The Excitement & Challenges of 24 GHz EME

By

Al Ward W5LUA

August 17, 2012

Introduction

- History
- Early Activity
- Present Activity
- Equipment
- Challenges
- Summary

The First 24 GHz EME QSO

- The First 24 GHz EME QSO occurred on August 18, 2001 when VE4MA contacted W5LUA
- Years of work optimizing feeds & dishes , LNAs, and optimizing TWTs and power supplies
- Our last missing link was the TWT and thanks to Paul Drexler, W2PED, both Barry and I were able to generate some power.

24 GHz EME Activity

- By 2008, several other stations had become active including RW3BP, AA6IW, VE7CLD, OK1UWA, LX1DB, G4NNS, DK7LJ, DF1OI, OK1KIR, PA0EHG, and DL7YC
- More recently F2CT, OZ1FF, RK3WWF, IK2RTI and F1PYR have been added to the list of active stations from Europe
- Recently, JA6CZD became the first Asian to make an EME QSO on 24 GHz by working OK1KIR. Congrats to both stations!

The 1.25 cm Amateur Band

- In the US, the 1.25 cm band extends from 24,000 to 24,250 MHz
- Original EME activity was centered around 24,192 MHz which was the center of terrestrial activity in the US and Canada.
- Migrated to 24048 MHz which is a primary frequency allocation in Europe and also where amateur satellite operation has taken place in the past.

Equipment

- What does it take?

Early 24 GHz EME dish at W5LUA

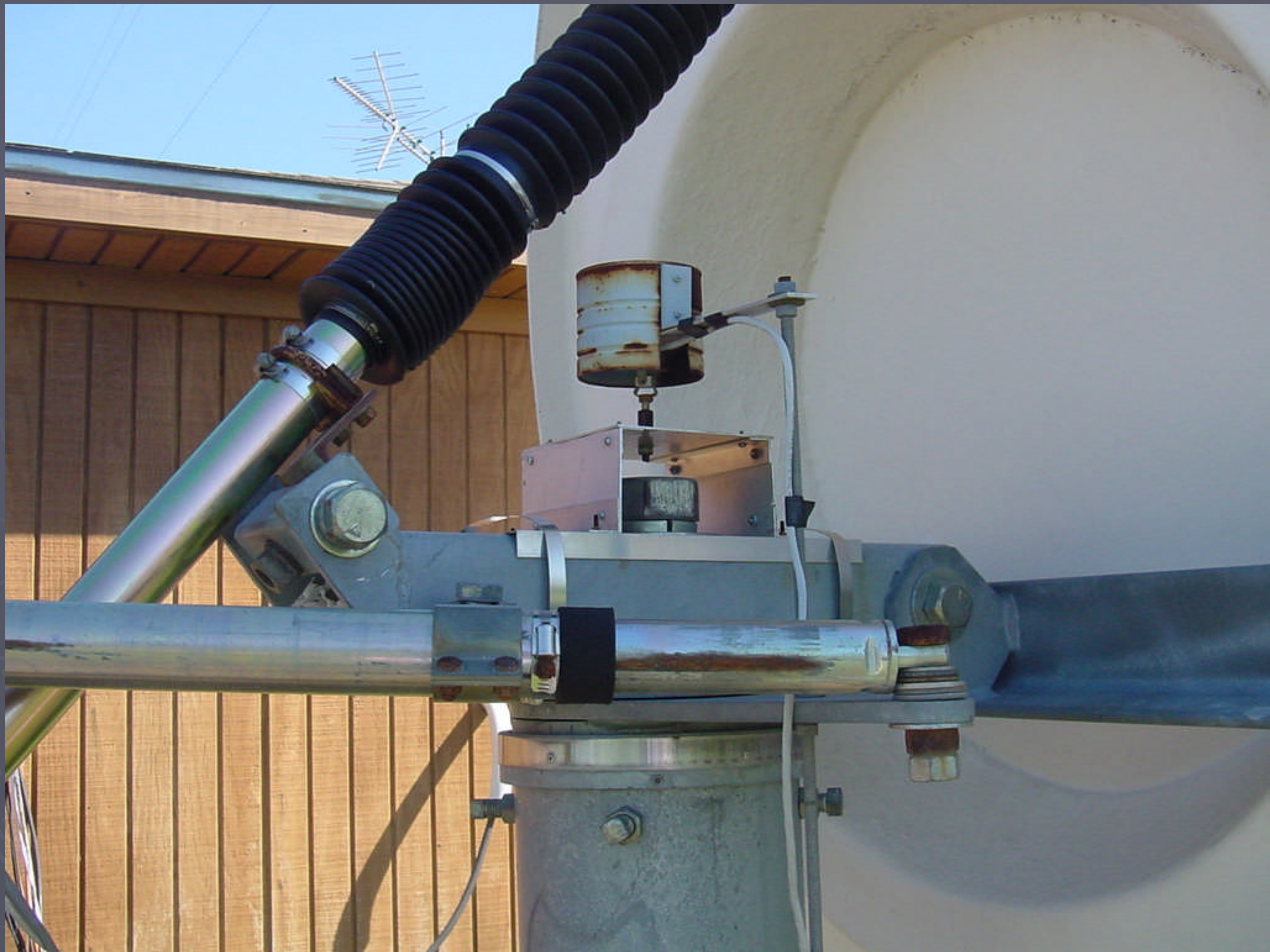
Andrews 3M prime focus dish with additional back structure to enhance parabolic curve

Scientific Atlanta positioner with additional drive reduction to slow down speed

VE4MA 2.4 M Offset Fed Dish

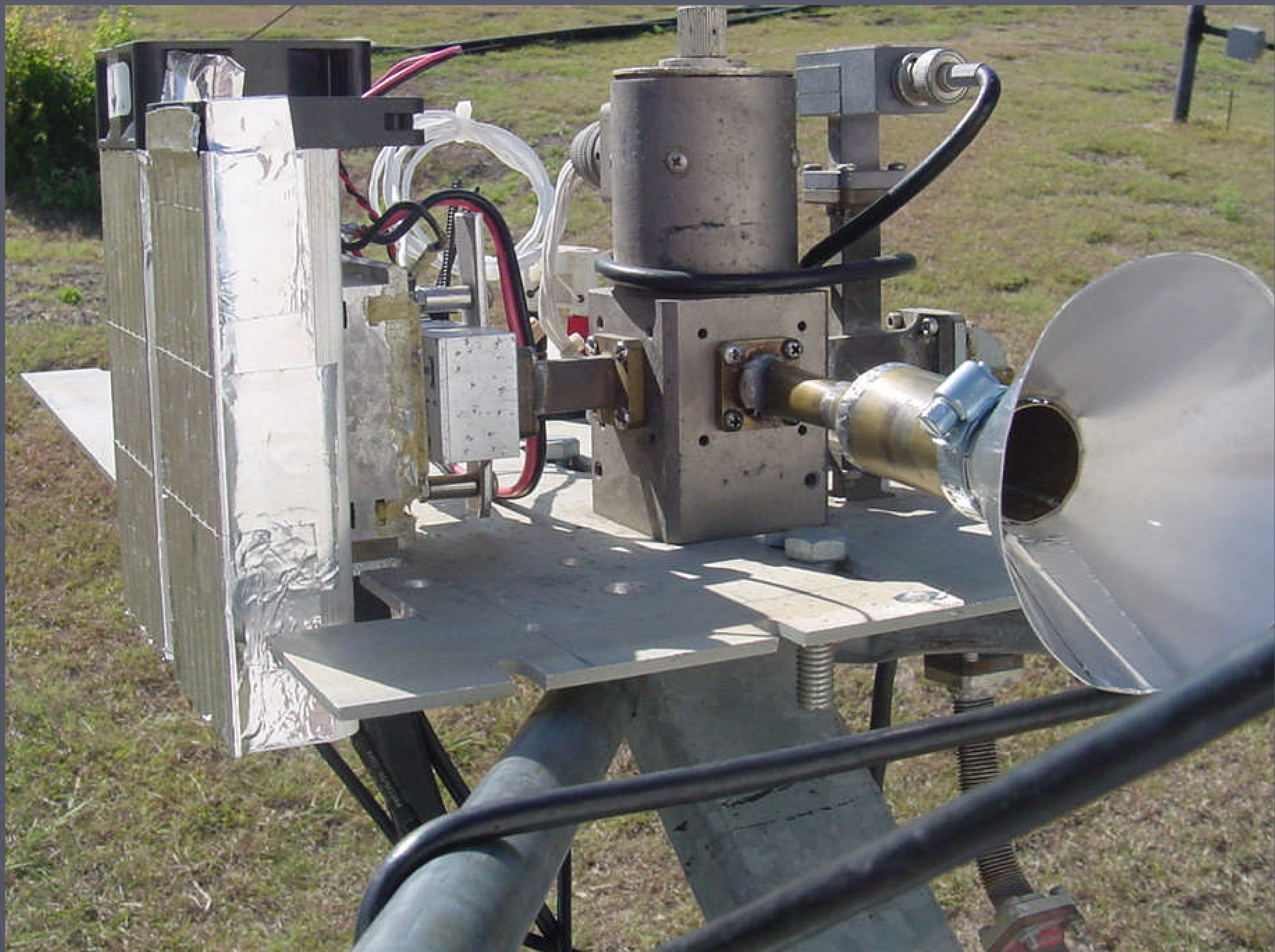
Present 2.4 M Offset Fed Dish at W5LUA

2.4M Az/El & Az Encoder

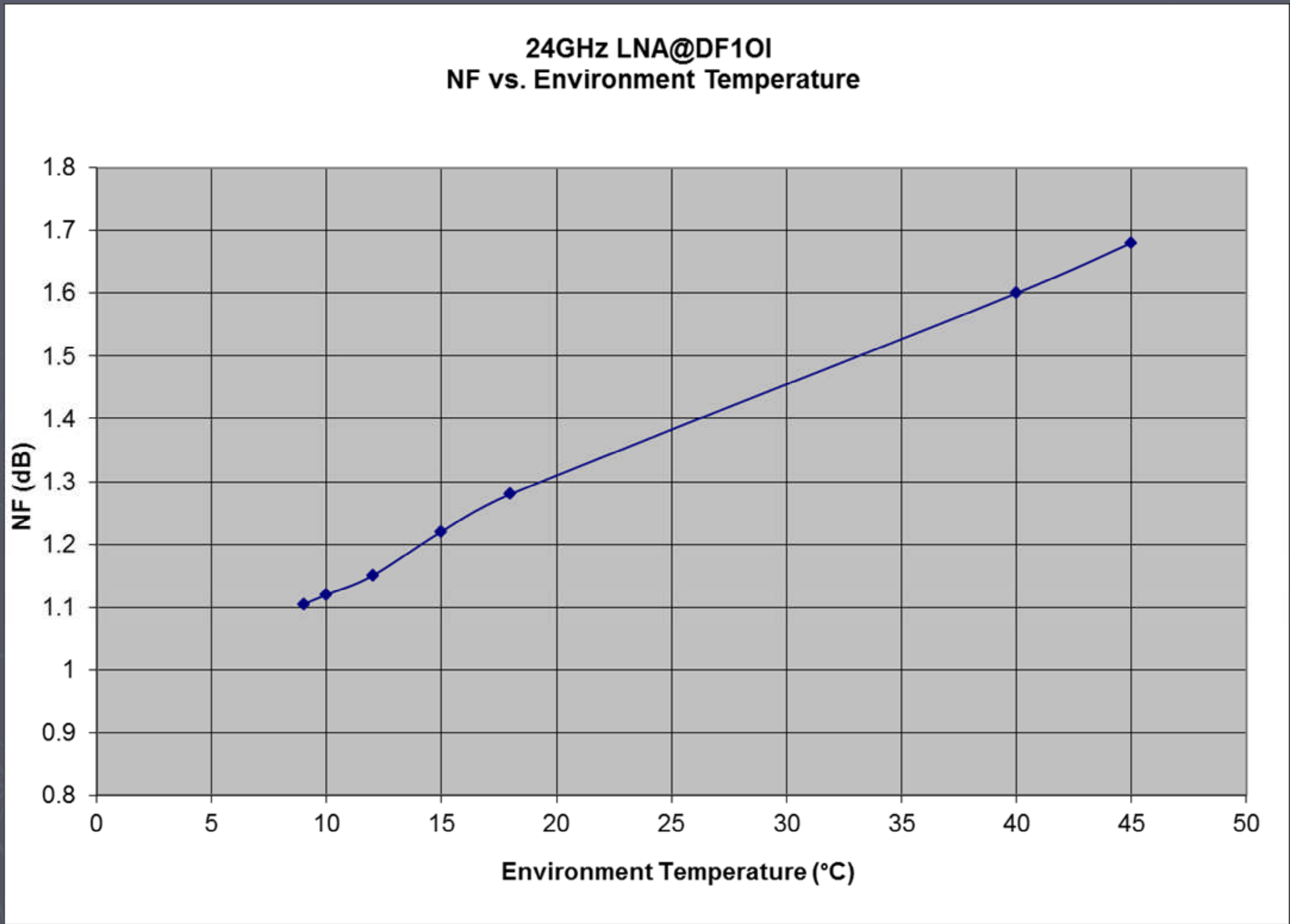


Feed/LNA/Waveguide Relay

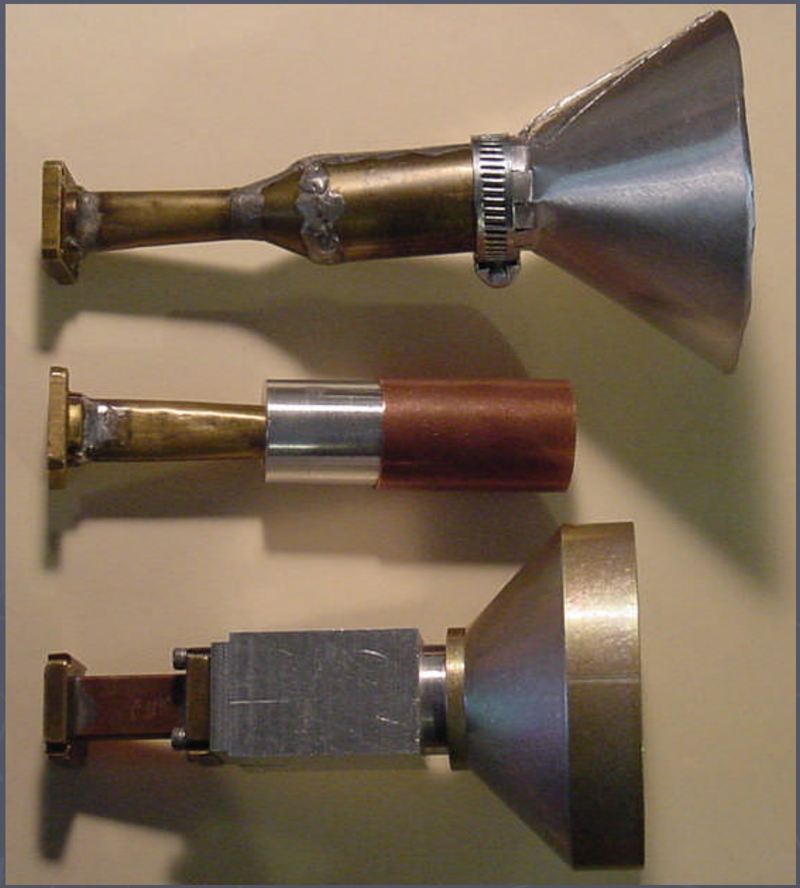
Peltier Cooler for LNA



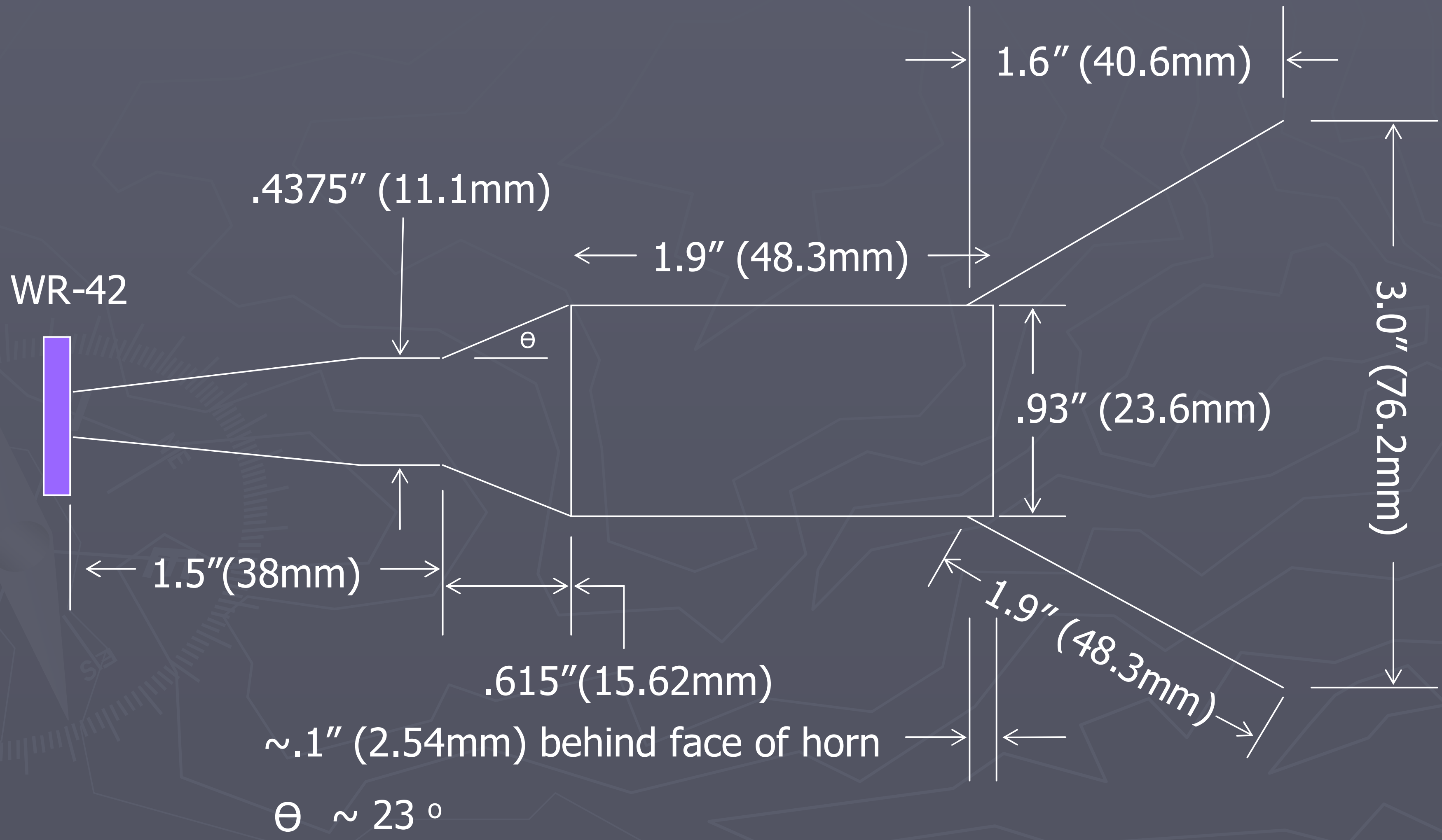
Cooling 24 GHz LNA @ DF1OI



Feed Experimentation

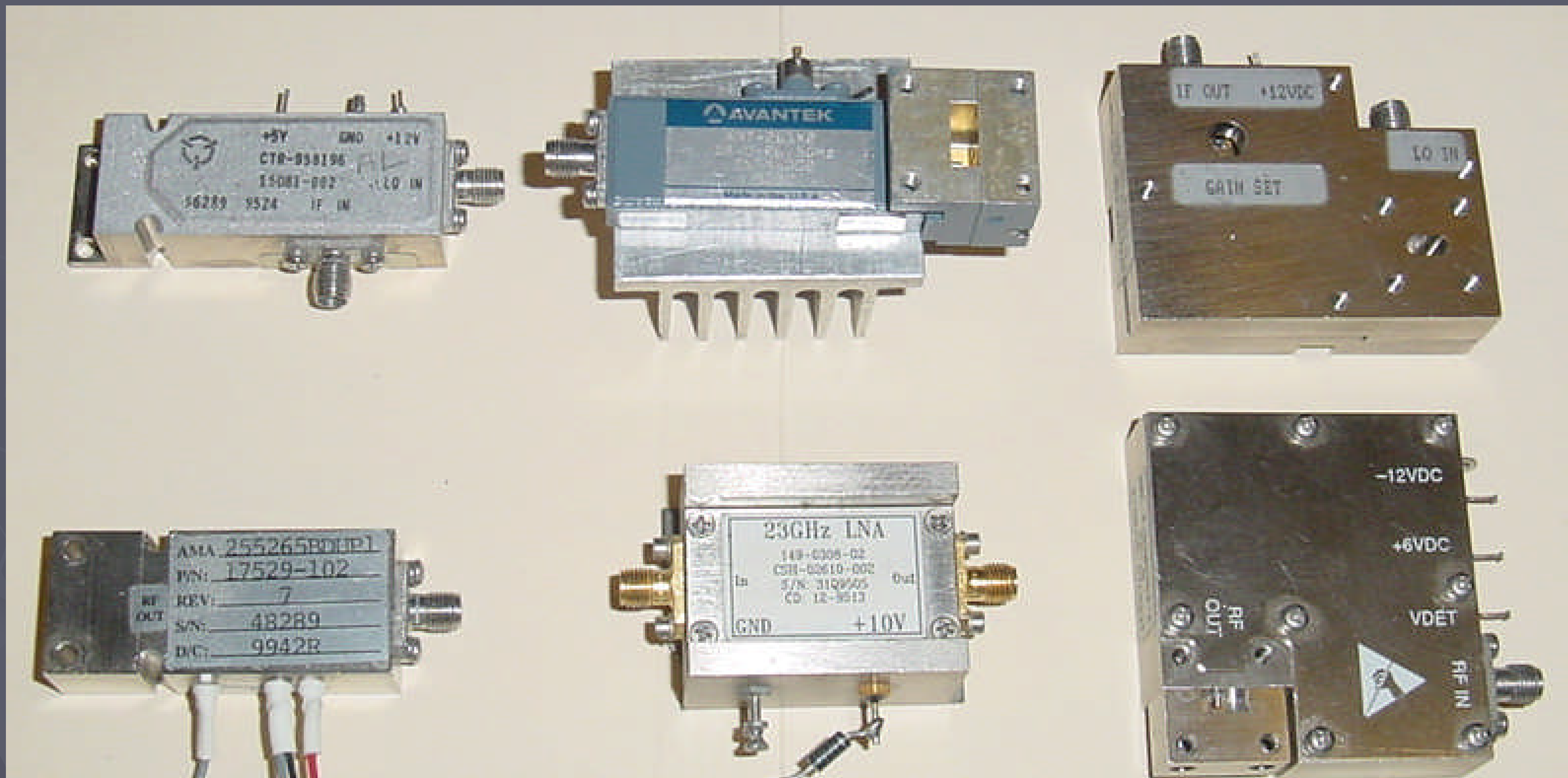


Modified W2IMU 24 GHz feed with flare used by W5LUA on 2.4M offset fed dish with f/d=.7

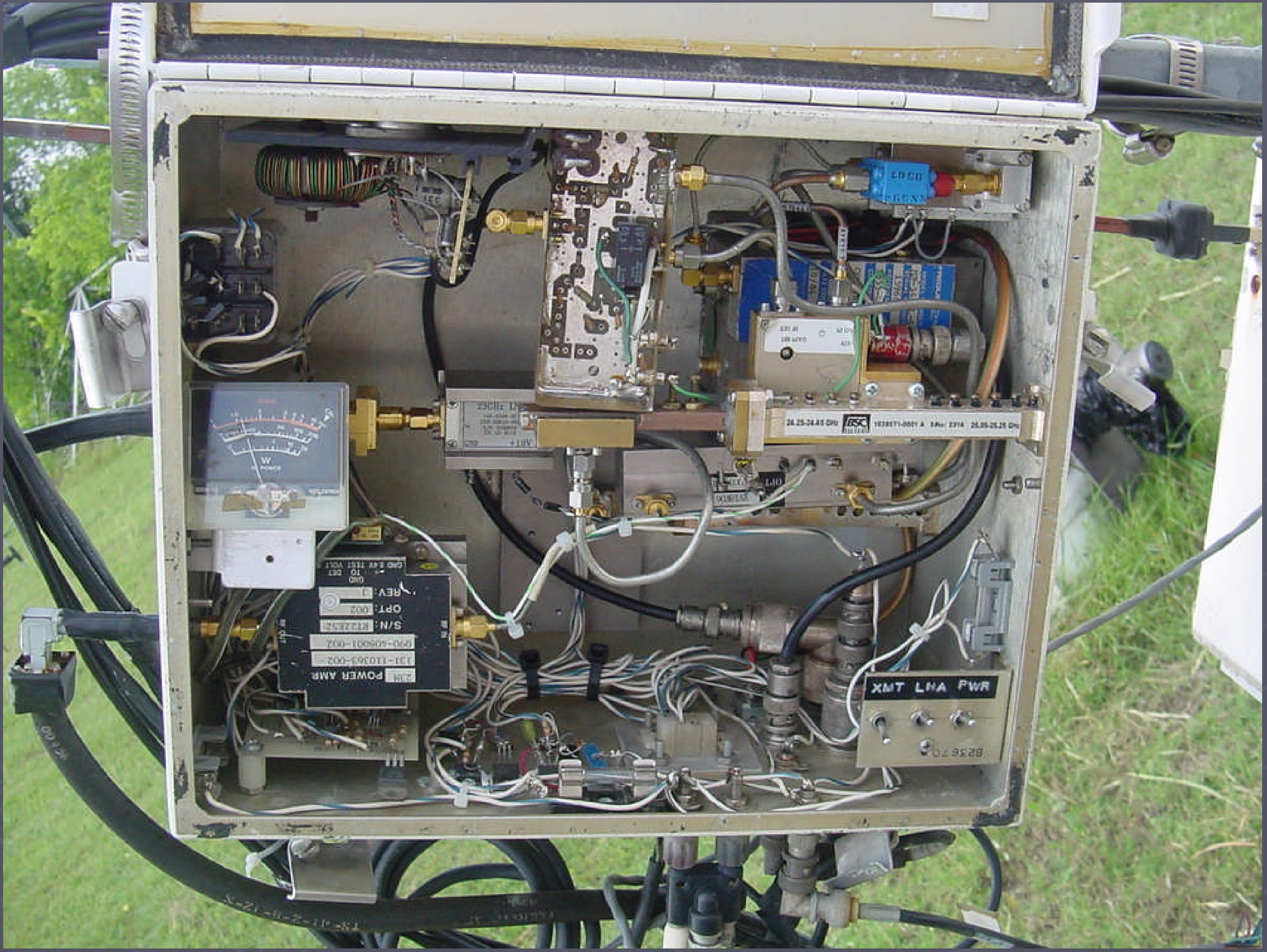


DMC 23 GHz Modules

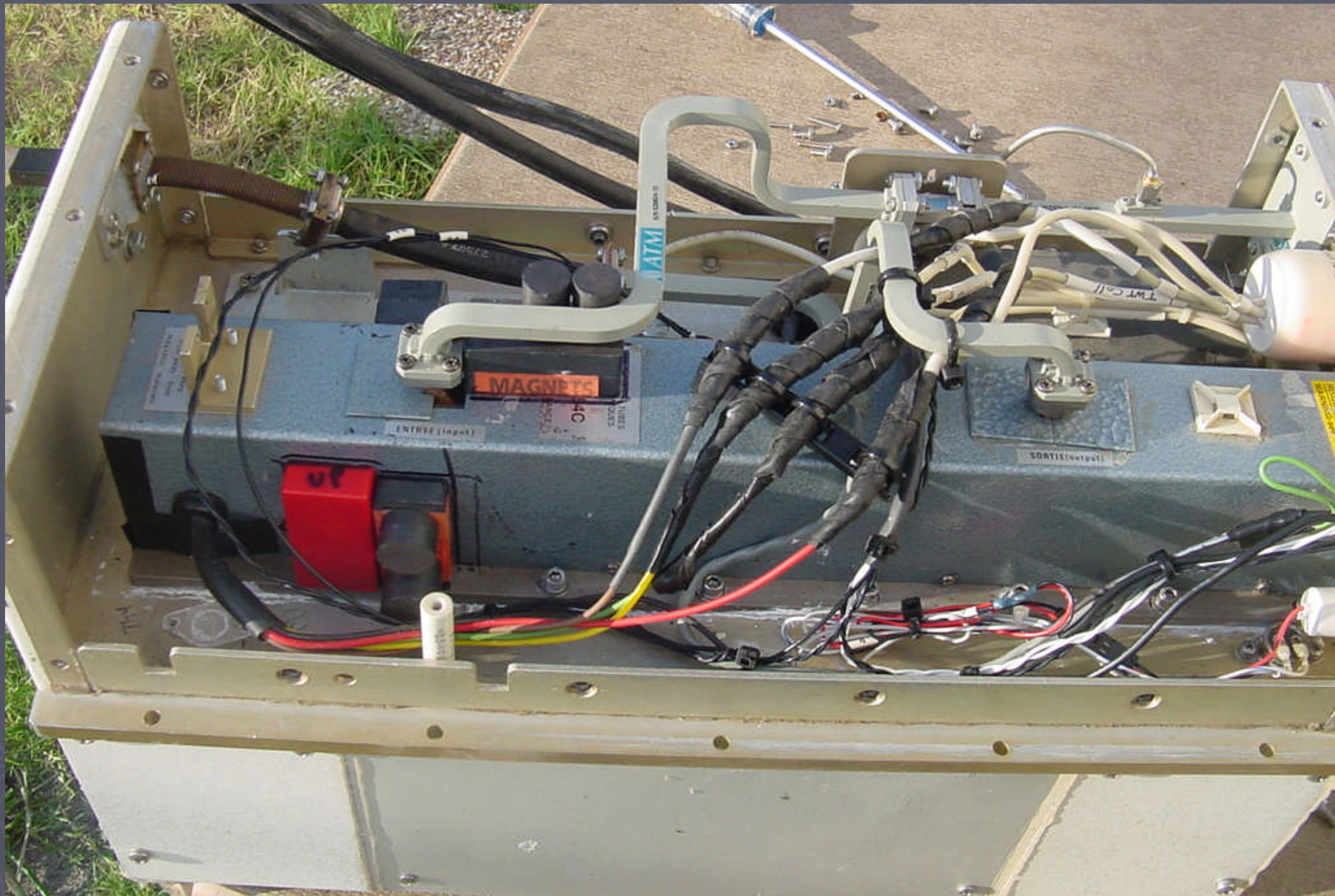
Various other 23 GHz Modules



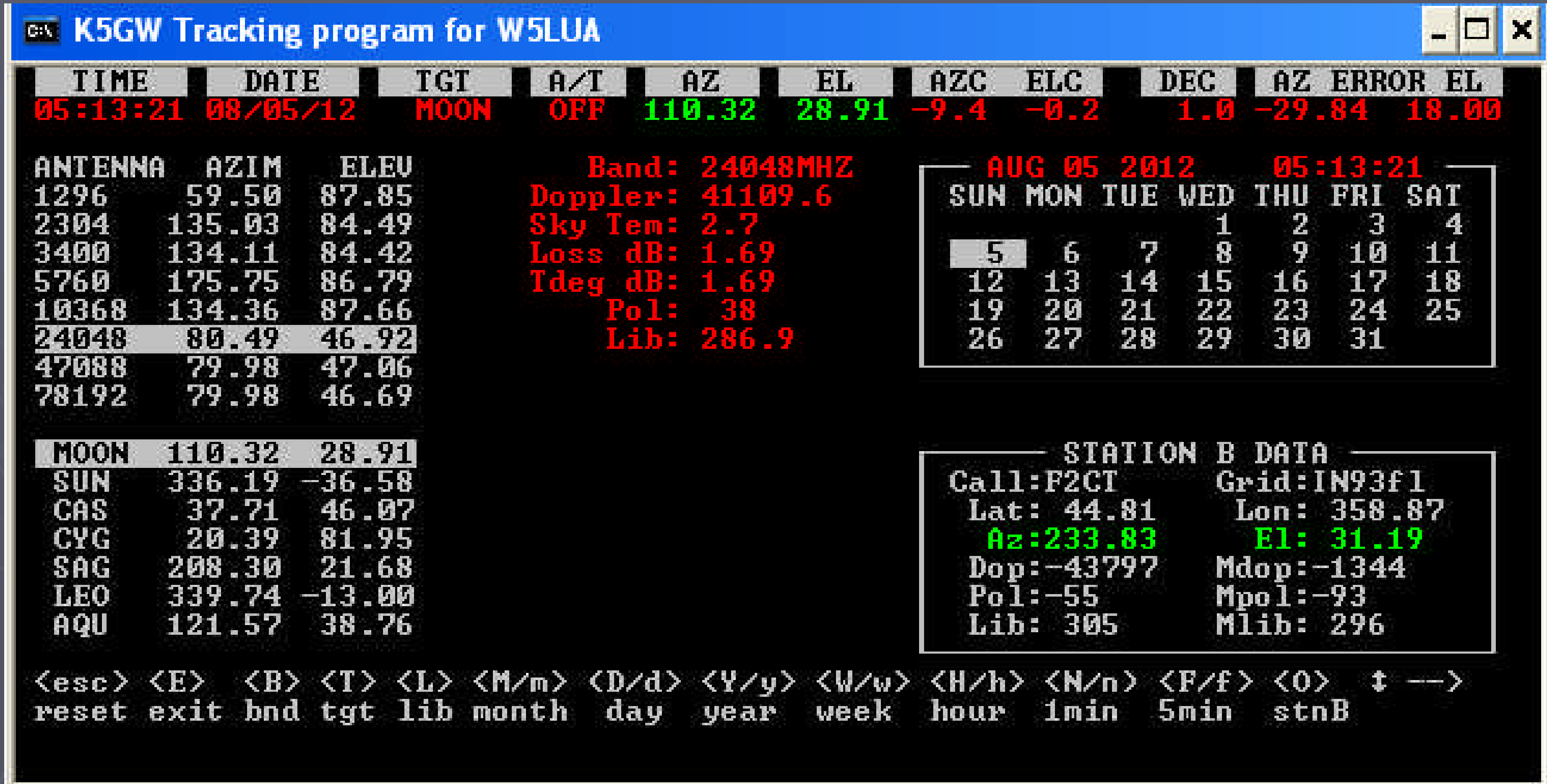
W5LUA 24048 MHz Transverter



Thompson TH-3864 100 watt TWT with magnet tuning



K5GW Tracking Software



Optimized Dual Mode F2L x L3.10L

Moon Noise vs Lunar Phase

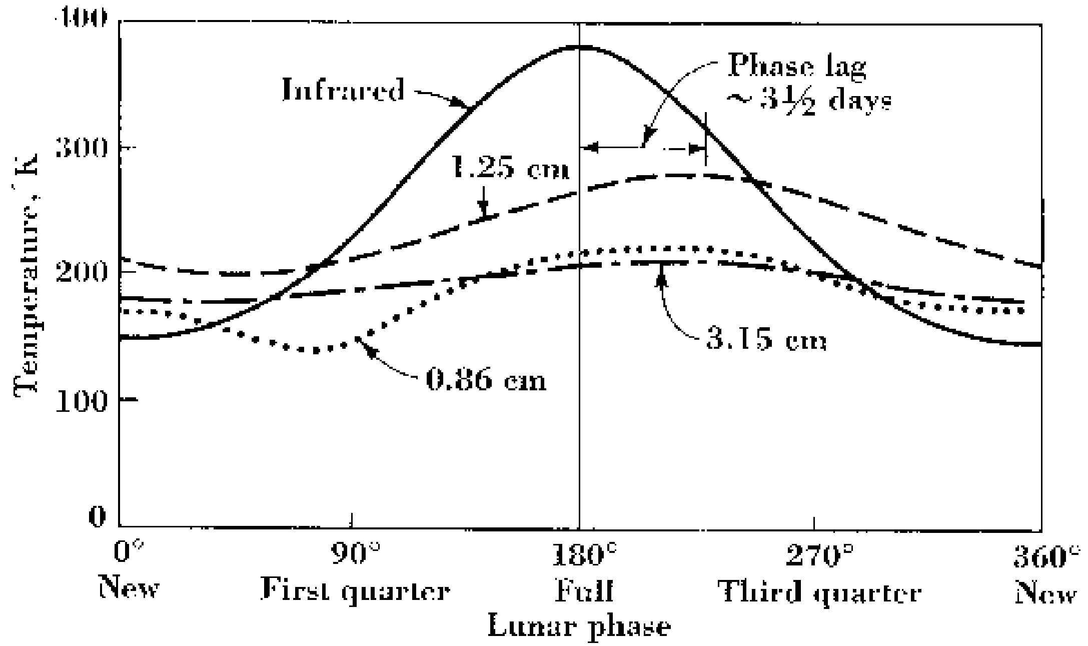


Fig. 8-28. Lunar temperature in degrees Kelvin as a function of lunar phase, showing the temperature variation at infrared wavelengths and at wavelengths of 0.86, 1.25, and 3.15 cm. The temperatures are those of an equivalent blackbody radiator.

Ref: John D. Kraus, Radio Astronomy, McGraw-Hill,1966, pp 339

The Real Challenges

- Doppler
- Spatial Offset
- Atmospheric Absorption
- So when is Perigee?

The Doppler Effect

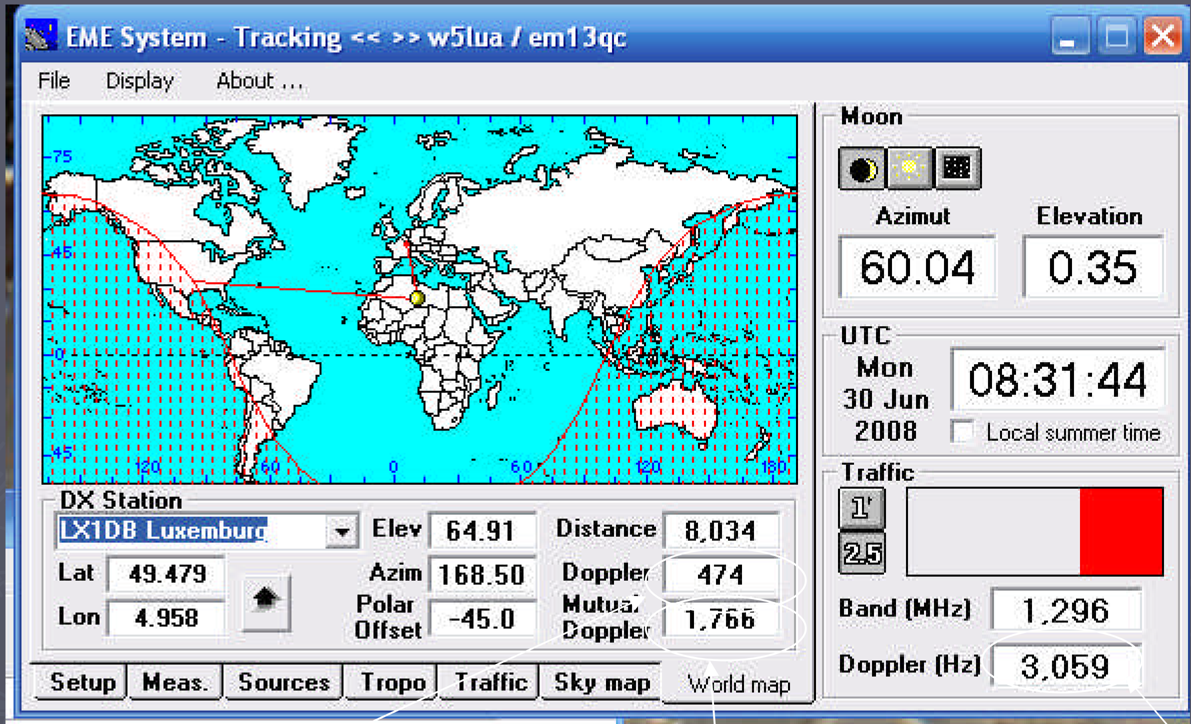
- Doppler effect is the change in frequency of a signal that occurs as a result of the source and the observer moving relative to each other.
- As the source and/or observer are moving closer to each other , the frequency will increase and as the source and/or observer are moving further away from each other the frequency will decrease.
- The doppler effect scales proportionally with frequency

The Doppler Effect

- Since the relative angular velocity of the earth is faster than the orbit of the moon, the doppler is at a maximum at both moon rise and moon set and zero around zenith.
- Therefore… at moon rise the doppler shifted signal will be highest in frequency (positive) gradually decreasing to zero offset from the transmitted frequency at zenith and continuing to decrease to its lowest frequency (negative) at moon set.
- Slight hook effect at the edges of the earth

F1EHN EME Program at W5LUA

Moon rising at W5LUA and near zenith at LX1DB



Self Doppler at LX1DB

Self Doppler at W5LUA

Mutual Doppler

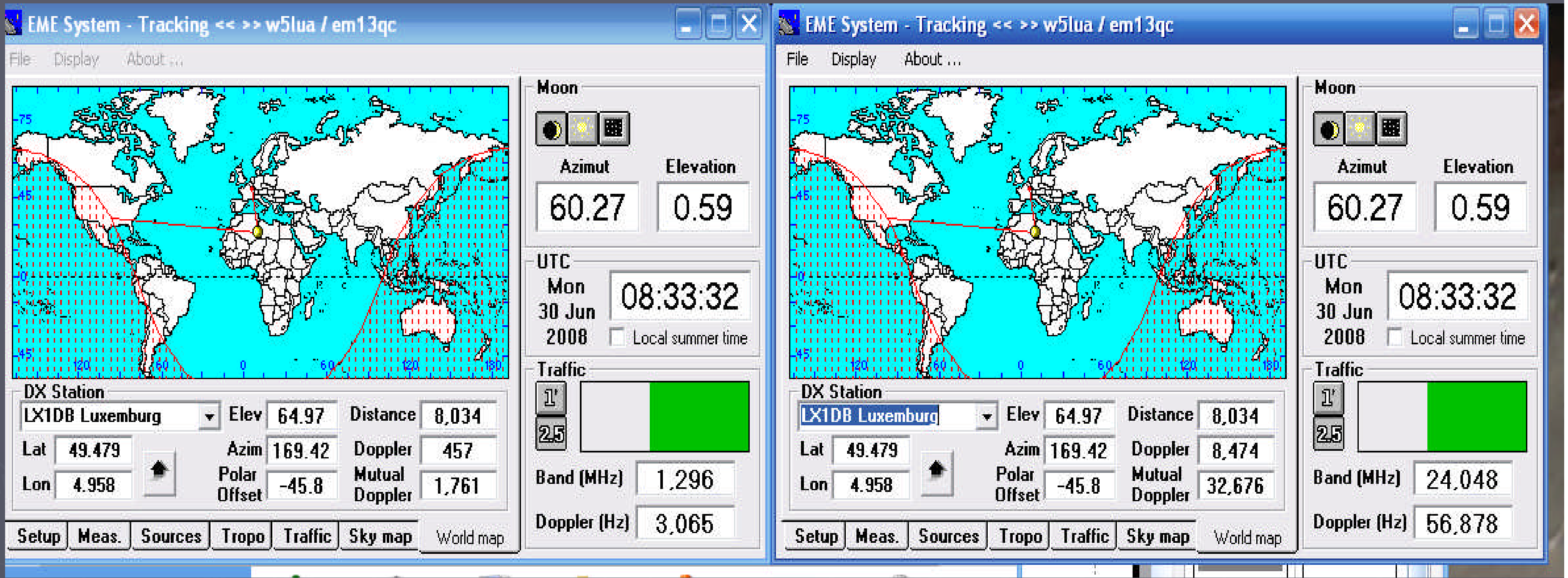
Random Operation on CW

- Random operation on CW is fairly straightforward – simply "net" your echoes on the frequency of the station calling CQ
- Even if you can't hear your own echoes, you know from the "self" doppler where your echoes would be if you could hear them
- More important is the fact that the "bigger" station most likely hear you and he will be tuning pretty close to the frequency at which he hears his own echoes

Random Operation on CW

- Station “A” in North America says he is setting his echoes on say 1296.010 or 10368.100 MHz – For other stations in North America that are very near the same location, other stations will find station “A” very near the “claimed” frequency
- Any station that is a significant distance away from station “A” will find “station “ at a significantly different frequency especially at 10 GHz and higher. This is a result of the “self doppler” being different at different locations, especially when traversing continents
- Solution – Never spot your echo frequency. Simply spot your exact transmit frequency, only then will any station any where (from a known QTH), on any frequency be able to find your signal based on the “mutual” doppler” frequency

Comparison of the Doppler between 1296 and 24048 MHz



Moon Rising at W5LUA and nearly at Zenith at LX1DB

Self Doppler – W5LUA +56.9 kHz, LX1DB +8.5 kHz

If we are both transmitting on 24048.100 MHz, then my echoes will be on .1569 and Willi's will be on .1085

Mutual Doppler is +32.7 kHz and is the same for both of us – What does this mean and how is it calculated?

Scheduled Operation on CW

- Self Doppler – W5LUA +56.9 kHz, LX1DB +8.5 kHz
- If we are both transmitting on 24048.100 MHz, then my echoes will be on .1569 on my dial and Willi's will be on .1085 on his dial
- Mutual Doppler is +32.7 kHz and is the same for both of us
- Mutual Doppler is calculated from the arithmetic mean or average of the individual stations self doppler
- Mutual Doppler =
  (Station #1 Doppler + Station #2 Doppler) / 2
- The mutual doppler frequency is the exact frequency at which Willi and I will both hear each other – therefore we will both hear each other on 24048.1327 MHz
- This also means that Willi will appear to be 56.9 – 32.7 = 24.2 kHz below my echoes on my receiver and I will appear to be 32.7 – 8.5 = 24.2 kHz above his echoes on his receiver
- Therefore when scheduling it is best just to transmit on the "exact" sked frequency and just tune to the "mutual doppler" frequency for the scheduled station – pretty simple….and it still works at 47 GHz!

Doppler Summary

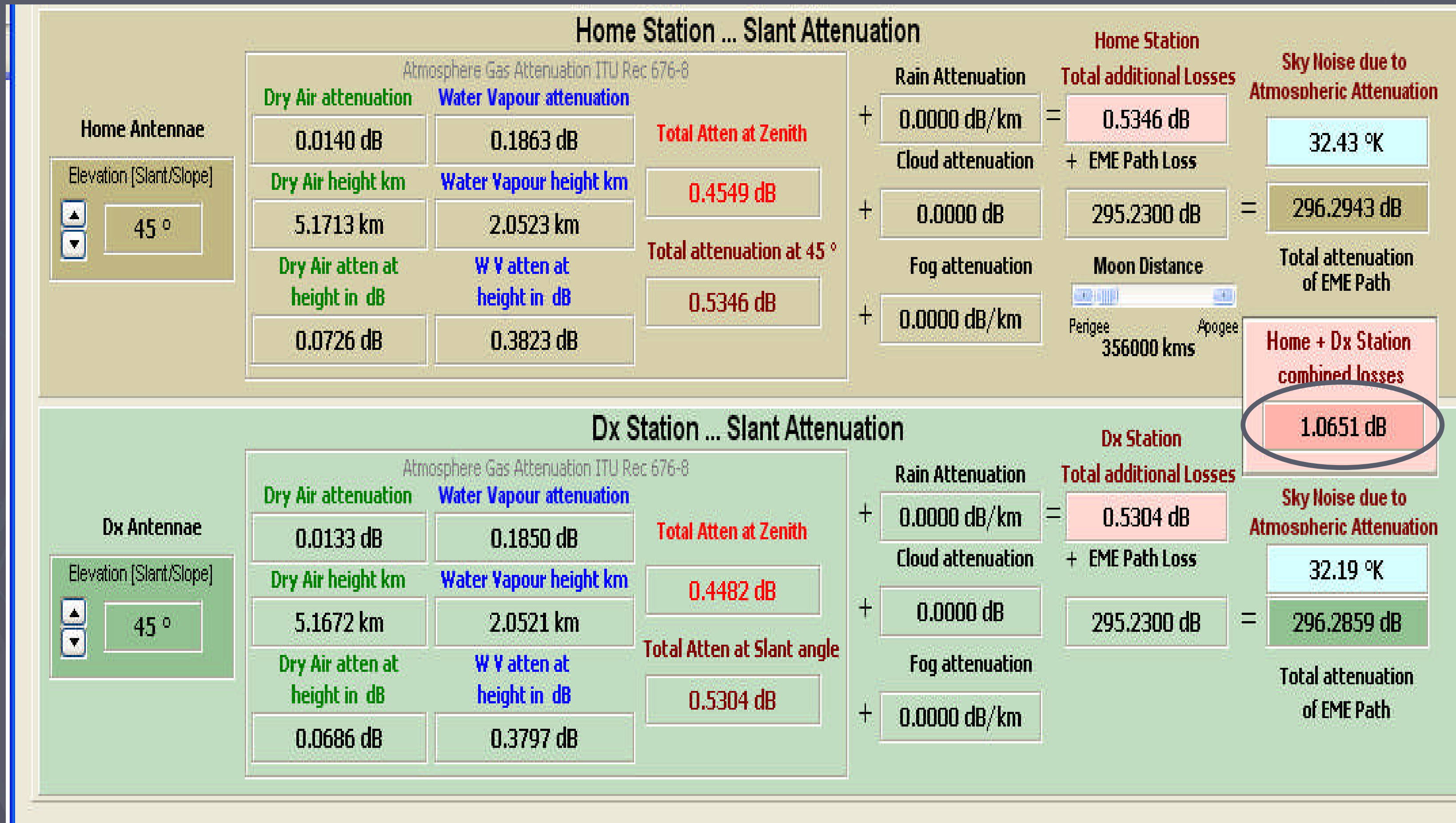
- CW – random, use "self doppler" offset for transmit
- CW – sked, use "mutual doppler" offset on receive and transmit only on schedule frequency

Spatial Offset

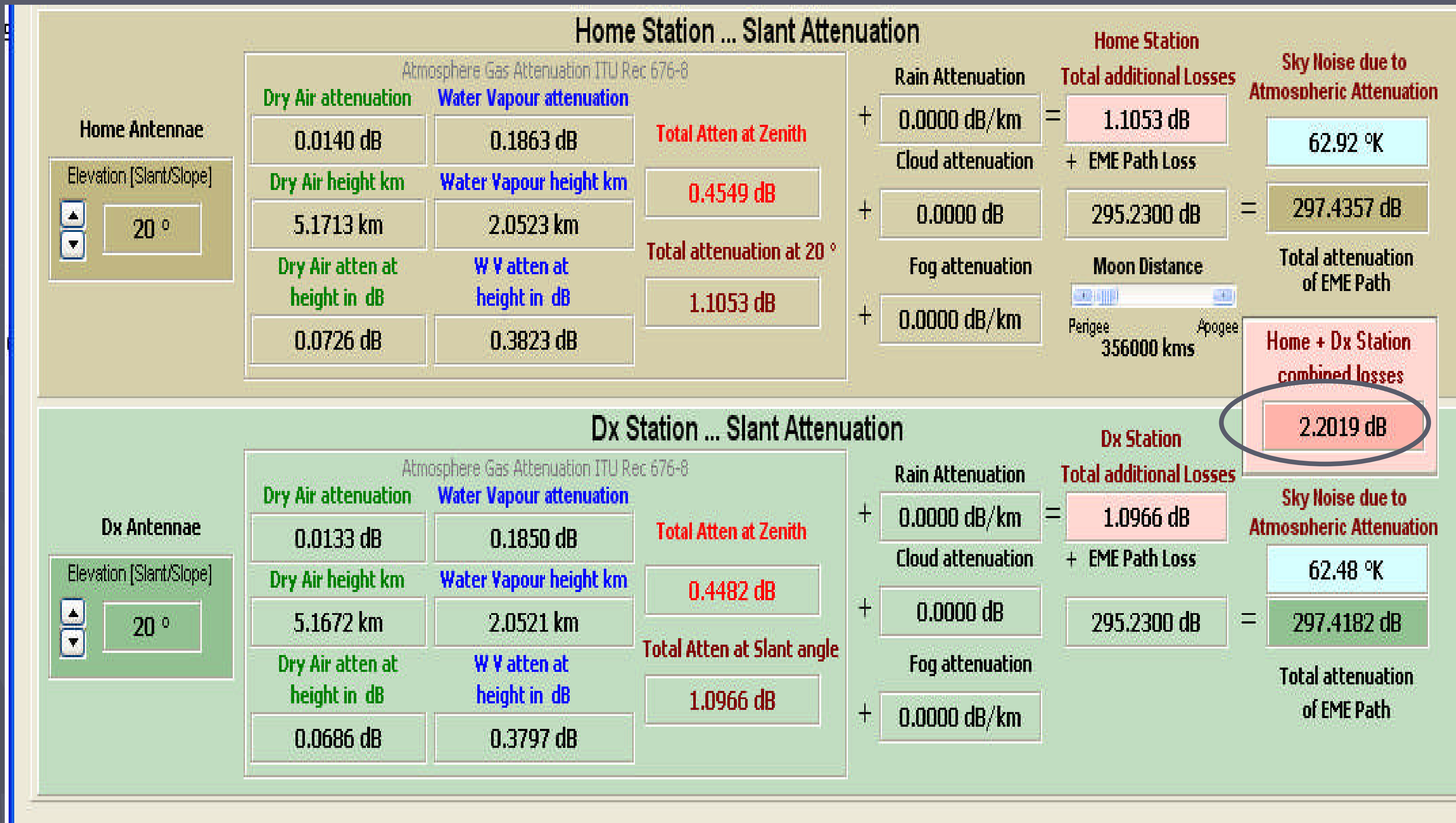
- Spatial offset refers to the signal attenuation due to the rotation of a linearly polarized signal as it is sent to the moon and reflected back to a different spot on the earth.
- The convention at 24 GHz is for everyone to use linear polarization.
- North America uses horizontal polarization
- Europe uses vertical polarization
- Since there is no Faraday rotation at 24 GHz, the only concern is polarity rotation due to the spatial offset on earth
- The spatial offset between NA and Europe is nominally 90 degrees and usually not much of a concern if the above convention is followed.
- The loss due to the spatial offset between different areas of the world can be calculated with several of the EME programs such as the F1EHN, VK3UM and K5GW programs.
- Compensation by rotation of the feedhorn polarity to compensate for spatial offset around the globe will enhance success.

Atmospheric Absorption at 24 GHz

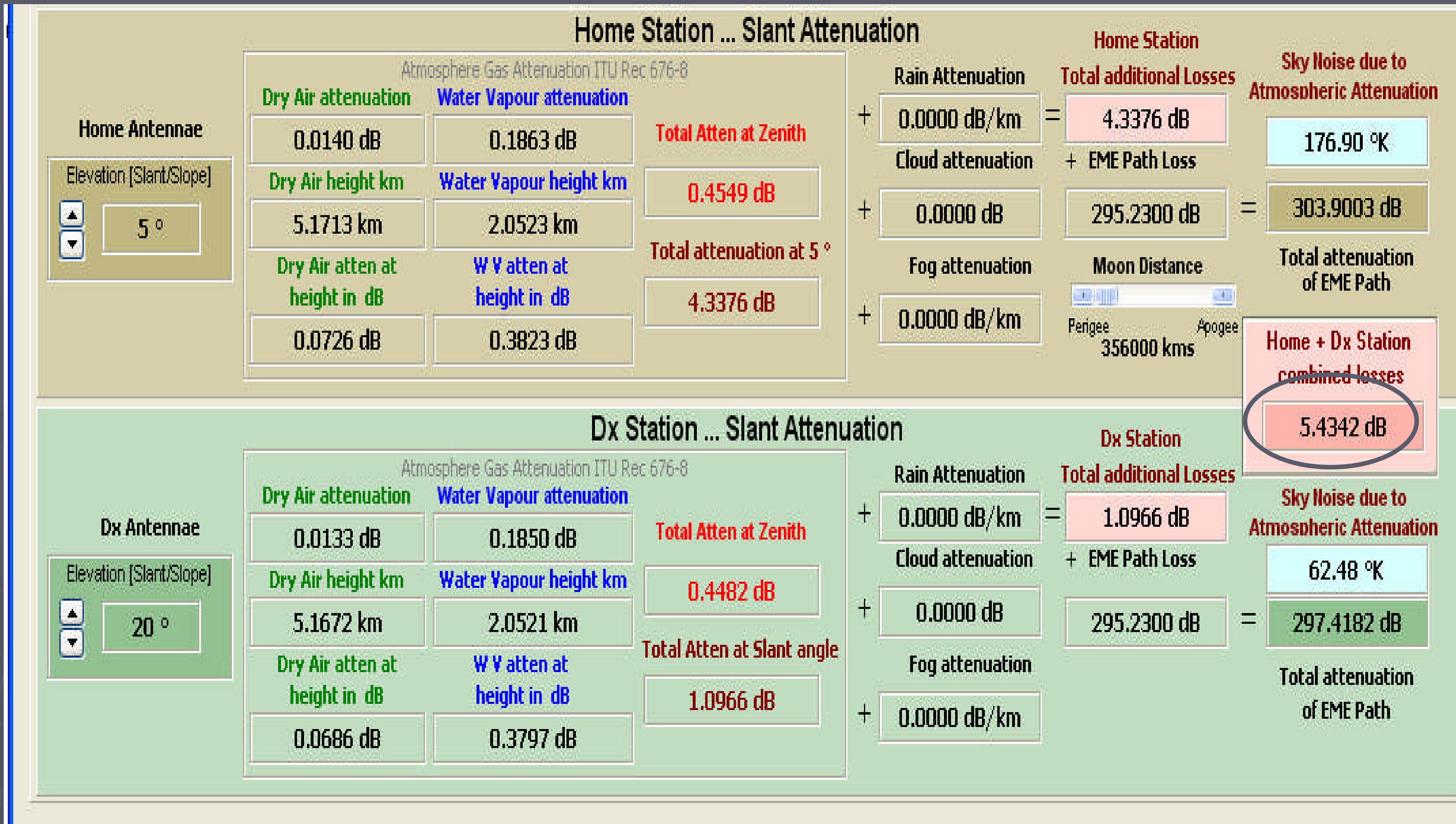
VK3UM Atmosphere Ver 1.18 when both antennas are aimed at 45 degrees elevation



VK3UM Atmosphere Ver 1.18 when both antennas are aimed at 20 degrees elevation



VK3UM Atmosphere Ver 1.18 when 1 antenna is aimed at 20 degrees elevation and the second is aimed at 5 degrees



So Where is Perigee?

- There is nearly a 2 dB difference in path loss between apogee and perigee
- 2 dB can be BIG at 24 GHz!
- Unfortunately for the next several years , perigee occurs very close to maximum southern declination which severally limits common moon time between continents.
- We must wait it out….Maybe 2017

47 GHz EME

- First accomplished back in 2005 by RW3BP, AD6FP, W5LUA & AD6FP
- No known activity since first QSOs

78 GHz EME

- Thanks to WA1MBA's LNA work, W5LUA & VE4MA have measured both sun and moon noise with 1 and 1.2 M dishes
- Transmit power is the next obstacle to overcome.

Summary

- 24 GHz EME can be a challenge of a life time but very well worth the adventure.
- Come check us out on the moon reflectors and the HB9Q logger.
- GL and 73 de Al W5LUA
- Any Questions?

Other 24 GHz EME Stations

RW3BP 2.4 M Offset Fed Dish

LX1DB 3M with 42 W SSPA at Feed

G4NNS

DF1OI 2.4 M Offset Fed Dish with Sub Reflector

OZ1FF 1.8M Offset Fed Dish

IK2RTI