Antenna Technical Works

16-April-2012

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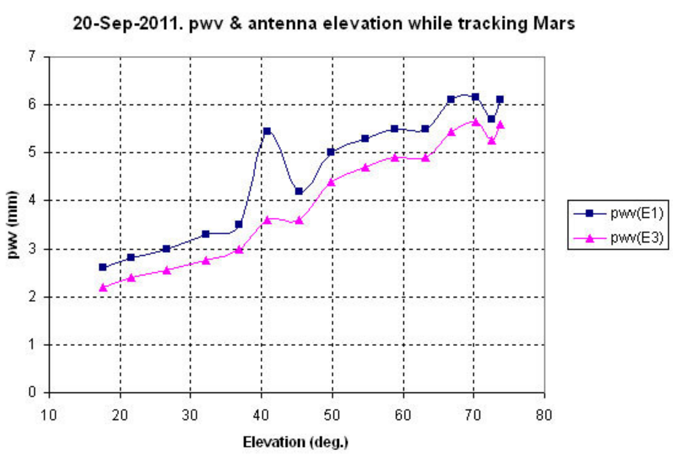
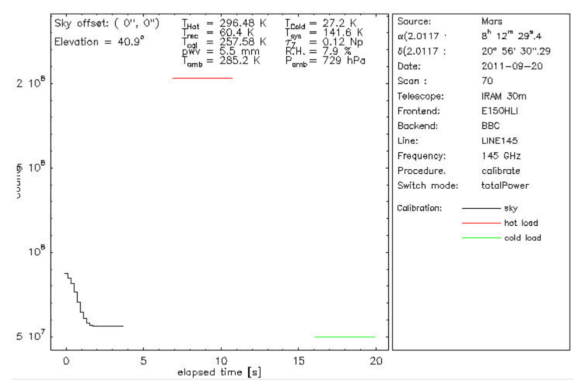
Topics
1. **Antenna Gain Elevation Curve**
2. **Antenna Gain with Wobbler Tilt**
3. **Antenna Behaviour after the Sun Rising**
4. **Antenna Beam Pattern Deformation at Low Elevations**
5. **Antenna Gain with Focus Offset, Axial and Lateral**
6. **Subreflector Rotation Effect in Antenna Gain, Focus and Pointing Corrections**

1. Antenna Gain Elevation Curve

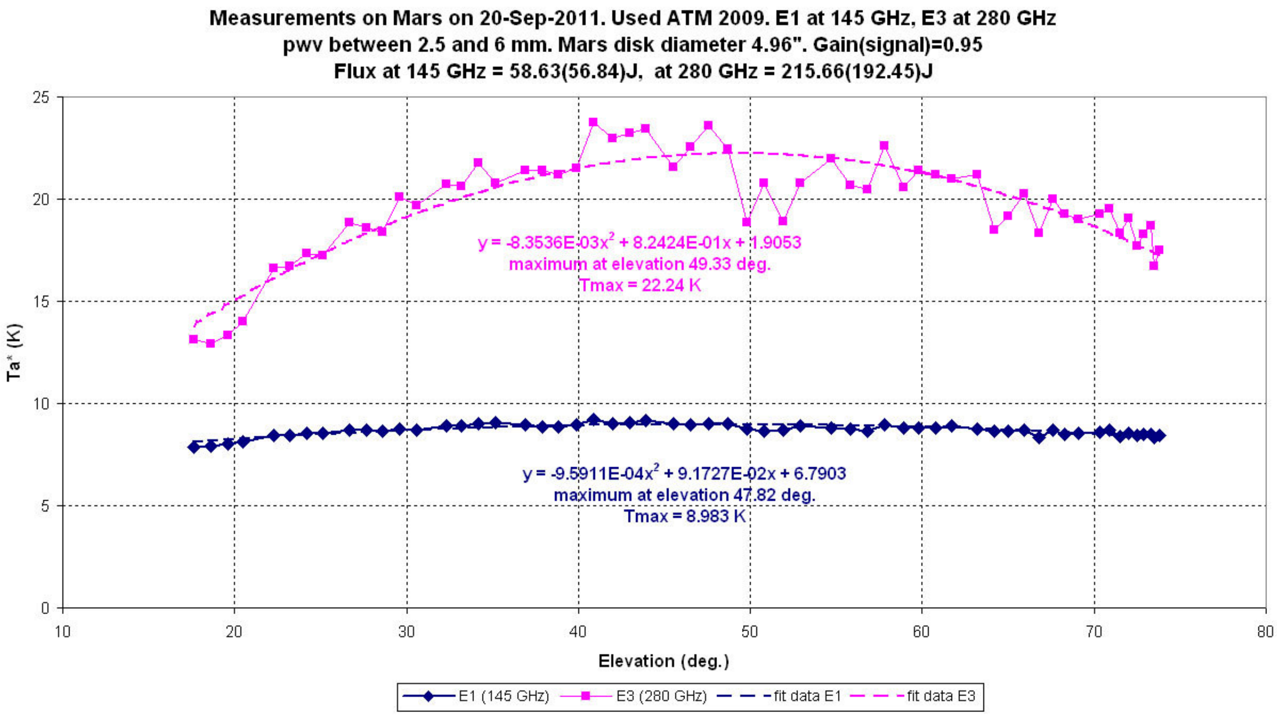
Measurements were done on 20-Sep-2011 to characterize the antenna gain-elevation curve. The planet Mars (diameter 4.96") was tracked at the elevation range 18^o (at 3:00 UT) to 74^o (at 8:30 UT) using the EMIR bands E1 and E3 at the frequencies 145 and 280 GHz respectively. The weather conditions were of clear sky, with the pwv profile depending on the antenna elevation while tracking Mars as shown in the following graphic.



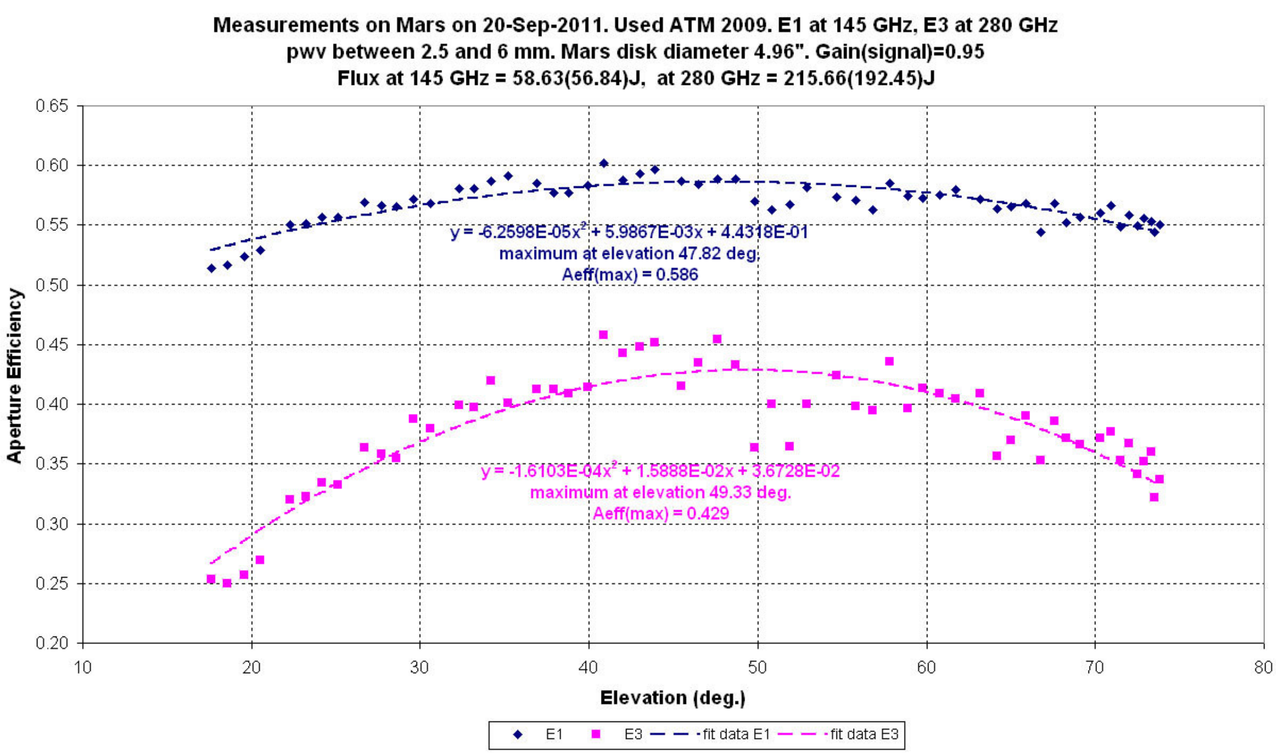


Systematically the pwv determined by the calibration scans was at E1 about 0.5 mm higher than at E3 as shown in the previous graphic. The calibration at 40 deg. elevation shows an irregularity identified as a wrong sky value (see graphic above right).

Calibrated pointing scans were carried out in beam switching mode using the broad band continuum BBC. At each elevation and at both frequencies, 145 and 280 GHz, the result from the vertical and horizontal polarizations have been averaged to get Ta*. Results are shown in the graphic below.

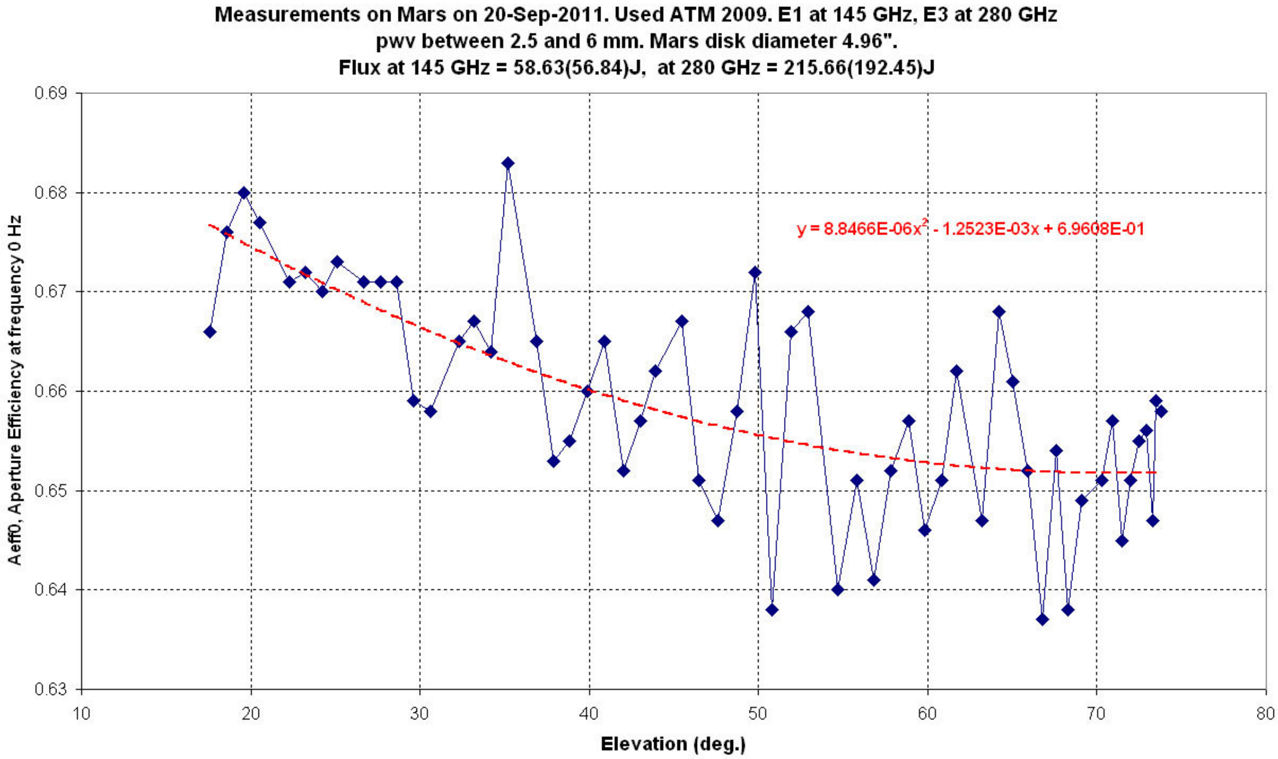


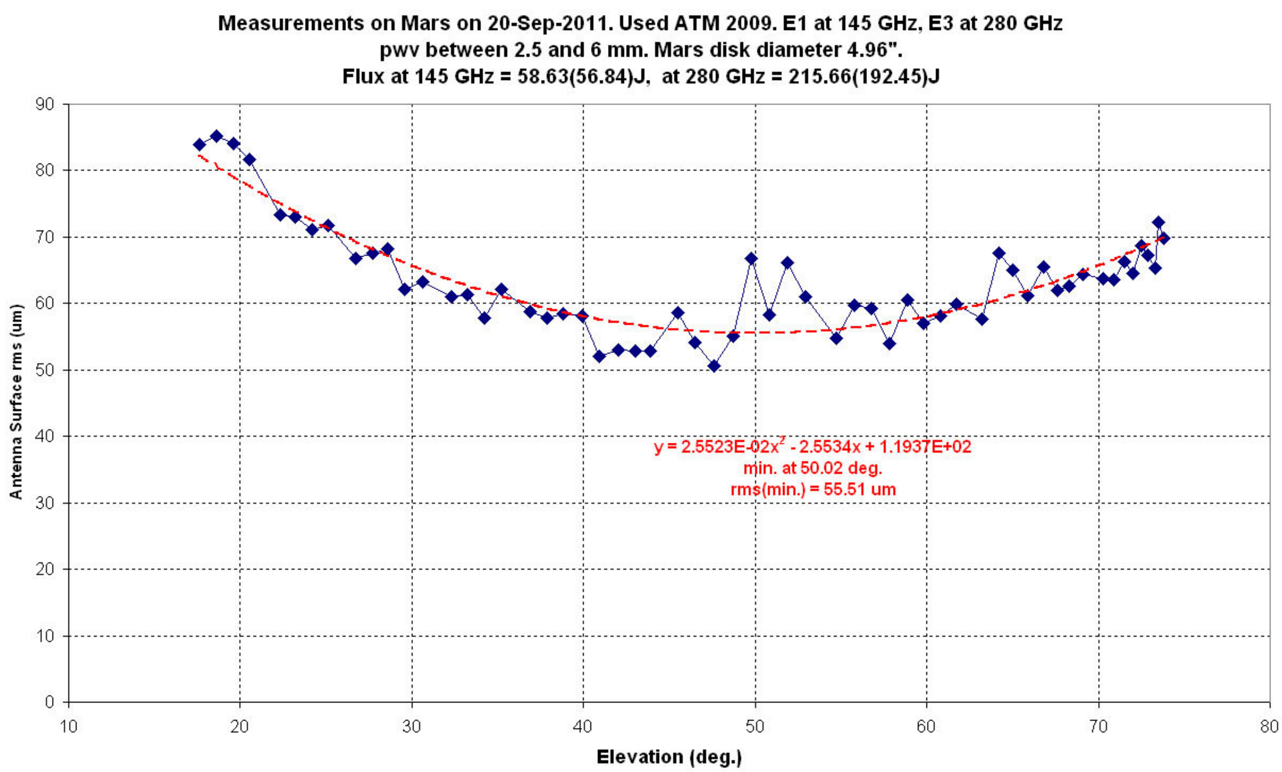
From the previous Ta* the antenna aperture efficiency Aeff has been calculated



From the antenna aperture efficiency Aeff at two frequencies, assuming the same antenna taping at both frequencies, is possible to conclude the surface roughness rms by fitting the Ruze formula

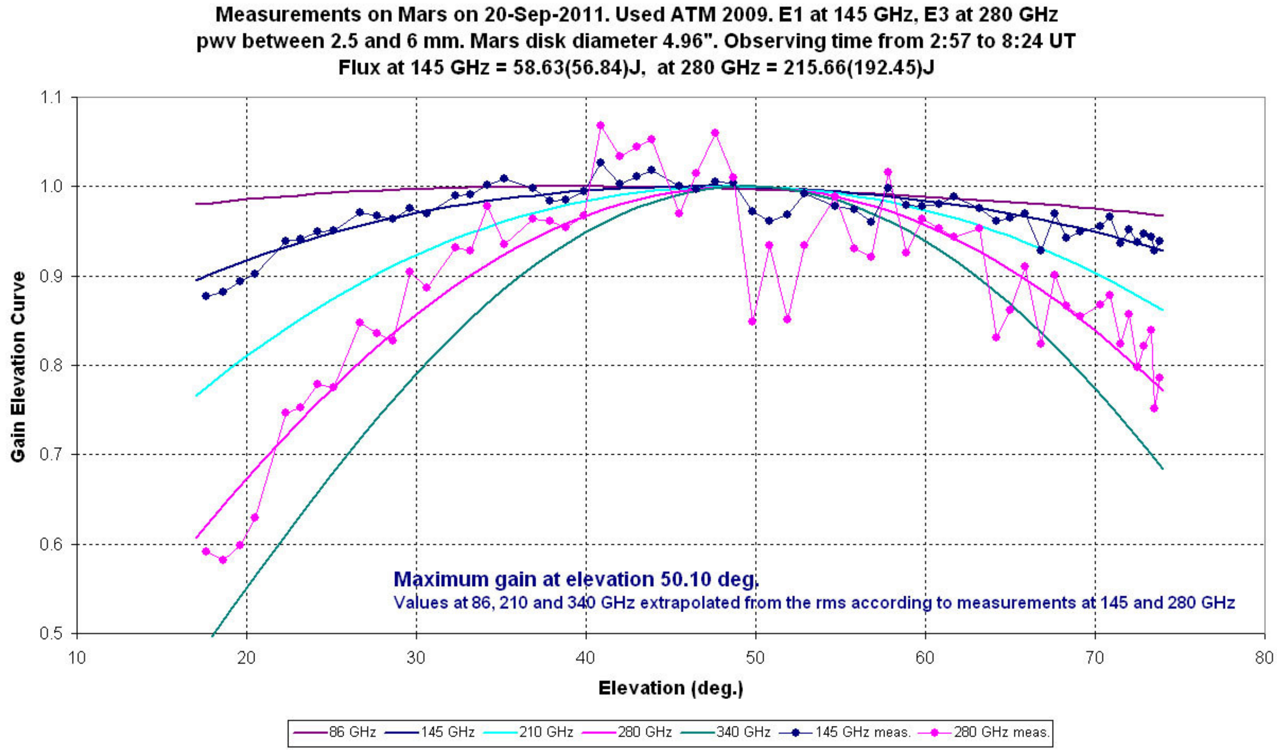
$A_{eff} = A_{eff\,0} \exp\left[-\left(\frac{4\pi(rms)}{\lambda}\right)^2\right]$, in fact both, the A_{eff0} (aperture efficiency at frequency 0) and the rms can be determined. Both are displayed below versus the antenna elevation.





The Aperture Efficiency at frequency 0 (A_{eff0}) should be the same with independence of the antenna elevation, but measurements seem to show a slightly higher value at lower elevations. The antenna surface rms shows its minimum at the antenna elevation 50^{o}.

From the previous fit, with A_{eff0} and rms determined versus antenna elevation, is possible to calculate the Aeff and then the Gain Elevation Curve at any observing frequency and antenna elevation. The graphic below shows the Gain Elevation Curve at five observing frequencies in the range 86 to 340 GHz, with the observations values made at 145 and 280 GHz superposed.



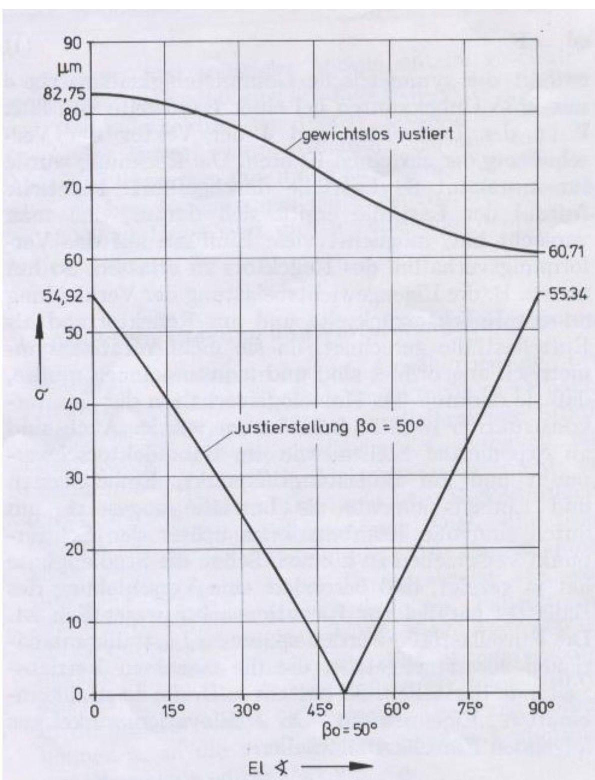
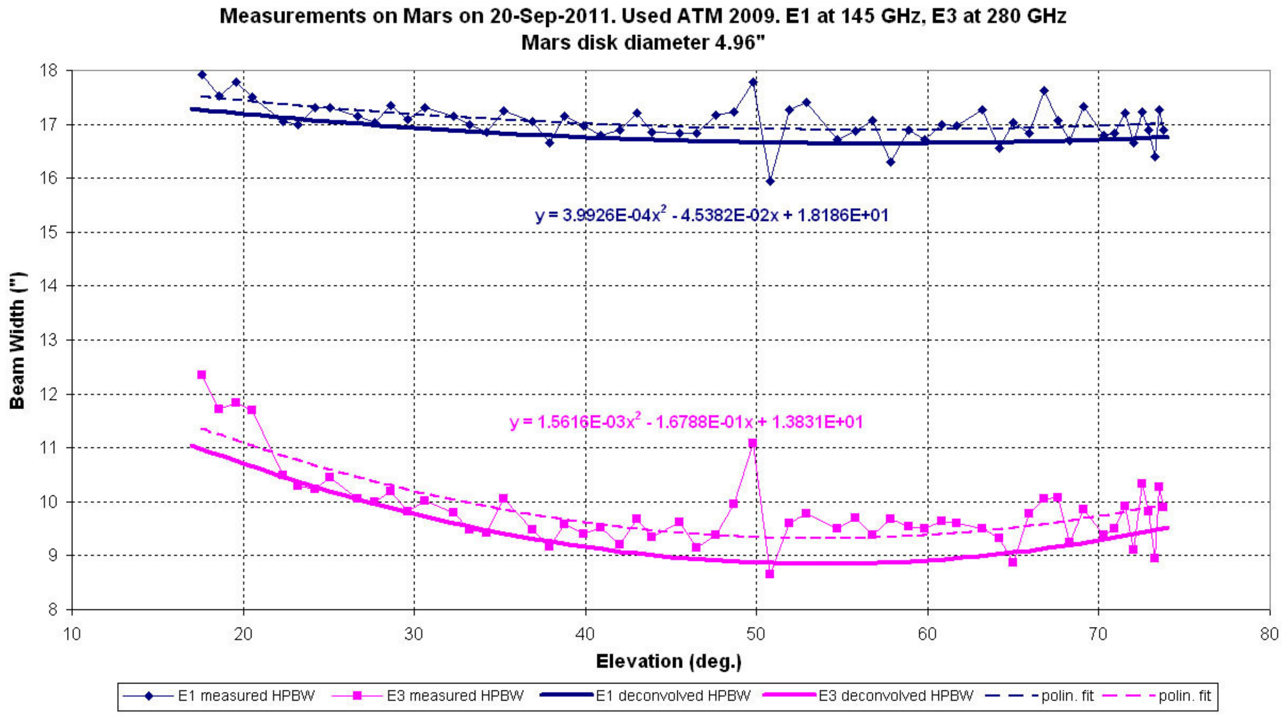


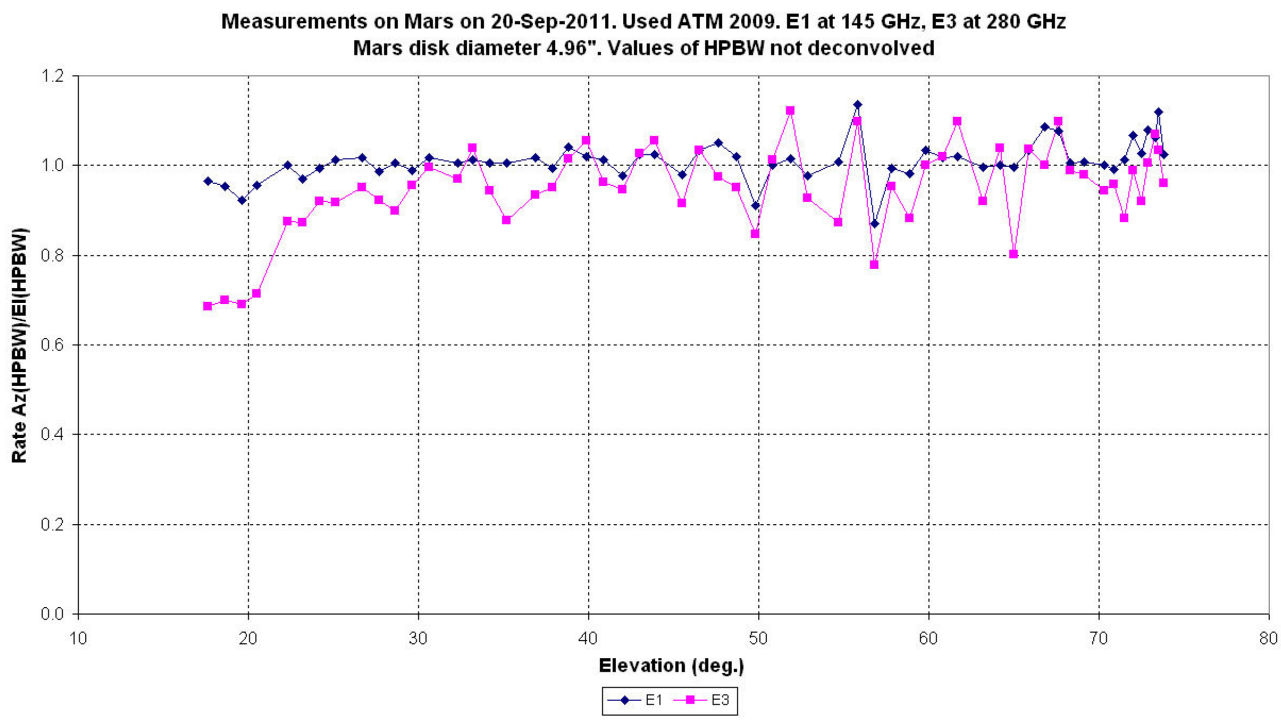
Bild 10 Verlauf des rms-Wertes σ bei Eigengewicht

The reason of the Gain Elevation Curve comes as a consequence that the antenna was not designed in a complete homology way. According to the design, the optimum rms is at the antenna elevation 50^o, and the rms increases up to approx. 55 µm when moving in elevation to 0^o or 90^o as shown in the left plot.

If the antenna gain drops when going out of the optimum elevation some power of the diffraction diagram must go some place. Some part of the power goes into the broadening of the antenna beam.

The graphic below shows the measured HPBW, together with the parabolic fit, and the values of the deconvolved HPBW. The HPBW is broader when going up or down the elevation with the maximum gain. Other part of the missing power must go into the large scale or first order error beam. Measurements of the antenna error beam should be carried out at different antenna elevations to confirm it.





The following steps show how to calculate the normalized antenna gain G depending on the observing frequency f and the antenna elevation El.

1) To determine the elevation with the maximum gain Elmax (in degrees) at a frequency f (in GHz) use the formula:

$$Elmax = 1.567E\text{-}06 * f^3 - 1.233E\text{-}03 * f^2 + 3.194E\text{-}01 * f + 2.203E{+}01$$

The reason why Elmax changes with the frequency is consequence that A_{eff0} is found to depend slightly on the antenna elevation as shown in the previous plot. But a good approximation is to consider Elmax = 48.5°, in that case the error calculating the gain G will be typically lower than 0.2 %.

2) The gain G at the elevation El will be G(El):

$$G(El) = A_{eff}(El) / A_{eff}(Elmax)$$

being

$$A_{eff}(El) = A_{eff\,0}(El)\exp\left[-\left(\frac{4\pi(rms(El))}{\lambda}\right)^2\right]$$

$$A_{eff0}(El) = 8.8466E\text{-}06 * El^2 - 1.2523E\text{-}03 * El + 6.9608E\text{-}01$$
$$rms(El) = 2.5523E\text{-}02 * El^2 - 2.5534 * El + 1.1937E\text{+}02$$

with rms(El) and λ expressed in microns and El in degrees

Finally below there are some graphics, first two graphics of the historical measurements concerning the antenna gain elevation curve at the 30m antenna and second the homology deformation

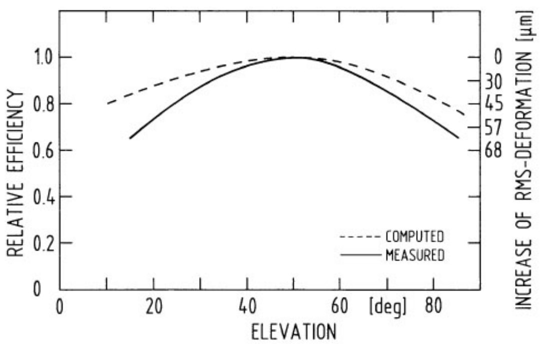


Fig. 9. The relative gain of the telescope as function of elevation angle, measured in March 1986 with the MPIfR Bolometer-receiver at 1.2 mm wavelength (solid) and that predicted from computed structural deformations (dashed). The effective additional surface deviation is also inserted along the righthand scale. The measured deviation (52 ± 5 μm at elevation 80°) is comparable to that predicted (40 ± 10 μm). (Measurements by Salter and Steppe, priv. comm.)

The IRAM 30-m millimetre radio telescope on Pico Veleta, Spain
J.W.M. Baars, B.G. Hooghoudt, P.G. Mezger, M.J. de Jonge
A&A, 175, 319-326 (1987)

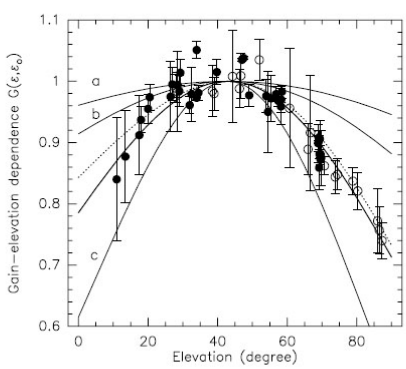


Fig. 1. Gain–elevation dependence measured with the MPIfR bolometer at 1.22 mm (245 GHz) on the quasar 0932+392 [open circles] and Mars (14″) [dots] (Feb. 1995). The heavy line shows the best–fit gain–elevation dependence Eq. (3) derived from these measurements; the dashed line shows the corresponding gain–elevation dependence derived for the surface deformations predicted from the finite element calculations. The other lines show the gain–elevation dependence at 3 mm (100 GHz): **a**), 2 mm (150 GHz): **b**), and 0.86 mm (350 GHz): **c**), derived from scaling of the 1.22 mm gain–elevation dependence (heavy line)

The gain-elevation correction of the IRAM 30-m telescope
A. Greve, R.Neri, A. Sievers
A&A Supl. Ser. 132, 413-416 (1998)

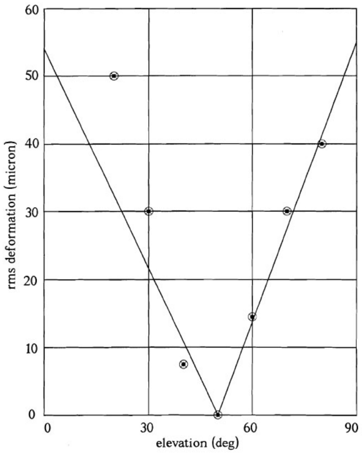


Fig. 10. The rms value of the residual gravitational deformation, calculated from the structural analysis, assuming a perfect setting of the reflector at 50° elevation. The dots are measured values, derived from the variation in aperture efficiency with elevation, measured at 1.3 and 0.8 mm wavelength. The estimated error of the calculation is 12 µm; thus the agreement is satisfactory. The high values at low elevation might be caused partially by an underestimated atmospheric attenuation.

Design parameters and measured performance of the IRAM 30-m Millimeter Radio Telescope

J.W.M. Baars, A. Greve, H. Hein, D. Morris, J. Peñalver, C. Thum
Proc. IEEE, Vol. 82, No. 5, p. 687 – 696
05/1994