Measurements of the DL0SHF 8 GHz Antenna

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Pointing Correction

Position errors had already been determined on a few days in June 2015. Quite surprisingly, they resulted in an already very satisfactory correction model. In August, a more comprehensive set of measurements completed the sky coverage (Fig. 1).

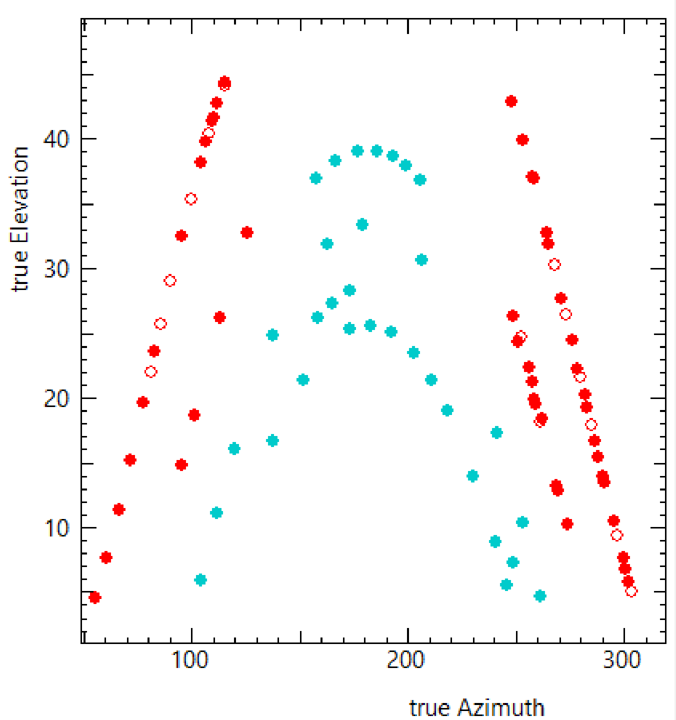

***Fig. 1** The sky coverage of position measurements taken for the pointing correction*

Since at one time the basic settings had to be changed, the data were matched together by adjusting the azimuth and elevation offsets of each portion. Despite this small complication, the complete set of measurements gave only cosmetic changes to the model, as shown in the Table which lists the residual r.m.s. errors. While the original Bodenschief model would be capable of providing a satisfactory fit, the Q-models give residuals close to the resolution of the positioning system.

Model	June 2015 data	All data
(original) Bodenschief	0.114°	0.118°
P-model	0.066	0.066
Q10	0.038	0.040
Q18	0.029	0.037
Q24	0.013	0.02

During these measurements, no problems with the positions were encountered. However, the elevation drive is extraordinarily slow in its slow mode, taking 2 minutes to cover the 0.2° of the final approach to the target, and which hence would put quite a heavy load on the motor.

Antenna Pattern

The radiation pattern is obtained by a drift scan of the Sun (Fig. 2). The main lobe is well represented by a Gaussian curve with a FWHM of 0.61°. The side lobes are below -15 dB of the peak value.

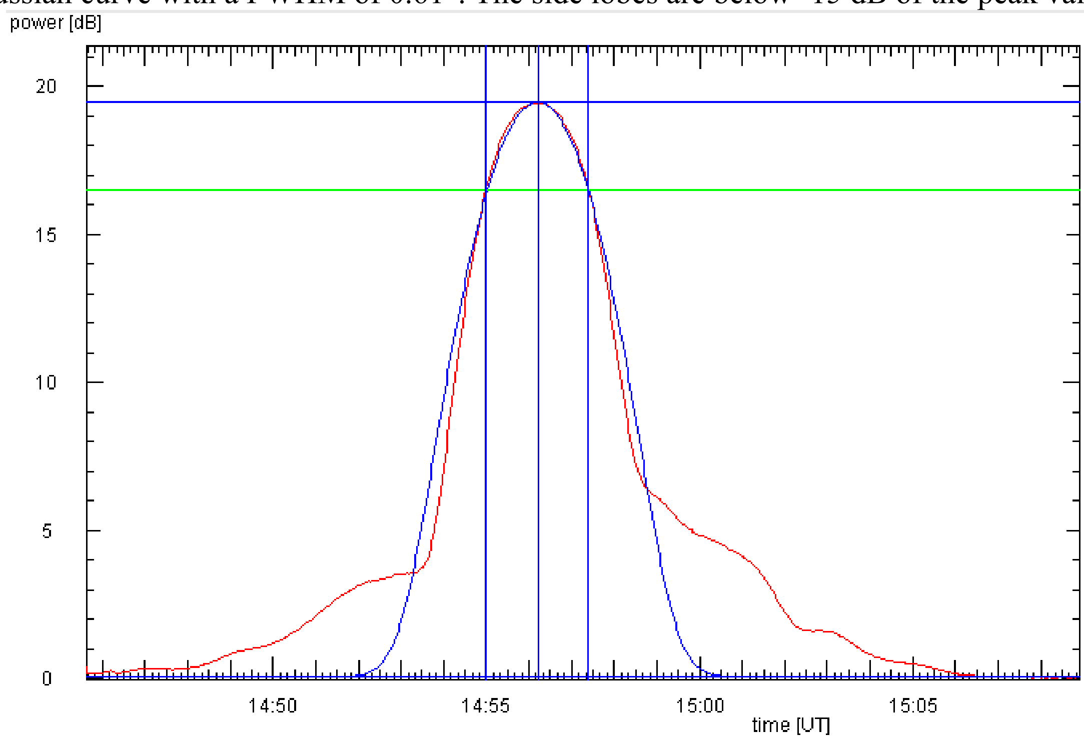

Fig. 2 *The main lobe of the 8 GHz antenna. The measured curve (red) is compared to a Gaussian function (blue curve). Horizontal blue lines mark the peak value and the adopted sky foreground level. The green line indicates the level of half maximum power; the vertical blue lines mark the times of the half-power points.*

Subtraction of the sky foreground and normalization to the peak level reveals the pattern in all detail (Fig. 3). The side lobes are below -15dB, with the western side (on the right in the figure) having a somewhat stronger shoulder. On the eastern side one clearly discerns four side lobes within 2.5° of the peak position. The pattern is confirmed by a subsequent drift scan of the Moon (Fig.4).

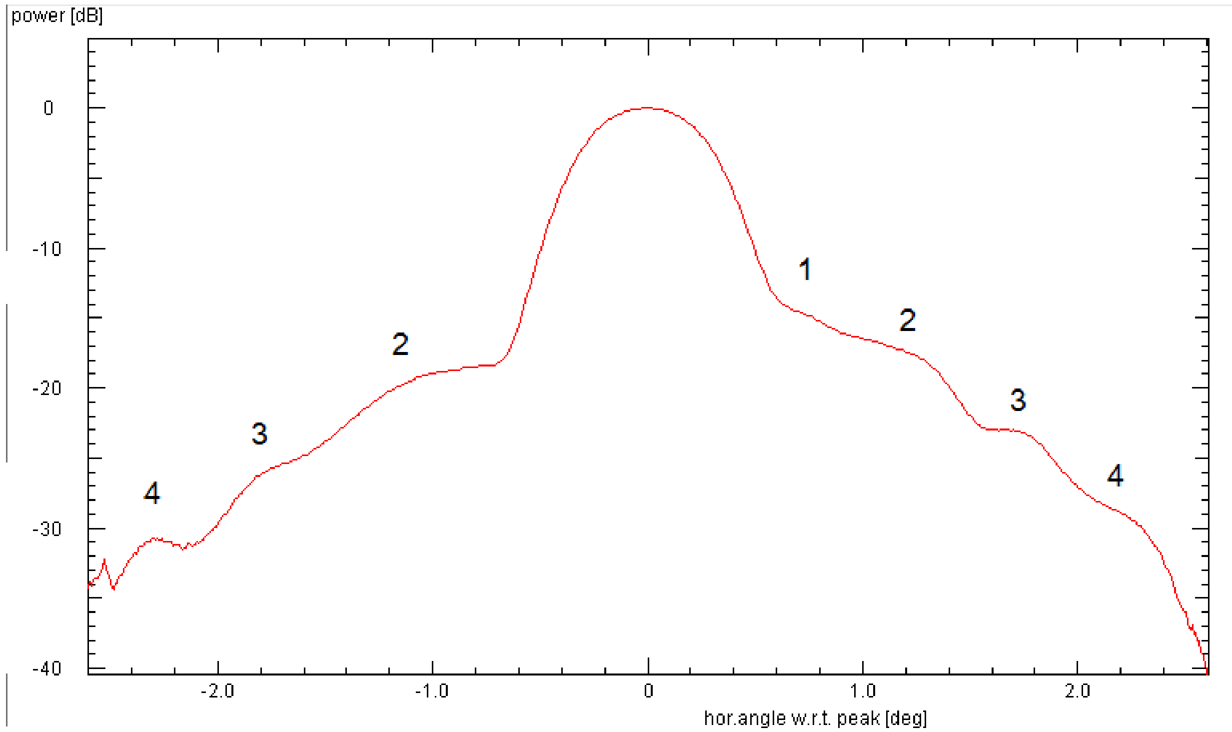

Fig. 3 *The radiation pattern of the 8 GHz antenna, from a solar drift scan taken in the early afternoon. The numbers indicate the side lobes.*

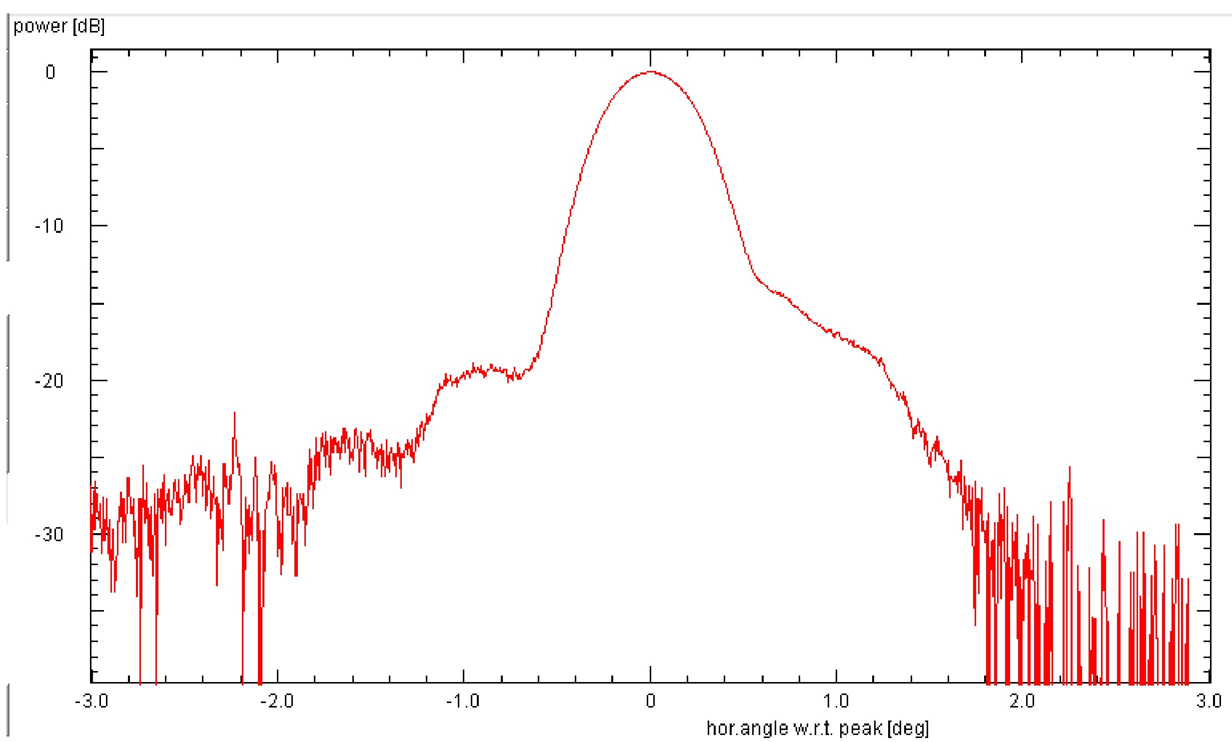

Fig. 4 *As Fig.3, but done with the Moon*

At the time of observation the sun's angular diameter is 0.526°, which is larger than the true HPBW of the antenna. Thus the explanation of the measured pattern needs to take this into account. Figure 5 presents the theoretical pattern of a 4.4 m diameter uniformly illuminated circular aperture, along with the pattern expected from convolution with the solar disk, which is assumed to be a uniformly bright circular disk. The first side lobe is 20 dB below the peak, and the fourth one is at -30 dB, which is in good agreement with the observed pattern.

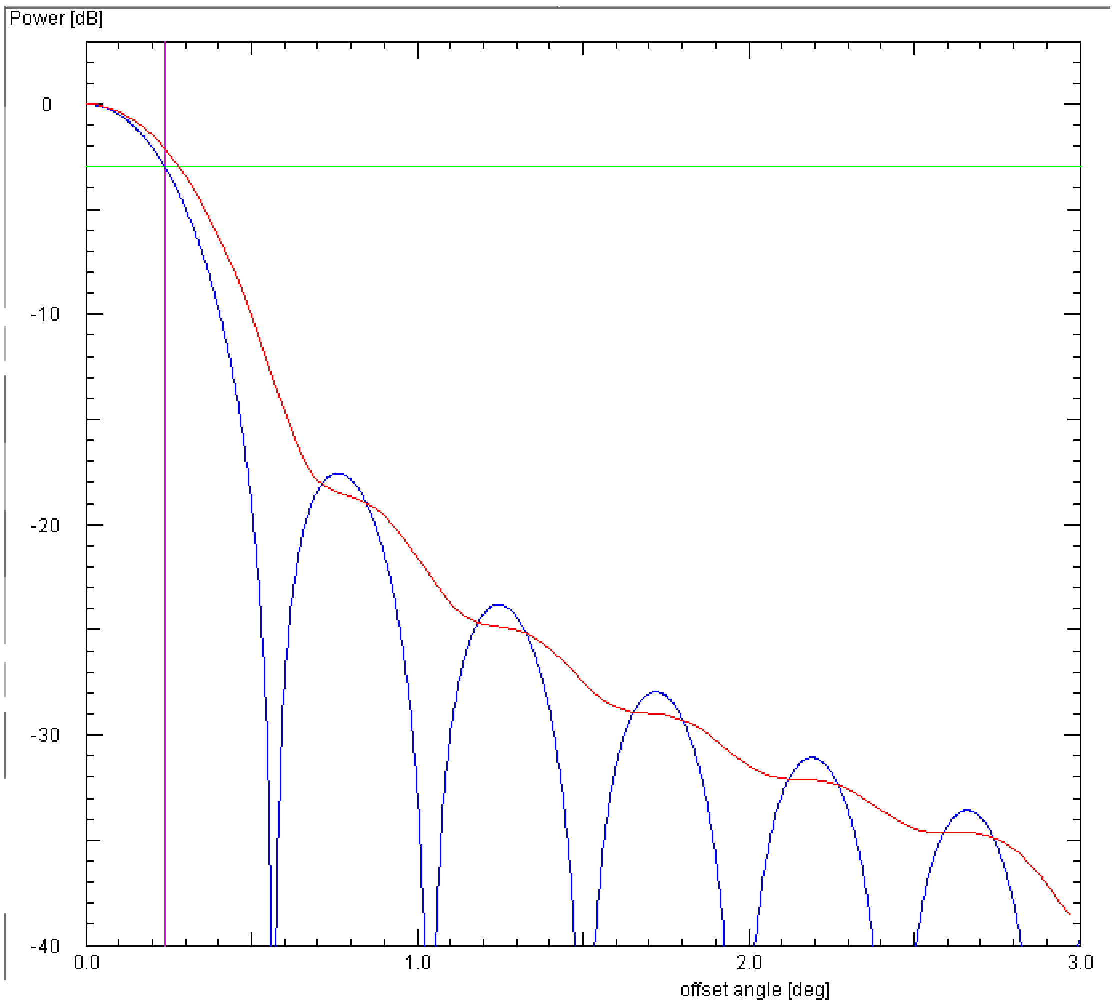

Fig. 5 *Theoretical radiation pattern for a 4.4 m uniformly illuminated circular antenna at 8 GHz (blue curve). The red curve is the observable pattern due to convolution with the Sun, which is modeled by a uniformly bright circular disk.*

Antenna diametre [m]	Theoretical HPBW [°]	FWHM (with Sun) [°]
7	0.297	0.490
5	0.420	0.724
4.4	0.480	0.560
4	0.524	0.603
3.5	0.600	0.662
3	0.696	0.750

From the above Table it appears that the width of 0.61° for the lobe measured with the Sun indicates an effective diametre of 4 m. However, the four side lobes observed within 2.5° of the centre are reproduced by a diametre of 4.4 m.

Adopting this larger value, the effective antenna area is 15.2 m^2. This gives a gain of +51.75 dBi. Since the mirror has an outer diametre of 7.2 m, the aperture efficiency is 0.37, which may indicate that there is still some room for improvement.

Since this antenna cannot be raised above 45° elevation, a direct measurement of the spill-over cannot be made. This would have given another constraint on the aperture efficiency.

System Temperature

Measurements of the sky noise at elevations 15, 20, 25, 30, and 40° and flux calibration in the small grove (Fig. 6) yield a system temperature around 100 K. On other days 130 K are found. Note that the measurement at 10° is already affected by the emission from the trees.
The zenith temperature is usually 5 to 6 K. The analysis depicted in Fig.6 comes from a day with overcast sky and light rain.

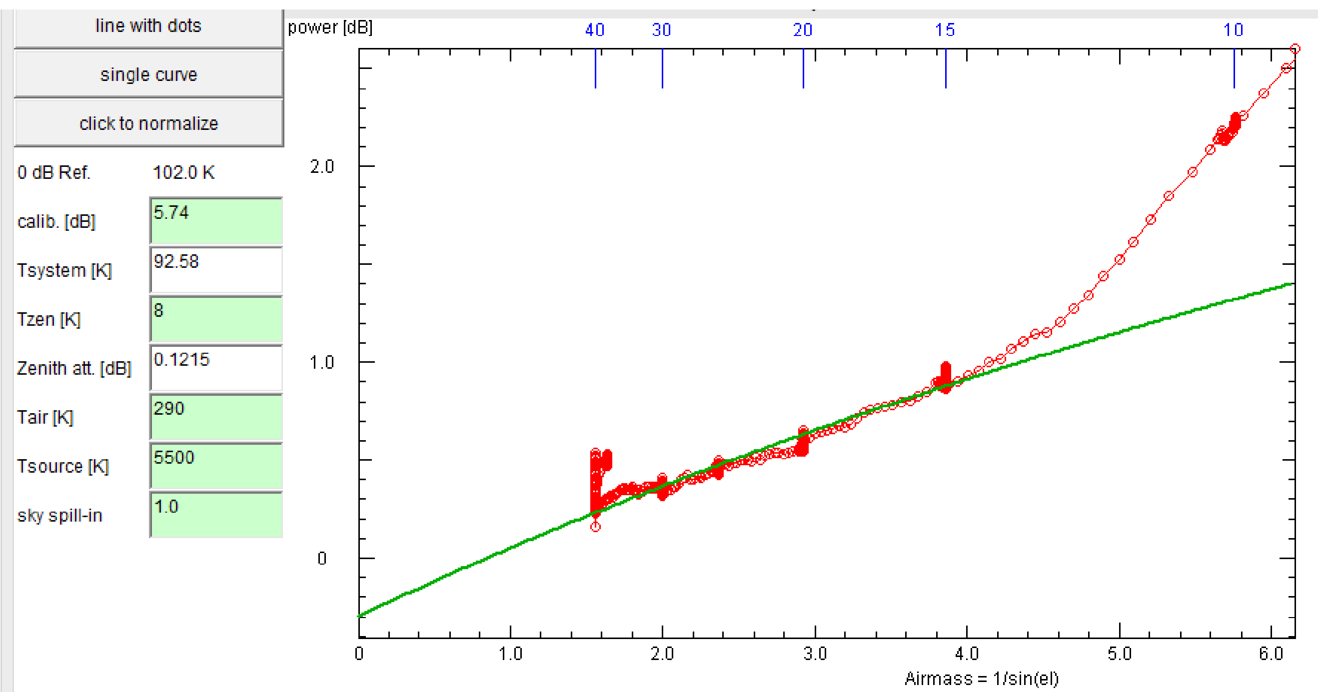

Fig. 6 *Interpretation of the sky profile taken in the late afternoon of 27 aug 2015, with overcast skies and light rain. Red symbols pertain to the observational data. The green curve is the relation between sky noise and elevation, predicted by a model for the atmospheric absorption and emission, assuming an air temperature of 290 K. The blue scale at the top marks the elevations.*

Atmospheric Absorption

As already shown in Fig.6, the zenith absorption is about 0.1 dB per airmass. The observation of the sunset – three hours later – gives very similar results, as shown in Fig.7. Due to the passage of clouds across the antenna beam there are variations of the signal level throughout the observation period. As a consequence the fit obtained differs somewhat from the results of the sky profile (Fig.6).

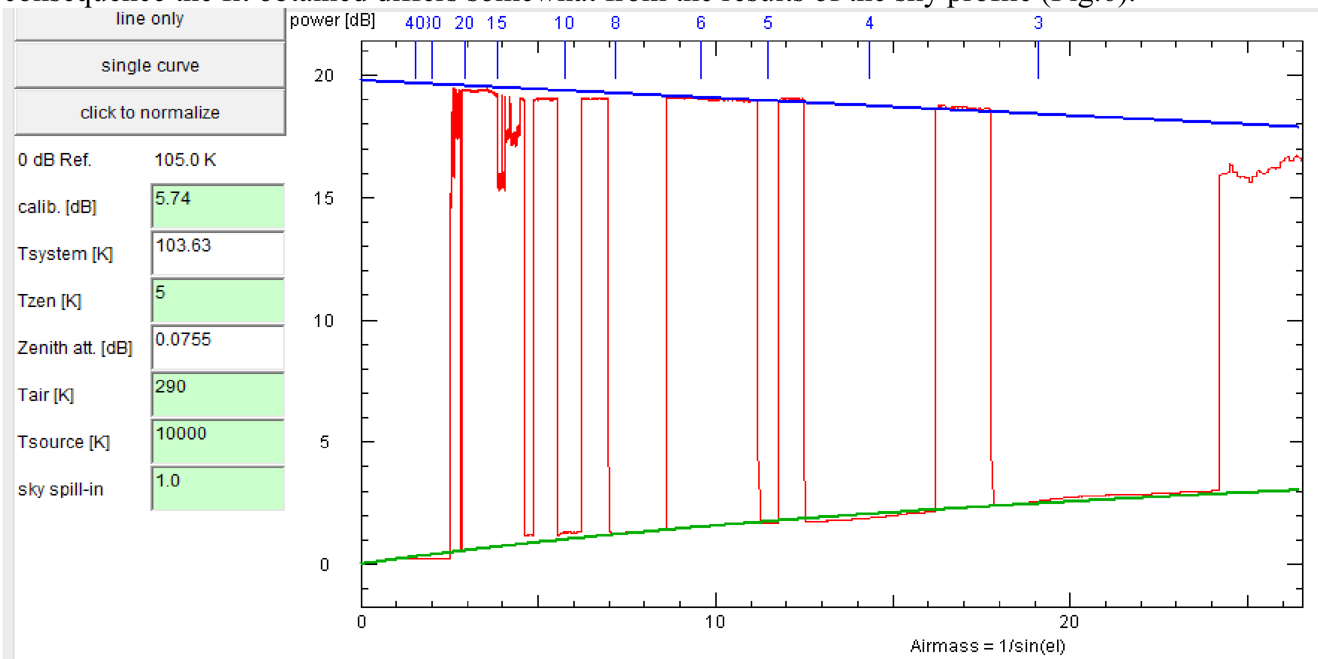

***Fig.** 7 Interpretation of sunset observations. The red curve depicts the measured signal level, with beam switching between the Sun's position and the sky foreground measured about 5° east of the Sun. The green curve is the predicted relation between sky noise and elevation, like in Fig.6. The blue curve is the predicted elevation dependence for the solar signal, computed from the model and the specified antenna temperature of the Sun.*

The data taken on several days (cf. Table below) indicate that the zenith temperature increases slightly when the sky is overcast and rainy.

Date	System temperature [K]	Zenith temperature [K]	Sky condition
Sunset 26 aug	100 (assumed)	4	Overcast, bright
Sky profile 27 aug	93	8	Overcast, rainy
Sunset 27 aug	104	5	Overcast, rainy
Sky profile 28 aug	131	6	Sunny
Sunset 28 aug	135	6	Sunny
Sky profile 29 aug	124	6	Sunny, high cirrus
Sunset 29 aug	132	5	Sunny, high cirrus
Moon rise/set 30 aug	130 (assumed)	7	Thin clouds … overcast
Sky profile 30 aug	129	7	Sunny, light clouds
Sunset 30 aug	114	6	Overcast

Solar Radio Flux

The observations of sunsets, along with the flux calibrations in conjunction with the sky profiles yield the antenna temperature for the Sun:

Date	Antenna temperature [K]	Sky conditions
26 aug	10800	Overcast, bright
27 aug	10000	Overcast, rainy
28 aug	14000	Sunny
29 aug	13000	Sunny, high cirrus
30 aug	10500	Overcast

There appears to be a correlation of higher antenna temperature with sunny weather. Note that the atmospheric absorption is fully modeled, and the analysis would give the proper antenna temperature. However, as the obtained higher values are also associated with higher system temperature (of 130 K), the interpretation might still be influenced by the uncertainty to find the best fit of the data by adjusting the relevant parameters.

- Therefore, we use the two values of 10000 and 14000 K.
- The effective antenna area of 15.2 m^2 implies a sensitivity of 5.5 mK/Jy or 182 Jy/K.
- This gives for the solar flux at 8.4 GHz the values 182 and 254 SFU.
- The solar fluxes interpolated for 8.4 GHz from the data published by NOAA, give values between 280 and 265 SFU for these days.

As the measurements obtained on sunny days agree very nicely with these values, we may conclude:

- the system temperature is indeed near the higher value of 130 K
- the effective diametre of the antenna is near 4.4 m, i.e. the effective area is 15.2 m^2

Lunar Flux Measurement

During one of these days, the Moon was tracked all day – for position determinations – but this also allowed to measure the lunar radio fluxes during rising and setting. Figure 8 shows that the data are fairly consistent, despite the increase of the cloud cover during the night.

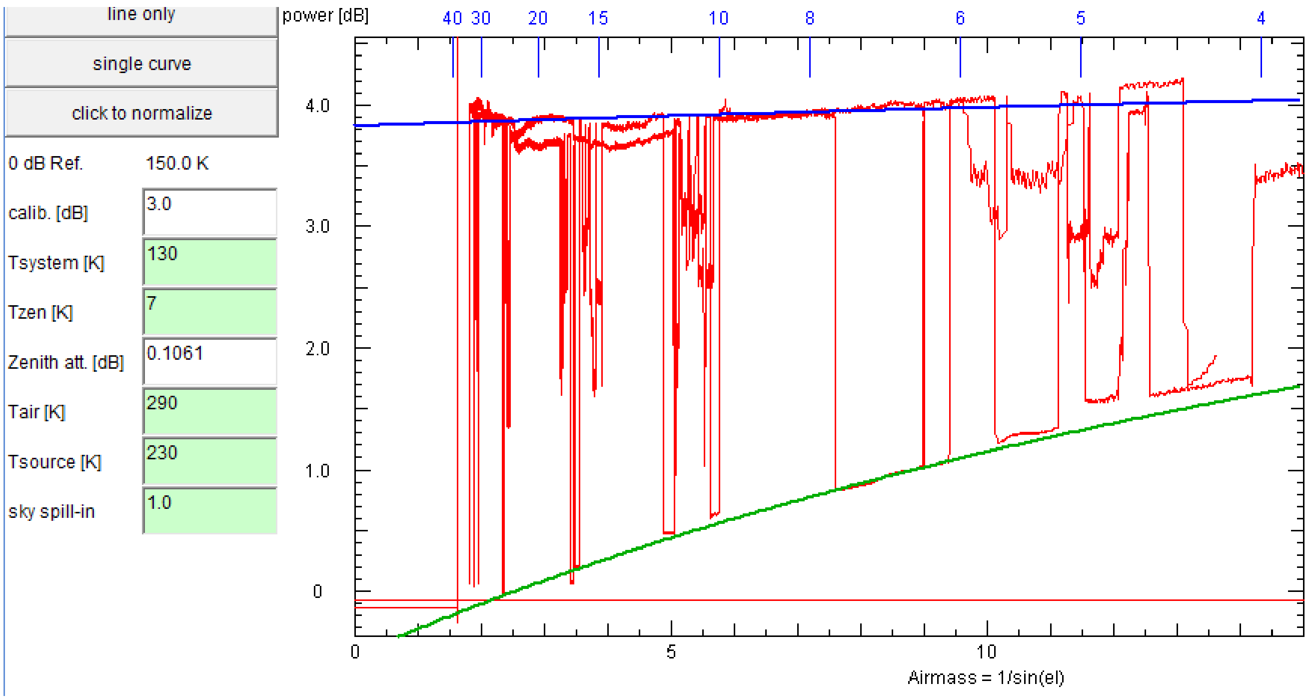

Fig. 8 *Like Fig.7, but for a full day of tracking the Moon, from rise to set, on 30 aug 2015. The drops in the lunar signal are position measurements.*

The antenna temperature of 230 K gives a radio flux of 42 kJy. A simple model for the lunar radio flux, based on the distance and the lunar phase-dependent surface temperature gives about 40 kJy for the day of observation, in very good agreement with the measurements.

Summary

The characteristics of this antenna are

- HPBW: 0.5°
- effective diametre: 4.4 m
- effective area: 15.2 m^2
- gain: 51.75 dBi
- sensitivity: 182 Jy/K
- aperture efficiency: 0.37
- system temperature: 130 K