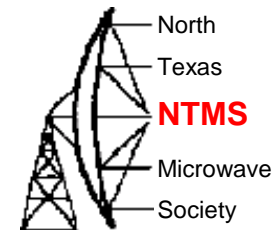


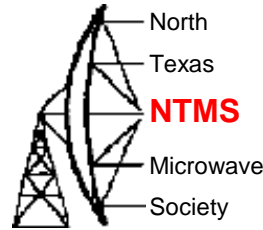
# 77 GHz EME at WA3ZKR/4 at Morehead State University



Al Ward W5LUA  
October 19, 2013



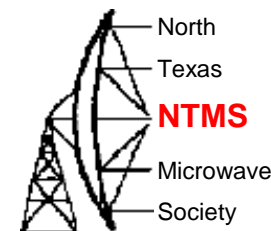
# Introduction



- After some discussion with Jeff at MUD and subsequent approval by the folks at Morehead State University, it was decided to try the 21M dish on 77 GHz during the Microwave Update time frame centered on the weekend of October 18/19<sup>th</sup>

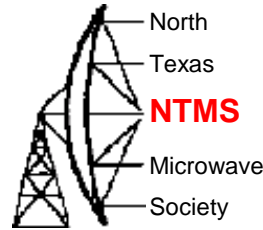
# Morehead State University

## EM88ge



- 21 M Prime focus Dish,  $f/d = .367$
- $1 \lambda = .1529$  inch at 77.184 GHz
- RMS error .020 inch =  $.13 \lambda$ , although greater than  $.1 \lambda$ , certainly worth an attempt. I am using my 14 GHz dish at 77 GHz successfully
- First try mapping the moon at 77 GHz using my LNA assembly and a new feed designed for lower  $f/d$
- Try for echoes using MMCW and JT-4 using 0.5 watt amplifier at feed to be supplied by WA1MBA

# 21M Dish Specifications



## Display

### Resolution

AZ/EL = 0.001 deg

POL = 0.01 deg

## Encoder

### Resolution

AZ/EL = 0.0003 deg (20 Bit)

## Tracking

### Accuracy

$\leq 5\%$  Received 3 dB

## Beamwidth

(0.028 deg RMS L-band)

(0.005 deg RMS Ku-Band)

## Pointing

### Accuracy

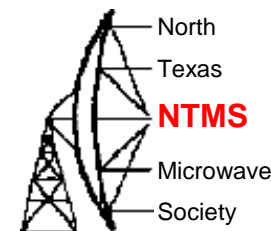
$\leq 0.01$  deg rms

Predicted 3dB Beamwidth

.013 deg @ 77GHz

2.3 deg @ 432 MHz

# W5LUA and RW3BP 77 GHz System with 2 dB of atmospheric attenuation at both ends



VK3UM EME Performance Calculator Ver 9:06

Two Station EME Rx Performance Source Pos. Planets Sky Map Home Data

**Tx A (Home Station)** WSLUA\_77GHz

77.500 GHz 306.74 dB 3.4 K 300 Hz Solid Dish -146.1 dBm -10.73 dB -31.81 dB

Frequency Path Loss CMB Rx BW 300 Hz Solid Dish -146.1 dBm -10.73 dB -31.81 dB

103 0.00 dB 4.30 dB 33.0 dB 2.0 dB 1.0 dB 9 K 0.00 K 1.18 dB

10.7m Solar Flux 0.0 K 490.5 K 0.1 K 9 K 0.00 K 1.18 dB

LNA Loss LNA Nt LNA Gain Coax Loss Rx Nt Spillover Feedthrough Sun Y 4.51 dB

Tx A Output Power Transmission Loss Power at Feed Moon Y 0.50 dB

1.0 Watts 0.00 dBW 3.0 dB 0.5 Watts -3.00 dBW 1,236,775 W EIRP

RxTK 490.7 K = 4.30 dB Receiver Noise Temperature

Ground Temperature 290 K 18 °C

Tsys 599.0 K = 4.86 dB System Noise Temperature

**Dx Station as received at Home Station ... 0.03 dB**

**Hm Atmosphere -2.00 dB** **Dx Atmosphere -2.00 dB**

**Home Station as received at Dx Station ... -21.59 dB**

**Tx B (Dx Station)** WSLUA\_77GHz

77.500 GHz 306.74 dB 3.4 K 300 Hz Solid Dish -145.3 dBm -10.73 dB -11.21 dB

Frequency Path Loss CMB Rx BW 300 Hz Solid Dish -145.3 dBm -10.73 dB -11.21 dB

103 0.00 dB 5.00 dB 33.0 dB 2.0 dB 1.0 dB 9 K 0.00 K 0.98 dB

10.7m Solar Flux 0.0 K 627.1 K 0.1 K 9 K 0.00 K 0.98 dB

LNA Loss LNA Nt LNA Gain Coax Loss Rx Nt Spillover Feedthrough Sun Y 4.35 dB

Tx B Output Power Transmission Loss Power at Feed Moon Y 0.44 dB

60 Watts 17.78 dBW 0.0 dB 60 Watts 17.78 dBW 159,457,649 W EIRP

RxTK 627.2 K = 5.00 dB Receiver Noise Temperature

Ground Temperature 290 K 17 °C

Tsys 735.6 K = 5.49 dB System Noise Temperature

Operating Frequency: 50 MHz, 144 MHz, 222 MHz, 432 MHz, 900 MHz, 1296 MHz, 2304 MHz, 3456 MHz, 5760 MHz, 10.368 GHz, 24.048 GHz, 47.088 GHz, 70 MHz, 408 MHz, 77.5 GHz

**Yagi Array** Single Yagi Gain in dB: 12.65 dBd, Number of Yagis: 13, G/T: N/A, E: 0.00 °, Array Type and Gain: 12.65 dBd, 14.80 dBi

**Parabolic Reflector** Focal length 1.63 m, Diameter: 2.40 m, Metric, f/D: 0.70, Efficiency: 65%, Beam Width: 0.113°, Gain: 2467937, Dish Gain: 61.77 dBd, 63.92 dBi

**Home Station ... Y Factor Calc**

Noise Source (Hot): Sagittarius A, Taurus A, Cassiopeia A, Virgo A, Cygnus A, Termination, Centaurus A

Quiet Source (Cold): Aquarius or Leo, Tsky (variable)

Noise [hot] Flux: 10 Jy, Quiet [cold] Sky: 3 K, System TK: 599.0 K

**Point Source Y Factor** 0.00 dB

YU1AW Aperture Source calculations. These are only valid for 144 and 432 MHz. Point Sources should be used for 1296 MHz and above.

**Yagi Array** 2295 MHz, Single Yagi Gain in dB: 12.65 dBd, Number of Yagis: 1, G/T: N/A, E: 0.00 °, Array Type and Gain: 12.65 dBd, 14.80 dBi

**Parabolic Reflector** Focal length 1.63 m, Diameter: 2.40 m, Metric, f/D: 0.70, Efficiency: 70%, Beam Width: 0.113°, Gain: 2657893, Dish Gain: 62.09 dBd, 64.24 dBi

**Effective Aperture** Tx A: 2.94 M², Tx B: 3.16 M², Beam Width Ratio: 4.59, S/F: Mn, Current Moon phase: 0.237°..85°..23.7%

**Moon Beam Fill Factor** Tx A: 14.58 x, Tx B: 14.58 x, Sun Beam Fill Factor: 15.73 x, 11.97 dB, 3613.45

**Moon Radar Equ.** 52.93 dB, Current Moon Distance: 384,851 kms, Moon Angular Diam: 0.517°..31°3.0", Actual Moon Temp: 179 K...179.0 K

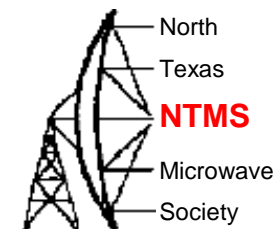
**Moon return Loss** 306.74 dB, Moon Flux 10°-22: Sv = 211.5337, Moon Declination: Dec. -8.47°, Corrected stu: 3937

Engineering Panel 77500 MHz

Save Data, Get Data, Default, Print, Exit

VK3UM Ver 9:06

# RW3BP and WA3ZKR 77 GHz System with 2 dB of atmospheric attenuation at both ends



VK3UM EME Performance Calculator Ver 9:06

Two Station EME Rx Performance Source Pos. Planets Sky Map Home Data

**Tx A (Home Station)** WA3ZKR

Frequency: 77.500 GHz Path Loss: 306.71 dB Rx BW: 3.4 K

Antenna: Solid Dish Sys Sensitivity: -145.9 dBm Effective ground 273 K

103 0.00 dB 4.30 dB 33.0 dB 2.0 dB 1.0 dB 27 K 0 K

10.7m Solar Flux LNA Loss LNA NF LNA Gain Coax Loss Rx NF Spillover Feedthrough

Tx A Output Power: 1.0 Watts Transmission Loss: 3.0 dB Power at Feed: 0.5 Watts

Ground Temperature: 291 K 18 °C

**RxTK 490.7 K = 4.30 dB** **Tsys 617.0 K = 4.94 dB**

**Dx Station as received at Home Station ... 18.85 dB**  
**Hm Atmosphere -2.00 dB** **Dx Atmosphere -2.00 dB**  
**Home Station as received at Dx Station ... -21.48 dB**

**Tx B (Dx Station)** WA3ZKR

Frequency: 77.500 GHz Path Loss: 306.71 dB Rx BW: 3.4 K

Antenna: Solid Dish Sys Sensitivity: -145.2 dBm Effective ground 284 K

103 0.00 dB 5.00 dB 33.0 dB 2.0 dB 1.0 dB 9 K 0 K

10.7m Solar Flux LNA Loss LNA NF LNA Gain Coax Loss Rx NF Spillover Feedthrough

Tx B Output Power: 60 Watts Transmission Loss: 0.0 dB Power at Feed: 60 Watts

Ground Temperature: 290 K 17 °C

**RxTK 627.2 K = 5.00 dB** **Tsys 735.6 K = 5.49 dB**

Operating Frequency: 50 MHz 144 MHz 222 MHz 432 MHz 900 MHz 1296 MHz 2304 MHz 3456 MHz 47.088 GHz 70 MHz 408 MHz 77.5 GHz

**Yagi Array**

Single Yagi Gain in dBd: 12.65 dBd Number of Yagis: 13 G/T: N/A

**Parabolic Reflector**

Focal length 7.77 m Diameter: 21.00 m Metric f/D: 0.37 Efficiency: 66% Beam Width: 0.013° Gain: 1.928808E8 Dish Gain: 80.70 dBd 82.85 dBi

**Home Station ... Y Factor Calc**

Noise Source (Hot): Sagittarius A, Cassiopeia A, Cygnus A, Centaurus A, Taurus A, Virgo A, Termination

Quiet Source (Cold): Aquarius or Leo, Tsky (variable)

Noise [hot] Flux: 1884 Jy Quiet [cold] Sky: 3 K System TK: 617.0 K

**Point Source Y Factor** 1.14 dB

**Yagi Array** 2295 MHz

Single Yagi Gain in dBd: 12.65 dBd Number of Yagis: 1 G/T: N/A

**Parabolic Reflector**

Focal length 1.68 m Diameter: 2.40 m Metric f/D: 0.70 Efficiency: 70% Beam Width: 0.113° Gain: 2657893 Dish Gain: 62.09 dBd 64.24 dBi

**Effective Aperture**

TxA: 229.68 M² Tx B: 3.16 M²

**Beam Width Ratio**

TxA: 40.22 Tx B: 4.60

**Sun Beam Fill Factor**

TxA: 1121.12 x Tx B: 14.64 x

**Moon Beam Fill Factor**

TxA: 30.50 dB Tx B: 11.66 dB

**Sun Beam Fill Factor**

TxA: 1204.44 x Tx B: 15.73 x

**G/T Ratio**

TxA: 312589.87 Tx B: 3613.45

**Current Moon Distance** 384,049 kms

**Moon Angular Diam** 0.519°, 31'6.9"

**Actual Moon Temp** 179 K ... 179.0 K

**Moon return Loss** 306.71 dB

**Moon Flux 10° -22** Sv = 212.4186

**Moon Declination** Dec. -9.28°

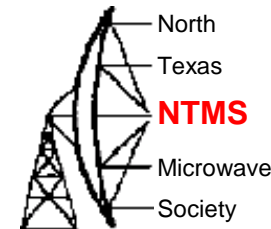
**Corrected sfu** 3937

Engineering Panel 77500 MHz

Save Data Get Data Default Print Exit

VK3UM Ver 9:06

# VK3UM Simulation with 2 dB of atmospheric attenuation at each station



Station	Ant	3dB BW	NF	Power @ Feed	Sun Noise	Moon Noise	Echo	RW3BP at WA3ZKR
W5LUA	2.4M OFD	.114 deg	4.3 dB	.5 W	4.5 dB	.5 dB	-21.07 dB	
RW3BP	2.4M OFD	.114 deg	5 dB	60 W	4.35 dB	.44 dB	-.48 dB	
WA3ZKR	21M PFD	.013 deg	4.3 dB	.5 W	4.54 dB	.5 dB	-2.18 dB	18.8 dB

The VK3UM analysis shows the echo strength at WA3ZKR with 0.5 W at the feed to be within 1.6 to 1.7 dB of the echoes achieved by RW3BP. Advantage at WA3ZKR is that we can run 100% duty cycle and maybe try the MMCW program or JT-4 with messages.

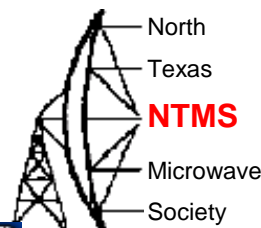
The analysis also shows that WA3ZKR could copy RW3BP up to 18 dB over the noise. We would be able to use the MMCW program at WA3ZKR to decode.

OFD = Offset Fed Dish

PFD = Prime Focus Dish



# Moon on October 18, 2013 for W5LUA and WA3ZKR



DOSBox 0.74, Cpu speed: 3000 cycles, Frameskip 0, Program: GWBASIC

TIME	DATE	TGT	A/T	AZ	EL	AZC	ELC	DEC	AZ ERROR	EL
01:59:45	10/18/13	MOON	OFF	106.21	34.86	0.0	0.0	7.4	0.00	0.00

ANTENNA	AZIM	ELEV
1296	0.00	0.00
2304	0.00	0.00
3400	0.00	0.00
5760	0.00	0.00
10368	0.00	0.00
24048	0.00	0.00
47088	0.00	0.00
78192	0.00	0.00

Band: 78192MHZ  
Doppler: 134285.5  
Sky Tem: .0  
Loss dB: 1.40  
Tdeg dB: 1.37  
Pol: 36  
Lib: 777.4

OCT 18 2013 01:59:45

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		

STATION B DATA

Call: WA3ZKR	Grid: EMB8GE
Lat: 38.18	Lon: 83.45
Az: 109.41	El: 32.98
Dop: 134285	Mdop: 134285
Pol: 36	Mpol: 0
Lib: 777	Mlib: 777

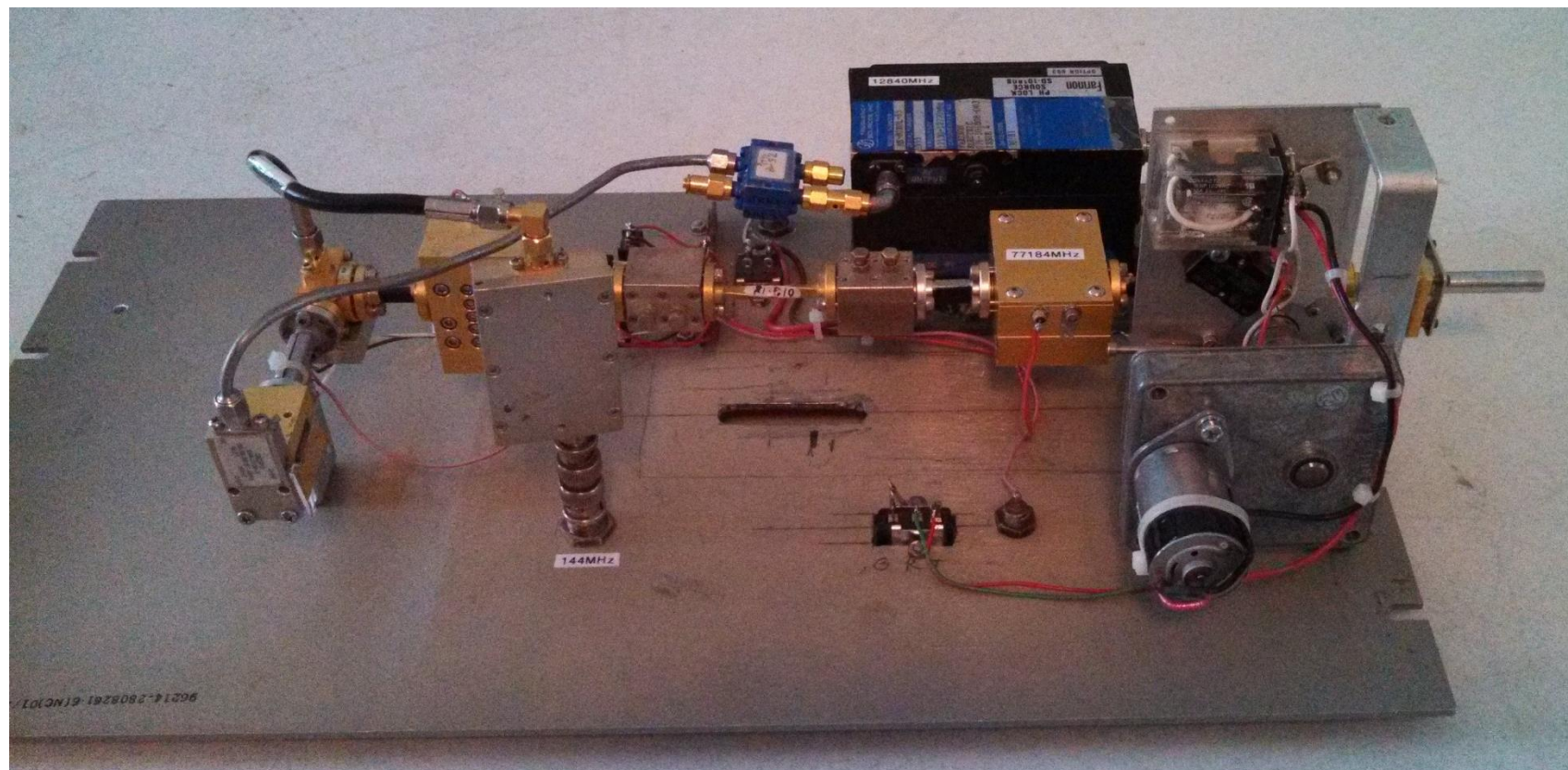
Perigee Oct 10  
Apogee Oct 26  
Full Moon Oct 18!

comport off

<esc> <E> <B> <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

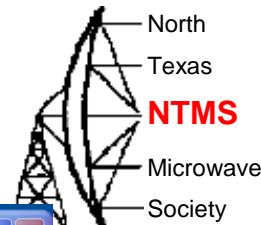


Q



My present system requires +13VDC, -20VDC, 107 MHz GPS locked and PTT and supplies a 144 MHz IF. I can adapt the mechanics to fit the big dish.

# Correcting the Flex1500 mutual doppler offset with K5GW software



FlexRadio Systems™ PowerSDR™ v2.6.4 FLEX-5000: 1708-2183

Setup Memory Wave Equalizer XVRTs CWX Mixer Antenna FlexControl ESC Get Help Hergs About

**START**

**MON TUN**  
**MOX**  
**MUT**

AF: 2  
AGC-T: 90  
Drive: 50  
AGC Preamp  
Fast On  
SQL: -56

RX1: ANT1  
TX: ANT1  
RX2: RX1 Tap

6/6/2013  
LOC 16:57:59  
CPU %: 21.9

**VFO A**  
77184.043 750  
Out of Band TX

**VFO Sync**  
VFO Lock  
7.000000  
Save Restore

Tune Step: -10Hz +

**VFO B**  
77184.156 246  
Out of Band

Rx1 Meter TX Meter  
Signal Fwd Pwr  
-97.8 dBm

1 3 7 9 +20 +40 +60

2m 70cm 902  
1296 2304 3400  
3456 5760 10368  
24048 24192 47088  
HF 78192 77184

LSB USB DSB  
CWL CWU FM  
AM SAM SPEC  
DIGL DIGU DRM

Part:

**SPLT** A > B  
0 Beat A < B  
IF->V A <> B

**NR** **ANF**  
**NB** **NB2**  
**SR** **BIN**

**XIT** 0 **RIT** 0  
0 0  
**VAC1** **VAC2**

TIME DATE TGT A/T AZ EL AZC ELC DEC AZ ERROR EL  
16:57:59 06/06/13 MOON OFF 181.92 74.78-19.2 -0.7 18.2 -99.48 -31.67

ANTENNA AZIM ELEU Band: 77184MHZ  
1296 71.93 86.89 Doppler:-13875.3  
2304 133.08 83.51 Sky Tem: 2.7  
3400 133.47 83.47 Loss dB: 2.13  
5760 168.05 85.94 Tdeg dB: 2.13  
10368 128.99 86.93 Pol: -88  
24048 213.70 43.67 Lib:1849.3  
47088 92.20 44.17  
77184 82.44 43.12

JUN 06 2013 16:57:59  
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

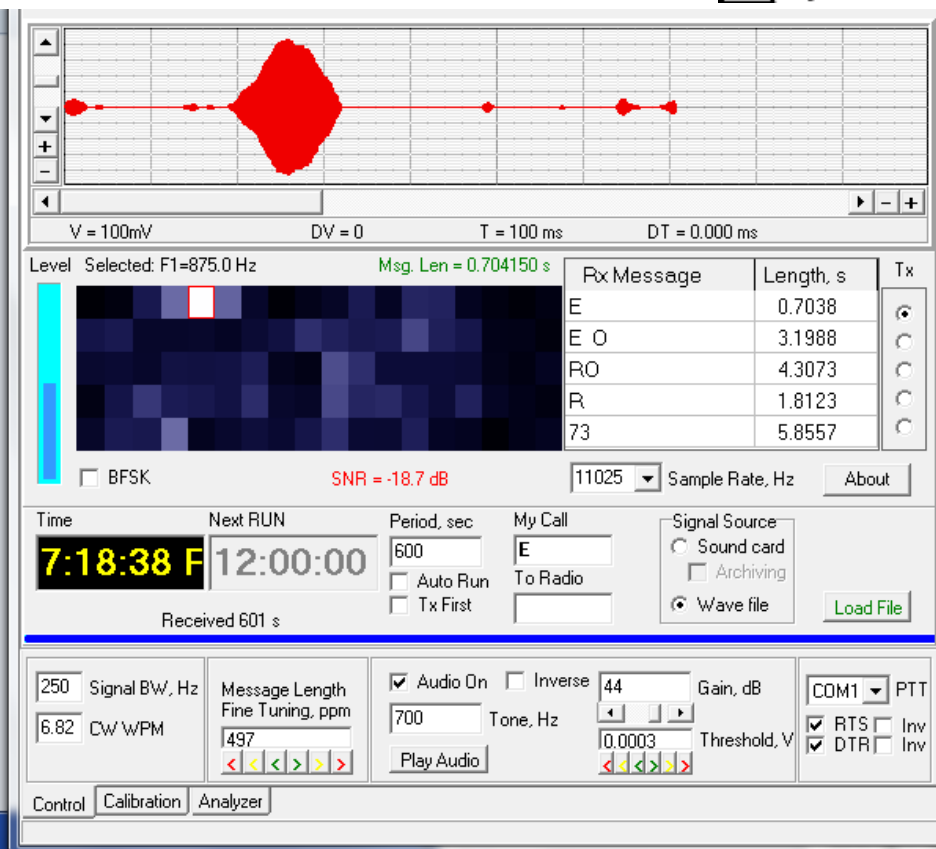
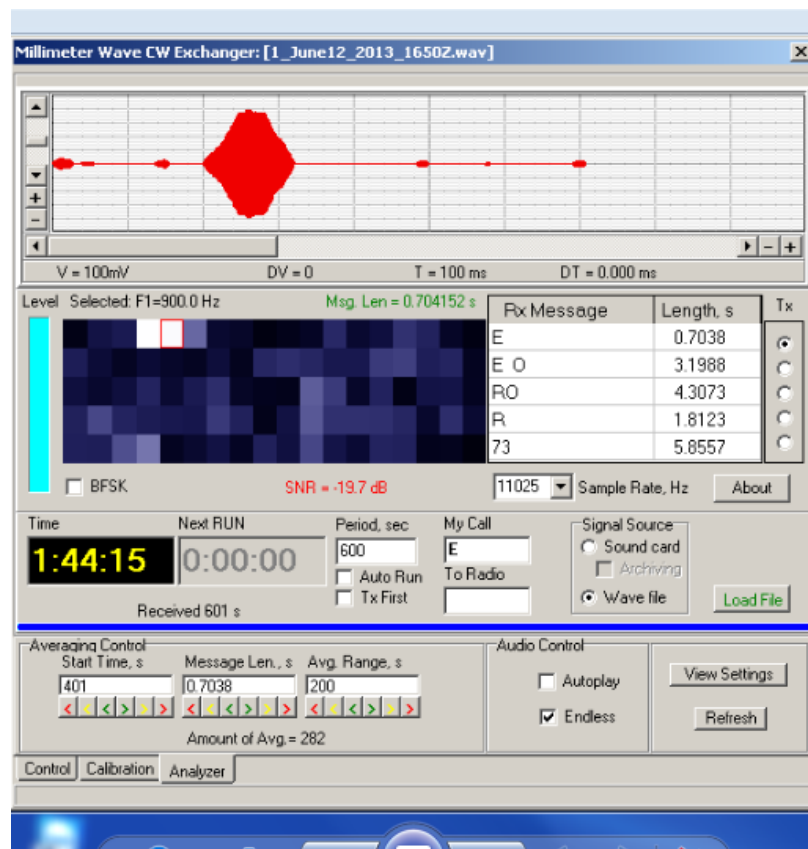
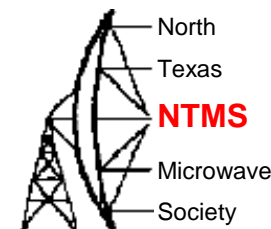
STATION B DATA  
Call:RU3BP Grid:K085WS  
Lat: 55.77 Lon: 322.125  
Az:317.51 El: -7.76  
Dop:-98624 Mdop:-56250  
Pol:-67 Mpol: 21  
Lib: 895 Mlib: 1372

OPMODE:USB TMODE:3 REX

Recur freq:77184.043754  
Xmtr freq:77184.156246  
Sked freq:77184.100000

<esc> <E> <B/b> <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

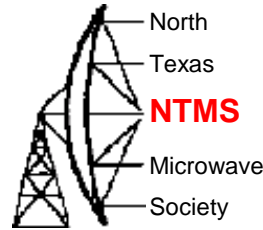
# Reception of RW3BP by W5LUA on 77184 MHz on June 12, 2013 using RW3BP's MMCW Program



.wav file as replayed by RW3BP

Same .wav file as replayed by W5LUA with 497 ppm correction to message length

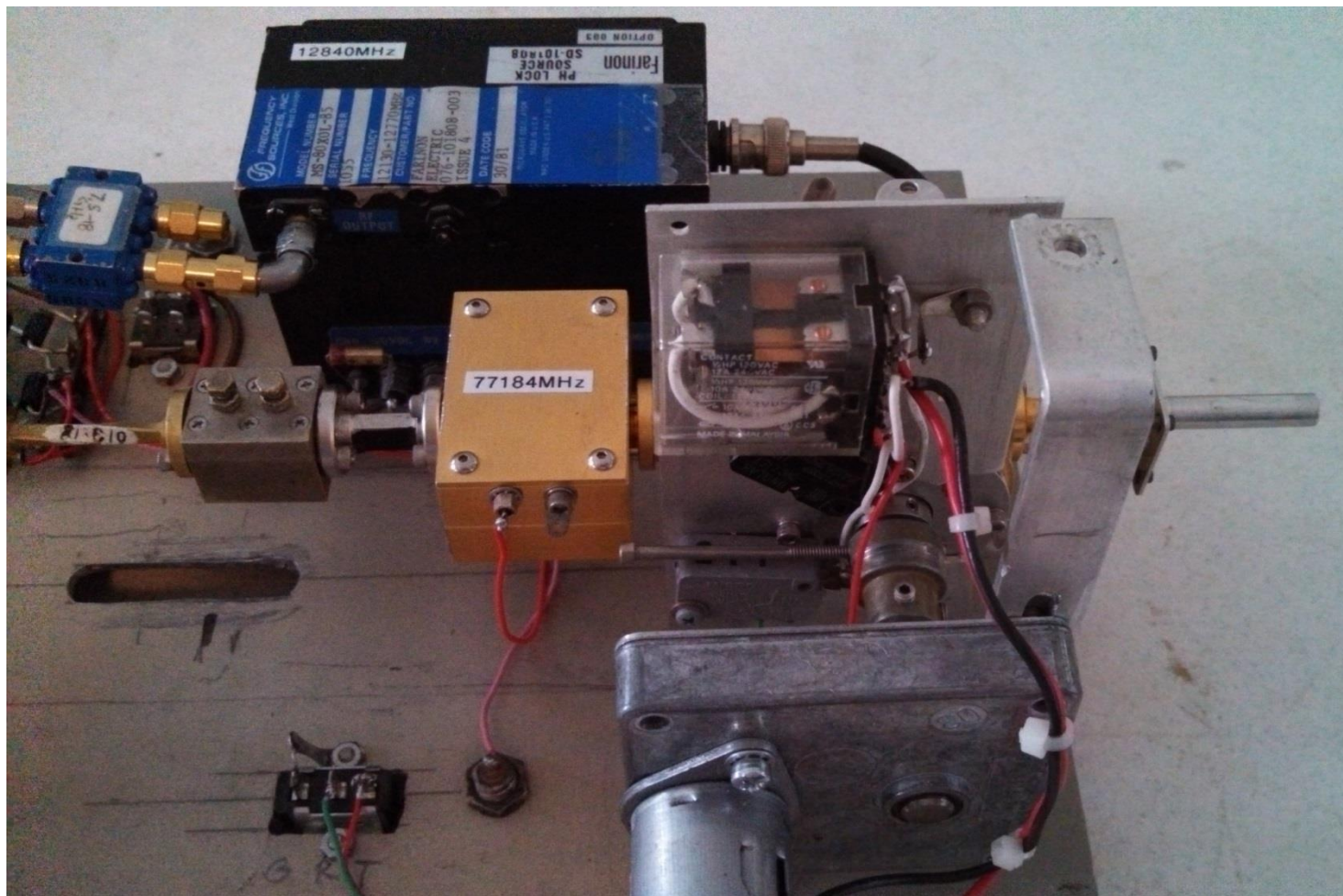
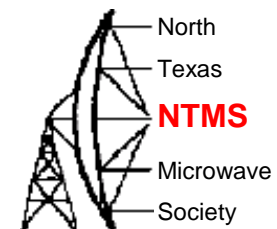
# 77 GHz Feed for big dish



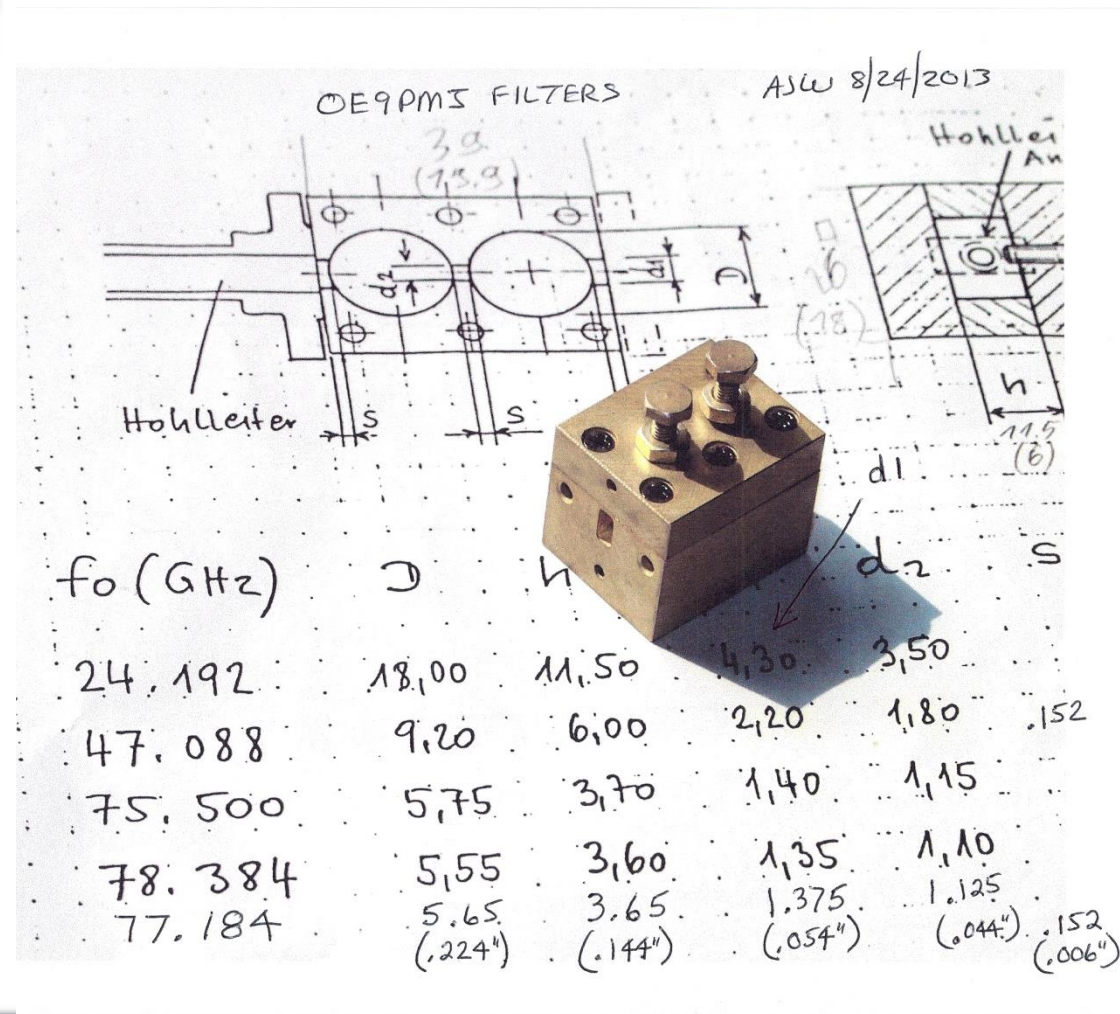
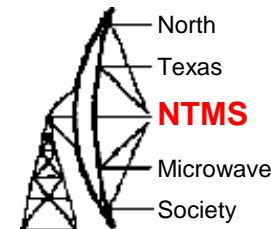
- According to the VK3UM program, the Super VE4MA Feed Horn provides maximum echo strength for a .37 f/d dish
- Considering the potential narrow 3 dB beam-width of 0.013 degree, it was decided to illuminate the dish with my existing W2IMU feed built by WA5JAT
- The larger higher gain W2IMU may tend to illuminate a smaller area creating a cleaner pattern of the 21M dish.



# Automating the WR-15 W/G Switch



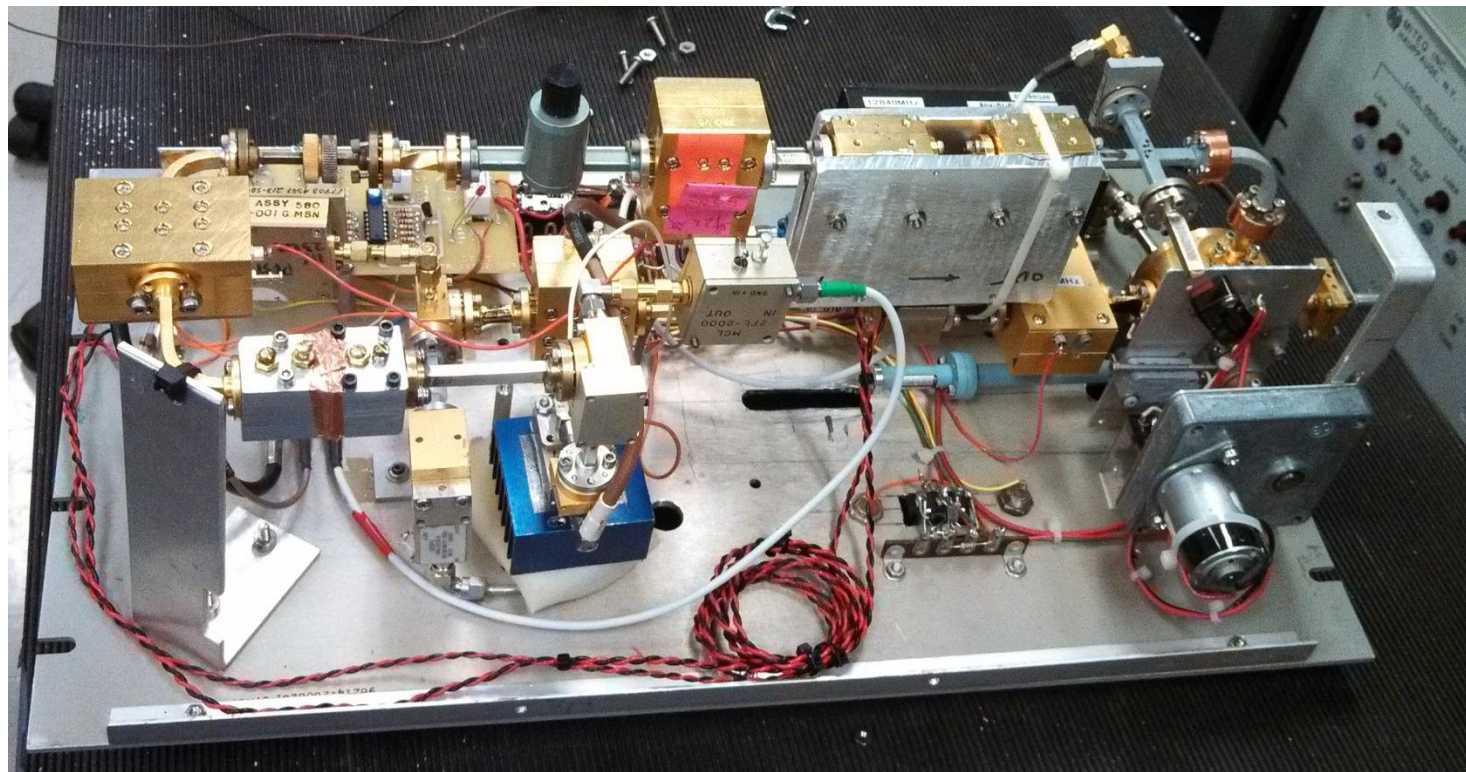
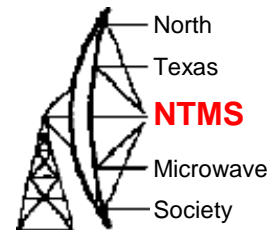
# Trying to Duplicate the OE9PMJ Filters at 77 GHz



Thanks to Bob WA5YWC for his many hours of help in trying to duplicate the OE9PMJ filters at 77 GHz



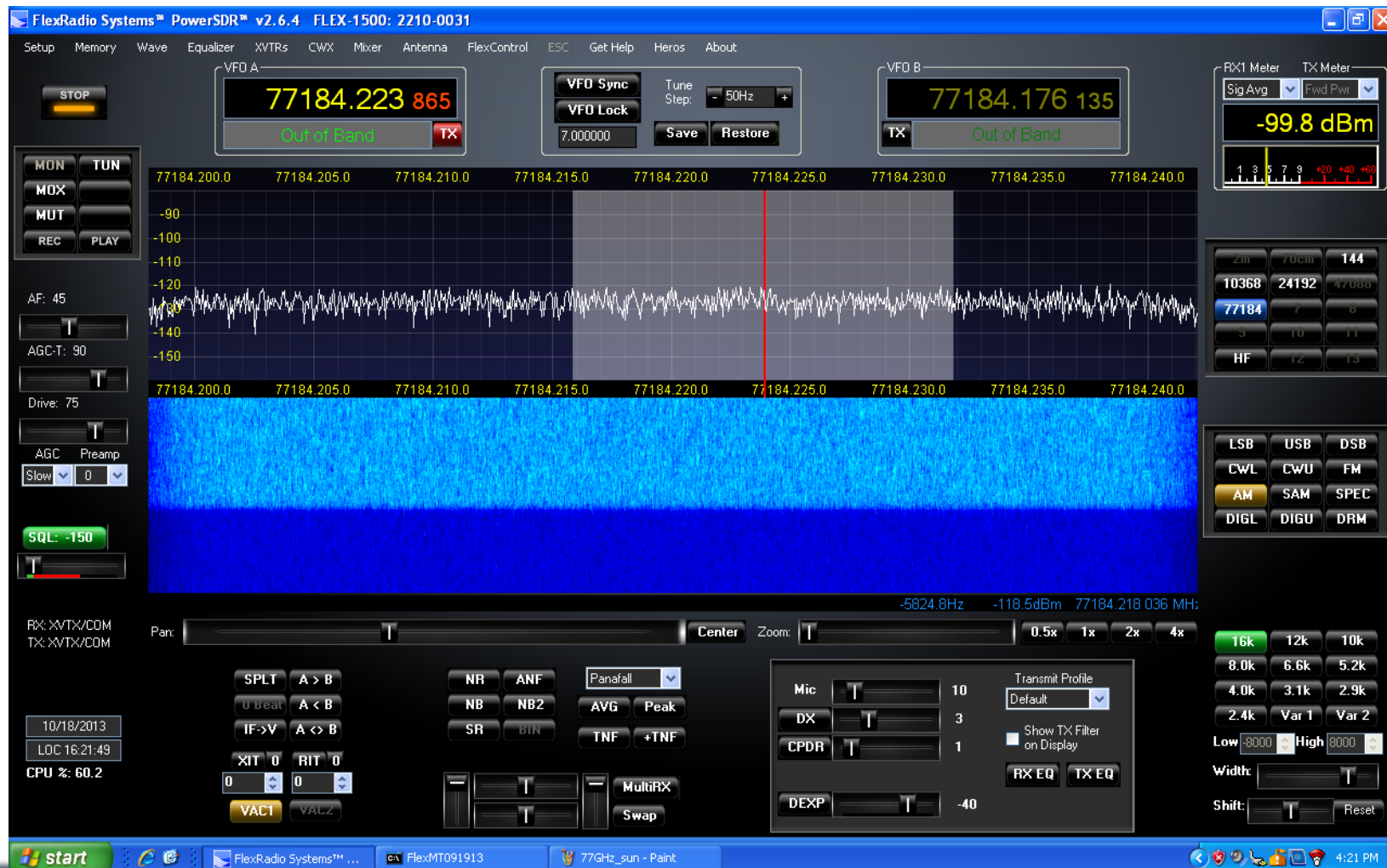
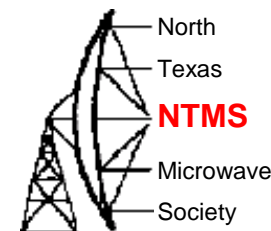
# Completed 77 GHz Assembly



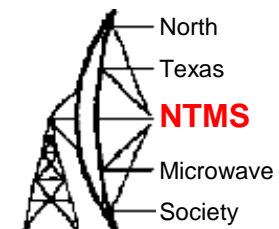
Thanks to WA1MBA, we have a 2 stage power amplifier capable of nearly 200 milli-watts at 77 GHz and a receive NF of approximately 4 dB



# 7.5 dB Sun Noise at Morehead State University 21M Dish

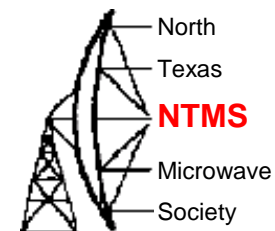


# Performance

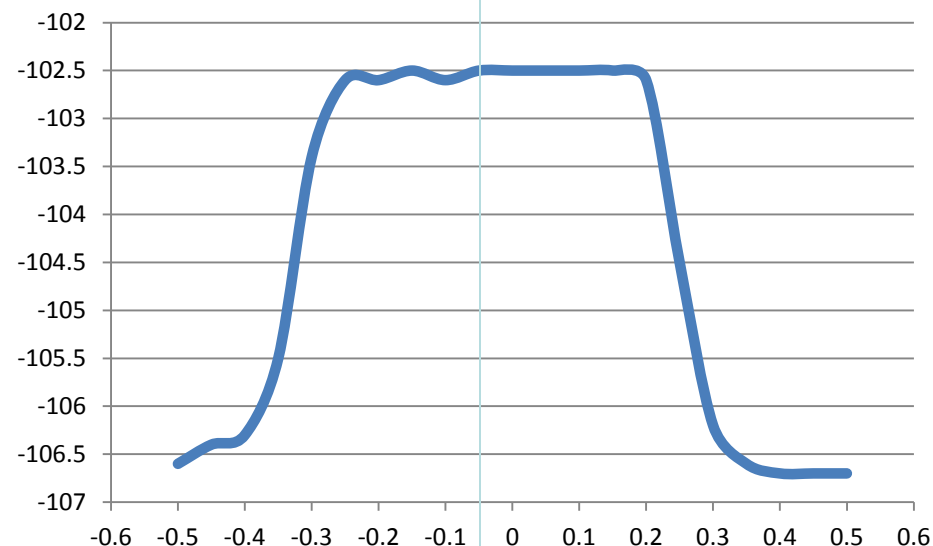


Station	Dish	3 dB BW	Gain @ 50% Eff	NF	Sun Noise	Moon Noise	50Ω over cold sky
W5LUA	2.4M	.11 deg	63 dBi	4 dB	5.5 dB	.4 dB	1.1 dB
WA3ZKR	21M	.012 deg	~ 80 dBi ??	4 dB	7.5 dB	.8 dB	1.1 dB
Dish beamwidth and gain are theoretical							
Biggest unknown is atmospheric absorption mainly moisture							

# Sweeping the Sun



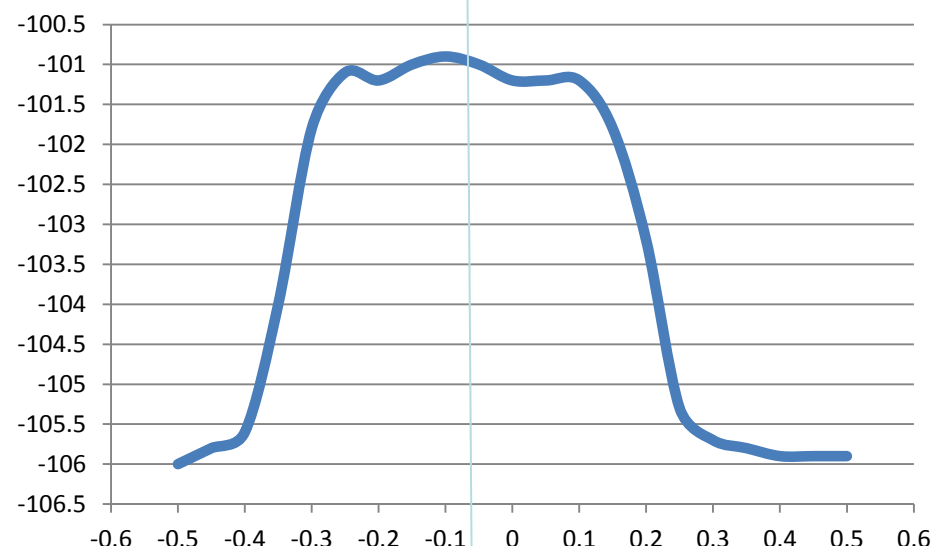
## Azimuth



Degree offset from boresight

~ .05 degree in azimuth

## Elevation

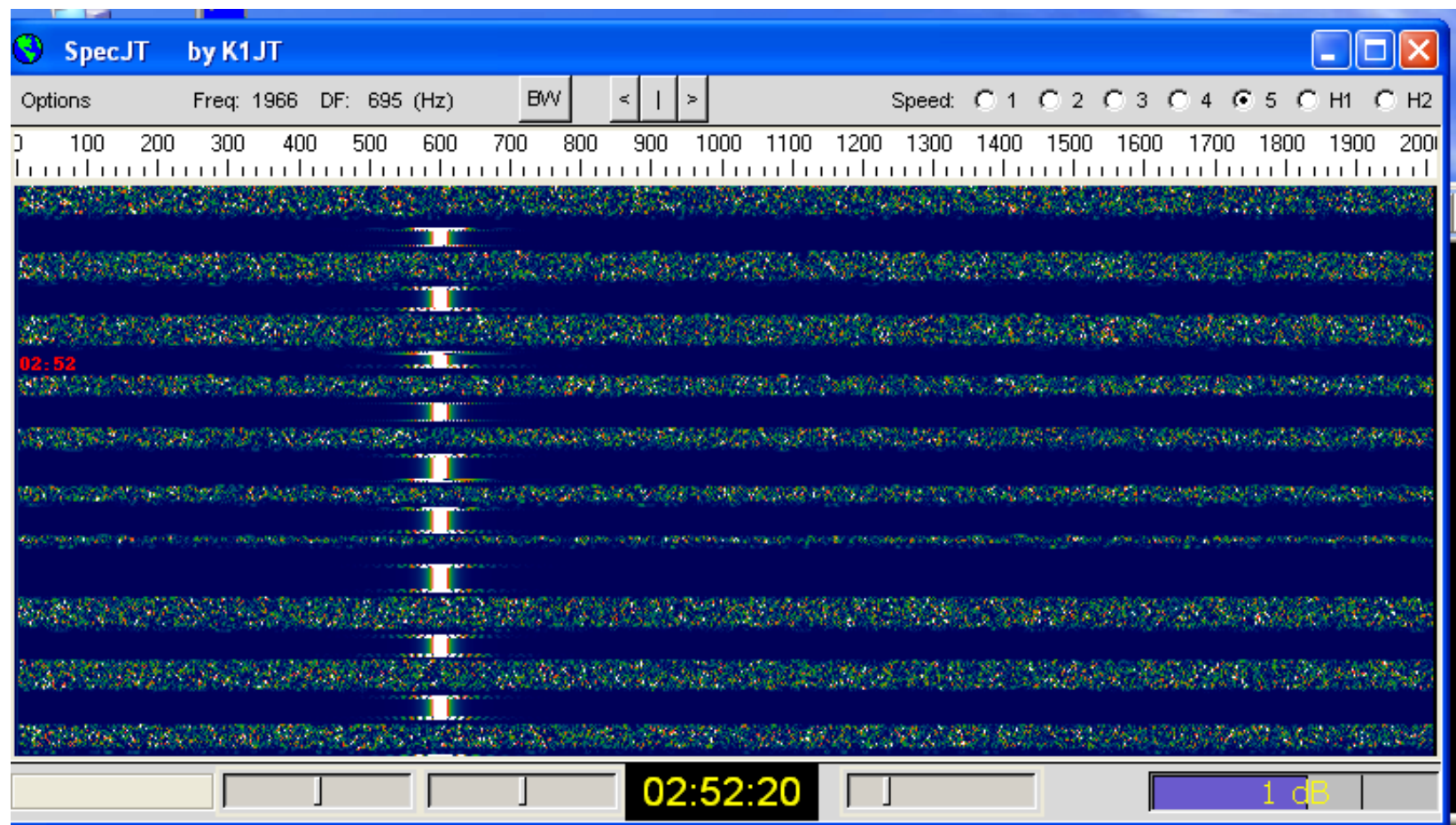
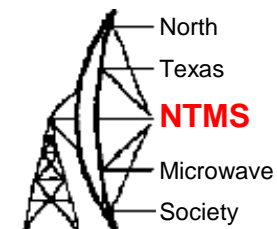


Degree offset from boresight

~ .06 degree in elevation

Ripple in data due to gain changing in down-converter and raining!

# Echo Testing



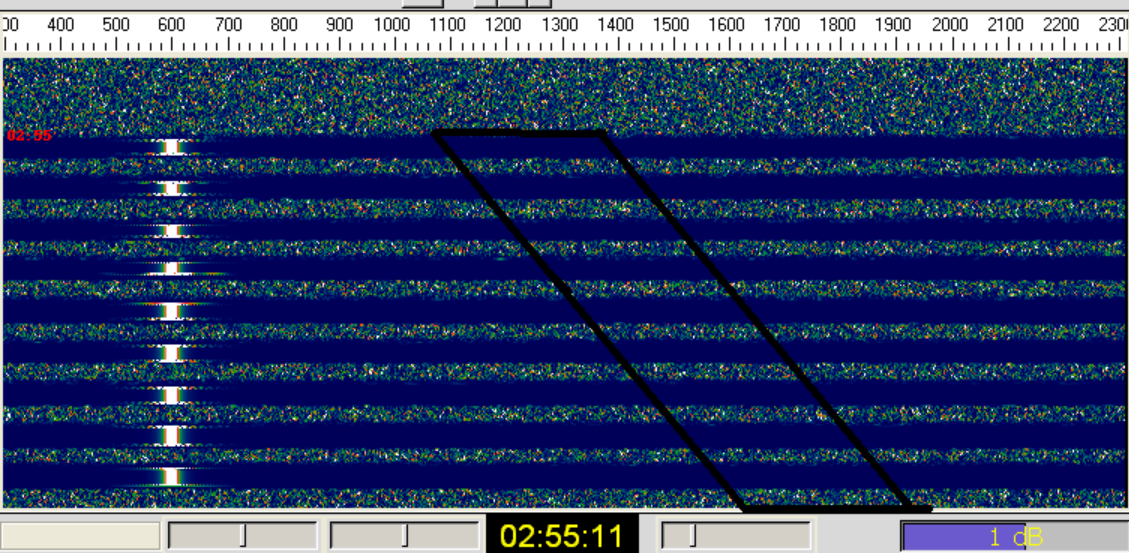
W5HN

My Documents

Setup

SpecJT by K1JT

Options Freq: 2320 DF: 1049 (Hz) BW: &lt; | &gt; Speed: 1 2 3 4 5 H1 H2



021254 21.0 20 8 00 -119 R27

Log QSO Stop Monitor Decode Erase Clear Avg Include Exclude TxStop

To radio: RV3BP Lookup

Grid: Add

☐ Tx First

Gen Msgs Auto is OFF

2013 Oct 19 02:55:11 Dsec: 0.0

1.0001 1.0001 Echo Freeze DF: 0 Rx noise: 2 dB T/R Period: 6 s Receiving

FlexRadio Systems® PowerSDR™ v2.6.4 FLEX-1500: 2210-0031

Setup Memory Wave Equalizer XVTRs CWX Mixer Antenna FlexControl ESC

STOP

VFO A: 77184.086 330

Out of Band TX

VFO Sync Tune Step: 7.000000 Save

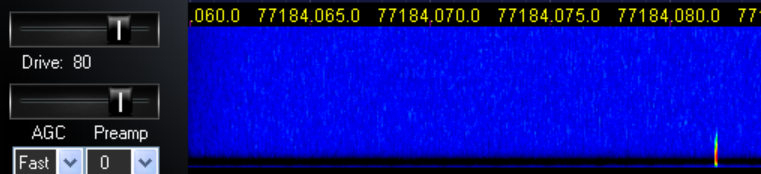
VFO Lock

AF: 45

AGC-T: 90

Drive: 80

AGC Preamp Fast 0



SQL: -150

Pan: Center Zoom: T

RX: XVTR/COM TX: XVTR/COM

SPLIT A > B NR ANF Panafall

U Beat A < B NB NB2 AVG Peak

IF->V A < B SR BIN TNF +TNF

10/19/2013

LOC 02:55:11

CPU %: 33.6

VAC1 VAC2

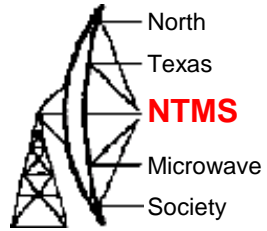
MultiRX Swap

TIME	DATE	TGT	A/T	AZ	EL	AZC	ELC	DEC	A
02:55:11	10/19/13	MOON	OFF	118.94	46.85-20.5	-0.7	11.5		
ANTENNA	AZIM	ELEV	Band: 77184MHZ						
1296	0.00	0.00	Doppler: 86705.7						
2304	0.00	0.00	Sky Ten: 2.7						
3400	0.00	0.00	Loss dB: 1.38						
5760	0.00	0.00	Tdeg dB: 1.38						
10368	0.00	0.00	Pol: 46						
24048	0.00	0.00	Lib: 1062.4						
47088	0.00	0.00							
77184	0.00	0.00							

start FlexMT091913 FlexRadio Systems... WSJT9 WSJT 9.5 r3033 ... SpecJT by K1JT echo\_test\_2 - Paint 2:55 AM



# Next Session



- 0200Z 10PM Tonight – test with RW3BP
- Any Questions?