

Using Sun Noise to Evaluate System Performance at VHF/ UHF and Microwave

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Using Sun Noise to Evaluate System Performance at VHF/UHF and Microwave

- Discover What You can do with Measurements
- Discuss the Radio system and Instrumentation Needed to Make Measurements
- How to Make Measurements
- How to Interpret the Results
- Result Predictions & Actual Values

Introduction to Using Sun Noise to Evaluate System Performance

- Most VHF/UHF Amateurs are Familiar with Noise Figure Measurements to Optimize Preamplifiers & RX Converters
- But Using the Sun as the Noise Source We can do Much More !
- This Presentation will Cover the Basics and Suggest Other Areas to Explore

Introduction to Using Sun Noise to Evaluate System Performance

- **Measurements Can Be Used to :**
 - **Compare Overall System Sensitivity**
 - How does one system perform relative to others?
 - **Validate System Performance**
 - Does it work as well as expected?
 - **Measure Antenna Gains**
 - Using a measured reference antenna

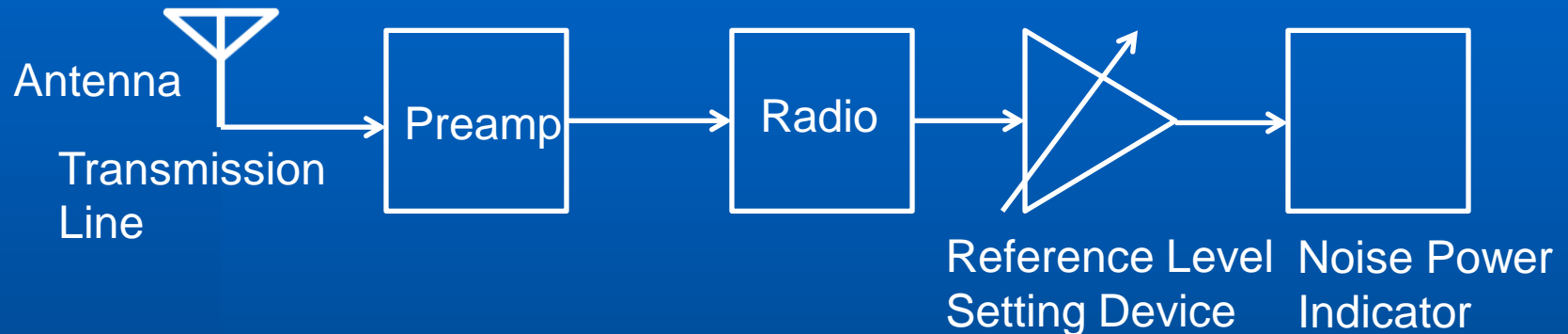
Noise Emissions from the Sun

- Sun Emits Noise from Optical spectrum down to ~30 GHz as a Black Body radiator of about 6000 deg K.
- Noise Between 100 MHz and 30 GHz Varies Greatly with Contribution from Corona and Chromosphere
- If Using Sun Noise for Long Term Comparisons, Must Note Solar Flux values and Compensate for Changes.

Noise Emissions from the Sky

- Sky Noise Also Varies with Frequency.
- Noise Between 1 and 10 GHz is About 3- 4 deg K from the Big Bang !
- Above 10 GHz Resonances of Oxygen and Water Vapor Increases Atmospheric Losses and the Sky Temperature Increases.
- Below 1 GHz the Noise Increases from Cosmic and Planetary Sources.

Measurement Technique

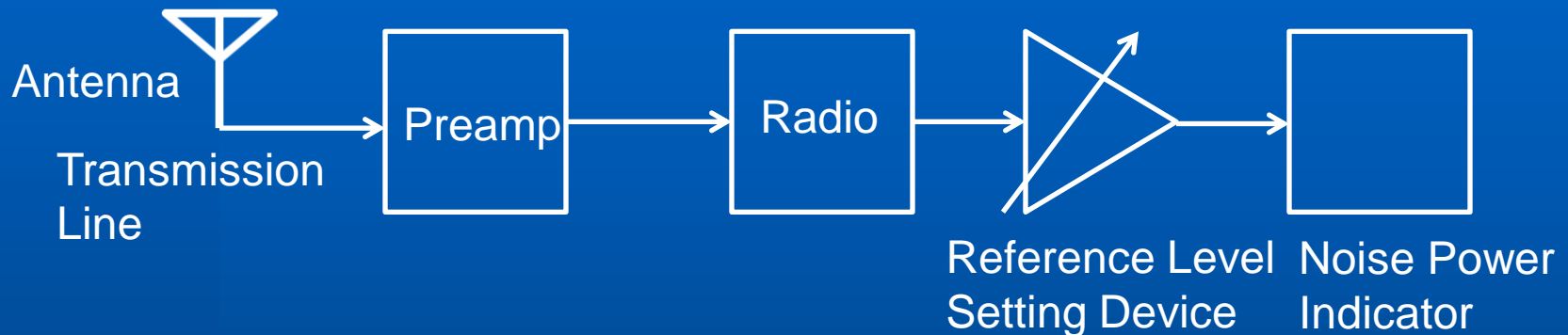


- **Need Antenna Capable of Pointing at Sun**
- **Take Noise Reading Pointed at Sun, Then Another at “Cold Sky”**
- **Noise Levels will Depend on Frequency, Antenna Gain, Preamplifier Sensitivity, etc.**

Antenna Requirements

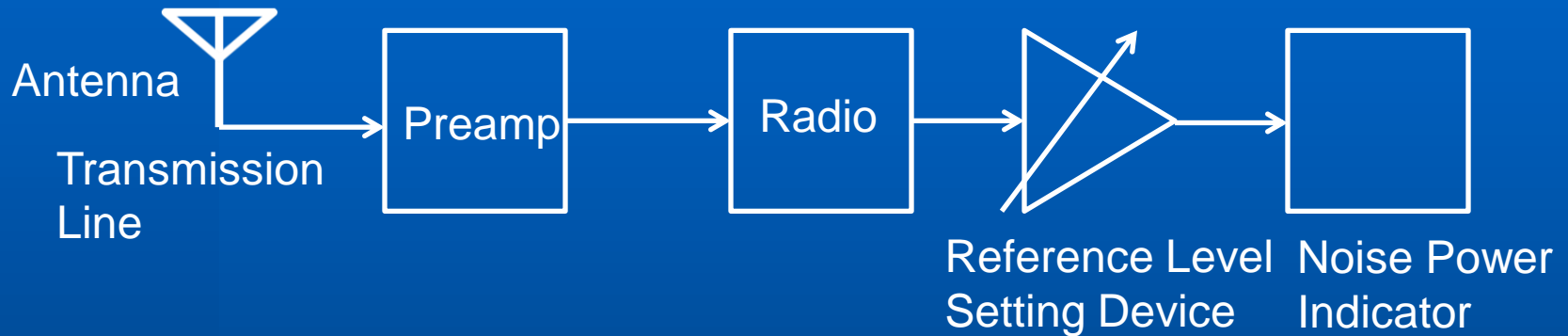
- **Need Antenna “Sharp Enough” to Point at Sun and Away From Other Noise Sources**
 - Ground, Man Made Emitters, Trees, Etc.
- **Should have a Clean Pattern**
 - Important Even for Terrestrial Operation!
- **Antenna Gains Need to be Less than 50dBi**
 - For a Beamwidth Less than 0.5 degrees the Sun/ Moon are No Longer Point Sources

Measurement Technique Cont'd



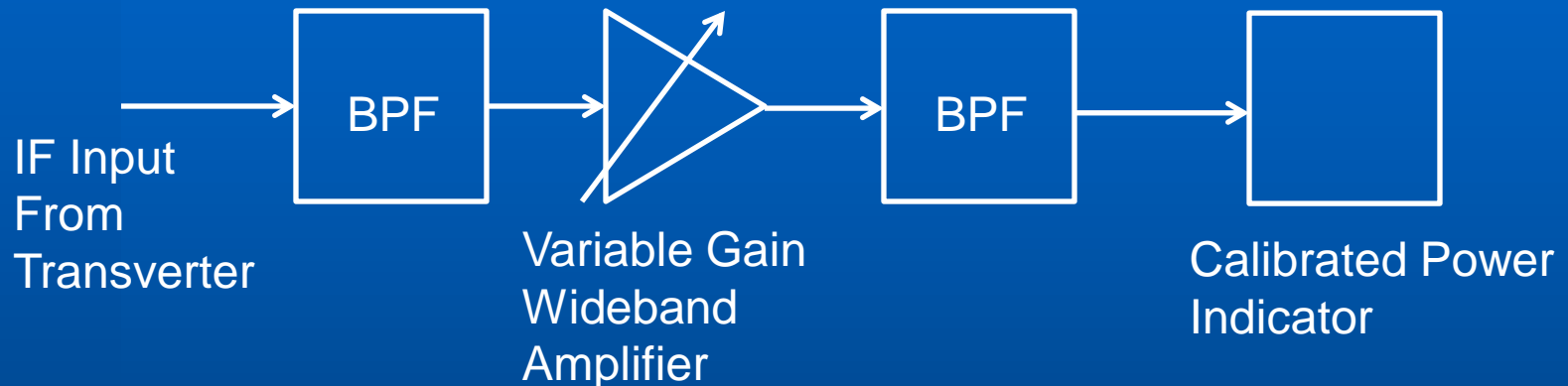
- **If Measuring Receive Audio, Must Disable the AGC, Unless Using “Precision” S meter**
- **Use Widest Bandwidth Possible to Average out Short Term Variations and Resolve Small Noise Level Changes**
- **Using $< 3\text{kHz}$ BW Requires Some Averaging**

Measurement Technique Cont'd



- **Best Measurements Done by taking Wideband IF measurements, typically at the Output of a RX Converter or Transverter**
- **Care has to be taken to ensure that the Output is “Clean” of spurs or LO Leakage**

Measurement Technique Cont'd



- **Basic Indicator is a Wideband “Power Meter”**
 - Need High Resolution and Stable Indication
 - Gain Stability of Whole System is Important !
- **Need BP Filtered but Variable Gain Amplifier to Set Levels**
 - >60 dB gain minimum
- **Linear Dynamic Range must be 12 dB above nominal Noise level**

Many Ways to Build a System

- Use a Low Power microwave power meter with analog indicator (HP 432, 435, etc.)
- Use a True RMS Voltmeter
- Use a Noise Figure Meter or Selective Level Meter
- W1GHZ Has Described Several Level Meters
- GR1215 or 1236 IF Amplifiers
- Use a Receiver with “Precision” S Meter
- Use an RTL Dongle and Noise Software

General Radio 1236 IF Amplifier

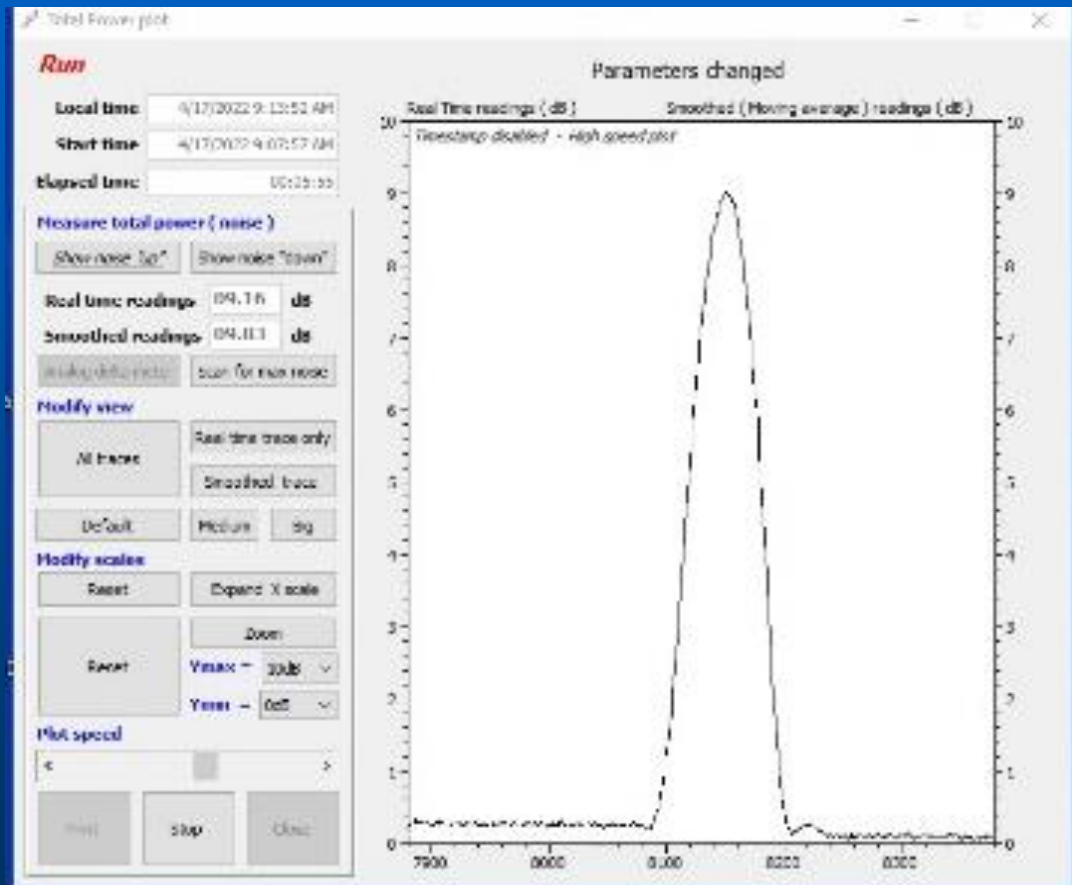


RTL Dongle & Noise Software

- **I0NAA Created “Total Power” software using RTL Dongle for receiver**
 - **Wide Band Frequency coverage**
 - **Up to 2.4 MHz Sampling Rate so Wide Bandwidth & Stable Readings**
 - **Wide Range of Operating Levels and Resolution**
 - **Many Features for Radio Astronomy Use**

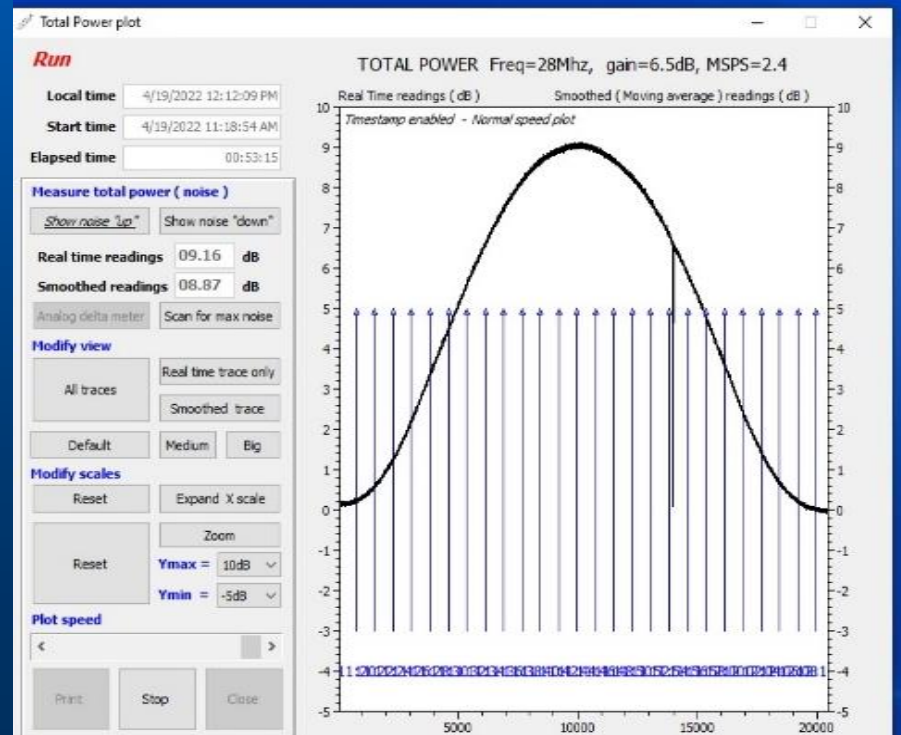
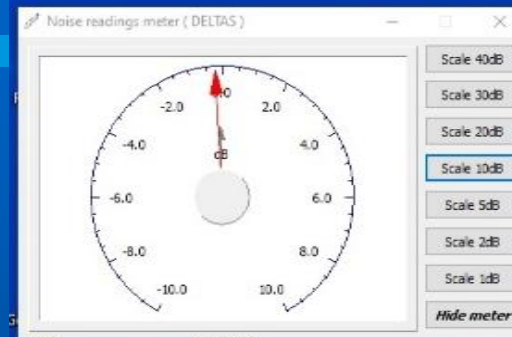
Total Power Software Example

- Sun Noise Response on Antenna Move
- Analog Meter available for Peaking Response



Total Power Software Example 2

- Response as Sun Moves Across Antenna Beam
- Can Determine Beam width with Time Ticks



Taking Measurements

- **System Must be Sensitive Enough to pick up Sun Noise:**
 - Adequate Combination of Antenna Gain, System Noise Figure and Down conversion Gain
- **Anticipated Performance can be Checked using VK3UM's EME Calculator program**
- **Expect Most Portable Terrestrial systems on 5.7, 10 & 24 GHz & Above should be good Enough to Use the Sun.**

VK3UM EME Calculator Program

Two Station EME Rx Performance Source Pos. Planets Sky Map Home Data
x 10 Multiplier
Note Pad
Feed Type X ref
Version History
VK3UM.com
Help About Exit

Tx A (Home Station) Default

10.368 GHz 287.94 dB **9 K** **500 Hz** **2.00 mm** **9.0 mm** -152.1 dBm -6.3 dB

Frequency Path Loss **Aqu or Leo** Rx BW **2.00 mm** **9.0 mm** -10.1 dB **9.0 mm** Effective ground T*K 274 °K

117 0.00 dB 0.65 dB **23.0 dB** 0.5 dB 1.0 dB **24 °K** **0 °K** 6.4 dB

Solar Flux LNA Loss LNA Nf LNA Gain Coax Loss Rx Nf Spillover Feedthrough Sun Y

Tx A Output Power Transmission Loss Power at Feed Moon Y

560 Watts 27.48 dBW **0.3 dB** 523 Watts 27.18 dBW 2,161,795 W EIRP

RxTK 47.4 °K = 0.66 dB Ground Temperature **Tsys 80.4 °K = 1.06 dB**

Dx Station as received at Home Station ... -9.9 dB

Apply Atmosphere Correction ?

Home Station as received at Dx Station ... 3.0 dB

Tx B (Dx Station) Default

10.368 GHz 287.94 dB **9 K** **120 Hz** **2.00 mm** **9.0 mm** -154.5 dBm 5.5 dB

Frequency Path Loss **Aqu or Leo** Rx BW **2.00 mm** **9.0 mm** -10.1 dB **9.0 mm** Effective ground T*K 248 °K

117 0.10 dB 0.40 dB **33.0 dB** 2.0 dB 1.0 dB **44 °K** **28 °K** 13.2 dB

Solar Flux LNA Loss LNA Nf LNA Gain Coax Loss Rx Nf Spillover Feedthrough Sun Y

Tx B Output Power Transmission Loss Power at Feed Moon Y

50 Watts 16.99 dBW **0.3 dB** 47 Watts 16.69 dBW 1,903,258 W EIRP

RxTK 35.5 °K = 0.50 dB Ground Temperature **Tsys 116.8 °K = 1.47 dB**

Operating Frequency User 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 47.088 GHz 2295 MHz

Yagi Array Number of Yagis E 38.3 ° Array Gain

Single Yagi Gain in dBi **12.65 dBi** 1 H 38.3 ° 10.50 dBd 12.65 dBi

Parabolic Reflector Feed Type VE4MA (Super) Linear Pol. Circular Pol.

Focal Length 0.90 ft Diameter Size 2.49 ft Imperial f/D 0.36 Efficiency 67% Beam Width 2.66 ° Gain 4584 Dish Gain 34.02 dBd 36.17 dBi

26.3 Lambda

Home Station ... Y Factor Calc Noise[hot] Flux Quiet [cold] Sky System TK

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

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

132 Jy 9 °K 80.4 °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 Number of Yagis E 38.3 ° Array Gain

Single Yagi Gain in dBi **12.65 dBi** 1 H 38.3 ° 10.50 dBd 12.65 dBi

Parabolic Reflector Feed Type VE4MA (Super) Linear Pol. Circular Pol.

Focal Length 1.05 m Diameter Size 2.44 m Metric f/D 0.43 Efficiency 65% Beam Width 0.83 ° Gain 45199 Dish Gain 43.96 dBd 46.11 dBi

84.2 Lambda

Effective Aperture	Beam Width Ratio	Note.. Both Moon and Sun correction factors are applied to Home and Dx Station calculations.	
0.30 M ²	0.21	Moon Beam Fill Factor	Sun Beam Fill Factor
		1.02 x 0.07 dB	1.01 x 0.06 dB
		G/T Ratio	Moon Temp @ 2.77cm Phase
		57.00	
Moon Radar Equ.	Moon Flux 10 ⁻²²	Moon Angular Diam	Actual Moon Temp
52.26 dB	5.2585	0.559 °	213 °K...9.4 °K
Moon Return Loss			Corrected sfu
287.94 dB	356400 kMs	223.80 dB	249

Free Space Loss at 10368 MHz at 10368 MHz

Save Data

Get Data

Default

Print

Exit

VK3UM Ver 8:02

Program Predictions for 30 inch Dish

- 5.7 GHz with a 0.65 dB NF (EME) preamp
~ 5.7 dB Noise increase
- 10 GHz with a 0.65 dB NF (EME) preamp
~ 6.4 dB Noise Increase
- 24 GHz with a 1.5 dB NF (EME) preamp
~ 5.3 dB Noise Increase
- 10 GHz with 1.0 dB NF DEMI & **18 inch** dish
~ 2.7 dB Noise Increase

Program Predictions for Yagi Antennas

- 144 MHz 2.12 WL M2 9SSB 11.96 dBi Gain with a 0.25 dB NF (EME) preamp
~ 3.42dB Noise increase
- 432 MHz 6.5 WL K1FO 22 el 17.85 dBi with a 0.25 dB NF (EME) preamp
~ 7.3 dB Noise Increase
- 1296 MHz 55el Directive Systems Loop'er with a 0.25 dB NF (EME) preamp
~ 2.44 dB Noise Increase

Some Measured Dish Results

- 10 GHz **18 inch Dish** 1.0 dB NF DEMI
2.0 dB Noise Increase
- 10 GHz **32 inch Dish** 0.65 dB (EME) preamp
6.25 dB Noise Increase
- 24 GHz **39 inch Dish** 1.5 dB (EME) preamp
10.2 dB Noise Increase

Some Measured Yagi Results

- 432 MHz, 25el K1FO, 0.3 dB NF EME preamp
~6.0 dB Noise Increase
- 1296 MHz 55 el Looper 0.25 dB (EME) preamp
3.5 dB Noise Increase
- Care Must be Taken to avoid Driven Element
Being Too Close to Ground
- Of Course VHF/ UHF Antenna Must be Clear of
Buildings, Trees, Etc. **Note Large Beamwidths**

Measurements of 5 ft TVRO Dish

- 2.3 GHz Offset Feed to Part of 10 ft Dish



Measured Results for 5 ft TVRO Dish

- 902 MHz ~ 22 dBi Gain, 0.5 dB NF
7.0 dB Noise Increase
- 1296 MHz ~25 dBi Gain, 0.25 dB NF
7.5 dB Noise Increase
- 2.3 GHz ~30 dBi Gain, 0.35 dB NF
>8 dB Noise Increase
- 3.4 GHz ~ 34 dBi Gain, 0.45 dB NF
9.0 dB Noise Increase
- 5.7 GHz ~ 38 dBi Gain, 0.5 dB NF
9.5 dB Noise Increase
- 10 GHz ~43 dBi Gain, 0.65 dB NF
Only 8.5 dB Noise Increase

Antenna Gain Can Be Too High !

- Tested 24 GHz Feedhorns from W1GHz with Increasing Gain to find Best G/T for 2.4 m 0.7 f/D dish
- Tests inconclusive ! ?



Antenna Gain Can Be Too High !

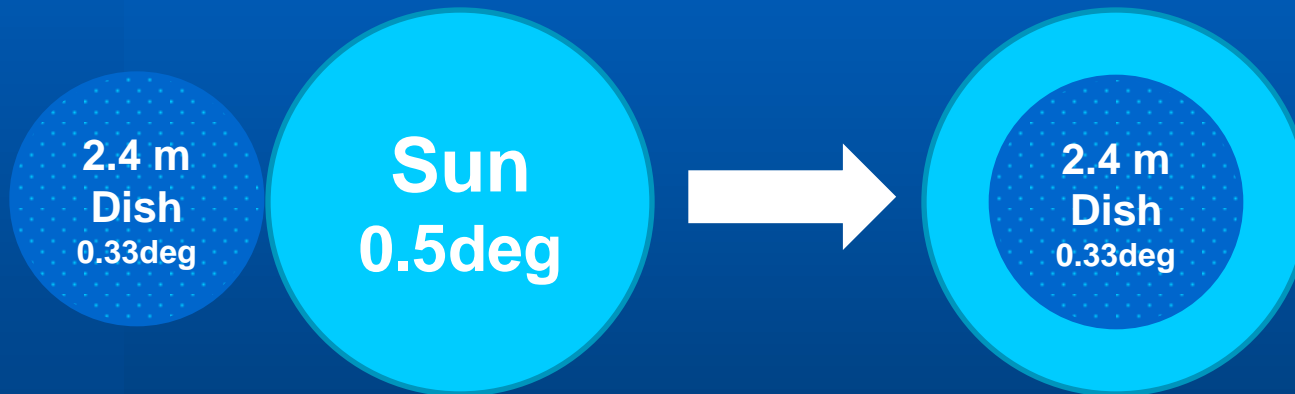
- Difficult to test in Mid November from VE4 due to low Sun and limited window before trees.
- Sun is 0.5 Deg Wide Dish BW ~ 0.3 deg, (54 dBi Gain)
- Needed to Re-Test on Smaller Dish

2010/10/16

8 ft Dish 3.4 - 78 GHz

24 GHz Sun Noise with 2.4 m Dish

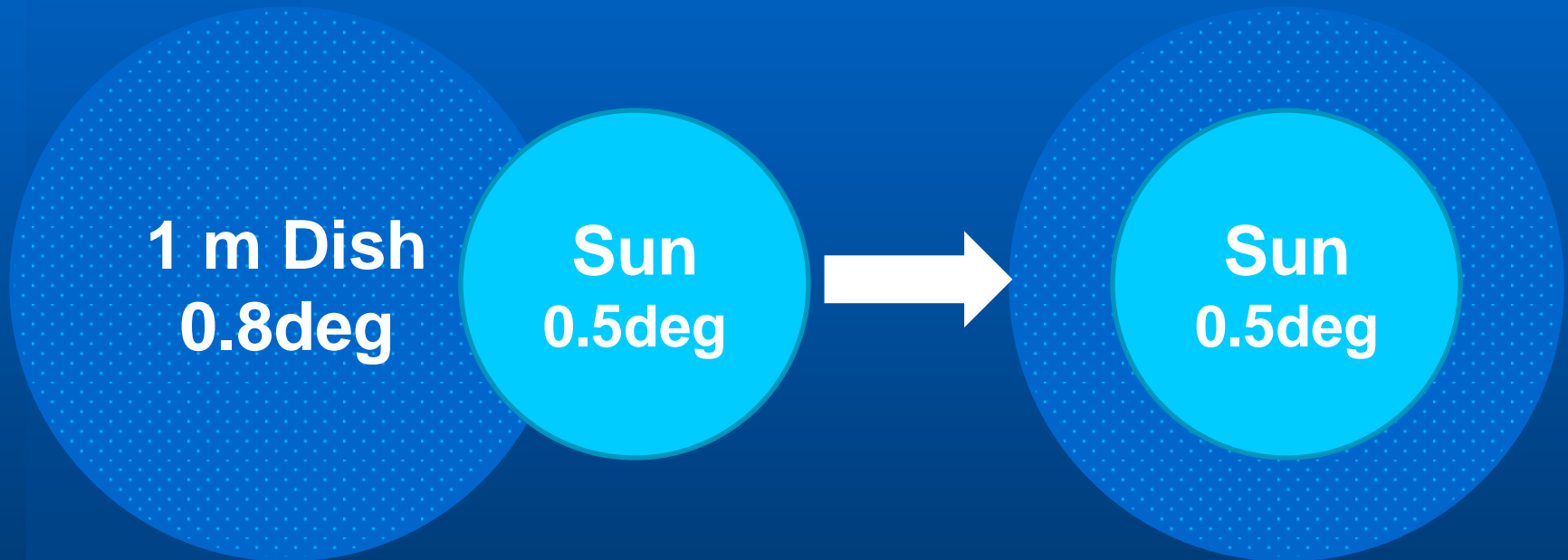
- **Antenna BW less than Sun/Moon Diameter**



- **Increasing Antenna Gain Does Not Increase Noise!**

24 GHz Sun Noise with 1m Dish

- Antenna BW Larger Than Sun Diameter

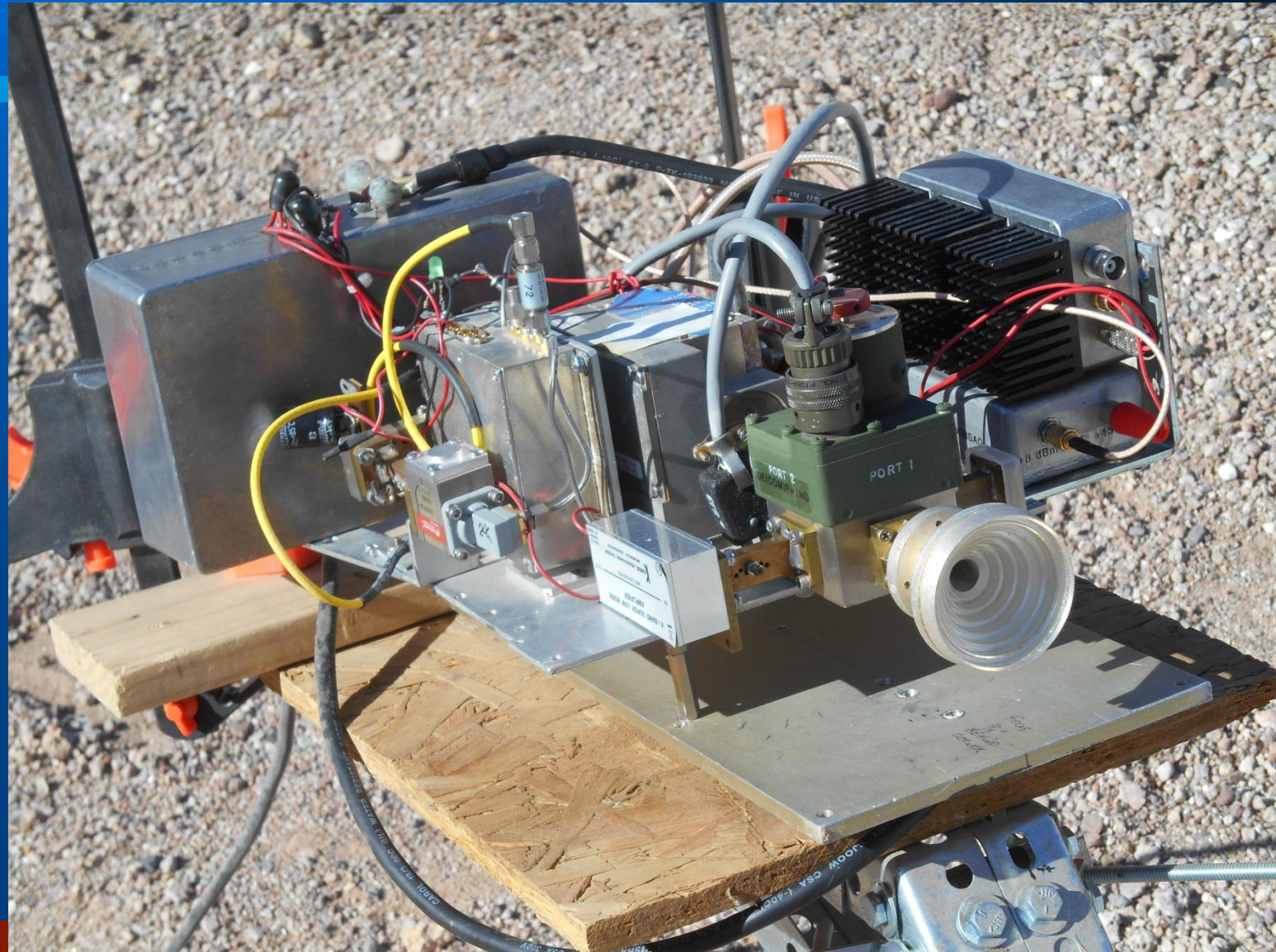


- Increasing Antenna Gain WILL Increase Noise Until BW Equals Sun Diameter

24 GHz Sun Noise on 1 m Dish



24 GHz Sun Noise on 1 m Dish



24 GHz Sun Noise on 1m Dish

- **Best Sun Noise was 10.2 dB ~46 dB Gain**
(I see 14 -16dB at home with 2.4 m dish ~54 dBi Gain)
- **Best Result from**
Corrugated Horn and
1.8 WL W2IMU Feedhorn



How to Compare Sun Noise Readings?

- At Low Ratios the measurements are actually Signal plus Noise.....???
- Consider a Reading of 3 dB.....the Sun Noise is the same level as the Noise (0 dB each)
- To convert to Signal to Noise, must convert dBs to Ratios then substitute into equation
$$S/N = (S + N)/ N + 1$$
So in our example $S/N = 1$

Converting $(S+N)/N$ to S/N Ratio

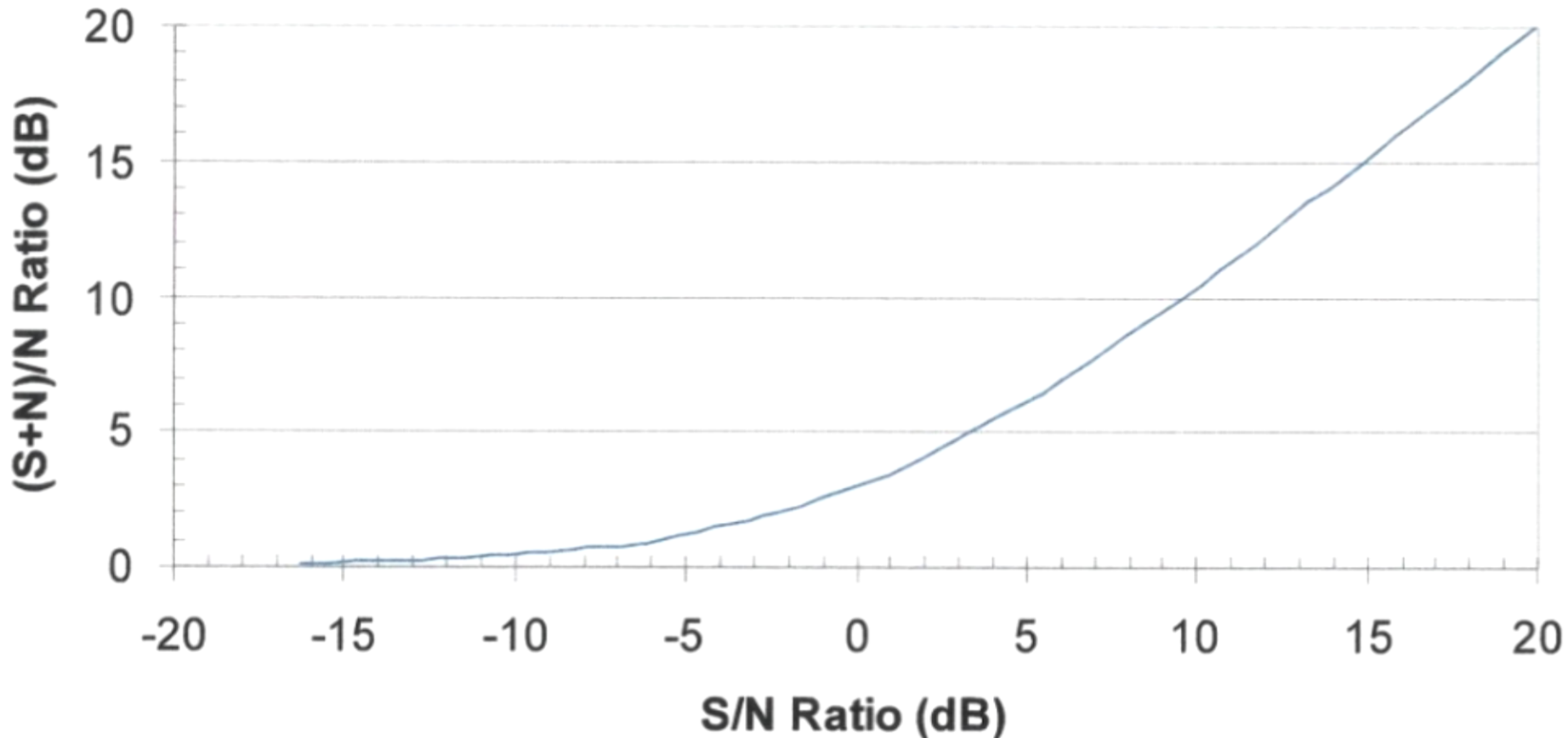
S+N/N	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
S/N	-19.4	-16.3	-13.3	-11.5	-10.2	-9.1	-8.3	-7.7	-6.9	-6.4

S+N/N	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
S/N	-5.9	-2.3	-0.0	1.8	3.3	4.7	6.0	7.3	8.4	9.5

S+N/N	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
S/N	10.6	11.7	12.8	13.8	14.9	15.9	16.9	17.9	18.9	20.0

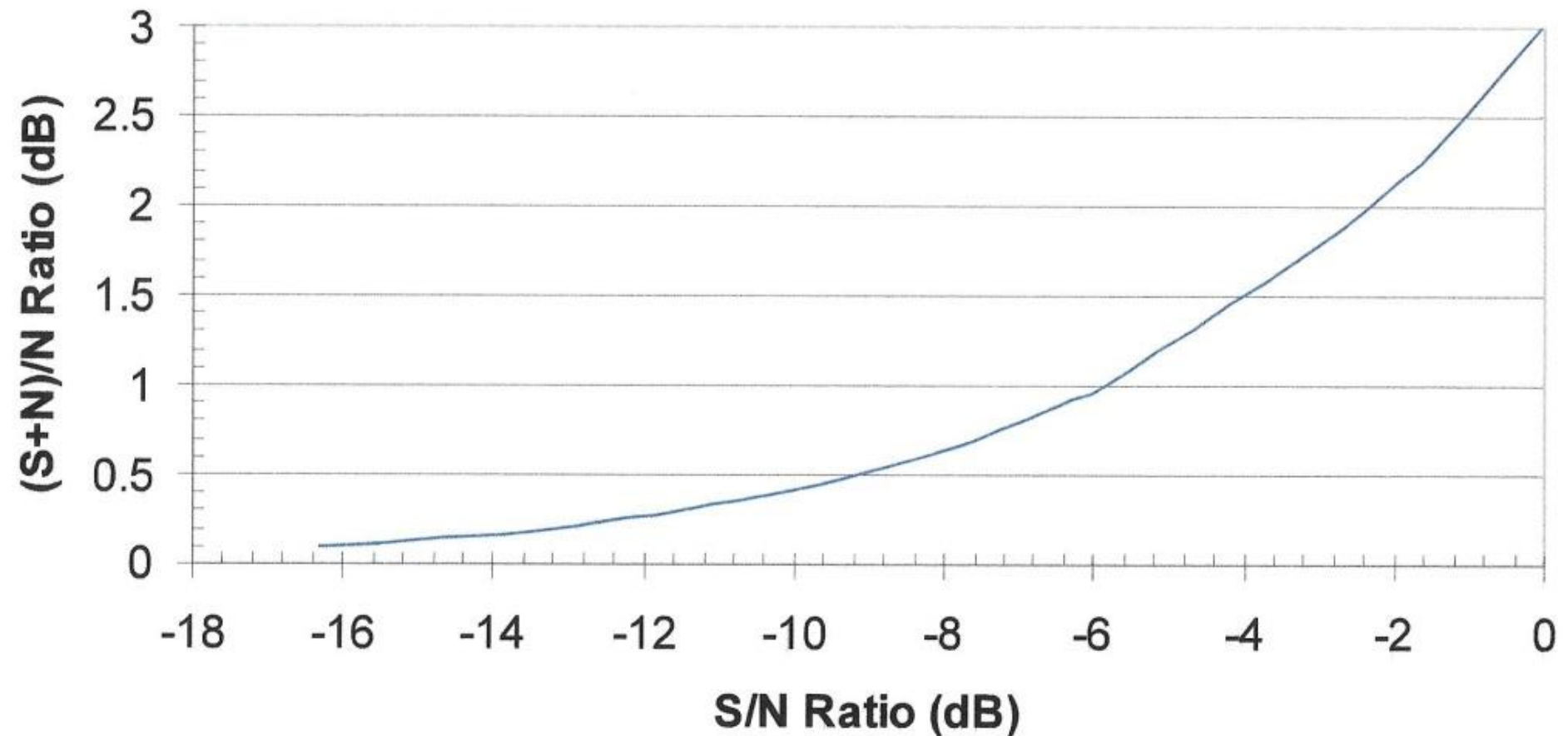
Converting $(S+N)/N$ to S/N Ratio

Converting $(S+N)/N$ to S/N Ratio



Converting $(S+N)/N$ to S/N Ratio

Expanded Scale



Measurement Method of Procedure

- Use the Graph or Table Values to convert $S+N / N$ Readings to S/N values
- Use S/N Values to Determine Antenna Gain using Reference Gain Antenna
- Use $S+N/ N$ Values to Evaluate System Performance Relative to VK3UM Predictions
- Use S/N Values to Compare Different Antennas

Sample Measurement Results

Callsign	Antenna Used	Sun Noise S+N/N (dB)	Signal to Noise (dB)	Comments
W0ZQ	24 in Offset	3.0	0.0	Best Measured
W0AUS	18 in Offset	2.0	-2.2	Loaner Rig
K00IYT	18 in Offset	2.0	-2.2	Dish Network
WA2VOI	24 in Prime	1.5	-4.0	
WB0LIC	18 in Offset	1.5	-4.0	
W0ZQ	20 dB Horn	~0.05	~-18	Tiny Rig
K0KFC	32 in Offset	3.25	~+1	Arizona
K0KFC	32 in Offset	6.25	~+5	AZ EME Preamp

For Further Enlightenment

- See W1GHz's "Antenna Measurement Using the Sun" at <http://www.qsl.net/n1bwt/chap10.pdf>
- See W5LUA's "Using Sun Noise to Evaluate System Performance" at <http://www.ntms.org/files/sun.pdf>
- See VK3UM's "Sun Noise Measurements" at http://www.vk3um.com/SunNoise_Measurements.pdf

For Further Enlightenment Cont'd

- See UA3AVR's "Solar Flux and Temperature at Millimetre Wavelengths" in **DUBUS 3/2016**
- See I0NAA's "Total Power" software at <http://i0naa.altervista.org/index.php/downloads>

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- How to Interpret the Results
- Result Predictions & Actual Results
- Questions?