

EME Measurements and EMECalc

Peter Blair

G3LTF

Contents

- Introduction
- Calculation of the received signal
- System Temperature, Spillover, Mesh Feed-through
 - Where do they come from?
- Y factor measurements of....
 - Ground, Sun, Moon, Radio Stars
- Derivation of solar flux data
- Concluding comment

The purpose of EMECalc

- Estimate SNR of own echoes and signals from other stations by entering system parameters; Antenna size and feed type, Noise figure, cable losses, Tx power
- Enables exploration of the sensitivity of an EME system to parameter changes
- Allows checking of some of the parameters by using measurements of noise power from known sources (sun, moon, radio stars, ground)

A few key points

- I will only be discussing applications at 1296MHz and above
- I will not cover yagis
- Remember that EMECalc is not a complete, comprehensive, system analysis and it contains some simplifying assumptions
- There is a wealth of detail in the Help section

Recent History

- EMECalc was in near continuous evolution until Feb 2016 when VK3UM became SK
- Major changes to parabola performance following W1GHZ paper at EME2014
- Changes to Solar flux acquisition
- Changes to Ground/ Cold Sky prediction
- Moon temperature and Radio star flux updated

The full EMECalc screen is tightly packed because its displaying a lot of data and variables. But don't be put off. You can start by altering the default screen to your own station.

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

Tx A (Home Station)

G3LTF_5760_3

5760 MHz | 283.87 dB | 6.0 K | 145 Hz | 1.00 mm | 6.00 mm | -156.8 dBm | 15.31 dB

Frequency | Path Loss | T Sky | Circ 6.41% | Effective ground 242 K | 0.30

IPS Learmonth Western Au 2019 Apr 15 1216z

10.7cm | 15.87 K | 46.82 K | 12.33 K

74 | 0.20 dB | 0.65 dB | 11.0 dB | 0.3 dB | 1.5 dB | 15.24 K | 9.30 K | 18.61 dB

Get stu

LNA Loss | LNA NF | LNA Gain | Coax Loss | Rx NF | Spillover | Feedthrough derived from Mesh size | Sun Y | 2.56 dB

Tx A Output Power | Transmission Loss | Power at Feed | Moon Y

40 Watts | 16.02 dBW | 0.1 dB | 39 Watts | 15.92 dBW | 3,510,886 W EIRP

RxTK 75.08 K = 1.00 dB | Repeater Noise Temperature

Ground Temperature | TSys 105.62 K = 1.35 dB | System Noise Temperature

290 K | 17 °C

Dx Station as received at Home Station 5.88 dB

Change Moon Distance | Moon noise included

Home Station as received at Dx Station 11.09 dB

Perigee | Apogee | 378,293 kms

Tx B (Dx Station)

Default

5760 MHz | 283.87 dB | 6.0 K | 120 Hz | 2.92 mm | 10.00 mm | -158.8 dBm | 1.66 dB

Frequency | Path Loss | T Sky | Circ 5.76% | Effective ground 223 K | 0.30

IPS Learmonth Western Au 2019 Apr 15 1216z

10.7cm | 7.32 K | 24.34 K | 0.15 K

74 | 0.10 dB | 0.35 dB | 33.0 dB | 2.0 dB | 1.0 dB | 34.10 K | 8.35 K | 12.91 dB

Get stu

LNA Loss | LNA NF | LNA Gain | Coax Loss | Rx NF | Spillover | Feedthrough derived from Mesh size | Sun Y | 0.81 dB

Tx B Output Power | Transmission Loss | Power at Feed | Moon Y

30 Watts | 14.77 dBW | 0.3 dB | 28 Watts | 14.47 dBW | 400,293 W EIRP

RxTK 31.81 K = 0.45 dB | Repeater Noise Temperature

Ground Temperature | TSys 80.25 K = 1.06 dB | System Noise Temperature

290 K | 17 °C

Operating Frequency

Click to enter a 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

x 10 Multiplier | Note Pad | Hint - Res | Ver. History | VK3UM.com | Help | About | Exit

Yagi Array 5760 MHz

Single Yagi Gain in dBd | Number of Yagis | G/T | Array Type and Gain

16.80 dBd | 1 | 0.00 | 18.54 ° | 18.54 ° | 16.80 dBd | 18.95 dBi

Stacking Distance | User Defined Yagi

Parabolic Reflector

Focal length 2.25 m | Feed Type | 6cm SM6PHZ Septum 0.743L | Linear Pol. | Circular Pol.

Diameter | Size | f / D | Efficiency | Beam Width | Gain | Dish Gain

6.00 m | Metric | 0.38 | 73.2% | 0.607° | 89817 | 47.38 dBd | 49.53 dBi

115.3 Lambdas

Home Station ... Y Factor Calc

Noise Source (Hot) | Quiet [cold] Sky | System TK

Sagittarius A | Taurus A | 304 Jy | 6 K | 105.62 K

Cassiopeia A | Virgo A

Cygnus A | Termination

Centaurus A

Point Source Y Factor | 0.09 dB

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

Noise Source Positions. | Y Figure Information

Yagi Array 5760 MHz

Single Yagi Gain in dBd | Number of Yagis | G/T | Array Type and Gain

18.00 dBd | 1 | 0.00 | 16.15 ° | 16.15 ° | 18.00 dBd | 20.15 dBi

Stacking Distance | User Defined Yagi

Parabolic Reflector

Focal length 1.07 m | Feed Type | VE4MA (Super) | Linear Pol. | Circular Pol.

Diameter | Size | f / D | Efficiency | Beam Width | Gain | Dish Gain

2.49 m | Metric | 0.43 | 67.2% | 1.46° | 14297 | 39.40 dBd | 41.55 dBi

47.8 Lambdas

Effective Aperture	Beam Width Ratio	Set Current Moon	Moon Data
TxA 19.36 M ²	0.87	S/F Update Moon	Phase 0.08
TxB 3.08 M ²	0.36		Illum 6.5 %
Moon Beam Fill Factor	Sun Beam Fill Factor	G/T Ratio	4th Quarter
TxA 1.28	1.08dB	1.30	850.39 29.30dB
TxB 1.05	0.19dB	1.05	178.15 22.51dB
Moon Radar Equ.	Current Moon Distance	Moon Angular Diam	Moon Temp
52.78 dB	378,293 kms	0.526° 31'35.3"	229 K
Moon return Loss	Moon Flux 10 ⁻²²	Moon Declination	Frequency adjusted stu
283.87 dB	Sv = 1.55	Dec. 20.56 °	140

Engineering Panel | 5760 MHz

Save Data | Get Data | Default | Print | Exit

VK3UM Ver 11.10

The full EMECalc screen is tightly packed but we don't need all of it for now. We can take out the Dx Station and Yagi sections. This is showing my 5.7GHz system.

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

Tx A (Home Station) G3LTF_5760_3

5760 MHz 283.87 dB 6.0 K 145 Hz 1.00 mm 6.00 mm -156.8 dBm 15.31 dB

Frequency Path Loss T Sky Circ 6.41% Effective ground 242 K 6.00 mm 0.90

IPS Learmonth Western Au 2019 Apr 15 1216z Loss 0.288 dB Mesh Gad to Cold Sky 4.09 dB

10.7cm 15.87 K 46.82 K 12.39 K

74 0.20 dB 0.65 dB 11.0 dB 0.3 dB 1.5 dB 15.24 K 9.30 K 18.61 dB

Get stu LNA Loss LNA NF LNA Gain Coax Loss Rx NF Spillover Feedthrough derived from Mesh size Sun Y 2.56 dB

Tx A Output Power Transmission Loss Power of Feed Moon Y 40 Watts 16.02 dBW 0.1 dB 39 Watts 15.92 dBW 3,510,886 WEIRP

RxTK 75.08 K = 1.00 dB Ground Temperature 230 K 17 °C T Sys 105.62 K = 1.35 dB System Noise Temperature

Change Moon Distance Moon noise included Perigee 378,293 kms Apogee

Parabolic Reflector Focal length 2.25 m Feed Type 6cm SM6FHZ Septum 0.749L Linear Pol. Circular Pol. Diameter 6.00 m Size Metric f/D 0.38 Efficiency 73.2% Beam Width 0.607° Gain 89817 Dish Gain 47.38 dBd 49.53 dBi 115.3 Lambda

Home Station ... Y Factor Calc Noise Source (Hot) Sagittarius A Taurus A Cassiopeia A Virgo A Cygnus A Centaurus A Termination Quiet Source (Cold) Aquarius or Leo T Sky (variable) Noise Source Positions Y Figure Information Noise[hot] Flux 304 Jy Quiet [cold] Sky 6 K System TK 105.62 K Point Source Y Factor 0.09 dB

Operating Frequency Click to enter a 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

Effective Aperture Beam Width Ratio Set Current Moon Moon Data
 Tx A 19.36 M² 0.87 S/F Update Moon Phase 0.08
 Tx B 3.08 M² 0.36 Illum 6.5 %
 Moon Beam Fill Factor Sun Beam Fill Factor G/T Ratio 4th Quarter
 Tx A 1.28 1.08dB 1.30 1.13dB 850.39 29.30dB P Angle 28°
 Tx B 1.05 0.19dB 1.05 0.20dB 178.15 22.51dB
 Moon Radar Equ. Current Moon Distance Moon Angular Diam Moon Temp
 52.78 dB 378,293 kms 0.526° 31'35.3" 229 K
 Moon return Loss Moon Flux 10⁻²² Moon Declination Frequency adjusted stu
 283.87 dB Sv = 1.55 Dec. 20.56° 140
 Engineering Panel 5760 MHz

Save Data Get Data Default Print Exit VK3UM Ver 11.10

EMECalc Key equation (1)

The radar equation for echos

$$Pr/Pt = G^2 * \lambda^2 * \rho / R^4 * (4*\pi)^3$$

G is the Antenna gain

Pt Transmitter power at the feed terminal

Pr Received power at the feed terminal

R moon distance

ρ Moon radar cross section

If we set $G=1$ (isotropic) Then Pr/Pt is called the “path loss” or the “moon return loss”

EMECalc uses Equation 1 to give the received echo SNR

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Frequency | Path Loss | T Sky | Circ: 6.41% | Effective ground 242 K

IPS Learmonth Western Au 2019 Apr 15 1216z

10.7cm | 15.81 K | 46.82 K | 12.33 K | 4.89 dB

74 | 0.20 dB | 0.65 dB | 11.0 dB | 0.3 dB | 1.5 dB | 15.24 K | 9.30 K | 18.61 dB

LNA Loss | LNA NF | LNA Gain | Coax Loss | Rx NF | Spillover | Feedthrough derived from Mesh size | Sun Y | 2.56 dB

Tx A Output Power | Transmission Loss | Power at Feed | Moon Y

40 Watts | 16.02 dBW | 0.1 dB | 39 Watts | 15.92 dBW | 3,510,886 W EIRP

RxTK 75.08 K = 1.00 dB | Receiver Noise Temperature | 230 K | 17°C | T Sys 105.62 K = 1.35 dB | System Noise Temperature

Dx Station as received at Home Station 5.88 dB

Home Station as received at Dx Station 11.09 dB

Change Moon Distance Moon noise included 378,293 kms

Tx B (Dx Station) Default

5760 MHz | 283.87 dB | 6.0 K | 120 Hz | 2.92 mm | 10.00 mm | -158.8 dBm | 1.66 dB

Frequency | Path Loss | T Sky | Circ: 5.16% | Effective ground 223 K

IPS Learmonth Western Au 2019 Apr 15 1216z

10.7cm | 7.32 K | 24.34 K | 0.15 K | 5.25 dB

74 | 0.10 dB | 0.35 dB | 33.0 dB | 2.0 dB | 1.0 dB | 34.10 K | 8.35 K | 12.91 dB

LNA Loss | LNA NF | LNA Gain | Coax Loss | Rx NF | Spillover | Feedthrough derived from Mesh size | Sun Y | 0.81 dB

Tx B Output Power | Transmission Loss | Power at Feed | Moon Y

30 Watts | 14.77 dBW | 0.3 dB | 28 Watts | 14.47 dBW | 400,293 W EIRP

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Yagi Array 5760 MHz

Single Yagi Gain in dBd | Number of Yagis | G/T | E | 18.54° | Array Type and Gain

16.80 dBd | 1 | 0.00 | 18.54° | 16.80 dBd | 18.95 dBd

Stacking Distance | User Defined Yagi

Parabolic Reflector

Focal length 2.25 m | Feed Type | 6cm 3M6FHZ Spectrum 0.749L | Linear Pol. | Circular Pol.

Diameter | Size | f / D | Efficiency | Beam Width | Gain | Dish Gain

6.00 m | Metric | 0.38 | 73.2% | 0.607° | 89817 | 47.38 dBd | 49.53 dBd

115.3 Lambda

Home Station ... Y Factor Calc

Noise Source (Hot) | Noise [Hot] Flux | Quiet [Cold] Sky | System TK

Sagittarius A | Taurus A | 304 Jy | 6 K | 105.62 K
 Cassiopeia A | Virgo A
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Point Source Y Factor 0.09 dB

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

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Yagi Array 5760 MHz

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18.00 dBd | 1 | 0.00 | 16.15° | 18.00 dBd | 20.15 dBd

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47.8 Lambda

Effective Aperture | Beam Width Ratio | Set Current Moon | Moon Data

TxA 19.36 M² | 0.87 | Update Moon | Phase 0.08
 TxB 3.08 M² | 0.36 | G/T Ratio | Illum 6.5 %

Moon Beam Fill Factor | Sun Beam Fill Factor

TxA 1.28 | 1.08dB | 1.30 | 1.13dB | 850.39 | 29.30dB
 TxB 1.05 | 0.19dB | 1.05 | 0.20dB | 178.15 | 22.51dB

Moon Radar Equ. | Current Moon Distance | Moon Angular Diam | Moon Temp

52.78 dB | 378,293 kms | 0.526° 31°35.3" | 229 K

Moon return Loss | Moon Flux 10°-22 | Moon Declination | Frequency adjusted stp

283.87 dB | Sv = 1.55 | Dec. 20.56° | 140

Engineering Panel | 5760 MHz

Save Data | Get Data | Default | Print | Exit

VK3UM Ver 11.10

Echo SNR =

$P_t - \text{Return loss} + 2 * \text{Antenna Gain}$

$\text{Noise Power} = 10 * \log(k * T_{\text{sys}} * B)$

The screenshot shows a software interface with several panels. The top panel is titled 'Tx A (Home Station)' and contains various input fields and sliders. The 'Echo SNR' field is highlighted with a red arrow and labeled 'SNR'. Below this, there are sections for 'Parabolic Reflector' and 'Home Station ... Y Factor Calc'. The 'Y Factor Calc' section shows 'Noise Source (Hot)' and 'Quiet Source (Cold)' options, with 'TSky (variable)' selected. The 'Point Source Y Factor' is shown as 0.09 dB. At the bottom, there is a section for 'Change Moon Distance' with 'Moon noise included' checked.

k is Boltzmanns constant $1.38 * 10^{-23}$ joules/ kelvin

**Where does EMECalc get T_{sys}
and Antenna gain from?**

And what is T_{sys} ?

System Noise Temperature, T_{sys} , definition

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

T_{rx} Receiver noise temperature contribution from line losses, LNA and following stages

T_{sky} Sky temperature

T_{spill} noise temperature contribution from spillover and sidelobes

T_{ft} noise temperature contribution from any mesh transparency

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

Solid dish
Tft = Zero

Software interface showing receiver performance metrics for station G3LTF_5760_3.

Station Parameters:
 Tx A (Home Station) | G3LTF_5760_3
 Frequency: 5760 MHz | Path Loss: 283.87 dB | T Sky: 6.0 K | Rx BW: 145 Hz | Diam: 1.00 mm | Mesh: 6.00 mm | Spacing H-V: 6.00 mm | Sensitivity: -156.8 dBm | Echo S/N: 15.31 dB

Receiver Performance Metrics:

15.87 K	46.82 K	12.39 K			15.24 K	9.30 K	18.61 dB
0.20 dB	0.65 dB	11.0 dB	0.3 dB	1.5 dB	Spillover	Feedthrough derived from Mesh size	Sun Y: 2.56 dB
LNA Loss	LNA NF	LNA Gain	Coax Loss	Rx NF			Moon Y

Power and Temperature Data:

Tx A Output Power: 40 Watts	Transmission Loss: 16.02 dBW	0.1 dB	Power at Feed: 39 Watts	15.92 dBW	3,510,886 W EIRP
RxTK 75.08 K = 1.00 dB Receiver Noise Temperature	Ground Temperature: 230 K / 17 °C		T Sys 105.62 K = 1.35 dB System Noise Temperature		

Additional Settings:
 Change Moon Distance: 378,293 kms (Perigee to Apogee)
 Moon noise included

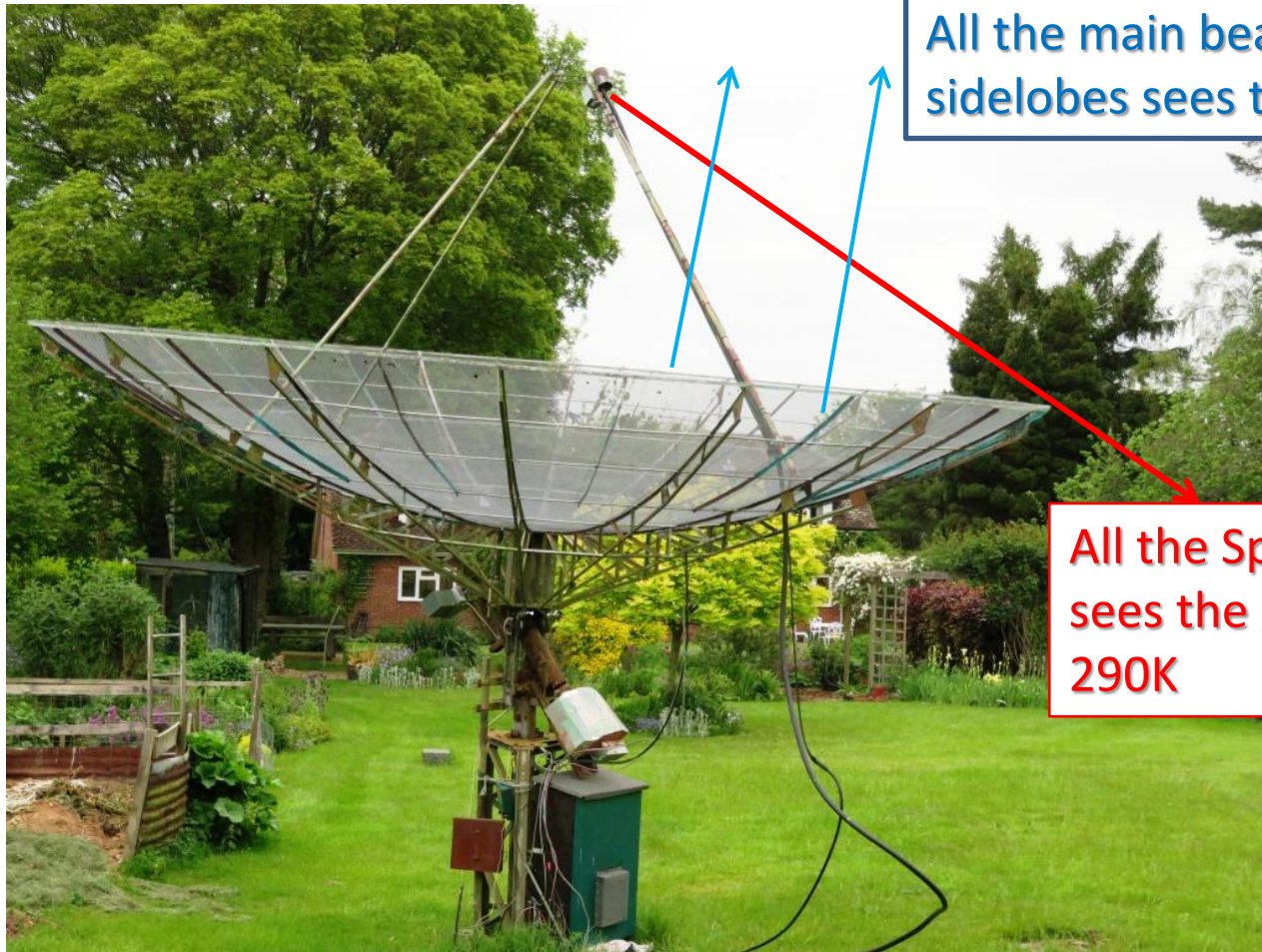
Spillover

- Solid dish + perfect receiver means....

$$\mathbf{T_{sys} = \cancel{T_{rx}} + T_{sky} + T_{spill} + \cancel{T_{ft}}}$$

- In the limit the Antenna determines the system performance.
- Putting an excellent VLNA on a poor antenna is a waste of time.
- Calling this quantity in EMECalc “Spillover” is not strictly correct but it’s historical and cant be changed now!

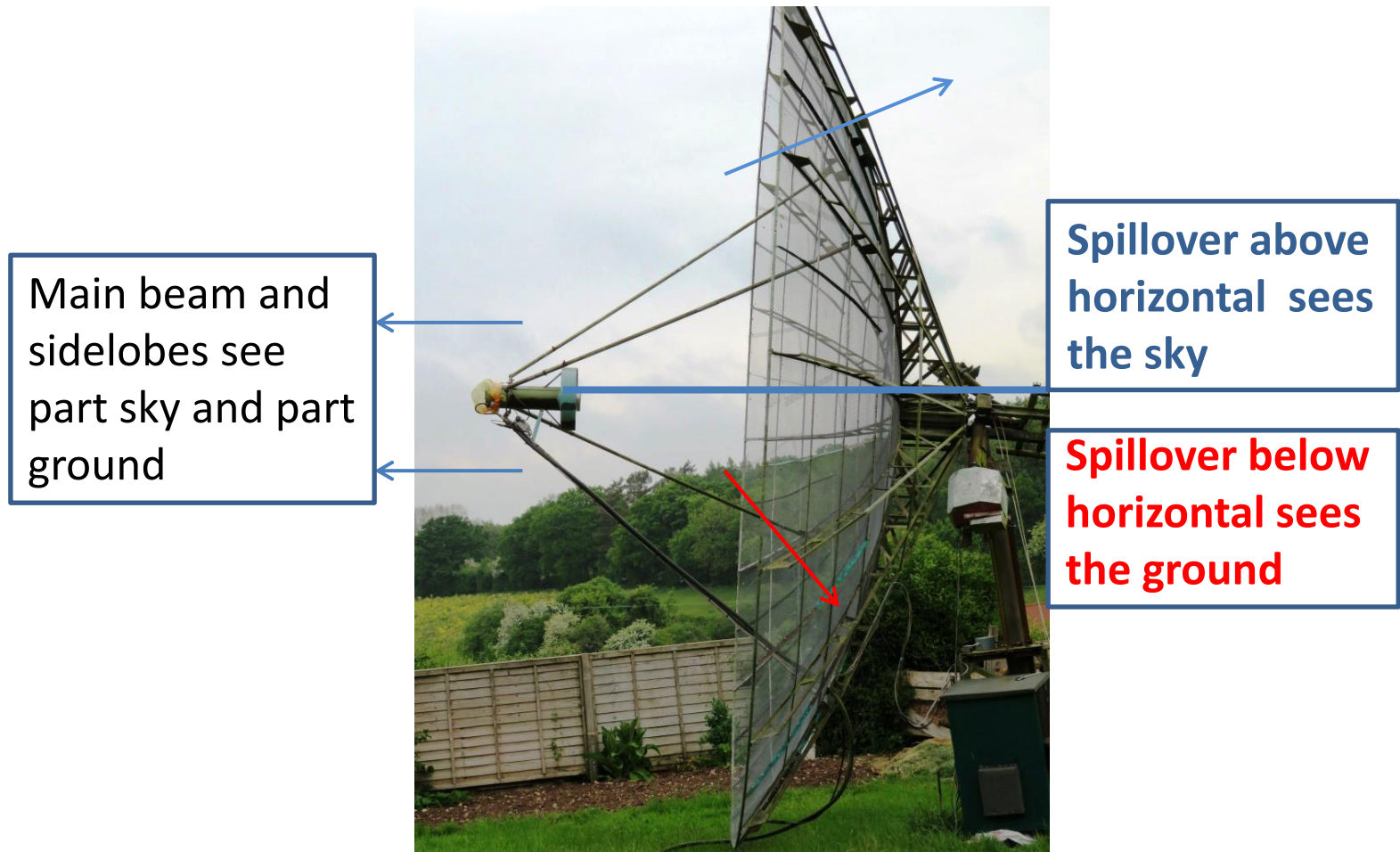
Dish pointing to Zenith (almost)



All the main beam and sidelobes sees the sky

All the Spillover sees the ground 290K

Dish pointing horizontal (almost!)

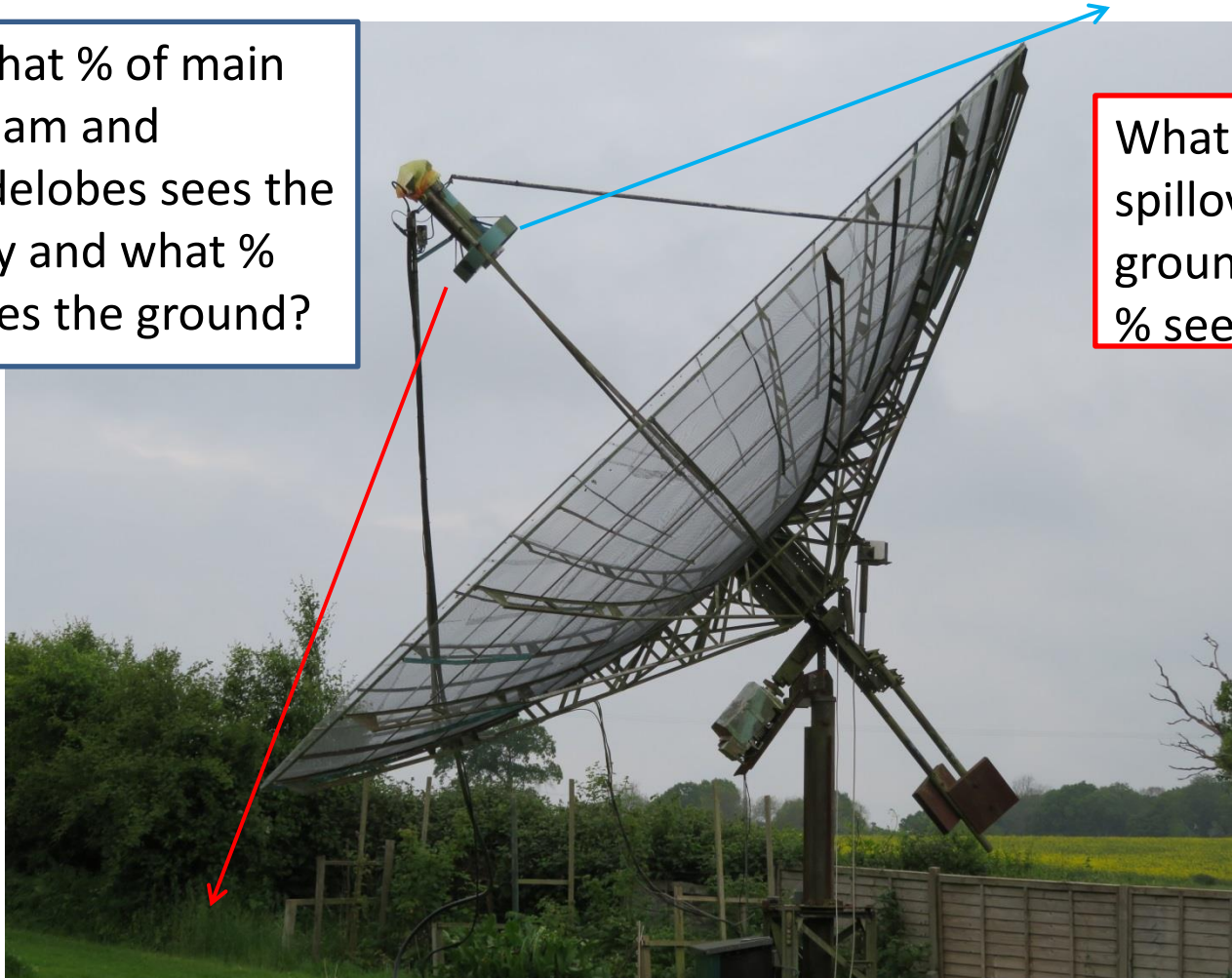


Dish pointing at 45 degrees

45 degrees is the standard elevation in EMECalc

What % of main beam and sidelobes sees the sky and what % sees the ground?

What % of spillover sees ground and what % sees the sky?



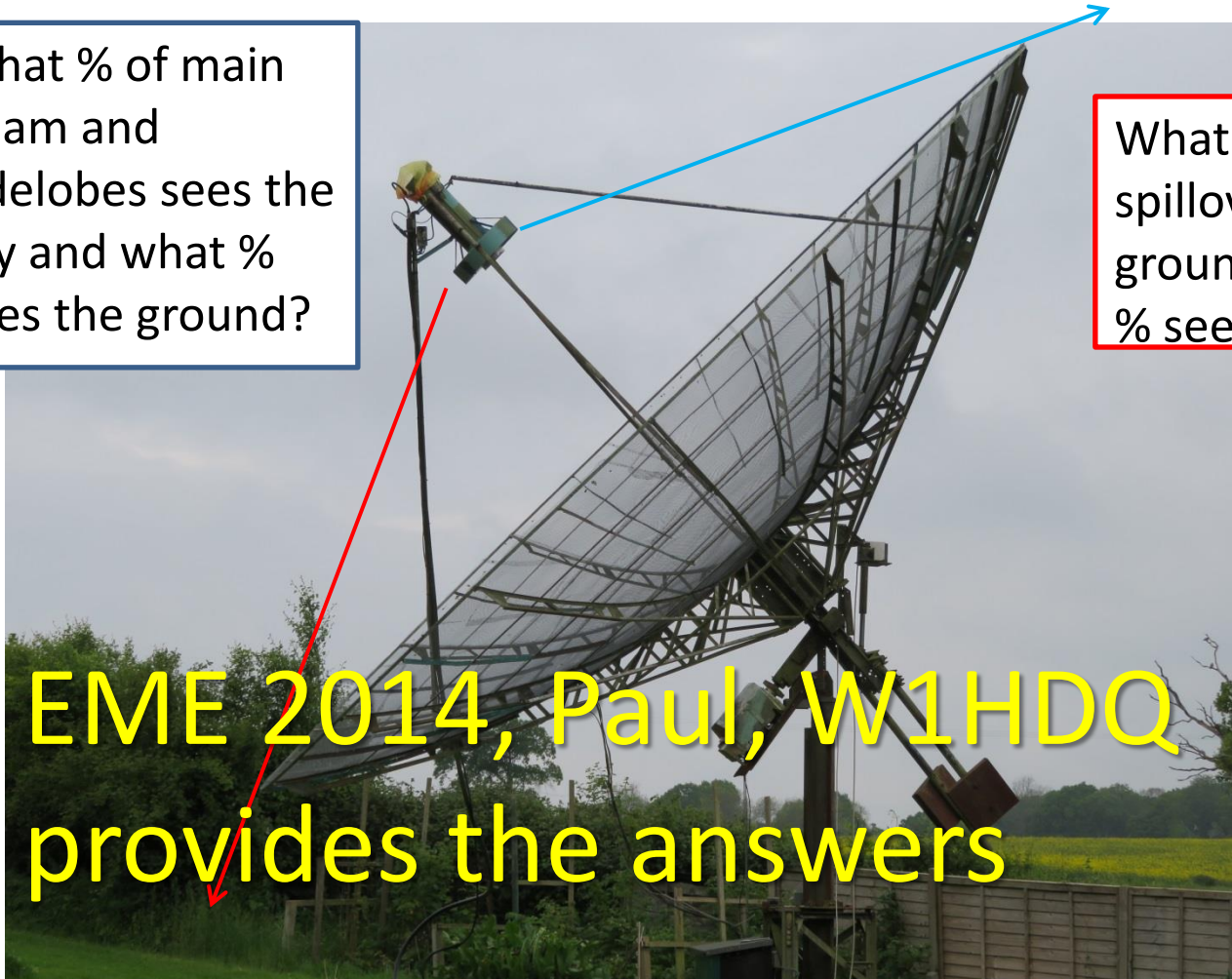
Dish pointing at 45 degrees

45 degrees is the standard elevation in EMECalc

What % of main beam and sidelobes sees the sky and what % sees the ground?

What % of spillover sees ground and what % sees the sky?

EME 2014, Paul, W1HDQ provides the answers



W1GHZ and SM6FHZ analysed a range of feeds with a dish and this was incorporated into EMECalc. (2015 SM meeting)
 For each feed, the Gain, G, and T (Tspill) are obtained from this analysis

A1	N2UO septum with W2IMU dual-mode horn																				
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T		
8	HalfAngle	f/D	Edgellum	XPOLtotal	Gain	Gain	Elevation=	10	10	20	20	30	30	40	40	45	45	50	50		
9	degrees	f/D	dB	Eff %	ratio	dBi		T (K)	G/T (dB)	T	G/T	T	G/T	T	G/T	T	G/T	T	G/T		
11	WARNING: Edge Diffraction not accounted for					Gain															T and G/T
12	G/T at f/D < 0.3 may be optimistic						dBi														
14	90	0.25	-27.06	35.52	1402.38	31.47			6.86	23.1	6.84	23.12	6.73	23.19	6.55	23.31	6.45	23.37	6.35	23.44	
15	89	0.254	-26.79	36.44	1438.61	31.58		6.91	23.18	6.89	23.2	6.78	23.27	6.6	23.39	6.5	23.45	6.4	23.52		
16	88	0.259	-26.51	37.37	1475.46	31.69		6.96	23.26	6.94	23.28	6.83	23.35	6.65	23.46	6.55	23.53	6.45	23.59		
17	87	0.263	-26.22	38.32	1512.94	31.8		7.02	23.34	7	23.35	6.88	23.42	6.7	23.54	6.6	23.6	6.51	23.67		
18	86	0.268	-25.92	39.78	1570.4	31.96		7.08	23.46	7.05	23.48	6.94	23.54	6.76	23.66	6.66	23.72	6.57	23.79		
19	85	0.273	-25.62	40.77	1609.69	32.07		7.14	23.53	7.12	23.54	7.01	23.61	6.83	23.73	6.73	23.79	6.63	23.85		
20	84	0.278	-25.31	41.78	1649.59	32.17		7.21	23.59	7.19	23.61	7.07	23.68	6.89	23.79	6.79	23.85	6.7	23.91		
21	83	0.283	-24.99	42.81	1690.11	32.28		7.28	23.66	7.26	23.67	7.15	23.74	6.97	23.85	6.87	23.91	6.77	23.97		
22	82	0.288	-24.66	43.85	1731.2	32.38		7.36	23.71	7.34	23.73	7.23	23.79	7.05	23.9	6.95	23.97	6.85	24.03		
23	81	0.293	-24.32	44.91	1772.84	32.49		7.45	23.77	7.42	23.78	7.31	23.85	7.13	23.95	7.03	24.02	6.93	24.08		
24	80	0.298	-23.97	45.97	1814.99	32.59		7.54	23.82	7.51	23.83	7.4	23.89	7.22	24	7.12	7.86	7.03	24.12		
25	79	0.303	-23.6	47.05	1857.61	32.69		7.64	23.86	7.61	23.87	7.5	23.94	7.32	24.04	7.22	7.96	7.13	24.16		
26	78	0.309	-23.22	48.14	1900.62	32.79		7.75	23.9	7.72	23.91	7.61	23.97	7.43	24.08	7.33	8.06	7.23	24.2		
27	77	0.314	-22.82	49.79	1965.61	32.93		7.86	23.98	7.84	23.99	7.73	24.05	7.55	24.16	7.45	8.2	7.35	24.27		
28	76	0.32	-22.41	50.91	2009.88	33.03		7.99	24	7.97	24.02	7.86	24.08	7.68	24.18	7.58	8.3	7.48	24.29		
29	75	0.326	-21.99	52.04	2054.36	33.13		8.14	24.02	8.11	24.04	8	24.1	7.82	24.2	7.72	8.39	7.62	24.31		
30	74	0.332	-21.57	53.17	2098.99	33.22		8.29	24.03	8.27	24.05	8.15	24.11	7.97	24.2	7.87	8.48	7.78	24.31		
31	73	0.338	-21.14	54.3	2143.68	33.31		8.46	24.04	8.44	24.05	8.32	24.11	8.14	24.2	8.04	8.57	7.95	24.31		
32	72	0.344	-20.7	55.43	2188.34	33.4		8.65	24.03	8.62	24.05	8.51	24.1	8.33	24.19	8.23	8.66	8.13	24.3		
33	71	0.35	-20.26	56.56	2232.9	33.49		8.85	24.02	8.83	24.03	8.71	24.09	8.54	24.18	8.44	8.74	8.34	24.28		
34	70	0.357	-19.82	57.68	2277.25	33.57		9.08	23.99	9.05	24.01	8.94	24.06	8.76	24.15	8.66	8.82	8.56	24.25		
35	69	0.364	-19.38	58.8	2321.3	33.66		9.32	23.96	9.3	23.97	9.19	24.03	9.01	24.11	8.91	8.9	8.81	24.21		

Edge diffraction is not included.

EMECalc allows a wide range of feeds to be examined in dishes with a range of f/D

Click on “Feed Type” to get this table

Feed Types .. Prime Focus .. Linear .. Offset

Feed Type	Direct Link	Link Reference	Feed Type
W2IMU dual-mode	Select	Fig 6.5-1 Page 2	70cm XE1XA Loop
VE4MA (Super .71L)	Select	Fig 7 Page 7	70cm Dipole reflector
VE4MA (Original -0.15L rim)	Select	Fig 3 Page 3	70cm Dipole reflector BFR
VE4MA (Small flush rim)	Select	Fig 17 Page 12	70cm ES5PC Patch
OK1DFC Septum (with choke ring)	Select	Fig 13 Page 10	70cm PY2BS Patch
OK1DFC Septum (no choke ring)	Select	Fig 5 Page 4	70cm PY2BS modified Patch
Chaparral 3 rings 0.20λ W x 0.33λ D. back 0.25λ	Select	Fig 39 Page 17	70cm DL4MEA Loop
RA3AQ Stepped Dual mode Septum (improved)	Select	Page 1 -7	70cm OK1DFC Loop
RA3AQ 2L dia .6L deep flush	Select	Fig 2 Page 2	70cm Dual Dipole square reflector
RA3AQ 2L dia .375L deep .175L back	Select	Fig 10 Page 8	70cm Dual Dipole circular reflector
Chaparral 3 rings 0.20λ W x 0.33λ D. back 0.05λ	Select	Fig 17 Page 25	70cm Dual Dipole in VK3UM dish
EIA Dual - Dipole (reference)	Select	Fig 6.2-6 Page 7	70cm CT1DMK Annular Ring
NBS Dual - Dipole (KF4JU)	Select	Fig 6.2-9 Page 11	
Dual Patch linear (W0LMD)	Select	Fig 2 Page 3	23cm G3LTF Dual feed
Dual Patch LHCP (W0LMD)	Select	Fig 4 Page 5	13cm G3LTF Dual feed
Dipole Splashplate (RSGB)	Select	Fig 6.2-2 Page 2	24 GHz W5LUA feed horn
Dipole rod reflector 0.24L	Select	Fig 6.2-1 Page 1	
Dipole over 1.25L sq refl.	Select	Fig 6.2-3 Page 4	23cm SM6FHZ Patch feed with BFR
Quad Loop opt. (KF4JU)	Select	Fig 6.2-14 Page 17	23cm SM6FHZ Patch feed without BFR
N2UO Septum in W2IMU	Select	Fig 6	23cm SM6FHZ 5 step Septum 0.710L
Optimum dual-mode. flare 2L x 3.10L long	Select	Fig 8	23cm SM6FHZ 5 step Septum 0.795L
Optimum dual-mode. flare 3L x 4.85L long	Select	Fig 6	9cm SM6FHZ 5 step Septum 0.748L
Optimum dual-mode. flare 4L x 6.55L long	Select	Fig 9	6cm SM6FHZ 5 step Septum 0.749L
Optimum dual-mode. flare 5L x 8.25L long	Select	Fig 10	3cm SM6FHZ 5 step Septum 0.692L
Optimum dual-mode. flare 6L x 10.0L long	Select	Fig 11	3cm SM6FHZ 5 step Septum 0.795L
70cm SM6FHZ BFR Loop	Select	Item 10	
70cm SM6FHZ BFR Loop with Choke	Select	Item 9	

Table Colour coding

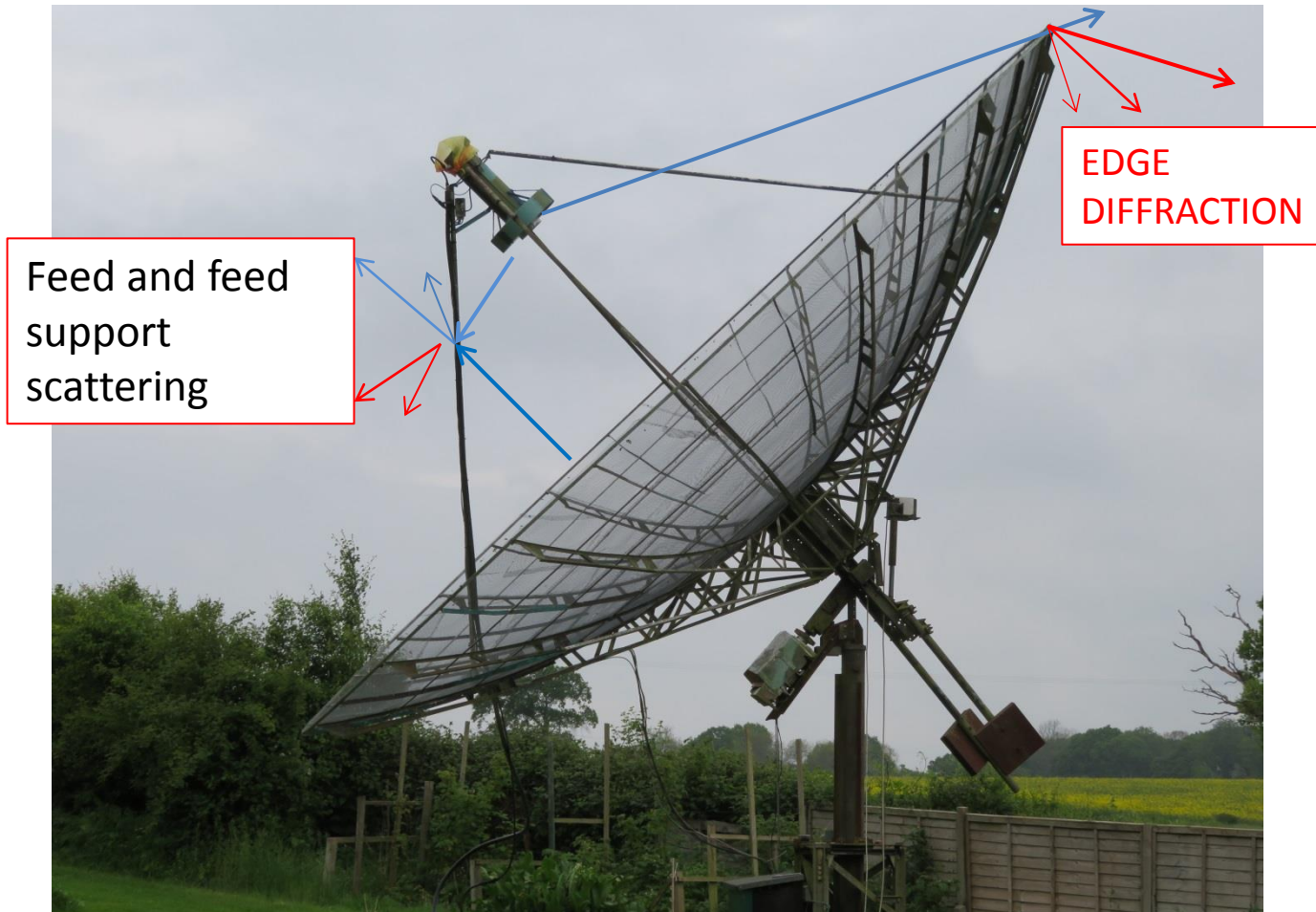
Red ..fully known feed characteristics computed by Paul W1GHZ and Ingolf SM6FHZ.

Grey .. off set feeds where spill over is assumed to be 20% of that if installed in a prime focus dish.

Blue .. Optimised feed spill over value computed from best available data.

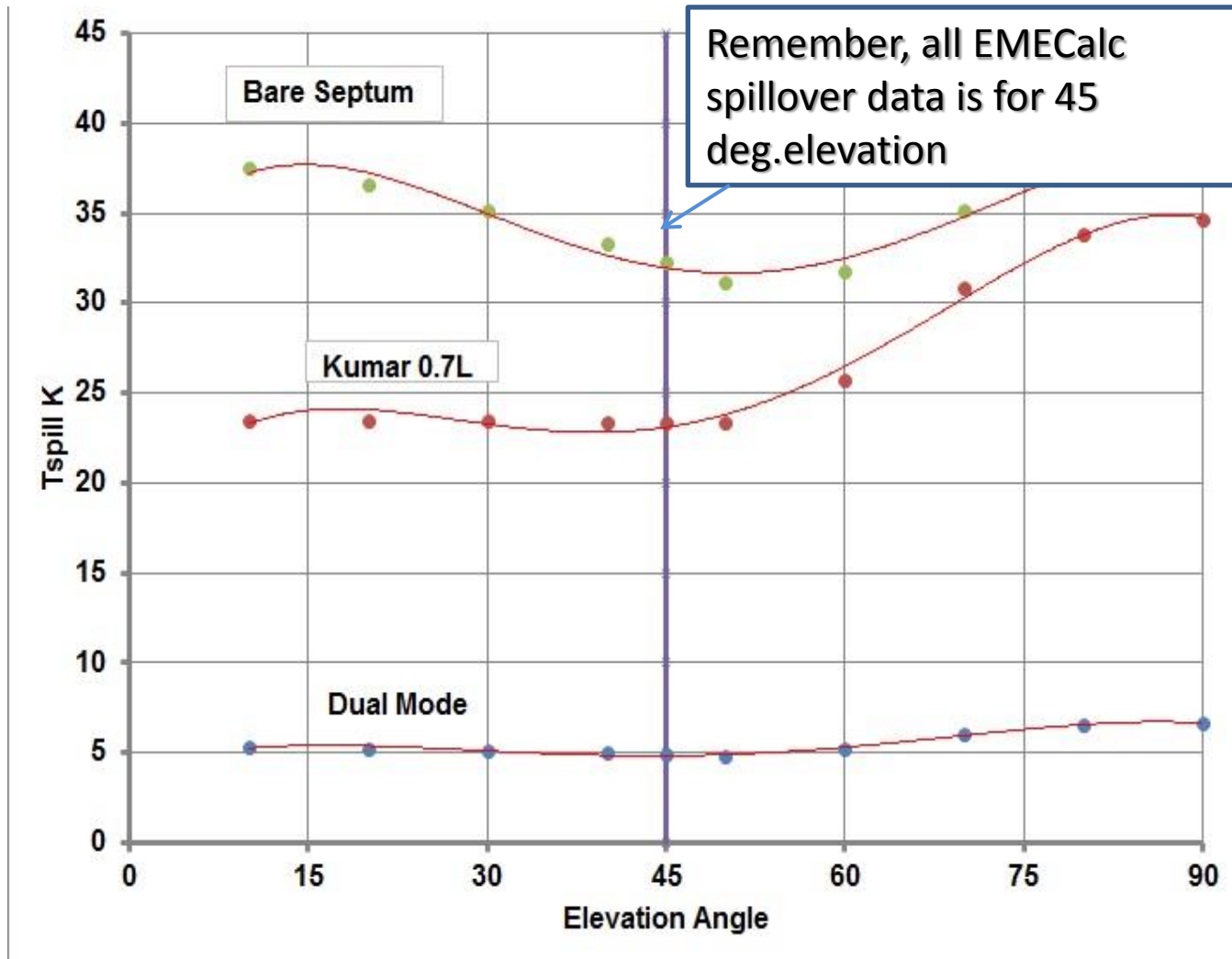
No colour .. values derived from polar plots.

Dish at 45 degrees elevation with edge diffraction
Also missing from “Spillover” is feed support scattering and feed support shadowing



Spillover contribution varies with Elevation

Examples at 0.4 f/D. 290K ground, 5.7K sky



Mesh Feed-through, Tft

- Mesh feed-through is calculated from the book by Otoshi, “Noise temperature theory and applications for deep space communications antenna systems”. P275 This is also in a spread sheet on the W1HDQ website
- The small gain loss is applied to the dish gain G.
- When the dish is at Zenith the feed horn sees the hot ground through the mesh and if the transparency is x% then Tft is $(x/100)*T_g$ where T_g is set by the ground temperature slider.
- When the dish is at 45 degrees this changes so that the horn sees some cold sky through the mesh and less hot ground and this is taken into account in the estimate.

Mesh Feedthrough controls

Press for solid dish

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

Tx A (Home Station) G3LTF_5760_3

5760 MHz	283.87 dB	6.0 K	Rx BW 145 Hz	Diam 1.00 mm	Mesh 6.00 mm	Spacing H-V 6.00 mm	Sensitivity -156.8 dBm	Echo SIN 15.31 dB
Frequency	Path Loss	T Sky		Circ 6.41%			Effective ground 242 K	

IPS Learmonth Western Au 2019 Apr 15 1216z

10.7cm	15.87 K	46.82 K	----- 12.39 K -----			0.90	4.89 dB	
74	0.20 dB	0.65 dB	11.0 dB	0.3 dB	1.5 dB	15.24 K	9.30 K	18.61 dB
Get sfu	LNA Loss	LNA NF	LNA Gain	Coax Loss	Rx NF	Spillover	Feedthrough derived from Mesh size	Sun Y 2.56 dB
								Moon Y
Tx A Output Power 40 Watts	16.02 dBW	Transmission Loss 0.1 dB	39 Watts	15.92 dBW	3,510,886 W EIRP			

RxTK 75.08 K = 1.00 dB
Receiver Noise Temperature

Ground Temperature
230 K 17 °C

TSys 105.62 K = 1.35 dB
System Noise Temperature

Y factor measurement

- If we point the antenna at the cold sky and then at a known source, the sun, moon, or radio star or the ground, then the power ratio observed is known as the Y factor.
- If we know the flux (or the temperature) of the source then we can derive G/T_{sys} .
- In EMECalc we can insert the parameters we believe we have and see if the measurement gives the predicted result.

Y factor measurement

- Accurate measurement requires widest bandwidth, B and long integration time, T
The smallest temperature change, T_{min} , that you can detect is.

$$T_{min} = T_{sys} / (B * T)^{0.5}$$

- Several analogue meter designs available.
- For measurement I use Spectravue in Continuum mode.

Ground / Cold Sky ratio
measurement is different from Y
factor measurement of sun,
moon and star measurement

We will describe Ground /
Cold Sky next

Ground / Cold Sky ratio measurement

- A useful measurement as a reference but not easy to make. The target must fill at least the projected area of the dish inside the near field, $2 \cdot D^2 / \lambda$ where D is dish diameter.
- The formula used in EMERCalc again takes account of the fact that a portion of both the feed-through and spillover sees cold sky.
- The target should ideally be a rough absorber otherwise the incident wave will reflect (reciprocity invoked). It should also not reflect the cold sky back to the dish. Trees in full leaf seem to work fairly well.
- A Slider is provided to adjust for target quality, Q .

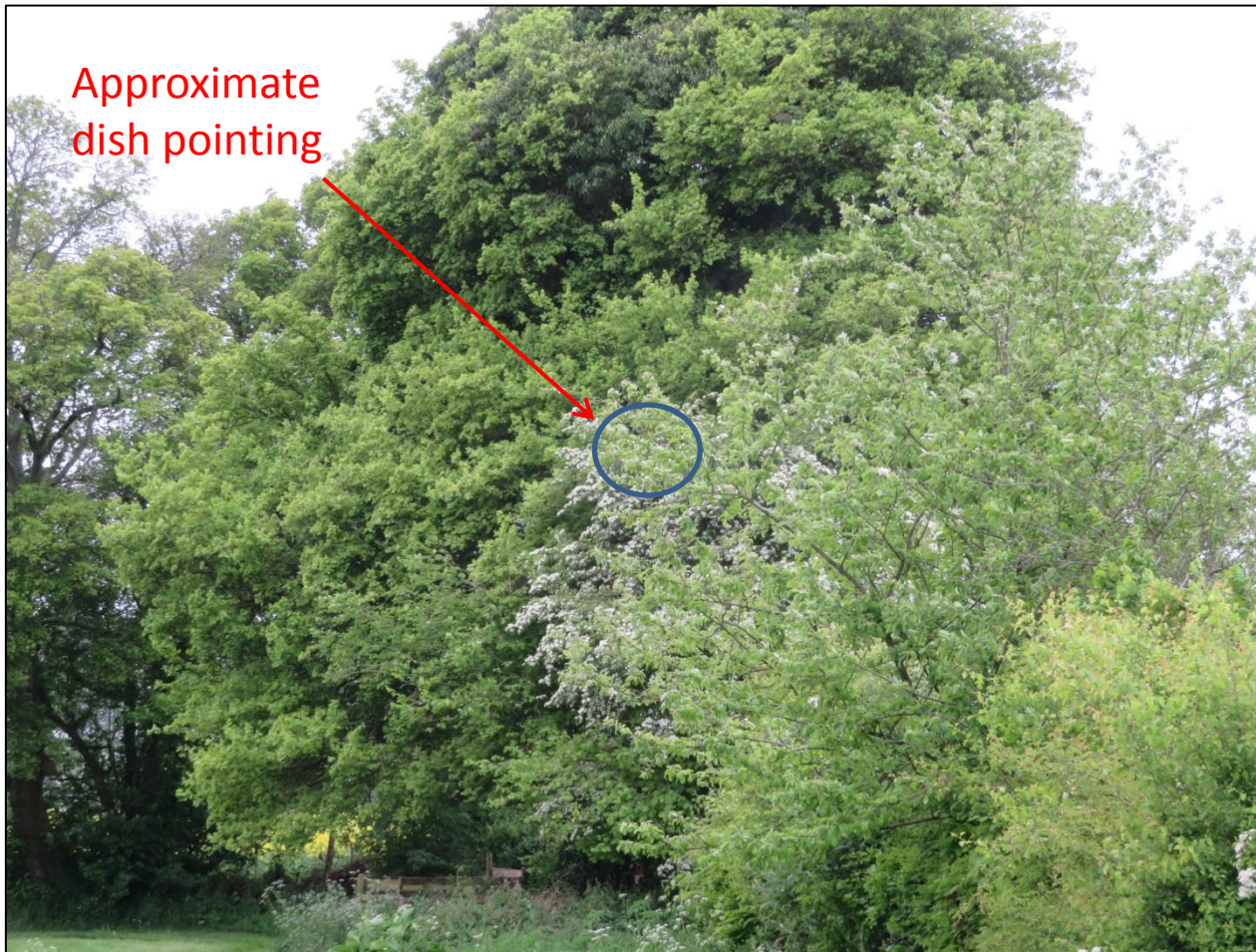
Ground / Cold Sky ratio location. Q slider

The screenshot displays a software interface for a radio station, titled "Tx A (Home Station)". The interface is divided into several sections:

- Navigation Tabs:** Two Station EME, Rx Performance, Source Pos., Planets, Sky Map, Home Data.
- Station Info:** Tx A (Home Station), G3LTF_5760_3.
- Frequency and Path Loss:** 5760 MHz, 283.87 dB.
- Antenna and Mesh Settings:** Rx BW: 6.0 K, Dism: 1.00 mm, Mesh: 6.00 mm, Spacing H-V: 6.00 mm.
- Sensitivity and Echo S/N:** -156.8 dBm, 15.31 dB.
- Effective ground:** 242 K, 4.89 dB. This section is highlighted with a red box.
- Losses and Gains:** Loss 0.268 dB, Mesh, Gnd to Cold Sky >.
- Power and Noise Metrics:** Tx A Output Power: 40 Watts, 16.02 dBW; Transmission Loss: 0.1 dB; Power at Feed: 39 Watts, 15.92 dBW; 3,510,886 W EIRP.
- System Noise Temperature:** RxTK 75.08 K = 1.00 dB (Receiver Noise Temperature); T Sys 105.62 K = 1.35 dB (System Noise Temperature).

Target used for Ground/Cold Sky tests

Clump of trees at 50m



Ground / Cold Sky measurements at 23 and 6cm with the tree target

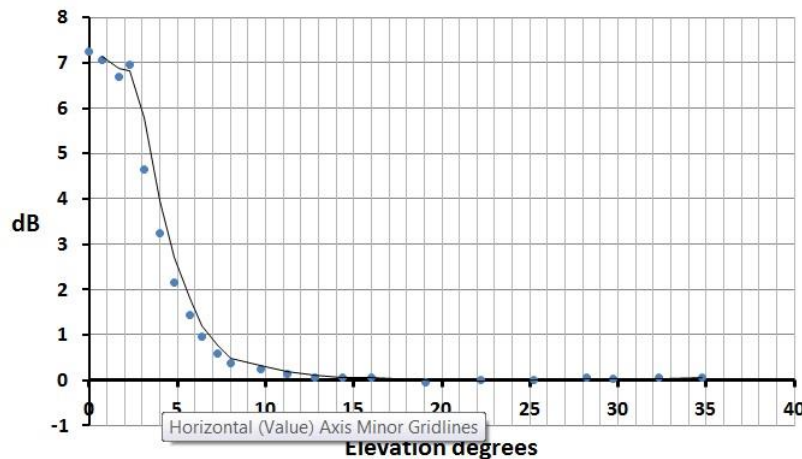
7.25dB. Prediction 7.3dB

Q 0.8 Tg 220K Tsky 10K

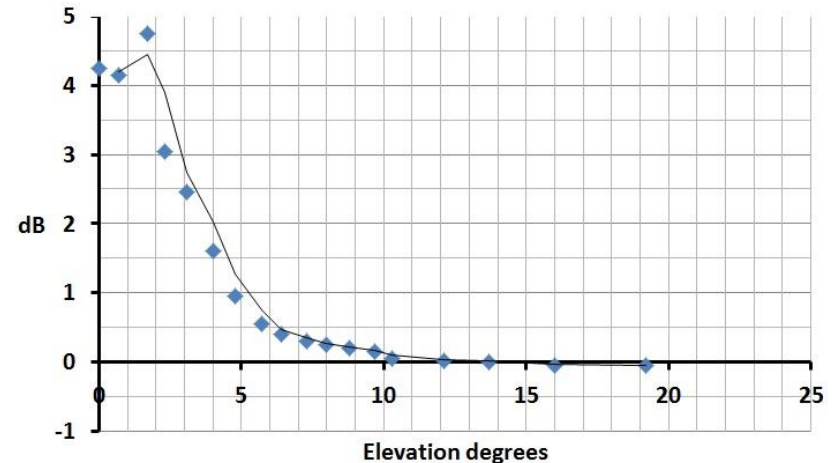
4.75dB. Prediction 4.9dB

Q 0.9 Tg 242K Tsky 7K

23cm tipping test



6cm tipping test



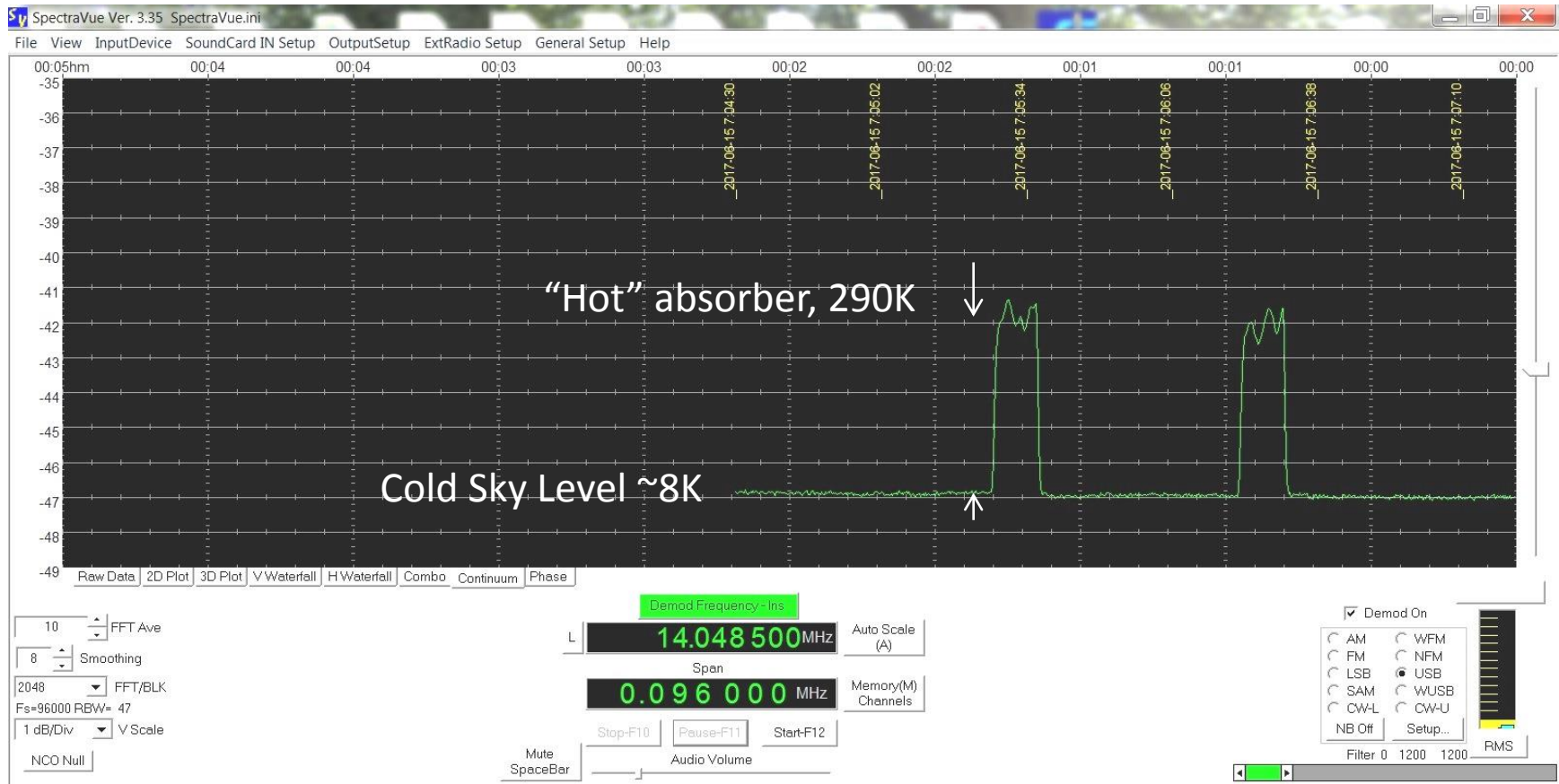
NF estimation using cold sky to ground. In this case a piece of X-band absorber is used at the “hot” ground



$$Y = [T_{rx} + T_{hot}] / [T_{rx} + T_{cold}]$$

Gives result $T_{rx} = 105-120K$

(More attention to detail needed for a definitive and more accurate result)



How EMECalc calculates Y factor from Sun, Moon and Stars

EMECalc Key equation (2)

$$Y = [G * \Psi * \lambda^2 / Tsys * K] - 1$$

G Antenna gain

Ψ Flux of the object being observed

λ Wavelength

Tsys System temperature

K contains the constants. $8 * \pi * k$

This formula is used for sun , moon and radio star measurements

Sun noise

$$Y = [G * \psi * \lambda^2 / T_{sys} * K] - 1$$

The screenshot shows the VK3UM software interface with several panels. Red arrows from the equation above point to the following fields:

- G**: Points to the **Gain** field in the **Parabolic Reflector** section, which is set to 89817.
- ψ**: Points to the **Effective ground** field in the **Tx A (Home Station)** section, which is set to 242 K.
- λ**: Points to the **Frequency** field in the **Tx A (Home Station)** section, which is set to 5760 MHz.
- T_{sys}**: Points to the **T Sys** field in the **Tx A (Home Station)** section, which is set to 105.62 K.
- K**: Points to the **System TK** field in the **Home Station ... Y Factor Calc** section, which is set to 105.62 K.

Other visible data in the software includes:

- Tx A (Home Station)**: Frequency 5760 MHz, Path Loss 283.87 dB, Rx B/W 6.0 K, Dim 1.00 mm, Mech 6.00 mm, Spacing H-V 6.00 mm, Sensitivity -156.8 dBm, Effective ground 242 K.
- Parabolic Reflector**: Diameter 6.00 m, Efficiency 73.2%, Beam Width 0.607°, Gain 89817, Dish Gain 47.38 dBd, Circular Pol.
- Home Station ... Y Factor Calc**: Noise Source (Hot) selected, System TK 105.62 K, Point Source Y Factor 0.09 dB.
- Operating Frequency**: 5760 MHz selected.
- Effective Aperture**: TxA 19.36 M², TxB 3.08 M², Moon Beam Fill Factor 0.36, Sun Beam Fill Factor 0.20 dB.
- Moon Data**: Phase 0.08, Illum 6.5%, 4th Quarter, P Angle 28°, Moon Temp 229 K.

$$Y = [G * \Psi * \lambda^2 / T_{sys} * K] - 1$$

The screenshot shows a software interface for radio astronomy calculations. Red arrows from the equation above point to the following parameters in the interface:

- G**: Points to the "Gain" field in the "Parabolic Reflector" section, which is set to 89817.
- Ψ**: Points to the "Sun Beam Fill Factor" field in the "Moon Data" section, which is set to 1.30.
- λ**: Points to the "Wavelength" field in the "Rx Performance" section, which is set to 6.00 mm.
- T_{sys}**: Points to the "System Noise Temperature" field in the "Rx Performance" section, which is set to 105.62 K.
- K**: Points to the "Point Source Y Factor" field in the "Point Source Y Factor" section, which is set to 6 K.

Other visible parameters include: Rx Performance (283.87 dB, 6.0 K, 145 Hz, 1.00 mm, 6.00 mm, -156.8 dBm, 15.3 dB), Parabolic Reflector (6.00 m, 0.38, 73.2%, 0.607°, 89817, 47.38 dBd), Home Station ... Y Factor Calc (Noise Source (Hot), Quiet Source (Cold)), and Moon Data (Effective Aperture, Beam Width Ratio, Moon Beam Fill Factor, Sun Beam Fill Factor, Moon Flux 10^-22, Moon Declination, Moon Temp).

Correction for an extended source

If the source has a comparable or greater angular extent than the antenna beamwidth then not all the flux will be collected by the antenna and a correction is made to reduce the flux value, in this case 1.3

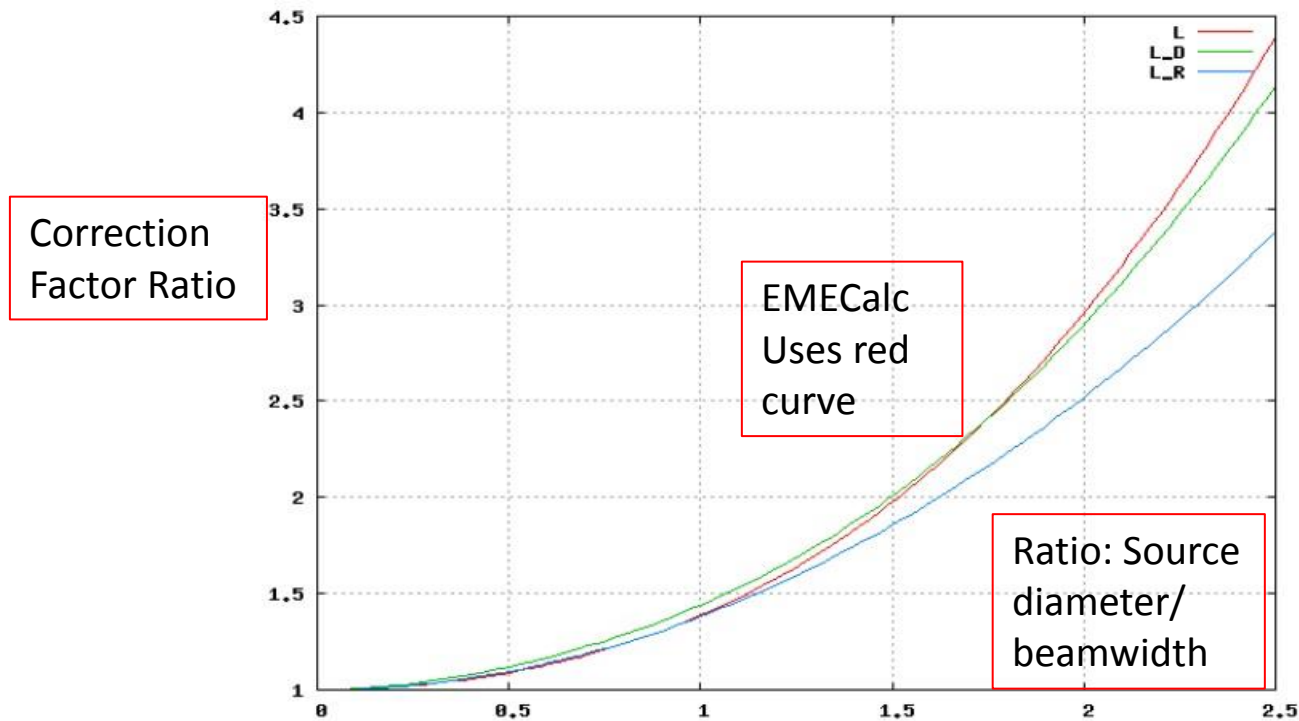
Moon Noise uses the same equation with an appropriate correction

The screenshot displays the VK3UM software interface, which is used for radio performance analysis and moon noise calculations. The interface is divided into several sections:

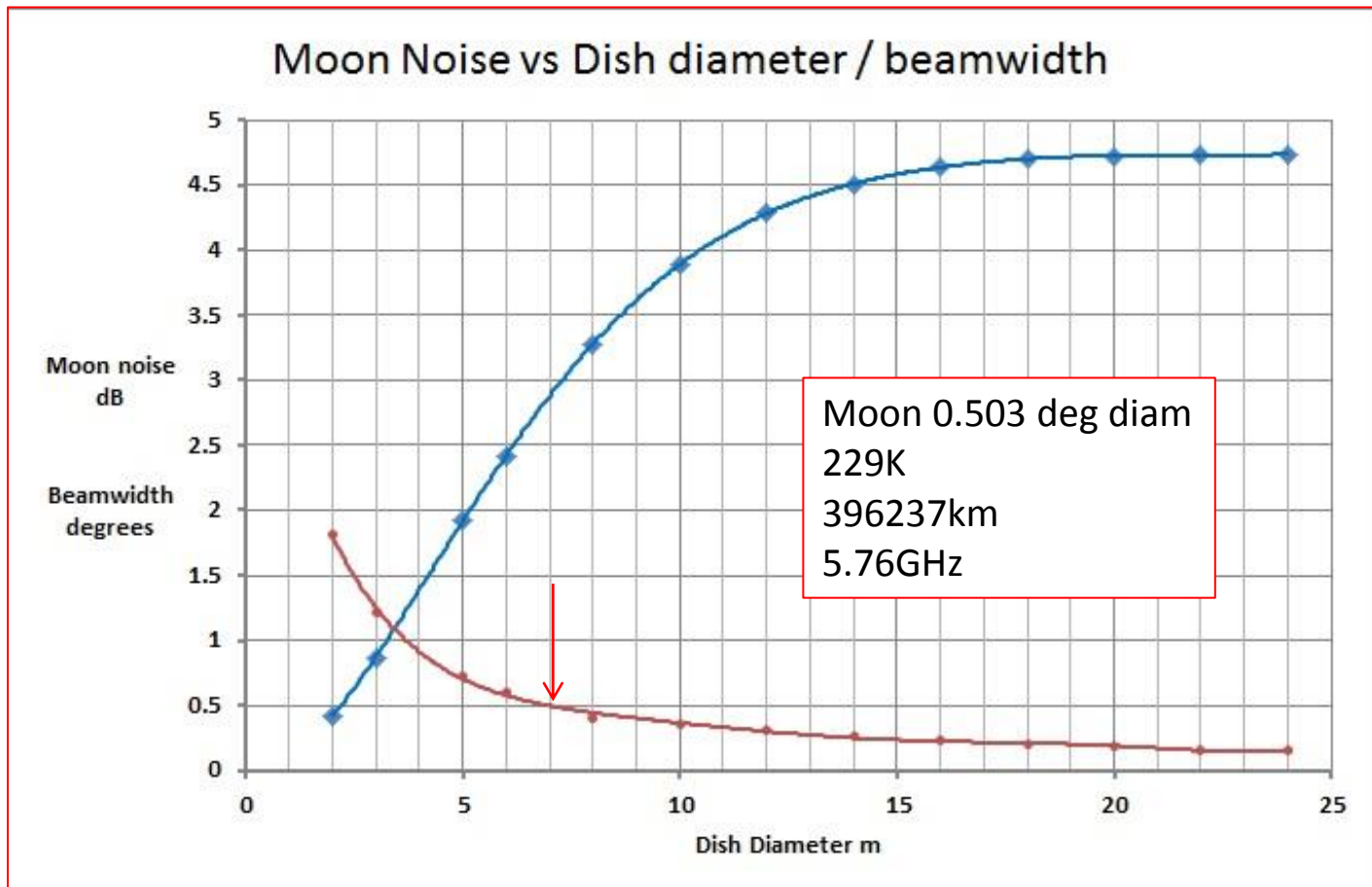
- Tx A (Home Station):** Shows frequency (5760 MHz), path loss (283.87 dB), T Sky (6.0 K), Rx BW (145 Hz), Dis (1.00 mm), Mesh (6.00 mm), Spacing H-V (6.00 mm), Sensitivity (-156.8 dBm), and Echo S/N (15.31 dB).
- IPS Learmonth Western Au 2019 Apr 15 1216z:** Displays various loss and gain parameters, including LNA Loss (0.20 dB), LNA NF (0.65 dB), LNA Gain (11.0 dB), Coax Loss (0.3 dB), Rx NF (1.5 dB), and Tx A Output Power (40 Watts).
- Change Moon Distance Moon noise included:** A section with a slider for Moon Distance, currently set at 378,293 kms.
- Parabolic Reflector:** Shows reflector details such as Diameter (6.00 m), Focal length (2.25 m), Efficiency (73.2%), and Gain (89817).
- Home Station ... Y Factor Calc:** Includes options for Noise Source (Hot) and Quiet Source (Cold), and a Y Factor of 0.09 dB.
- Operating Frequency:** A grid of radio frequency options, with 5760 MHz selected.
- Effective Aperture and Moon Data:** Shows Effective Aperture (19.36 M²), Moon Beam Fill Factor (1.28), Moon Radar Equ. (52.78 dB), Current Moon Distance (378,293 kms), Moon Angular Diam (0.526° 31'35.3"), and Moon Temp (229 K).

For derivation of moon temperature see my 2013 paper at this conference.
 Moon temperature is converted into flux

When the source has an angular extent larger than the beamwidth then less of the total flux is collected. The flux value used in the Y factor equation has to be modified. The correction is affected by beam shape and source shape



Moon noise and sun noise limits as dish size increases

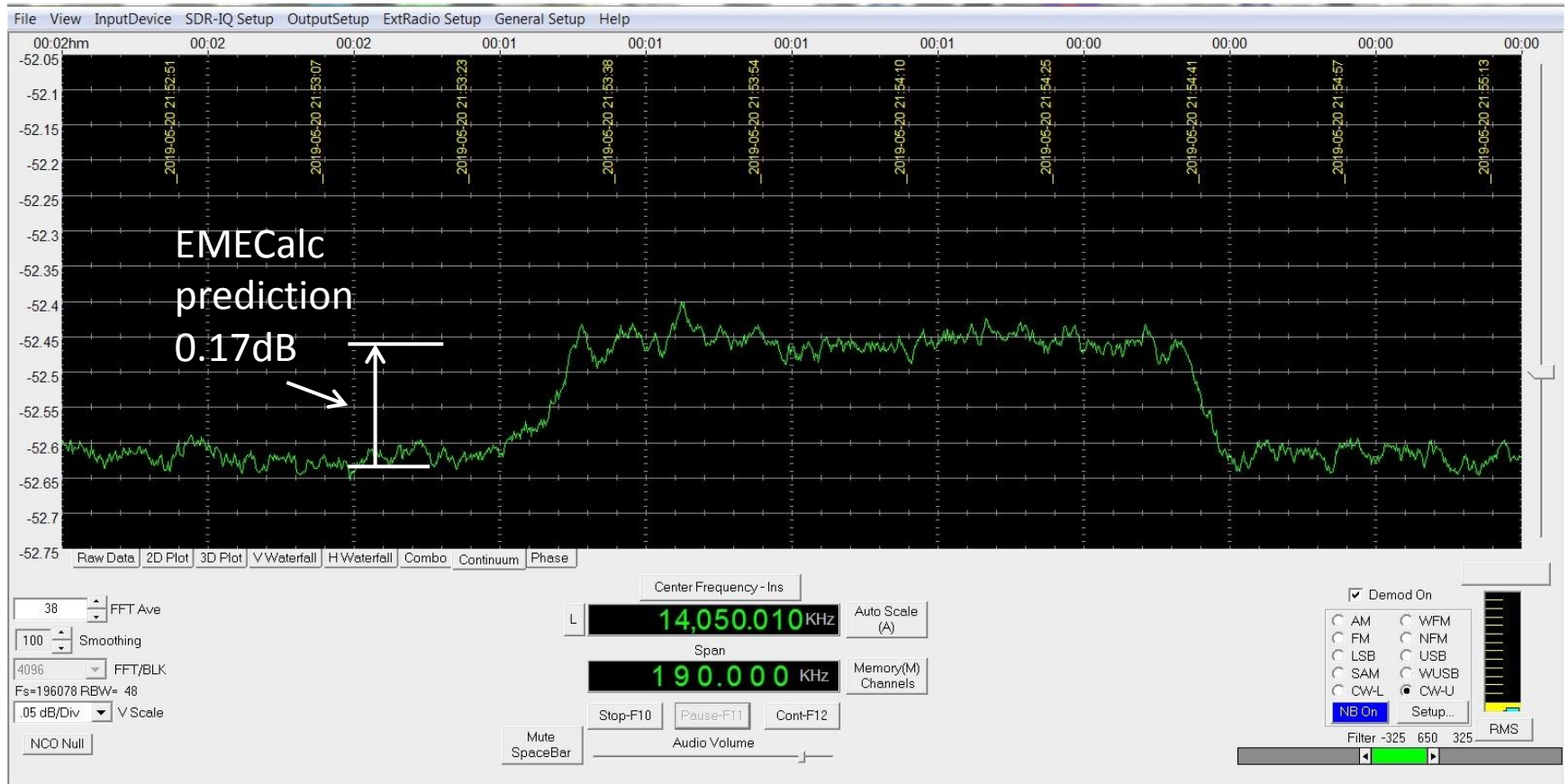


Radio Star flux data was provided by Franck, F5SE

The screenshot displays the VK3UM software interface, which is used for radio astronomy observations. The interface is divided into several sections:

- Top Station EME / Rx Performance:** Shows the current station configuration for 'Tx A (Home Station)'. Key parameters include:
 - Frequency: 5760 MHz
 - Path Loss: 283.87 dB
 - T Sky: 6.0 K
 - Rx BW: 145 Hz
 - Displacement: 1.00 mm
 - Mech: 6.00 mm
 - Sensitivity: -156.8 dBm
 - Echo S/N: 15.31 dB
- IPS Learmonth Western Au 2019 Apr 15 1216z:** Displays the current observation parameters:
 - Frequency: 74 MHz
 - LNA Loss: 0.20 dB
 - LNA NF: 0.65 dB
 - LNA Gain: 11.0 dB
 - Cable Loss: 0.3 dB
 - Rx NF: 1.5 dB
 - Spillover: 15.24 K
 - Feedthrough: 9.30 K
 - Power at Feed: 18.61 dB
 - Transmission Loss: 2.56 dB
 - Tx A Output Power: 40 Watts
 - Receiv. Noise Temperature: 16.02 dBW
 - System Noise Temperature: 105.62 K
 - TSys: 105.62 K = 1.35 dB
- Parabolic Reflector:** Shows the antenna configuration:
 - Diameter: 6.00 m
 - f/D: 0.38
 - Efficiency: 73.2%
 - Beam W/Width: 0.607°
 - Gain: 89817
 - Disk Gain: 47.38 dBd
 - 49.53 dBi
- Home Station ... Y Factor Calc:** A section for calculating the Y Factor, which is used to determine the flux density of a radio star. It includes:
 - Noise Source (Hot): Sagittarius A, Cassiopeia A, Cygnus A, Centaurus A, Taurus A, Virgo A, Termination.
 - Quiet Source (Cold): Aquarius or Leo, TSky (variable).
 - Point Source Y Factor: 0.09 dB
 - System TK: 105.62 K
- Operating Frequency:** A list of available frequencies for observation, including 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, 406 MHz, and 2295 MHz.
- Bottom Right Panel:** Contains a 'Save Data' button, 'Get Data', 'Default', 'Print', and 'Exit' buttons. It also shows the version number: VK3UM Ver 11.10.

Virgo A (M87) measured at 23cm with 6m dish and SM6FHZ Kumar feed. Tsys 44.4K



Derivation of Solar Flux in EMECalc

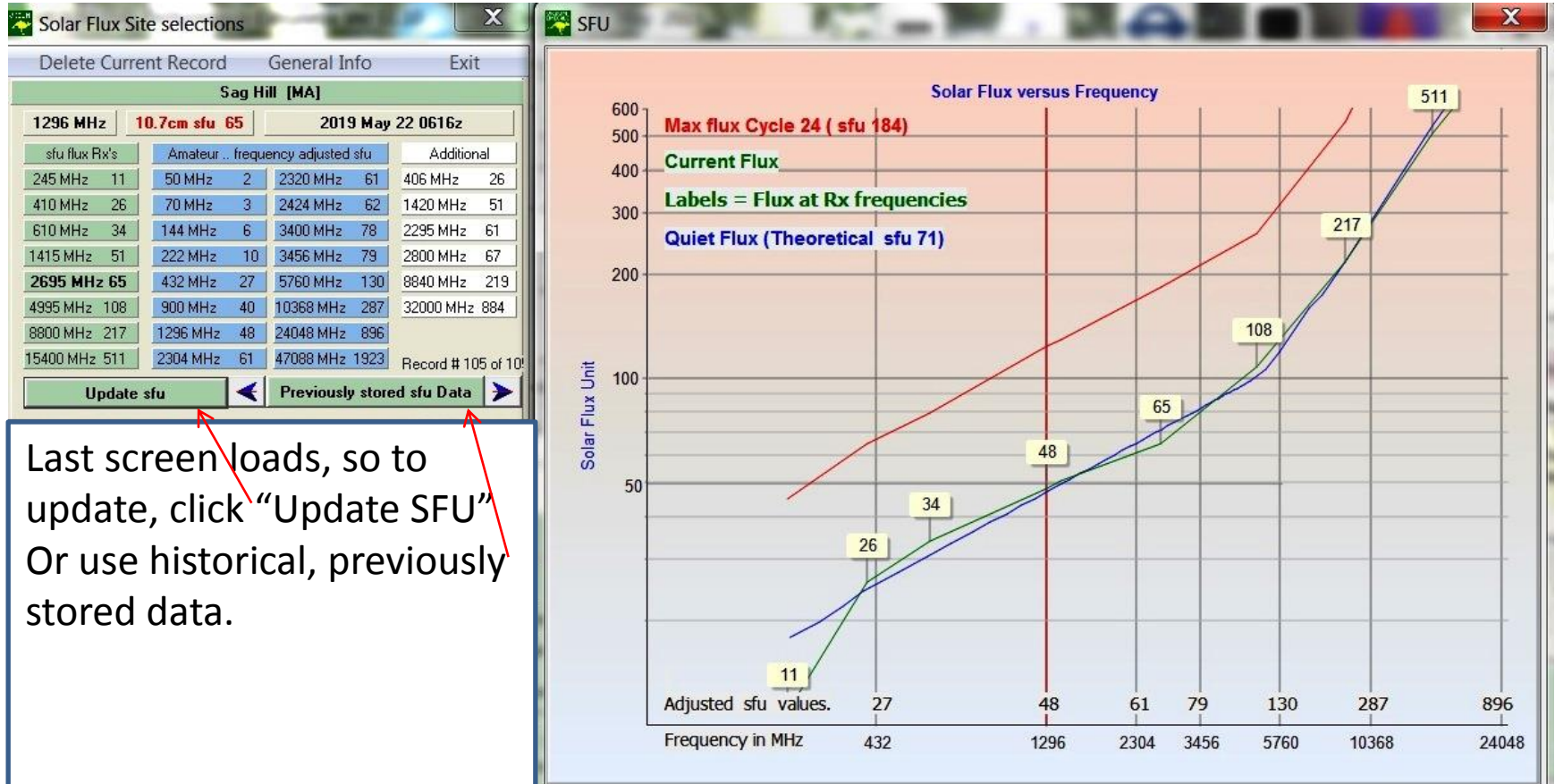
Updates from the NOAA database from world wide stations with multiple frequency measurements

Click "Get SFU"

The screenshot displays the EMECalc software interface with the following data and controls:

- Station Info:** Tx A (Home Station), G3LTF_5760_3
- Frequency:** 5760 MHz
- Path Loss:** 283.87 dB
- T Sky:** 6.0 K
- Rx BW:** 145 Hz
- Diam:** 1.00 mm
- Mesh:** 6.00 mm
- Spacing H-V:** 6.00 mm
- Sensitivity:** -156.8 dBm
- Echo S/N:** 15.31 dB
- Effective ground:** 242 K
- Loss:** 0.286 dB
- Mesh:** 6.00 mm
- Gnd to Cold Sky:** 0.90
- IPS Learmonth Western Au 2019 Apr 15 1216z**
- 10.7cm:** 15.87 K, 46.82 K, 12.33 K
- 74** (highlighted with a red arrow)
- 0.20 dB** (LNA Loss)
- 0.65 dB** (LNA NF)
- 11.0 dB** (LNA Gain)
- 0.3 dB** (Coax Loss)
- 1.5 dB** (Rx NF)
- 15.24 K** (Spillover)
- 9.30 K** (Feedthrough derived from Mesh size)
- 18.61 dB** (Sun Y)
- 2.56 dB** (Moon Y)
- Get sfu** (button)
- Tx A Output Power:** 40 Watts
- Transmission Loss:** 16.02 dBW
- Power at Feed:** 0.1 dB, 39 Watts, 15.92 dBW
- 3,510,886 W EIRP**
- RxTK 75.08 K = 1.00 dB** (Receiver Noise Temperature)
- Ground Temperature:** 230 K, 17 °C
- T Sys 105.62 K = 1.35 dB** (System Noise Temperature)

Derivation of Solar Flux in EMECalc



Last screen loads, so to update, click "Update SFU"
Or use historical, previously stored data.

Derivation of Solar Flux in EMECalc

Solar Flux Site selection

NOAA, Space Weather Prediction Center Issued: 2019 May 22 1216z

	W.Aust	S.Italy	USA [MA]	Canada BC	Canada BC	Hawaii	Canada BC	W.Aust
	Learmonth	San Vito	Sag Hill	Penticton	Penticton	Palehua	Penticton	Learmonth
UTC	0400	1000	1700	1700	2000	2300	2300	
245 MHz	12	12	11	-1	-1	11	-1	
410 MHz	27	28	26	-1	-1	28	-1	
610 MHz	35	-1	34	-1	-1	31	-1	
1415 MHz	44	43	51	-1	-1	45	-1	
2695 MHz	68	-1	65	-1	-1	70	-1	
4995 MHz	111	116	108	-1	-1	123	-1	
8800 MHz	217	228	217	-1	-1	234	-1	
15400 MHz	523	529	511	-1	-1	509	-1	
	Select	Select	Select	Select	Select	Select	Select	Select

Update NOAA

1 Get a NOAA prev. issue

NOAA History of records
1 = current information
approx 8 updates per day

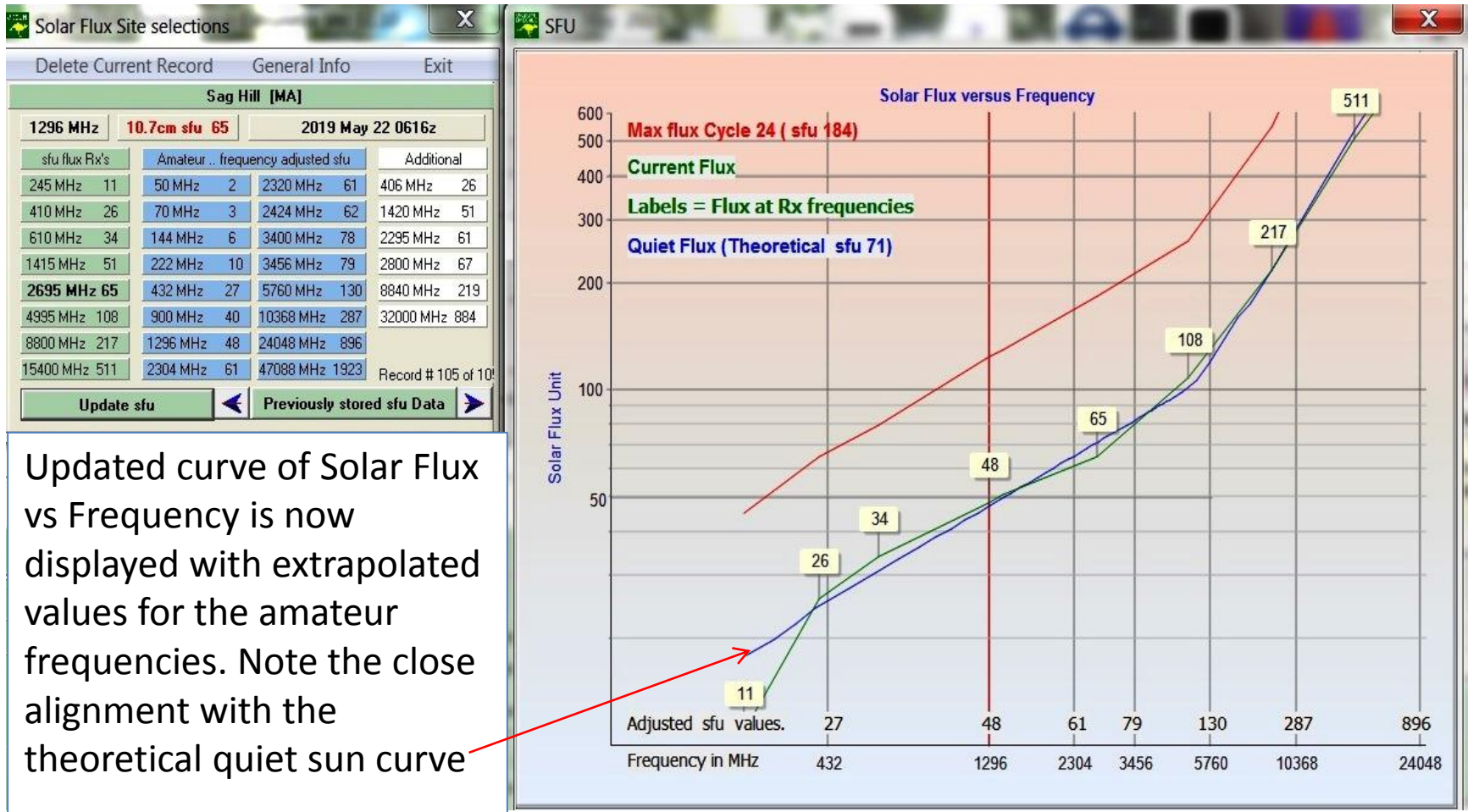
Update IPS

Issued: 2019 May 22 1216z

Latest Update

Click "Update NOAA" and select the most relevant site.

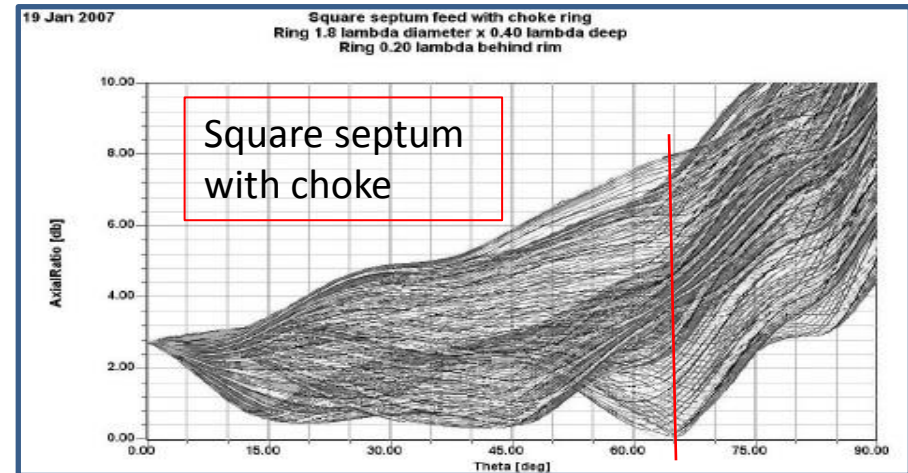
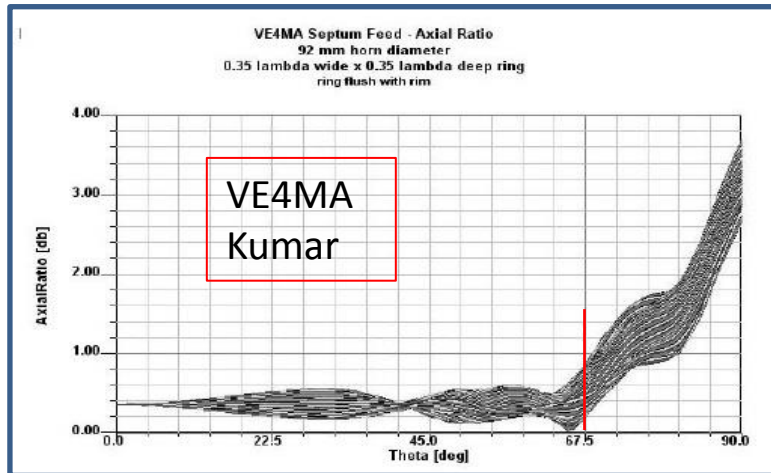
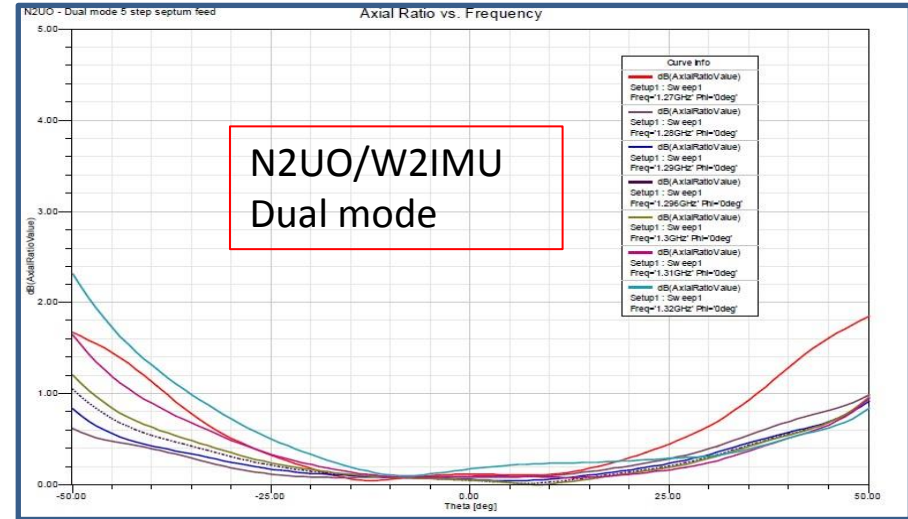
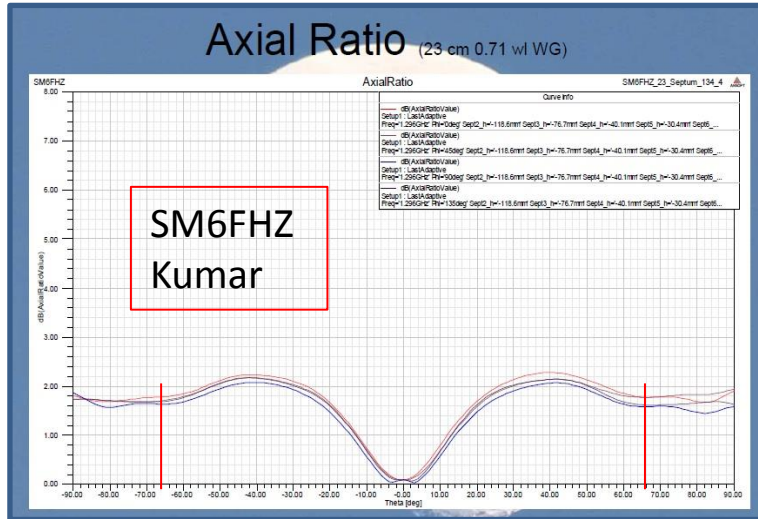
Derivation of Solar Flux in EMECalc



**Finally, a comment on measurement
and actual operation**

**Cross-polar performance is important
and mostly neglected**

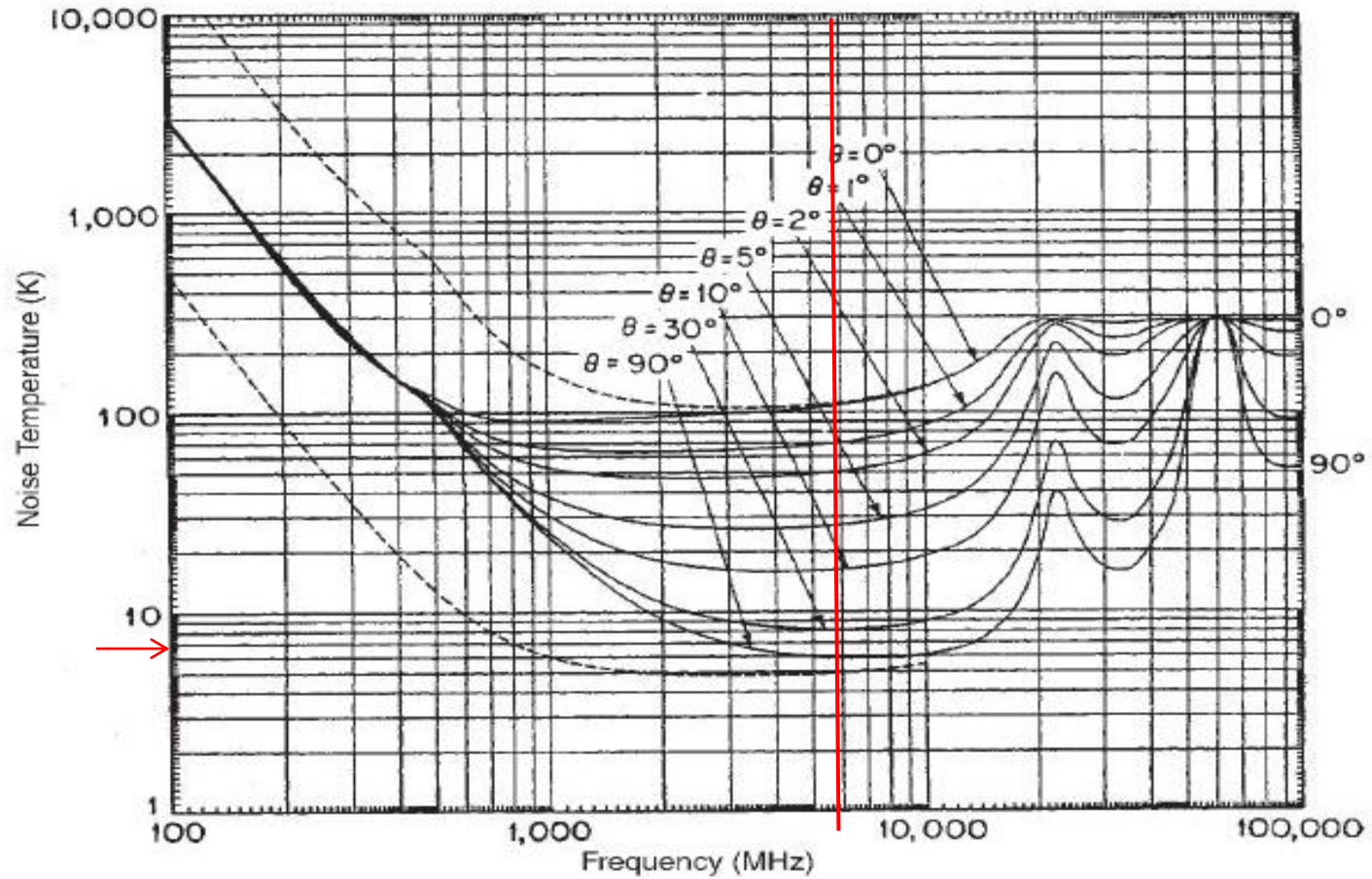
All our sun, moon, star measurements are using noise as the signal, but we communicate with coherent signals. Good CP across the whole aperture is important. Circular feeds are significantly better than square ones.



Acknowledgements

- To Doug, VK3UM (RIP) who created this wonderful toolset.
- To Paul W1GHZ and Ingolf SM6FHZ for their feed analysis.
- To the many others who gave Doug help, advice and suggestions.

Thank you for listening



Sky Noise Temperature

5.7GHz 45 deg. Elevation $T_{\text{sky}} = 7\text{K}$

At 10 deg. Elevation it is 14K