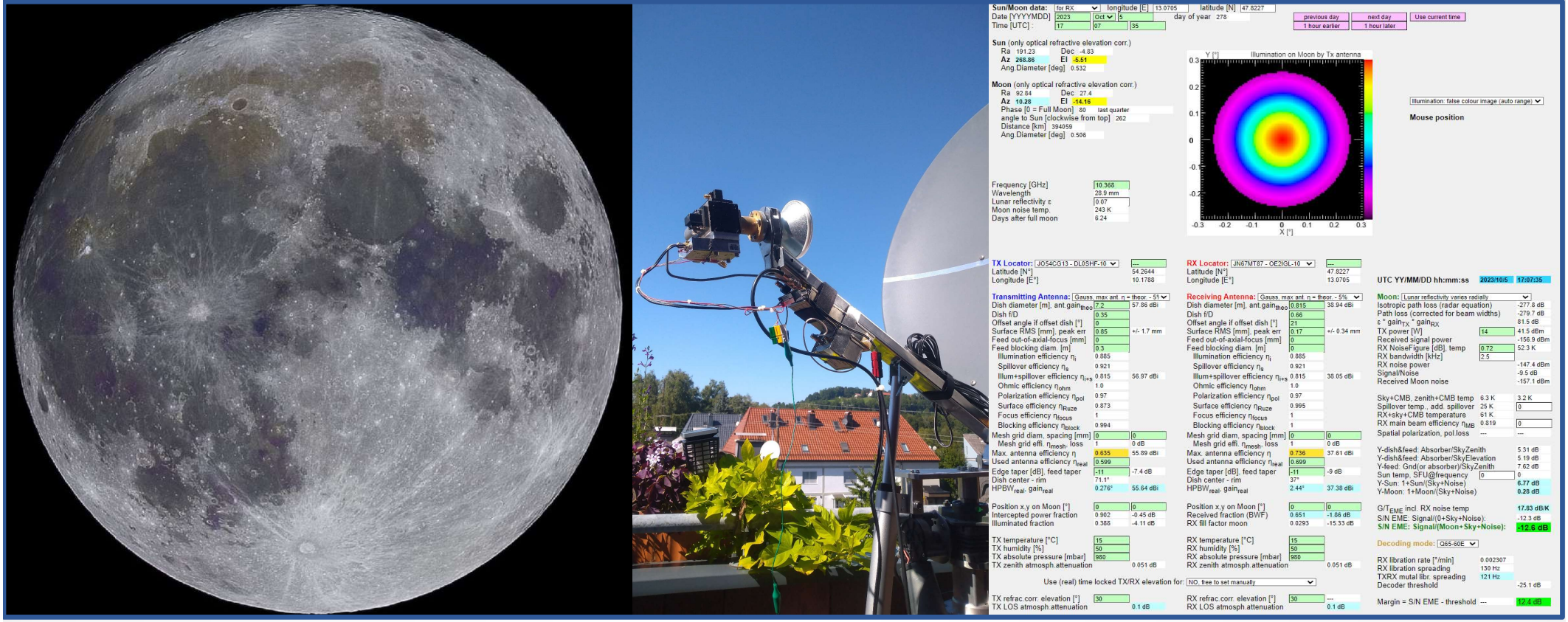


EME Link Budget & Analysis Tool von 1 - 100 GHz

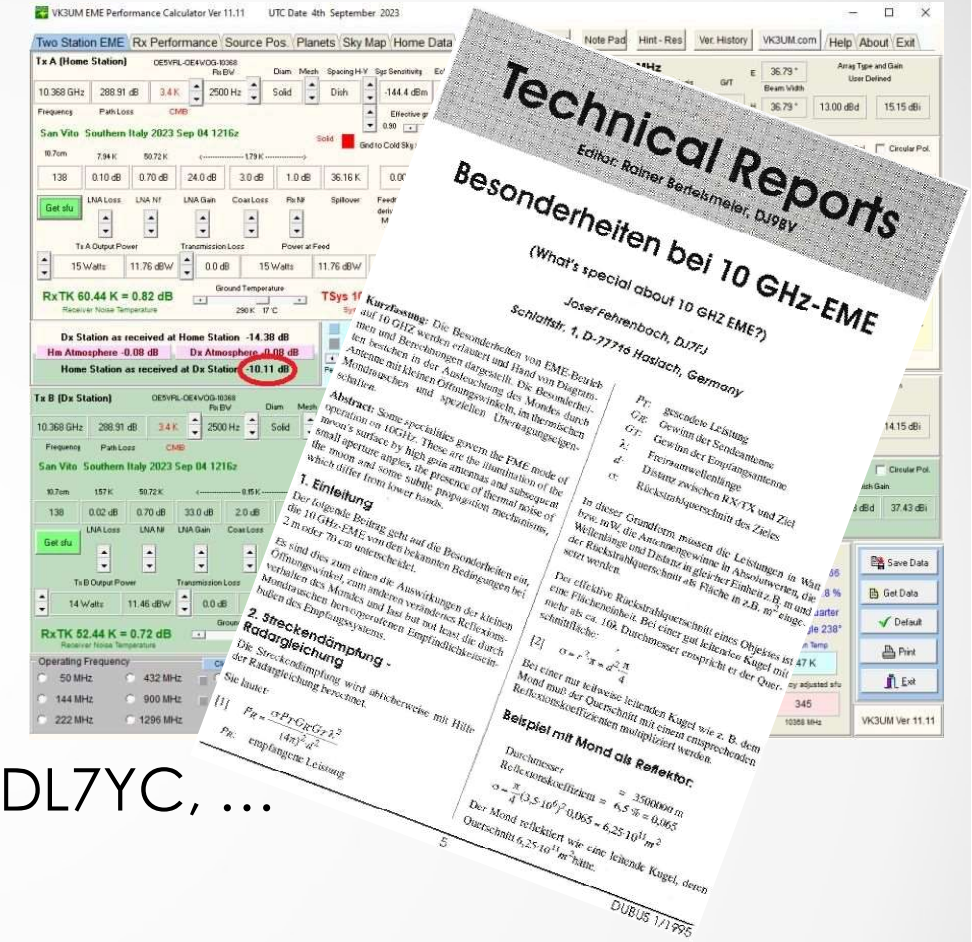
Zweck der Präsentation

- 10 GHz EME ist Standard,
  47 GHz ist eine Herausforderung,
  2005 erstes QSO, seitdem nichts

- Mit EME calc, VK3UM (SK),
  das System verbessern.
  Zeigt Schwächen >10 GHz
  Warum?

- EME Conference 2022
  angeregt durch Diskussionen mit DL7YC, …

- **Kann man EME calc verbessern?**



Ich bin Physiker mit der Leidenschaft Dinge zu verstehen, zu verknüpfen, berechenbar zu machen.
Ich habe die Erkenntnisse, bekannt seit den 1940er Jahren, zu einem Bild zusammengefügt.
-> **„learn from the professionals“**

Übersicht

- **Allgemeine Form der Radargleichung**
- EME Einflussfaktoren (>10 GHz)
- Übersicht EME Link Analysis Tool + Beispiele
- Zusammenfassung

QR-Code EME tool

Die allgemeine Radargleichung[1] berücksichtigt Effekte die wir bisher „vergessen“ hatten

Nur für Spezialfall „Punktquelle“ gültig

2. Echo Power

2.1. The Radar Equation for a Distributed Target

The radar equation is normally stated in a manner that is proper for the observation of "point targets," i.e., objects which when viewed from the radar subtend an angular diameter much smaller than that of the antenna beam. In this case the received echo power P_r may be stated as

$$P_r = \frac{P_t G A \sigma}{(4\pi R^2)^2} \text{ watts} \qquad (1)$$

where P_t = transmitted power (watts), G = antenna gain, A = antenna aperture (m^2), σ the cross section of the target (m^2), and R is the target's range (m). Of all the celestial objects detectable by means of radar, the Moon (and perhaps the Sun) are the only ones in

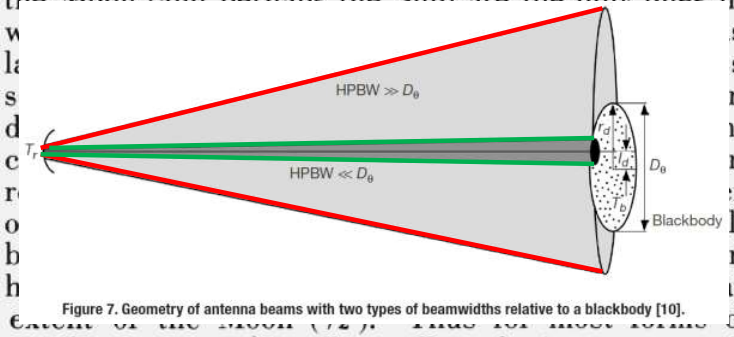


Figure 7. Geometry of antenna beams with two types of beamwidths relative to a blackbody [10].

simple antennas this effect will not be important until the antenna diameter becomes larger than 100 λ where λ is the radio wavelength.

Radar echoes from any of the nearby objects in the solar system can, however, be resolved in range delay or in frequency. For example, it is readily possible

more by determining the peak echo power observed when pulses of 11.6 msec or longer are transmitted. In practice, echoes from the Moon are found to fade as a consequence of constructive and destructive interference between signals arriving from different parts of the lunar surface. Thus, an average value for the peak echo power (or mean square of the echo amplitude) must be obtained from many pulses to determine σ reliably. Alternatively, with a CW radar, many independent determinations of the echo power are required. In some of the earliest radar observations of the Moon [e.g., DeWitt and Stodola, 1949] this was not recognized and only the maximum value of the echo intensity was reported.

When the antenna beam width is comparable with the diameter of the Moon, it is possible to compute σ if the distribution of incident power over the surface is known (defined by the antenna pattern) and the brightness distribution observed for the lunar disk for uniform illumination is also known. Thus, if the axis of the antenna beam is directed at the center of the Moon, and the antenna pattern is circularly symmetrical about this axis, the echo power is given by

$$P_r = \frac{P_t G_0^2 \lambda^2 \sigma}{64\pi^3 R^4} \int_\theta F^2(\theta) B(\theta) 2\pi \sin\theta d\theta, \qquad (2)$$

Allg. Form

in which G_0 is the gain of the antenna on axis and λ is the radio wavelength. Here θ is the angle subtended at the radar between the beam axis and an annulus of width $d\theta$ on the lunar surface, $F(\theta)$ is the normalized antenna pattern (power versus angle, $F(\theta)=1$ for $\theta=0°$), and $B(\theta)$ is the distribution of surface brightness that would be observed for uniform illumination; $B(\theta)$ is normalized so that the integral in (2) tends to unity for broadbeam antennas. The term $F(\theta)$ ap-

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Die wichtigsten EME S/N Einflussfaktoren liefern aufschlussreiche Details

Faktoren (nach Wichtigkeit > 10 GHz)	Schwankung S/N	Bemerkung
1) **Verluste** durch schmale Antennenkeulen auf dem Mond (nicht punktförmige Quellen)	bis zu -10 dB	allg. Radargleichung [1] DF3GJ & OE2IGL [4], OE2IGL [3]
2) **Verlust** durch nichtsynchrone Positionier- & Nachführgenauigkeit beider Antennen	bis zu -10 dB	EA EME Gruppe[9] : hat ein hochgenaues Trackingsystem entwickelt (max. ±0,03°)
3) **Verlust** (2-Weg) durch atmosphärische Dämpfung bei Elevation zwischen 10° und 65°	-4 bis -8 dB	ITU-R P.xxx [3]
4) Antennenwirkungsgrad: **Verluste** durch Spiegelungenauigkeiten (65% -> 30%)	bis zu -3 dB	J. Ruze [7] H. Scheffler [8]
5) **Verluste** (2-Weg) bei unterschiedlichen Wetter-bedingungen (Temp, Feuchte, Luftdruck)	bis zu -2,5 dB	ITU-R P.xxx [3] geht zusätzlich in die atmosph. Dämpfung ein
6) Mond Reflektivität: 0,075 ±0,013	± 0,75 dB	J.V. Evans [1] A. Giraud [6] J. Linsky [10]
7) Mond Temperatur	± 0,75 dB	DF3GJ: Übersicht wissenschaftlicher Daten [5]
8) Mond Distanz (2-Weg) NF ±0,5 dB; Tx power ±0,5 dB	± 0,95 dB ± 0,5 dB	

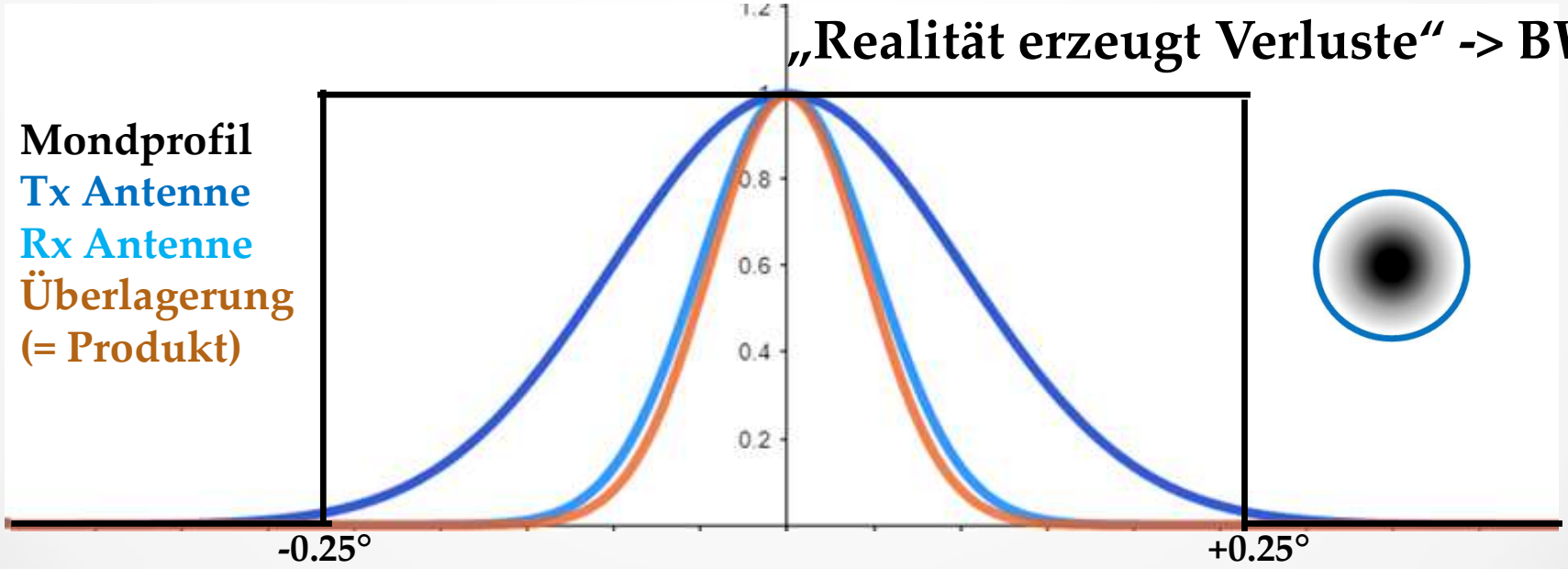
Faktor 1:
Schmale Antennenkeulen auf dem Mond (BWF)

- 2x Antennen Gauss Profil -> $F_{(\theta)}$
- Mond Tophat Profil -> $B_{(\theta)}$

beam width factor BWF ≤ 1

$$P_r = \frac{P_t G_0^2 \lambda^2 \sigma}{64\pi^3 R^4} \int_\theta F^2(\theta) B(\theta) 2\pi \sin\theta d\theta$$

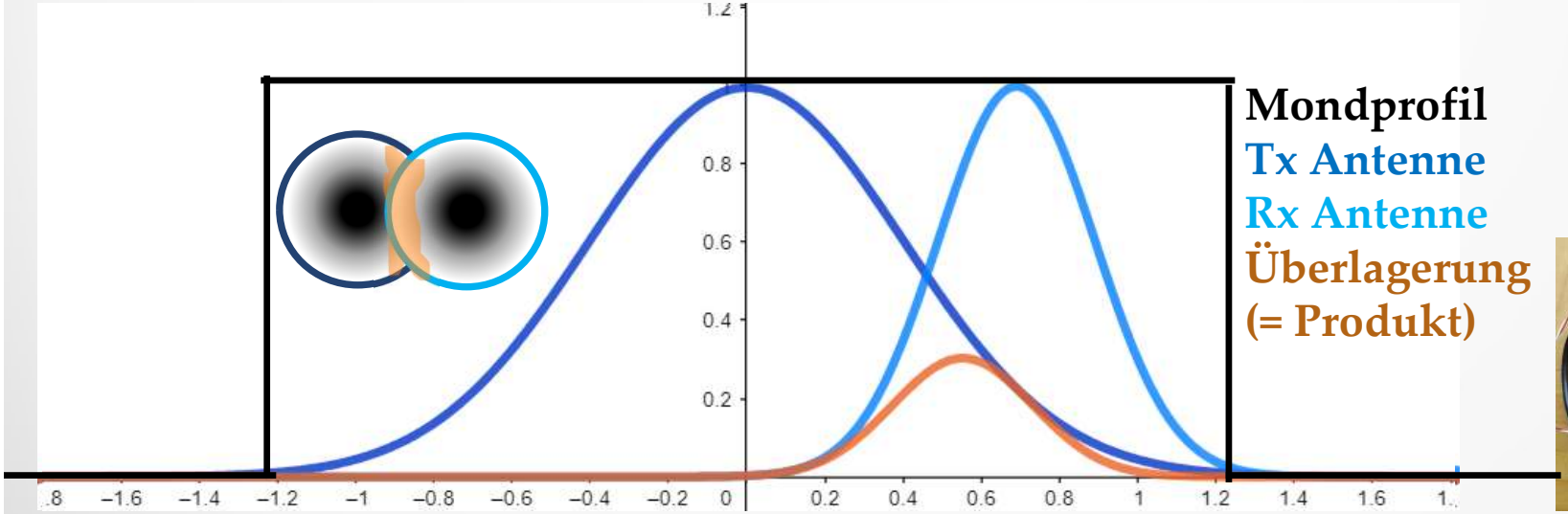
- Überlagerung von drei 3-dimensionalen Körpern deren resultierendes Volumen einer normierten Leistung entspricht.

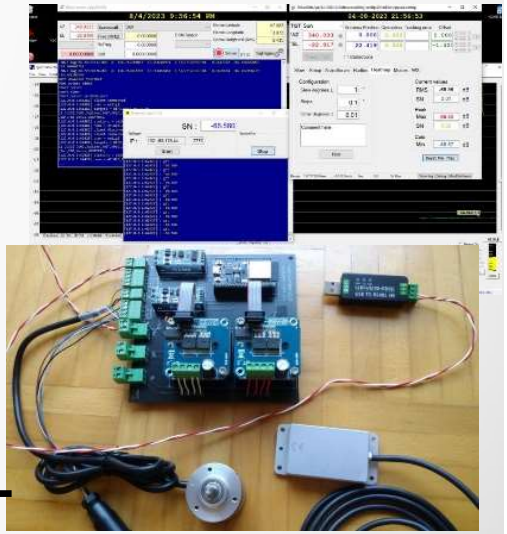


Faktor 2:
Positionier- & Nachführgenauigkeit von Antennen

- Ungenauigkeiten treten in jedem Antennensystem auf:
  - Mechanische Instabilitäten (zusätzlich abhängig von der Elevation)
  - Antrieb-/Getriebespiel & Azimut und Elevation Encoder Linearität/Auflösung
  - Mondpositionsdaten & Regelung der Nachführeinheit
- Um immer auf denselben Mondpunkt zu zeigen, müssen beide Antennen möglichst genau und synchron bewegt werden. Umso schwieriger je schmäler die Antennenkeulen sind.

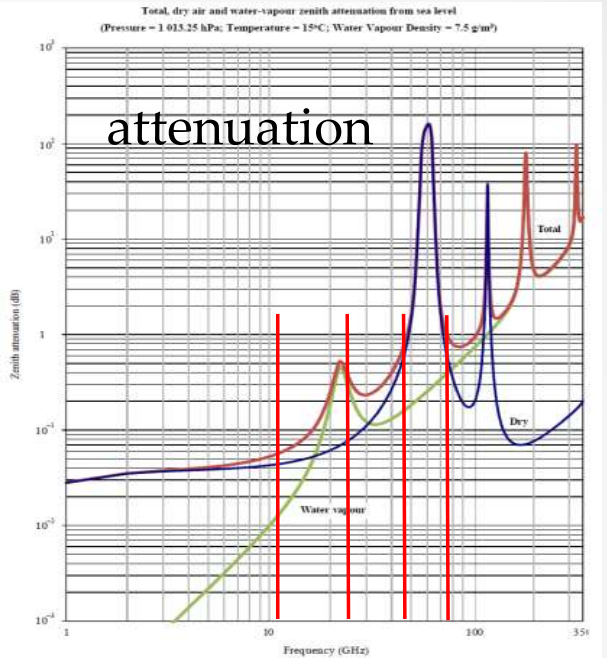
- Berechnung wie der „beam width factor“ (BWF), wobei beide Antennenprofile + Mondprofil gegeneinander verschoben sind.

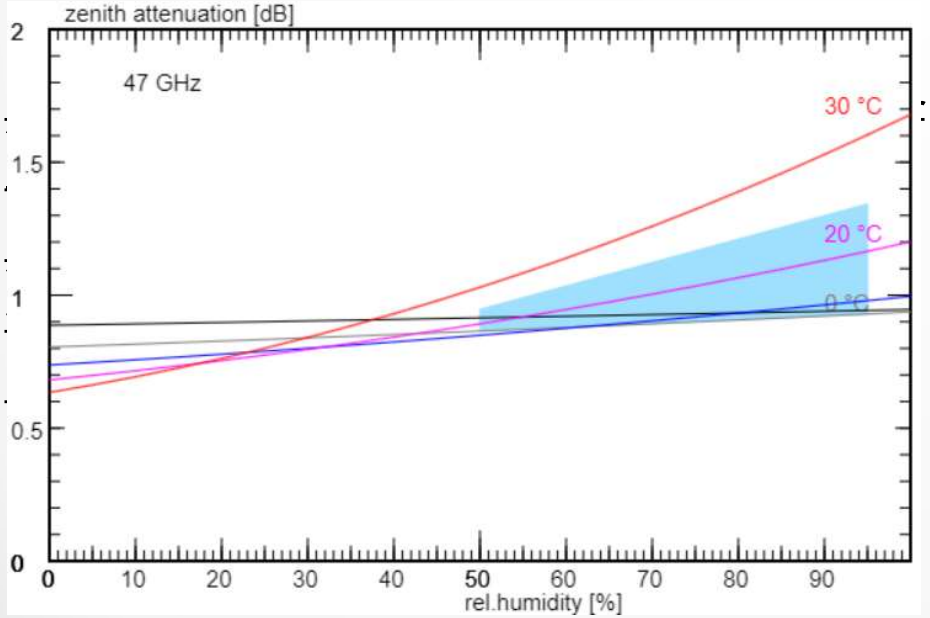


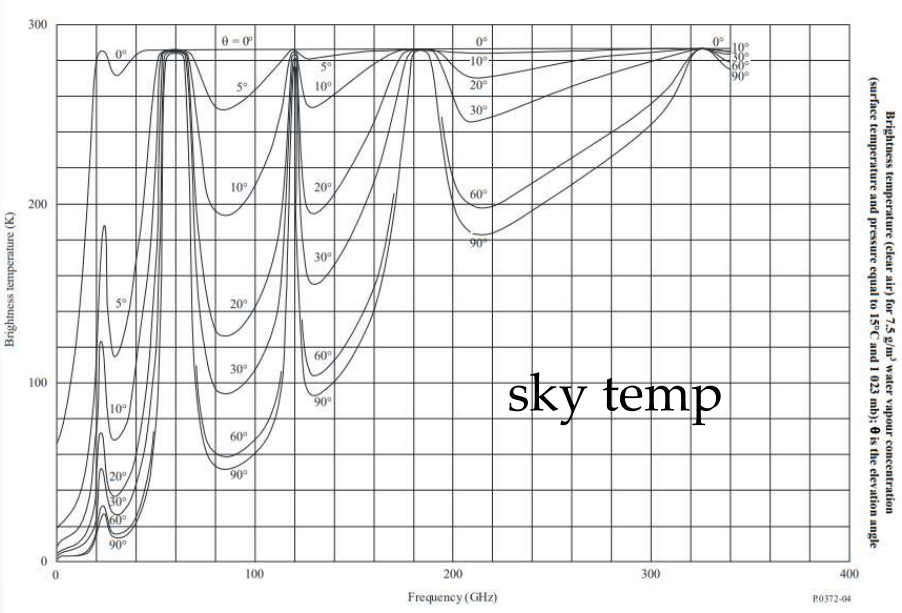


Faktor 3: Atmosphärische Dämpfung an Gasen und Wasserdampf (abhängig vom Wetter & Elevation)

- Berechnung über ein Model der ITU
- Entweder Temperatur, Luftfeuchte und Luftdruck am Boden verwenden …
- … oder über Radiosonden-Aufstieg den gesamten Wasserdampf in der Atmosphäre messen
-







Faktor 4:
„Ruze“ Verluste durch Spiegelungenauigkeiten

- Loss [dB]= 685 $\left(\frac{RMS}{\lambda}\right)^2$ RMS … root mean square ≈ $\frac{max_{peak} - min_{peak}}{4}$

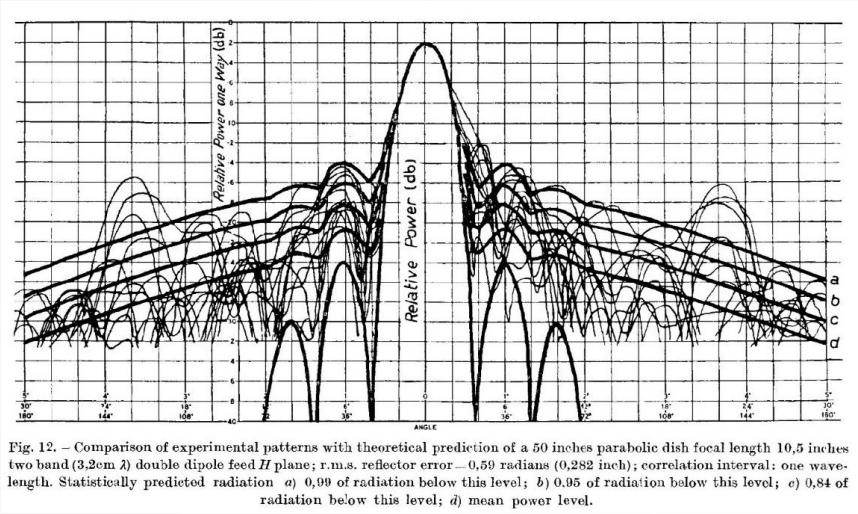


Fig. 12. – Comparison of experimental patterns with theoretical prediction of a 50 inches parabolic dish focal length 10,5 inches two band (3,2cm λ) double dipole feed H plane; r.m.s. reflector error — 0,59 radians (0,282 inch); correlation interval: one wavelength. Statistically predicted radiation *a*) 0,99 of radiation below this level; *b*) 0,95 of radiation below this level; *c*) 0,84 of radiation below this level; *d*) mean power level.

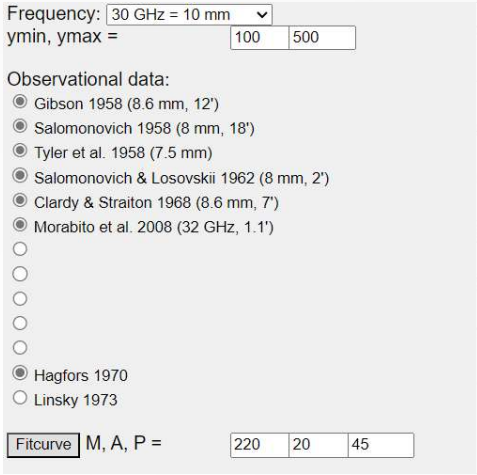
- Beispiele für gute Standardspiegel
  - 0,8 m -> RMS = 0,17 mm loss (47 GHz) = 0,5 dB
  - 1,2 m -> RMS = 0,20 mm loss (47 GHz) = 0,7 dB
  - 2,4 m -> RMS = 0,30 mm loss (47 GHz) = 1,7 dB
  - 3,0 m -> RMS = 0,35 mm loss (47 GHz) = 2,3 dB

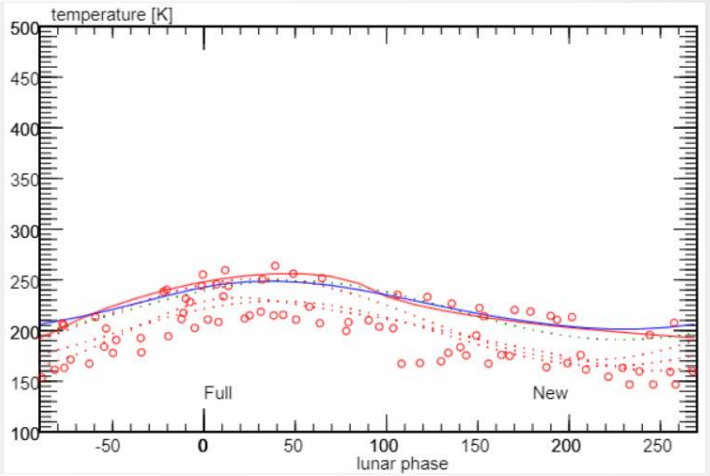
- Beispiel für sehr guten Spiegel
  - 2,1 m -> RMS = 0,06 mm loss (47 GHz) = 0,06 dB

Faktor 5:
Mond Strahlungstemperatur & Reflektivität

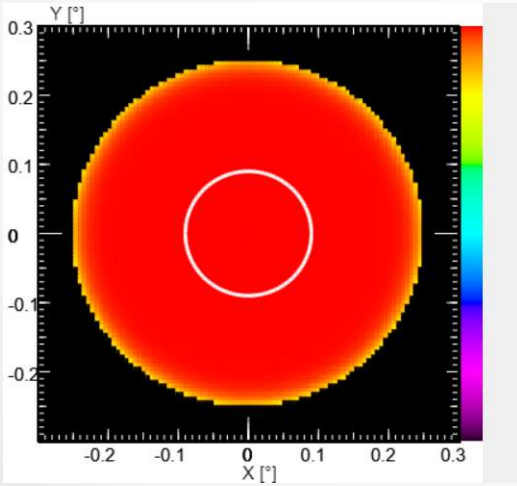
- Monddaten vornehmlich aus den 1960's, 70's und 80's vorhanden.

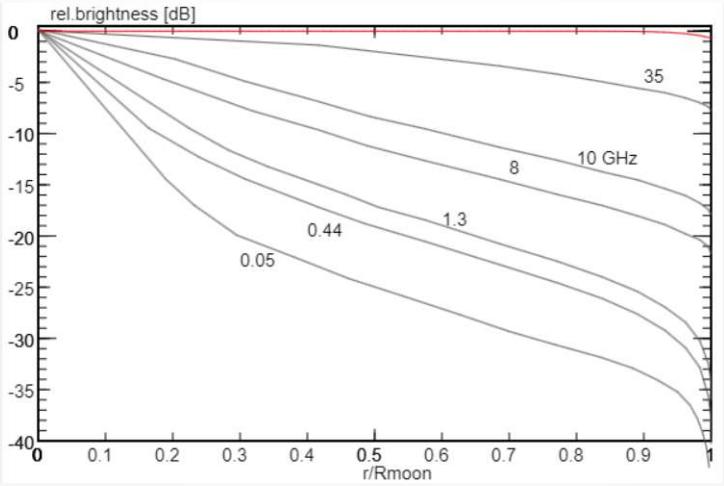
- **Temperatur:**
  Mittelwert & Schwankung abhängig von Frequenz, Messwerte schwanken stark. 30 - 75 GHz keine Messdaten verfügbar.





- **Reflektivität:** erst ab 40 GHz Tophat Profil





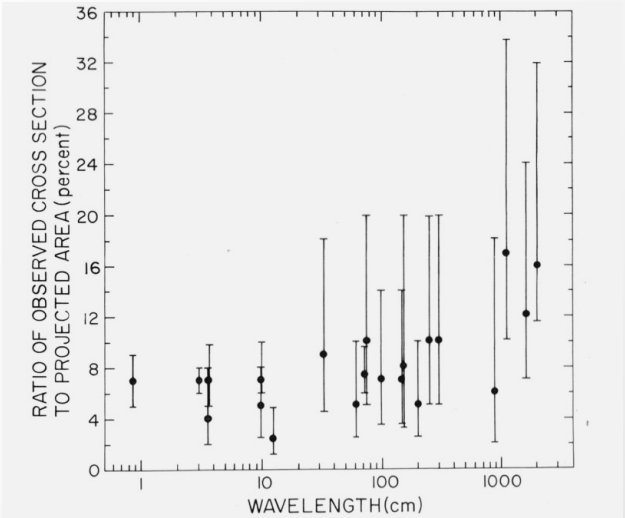


FIGURE 2. *The variation of the total cross section σ as a function of the radar wavelength λ.*
These values are expressed as a fraction of the moon's projected disk πa^2 and have been obtained from the papers listed in table 1.

Übersicht

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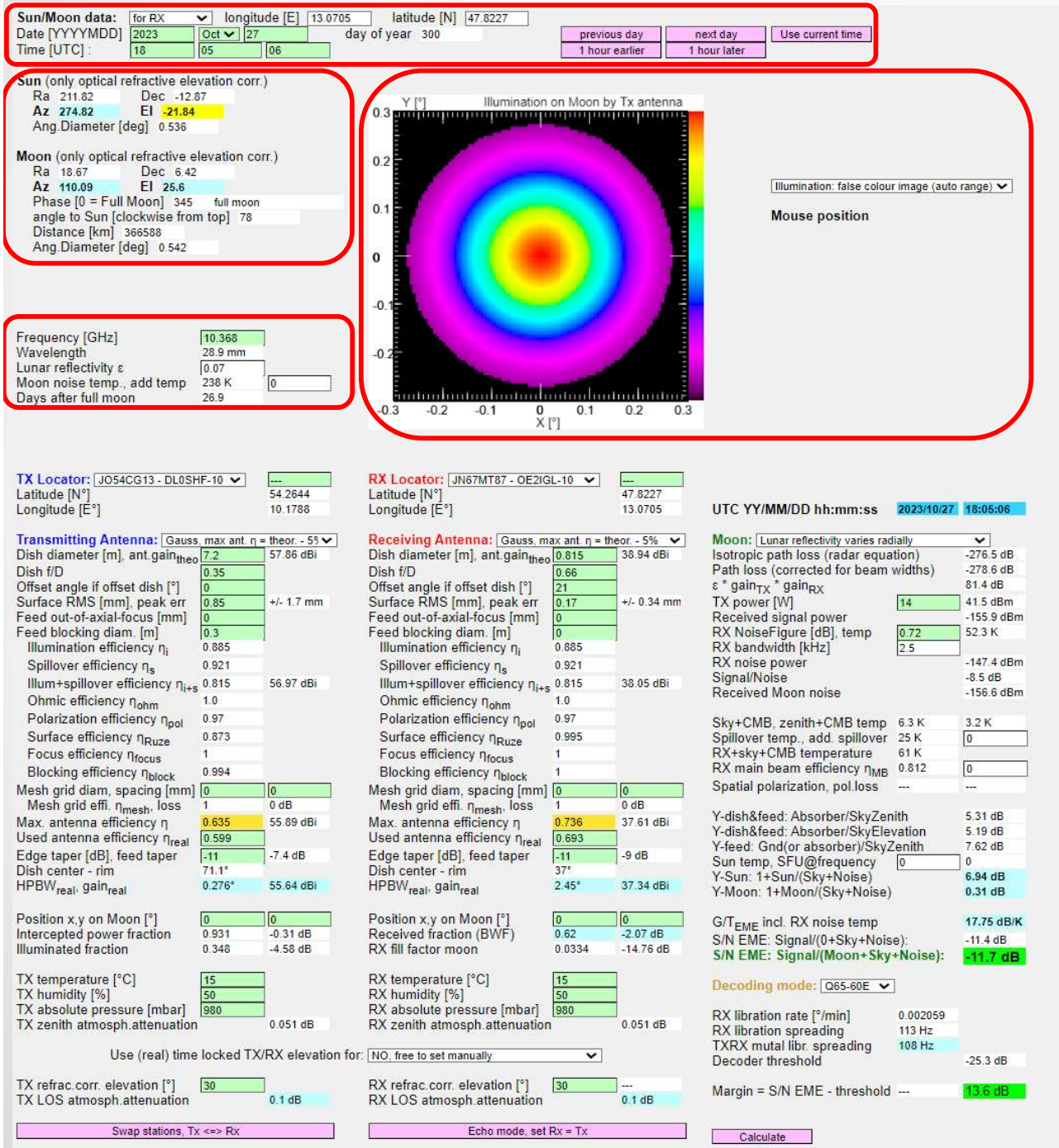
- Zusammenfassung

QR-Code EME tool

EME Link Analysis Tool von OE2IGL

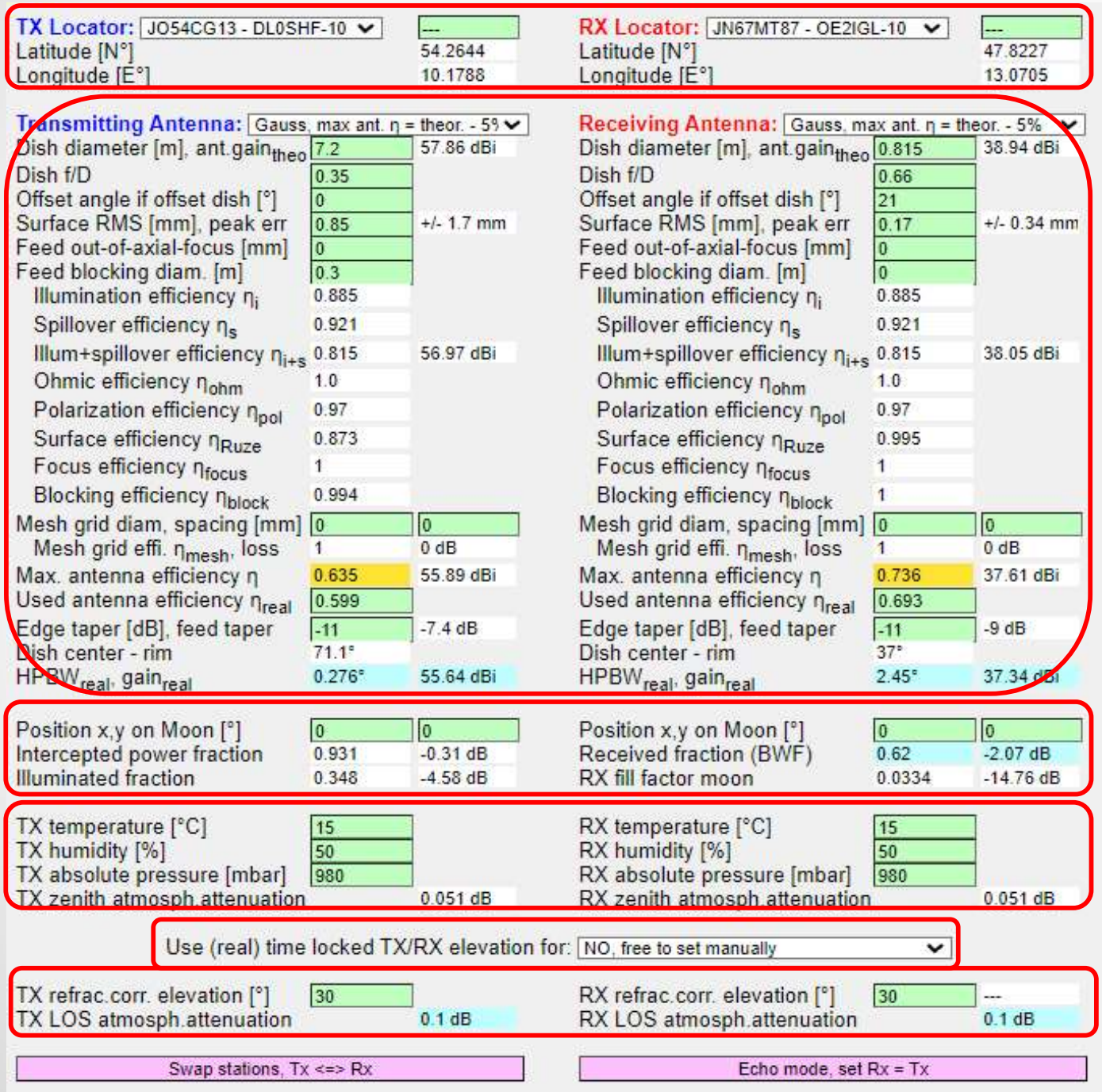


- Als webbasierte Version 2023 entwickelt, Vorarbeit Ende 2022 von DF3GJ
- Alle bekannten Effekte sind inkludiert
- Mond/Sonnenrauschen EME S/N Berechnung
- Analysetool zum Variieren der Parameter

https://wettersat.bplaced.net/EME/EME.html

Dorsten, 17.02.2024

EME Link Analysis Tool: Tx und Rx Eingabe

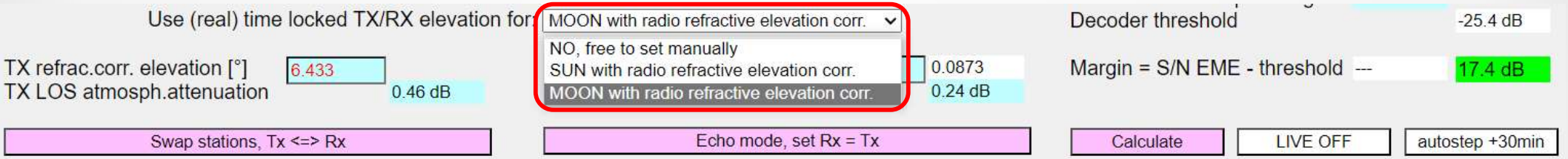


TX Locator: JO54CG13 - DL0SHF-10			RX Locator: JN67MT87 - OE2IGL-10		
Latitude [N°]		54.2644	Latitude [N°]		47.8227
Longitude [E°]		10.1788	Longitude [E°]		13.0705
Transmitting Antenna: Gauss, max ant. η = theor. - 5%			**Receiving Antenna:** Gauss, max ant. η = theor. - 5%		
Dish diameter [m], ant.gain$_{theo}$	7.2	57.86 dBi	Dish diameter [m], ant.gain$_{theo}$	0.815	38.94 dBi
Dish f/D	0.35		Dish f/D	0.66	
Offset angle if offset dish [°]	0		Offset angle if offset dish [°]	21	
Surface RMS [mm], peak err	0.85	+/- 1.7 mm	Surface RMS [mm], peak err	0.17	+/- 0.34 mm
Feed out-of-axial-focus [mm]	0		Feed out-of-axial-focus [mm]	0	
Feed blocking diam. [m]	0.3		Feed blocking diam. [m]	0	
Illumination efficiency η_i	0.885		Illumination efficiency η_i	0.885	
Spillover efficiency η_s	0.921		Spillover efficiency η_s	0.921	
Illum+spillover efficiency η_{i+s}	0.815	56.97 dBi	Illum+spillover efficiency η_{i+s}	0.815	38.05 dBi
Ohmic efficiency η_{ohm}	1.0		Ohmic efficiency η_{ohm}	1.0	
Polarization efficiency η_{pol}	0.97		Polarization efficiency η_{pol}	0.97	
Surface efficiency η_{Ruze}	0.873		Surface efficiency η_{Ruze}	0.995	
Focus efficiency η_{focus}	1		Focus efficiency η_{focus}	1	
Blocking efficiency η_{block}	0.994		Blocking efficiency η_{block}	1	
Mesh grid diam, spacing [mm]	0	0	Mesh grid diam, spacing [mm]	0	0
Mesh grid effi. η_{mesh}, loss	1	0 dB	Mesh grid effi. η_{mesh}, loss	1	0 dB
Max. antenna efficiency η	0.635	55.89 dBi	Max. antenna efficiency η	0.736	37.61 dBi
Used antenna efficiency η_{real}	0.599		Used antenna efficiency η_{real}	0.693	
Edge taper [dB], feed taper	-11	-7.4 dB	Edge taper [dB], feed taper	-11	-9 dB
Dish center - rim	71.1°		Dish center - rim	37°	
HPBW$_{real}$, gain$_{real}$	0.276°	55.64 dBi	HPBW$_{real}$, gain$_{real}$	2.45°	37.34 dBi
Position x,y on Moon [°]	0	0	Position x,y on Moon [°]	0	0
Intercepted power fraction	0.931	-0.31 dB	Received fraction (BWF)	0.62	-2.07 dB
Illuminated fraction	0.348	-4.58 dB	RX fill factor moon	0.0334	-14.76 dB
TX temperature [°C]	15		RX temperature [°C]	15	
TX humidity [%]	50		RX humidity [%]	50	
TX absolute pressure [mbar]	980		RX absolute pressure [mbar]	980	
TX zenith atmosph.attenuation		0.051 dB	RX zenith atmosph.attenuation		0.051 dB
Use (real) time locked TX/RX elevation for: NO, free to set manually					
TX refrac.corr. elevation [°]	30		RX refrac.corr. elevation [°]	30	---
TX LOS atmosph.attenuation		0.1 dB	RX LOS atmosph.attenuation		0.1 dB
Swap stations, Tx <=> Rx			Echo mode, set Rx = Tx		

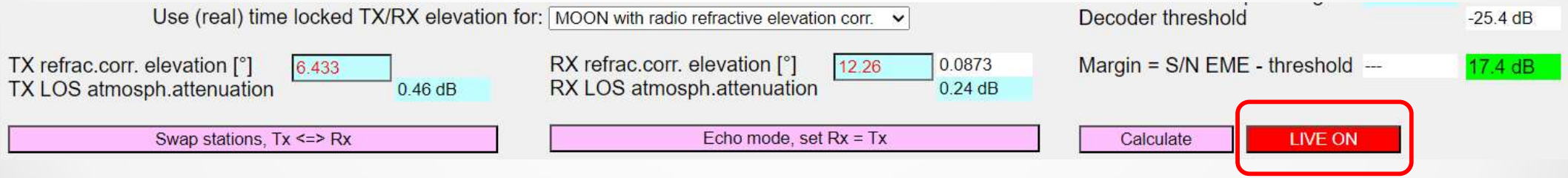
- >40 EME Anlagen sind integriert
- Antennenparameter Edge Taper, HPBW, Wirkungsgrade, Antennen Gain, …
- Verluste aufgrund Antennen Nachführ-ungenauigkeiten
- „Beam Width Factor“
- Atmosphärische Dämpfung
- EME Echtzeitbetrieb

EME Link Analysis Tool: Echtzeitbetrieb

- „Use (real) time locked Tx/Rx elevation for:“ für Mond oder Sonne auswählen

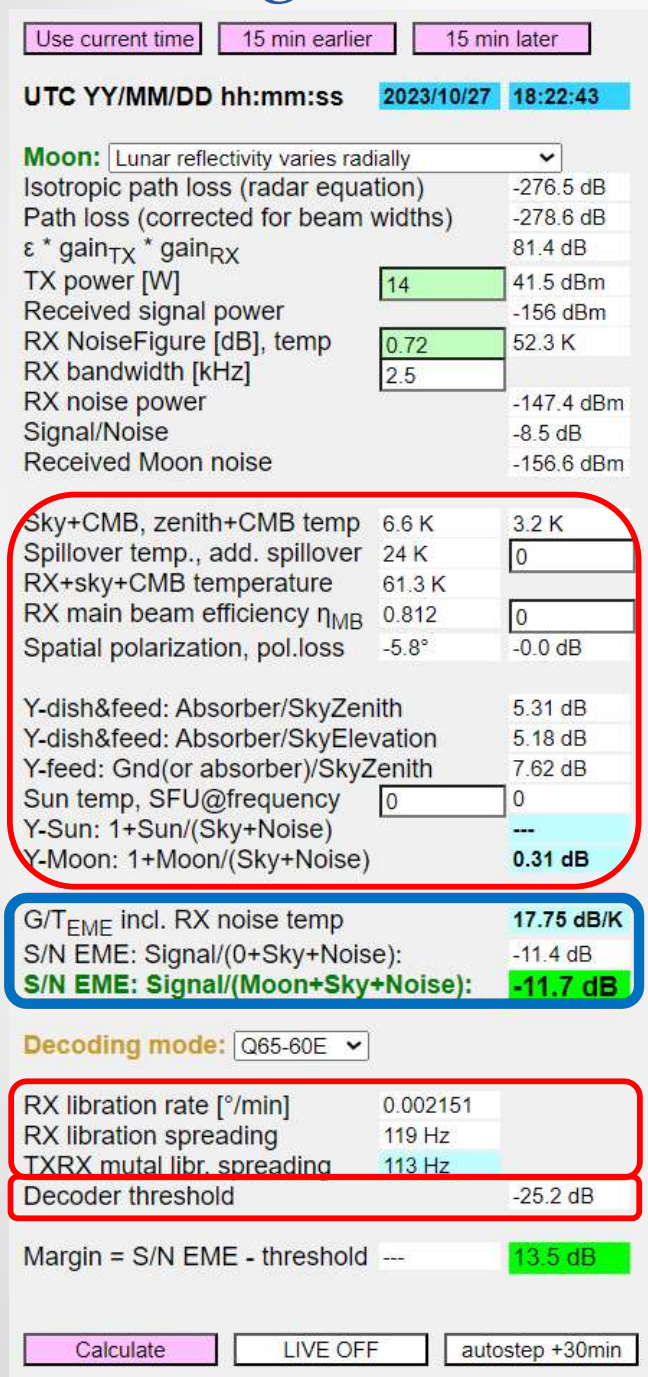


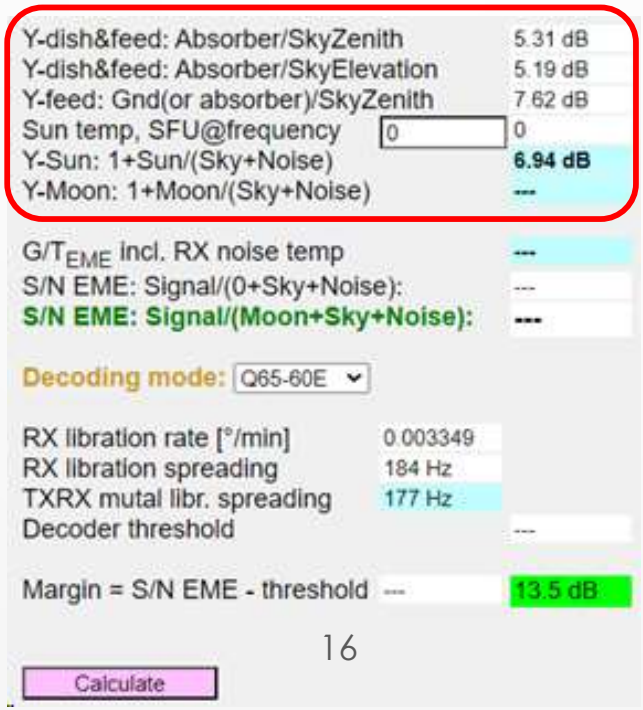
- Button „LIVE OFF“ drücken damit dieser auf „LIVE ON“ geht.



- Ab jetzt wird alle 5 sec S/N, … aufgrund der aktuellen Uhrzeit, Elevationen der Rx/Tx Stationen LIVE berechnet.

EME Link Analysis Tool: Ausgabe S/N, Libration, $Y_{moon/sun}$, …

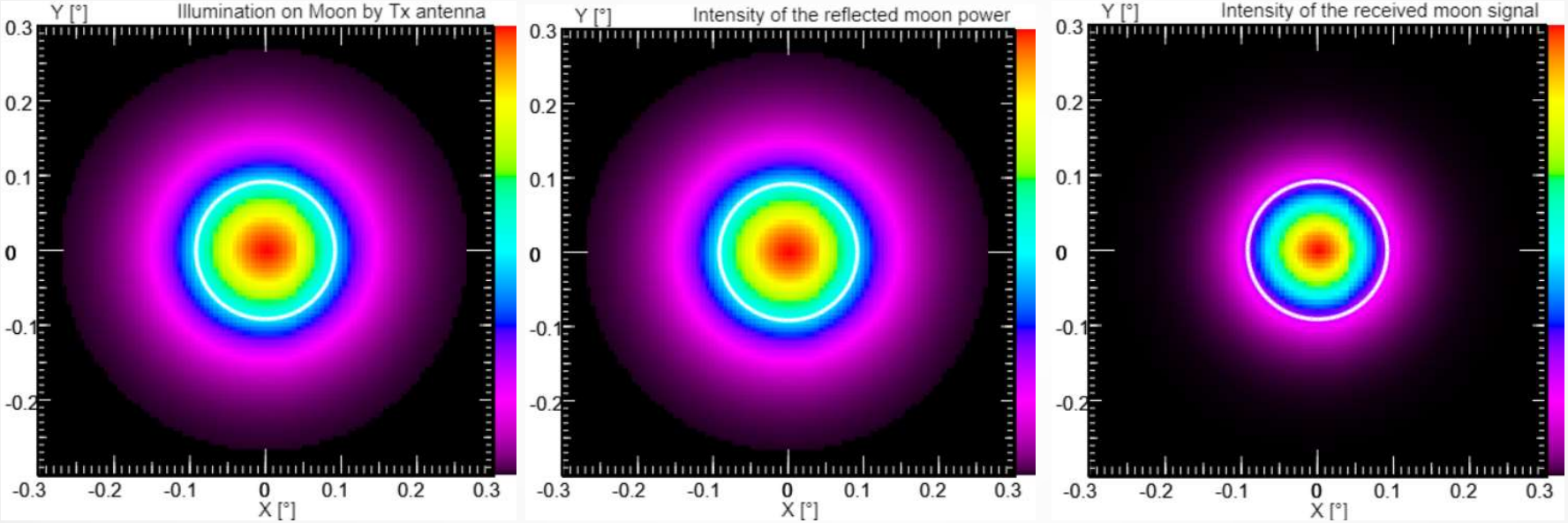




- Sky-Temp, Spillover und main beam Wirkungsgrad haben Einfluss auf Y_{sun}, Y_{moon}
- Mond Libration (auch abhängig vom BWF)
- Decoder Threshold und S/N sagt uns ob Signal decodierbar ist.

Grafik zum besseren Verständnis:
Mond Ausleuchtung – Mond Reflexion – Rx Antenne

- 47 GHz, 2x 2,4 m Spiegel, Tx/Rx Antenne Mondmitte

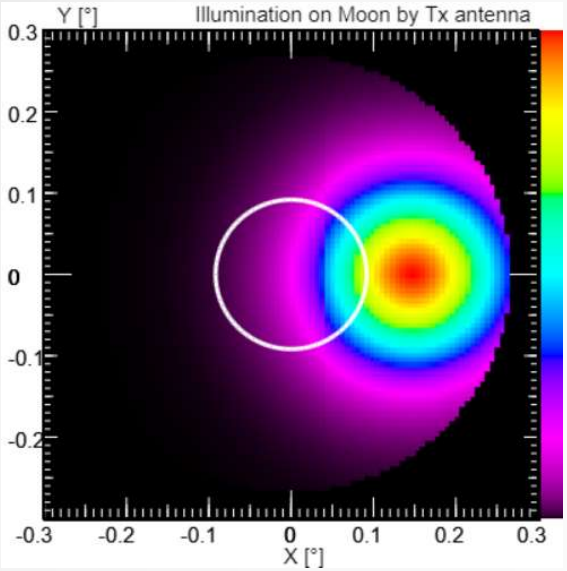


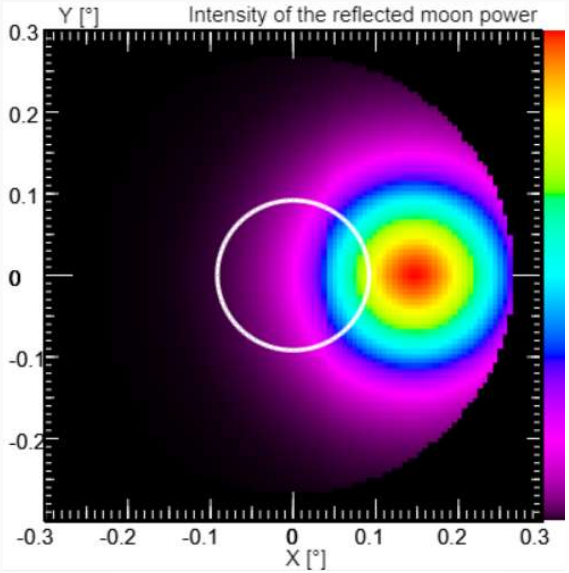
* Relative Werte (keine Absolutwerte)

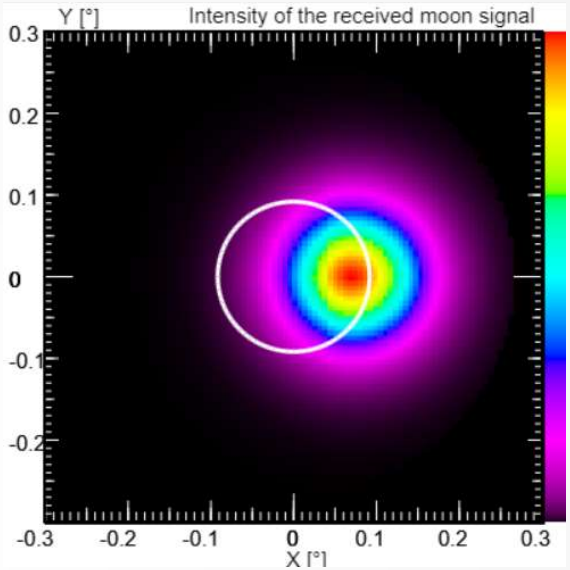
Grafik zum besseren Verständnis:
Mond Ausleuchtung – Mond Reflexion – Rx Antenne

- 47 GHz, 2x 2,4 m Spiegel

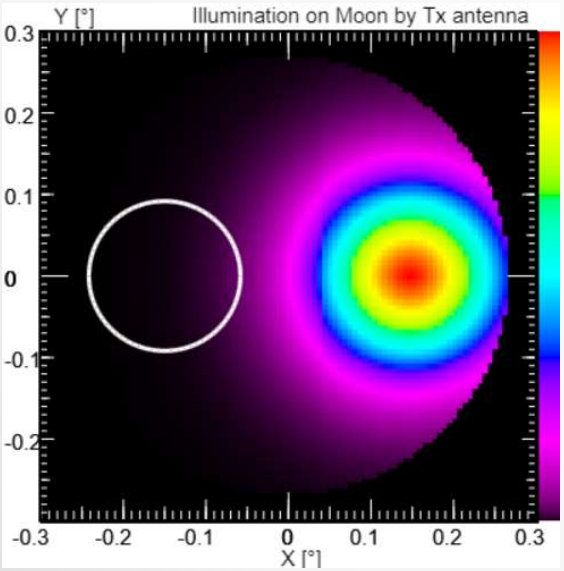
* Relative Werte (keine Absolutwerte)

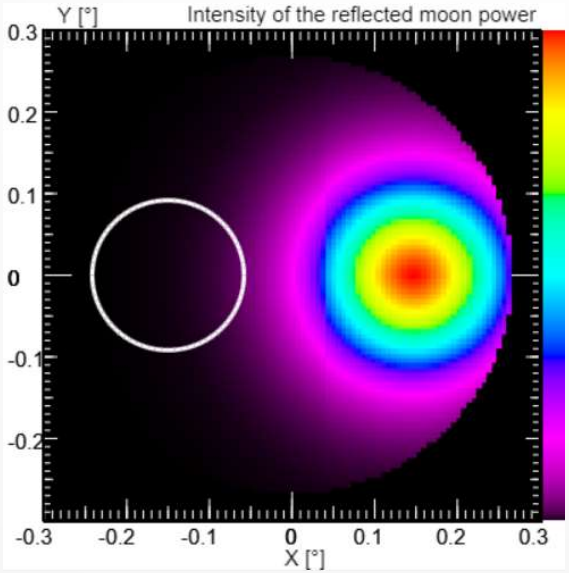


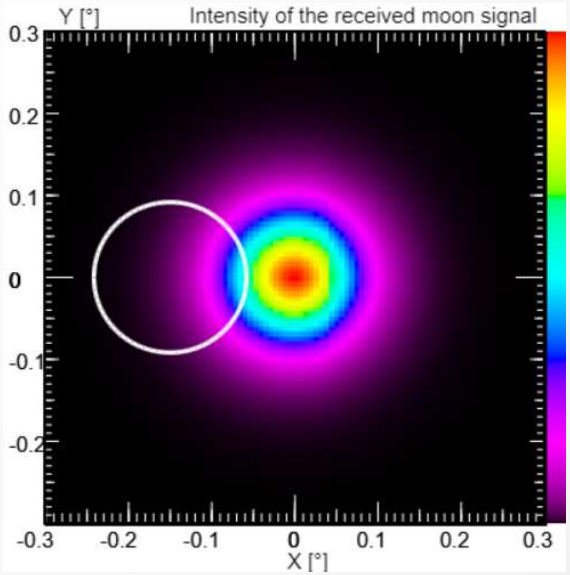




Tx +0,15°





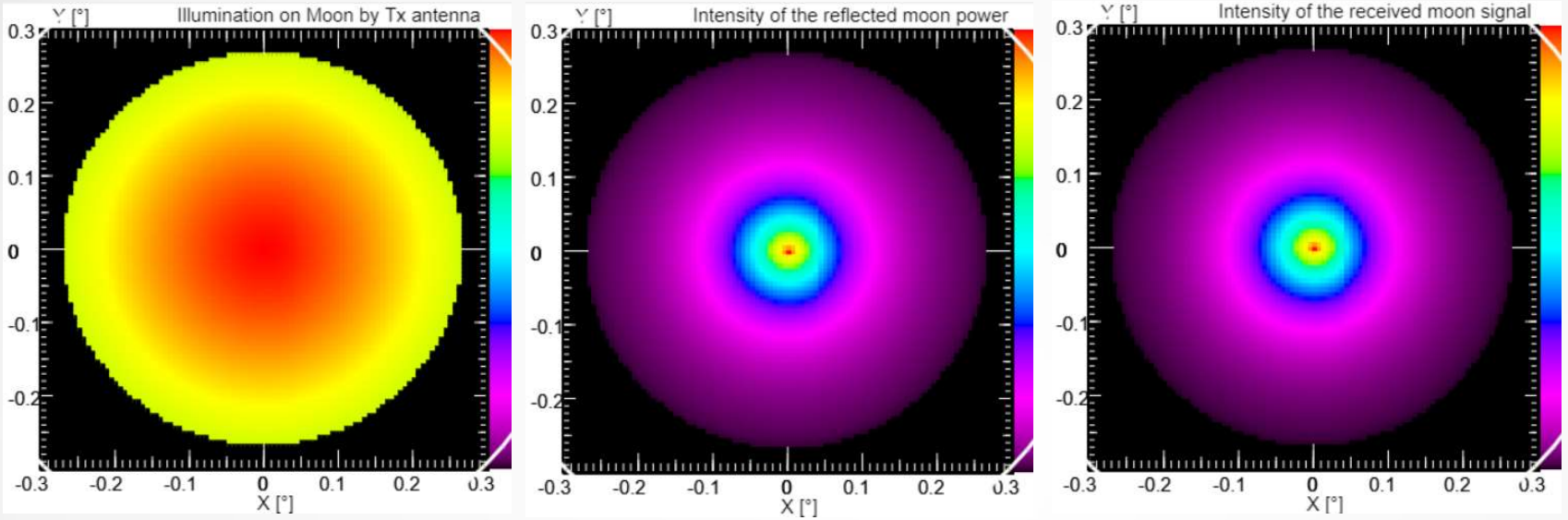


Tx +0,15°
Rx -0,15°

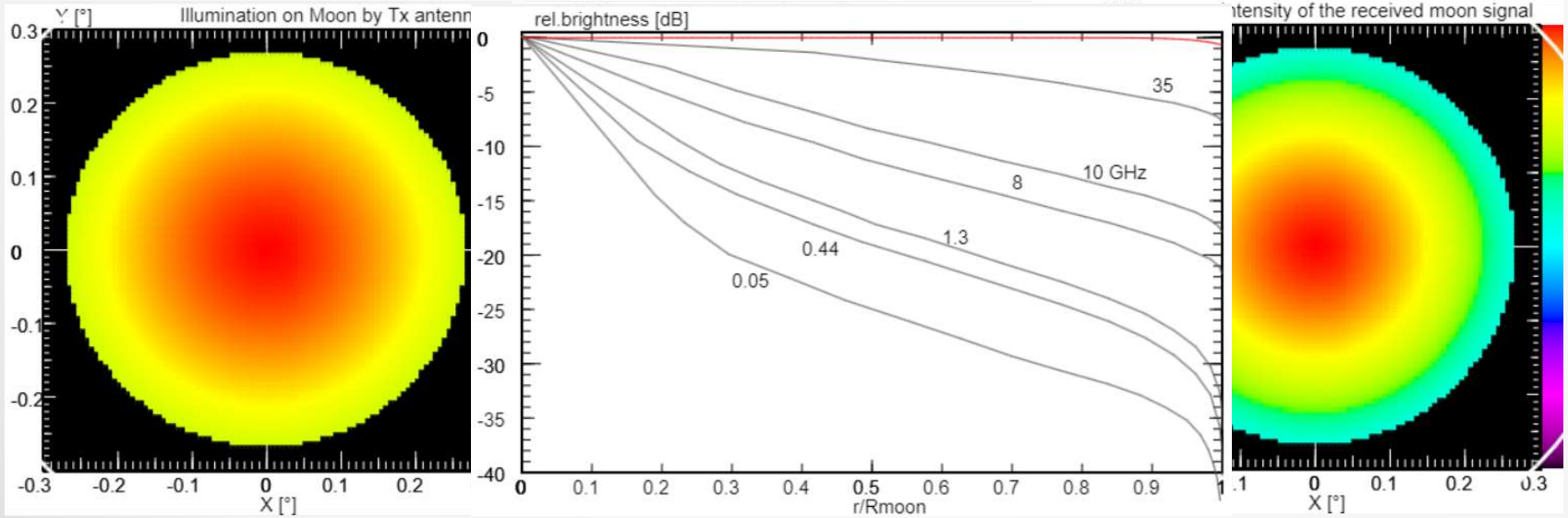
Grafik zum besseren Verständnis: Einfluss Mond Profil

- 10 GHz, 2x 2,4 m Spiegel

* Relative Werte (keine Absolutwerte)



Mond Gauss Profil



Bsp 1: Echo (Tx & Rx Antenne gleich groß)

TX Locator: IM68BN - CT1BYM-47			**RX Locator:** IM68BN - CT1BYM-47		
Latitude [N°]	38.5644		Latitude [N°]	38.5644	
Longitude [E°]	-7.87118		Longitude [E°]	-7.87118	
Transmitting Antenna: Gauss, max ant. η = theor. - 5%			**Receiving Antenna:** Gauss, max ant. η = theor. - 5%		
Dish diameter [m], ant.gain$_{theo}$	1.2	55.44 dBi	Dish diameter [m], ant.gain$_{theo}$	1.2	55.44 dBi
Dish f/D	0.66		Dish f/D	0.66	
Offset angle if offset dish [°]	21		Offset angle if offset dish [°]	21	
Surface RMS [mm], peak err	0.2	+/- 0.4 mm	Surface RMS [mm], peak err	0.2	+/- 0.4 mm
Feed out-of-axial-focus [mm]	0		Feed out-of-axial-focus [mm]	0	
Feed blocking diam. [m]	0		Feed blocking diam. [m]	0	
Illumination efficiency η_i	0.847		Illumination efficiency η_i	0.847	
Spillover efficiency η_s	0.95		Spillover efficiency η_s	0.95	
Illum+spillover efficiency η_{i+s}	0.805	54.5 dBi	Illum+spillover efficiency η_{i+s}	0.805	54.5 dBi
Ohmic efficiency η_{ohm}	1.0		Ohmic efficiency η_{ohm}	1.0	
Polarization efficiency η_{pol}	0.97		Polarization efficiency η_{pol}	0.97	
Surface efficiency η_{Ruze}	0.856		Surface efficiency η_{Ruze}	0.856	
Focus efficiency η_{focus}	1		Focus efficiency η_{focus}	1	
Blocking efficiency η_{block}	1		Blocking efficiency η_{block}	1	
Mesh grid diam, spacing [mm]	0	0	Mesh grid diam, spacing [mm]	0	0
Mesh grid effi. η_{mesh}, loss	1	0 dB	Mesh grid effi. η_{mesh}, loss	1	0 dB
Max. antenna efficiency η	0.618	53.35 dBi	Max. antenna efficiency η	0.618	53.35 dBi
Used antenna efficiency η_{real}	0.6		Used antenna efficiency η_{real}	0.6	
Edge taper [dB], feed taper	-13	-11 dB	Edge taper [dB], feed taper	-13	-11 dB
Dish center - rim	37°		Dish center - rim	37°	
HPBW$_{real}$, gain$_{real}$	0.368°	53.22 dBi	HPBW$_{real}$, gain$_{real}$	0.368°	53.22 dBi
Position x,y on Moon [°]	0	0	Position x,y on Moon [°]	0	0
Intercepted power fraction	0.777	-1.09 dB	Received fraction (BWF)	0.318	-4.97 dB
Illuminated fraction	0.516	-2.87 dB	RX fill factor moon	0.777	-1.09 dB
TX temperature [°C]	15		RX temperature [°C]	15	
TX humidity [%]	50		RX humidity [%]	50	
TX absolute pressure [mbar]	980		RX absolute pressure [mbar]	980	
TX zenith atmosph.attenuation		0.87 dB	RX zenith atmosph.attenuation		0.87 dB
Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr.					
TX refrac.corr. elevation [°]	46.3		RX refrac.corr. elevation [°]	46.3	0.0186
TX LOS atmosph.attenuation		1.2 dB	RX LOS atmosph.attenuation		1.2 dB

Use current time | 15 min earlier | 15 min later

UTC YY/MM/DD hh:mm:ss	2023/10/27	21:12:04
Moon: Lunar reflectivity varies radially		
Isotropic path loss (radar equation)		-289.7 dB
Path loss (corrected for beam widths)		-294.7 dB
ε * gain$_{TX}$ * gain$_{RX}$		94.9 dB
TX power [W]	42	46.2 dBm
Received signal power		-155.9 dBm
RX NoiseFigure [dB], temp	2	170 K
RX bandwidth [kHz]	2.5	
RX noise power		-142.3 dBm
Signal/Noise		-13.6 dB
Received Moon noise		-144.1 dBm
Sky+CMB, zenith+CMB temp	65 K	49 K
Spillover temp., add. spillover	41 K	0
RX+sky+CMB temperature	235 K	
RX main beam efficiency η_{MB}	0.727	0
Spatial polarization, pol.loss	0.0°	0.0 dB
Y-dish&feed: Absorber/SkyZenith		2.49 dB
Y-dish&feed: Absorber/SkyElevation		2.3 dB
Y-feed: Gnd(or absorber)/SkyZenith		3.16 dB
Sun temp, SFU@frequency	0	0
Y-Sun: 1+Sun/(Sky+Noise)		---
Y-Moon: 1+Moon/(Sky+Noise)		**1.56 dB**
G/T$_{EME}$ incl. RX noise temp		**26.89 dB/K**
S/N EME: Signal/(0+Sky+Noise):		-16.8 dB
S/N EME: Signal/(Moon+Sky+Noise):		**-18.4 dB**
Decoding mode: Q65-60E		
RX libration rate [°/min]	0.00294	
RX libration spreading	527 Hz	
TXRX mutal libr. spreading	527 Hz	
Decoder threshold		-20.4 dB
Margin = S/N EME - threshold	---	2.0 dB

Bsp 2: Tx-Ant groß, Rx-Ant klein

Was ist besser? Großer Spiegel beim Senden oder Empfangen?

TX Locator: JO62PK - DL7YC-47		---
Latitude [N°]		52.4394
Longitude [E°]		13.2955
Transmitting Antenna: Gauss, max ant. η = theor. - 5%		
Dish diameter [m], ant.gain$_{theo}$	2.4	61.46 dBi
Dish f/D	0.4	
Offset angle if offset dish [°]	0	
Surface RMS [mm], peak err	0.3	+/- 0.6 mm
Feed out-of-axial-focus [mm]	0	
Feed blocking diam. [m]	0.2	
Illumination efficiency η_i	0.885	
Spillover efficiency η_s	0.921	
Illum+spillover efficiency η_{i+s}	0.815	60.57 dBi
Ohmic efficiency η_{ohm}	1.0	
Polarization efficiency η_{pol}	0.97	
Surface efficiency η_{Ruze}	0.705	
Focus efficiency η_{focus}	1	
Blocking efficiency η_{block}	0.976	
Mesh grid diam, spacing [mm]	0	0
Mesh grid effi. η_{mesh}, loss	1	0 dB
Max. antenna efficiency η	0.493	58.39 dBi
Used antenna efficiency η_{real}	0.493	
Edge taper [dB], feed taper	-11	-8.1 dB
Dish center - rim	64°	
HPBW$_{real}$, gain$_{real}$	0.179°	58.39 dBi
Position x,y on Moon [°]	0	0
Intercepted power fraction	0.997	-0.01 dB
Illuminated fraction	0.167	-7.78 dB
TX temperature [°C]	15	
TX humidity [%]	50	
TX absolute pressure [mbar]	980	
TX zenith atmosph.attenuation		0.87 dB
TX refrac.corr. elevation [°]	44.52	
TX LOS atmosph.attenuation		1.2 dB

RX Locator: JO62PK - DL7YC-47		---
Latitude [N°]		52.4394
Longitude [E°]		13.2955
Receiving Antenna: Gauss, max ant. η = theor. - 5%		
Dish diameter [m], ant.gain$_{theo}$	1.2	55.44 dBi
Dish f/D	0.4	
Offset angle if offset dish [°]	0	
Surface RMS [mm], peak err	0.2	+/- 0.4 mm
Feed out-of-axial-focus [mm]	0	
Feed blocking diam. [m]	0.2	
Illumination efficiency η_i	0.885	
Spillover efficiency η_s	0.921	
Illum+spillover efficiency η_{i+s}	0.815	54.55 dBi
Ohmic efficiency η_{ohm}	1.0	
Polarization efficiency η_{pol}	0.97	
Surface efficiency η_{Ruze}	0.856	
Focus efficiency η_{focus}	1	
Blocking efficiency η_{block}	0.906	
Mesh grid diam, spacing [mm]	0	0
Mesh grid effi. η_{mesh}, loss	1	0 dB
Max. antenna efficiency η	0.563	52.95 dBi
Used antenna efficiency η_{real}	0.563	
Edge taper [dB], feed taper	-11	-8.1 dB
Dish center - rim	64°	
HPBW$_{real}$, gain$_{real}$	0.358°	52.95 dBi
Position x,y on Moon [°]	0	0
Received fraction (BWF)	0.135	-8.69 dB
RX fill factor moon	0.774	-1.11 dB
RX temperature [°C]	15	
RX humidity [%]	50	
RX absolute pressure [mbar]	980	
RX zenith atmosph.attenuation		0.87 dB
RX refrac.corr. elevation [°]	44.52	0.0197
RX LOS atmosph.attenuation		1.2 dB

Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr.

Use current time | 15 min earlier | 15 min later

UTC YY/MM/DD hh:mm:ss	2023/10/30	21:30:15
Moon: Lunar reflectivity varies radially		
Isotropic path loss (radar equation)		-290.3 dB
Path loss (corrected for beam widths)		-298.9 dB
ε * gain$_{TX}$ * gain$_{RX}$		99.8 dB
TX power [W]	42	46.2 dBm
Received signal power		-155.4 dBm
RX NoiseFigure [dB], temp	2	170 K
RX bandwidth [kHz]	2.5	
RX noise power		-142.3 dBm
Signal/Noise		-13.1 dB
Received Moon noise		-144.4 dBm
Sky+CMB, zenith+CMB temp	67 K	49 K
Spillover temp., add. spillover	45 K	0
RX+sky+CMB temperature	237 K	
RX main beam effic. η_{MB}, η_F	0.659	0.85
Spatial polarization, pol.loss	0.0°	0.0 dB
Y-dish&feed: Absorber/SkyZenith		2.47 dB
Y-dish&feed: Absorber/SkyElevation		2.28 dB
Y-feed: Gnd(or absorber)/SkyZenith		3.16 dB
Sun temp, SFU@frequency	0	0
Y-Sun: 1+Sun/(Sky+Noise)		---
Y-Moon: 1+Moon/(Sky+Noise)		**1.48 dB**
G/T$_{EME}$ incl. RX noise temp		**26.50 dB/K**
S/N EME: Signal/(0+Sky+Noise):		-16.7 dB
S/N EME: Signal/(Moon+Sky+Noise):		**-18.2 dB**
Decoding mode: Q65-60E		
RX libration rate [°/min]	0.002323	
RX libration spreading	272 Hz	
TXRX mutal libr. spreading	272 Hz	
Decoder threshold		-22.8 dB
Margin = S/N EME - threshold	---	4.7 dB

Bsp 3: Tx-Ant klein, Rx-Ant groß

S/N um 0,7 dB schlechter!

TX Locator: JO62PK - DL7YC-47			**RX Locator:** JO62PK - DL7YC-47		
Latitude [N°]	52.4394		Latitude [N°]	52.4394	
Longitude [E°]	13.2955		Longitude [E°]	13.2955	
Transmitting Antenna: Gauss, max ant. η = theor. - 5%			**Receiving Antenna:** Gauss, max ant. η = theor. - 5%		
Dish diameter [m], ant.gain$_{theo}$	1.2	55.44 dBi	Dish diameter [m], ant.gain$_{theo}$	2.4	61.46 dBi
Dish f/D	0.4		Dish f/D	0.4	
Offset angle if offset dish [°]	0		Offset angle if offset dish [°]	0	
Surface RMS [mm], peak err	0.2	+/- 0.4 mm	Surface RMS [mm], peak err	0.3	+/- 0.6 mm
Feed out-of-axial-focus [mm]	0		Feed out-of-axial-focus [mm]	0	
Feed blocking diam. [m]	0.2		Feed blocking diam. [m]	0.2	
Illumination efficiency η_i	0.885		Illumination efficiency η_i	0.885	
Spillover efficiency η_s	0.921		Spillover efficiency η_s	0.921	
Illum+spillover efficiency η_{i+s}	0.815	54.55 dBi	Illum+spillover efficiency η_{i+s}	0.815	60.57 dBi
Ohmic efficiency η_{ohm}	1.0		Ohmic efficiency η_{ohm}	1.0	
Polarization efficiency η_{pol}	0.97		Polarization efficiency η_{pol}	0.97	
Surface efficiency η_{Ruze}	0.856		Surface efficiency η_{Ruze}	0.705	
Focus efficiency η_{focus}	1		Focus efficiency η_{focus}	1	
Blocking efficiency η_{block}	0.906		Blocking efficiency η_{block}	0.976	
Mesh grid diam, spacing [mm]	0	0	Mesh grid diam, spacing [mm]	0	0
Mesh grid effi. η_{mesh}, loss	1	0 dB	Mesh grid effi. η_{mesh}, loss	1	0 dB
Max. antenna efficiency η	0.563	52.95 dBi	Max. antenna efficiency η	0.493	58.39 dBi
Used antenna efficiency η_{real}	0.563		Used antenna efficiency η_{real}	0.493	
Edge taper [dB], feed taper	-11	-8.1 dB	Edge taper [dB], feed taper	-11	-8.1 dB
Dish center - rim	64°		Dish center - rim	64°	
HPBW$_{real}$, gain$_{real}$	0.358°	52.95 dBi	HPBW$_{real}$, gain$_{real}$	0.179°	58.39 dBi
Position x,y on Moon [°]	0	0	Position x,y on Moon [°]	0	0
Intercepted power fraction	0.774	-1.11 dB	Received fraction (BWF)	0.135	-8.69 dB
Illuminated fraction	0.518	-2.86 dB	RX fill factor moon	0.997	-0.01 dB
TX temperature [°C]	15		RX temperature [°C]	15	
TX humidity [%]	50		RX humidity [%]	50	
TX absolute pressure [mbar]	980		RX absolute pressure [mbar]	980	
TX zenith atmosph.attenuation		0.87 dB	RX zenith atmosph.attenuation		0.87 dB
Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr.					
TX refrac.corr. elevation [°]	44.52		RX refrac.corr. elevation [°]	44.52	0.0197
TX LOS atmosph.attenuation		1.2 dB	RX LOS atmosph.attenuation		1.2 dB

Use current time | 15 min earlier | 15 min later

UTC YY/MM/DD hh:mm:ss 2023/10/30 21:30:15

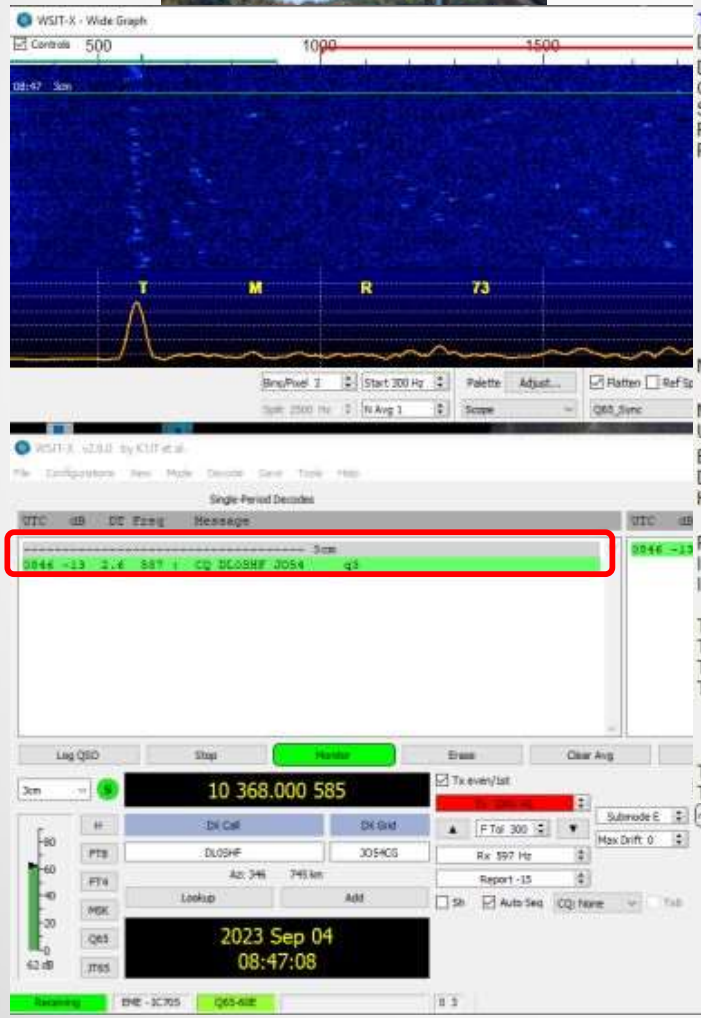
Moon: Lunar reflectivity varies radially

Isotropic path loss (radar equation)		-290.3 dB
Path loss (corrected for beam widths)		-298.9 dB
ε * gain$_{TX}$ * gain$_{RX}$		99.8 dB
TX power [W]	42	46.2 dBm
Received signal power		-155.4 dBm
RX NoiseFigure [dB], temp	2	170 K
RX bandwidth [kHz]	2.5	
RX noise power		-142.3 dBm
Signal/Noise		-13.1 dB
Received Moon noise		-143.9 dBm
Sky+CMB, zenith+CMB temp	67 K	49 K
Spillover temp., add. spillover	51 K	0
RX+sky+CMB temperature	237 K	
RX main beam effic. η_{MB}, η_F	0.577	0.85
Spatial polarization, pol.loss	0.0°	0.0 dB
Y-dish&feed: Absorber/SkyZenith		2.45 dB
Y-dish&feed: Absorber/SkyElevation		2.28 dB
Y-feed: Gnd(or absorber)/SkyZenith		3.16 dB
Sun temp, SFU@frequency	0	0
Y-Sun: 1+Sun/(Sky+Noise)		---
Y-Moon: 1+Moon/(Sky+Noise)		**1.63 dB**
G/T$_{EME}$ incl. RX noise temp		**31.46 dB/K**
S/N EME: Signal/(0+Sky+Noise):		-17.3 dB
S/N EME: Signal/(Moon+Sky+Noise):		**-18.9 dB**

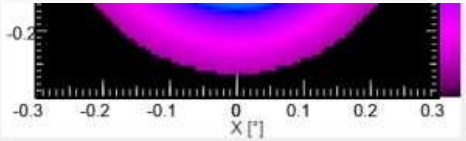
Decoding mode: Q65-60E

RX libration rate [°/min]	0.002323	
RX libration spreading	272 Hz	
TXRX mutal libr. spreading	272 Hz	
Decoder threshold		-22.8 dB
Margin = S/N EME - threshold	---	3.9 dB

Bsp 4: 82 cm Offset-Spiegel & DL0SHF @10368 MHz



Frequency [GHz]	10.368	
Wavelength	28.9 mm	
Lunar reflectivity ε	0.07	
Moon noise temp.	245 K	
Days after full moon	4.57	



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

Transmitting Antenna: Gauss, max ant. η = theor. - 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 diam. [m]	0.3	
Illumination efficiency η_i	0.885	
Spillover efficiency η_s	0.921	
Illum+spillover efficiency η_{i+s}	0.815	56.97 dBi
Ohmic efficiency η_{ohm}	1.0	
Polarization efficiency η_{pol}	0.97	
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	0.635	55.89 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$_{real}$	0.276°	55.64 dBi
Position x,y on Moon [°]	0	0
Intercepted power fraction	0.924	-0.35 dB
Illuminated fraction	0.359	-4.44 dB
TX temperature [°C]	15	
TX humidity [%]	50	
TX absolute pressure [mbar]	980	
TX zenith atmosph.attenuation		0.051 dB
TX refrac.corr. elevation [°]	12.86	
TX LOS atmosph.attenuation		0.23 dB

Receiving Antenna: Gauss, max ant. η = theor. - 5%		
Dish diameter [m], ant.gain$_{theo}$	0.815	38.94 dBi
Dish f/D	0.66	
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 diam. [m]	0	
Illumination efficiency η_i	0.885	
Spillover efficiency η_s	0.921	
Illum+spillover efficiency η_{i+s}	0.815	38.05 dBi
Ohmic efficiency η_{ohm}	1.0	
Polarization efficiency η_{pol}	0.97	
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	0.736	37.61 dBi
Used antenna efficiency η_{real}	0.699	
Edge taper [dB], feed taper	-11	-9 dB
Dish center - rim	37°	
HPBW$_{real}$, gain$_{real}$	2.44°	37.38 dBi
Position x,y on Moon [°]	0	0
Received fraction (BWF)	0.629	-2.01 dB
RX fill factor moon	0.0324	-14.9 dB
RX temperature [°C]	17	
RX humidity [%]	55	
RX absolute pressure [mbar]	940	
RX zenith atmosph.attenuation		0.052 dB
RX refrac.corr. elevation [°]	9.914	0.107
RX LOS atmosph.attenuation		0.3 dB

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

Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr.

Use current time | 15 min earlier | 15 min later

UTC YY/MM/DD hh:mm:ss	2023/9/4	08:51:42

Moon: Lunar reflectivity varies radially		
Isotropic path loss (radar equation)		-276.9 dB
Path loss (corrected for beam widths)		-279 dB
ε * gain$_{TX}$ * gain$_{RX}$		81.5 dB
TX power [W]	15	41.8 dBm
Received signal power		-156.3 dBm
RX NoiseFigure [dB], temp	0.715	51.9 K
RX bandwidth [kHz]	2.5	
RX noise power		-147.5 dBm
Signal/Noise		-8.8 dB
Received Moon noise		-156.8 dBm
Sky+CMB, zenith+CMB temp	18 K	3.3 K
Spillover temp., add. spillover	21 K	0
RX+sky+CMB temperature	72.6 K	
RX main beam efficiency η_{MB}	0.819	0
Spatial polarization, pol.loss	6.1°	-0.0 dB
Y-dish&feed: Absorber/SkyZenith		5.33 dB
Y-feed: Gnd(or absorber)/SkyZenith		7.67 dB
Sun temp, SFU@frequency	15350	345
Y-Sun: 1+Sun/(Sky+Noise)		---
Y-Moon: 1+Moon/(Sky+Noise)		0.28 dB
G/T$_{EME}$ incl. RX noise temp		17.45 dB/K
S/N EME: Signal/(0+Sky+Noise)		
S/N EME: Signal/(Moon+Sky+Noise):		**-12.2 dB**

Decoding mode: Q65-60E

RX libration rate [°/min]	0.0004616	
RX libration spreading	25.6 Hz	
TXRX mutal libr. spreading	27 Hz	
Decoder threshold		-26.9 dB
Margin = S/N EME - threshold	---	14.6 dB

Bsp 5: Minimale Anforderungen für 47.088 GHz

TX Locator: JO62QJ - DC7KY-47		---
Latitude [N°]		52.3977
Longitude [E°]		13.3788
Transmitting Antenna: Gauss, max ant. η = theor. - 5%		
Dish diameter [m], ant.gain$_{theo}$	2.4	61.46 dBi
Dish f/D	0.65	
Offset angle if offset dish [°]	21	
Surface RMS [mm], peak err	0.3	+/- 0.6 mm
Feed out-of-axial-focus [mm]	0	
Feed blocking diam. [m]	0	
Illumination efficiency η_i	0.885	
Spillover efficiency η_s	0.921	
Illum+spillover efficiency η_{i+s}	0.815	60.57 dBi
Ohmic efficiency η_{ohm}	1.0	
Polarization efficiency η_{pol}	0.97	
Surface efficiency η_{Ruze}	0.705	
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	0.507	58.51 dBi
Used antenna efficiency η_{real}	0.5	
Edge taper [dB], feed taper	-11	-9 dB
Dish center - rim	37.6°	
HPBW$_{real}$, gain$_{real}$	0.18°	58.45 dBi
Position x,y on Moon [°]	0	0
Intercepted power fraction	0.996	-0.02 dB
Illuminated fraction	0.179	-7.47 dB
TX temperature [°C]	15	
TX humidity [%]	50	
TX absolute pressure [mbar]	980	
TX zenith atmosph.attenuation		0.87 dB
TX refrac.corr. elevation [°]	38	
TX LOS atmosph.attenuation		1.4 dB

RX Locator: JO62PK - DL7YC-47		---
Latitude [N°]		52.4394
Longitude [E°]		13.2955
Receiving Antenna: Gauss, max ant. η = theor. - 5%		
Dish diameter [m], ant.gain$_{theo}$	2.4	61.46 dBi
Dish f/D	0.4	
Offset angle if offset dish [°]	0	
Surface RMS [mm], peak err	0.3	+/- 0.6 mm
Feed out-of-axial-focus [mm]	0	
Feed blocking diam. [m]	0.2	
Illumination efficiency η_i	0.885	
Spillover efficiency η_s	0.921	
Illum+spillover efficiency η_{i+s}	0.815	60.57 dBi
Ohmic efficiency η_{ohm}	1.0	
Polarization efficiency η_{pol}	0.97	
Surface efficiency η_{Ruze}	0.705	
Focus efficiency η_{focus}	1	
Blocking efficiency η_{block}	0.976	
Mesh grid diam, spacing [mm]	0	0
Mesh grid effi. η_{mesh}, loss	1	0 dB
Max. antenna efficiency η	0.493	58.39 dBi
Used antenna efficiency η_{real}	0.49	
Edge taper [dB], feed taper	-11	-8.1 dB
Dish center - rim	64°	
HPBW$_{real}$, gain$_{real}$	0.179°	58.36 dBi
Position x,y on Moon [°]	0	0
Received fraction (BWF)	0.0908	-10.42 dB
RX fill factor moon	0.996	-0.02 dB
RX temperature [°C]	15	
RX humidity [%]	50	
RX absolute pressure [mbar]	980	
RX zenith atmosph.attenuation		0.87 dB
RX refrac.corr. elevation [°]	38.05	0.0245
RX LOS atmosph.attenuation		1.4 dB

Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr.

Use current time | 15 min earlier | 15 min later

UTC YY/MM/DD hh:mm:ss	2023/11/2	06:52:58
Moon: Lunar reflectivity varies radially		
Isotropic path loss (radar equation)		-290.8 dB
Path loss (corrected for beam widths)		-301.3 dB
ε * gain$_{TX}$ * gain$_{RX}$		105.3 dB
TX power [W]	10	40 dBm
Received signal power		-158.8 dBm
RX NoiseFigure [dB], temp	2	170 K
RX bandwidth [kHz]	2.5	
RX noise power		-142.3 dBm
Signal/Noise		-16.5 dB
Received Moon noise		-144.1 dBm
Sky+CMB, zenith+CMB temp	75 K	49 K
Spillover temp., add. spillover	52 K	0
RX+sky+CMB temperature	245 K	
RX main beam effic. η_{MB}, η_F	0.574	0.85
Spatial polarization, pol.loss	-0.1°	-0.0 dB
Y-dish&feed: Absorber/SkyZenith		2.45 dB
Y-dish&feed: Absorber/SkyElevation		2.17 dB
Y-feed: Gnd(or absorber)/SkyZenith		3.16 dB
Sun temp, SFU@frequency	0	0
Y-Sun: 1+Sun/(Sky+Noise)		---
Y-Moon: 1+Moon/(Sky+Noise)		1.52 dB
G/T$_{EME}$ incl. RX noise temp		31.44 dB/K
S/N EME: Signal/(0+Sky+Noise):		-20.8 dB
S/N EME: Signal/(Moon+Sky+Noise):		**-22.4 dB**
Decoding mode: Q65-60E		
RX libration rate [°/min]	0.00152	
RX libration spreading	146 Hz	
TXRX mutal libr. spreading	145 Hz	
Decoder threshold		-24.7 dB
Margin = S/N EME - threshold	---	2.3 dB

Bsp 6: Minimale Anforderungen für 47.088 GHz

mit ungenauer Antennenpositionierung um 4 dB geringeres SNR!

TX Locator:	JO62QJ - DC7KY-47	---	**RX Locator:**	JO62PK - DL7YC-47	---	Use current time	15 min earlier	15 min later
Latitude [N°]		52.3977	Latitude [N°]		52.4394			
Longitude [E°]		13.3788	Longitude [E°]		13.2955	**UTC YY/MM/DD hh:mm:ss**	2023/11/2	06:52:58
Transmitting Antenna:	Gauss, max ant. η = theor. - 5%		**Receiving Antenna:**	Gauss, max ant. η = theor. - 5%		**Moon:**	Lunar reflectivity varies radially	
Dish diameter [m], ant.gain$_{theo}$	2.4	61.46 dBi	Dish diameter [m], ant.gain$_{theo}$	2.4	61.46 dBi	Isotropic path loss (radar equation)		-290.8 dB
Dish f/D	0.65		Dish f/D	0.4		Path loss (corrected for beam widths)		-305.5 dB
Offset angle if offset dish [°]	21		Offset angle if offset dish [°]	0		ε * gain$_{TX}$ * gain$_{RX}$		105.3 dB
Surface RMS [mm], peak err	0.3	+/- 0.6 mm	Surface RMS [mm], peak err	0.3	+/- 0.6 mm	TX power [W]	10	40 dBm
Feed out-of-axial-focus [mm]	0		Feed out-of-axial-focus [mm]	0		Received signal power		-163 dBm
Feed blocking diam. [m]	0		Feed blocking diam. [m]	0.2		RX NoiseFigure [dB], temp	2	170 K
Illumination efficiency η_i	0.885		Illumination efficiency η_i	0.885		RX bandwidth [kHz]	2.5	
Spillover efficiency η_s	0.921		Spillover efficiency η_s	0.921		RX noise power		-142.3 dBm
Illum+spillover efficiency η_{i+s}	0.815	60.57 dBi	Illum+spillover efficiency η_{i+s}	0.815	60.57 dBi	Signal/Noise		-20.7 dB
Ohmic efficiency η_{ohm}	1.0		Ohmic efficiency η_{ohm}	1.0		Received Moon noise		-144.2 dBm
Polarization efficiency η_{pol}	0.97		Polarization efficiency η_{pol}	0.97				
Surface efficiency η_{Ruze}	0.705		Surface efficiency η_{Ruze}	0.705		Sky+CMB, zenith+CMB temp	75 K	49 K
Focus efficiency η_{focus}	1		Focus efficiency η_{focus}	1		Spillover temp., add. spillover	52 K	0
Blocking efficiency η_{block}	1		Blocking efficiency η_{block}	0.976		RX+sky+CMB temperature	245 K	
Mesh grid diam, spacing [mm]	0	0	Mesh grid diam, spacing [mm]	0	0	RX main beam effic. η_{MB}, η_F	0.574	0.85
Mesh grid effi. η_{mesh}, loss	1	0 dB	Mesh grid effi. η_{mesh}, loss	1	0 dB	Spatial polarization, pol.loss	-0.1°	-0.0 dB
Max. antenna efficiency η	0.507	58.51 dBi	Max. antenna efficiency η	0.493	58.39 dBi			
Used antenna efficiency η_{real}	0.5		Used antenna efficiency η_{real}	0.49		Y-dish&feed: Absorber/SkyZenith		2.45 dB
Edge taper [dB], feed taper	-11	-9 dB	Edge taper [dB], feed taper	-11	-8.1 dB	Y-dish&feed: Absorber/SkyElevation		2.17 dB
Dish center - rim	37.6°		Dish center - rim	64°		Y-feed: Gnd(or absorber)/SkyZenith		3.16 dB
HPBW$_{real}$, gain$_{real}$	0.18°	58.45 dBi	HPBW$_{real}$, gain$_{real}$	0.179°	58.36 dBi	Sun temp, SFU@frequency	0	0
						Y-Sun: 1+Sun/(Sky+Noise)		---
Position x,y on Moon [°]	0.075	0	Position x,y on Moon [°]	-0.075	0	Y-Moon: 1+Moon/(Sky+Noise)		1.5 dB
Intercepted power fraction	0.981	-0.08 dB	Received fraction (BWF)	0.0345	-14.62 dB			
Illuminated fraction	0.176	-7.53 dB	RX fill factor moon	0.981	-0.08 dB	G/T$_{EME}$ incl. RX noise temp		31.47 dB/K
						S/N EME: Signal/(0+Sky+Noise):		-25.0 dB
						S/N EME: Signal/(Moon+Sky+Noise):		**-26.5 dB**
TX temperature [°C]	15		RX temperature [°C]	15		**Decoding mode:**	Q65-60E	
TX humidity [%]	50		RX humidity [%]	50				
TX absolute pressure [mbar]	980		RX absolute pressure [mbar]	980		RX libration rate [°/min]	0.00152	
TX zenith atmosph.attenuation		0.87 dB	RX zenith atmosph.attenuation		0.87 dB	RX libration spreading	89.7 Hz	
						TXRX mutal libr. spreading	89.7 Hz	
Use (real) time locked TX/RX elevation for:	MOON with radio refractive elevation corr.					Decoder threshold		-25.6 dB
TX refrac.corr. elevation [°]	38		RX refrac.corr. elevation [°]	38.05	0.0245			
TX LOS atmosph.attenuation		1.4 dB	RX LOS atmosph.attenuation		1.4 dB	Margin = S/N EME - threshold	---	-0.9 dB

Wissenswertes zum Mitnehmen

- Mit der allgemeinen Radargleichung können wir EME-Verbindungen auch bei >10 GHz genauer berechnen

- Mit dem „**EME Link Analysis tool**“ können wir die Auswirkungen unserer Optimierungen zuerst analysieren und Prioritäten richtig setzen (zeit- und kostenschonend)

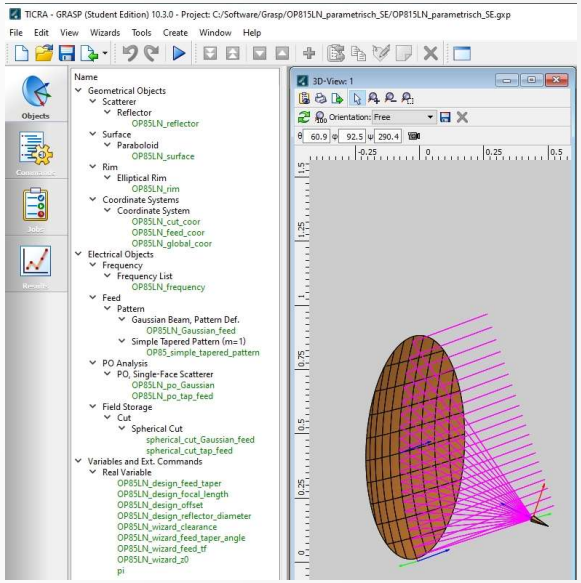
- Das Tool ist open source und Interessierte sehen was wie programmiert wurde

- Wir sind Amateure und müssen keine Profis sein, aber wir können/sollen von den Profis lernen!

„work smarter, not harder“
„learn from the professionals“ -> Radioastronomen

… und es geht weiter

- Einfache, aber sehr genaue Berechnung der wichtigsten Antennenparameter (taper/illumination & spillover Wirkungsgrad, Feed Wirkungsgrad, Antennen vorwärts Wirkungsgrad, Antennen Gain)



- Teilsimulation vom Feed/Antennen System mit OpenEMS, free CST und GRASP-SE (Industriestandard seit 45 Jahren für Reflektorantennen)

- Fehlerabweichung zur Vollsimulation vom Feed/Antennen System mit der „professional version“ von CST, GRASP(TICRA)

- Der Profi als mein Lehrer: Willi Göldi HB9PZK

Quellen und weiterführende Literatur

- [1] J.V.Evans, „Radar Studies of the Moon" in J.Res. National Bureau of Standards, Section D, p.1637 (1969), https://nvlpubs.nist.gov/nistpubs/jres/69D/jresv69Dn12p1637_A1b.pdf
- [2] G.Ihninger OE2IGL, Dorsten 2019 „Sun Noise Messungen in den oberen GHz Bändern", Dorsten 2020 „Bestimmung von Empfänger Rauschzahl & Antennenwirkungsgrad in den oberen GHz Bändern"
- [3] Rec. ITU-R P.676-11, Figure 6, https://www.itu.int/rec/R-REC-P.676/en
- [4] J. Köppen DF3GJ, DUBUS 2/2023, „ EME with Narrow Beam Antennas", https://portia.astrophysik.uni-kiel.de/~koeppen/JS/TwoBeams.html
- [5] J. Köppen DF3GJ, DUBUS 3/2021, „ Noise from the Moon", https://portia.astrophysik.uni-kiel.de/~koeppen/JS/LunarTemps.html
- [6] A. Giraud, „A Note on the Radio Reflectivity of the Lunar Surface", https://nvlpubs.nist.gov/nistpubs/jres/69D/jresv69Dn12p1677_A1b.pdf
- [7] John Ruze, 1952 & 1966, „The Effect of Aperture Errors on the Antenna Radiation Pattern" & "Antenna Tolerance Theory – A Review"
- [8] H. Scheffler, 1962, „Über die Genauigkeitsforderungen bei der Herstellung optischer Flächen für astronomische Teleskope"
- [9] EA3HMJ Antenna Tracking System, https://github.com/ea3hmj/HMJTS
- [10] J. L. Linsky, „The Moon as a Proposed Radiometric Standard for Microwave and Infrared Observations of Extended Sources", https://adsabs.harvard.edu/full/1973ApJS...25..163L

- Jacob W.M. Baars, "The Paraboloidal Reflector Antenna in Radio Astronomy and Communication"
- Thomas A.Milligan, „Modern Antenna Design", 2nd edition
- Constantine A. Balanis, „Antenna Theory – Analysis and Design", 3rd edition
- J.D. Kraus, „Radio Astronomy"
- T.L. Wilson, K. Rohlfs, S. Hüttemeister, „Tools of Radio Astronomy"
- W. L. Stutzman, G. A. Thiele, „Antenna Theory and Design", 3rd Edition
- Joachim Köppen DF3GJ, https://portia.astrophysik.uni-kiel.de/~koeppen/jsindex.html#RADIOASTRO
- Gerald Ihninger OE2IGL, Feed & Antenna basics, https://wettersat.bplaced.net/antennabasics.html
- Gerald Ihninger OE2IGL, EME tool, https://wettersat.bplaced.net/EME/EME.html

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