Practical Optimization of 432MHz and up EME systems using VK3UM's EMECalc Programme

Peter K Blair, G3LTF

Content of the Presentation

A short description of EME Calc.

How we got here

Noise measurements

Receiver system issues

Antenna system issues

Antenna adjustments and measurements

Whole system checks

Acknowledgements

EMECalc description

All the elements of the eme link budget, antenna, Tx power, receive bandwidth,NF for both own and Dx stations are incorporated into calculations of received signal level and echo strength

Y factor ratios can be predicted for observations of sun, moon and radio star sources.

Antenna selection includes yagis and dishes with a wide range of feed types and f/d ratios.

Validated by measurements by many eme operators.

Questions, Questions!

W9BIG has the same size dish as me, he just gave T1NY 559 and I can only truthfully give him M copy!

How do I know how well my EME system is working?

Am I hearing the weaker stations as well as I should?

Is it the feed, the dish, the preamp, the relay.......?

EMECalc can help answer these questions and guide us to the solutions.

Squeezing out the last fraction of a dB of system performance has a long history.... and has lead to some amazing discoveries.....

“I still can't account for that last 3.5 degrees Kelvin....”

Dick Turrin, W2IMU explained how to evaluate EME systems in his technical notes, 40 years ago. Add the work by Paul Wade W1GHZ in his on-line Antenna book and we have the core of VK3UM's EMECalc

3. System Considerations for the EME Path.

Must reading for all EME enthusiasts. Details how to evaluate system performance. Never obsolete.

11. Use of Solar Noise in EME System Evaluation.

Very useful information for measuring system performance withou calibrated laboratory test equipment. Required reading along wi Report # 3.

We will concern ourselves with receive performance as this is the most difficult to optimise.

Transmit performance can be derived from Tx power, transmit feeder loss and antenna gain, G.

For the best receive performance we need to maximise the ratio G/Tsys

G is the gain of the antenna and Tsys is the system noise temperature

System Noise Temperature, Tsys

$$T_{sys} = T_{sky} + T_{spill} + T_{ft} + T_{rx}$$

Tsky Sky temperature

Tspill Noise temperature contribution from spill-over

Tft Noise temperature contribution from mesh transparency

Trx Receiver Noise temperature including feedline loss and following stages

How do we measure G/T?

If we point an antenna at a noise source, e.g the sun, and then away at the cold sky the noise output of the receiver will change by a ratio Y.

$$G/Tsys \sim \frac{(Y-1)}{F} * (freq)^2$$

F is the noise flux of the source. We can use sun, moon, radio stars.

Measure Y and EMECalc does the calculations

Typical values for G/T for my HB 6m dish

Freq.	Actual	Theory	
432	5	8.7	
1296	79	79	
2320	133	253	
3400	218	543	
5760	218	693	(4.5m)
10368	176	2247	(4.5m)

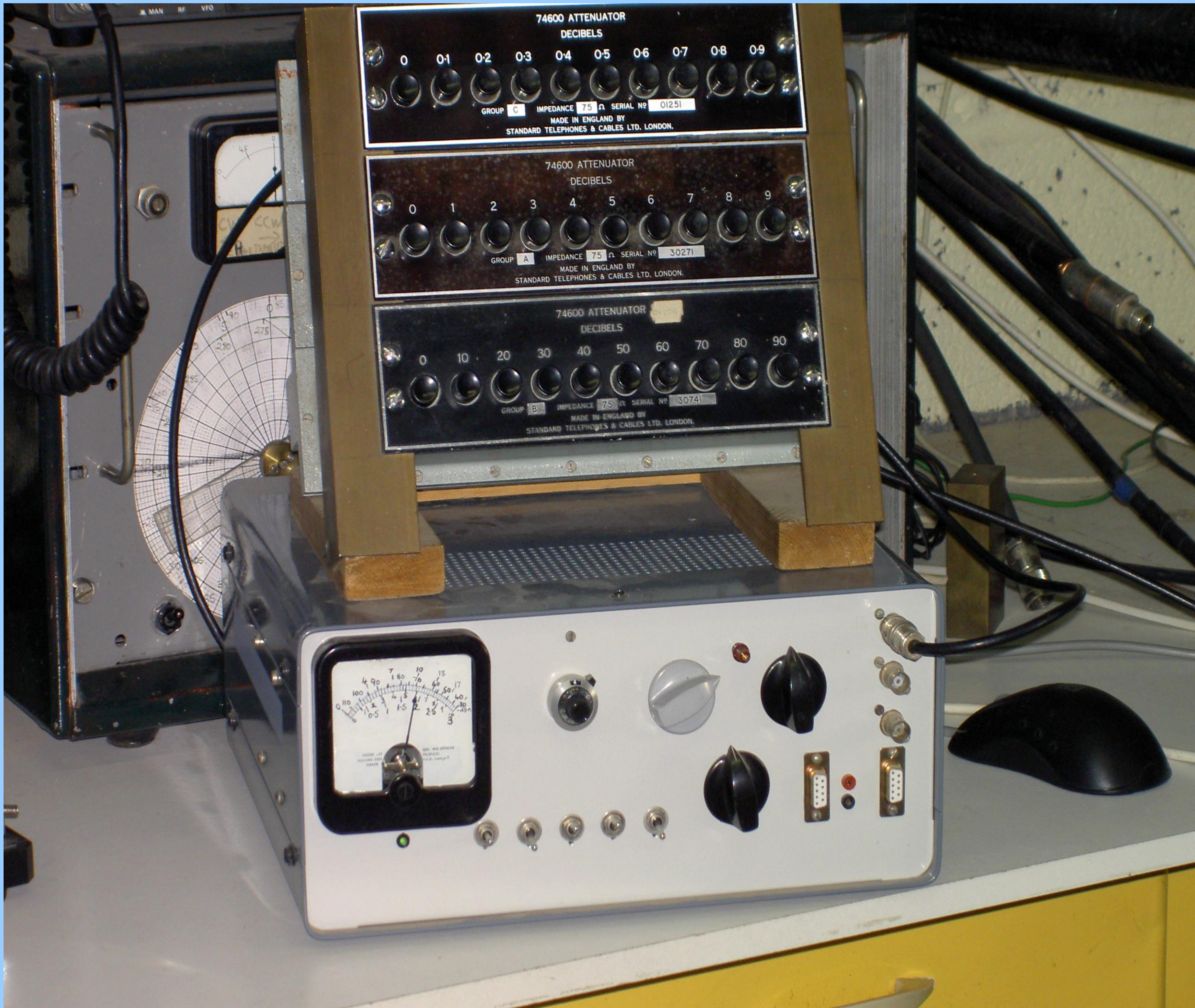
Measuring the Noise Ratio, Y

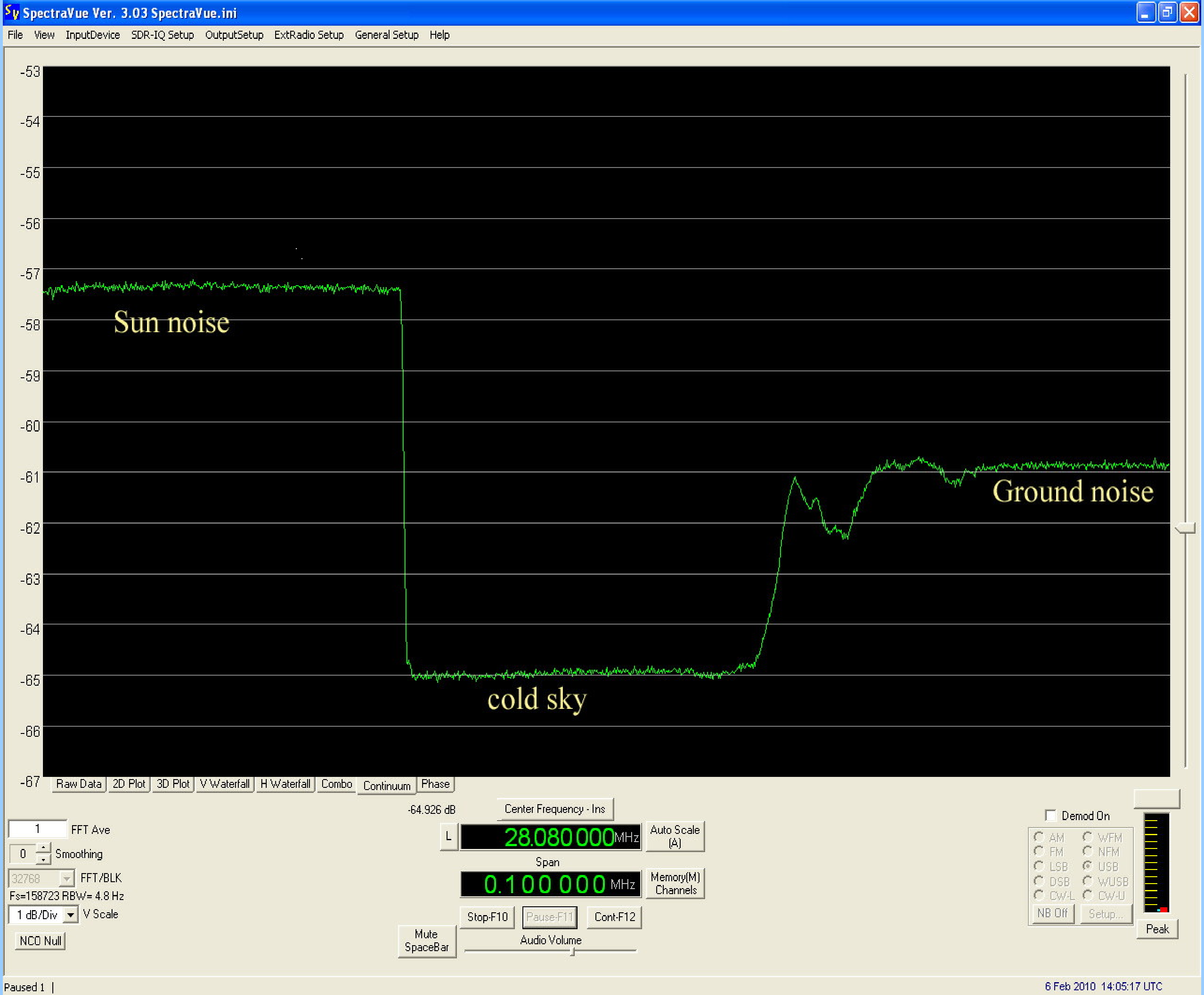
Wide bandwidth noise receiver with a long integration time and a power output indicator plus a calibrated attenuator.

Several good designs in the paper references

You can start off with an audio power meter and an attenuator.

Spectravue SDR-IQ continuum mode works well.

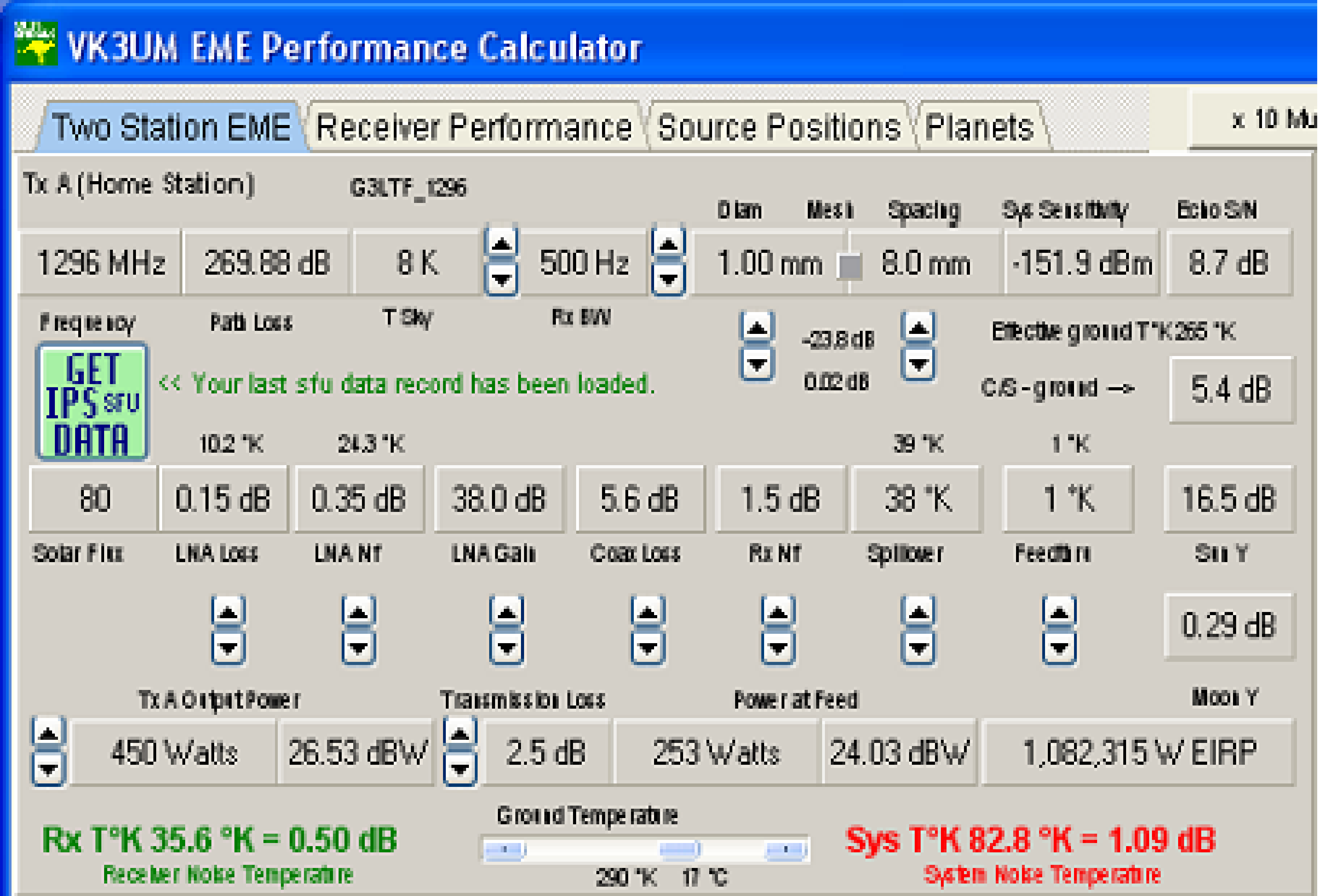

74600 ATTENUATOR
DECIBELS
0 0·1 0·2 0·3 0·4 0·5 0·6 0·7 0·8 0·9
GROUP C IMPEDANCE 75 Ω SERIAL Nº 01251
MADE IN ENGLAND BY
STANDARD TELEPHONES & CABLES LTD. LONDON.
74600 ATTENUATOR
DECIBELS
0 1 2 3 4 5 6 7 8 9
GROUP A IMPEDANCE 75 Ω SERIAL Nº 30271
MADE IN ENGLAND BY
STANDARD TELEPHONES & CABLES LTD. LONDON.
74600 ATTENUATOR
DECIBELS
0 10 20 30 40 50 60 70 80 90
GROUP B IMPEDANCE 75 Ω SERIAL Nº 30741
MADE IN ENGLAND BY
STANDARD TELEPHONES & CABLES LTD. LONDON.


SpectraVue Ver. 3.03 SpectraVue.ini
File View InputDevice SDR-IQ Setup OutputSetup ExtRadio Setup General Setup Help
-53
-54
-55
-56
-57
-58
-59
-60
-61
-62
-63
-64
-65
-66
-67
Sun noise
cold sky
Ground noise
Raw Data 2D Plot 3D Plot V Waterfall H Waterfall Combo Continuum Phase
-64.926 dB
Center Frequency - Ins
28.080000 MHz
Auto Scale (A)
Span
0.100000 MHz
Memory(M) Channels
1 FFT Ave
0 Smoothing
32768 FFT/BLK
Fs=158723 RBW= 4.8 Hz
1 dB/Div V Scale
NCO Null
Stop-F10 Pause-F11 Cont-F12
Mute SpaceBar
Audio Volume
Demod On
AM WFM FM NFM LSB USB DSB WUSB CW-L CW-U
NB Off Setup...
Peak
Paused 1
6 Feb 2010 14:05:17 UTC

+V
−V
ON
VK3FMD
FAST
SLOW
dB RANGE
FULL
1O
2·O
1·O
O·5
DET - OUT
RF

EMECalc Receiver Section

screen view



VK3UM EME Performance Calculator
Two Station EME
Receiver Performance
Source Positions
Planets
Tx A (Home Station)
G3LTF_1296
1296 MHz
269.88 dB
8 K
500 Hz
1.00 mm
8.0 mm
-151.9 dBm
8.7 dB
Path Loss
T Sky
Rx BW
Mesh
Spacing
Echo S/N
-23.8 dB
0.02 dB
C/S - ground
5.4 dB
GET IPS SFU DATA
<< Your last sfu data record has been loaded.
10.2 °K
24.3 °K
39 °K
1 °K
80
0.15 dB
0.35 dB
38.0 dB
5.6 dB
1.5 dB
38 °K
1 °K
16.5 dB
LNA Loss
LNA Nf
Coax Loss
Rx Nf
Spillover
0.29 dB
Moon Y
Power at Feed
450 Watts
26.53 dBW
2.5 dB
253 Watts
24.03 dBW
1,082,315 W EIRP
Rx T°K 35.6 °K = 0.50 dB
Sys T°K 82.8 °K = 1.09 dB

Receiver System Issues

Relay and cable losses ahead of LNA.

LNA Noise figure

Effects of following stages

Noise figure estimation using the feedhorn to measure cold sky to ground ratio, Y, and EMECalc

Noise Figure Estimation using EME Calc.

Connect LNA directly to the feedhorn

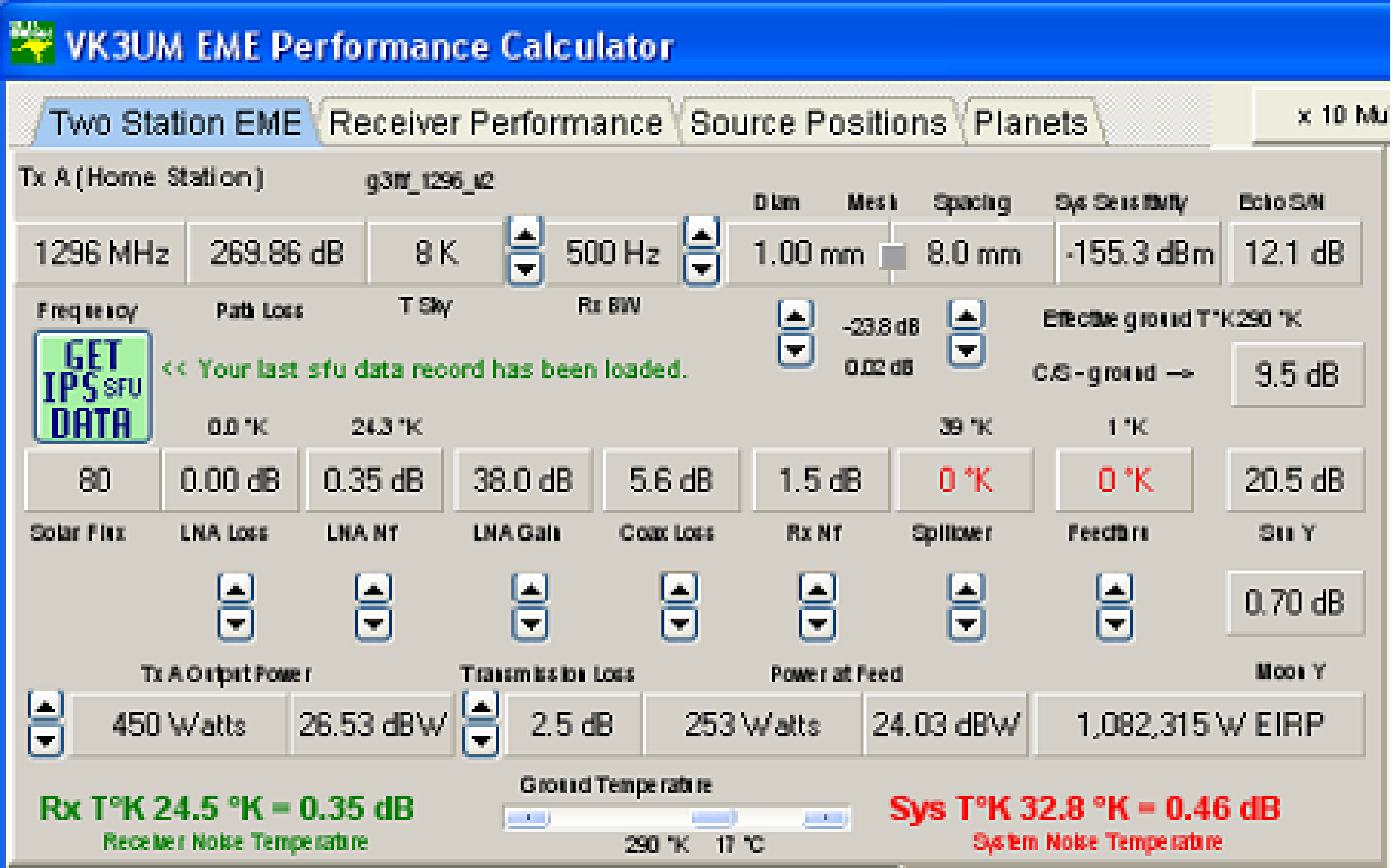
Select area with at least 130 degree cone of clear sky. Beware of local beacons and OOB signals

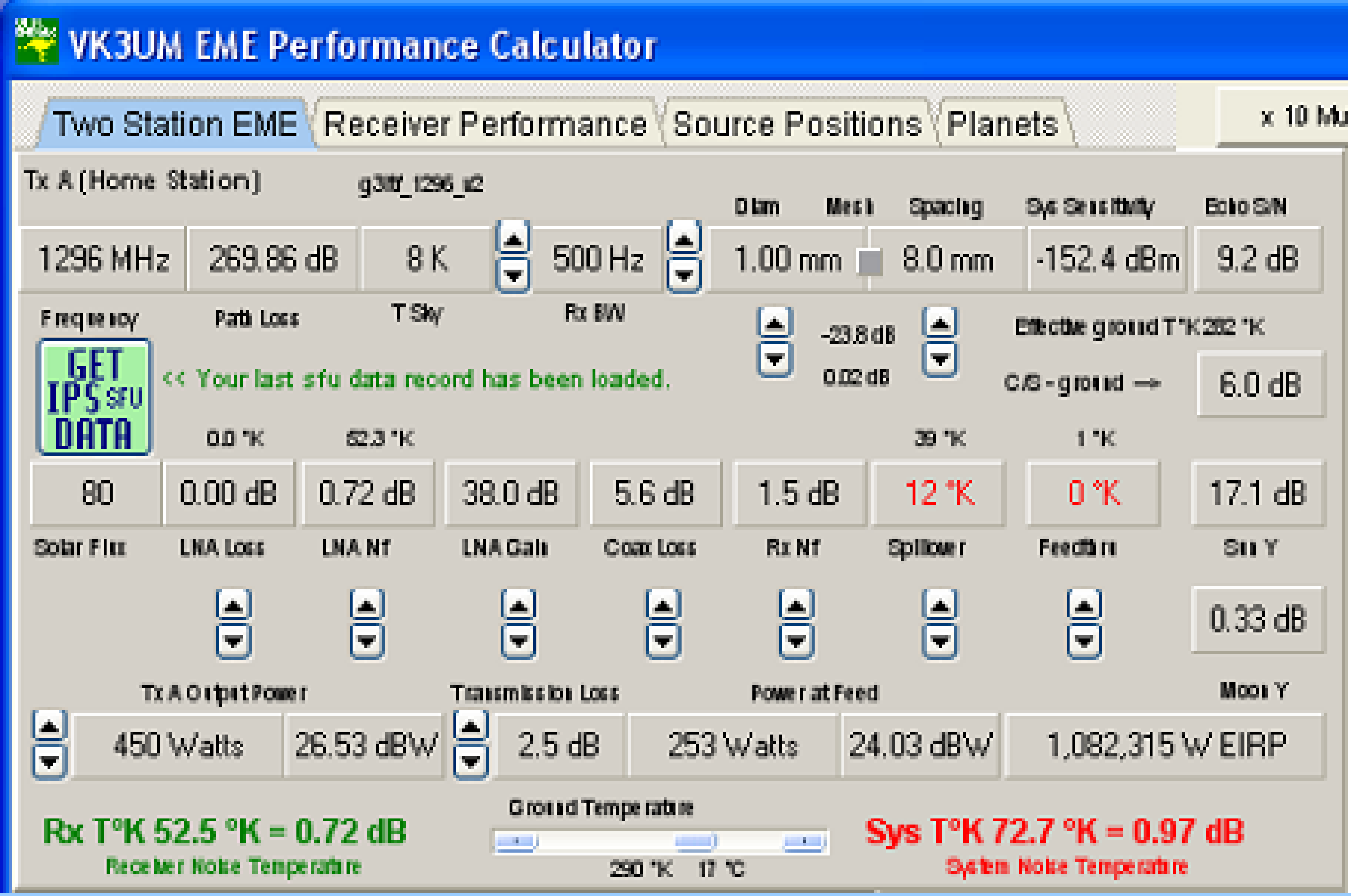
Point feedhorn to zenith and record noise level.

Point feedhorn at ground several wavelengths away and record noise level.

Repeat with relay and cable ahead of LNA.

Interpret results with EMECalc


VK3UM EME Performance Calculator
Two Station EME
Receiver Performance
Source Positions
Planets
x 10 Mu
Tx A (Home Station)
g3ltf_1296_s2
1296 MHz
269.86 dB
8 K
500 Hz
1.00 mm
8.0 mm
-155.3 dBm
12.1 dB
Frequency
Path Loss
T Sky
Rx BW
-23.8 dB
0.02 dB
C/S - ground -->
9.5 dB
GET IPS SFU DATA
<< Your last sfu data record has been loaded.
0.0 °K
24.3 °K
39 °K
1 °K
80
0.00 dB
0.35 dB
38.0 dB
5.6 dB
1.5 dB
0 °K
0 °K
20.5 dB
Solar Flux
LNA Loss
LNA NF
LNA Gain
Coax Loss
Rx NF
Spillover
Sun Y
0.70 dB
Tx A Output Power
Power at Feed
Moon Y
450 Watts
26.53 dBW
2.5 dB
253 Watts
24.03 dBW
1,082,315 W EIRP
Rx T°K 24.5 °K = 0.35 dB
Receiver Noise Temperature
290 °K
17 °C
Sys T°K 32.8 °K = 0.46 dB
System Noise Temperature


VK3UM EME Performance Calculator
Two Station EME
Receiver Performance
Source Positions
Planets
Tx A (Home Station)
1296 MHz
269.86 dB
8 K
500 Hz
1.00 mm
8.0 mm
-152.4 dBm
9.2 dB
Frequency
Path Loss
T Sky
Rx BW
Mesh
Spacing
Echo S/N
GET IPS SFU DATA
<< Your last sfu data record has been loaded.
-23.8 dB
0.02 dB
C/S - ground
6.0 dB
0.0 °K
52.3 °K
39 °K
1 °K
80
0.00 dB
0.72 dB
38.0 dB
5.6 dB
1.5 dB
12 °K
0 °K
17.1 dB
Solar Flux
LNA Loss
LNA Nf
LNA Gain
Coax Loss
Rx Nf
Spillover
Sun Y
0.33 dB
Moon Y
450 Watts
26.53 dBW
2.5 dB
253 Watts
24.03 dBW
1,082,315 W EIRP
Power at Feed
Rx T°K 52.5 °K = 0.72 dB
Ground Temperature
Sys T°K 72.7 °K = 0.97 dB
System Noise Temperature

Comments

This is not a precision method but its much better than guessing.

Keep good notes of what you do.

If you get a weird result there has to be a reason for it!!

Calibration to a PANFI later will improve your measurement process.

Antenna System Issues

Choice of feed affects gain and noise temperature

EMECalc contains wide range of feed types

The effect of feed choice and dish parameters can be fully explored

EMECalc uses the feed analysis results from W1GHZ on-line antenna book

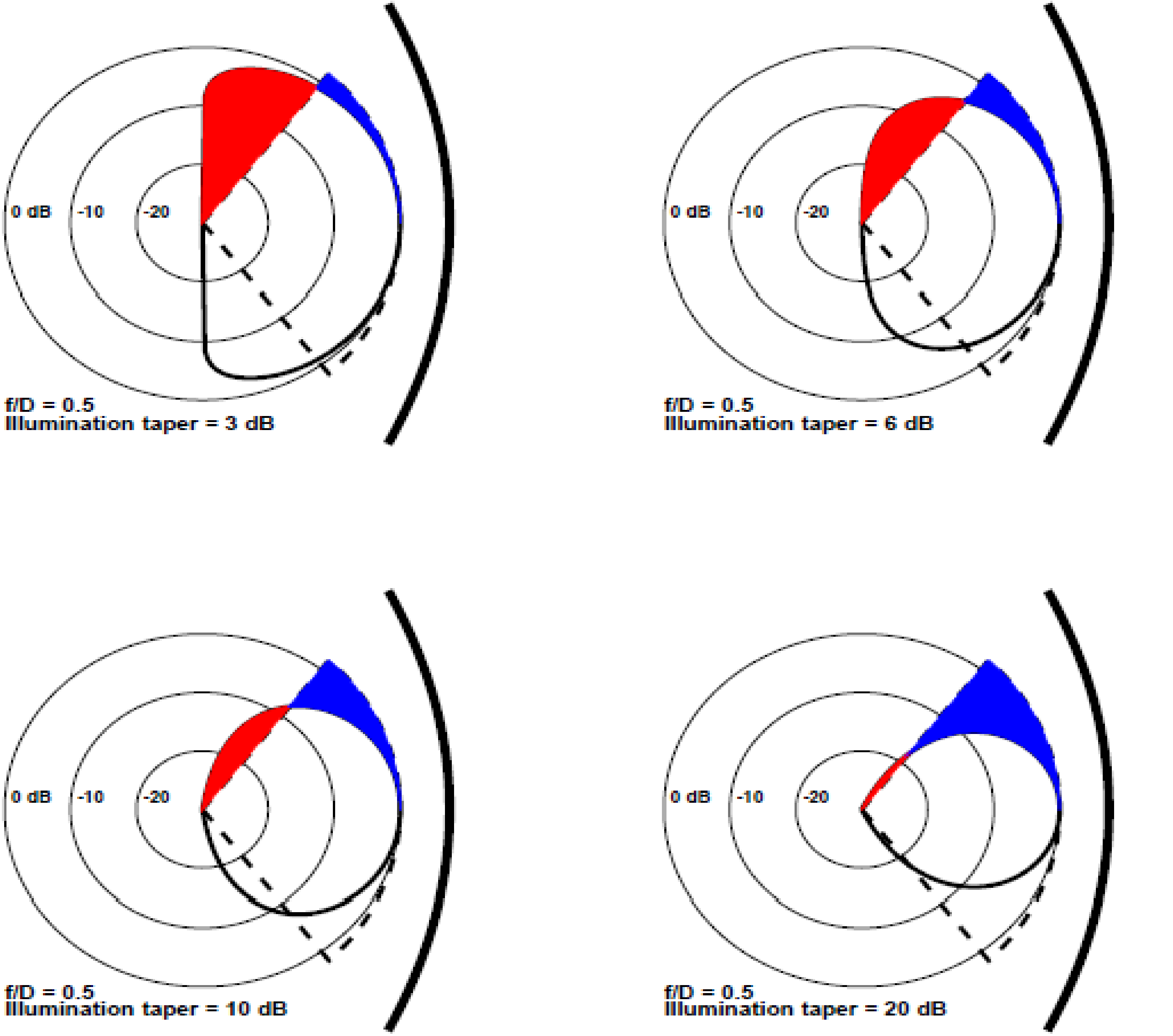
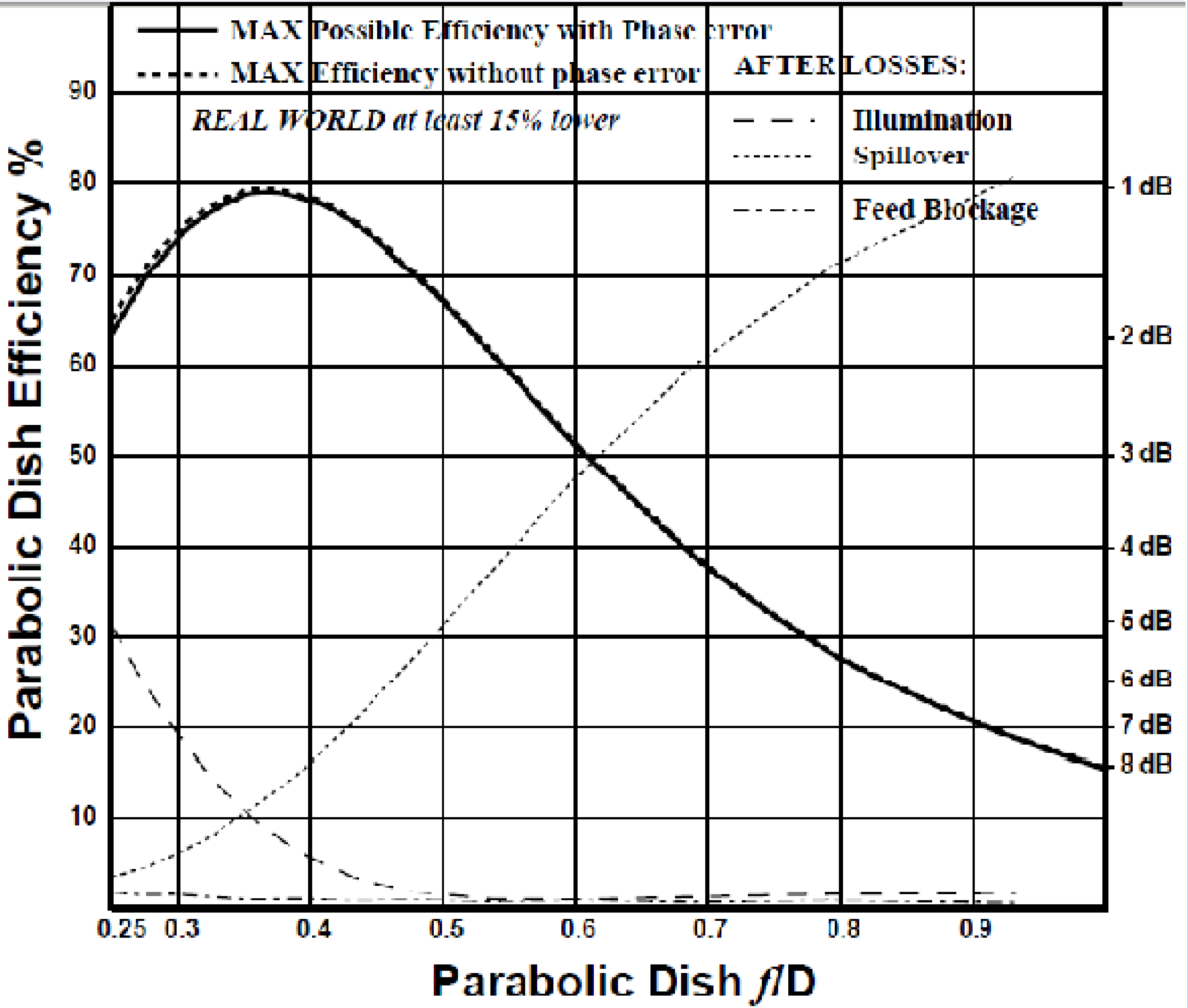
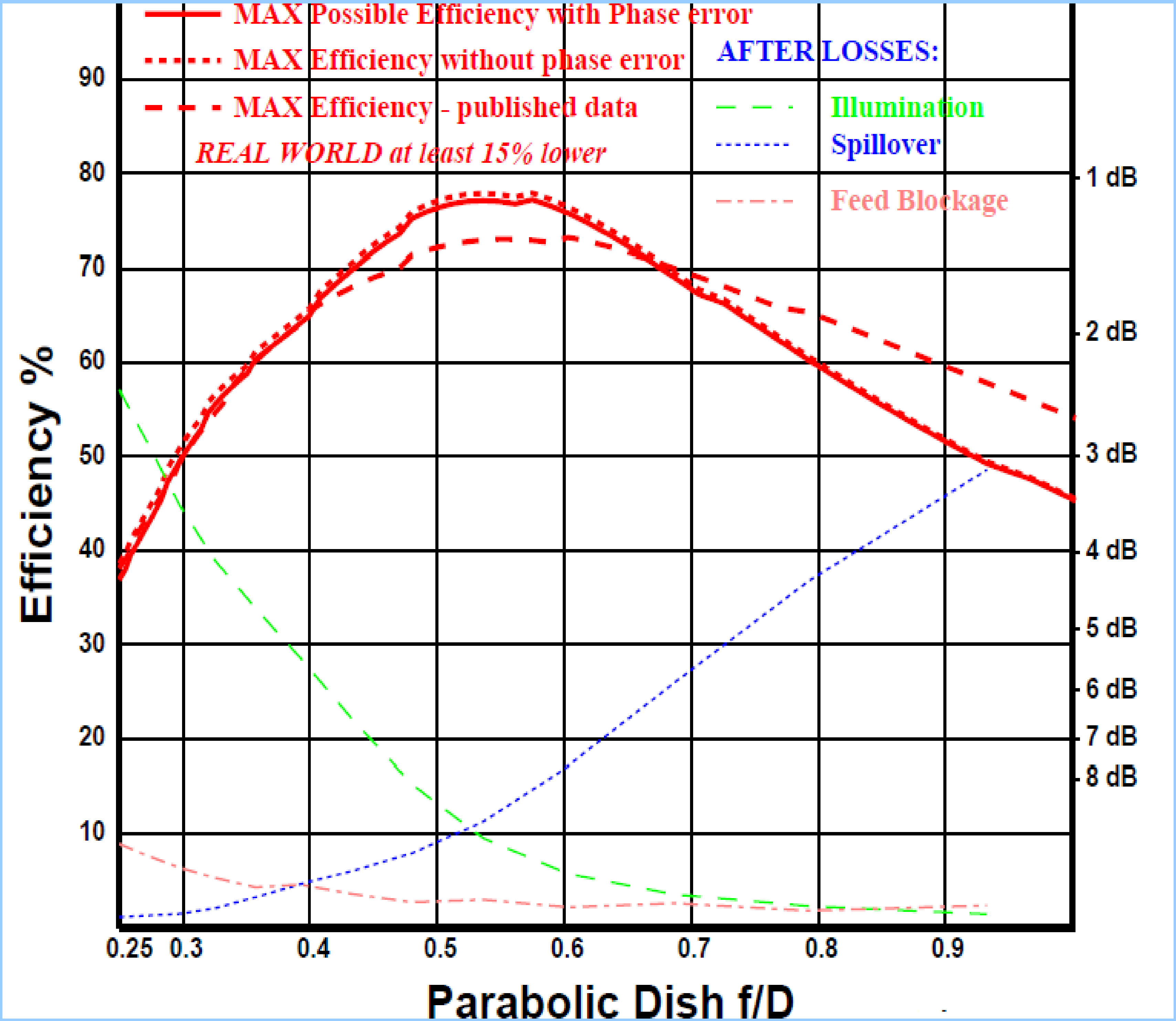


Figure 4-6. Dish Illumination with Various Illumination Tapers

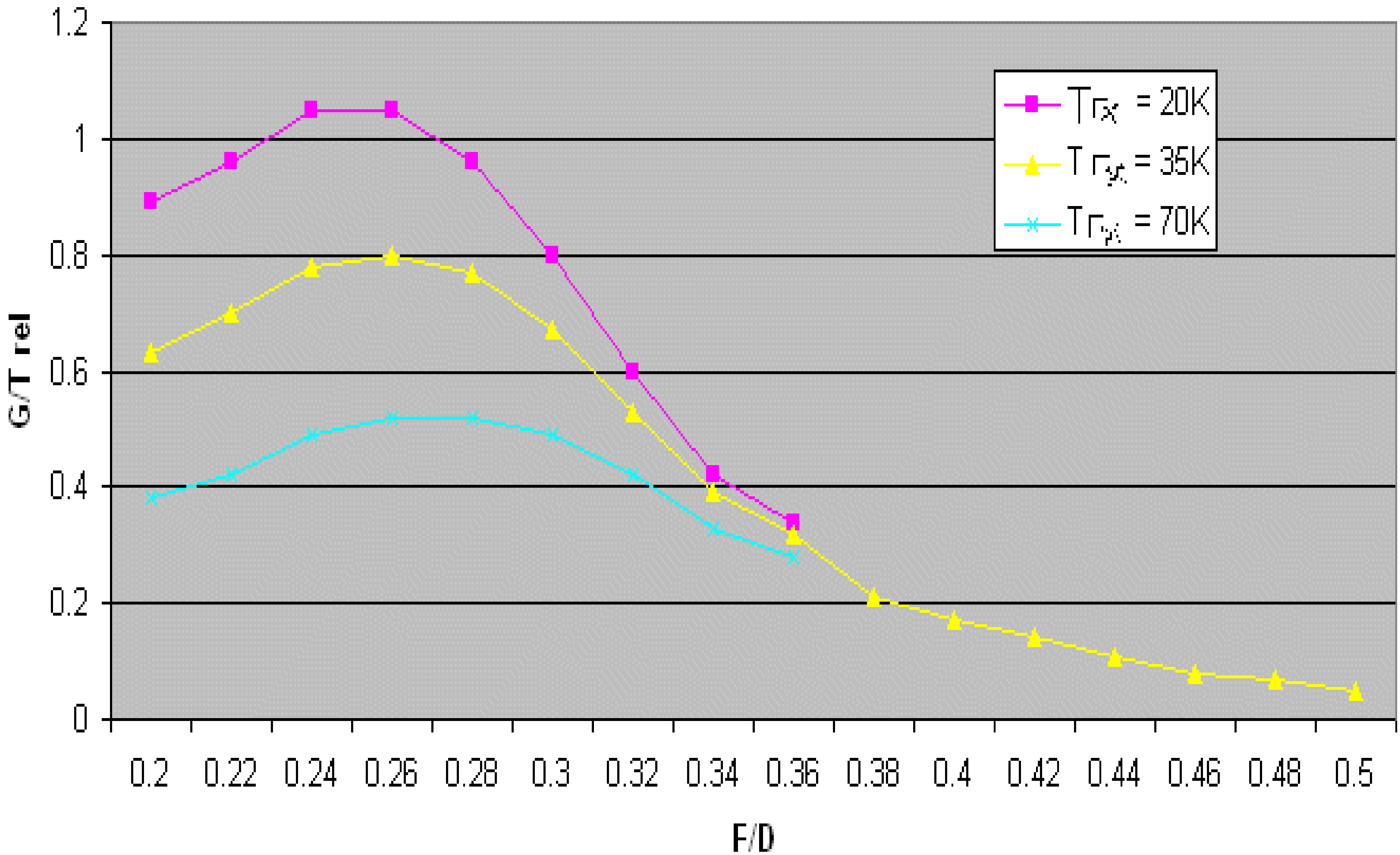
N1BWT 1994



MAX Possible Efficiency with Phase error
MAX Efficiency without phase error
AFTER LOSSES:
REAL WORLD at least 15% lower
Illumination
Spillover
Feed Blockage
Parabolic Dish Efficiency %
90
80
70
60
50
40
30
20
10
1 dB
2 dB
3 dB
4 dB
5 dB
6 dB
7 dB
8 dB
0.25
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Parabolic Dish f/D



MAX Possible Efficiency with Phase error
MAX Efficiency without phase error
MAX Efficiency - published data
REAL WORLD at least 15% lower
AFTER LOSSES:
Illumination
Spillover
Feed Blockage
Efficiency %
90
80
70
60
50
40
30
20
10
1 dB
2 dB
3 dB
4 dB
5 dB
6 dB
7 dB
8 dB
0.25
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Parabolic Dish f/D



G/T rel
F/D
Trx = 20K
Trx = 35K
Trx = 70K
1.2
1
0.8
0.6
0.4
0.2
0
0.2
0.22
0.24
0.26
0.28
0.3
0.32
0.34
0.36
0.38
0.4
0.42
0.44
0.46
0.48
0.5

Antenna Adjustments and Measurements

Adjust feed to set phase centre at the focus

Ensure feed points at dish centre

Measure beamwidth, EME calc provides corrections

Measure sidelobe levels

Whole System Checks

Measure sun, moon and radio-star noise levels with Y-factor method.

Make Cold Sky to Ground measurement with dish

Check Cold Sky to 50R load with protection relay

Check echo strengths.

If the result is significantly different from predicted then there probably is a real problem!

Acknowledgements

Doug Mc Arthur, VK3UM
Paul Wade W1GHZ

And all the many emers who have put in suggestions and tested and verified the work.