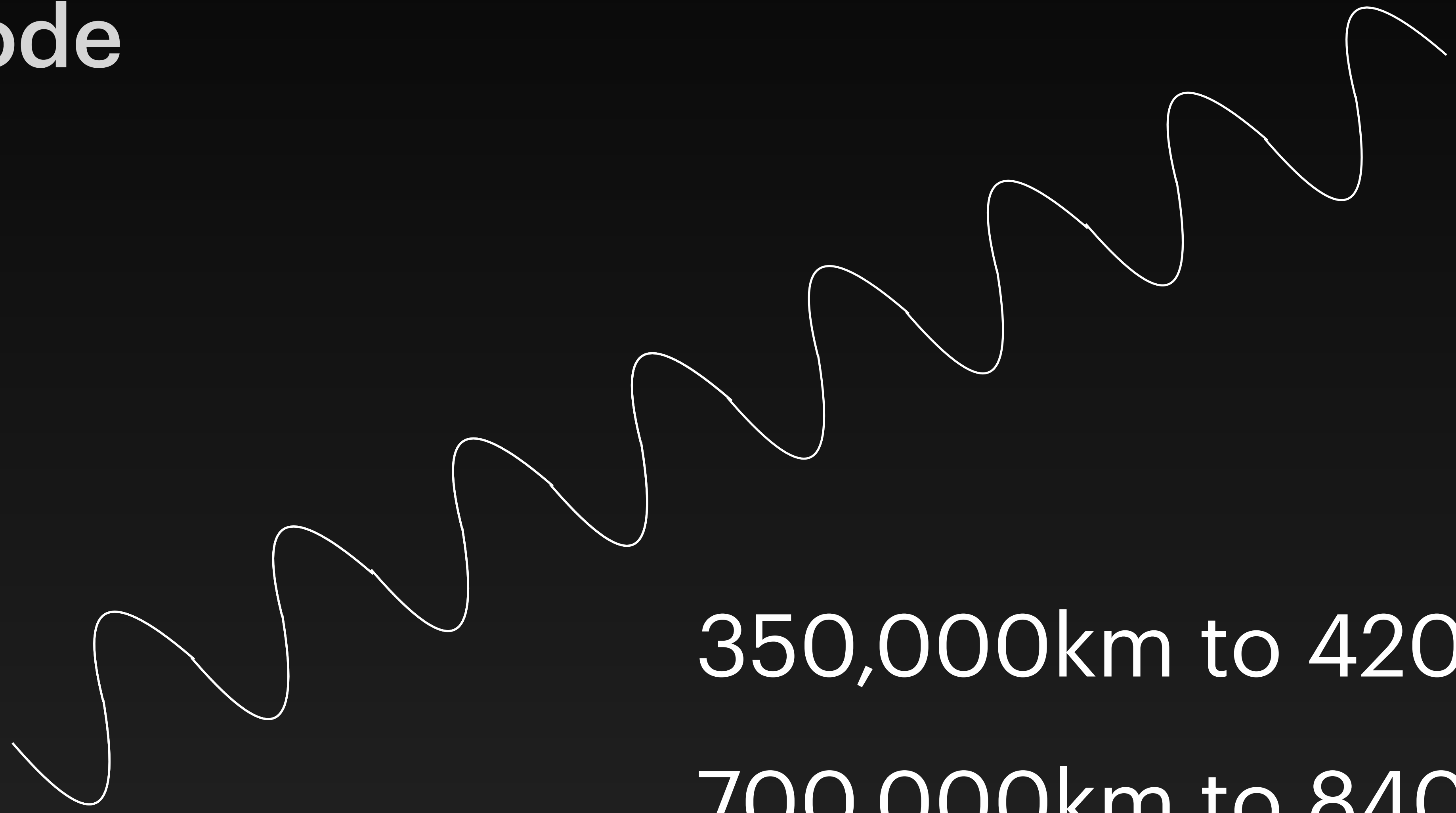
Moonbounce

Using the moon as a reflector

Mick Price - HADARC April 2021

Some background

The ultimate DX mode



350,000km to 420,000km to the moon

700,000km to 840,000km there and back!

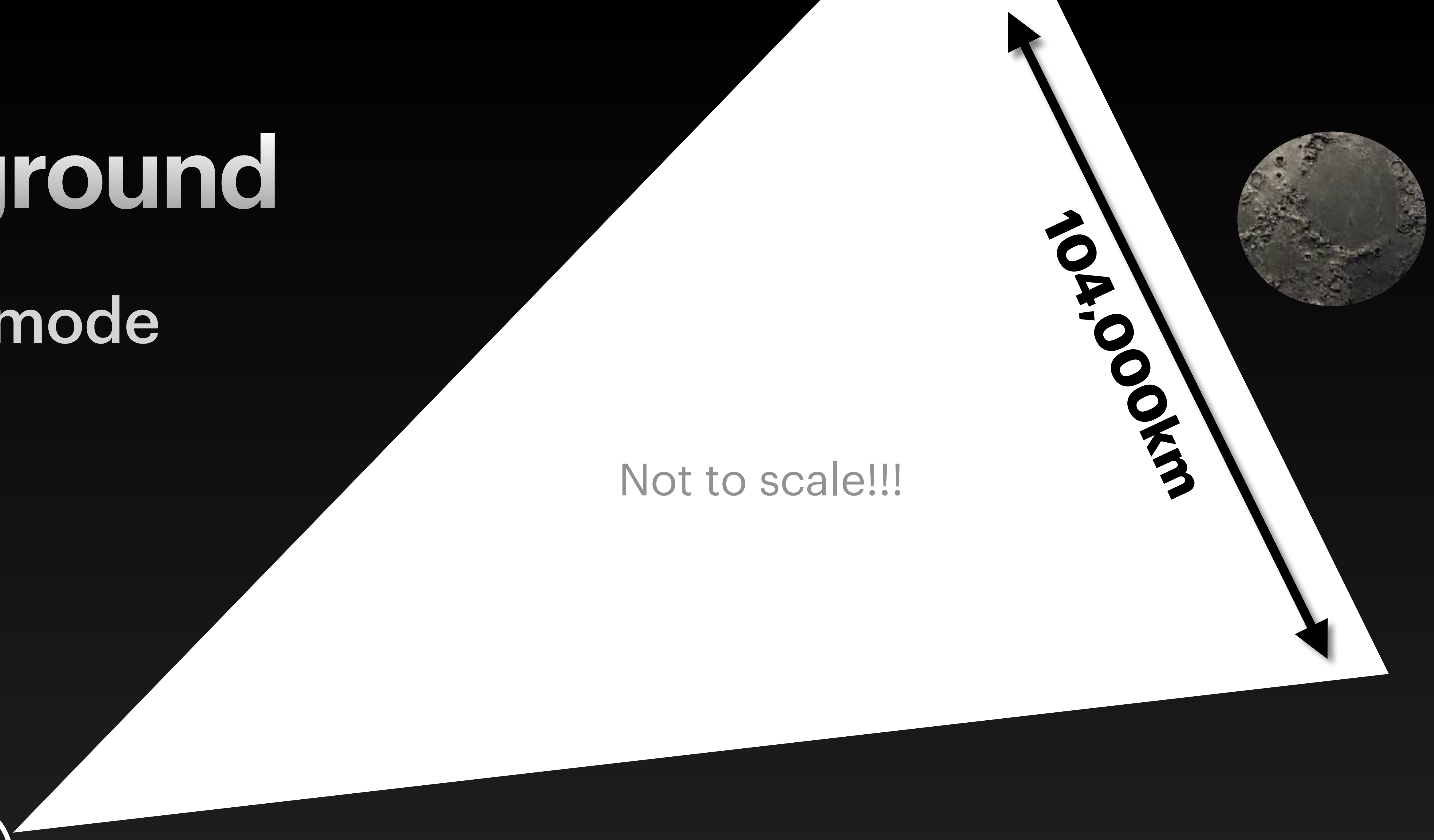
That's 2.5 seconds at the speed of light one way propagation time.

Geostationary satellite (37,000km) one way propagation delay ~ 0.25 second

Sydney to Melbourne Datalink propagation delay on fibre network ~ 10mS !!!

Some background

The ultimate DX mode



Beamwidth of typical 4 yagi station is ~15 degrees

Thats a 104,000km wide beam width at the moon

Moon diameter is only 3,472 km

Moon is a passive reflector made of dirt!

About ~ 2 - 3% of TX signal is reflected back to earth

Some background

Doppler

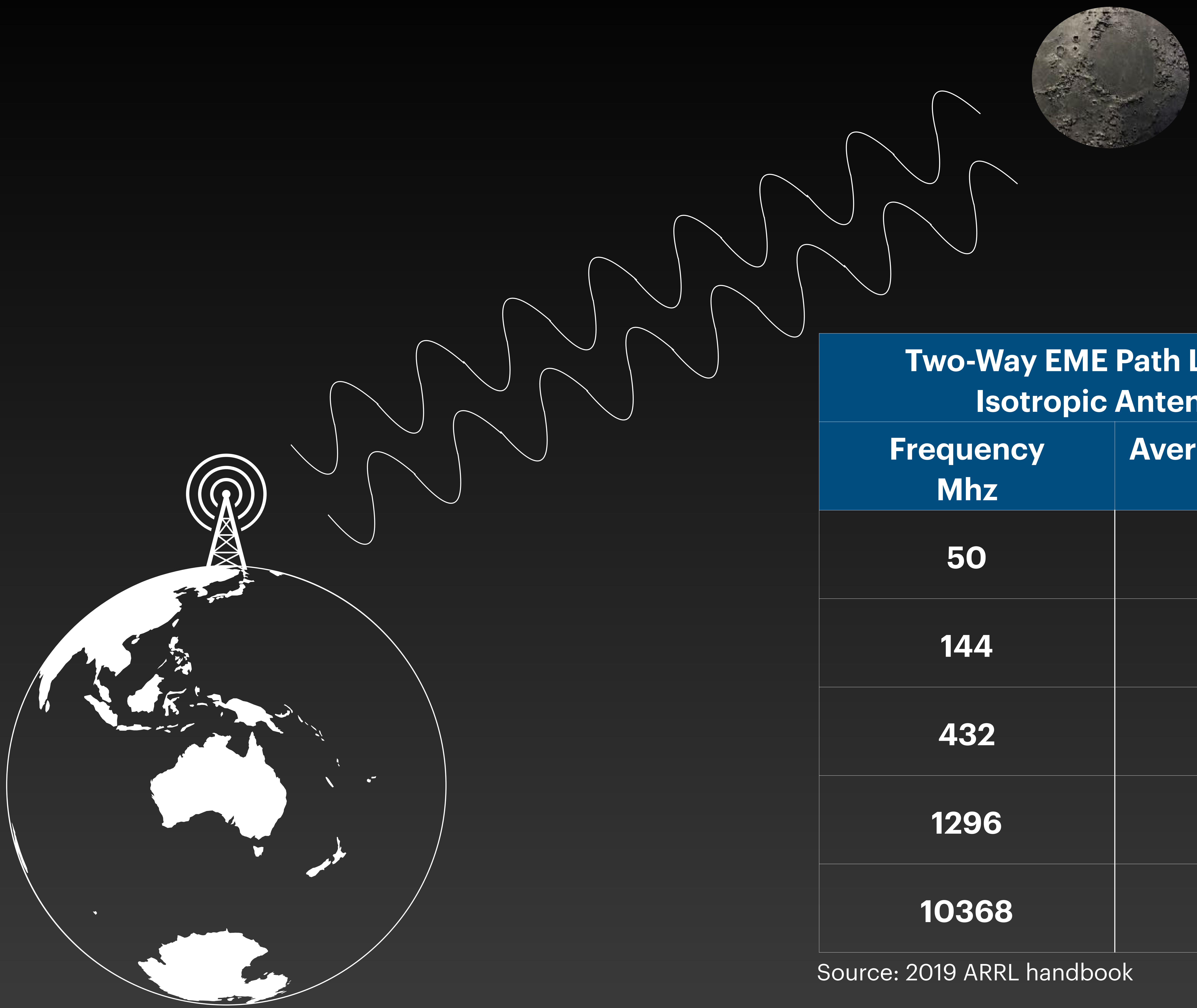
Revolution around earth 27.3 days.

Mean orbital velocity 1.022 km/s.

Doppler is positive at moonrise and negative at moon set.

About +/- 1Khz at 432Mhz

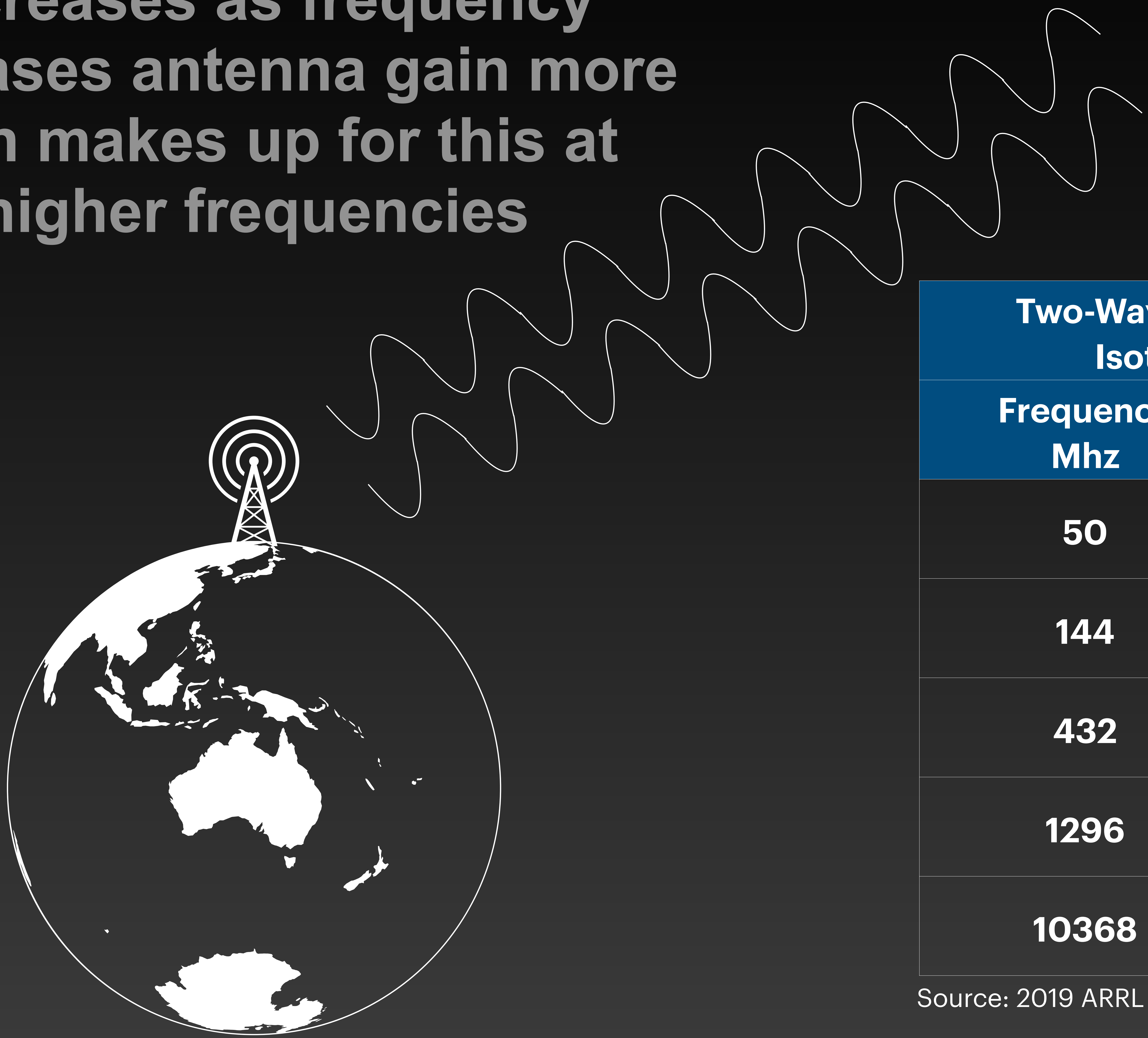
About +/- 3Khz at 1296 Mhz



Two-Way EME Path Loss with Isotropic Antennas	
Frequency Mhz	**Average Path Loss dB**
50	-242.9
144	-252.1
432	-261.6
1296	-271.2
10368	-289.2

Source: 2019 ARRL handbook

Although the path loss increases as frequency increases antenna gain more than makes up for this at higher frequencies



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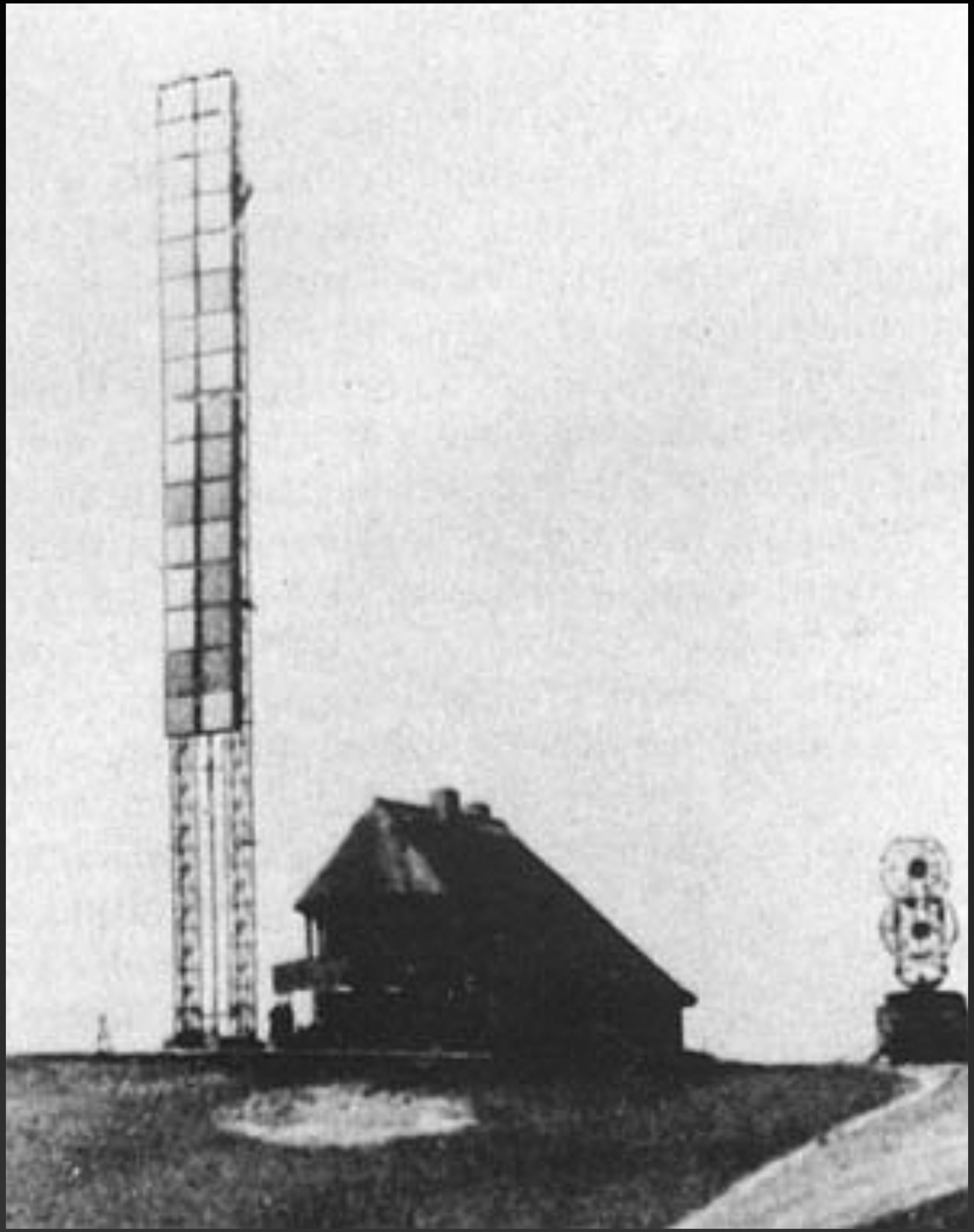
Source: 2019 ARRL handbook

First reception of lunar (EME) echo in 1944

- 564 Mhz German radar inadvertently beamed towards moon at moonrise
- Collinear horizontally polarised array at 36m height
- TX 120kW peak and 1.5us pulse
- Noticed a 2.5 second echo
- Tested again the next day at moonrise
- Check out ok2kkw.com EME pages for some great reading

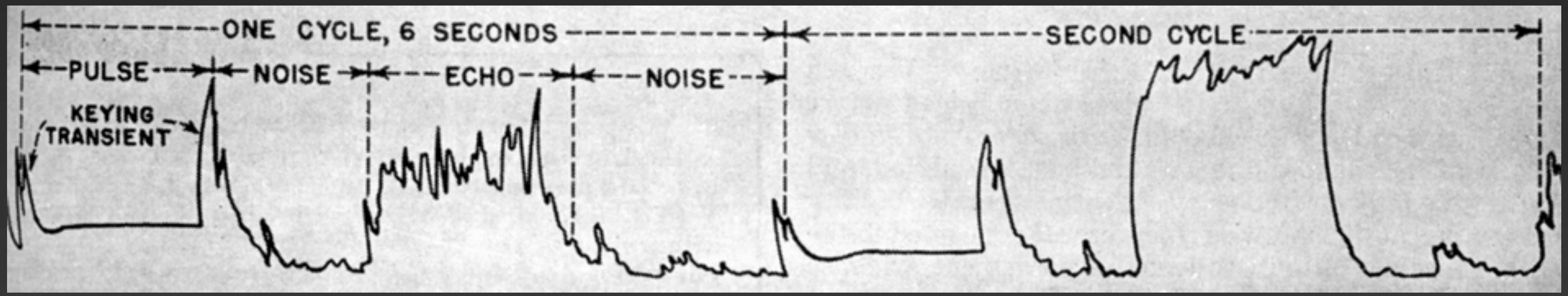


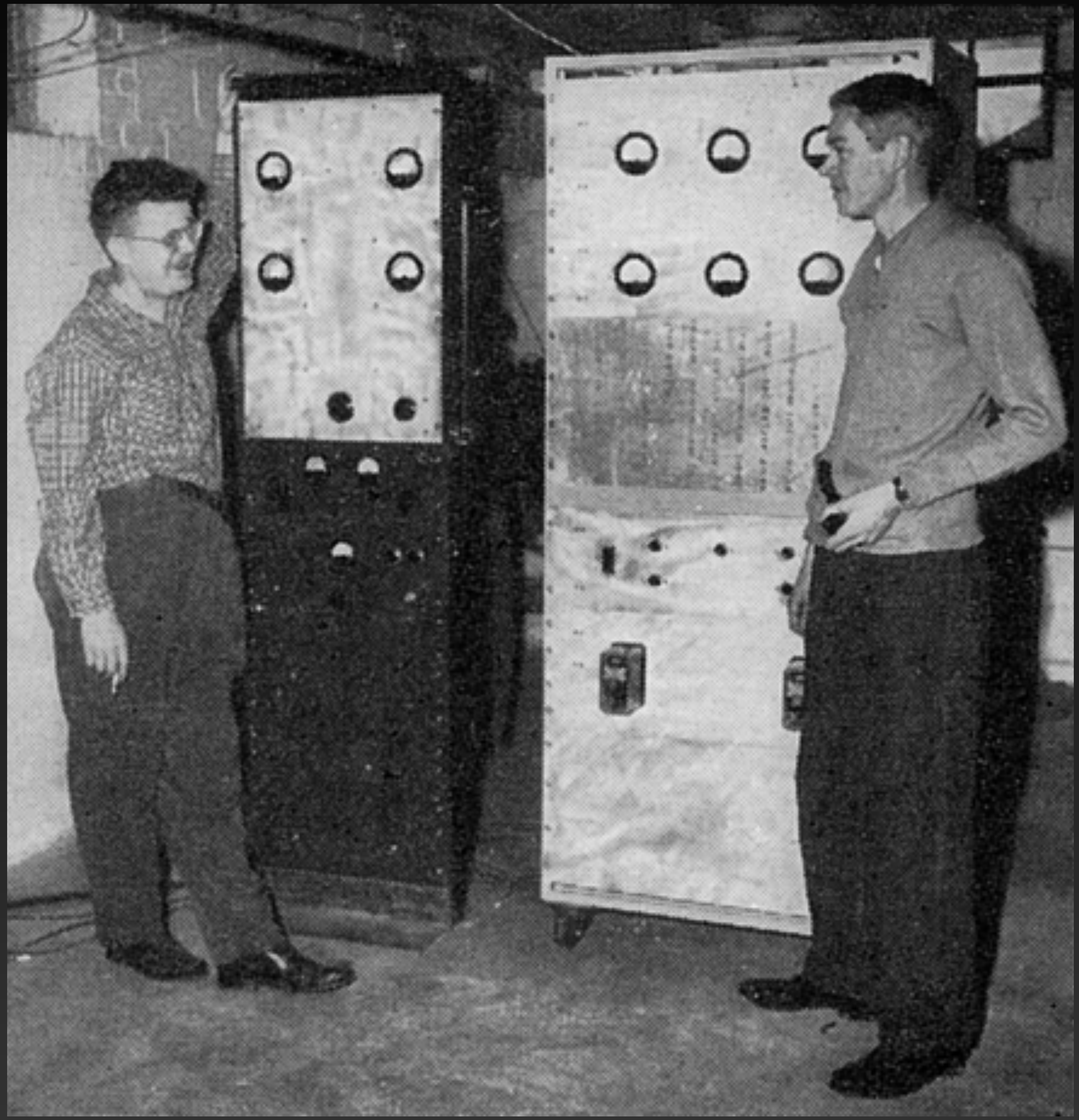
Wurzmann radar in Gohren on Rugenn island

http://www.ok2kkw.com/eme1960/eme1960eng.htm

First amateur detection of lunar echos in 1953 by Project Moonbeam

- 5.03AM on July 15, 1953 detect echos
- Fixed antenna - stacked rhombic
- Keep working on receiver and antenna improvements for the next few years
- First demonstration of the patience required to participate in EME!



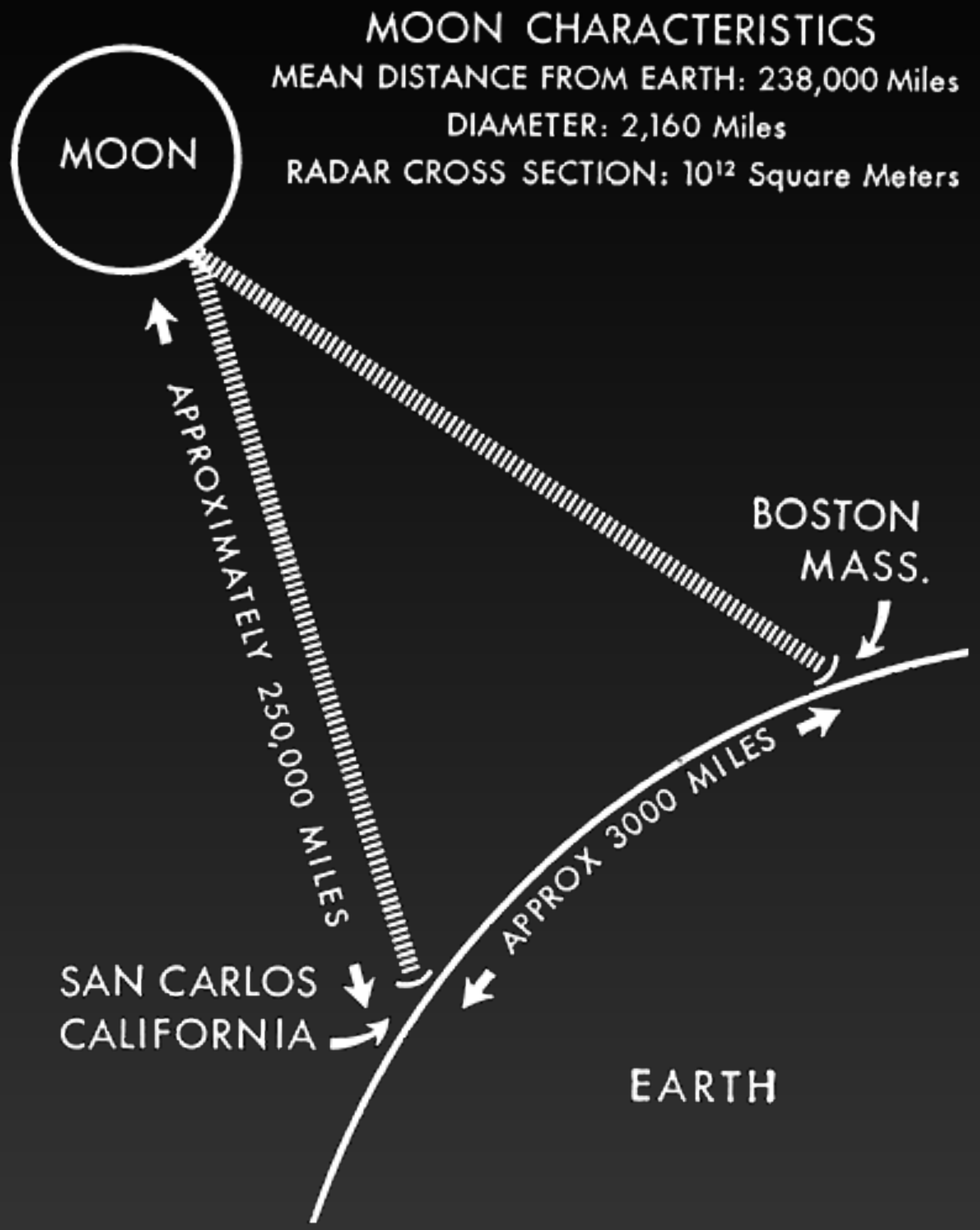


W4AO and W3GKP and their 1KW 2 meter "rig"

http://www.ok2kkw.com/eme1960/eme1960eng.htm

First amateur two way EME QSO in 1960

- Project Moonbouce
- Two radio clubs Eimac radio club and Rhododendron Swamp VHF society
- Huge effort with lots of smart hams involved at both ends
- July 17, 1960 on 1296Mhz
- 18 ft Kennedy dish and 1KW (input) Eimac KPA



Path of 1296 Mhz signal of W1BU/ W1FZL - W6HB

http://www.ok2kkw.com/eme1960/eme1960eng.htm

Earth Moon Earth amateur moonbounce milestones

Amateur EME Milestones

1953	W3GKP and W4AO detect lunar echoes on 144 MHz
1960	First amateur 2-way EME contact: W6HB works W1FZJ, 1296 MHz
1964	W6DNG works OH1NL, 144 MHz
1964	KH6UK works W1BU, 432 MHz
1970	WB6NMT works W7CNK, 222 MHz
1970	W4HHK works W3GKP, 2.3GHz
1972	W5WAX and K5WVX work WA5HNK and W5SXD, 50 MHz
1987	W7CNK and KA5JPD work WA5TNY and KD5RO, 3.4 GHz
1987	W7CNK and KA5JPD work WA5TNY and KD5RO, 5.7 GHz
1988	K5JL works WA5ETV, 902 MHz
1988	WA5VJB and KF5N work WA7CJO and KY7B, 10 GHz
2001	W5LUA works VE4MA, 24 GHz
2005	AD6FP, W5LUA and VE4MA work RW3BP, 47 GHz
2005	RU1AA works SM2CEW, 28 MHz
2009	GDØTEP works ZS6WAB, 70 MHz
2018	VK2CMP works HB9Q for his first EME QSO on 432Mhz

Source: 2019 ARRL handbook & VK2CMP logbook

When is H pol really V pol?

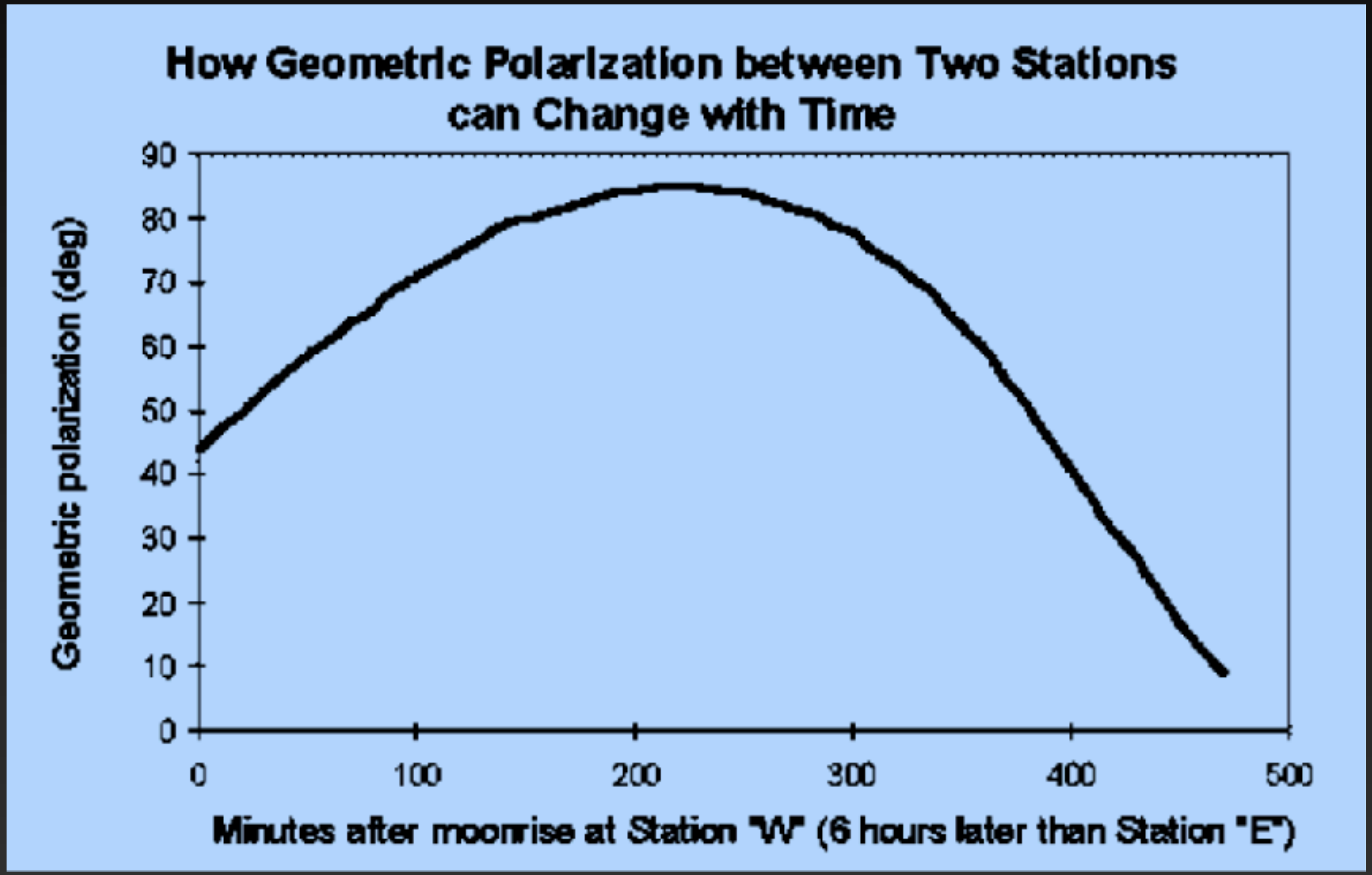
Its a matter of perspective!

Photos from nasa.gov

Geometric rotation

or Spatial Polarisation

- On 432Mhz linear polarisation is used
- 27 degrees polarisation error = 1dB loss
- Geometric Rotation = station position + moon position
- Changes during the moon pass
- TX H-pol can arrive back as V-pol
- Can be predicted with programs such as MoonSked



Source: Polarisation and One Way EME propagation, Paris 432Mhz and Above EME Conference, 1998

Faraday Rotation

the ionosphere's impact on VHF/ UHF EME signals

- Occurs when linear polarised signals passes thru the ionosphere
- Cumulative happens twice for EME signals - up & back
- Rotates signal in the same direction
- Greatest during daytime, for stations well away from equator, and at low frequencies
- Changes with ionisation levels i.e. sunrise/set
- Issue for 432Mhz and below

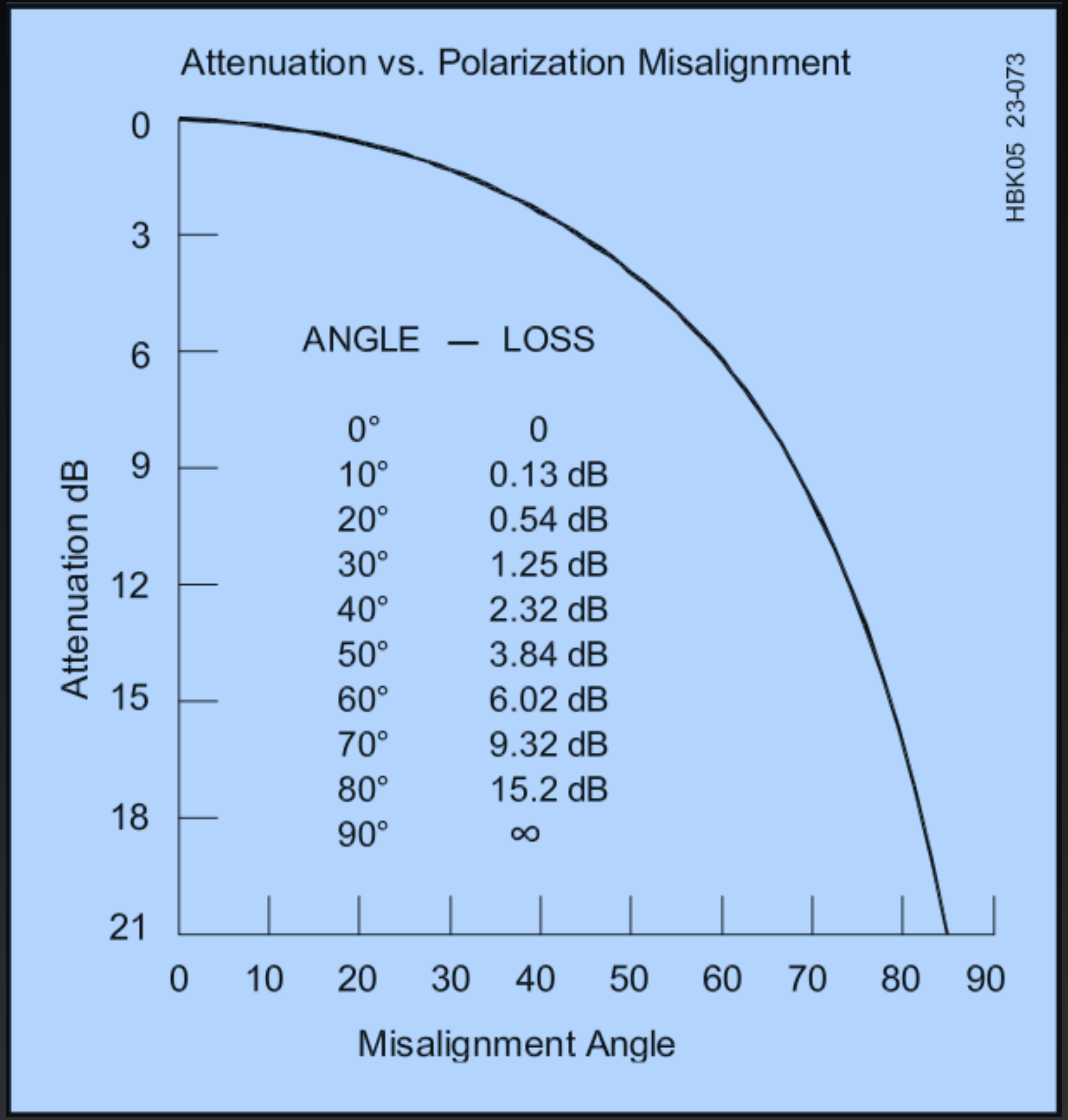
Michael Faraday and John Frederic Daniell

www.britannica.com/biography/Michael-Faraday/Theory-of-electrochemistry

Faraday Rotation

the ionosphere's impact on VHF/ UHF EME signals

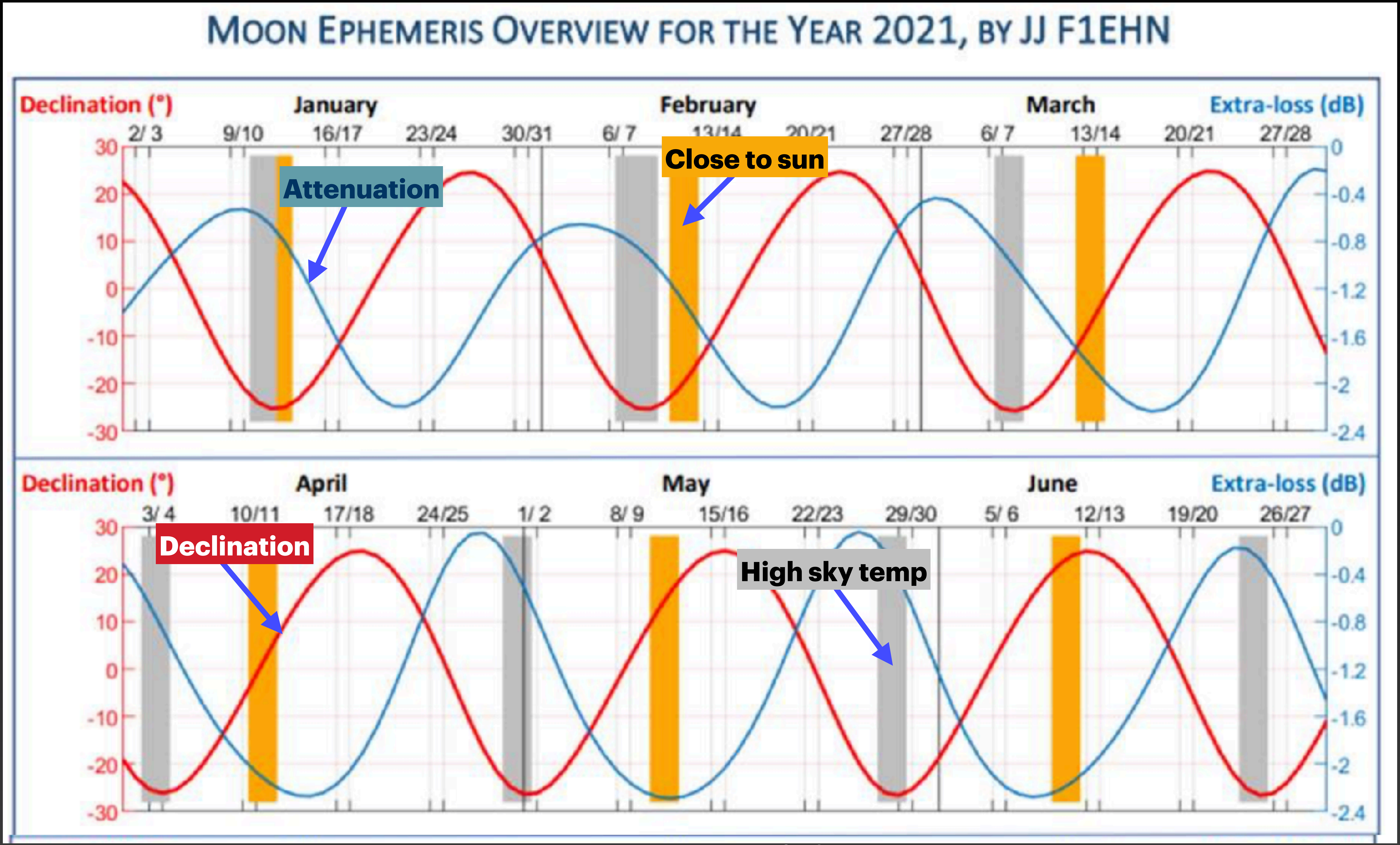
- Unpredictable
- Changes with time
- Combined with geometric rotation can cause one-way propagation
- Some stations rotate array to overcome
- Can be countered with adaptive polarisation systems



Attenuation caused by misalignment if linearly polarised signal

ARRL handbook: Space communications fig. 62

The sun, sky noise and the distance to the moon

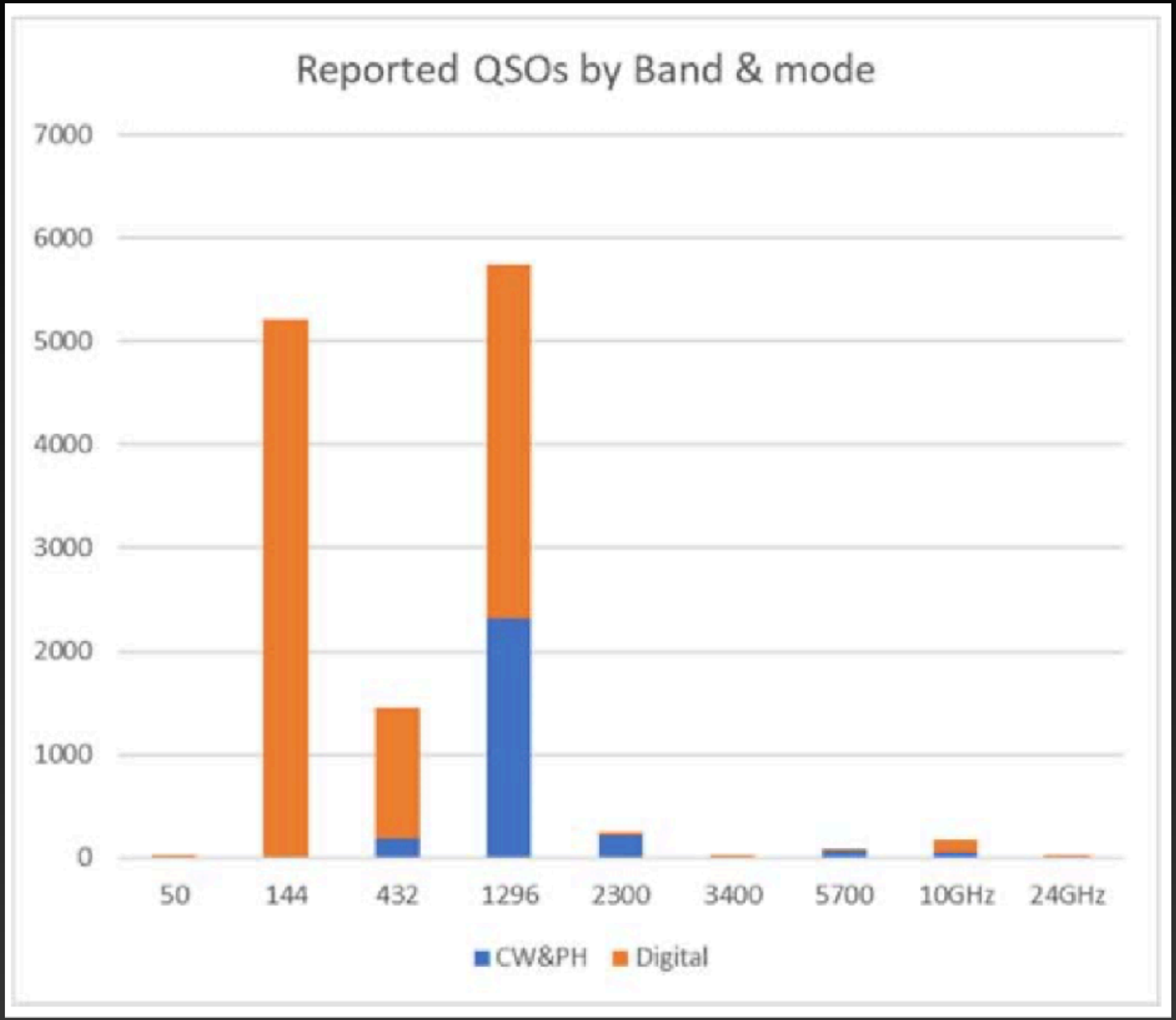


Source: F1EHN www.f1ehn.org

Activity on the moon

ARRL contest activity

- ARRL 2020 results
- First time 1296Mhz had most activity
- Traditionally 144Mhz has most activity



Source: 2020 ARRL EME Contest Full results - Version 1.1

All modes
All bands

- 6m as you would expect has its own following
- Microwave activity increasing

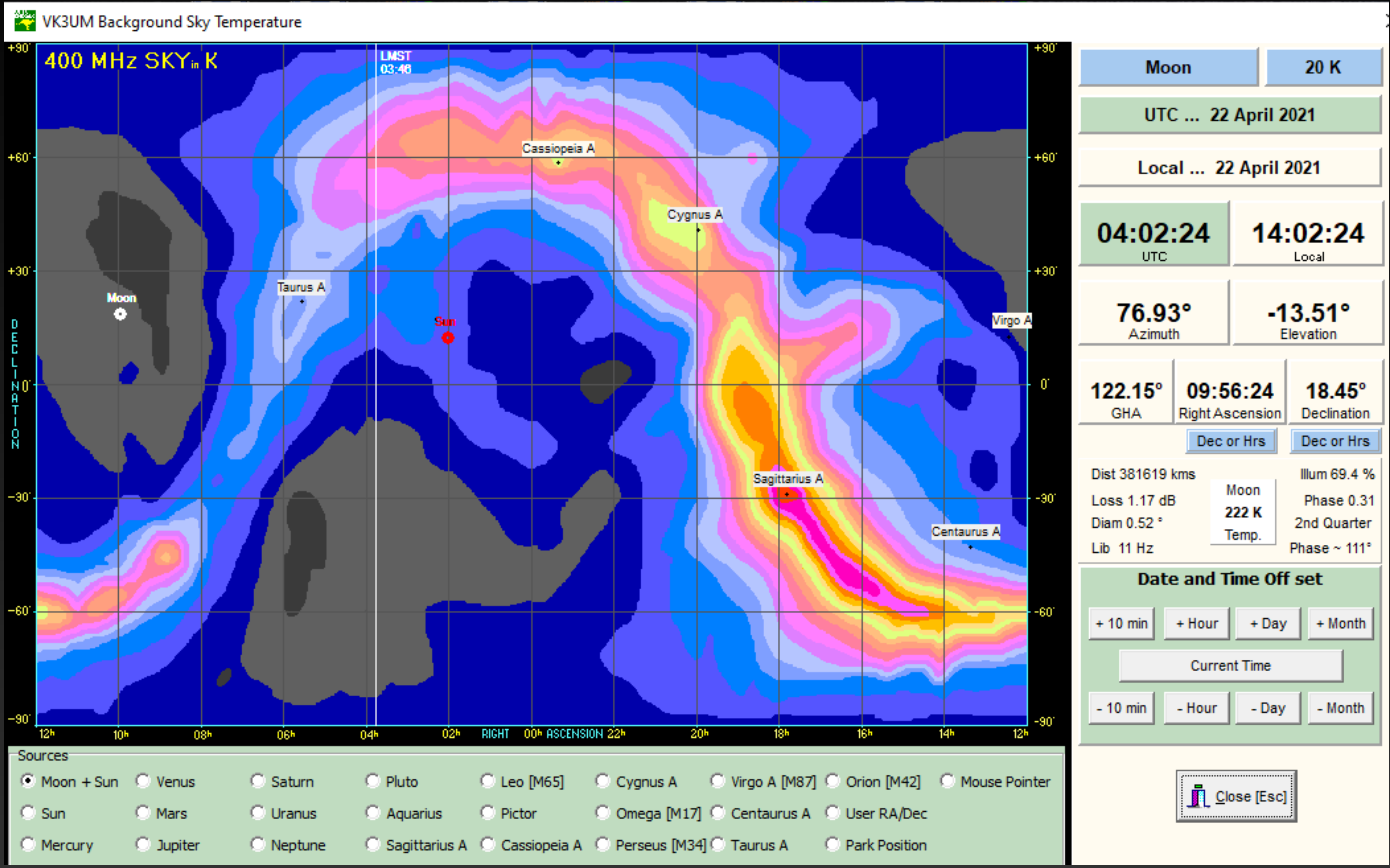
Total QSOs Reported by Band and Mode				
Band	**CW&PH**	**Digital**	**Total QSOs**	**Logs**
50	0	27	27	2
144	2	5,215	5,217	121
222	0	15	15	3
432	190	1,253	1,443	83
1.2GHz	2,316	3,416	5,732	108
2.3GHz	210	43	253	20
3.4GHz	11	2	13	5
5.7GHz	76	1	77	7
10GHz	50	126	176	13
24GHz	5	3	8	2
Total	**2,860**	**10,101**	**12,961**	

Source: 2020 ARRL EME Contest Full results - Version 1.1

Sky noise

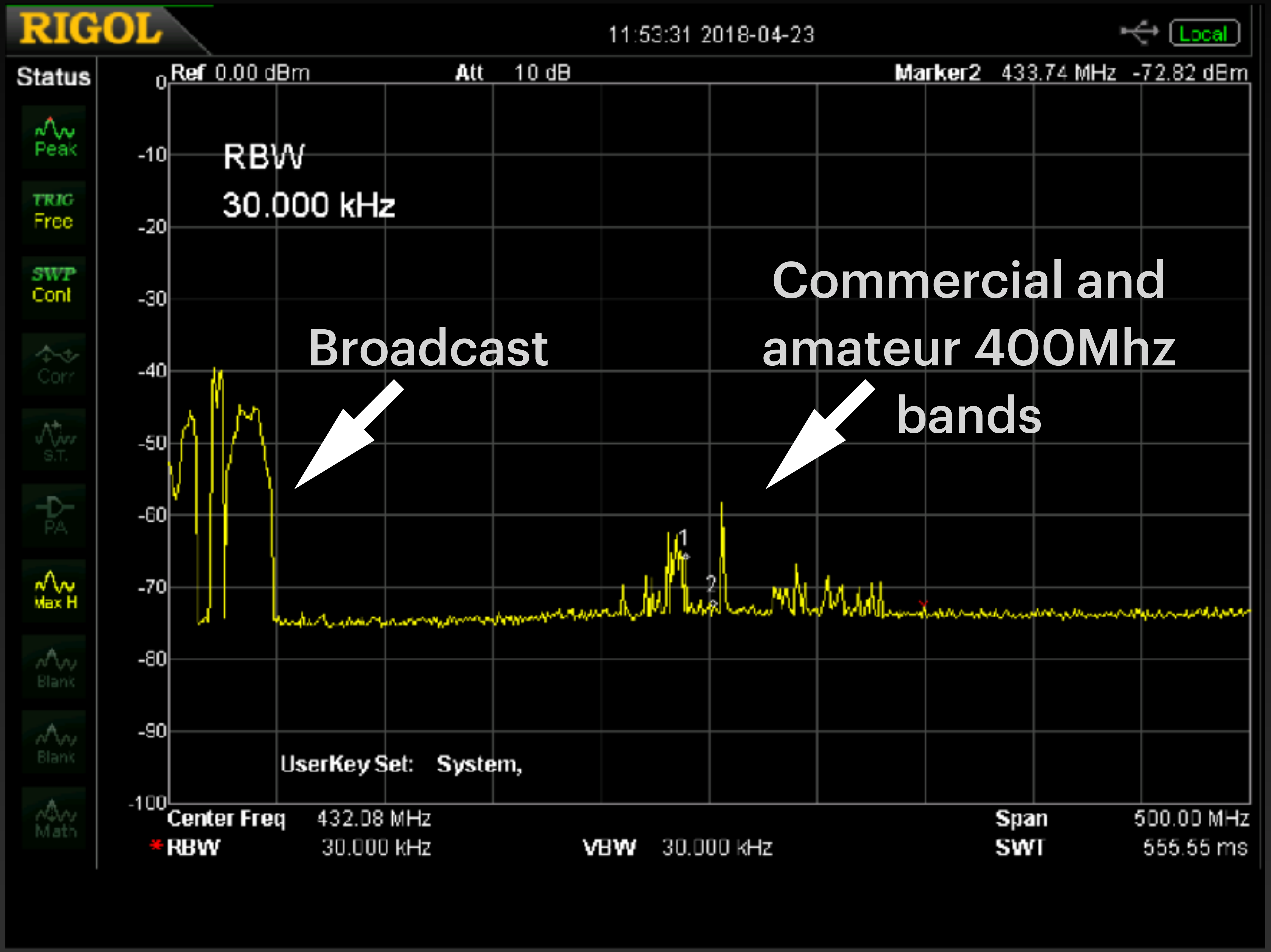
sun, moon and the stars

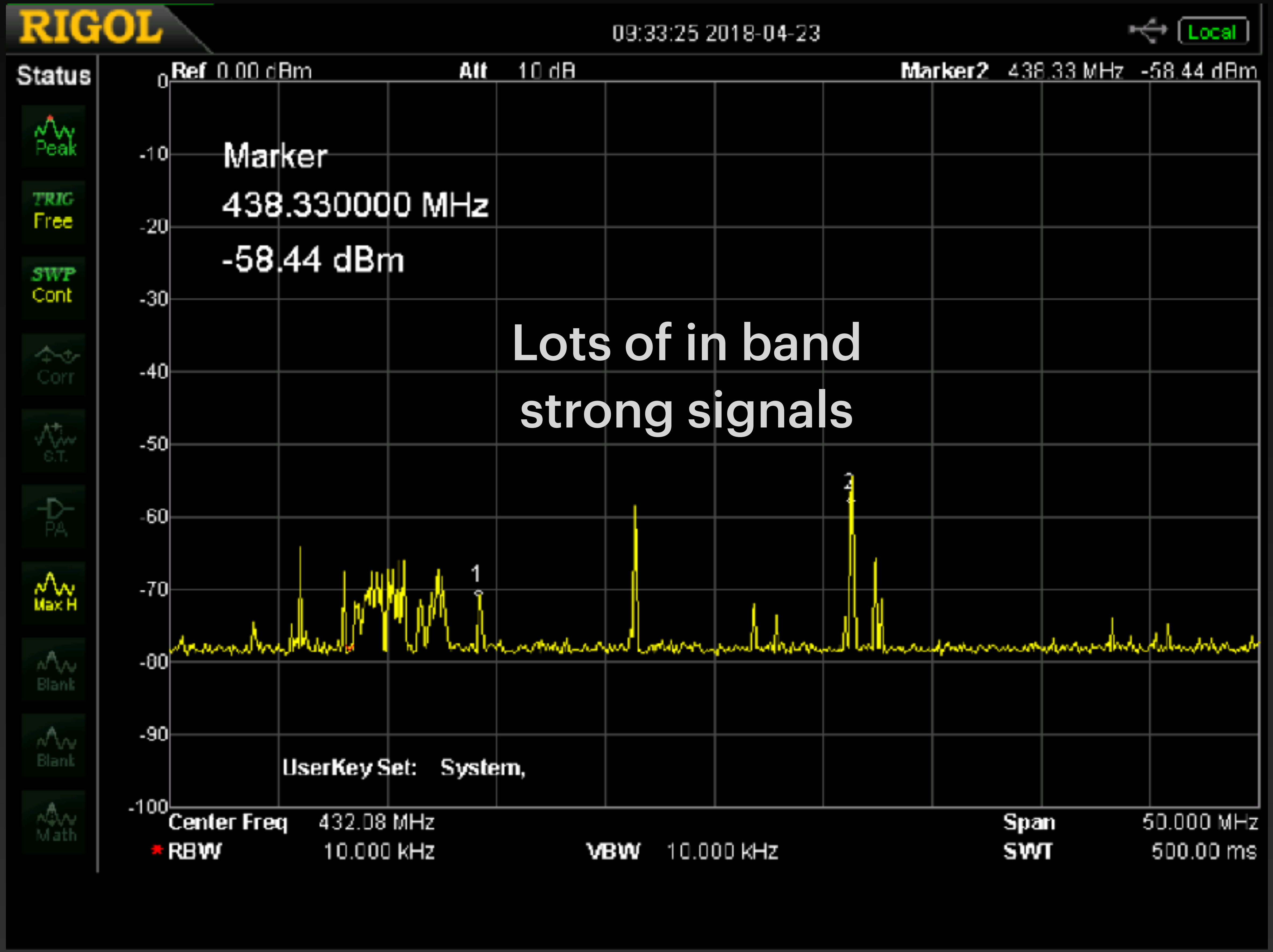
- The sun and the galaxy (sky) produce different broadband noise.
- The wider the antenna beam width the more sky noise will be picked up.
- This makes EME 'un-usable' for a few days each month.
- On the plus side the sun is a known noise source and can be used for calibration and performance measurement.
- The 'cold' areas of sky are also used to measure the noise of the stations receive chain.



Source: VK3UM EME calculator

QRM *or living in the city..*



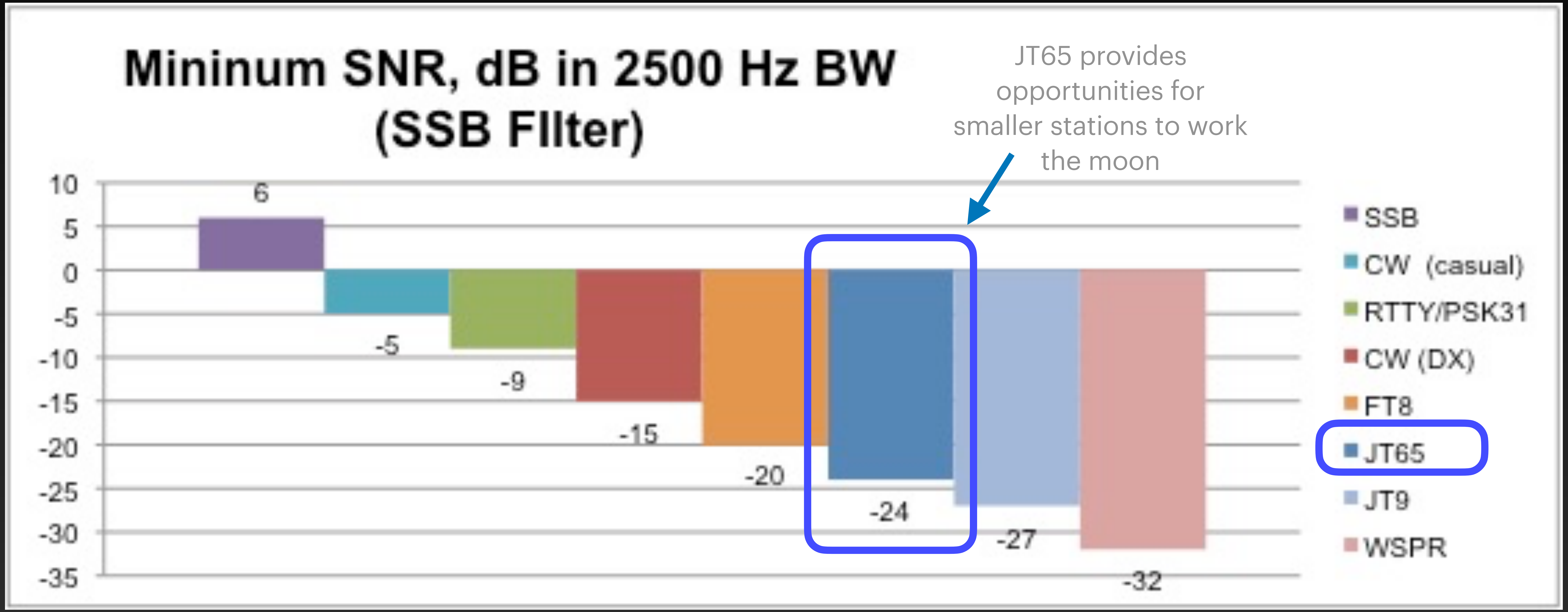


- Noise floor is typically -110dBm optimised for weak signals
- Requires LNAs with high P1dB specifications not just NF

Source: measurements at VK2CMP using omni directional vertical antenna

Why there has never been a better time to build an EME station

Why you no longer need to be a 'big gun'



- The new Q65 digital mode provides a further 3dB headroom over JT65
- 4 yagi station can operate CW in the right conditions
- 4 yagi station should be able to work another 4 yagi station at 1KW most days on JT65
- Single yagi stations can work large stations and even 4 yagi stns in good conditions

Source graphic : https://kf6hi.net/radio/SNR.html

EME the big guns *or what dreams are made of..*

HB9Q Dan has a couple of big dish's and has a 15.3m dish on 432Mhz. 70cm feed is 2x 7 element LFA yagi (H & V pol)

DL7APV Bernd has 128x 11element yagi's with open wire feeder. The array sits on a bearing from a Caterpillar earth moving equipment!

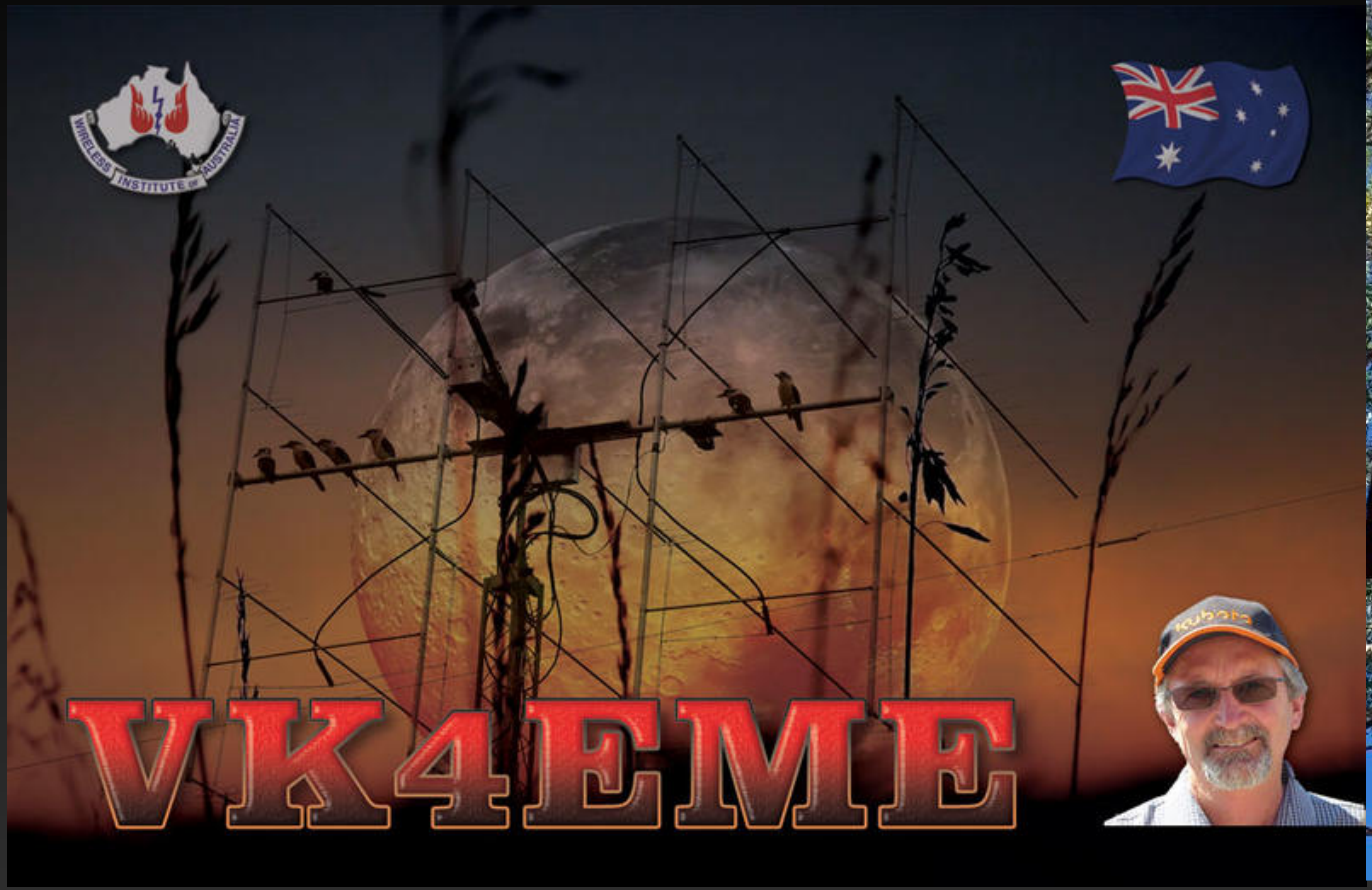
2/2 EME the big guns *or what dreams are made of..*

Frank NC1I has 48x 15 element yagi and has polarity rotation

KL6M Mike has a 30ft dish and operates 144Mhz thru 5Ghz mainly on CW

Meanwhile back in VK

or what dreams are made of..



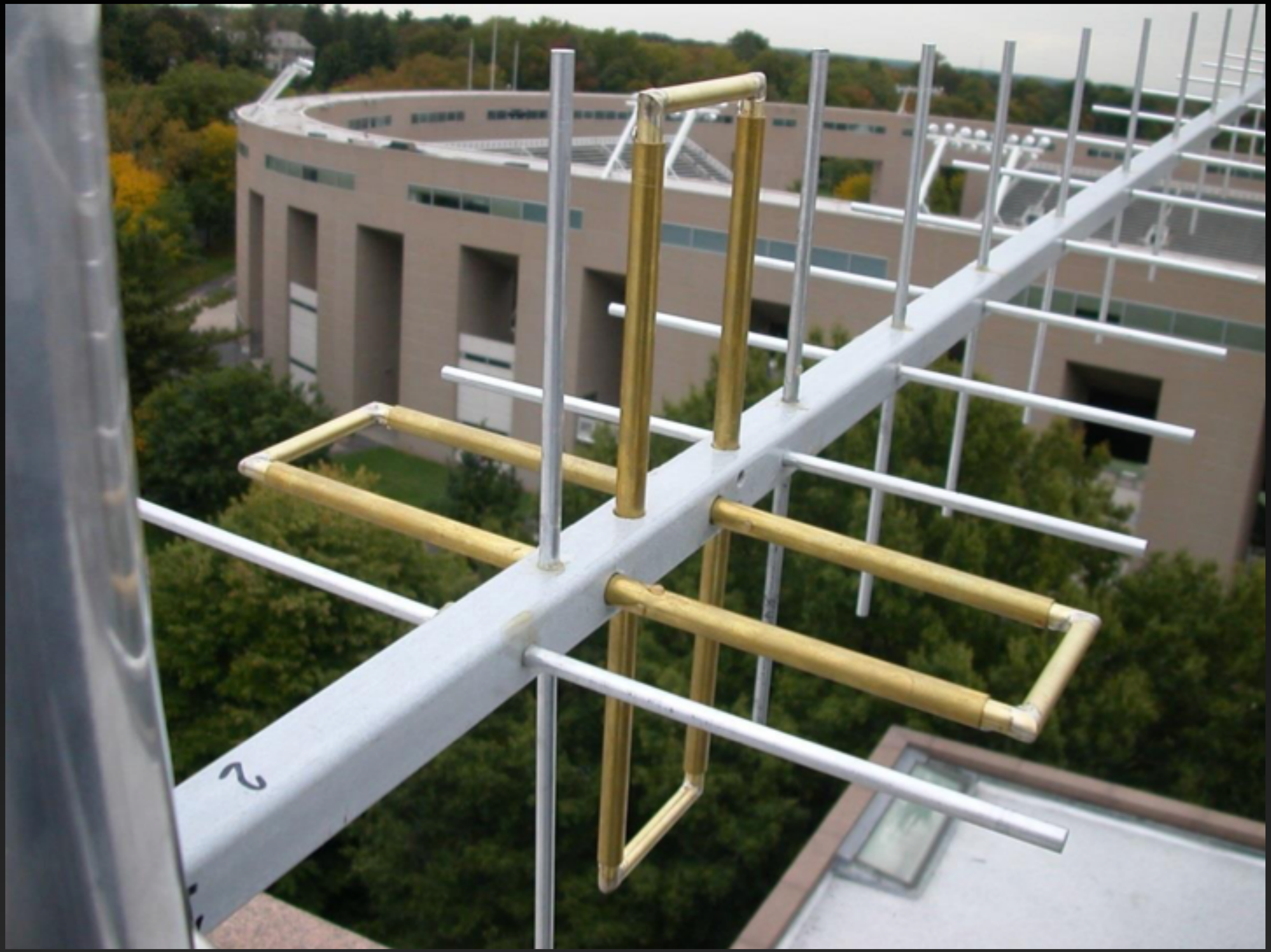
VK4EME Allan has 16x 15 element yagi and can rotate the array to change polarisation

VK2CMP operates 4x 15LFA-JT X-pol LFA yagi. Consists of 4x 15 element H-pol and 4x 15 element V-pol yagi.

Adaptive polarisation

High performance small stations

- Uses H and V pol yagi on same fibreglass boom
- No faraday lock out
- Can TX V or H pol
- Uses Linrad SDR with high performance noise blanker
- MAP65 visibility of entire band
- 4 instances of WSJT-X at 0, 45, 90 and 135 degrees

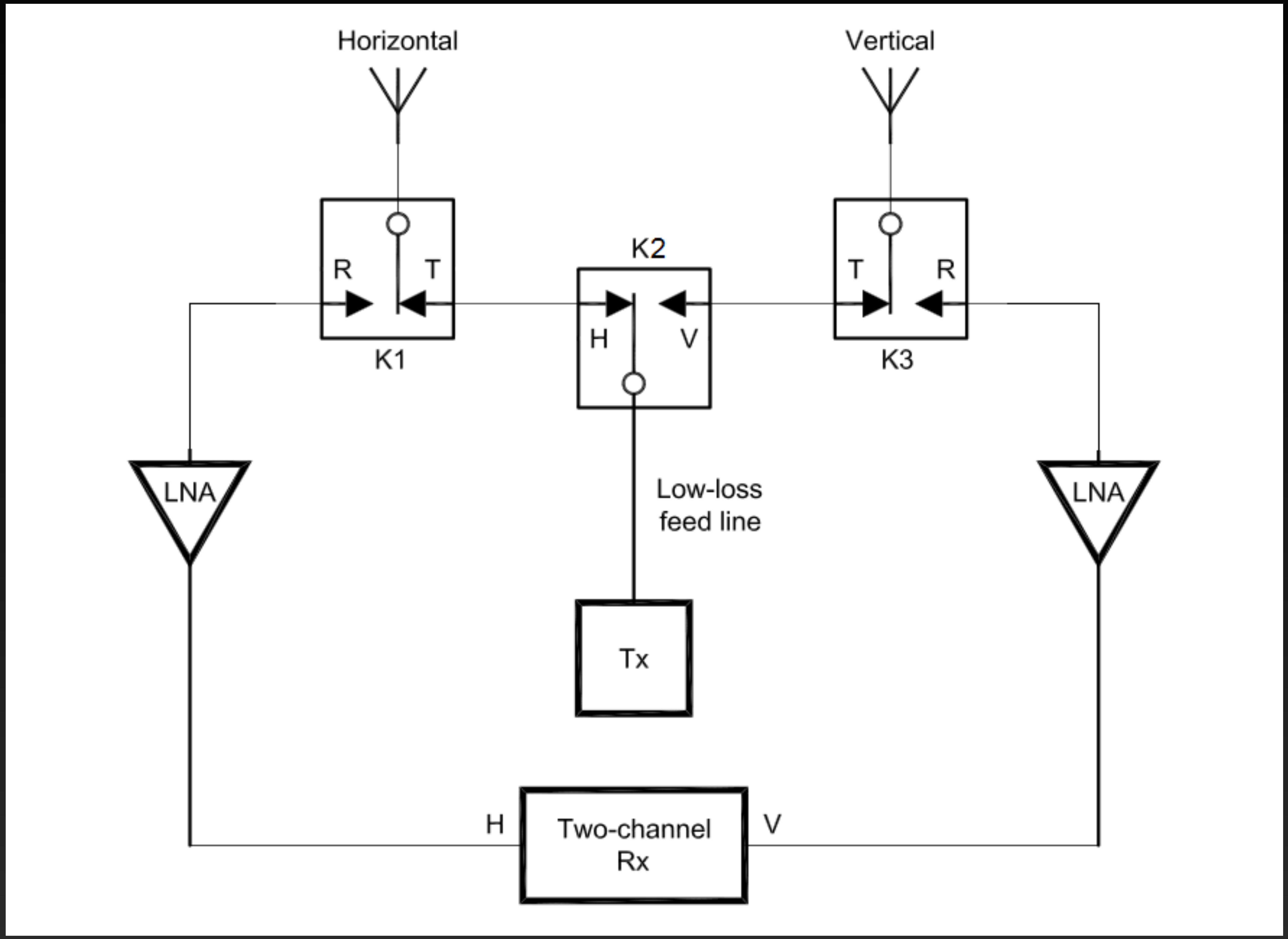


4x 30 element (15H/ 15V) 15LFA-JT yagi designed by Justin Johnston G0KSC of InnoVAntennas & Joe Taylor K1JT at W2PU

Adaptive polarisation

High performance small stations

- TX relay enables V or H transmit
- 2x Antenna relays switch between TX and RX feeds
- Requires 3 coax runs
- No relay required in PA
- LFA yagi optimised for low noise with small sidelobes
- LNA typically includes some sort of filtering in the city

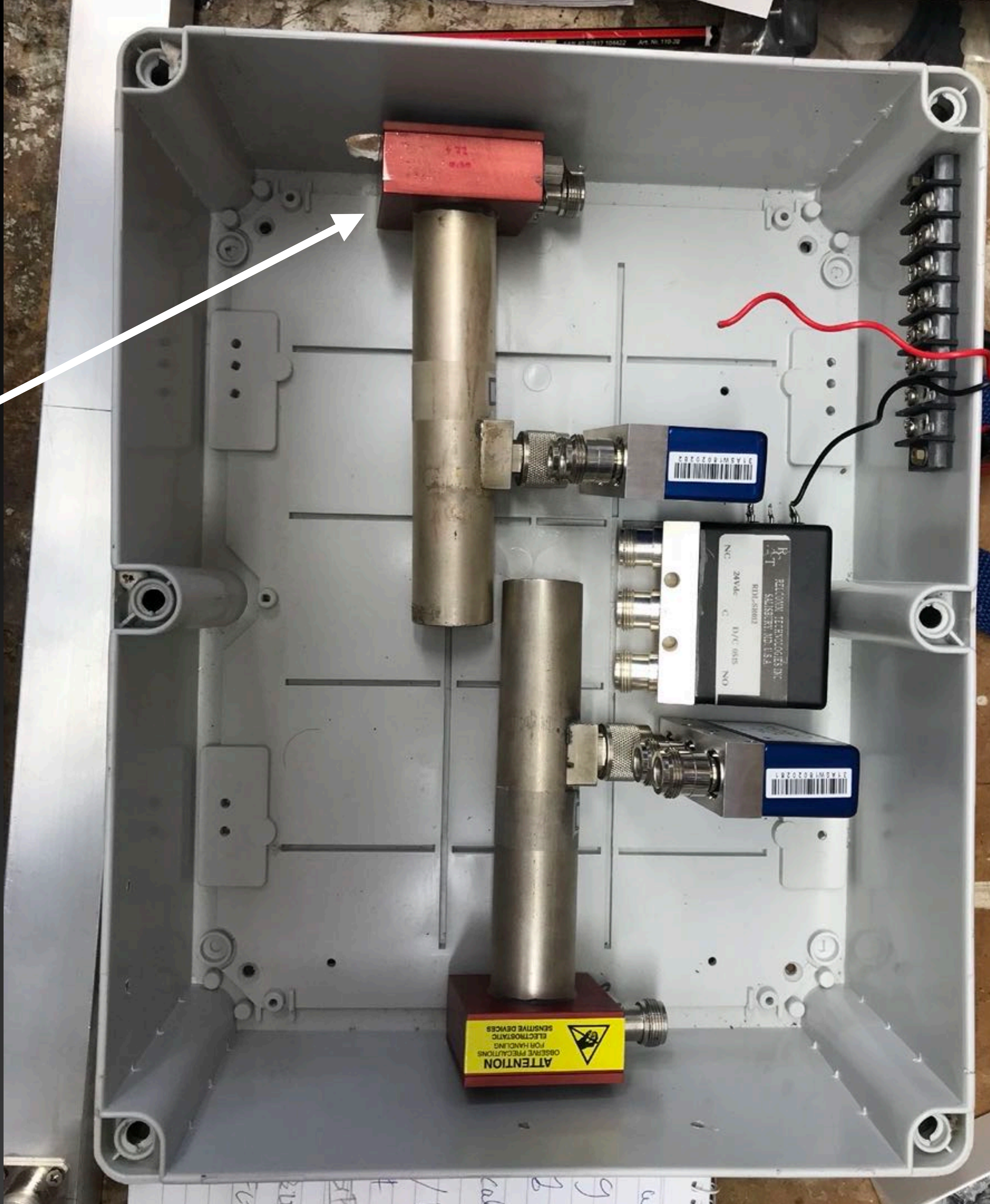


Feedline arrangement using 3 relays and 2 channel receiver.

VK2CMP design choices

Life on top of a hill in the city

- WD2AGO custom built LNA has cavity front end followed by 2 further stages of filtering on PCB and still returns NF <0.25dB with high P1dB
- Followed by external 2nd stage Kuhne LNA (NF<0.45dB) to provide gain required
- 4x 15LFA-JT spaced at 1.2m to optimise low noise design

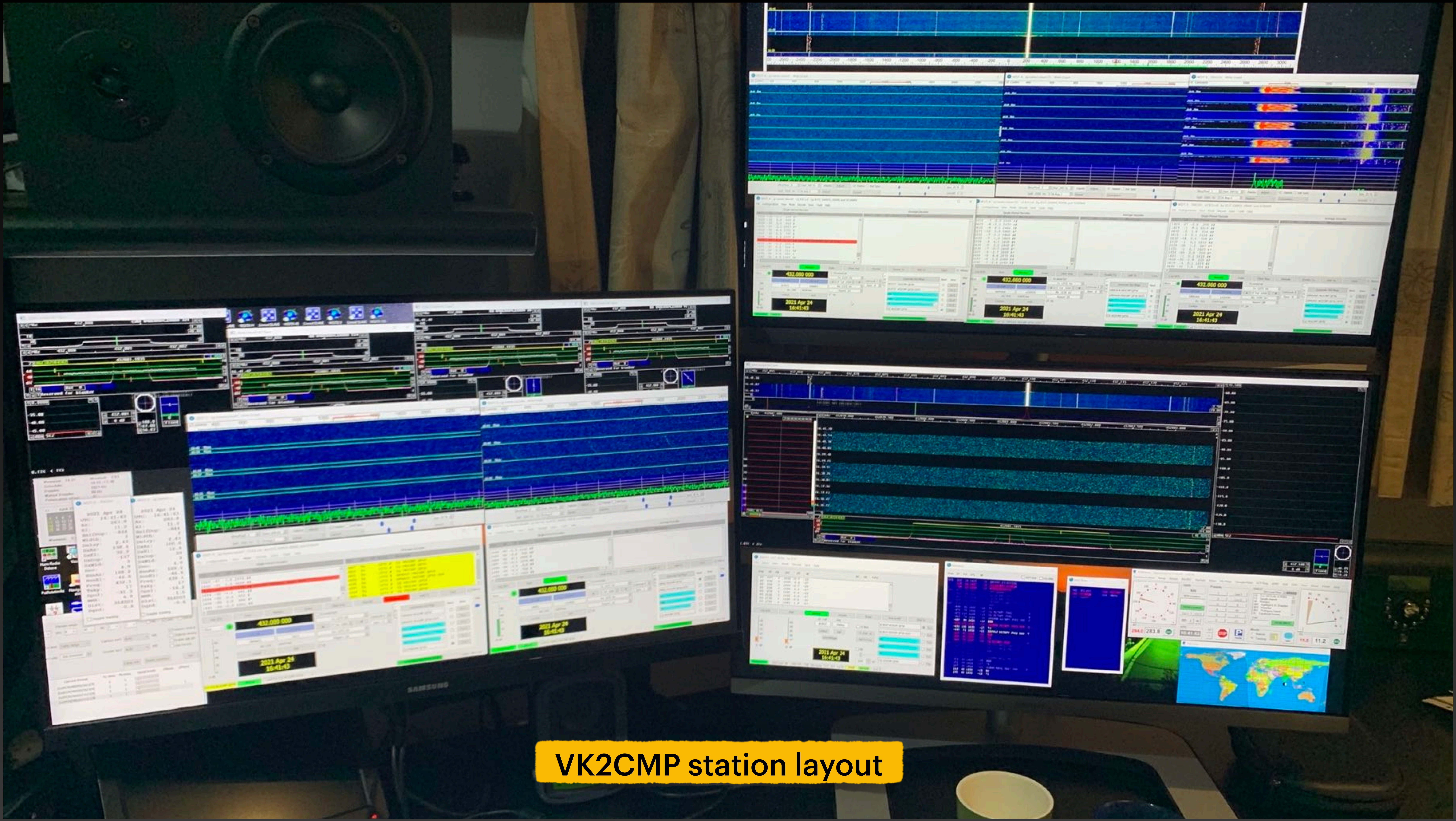


VK2CMP design choices

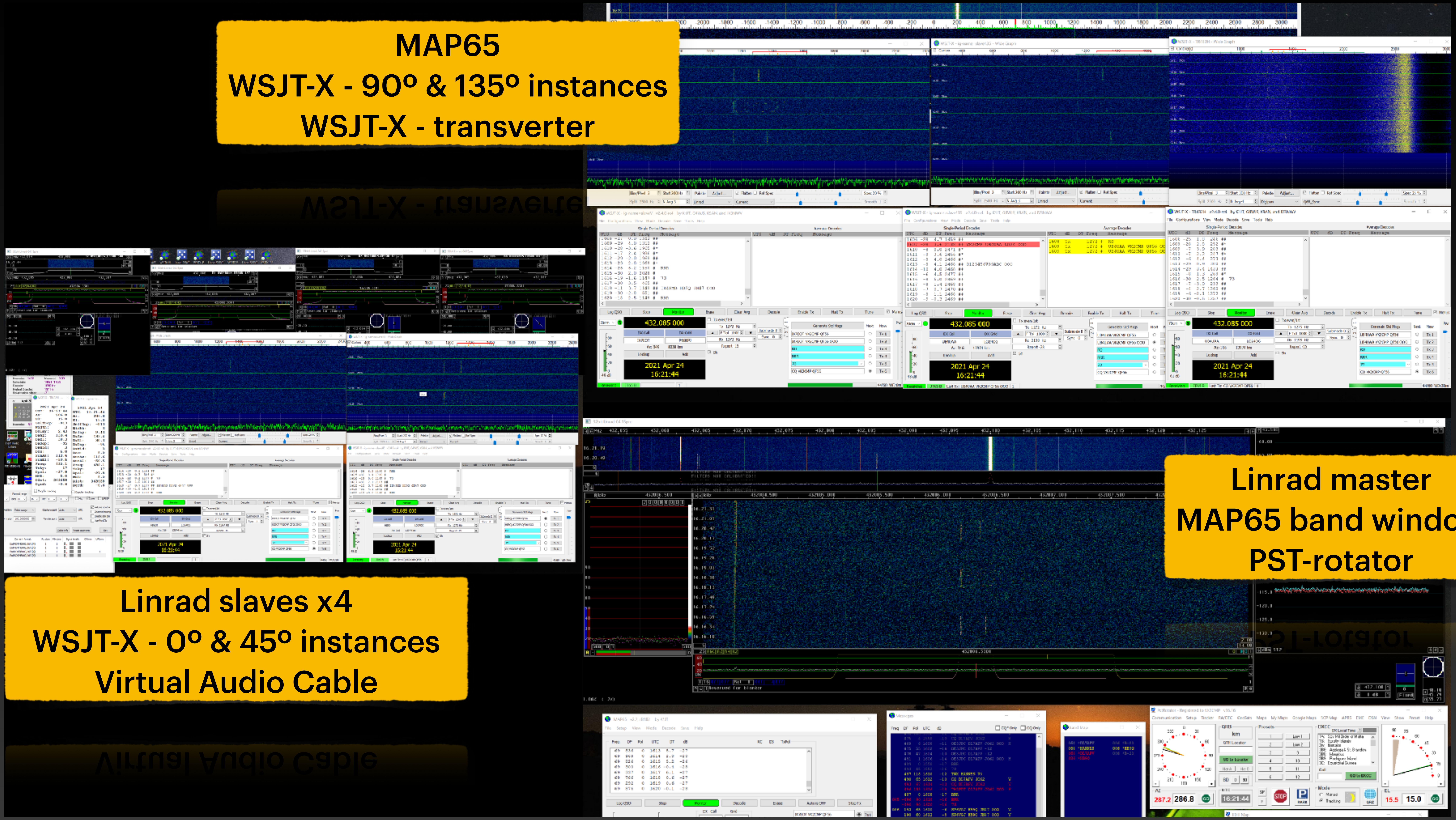
Life on top of a hill in the city

- Receiver consists of LinkRF IQ+ high performance 432Mhz 2 channel RX with I+Q outputs to sound card
- High performance LinkRF UADC4 4 channel sound card optimised for IQ signals not music
- Linrad front end provide smart as well as dumb noise blankers
- Linrad provide polarisation information to MAP65 and slave instances

VK2CMP station layout
W6PQL PA
Az/el controller
10Mhz Rb reference
Transverter
UADC4
IQ+
FT2000D

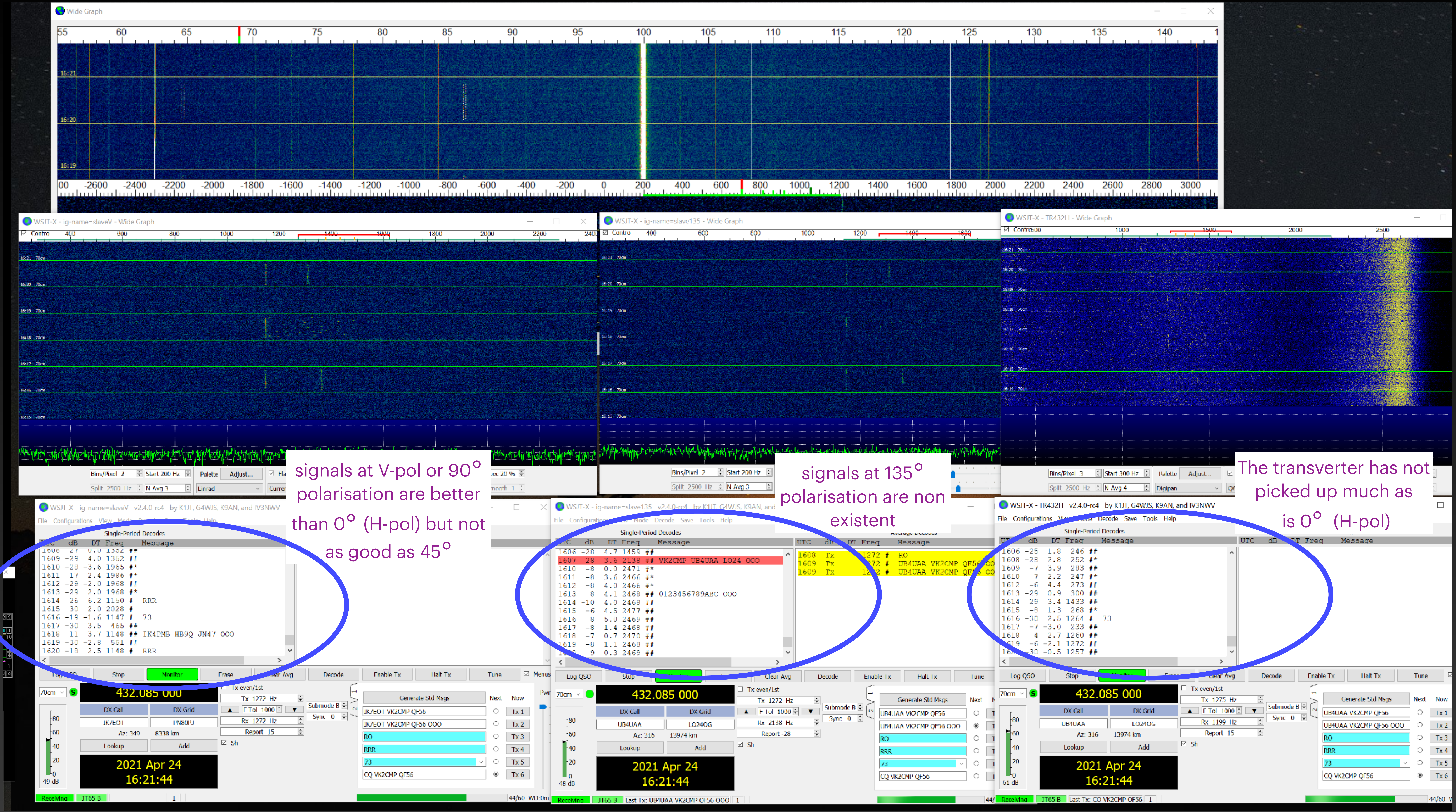


VK2CMP station layout



MAP65
WSJT-X - 90º & 135º instances
WSJT-X - transverter
Linrad master
MAP65 band window
PST-rotator
Linrad slaves x4
WSJT-X - 0º & 45º instances
Virtual Audio Cable


sending RRR
sending call & 'OOO'
much stronger signal at 45°
signals at 0°
polarisation on a good day
would be = R-9
signals at 45°
polarisation are better
than H - pol


signals at V-pol or 90° polarisation are better than 0° (H-pol) but not as good as 45°
signals at 135° polarisation are non existent
The transverter has not picked up much as is 0° (H-pol)

References and further information

in no particular order

- EME with Adaptive Polarisation KIJT & G0KSC   https://www.physics.princeton.edu/pulsar/K1JT/EME_with_Adaptive_Polarization_at_432_MHz.pdf
- Adaptive Polarisation on 432Mhz K1JT   https://www.physics.princeton.edu/pulsar/K1JT/Moonbounce_at_W2PU.pdf
- Good VHF/UHF references from KA1GT https://bobatkins.com/radio/Q65_1296_setup.html
- LinkRF IQ+ and UADC4 http://www.linkrf.ch
- Lunar calendar from DL7APV http://dl7apv.de/moon2010/moon2010.htm
- Linrad and and host of other RF stuff from SM5BSZ http://www.sm5bsz.com
- History of moonbounce from radio club OK2KKW pages http://www.ok2kkw.com/eme1960/eme1960eng.htm
- 432Mz and up newsletter http://www.nitehawk.com/rasmit/em70cm.html
- EME directory by PA0PLY http://www.pa0ply.nl/directory.htm
- Moon-net forum PE1ITR (you might need to join this one) http://mailman.pe1itr.com/pipermail/moon-net/
- WSJT-X, MAP65 & WSPR home page https://physics.princeton.edu/pulsar/k1jt/
- VK3UM's EME calculator and other good oil https://www.vk5dj.com/doug.html
- LFA arrays by G0KSC https://www.kkn.net/dayton2014/DaytonHamvention-V2.2.pdf
- Polarization and 'One Way' EME propagation GM3SEK http://www.ifwtech.co.uk/g3sek/eme/pol4.htm
- K1JT reference pages   https://www.physics.princeton.edu/pulsar/K1JT/refs.html

- Next talk we will cover in detail design principles of a high performance small station.
- Choices available and selection of key components to provide best performance in typical QRM environments.
- And what can be applied to our HF/ VHF/ UHF stations to optimise performance