, Revision-; SN001, SN002, SN003



Notice the RFI/EMI Spikes, may retake measurements in Faraday Cage

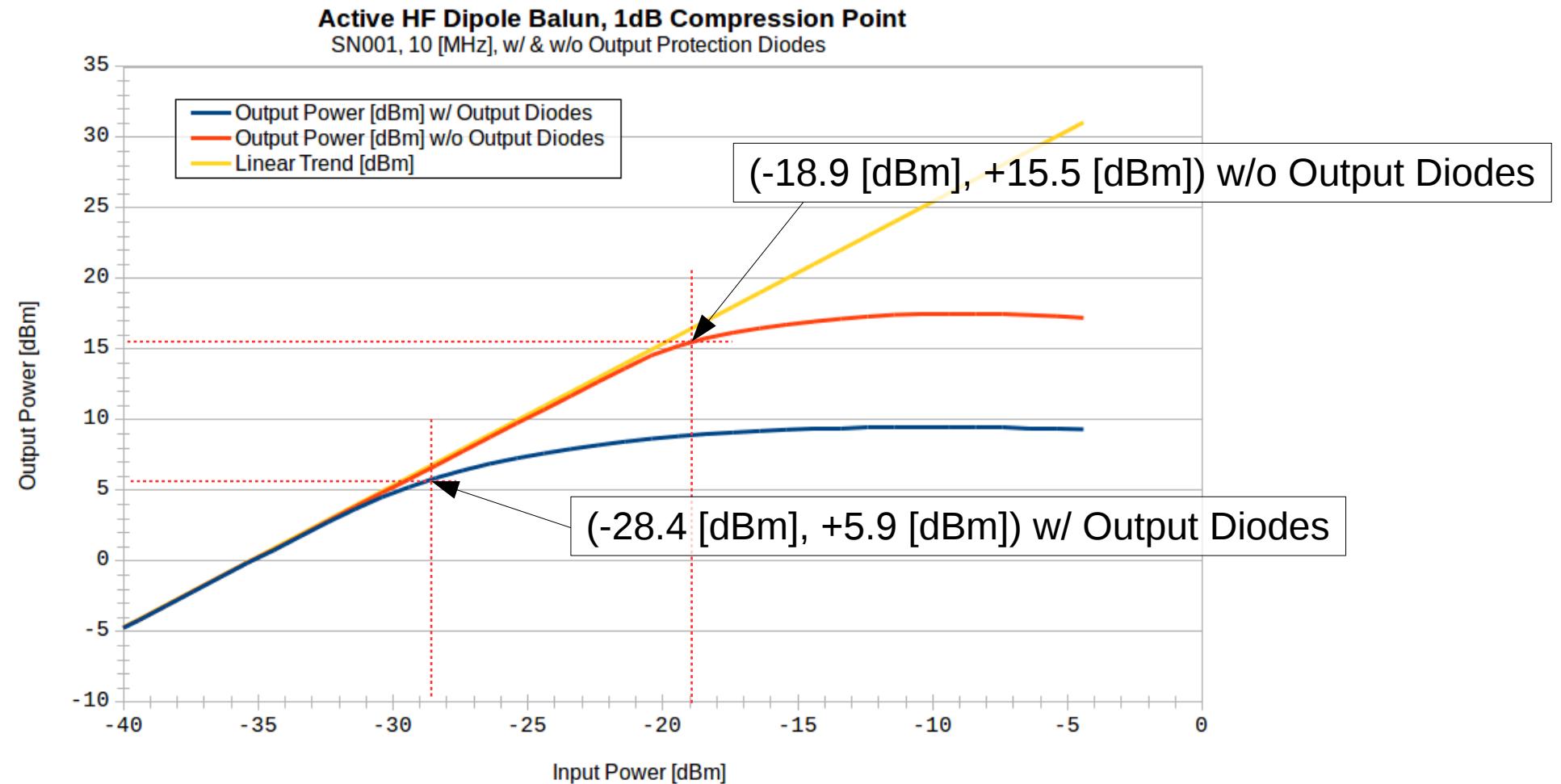
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

1dB Compression Point @ 10 MHz, SN001



$$\nabla \cdot D = \rho$$

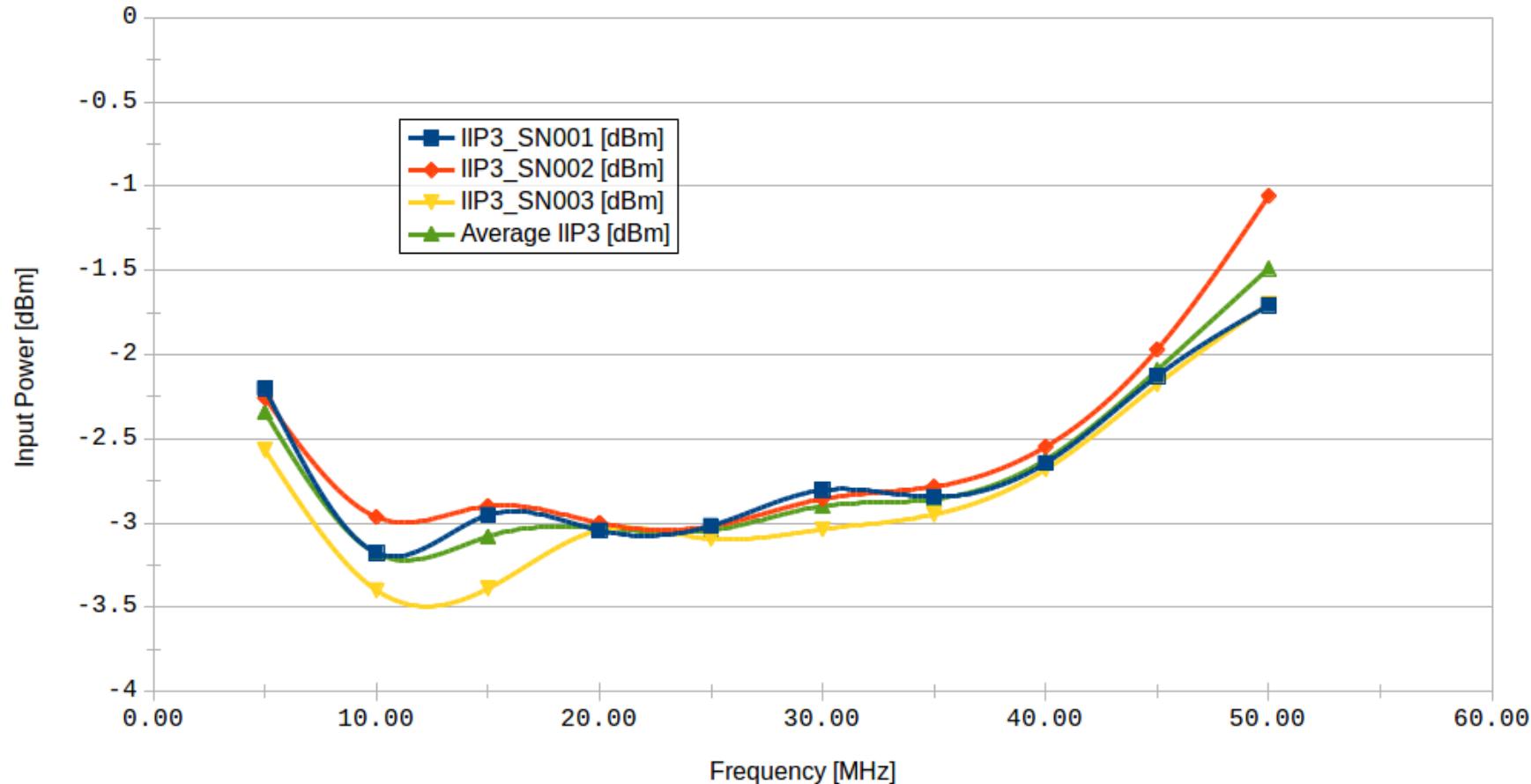
$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

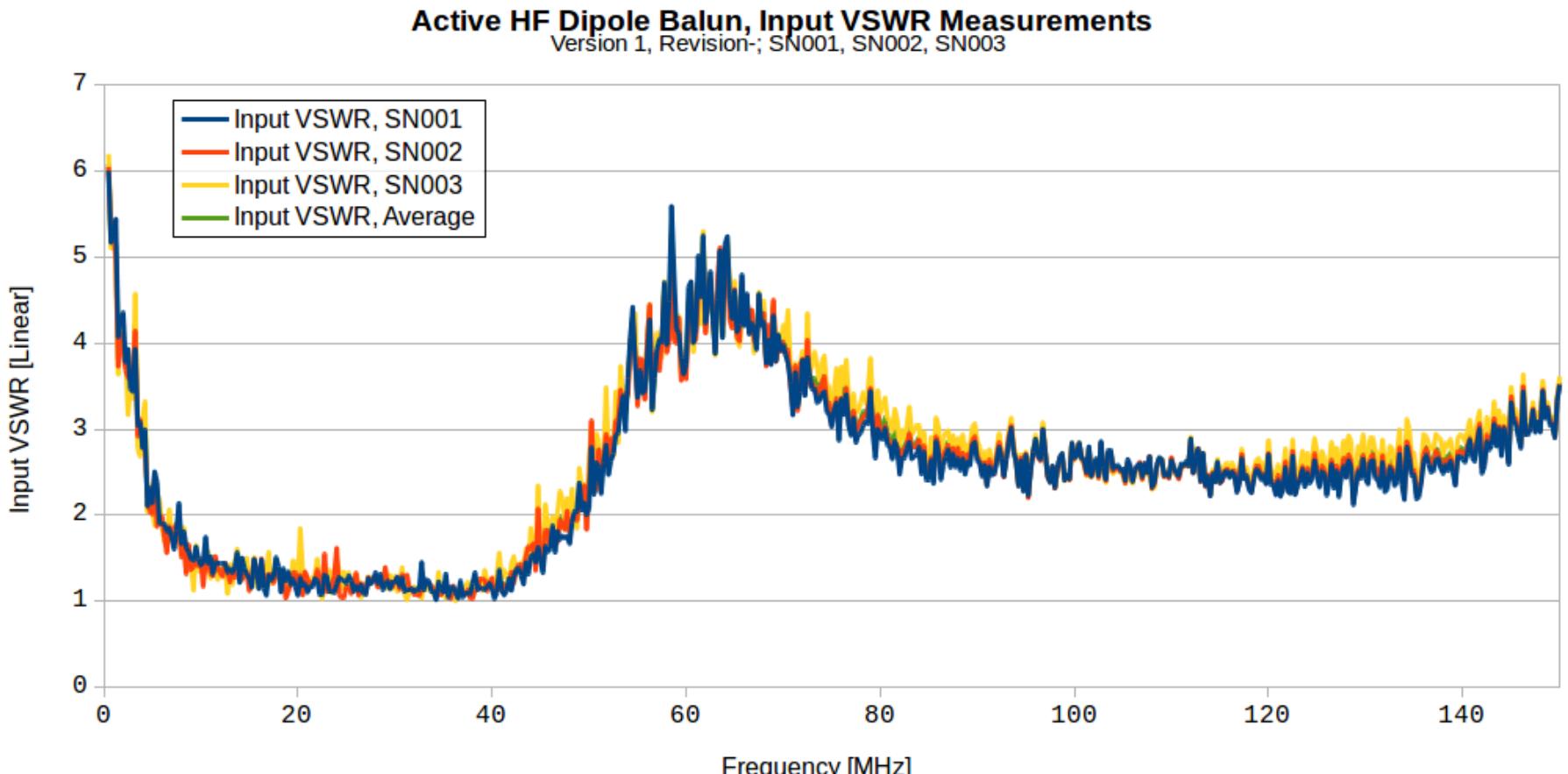
Input Third Order Intercept Point (IIP3)

Active HF Dipole Balun, Input Third Order Intercept Point Measurements
Version 1, Revision-; SN001, SN002, SN003



$$\nabla \cdot D = \rho$$
$$\nabla \cdot B = 0$$
$$\nabla \times E = -\frac{\partial B}{\partial t}$$
$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

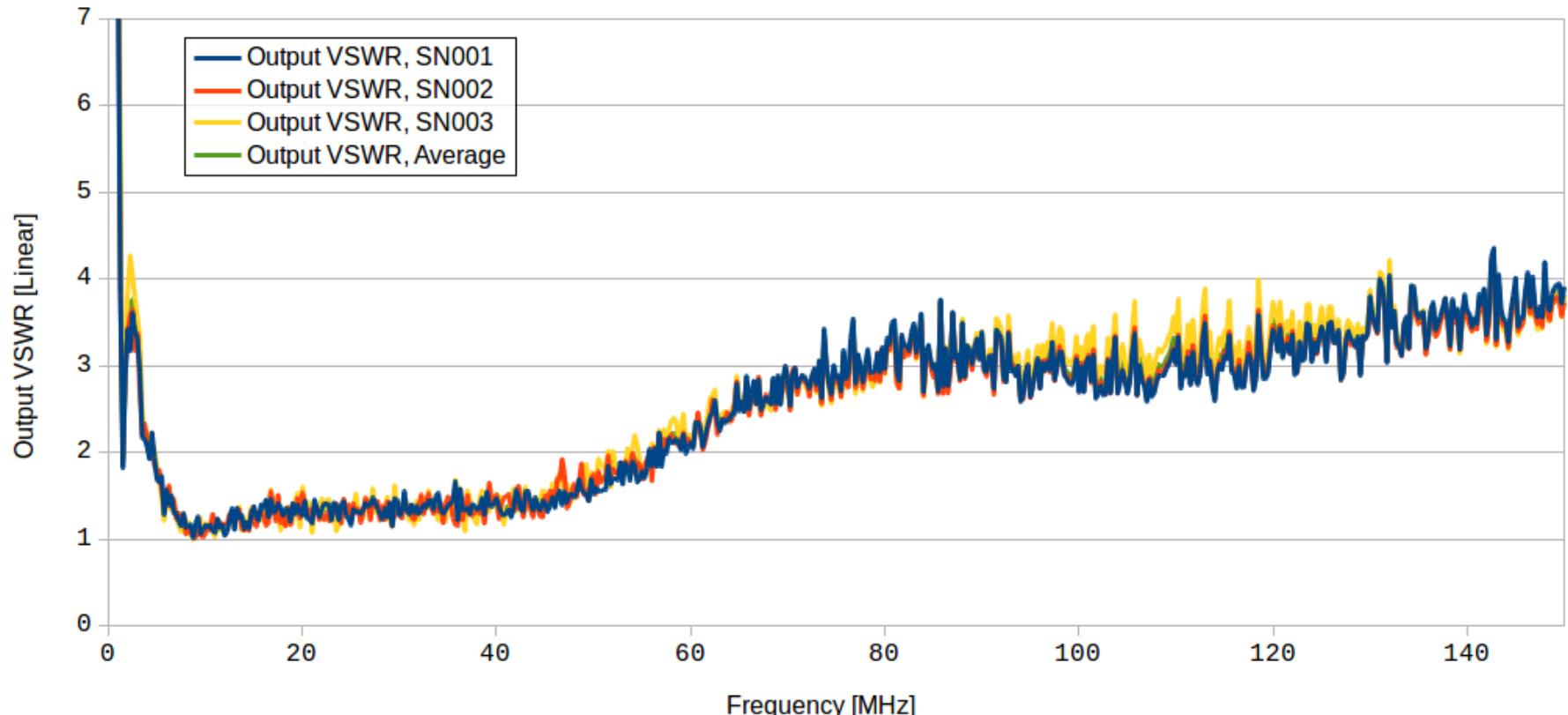
Input VSWR

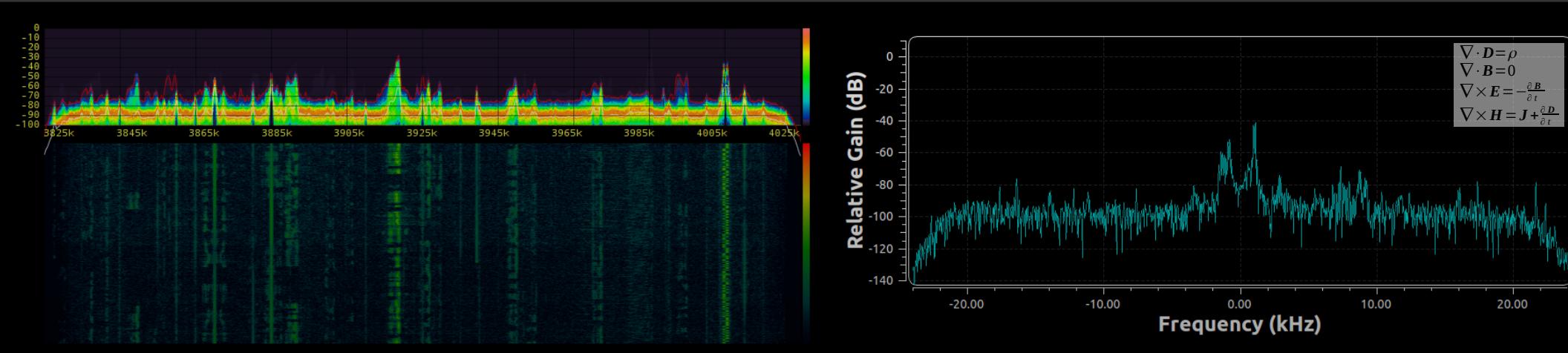


$$\nabla \cdot D = \rho$$
$$\nabla \cdot B = 0$$
$$\nabla \times E = -\frac{\partial B}{\partial t}$$
$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Output VSWR

Active HF Dipole Balun, Output VSWR Measurements
Version 1, Revision-; SN001, SN002, SN003





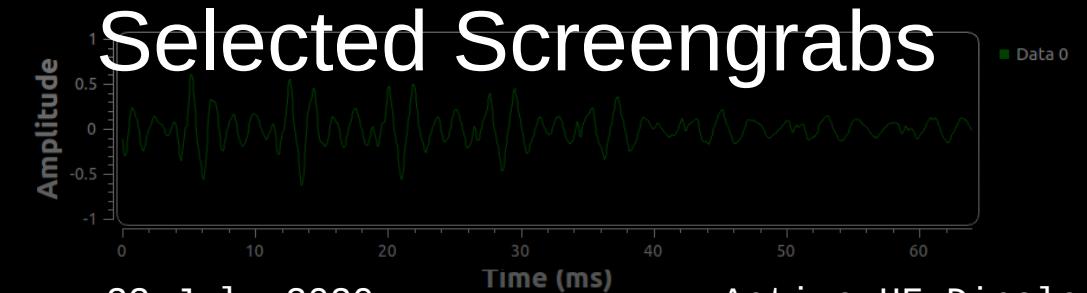
rx_freq: 3.925M if_attn: 40 rx_gain: 30 lna_attn: 0 agc

lpf_cutoff: 1.2k decay_rate: Fast, Medium, Slow

On Air Test Measurements

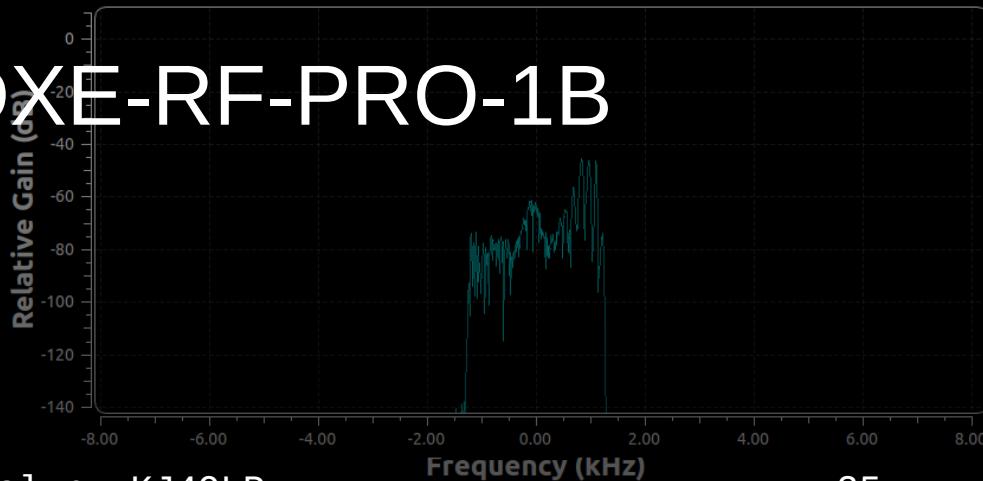
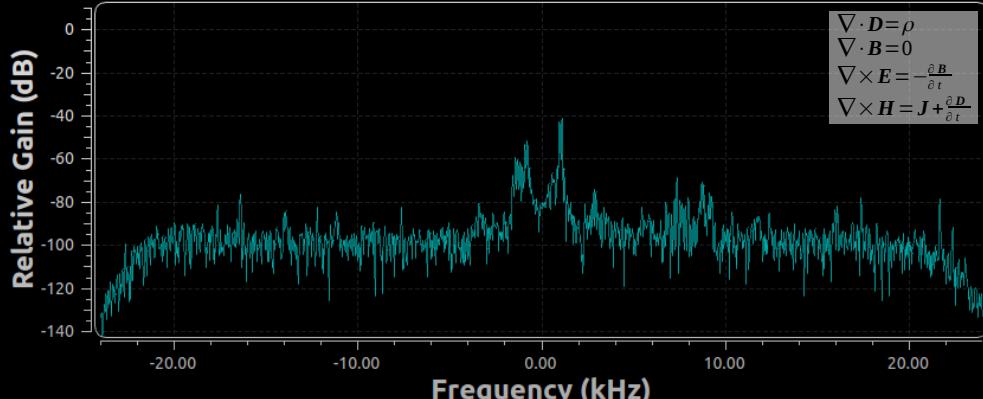
coarse_freq: -7310 volume: 8

Comparison to T2FD and DXE-RF-PRO-1B



23 July 2020

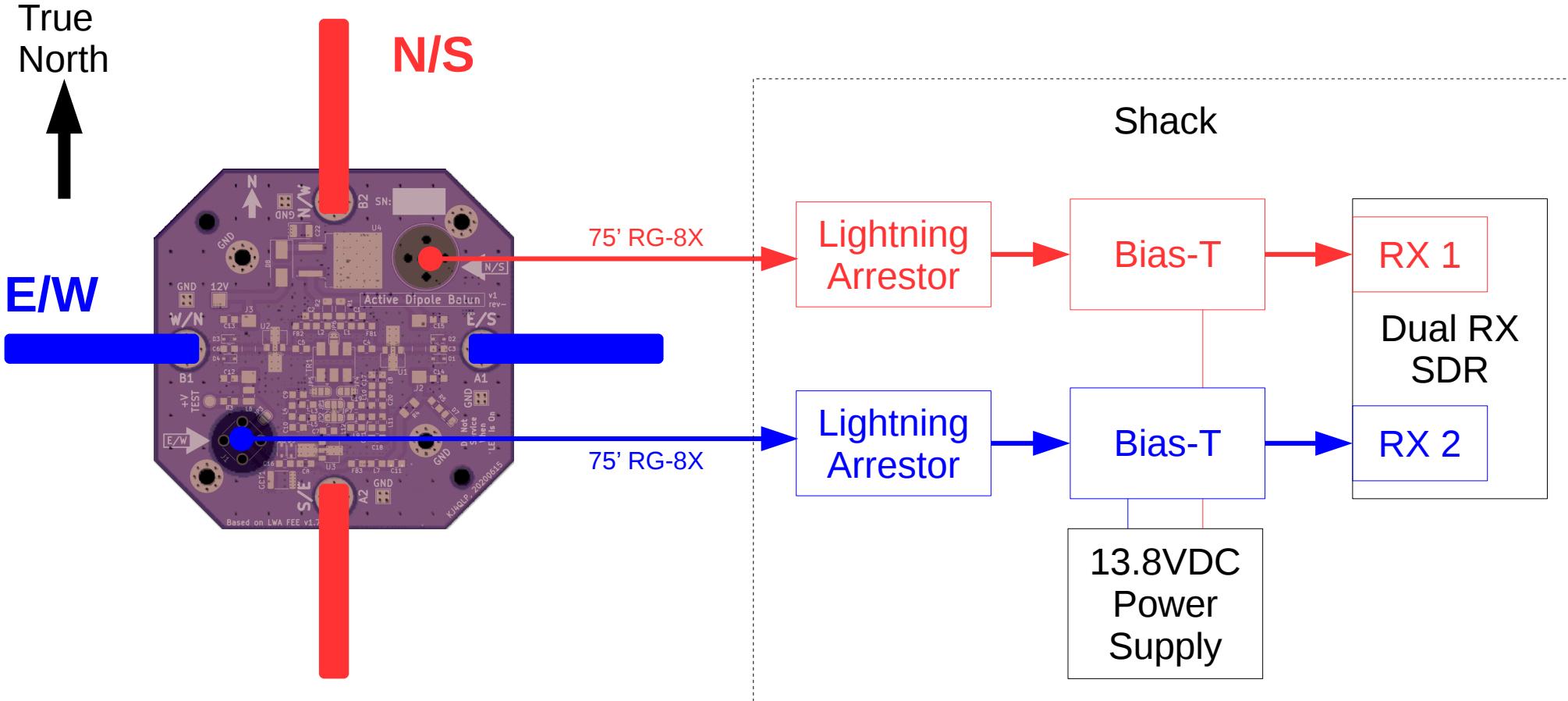
Active HF Dipole Balun, KJ4QLP



25

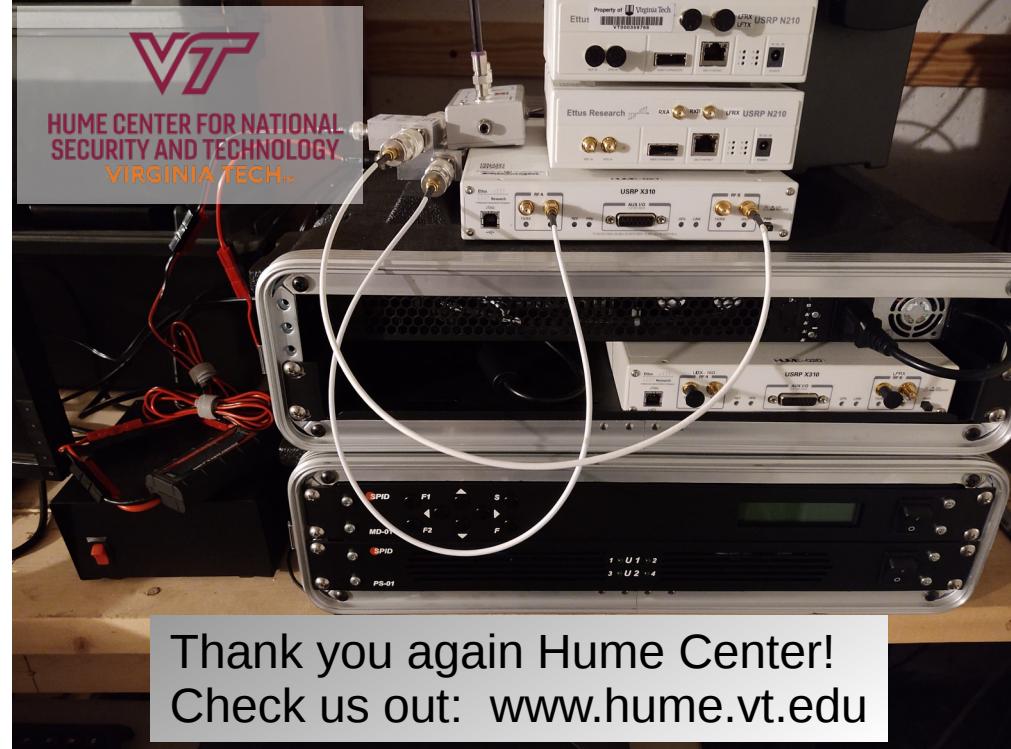
$$\begin{aligned}\nabla \cdot D &= \rho \\ \nabla \cdot B &= 0 \\ \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \times H &= J + \frac{\partial D}{\partial t}\end{aligned}$$

Dual Polarization High Level System Diagram



$$\begin{aligned}\nabla \cdot D &= \rho \\ \nabla \cdot B &= 0 \\ \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \times H &= J + \frac{\partial D}{\partial t}\end{aligned}$$

On Air Measurement Setup



Thank you again Hume Center!
Check us out: www.hume.vt.edu

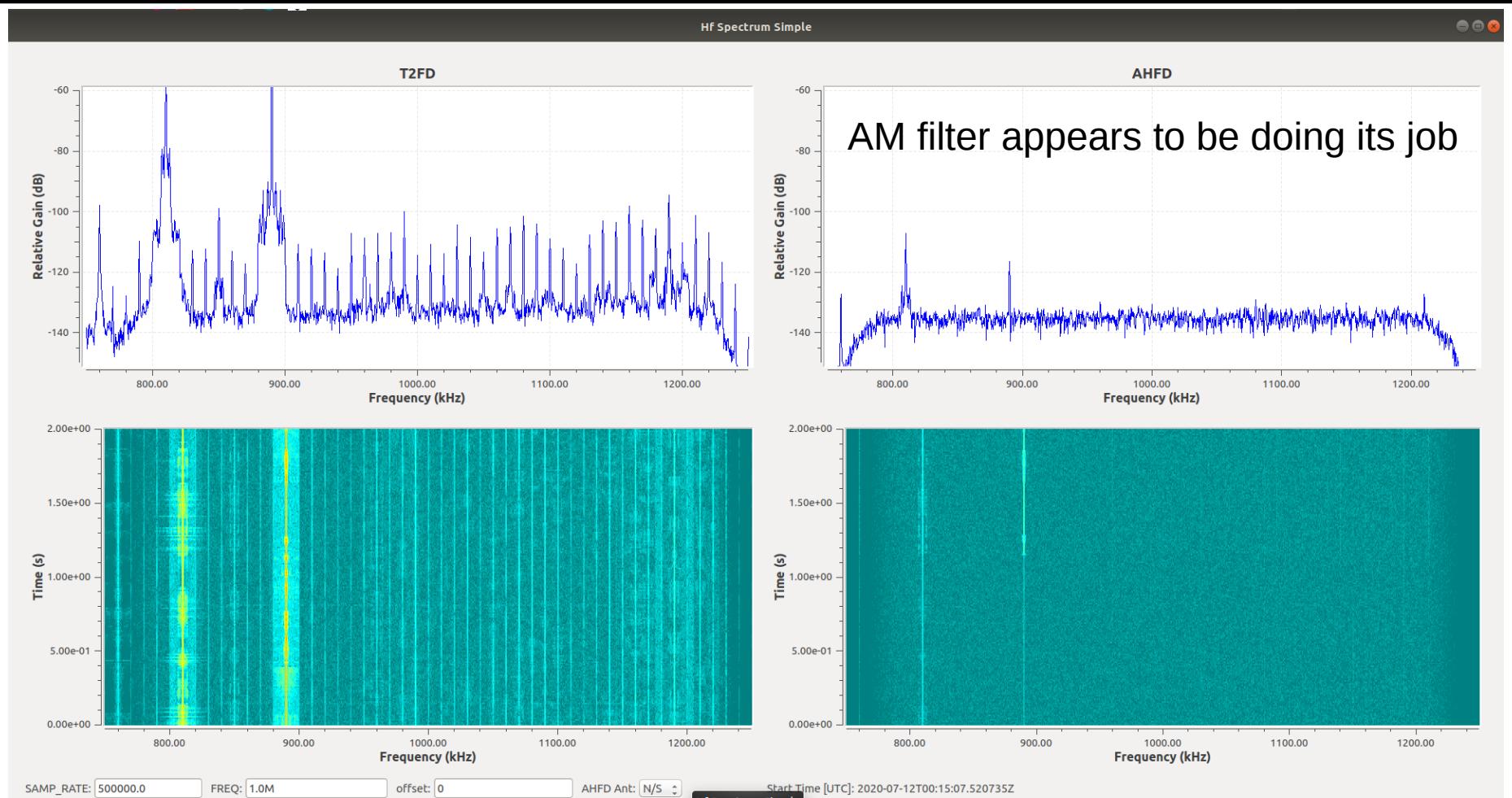
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

T2FD vs Active HF Dipole - 1.0 MHz



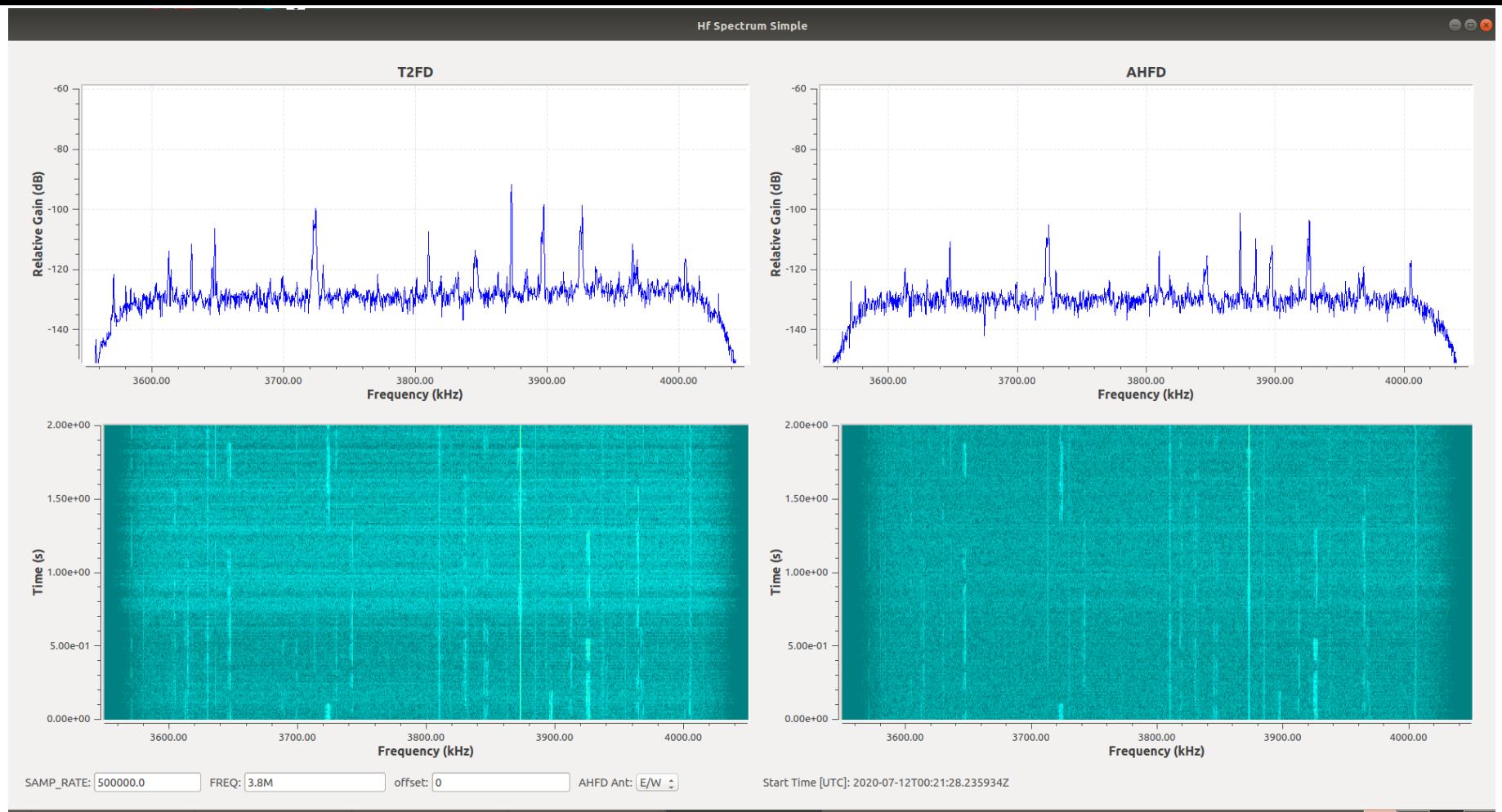
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

T2FD vs Active HF Dipole - 3.8 MHz



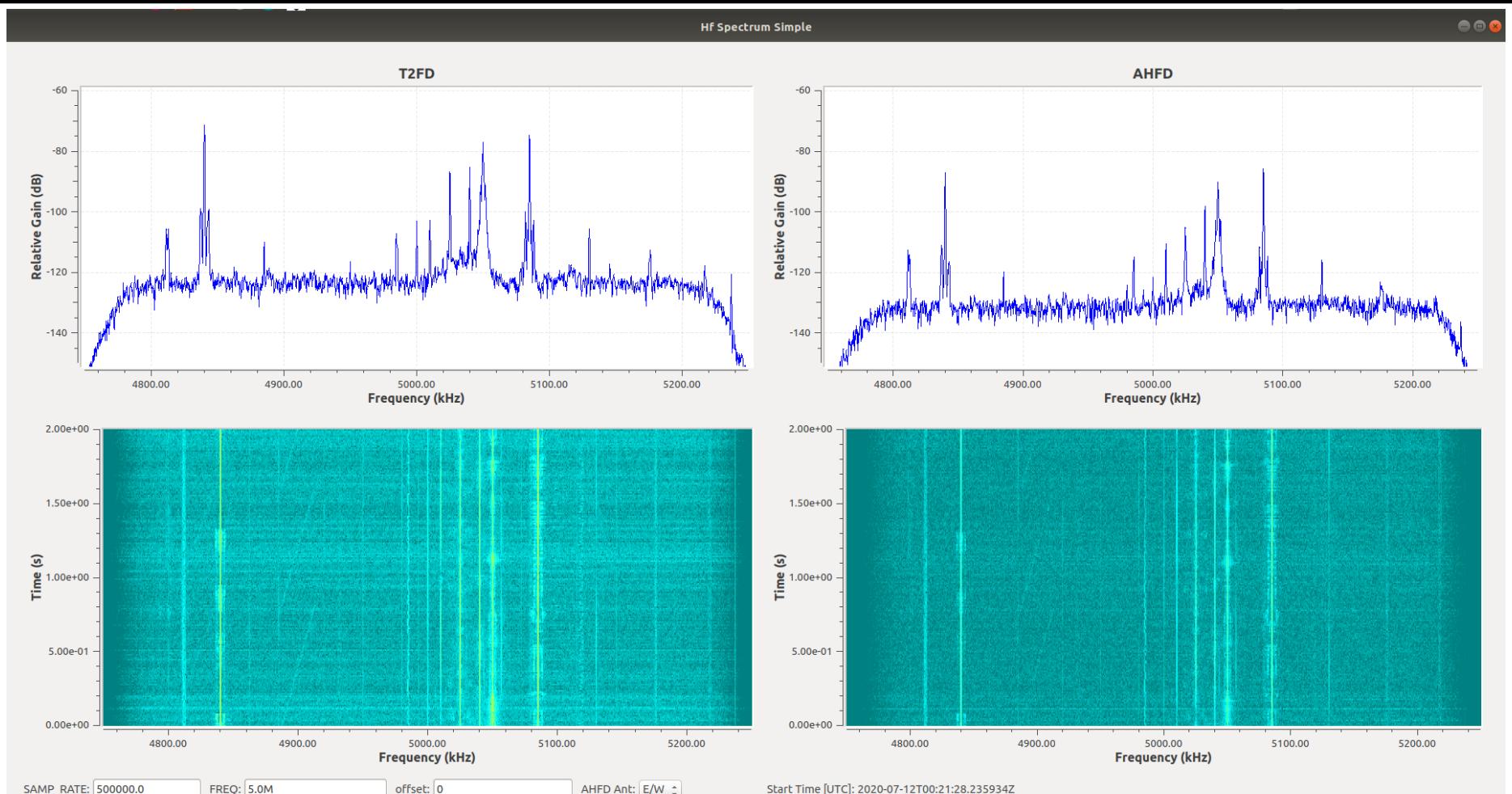
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

T2FD vs Active HF Dipole - 5.0 MHz



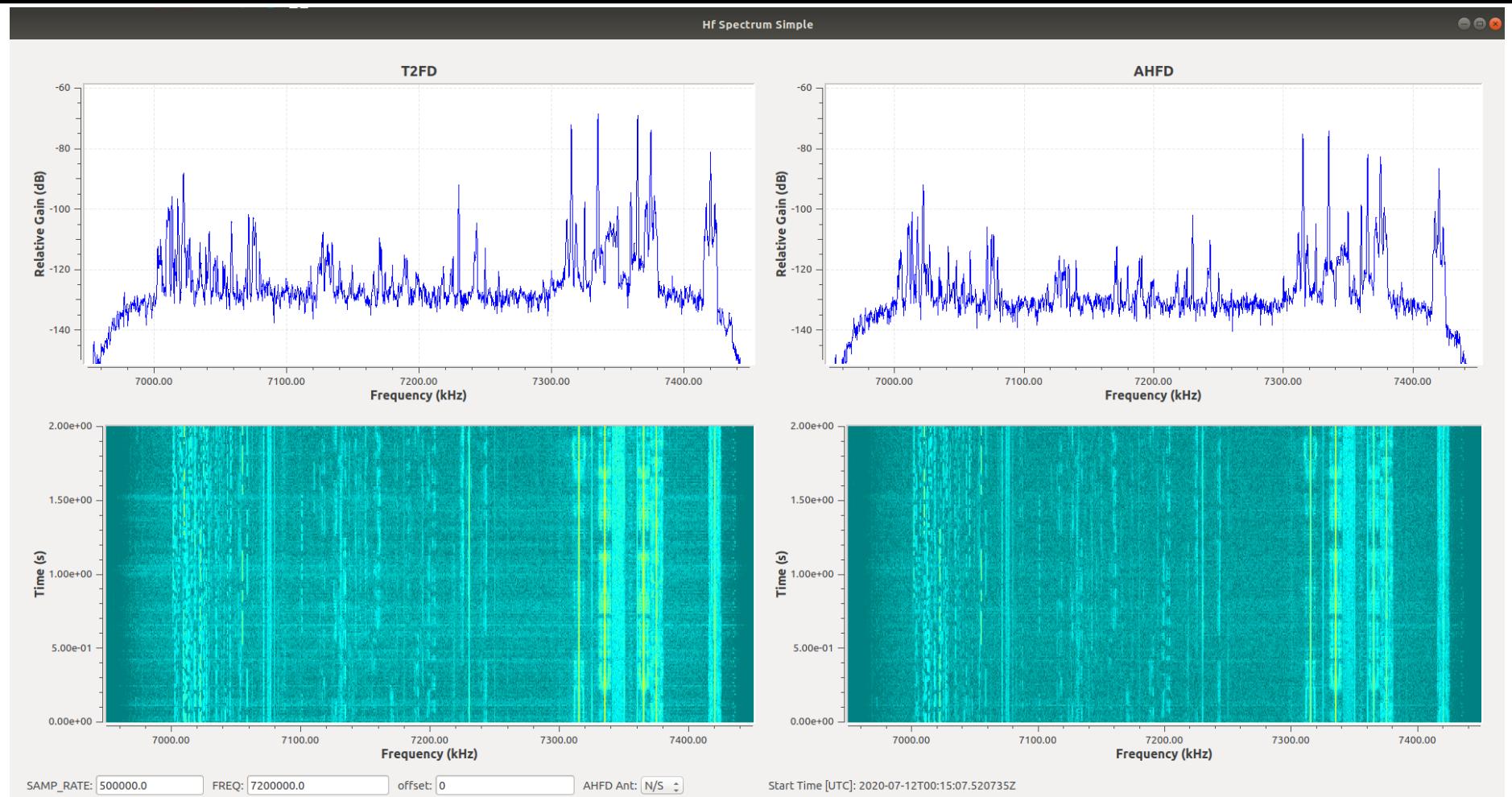
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

T2FD vs Active HF Dipole - 7.2 MHz



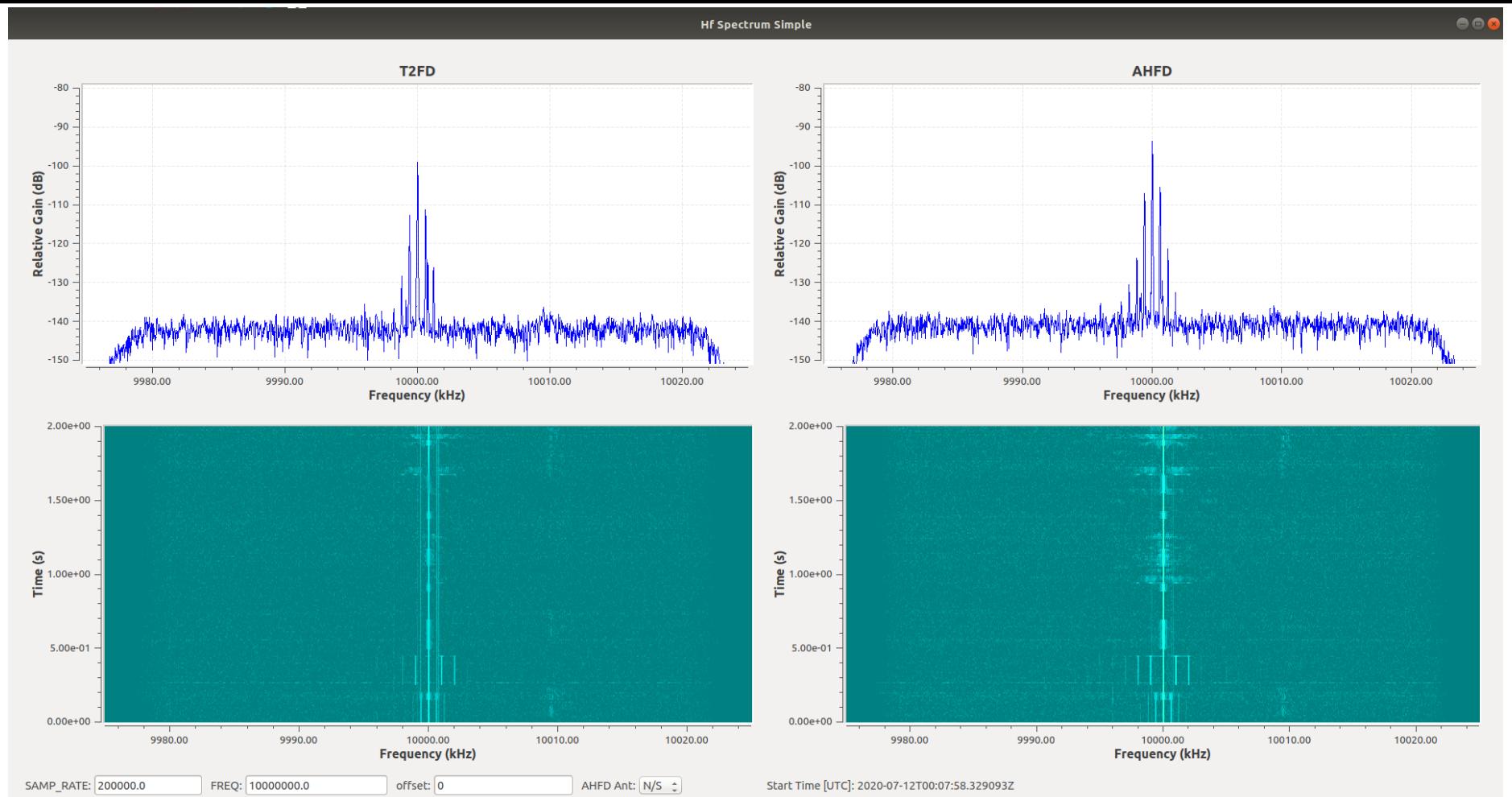
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

T2FD vs Active HF Dipole - 10.0 MHz



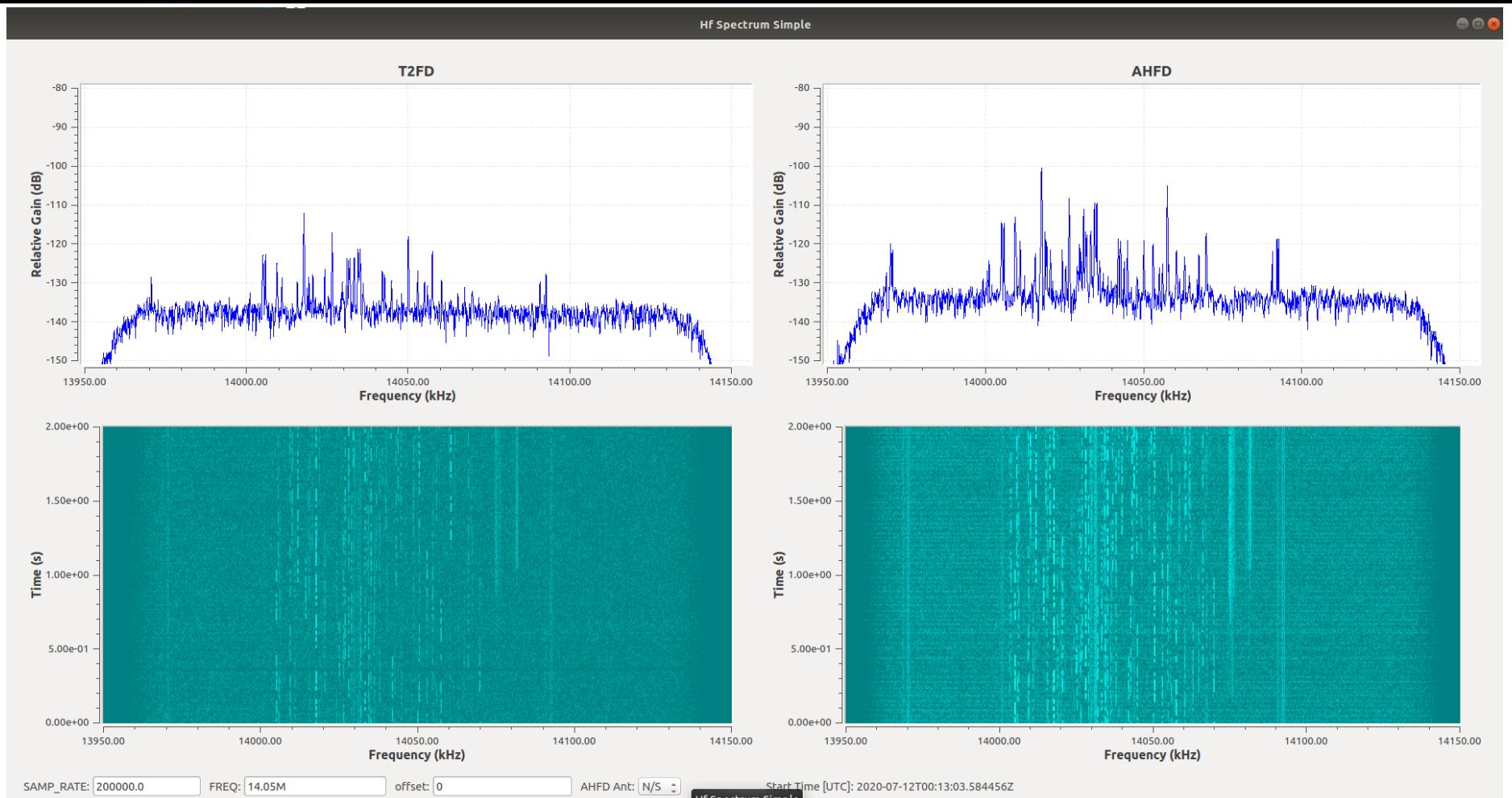
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

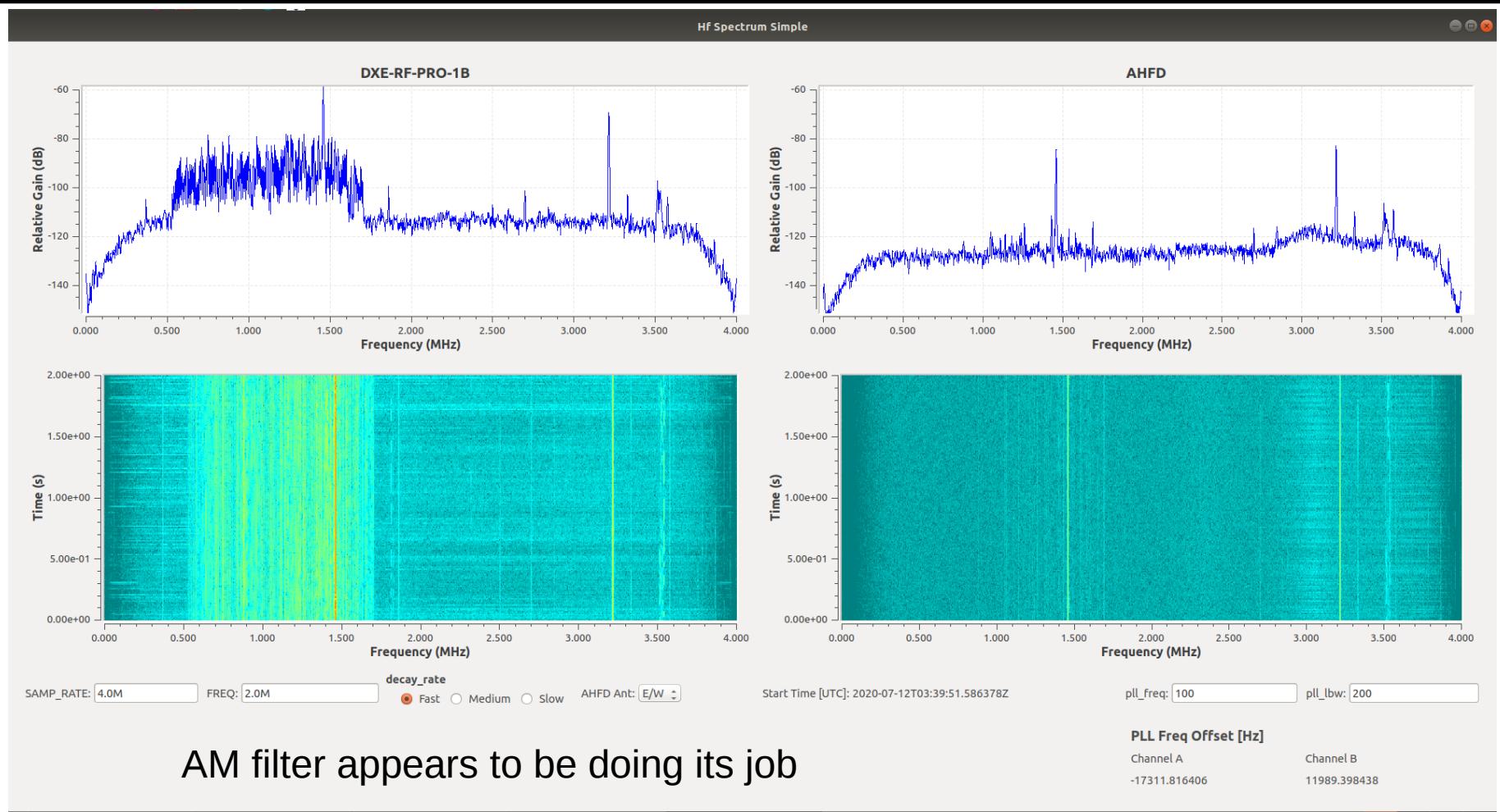
$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

T2FD vs Active HF Dipole - 14.05 MHz



DXE-RF-PRO-1B vs Active HF Dipole - 2.0 MHz

$$\begin{aligned}\nabla \cdot D &= \rho \\ \nabla \cdot B &= 0 \\ \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \times H &= J + \frac{\partial D}{\partial t}\end{aligned}$$



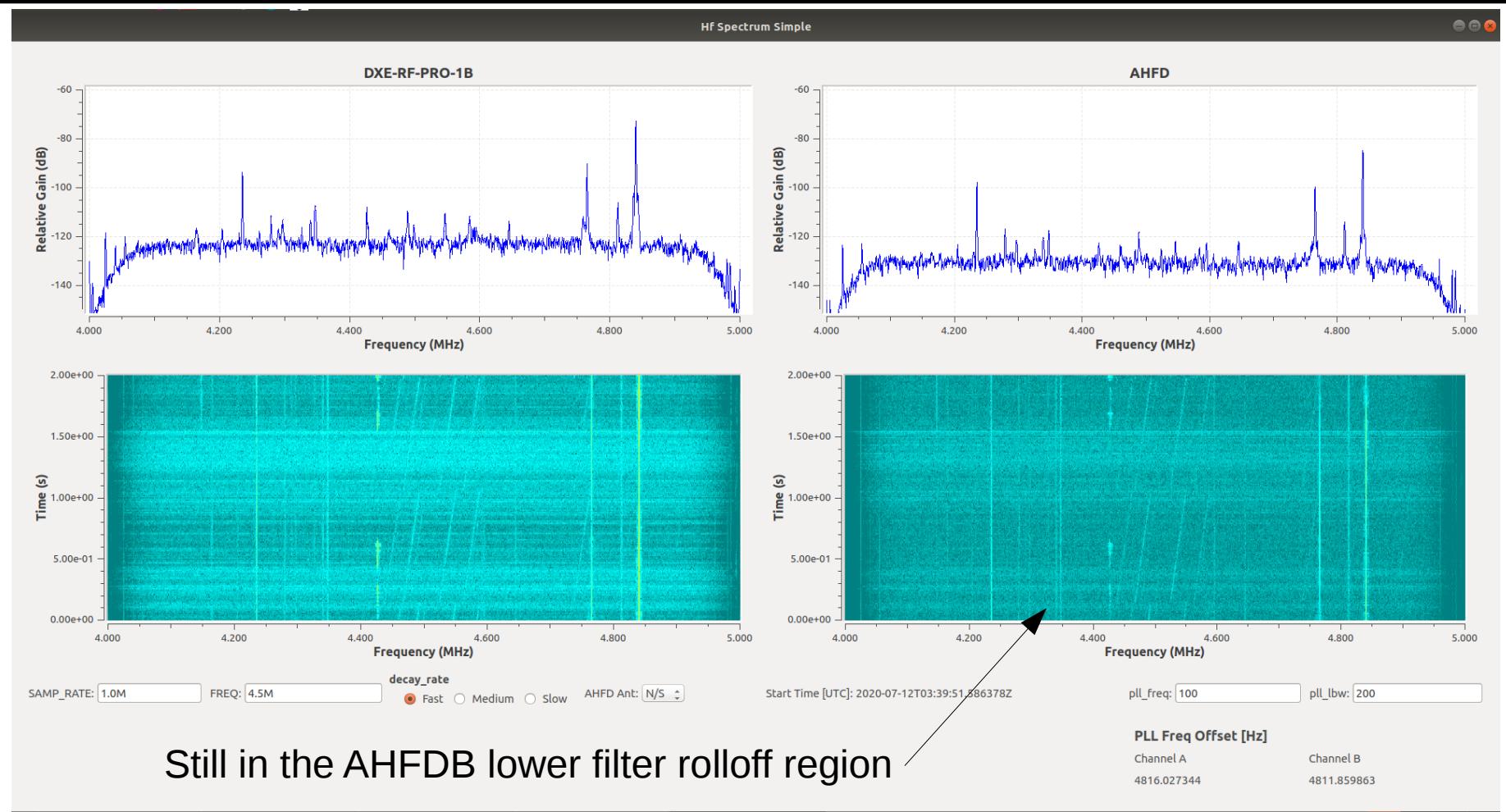
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

DXE-RF-PRO-1B vs Active HF Dipole - 4.5 MHz



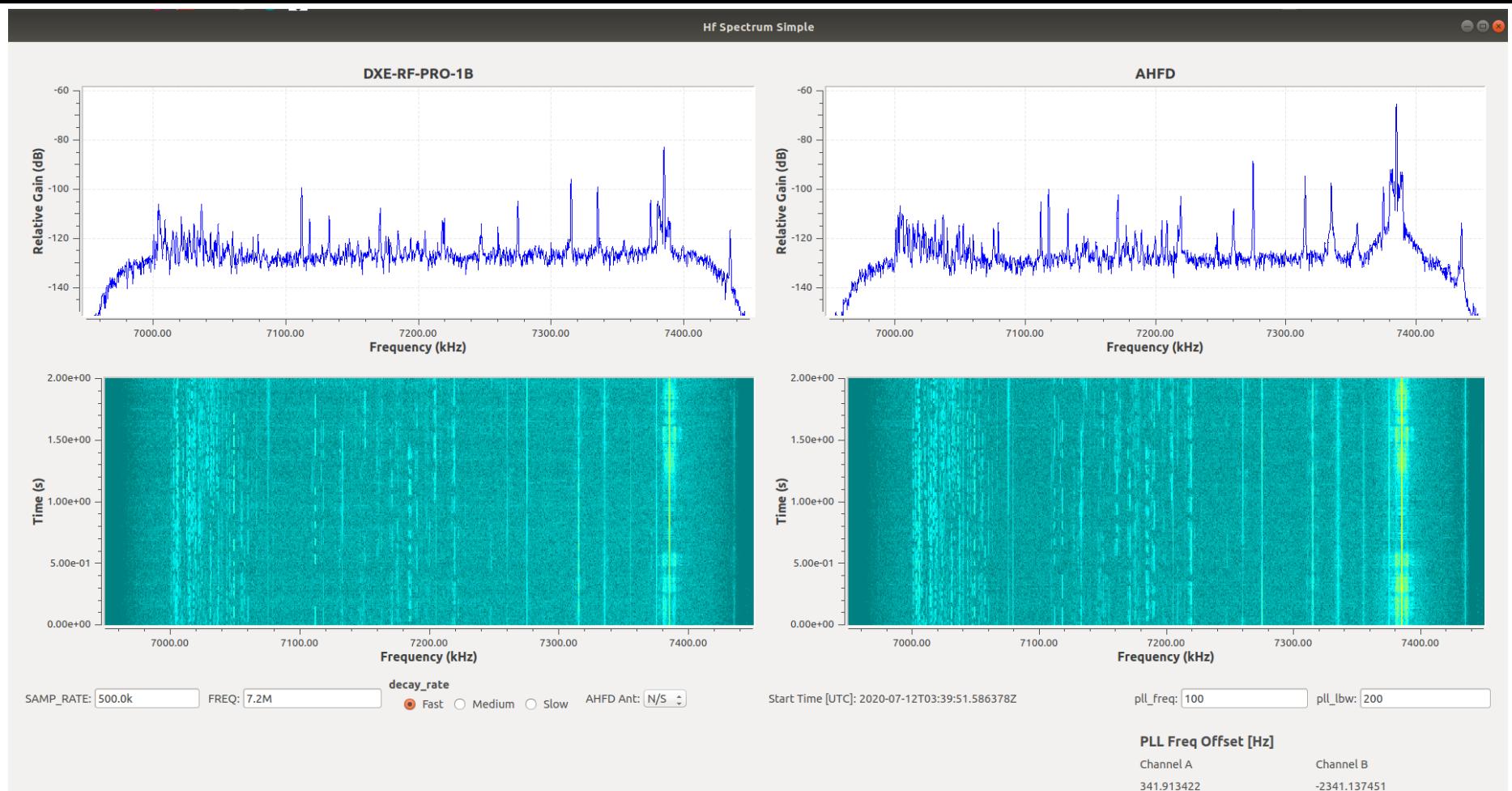
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

DXE-RF-PRO-1B vs Active HF Dipole - 7.2 MHz



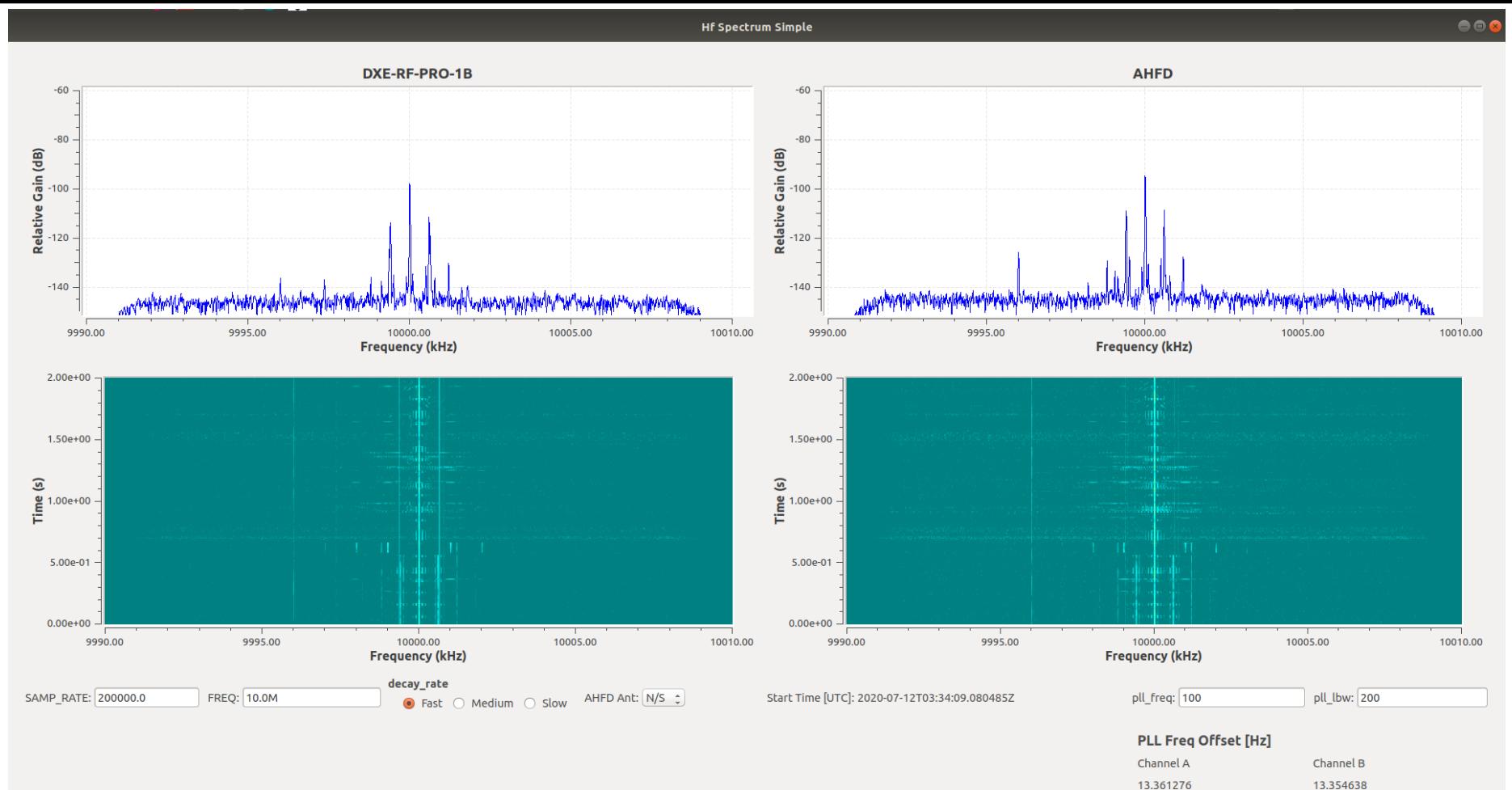
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

DXE-RF-PRO-1B vs Active HF Dipole - 10.0 MHz



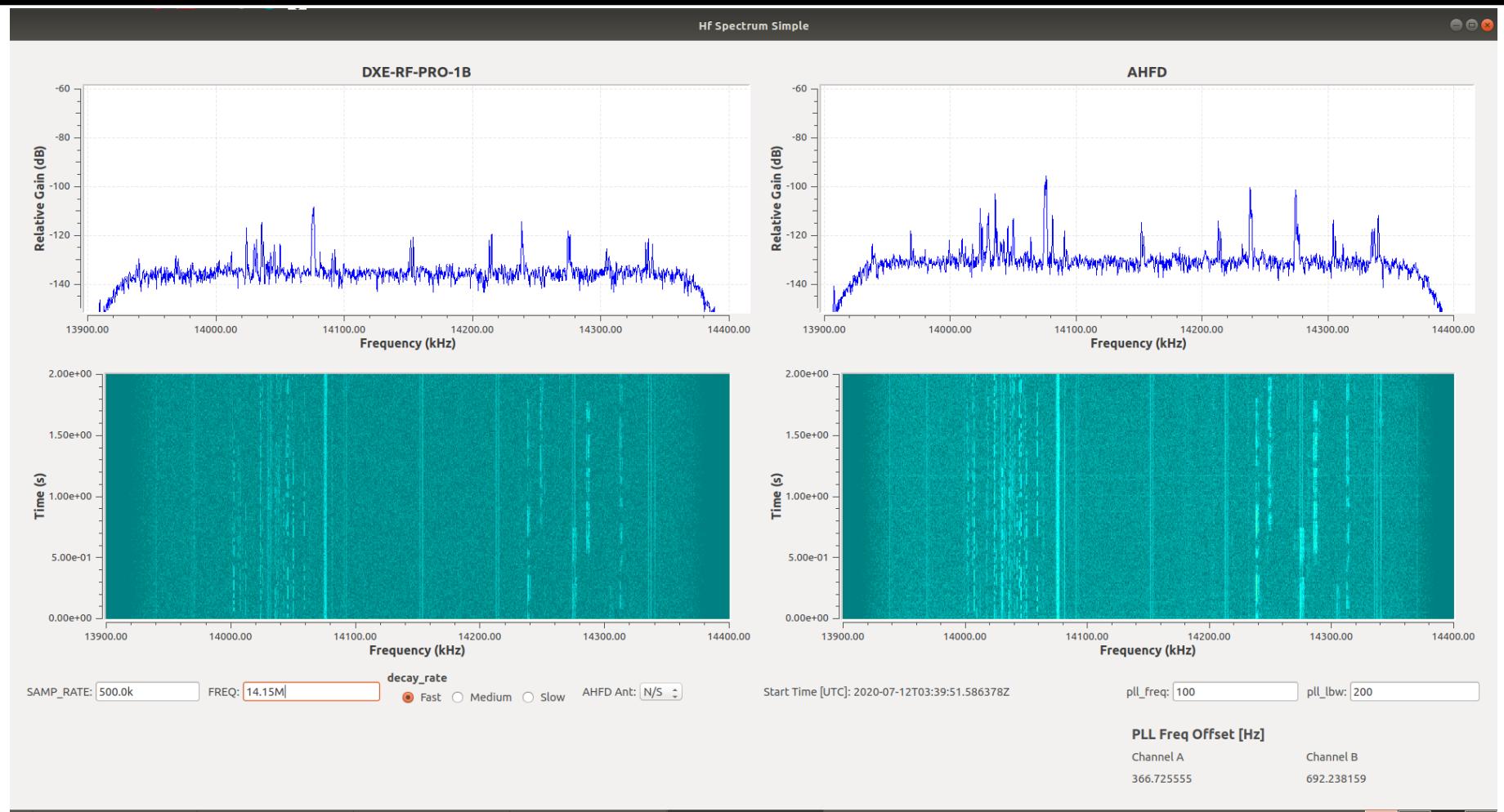
$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

DXE-RF-PRO-1B vs Active HF Dipole - 14.15 MHz



$$\begin{aligned}\nabla \cdot D &= \rho \\ \nabla \cdot B &= 0 \\ \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \times H &= J + \frac{\partial D}{\partial t}\end{aligned}$$

Next Steps / To Do

- Documentation!
 - Documentation!
 - Documentation!
 - Documentation!
- Investigate PGA-103 replacement for GALI-74s
 - More measurements!
- Next Revision of PCB
 - Bigger keepout around antenna element mounting holes
 - Wire to PCB terminal (screw lock)?
- Schematic / Layout / PCB for Bias-T
 - v1,rev1 out to Osh Park...more measurements to come!
- And bunch of other areas for experimentation...
 - Antenna patterns and element selection (better than the ~5ft 14AWG wire...4NEC2!)
 - SDRs and phasing for Circular/Elliptical Polarization

$$\nabla \cdot D = \rho$$

$$\nabla \cdot B = 0$$

$$\nabla \times E = -\frac{\partial B}{\partial t}$$

$$\nabla \times H = J + \frac{\partial D}{\partial t}$$

Thank You!

