SUN VS. SKY DE-MYSTIFIED

A Practical Guide to Improving Your Microwave Receiver Noise Floor

Rein Smit, W6SZ – Brian Thorson AF6NA

May 2014

Acknowledgement

Rein Smit, W6SZ, has been a licensed radio amateur since 1955, the year SBMS was founded. I have found his knowledge of communications and microwave principles to be extensive. He has been a mentor and a friend to me since I joined SBMS in 2009. Rein designed and implemented the Sun-Sky Noise indication system that I used for the testing described in this material.

So Why Sun vs. Sky?

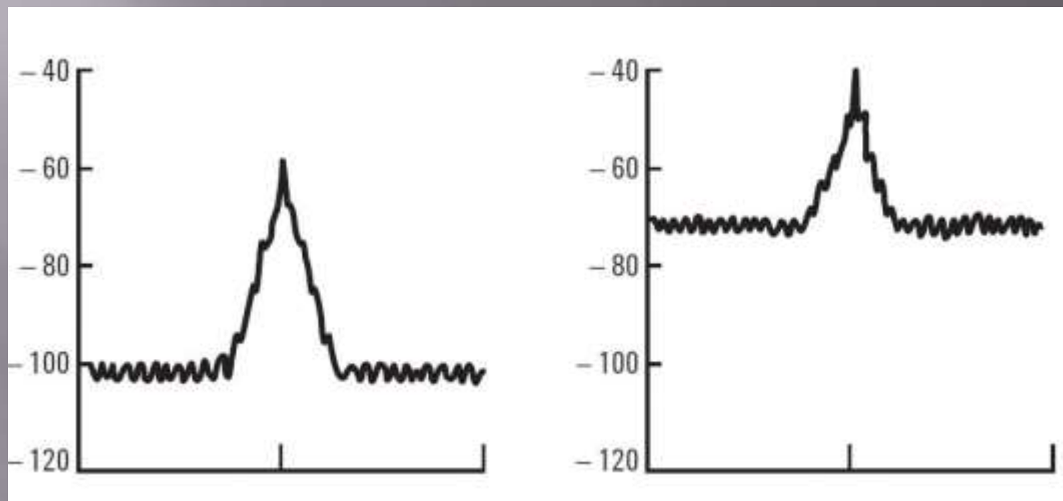
- It is the only RF noise measurement method that will test your entire receive system,

  including the reflector and feed system.

- It only takes a few minutes to evaluate changes to your system.

- If you adjust your feed position for maximum Sun and minimum noise, you will get very close to top antenna efficiency.

A Tale of Two Noise Floors



Source: hp Application Note 57-1

How Deep Can Your Microwave Receiver Dig?

Will your receive system “bury” a weak signal?

Ready to Go in My Driveway

Saturday, 12 April 2014

Why Are You Doing This? Why Does This Even Work?

The Sun and the galaxy (sky) produce different broadband noise power densities at the earth’s surface and are monitored by radio observatories.

- We are going to use these 2 predictable Radio Noise sources and see what power levels they produce in our receiver.
- Then we will compare those two levels.
- The lower level will be related to our receiver sensitivity.

Some Typical Radio Noise Levels

Radio Noise Source	Deg. K
Sun Noise @ 10.4 GHz	350
Earth / Terrestrial Noise	290
DEMI 10 GHz Xverter	120
DB6NT Xverter	92
DB6NT EME LNA	47
Galactic Noise	4-6

The Goals:

Establish a method to measure
changes in sensitivities of pre-amps

An indicator to enable optimization
of weak signal systems

Maximize the difference in noise levels

To measure noise power in degrees Kelvin

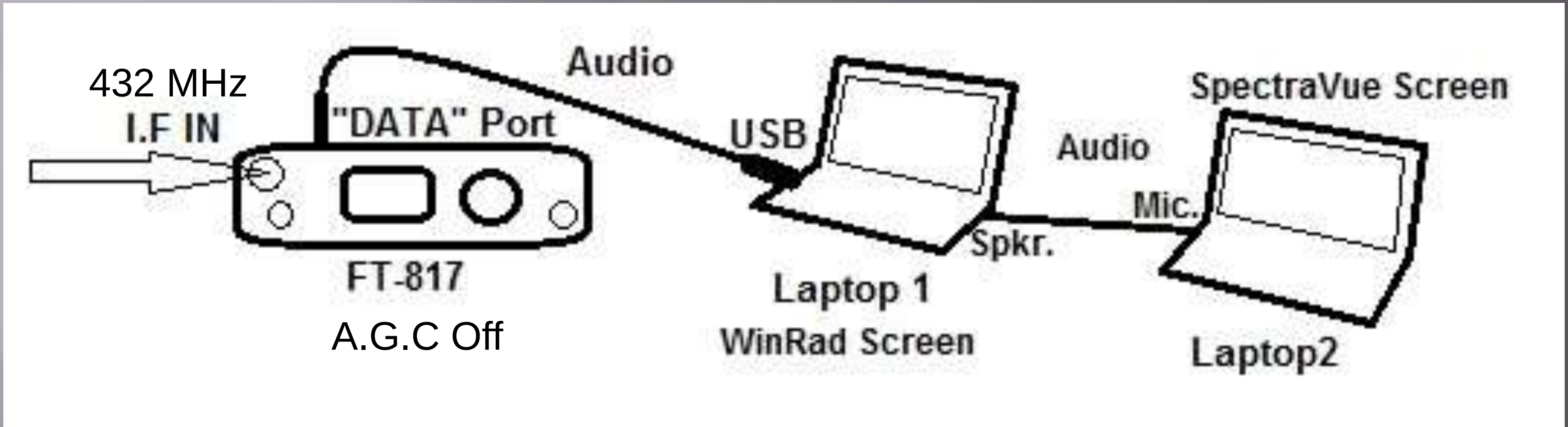
What it Is and What It's Not

- NOT a NF or Sun Noise measurement system
- NOT for reliable absolute value readings
- NOT able to resolve small changes reliably

- <u>It is</u> a qualitative indication system
- <u>It is</u> able to indicate relative values of noise
- <u>It is</u> able to indicate changes 0.5 dB or more

- System indication is a "Y" factor
- It can be used to evaluate hardware changes
- Results can be produced in about 5 minutes

The Setup



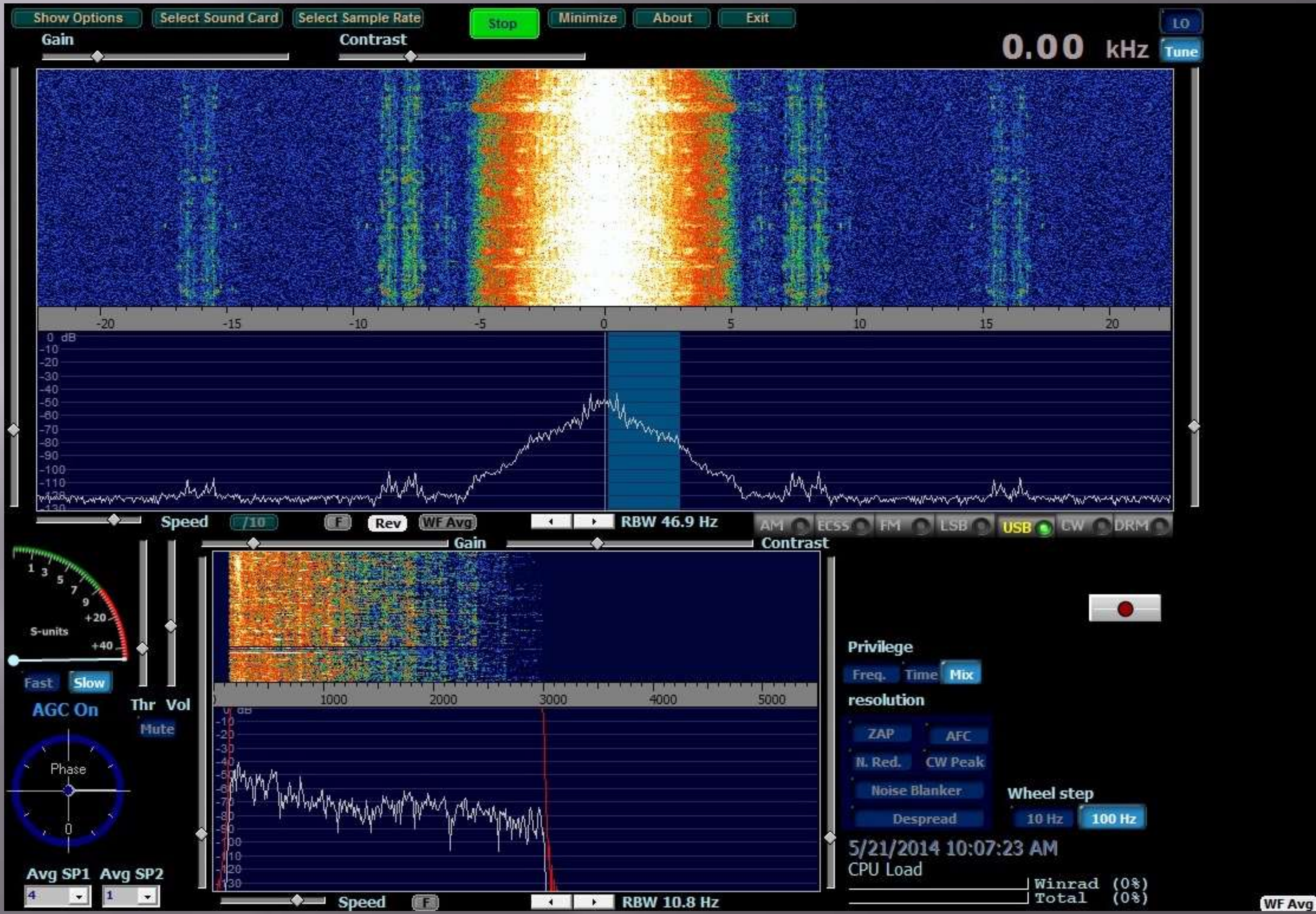
- Output from FT-817 “Data” Connector
- FT-817 A.G.C. turned “off” (menu item)
- USB Input to Laptop1 – Audio Signal – WinRad
- Audio Input to Laptop2 – Audio Signal – SpectraVue

Why 2 Laptops?

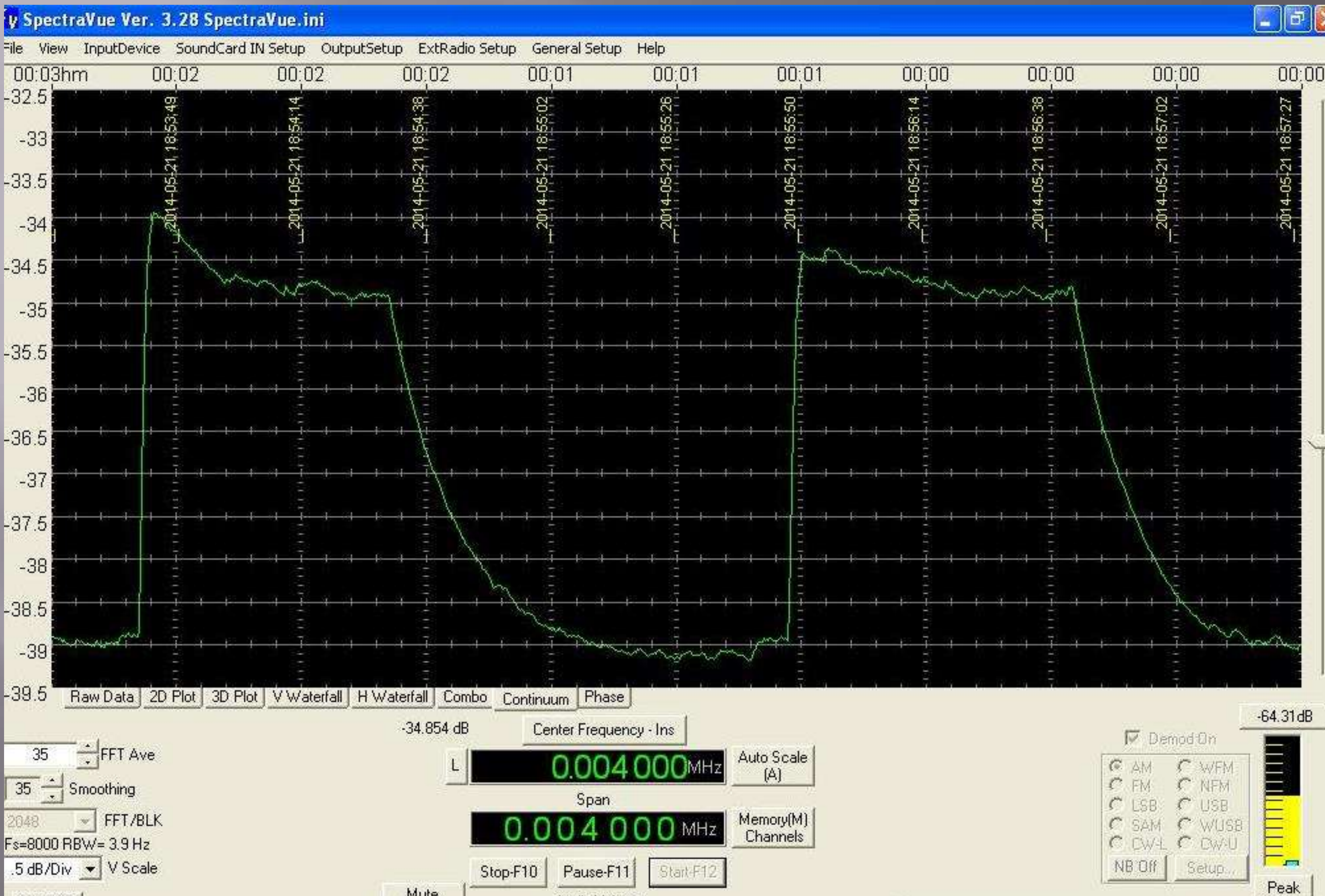
- The system was designed for use with a SDR "dongle."
- The dongle SDR system worked well into the "WinRad" software.
- <u>This indication system could be implemented with just one laptop with SpectraVue.</u>

- The **SpectraVue software** has the advantage of adjustability so the decibel scale can be set for 0.5 dB resolution and a very <u>slow sweep time</u>.
- Any <u>**Audio**</u> detection system or test instrument could be used.

The "WinRad" Screen



The SpectraVue Screen: 0.5 dB / Div.



Checklist

- Msmt. System - Ready
- Elevation Over Azimuth Adjustment Provision
- **AGC "off"** – a menu item for FT-817
- <u>Clear Sky Area – No trees – Important!</u>

Optional:

- Beige Packing Tape
- 3x5 card at feed

Clear Sky vs. Obstructed Sky

Trees have a noise temperature of nearly 290 deg. K

Procedure

1. Point reflector at the **Sun**
2. Adjust Azimuth and Elevation for a peak signal
3. Secure the dish and feed
4. Note reading and record
5. Swing reflector azimuth only to **clear sky**
6. Note reading and record
7. The value from this system was expressed in dB, but could be millivolts.

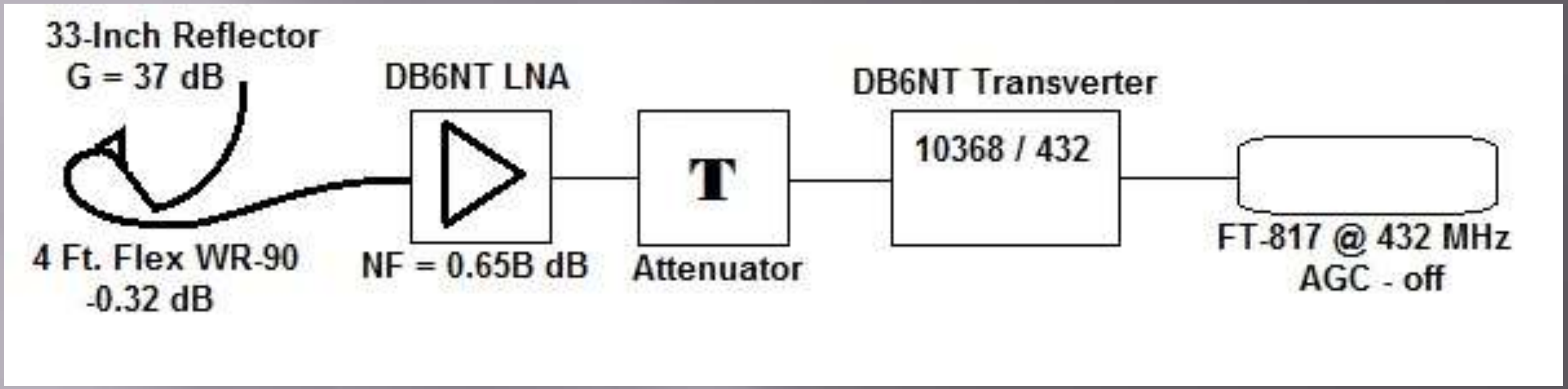
How do I know I'm pointed at the sun ?

Note the "bright spot" at the feedhorn

Is this OK?

Yes, the sun is very much “hotter” than the sky

Sun vs. Sky – AF6NA System



- Big Question – How much Attenuation?
- Stared out at 21 dB attenuation for 2.5 dB ratio
- I tried different amounts of attenuation
- Finished at 7.1 dB with 0 dB attenuation
- That is better than a doubling of the receiver sensitivity
- Kept 3 dB in the system to protect my Xverter

Now that I have a "Y" factor…

I know my RCVR noise floor is 7 dB down
from the Sun Noise at 10368 MHz.
But -7dB from what?

NOAA Web Site:

http://www.swpc.noaa.gov/ftpdir/lists/radio/45day_rad.txt

This site has 45 days of historical radio noise values

NOAA Web Site

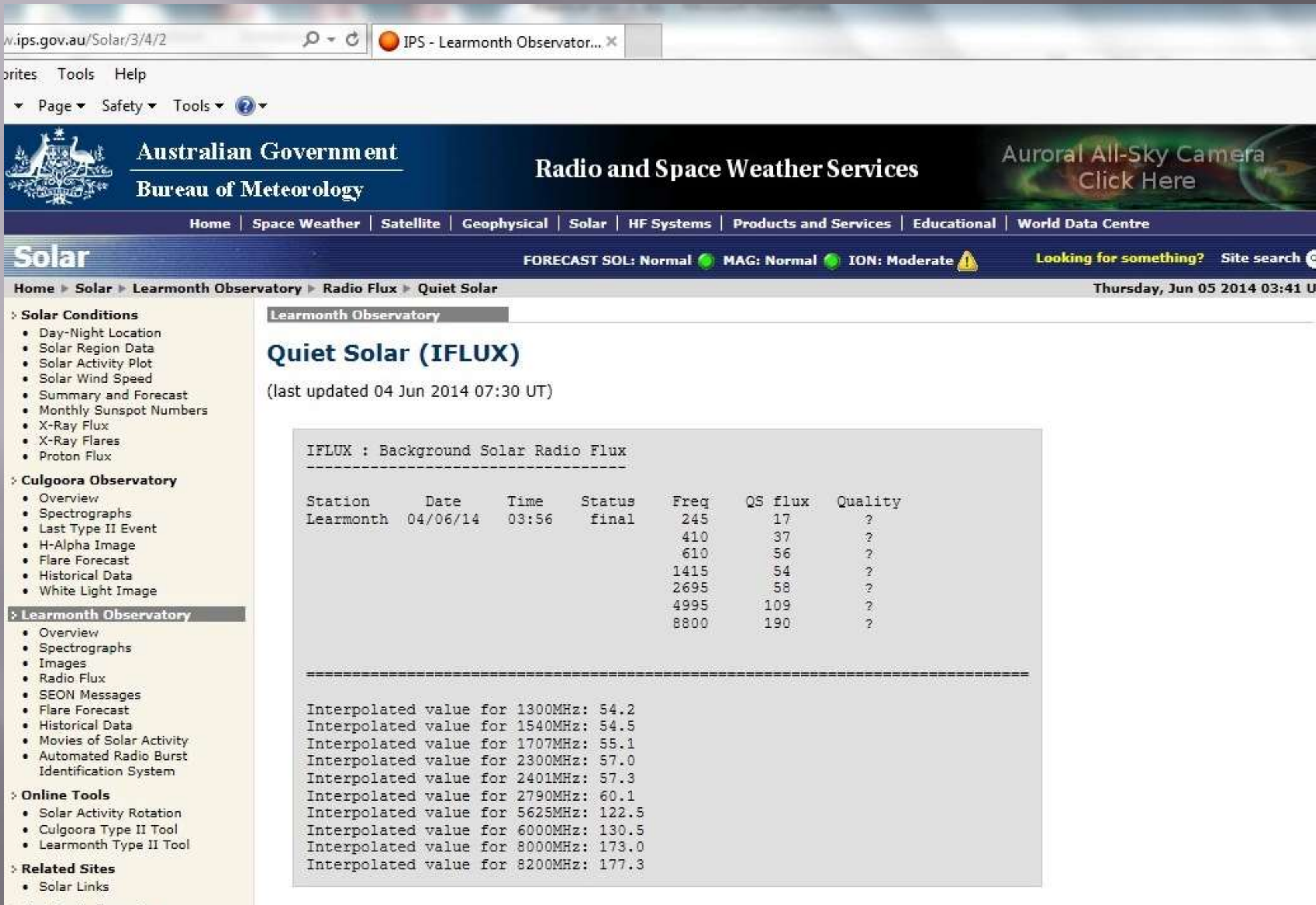
http://www.swp.../30day_rad.txt

www.swpc.noaa.gov/ftpdir/lists/radio/30day_rad.txt

```
:Product: Solar Radio Data                   30day_rad.txt
:Issued: 1612 UTC 13 May 2014
#
# Prepared by the U.S. Dept. of Commerce, NOAA, Space Weather Prediction Center
# Please send comments and suggestions to SWPC.Webmaster@noaa.gov
#  Units: 10^-22 W/m^2/Hz
#  Missing Data:  -1
#
#    Daily local noon solar radio flux values - Updated once an hour
#
  Freq  Learmonth  San Vito  Sag Hill  Penticton  Penticton  Palehua  Penticton
   MHZ   0500 UTC  1200 UTC  1700 UTC   1700 UTC   2000 UTC  2300 UTC  2300 UTC


2014 Apr 14
   245        20        23        20         -1         -1        19         -1
   410        43        48        43         -1         -1        45         -1
   610        74        -1        69         -1         -1        68         -1
  1415       117       125       113         -1         -1       116         -1
  2695       130       134       137         -1         -1       143         -1
  2800        -1        -1        -1        149        150        -1        150
  4995       173       183       184         -1         -1       186         -1
  8800       272       292       296         -1         -1       301         -1
 15400       569       541       578         -1         -1       586         -1
```

Learmonth Solar Observatory


w.ips.gov.au/Solar/3/4/2

IPS - Learmonth Observator...

rites Tools Help

Page ▾ Safety ▾ Tools ▾

Australian Government
Bureau of Meteorology

Radio and Space Weather Services

Auroral All-Sky Camera Click Here

Home | Space Weather | Satellite | Geophysical | Solar | HF Systems | Products and Services | Educational | World Data Centre

Solar

FORECAST SOL: Normal MAG: Normal ION: Moderate

Looking for something? Site search

Home ▸ Solar ▸ Learmonth Observatory ▸ Radio Flux ▸ Quiet Solar

Thursday, Jun 05 2014 03:41 UT

Solar Conditions
- Day-Night Location
- Solar Region Data
- Solar Activity Plot
- Solar Wind Speed
- Summary and Forecast
- Monthly Sunspot Numbers
- X-Ray Flux
- X-Ray Flares
- Proton Flux

Culgoora Observatory
- Overview
- Spectrographs
- Last Type II Event
- H-Alpha Image
- Flare Forecast
- Historical Data
- White Light Image

Learmonth Observatory
- Overview
- Spectrographs
- Images
- Radio Flux
- SEON Messages
- Flare Forecast
- Historical Data
- Movies of Solar Activity
- Automated Radio Burst Identification System

Online Tools
- Solar Activity Rotation
- Culgoora Type II Tool
- Learmonth Type II Tool

Related Sites
- Solar Links

Section Information

Learmonth Observatory

Quiet Solar (IFLUX)

(last updated 04 Jun 2014 07:30 UT)

```
IFLUX : Background Solar Radio Flux
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Station      Date      Time    Status    Freq    QS flux   Quality
Learmonth  04/06/14   03:56    final      245       17        ?
                                          410       37        ?
                                          610       56        ?
                                         1415       54        ?
                                         2695       58        ?
                                         4995      109        ?
                                         8800      190        ?

==============================================================================

Interpolated value for 1300MHz: 54.2
Interpolated value for 1540MHz: 54.5
Interpolated value for 1707MHz: 55.1
Interpolated value for 2300MHz: 57.0
Interpolated value for 2401MHz: 57.3
Interpolated value for 2790MHz: 60.1
Interpolated value for 5625MHz: 122.5
Interpolated value for 6000MHz: 130.5
Interpolated value for 8000MHz: 173.0
Interpolated value for 8200MHz: 177.3
```

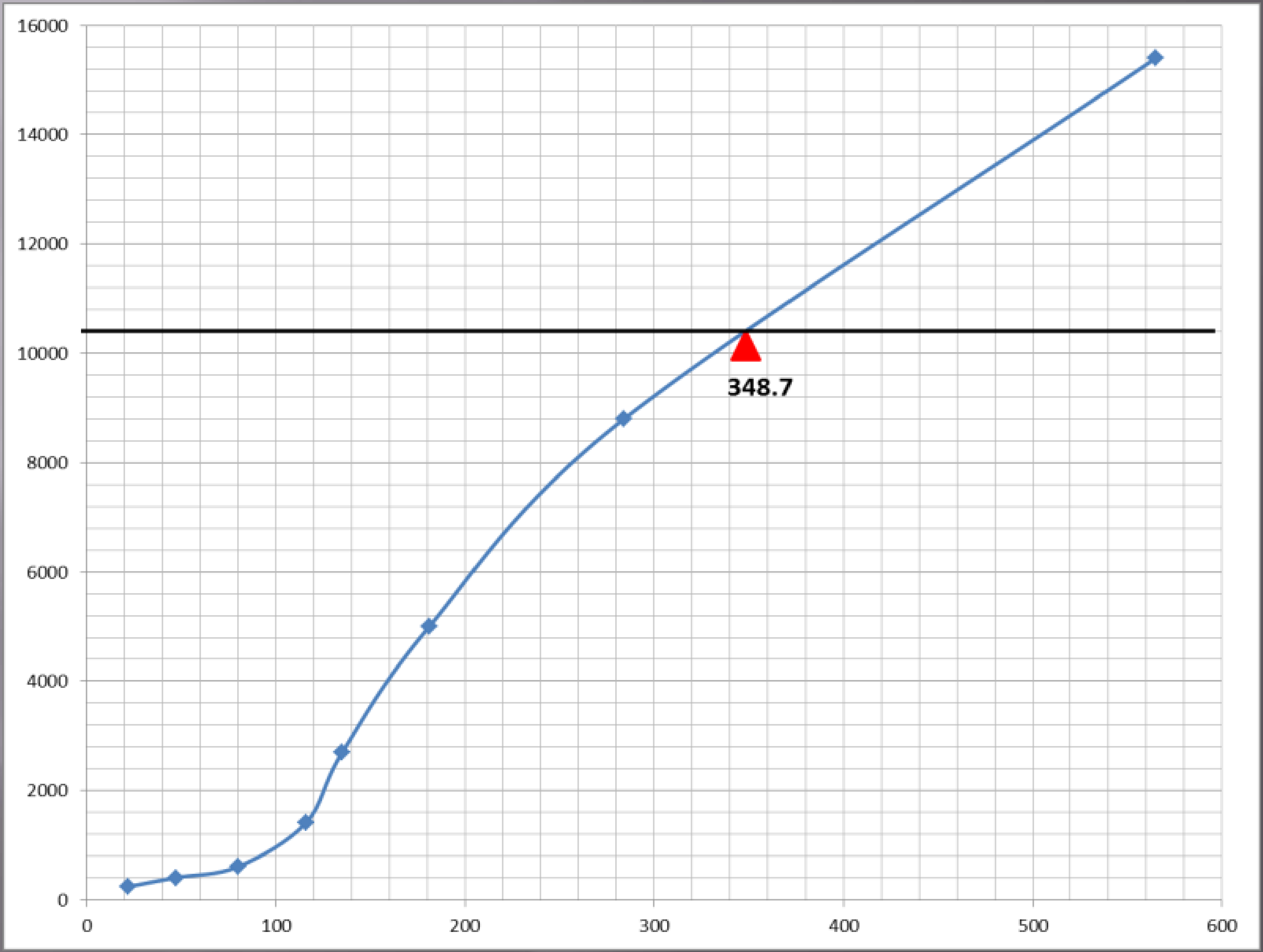
Learmonth, Australia

Our "Noisy" Sun

- Learmonth gave an interpolated value of 373.1 deg. Kelvin

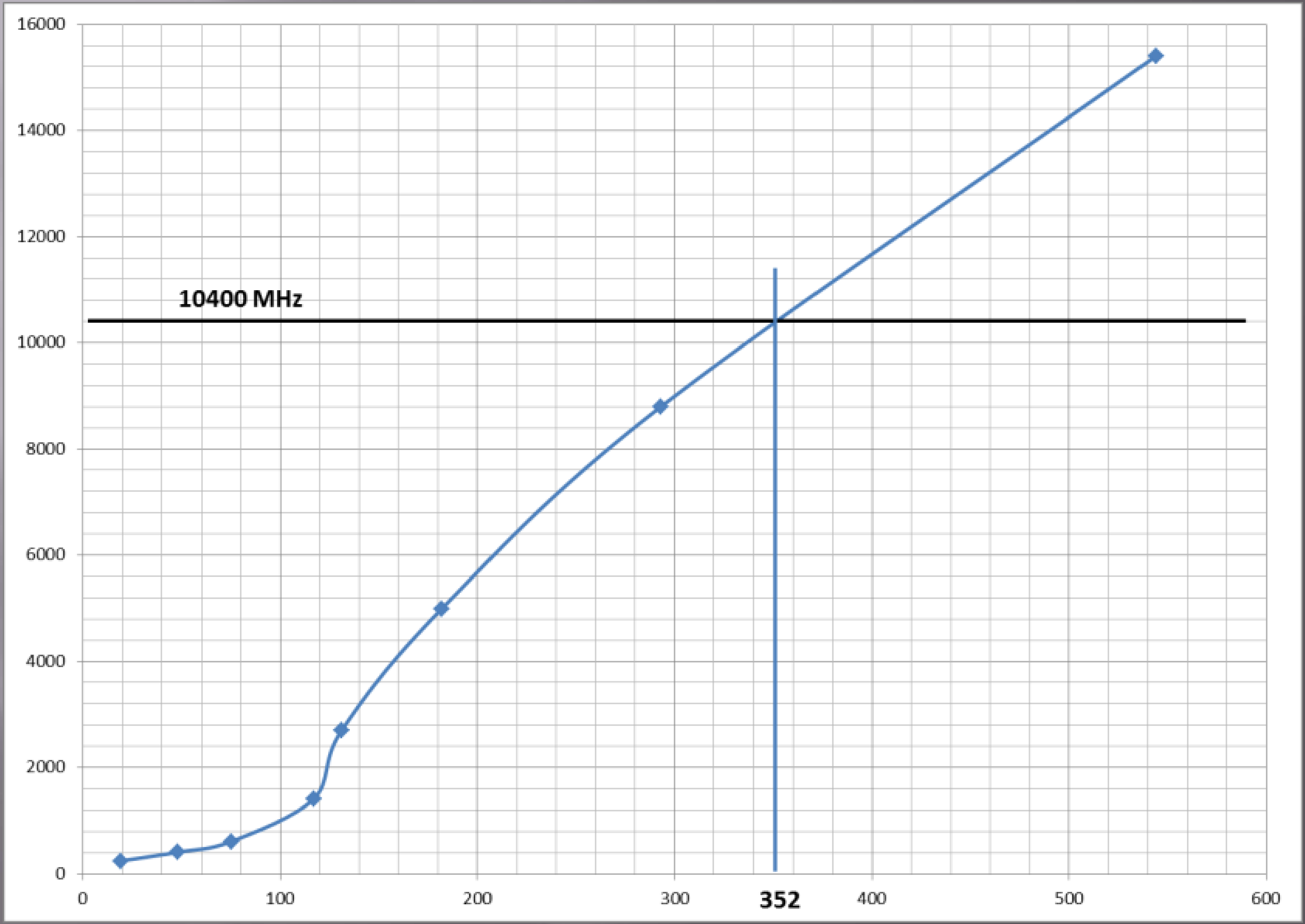
- The NOAA Data I had to interpolate
- I used Excel and graphed it
- I got values of 349, 352, 360 and 365 from NOAA

Learmonth



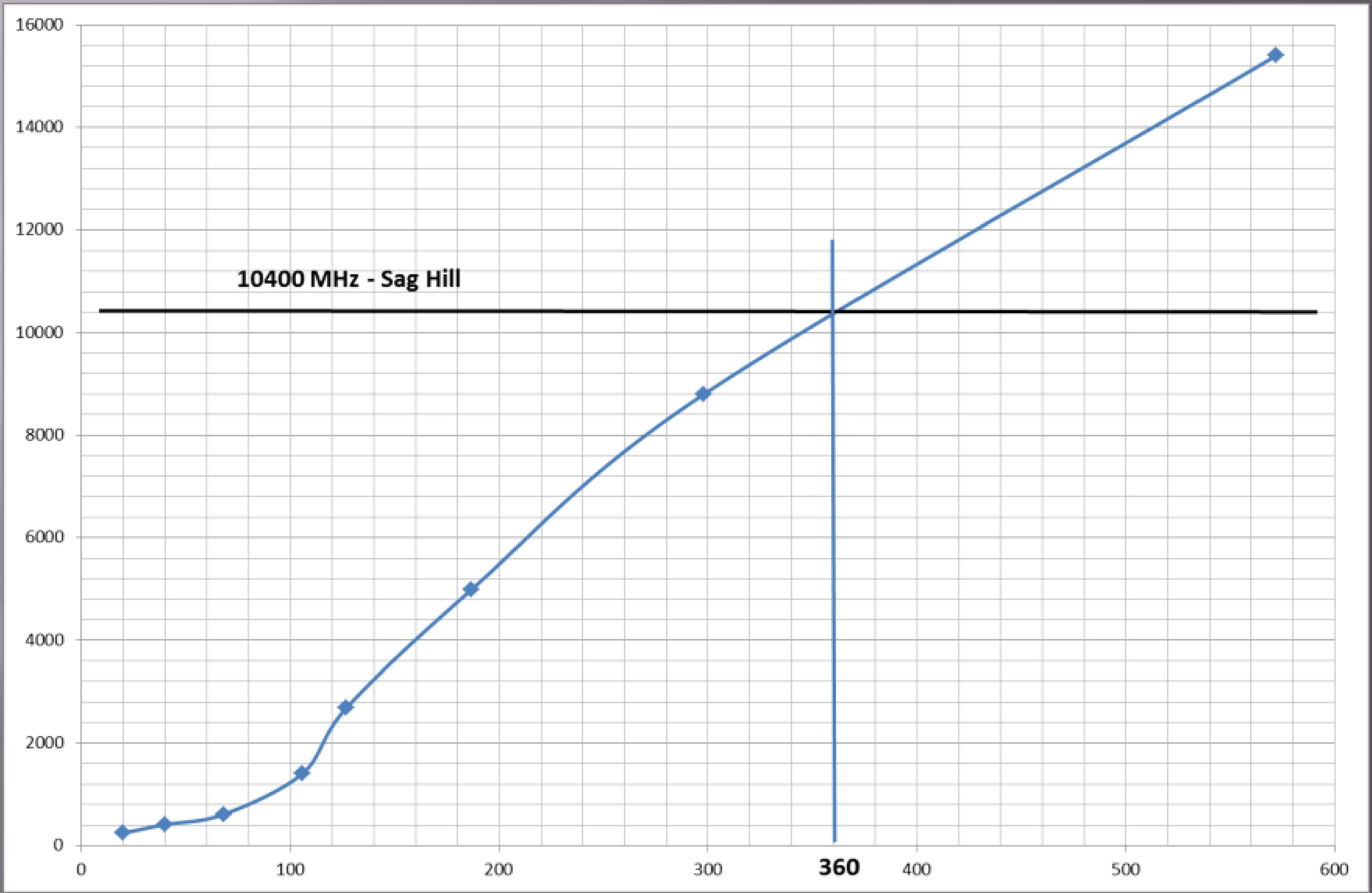
16000
14000
12000
10000
8000
6000
4000
2000
0
0
100
200
300
400
500
600
348.7

San Vito



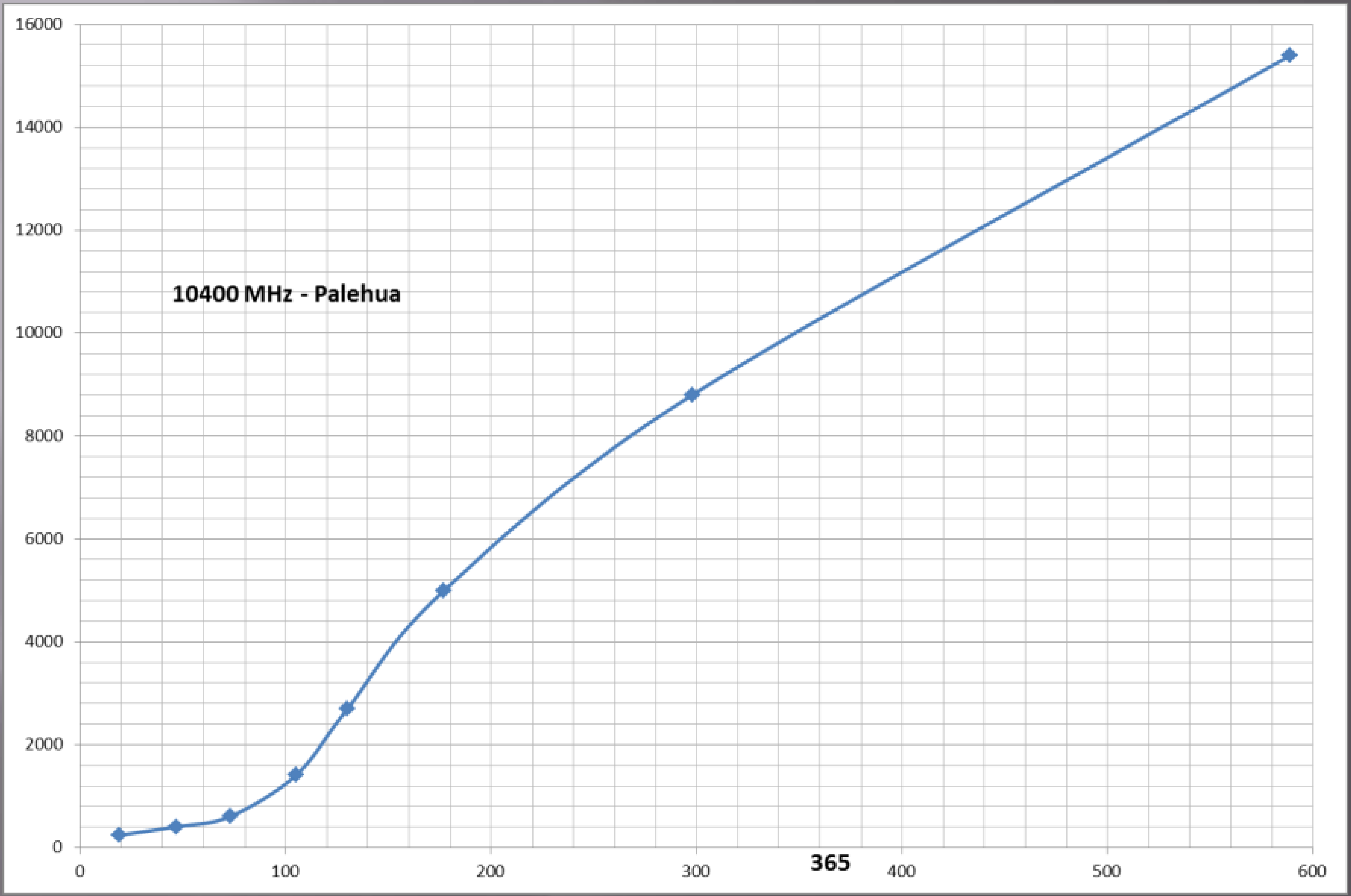
16000
14000
12000
10000
8000
6000
4000
2000
0
10400 MHz
0
100
200
300
352
400
500
600

Sag Hill



10400 MHz - Sag Hill
16000
14000
12000
10000
8000
6000
4000
2000
0
0
100
200
300
360
400
500
600

Palehua Observatory



What Does It All Mean?

My Information Search

- I read several articles and made several internet searches for reliable information on how to make sense out of a sun-sky measurement.
- I found several amateur radio experts have material on the topic and some make it easier to grasp than others.
- Then it dawned on me, this stuff has been common engineering knowledge since the first Bell System buildout in the 40’s.

www.Satsig.net/Noise

Satellite Signals

Noise temperature, Noise Figure (NF) and noise factor

The basic formulae are:

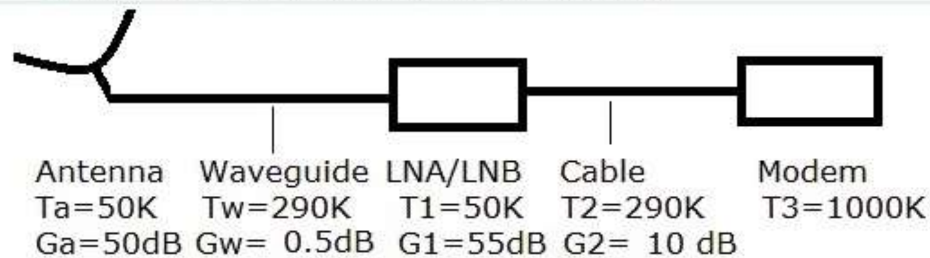
Noise temperature (T) = 290 * (10^(Noise Figure/10)-1)   K

Noise Figure (NF) = 10 * log (noise factor)   dB

Note that log must be to base 10. When using calculators and spreadsheets make sure that base 10 is selected. As a test, 10 * log(2) should give an answer of +3 dB. Noise temperature is measured in units called Kelvin (K) and these are like Celsius (C) temperature degrees but start at zero for absolute zero temperature so 0 K = -273 deg C, 273 K = 0 deg C (ice melts) and 290 K = 17 deg C (ambient temperature of a waveguide, for example)

Table to convert Noise Figure (NF dB) to Noise Temperature (T). This is useful for working out LNA or LNB noise temperatures from advertised Noise Figures.

NF(dB)	T (K)	NF(dB)	T (K)	NF(dB)	T (K)	NF(dB)	T (K)
0.1	7	1.1	84	2.1	180	3.1	302
0.2	14	1.2	92	2.2	191	3.2	316
0.3	21	1.3	101	2.3	202	3.3	330
0.4	28	1.4	110	2.4	214	3.4	344
0.5	35	1.5	120	2.5	226	3.5	359
0.6	43	1.6	129	2.6	238	3.6	374
0.7	51	1.7	139	2.7	250	3.7	390
0.8	59	1.8	149	2.8	263	3.8	406
0.9	67	1.9	159	2.9	275	3.9	422
1.0	75	2.0	170	**3.0**	**289**	4.0	438



Example figures only - not same as defaults below

			Noise contribution
Antenna gain Ga	55	dBi	
Antenna temp Ta	30	K	
Waveguide loss Gw	0.49	dB	
Waveguide temp Tw	290	K	
LNB gain G1	60	dB	
* LNB noise factor f or		num	
LNB Noise Figure NF or		dB	
LNB Temp T1	30	K	
Cable loss G2	18.0	dB	
Cable temp T2	290	K	

When In Doubt, Ask SBMS

W6OYJ to The Rescue

Ed Munn, W6OYJ

wrote a very easy to use Excel spreadsheet in 2002
that converts "Y" factor to Noise Figure.
Two spreadsheets, actually,
one takes an input in dB
One takes an input in 2 voltage levels
Link is on the SBMS Web Site and here:

http://www.ham- radio.com/sbms/sd/earthsky.zip

W6OYJ to The Rescue

	A	B	C	D	E	F	G
1	**Noise Figure Measurement from Earth/Cold Sky Comparison**						
2	**using decibel change value**			W6OYJ - 27 APR 2002			
3							
4	Point your antenna at Earth then Cold Sky (Elev above 50 degrees)						
5	Determine Rcvr i.f. noise power output change in dB. Output must be						
6	linear (not saturated) (no AGC action) and include no extraneous signals.						
7							
8	*Enter result here:*	7	dB	(Y factor in dB)			
9							
10	**Calculated Values**						
11	Earth Temperature	373.1	Kelvin	(assumed value)			
12	Cold Sky Temp.	30	Kelvin	(assumes Earth sidelobe contribution *)			
13							
14	Y factor	5.0119	(ratio)	(converted from dB)			
15							
16	System Noise Temp.	55.521	Kelvin				
17	System Noise Figure	0.6025	dB				
18							
19	*Note: If your antenna has very low sidelobes this temp can be reduced to						
20	as low as 6 degrees Kelvin, the Noise Temp of coldest part of the sky						

Is There Another Way to do This?

- YES – Ground Noise (290 deg. Kelvin) vs. sky

- The procedure and calculations are the same, but the noise source is the ground rather than the sun.

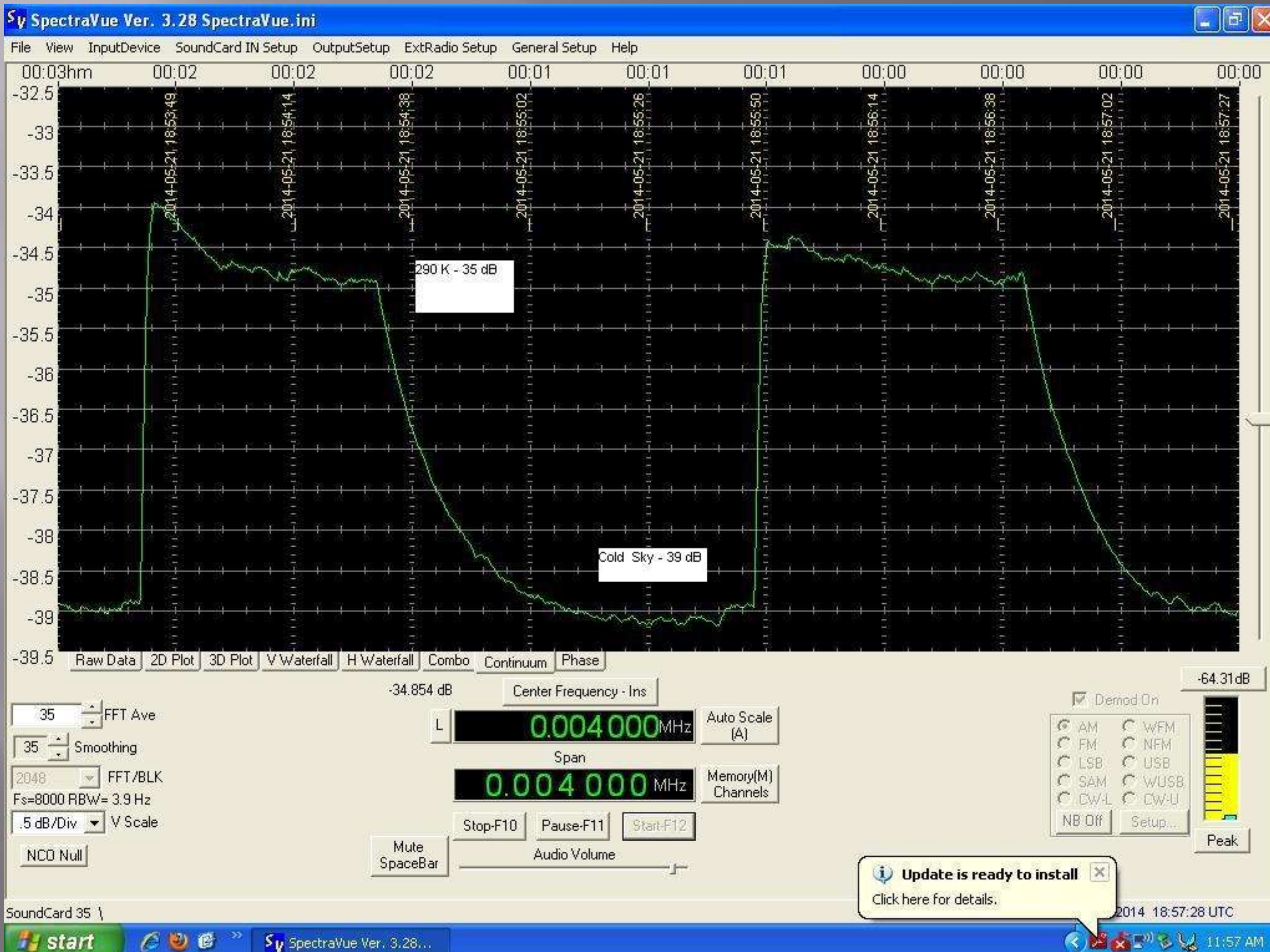
- Rein has found a very predictable and repeatable 290 deg. K noise source.

Rein's Ground Noise Setup

Rein's "Cold Sky" Setup

Rein takes advantage of the excellent front-to-back ratio of the Ku band feedhorn to reject ground noise. Plus it is pointed as far away from the ground as practically possible.

Rein's Comparison



W6OYJ to The Rescue

	A	B	C	D	E	F	G
1	**Noise Figure Measurement from Earth/Cold Sky Comparison**						
2	**using decibel change value**			W6OYJ - 27 APR 2002			
3							
4	Point your antenna at Earth then Cold Sky (Elev above 50 degrees)						
5	Determine Rcvr i.f. noise power output change in dB. Output must be						
6	linear (not saturated) (no AGC action) and include no extraneous signals.						
7							
8	*Enter result here:*	4	dB	(Y factor in dB)			
9							
10	**Calculated Values**						
11	Earth Temperature	290	Kelvin	(assumed value)			
12	Cold Sky Temp.	30	Kelvin	(assumes Earth sidelobe contribution *)			
13							
14	Y factor	2.5119	(ratio)	(converted from dB)			
15							
16	System Noise Temp.	141.97	Kelvin				
17	System Noise Figure	1.7306	dB				
18							
19	*Note: If your antenna has very low sidelobes this temp can be reduced to						
20	as low as 6 degrees Kelvin, the Noise Temp of coldest part of the sky						

Comments - Perspective