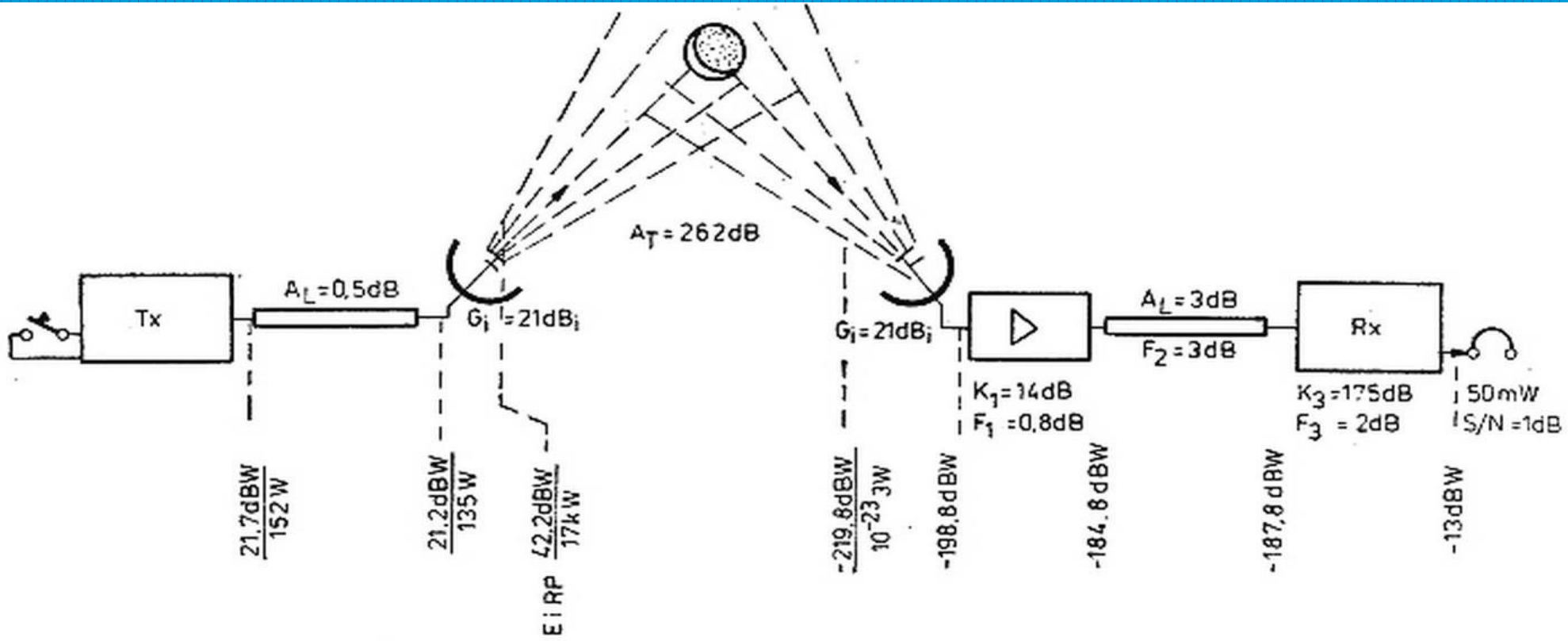
Szum w bilansie łącza radiowego teoria a rzeczywistość

Tomasz Salwach SQ6QV

Zieleniec 2025, 30.09.2025

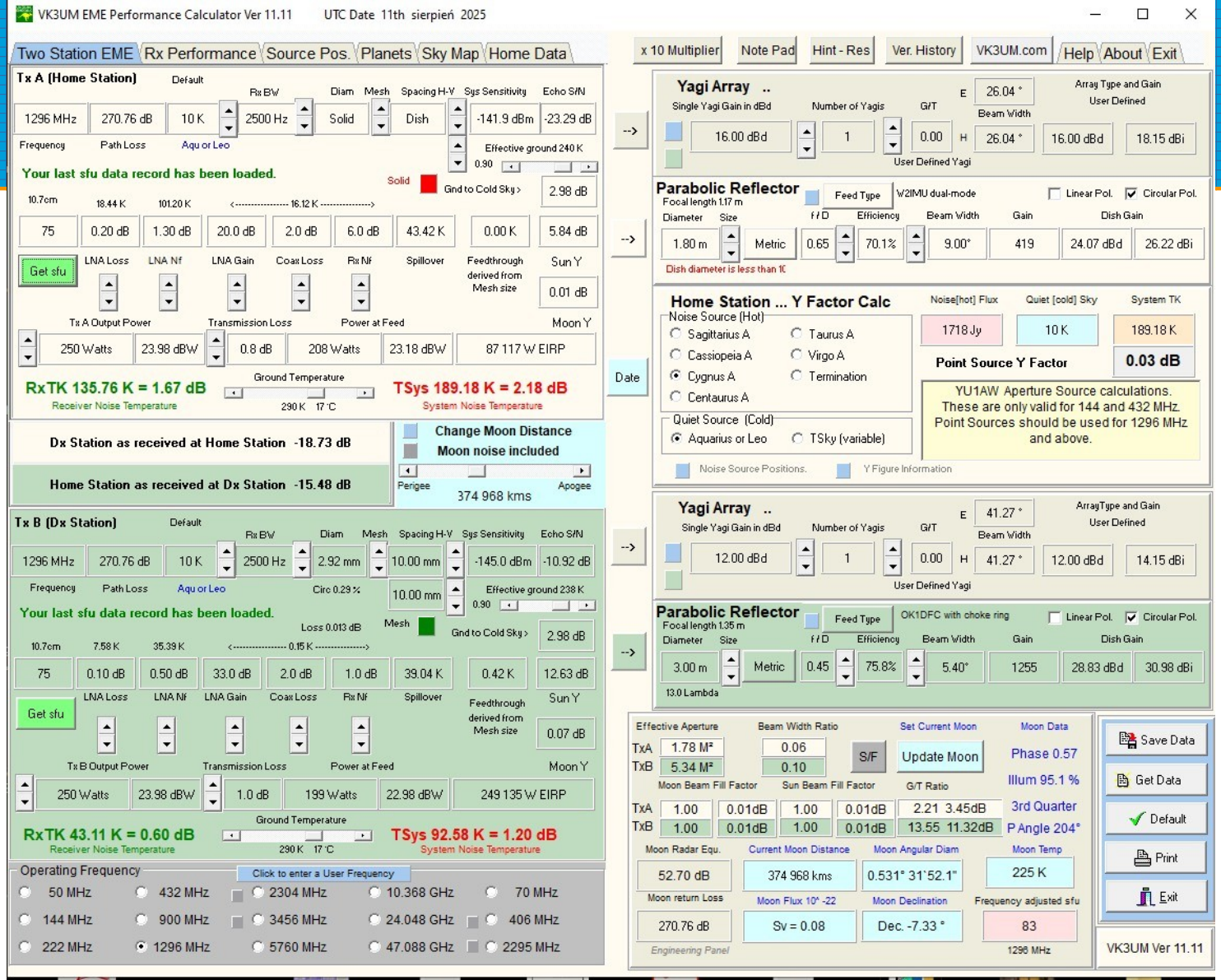
Bilans łącza radiowego (SP6LB 1988 r.)



4.6. Bilans łącza EME

Bilans

VK3UM 2002 r.



Bilans
OE2IGL & DF3GJ
2022 r.
https://wettersat.bplaced.net/EME/EME.html

Frequency [GHz]	10.368	
Wavelength	28.9 mm	
Lunar reflectivity ε	0.07	
Moon temp. center, average	242 K	235 K
Rx antenna temp. of moon	7.97 K	---
Days after full moon	6.37	

TX Locator:	JO54CG13 - DL0SHF-10	---
Latitude [N°]		54.2644
Longitude [E°]		10.1788

RX Locator:	JN67MT87 - OE2IGL-10	---
Latitude [N°]		47.8227
Longitude [E°]		13.0705

UTC YY/MM/DD hh:mm:ss	2025/8/1	14:24:31

Transmitting Antenna:	Gauss, max ant. η = theor.-2.5%	
Dish diameter [m], ant.gain$_{theo}$	7.2	57.86 dBi
Dish f/D	0.35	
Offset angle if offset dish [°]	0	
Surface RMS [mm], peak err	0.85	+/- 1.7 mm
Feed out-of-axial-focus [mm]	0	
Feed blocking area [m^2]	0.0707	
Ohmic efficiency η_{ohm}	1.0	
Illumination efficiency η_{i}	0.885	
X-polarization efficiency η_{pol}	0.985	
Spillover efficiency η_{s}	0.921	
Phase efficiency η_{phase}	1	
Illum*phase*spill*xpol $\eta_{i*p*s*x}$	0.802	56.9 dBi
Surface efficiency η_{Ruze}	0.873	
Focus efficiency η_{focus}	1	
Blocking efficiency η_{block}	0.994	
Mesh grid diam, spacing [mm]	0	0
Mesh grid effi. η_{mesh}, loss	1	0 dB
Max. antenna efficiency η_{max}	0.671	56.13 dBi
Used antenna efficiency η_{real}	0.599	
Edge taper [dB], feed taper	-11	-7.4 dB
Dish center - rim	71.1°	
HPBW$_{real}$, gain$_{real}$	0.266°	55.64 dBi
Position x,y on Moon [°]	0	0
Intercepted power fraction	0.941	-0.26 dB
Illuminated fraction	0.332	-4.79 dB
TX temperature [°C]	15	
TX humidity [%]	50	
TX absolute pressure [mbar]	980	
TX zenith atmosph.attenuation		0.048 dB
TX azimuth [°]	---	
TX refrac.corr. elevation [°]	30	
TX LOS atmosph.attenuation		0.096 dB
additional cloud loss [dB]	0	

Receiving Antenna:	Gauss, max ant. η = theor.-2.5%	
Dish diameter [m], ant.gain$_{theo}$	0.815	38.94 dBi
Dish f/D	0.67	
Offset angle if offset dish [°]	21	
Surface RMS [mm], peak err	0.17	+/- 0.34 mm
Feed out-of-axial-focus [mm]	0	
Feed blocking area [m^2]	0	
Ohmic efficiency η_{ohm}	1.0	
Illumination efficiency η_{i}	0.866	
X-polarization efficiency η_{pol}	0.985	
Spillover efficiency η_{s}	0.937	
Phase efficiency η_{phase}	1	
Illum*phase*spill*xpol $\eta_{i*p*s*x}$	0.8	37.97 dBi
Surface efficiency η_{Ruze}	0.995	
Focus efficiency η_{focus}	1	
Blocking efficiency η_{block}	1	
Mesh grid diam, spacing [mm]	0	0
Mesh grid effi. η_{mesh}, loss	1	0 dB
Max. antenna efficiency η_{max}	0.77	37.8 dBi
Used antenna efficiency η_{real}	0.69	
Edge taper [dB], feed taper	-12	-11 dB
Dish center - rim	36.5°	
HPBW$_{real}$, gain$_{real}$	2.38°	37.33 dBi
Position x,y on Moon [°]	0	0
Received fraction (BWF)	0.607	-2.17 dB
RX fill factor moon	0.0348	-14.58 dB
RX temperature [°C]	15	
RX humidity [%]	50	
RX absolute pressure [mbar]	980	
RX zenith atmosph.attenuation		0.048 dB
RX azimuth [°]	---	
RX refrac.corr. elevation [°]	30	---
RX LOS atmosph.attenuation		0.096 dB
additional cloud loss [dB]	0	

Moon:	Lunar reflectivity varies radially	
Isotropic path loss (radar equation)		-276.7 dB
Path loss (corrected for beam widths)		-278.9 dB
ε * gain$_{TX}$ * gain$_{RX}$		81.4 dB
TX power [W]	28	44.5 dBm
Received signal power		-153.2 dBm
RX NoiseFigure [dB], temp	0.72	52.3 K
RX bandwidth [kHz]	2.5	
RX noise power		-147.4 dBm
Signal/Noise		-5.7 dB
Received Moon noise		-156.4 dBm
Sky+CMB, zenith+CMB temp	8.36 K	5.4 K
Spillover temp., add. spillover	140 K	0
RX antenna noise temp.	28.1 K	
RX main beam effic. η_{MB}, η_{F}	0.84	0.85
Spatial polarization, pol.loss	---	---
use +/-90° feed rotation	---	---
Y-dish&feed: Absorber/SkyZenith		5.74 dB
Y-dish&feed: Gnd/SkyZenith		5.17 dB
Y-dish&feed: Absorber/Sky@Elevation		6.27 dB
Y-dish&feed: Gnd/Sky@Elevation		5.69 dB
Y-feed: Gnd(or absorber)/SkyZenith		7.63 dB
SFU@frequency, Sun temp.	0	12530 K
Y-Sun: 1+Sun/(Sky+Noise)		**7.2 dB**
Y-Moon: 1+Moon/(Sky+Noise)	---	**0.34 dB**
G/T$_{EME}$ incl. RX noise temp		**17.92 dB/**
S/N EME: Signal/(0+Sky+Noise):		-8.3 dB
S/N EME: Signal/(Moon+Sky+Noise):		**-8.7 dB**

Decoding mode: Q65-60E

RX libration rate [°/min]	0.003052	
RX libration spreading	213 Hz	
Mutual libr. spread, beam corr.	201 Hz	156 Hz
Doppler libration	0 Hz	
CW integr. time [s], x-sigma decoder threshold		-23.8 dB
Margin = S/N EME - threshold	---	**15.1 dB**

Use time locked TX/RX azimuth/elevation for: NO, set elevation manually

Swap stations, Tx <=> Rx

Echo mode, set Rx = Tx

Calculate

Szum – definicja (ITU-R P.372-17)

Źródła naturalne:

- emisje z gazów atmosferycznych i hydrometeorów
- powierzchnia Ziemi; np. emisyjność lądu, oceanu i innych przeszkód znajdujących się w zasięgu anteny
- promieniowanie pochodzące z kosmicznych źródeł radiowych
- promieniowanie pochodzące z wyładowań atmosferycznych i innych wyładowań elektrostatycznych (szum atmosferyczny)

Szum – definicja (ITU-R P.372-17)

Źródła pochodzenia ludzkiego:

- w szczególności w przypadku anten zewnętrznych, zagregowane niezamierzone promieniowanie pochodzące z maszyn elektrycznych, urządzeń elektrycznych i elektronicznych oraz sieci, linii przesyłowych energii elektrycznej, komunikacji energetycznej, bezprzewodowego przesyłu energii, urządzeń przemysłowych, naukowych i medycznych (ISM) lub z zapłonu silników spalinowych, a także promieniowanie elektromagnetyczne pochodzące z niedoskonale ekranowanych obudów, linii przesyłowych i kabli

Szum – definicja (ITU-R P.372-17)

Źródła pochodzenia ludzkiego:

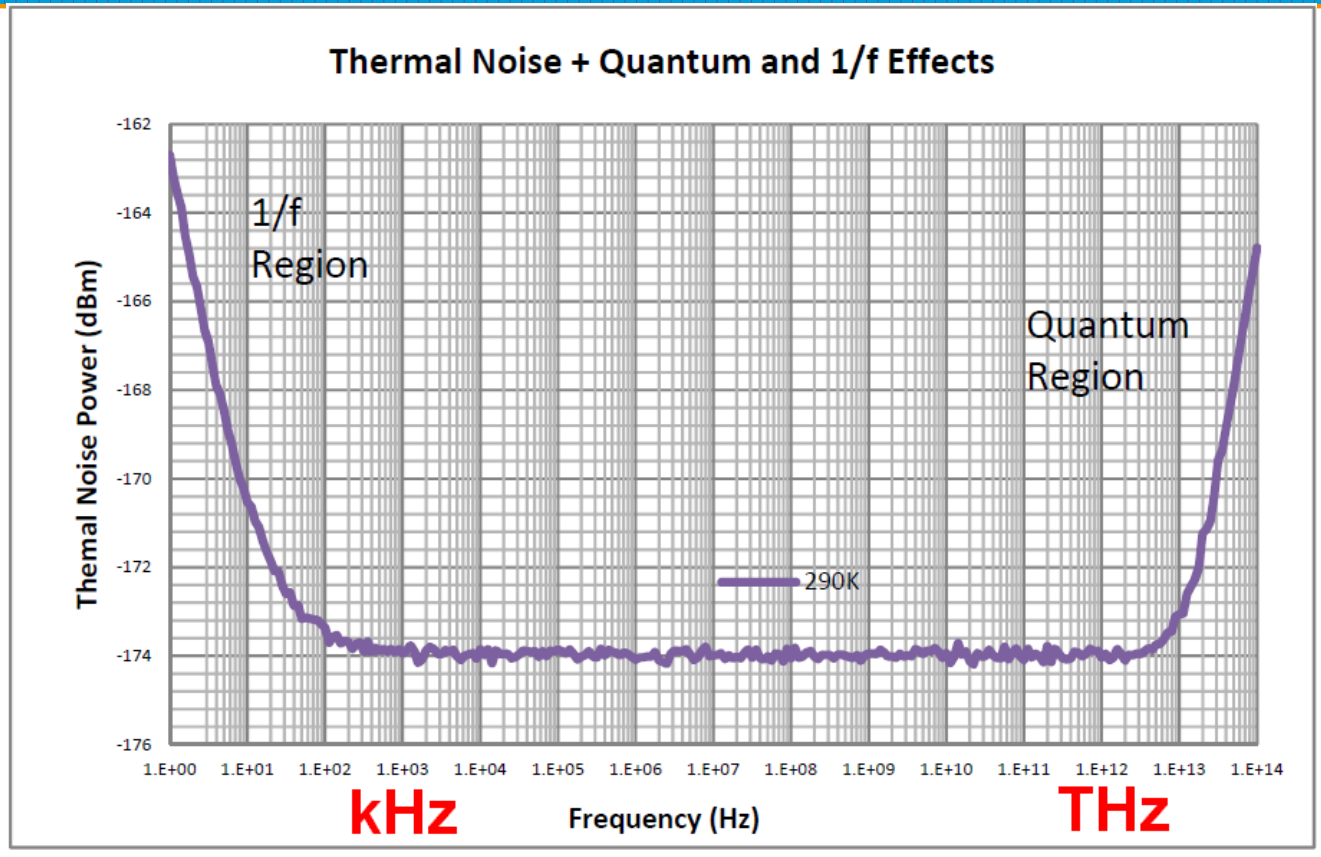
- w pomieszczeniach lub w przypadku anten znajdujących się w pobliżu przeszkód, zagregowane promieniowanie niezamierzone, jak powyżej, w możliwym zakresie, ale również obejmujące typowe poziomy promieniowania pochodzące z pojedynczych lub niewielkiej liczby źródeł, w określonych typowych środowiskach.

Szum – definicja (ITU-R P.372-17)

Szum w systemie odbiorczym ma wiele źródeł.

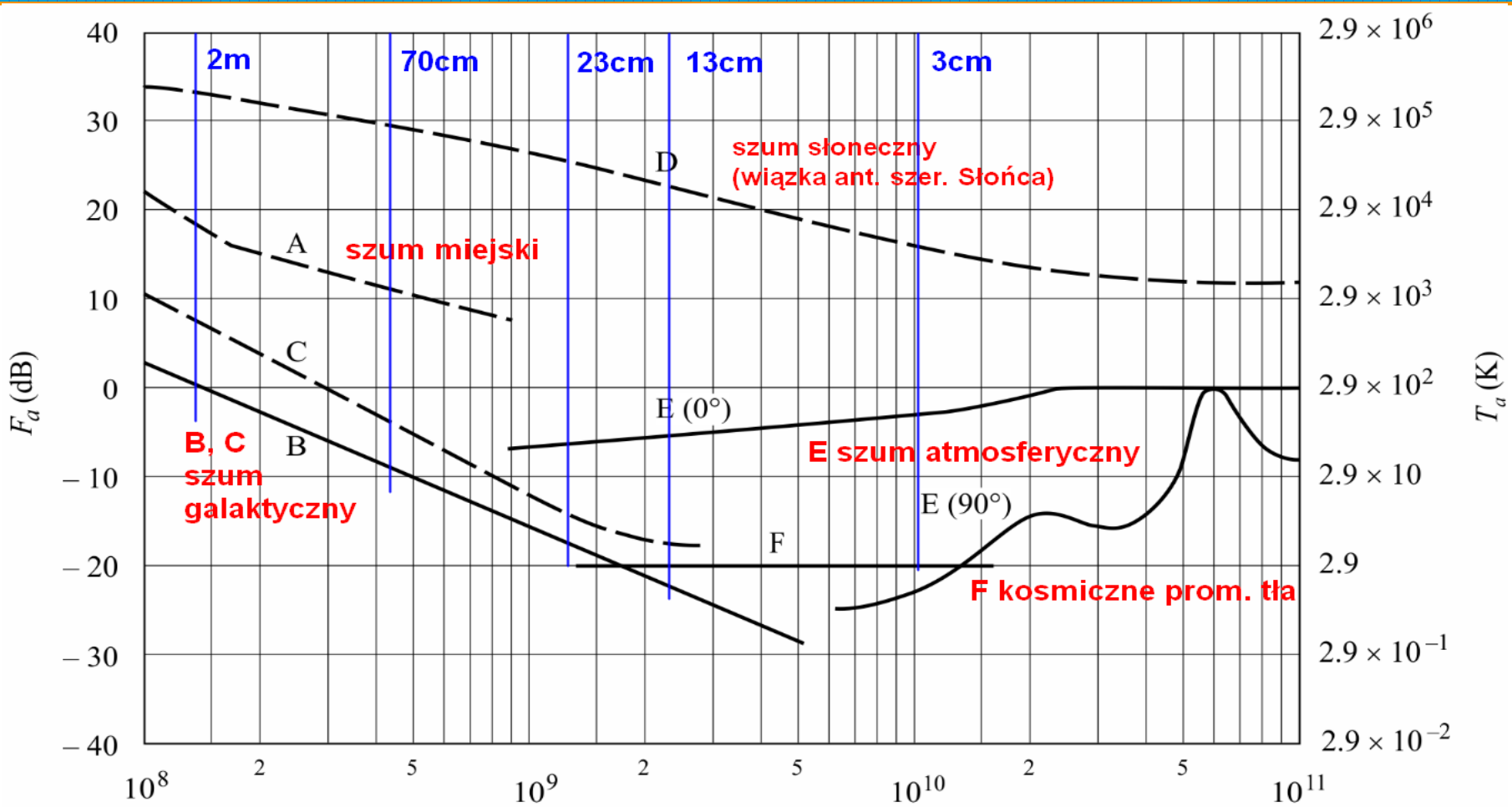
- Należy wziąć pod uwagę zarówno szum zewnętrzny, jak i szum wewnętrzny generowany w odbiorniku.
- Jedynym odpowiednim punktem odniesienia dla ogólnego szumu roboczego systemu odbiorczego są zaciski równoważnej bezstratnej anteny odbiorczej. (Taka antena nie istnieje fizycznie).

Fizyka – temperatura szumowa

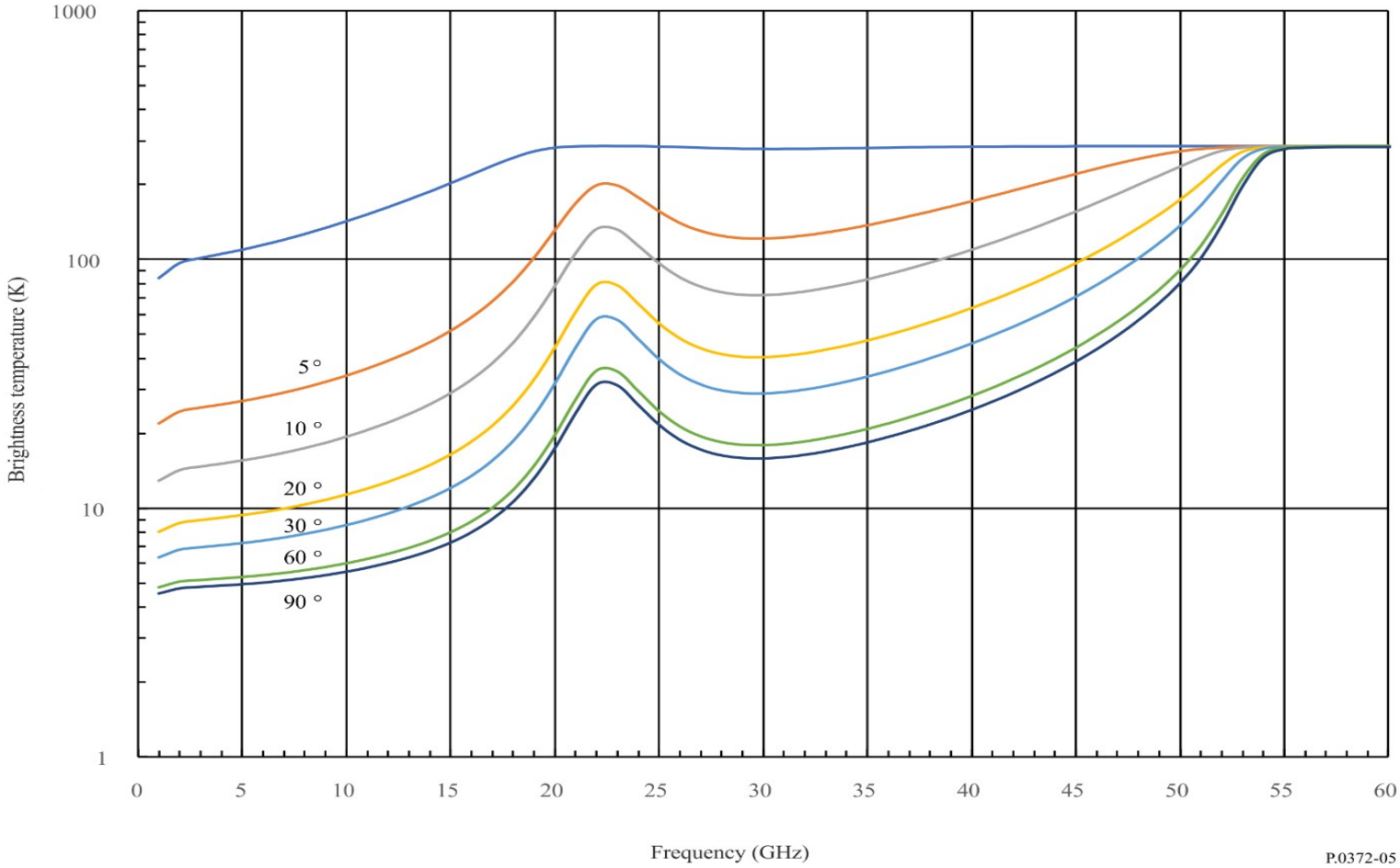


- https://www.microwaves101.com/encyclopedias/noise-notes

Fizyka – źródła w zależności od częstotliwości (ITU-R P.372-17 Fig. 3)

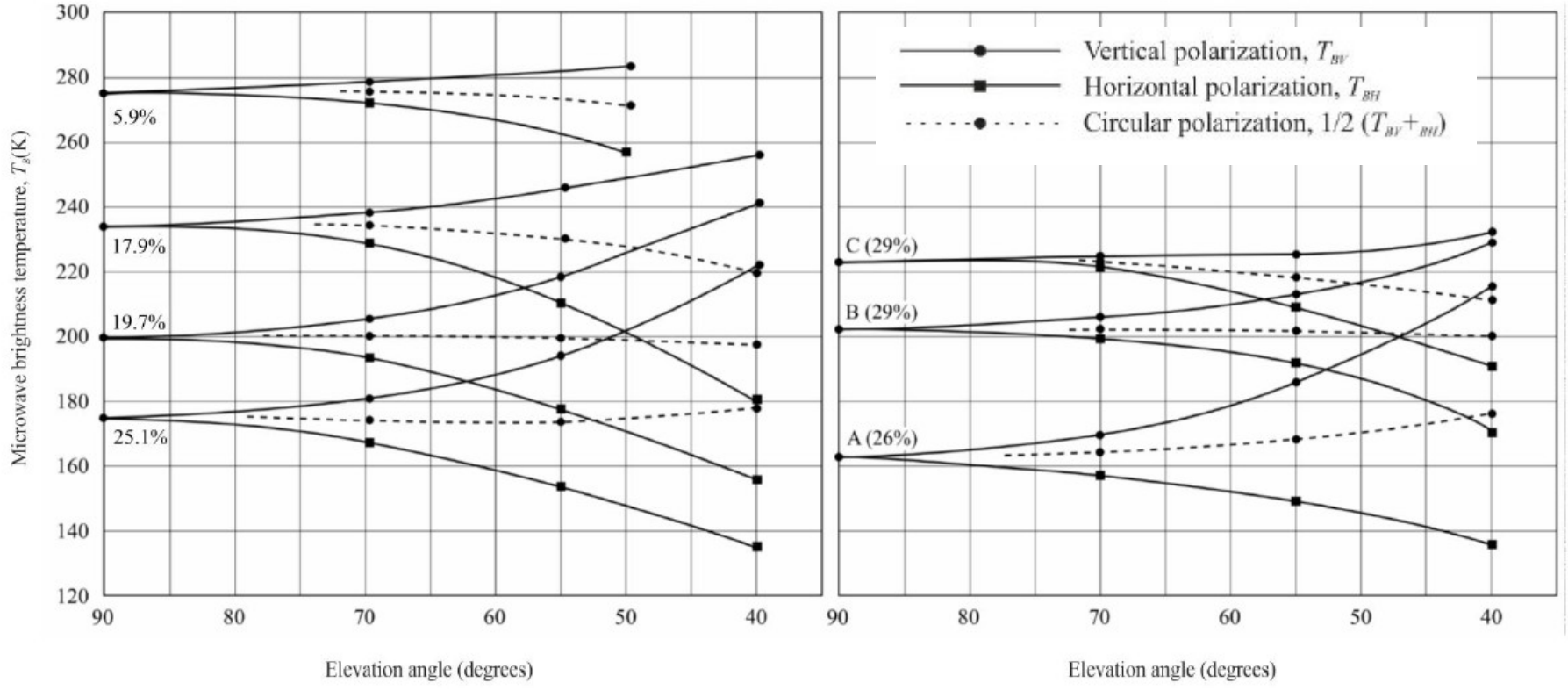


Fizyka – szum atmosferyczny (brightness temperature) (ITU-R P.372-17 Fig. 5)



Fizyka – Ziemia z kosmosu. Szum jest spolaryzowany! (ITU-R P.372-17 Fig. 8)

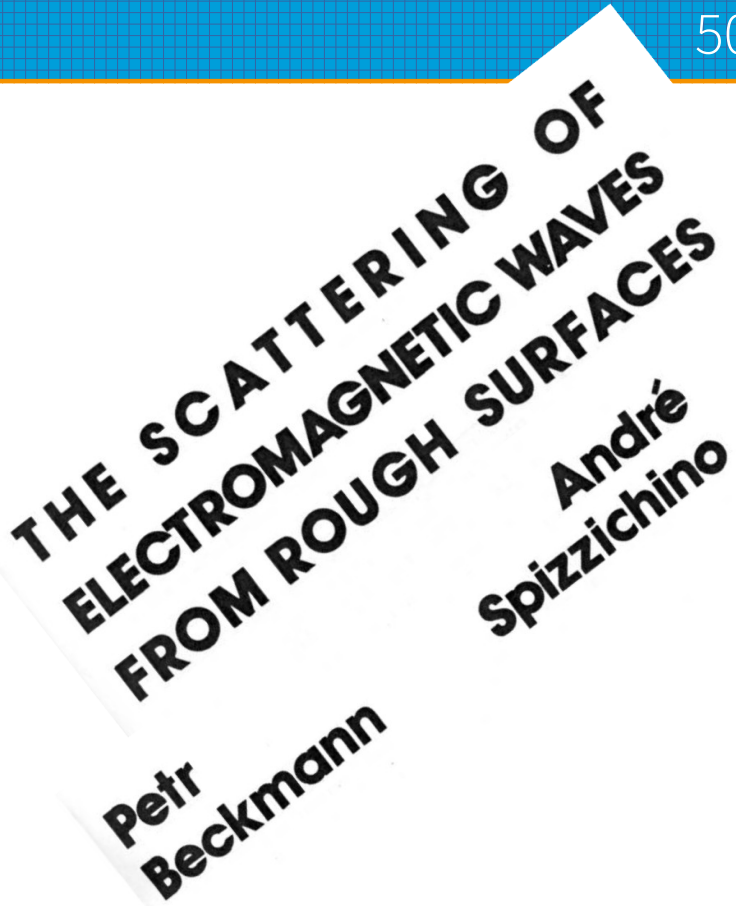
Brightness temperature at 1 430 MHz of the ground as a function of elevation angle



a) Moisture content from 5.9% to 25.1% for a bare, smooth field

b) For (A) smooth field (B) medium roughness and (C) rough (deeply ploughed) field with percentage water content as indicated

Fizyka – komunikacji troposferycznej i odbicia od nierównych powierzchni
500 stron – 60 lat temu



Temperatura szumowa anteny (Dragoslav Dobričić, YU1AW)
VHF Antenna Noise Temperature, antenneX Issue No. 132 – April 2008

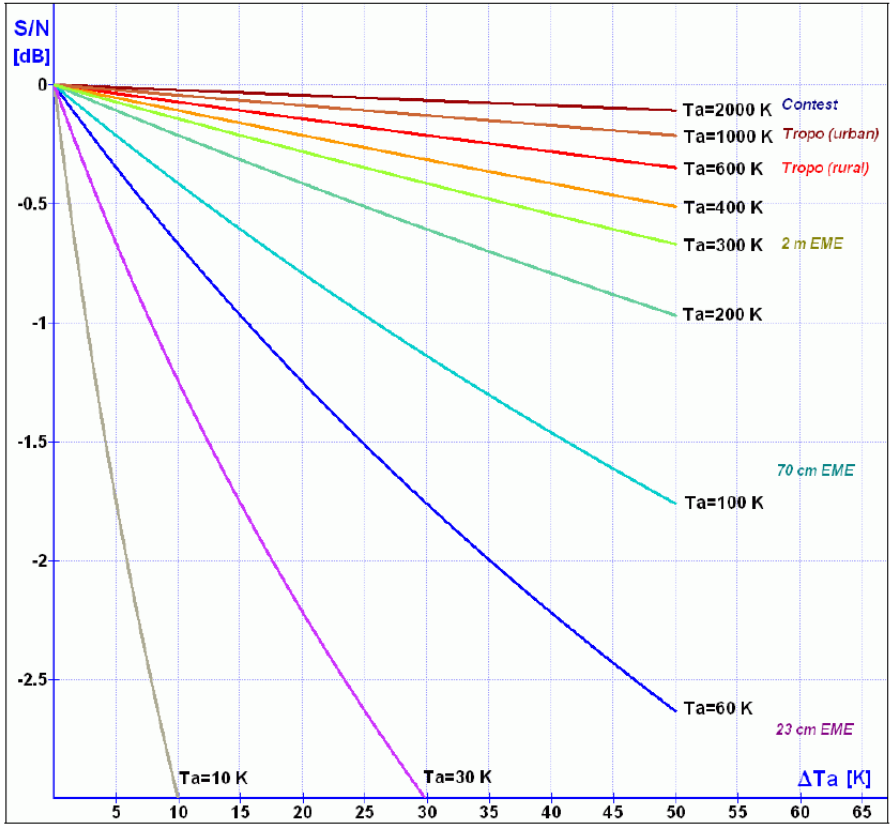


Fig. 5: Relative S/N versus antenna noise difference ΔTa

Temperatura szumowa anteny (Dragoslav Dobričić, YU1AW)
VHF Antenna Noise Temperature, antenneX Issue No. 132 – April 2008

Temperatura szumowa anteny zależy całkowicie od środowiska anteny, rodzaju komunikacji i częstotliwości roboczej. Analiza pokazuje, że wpływ temperatury szumu anteny Ta na zdolność odbiorczą anteny wyrażoną jako stosunek sygnału do szumu S/N jest marginalny w pasmach VHF. Nawet w przypadku komunikacji kosmicznej, takiej jak EME, wpływ ten nie jest tak istotny, jak można by się spodziewać. Różnica temperatury szumu anteny między podobnymi antenami o podobnej długości wysięgnika, wynosząca około 20-30 K, wytwarzana w systemach łączności EME o długości 2 metrów, daje różnicę w stosunku S/N wynoszącą zaledwie 0,3 dB!
W przypadku pracy naziemnej z wykorzystaniem rozpraszania troposferycznego, ze względu na wyższą temperaturę szumu anteny Ta, różnica ta jest jeszcze mniejsza.)

Temperatura szumowa anteny (Rastislav OM6AA et al.)

https://www.researchgate.net/publication/301657591_Parabolic_Antenna_Noise_Characteristic_with_Dual-Mode_Feed

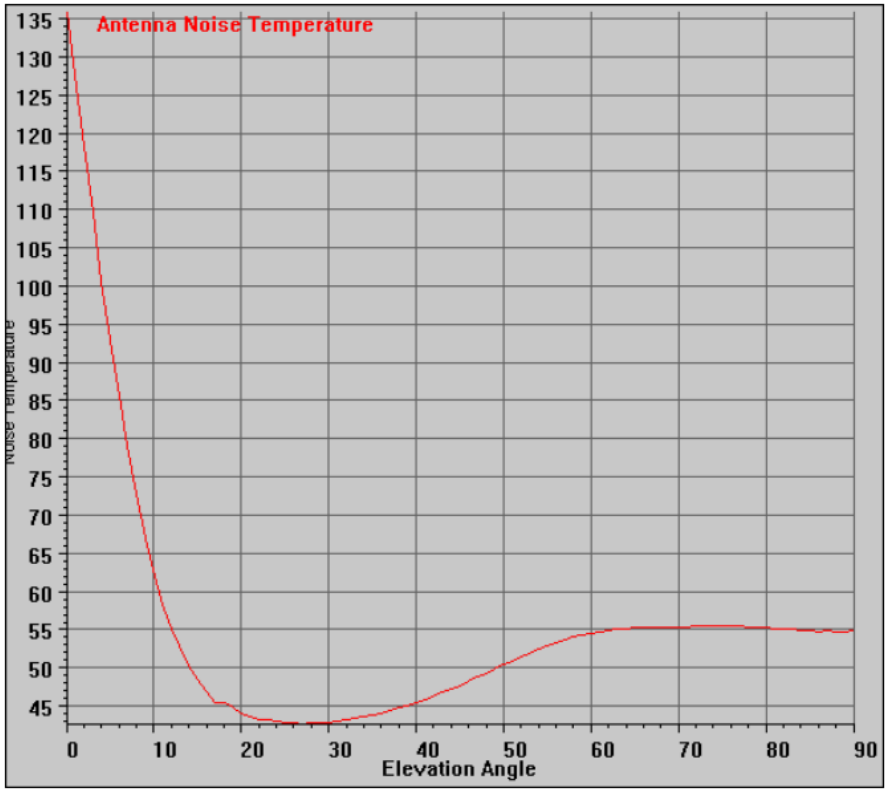


Fig. 7 - Dependence of antenna noise temperature on elevation angle for a dish with f/D ratio 0.65. Note accrual of antenna noise temperature for higher elevation angles, above 50 degrees, due to antenna spillover.

Temperatura szumowa anteny (Rastislav OM6AA et al.)

https://www.researchgate.net/publication/301657591_Parabolic_Antenna_Noise_Characteristic_with_Dual-Mode_Feed

Fig. 6 shows that maximum antenna gain for a prime focus antenna configuration employing the W2IMU dual-mode feed is attained with a dish having an *f/D* ratio of 0.6. Such antenna configurations are best used for transmitting and will be referred to as TX optimum.

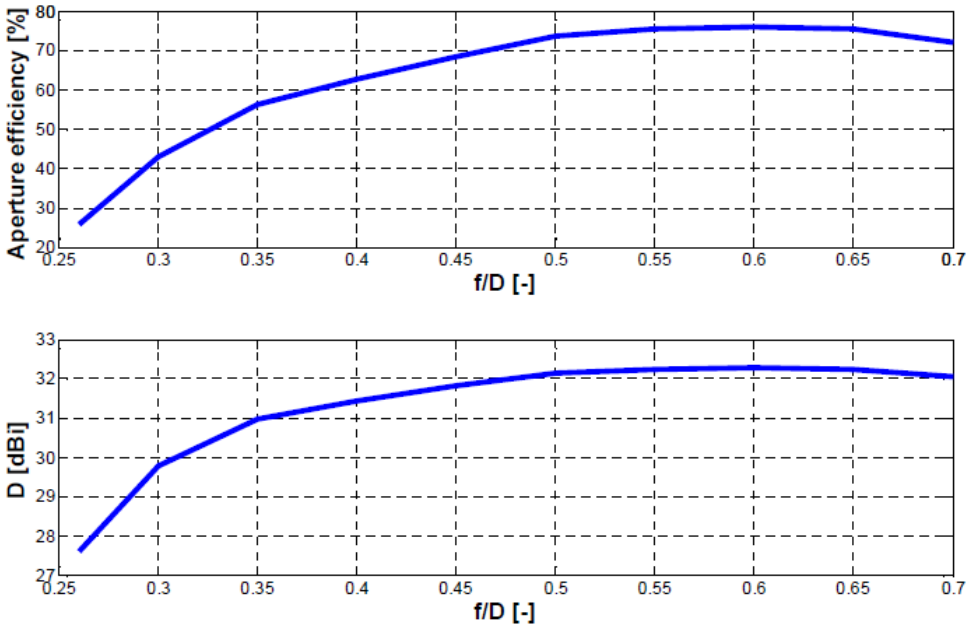
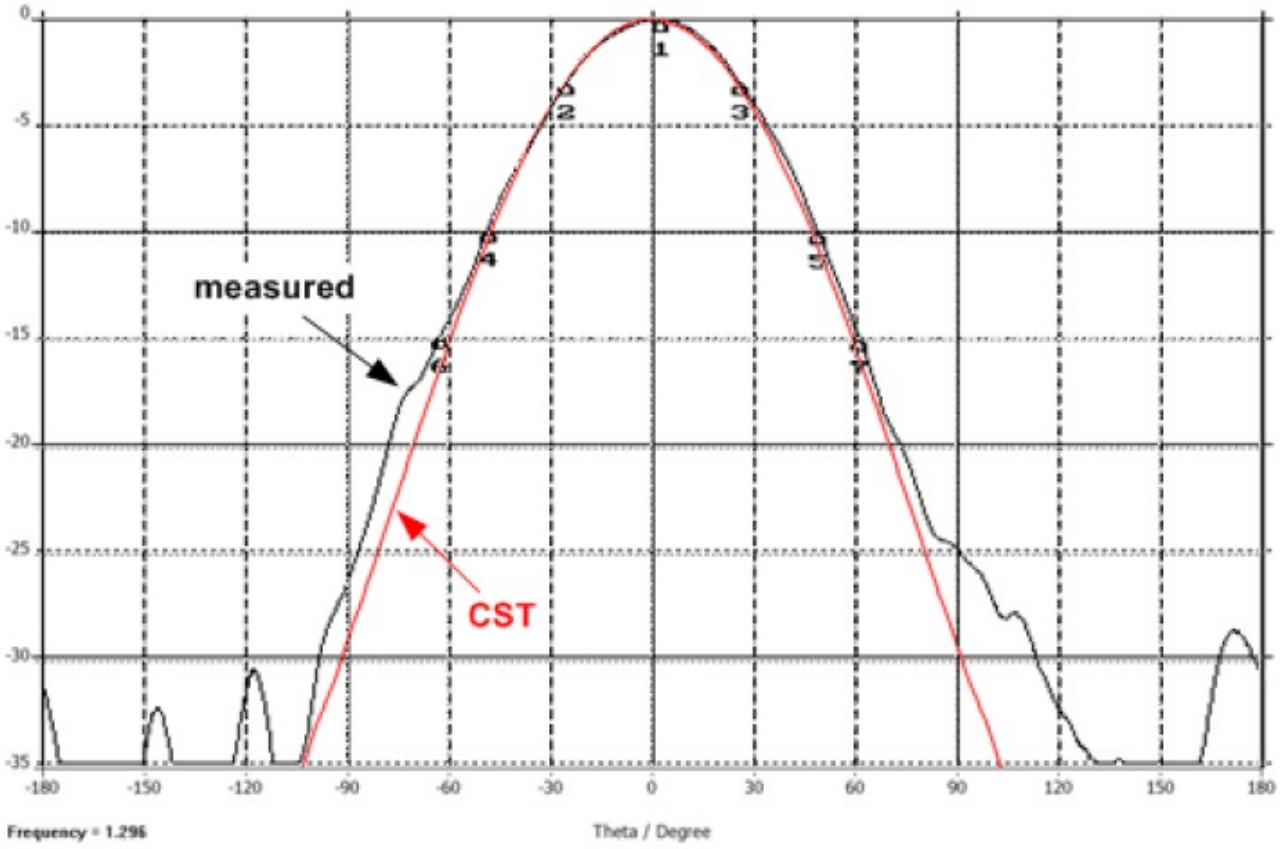


Fig. 6 - Antenna efficiency and directivity

Temperatura szumowa anteny (Rastislav OM6AA et al.)

https://www.researchgate.net/publication/301657591_Parabolic_Antenna_Noise_Characteristic_with_Dual-Mode_Feed



Temperatura szumowa anteny (Rastislav OM6AA et al.)

https://www.researchgate.net/publication/301657591_Parabolic_Antenna_Noise_Characteristic_with_Dual-Mode_Feed

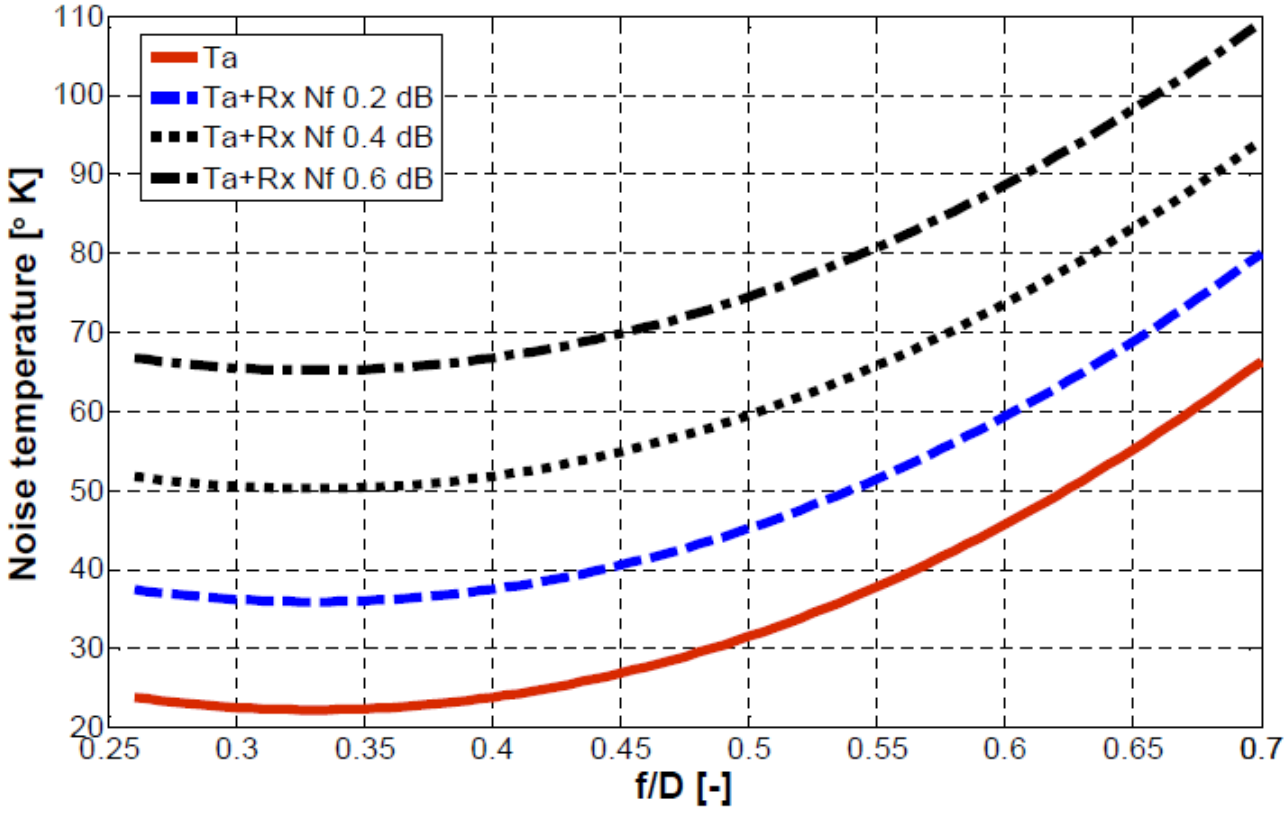


Fig. 8 - Average antenna and system noise temperature

Temperatura szumowa anteny (Rastislav OM6AA et al.)

https://www.researchgate.net/publication/301657591_Parabolic_Antenna_Noise_Characteristic_with_Dual-Mode_Feed

5. Optimal receiving (RX) performance, G/Ts ratio

The computed G/Ts curves from the above results (Figs. 6 and 8) are shown in Fig. 9.

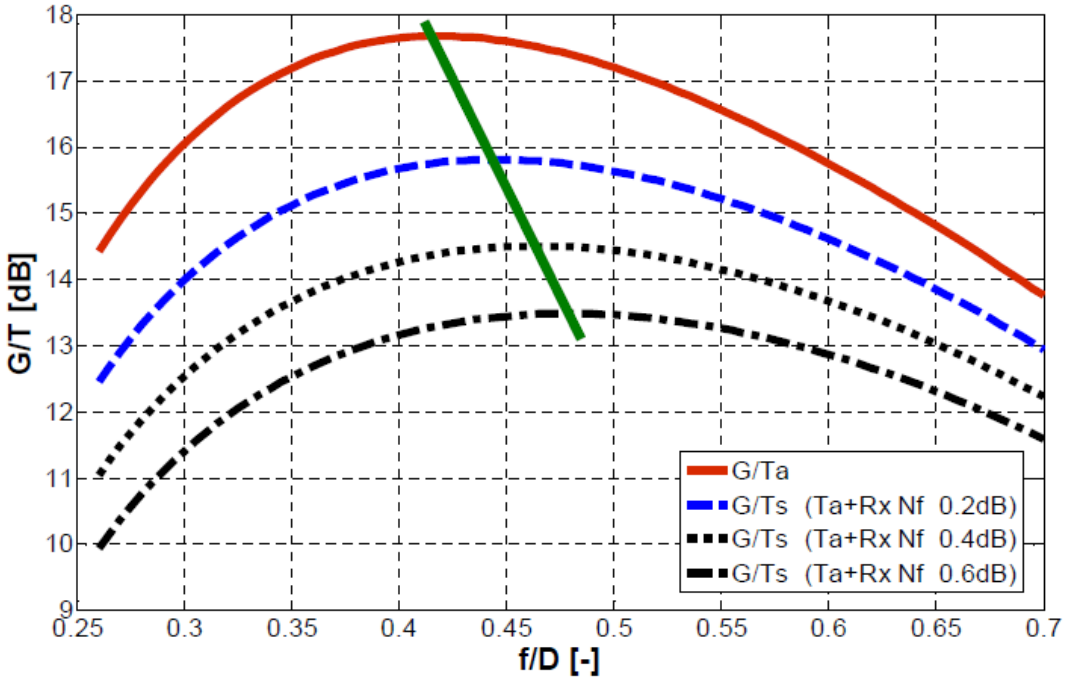


Fig. 9 - Antenna and System G/T ratio

Low Noise Amplifier with 7 K Noise at 1.4GHz and 25 °C

Sander Weinreb, Life Fellow, IEEE and Jun Shi, Member, IEEE

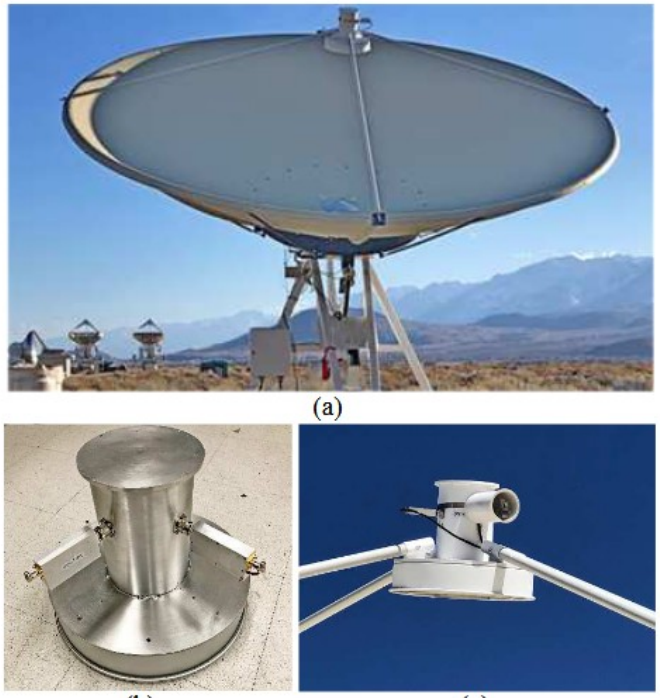


Fig. 9. (a) 4.6 m prime focus paraboloid, (b) LNAs mounted on low-loss, dual-linear polarization feed, and (c) feed mounted at prime focus of paraboloid.

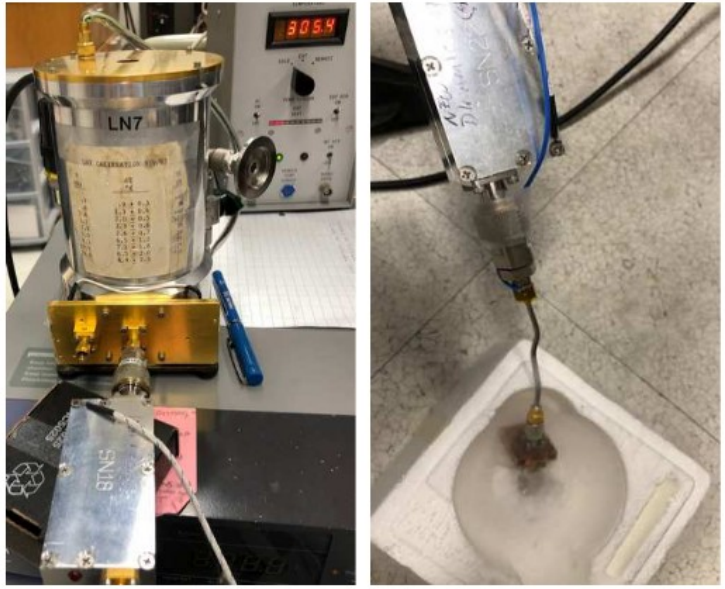


Fig. 10. Two methods of using LN2 cooled terminations to measure the noise of an LNA and then calibrate noise diodes for faster measurements.

Low Noise Amplifier with 7 K Noise at 1.4GHz and 25 °C

Sander Weinreb, Life Fellow, IEEE and Jun Shi, Member, IEEE

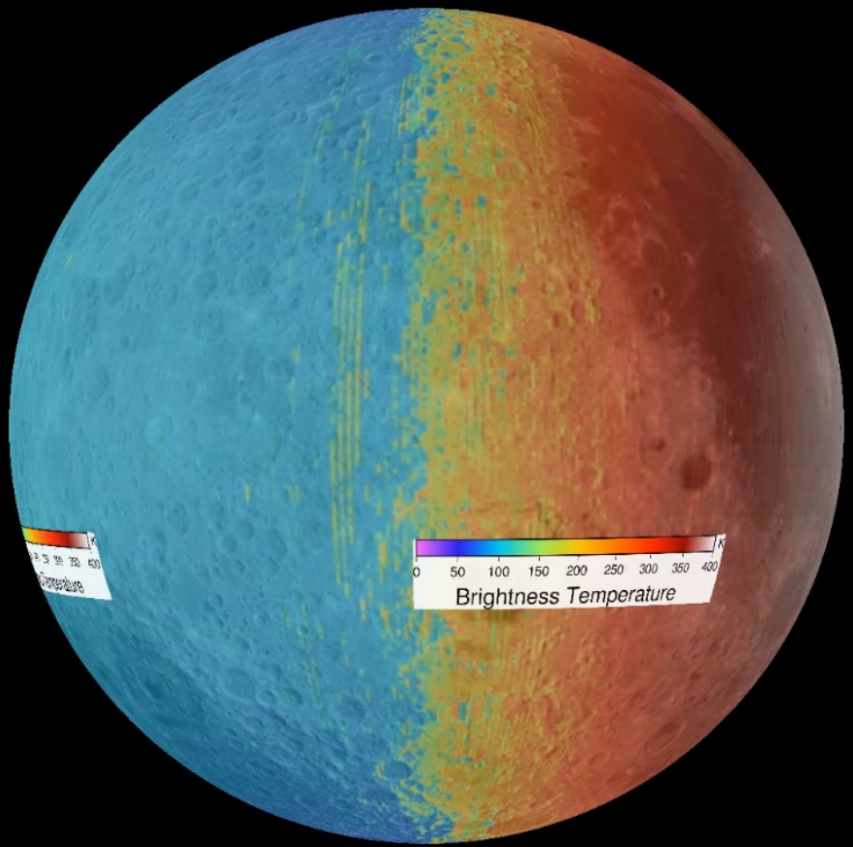
TABLE III
COMPOSITION OF MEASURED SYSTEM NOISE

Source	Noise (K)	Comment
Cosmic Background	2.7	Measured to mK accuracy in hundreds of experiments
Galactic	1	Spatial average of many discrete sources and will vary with location of galactic plane in antenna beam
Atmosphere	3	Oxygen and water at 30-degree zenith angle
Spillover	3	Calculated from feed pattern; higher at zenith
Feed Blockage	2	Estimate based upon 0.38 m feed diameter and 150 K average brightness of scatterd pattern
Feed Loss	2	EM integration of surface current and surface resistance
T_{LNA} **NF = 0.10 dB**	7	Measure in laboratory with noise source calibrated with LN_2
Post LNA Noise	1	Due to 600 K next stage, 3 dB cable loss, and 36 dB LNA gain + fiber link noise
Total **NF = 0.31 dB**	21.7	Total measured with absorber vs sky, Feb 20, 2020

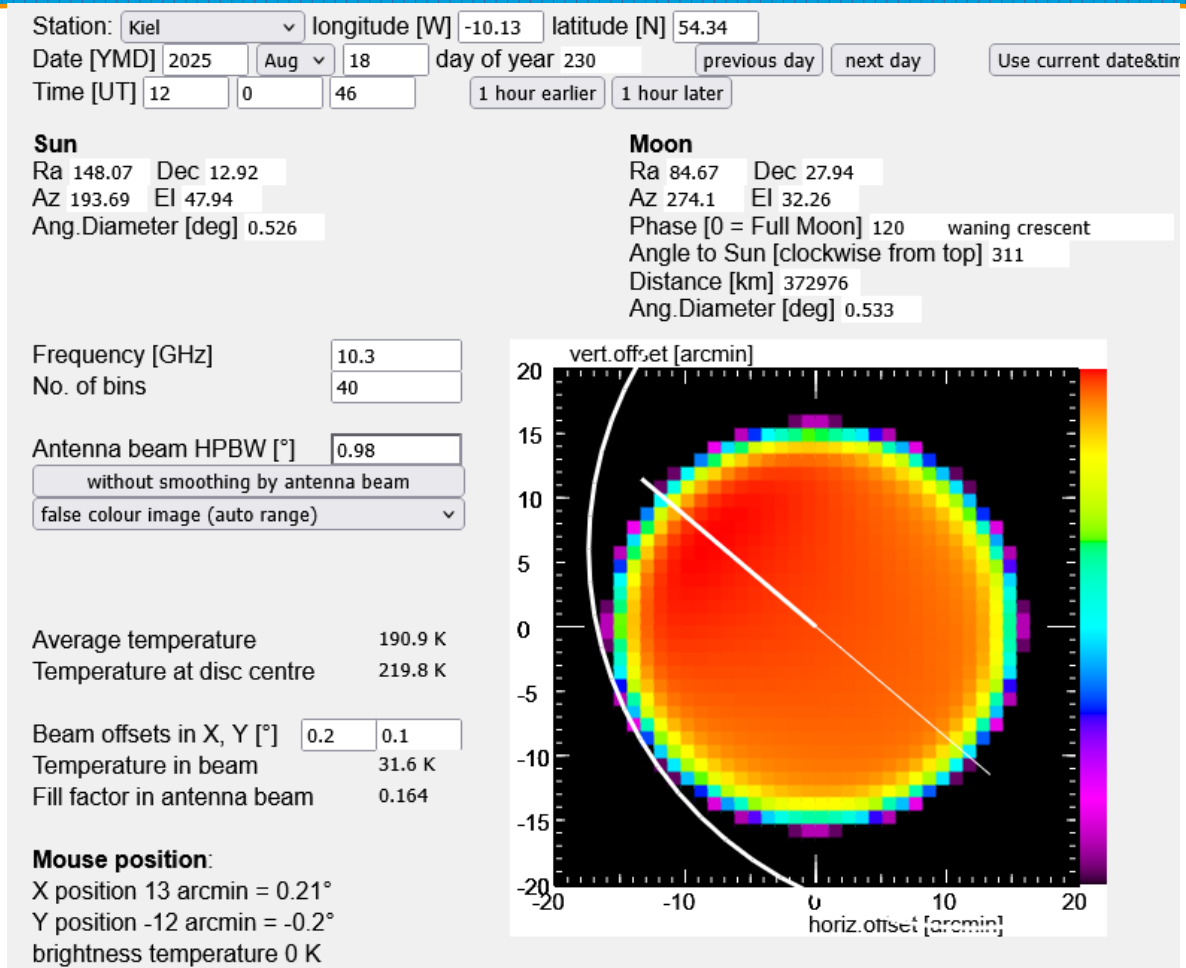
Nasze amatorskie pomiary…
https://pa0ehg.com/10_ghz_stations.htm

Info from other EME stations							
Call Sign	Dish size (Mtr)	Moon noise		Solar Noise		Ground Noise	
W6HD	3	1.6	dB	14.8	dB	4.9	dB
WA7CJO	4.9	2.9	dB	17.8	dB	x	dB
SM4DHN	6	2.8	dB	16	dB	x	dB
W5LUA	5	1.8	dB	16	dB	x	dB
PA0BAT	3.7	1.95	dB	16.2	dB	6.2 feed only	dB
PA3CSG	3	1.7	dB	15.5	dB	x	dB
AA5C	3.3	1.0	dB	13	dB	x	dB
F6KSX	3	2.0	dB	16	dB	x	dB
PA0EHG	3	1.7	dB	15	dB	5.1	dB
LA8LF	4.6	3.1	dB	20.3	dB	#22	

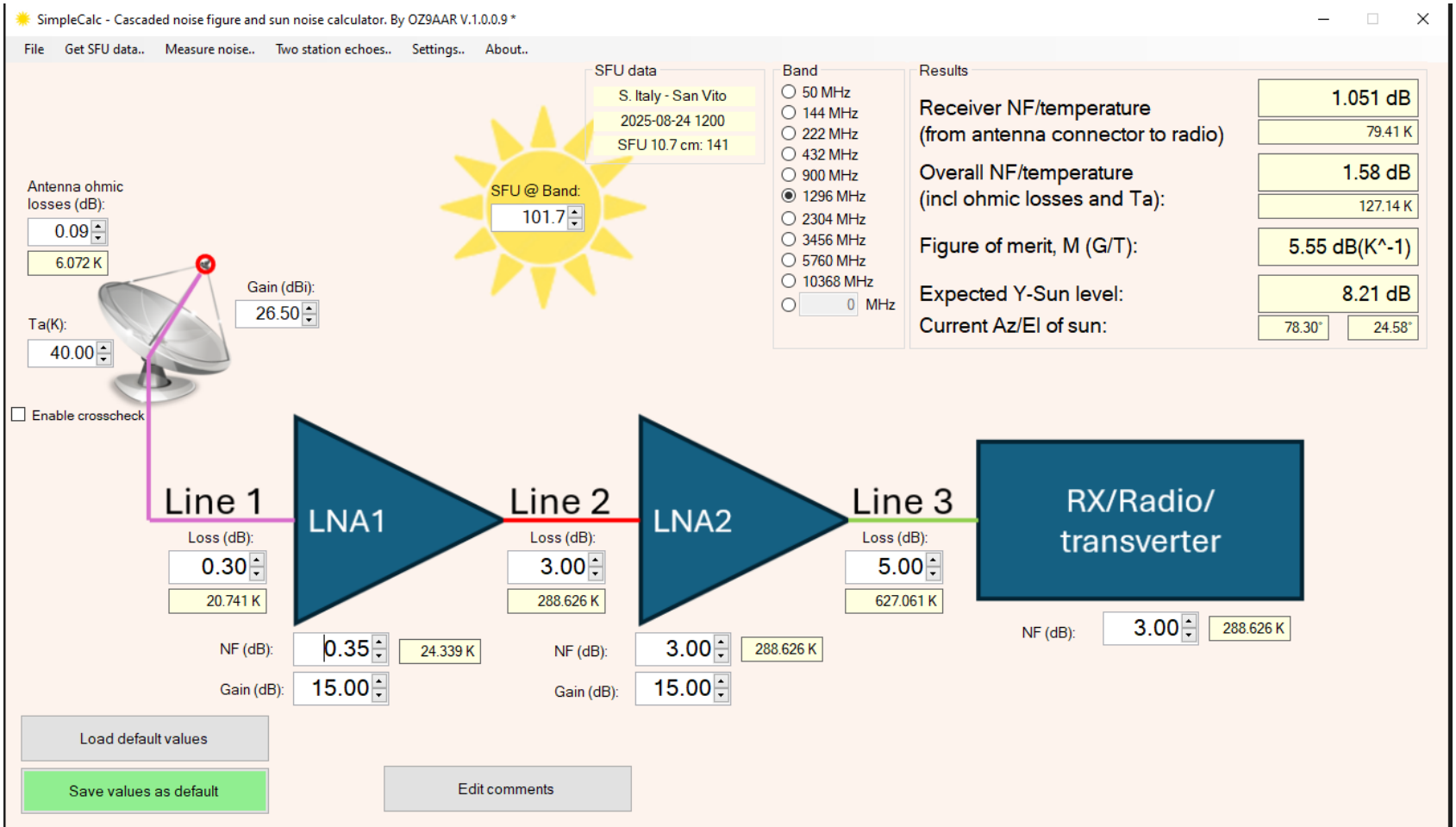
Zmienna temperatura powierzchni Księżyca
https://sos.noaa.gov/catalog/datasets/moon-surface-temperature/



Temperatura księżyca z uwzg. szerokości wiązki anteny i błędu śledzenia (Joachim Köppen DF3GJ) https://portia.astrophysik.uni-kiel.de/~koeppen/JS/AimRadioMoon.html



Kalkulator współczynnika Y dla szumu Słońca
SimpleCalc, Carsten OZ9AAR



Kalkulator współczynnika Y dla szumu Słońca
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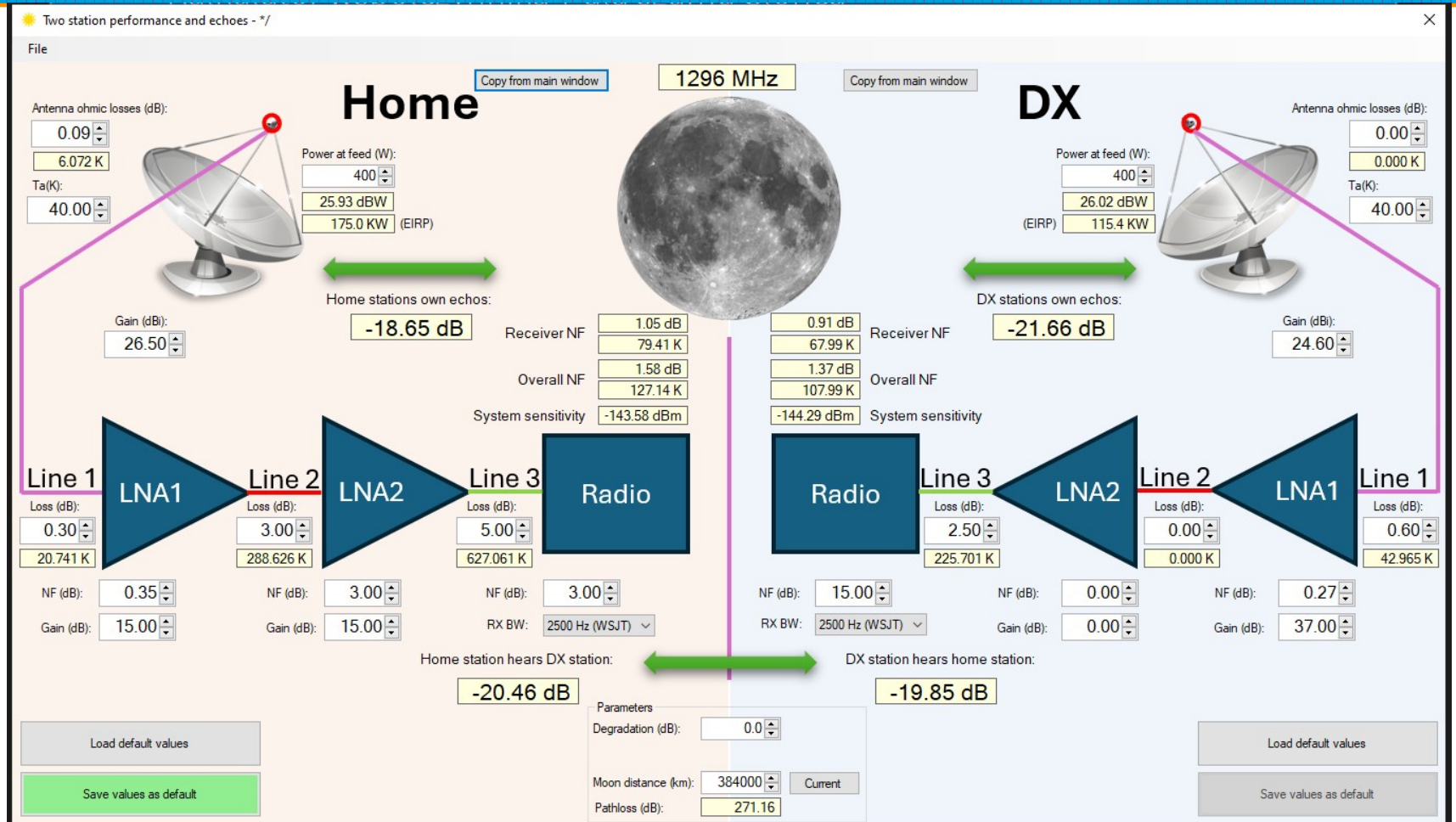

Bilans
OE2IGL & DF3GJ
2022 r.
https://wettersat.bplaced.net/EME/EME.html

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TX refrac.corr. elevation [°]	30	
TX LOS atmosph.attenuation		0.096 dB
additional cloud loss [dB]	0	

Receiving Antenna:	Gauss, max ant. η = theor.-2.5%	
Dish diameter [m], ant.gain$_{theo}$	0.815	38.94 dBi
Dish f/D	0.67	
Offset angle if offset dish [°]	21	
Surface RMS [mm], peak err	0.17	+/- 0.34 mm
Feed out-of-axial-focus [mm]	0	
Feed blocking area [m^2]	0	
Ohmic efficiency η_{ohm}	1.0	
Illumination efficiency η_{i}	0.866	
X-polarization efficiency η_{pol}	0.985	
Spillover efficiency η_{s}	0.937	
Phase efficiency η_{phase}	1	
Illum*phase*spill*xpol $\eta_{i*p*s*x}$	0.8	37.97 dBi
Surface efficiency η_{Ruze}	0.995	
Focus efficiency η_{focus}	1	
Blocking efficiency η_{block}	1	
Mesh grid diam, spacing [mm]	0	0
Mesh grid effi. η_{mesh}, loss	1	0 dB
Max. antenna efficiency η_{max}	0.77	37.8 dBi
Used antenna efficiency η_{real}	0.69	
Edge taper [dB], feed taper	-12	-11 dB
Dish center - rim	36.5°	
HPBW$_{real}$, gain$_{real}$	2.38°	37.33 dBi
Position x,y on Moon [°]	0	0
Received fraction (BWF)	0.607	-2.17 dB
RX fill factor moon	0.0348	-14.58 dB
RX temperature [°C]	15	
RX humidity [%]	50	
RX absolute pressure [mbar]	980	
RX zenith atmosph.attenuation		0.048 dB
RX azimuth [°]	---	
RX refrac.corr. elevation [°]	30	---
RX LOS atmosph.attenuation		0.096 dB
additional cloud loss [dB]	0	

Moon:	Lunar reflectivity varies radially	
Isotropic path loss (radar equation)		-276.7 dB
Path loss (corrected for beam widths)		-278.9 dB
ε * gain$_{TX}$ * gain$_{RX}$		81.4 dB
TX power [W]	28	44.5 dBm
Received signal power		-153.2 dBm
RX NoiseFigure [dB], temp	0.72	52.3 K
RX bandwidth [kHz]	2.5	
RX noise power		-147.4 dBm
Signal/Noise		-5.7 dB
Received Moon noise		-156.4 dBm
Sky+CMB, zenith+CMB temp	8.36 K	5.4 K
Spillover temp., add. spillover	140 K	0
RX antenna noise temp.	28.1 K	
RX main beam effic. η_{MB}, η_{F}	0.84	0.85
Spatial polarization, pol.loss	---	---
use +/-90° feed rotation	---	---
Y-dish&feed: Absorber/SkyZenith		5.74 dB
Y-dish&feed: Gnd/SkyZenith		5.17 dB
Y-dish&feed: Absorber/Sky@Elevation		6.27 dB
Y-dish&feed: Gnd/Sky@Elevation		5.69 dB
Y-feed: Gnd(or absorber)/SkyZenith		7.63 dB
SFU@frequency, Sun temp.	0	12530 K
Y-Sun: 1+Sun/(Sky+Noise)		**7.2 dB**
Y-Moon: 1+Moon/(Sky+Noise)	---	**0.34 dB**
G/T$_{EME}$ incl. RX noise temp		**17.92 dB/**
S/N EME: Signal/(0+Sky+Noise):		-8.3 dB
S/N EME: Signal/(Moon+Sky+Noise):		**-8.7 dB**

Decoding mode: Q65-60E

RX libration rate [°/min]	0.003052	
RX libration spreading	213 Hz	
Mutual libr. spread, beam corr.	201 Hz	156 Hz
Doppler libration	0 Hz	
CW integr. time [s], x-sigma decoder threshold		-23.8 dB
Margin = S/N EME - threshold	---	**15.1 dB**

Use time locked TX/RX azimuth/elevation for: NO, set elevation manually

Swap stations, Tx <=> Rx

Echo mode, set Rx = Tx

Calculate

Podstawy radioastronomii
(Joachim Köppen DF3GJ)
https://portia.astrophysik.uni-kiel.de/~koeppen/Haystack/basics.html