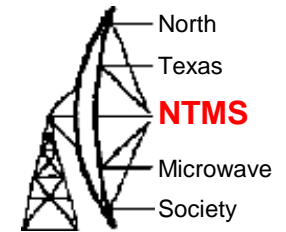


Earth-Moon-Earth (EME) Communications from 902 MHz to 78 GHz

by
Al Ward W5LUA

presented at
HAMCOM
June 10th, 2011

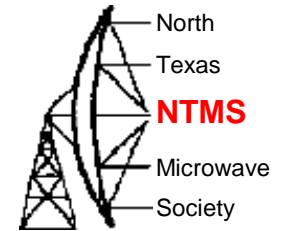
The Microwave Bands



Band	Frequency Range	Weak signal work in NA
33 cm	902 to 928 MHz	902 MHz
23 cm	1240 to 1300 MHz	1296 MHz
13 cm	2300 to 2310 MHz	2304 MHz (2301, 2320 and 2424 MHz used outside NA)
	2390 to 2450 MHz	
9 cm	3300 to 3500 MHz	3456 MHz (3400 MHz used for EME)
6 cm	5650 to 5925 MHz	5760 MHz
3 cm	10000 to 10500 MHz	10368 MHz (10450 MHz used by JA)
1.25cm	24000 to 24250 MHz	24192 MHz (24048 MHz used for EME)
.6 cm	47000 to 47200 MHz	47088 MHz
.35 cm	77000 to 81000 MHz	78192 MHz

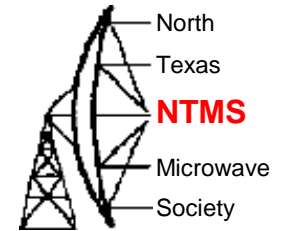
The problem...Not all countries have same allocation as us.....

How long have hams been doing EME on the upper bands?



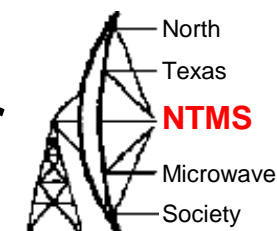
- First 902 MHz EME QSO on January 22, 1988 between K5JL and WA5ETV
- First 1296 MHz EME QSO in 1960 between W1BU and W6HB
- First 2304 MHz EME QSO in 1970 between W4HHK and W3GKP
- First 3456 MHz EME QSO on April 7, 1987 between W7CNK and KD5RO
- First 5760 MHz EME QSO on April 24, 1987 between W7CNK and WA5TNY
- First 10368 MHz EME QSO on August 27, 1988 between WA7CJO and WA5VJB
- First 24192 MHz EME QSO on August 18, 2000 between W5LUA and VE4MA
- First 47088 MHz EME QSO in January 2005 between RW3BP and AD6FP
- First 78192 MHz EME QSO TBD but being actively pursued by VE4MA and W5LUA – 2012?

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!

VK3UM EME Performance Calculator



VK3UM EME Performance Calculator

Two Station EME | Receiver Performance | Source Positions | Planets | x 10 Multiplier | Note Pad | Help | About | Exit

Tx A (Home Station) Default

Frequency: 2304 MHz | Path Loss: 274.87 dB | T Sky: 5 K | Rx BW: 120 Hz | Diam: 1.00 mm | Mesh: 1.8 mm | Spacing: 1.8 mm | Sys Sensitivity: 159.7 dBm | Echo SNR: 15.4 dB

GET IPS SPT DATA << Your last spt data record has been loaded >>

Effective ground TK 274 K | C/S - ground -> 5.5 dB

Solar Flux: 72 | LNA Loss: 0.10 dB | LNA NF: 0.40 dB | LNA Gain: 33.0 dB | Coax Loss: 2.0 dB | Rx NF: 1.0 dB | Spillover: 24.6 K | Feedthru: 0.0 K | Sun Y: 15.0 dB

Tx A Output Power: 200 Watts | Transmission Loss: 23.01 dBW | Power at Feed: 200 Watts | 23.01 dBW | 1,500,307 W EIRP

Rx T*K 35.5 K = 0.50 dB | Receiver Noise Temperature: 290 K | 17 °C | Sys T*K 65.1 K = 0.88 dB | System Noise Temperature

Dx Station as received at Home Station ... 0.3 dB

Home Station as received at Dx Station ... 6.5 dB

Moon Distance: Perigee: 356400 kms | Apogee: 405400 kms

Tx B (Dx Station) Default

Frequency: 2304 MHz | Path Loss: 274.87 dB | T Sky: 5 K | Rx BW: 50 Hz | Diam: 1.00 mm | Mesh: 12.7 mm | Spacing: 12.7 mm | Sys Sensitivity: 160.9 dBm | Echo SNR: 2.6 dB

GET IPS SPT DATA << Your last spt data record has been loaded >>

Effective ground TK 251 K | C/S - ground -> 3.9 dB

Solar Flux: 72 | LNA Loss: 0.13 dB | LNA NF: 0.50 dB | LNA Gain: 24.0 dB | Coax Loss: 5.3 dB | Rx NF: 1.0 dB | Spillover: 44.6 K | Feedthru: 19.6 K | Sun Y: 7.0 dB

Tx B Output Power: 00 Watts | Transmission Loss: 19.03 dBW | Power at Feed: 04 Watts | 10.03 dBW | 33,202 W EIRP

Rx T*K 49.2 K = 0.68 dB | Receiver Noise Temperature: 290 K | 17 °C | Sys T*K 118.3 K = 1.49 dB | System Noise Temperature

Operating Frequency

50 MHz | 432 MHz | 2304 MHz | 10.368 GHz | 70 MHz | 144 MHz | 900 MHz | 3456 MHz | 24.048 GHz | 406 MHz | 222 MHz | 1296 MHz | 5760 MHz | 47.000 GHz | 2235 MHz

Yagi Array Number of Yagis: 1 | E: 38.3° | Array Gain: 10.50 dBd | 12.65 dBi | Beam Width: 30.3°

Parabolic Reflector Feed Type: Septum (with choke ring) | Linear Pol: ☐ | Circular Pol: ☒ | Diameter: 5.0 m | Size: Metric | f/D: 0.37 | Efficiency: 73% | Beam Width: 1.84° | Gain: 7542 | Dish Gain: 36.62 dBd | 38.77 dBi

Home Station ... Y Factor Calc

Noise Source: Sagittarius | Cassiopeia | Cygnus | Taurus A | Virgo | Termination | Quiet Source: Termination | Aquarius | Leo | Taurus

Noise Flux: 290 K | Quiet Flux: 5 K | System Tk: 65.1 K | Point Source Y Factor: 6.49 dB

Aperture Source Y Factor calculations are only provided for 144 and 432 MHz

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

Parabolic Reflector Feed Type: VE4MA (Super) | Linear Pol: ☐ | Circular Pol: ☒ | Diameter: 2.0 m | Size: Metric | f/D: 0.43 | Efficiency: 63% | Beam Width: 4.55° | Gain: 1467 | Dish Gain: 29.51 dBd | 31.66 dBi

Effective Aperture: 10.16 m² | Beam Width Ratio: 0.30 | Note... Both Moon and Sun correction factors are applied to Home and Dx Station calculations. G/T Ratio: 115.83 | Moon Temp: 222 K

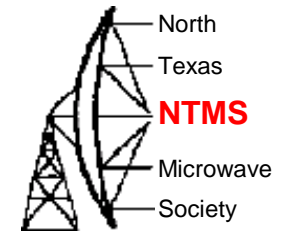
Moon Beam Fill Factor: 1.03 x | 0.14 dB | Sun Beam Fill Factor: 1.03 x | 0.13 dB | Moon Radar Equ: 52.26 dB | Moon Flux 10-22: 0.2039 | Moon Angular Diam: 00° 33.50" | Corrected spt: 67

Moon Return Loss: 274.87 dB | 356400 kms | Free Space Loss at 2304 MHz: 210.74 dB | kms

Save Data | Get Data | Default | Print | Exit

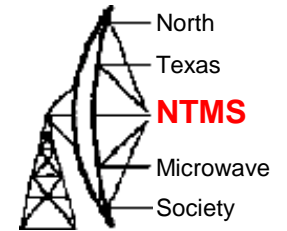
VK3UM Ver 6.01

Doppler



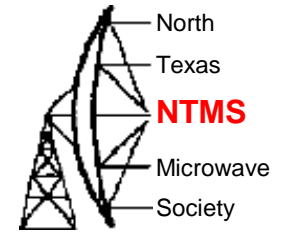
- The doppler shift is a change in frequency of the signal reflected off the moon and received back on earth.
- Doppler scales with frequency and is an indication of the relative motion of the moon with respect to the earth.
- When the moon is rising the doppler will be positive and when the moon is 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.
- 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

Faraday Rotation



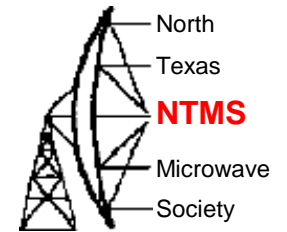
- According to Skolnik's Radar handbook.. "The Faraday rotation of the plane of polarization can be 2 to 5 revolutions in the UHF range, but since it scales as $1/f^2$, is negligible at and above L band" L band is defined in Skolnik as 1000 MHz to 2000 MHz and UHF is defined as 300 to 1000 MHz
- If we scale from 144 to 432 MHz the effect is 1/9
- If we scale from 432 to 1296 MHz it is another 1/9
- 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 so....
- In terms of what we hear, does this scale the time in between max and min signal strength or the level in dB between max and min or both?
- Most likely it is scaling the amount of rotation of a linear polarized signal and decreases significantly at 902 MHz and higher

The transition from 1296 to 2304 MHz



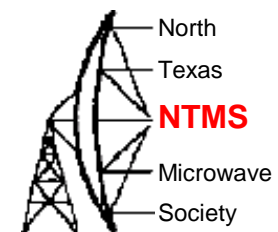
- Noise figures are very comparable – most sub 0.4 dB.
- Power levels of 200 watts are easily obtainable at 2304 MHz and can be more easily mounted at the feed offering a bonus on 2304 over 1296 – minimal feedline loss.
- Very efficient feeds from OK1DFC, RA3AQ and WD5AGO
- Easier to track the moon because now we are able to see moon noise – why is this?
- VK3UM program to analyze path loss

Bottom Line

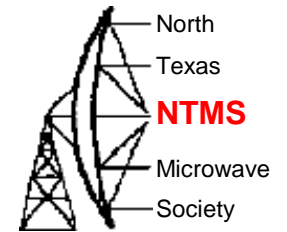


- With similar equipment on 13 cm and the same size dish, the echoes will be nearly 5 dB stronger on 2304 MHz than they were on 1296 MHz plus we can now track the moon better because we can now see noticeable moon noise
- And it gets even better as we go higher in frequency!

WD5AGO 8ft Dish for 2304 MHz



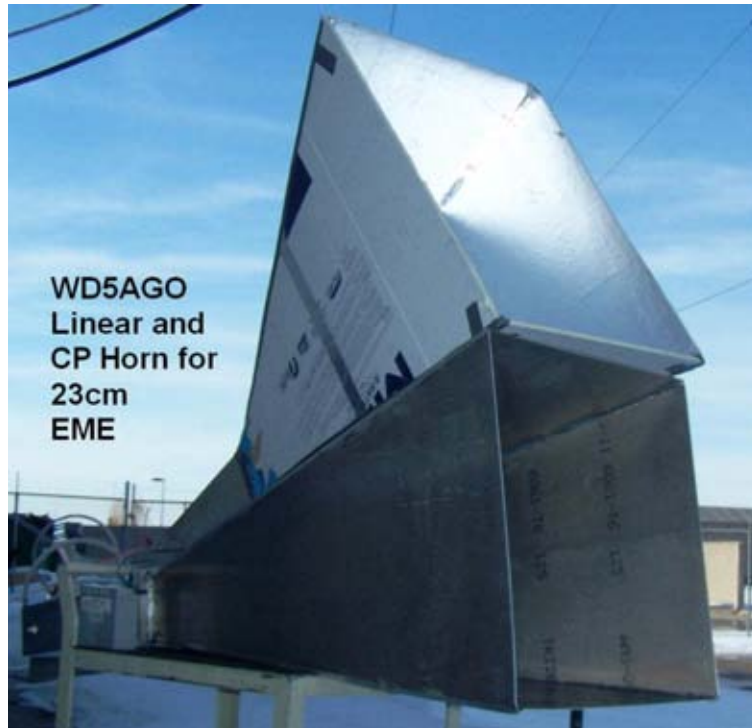
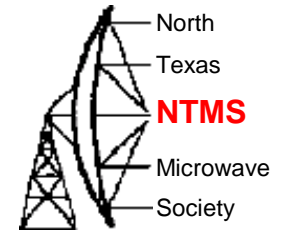
WD5AGO 3.1M Expanded TVRO Dish



Tommy uses this dish on 1296, 2304 and 5760 MHz from Tulsa, OK.

Tommy has done a lot of work on optimizing feed horns and LNAs

WD5AGO & Student using a Horn to make EME QSOs on 1296 MHz

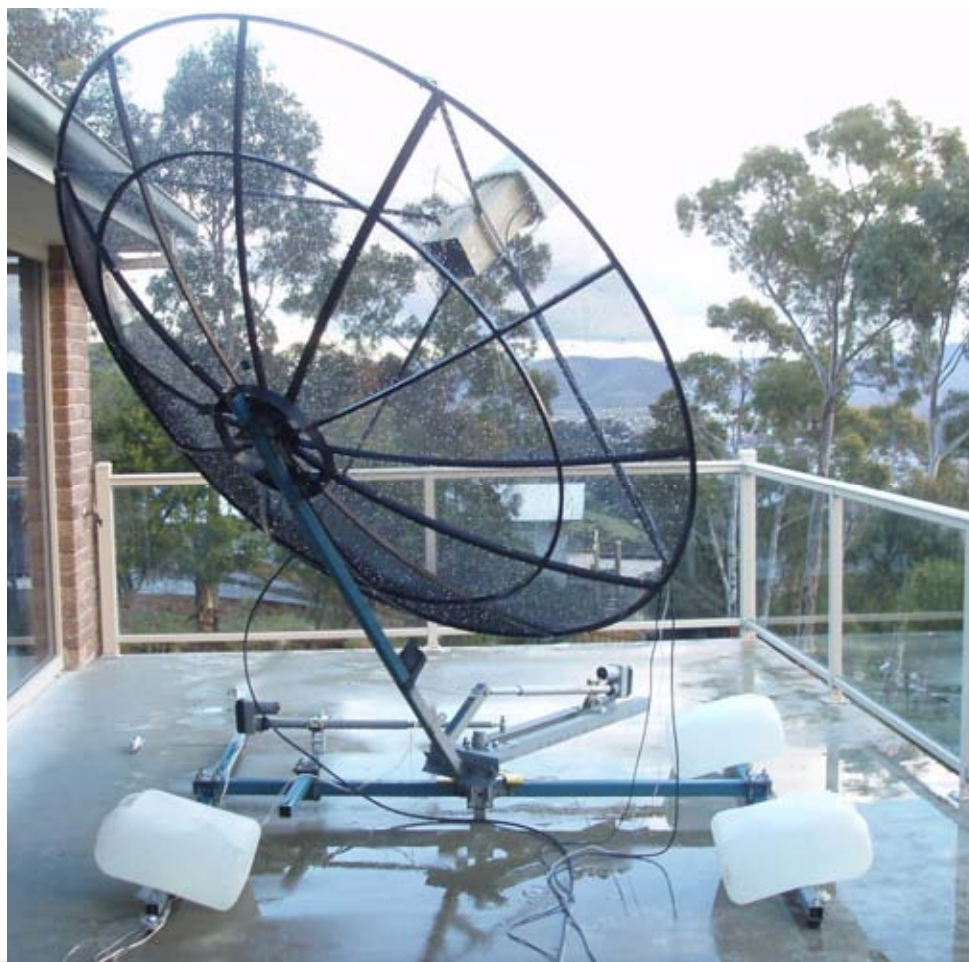
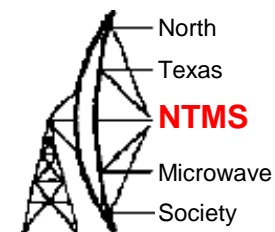


Large aperture horns can also be used to make QSOs via the moon. Horns have very clean patterns with low side lobes

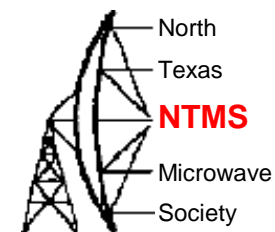


W5HN

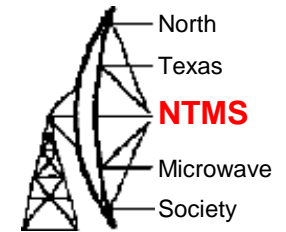
VK7MO 3M Dish on 1296 & 2304 MHz



WA5WCP/1 Four States on 1296 EME in 16 Days Aug 2006

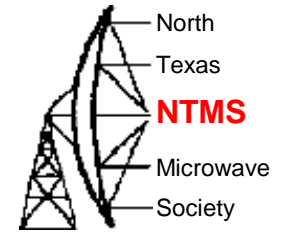


3M (10ft) Diameter Dish

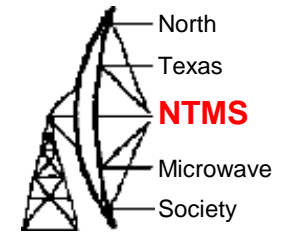


- 1296 MHz
- 3dB BW 5.3 degrees
- 1 dB BW 3 degrees
- First null at +/-9 deg.
- Gain 30 dBi at 55% efficiency
- Need to be within a couple of degrees
- 2304 MHz
- 3dB BW 3 degrees
- 1dB BW 1.7 degree
- First null at +/-5 deg.
- Gain 35 dBi at 55% efficiency
- Need to be within a degree
- Less is always better!

Azimuth Rotator Options



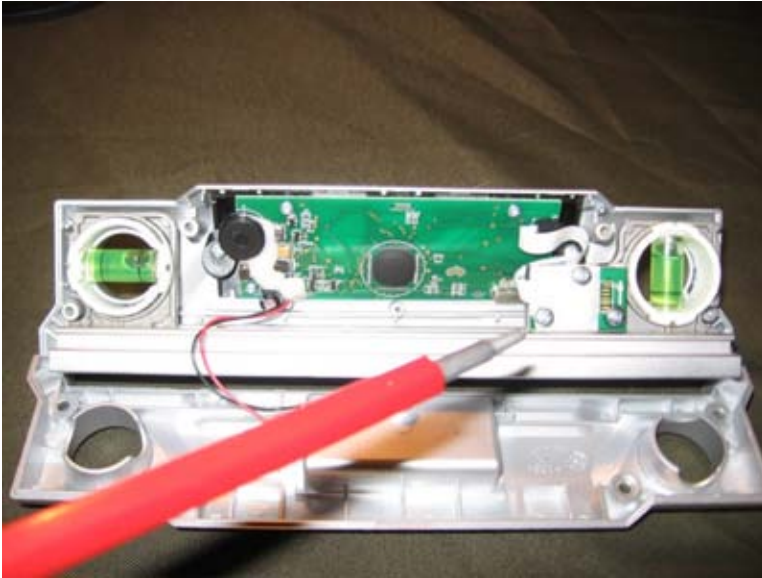
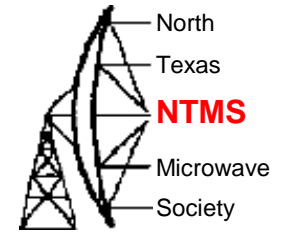
- Ham-M and Tailwister can only get you with 4 to 5 degrees due to the break wedge – not good enough
- Yaesu G-2800DXA or equivalent with friction break is an option
- M2 2800 with readout to 0.1 degree
- Alpha Spid Rotator
- Prosistel Rotator
- Old prop pitch rotor
- Motor and gearbox
- Linear actuator



Knowing Where We Are Pointed

- Potentiometers used in bridge circuit with a regulated 5V supply – pot linearity a big issue – 10 turn pots a better solution – WW2R has a digital readout board that will work with potentiometers
- US Digital Absolute Encoders are a very good solution but pricey – use a shaft encoder for AZ and an inclinometer for EL – connect to pc through the USB or RS-232 port – read by programs like K5GWs and F1EHNs – resolution as high as .01 degree
- Less expensive option is US Digital's incremental encoders which can be read by W2DRZ's controller board – K1RQG and K2DH use this setup with excellent results

WA8RJF Digital Level Modified for Elevation Readout



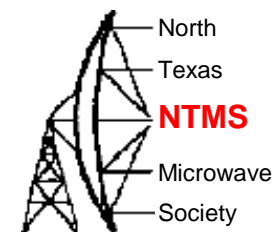
Unmodified



Modified for remote operation
Will read to 0.1 degree

Proceedings of Microwave Update 2008, Bloomington, Mn; page 206

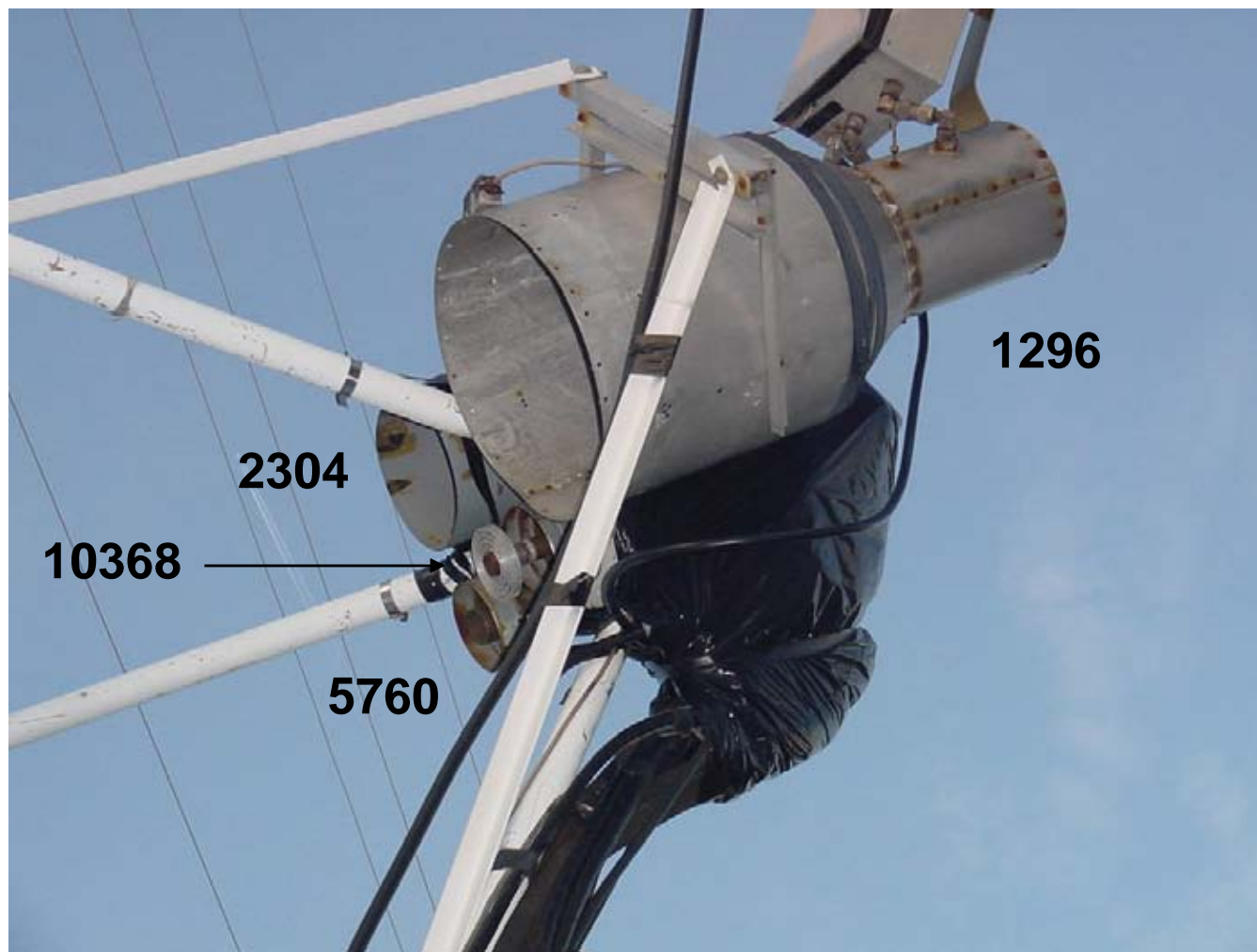
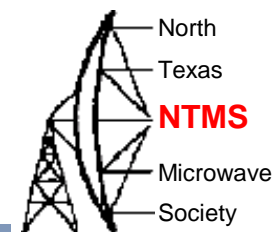
5 Meter Dish at W5LUA



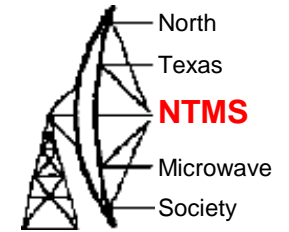
**Used for
EME on**

**432 MHz
902 MHz
1296 MHz
2304 MHz
3456 MHz
5760 MHz
10368 MHz**

Multi-Band Feed System



AZ EL Mount for 5 Meter Dish

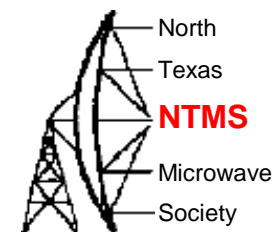


Hydraulics for elevation drive

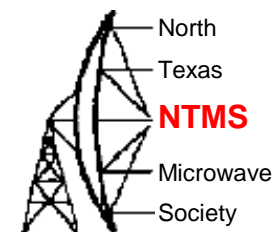
Prop pitch rotor for azimuth drive

US Digital Absolute Encoders for readout and K5GW tracking program

Prop-Pitch Motor for Azimuth



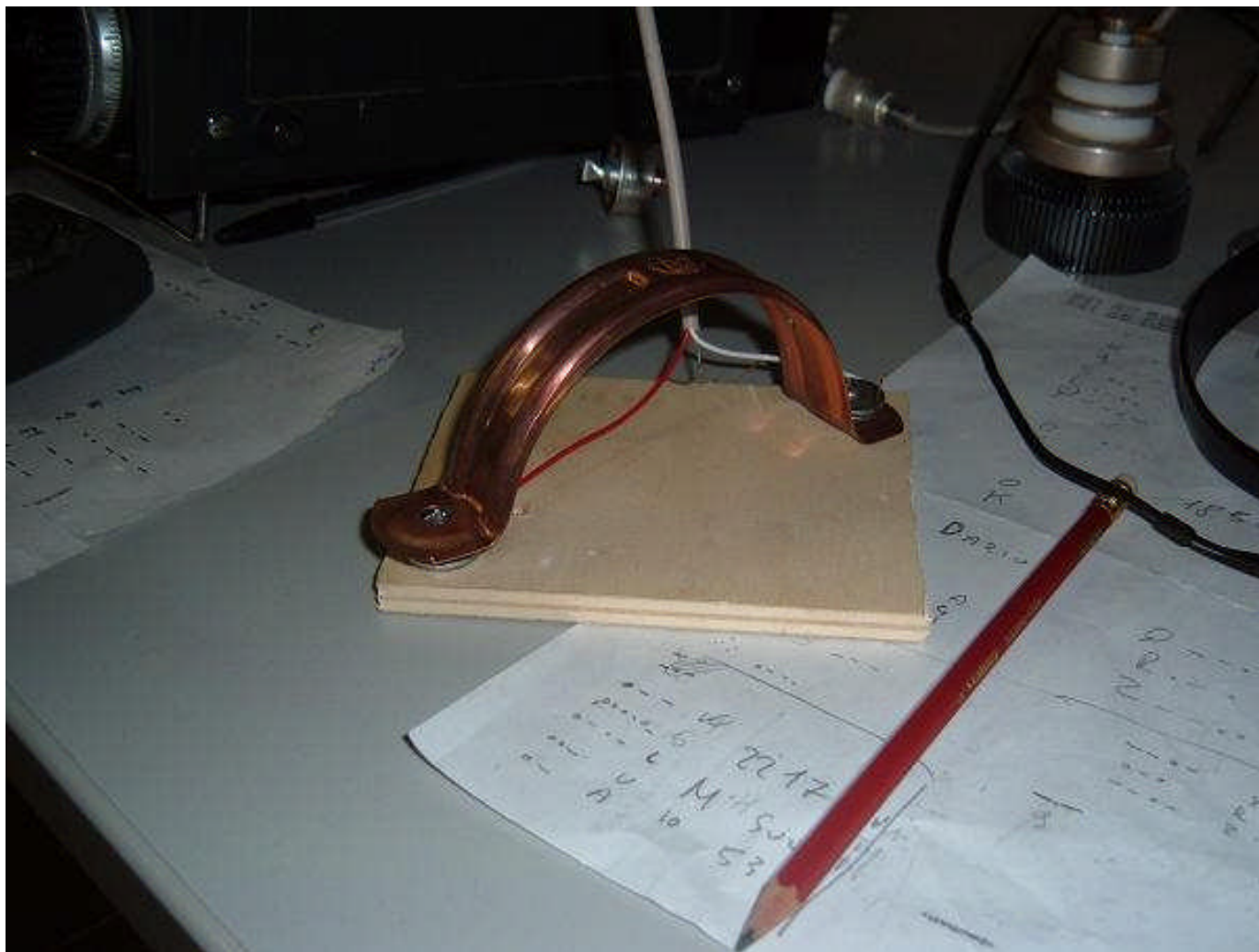
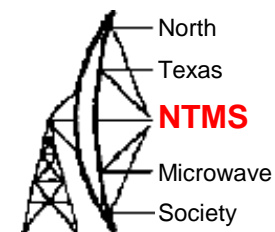
IW2FZR on 1296 and 2304



So you don't think
you are good
enough at CW?
Check out Dario's
hand key!

Now look closer!

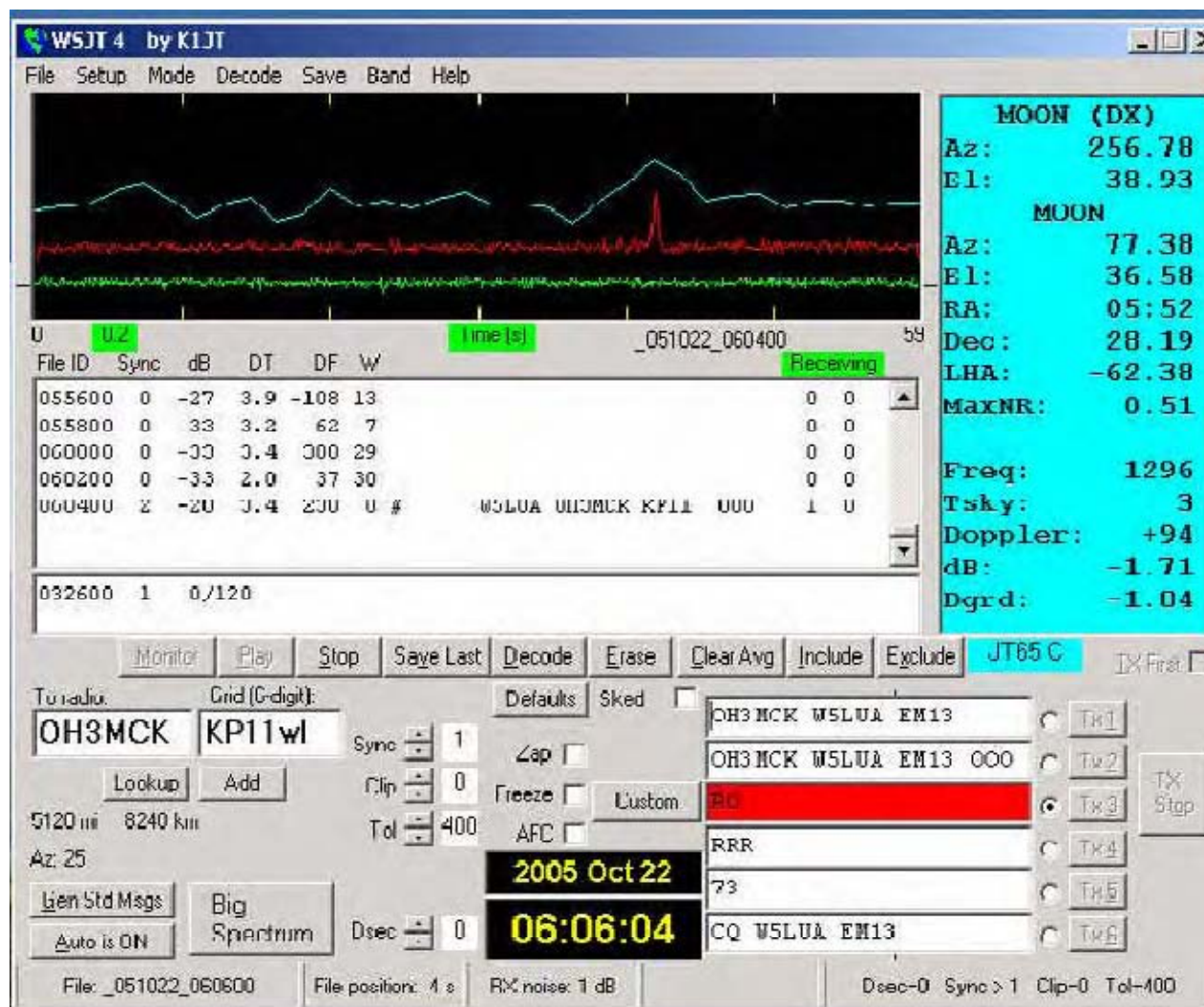
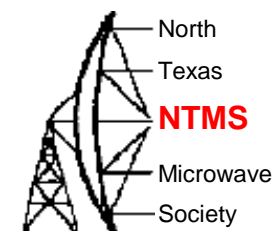
IW2FZR Homebrew Key



Now this is dedication! ... by doing what you have to do to make the contact!

And Dario is still very active with great signals on 1296 and 2304 MHz!

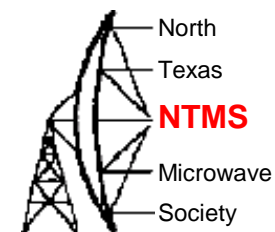
OH3MCK on 1296 MHz JT-65C



4 Yagis 27 dBi
200 watts

W5HN

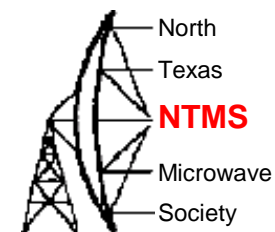
DL3OCH/DU on 1296 MHz JT-65C



110 Watts and 55 ele Yagi on 1296 MHz EME!

W5HN

DL3OCH Bodo / 5N0 (Nigeria) EME

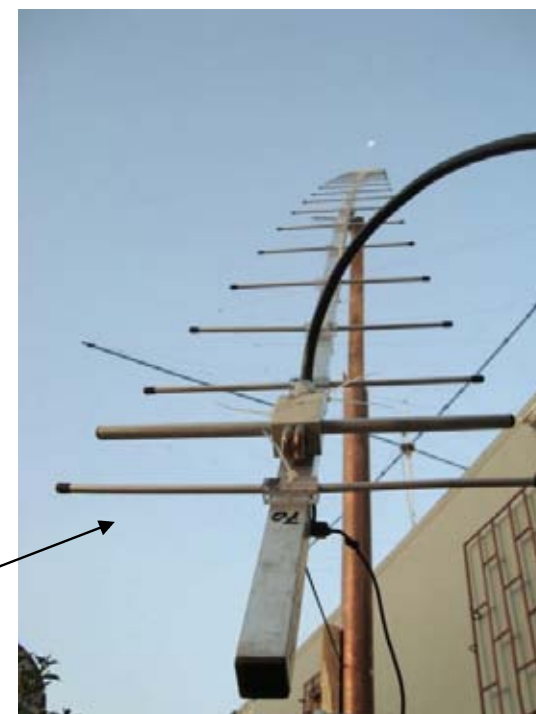


← 2M EME

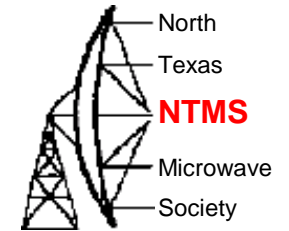


432 MHz EME

1296 MHz EME



2.4M Offset Fed Dish at W5LUA



Feed Assembly



Dish used on 24 GHz and 47 GHz
EME and tested on 78 GHz

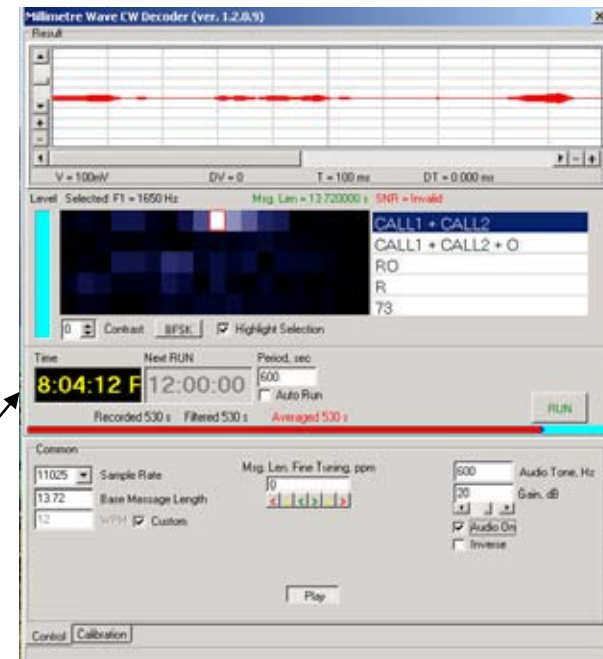
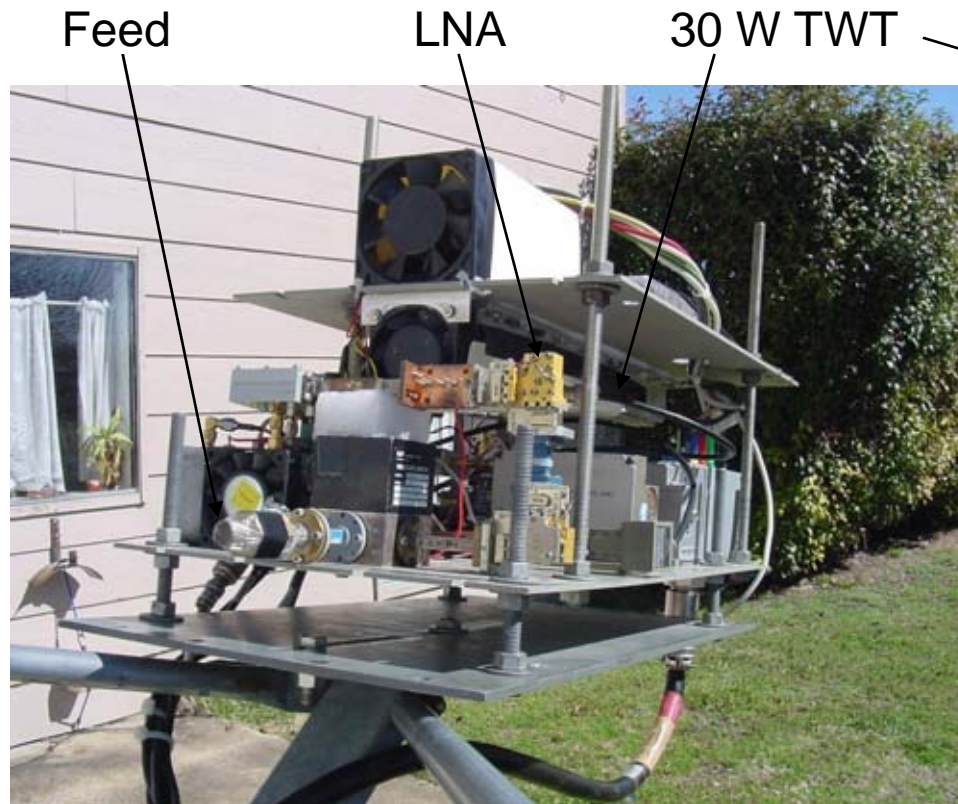
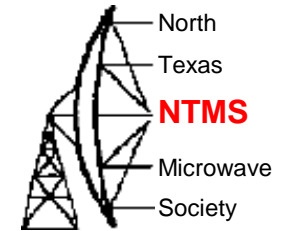


100 W TWT

Transverter

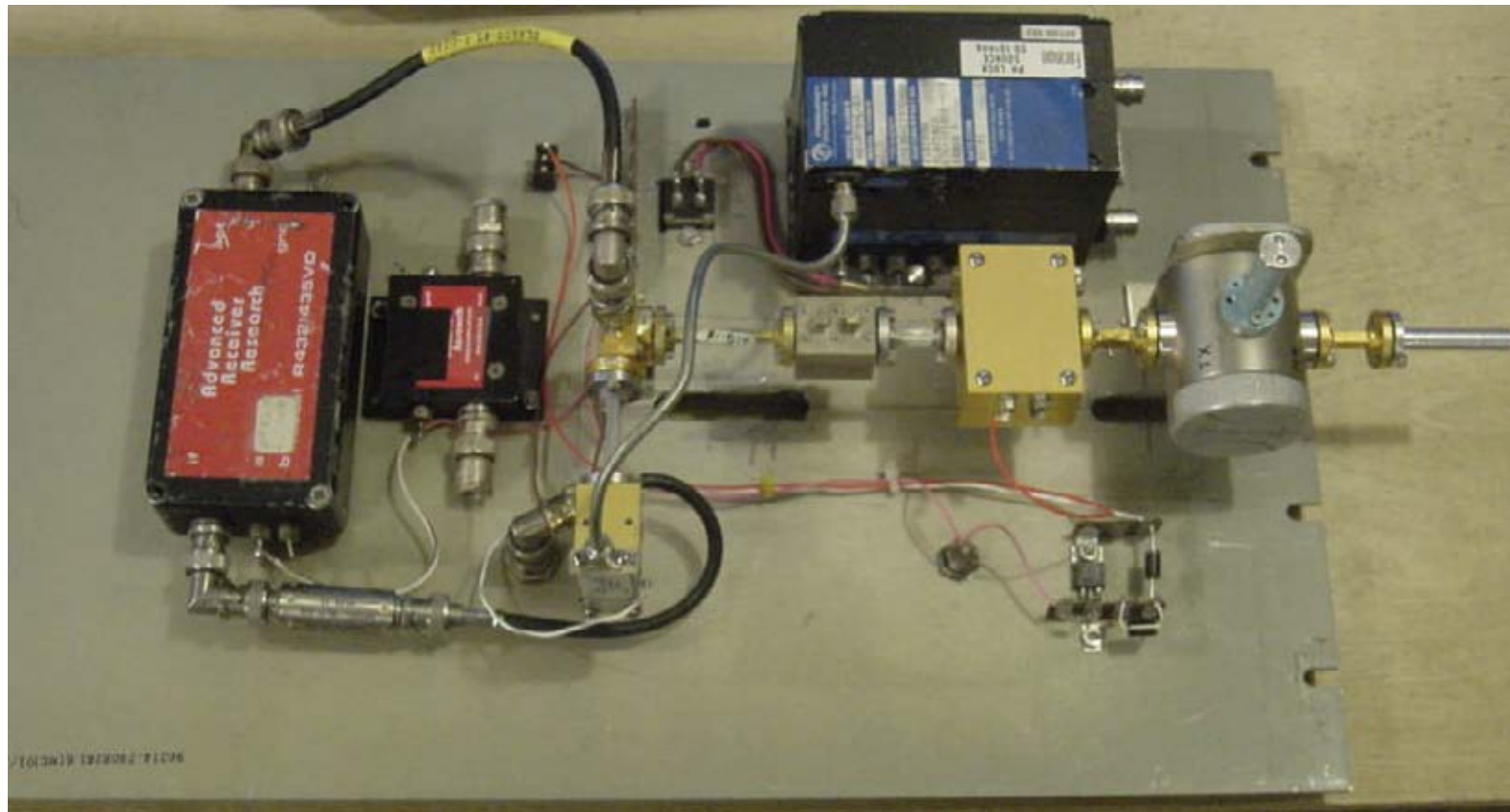
W5HN

47 GHz System for 2.4M Dish at W5LUA



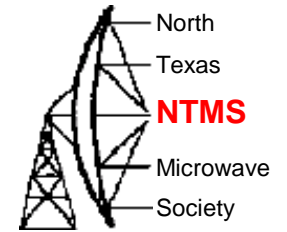
Special software designed by RW3BP to do 10 minute averaging to improve S/N

78 GHz Converter



W5HN

1 m Winegard Offset Fed Dish with W2IMU Feedhorn built by WA5JAT



System NF = 3.5 dB (359K)

Sun Noise / cold sky =
7.2 dB w / W2IMU Feedhorn
SFI = 87, 3, 0

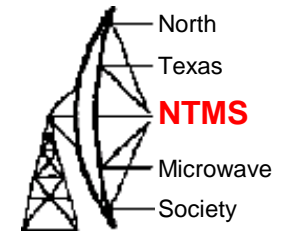
Moon Noise / cold sky =
0.75 dB

50Ω / cold sky = 1.2 dB,
NF = 3.5 dB, Ta = 133 K

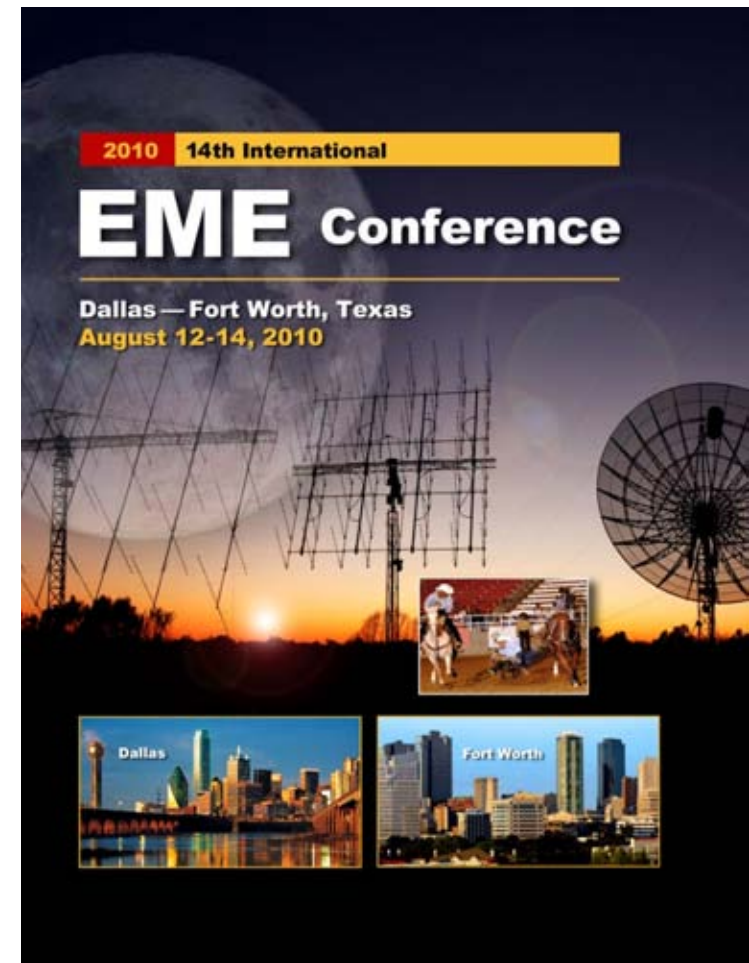
Feed position still not
optimized!

Dew point is quite a factor in
the measurements = moisture
and oxygen absorption!

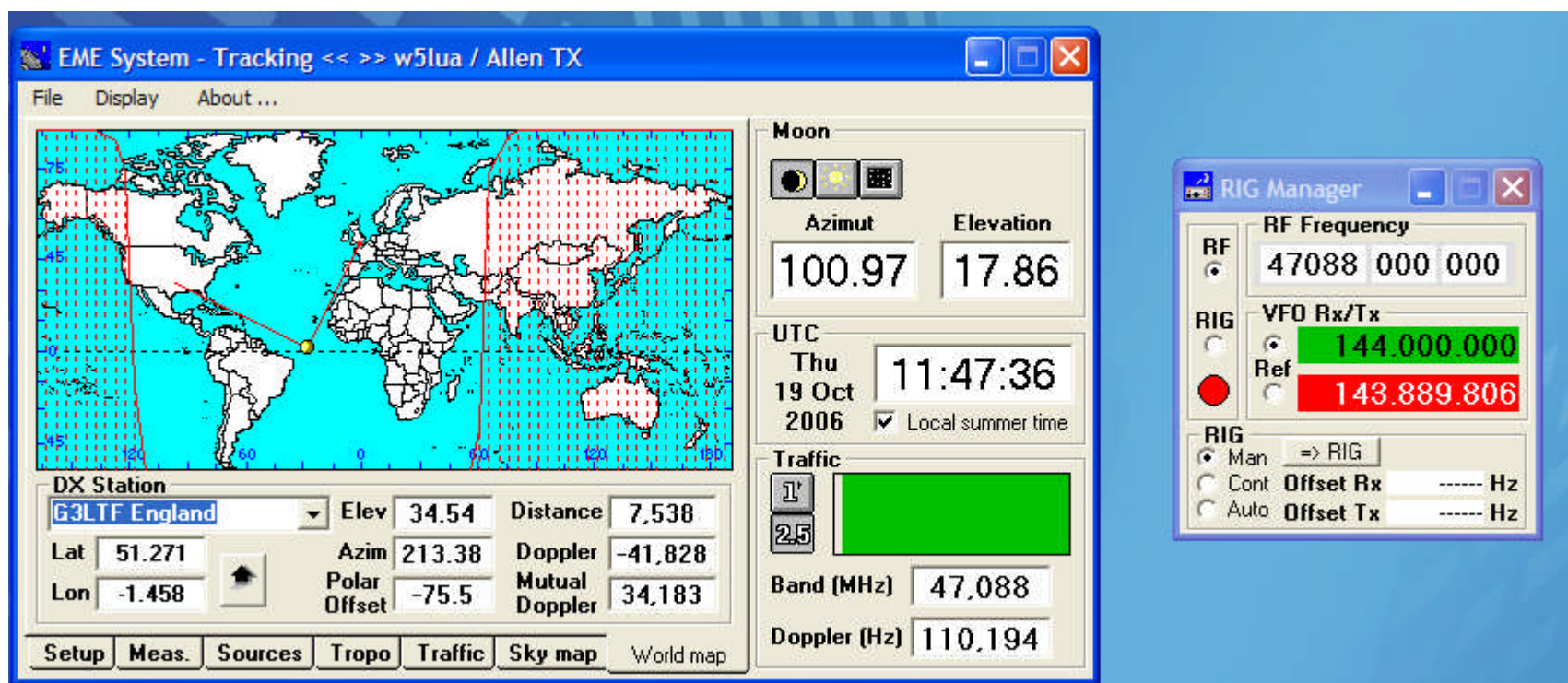
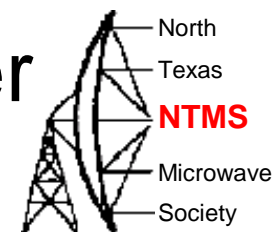
International EME Conference



- Premier EME Conference for EME Enthusiasts
- Semi-Annual Conference held at various locations through out the world
- The North Texas Microwave Society sponsored the 14th International EME Conference in Irving, Texas in August of 2010
- The 15th International EME Conference will be held at Churchill College, Cambridge in the UK August 16th through the 18th in 2012.
- Check <http://www.eme2012.com/> for conference schedule and updates



F1EHN Tracking Software with Doppler Calculation & RX Tuning

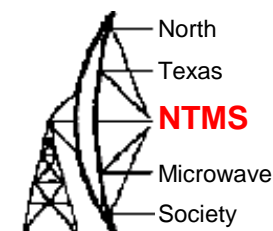


• <http://www.f1ehn.org/>

W5HN

VK3UM EME Planner and Tracking Software

<http://www.ve1alq.com/vk3um/>



VK3UM EME Planner 2009

Main Planner Spatial Sources Sky Noise Display Distance Calculator Home Set up Help About Exit

UTC 31 May 2009

20:56:14

Moon distance 379,104 kms ... Loss -0.75 dB Diam ... 0.53°

HOME STATION w5lua Allen, TX em13qc 200m ASL Refraction Off

Local 31 May 2009

15:56:14

Home Azimuth 105.63 Home Elevation 22.44

Home - Home Home - Dx Dx - Dx Spatial Off-Set Distance Bearing

2547 Hz 567 Hz -1864 Hz -78 7601.1 kms 42.0°

Doppler Shift

DX STATION G England IO91sl 0m ASL

31 May 2009 DX Azimuth DX Elevation

21:56:14

221.02

30.75

Dx Local Time

1296 MHz Ver 1.44

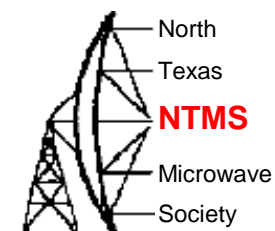
Dec 0.53° R.A. 11:16:22

GHA 34.45° Sky 2 °k

Dx selection Save Data Base HOME selection

LOCATION	CALL	UTC	GRID	Hz
France	F	1	JN10eu	
Crozet	FT8W	0	FM08pb	
Kerguelen	FT8X	5	ME44ns	
Amsterdam Island	FT8Z	1	MF93aa	
Guadeloupe	FG	-4	FK96da	
Mayotte Island	FH	3	LH27nd	
New Caledonia	FK	11	RG37fq	
Chesterfield Island	FK	11	LH90es	
Martinique	FM	-4	FK94lo	
Austral Island	FO	-3	OC53hm	
Clipperton Island	FO	-8	DK40aa	
French Polynesia	FO	-10	BH52fl	
Marquesas Island	FO	-10	BI91xc	
St Pierre & Miquelon	FP	-6	FN36lj	
Glorioso Island	FR/G	-10	BH52fl	
Juan de Nova	FR/J	2	LH12pw	
Reunion Island	FR	3	LG78tv	
Tromelin Island	FR/T	4	LH74ed	
Saint Martin	FS	-4	FK88lb	
Wallis & Futuna Isl...	FW	-12	AH16vq	
French Guiana	FY	-3	GJ34uw	
England	G	0	IO91sl	
Isle of Man	GD	0	IO74sd	
Nth Ireland	GI	0	IO74an	
Jersey	GJ	0	IN89qe	
Scotland	GM	0	IO85pw	
Guernsey	GU	0	IN89rk	
Wales	GW	0	IO81jl	
Solomon Island	H4	-10	QI90xn	
Temotu Province	H4O	11	LH74fd	
Hungary	HA	1	JN97nm	
Switzerland	HB	1	JN36nw	

K5GW Tracking Software



W5LUA_MT050511.bat

TIME	DATE	TGT	A/T	AZ	EL	AZC	ELC	DEC	AZ ERROR	EL
05:19:49	06/08/11	MOON	OFF	270.69	6.82	2.2	2.5	4.8	99.99	81.00

ANTENNA	AZIM	ELEV
1296	69.57	87.82
2304	144.12	82.26
3400	143.56	82.43
5760	172.82	84.70
10368	142.94	85.34
24048	98.12	57.57
47088	100.63	57.50
78192	100.72	57.13

MOON	AZ	EL
SUN	342.12	-31.93
CAS	30.90	18.16
CYG	62.81	42.35
SAG	155.24	23.23
LEO	308.01	15.51
AQU	85.65	-6.64

Band: 1296MHZ
Doppler: -3022.7
Sky Tem: 3.4
Loss dB: 0.95
Tdeg dB: 1.05
Pol: -33
Lib: 6.50

JUN 08 2011 05:19:48

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		

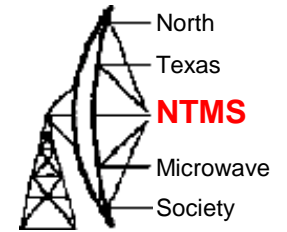
STATION B DATA

Call: JA4BLC	Grid: PM65NM
Lat: 35.52	Lon: 226.87
Az: 114.78	El: 36.70
Dop: 2506	Mdop: -259
Pol: 42	Mpol: 75
Lib: 15	Mlib: 10

<esc> <E> <T> <A> <M> <U> <Z> <C> <F> <O> <L> <P> <+> <->

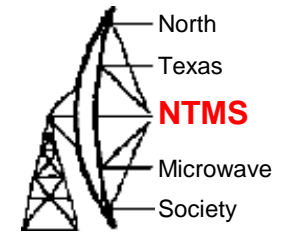
exit bnd tgt a/t man pos a/z cal f/t stnB lib plan

When is the Best MW EME Activity?



- Perigee when the moon is closest to the earth
- High declination best for northern hemisphere activity – most hours of moon
- Perigee and High declination not always occurring at the same time of the month –
- Stay away from new moon
- Mainly weekend activity unless retired

Coordination of Activity

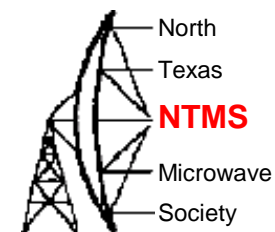


- Band by band activity weekends and many contests during the year – best to stay tuned in to the newsletter, net notes, reflectors and the 20M net.
- Bands like 1296 MHz have considerable activity each month.
- Improved random activity on 2304 and more recently 3400 MHz.
- Best to coordinate other bands with individual operators known to be active

W5HN

HB9Q Logger for real time chat

<http://hb9q.ch/joomla/index.php>



EME Logger - Windows Internet Explorer

<http://hb9q.ch/joomla/index.php>

EME Logger (cw, SSB, JT)

50MHz 144MHz 432MHz **1296MHz** 2304MHz and up

add new comment:

This Logger is designed for Internet Explorer 7 and Firefox. Optimal screen size is 1280x1024px or up.

Logout

Day UTC	Callsign	Name	Comment
30 01:22:48	PA0PLY	Jan	jt gaat wel veel eenvoudiger hi
30 01:22:27	PA7JB	John	Zo hij gaat goed :-))
30 01:22:11	ur5lx	Sergey	jan qrg?
30 01:19:45	PA0PLY	Jan	en 4 cw qso al
30 01:18:43	PA7JB	John	Dag Jan nog geen maan wel mooi van je echo :-)
30 01:16:10	PA0PLY	Jan	hi john
30 01:02:32	PA7JB	John	GD all have no moon yet but hope to have it in 1/2 hour
30 00:50:15	ur5lx	Sergey	qrg?
30 00:48:46	UN6PD	Nikolai	Hello all
29 23:59:50	S57SU	Uros	due to low PWR and small dish I will be only QRV on JT.... if someone will hear me, hi
29 23:59:16	S57SU	Uros	bye Phil, gl
29 23:58:49	VK4CDI	Phil	JT65 today.....060
29 23:58:02	VK4CDI	Phil	Off logger for test.....cheers all
29 23:57:58	ur5lx	Sergey	vk4cdi ga cw or jt65c?
29 23:56:41	VK4CDI	Phil	RR Alexander, have very short window today, tomorrow better.....
29 23:56:03	4Z8LV	Alexander	Ge Phil, I am not in contest, only for some QSO may be
29 23:54:22	4Z8LV	Alexander	Jan there is power 70W, the attenuator has been used like dummy load
29 23:54:18	VK4CDI	Phil	GD all, QRV 2359 for contest.....
29 23:54:04	ur5lx	Sergey	pa0ply ge we will try?
29 23:53:46	4Z5LV	Alexander	Jan there is power 70W, the attenuator has been used like dummy load
29 23:47:25	S57SU	Uros	hi Ned, hpe to work u this time, gl

online:

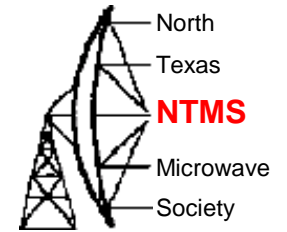
W5LUA

UN6PD
VK4CDI
JH0TOG
RN3ARU
SV1CAL
SM0ERR
s59dcd
S57SU
W7IUV
LU8ENU
VE7BBG
OH3MCK
YO8BCF
VK2JDS
PA0PLY
DH6NAH
UY2QQ
KF4OD
PA7JB
ur5lx
UA9UHN
DJ9YW
LZ1DX
PY2BS
DJ3JJ

Done

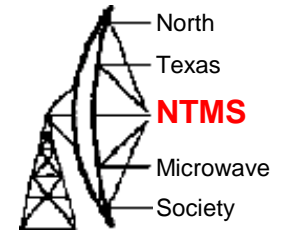
Internet 100%

Moonbounce Reflectors



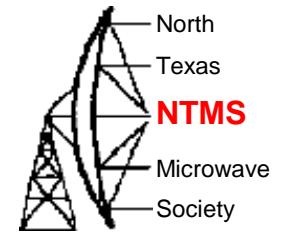
- Moon-Net -
<http://www.nlsa.com/nets/moon-net-help.html>
- Moon -
<http://www.moonbounce.info/mailman/listinfo/moon>

EME Net



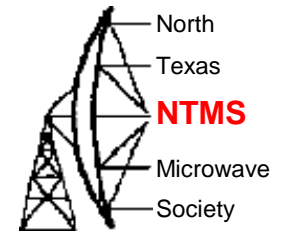
- Meets Saturday and Sunday Mornings at 9AM Central time on 14.345 MHz – NET Controls are N4PZ & K1RQG
- Also informal activity during the week on 14.345 MHz starting at 9AM Central

432 MHz and Above EME Newsletter



- Edited and distributed monthly by Al Katz, K2UYH since 1972 – send reports to a.katz@ieee.org
- Available from Rein W6/PA0ZN now W6SZ via the internet at <http://www.nitehawk.com/rasmit/em70cm.html>
- Available from Warren Butler wbutler@comcast.net in .pdf format

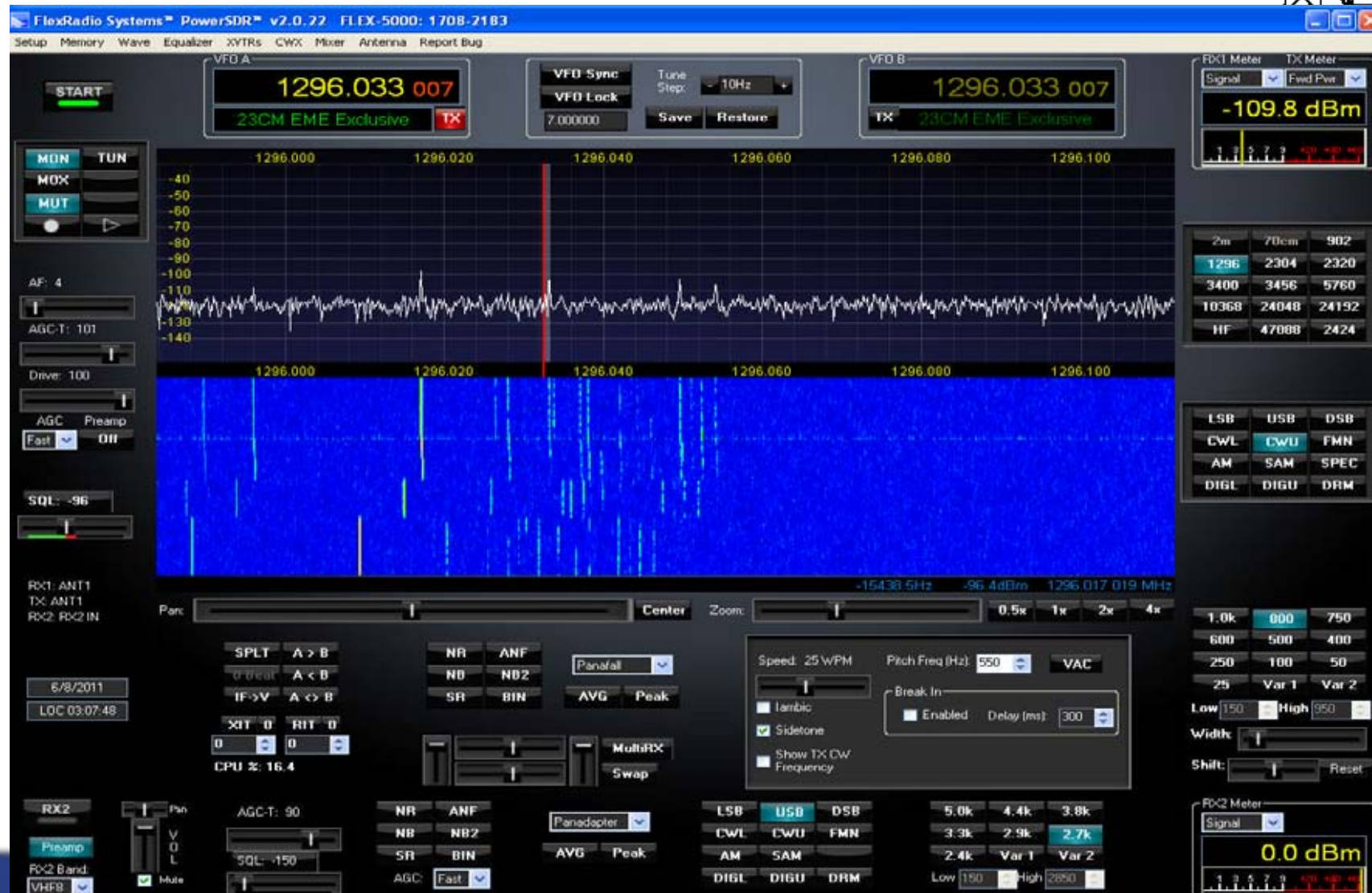
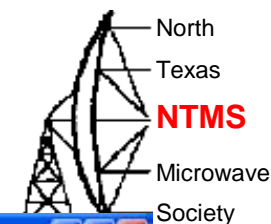
Websites for more Information



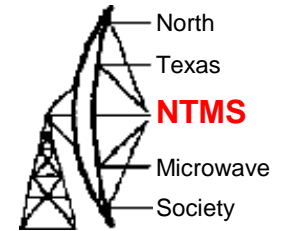
- NTMS – <http://www.ntms.org/>
- VE1ALQ - <http://www.ve1alq.com/>
- F1EHN - <http://www.f1ehn.org/>
- W2DRZ - <http://www.w2drz.ramcoinc.com/index.htm>
- W1GHZ – www.w1ghz.org
- DEMI - <http://www.downeastmicrowave.com/>
- A Short Primer on Getting Started on 13 cm EME By Al Ward W5LUA
<http://www.ntms.org/files/2304EME-primer.pdf>

W5HN

Using the Flex 5000 Software Defined Radio at W5LUA



Schedule



**1:00 PM Introduction to Microwaves and the NTMS
by Al Ward W5LUA and Bob Gormley WA5YWC**

**1:30 PM Building equipment and operating on 10 GHz by
Bob Gormley WA5YWC and Al Webb W5RLG**

**2:15 PM Microwave EME from 902 MHz to 78 GHz by
Al Ward W5LUA**

2:45 PM Wrap up & Q&A

W5HN

Questions?

