

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

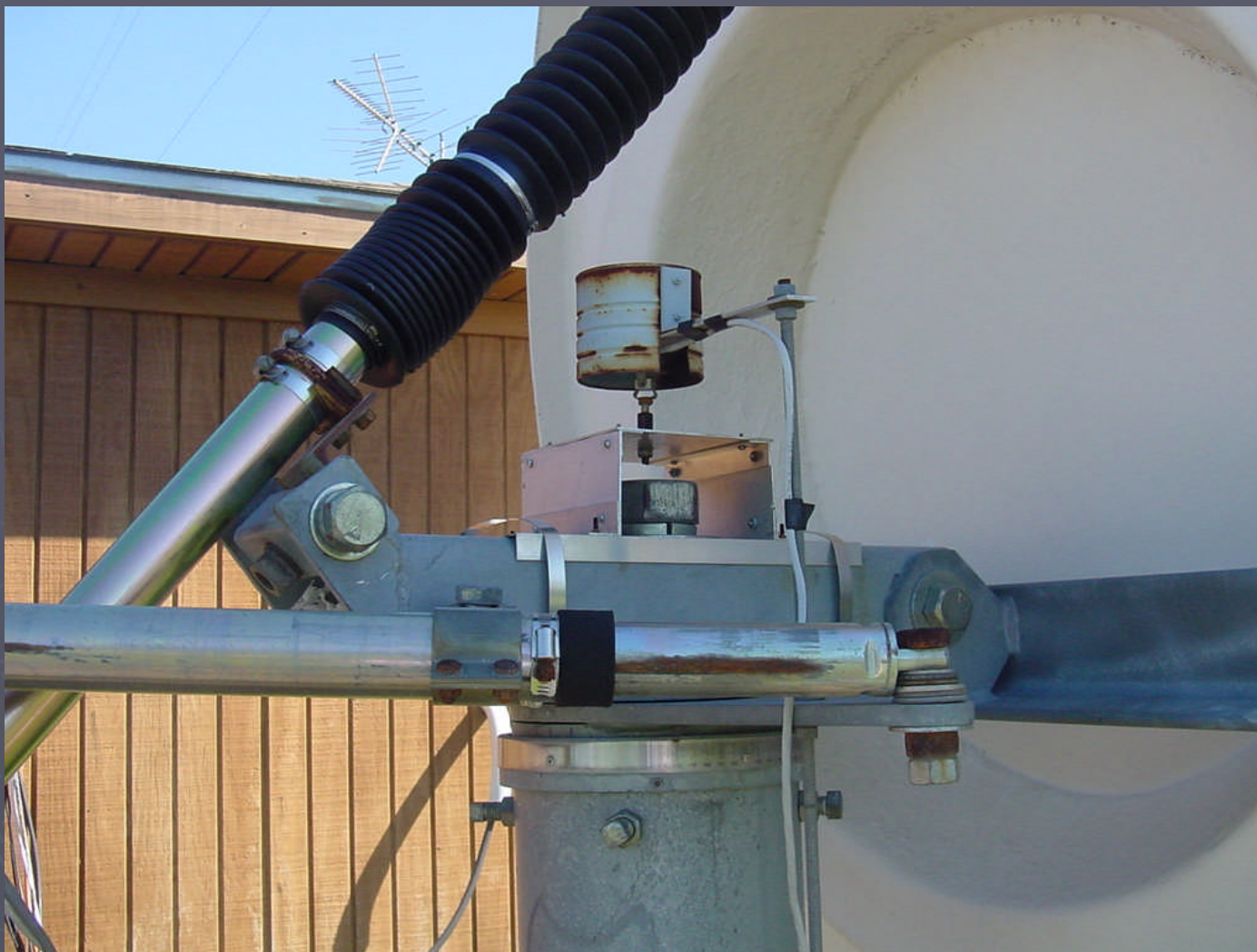
VE4MA 2.4 M Offset Fed Dish



Present 2.4 M Offset Fed Dish at W5LUA



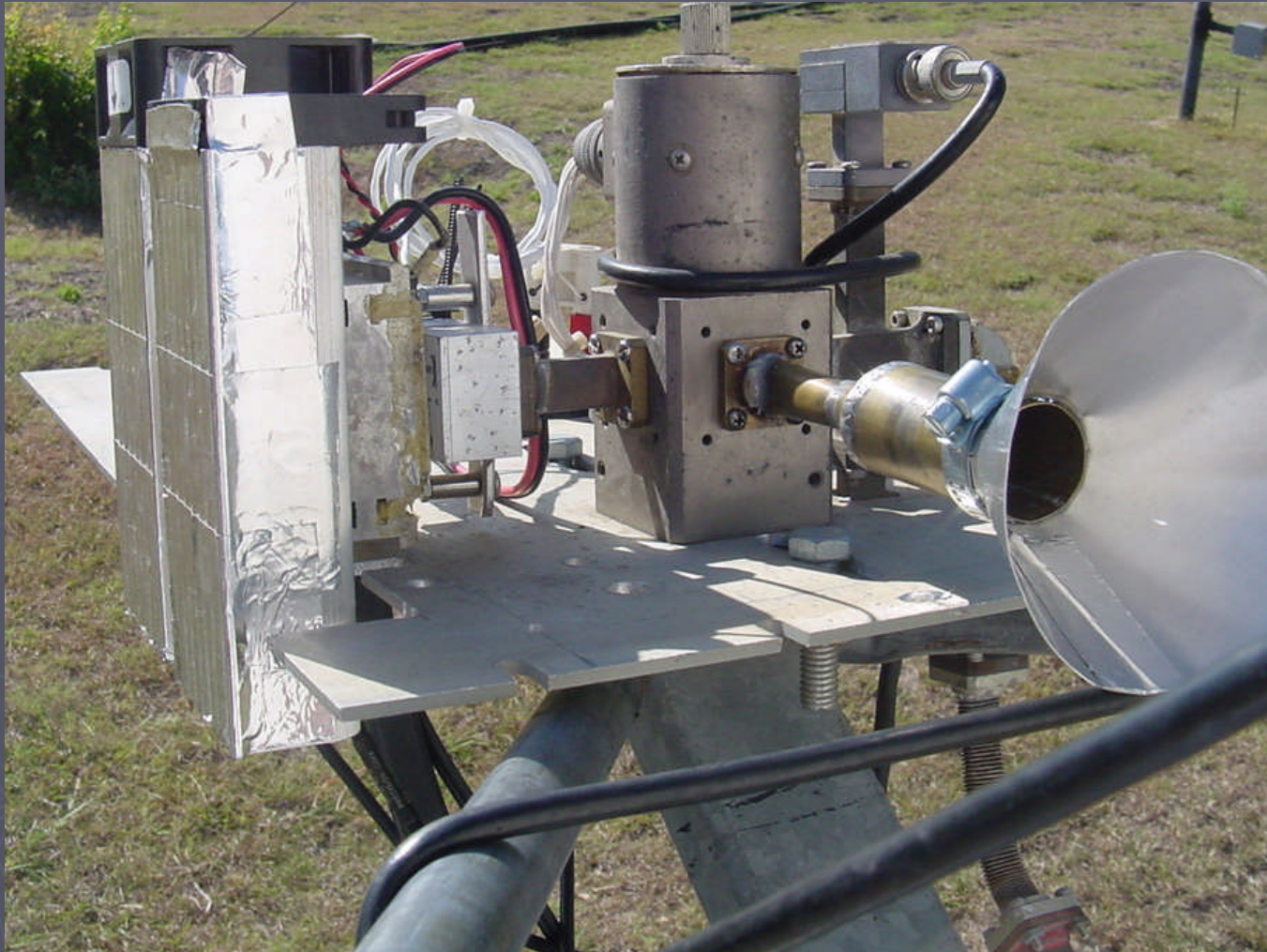
2.4M Az/EI & Az Encoder



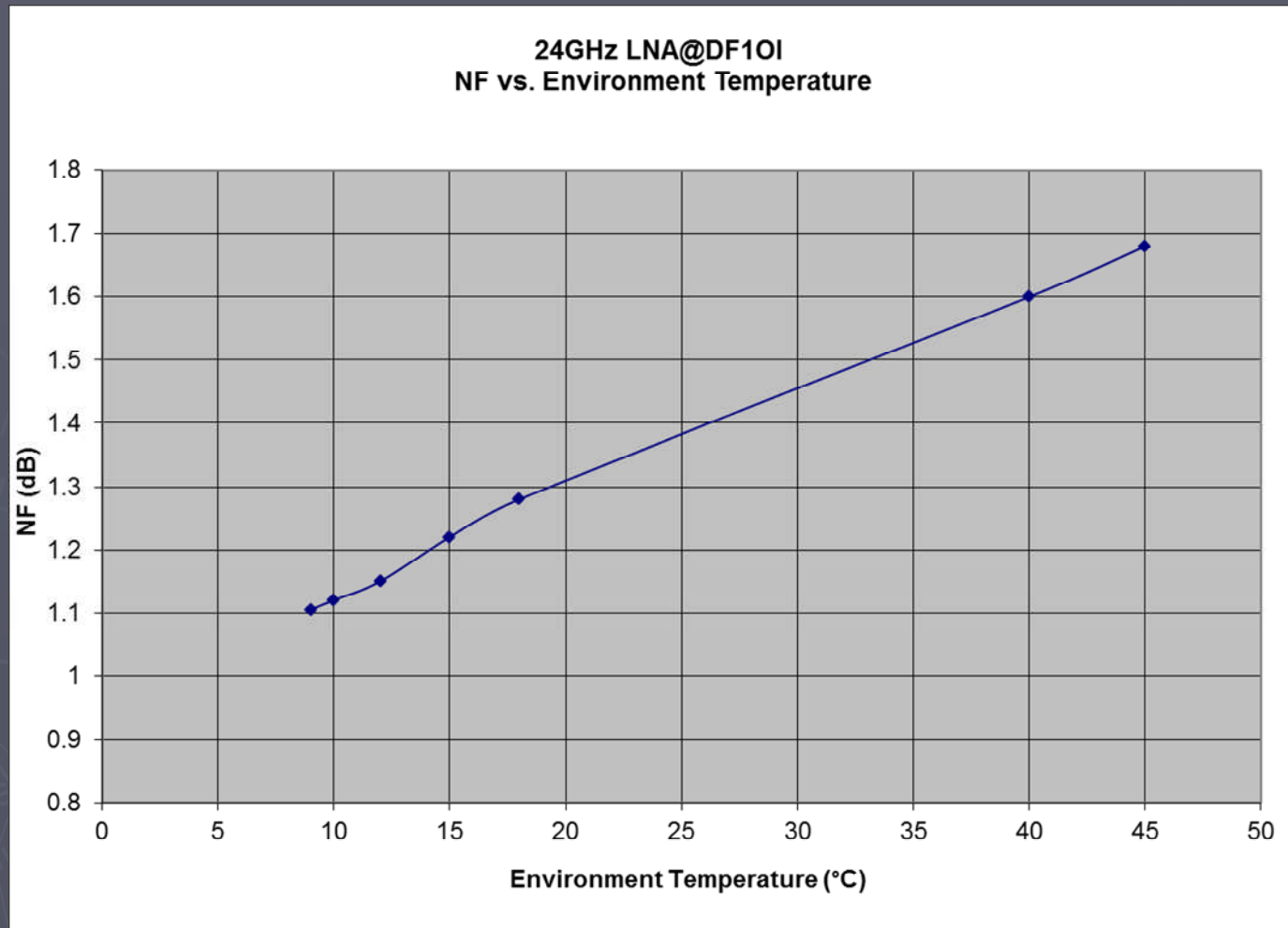
Feed/LNA/Waveguide Relay



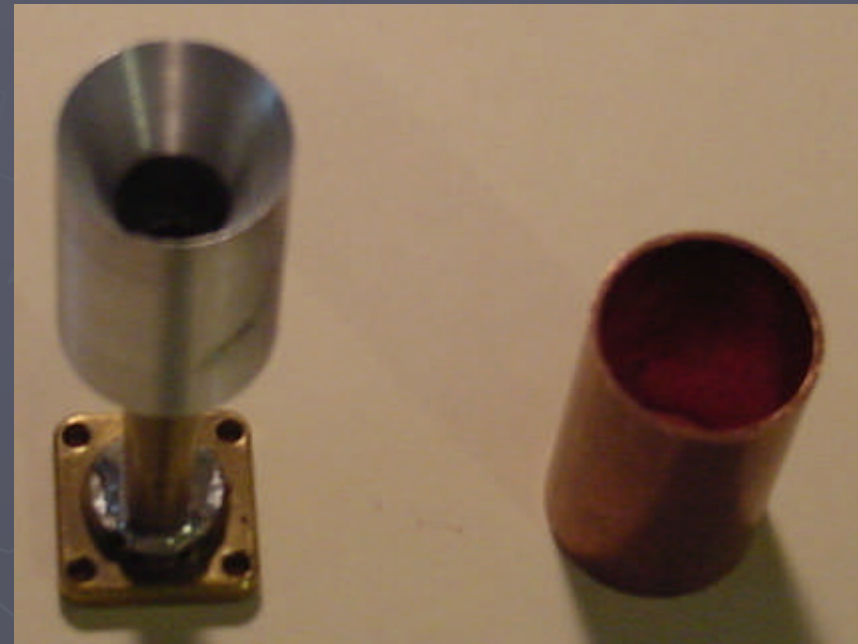
Peltier Cooler for LNA



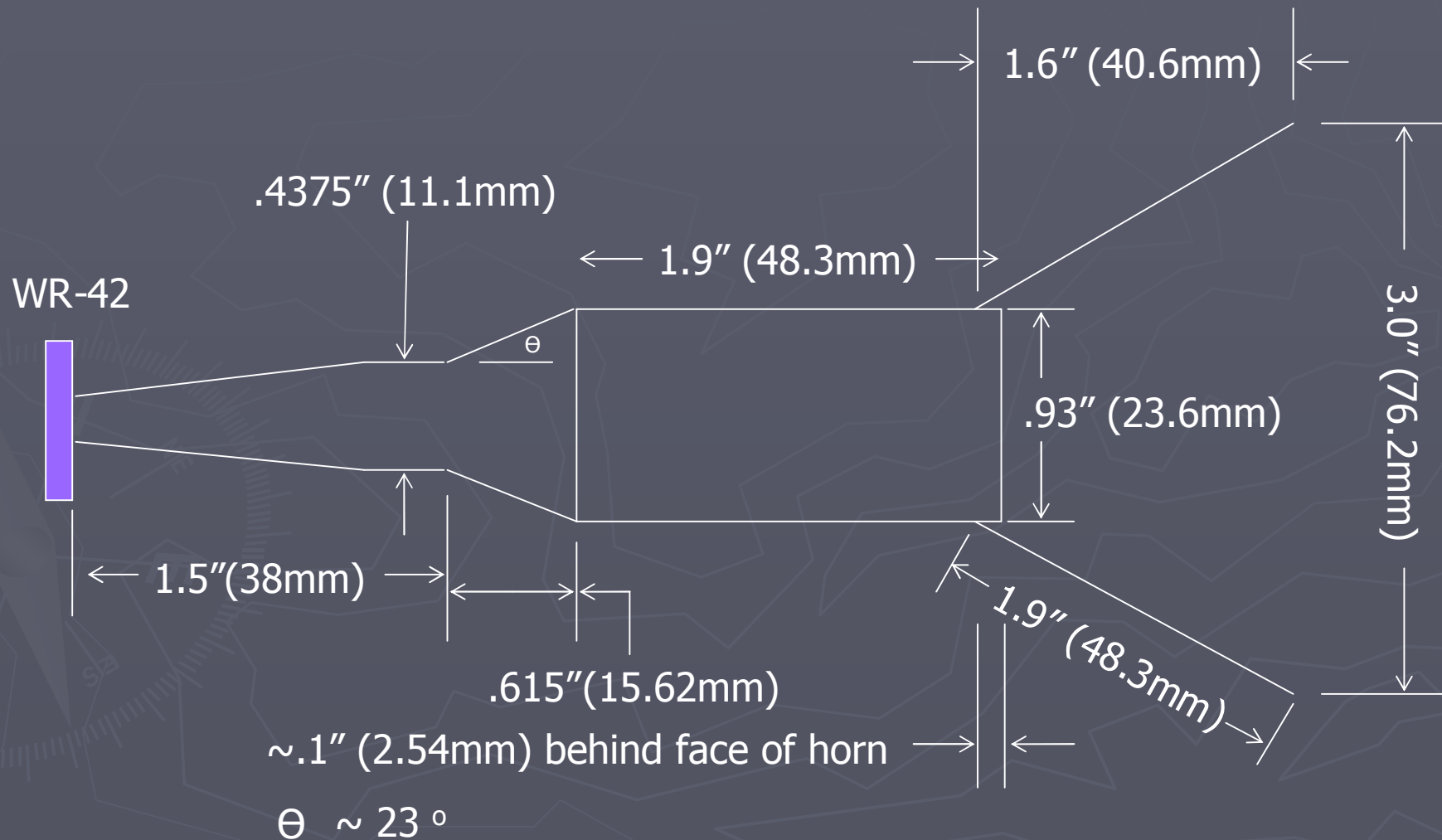
Cooling 24 GHz LNA @ DF10I



Feed Experimentation



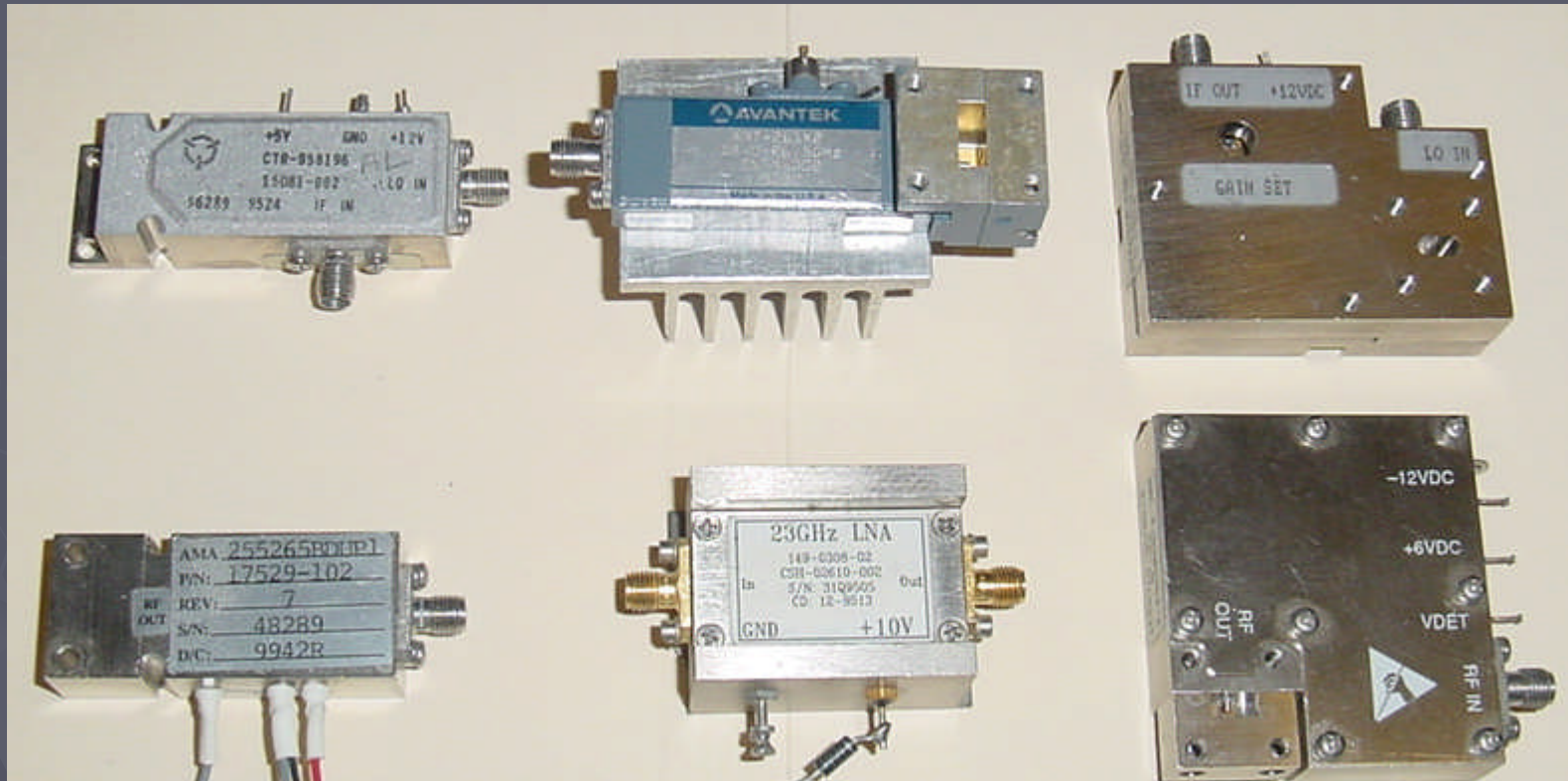
Modified W2IMU 24 GHz feed with flare used by W5LUA on 2.4M offset fed dish with $f/d=.7$



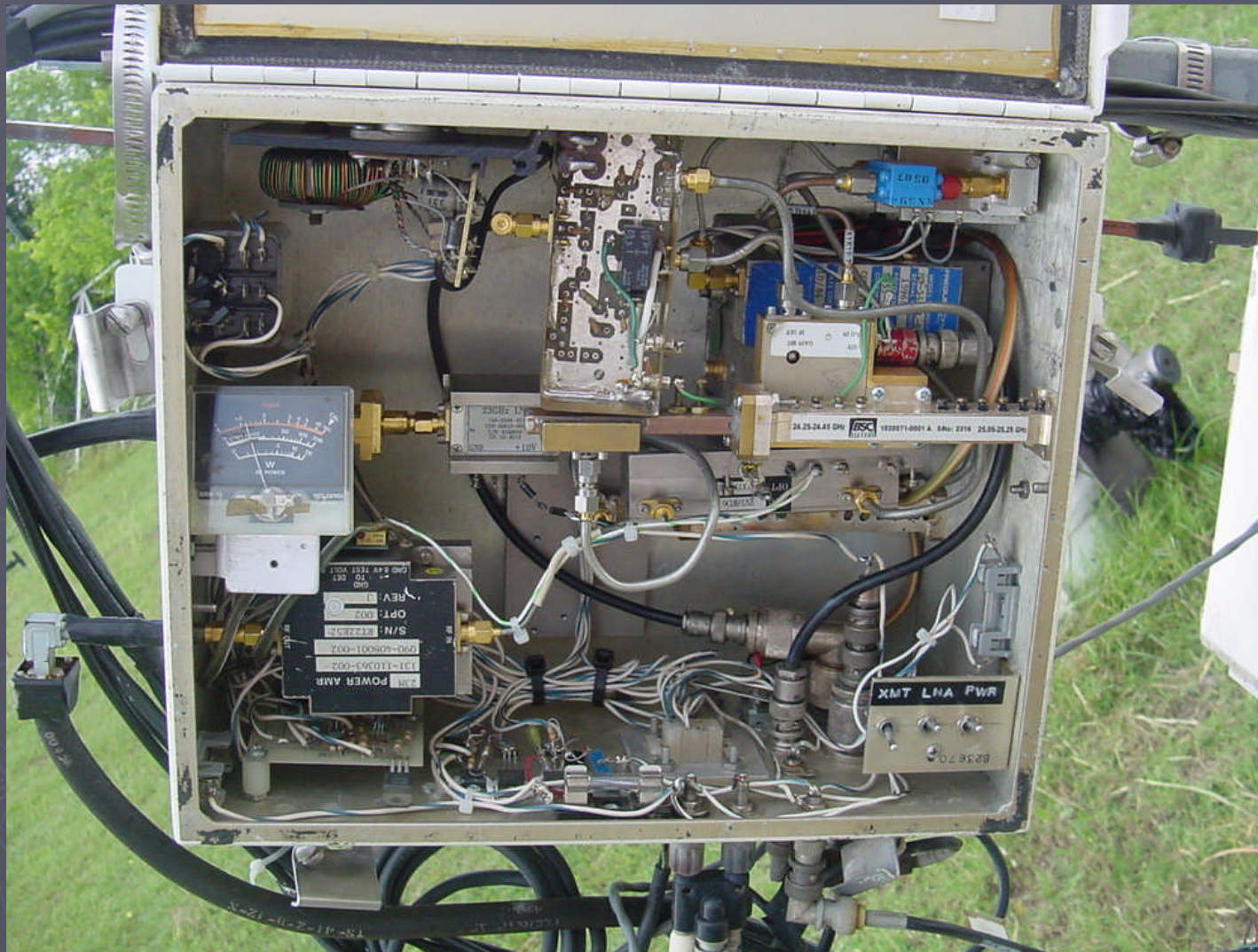
DMC 23 GHz Modules



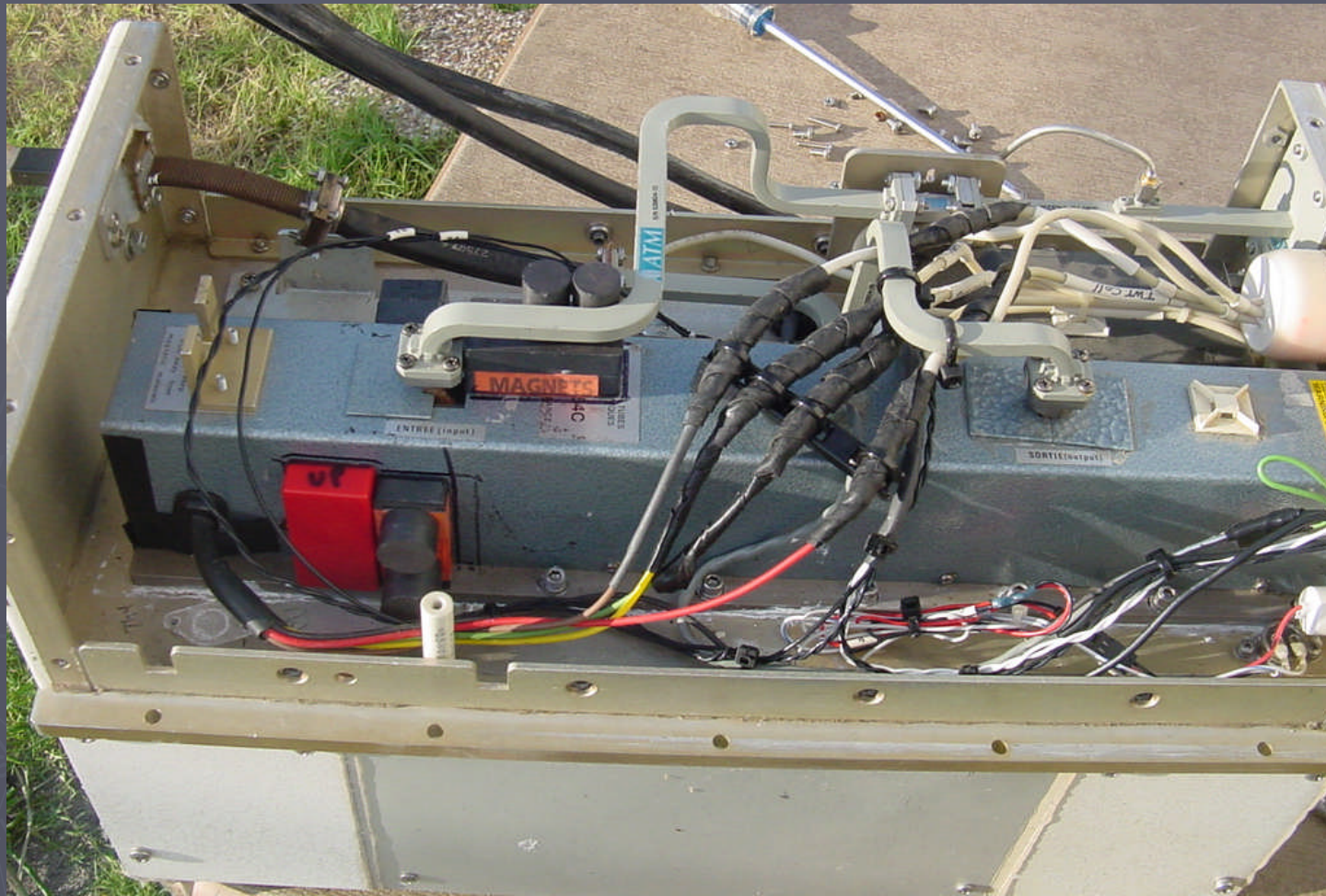
Various other 23 GHz Modules



W5LUA 24048 MHz Transverter



Thompson TH-3864 100 watt TWT with magnet tuning



K5GW Tracking Software

K5GW Tracking program for W5LUA
_ □ X

TIME	DATE	TGT	A/I	AZ	EL	AZC	ELC	DEC	AZ ERROR	EL
05:13:21	08/05/12	MOON	OFF	110.32	28.91	-9.4	-0.2	1.0	-29.84	18.00

ANTENNA	AZIM	ELEV
1296	59.50	87.85
2304	135.03	84.49
3400	134.11	84.42
5760	175.75	86.79
10368	134.36	87.66
24048	80.49	46.92
47088	79.98	47.06
78192	79.98	46.69

Band:	24048MHZ
Doppler:	41109.6
Sky Tem:	2.7
Loss dB:	1.69
Tdeg dB:	1.69
Pol:	38
Lib:	286.9

AUG 05 2012 05:13:21						
SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

MOON	110.32	28.91
SUN	336.19	-36.58
CAS	37.71	46.07
CYG	20.39	81.95
SAG	208.30	21.68
LEO	339.74	-13.00
AQU	121.57	38.76

STATION B DATA	
Call: F2CT	Grid: IN93f1
Lat: 44.81	Lon: 358.87
Az: 233.83	El: 31.19
Dop: -43797	Mdop: -1344
Pol: -55	Mpol: -93
Lib: 305	Mlib: 296

<esc> <E> <T> <L> <M/m> <D/d> <Y/y> <W/w> <H/h> <N/n> <F/f> <O> † -->
 reset exit bnd tgt lib month day year week hour 1min 5min stnB

Optimized Dual Mode F2L x L3.10L

VK3UM EME Performance Calculator

Two Station EME | Receiver Performance | Source Positions | Planets | x 10 Multiplier | Note Pad | Feed Type X ref | Version History | Help | About | Exit

Tx A (Home Station)

Default | Diam: Solid | Mesh: Dish | Spacing: 120 Hz | Sys Sensitivity: -152.2 dBm | Echo S/N: 14.6 dB

Frequency: 24.048 GHz | Path Loss: 295.24 dB | Rx BW: 72 K | Effective ground T°K: 285 °K

Path Loss: 6.8 °K | LNA Loss: 129.2 °K | LNA Nf: 33.0 dB | LNA Gain: 2.0 dB | Coax Loss: 1.0 dB | Rx Nf: 11 °K | Spillover: 0 °K | Feedthrough: 1.2 dB

Solar Flux: 139 | Tx A Output Power: 100 Watts | Transmission Loss: 20.00 dBW | Power at Feed: 100 Watts | Moon Y: 2.23 dB

Rx T°K 139.1 °K = 1.70 dB | Receiver Noise Temperature: 290 °K | 17 °C | Sys T°K 221.1 °K = 2.46 dB | System Noise Temperature

Tx B (Dx Station)

Default | Diam: Solid | Mesh: Dish | Spacing: 50 Hz | Sys Sensitivity: -151.6 dBm | Echo S/N: 4.3 dB

Frequency: 24.048 GHz | Path Loss: 295.24 dB | Rx BW: 72 K | Effective ground T°K: 260 °K

Path Loss: 6.8 °K | LNA Loss: 129.2 °K | LNA Nf: 24.0 dB | LNA Gain: 5.3 dB | Coax Loss: 1.0 dB | Rx Nf: 61 °K | Spillover: 0 °K | Feedthrough: 0.2 dB

Solar Flux: 139 | Tx B Output Power: 20 Watts | Transmission Loss: 13.01 dBW | Power at Feed: 20 Watts | Moon Y: 1.57 dB

Rx T°K 142.8 °K = 1.74 dB | Receiver Noise Temperature: 290 °K | 17 °C | Sys T°K 274.8 °K = 2.90 dB | System Noise Temperature

Yagi Array

Single Yagi Gain in dBi: 12.65 dBi | Number of Yagis: 1 | E: 38.3 ° | Array Gain: 10.50 dBd | H: 38.3 ° | Beam Width: 12.65 dBi

Parabolic Reflector

Feed Type: Opt dual-mode F2L x L3.10L | Linear Pol. | Circular Pol. | Diameter: 2.40 m | Size: Metric | f/D: 0.70 | Efficiency: 66% | Beam Width: 0.36° | Gain: 241537 | Dish Gain: 51.68 dBd | 53.83 dBi | 192.1 Lambda

Home Station ... Y Factor Calc

Noise Flux: 290 °K | Quiet Flux: 72 °K | System Tk: 221.1 °K

Point Source Y Factor: 1.18 dB

Accurate data is not available for this frequency or Noise Source. Approximate data has been used for the calculation.

Yagi Array

Single Yagi Gain in dBi: 17.30 dBi | Number of Yagis: 4 | E: 11.6 ° | Array Gain: 20.85 dBd | H: 11.6 ° | Beam Width: 23.00 dBi

Parabolic Reflector

Feed Type: W2IMU dual-mode | Linear Pol. | Circular Pol. | Diameter: 2.20 m | Size: Metric | f/D: 0.70 | Efficiency: 58% | Beam Width: 0.40° | Gain: 177660 | Dish Gain: 50.35 dBd | 52.50 dBi | 176.5 Lambda

Effective Aperture: 2.99 M² | **Beam Width Ratio**: 1.53

Moon Beam Fill Factor: 2.06 x | **Sun Beam Fill Factor**: 3.14 dB | **G/T Ratio**: 1.98 x | **Moon Temp @ 2.77cm Phase**: 2.97 dB | 1092.49

Moon Radar Equ.: 52.26 dB | **Moon Flux 10⁻²²**: 28.2896 | **Moon Angular Diam**: 0.559° | **Actual Moon Temp**: 213 °K...213.0 °K

Moon Return Loss: 295.24 dB | **Free Space Loss at 24048 MHz**: 356400 kMs | **Corrected sfu**: 231.11 dB | **732**

Save Data | Get Data | Default | Print | Exit

VK3UM Ver 7.04

start | In-box - Microsoft Out... | Microsoft PowerPoint ... | 24GHz_EME_Plus_D - ... | VK3UM EME Performa... | 5:20 PM

Moon Noise vs Lunar Phase

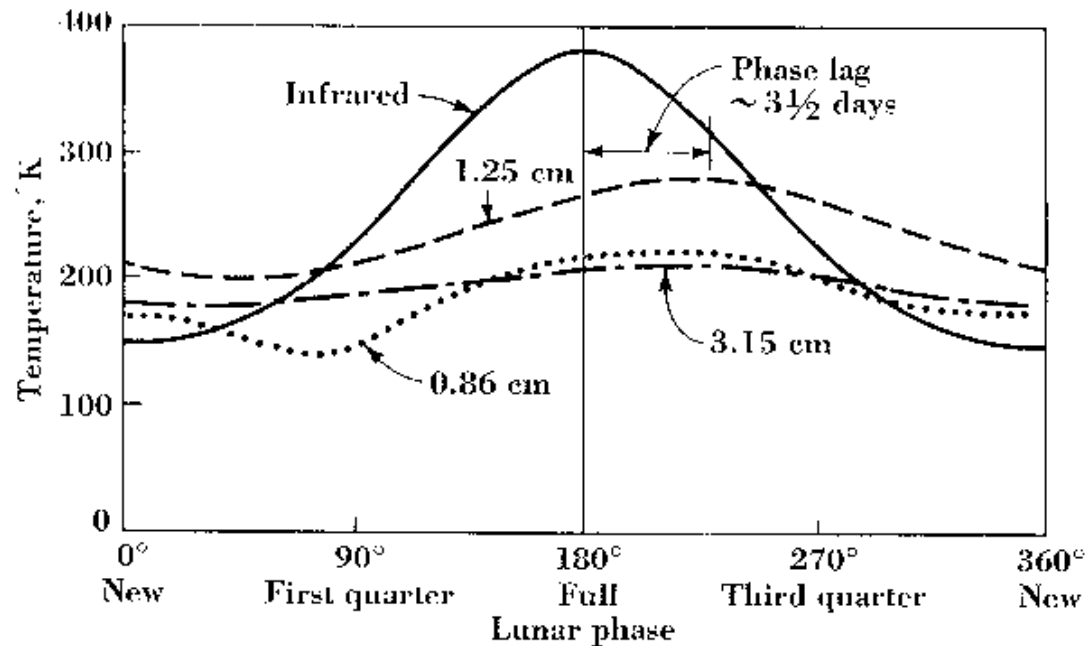


Fig. 3-28. Lunar temperature in degrees Kelvin as a function of lunar phase, showing the temperature variation at infrared wavelengths and at wavelengths of 0.86, 1.25, and 3.15 cm. The temperatures are those of an equivalent blackbody radiator.

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

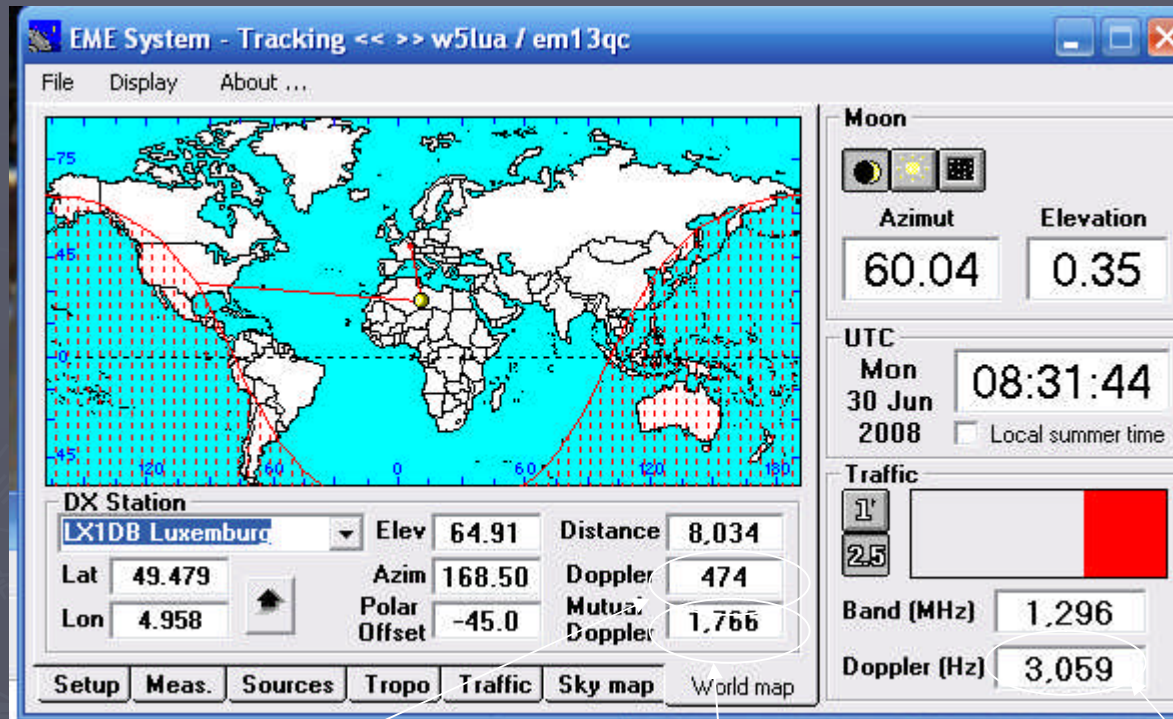
- ▶ Doppler effect is the change in frequency of a signal that occurs as a result of the source and the observer moving relative to each other.
- ▶ As the source and/or observer are moving closer to each other , the frequency will increase and as the source and/or observer are moving further away from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

Mutual Doppler

Self Doppler at W5LUA

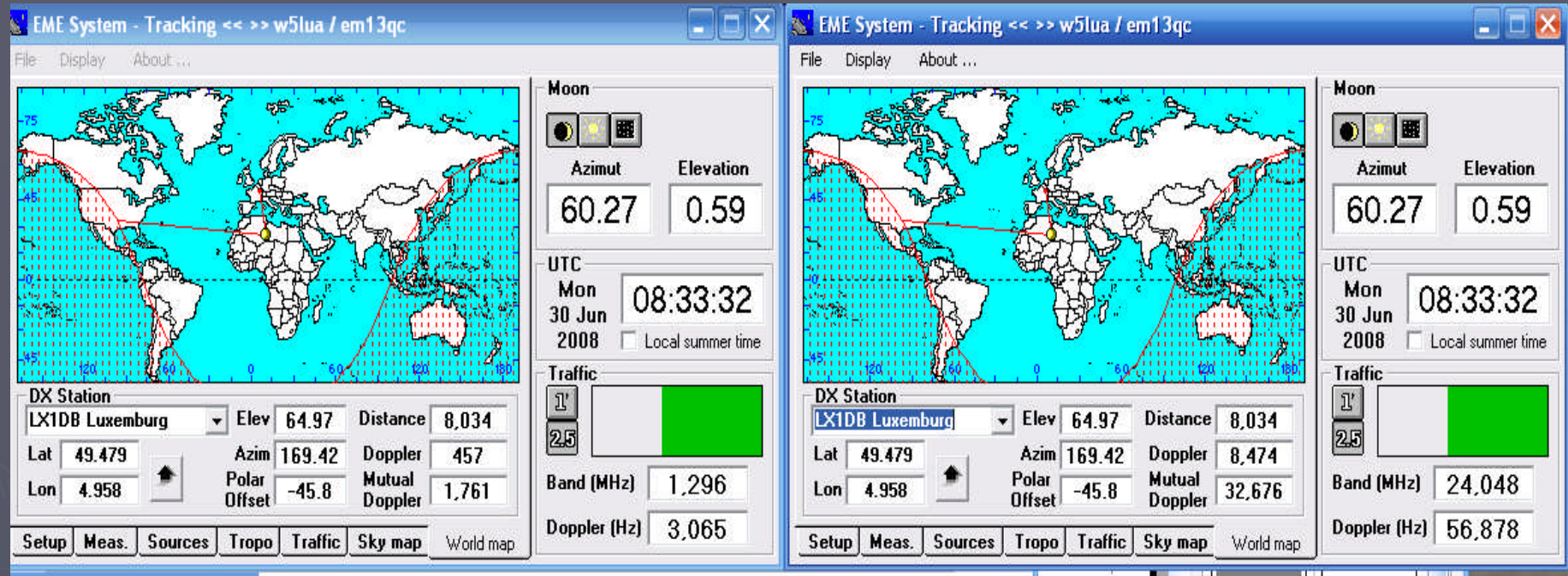
Random Operation on CW

- ▶ 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 =
 $(\text{Station \#1 Doppler} + \text{Station \#2 Doppler}) / 2$
- ▶ 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

Home Station ... Slant Attenuation

Atmosphere Gas Attenuation ITU Rec 676-8

Home Antennae	Dry Air attenuation	Water Vapour attenuation	Total Atten at Zenith			
Elevation [Slant/Slope]	0.0140 dB	0.1863 dB	0.4549 dB			
▲ 45 ° ▼	Dry Air height km	Water Vapour height km		Total attenuation at 45 °		
	5.1713 km	2.0523 km		0.5346 dB		
	Dry Air atten at height in dB	W V atten at height in dB				
	0.0726 dB	0.3823 dB				

	Rain Attenuation		Home Station Total additional Losses		
	0.0000 dB/km	=	0.5346 dB		Sky Noise due to Atmospheric Attenuation
	Cloud attenuation	+	EME Path Loss	=	32.43 °K
	0.0000 dB		295.2300 dB		296.2943 dB
	Fog attenuation		Moon Distance		Total attenuation of EME Path
	0.0000 dB/km		Perigee Apogee 356000 kms		

Dx Station ... Slant Attenuation

Atmosphere Gas Attenuation ITU Rec 676-8

Dx Antennae	Dry Air attenuation	Water Vapour attenuation	Total Atten at Zenith			
Elevation [Slant/Slope]	0.0133 dB	0.1850 dB	0.4482 dB			
▲ 45 ° ▼	Dry Air height km	Water Vapour height km		Total Atten at Slant angle		
	5.1672 km	2.0521 km		0.5304 dB		
	Dry Air atten at height in dB	W V atten at height in dB				
	0.0686 dB	0.3797 dB				

	Rain Attenuation		Dx Station Total additional Losses		
	0.0000 dB/km	=	0.5304 dB		Sky Noise due to Atmospheric Attenuation
	Cloud attenuation	+	EME Path Loss	=	32.19 °K
	0.0000 dB		295.2300 dB		296.2859 dB
	Fog attenuation				Total attenuation of EME Path
	0.0000 dB/km				

Home + Dx Station combined losses

1.0651 dB

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

Home Station ... Slant Attenuation

Atmosphere Gas Attenuation ITU Rec 676-8

Home Antennae	Dry Air attenuation	Water Vapour attenuation	Total Atten at Zenith			
Elevation [Slant/Slope]	0.0140 dB	0.1863 dB	0.4549 dB			
<input type="button" value="▲"/> <input type="button" value="▼"/> 20 °	Dry Air height km	Water Vapour height km	Total attenuation at 20 °			
	5.1713 km	2.0523 km	1.1053 dB			
	Dry Air atten at height in dB	W V atten at height in dB				
	0.0726 dB	0.3823 dB				

Rain Attenuation	+ 0.0000 dB/km	Total additional Losses	= 1.1053 dB		
Cloud attenuation	+ 0.0000 dB	+ EME Path Loss	295.2300 dB	=	297.4357 dB
Fog attenuation	+ 0.0000 dB/km	Moon Distance	<input type="text" value="356000 kms"/>		
		Perigee		Apogee	

		Sky Noise due to Atmospheric Attenuation	62.92 °K		
		Total attenuation of EME Path	297.4357 dB		
		Home + Dx Station combined losses	2.2019 dB		

Dx Station ... Slant Attenuation

Atmosphere Gas Attenuation ITU Rec 676-8

Dx Antennae	Dry Air attenuation	Water Vapour attenuation	Total Atten at Zenith		
Elevation [Slant/Slope]	0.0133 dB	0.1850 dB	0.4482 dB		
<input type="button" value="▲"/> <input type="button" value="▼"/> 20 °	Dry Air height km	Water Vapour height km	Total Atten at Slant angle		
	5.1672 km	2.0521 km	1.0966 dB		
	Dry Air atten at height in dB	W V atten at height in dB			
	0.0686 dB	0.3797 dB			

Rain Attenuation	+ 0.0000 dB/km	Total additional Losses	= 1.0966 dB		
Cloud attenuation	+ 0.0000 dB	+ EME Path Loss	295.2300 dB	=	297.4182 dB
Fog attenuation	+ 0.0000 dB/km				

		Sky Noise due to Atmospheric Attenuation	62.48 °K		
		Total attenuation of EME Path	297.4182 dB		

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

Home Station ... Slant Attenuation

Home Antennae

Elevation [Slant/Slope]

▲ 5 ° ▼

Atmosphere Gas Attenuation ITU Rec 676-8

Dry Air attenuation	Water Vapour attenuation	Total Atten at Zenith
0.0140 dB	0.1863 dB	
Dry Air height km	Water Vapour height km	0.4549 dB
5.1713 km	2.0523 km	Total attenuation at 5 °
Dry Air atten at height in dB	W V atten at height in dB	
0.0726 dB	0.3823 dB	4.3376 dB

Rain Attenuation + 0.0000 dB/km =

Cloud attenuation + 0.0000 dB =

Fog attenuation + 0.0000 dB/km =

Home Station

Total additional Losses = 4.3376 dB

+ EME Path Loss = 295.2300 dB =

Moon Distance = 356000 kms

Perigee Apogee

Sky Noise due to Atmospheric Attenuation = 176.90 °K

Total attenuation of EME Path = 303.9003 dB

Dx Station ... Slant Attenuation

Dx Antennae

Elevation [Slant/Slope]

▲ 20 ° ▼

Atmosphere Gas Attenuation ITU Rec 676-8

Dry Air attenuation	Water Vapour attenuation	Total Atten at Zenith
0.0133 dB	0.1850 dB	
Dry Air height km	Water Vapour height km	0.4482 dB
5.1672 km	2.0521 km	Total Atten at Slant angle
Dry Air atten at height in dB	W V atten at height in dB	
0.0686 dB	0.3797 dB	1.0966 dB

Rain Attenuation + 0.0000 dB/km =

Cloud attenuation + 0.0000 dB =

Fog attenuation + 0.0000 dB/km =

Dx Station

Total additional Losses = 1.0966 dB

+ EME Path Loss = 295.2300 dB =

Sky Noise due to Atmospheric Attenuation = 62.48 °K

Total attenuation of EME Path = 297.4182 dB

Home + Dx Station combined losses = 5.4342 dB

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 AI W5LUA
- ▶ Any Questions?

Other 24 GHz EME Stations



RW3BP 2.4 M Offset Fed Dish



LX1DB 3M with 42 W SSPA at Feed



G4NNS



DF10I 2.4 M Offset Fed Dish with Sub Reflector



OZ1FF 1.8M Offset Fed Dish



IK2RTI

