Moonbounce Basics

Presented to the

Collins Amateur Radio Club

by

Al Ward

W5LUA

March 23, 2021

Motivation for building a moonbounce system

- My motivation was the pure excitement of hearing my echoes return from the moon.
- Average echo delay is 2.5 sec for the roughly 500,000 mi round trip to the moon.
- 6m is the only VHF band that does not require the use of EME to work WAS.
- Outside of tropospheric bending, Aurora, Es, If you lived in the center of the US, you could never work Alaska and Hawaii unless you had EME capability on 2m.
- My first 2m EME system used 4 Oliver Swan 14 element yagis AZ/EL at 50 ft with a pair of 4CX250b's about 550 watts output and a TI MS-175te preamp with about a 1.5 dB noise figure. I heard my first echoes in late 1974. What a thrill!

Some moon characteristics

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- The moon is on a 28 day cycle as it orbits the earth.
- The moon's declination varies from a max southerly declination of about -25 degrees to a maximum of about +25 degrees.
- For us in the DFW area, this means the maximum elevation at hi dec is approximately 82 deg and only 31 deg at max southerly declination
- Since the majority of EME operation occurs in the northern hemisphere, generally high declination is preferred as it provides more moon time for us in the northern hemisphere but makes it harder to find a common window for VK's and ZL's

More moon characteristics

- During each cycle, the moon cycles through its phases from new moon to full moon.
- Although one might think that a full moon would offer the strongest echo returns, it all depends on when perigee occurs.
- Perigee, when the moon is closest to the earth, provides a nominal 2 dB improvement in received signal strength. When signals are close to the noise this can make or break a contact.
- Perigee does not always occur at high declination. At the moment, perigee occurs at a declination of -19 degrees.

Two Way EME Path Loss

Frequency (MHz)	Average Path Loss
144	252.1 dB
432	261.6 dB
1296	271.1 dB
2300	276.1 dB
3400	279.5 dB
5700	283.9 dB
10368	289.1 dB

Mean distance to the moon of 238,000 statute miles
Assumes lunar reflectivity of .065 or a reflection loss of -11.9 dB

Path Loss

- According to the Radar equation, the path loss increases by 6 dB every time the frequency is doubled
- However, dish gain also increases by 6 dB every time frequency is doubled
- Since we gain the same 6dB on both receive and transmit and assuming we use the same power and the same NF as we go up in frequency, our echoes will improve as frequency is increased – this is in fact what we see!
- But there are obvious limitations as we go higher in frequency, like power is harder to generate and noise figures are higher
- Fortunately, there is a program written by Doug VK3UM (sk) that helps us evaluate the various system parameters.

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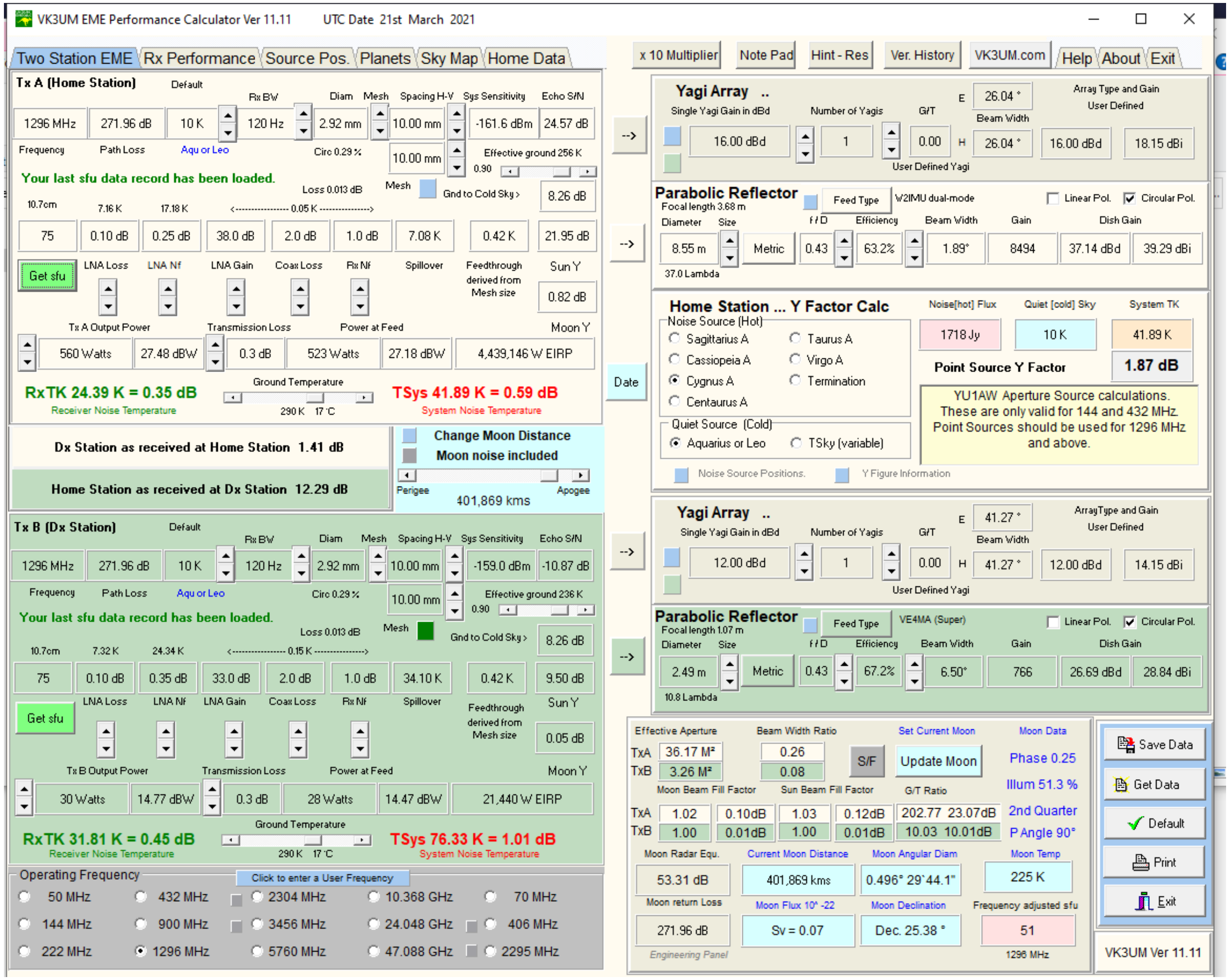
VK3UM EME Calculator



Doug VK3UM passed away in 2016 but his high school friend VK5DJ is making the download available at

https://www.vk5dj.com/doug.html

Also available is an EME planner / tracking program and other useful programs

Doppler Shift

- The doppler shift is a change in frequency of the signal reflected off the moon and received back on earth.
- When the moon is rising the doppler will be positive and when the moon is setting the doppler will be negative. The doppler is at a maximum when the moon is on the horizon and at a minimum at zenith.
- Doppler shift scales with frequency
- While doppler may be several hundred Hz at 2M, it is over 3 kHz at 1296 MHz and greater than 100 kHz at 47 GHz!

Libration

- Libration is caused by the wobble of the moon in its orbit (both latitude wise and longitude wise) and the relative motion of the moon with respect to an observer on earth.
- Libration can cause rapid fading on VHF signals causing parts of a signal to be missing while on microwave frequencies it can make signals sound rough or aurora like.
- Periods of minimum libration occur twice daily at moon elevations close to the horizon on both moon rise and moon set.
- Easily predicted with today's tracking programs

Faraday Rotation

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- According to Skolnik's Radar handbook..."The Faraday rotation of the plane of polarization can be 2 to 5 revolutions in the UHF range, but since it scales as $1/f^2$, is negligible at and above L band"
- We know that time between signal peaks on 6M can be about 5 minutes, and 15 to 20 minutes on 2M and up to hours or days on 432 MHz.
- Having the capability to switch polarity on 902 MHz, I have observed some Faraday rotation at 902 MHz. However, it is very slow and does not have the deep fades as we have observed on the VHF/UHF bands.
- Faraday rotation is for the most part, non-existent at 1296 MHz and higher, but there are other obstacles that we must contend with.

Spatial Offset

- One of the obstacles is spatial offset between 2 stations in distant parts of the globe. For example, if we send a 10 GHz horizontally polarized signal from the states, it will arrive at a nearly 90 degree offset or vertical in Europe.
- We get around this problem by running circular polarity on 1296 through 5760 MHz. Convention is transmit RHCP and receive LHCP. The sense is reversed as the signal is reflected off the moon.
- There has been much debate over the years regarding the use of CP on 10 GHz. Some stations use CP but for the most part NA is running horizontal and Europe vertical. Other parts of the world will vary. There is generally enough smearing of the reflected signal that the signal comes back at multiple angles anyway.

Atmospheric & Weather Effects

- Normally rain does not have a major impact on EME conditions through 5760 MHz – some effect on 10 GHz
- Humidity and heavy cloud cover cause increased absorption at 24 GHz – best conditions occur on a cold crisp night in the middle of winter!
- At 47 GHz oxygen absorption is another major contributor – there are no good times to operate other planning during periods of minimum libration!

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K5GW Tracking Software with Doppler Calculation & RX Tuning

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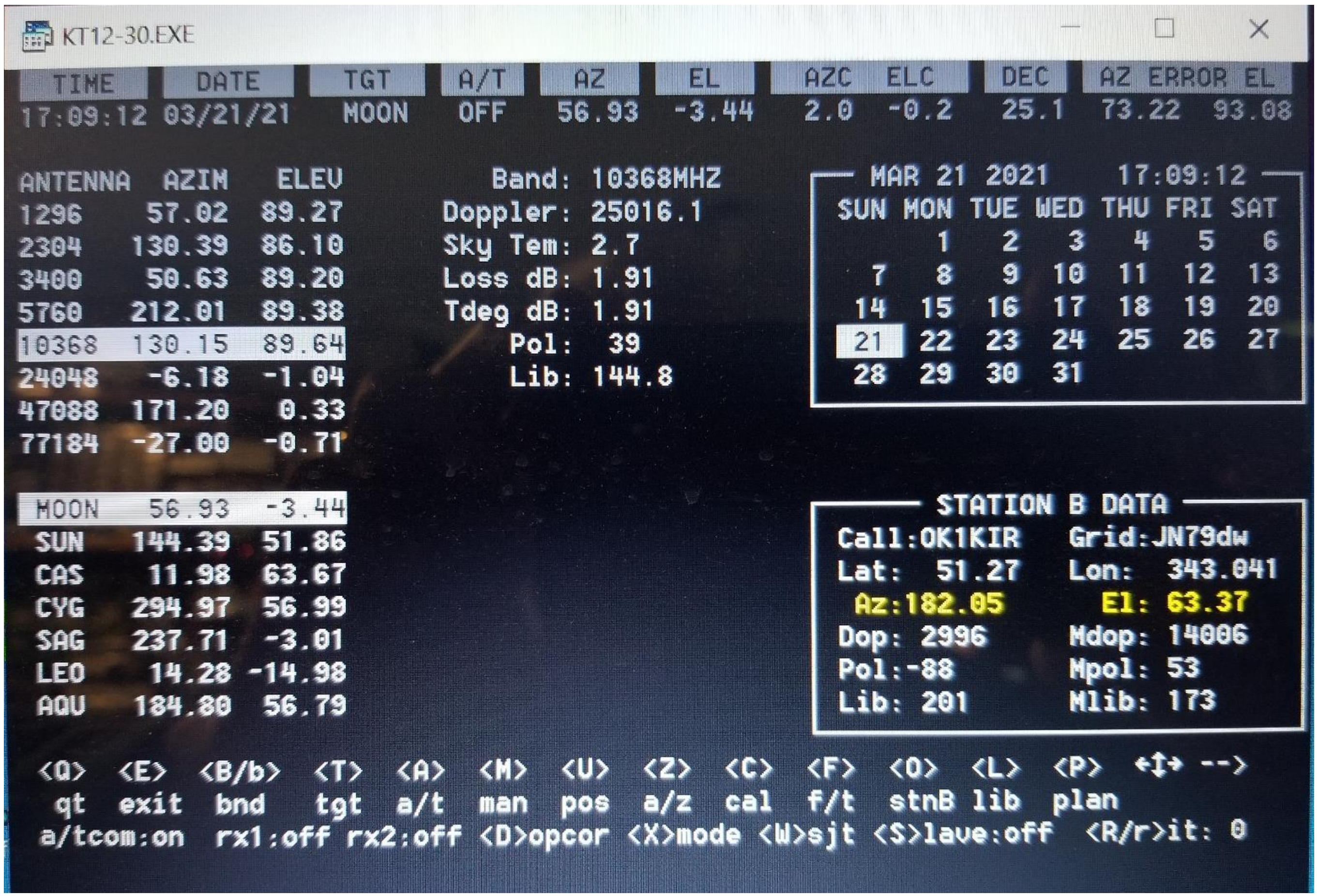

Dos Program run on a 32 bit Win 10 laptop

Besides providing the usual tracking information, the program allows me to input my offsets for my various feeds which are not all at the focal point. No other program allows me to do this.
I would like to convert this to a Windows program.

Thanks Gerald for his fine work on this program

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F1EHN Tracking Software with Doppler Calculation & RX Tuning

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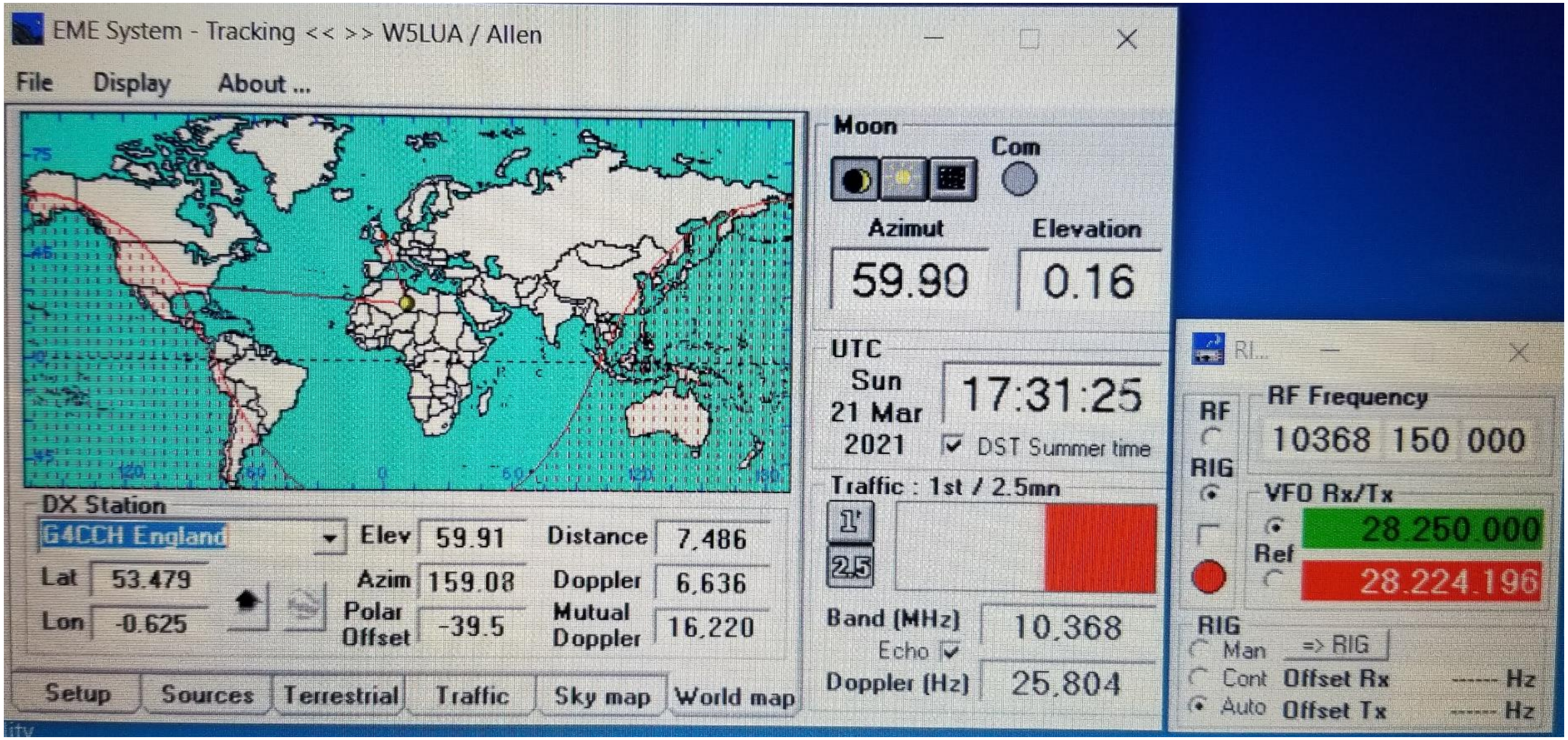

http://www.f1ehn.org/

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6m (50 – 54 MHz)

- 6m is probably the most difficult band for EME as atmospheric noise is high and antennas are rather large.
- The first 6m EME QSO took place on July 30, 1972 between W5HNK(sk)/W5SXD and K5WVX(K5CM)/W5WAX(K5SW)
- With the recent downturn in solar activity, hams like Lance Collister W7GJ put forth a major effort to further promote EME activity on 6m.
- Early EME operation on 6m was on CW but all recent operations use WSJT JT-65A mode.
- Migration to the new WSJT Q65 modes is possible.
- My first operation on 6m EME utilized a 13 element rope yagi about 80 ft long designed by WD5AGO. Amp was a KW with 3-500Zs. I worked a half dozen guys using JT-65A.
- Coordination of skeds takes place on the ON4KST EME chat page.
- Check out W7GJ's web site for all you need to know about 6m EME - http://www.bigskyspaces.com/

13 Element 80 ft Phillystran Rope Yagi for 6 M @ W5LUA

WD5AGO
Scaled 2 M
Antenna
G = 13.5 dBd
32 degree
3 dB BW
1 Hour Moon
Time
Fixed Az – El
Coax Loss
= 0.6 dB

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Rope Yagi Tensioned with John Deere Tractor

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2m (144 - 148 MHz)

- The first EME contact occurred on April 12, 1964 between W6DNG and OH1NL
- EME activity from 144.1 to 144.150 MHz
- 99% of the activity is using the WSJT JT-65B mode with MAP65 being very popular due to its's broad bandwidth decoding capability
- Some amateurs experimenting with the newer Q65 modes with various tone spacings and transmission lengths.
- You can work 2m EME on the horizon with a single yagi and a couple hundred watts.
- 4 yagis and several hundred watts and az/el will work very well and provide an opportunity to work DXCC.
- Having both H and V polarized antennas will help minimize Faraday fading.
- W5ZN reports a lot of activity and worked 85 stations on 2m EME in the ARRL VHF contest last year!
- Coordination of skeds takes place on the N0UK logger

TNX W5ZN

AA5C 2m EME Array

4 K5GW 10 element antennas each on a 17 ft boom

Spaced 10 ft in both directions

Ham M rotor for AZ

Actuator for EL

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135 cm (222-225 MHz)

- Region 2 allocation only which includes North and South America
- The first 220 MHz EME contact took place on March 15, 1970 between W7CNK and WB6NMT(KG6UH)
- Most activity at the moment is from the US and Canada
- EME activity from 222.070 to 222.085 MHz
- 99% of the activity is using the WSJT JT-65B mode with some migration to the newer Q65 modes.
- It is possible for a 2 yagi station to work a 1 yagi station using Horizon gain.
- A popular antenna is the K1FO 16 el yagi 17ft boom spaced 8 ft and a 500 w SSPA or an 8877.
- Initial WAS's were completed back in 1984.
- Resurgence of interest in the band has prompted about a dozen stations to be actively pursuing WAS
- Coordination of skeds takes place on the HB9Q logger
- 222Activity@groups.io

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W5ZN 144/222 MHz EME Antenna

4 CC 17b2s on 2m
12.5 ft spacing

2 16 ele K1FOs on
222 MHz – 8 ft spacing

AZ Orion 2800
EL Orion MT1000

70 cm (432 MHz)

- The first 432 MHz EME contact took place on May 20, 1964 between KH6UK and W1BU
- EME Activity from 432.0 to 432.150 MHz
- CW activity from 432.0 to 432.050 MHz
- WSJT activity from about 432.050 MHz to 432.150 MHz
- JT65B with a migration to the newer Q65 modes with various tone spacings and transmission lengths
- 4 yagis and several hundred watts will work well.
- With my 5m dish and a KW, I have worked numerous single yagi expeditions.
- Faraday rotation can be a big issue on 432. Having the ability to rotate a linear polarized array or switchable polarity can really help in making contacts
- Coordination of skeds on HB9Q logger

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5m and 2.4m Dishes at W5LUA

Used on 432 MHz through 10 GHz

Used on 24, 47 and 77 GHz

Multi-band Feed System

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WD5AGO Septum Feeds for 2304 and 5760

OK1DFC Septum Feed For 1296

10 GHz Feed in Center

3400 and 432 Feeds slide in to 1296 feed

Main Operating Area

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Flex-6600M for microwave bands

K3 for 160 to 2m and 432 MHz

Flex 6600 shows reception of our 10 GHz beacon located on top of the TWU dorm in Denton – height 180 ft

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Various Amplifiers in the Shack

Trimble GPS

SSPA for 5760 MHz
150 watts output

8877 for 2m
W6PO Design
KW + output

8938 for 432 MHz
K1FO Design
KW + output

TH-327 for 1296 MHz
DL9EBL Design
1500 watts output

500W SSPA
for 902 MHz

902 to 928 MHz

- The first 902 MHz EME contact took place on January 22, 1988 between K5JL and WA5ETV
- Shared by Region 2 only including North and South America
- 17 Stations operational over the years including W, VE, KL6M and PY2BS
- Station Requirements – 3m Dish with dual dipole feed, 150/300/600 watt solid state amplifiers
- Active and past active stations include K5JL, WA5ETV, W5LUA, K2DH, W0RAP,WB0TEM, VE4MA, NU7Z, WA8WZG, AF1T, WA8RJF (K8ZR), WW2R, VE6TA, K2UYH, N8DJB, KL6M, PY2BS and K5DOG
- Interference from ISM and part 15 devices is a real problem on this band
- Linear polarity feed, either switchable or rotatable feed
- HB9Q logger used for sked coordination.

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1240 to 1300 MHz

- World-wide allocation
- The first EME contact took place on July 21, 1960 between W1BU and W6HB
- Primary operation between 1296.0 and 1296.150 MHz
- CW and SSB between 1296.0 and 1296.050 MHz
- WSJT JT-65C from 1296.050 to 1296.150 MHz
- 450 + stations operational over the years
- Minimum Station Requirements – 3m Dish with VE4MA or Septum type feed and 150 watts from 2C39s or GS15b or SSPAs
- Best to use circular polarity with a dish – receive LHCP and transmit RHCP
- Big stations run 7 or 8 meter dishes and kw plus from TH-327/347 or YL-1050, W6PQL SSPAs are very popular
- This is an excellent random CW band with a lot of digital operation as well – A good band to start on.
- EME Beacon – ON0EME beacon in JO21jg when the moon is up at least 10 degrees elevation in JO21jg- http://users.skynet.be/on0eme/ON0EME/Welcome.html
- HB9Q logger used for sked coordination.

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1296 Echoes at W5LUA

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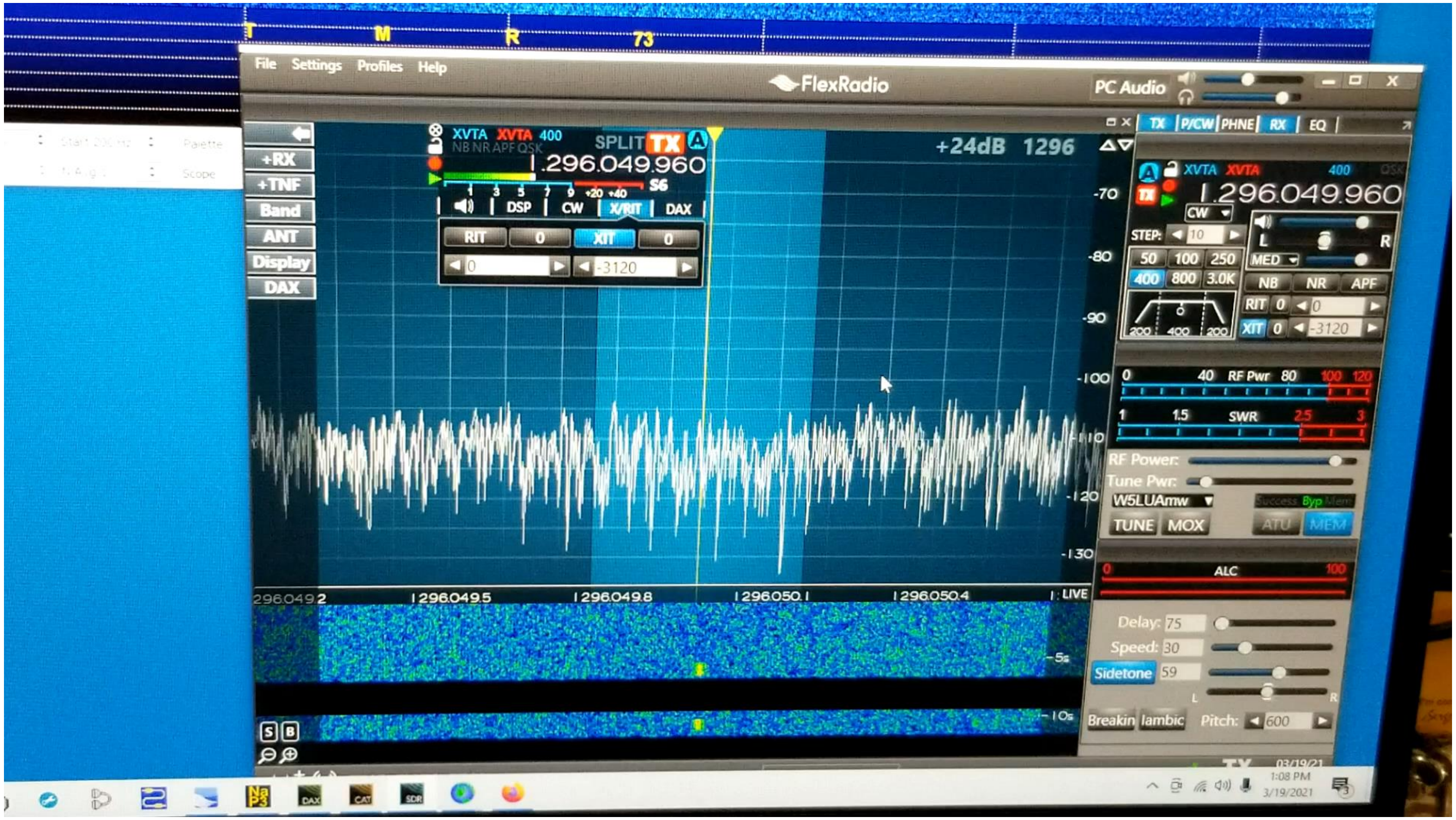

Moon at Apogee
5m dish
Kw+ output in shack

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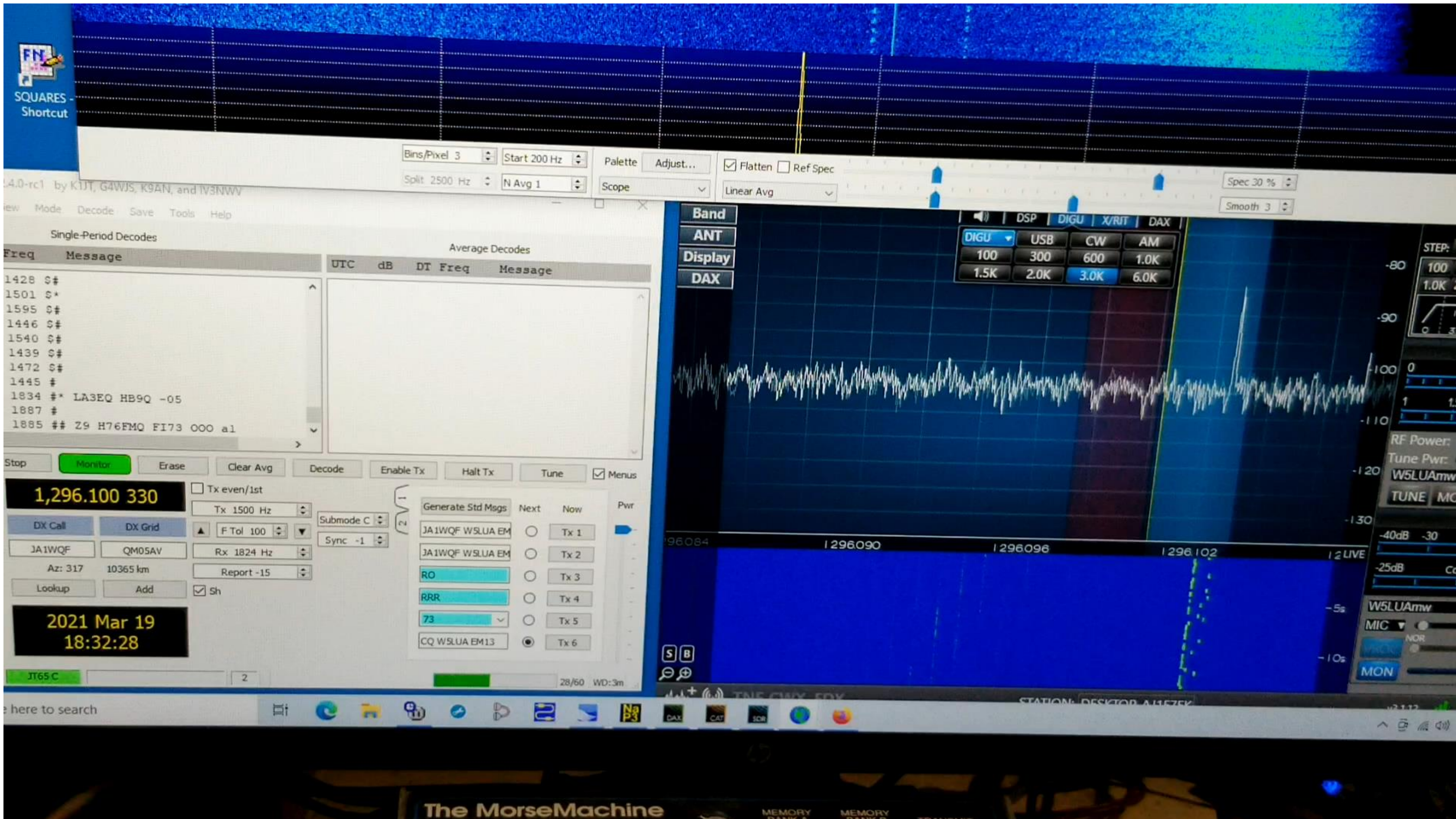
HB9Q JT-65C 10m Dish

Moon at apogee



2300 - 2310 and 2390 - 2450 MHz

- The first EME contact took place on October 19, 1970 between W4HHK and W3GKP
- Most EME operation between 2304.0 and 2304.150 MHz
- Some of Europe including the UK can only operate at 2320 MHz - no allocation at 2304 MHz - cross band between 2304 and 2320 MHz. We lost 2310 to 2390 because of services like Sirius/XM
- Japanese operate at 2400 MHz - no allocation at 2304 MHz – cross band between 2304 and 2400 MHz or simplex 2400 MHz
- Crossband operation requires extra receive converters
- Over 150 stations operational over the years
- Station Requirements – 3m Dish, 100 watts
- Tubes, TWT, Klystron, or SSPAs
- Circular Polarity – same convention as 1296
- Coordinate activities on HB9Q logger

VA-802B Klystron for 2304 MHz

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Runs about 400 watts output

Capable of a KW output

Originally used by W4HHK for the first 2304 MHz EME contact in 1970.

Still running fine in 2021!

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3300 to 3500 MHz

- The first 3456 MHz EME contact took place on April 7 1987 between KD5RO and W7CNK
- The 9 cm allocation is not a worldwide allocation yet all continents are represented. EME operation migrated from 3456 to 3400 MHz
- Approximately 100 stations have been active over the years.
- The US will cease operation above 3450 MHz some time in 2022 due to 5G expansion
- We have long been operating EME at 3400 MHz as a good number of countries have an allocation here. An exception are the VKs who have 3398 to 3400 MHz.
- Station Requirements – 3m Dish, 50 watts, Circular Polarity is used with same convention as 1296 and 2304 MHz.
- Coordinate activities on HB9Q logger

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5650 to 5925 MHz

- The first EME contact on 5760 MHz took place on April 24, 1987 between WA5TNY and W7CNK
- The 6 cm band is an international allocation with all continents represented.
- Over 100 stations have been operational over the years.
- Most operation between 5760.050 and 5760.150 MHz
- WIFI interference can be very bad at times making the band a real challenge.
- Station Requirements – 3m Dish, 25 watts, Circular Polarity is used with same convention as 1296 and 2304 MHz.
- Coordination is on HB9Q logger

10000 to 10500 MHz

- The first 10368 MHz EME contact took place on August 27, 1988 between WA5VJB and WA7CJO (W7CJO)
- The 3 cm band is also an international allocation with all continents represented
- Most operation between 10368.050 and 10368.150 MHz
- JAs operational on 10450 MHz - another cross-band challenge –
- More than 150 stations operational over the years
- W.A.C has been achieved by many stations
- Minimum station requirements – .8m or 1m dish with 50 watts. Of course, more is always better!
- Coordinate activities on HB9Q logger

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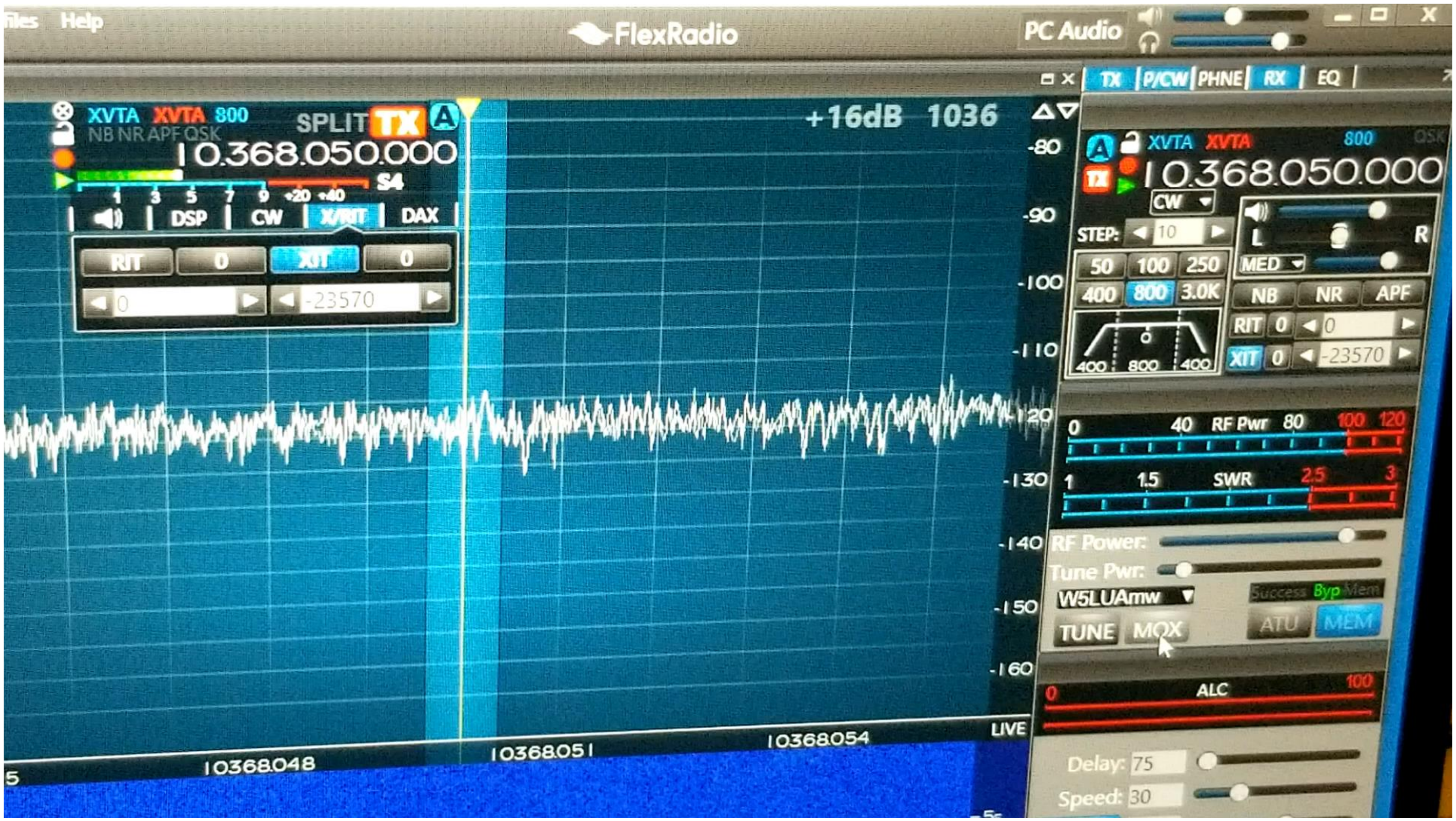
10 GHz Echos at W5LUA

5m Dish 250 w TWT in shack, 120 watts at feed – moon at apogee



W5LUA Portable EME Set-Up

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Heavy duty manual AZ-EL mount built by TerraCom that was originally used for portable point to point microwave link with a 4 ft fiberglass dish

Mounted a 1 m Winegard off set fed dish to mount
Gain ~ 37 to 38 dBi
3dB BW ~ 2.2 deg
First null at 2.8 deg

Extended and raised feed support arms to handle weight of new feed/wg relay/LNA/SSPS

NF .7 dB from DB6NT LNA, Power out is 30 watts from a GaAn device

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Behind the dish

GR1216 for measuring sun and moon noise

DEMI 10GHz XVTR

W1GHZ 2/10m XVTR

Power Meter

Sequencer

ISOTEMP 10 MHz TCXO

KX3/PX3 for IF

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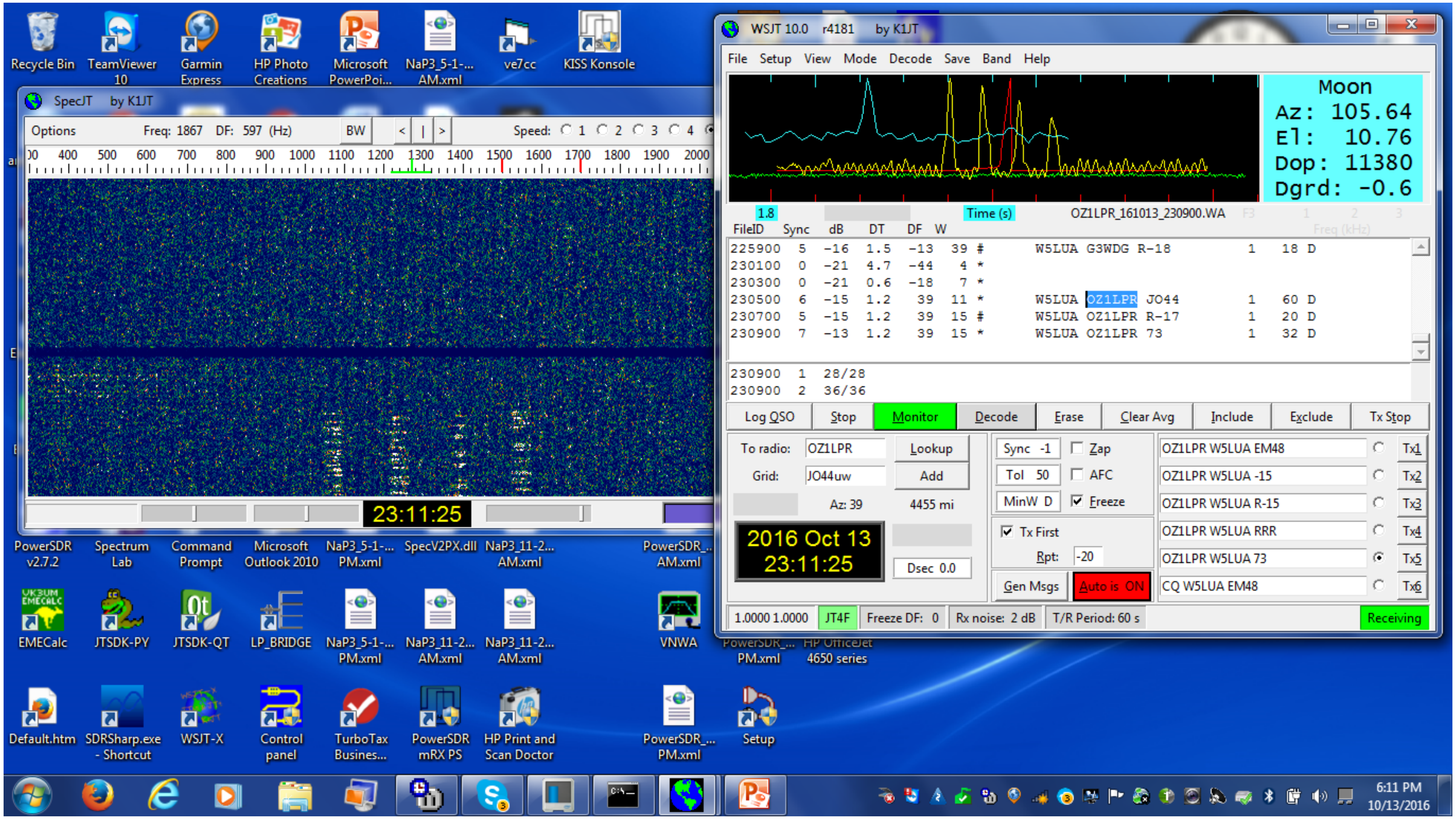
W5LUA/0 QSO with OZ1LPR



QSO took place in St. Louis, MO at Microwave Update Conference in Oct 2016

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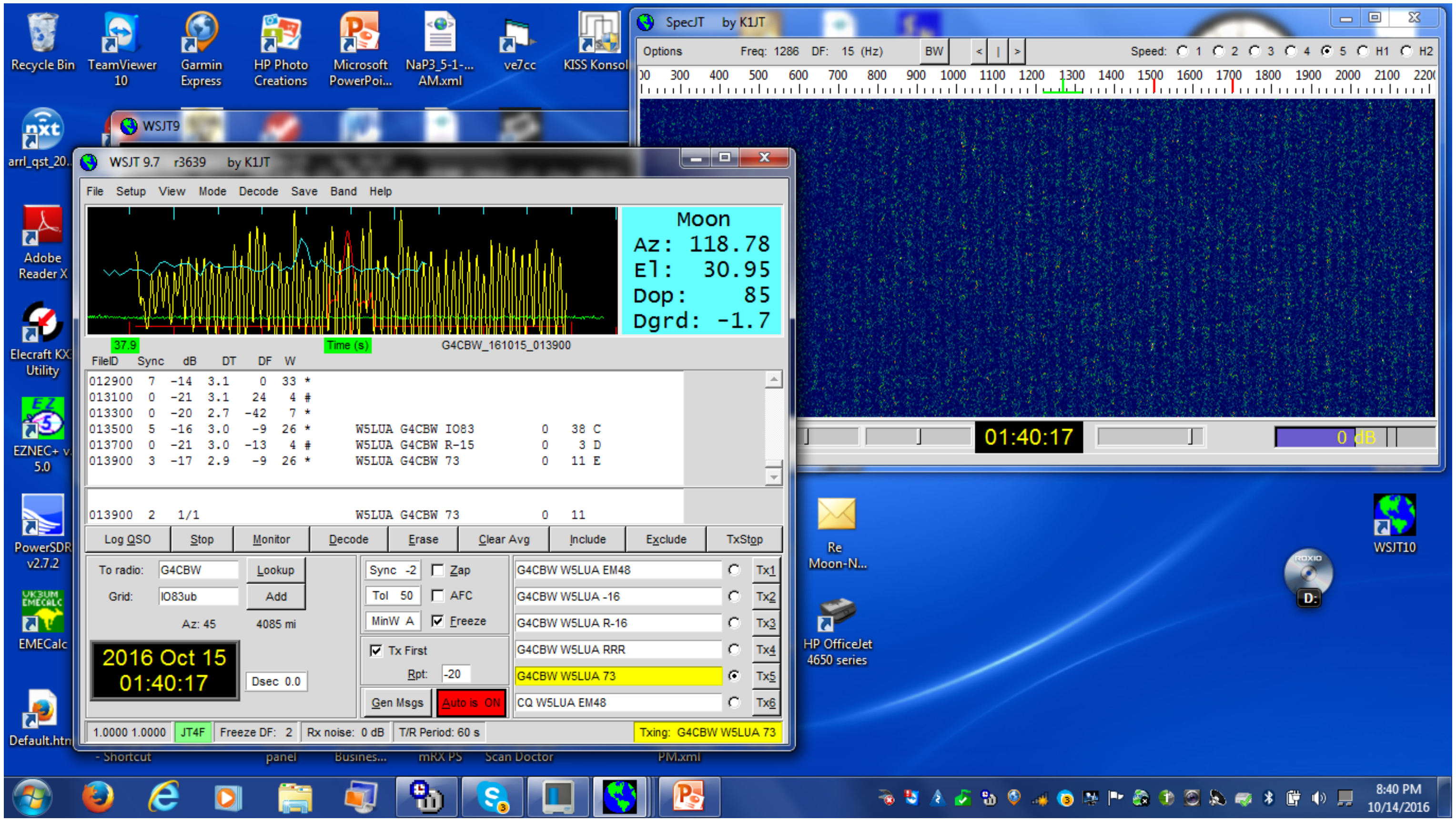
Big surprise – G4CBW called us!



I was having some difficulties with some low frequency spurs getting into my sound card

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Screen at G4CBW – 1.5m dish/75W

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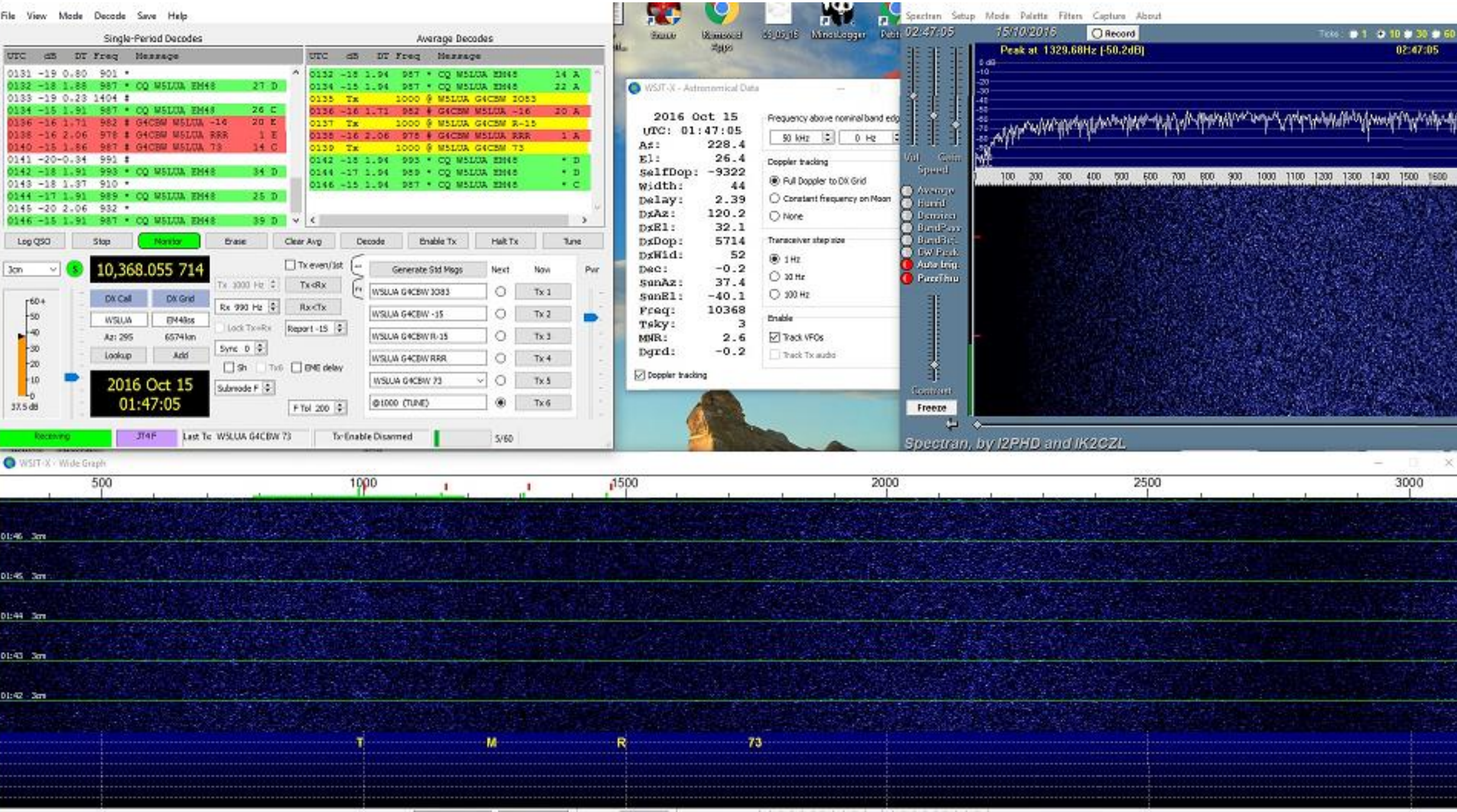

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24000 to 24250 MHz

- Operation originally occurred at 24192.100 MHz – migrated to 24048.1 MHz which is an international allocation.
- VE4MA & W5LUA made the first 24 GHz EME QSO on Aug 18, 2001 with RW3BP, AA6IW, and VE7CLD becoming operational later in 2001 and 2002
- Presently there are more than several dozen stations active or have been active
- Minimum station Requirements – 3m prime focus or 1.8m 2.4m offset fed dish and 20 watts

47000 to 47200 MHz

- The first 47 GHz EME QSO was made in January 2005 with AD6FP(K6MG) working RW3BP. This contact was followed up by RW3BP working W5LUA and VE4MA
- Operation at 47088.100 MHz
- Station Requirements – 1.8 or 2.4 M offset fed dish and W2IMU type feed and 30 watts minimum
- The first QSOs were made on CW using a program written by RW3BP that utilized 10 minute transmissions to take advantage of longer integration times.
- More recent tests utilizing WSJT modes like JT4F and QRA-64D have resulted in DL7YC and JA1WQF decoding W5LUA.

W5LUA received at JA1WQF 47088.1 MHz Feb 10, 2020

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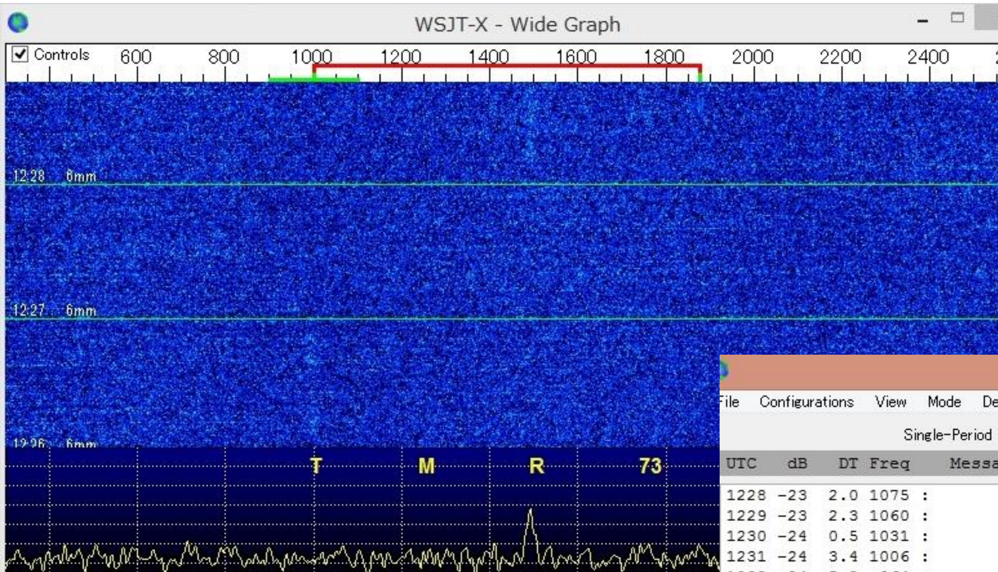
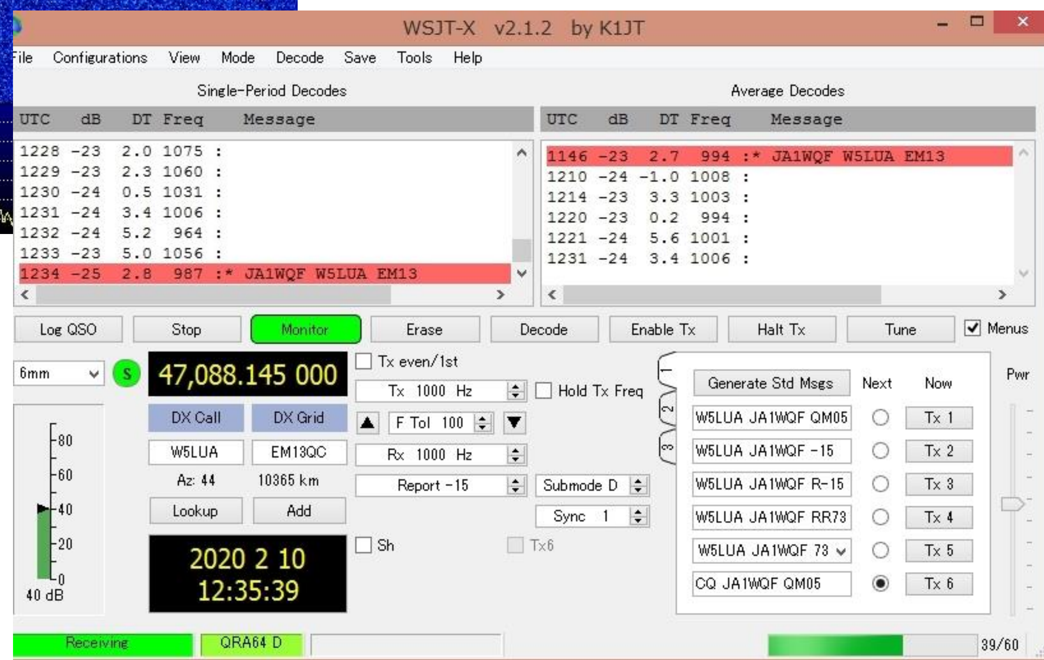


2.4m offset fed dishes at both stations

W5LUA runs a 30 watt TWT



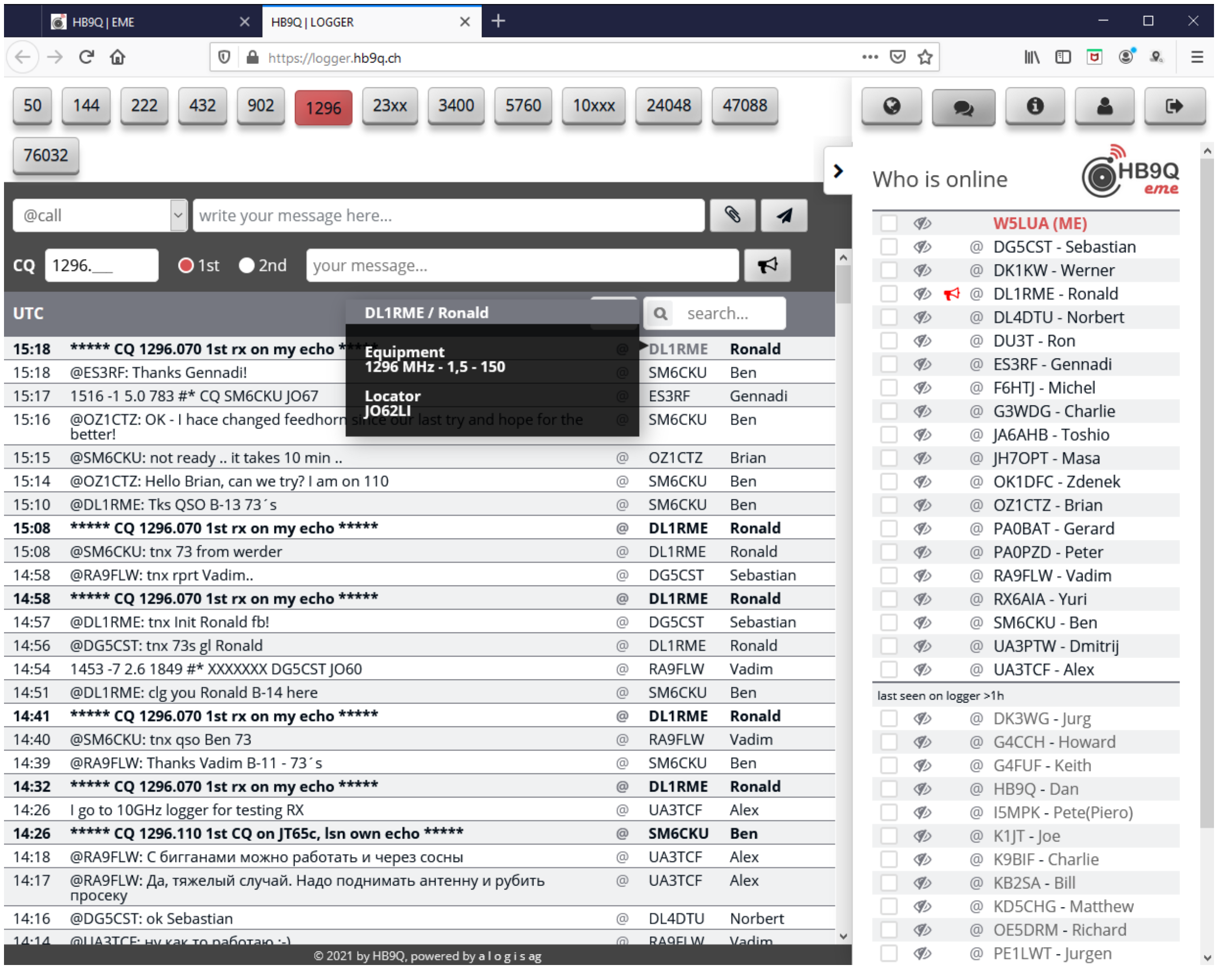
76000 to 81000 MHz

- Initial EME tests were run at 77184.1 MHz.
- RW3BP copied his echoes. Sergei was running a 100 watt pulse rated tube and a 2.4 m offset fed dish.
- W5LUA and VE4MA copied his weak signal via the moon.
- We did not and still do not have the power necessary to complete the contact.
- Even if we did, thanks to collision avoidance restrictions, we are limited to +55 dBmi or 316 mW EIRP.
- When we come up with enough power, we will have to ask the FCC for a waiver or special license.

Coordination

- N0UK Logger for 6m and 2m https://www.chris.org/cgi-bin/jt65emeA
- HB9Q Logger for schedule coordination and chat on 222 MHz and higher https://logger.hb9q.ch/
- 432 MHz and Above newsletter published every month for nearly 50 years by K2UYH http://www.nitehawk.com/rasmit/em70cm.html
- 2m EME Newsletter http://www.df2zc.de/newsletter/
- Moon-Net Reflector http://mailman.pe1itr.com/mailman/listinfo/moon-net
- Moon Reflector http://moonbounce.info/mailman/listinfo/moon
- Microwave Reflector http://www.wa1mba.org/reflect.htm

HB9Q Logger



www.hb9q.ch

You must log in with a password

Very cordial group

Always interested in helping people out

Don't hesitate to ask a question

Left click on a call sign to see what the other station is running

A few web sites to check out

- Down East Microwave, https://www.downeastmicrowave.com/
- Q5 Signal, http://www.q5signal.com/
- Kuhne Electronic, https://shop.kuhne-electronic.com/kuhne/en/
- Directive Systems, https://directivesystems.com/
- W6PQL, https://www.w6pql.com/
- KA1GT, http://bobatkins.com/radio/
- W1GHZ, http://www.w1ghz.org/
- OK1DFC, https://www.ok1dfc.com/

- The presentation will be available shortly at www.ntms.org
- Questions?
- Thanks for having me at your meeting
- See you off the moon de W5LUA