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

Peter K Blair, G3LTF

1. Introduction.

The aim of this paper is to explain how the EME system modelling programme, EMECalc, produced by Doug McArthur, VK3UM, can be used to optimise the performance of an eme system, both by guiding the designer to the correct choice of components, and by the interpretation of straightforward and simple measurements using the radiation from sun, moon and radio stars. The paper will deal with the receive performance in some detail, the transmit performance can be easily derived from the antenna considerations and the available transmitter power.

It is relatively easy these days to put together the components for an EME system, but how do we know how well it is performing? Even if we hear stations, should they be stronger?... are we copying the weaker ones as well as we could? How many more dBs are there to be squeezed out and where should we squeeze? These questions have been challenging us for a long time. In 1970 Dick Turin, W2IMU, wrote EME note #3 “System consideration for the EME path “ and in 1972 “The use of solar noise in EME system evaluation” These were the first amateur publications aimed at EME system optimisation.

Interestingly, the 60ft dish at Crawford Hill, regularly used by Dick and the Bell labs group when the EME notes were written, stood next to the horn antenna used in 1964 by Penzias and Wilson to discover the 3 degree K cosmic microwave background (CMB)... and that happened because they were trying to track down the last fraction of a dB difference between measured and predicted system performance in the Echo balloon experiments. See reference 1 for more on this.

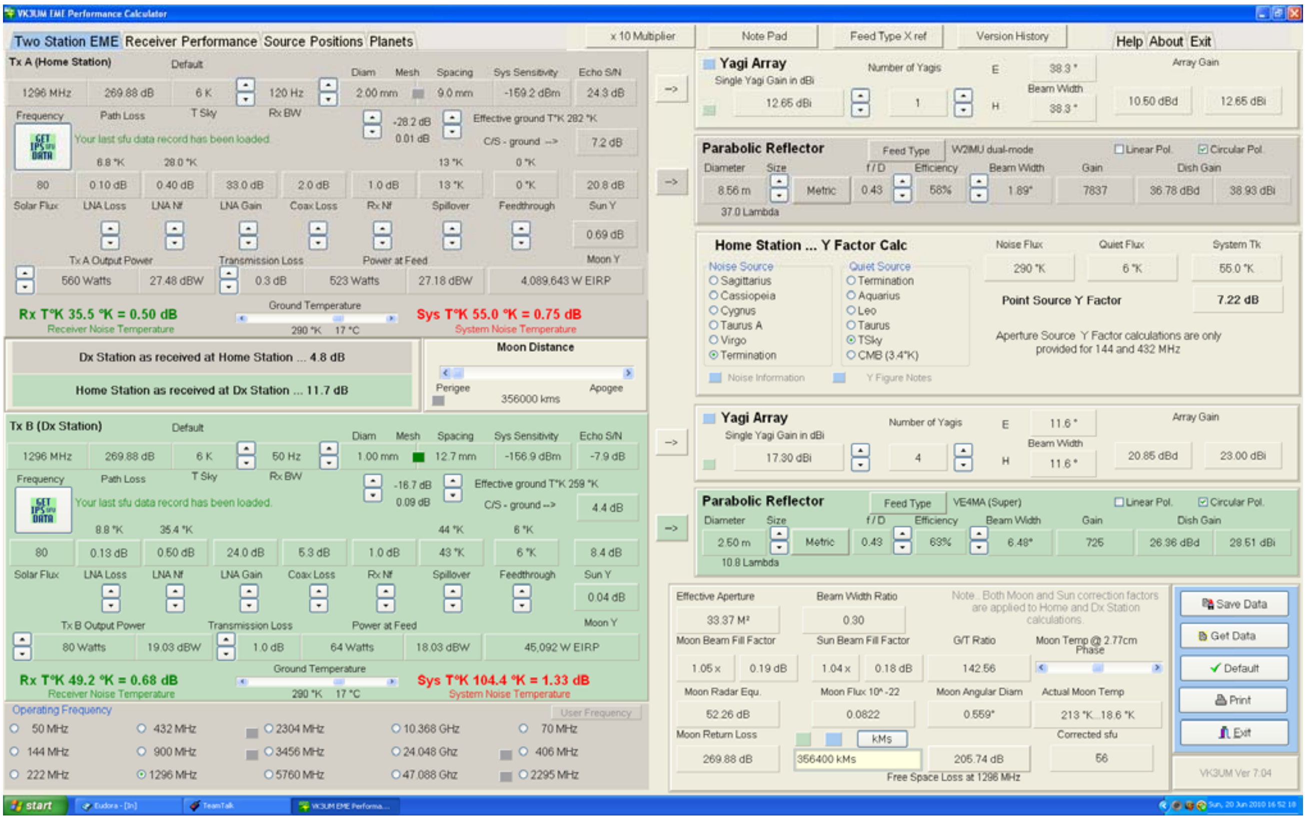
So, forty years on, we have the same issue to contend with, but now we don't have to do the sums longhand, we have EMECalc to help us to do the trade off's and to interpret our measurements.

2. A short description of the programme

The programme takes all of the elements of the EME link budget for both echoes and home station to dx station cases and calculates the received signal level. It also enables the Y factor ratios (see later) from moon, sun and galactic sources to be predicted as well as cold sky to ground ratio. All of the system parameters such as noise figure, antenna gain and cable losses can be varied over wide ranges. The parameters can be independently set for both home and dx station The variations in parameters such as moon distance and phase, ground temperature and solar flux can all be accommodated and a function is provided that will obtain the current solar flux value from the IPS Learmonth observatory. Amateur band frequencies from 50MHz to 47GHz can be selected and the programme has been verified by EMEers on virtually all of these bands.

The antenna selection incorporated in the programme includes both yagis and parabolic reflectors. For the latter a very useful facility is available which enables the effect on parameters such as gain and spill-over to be observed for a range of feed types and F/D ratios. This makes use of the extensive work done by Paul Wade, W1GHZ, on feed antenna modelling and published in his on-line antenna book. Where the dish has a mesh surface, the effect of this on gain and system noise temperature can be incorporated (See section 5). This paper will not describe the functions of the programme in full, but will show how some of them can be used in EME system optimisation. For a full description of all the facilities the user should refer to the extensive help section.

There are some known limitations and simplifications, for example the spillover and mesh feed-through contributions to system temperature will vary with the elevation angle of the antenna, however a fixed elevation of 45 degrees is assumed. The effect of feed and feed support blockage is not included, and both will contribute to gain loss and system noise temperature. When yagis are selected as the antenna the estimation of side lobe and rear lobe noise contribution is currently under development as there is no equivalent to the modelling that W1GHZ has done for dish feeds. These limitations and simplifications do not detract in any significant way from the usefulness of this software and indeed, the experienced user can read back into the associated literature and make appropriate adjustments. Much other useful data is included in EMECalc, for example radio star data and, for the really ambitious, planetary return losses and delays. The programme can be downloaded from the SM2CEW or VE1ALQ websites, http://www.sm2cew.com/download.htm or http://www.ve1alq.com/vk3um . The start-up screen of EMECalc, showing many of the capabilities, is shown in Figure 1.



Tx A (Home Station) Default

Frequency	Path Loss	T Sky	Rx BW	Diam	Mesh	Spacing	Sys Sensitivity	Echo S/N
1296 MHz	269.88 dB	6 K	120 Hz	2.00 mm	▨	9.0 mm	-159.2 dBm	24.3 dB

-28.2 dB
0.01 dB
Effective ground T°K 282 °K
C/S - ground --> 7.2 dB

Your last sfu data record has been loaded

	6.8 °K	28.0 °K				13 °K	0 °K	
80	0.10 dB	0.40 dB	33.0 dB	2.0 dB	1.0 dB	13 °K	0 °K	20.8 dB
Solar Flux	LNA Loss	LNA Nf	LNA Gain	Coax Loss	Rx Nf	Spillover	Feedthrough	Sun Y

Moon Y 0.69 dB

Tx A Output Power		Transmission Loss	Power at Feed		
560 Watts	27.48 dBW	0.3 dB	523 Watts	27.18 dBW	4,089,643 W EIRP

Rx T°K 35.5 °K = 0.50 dB Receiver Noise Temperature
Ground Temperature 290 °K 17 °C
Sys T°K 55.0 °K = 0.75 dB System Noise Temperature

Dx Station as received at Home Station ... 4.8 dB
Home Station as received at Dx Station ... 11.7 dB

Moon Distance
Perigee Apogee
356000 kms

Tx B (Dx Station) Default

Frequency	Path Loss	T Sky	Rx BW	Diam	Mesh	Spacing	Sys Sensitivity	Echo S/N
1296 MHz	269.88 dB	6 K	50 Hz	1.00 mm	🟩	12.7 mm	-156.9 dBm	-7.9 dB

-16.7 dB
0.09 dB
Effective ground T°K 259 °K
C/S - ground --> 4.4 dB

Your last sfu data record has been loaded.

	8.8 °K	35.4 °K				44 °K	6 °K	
80	0.13 dB	0.50 dB	24.0 dB	5.3 dB	1.0 dB	43 °K	6 °K	8.4 dB
Solar Flux	LNA Loss	LNA Nf	LNA Gain	Coax Loss	Rx Nf	Spillover	Feedthrough	Sun Y

Moon Y 0.04 dB

Tx B Output Power		Transmission Loss	Power at Feed		
80 Watts	19.03 dBW	1.0 dB	64 Watts	18.03 dBW	45,092 W EIRP

Rx T°K 49.2 °K = 0.68 dB Receiver Noise Temperature
Ground Temperature 290 °K 17 °C
Sys T°K 104.4 °K = 1.33 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 ○ 47.088 Ghz ○ 2295 MHz

Yagi Array

Single Yagi Gain in dBi	Number of Yagis	Beam Width E	Beam Width H	Array Gain	
12.65 dBi	1	38.3 °	38.3 °	10.50 dBd	12.65 dBi

Parabolic Reflector W2IMU dual-mode ☐ Linear Pol. ☑ Circular Pol.

Diameter	Size	f / D	Efficiency	Beam Width	Gain	Dish Gain	
8.56 m	Metric	0.43	58%	1.89°	7837	36.78 dBd	38.93 dBi

37.0 Lambda

Home Station ... Y Factor Calc

Noise Source
○ Sagittarius
○ Cassiopeia
○ Cygnus
○ Taurus A
○ Virgo
● Termination

Quiet Source
○ Termination
○ Aquarius
○ Leo
○ Taurus
● TSky
○ CMB (3.4°K)

Noise Flux	Quiet Flux	System Tk
290 °K	6 °K	55.0 °K

Point Source Y Factor **7.22 dB**

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

Yagi Array

Single Yagi Gain in dBi	Number of Yagis	Beam Width E	Beam Width H	Array Gain	
17.30 dBi	4	11.6 °	11.6 °	20.85 dBd	23.00 dBi

Parabolic Reflector VE4MA (Super) ☐ Linear Pol. ☑ Circular Pol.

Diameter	Size	f / D	Efficiency	Beam Width	Gain	Dish Gain	
2.50 m	Metric	0.43	63%	6.48°	725	26.36 dBd	28.51 dBi

10.8 Lambda

Effective Aperture 33.37 M²
Beam Width Ratio 0.30
Note.. Both Moon and Sun correction factors are applied to Home and Dx Station calculations.
Moon Beam Fill Factor 1.05 x 0.19 dB
Sun Beam Fill Factor 1.04 x 0.18 dB
G/T Ratio 142.56
Moon Temp @ 2.77cm Phase
Moon Radar Equ. 52.26 dB
Moon Flux 10^-22 0.0822
Moon Angular Diam 0.559°
Actual Moon Temp 213 °K...18.6 °K
Moon Return Loss 269.88 dB
356400 kMs
205.74 dB Free Space Loss at 1296 MHz
Corrected sfu 56
VK3UM Ver 7.04
Sun, 20 Jun 2010 16 52 18

Figure 1 Opening Screen of the EMECalc Program

3. Noise Measurements

Few of us are equipped with the sort of microwave measurement set up that can accurately measure all the parameters of an EME system; however, with the capability to measure relative noise levels we can use the EMECalc to deduce most of them. By measuring the ratio of the noise power received when an antenna is directed at the sun, for example, compared to the cold sky we can deduce a lot about our system. These ratios are known as Y factors.

The first thing to note is that to distinguish small differences in noise level (small values of Y) the bandwidth, Bw, in which the noise power is measured should be as wide as possible and the detector should average the result over as long a time, t, as possible.

If you want the theory behind this go to reference 2.

The resolution, or the minimum measurable temperature increase, for a total power measurement system, (which is what we use) is given by.

$$T_{min} = T_{sys} / \sqrt{Bw \cdot t}$$

Where Tsys is the overall system noise temperature in degrees Kelvin.

If we assume Tsys = 60 deg.K and that we use a bandwidth of 1 MHz with an integration time of 10 mS then we could expect to distinguish temperature differences of about 0.6 deg.K.

For suitable wideband 144MHz amplifier design and construction details, look at references 3, 4 and 5. There is also a 28MHz, 360 kHz bandwidth, design which works well, known as the RATS; it is described in reference 6. The DJ9BV PANFI, reference 7, has also been used. Many stations now use SDRs, the Spectravue SDR-IQ provides a “continuum” measurement facility which measures the total noise power in the full input bandwidth, typically 100 kHz at 28 MHz, see Figure 2 below.

SpectraVue Ver. 3.03 SpectraVue.ini

1 FFT Ave

0 Smoothing

Fs=158723 RBW= 4.8Hz

1 dB/Div V Scale

-64.926 dB

28.080000 MHz

Span 0.100000 MHz

Paused 1

6 Feb 2010 14:05:17 UTC

Figure 2 Spectravue SDR-IQ display of Total Signal Power

If you are using a transverter with an accessible IF, 144, 28MHz or similar, then the wideband amplifier noise measurement systems are easy to hook on, otherwise construct a simple down converter for the RATS, PANFI or the SDR solution.

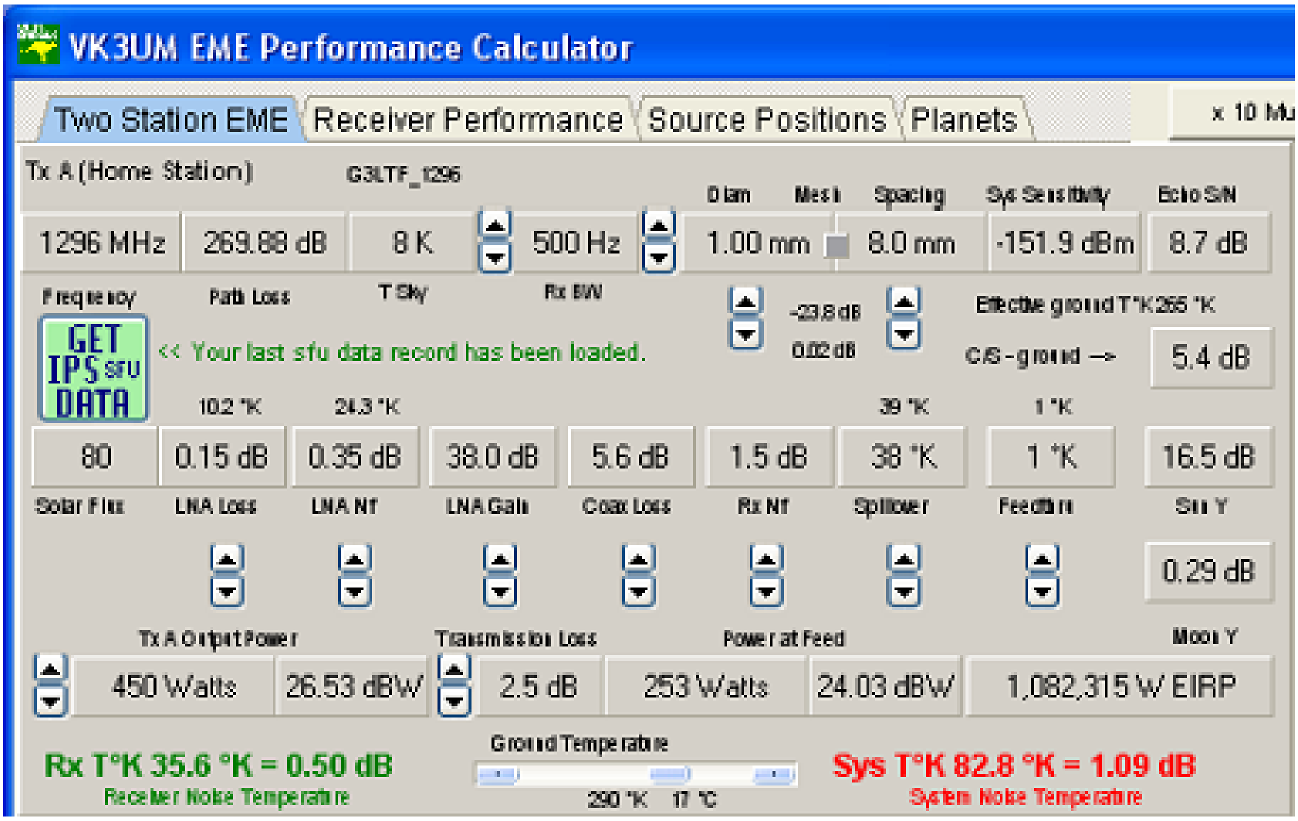
It is possible to make reasonable noise measurements with an Audio power meter but, the bandwidth of the measurement will be only that of the receiver IF, 2-12 KHz and the AGC must be off, or the RF gain backed off, and an RF attenuator at IF used to keep the output audio power indicator at the same level. Many of us used systems like this for many years and although they are certainly not as useful as the wideband solution or the SDR they are better than nothing and when used with care, can be useful. If you build an audio power meter with a 300mS time constant on the detector and use a 12 kHz IF bandwidth you still have a system which will see a difference of 1 deg. K. Two points to keep in mind are that you need about 20dB of linear headroom above the noise level you are measuring to avoid limiting and to beware of signal pick-up from sources like beacons or signals that are normally out of band; they can be in-band on a wideband receiver system.

If you have not done these sort of measurements before, don't be put off, read references 3 and 4 which are written by people with a lot of experience in this area, and then make a start and learn how to do it yourself. The paper, reference 8, presented by CT1DMK at the EME conference in Paris in 2000 also contains much useful theory and advice on making measurements of small temperature differences in radio astronomy.

One more tip, keep notes of what you do and what results you measure with what set up. There is a notes facility in the EMECalc programme but there is nothing wrong with the good old fashioned engineer's notebook.

4. Receiver System Issues

We will now explore some of the programme features, test the sensitivities of various parameters and then show how we can estimate the receiver noise temperature. Figure 3 shows a section of the screen with the parameters of my 1296MHz system.



Tx A (Home Station) G3LTF_1296

Frequency 1296 MHz
Path Loss 269.88 dB
T Sky 8 K
Rx BW 500 Hz
Diam 1.00 mm
Mesh
Spacing 8.0 mm
Sys Sensitivity -151.9 dBm
Echo S/N 8.7 dB

-23.8 dB
0.02 dB
Effective ground T°K 265 °K
C/S - ground --> 5.4 dB

<< Your last sfu data record has been loaded.

Solar Flux 80
LNA Loss 0.15 dB (10.2 °K)
LNA NF 0.35 dB (24.3 °K)
LNA Gain 38.0 dB
Coax Loss 5.6 dB
Rx NF 1.5 dB
Spillover 38 °K (39 °K)
Feedhorn 1 °K (1 °K)
Sun Y 16.5 dB
Moon Y 0.29 dB

Tx A Output Power 450 Watts 26.53 dBW
Transmission Loss 2.5 dB
Power at Feed 253 Watts 24.03 dBW
1,082,315 W EIRP

Rx T°K 35.6 °K = 0.50 dB
Receiver Noise Temperature

Ground Temperature 290 °K 17 °C

Sys T°K 82.8 °K = 1.09 dB
System Noise Temperature

Figure 3 1296 MHz Station Parameter Screen

Suppose we want to know what would happen if a higher loss cable loss was used between the LNA and receiver, currently it is 5.6dB, how high can it be before we lose 0.5dB of echo performance? Using the buttons underneath "coax loss" and observing the echo S/N of 8.9dB we find that the answer is 22dB! Or, to find out how low the LNA gain can be before we see the same drop in echoes we use the buttons under LNA gain and find the answer to be 20.5dB. It is obvious how these facilities can be used to predict the performance of a system from components when building up an EME system from scratch.

The effect of losses before the LNA is of course much more dramatic. The LNA loss is the loss of any isolation relay, connectors and cable between the antenna connector and the LNA. For a 0.5dB drop in echoes we only need to increase the LNA loss from 0.15 to

0.29dB.

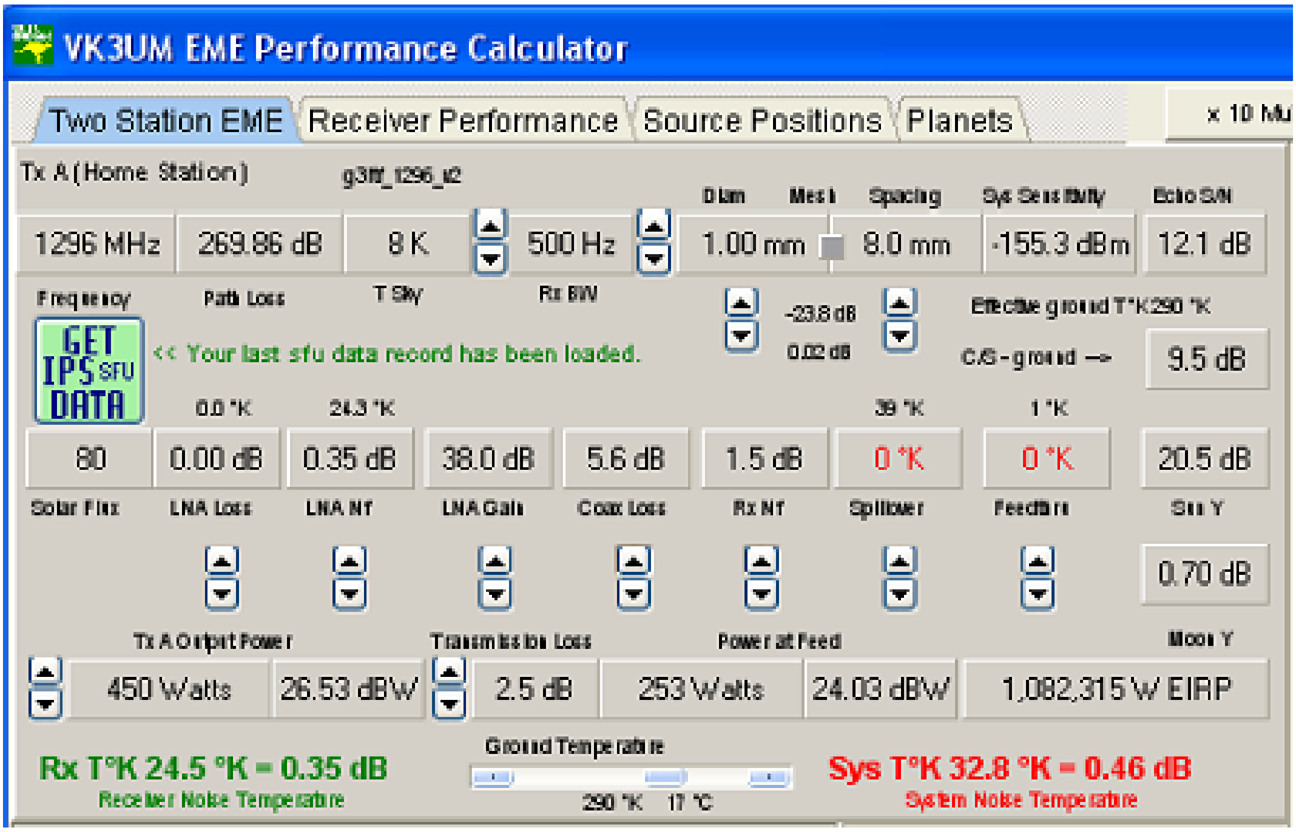
The way to keep the LNA loss down is, obviously, to use as little cable and as few connectors as possible. To do this fit the receive port on the feed with the same type of connector as you will use for the relay; match the connector sex to the relay connectors so that no adaptors are used. Often a simple right angle fitting can be used here. On the LNA side of the relay, if you are using a home-brew LNA you can save a connector by fitting a minimal length of coax directly to the LNA so that it fits directly onto the relay. My preference is for SMA type connectors on the receive side. The examples here are for 1296MHz; at higher frequencies it is even harder to keep these losses to a minimum. One more tip, make sure the connectors are clean, and use a cotton tip bud to clean both the PTFE face and the threads.

Looking now at the LNA noise figure, going from 0.35 to 0.25dB NF gains us 0.4dB in echoes and from 0.35 to 0.5 loses 0.5dB, a similar sensitivity to the LNA losses.

How do we measure these values, or more correctly, estimate them? We can use the feed horn, without the dish. Assume for the moment that we have a feed horn with zero radiation in the rear 180 degrees and in the forward sector a pattern designed to illuminate the dish edge at a level of -10 to -15dB compared to the centre. For a dish with an f/d of 0.45 this is a beam width of about 120 degrees. If we connect the LNA directly to the feed horn, without its associated relay and connecting cables and point it to the cold sky(C/S), say the Zenith, and then point it at the ground, the noise output from the receiver measured as described in section 3, will change, by several dB.

If we look at EMECalc we can see by how much it should change. Setting the spillover and the feed-through to zero and the LNA loss to zero we see in Figure 4 that the C/S to ground ratio is 9.5dB.

You will not see this much however! We have to make some allowances for the practical level of the rear and side sector pick up and for feeds such as the W2IMU dual mode horn and the VE4MA and RA3AQ, about 10 -12 degrees K needs to be added in to the spillover reducing the C/S - ground to 8dB. If the value measured is different (usually lower!) then adjusting the LNA NF value until the measured value is obtained provides an estimate of the NF. So, if we actually measure 6dB then that would indicate a NF of 0.72dB, see Figure 5. This is not a precision measurement method, if you have a good NF measuring instrument then that will give you a more accurate result, but without one, and wishing to do diagnostics on the system, this is better than guessing! If the isolation relay and cable are added in front of the LNA and the measurement is repeated the C/S-ground value obtained will be reduced and then by adjusting the LNA loss button to match the indicated value to the measured value the LNA loss figure can be checked.



Tx A (Home Station) g3ltf_1296_r2

Frequency 1296 MHz; Path Loss 269.86 dB; T Sky 8 K; Rx BW 500 Hz; Diam 1.00 mm; Mesh 8.0 mm; Spacing; Sys Sensitivity -155.3 dBm; Echo S/N 12.1 dB

-23.8 dB; 0.02 dB

Effective ground T°K 290 °K

C/S - ground → 9.5 dB

<< Your last sfu data record has been loaded.

0.0 °K; 24.3 °K; 39 °K; 1 °K

Solar Flux 80; LNA Loss 0.00 dB; LNA NF 0.35 dB; LNA Gain 38.0 dB; Coax Loss 5.6 dB; Rx NF 1.5 dB; Spillover 0 °K; Feedthru 0 °K; Sun Y 20.5 dB

Moon Y 0.70 dB

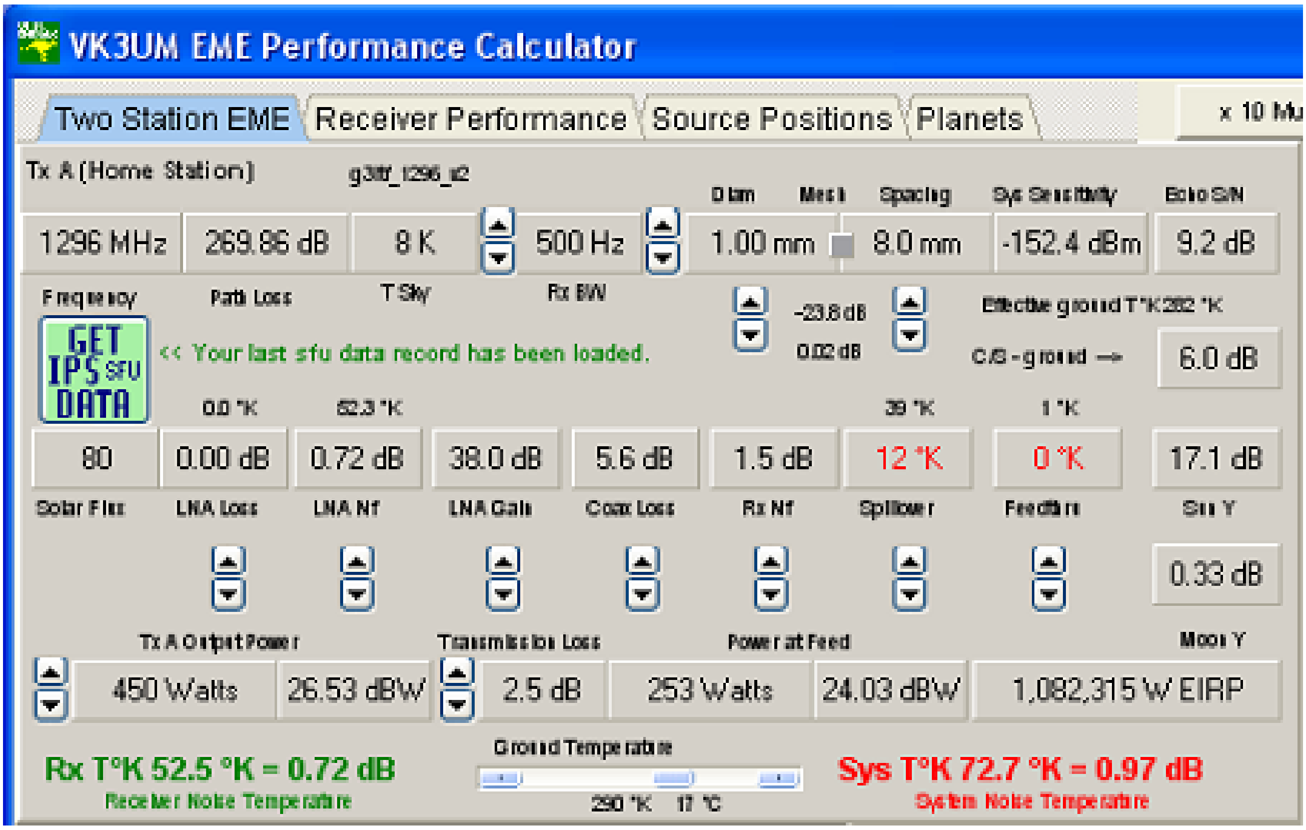
Tx A Output Power 450 Watts 26.53 dBW; Transmission Loss 2.5 dB; Power at Feed 253 Watts 24.03 dBW; 1,082,315 W EIRP

Rx T°K 24.5 °K = 0.35 dB
Receiver Noise Temperature

Ground Temperature 290 °K 17 °C

Sys T°K 32.8 °K = 0.46 dB
System Noise Temperature

Figure 4 Change in Cold Sky to Ground Ratio



Tx A (Home Station) g3ltf_1296_r2

Frequency 1296 MHz; Path Loss 269.86 dB; T Sky 8 K; Rx BW 500 Hz; Diam 1.00 mm; Mesh 8.0 mm; Spacing; Sys Sensitivity -152.4 dBm; Echo S/N 9.2 dB

-23.8 dB; 0.02 dB

Effective ground T°K 282 °K

C/S - ground → 6.0 dB

<< Your last sfu data record has been loaded.

0.0 °K; 52.3 °K; 39 °K; 1 °K

Solar Flux 80; LNA Loss 0.00 dB; LNA NF 0.72 dB; LNA Gain 38.0 dB; Coax Loss 5.6 dB; Rx NF 1.5 dB; Spillover 12 °K; Feedthru 0 °K; Sun Y 17.1 dB

Moon Y 0.33 dB

Tx A Output Power 450 Watts 26.53 dBW; Transmission Loss 2.5 dB; Power at Feed 253 Watts 24.03 dBW; 1,082,315 W EIRP

Rx T°K 52.5 °K = 0.72 dB
Receiver Noise Temperature

Ground Temperature 290 °K 17 °C

Sys T°K 72.7 °K = 0.97 dB
System Noise Temperature

Figure 5 Indication of Noise Figure

Some pitfalls to watch out for; remember the horn beam-width is wide, 120 degrees, so make sure the horn, when pointed at the cold sky does not see any trees or buildings in that sector. When pointing at the ground do not point directly downwards as this will possibly affect the return loss, although a termination on the transmit port will reduce this.

Feed horns such as simple un-choked waveguides are unsuitable for this measurement as they tend to have higher rear radiation. There are ways of refining this measurement process, but even in its simple form it is very useful. Keeping notes of what you do and the results obtained is essential.

5. Antenna System Issues

One of the most useful functions of EMECalc is the facility to see the results on the overall system performance of changing the combination of feed and dish. The choice of feed type affects both efficiency and gain, and the noise performance of the system.

The overall noise temperature of the system, Tsys, can be expressed as

Tsys = Tsky + Tspill +Tft +Trx

In the previous section we explored the effect of LNA NF and all the other parameters associated directly with the LNA and these are represented in the above equation as Trx.

Tspill is the temperature contribution from the objects seen by the feed outside the area of the dish. If the dish is pointing at zenith then the objects are the ground. If pointing at 45 degrees elevation then the feed sees part sky and part ground.

Tft is the temperature contribution from the transparency of the reflector surface of the dish. If it is solid then this is zero, but if it is a mesh surface then the feed will see, through the mesh, a combination of ground and sky, depending upon elevation as described above for Tspill .The programme enables the loss through the mesh to be displayed (this affects the gain) and it calculates the noise temperature contribution. The important parameters for the mesh are the spacing and the wire diameter. If the mesh is not square then use the average of the two dimensions of the aperture to get an approximate value. Spillover and feed-through can be seen displayed in figures 2 to 4 in the right hand half of the screen.

We will now look in more detail at the interaction of feed and dish. There is an excellent discussion of this issue in chapter 4 of the W1GHZ Online Microwave Antenna Book, reference 9. If you are a beginner in this area then I recommend that you read it in conjunction with your use of EMECalc. The EMECalc programme makes extensive use of the results of Paul's work which is a cache of truly invaluable information for the EME community.

Figure 6 is an extract from chapter 4 of the book and shows very clearly the trade-offs involved. The ideal illumination pattern for the dish is shown as a dashed line. The solid black line is the pattern of a feed which gives the taper indicated, i.e. 3dB to 20dB. The illumination loss compared to the ideal pattern is in blue and the spillover is in red. The higher the edge taper the lower the gain and the wider the beam-width but, the lower is the spillover.

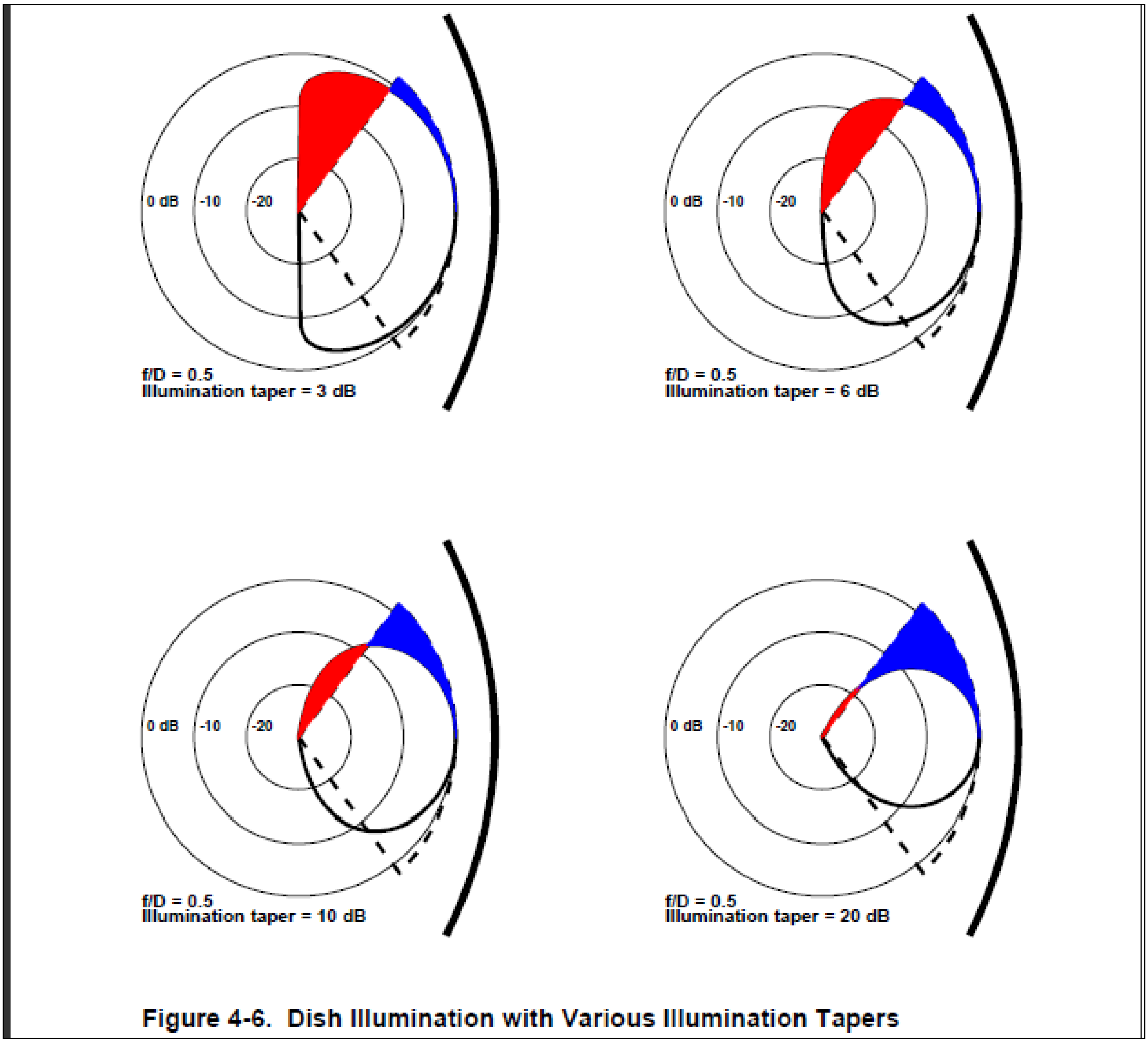


Figure 4-6. Dish Illumination with Various Illumination Tapers

Figure 6 Extract from Chapter 4 of W1GHZ On-Line Antenna Book

The feed pattern is therefore crucial to optimising dish performance as part of an EME system where we would like to minimum noise contribution from spillover but also achieve maximum gain. Several classes of feeds exist using a variety of physical shapes, such as chokes, cavities and tapers, to control the pattern. W1GHZ has extensively modelled these and published the results in the on-line antenna book. For many of them the characteristics are presented in graphical form for a range of focal length to diameter ratios, f/D. For example, Figures 7 and 8 show the results for two quite different feeds, the super VE4MA and the W2IMU dual mode feed. The efficiency curves peak at significantly different f/D ratios, 0.38 and 0.55. The efficiency and spillover curves for 25 different feeds have been entered into EMECalc and so for any value of reflector f/D ratio a feed may be selected and the resulting dish gain and spillover contribution to the system performance is then displayed. Different feeds may be compared or the f/D can be varied for a given feed to find the best f/D to choose if a new dish is being built from scratch. Although the EMECalc programme contains quite a wide range of feed performance data they are for representative sets and if you read into the W1GHZ simulation material you will find a lot more results on the variation of feed parameters, it is quite easy to interpret these and enter the spillover and gain figures into the various boxes by using the up/down buttons.

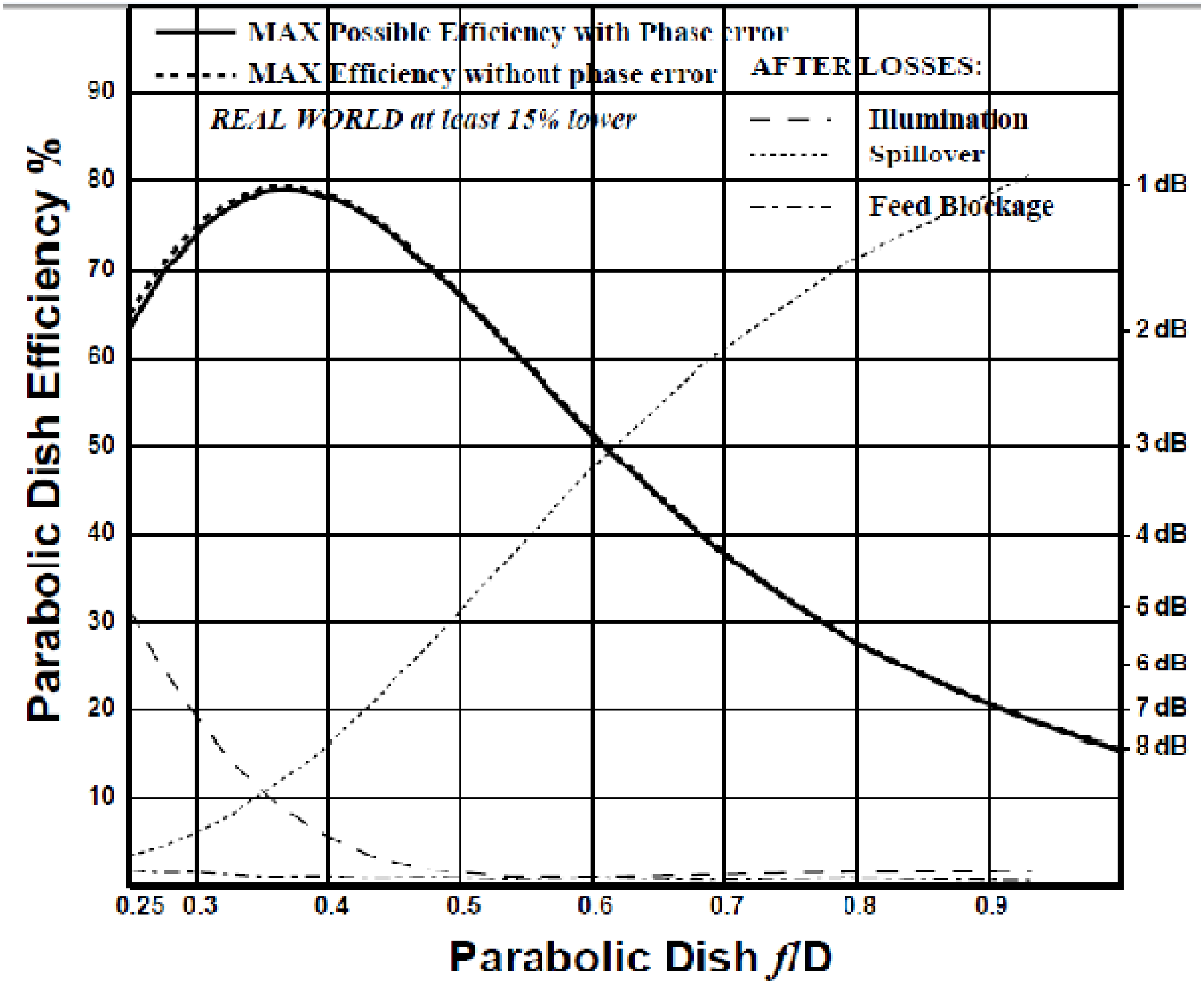


Figure 7 Simulation Results for a typical Super VE4MA feed

Examine Figures 9 and 10 which show the difference between the super VE4MA feed and the W2IMU dual mode feed used on the G3LTF dish. The W2IMU feed would give 0.5dB receive improvement. The difference increases to 0.6dB if the noise figure is lowered to 0.2 dB. The programme displays the G/Tsys ratio which is the figure that determines the receive performance of the system. G is the antenna gain.

To achieve maximum radiated power from a dish with a given f/D ratio we should choose a feed whose efficiency peaks at that value. However this will not give the best receive performance. By using the programme to vary f/d we can easily see that the highest G/T values occur when the dish is under illuminated and the best operating point is to the left hand side of the efficiency peak. The lower the receiver noise temperature the more marked is this effect. Obviously there is a loss of radiated power but this can be made up if sufficient transmitter power is available.

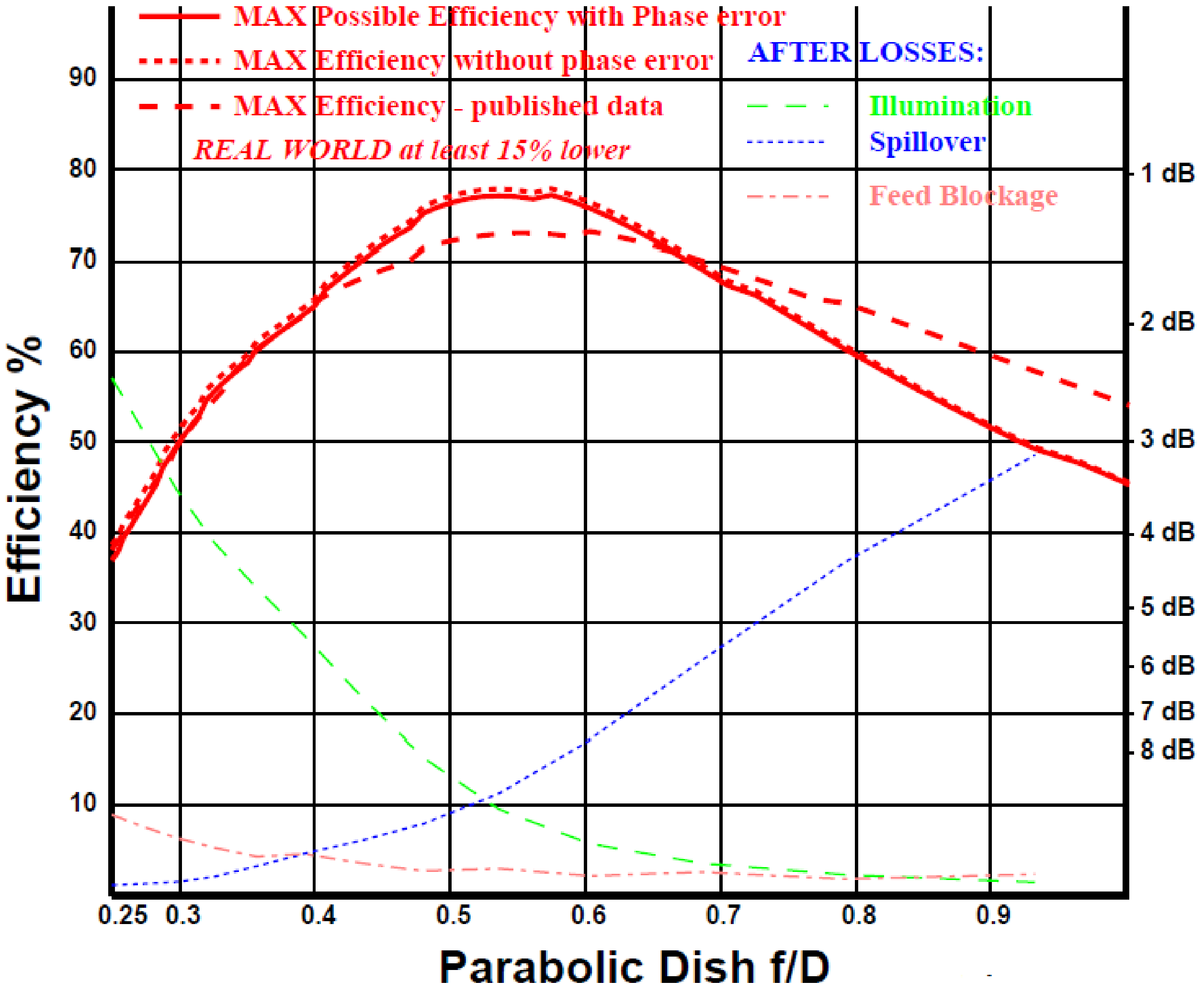


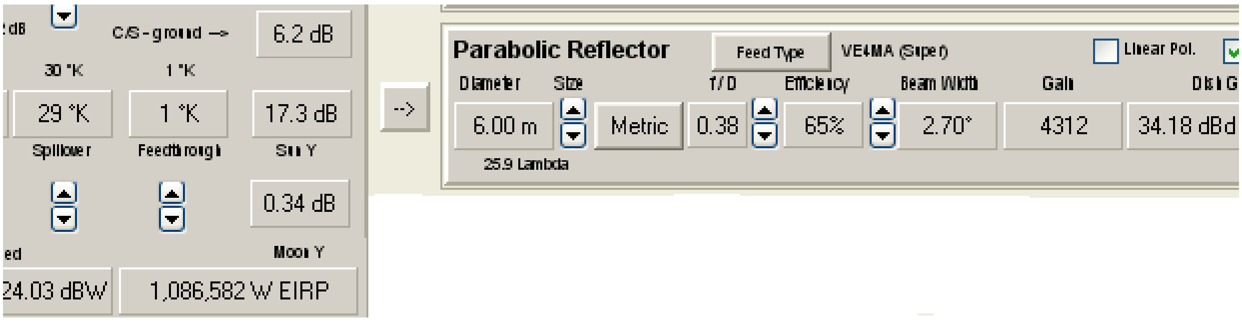
Figure 8 Simulation results for a W2IMU Dual mode horn feed

6. Antenna Adjustments and Measurements

By measuring the sun noise Y factor we can set up the antenna by observing changes as the feed is moved in and out and parameters such as choke position are varied. Another useful check is to estimate the antenna beam-width to -3dB points by letting the sun drift though the static beam or if the readout accuracy is sufficient, to measure it by moving the antenna. The result should be fairly close to that value in EMECalc. If the sun noise to cold sky ratio is below 13dB the 3dB points will not be 3dB below the peak but a smaller figure because what we are observing is (Signal + Noise) / Noise. See Figure 11 For example, if we see a (S+N)/N of 8dB then this is a S/N ratio of 7.3dB. 3dB down on this is 4.3dB S/N which translates to 5.7dB (S+N)/N. Thus the -3dB points are only 2.3dB below the beam peak. For antennas with beam-widths of under 1.5 degrees the correction for the finite size of the sun, when used as a source, is available in the programme.

With a reasonable level of sun noise the first side lobe levels may be seen as a very small increase in noise and again the (S+N) /N corrections need to be made. For the sort of feeds that are being used here a level for the first side lobe of -18 to -20 dB may be seen. Obviously if the dish is being stressed to the limit of its frequency range in terms of surface accuracy then the first side lobe levels will be higher and quite probably uneven.

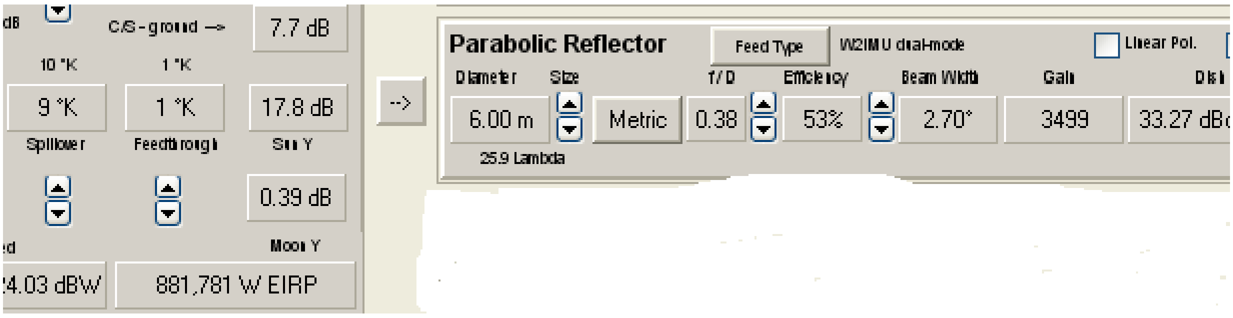
An error that is often made is to fit the feed correctly at the focal point but not with the centre of its pattern pointing exactly to the dish centre. This can have a “double whammy” effect; there is a loss of gain from under-illumination of the available aperture but also increased spillover and a pickup of more ground noise. Careful alignment or the fitting of a temporary sighting tube on the feed will avoid this.



dB
C/S - ground -->
6.2 dB
30 °K
1 °K
29 °K
1 °K
17.3 dB
Spillover
Feedthrough
Sun Y
0.34 dB
ed
Moon Y
24.03 dBW
1,086,582 W EIRP

Parabolic Reflector
Feed Type
VE4MA (Super)
☐ Linear Pol.
☑
Diameter
Size
f / D
Efficiency
Beam Width
Gain
Dish G
6.00 m
Metric
0.38
65%
2.70°
4312
34.18 dBd
25.9 Lambda

Figure 9 Antenna characteristics with Super VE4MA feed



dB
C/S - ground -->
7.7 dB
10 °K
1 °K
9 °K
1 °K
17.8 dB
Spillover
Feedthrough
Sun Y
0.39 dB
ed
Moon Y
24.03 dBW
881,781 W EIRP

Parabolic Reflector
Feed Type
W2IMU dual-mode
☐ Linear Pol.
Diameter
Size
f / D
Efficiency
Beam Width
Gain
Dish
6.00 m
Metric
0.38
53%
2.70°
3499
33.27 dB
25.9 Lambda

Figure 10 Antenna characteristics with W2IMU dual mode feed.

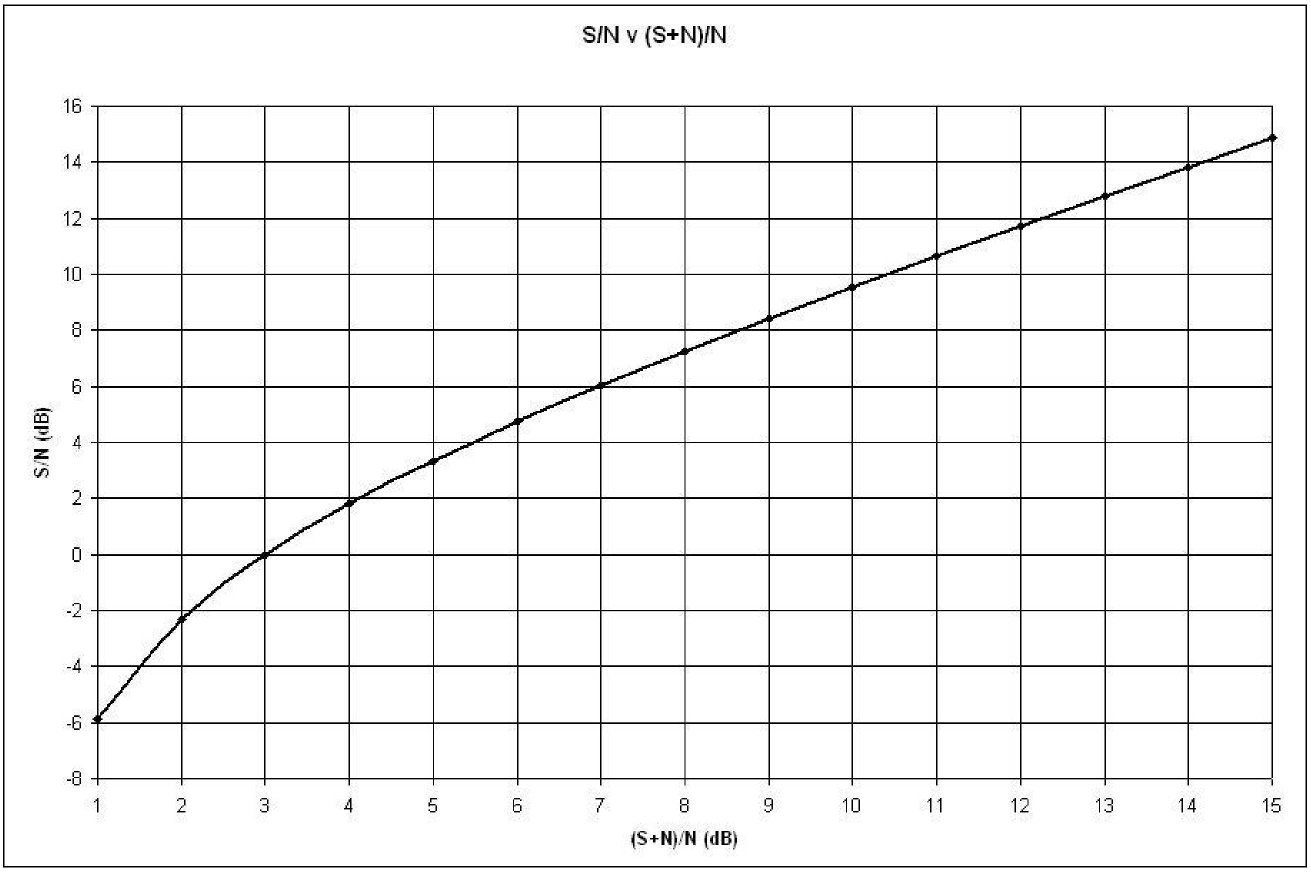


Figure 11 Graph of S/N vs (S+N)/N

7. Whole System Checks

When the antenna has been optimised then whole system measurements can be made. EME Calc can provide predicted Y figures for sun, moon and a number of radio sources.

Smaller systems will only be able to use the sun and this does have variability especially as we begin to see more sunspot activity. The on-line sourcing of the data from the Learmonth Observatory has already been mentioned. Larger antennas will be able to see moon noise, for example a 6m dish at 23cm will see around 0.3dB at 23cm and 0.9dB at 9cm. The variation of this with moon distance and moon phase is significant and is catered for in the programme. Measurements of Y factor at the 0.3dB level do require a sensitive wideband noise measurement system, see section 3. The programme allows selection of specific "cold sky" points but for general adjustments like feed position the cold sky at a nearby convenient point can be used as the reference, however when comparing your results to the predicted values be sure that the cold reference point is the same as the one you are using. The default is Aquarius.

If the receive system has checked out satisfactorily with the measurement of NF by a known quality instrument or by the C/S to Ground measurements described earlier, then the result obtained by measuring sun noise should be quite close to the predicted value, probably within 1.5dB. It is more difficult to generalise on moon noise but probably the result should be within 0.2 dB of the predicted value. Cold sky to ground measurements of the whole system in the dish are quite hard to make unless the dish can be pointed at something like a thick hedge or trees in full leaf. Looking at the ground at a small incident angle, say < 20 degrees, will not give a predictable result due to ground reflection of the cold sky, The result will be lower than that obtained for the measurement of the feed horn alone because of the effect of spillover and it is possible to start to dis-entangle the actual spillover contribution from the two measurements.

When the final system measurements are completed and the comparisons made then it should be possible to start to deduce where the short falls (if any!) are. For example, if the dish beam-width measurement agrees and the receiver NF and losses are known then higher spillover may be the reason. If a specific part of the system is suspect then the simulation can be used to test the assumption and see if the level of the suspected under-performance of the component can feasibly be the cause.

Keep in mind that the simulations are pretty good and comprehensive and have been verified by a number of stations making measurements with continual refinement of the programme. If you see a big difference with the predicted values then there is probably something under-performing in the system.

8. Acknowledgements

Without the sterling efforts over many years of Doug McArthur, VK3UM, we would not have this extremely useful tool. It has been very much enhanced by incorporating the simulations of many different feeds performed by Paul Wade, W1GHZ and I am grateful to him for allowing the use of some of his material. Sam Jewell G4DDK produced the SDR noise measurement picture, which first appeared in the RSGB Radcom magazine.

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