## EME Earth-Moon-Earth

"You may think it's a long way down the road to the chemist's but that's just peanuts to space!" -Douglas Adams

> Sam - WB6RJH SLV ARC - 4 February 2022

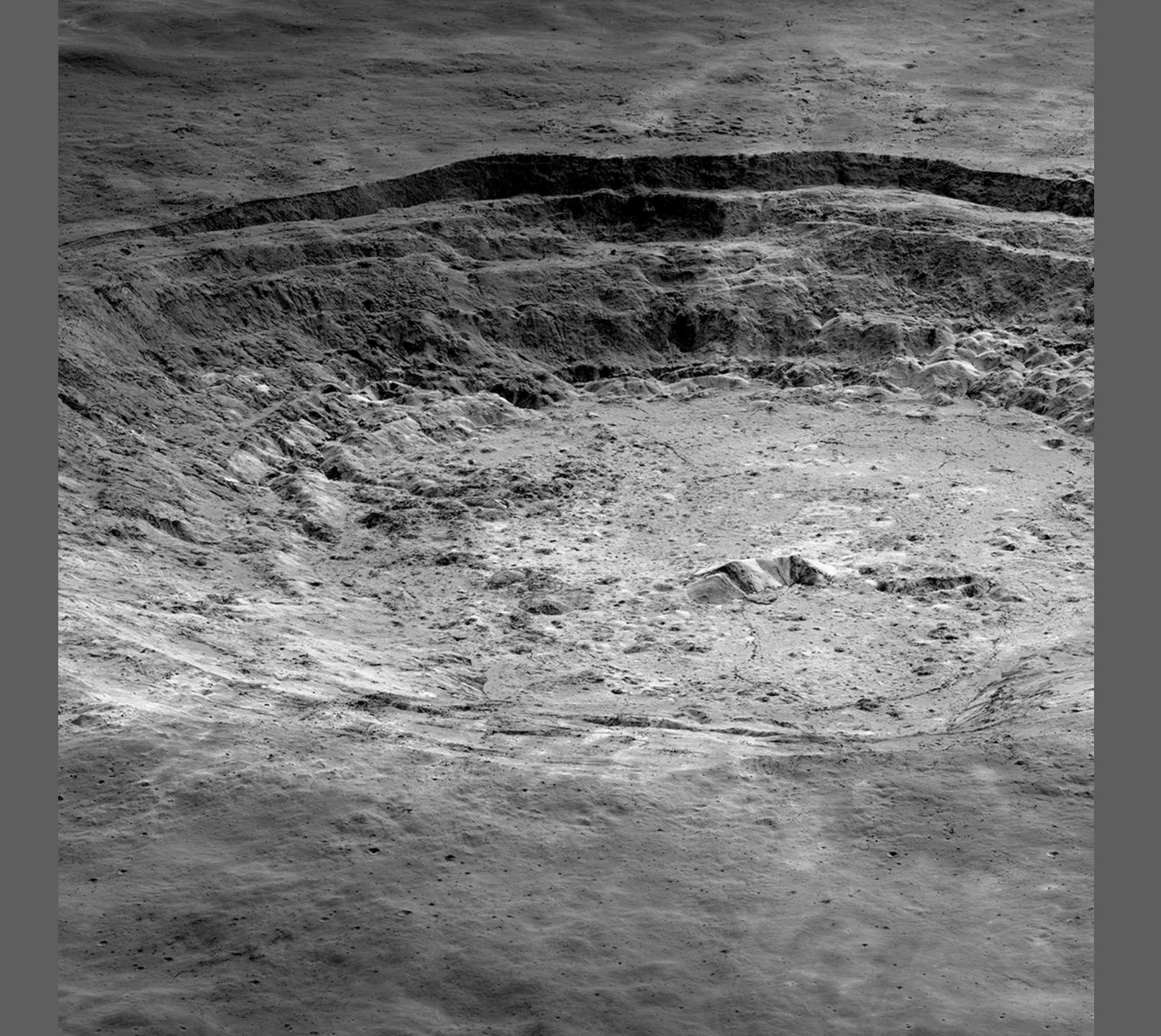


"It was dusk when he returned to the little room." A hundred miles above his head, tenuous and invisible, the Heaviside Layer would be expanding outward toward the stars as the sun went down. So it had done every evening for millions of years, and for half a century only, Man had used it for his own purposes, to reflect around the world his messages of hate or peace, to echo with trivialities or to sound with music once called immortal."

-Arthur C Clarke, "The Forgotten Enemy", 1949

#### "An ambassador is shot by a would-be assassin. To remove the bullet, a surgeon needs to consult a colleague on a cruise ship in the Pacific. Scientists bounce a TV signal off the moon to the ship so he can watch and direct the operation."

Science Fiction Theatre, "Signals from the Moon", S2-E29, 1956 IMDB: In this science-fiction anthology series host Truman Bradley introduces stories extrapolated from actual scientific data available in the 1950s, concentrating on such concepts as space flight, UFO's and mental telepathy.



- Massive path loss order of 250dB, this practically defines "weak signal work"
- Doppler shift Moon-Earth as well as Earth's rotation
- Polarization atmospheric "Faraday rotation", geometry
- Radio astronomy "degradation" from background sources, Milky Way especially
- Contest of course there are EME contests! But it's helpful to beginners, too.
- Amateur protocols mainly JT65, Q65, in WSJT-X and others
- Challenge for its own sake education and engineering challenge, "everything I know"
- Foretold by my 4Runner's license plate assigned in 2003 having "EME" in it

## EME is hard



## Bands

- 6m, 2m, 1.25m, 70cm, 23cm, and up-up-up
- I'm only doing 2m for now!
- 6m EME can take some very serious antenna construction see W6UC's page on QRZ
- 2m seems most popular, especially at the entry level
- once you get to 23cm you're getting into the territory of dishes and waveguides, but yagis are still viable

## Power restrictions on 70cm

- California has geographical restrictions Pave PAWS military radar
- Beale AFB and Pt Mugu installations
- Waivers required to exceed 50W in certain areas, including most of SLV
- But if you're directing most all your power up...well, it still matters
- See the ARRL website for more info

## Equipment

- Every tenth of a dB matters! Don't use so-called "UHF" connectors above 6m
- Good weak signal rig desirable but older equipment can be made to work
- As much power as you can muster, long TX cycles derate amplifier output
- LNA Low Noise Amplifier, the best pre-amp(s) you can get/afford
- Low loss transmission lines LMR-400 a bare minimum, Heliax preferred
- May have multiple runs of coax, e.g., one for TX plus two for H and V receive, with relays
- May have LNAs and even power amp out at the antennae
- Array of antennae with phasing harness and power splitter
- Az-El rotator system and tracking software (optional, at least initially)
- More optional gear than you can imagine, especially for dealing with polarization

#### If you start out small, look for the big dogs



## My little puppy "array"





#### Cross-boom, phasing harness, power splitter, LNA

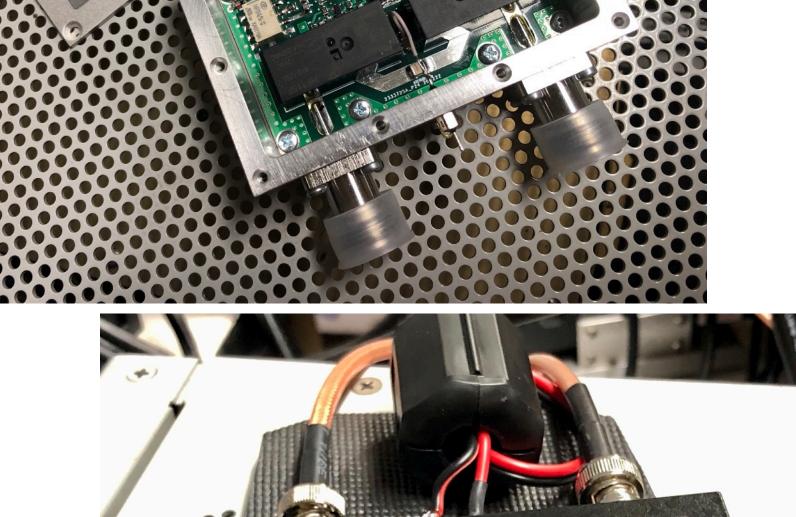


# Making a phasing harness

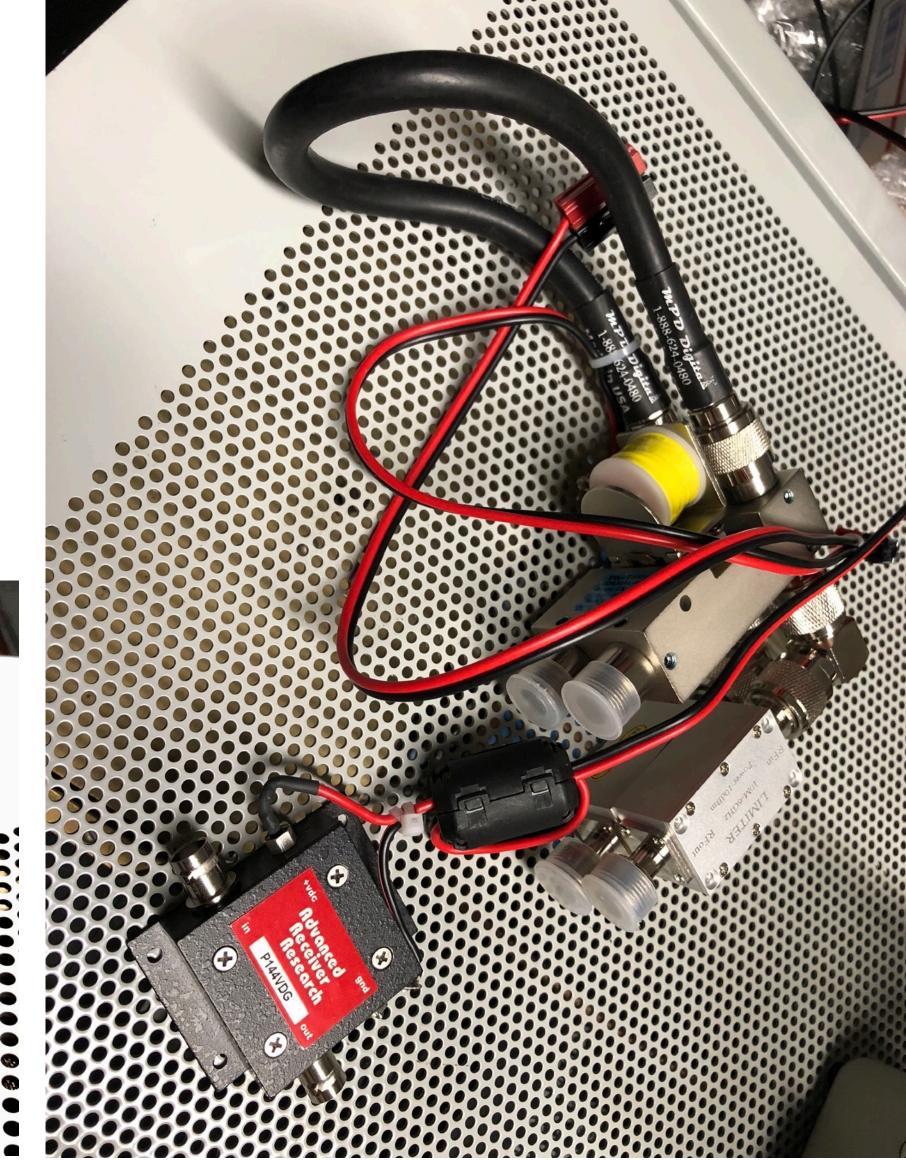
- Match the cables to a couple degrees (e.g., 1-2 cm on 2m)
- Must be electrically matched, not just physically
- Build or buy
- Use something like a NanoVNA
- takes some trial and error

• See "how to" pages on the net, see Resources at end; it's a bit tricky and

# LNAs, pre-amps, lumps of coal







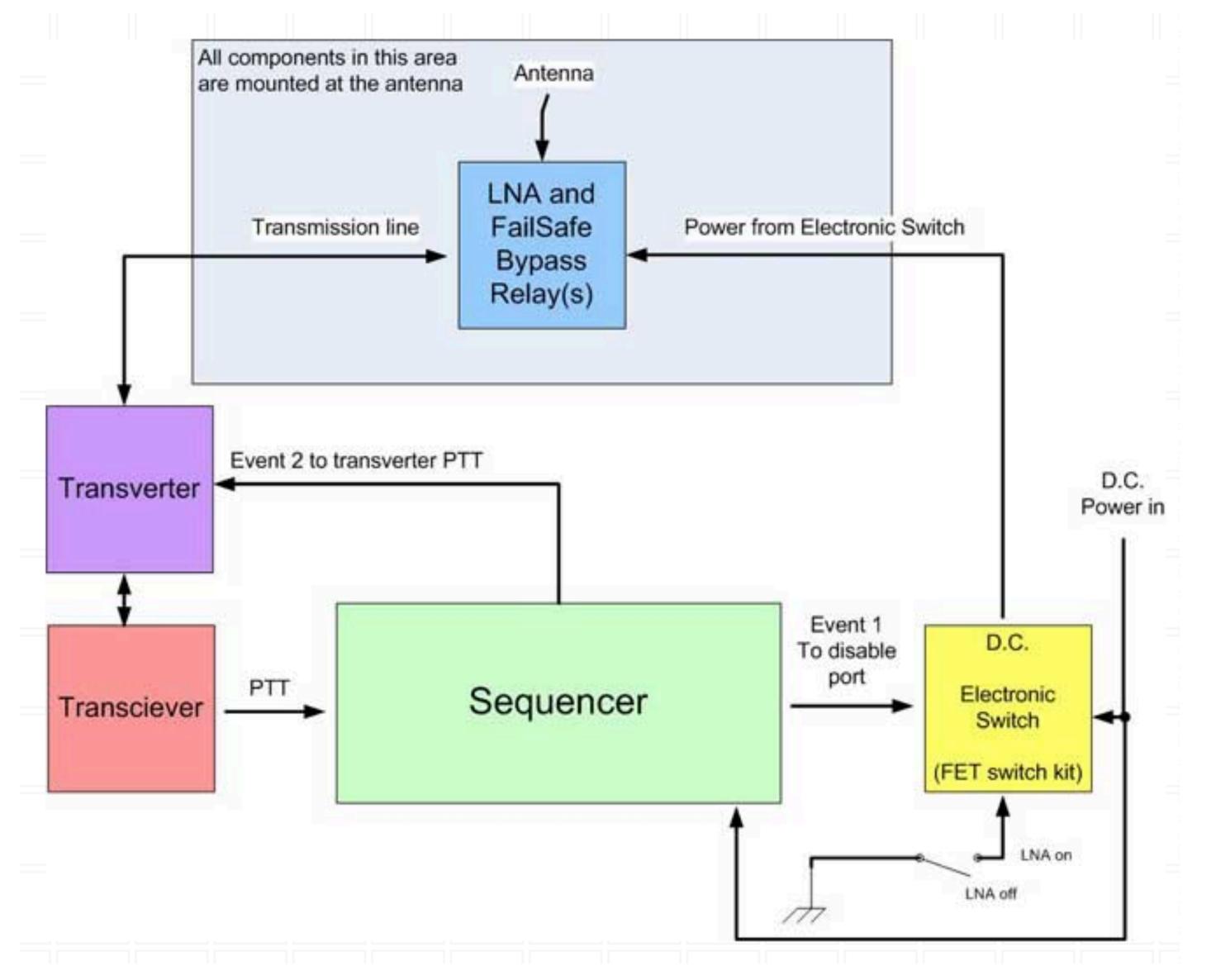
### 2m QRO, you betcha! Upgrade on order



## The rig

- My primary: IC-9700 (built-in sequencer and bias-tee)
- My backup: TS-2000 (needs a bunch of help, but usable)
- An external sequencer may be needed depending on the complexity of your setup, for control of antenna relays, pre-amp, linear, transmitter
- "Sidecar" SDRs commonly used, even for primary receiver, but also for simultaneous reception of H and V polarization

## Sequencing example - W6PQL



## Accuracy vs Stability

- Absolute time accuracy similar to FT8
- Note specific DT for EME vs terrestrial about 2.5 vs 0.5
- Frequency accuracy nice, stability a bigger issue GPSDO can help both
- Long transmissions challenge rig's thermal stability
- Everyone has to deal with Doppler drift
- Doppler computations included in various software packages  $\bullet$
- Settings and usage of software very important

## Methods of Coordination

- The Internet, of course!
- It's fairly unlikely to make random EME contacts, unless you've got a big signal and call CQ a lot on the most common frequencies
- Even with coordination, it may take a while for you to get decoded, due to polarization rotation, software averaging, etc.
- If someone knows you're calling CQ, they can get better decoding by entering your callsign in the DX field to give the software some help
- Practically everyone announces on EME-1 (see the Resources page), including during contests

#### What it looks like in WSJT-X

💘 EME —				📀 WSJT-X v2.5.4 I	by K1JT, G4WJS, K9AN,
Setup Band Sequence Map	Radio Links			File Configurations	View Mode Decod
Moon Tr				UTC dB DI	Single Freq Messa
144 N	1Hz				1361 #*
Azimuth	tion			1000	1557 #
176.42° 5	0.49°			2313 -30 -0.5 2315 -30 0.1 2317 -30 5.5	
SUN AZ: 227.22° EL:	A CONTRACTOR OF			2319 -30 5.8	1368 #
Geocentric Topoc RA: 00:23:27 RA:	entric 00:23:35			2321 -30 -2.3 2321 -19 -2.3	1303 #* 01234
DEC: -1.84* DEC	: -2.44*			2021 19 2.0	1200 ##
GHA: 119.88* LHA:	357.72*				
Sequence	East	and the second second			
23:22:33 <b>TX</b>	1 min				
	594 Km				
Path loss: 1.28 Moon diameter: 31.1					
Doppler: -47 H	lz dialate				
Sky temperature: 246* Degradation: 2.02					
Call: Loca	ator:				
AZ: LAT:	A CANADA CAN A CANADA				
EL: LON Moonrise: Moor				Log QSO	Stop
Schedule:				2m ~ S	144.13
Doppler: Mutual Doppler:					I   11.I.J
Polarisation offset:				Г	DX Call
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6 7 8 9 10 11 12	23:22			-40	Lookup
13 14 15 16 17 18 19 20 21 22 23 24 25 26	<< <<			-20	
27 28	PC Time			E E	2022 Fel
Moonrise: 17:35 Moo	nset: 4:32			0 dB	23:22:
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<ul> <li>WSJT-X - Wide Graph</li> <li>Controls 500</li> </ul>		1000	1500	Tx: CQ WB6RJH CM87	TS-2000 J
Controls 500		1000		1	2000
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l, and IV3NWV

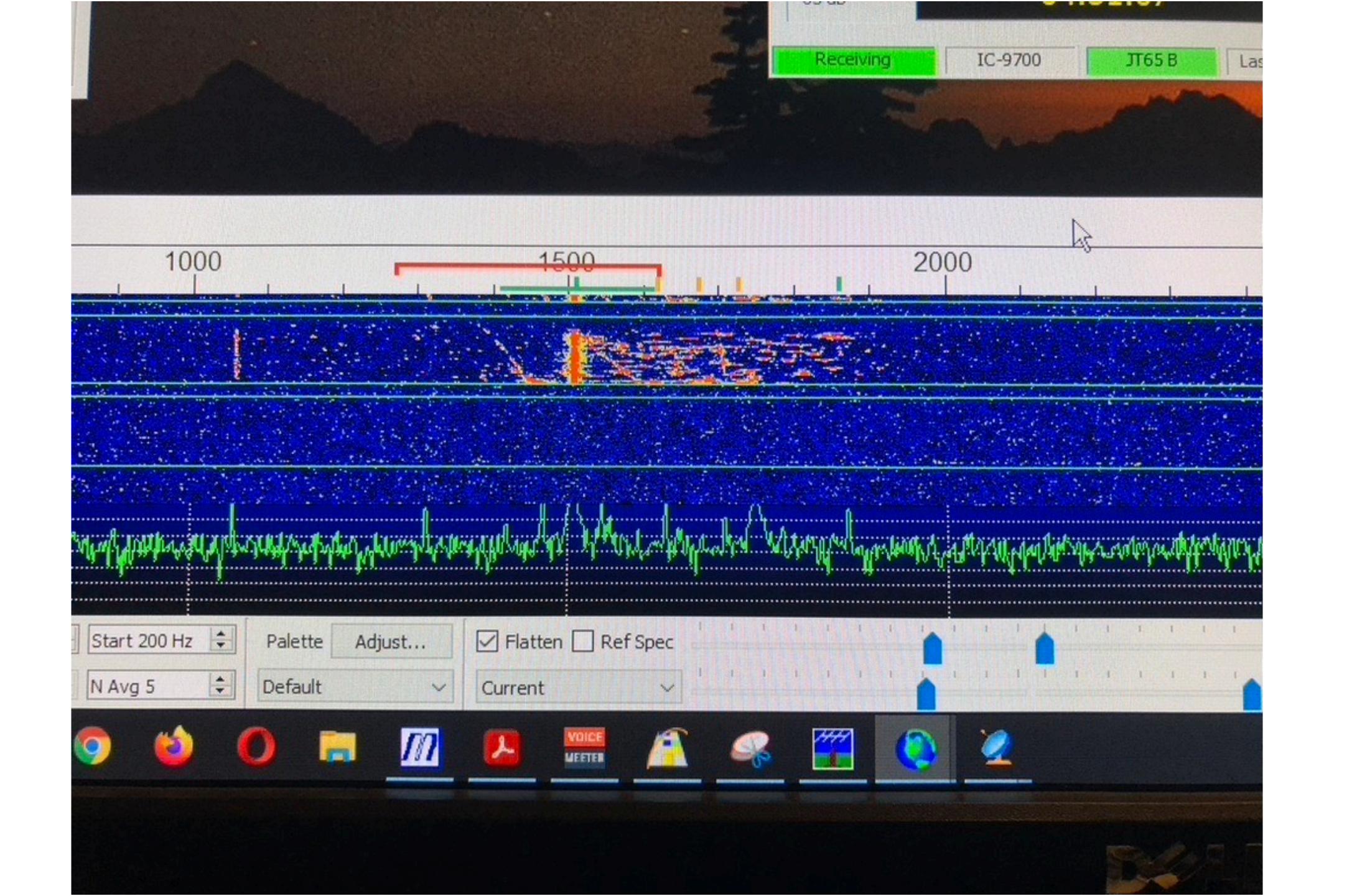
de Save Tools Help

-Period Decodes Average Decodes UTC dB DT Freq Message ge 2308 Tx 1270 # CQ WB6RJH CM87 2310 Tx 1270 # CQ WB6RJH CM87 2312 Tx 1270 # CQ WB6RJH CM87 2314 Tx 1270 # CQ WB6RJH CM87 2316 Tx 1270 # CQ WB6RJH CM87 2318 Tx 1270 # CQ WB6RJH CM87 456789ABC d5 2320 Tx 1270 # CQ WB6RJH CM87 2322 Tx 1270 # CQ WB6RJH CM87 Menus Monitor Erase Clear Avg Decode Enable Tx Halt Tx Tune Tx even/1st Generate Std Msgs Next Now Tx 1270 Hz -Submode B 🚔 O Tx 1 F4HBY WB6RJH CM87 DX Grid 🔺 🛛 F Tol 200 🚔 🛛 🔻 Sync 0 韋 O Tx 2 F4HBY WB6RJH CM87 OOO IN97 Rx 1270 Hz -O Tx 3 '4 km + Report 0 Add Sh Sh O Tx 4 0 Tx 5 73  $\sim$ Tx 6 CQ WB6RJH CM87 Last Tx: CQ WB6RJH CM87 2 33/60 WD:30m 2500 30 PstRotator - Registered to WB6RJH v16.72  $\times$ -----Communication Setup Tracker RA/DEC GeoSats Maps My Maps Google Maps APRS EME DSN View Show Preset Help QRB-Presets DXCC 0 DX Local Time: ? 90 75 330 km 1A: Sov Mil Order of Malta • 60 7 ~ 60 1S: Spratly Islands 300 ٠ QTH Locator 45 3A: Monaco 3B6: Agalega & St. Brandon 3B8: Mauritius 2 8 ٠ 3 9 30 • 90 270 🔸 3B9: Rodriguez Island 3C: Equatorial Guinea GO to Locator 10 • 4 V 240 • 120 Hot A Hot B 5 11 Call GO to DXCC 12 6 150 BD 0 90 210 180 Mode -AZ-UTC-EL P QRZ SP F STOP C Manual 175 176.4 💿 23:22:33 GO 50.5 50 Tracking 1 1 PARK

– 🗆 X

	Single-Period Decodes		
UTC dB	DT Freq Message	Average Deco UTC dB DT Freq Message	des
0812 -30 -			
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0816 -21	2.6 1114 ##	0805 Tx 1270 # EB5EEO WB6RJH CM87	
	2.6 1115 #* WB6RJH EB5EEO IM 2.6 1118 ##	98 1270 # EBSEEO WB6RJH CM87 E 1270 # EBSEEO WB6RJH CM87 0809 Tx 1270 # EBSEEO WB6RJH CM87	
	2.6 1114 #* WB6RJH EB5EEO IM	98 0811 Tx 1270 # EB5EEO WB6RJH CM87	
	2.6 1111 ##	0813 Tx 1270 # EB5EEO WB6RJH CM87 0815 Tx 1270 # EB5EEO WB6RJH CM87	
	2.6 1112 #* WB6RJH EB5EEO IM 2.6 1115 ##	O817 Tx 1270 # EBSEEO WB6RJH CM87	000
	2.5 1111 #* WB6RJH EB5EEO IM	98 0819 Tx 1270 # EB5EEO WB6RJH CM87 0821 Tx 1270 # EB5EEO WB6RJH CM87	
	2.5 1110 ## 2.6 1109 #* WB6RJH EB5EEO IM	0823 Tx 1270 # EB5EEO WB6RJH CM87	000
	2.6 1108 ##	DOB25 TX 1270 # EB5EEO WB6RJH CM87 0827 TX 1270 # EB5EEO WB6RJH CM87	
	2.6 1108 #* CQ EB5EEO IM98	0829 Tx 1270 # CQ WB6RJH CM87	
	2.5 1110 ## 0.3 1395 #*	0831 Tx 1270 # CQ WB6RJH CM87 0833 Tx 1270 # CQ WB6RJH CM87	
	3.0 1397 #*	0835 Tx 1270 # CQ WB6RJH CM87	
	4.9 1170 #* 5.7 1194 #	0837 Tx 1270 # CQ WB6RJH CM87 0839 Tx 1270 # CQ WB6RJH CM87	
	0.7 1025 ##	0839 Tx 1270 # CQ WB6RJH CM87 0840 -27 2.6 1121 ## 0123456789ABC 000	d*7
0840 -25 2	2.7 1121 #* WB6RJH DL8II JN4		000
	2.6 1121 ## 0.8 1116 # RO	0843 Tx 1270 # RRR 0845 Tx 1270 # CQ WB6RJH CM87	
	5.9 1110 # 73	<mark>0847 Tx 1270 # CQ WB6RJH CM87</mark> ▼	
0846 - 30 4	4.8 1141		HaltTx Tune
Log QSO	Stop Ma	mitor Erase Clear Avg Decode Enable TX	
2m ~	144.132 000	Tx even/1st C Generate Std Msgs	Next
2m ~		Tx 1270 Hz 🔹 Submode B 🚖 🕥 DI STI WB6P 1H CM87	0
	DX Call DX Grid		
-80	DL8II JN49	Rx 1110 Hz	0
-60	Az: 29 9285 km	Report -25	
-40	Lookup Add	RRR Sh	
			<u> </u>
-20	2022 Jan 22	CQ WB6RJH CM87	
0	02.47.56		





## Just a beginner, but...

- Started a few months ago
- Initially was just able to copy a station with one beam
- Then got the amp, hooked up the second antenna and LNA
- High point was working about 15 stations in one contest evening
- How else do you work 2m grids in Europe?
- Looking forward to much more success and VUCC 2m



## Any Questions?

### Resources

- WSJT-X download: <u>https://physics.princeton.edu/pulsar/k1jt/wsjtx.html</u>
- EME with JT65: https://physics.princeton.edu/pulsar/K1JT/WA50\_June05.pdf (especially note the photo at the end)
- EME-1 chat: <u>https://www.chris.org/cgi-bin/jt65emeA</u>
- Channel 5-eme on VHF-Chat group in Slack: <u>vhf-chat.slack.com</u>
- Great gear and info: <u>http://www.w6pql.com/</u> especially on sequencing: <u>http://www.w6pql.com/</u> <u>Ina sequencing and protection.htm</u>
- Phase matching with NanoVNA: <a href="https://nuclearrambo.com/wordpress/make-your-own-phased-matched-cables-with-nanovna/">https://nuclearrambo.com/wordpress/make-your-own-phased-</a> matched-cables-with-nanovna/
- ARRL, 70cm power limitation info: http://www.arrl.org/us270