



Sun/Moon data: for RX [v] longitude [E] 13.0705 latitude [N] 47.8227
 Date [YYYYMMDD] 2023 Oct 5 13:0705 day of year 278 previous day next day
 Time [UTC] 17:07:35 1 hour earlier 1 hour later Use current time

Sun (only optical refractive elevation corr.)
 Ra 191.23 Dec -4.83
 Az 286.85 El 8.51
 Ang Diameter [deg] 0.532

Moon (only optical refractive elevation corr.)
 Ra 92.84 Dec 27.4
 Az 10.28 El 14.16
 Phase [0 = Full Moon] 60 last quarter
 angle to Sun [clockwise from top] 262
 Distance [km] 39499
 Ang Diameter [deg] 0.508

Frequency [GHz] 10.368
 Wavelength 28.9 mm
 Lunar reflectivity ϵ 0.07
 Moon noise temp. 243.4 K
 Days after full moon 6.24

TX Locator: J054CG13-DL0SHF-10
 Latitude [N°] 54.2844
 Longitude [E°] 10.1780

RX Locator: JH87MT87-OE2IGL-10
 Latitude [N°] 47.8227
 Longitude [E°] 13.0705

UTC YY/MM/DD hh:mm:ss 2023/10/5 17:07:35

Transmitting Antenna: [Gauss_max ant n = theor. -51%]
 Dish diameter [m] ant.gain_{theo} 7.2 57.98 dBi
 Dish f/D 0.35
 Offset angle if offset dish [°] 0
 Surface RMS [mm] peak err +/- 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_{is} 0.815 56.97 dBi
 Ohmic efficiency η_{ohm} 1.0
 Polarization efficiency η_{pol} 0.97
 Surface efficiency η_{sur} 0.873
 Focus efficiency η_{focus} 1
 Blocking efficiency η_{block} 0.994
 Mesh grid diam. spacing [mm] 0 0 dB
 Mesh grid eff. 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 -7.4 dB
 Dish center - rim 71.1
 HPBW_{real} gain_{real} 0.276° 55.64 dBi

Position x, y on Moon [°]
 Intercepted power fraction 0.302 -0.45 dB
 Illuminated fraction 0.388 -4.11 dB

TX temperature [°C] 15
 TX humidity [%] 50
 TX absolute pressure [mbar] 989
 TX zenith atmosphere attenuation 0.051 dB

Use (real) time locked TX/RX elevation for: [NO, free to set manually]

RX refraction elevation [°] 50 0.1 dB
 TX LOS atmosphere attenuation 0.1 dB

Receiving Antenna: [Gauss_max ant n = theor. -5%]
 Dish diameter [m] ant.gain_{theo} 0.815 38.94 dBi
 Dish f/D 0.65
 Offset angle if offset dish [°] 21
 Surface RMS [mm] peak err +/- 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_{is} 0.815 38.05 dBi
 Ohmic efficiency η_{ohm} 1.0
 Polarization efficiency η_{pol} 0.97
 Surface efficiency η_{sur} 0.995
 Focus efficiency η_{focus} 1
 Blocking efficiency η_{block} 1
 Mesh grid diam. spacing [mm] 0 0 dB
 Mesh grid eff. 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 -9 dB
 Dish center - rim 277
 HPBW_{real} gain_{real} 2.44° 37.38 dBi

Position x, y on Moon [°]
 Intercepted power fraction 0.651 -1.86 dB
 RX fill factor moon 0.0293 -15.33 dB

RX temperature [°C] 15
 RX humidity [%] 50
 RX absolute pressure [mbar] 980
 RX zenith atmosphere attenuation 0.051 dB

RX refraction elevation [°] 50 0.1 dB
 RX LOS atmosphere attenuation 0.1 dB

Moon: [Lunar reflectivity varies radially]
 Isotropic path loss [radar equation] -277.6 dB
 Path loss [corrected for beam widths] -279.7 dB
 $\epsilon \cdot \text{gain}_{TX} \cdot \text{gain}_{RX}$ 81.5 dB
 TX power [W] 14 41.5 dBm
 Received signal power -156.9 dBm
 RX NoiseFigure [dB] temp 0.72 52.3 K
 RX bandwidth [kHz] 2.5
 RX noise power -147.4 dBm
 Signal/Noise -9.5 dB
 Received Moon noise -157.1 dBm

Sky+CMB_zenith+CMB temp 6.3 K 3.2 K
 Spillover temp, add spillover 25 K 0
 RX+sky+CMB temperature 61 K
 RX main beam efficiency η_{MB} 0.819 0
 Spatial polarization, pol.loss ---

Y-dish/feed: Absorber/Sky/Zenith 5.31 dB
 Y-dish/feed: Absorber/Sky/Elevation 5.19 dB
 Y-feed: Grid/absorber/Sky/Zenith 7.62 dB
 Sun temp. SFU@frequency 0 0
 Y-Sun: 1+Sun(Sky+Noise) 6.77 dB
 Y-Moon: 1+Moon(Sky+Noise) 6.28 dB

G/T_{EME} incl. RX noise temp 17.83 dB/K
 S/N_{EME}: Signal/(0+Sky+Noise) -12.3 dB
 S/N_{EME}: Signal/(Moon+Sky+Noise) 172.6 dB

Decoding mode: G65-50E
 RX libration rate [°/min] 0.002307
 RX libration spreading 130 Hz
 TXRX metal libr. spreading 121 Hz
 Decoder threshold -25.1 dB
 Margin = S/N_{EME} - threshold 124.3 dB

Y [°] Illumination on Moon by Tx antenna
 X [°]
 Illumination: false colour image (auto range)
 Moon position

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?**

The screenshot shows the VK3UM EME Performance Calculator interface. The main window displays technical data for a station (Tx A) and a receiving station (Tx B). The receiving station data shows a noise temperature of 52.44 K and a signal-to-noise ratio of 0.72 dB. A technical report titled "Technical Reports Besonderheiten bei 10 GHz-EME" is overlaid on the right side of the screen. The report discusses the challenges of 10 GHz EME and provides a detailed analysis of the system's performance, including a calculation for the effective cross-section of the Moon as a reflector.

Technical Reports
Besonderheiten bei 10 GHz-EME
(What's special about 10 GHz-EME?)
Editor: Rainer Bartschmeier, DL9BV
Josef Fehrenbach, DL7JJ
Schlüsselwörter: 1, D-77716 Haslach, Germany

Abstract: Some specialities govern the EME mode of operation at 10 GHz. These are the illumination of the moon's surface by high gain antennas and subsequent reflections with small aperture angles, the presence of thermal noise of the moon and some subtle propagation mechanisms, which differ from lower bands.

1. Einleitung
Der folgende Beitrag geht auf die Besonderheiten der 10 GHz-EME von den bekannten Bedingungen bei 2 m oder 70 cm über. Es sind dies zum einen die Auswirkungen der kleinen Öffnungswinkel, zum anderen verändertes Reflexionsverhalten des Mondes und last but not least die durch höheren Frequenzen hervorgerufenen Empfindlichkeitsverluste.

2. Streckendämpfung - Radargleichung
Die Streckendämpfung wird üblicherweise mit Hilfe der Radargleichung berechnet.
Sie lautet:
$$P_R = \frac{\alpha P_T G_T G_R \lambda^2}{(4\pi R)^2 d^2}$$

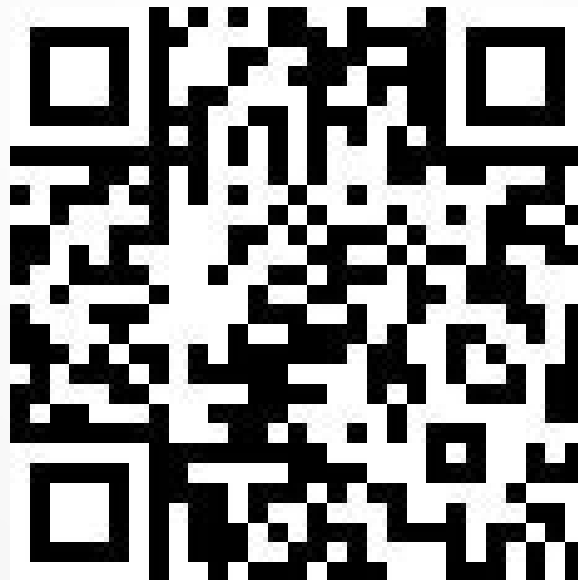
P_R: empfangene Leistung

Beispiel mit Mond als Reflektor:
Durchmesser = 3500000 m
Reflexionskoeffizient = 0,5
 $\alpha = \frac{\pi}{4} (0,5 \cdot 10^6)^2 \cdot 0,005 = 6,25 \cdot 10^{11} \text{ m}^2$
Der Mond reflektiert wie eine leuchtende Kugel, deren Querschnitt $6,25 \cdot 10^{11} \text{ m}^2$ beträgt.

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“

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



QR-Code EME tool

Die allgemeine Radargleichung¹ berücksichtigt Effekte die wir bisher „vergessen“ hatten



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

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

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

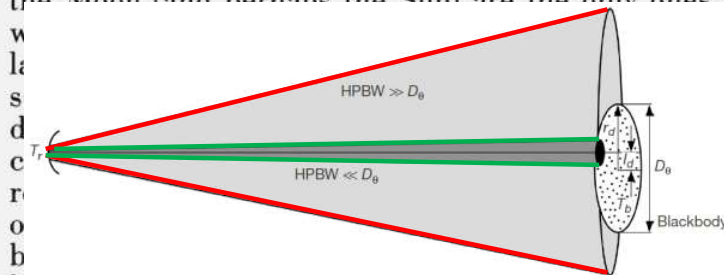


Figure 7. Geometry of antenna beams with two types of beamwidths relative to a blackbody [10].

simple antennas this effect will not be important until the antenna diameter becomes larger than 100λ 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

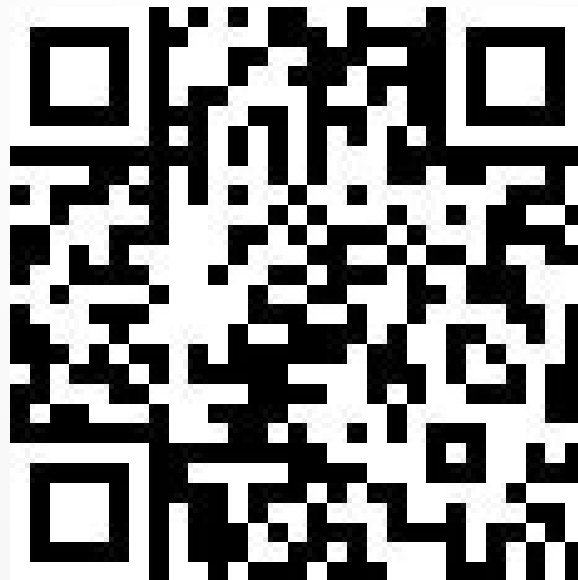
$$P_r = \frac{P_t G_0^2 \lambda^2 \sigma}{64\pi^3 R^4} \int_{\theta} F^2(\theta) B(\theta) 2\pi \sin \theta d\theta, \quad (2) \text{ Allg. Form}$$

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 $\theta=0^\circ$), 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-

Nur für Spezialfall „Punktquelle“ gültig

Übersicht

- Allgemeine Form der Radargleichung
- **EME Einflussfaktoren**
- Übersicht EME Link Analysis Tool + Beispiele
- Zusammenfassung



QR-Code EME tool

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 (<u>nicht punktförmige</u> Quellen)	bis zu -10 dB	allg. Radargleichung ¹ DF3GJ & OE2IGL ⁴ , OE2IGL ³
2) Verlust durch nicht <u>synchrone</u> Positionier- & Nachführgenauigkeit <u>beider</u> Antennen	bis zu -10 dB	EA EME Gruppe ⁹ : hat ein hochgenaues Trackingsystem entwickelt (max. $\pm 0,03^\circ$)
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 Wetterbedingungen (Temp, Feuchte, Luftdruck)	bis zu -2,5 dB	ITU-R P.xxx ³ geht zusätzlich in die atmosph. Dämpfung ein
6) Mond Reflektivität: $0,075 \pm 0,013$	$\pm 0,75$ dB	J.V. Evans ¹ A. Giraud ⁶ J. Linsky ¹⁰
7) Mond Temperatur	$\pm 0,75$ dB	DF3GJ: Übersicht wissenschaftlicher Daten ⁵
8) Mond Distanz (2-Weg) NF $\pm 0,5$ dB; Tx power $\pm 0,5$ dB	$\pm 0,95$ dB $\pm 0,5$ dB	

Faktor 1:

Schmale Antennenkeulen auf dem Mond (BWF)

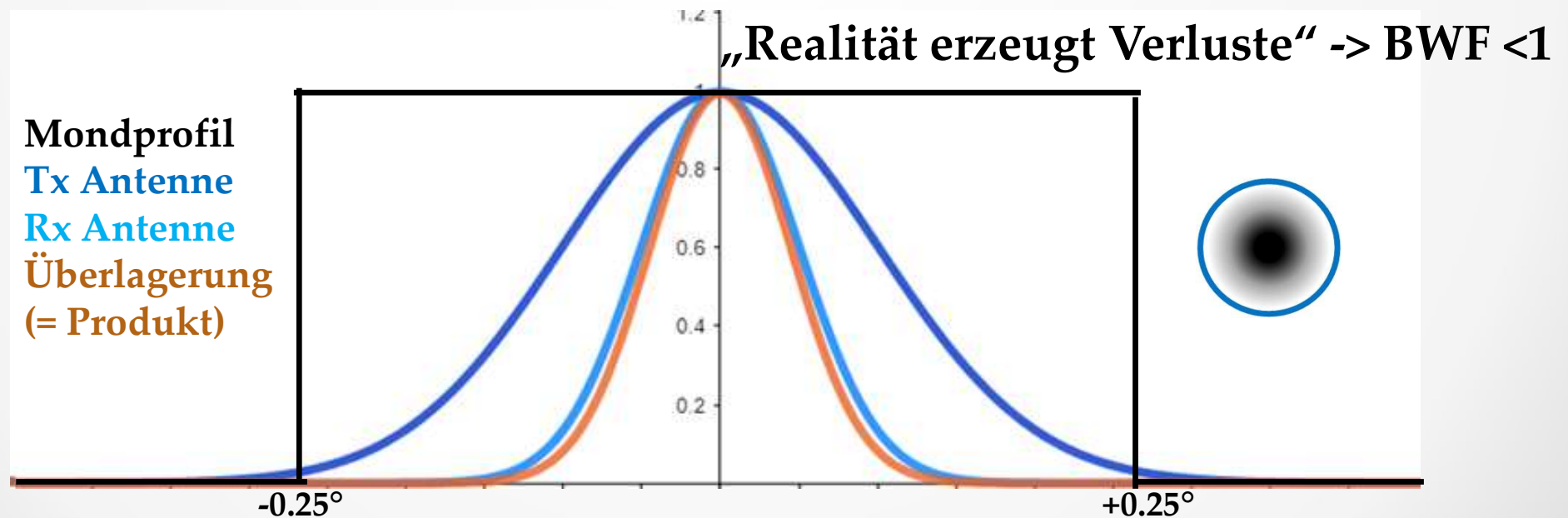


beam width factor $BWF \leq 1$

- 2x Antennen Gauss Profil -> $F(\theta)$
- Mond Tophat Profil -> $B(\theta)$

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

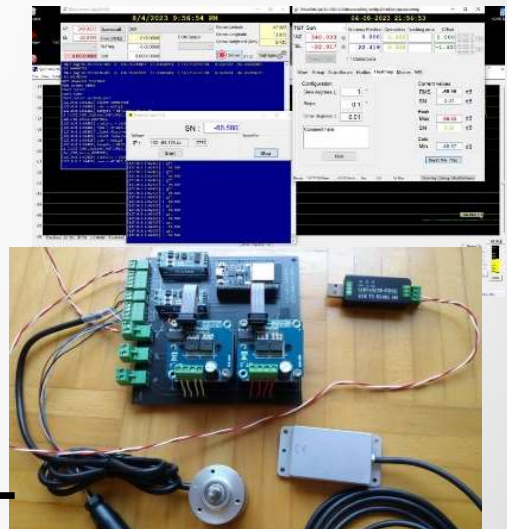
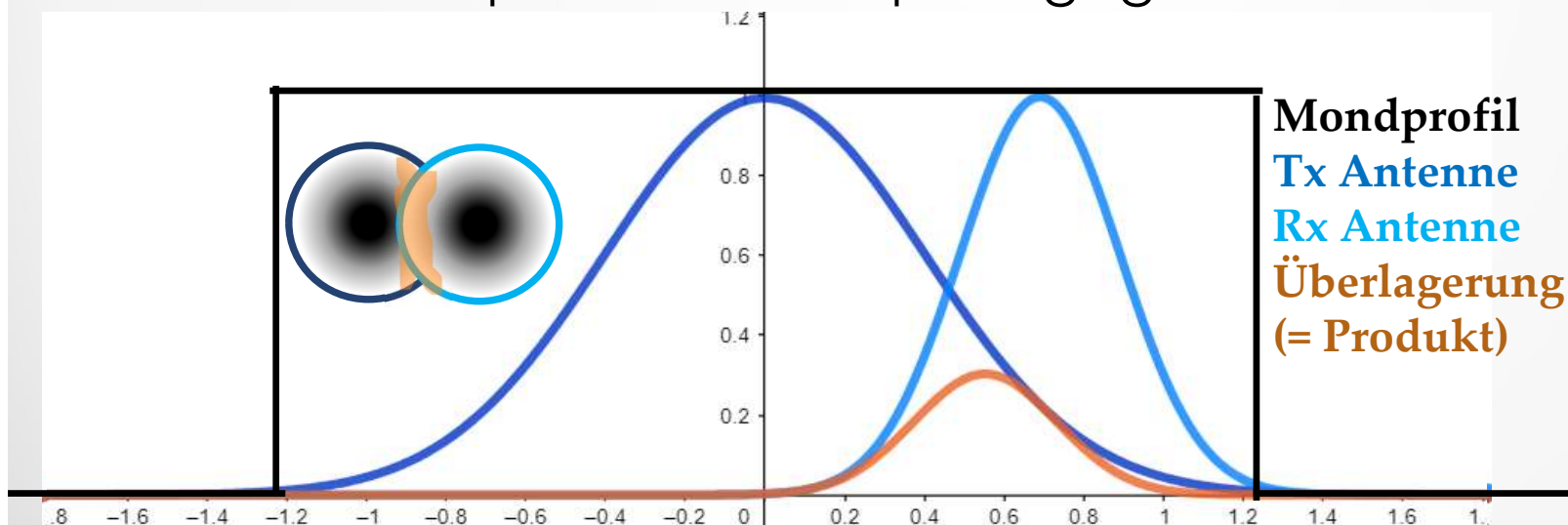
- Überlagerung von drei 3-dimensionalen Körpern deren resultierendes Volumen einer normierten Leistung entspricht.



Faktor 2:

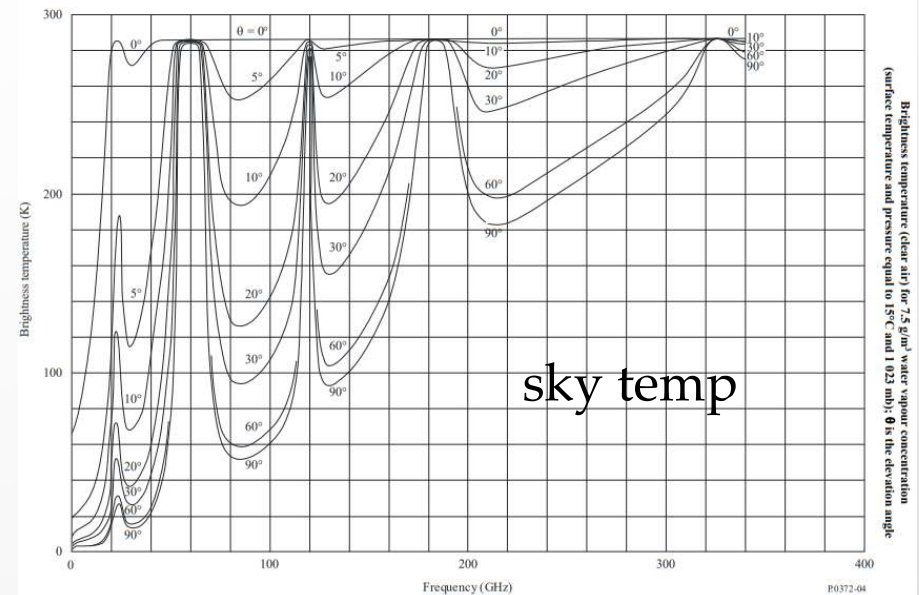
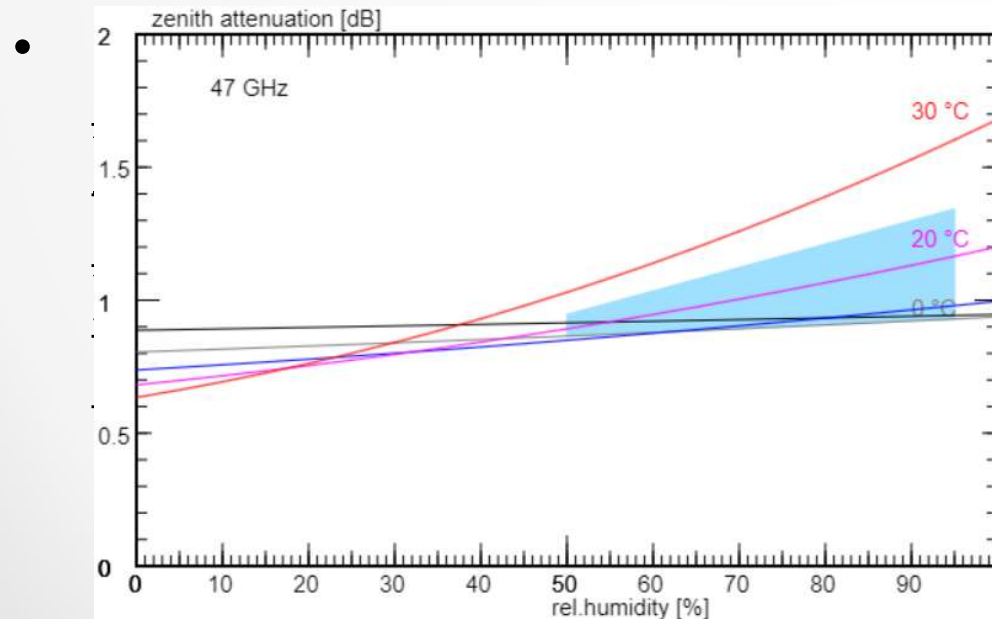
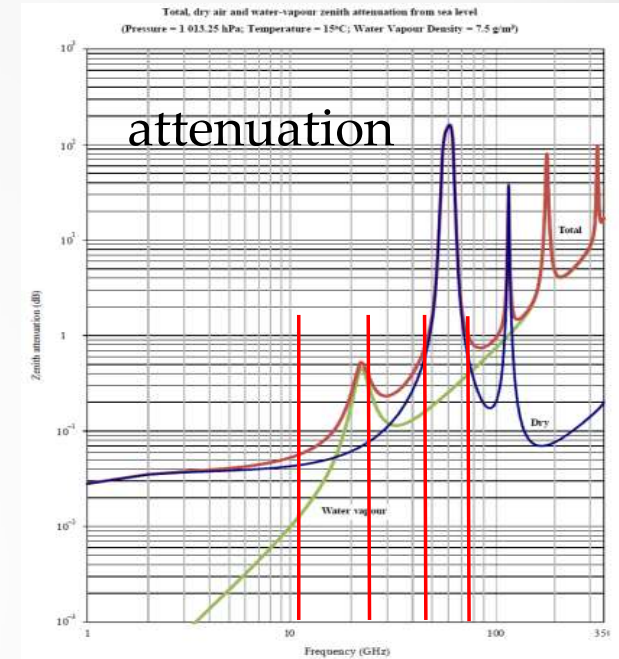
Positionier- & Nachführgenauigkeit von Antennen

- 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 schmaler 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 $\approx \frac{\max_{peak} - \min_{peak}}{4}$

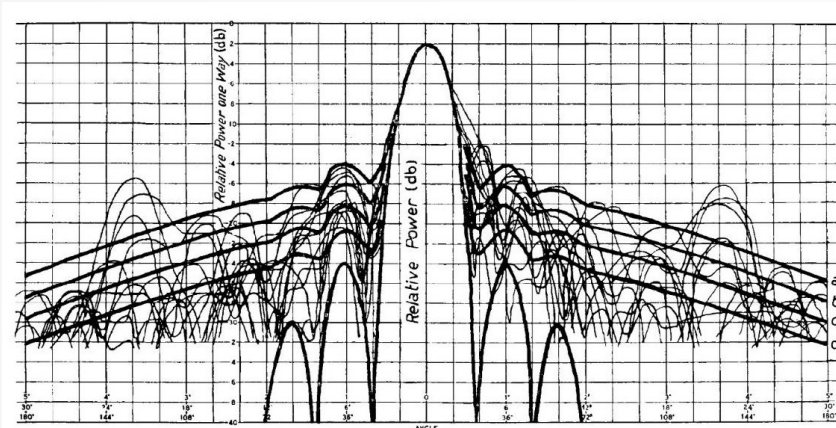


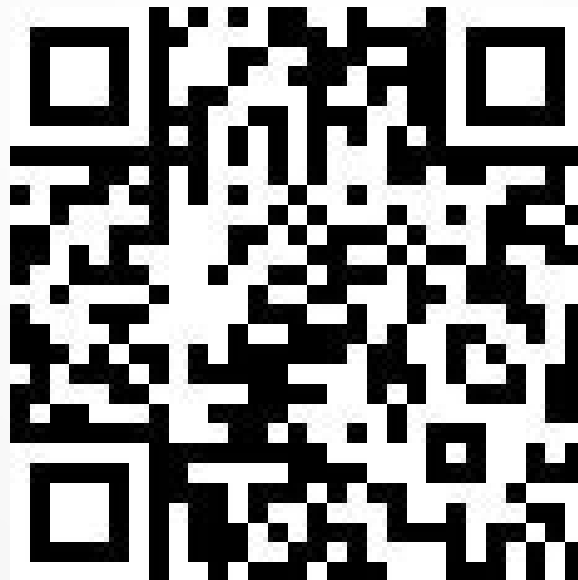
Fig. 12. - Comparison of experimental patterns with theoretical prediction of a 50 inches parabolic dish focal length 10,5 inches two band (3,2cm λ) double dipole feed H plane; r.m.s. reflector error - 0,59 radians (0,282 inch); correlation interval: one wavelength. Statistically predicted radiation 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

Übersicht

- Allgemeine Form der Radargleichung
- EME Einflussfaktoren
- **Übersicht EME Analysis Tool + Beispiele**
- Zusammenfassung



QR-Code EME tool

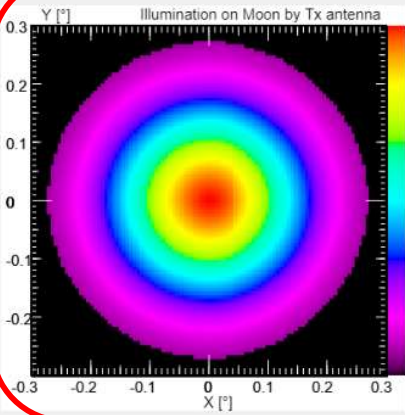
EME Link Analysis Tool von OE2IGL

Sun/Moon data: for RX longitude [E] 13.0705 latitude [N] 47.8227
 Date [YYYYMMDD] 2023 Oct 27 day of year 300
 Time [UTC]: 18:05:06
 previous day next day Use current time
 1 hour earlier 1 hour later

Sun (only optical refractive elevation corr.)
 Ra 211.82 Dec -12.87
 Az 274.82 El -21.84
 Ang. Diameter [deg] 0.536

Moon (only optical refractive elevation corr.)
 Ra 18.67 Dec 6.42
 Az 110.09 El 25.6
 Phase [0 = Full Moon] 345 full moon
 angle to Sun [clockwise from top] 78
 Distance [km] 366588
 Ang. Diameter [deg] 0.542

Frequency [GHz] 10.368
 Wavelength 28.9 mm
 Lunar reflectivity ϵ 0.07
 Moon noise temp., add temp 238 K
 Days after full moon 26.9

Illumination on Moon by Tx antenna

 Illumination: false colour image (auto range)
 Mouse position

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 2023/10/27 18:05:06

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°
 HRPBW_{real}, gain_{real} 0.276° 55.64 dBi

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} 0.693
 Edge taper [dB], feed taper -11 -9 dB
 Dish center - rim 37°
 HRPBW_{real}, gain_{real} 2.45° 37.34 dBi

Moon: [Lunar reflectivity varies radially]
 Isotropic path loss (radar equation) -276.5 dB
 Path loss (corrected for beam widths) -278.6 dB
 $\epsilon * gain_{TX} * gain_{RX}$ 81.4 dB
 TX power [W] 14 41.5 dBm
 Received signal power -155.9 dBm
 RX NoiseFigure [dB], temp 0.72 52.3 K
 RX bandwidth [kHz] 2.5
 RX noise power -147.4 dBm
 Signal/Noise -8.5 dB
 Received Moon noise -156.6 dBm

Sky+CMB, zenith+CMB temp 6.3 K 3.2 K
 Spillover temp., add. spillover 25 K 0
 RX+sky+CMB temperature 61 K
 RX main beam efficiency η_{MB} 0.812 0
 Spatial polarization, pol.loss --- ---

Y-dish&feed: Absorber/SkyZenith 5.31 dB
 Y-dish&feed: Absorber/SkyElevation 5.19 dB
 Y-feed: Gnd(or absorber)/SkyZenith 7.62 dB
 Sun temp. SFU@frequency 0 0
 Y-Sun: 1+Sun/(Sky+Noise) 6.94 dB
 Y-Moon: 1+Moon/(Sky+Noise) 0.31 dB

G/T_{EME} incl. RX noise temp 17.75 dB/K
 S/N EME: Signal/(0+Sky+Noise): -11.4 dB
S/N EME: Signal/(Moon+Sky+Noise): -11.7 dB

Decoding mode: Q65-60E

RX libration rate [°/min] 0.002059
 RX libration spreading 113 Hz
 TXRX mutal libr. spreading 108 Hz
 Decoder threshold -25.3 dB

Margin = S/N EME - threshold --- 13.6 dB

TX temperature [°C] 15
 TX humidity [%] 50
 TX absolute pressure [mbar] 980
 TX zenith atmosph. attenuation 0.051 dB

RX temperature [°C] 15
 RX humidity [%] 50
 RX absolute pressure [mbar] 980
 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
 TX LOS atmosph. attenuation 0.1 dB

RX refrac. corr. elevation [°] 30
 RX LOS atmosph. attenuation 0.1 dB

Swap stations, Tx <=> Rx Echo mode, set Rx = Tx Calculate

- 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://wetersat.bplaced.net/EME/EME.html>



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. $\eta_{mesh, loss}$	1 0 dB	Mesh grid effi. $\eta_{mesh, loss}$	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 Nachführungenauigkeiten
- „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

Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr. ▾ Decoder threshold -25.4 dB

TX refrac.corr. elevation [°] 6.433 NO, free to set manually
TX LOS atmosph.attenuation 0.46 dB SUN with radio refractive elevation corr. 0.0873
MOON with radio refractive elevation corr. 0.24 dB Margin = S/N EME - threshold 17.4 dB

Swap stations, Tx <=> Rx Echo mode, set Rx = Tx Calculate LIVE OFF autostep +30min

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

Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr. ▾ Decoder threshold -25.4 dB

TX refrac.corr. elevation [°] 6.433 RX refrac.corr. elevation [°] 12.26 0.0873
TX LOS atmosph.attenuation 0.46 dB RX LOS atmosph.attenuation 0.24 dB Margin = S/N EME - threshold 17.4 dB

Swap stations, Tx <=> Rx Echo mode, set Rx = Tx Calculate LIVE ON

- 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, $Y_{\text{moon/sun}}$, ...

Use current time | 15 min earlier | 15 min later

UTC YY/MM/DD hh:mm:ss **2023/10/27 18:22:43**

Moon: Lunar reflectivity varies radially

Isotropic path loss (radar equation)	-276.5 dB
Path loss (corrected for beam widths)	-278.6 dB
$\epsilon * \text{gain}_{\text{TX}} * \text{gain}_{\text{RX}}$	81.4 dB
TX power [W]	14 41.5 dBm
Received signal power	-156 dBm
RX NoiseFigure [dB], temp	0.72 52.3 K
RX bandwidth [kHz]	2.5
RX noise power	-147.4 dBm
Signal/Noise	-8.5 dB
Received Moon noise	-156.6 dBm

Sky+CMB, zenith+CMB temp	6.6 K	3.2 K
Spillover temp., add. spillover	24 K	0
RX+sky+CMB temperature	61.3 K	
RX main beam efficiency η_{MB}	0.812	0
Spatial polarization, pol.loss	-5.8°	-0.0 dB
Y-dish&feed: Absorber/SkyZenith	5.31 dB	
Y-dish&feed: Absorber/SkyElevation	5.18 dB	
Y-feed: Gnd(or absorber)/SkyZenith	7.62 dB	
Sun temp, SFU@frequency	0	0
Y-Sun: 1+Sun/(Sky+Noise)	---	
Y-Moon: 1+Moon/(Sky+Noise)	0.31 dB	

G/T _{EME} incl. RX noise temp	17.75 dB/K
S/N EME: Signal/(0+Sky+Noise):	-11.4 dB
S/N EME: Signal/(Moon+Sky+Noise):	-11.7 dB

Decoding mode: Q65-60E

RX libration rate [°/min]	0.002151
RX libration spreading	119 Hz
TXRX mutal libr. spreading	113 Hz
Decoder threshold	-25.2 dB

Margin = S/N EME - threshold --- **13.5 dB**

Calculate | LIVE OFF | autostep +30min

- 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.

Y-dish&feed: Absorber/SkyZenith	5.31 dB
Y-dish&feed: Absorber/SkyElevation	5.19 dB
Y-feed: Gnd(or absorber)/SkyZenith	7.62 dB
Sun temp, SFU@frequency	0 0
Y-Sun: 1+Sun/(Sky+Noise)	6.94 dB
Y-Moon: 1+Moon/(Sky+Noise)	---

G/T _{EME} incl. RX noise temp	---
S/N EME: Signal/(0+Sky+Noise):	---
S/N EME: Signal/(Moon+Sky+Noise):	---

Decoding mode: Q65-60E

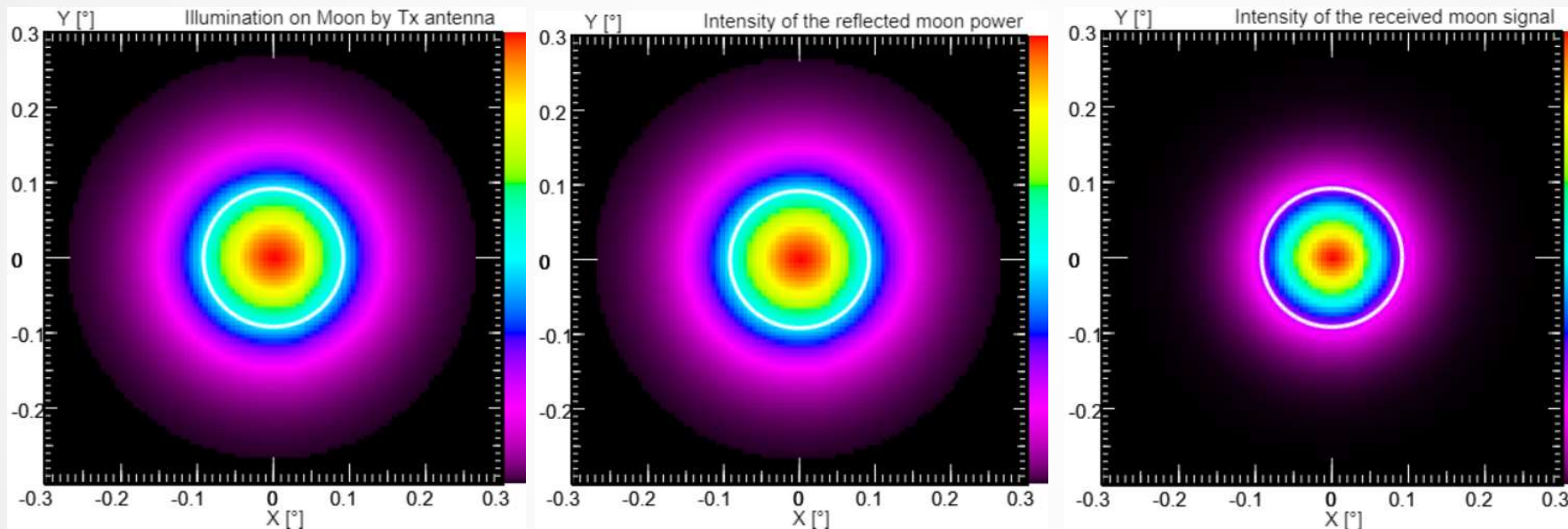
RX libration rate [°/min]	0.003349
RX libration spreading	184 Hz
TXRX mutal libr. spreading	177 Hz
Decoder threshold	---

Margin = S/N EME - threshold --- **13.5 dB**

Calculate

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

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

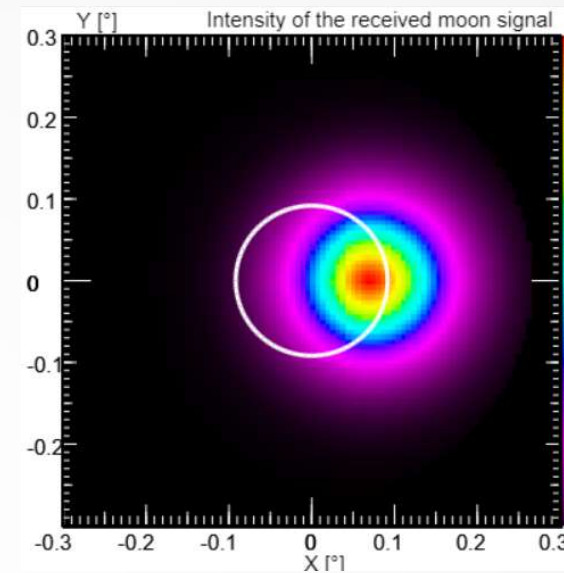
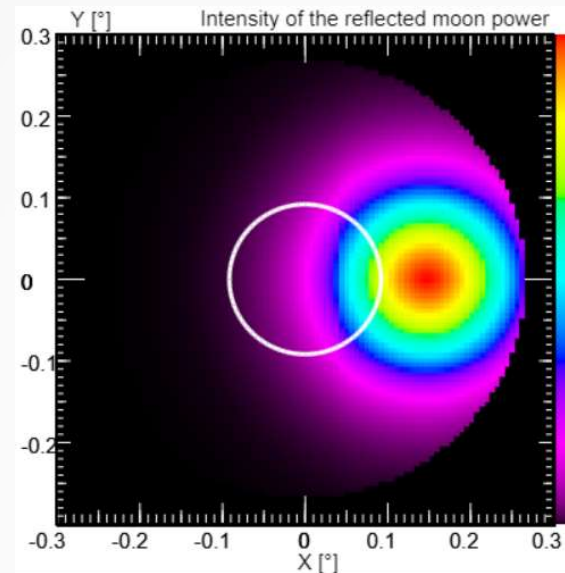
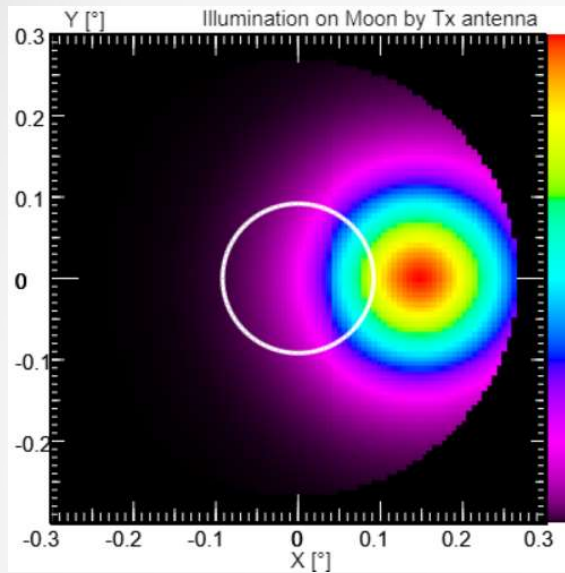


* Relative Werte (keine Absolutwerte)

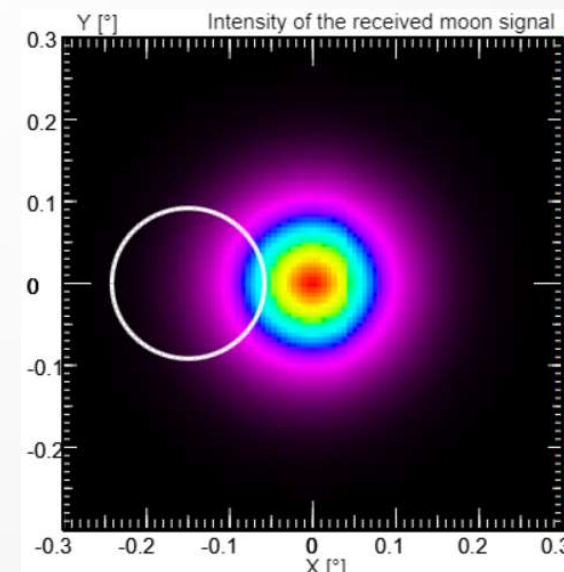
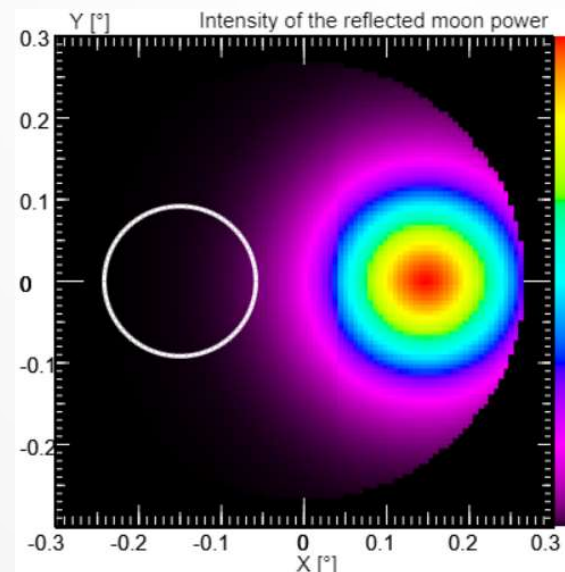
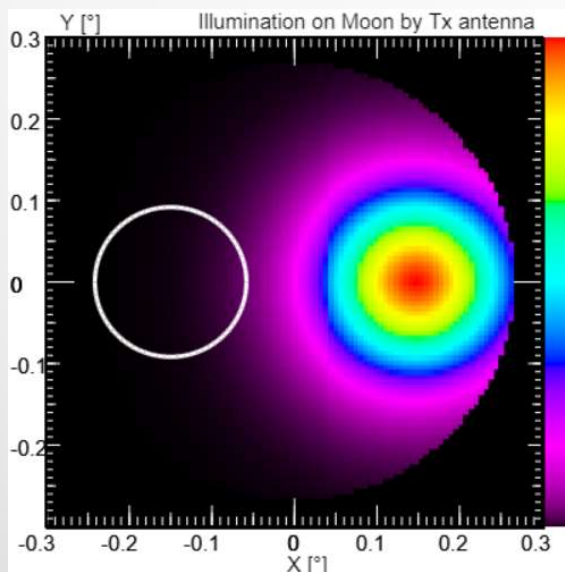
Grafik zum besseren Verständnis: Mond Ausleuchtung – Mond Reflexion – Rx Antenne

- 47 GHz, 2x 2,4 m Spiegel

* Relative Werte (keine Absolutwerte)



Tx +0,15°

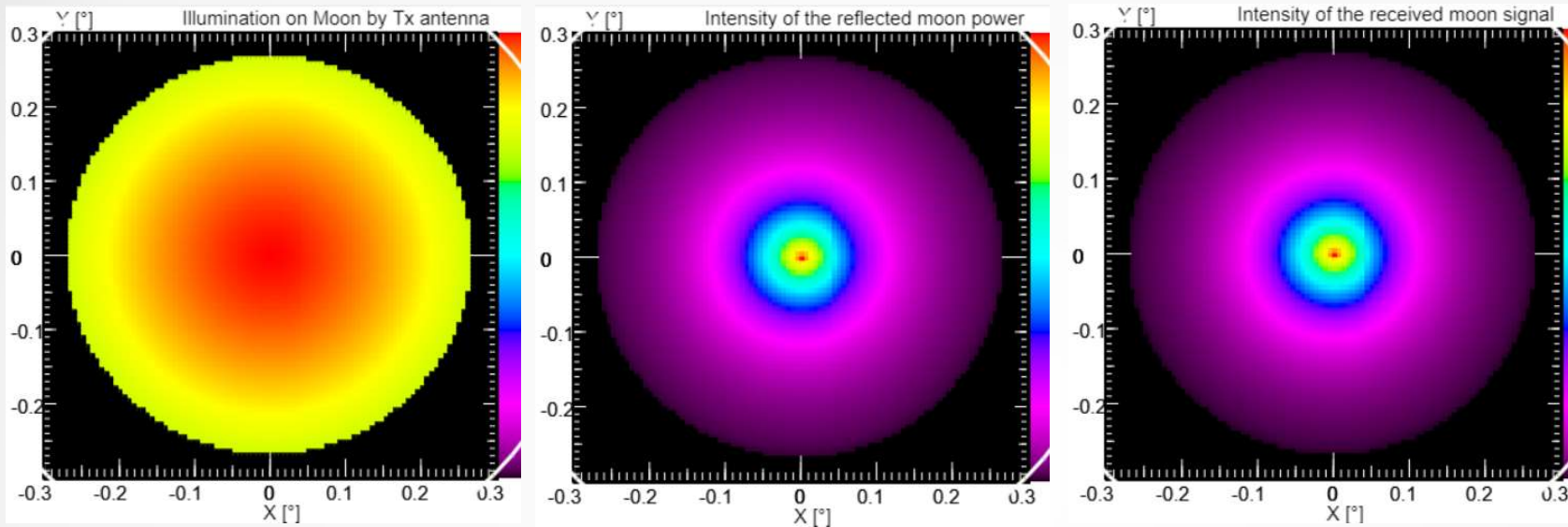


Tx +0,15°
Rx -0,15°

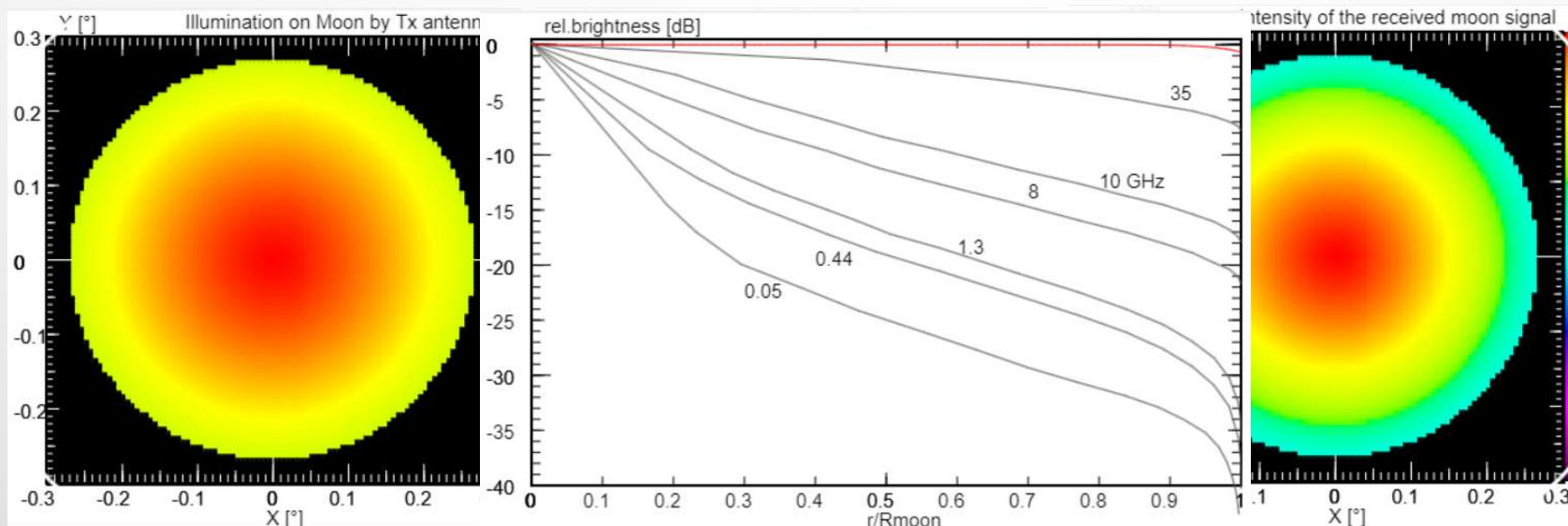
Grafik zum besseren Verständnis: Einfluss Mond Profil

- 10 GHz, 2x 2,4 m Spiegel

* Relative Werte (keine Absolutwerte)



Mond Gauss
Profil



~~Mond
Tonat
Profil~~

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

TX Locator: IM68BN - CT1BYM-47

Latitude [N°]

Longitude [E°]

RX Locator: IM68BN - CT1BYM-47

Latitude [N°]

Longitude [E°]

UTC YY/MM/DD hh:mm:ss 2023/10/27 21:12:04

Transmitting Antenna: Gauss, max ant. η = theor. - 5%		Receiving Antenna: Gauss, max ant. η = theor. - 5%	
Dish diameter [m], ant.gain _{theo}	<input type="text" value="1.2"/> 55.44 dBi	Dish diameter [m], ant.gain _{theo}	<input type="text" value="1.2"/> 55.44 dBi
Dish f/D	<input type="text" value="0.66"/>	Dish f/D	<input type="text" value="0.66"/>
Offset angle if offset dish [°]	<input type="text" value="21"/>	Offset angle if offset dish [°]	<input type="text" value="21"/>
Surface RMS [mm], peak err	<input type="text" value="0.2"/> +/- 0.4 mm	Surface RMS [mm], peak err	<input type="text" value="0.2"/> +/- 0.4 mm
Feed out-of-axial-focus [mm]	<input type="text" value="0"/>	Feed out-of-axial-focus [mm]	<input type="text" value="0"/>
Feed blocking diam. [m]	<input type="text" value="0"/>	Feed blocking diam. [m]	<input type="text" value="0"/>
Illumination efficiency η _i	<input type="text" value="0.847"/>	Illumination efficiency η _i	<input type="text" value="0.847"/>
Spillover efficiency η _s	<input type="text" value="0.95"/>	Spillover efficiency η _s	<input type="text" value="0.95"/>
Illum+spillover efficiency η _{i+s}	<input type="text" value="0.805"/> 54.5 dBi	Illum+spillover efficiency η _{i+s}	<input type="text" value="0.805"/> 54.5 dBi
Ohmic efficiency η _{ohm}	<input type="text" value="1.0"/>	Ohmic efficiency η _{ohm}	<input type="text" value="1.0"/>
Polarization efficiency η _{pol}	<input type="text" value="0.97"/>	Polarization efficiency η _{pol}	<input type="text" value="0.97"/>
Surface efficiency η _{Ruze}	<input type="text" value="0.856"/>	Surface efficiency η _{Ruze}	<input type="text" value="0.856"/>
Focus efficiency η _{focus}	<input type="text" value="1"/>	Focus efficiency η _{focus}	<input type="text" value="1"/>
Blocking efficiency η _{block}	<input type="text" value="1"/>	Blocking efficiency η _{block}	<input type="text" value="1"/>
Mesh grid diam, spacing [mm]	<input type="text" value="0"/> <input type="text" value="0"/>	Mesh grid diam, spacing [mm]	<input type="text" value="0"/> <input type="text" value="0"/>
Mesh grid effi. η _{mesh} , loss	<input type="text" value="1"/> 0 dB	Mesh grid effi. η _{mesh} , loss	<input type="text" value="1"/> 0 dB
Max. antenna efficiency η	<input type="text" value="0.618"/> 53.35 dBi	Max. antenna efficiency η	<input type="text" value="0.618"/> 53.35 dBi
Used antenna efficiency η _{real}	<input type="text" value="0.6"/>	Used antenna efficiency η _{real}	<input type="text" value="0.6"/>
Edge taper [dB], feed taper	<input type="text" value="-13"/> -11 dB	Edge taper [dB], feed taper	<input type="text" value="-13"/> -11 dB
Dish center - rim	<input type="text" value="37°"/>	Dish center - rim	<input type="text" value="37°"/>
HPBW _{real} , gain _{real}	<input type="text" value="0.368°"/> 53.22 dBi	HPBW _{real} , gain _{real}	<input type="text" value="0.368°"/> 53.22 dBi
Position x,y on Moon [°]	<input type="text" value="0"/> <input type="text" value="0"/>	Position x,y on Moon [°]	<input type="text" value="0"/> <input type="text" value="0"/>
Intercepted power fraction	<input type="text" value="0.777"/> -1.09 dB	Received fraction (BWF)	<input type="text" value="0.318"/> -4.97 dB
Illuminated fraction	<input type="text" value="0.516"/> -2.87 dB	RX fill factor moon	<input type="text" value="0.777"/> -1.09 dB
TX temperature [°C]	<input type="text" value="15"/>	RX temperature [°C]	<input type="text" value="15"/>
TX humidity [%]	<input type="text" value="50"/>	RX humidity [%]	<input type="text" value="50"/>
TX absolute pressure [mbar]	<input type="text" value="980"/>	RX absolute pressure [mbar]	<input type="text" value="980"/>
TX zenith atmosph.attenuation	<input type="text" value="0.87 dB"/>	RX zenith atmosph.attenuation	<input type="text" value="0.87 dB"/>

Use (real) time locked TX/RX elevation for:

TX refrac.corr. elevation [°]	<input type="text" value="46.3"/>	RX refrac.corr. elevation [°]	<input type="text" value="46.3"/> 0.0186
TX LOS atmosph.attenuation	<input type="text" value="1.2 dB"/>	RX LOS atmosph.attenuation	<input type="text" value="1.2 dB"/>

Moon: Lunar reflectivity varies radially

Isotropic path loss (radar equation)

Path loss (corrected for beam widths)

ε * gain_{TX} * gain_{RX}

TX power [W] 46.2 dBm

Received signal power

RX NoiseFigure [dB], temp 170 K

RX bandwidth [kHz]

RX noise power

Signal/Noise

Received Moon noise

Sky+CMB, zenith+CMB temp

Spillover temp., add. spillover

RX+sky+CMB temperature

RX main beam efficiency η_{MB}

Spatial polarization, pol.loss

Y-dish&feed: Absorber/SkyZenith	<input type="text" value="2.49 dB"/>
Y-dish&feed: Absorber/SkyElevation	<input type="text" value="2.3 dB"/>
Y-feed: Gnd(or absorber)/SkyZenith	<input type="text" value="3.16 dB"/>
Sun temp, SFU@frequency <input type="text" value="0"/>	<input type="text" value="0"/>
Y-Sun: 1+Sun/(Sky+Noise)	<input type="text" value="---"/>
Y-Moon: 1+Moon/(Sky+Noise)	<input type="text" value="1.56 dB"/>
G/T _{EME} incl. RX noise temp	<input type="text" value="26.89 dB/K"/>
S/N _{EME} : Signal/(0+Sky+Noise):	<input type="text" value="-16.8 dB"/>
S/N _{EME} : Signal/(Moon+Sky+Noise):	<input type="text" value="-18.4 dB"/>

Decoding mode:

RX libration rate [°/min]	<input type="text" value="0.00294"/>
RX libration spreading	<input type="text" value="527 Hz"/>
TXRX mutal libr. spreading	<input type="text" value="527 Hz"/>
Decoder threshold	<input type="text" value="-20.4 dB"/>

Margin = S/N_{EME} - threshold

Bsp 2: Tx-Ant groß, Rx-Ant klein

Was ist besser? Großer Spiegel beim Senden oder Empfangen?

TX Locator: JO62PK - DL7YC-47	---	RX Locator: JO62PK - DL7YC-47	---	Use current time	15 min earlier	15 min later
Latitude [N°]	52.4394	Latitude [N°]	52.4394	UTC YY/MM/DD hh:mm:ss 2023/10/30 21:30:15		
Longitude [E°]	13.2955	Longitude [E°]	13.2955			
Transmitting Antenna: Gauss, max ant. $\eta = \text{theor.} - 5\%$		Receiving Antenna: Gauss, max ant. $\eta = \text{theor.} - 5\%$		Moon: Lunar reflectivity varies radially		
Dish diameter [m], ant.gain _{theo}	2.4 61.46 dBi	Dish diameter [m], ant.gain _{theo}	1.2 55.44 dBi	Isotropic path loss (radar equation)	-290.3 dB	
Dish f/D	0.4	Dish f/D	0.4	Path loss (corrected for beam widths)	-298.9 dB	
Offset angle if offset dish [°]	0	Offset angle if offset dish [°]	0	$\epsilon * \text{gain}_{\text{TX}} * \text{gain}_{\text{RX}}$	99.8 dB	
Surface RMS [mm], peak err	0.3 +/- 0.6 mm	Surface RMS [mm], peak err	0.2 +/- 0.4 mm	TX power [W]	42 46.2 dBm	
Feed out-of-axial-focus [mm]	0	Feed out-of-axial-focus [mm]	0	Received signal power	-155.4 dBm	
Feed blocking diam. [m]	0.2	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 54.55 dBi	Signal/Noise	-13.1 dB	
Ohmic efficiency η_{ohm}	1.0	Ohmic efficiency η_{ohm}	1.0	Received Moon noise	-144.4 dBm	
Polarization efficiency η_{pol}	0.97	Polarization efficiency η_{pol}	0.97	Sky+CMB, zenith+CMB temp	67 K 49 K	
Surface efficiency η_{Ruze}	0.705	Surface efficiency η_{Ruze}	0.856	Spillover temp., add. spillover	45 K 0	
Focus efficiency η_{focus}	1	Focus efficiency η_{focus}	1	RX+sky+CMB temperature	237 K	
Blocking efficiency η_{block}	0.976	Blocking efficiency η_{block}	0.906	RX main beam eff. $\eta_{\text{MB}}, \eta_{\text{F}}$	0.659 0.85	
Mesh grid diam, spacing [mm]	0 0	Mesh grid diam, spacing [mm]	0 0	Spatial polarization, pol.loss	0.0° 0.0 dB	
Mesh grid effi. $\eta_{\text{mesh}}, \text{loss}$	1 0 dB	Mesh grid effi. $\eta_{\text{mesh}}, \text{loss}$	1 0 dB	Y-dish&feed: Absorber/SkyZenith	2.47 dB	
Max. antenna efficiency η	0.493 58.39 dBi	Max. antenna efficiency η	0.563 52.95 dBi	Y-dish&feed: Absorber/SkyElevation	2.28 dB	
Used antenna efficiency η_{real}	0.493	Used antenna efficiency η_{real}	0.563	Y-feed: Gnd(or absorber)/SkyZenith	3.16 dB	
Edge taper [dB], feed taper	-11 -8.1 dB	Edge taper [dB], feed taper	-11 -8.1 dB	Sun temp, SFU@frequency	0 0	
Dish center - rim	64°	Dish center - rim	64°	Y-Sun: 1+Sun/(Sky+Noise)	---	
HPBW _{real} , gain _{real}	0.179° 58.39 dBi	HPBW _{real} , gain _{real}	0.358° 52.95 dBi	Y-Moon: 1+Moon/(Sky+Noise)	1.48 dB	
Position x,y on Moon [°]	0 0	Position x,y on Moon [°]	0 0	G/T _{EME} incl. RX noise temp	26.50 dB/K	
Intercepted power fraction	0.997 -0.01 dB	Received fraction (BWF)	0.135 -8.69 dB	S/N EME: Signal/(0+Sky+Noise):	-16.7 dB	
Illuminated fraction	0.167 -7.78 dB	RX fill factor moon	0.774 -1.11 dB	S/N EME: Signal/(Moon+Sky+Noise):	-18.2 dB	
TX temperature [°C]	15	RX temperature [°C]	15	Decoding mode: Q65-60E		
TX humidity [%]	50	RX humidity [%]	50	RX libration rate [°/min]	0.002323	
TX absolute pressure [mbar]	980	RX absolute pressure [mbar]	980	RX libration spreading	272 Hz	
TX zenith atmosph.attenuation	0.87 dB	RX zenith atmosph.attenuation	0.87 dB	TXRX mutal libr. spreading	272 Hz	
				Decoder threshold	-22.8 dB	
Use (real) time locked TX/RX elevation for:	MOON with radio refractive elevation corr.			Margin = S/N EME - threshold	---	4.7 dB
TX refrac.corr. elevation [°]	44.52	RX refrac.corr. elevation [°]	44.52			
TX LOS atmosph.attenuation	1.2 dB	RX LOS atmosph.attenuation	0.0197 1.2 dB			

Bsp 3: Tx-Ant klein, Rx-Ant groß

S/N um 0,7 dB schlechter!

TX Locator: JO62PK - DL7YC-47 Latitude [N°] 52.4394 Longitude [E°] 13.2955		RX Locator: JO62PK - DL7YC-47 Latitude [N°] 52.4394 Longitude [E°] 13.2955		<input type="button" value="Use current time"/> <input type="button" value="15 min earlier"/> <input type="button" value="15 min later"/>
Transmitting Antenna: Gauss, max ant. $\eta = \text{theor.} - 5\%$		Receiving Antenna: Gauss, max ant. $\eta = \text{theor.} - 5\%$		UTC YY/MM/DD hh:mm:ss 2023/10/30 21:30:15
Dish diameter [m], ant.gain _{theo} 1.2 55.44 dBi		Dish diameter [m], ant.gain _{theo} 2.4 61.46 dBi		Moon: Lunar reflectivity varies radially
Dish f/D 0.4		Dish f/D 0.4		Isotropic path loss (radar equation) -290.3 dB
Offset angle if offset dish [°] 0		Offset angle if offset dish [°] 0		Path loss (corrected for beam widths) -298.9 dB
Surface RMS [mm], peak err 0.2 +/- 0.4 mm		Surface RMS [mm], peak err 0.3 +/- 0.6 mm		$\epsilon * \text{gain}_{\text{TX}} * \text{gain}_{\text{RX}}$ 99.8 dB
Feed out-of-axial-focus [mm] 0		Feed out-of-axial-focus [mm] 0		TX power [W] 42 46.2 dBm
Feed blocking diam. [m] 0.2		Feed blocking diam. [m] 0.2		Received signal power -155.4 dBm
Illumination efficiency η_i 0.885		Illumination efficiency η_i 0.885		RX NoiseFigure [dB], temp 2 170 K
Spillover efficiency η_s 0.921		Spillover efficiency η_s 0.921		RX bandwidth [kHz] 2.5
Illum+spillover efficiency η_{i+s} 0.815 54.55 dBi		Illum+spillover efficiency η_{i+s} 0.815 60.57 dBi		RX noise power -142.3 dBm
Ohmic efficiency η_{ohm} 1.0		Ohmic efficiency η_{ohm} 1.0		Signal/Noise -13.1 dB
Polarization efficiency η_{pol} 0.97		Polarization efficiency η_{pol} 0.97		Received Moon noise -143.9 dBm
Surface efficiency η_{Ruze} 0.856		Surface efficiency η_{Ruze} 0.705		Sky+CMB, zenith+CMB temp 67 K 49 K
Focus efficiency η_{focus} 1		Focus efficiency η_{focus} 1		Spillover temp., add. spillover 51 K 0
Blocking efficiency η_{block} 0.906		Blocking efficiency η_{block} 0.976		RX+sky+CMB temperature 237 K
Mesh grid diam, spacing [mm] 0 0		Mesh grid diam, spacing [mm] 0 0		RX main beam eff. $\eta_{\text{MB}}, \eta_{\text{F}}$ 0.577 0.85
Mesh grid effi. $\eta_{\text{mesh}}, \text{loss}$ 1 0 dB		Mesh grid effi. $\eta_{\text{mesh}}, \text{loss}$ 1 0 dB		Spatial polarization, pol.loss 0.0° 0.0 dB
Max. antenna efficiency η 0.563 52.95 dBi		Max. antenna efficiency η 0.493 58.39 dBi		Y-dish&feed: Absorber/SkyZenith 2.45 dB
Used antenna efficiency η_{real} 0.563		Used antenna efficiency η_{real} 0.493		Y-dish&feed: Absorber/SkyElevation 2.28 dB
Edge taper [dB], feed taper -11 -8.1 dB		Edge taper [dB], feed taper -11 -8.1 dB		Y-feed: Gnd(or absorber)/SkyZenith 3.16 dB
Dish center - rim 64°		Dish center - rim 64°		Sun temp, SFU@frequency 0 0
HPBW _{real} , gain _{real} 0.358° 52.95 dBi		HPBW _{real} , gain _{real} 0.179° 58.39 dBi		Y-Sun: 1+Sun/(Sky+Noise) ---
Position x,y on Moon [°] 0 0		Position x,y on Moon [°] 0 0		Y-Moon: 1+Moon/(Sky+Noise) 1.63 dB
Intercepted power fraction 0.774 -1.11 dB		Received fraction (BWF) 0.135 -8.69 dB		G/T _{EME} incl. RX noise temp 31.46 dB/K
Illuminated fraction 0.518 -2.86 dB		RX fill factor moon 0.997 -0.01 dB		S/N EME: Signal/(0+Sky+Noise): -17.3 dB
TX temperature [°C] 15		RX temperature [°C] 15		S/N EME: Signal/(Moon+Sky+Noise): -18.9 dB
TX humidity [%] 50		RX humidity [%] 50		Decoding mode: Q65-60E
TX absolute pressure [mbar] 980		RX absolute pressure [mbar] 980		RX libration rate [°/min] 0.002323
TX zenith atmosph.attenuation 0.87 dB		RX zenith atmosph.attenuation 0.87 dB		RX libration spreading 272 Hz
Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr.		Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr.		TXRX mutal libr. spreading 272 Hz
TX refrac.corr. elevation [°] 44.52		RX refrac.corr. elevation [°] 44.52 0.0197		Decoder threshold -22.8 dB
TX LOS atmosph.attenuation 1.2 dB		RX LOS atmosph.attenuation 1.2 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

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

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 eff. $\eta_{mesh, loss}$: 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

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 eff. $\eta_{mesh, loss}$: 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
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

RX temperature [°C]: 17
RX humidity [%]: 55
RX absolute pressure [mbar]: 940
RX zenith atmosph attenuation: 0.052 dB

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

TX refrac. corr. elevation [°]: 12.86
TX LOS atmosph attenuation: 0.23 dB

RX refrac. corr. elevation [°]: 9.914 | 0.107
RX LOS atmosph attenuation: 0.3 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

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): 11.6 dB
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
TRX mutal libr. spreading: 27 Hz
Decoder threshold: -26.9 dB

Margin = S/N EME - threshold: 14.6 dB

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
 $\epsilon * gain_{TX} * gain_{RX}$: 81.5 dB

WSJT-X - Wide Graph
Controls: 500 | 1000 | 1500
08:47 3m
0844 -13 2.4 587 | CQ DL0SHF JO54 q3

10 368.000 585
DL0SHF
2023 Sep 04 08:47:08

DL09-F OE2IGL JN67
DL09-F OE2IGL -15
DL09-F OE2IGL R-15
DL09-F OE2IGL RR73
DL09-F OE2IGL 73
CQ OE2IGL JN67

Bsp 5: Minimale Anforderungen für 47.088 GHz

TX Locator: JO62QJ - DC7KY-47 <input type="text" value="---"/>		RX Locator: JO62PK - DL7YC-47 <input type="text" value="---"/>		<input type="button" value="Use current time"/> <input type="button" value="15 min earlier"/> <input type="button" value="15 min later"/>	
Latitude [N°] 52.3977		Latitude [N°] 52.4394		UTC YY/MM/DD hh:mm:ss 2023/11/2 06:52:58	
Longitude [E°] 13.3788		Longitude [E°] 13.2955			
Transmitting Antenna: Gauss, max ant. η = theor. - 5% <input type="text" value="---"/>		Receiving Antenna: Gauss, max ant. η = theor. - 5% <input type="text" value="---"/>		Moon: Lunar reflectivity varies radially <input type="text" value="---"/>	
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)	-301.3 dB
Offset angle if offset dish [°]	21	Offset angle if offset dish [°]	0	$\epsilon * \text{gain}_{\text{TX}} * \text{gain}_{\text{RX}}$	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	-158.8 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	-16.5 dB
Ohmic efficiency η_{ohm}	1.0	Ohmic efficiency η_{ohm}	1.0	Received Moon noise	-144.1 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. $\eta_{\text{MB}}, \eta_{\text{F}}$	0.574 0.85
Mesh grid effi. $\eta_{\text{mesh}}, \text{loss}$	1 0 dB	Mesh grid effi. $\eta_{\text{mesh}}, \text{loss}$	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	Y-dish&feed: Absorber/SkyZenith	2.45 dB
Used antenna efficiency η_{real}	0.5	Used antenna efficiency η_{real}	0.49	Y-dish&feed: Absorber/SkyElevation	2.17 dB
Edge taper [dB], feed taper	-11 -9 dB	Edge taper [dB], feed taper	-11 -8.1 dB	Y-feed: Gnd(or absorber)/SkyZenith	3.16 dB
Dish center - rim	37.6°	Dish center - rim	64°	Sun temp, SFU@frequency	0 0
HPBW _{real} , gain _{real}	0.18° 58.45 dBi	HPBW _{real} , gain _{real}	0.179° 58.36 dBi	Y-Sun: 1+Sun/(Sky+Noise)	---
				Y-Moon: 1+Moon/(Sky+Noise)	1.52 dB
Position x,y on Moon [°]	0 0	Position x,y on Moon [°]	0 0	G/T _{EME} incl. RX noise temp	31.44 dB/K
Intercepted power fraction	0.996 -0.02 dB	Received fraction (BWF)	0.0908 -10.42 dB	S/N _{EME} : Signal/(0+Sky+Noise):	-20.8 dB
Illuminated fraction	0.179 -7.47 dB	RX fill factor moon	0.996 -0.02 dB	S/N_{EME}: Signal/(Moon+Sky+Noise):	-22.4 dB
TX temperature [°C]	15	RX temperature [°C]	15	Decoding mode: Q65-60E <input type="text" value="---"/>	
TX humidity [%]	50	RX humidity [%]	50	RX libration rate [°/min]	0.00152
TX absolute pressure [mbar]	980	RX absolute pressure [mbar]	980	RX libration spreading	146 Hz
TX zenith atmosph.attenuation	0.87 dB	RX zenith atmosph.attenuation	0.87 dB	TXRX mutal libr. spreading	145 Hz
				Decoder threshold	-24.7 dB
Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr. <input type="text" value="---"/>					
TX refrac.corr. elevation [°]	38	RX refrac.corr. elevation [°]	38.05 0.0245	Margin = S/N _{EME} - threshold	---
TX LOS atmosph.attenuation	1.4 dB	RX LOS atmosph.attenuation	1.4 dB		2.3 dB

Bsp 6: Minimale Anforderungen für 47.088 GHz mit ungenauer Antennenpositionierung um 4 dB geringeres SNR!

TX Locator: JO62QJ - DC7KY-47 Latitude [N°] 52.3977 Longitude [E°] 13.3788		RX Locator: JO62PK - DL7YC-47 Latitude [N°] 52.4394 Longitude [E°] 13.2955		Use current time 15 min earlier 15 min later	UTC YY/MM/DD hh:mm:ss 2023/11/2 06:52:58
Transmitting Antenna: Gauss, max ant. $\eta = \text{theor.} - 5\%$ 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		Receiving Antenna: Gauss, max ant. $\eta = \text{theor.} - 5\%$ 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		Moon: Lunar reflectivity varies radially Isotropic path loss (radar equation) -290.8 dB Path loss (corrected for beam widths) -305.5 dB $\epsilon * \text{gain}_{TX} * \text{gain}_{RX}$ 105.3 dB TX power [W] 10 40 dBm Received signal power -163 dBm RX NoiseFigure [dB], temp 2 170 K RX bandwidth [kHz] 2.5 RX noise power -142.3 dBm Signal/Noise -20.7 dB Received Moon noise -144.2 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 effi. 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) 1.5 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	
Position x,y on Moon [°] 0.075 0 Intercepted power fraction 0.981 -0.08 dB Illuminated fraction 0.176 -7.53 dB		Position x,y on Moon [°] -0.075 0 Received fraction (BWF) 0.0345 -14.62 dB RX fill factor moon 0.981 -0.08 dB		Decoding mode: Q65-60E RX libration rate [°/min] 0.00152 RX libration spreading 89.7 Hz TXRX mutal libr. spreading 89.7 Hz Decoder threshold -25.6 dB	
TX temperature [°C] 15 TX humidity [%] 50 TX absolute pressure [mbar] 980 TX zenith atmosph.attenuation 0.87 dB		RX temperature [°C] 15 RX humidity [%] 50 RX absolute pressure [mbar] 980 RX zenith atmosph.attenuation 0.87 dB		Margin = S/N _{EME} - threshold --- -0.9 dB	
Use (real) time locked TX/RX elevation for: MOON with radio refractive elevation corr.					
TX refrac.corr. elevation [°] 38 TX LOS atmosph.attenuation 1.4 dB		RX refrac.corr. elevation [°] 38.05 0.0245 RX LOS atmosph.attenuation 1.4 dB			

Wissenswertes zum Mitnehmen

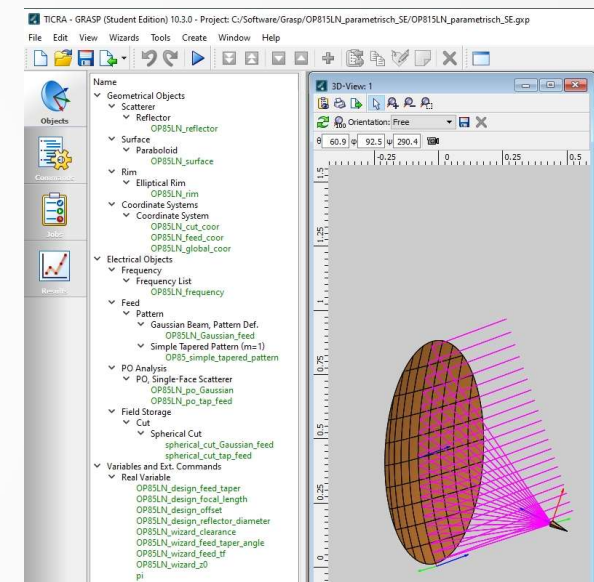
- Mit der allgemeinen Radargleichung können wir EME-Verbindungen auch bei >10 GHz genauer berechnen
- Mit dem „**EME Link Analysis tool**“ können wir die Auswirkungen unserer Optimierungen zuerst analysieren und Prioritäten richtig setzen (zeit- und kostenschonend)
- Das Tool ist open source und Interessierte 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**

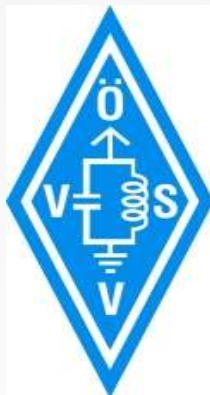
... und es geht weiter

- 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. Rohlf, 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://wattersat.bplaced.net/antennabasics.html>
- Gerald Ihninger OE2IGL, EME tool, <https://wattersat.bplaced.net/EME/EME.html>



Danke für die Aufmerksamkeit

Besten Dank an die weltweiten EME Kollegen für die zahlreichen Diskussionen und zur Verfügungstellung ihrer EME Systemparameter.

Spezieller Dank gebührt **Joachim Köppen DF3GJ**, der von September – Dezember 2022 jeden Tag für Diskussionen zur Verfügung stand, um mir das fehlende Wissen beizubringen und einen Teil des Softwarecodes entwickelt hat.

Gerald, OE2IGL

<https://wetersat.bplaced.net>

OE2IGL@inode.at

