Antenna Gain depending on Wobbler Tilt

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Abstract

Astronomical observations using the tilt of the secondary mirror M2 by means of the wobbling switching operation permit an optimum quality because the optimum base line due to the fast ON-OFF switching in the sky. But the tilt axis of the hyperboloid subreflector (mirror M2) is 380 mm behind its vertex, while the focus of the hyperboloid is 687 mm behind its vertex. This difference of distances is motivated by the mechanical design of the wobbling mechanism in order to get the optimum balance of loads, and as a consequence of that the geometry of the optics M1 – M2 results distorted producing the gain loss.

The measurements analyzed in this work resume this gain loss in the four EMIR bands covering from 86 to 340 GHz and the changes of the half power beam width (HPBW).

1. Previous and actual Measurements

The M2 wobbling switching permits a maximum switching of the antenna beam in the sky of ± 120" with respect to its central position, this switching is obtained by the tilt of the mirror M2 with respect to its central position. And as much as the tilt of the mirror M2 increases the gain loss also increases. To get an offset in the sky of 120" the mirror M2 must be tilted 0.4°.

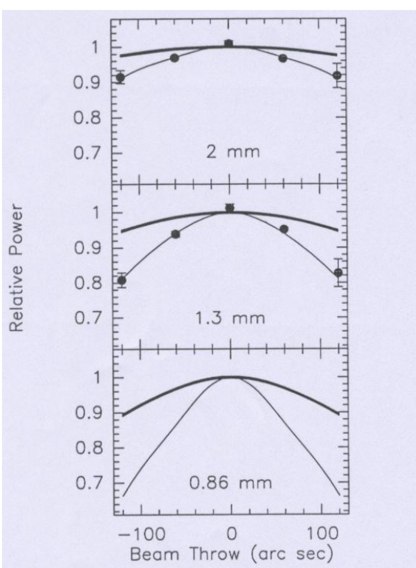

Fig. 6. IRAM 30–m telescope loss in peak power in observations with the wobbling subreflector. Dots: measurements; thin lines: loss in peak power calculated for the wavefront deformation of Eq.(13–14); thick lines: restauration of peak power by application of the 52–element piston corrector of Fig. 4. [There are no observations at 0.86 mm].

Figure 1

The gain loss analyzed here is known since the wobbling switching mechanism is in operation. Figure 1 is extracted from the work "Near-focus active optics: An inexpensive method to improve millimetre-wavelength radio telescopes", Radio Science 1996, A. Greve et al.

In other several occasions these measurements have been carried out with similar results, although without data at high frequencies. In this occasion the weather conditions were excellent, with an average p.w.v. below 1 mm permitting optimum results.

Measurements have been done on 17-Nov-2015. The mirror M2 has been inclined in the sky range ± 120" using the wobbling mechanism. With consecutive pointing scans using the chopper wheel the gain at any tilt has been determined. The source used has been Mars (4.5" diameter) in the elevation range 32° to 52°. Simultaneously to the gain loss due to the tilt of M2 a broadening of the beam is produced, this broadening also has been characterized and resumed in the paragraph 3.

2. Antenna Axial Gain

Two set of measurements have been carried out, with the bands combination E0 – E2 and E1 – E3. Results of the antenna axial gain are shown in the Figures 2 and 3 respectively.

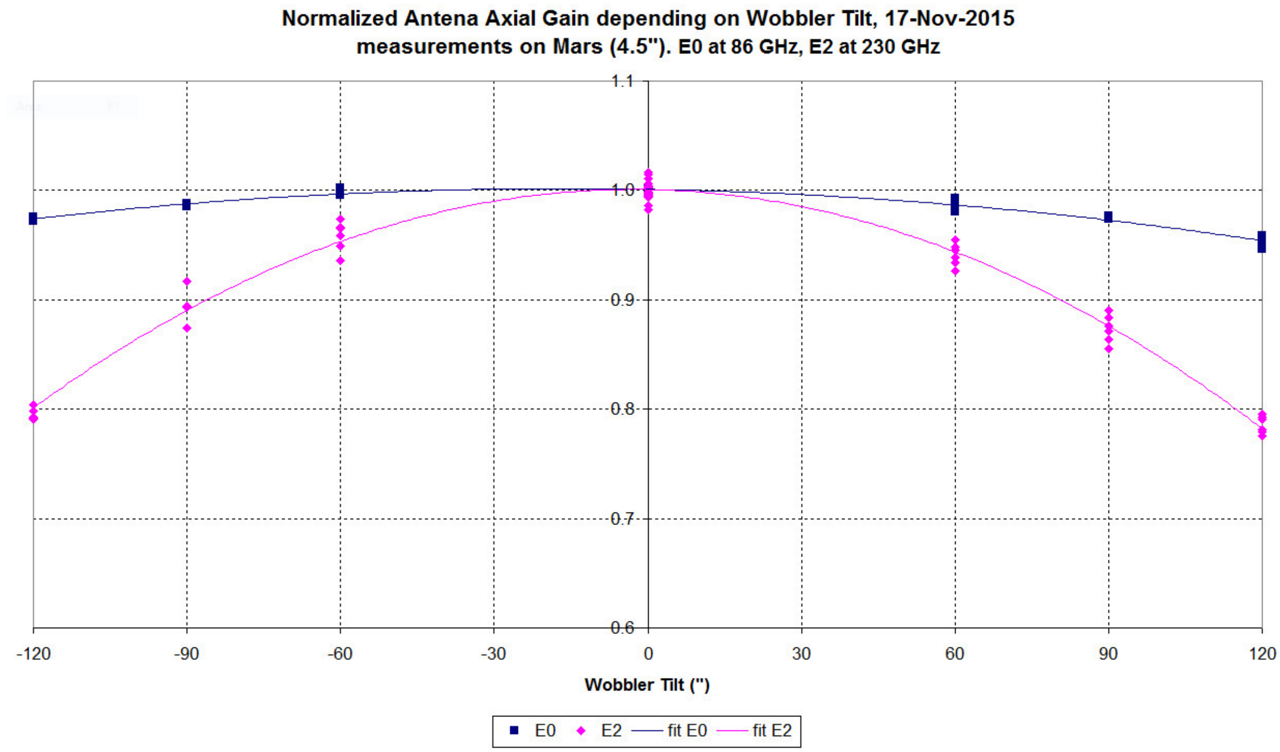

Figure 2

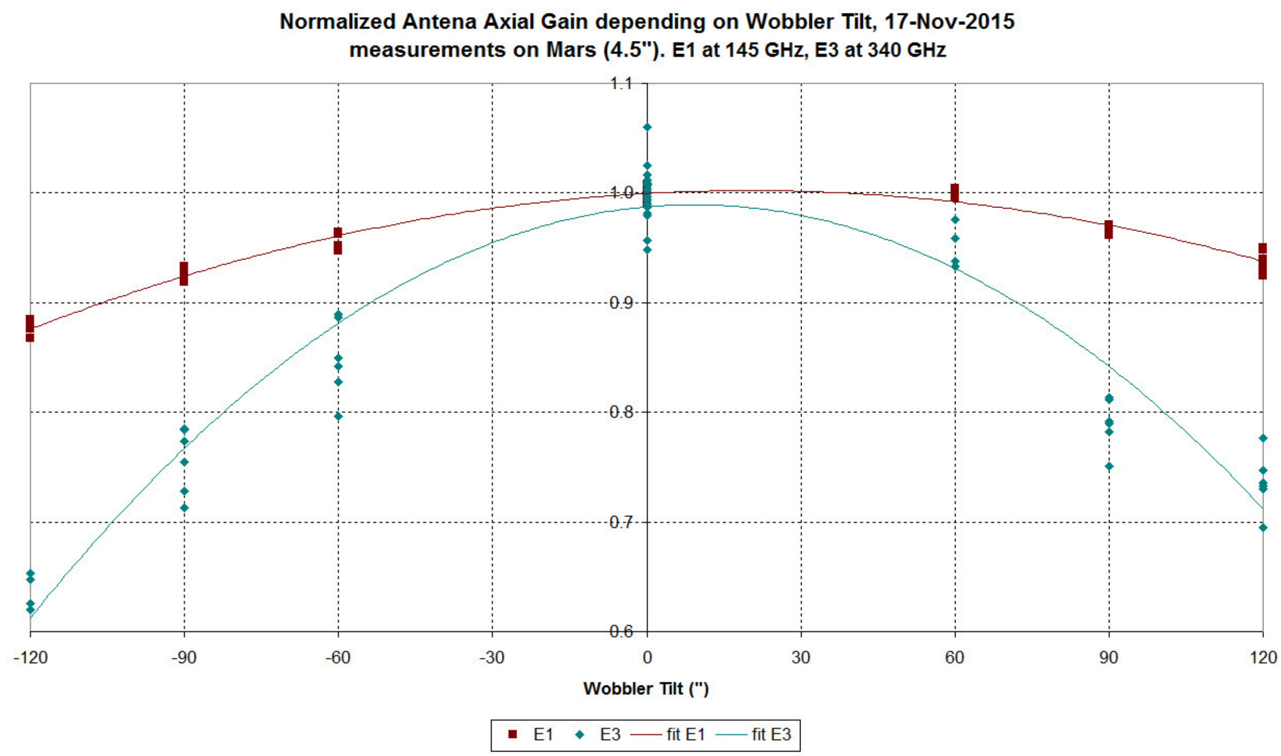

Figure 3

The combinations E0 – E2 and E1 – E3 use two different windows of the EMIR receiver. The result of E0 – E2 (Figure 2) shows a good symmetry for both positive and negative values of the M2 tilt, while for the combination E1 – E3 the gain loss is a bit less for the positive values of the tilt. The reason of the difference between the positive and negative tilt of E1 – E3 is not clear, but should be due to an illumination of M2 slightly misaligned.

Figure 4 shows the result of the four bands in just one graphic. The values of the positive and negative tilts of M2 have been combined to produce a symmetrical plot and the parabola fit has been normalized.

With the tilt of M2 the beam width is also broadened, that means that the power measured with the pointing scans is not proportional to the true source flux throughout the range of tilt 0” to 120”. This effect is more prominent at 340 GHz where the HPBW changes from 7.5” (M2 sky tilt 0”) to 8,2” (M2 sky tilt 120”) being the change of the measured power for this two cases 2%. This effect has not being considered in the analysis.

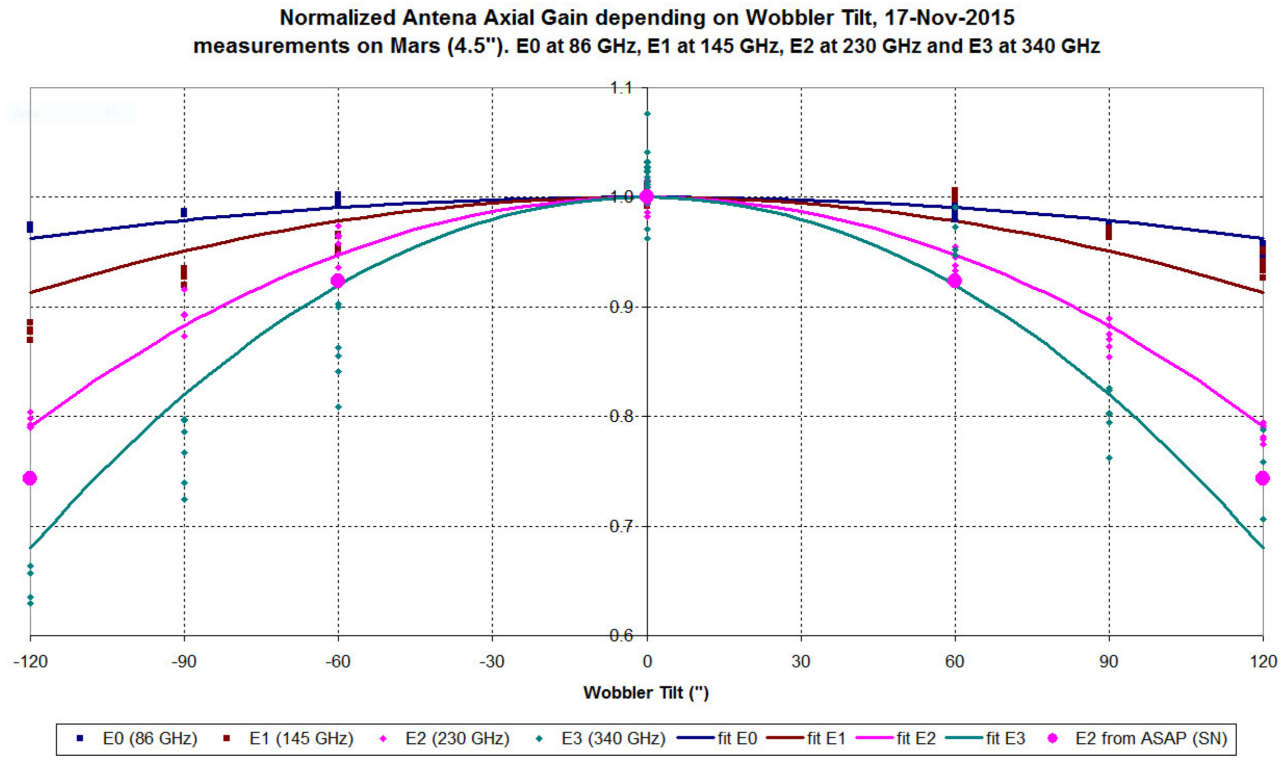

Figure 4

Figure 4 also shows the drop of gain predicted by the optical software ASAP for the M2 sky tilts 60” and 120” (S. Navarro).

With the normalized gain characterized at four frequencies, as shown in Figure 4, we can predict the normalized gain for any frequency and wobbler tilt according to the following formula:

$NormGain(f,tilt) = a(f) * tilt^2 + 1$ and $a(f) = -7.9619E-08 * f + 4.5705E-06$

being f the frequency in GHz and tilt the wobbler tilt in arcsec. This modelling has a maximum absolute error of 1.3 % at the four frequencies characterized.

The normalized antenna axial gain shown in Figure 4 with the drop of gain occurring with the wobbler tilt also reflects what happens with the normalized aperture efficiency.

3. HPBW with the M2 tilt

The half power beam width HPBW has been calculated from the measured half power width MHPW of the pointing scans according to the formula

$$HPBW = MHPW\sqrt{1-\frac{\ln 2}{2}\left(\frac{D_{Source}}{MHPW}\right)^2}$$

formula valid for D_{Source}/HPBW < 1, being D_{Source} equal to 4.5" corresponding to the diameter of Mars the day of the observations.

At the lower frequency (E0) the HPBW practically doesn't change in all the range of the M2 tilt, but with the increasing of frequency the broadening of the HPBW is more significant. The Table 1 resumes numerically the HPBW for the complete range of the M2 tilt.

HPBW	Wobbling Sky Tilt					rms
Frequency	± 0"	± 30"	± 60"	± 90"	± 120"	|measured – fit|
86 GHz	28.3"	28.3"	28.3"	28.3"	28.3"	0.08"
145 GHz	16.8"	16.8"	16.9"	17.0"	17.1"	0.09"
230 GHz	10.4"	10.5"	10.5"	10.7"	10.8"	0.07"
340 GHz	7.5"	7.5"	7.7"	7.9"	8.2"	0.12"

Table 1. HPBW of the four bands for several wobbling tilt

Figures 5 and 6 show the HPBW of E0 – E1 and E2 – E3 respectively for the complete range of M2 wobbling tilt.

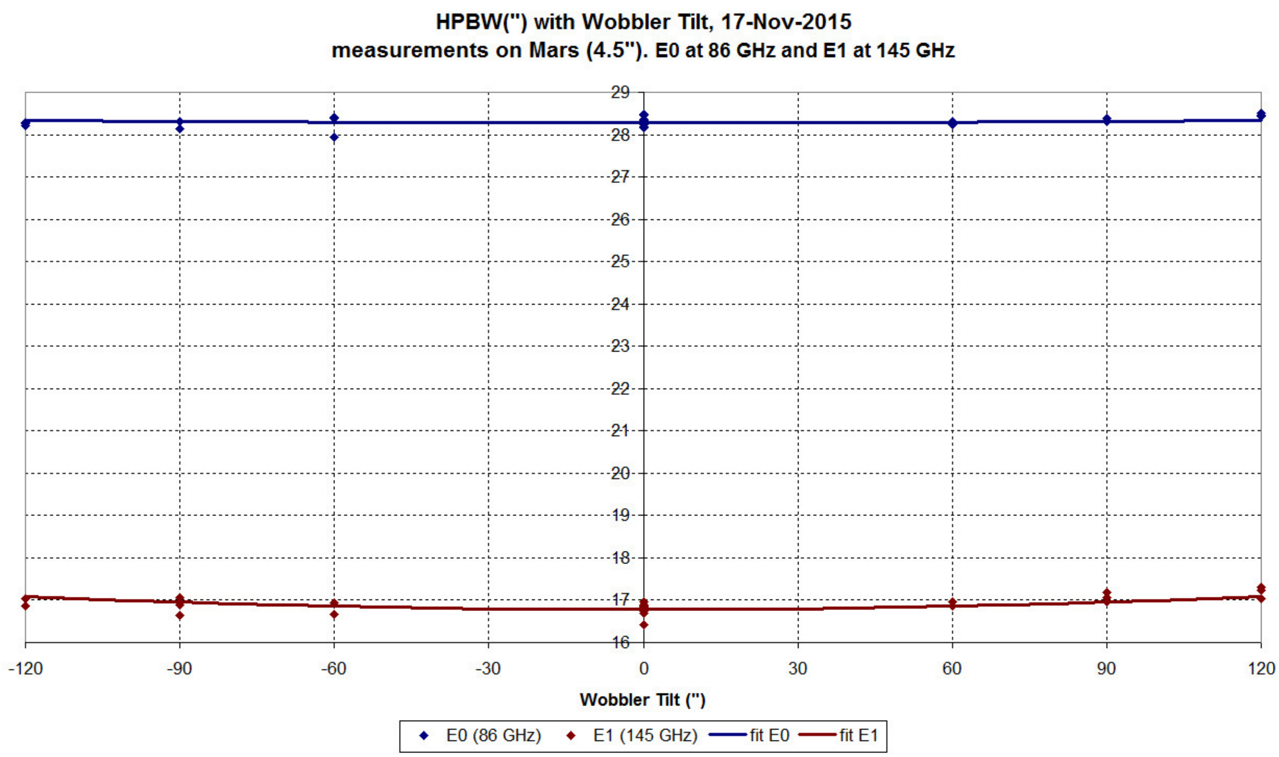

Figure 5

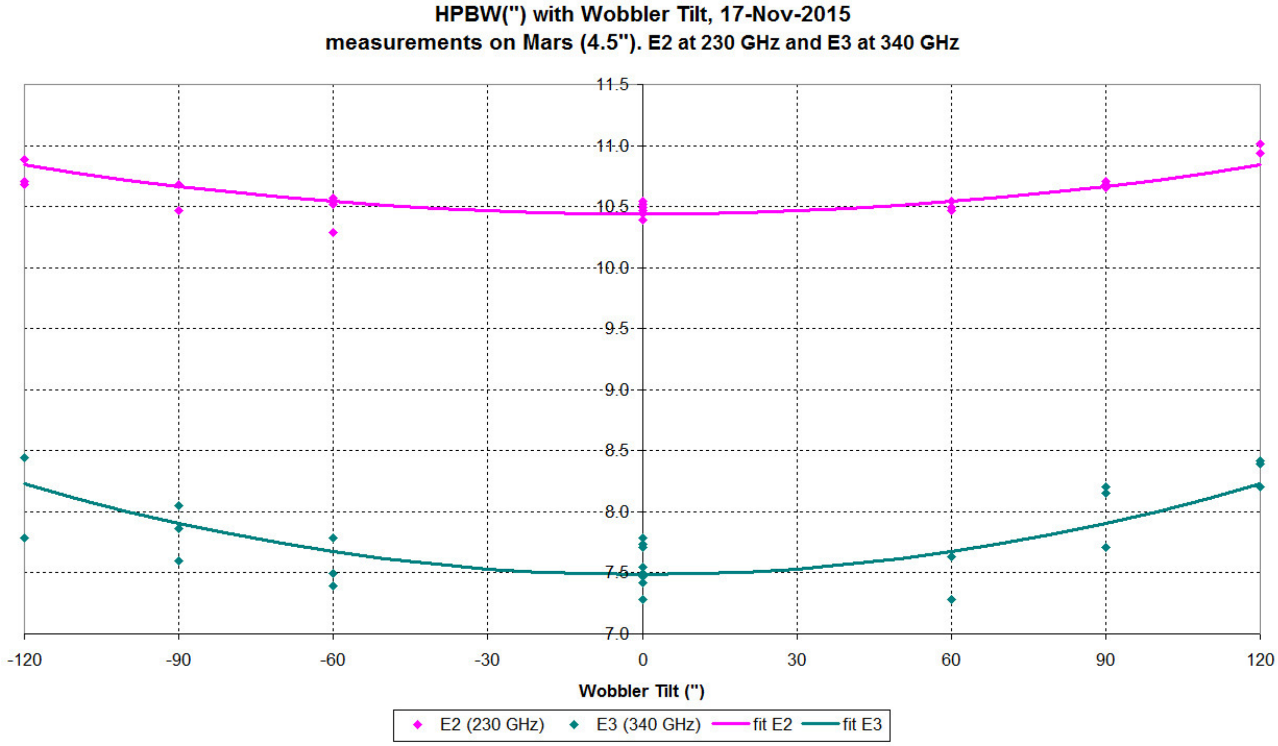

Figure 6

4. Normalized Antenna Beam Gain

The axial gain of the antenna changes with the wobbling tilt as shown in the Figure 4. Simultaneously the HPBW is broadened as shown in the Figures 5 and 6. As a consequence of both, the antenna main beam gain decreases in lesser extent than the axial gain. Figure 7 shows that decreasing, considering for the display the fit values of the mentioned Figures.

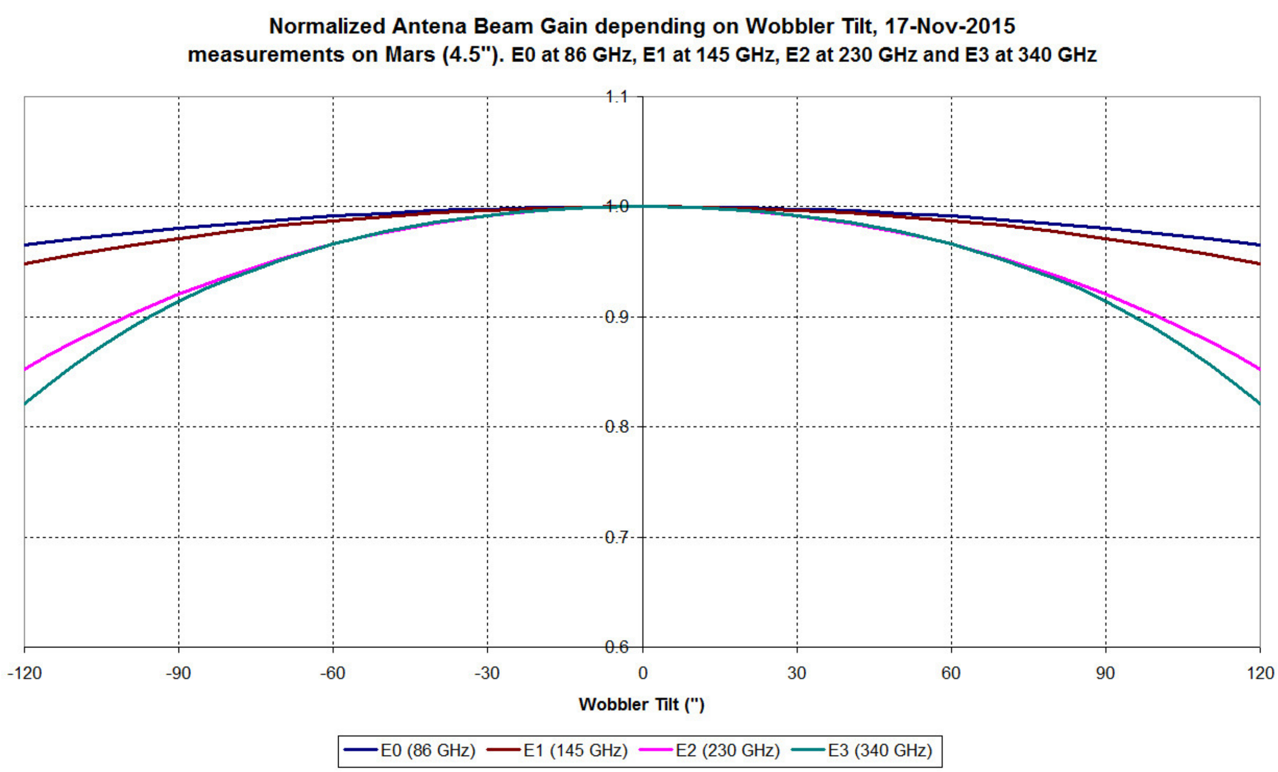

Figure 7

The normalized antenna beam gain shown in Figure 7 with the drop of gain occurring with the wobbler tilt also reflects what happens with the normalized main beam efficiency.

5. Conclusions

Antenna gain has been measured in the four frequency bands of EMIR for the M2 tilt according to the wobbling operation. Results are consistent with previous measurements with the advantage that in this series of measurements the weather conditions have been excellent, permitting a good determination of the results, including at the high frequency 340 GHz of band E3.

For the whole range of the wobbler operation (± 120" in the sky) has been determined the antenna axial gain, the beam gain and the HPBW. Due to the broadening of the HPBW with the M2 tilt, the drop of the main beam gain is less than the drop of the axial gain.