Measurements of the DL0SHF 10 GHz Antenna

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Pointing Correction

The position measurements done in March/April 2015 cover a good portion of the sky with particular emphasis for the Moon (Fig.1) allow to derive a good correction model.

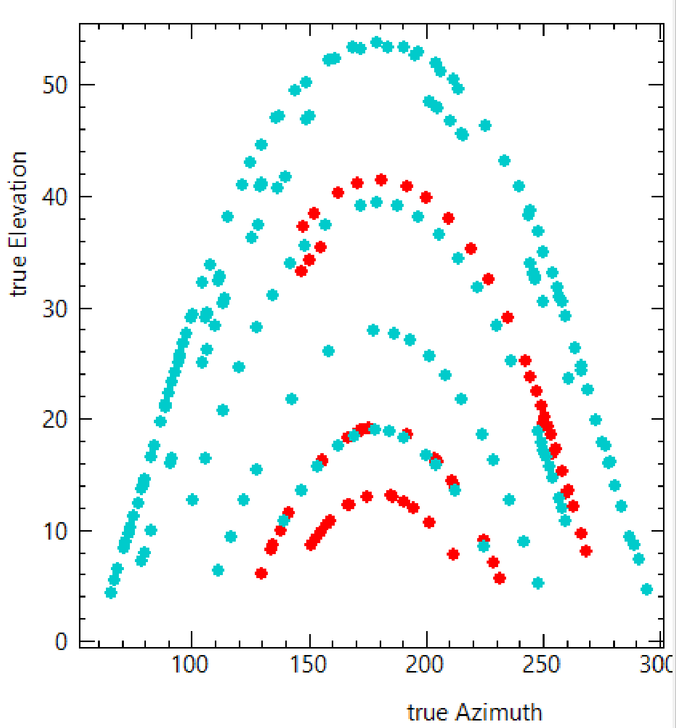

Fig.1 *Sky coverage of the position measurements. Red dots indicate the Sun, blue-green dot the Moon.*

The azimuth errors of this antenna become rather large for azimuths greater than about 240°. To compensate this rapid change, correction terms depending on 2*azimuth and 3*azimuth are necessary, which give a very good match of the data (Fig.2).

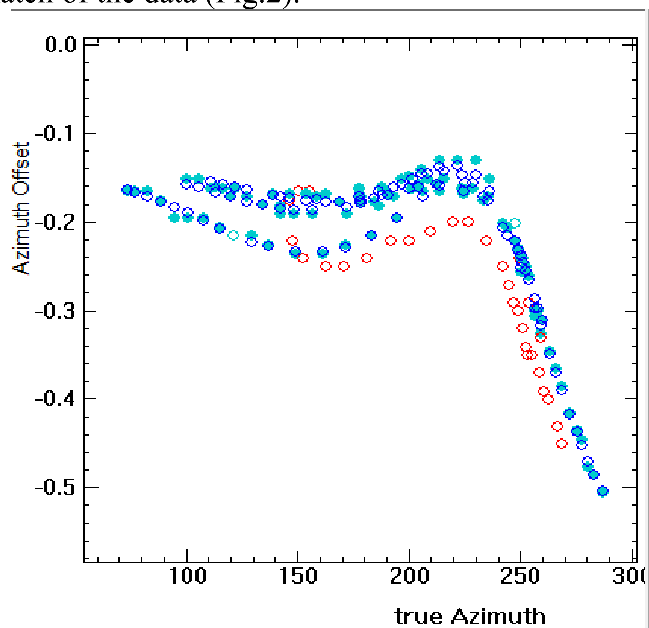

Fig.2 *The azimuth errors as a function of azimuth. The open blue circles are the predictions from a best-fit model derived from the lunar positions only. The red circles are the solar data which are not considered here.*

However, there remains a small problem: There is a systematic offset of about 0.05° between the solar and lunar positions (Fig.3). Most probably this is due to a small error in the position predicted in the March/April version of the program. As the error is much smaller than the antenna's beam width, hence is of little consequence for the accurate tracking of the Moon, there was no urgent necessity to have it further investigated. It would be advisable to look into this issue more closely the next time when extensive position measurements are made.

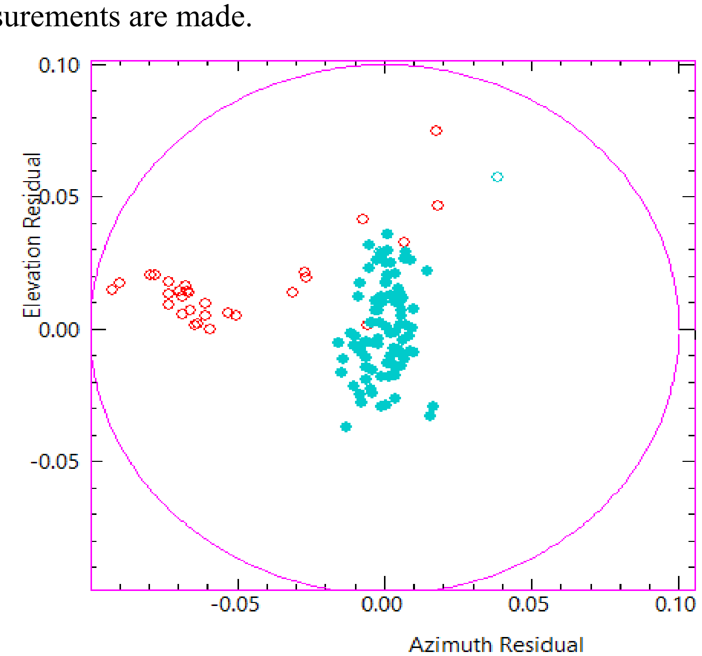

Fig.3 *The residual errors of the data with respect to the models from Fig.2.*

Antenna Pattern

Two solar drift scans are done in September 2015 to measure the radiation pattern (Fig.4). Both show a slight asymmetry of the central portion of the main lobe, in that the maximum is shifted to the west by about 0.02°. Nonetheless the main lobe can well be represented by a Gauss function of a Half Poer Beam Width of 0.51°. The flanks are a bit steeper than a Gauss function. The side lobes are at least 15 dB below the maximum.

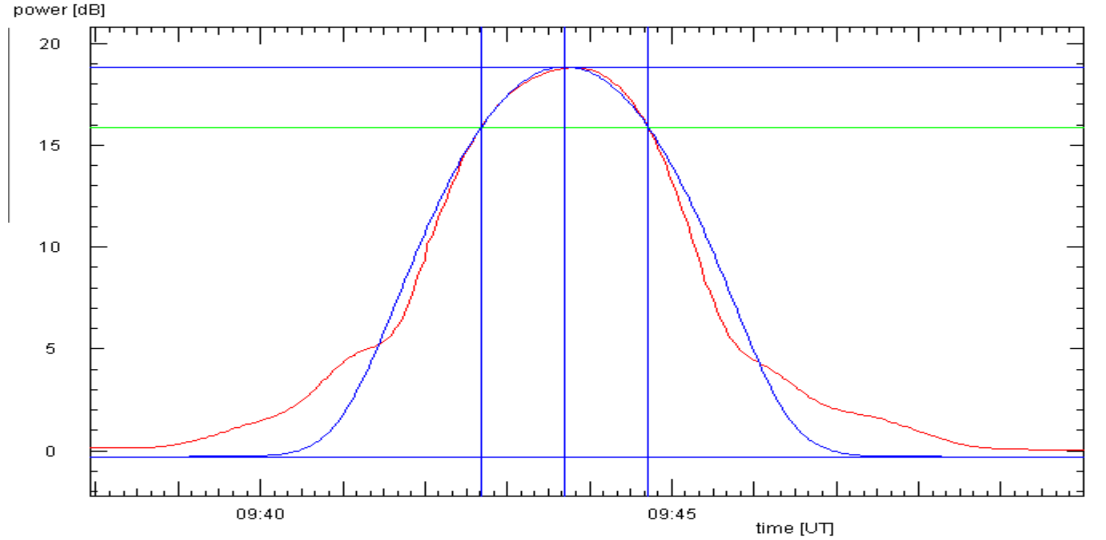

Fig.4 *The raw data of a solar drift scan (red curve) compared to a Gauss function (blue curve). The horizontal blue lines mark the adopted level of the sky foreground and the maximum value. The green line indicates the level of half maximum power. The blue vertical lines mark the times of the peak and the two half power points.*

Subtraction of the sky foreground and normalization to the maximum value give the antenna pattern. Figure 5 shows that there are four side lobes within 2° of the centre. Despite some deviations the overall pattern is fairly symmetric. There is no prominent side lobe sticking out on one side.

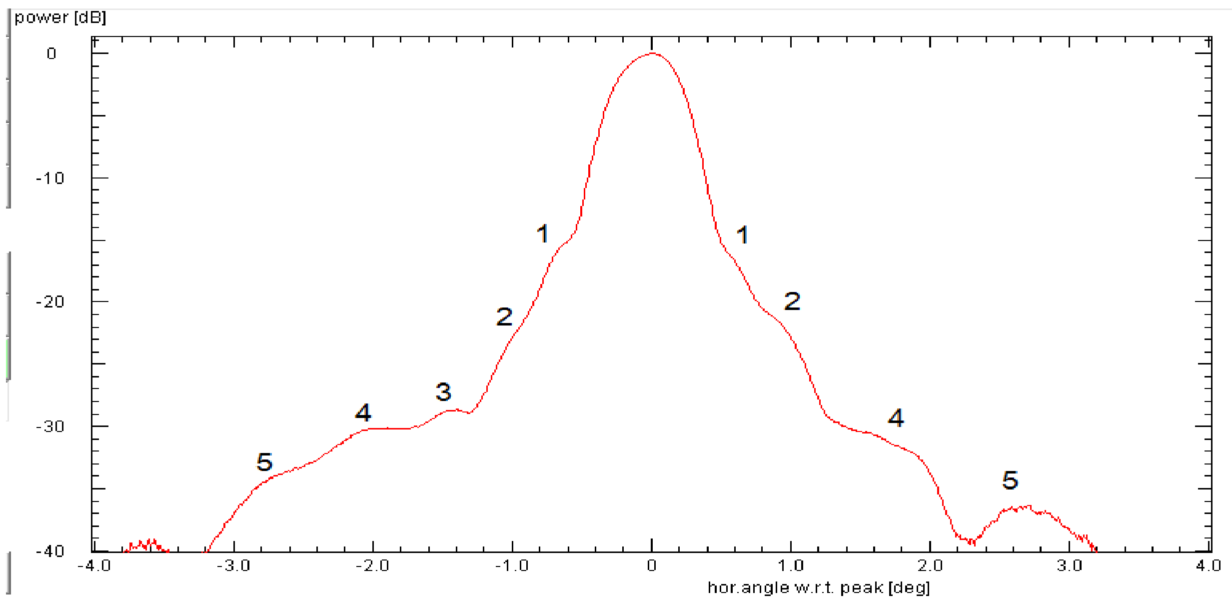

Fig.5 *The radiation pattern of the DL0SHF 10 GHz antenna. The numbers indicate the side lobe peaks*

As the theoretical beam width of this 7.2 m diameter antenna is smaller than the angular diameter of the Sun, the interpretation of the measured pattern can only be done by taking into account the finite source size. At the time of observation, the solar diameter is 0.53°. At 10 GHz the radiation comes from the lower transition region, hence the Sun can be represented by a disk of uniformly brightness. Theoretical antenna patterns are computed for uniformly illuminated circular apertures, and give the antenna's HPBW and the Full Width at Half Maximum of the observable data:

Diameter [m]	HPBW [°]	FWHM [°]
7	0.244	0.475
6	0.283	0.495
5	0.370	0.500
4	0.426	0.531
3	0.582	0.626

This suggests that the effective diameter is close to 5 m. The radiation pattern (Fig. 6) of a dish of such diameter shows 4 side lobes within 2° of the centre, which agrees with the observed pattern.

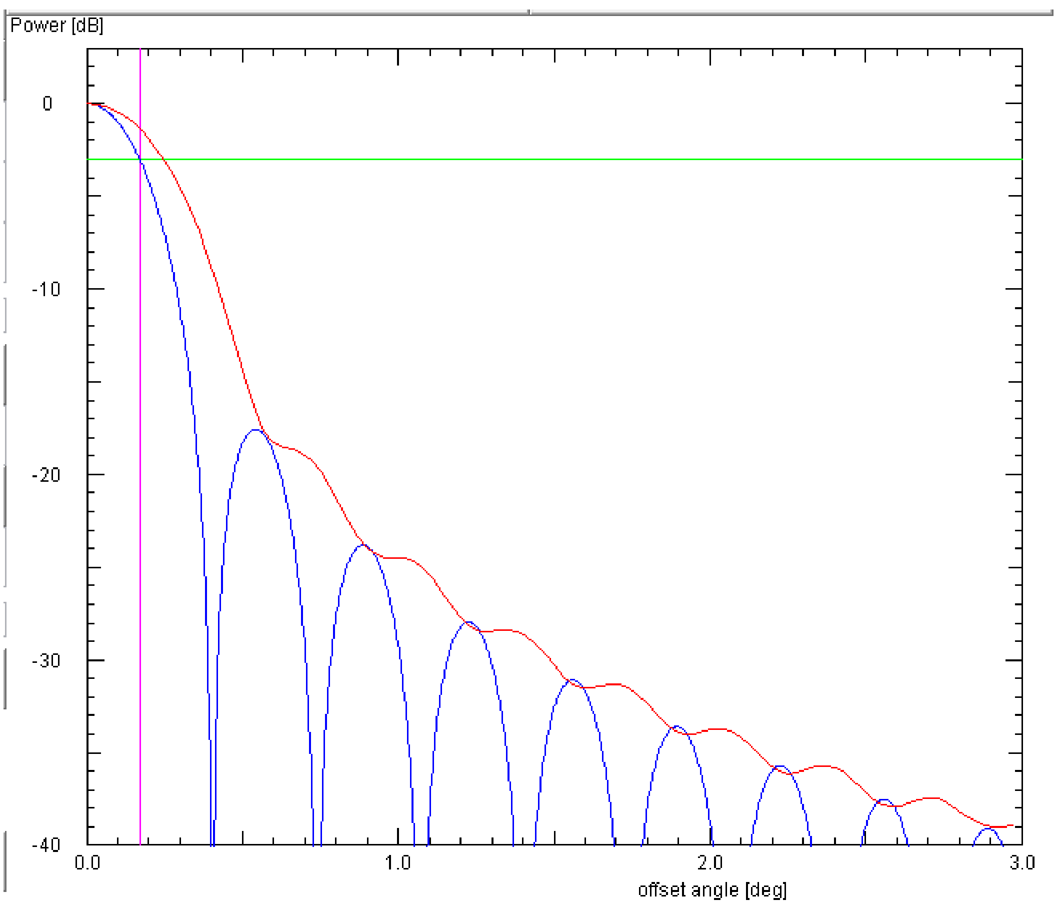

Fig.6 *The theoretical radiation pattern of a uniformly illuminated circular aperture of 5m diameter (blue curve), and the pattern that would be observed with the Sun as a source.*

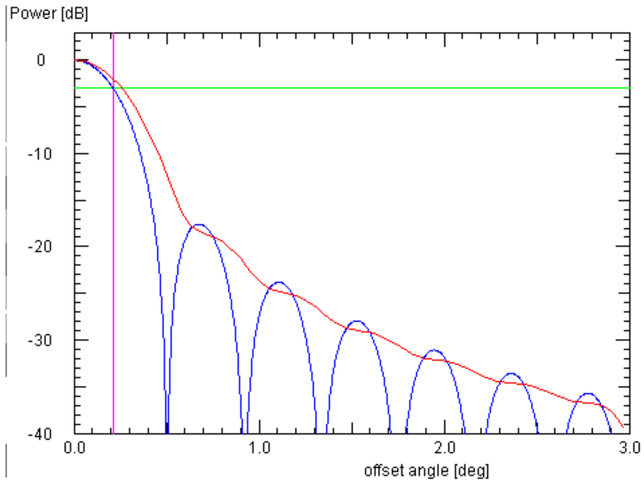	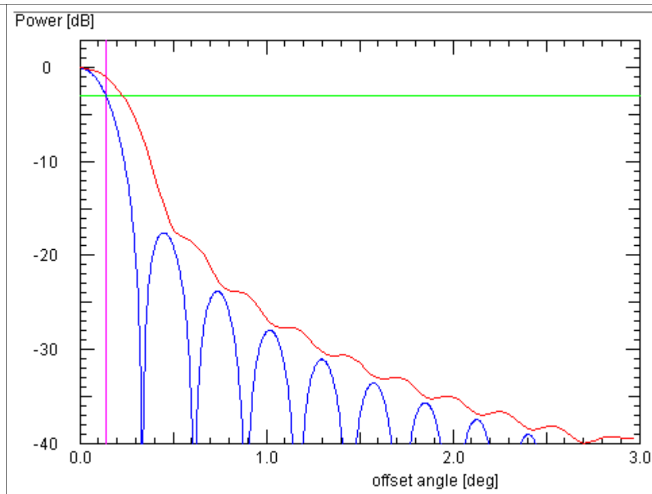
Fig.7a *Theoretical pattern of a 4m antenna would show 3 side lobes within 2°*	***Fig.7b*** *The pattern of a 6m antenna has almost 6 side lobe peaks within 2°*

For comparison, Fig.7a,b show that the patterns for 4 and 6m diameter antenna have too few or too many side lobe peaks.
One may therefor adopt 5.0m as the effective diameter of the 10 GHz antenna. This implies:

- effective area: 19.6 m^2
- gain: 54.73 dBi
- with a geometrical diameter of 7.2m the aperture efficiency is 0.48
- sensitivity: 7.1 mK/Jy or 151 Jy/K
- true HPBW: 0.37°

System Temperature

This is derived from the measurement of the ground thermal radiation and of the sky foreground taken at several elevations. The interpretation is shown in Fig. 8.

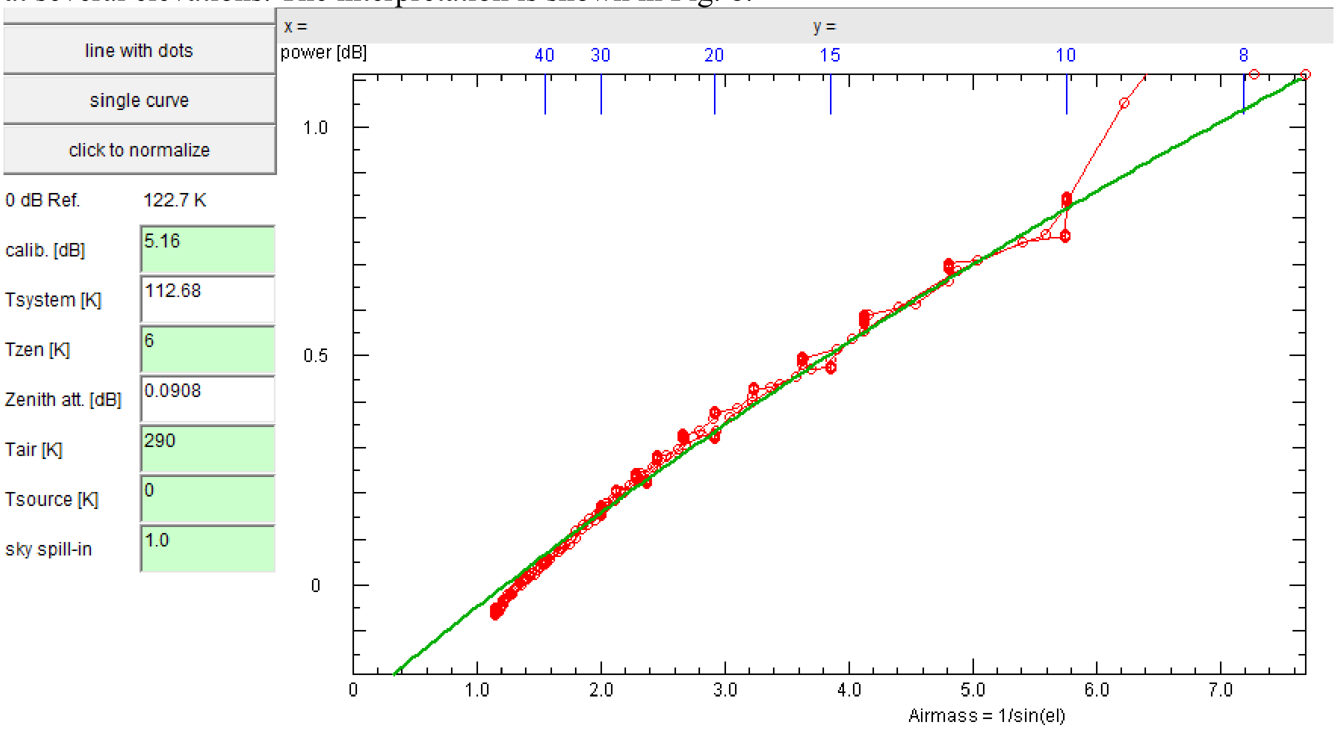

Fig.8 *The sky profile measurements from 6 June 2015 (red curve and dots) are matched with the predictions of a model for the absorption and emission of the atmosphere (green curve). A constant air temperature of 290 K is assumed. From the ground calibration the system temperature is derived. The blue numbers at top indicate the elevation angles corresponding to the abscissa in air mass.*

This particular data set – taken after the sunset on 6 June 2015 – is quite remarkable because the curvature of the measured curve cannot be accurately matched by the model predictions, although they already take into account atmospheric absorption. The sky at that time was bright and covered with only light cirrus clouds, thus ideal conditions. If one wants to fit the low elevation data, one obtains a zenith temperature of 6 K, as shown. To match the observations at elevations between 20 and 40° a zenith temperature of 7 K is necessary. In either case, the system temperature remains very close to 110 K.

The alternative method of interpretation – fitting a straight line to the data – is shown in Figs 9 and 10. Modeling the data without atmospheric absorption yields a system temperature of 114 K and a zenith temperature of 5.4 K (Fig.9). When absorption is included, the best fit is reached with 0.4 dB zenith absorption (Fig.10). This also gives system temperature 110 K and zenith temperature 7 K. The latter would imply an air temperature of only 80 K. This unreasonable value is only the consequence of the impossibility of matching the data by a simple atmospheric model (as in Fig.8).

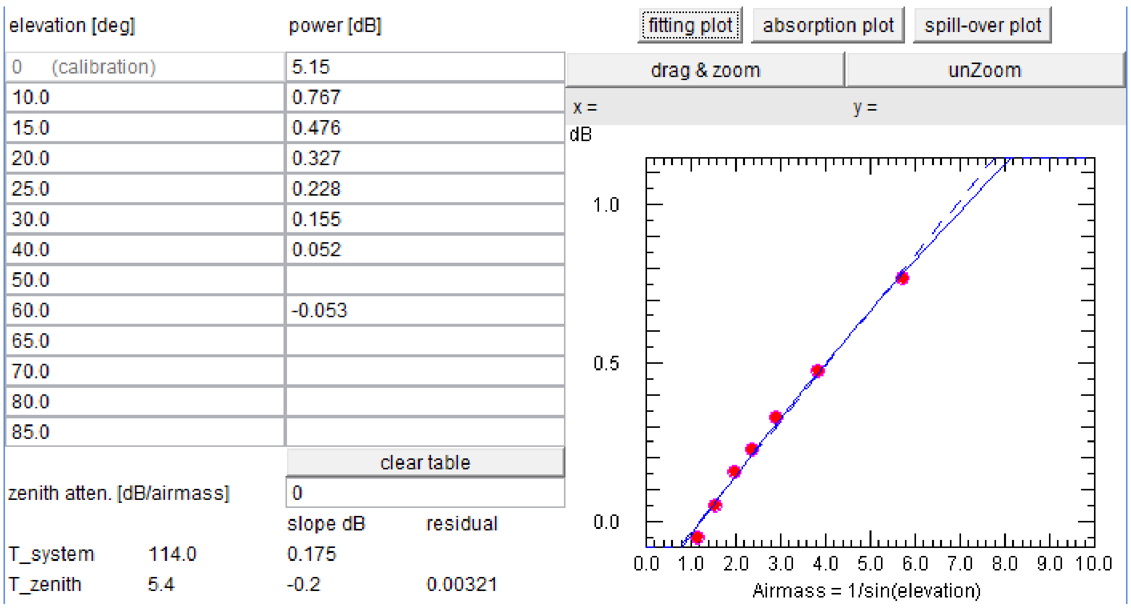

Fig.9 *The sky profile data of Fig.8, fitted by a simple straight line*

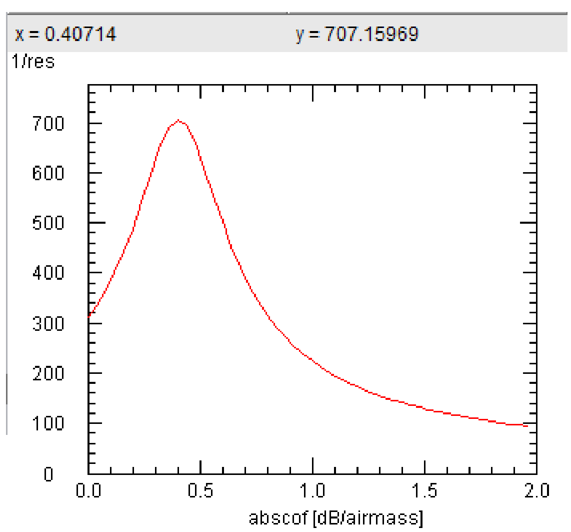

Fig.10 *Searching the best fit of a straight line through the data given in Fig.9 but modified for atmospheric absorption, shows an optimum for zenith absorption of 0.4 dB.*

Despite these complications – which have not been fully cleared up yet – the system temperature of the 10 GHz antenna is found as 110 K.

Solar Observations

The sunset on 6 June 2015 is followed by tracking the Sun and making regular measurements of the empty sky, about 10° east of the Sun. Along with the ground calibration, taken immediately after sunset, these data allow to determine system temperature, atmospheric absorption, and antenna temperature of the Sun.

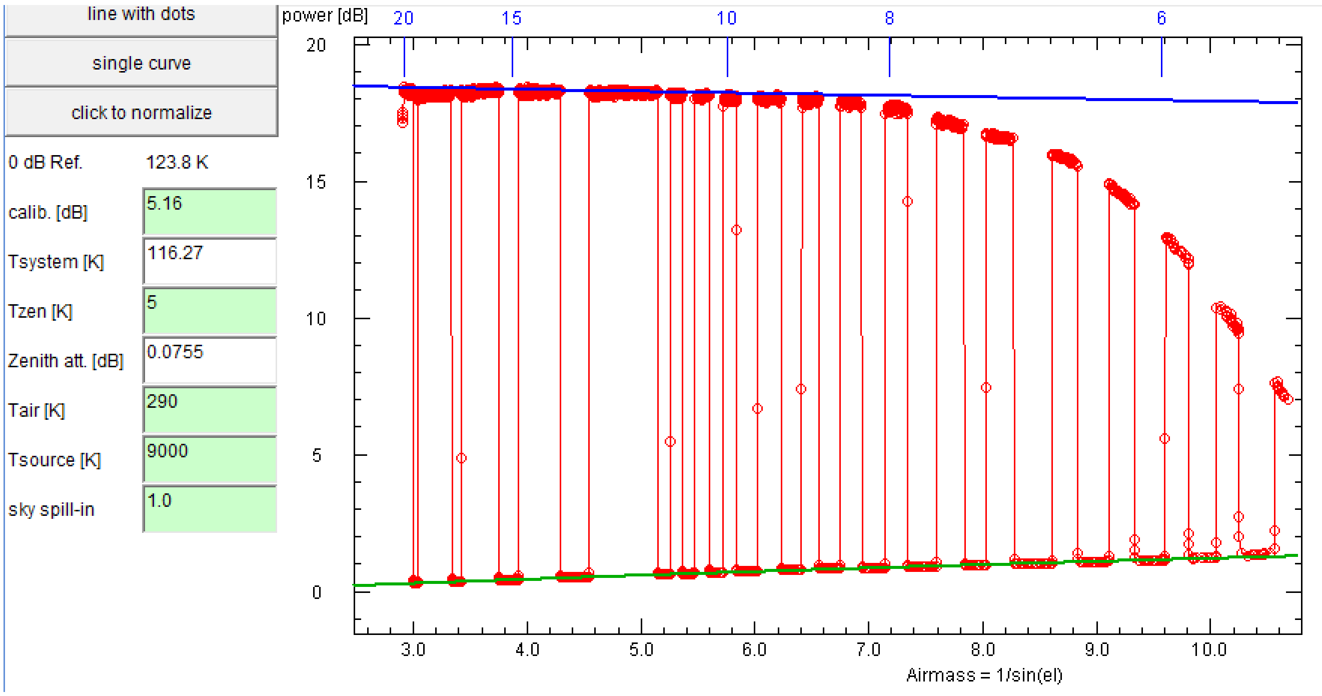

Fig.11 *Interpretation of the observations of the setting Sun (6 June 2015). Explanations as in Fig.8*

Figure 11 shows the interpretation of these data. For elevations above 10° the solar signal is constant, which indicates that at 10 GHz atmospheric absorption is negligible. However, below 10° elevation the signal level drops quite strongly and rapidly. Here the tracking of the Sun becomes rather poor! Hence the pointing correction would still need some further improvement at low elevations.

The solar antenna temperature is 9000 K. With a sensitivity of 151 Jy/K this gives a solar radio flux of 1.36 MJy or 136 SFU. At the time of observation, the solar radio fluxes published by NOAA are interpolated to 10.4 GHz to give 350 SFU. This implies an efficiency of 0.39, which is quite a bit below the aperture efficiency derived from the antenna pattern. This requires further attention.

Summary

The 10 GHz antenna has the following characteristics

- effective diameter: 5.0 m
- effective area: 19.6 m^2
- gain: 54.73 dBi
- aperture efficiency: 0.48
- sensitivity: 7.1 mK/Jy or 151 Jy/K
- true HPBW: 0.37°
- system temperature: 110 K