EDGES MEMO #337

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To: EDGES Group

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Subject: Simulations of the chromaticity of the lowband antenna on an uneven ground plane

In memo 336 it was found that the low2-45 data has rms residuals at certain Galactic Hour Angles (GHA) that are not reduced to reasonable levels by beam correction even though the beam correction includes effects of a ground plane that is tilted. The rms residuals at GHA = 2, 3, 4 and 21 hours are reduced by beam correction but still remain at the 200 – 400 mK level with 5 physical terms removed from 52 – 95 MHz in Figure 1 of memo 336.

As pointed out in memo 336 it requires beam effects from a large structure for the beam effects to be very different on a scale of one hour as calibration errors, antenna and ground plane losses depend largely on the sky temperature integrated over the whole beam which change smoothly with time on a scale of several hours. Even the presence of a strong radio source or large error in the sky maps will change the beam chromaticity smoothly on a scale of several hours. Current beam modeling using FEKO includes the effects of reflections from the edges of the ground plane but assumes an even flat mesh structure without bumps and dips. In this memo we examine the effects of an uneven ground plane.

In order to obtain some initial results simulations are made by placing a square region of metal connected to a PEC ground. The results are shown in Table 1 below:

Height cm above PEC	Size m	Distance from antenna m	Azimuth from antenna deg	av. rms mK over GHA	rms at GHA=21
10	5 × 5	10	270	72	110
10	5 × 5	10	0	28	36
10	5 × 5	20	270	23	64
20	5 × 5	10	270	152	180
5	5 × 5	10	270	36	69
10	2.5 × 2.5	10	270	33	28
10	5 × 5	5	270	54	71
10	5 × 5	10	90	139	450
10	5 × 5	10	100	132	437
10	5 × 5	10	80	122	452
10	5 × 5	10	70	112	421
10	5 × 5	9	70	128	356
10	5 × 5	11	70	80	235
5	5 × 5	11	70	40	101
10	2.5 × 2.5	10	70	43	91

10	10 × 10	10	70	86	388

Table 1. average rms over 1 hour blocks of GHA and rms for GHA = 21 hours for metal raised above the rest of the infinite ground plane for 5 physical terms 52 – 95 MHz and low2-45 antenna geometry

The simulations use FEKO beam without the raised metal region on the infinite PEC ground as a reference. These simulations show that the chromaticity is approximately proportional to size and height of the region and inversely proportional to its distance from the antenna. There is a large variation with the azimuth relative to the direction to which the antenna is pointed especially the effect at a particular GHA. The inverse proportionality with distance flattens closer than 5 m from the antenna. Tests were made of the effect of the shape using a rectangular raised metal region which show that it is very approximately proportional to the square root of the area for shapes close to a square.

Height cm	Size m	azimuth deg	distance m	av rms mK	rms at GHA = 21
10	5 × 5	70	10	112	421
10	5 × 2.5	70	10	91	267
10	2.5 × 5	70	10	62	255
10	0.625 × 5	70	10	32	134
10	0.3125 × 5	70	10	17	69
10	5 × 0.3125	70	10	94	321
10	5 × 0.15625	70	10	63	221

Table 2. Effect of size of raised metal area. The first dimension is the length of the side of the rectangle closest to the antenna so the entry 2.5 × 5 has the short side towards antenna. The rms residuals are for 5 physical terms 52 – 95 MHz.

For an extreme case like the last two entries where the structure is close to part of a wall around the antenna the effect depends of the length of the wall until the wall becomes thin and the effect decreases.

The effect of the region increases with the length the region that is normal to the direction from the antenna. A long straight area bump or dip produces a reflection from strong regions of the sky producing a large chromaticity when the beam from the sky and the reflection are both picked up by the antenna.

Proceeding to a test of the effect of an elevated region of the low2-45 ground plane Figure 1 shows the geometry of the elevated region used in FEKO for an initial test using still using a PEC ground. The elevated mesh is connected to the PEC ground on all sides. Table 3 gives the results

height cm	distance of bottom edge from antenna m	distance of top edge from antenna m	av. Rms mK	rms at GHA = 21h	rms at GHA = 23h
10	7.5	7.5	81	358	91
10	7.0	8.0	62	289	67
10	6.5	8.5	24	134	25
20	6.5	8.5	52	300	56

10/20	7.5	7.5	87	377	97

Table 3. Simulations of the effects of uneven ground plane using FEKO model of a raised area south of the low2-45 antenna.

The last entry of the table is for additional 10 cm elevation for the southern tips of the 2 triangles. These tests show that spreading out the rise of the leading edge lowers the effects by a factor of about 3 for a rise over meters. The 10 cm rise over 2 meters corresponds to a slope of about 2 degrees. The reason is because 2 meters at 75 MHz which corresponds to half a wavelength smears phase of the reflection which reduces the effect.

height cm	distance of edge of area to antenna m	orientation	av rms mK	rms at GHA=21h	rms at GHA=23h
10	7.5	south	81	358	91
10	7.5	east	92	259	190
10	7.5	north	61	103	184
10	7.5	west	123	213	350
10	7.5	south	86	304	120

Table 4. Effect of the location of the raised region vs location relative to the antenna.

Placing the raised region on the south has the largest effect of the residuals at GHA = 21h. The GHA = 22h is the largest effected when raised region is east of the antenna. With the raised region on the west side of the antenna GHA = 3h is the largest effected. The last entry is for a simulation using a full FEKO model shown in Figure 2 with mesh ground plane over soil with dielectric 3.5 and conductivity 4e-2 S/m. Figure 3 shows a plot of the simulated residuals for which the data was processed with the FEKO model without the raised area shown in Figure 2.

Figure 4 shows the residuals obtained when a region with 5cm height is added to the FEKO model used to process the data from low2-45 days 2020 55 – 140. The average rms is increased from the 126.9 mK of Figure 1 of memo 336 to 138.9 mK but the rms at GHA=21h is reduced from 410 mK to 330 mK.

It is difficult to model dips in the ground plane a simulation was run with the 30x30 m perforated ground plane in space. Figure 5a and Figure 5b show the residuals for a 20 cm dip and 20 cm bump in a 2.5x2.5 square 7.5 m from the antenna using a flat ground plane as a reference. The plots show that the dip and bump produce about the same magnitude of rms but with approximately opposite sign.

Summary

This memo shows uneven regions of the ground plane which deviate by 5 to 10 cm from a flat surface which extend for more than a meter result in an increase rms residuals at the 100 mK level for a 5-therm physical model over a 52 – 95 MHz band. It is also shown that uneven regions need to be more than about 5 meters from the antenna to have effects which change from one hour GHA to the next. The effects are consistent with the concept that the deviations in the ground plane act in a similar manner to the effects of deviations in the shape of an antenna reflector in that deviations further away from the feed have a larger effect on the fine angular structure of the beam than those deviations closer to the feed.

While in principle it should be possible to correct the effects of deviations in the flatness of the ground plane I have not been able to improve the overall residuals of low2-45 by modeling what are currently just guesses of where the deviations might be located based on information visual checks of the low2 ground plane during site visits. It is also possible that damage to ground plane mesh connections which result in a slot antenna may be the cause of the large rems residuals at GHA = 21h in the low2-45 data but it is also possible that a combination of several bumps and dips in the mesh might result in what we observe. See memos 168, 207 and 209 for simulations of the effects of slots in a ground plane.

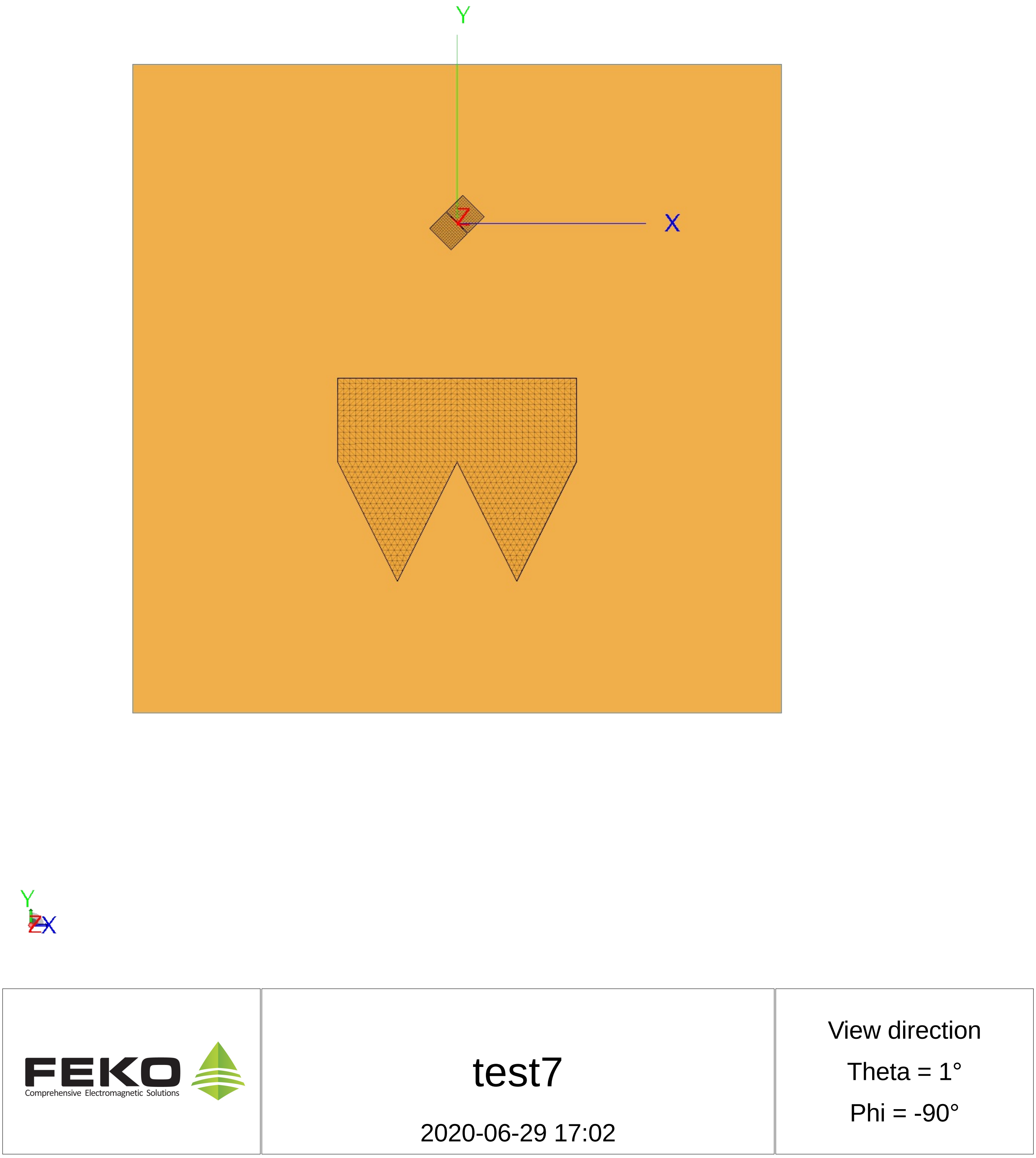

Figure 1. FEKO model for tests using PEC ground plane.

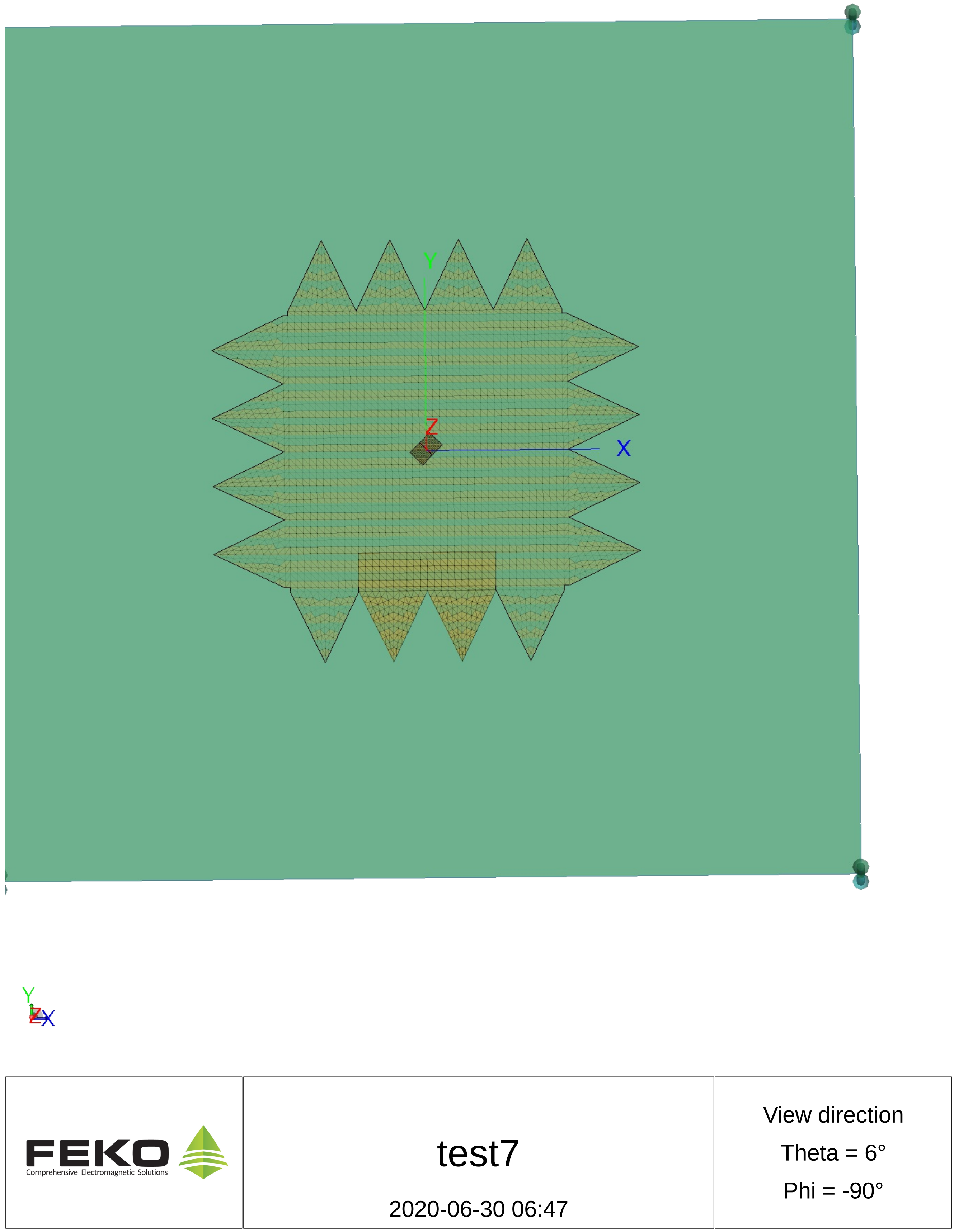

Figure 2. FEKO model for tests with 30×30 m perforated ground plane.

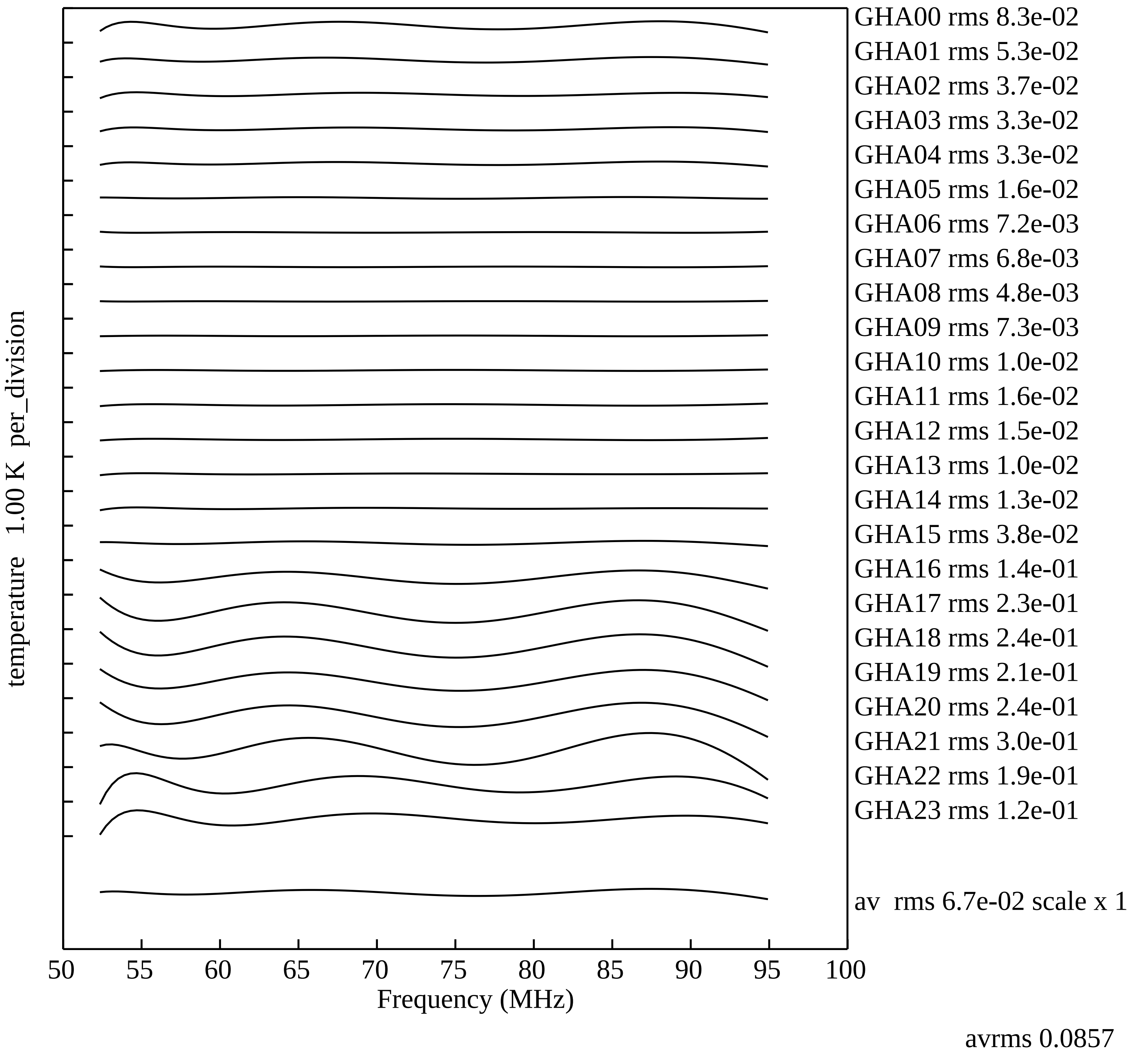

Figure 3. rms residuals for a simulation of a raised area south of the antenna in the last entry of Table 4.

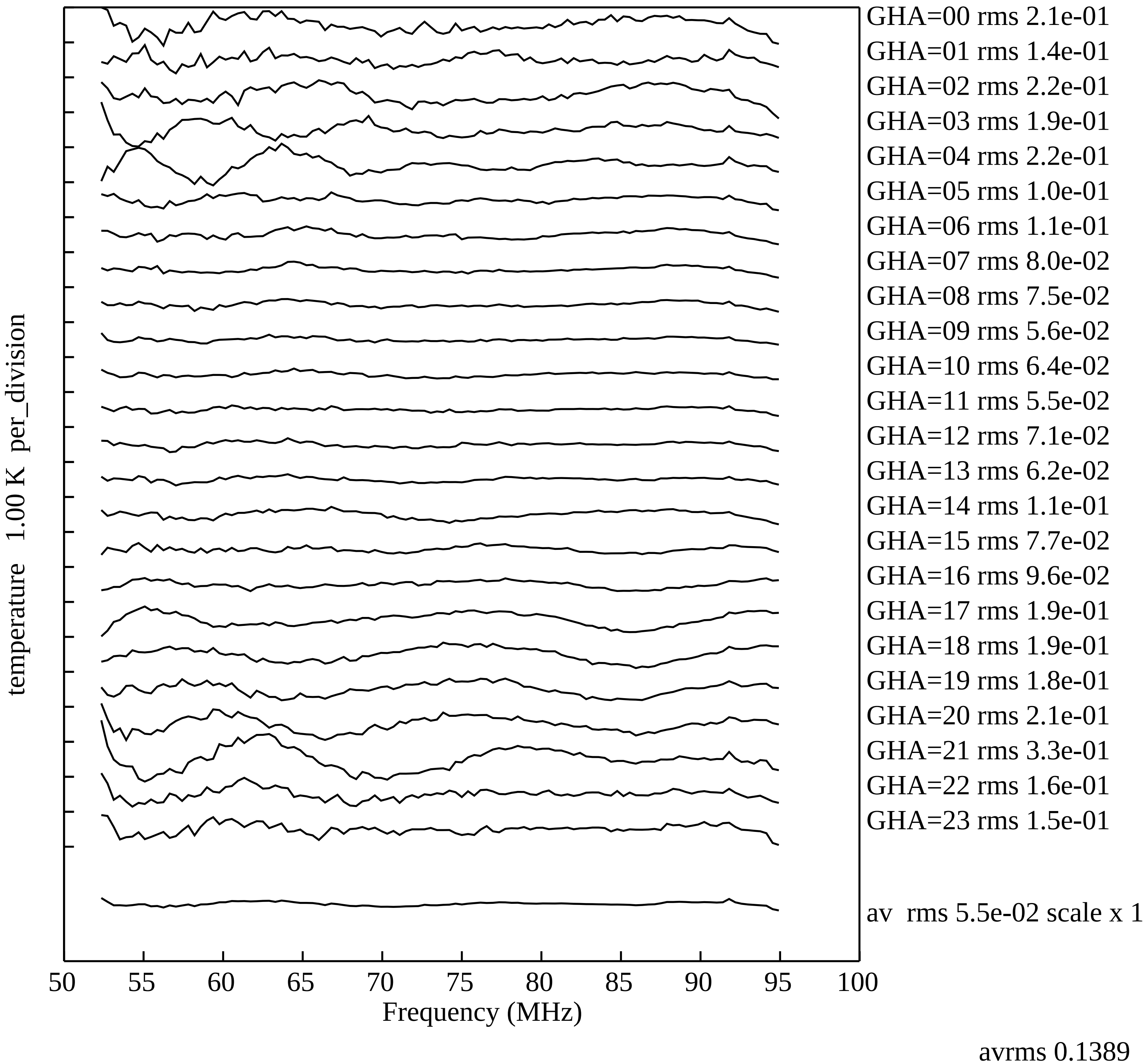

Figure 4. rms residuals for low2-45 data with addition of a raised area.

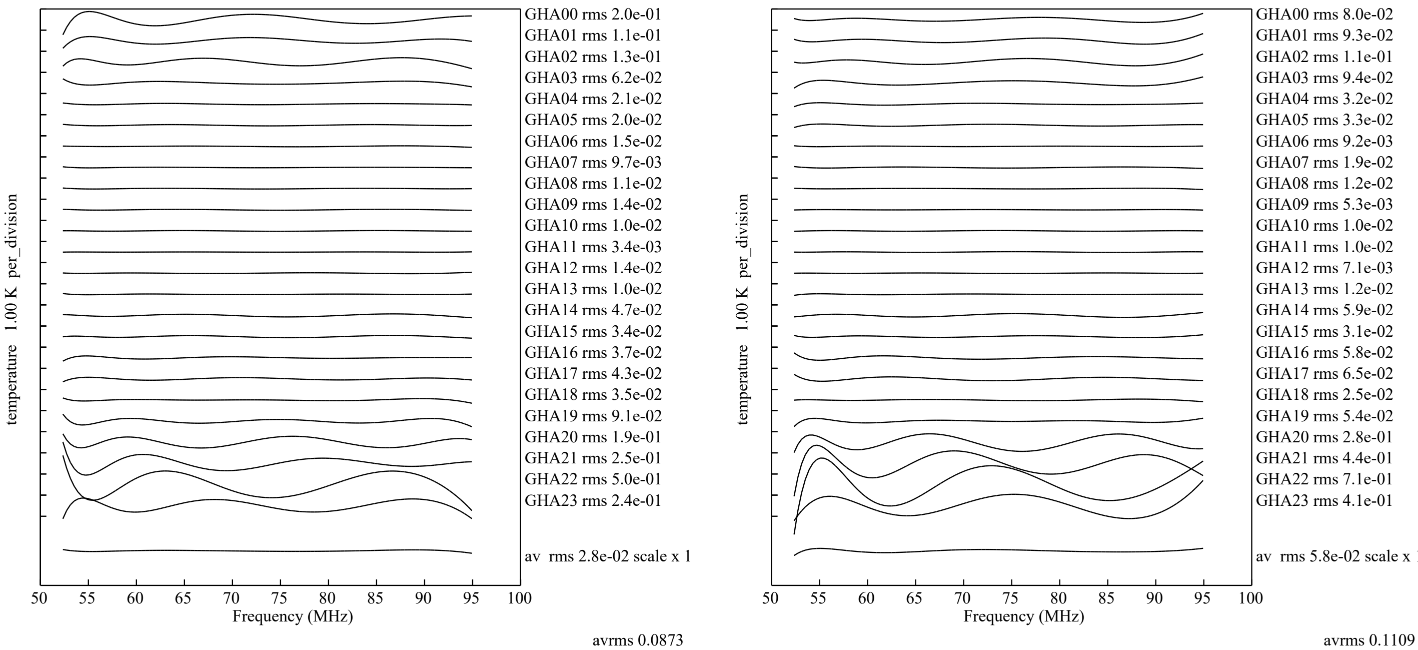

Figure 5a and 5b. Simulations of 20 cm “bump” in plot on the left and “dip” in plot on the right in 30×30 m perforated ground plane.