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March 1, 2021

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To: EDGES Group

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Subject: Effects of a tilted and uneven ground plane vs Galactic Hour Angle.

The effects of uneven edges of the ground plane studied in memo 337 are extended to look at deviations from flatness studied in memo 355 in more detail with the goal of being able to make corrections to the beam upon completion of a survey of the ground planes at the MRO.

case	bump height cm	distance m	size m	rms at GHA=04	average rms mK
midband	5	5	2.5x2.5	119	40
	10	5	1.25x1.25	169	47
	10	5	5x5	285	78
	10	7	5x5	380	126
	10	10	5x5	91	42
	10	1	2.5x2.5	76	25
	10	2	2.5x2.5	175	70
	10	3	2.5x2.5	182	73
	10	5	2.5x2.5	275	69
	10	7	2.5x2.5	211	57
	10	8	2.5x2.5	135	32
	10	10	2.5x2.5	16	14
	20	10	2.5x2.5	32	29
lowband	10	5	2.5x2.5	259	109

Table 1. rms residuals for 5-physical terms 55 – 110 MHz for midband with bump at 55 degrees azimuth on an infinite PEC ground plane.

In the last entry the midband antenna is replaced by the larger lowband antenna with the same orientation. The average rms is the average of the 24 rms 5-term residuals for each hour of GHA.

Table1 gives the result of simulations for “bumps” (raised areas) on the ground plane. Figure 1 shows the residuals vs GHA for the each of the first entry of Table 1 for 2,3,4 and 5 physical terms and Figure 2 shows the residuals vs GHA for 2 degrees tilt of the midband antenna pointed at azimuth of 85 degrees for 2,3,4 and 5-physical terms removed. The effects of tilt and roll vary relatively smoothly with GHA compared with the effects of an uneven ground plane.

antenna	ground plane	tilt	roll	maximum rms mK	avrms mK
Low2_45	PEC	+2.0	0.0	260 at GHA=04	95
Low2_45	PEC	0.0	+2.0	590 at GHA=19	198
Midband_EW	PEC	+2.0	0.0	76 at GHA=03	24
Midband_EW	PEC	0.0	+2.0	19 at GHA=22	7

Table 2. rms residual for 5-physical terms 55-110 MHz for tilt and roll of different antennas

The magnitude of the effects of bumps are proportional to the height of the bump, at first increase with distance from the antenna up to a maximum about 5m and then at about 7m starts decreasing rapidly with distance. The dependence on size starts being approximately proportional to size and beyond about 8m becomes approximately proportional to area. The effect of the bump on a particular GHA is strongly dependent of the azimuth of the bump as shown in figure 3 of memo 355.

The effects are similar for the low and midband antennas and the simulations in memo 337 show that the effects of an uneven ground plane are not reduced by using an electrically small antenna. The results in Table 2 show that the effects of tilt and roll are reduced for the electrically smaller midband antenna and simulations show that going electrically small in this case could be an advantage.

A test of the effect of dip using a finite ground plane is found to produce residuals which are the approximately the negative of those from a bump of the same magnitude. This suggests that ground plane with a combination of bumps and dips might be approximated by making separate beam maps for regions with bumps and dips on an infinite PEC ground plane and adding the difference to the beam map without bumps and dips. Further, if this approximation can be extended to just adding the difference using a PEC ground to a beam map for a finite ground plane without bumps and dips, the long compute time needed to run a FEKO model for a large uneven ground plane on soil might be avoided.

Figure 3 shows a simulation of a bump and a dip of 10 cm in one of the 25 2.5x2.5 m square sections of a 12.5x12.5m ground plane of overall height of 10 cm on an infinite PEC ground plane. The dip is made by the absence of a 2.5x2.5 m section and a bump with a 20 cm 2.5x2.5m section. The bump is the first of each pair at each GHA. Figure 4 is for a simulation with 49 square sections. While Figures 3 and 4 are similar they are not the same indicating the larger structure has an effect and approximations discussed below will be limited to small changes.

Next an examination of the effects of the shape of the uneven region and how well the beam might be approximated using antenna beam on a finite even ground plane and the beam for the antenna on an uneven structure of a PEC ground plane.

The shapes in Table 3 are round and square. The round bump is a section of a sphere with zero height at the rim and height listed in the table at the center. The average height is about half the height at the center. Figure 5a shows the FEKO model with round bump of 2.5 m diameter with center 5m from the antenna oriented so the North is up on the page. Figure 5b shows the change in beam model due to the bump. The square flat bump is a square region raised by a constant height and oriented with a side facing the antenna while the diamond flat is a square rotated by 45 degrees so that the diagonal is pointed at the antenna.

shape	height cm	distance m	size m	max rms at mK	average rms mK
round bump	20	3	2.5	165 at GHA=05	49
square flat	10	3	2.5	253 at GHA=03	73
diamond flat	10	3	2.5	204 at GHA=04	57
round bump	10	3	2.5	87 at GHA=05	28
round bump	20	5	2.5	269 at GHA=03	69
square flat	10	5	2.5	375 at GHA=05	86
diamond flat	10	5	2.5	91 at GHA=05	28

Table 3. Simulations of different shapes of bumps. rms residuals for 5-physical terms 55 – 110 MHz for midband pointed at 85 degrees azimuth with bump at 55 degrees azimuth on an infinite ground plane.

shape	height cm	distance m	size m	max rms at	average rms mK
round bump	20	5	2.5	130 at GHA=04	48
square flat	10	5	2.5	166 at GHA=04	68
diamond flat	10	5	2.5	28 at GHA=04	16
diamond flat	10	5	1.25	97 at GHA=04	37

Table 4. Simulations of 4 hour blocks at GHA = 00,04,08,12,16 and 20.

Table 4 shows that with integrations of 4 hours the effects tend to average down.

case	shape	bump number	height cm	distance m	size m	azimuth deg	rms mK
1	round	1	20	5	2.5	55	130
2	round	2	20	5	2.5	85	345
3 bumps 1 and 2							493
7 bumps 1 and 2							465

Table 5. Simulation of method of combining beams with 2 bumps with rms residuals for 4 hour block at GHA = 04

Table 5 along with plots in Figure 6 show the results of 5-physical terms 55 – 110 MHz for simulations of 4-hour blocks at GHA =04 hours. Case 1 is the same as the first entry in Table 4. Case 2 is from a separate FEKO beam for a second bump and case 3 is from a beam derived from FEKO using both bumps. The beam for case 7 is derived from sum of the differences to the reference case added to the reference case:

$$b7 = b0 + (b1 - b0) + (b2 - b0)$$

where the beams are a function of azimuth and elevation for each frequency in units of dB. b1 and b2, are the beams for cases 1 and 2 and b0 is the reference beam with no bumps and b7 is an approximation for b3. This approximation may be extended to the sum of the differences to the PEC reference to the beam for a finite ground plane on soil.

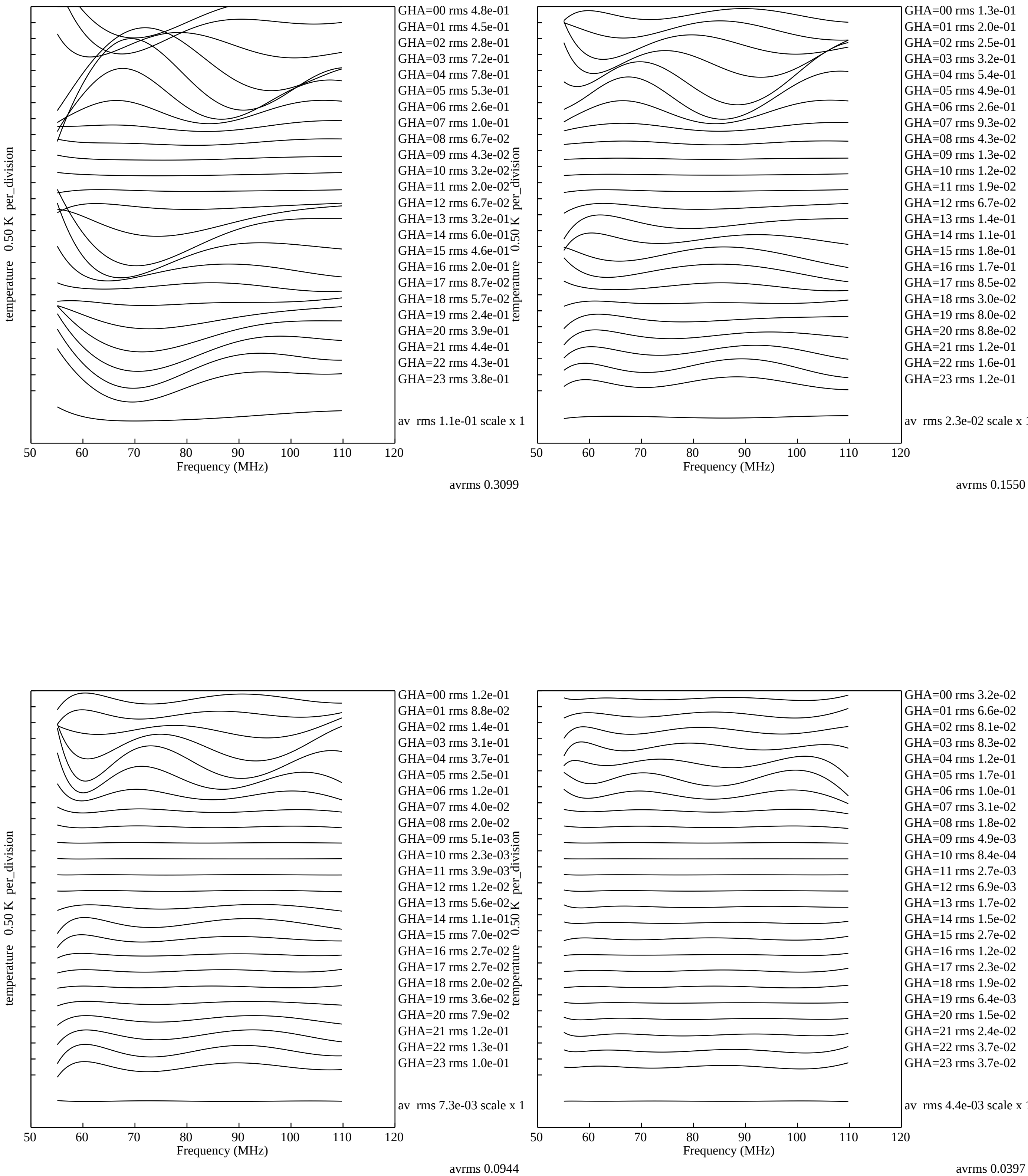

Figure 1. Residuals vs GHA for the each of the first entry of Table 1 for 2,3,4 and 5 physical terms from top left, top right, bottom left, to bottom right.

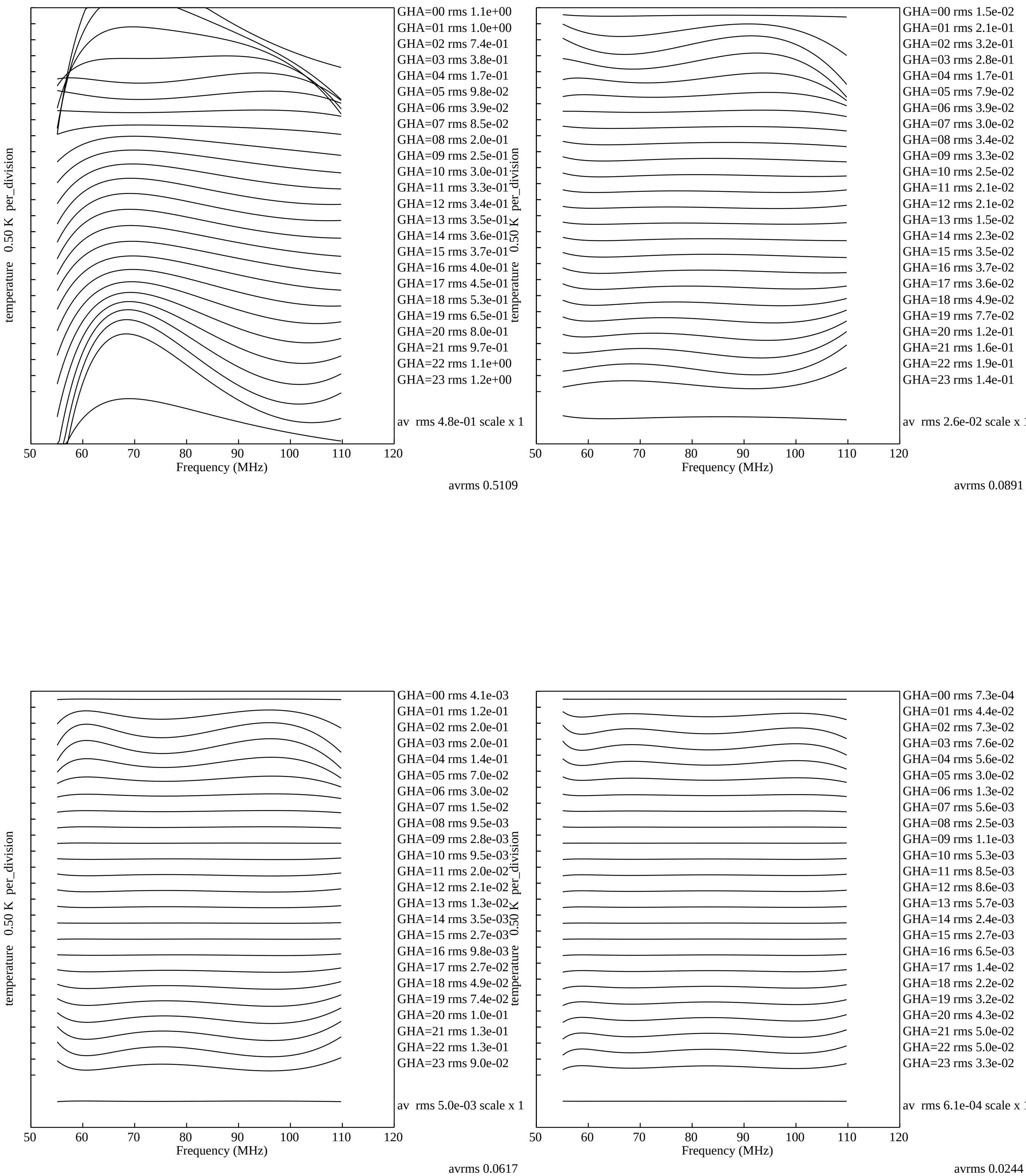

Figure 2. Residuals vs GHA for 2 degrees tilt of the midband antenna pointed at azimuth of 85 degrees for 2,3,4 and 5-physical terms removed.

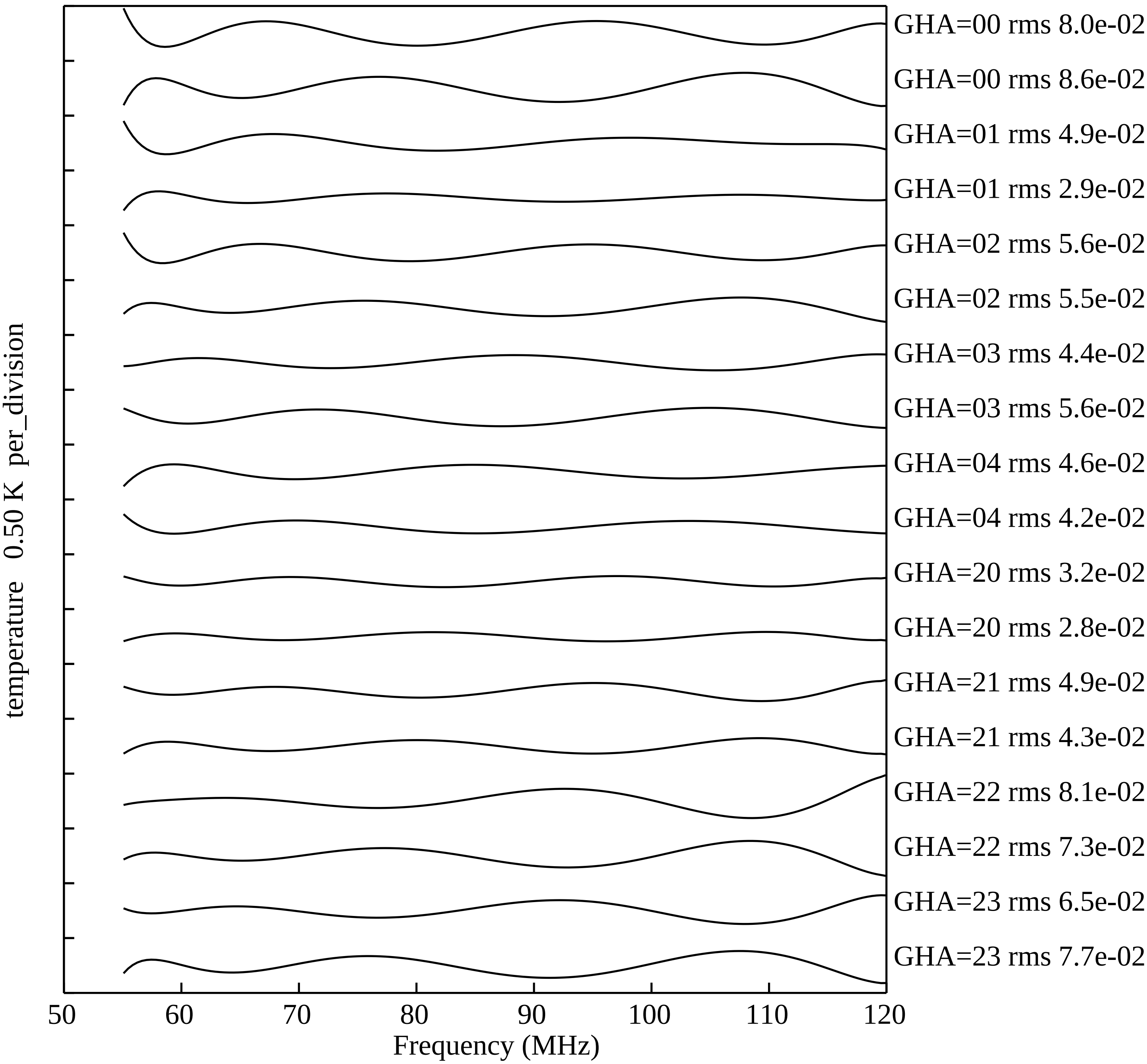

Figure 3. Simulation of a bump and a dip of 10 cm in one of the 25 2.5x2.5 m square sections of a 12.5x12.5m ground plane of overall height of 10 cm on an infinite PEC ground plane.

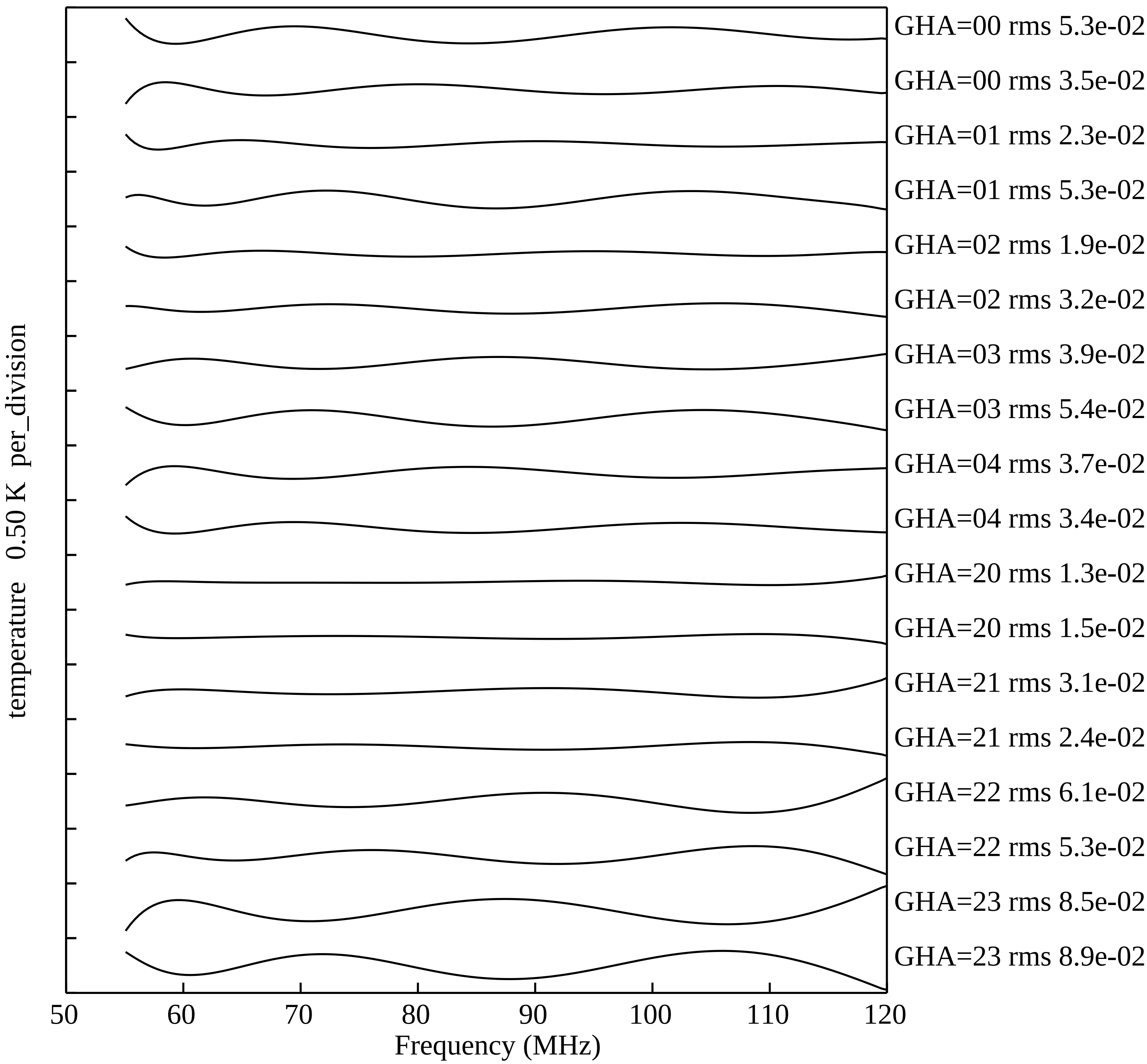

Figure 4. Simulation with region extended from 25 to 49 2.5x2.5 m square sections.

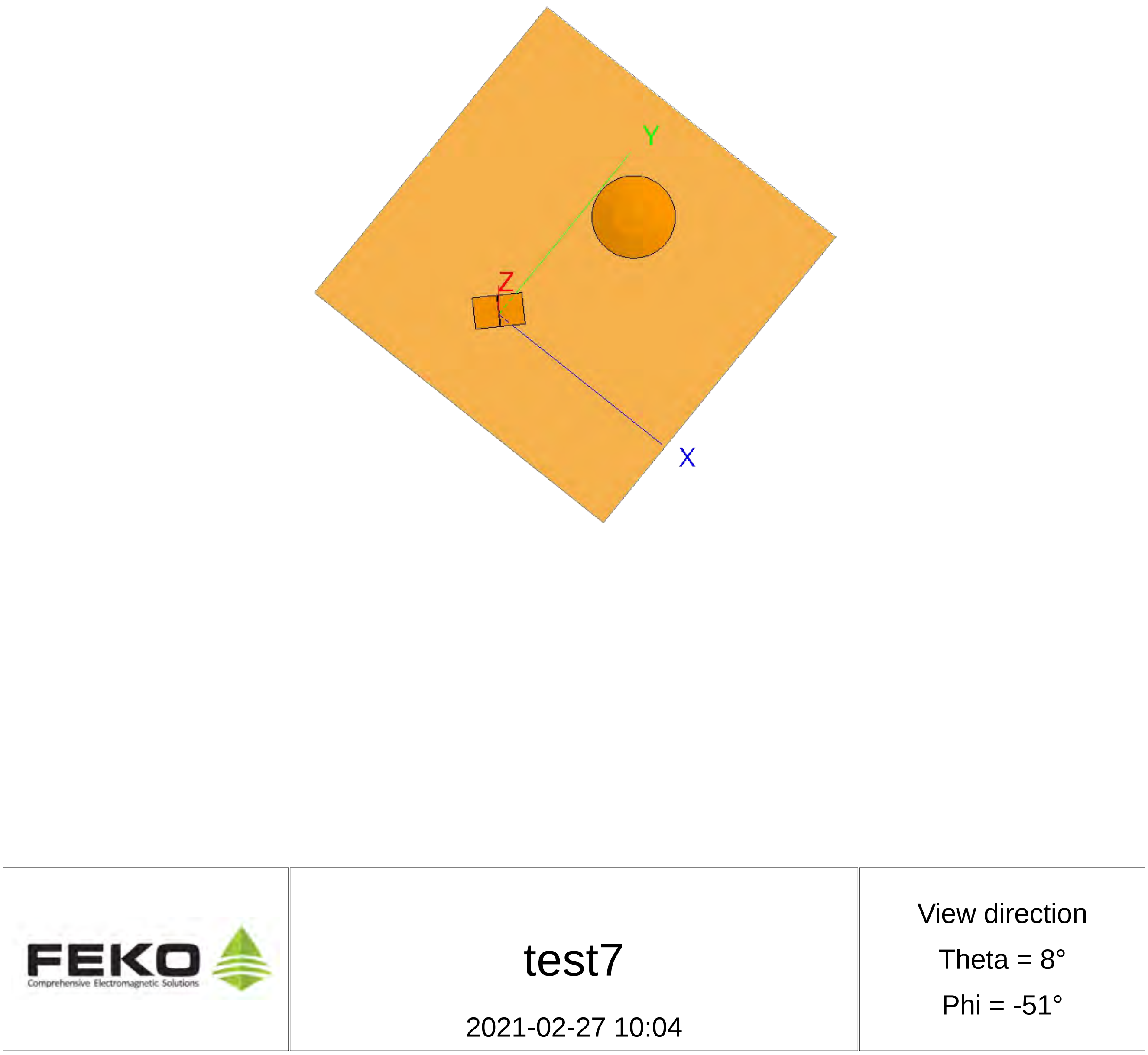

Figure 5a. FEKO model with round bump of 2.5 m diameter with center 5m from the antenna oriented so the North is up on the page and the antenna in pointed at an azimuth of 85 degrees.

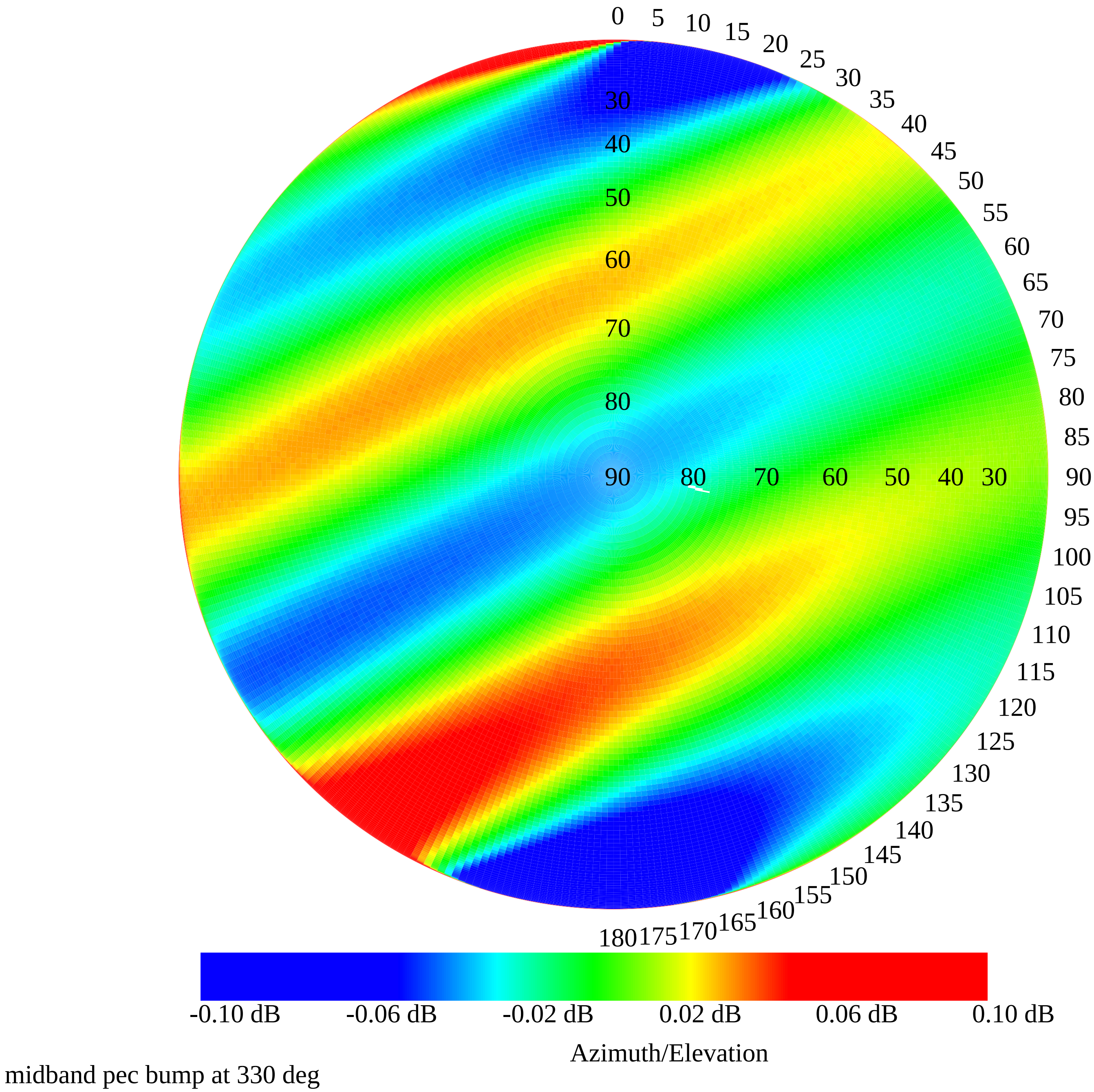

Figure 5b. Change in beam at 76 MHz due to bump with azimuth relative to antenna direction. Fringe pattern moves with frequency.

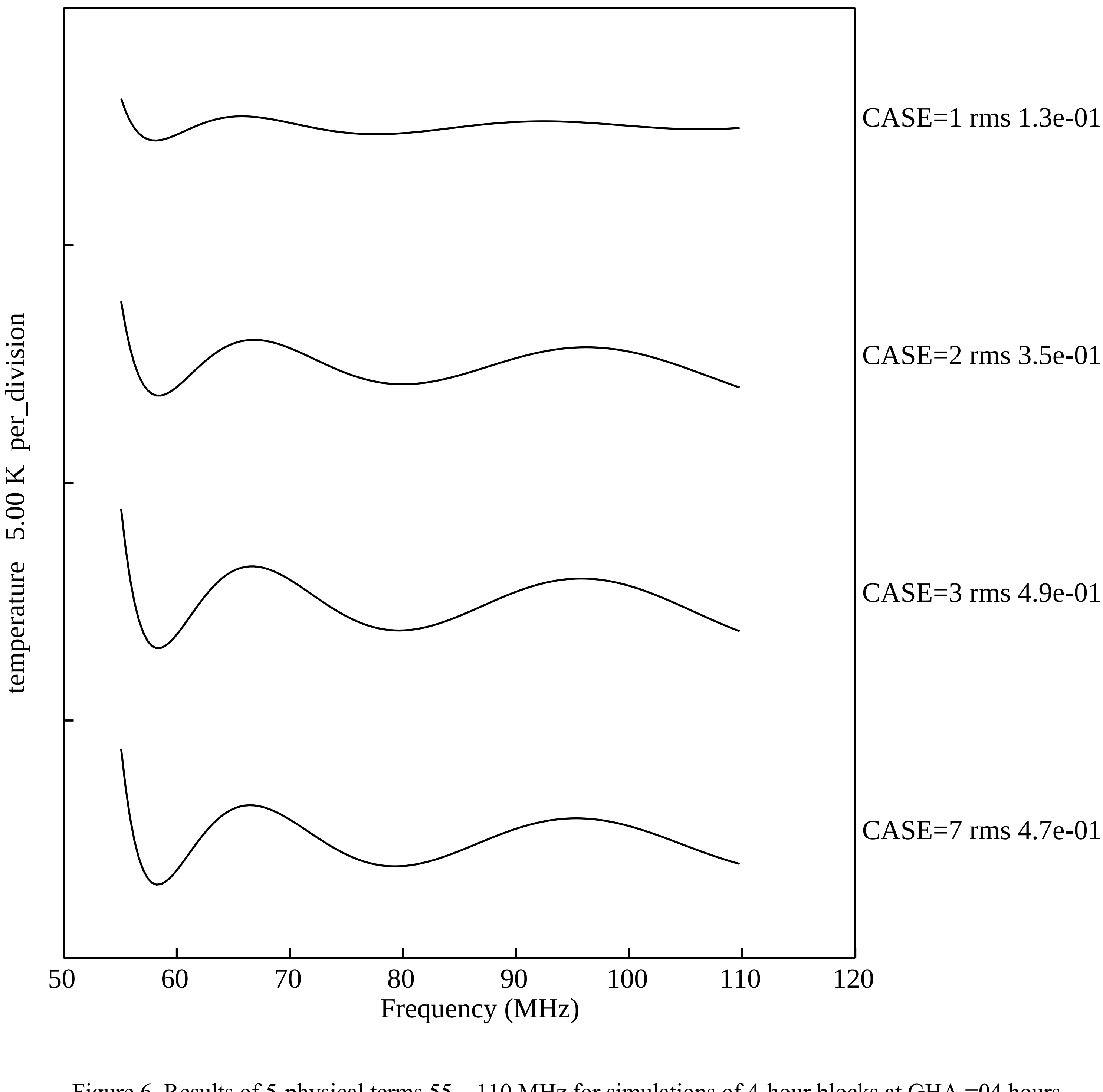

Figure 6. Results of 5-physical terms 55 – 110 MHz for simulations of 4-hour blocks at GHA =04 hours for cases in Table 5. The bottom trace is for case 7 which is the approximation for case 3 made by adding the differences of case 1 and 2 from the reference beam to the reference beam.