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To: EDGES Group

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Subject: Effects of rocks and brush southeast of low2-45

FEKO simulations in memo 340 show that trees and brush within 100m of the antenna may have an effect on the fine structure of the antenna beam which produces fine scale chromaticity that changes residuals on a time scale of less than an hour of LST. It is also shown that the effects of this structure on the residuals to 5 term fits is relatively insensitive to the sky map used in the convolution of the beam.

In this memo some simulations are made by placing dielectric cubes in the area southeast of the low2-45 antenna guided by photographs taken of the area in the deployment of low2-45 in February 2020 described in memo 326.

The initial simulations started by FEKO modeling of single structures 50m to the southeast in memo 340 but then moved to testing the effects of multiple structures closer to the antenna in order to try to reproduce the structure seen at GHA = 21 hours in Figure 1 of memo 336. The structure in the residuals dips sharply at 55 MHz, peaks at 62 MHz and then has a broad dip at 72 MHz. What is unique is that it only shows up at 21 hours with a slight peak at 60 MHz in the residuals at GHA = 20 hours. Simulations in memo 337 show that an uneven ground plane has an effect at GHA = 21 hours but the effect is largest at GHA = 22 hours at least for a raised portion of the southern tips of the ground plane.

Simulations show that in order to get the residuals at 21 hours in low2-45 the scatter has to come from something further from the antenna and one possibility examined in this memo is a line of rocks, brush and old tree stumps running between the road and the southern tips of the ground plane at about 18m south of the antenna. This region is indicated by the blue line placed on the google map view of the low2 ground plane in Figure 1.

Figure 2 shows the locations of a line of 19 dielectric cubes 18m south of the antenna used in the initial FEKO simulation. Figure 3 shows the residuals of simulated data with 5-physical terms removed for the low2-45 antenna with a infinite PEC as a reference. Unfortunately FEKO doesn't support including dielectric cubes on a layered ground so soil effects are not included but the simulations in memo 340 show that the soil has little effect on the scattering of a region of high sky brightness from an object on the ground and then back to the antenna to correlate with the direct signal from the sky. Each cube is 0.55x0.55x0.55 m and the bottom side is 0.27 m off the ground. A dielectric of 5 and a loss tangent of 3e-1 is chosen based on He el al. 2001 and other papers to account for the combination of rock and brush. It is possible to include the 30x30 m ground plane on lossy soil with dielectric cubes above the ground and soil below the perforated ground plane using the "reflection ground plane approximation" in FEKO. However this approximation requires a soil conductivity of 3e2 S/m to give accurate results. Soil conductivity below about 3e1 S/m results in large unrealistic differences compared with using the Green's function (GF) method used in almost all FEKO simulations of EDGES antennas on a ground plane on soil.

After trying several configurations of dielectric cubes simulations using only 3 cubes were seen to give reasonable results in emulating what is seen in the low2-45 data at GHA = 21 hours. Table 1 shows the results of simulations using 3 dielectric cubes in line 17m south of the antenna centered at 6.8, 7.85 and 8.9m east of the antenna. Each cube is 0.7x0.7x0.7m with bottom 0.7 m off the ground. The total volume of dielectric 1.029 m^3 with dielectric 5.0 and loss tangent 3e-1.

case		GHA=21hr	GHA=22hr	GHA=23hr	average rms (mK)
A	Low2-45 on 30x30m	484	194	242	131
B	PEC ground	488	196	249	132
C	without cubes	119	245	318	100
D	half size antenna	339	180	196	71
E	half size without cubes	11	15	30	12
F	Small vertical antenna	732	771	991	876

Table 1. Simulations of the effects of scatter from dielectric material on the residuals to 5-physical terms 52 – 95 MHz with and without the 3 dielectric cubes.

These simulations results show that the influence of material beyond the edges of the ground plane does not depend significantly on whether the ground is soil or PEC It also shows that the effects of the cubes are not significantly reduced by reducing the size of the antenna. The “half size” which makes the low2 antenna electrically small includes reducing the height of the panels above the ground. The implication is that going electrically small still requires a large ground plane and clearing the land out the same distance needed for the low2 dipole. Case D in table 1 shows a lower rms residual than for case A at GHA=21 hours but the difference between the rms with and without the cubes for the antenna sizes is small. Tests of adding a wall between the antenna and the cubes results in added beam chromaticity owing to reflections from the wall and fails to reduce the influence of the cubes at least for the range of wall height up to 0.5 at 3m to 10m from the antenna. The main motivation for these tests being to see if it is possible to make a more compact instrument for global 21-cm measurements. Case F shows that a vertically polarized antenna is even more sensitive to the dielectric cubes while without the cubes the residuals in this case are below 1 mK.

The results of using the beams from FEKO to correct the chromaticity of the low2-45 data from 2020_055 to 2020_140 are given in Table 2.

case	GHA=21 hr	GHA=22 hr	GHA=23 hr	average rms (mK)
with cubes	295	247	261	168
without cubes	423	271	155	166

Table 2. Residuals for 5-physical terms removed 52 – 95 MHz for low2-45 2020 days 55 to 140 with and without added rock and brush modeled with the 3 dielectric cubes used in the simulations in table 1.

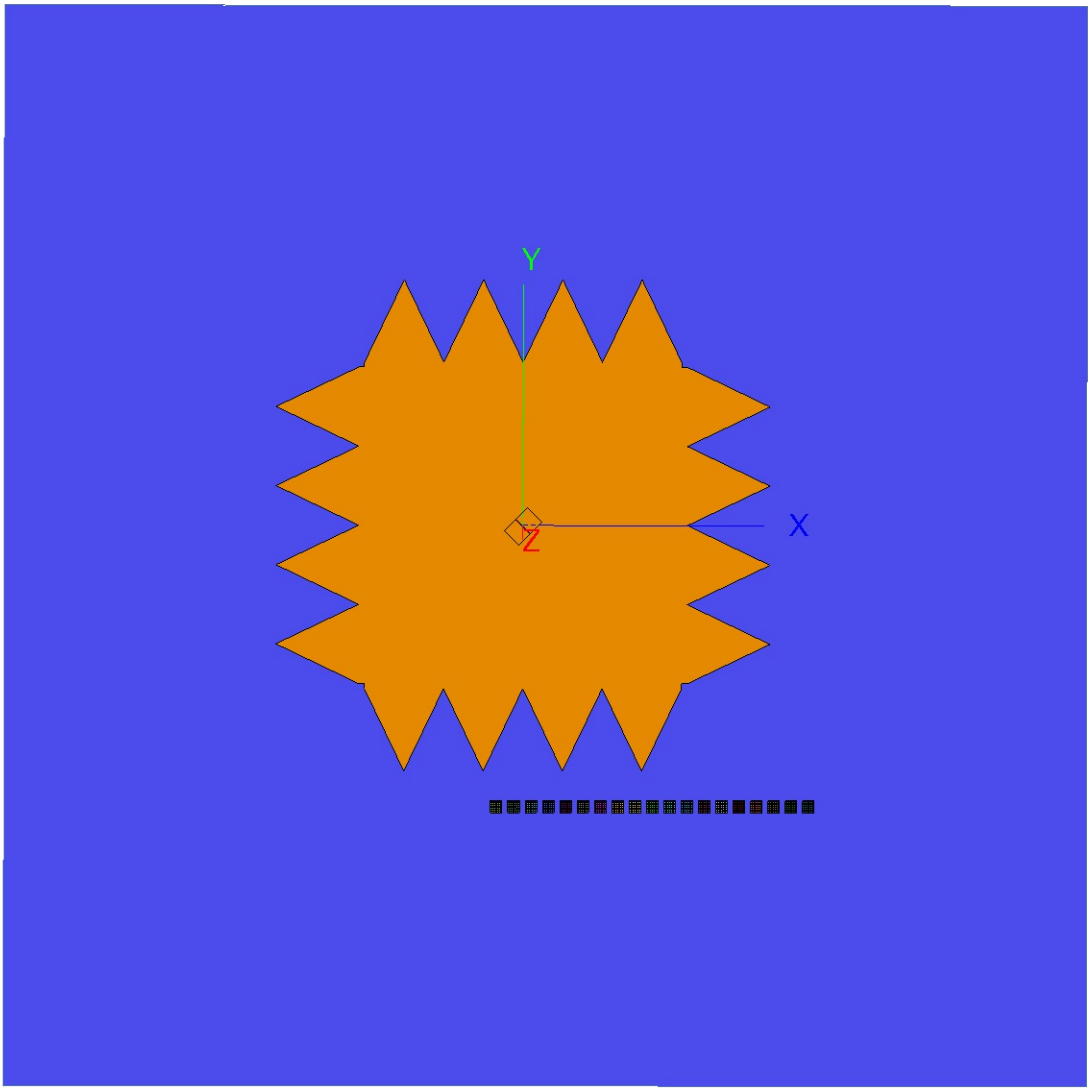
Figures 4 and 5 show the residuals for all 24 blocks of GHA. The average of residuals are higher than those in memo 336 because it was not possible to model the soil with a conductivity of 4e-2 S/m owing to the limitations of the “reflection ground plane approximation” in FEKO needed to model the dielectric cubes above the ground.

Summary

In order to reduce the fine structure in the antenna beam EDGES which started with a 10x10m ground moved to a 30x30m ground plane with perforated edges. Now based on simulations and recent data there is a need for an even larger ground plane of 48x48m. In addition the ground plane needs to be flat and level with significant brush beyond the edges of the ground plane removed. The level of a cubic meter is significant within about 20 meters from the antenna increasing to a level of tens of cubic meters out to about 60 meters based on the dependence on the square of distance from memo 340. The removal of significant debris is needed in order to reduce the beam chromaticity to a level to make it possible to obtain 21-cm absorption profiles for each hour of Galactic hour angle.

He, Jiangqi, Norbert Geng, Lam Nguyen, and Lawrence Carin. "Rigorous modeling of ultrawideband VHF scattering from tree trunks over flat and sloped terrain." *IEEE transactions on geoscience and remote sensing* 39, no. 10 (2001): 2182-2193.

Figure 1. View of the low2 ground plane from google maps with region containing rocks, brush and old tree stumps marked with blue line.



FEKO Comprehensive Electromagnetic Solutions	test7 2020-08-17 06:56	View direction Theta = 3° Phi = 90°

Figure 2. FEKO model of low2 _45 antenna on 30x30m ground plane with dielectric cubes to model rocks and brush.

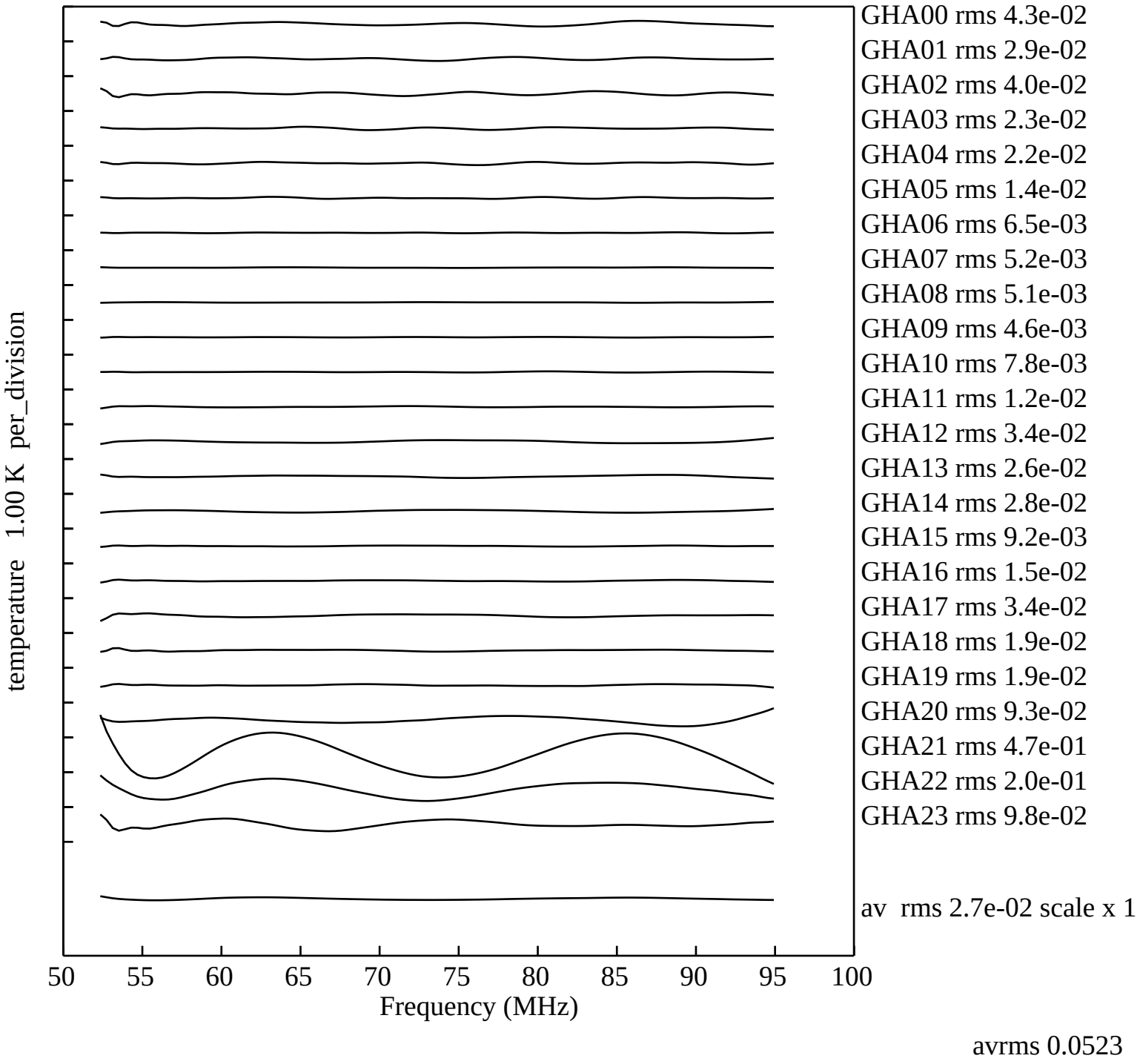


Figure 3. Residuals for 5-physical terms removed from simulated data for low2-45.

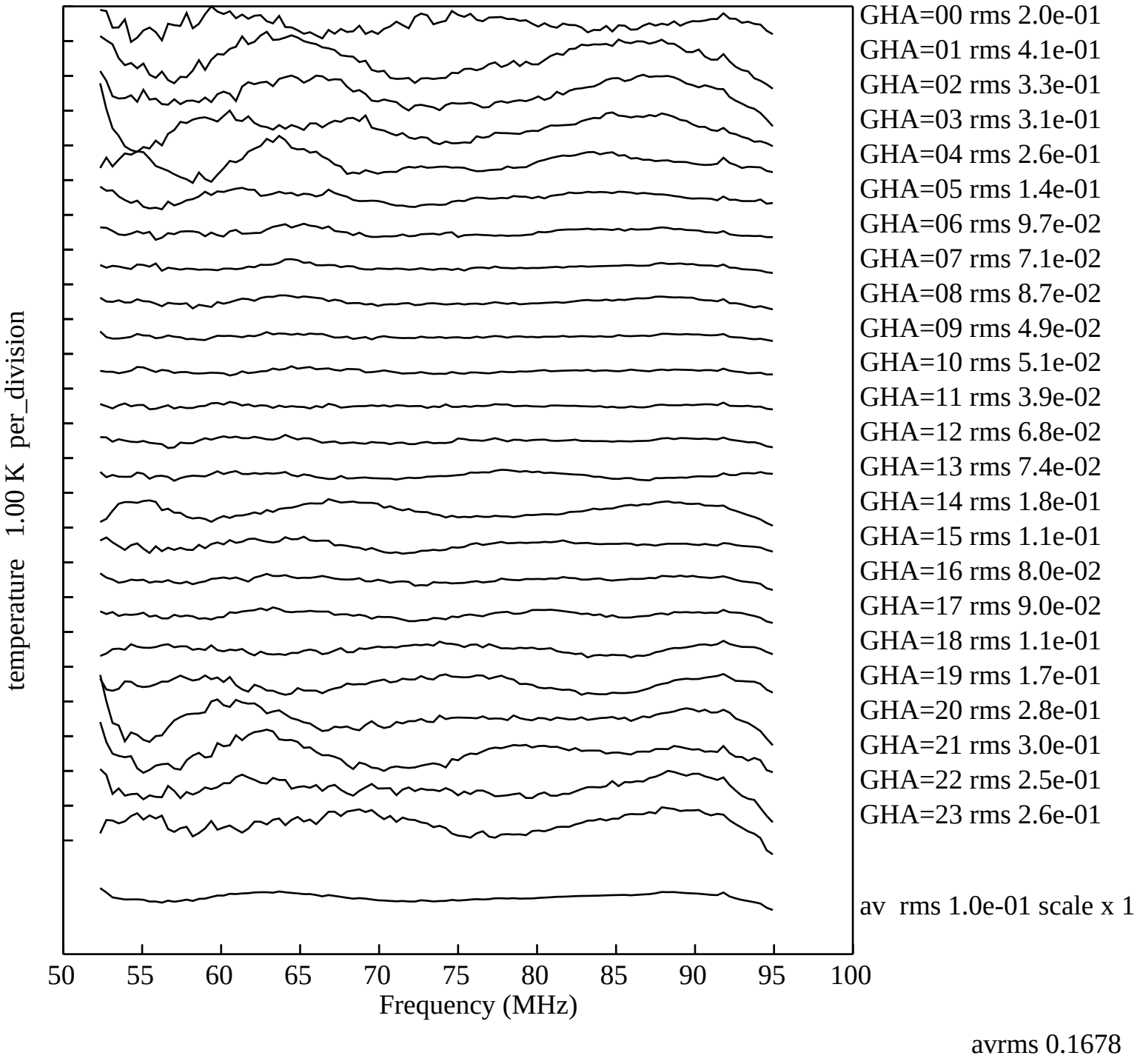


Figure 4. Residuals for 5-physical terms removed for low2-45 data from 2020 days 55 to 140 with 3 dielectric cubes to model rocks and brush south of the 30x30m ground plane.

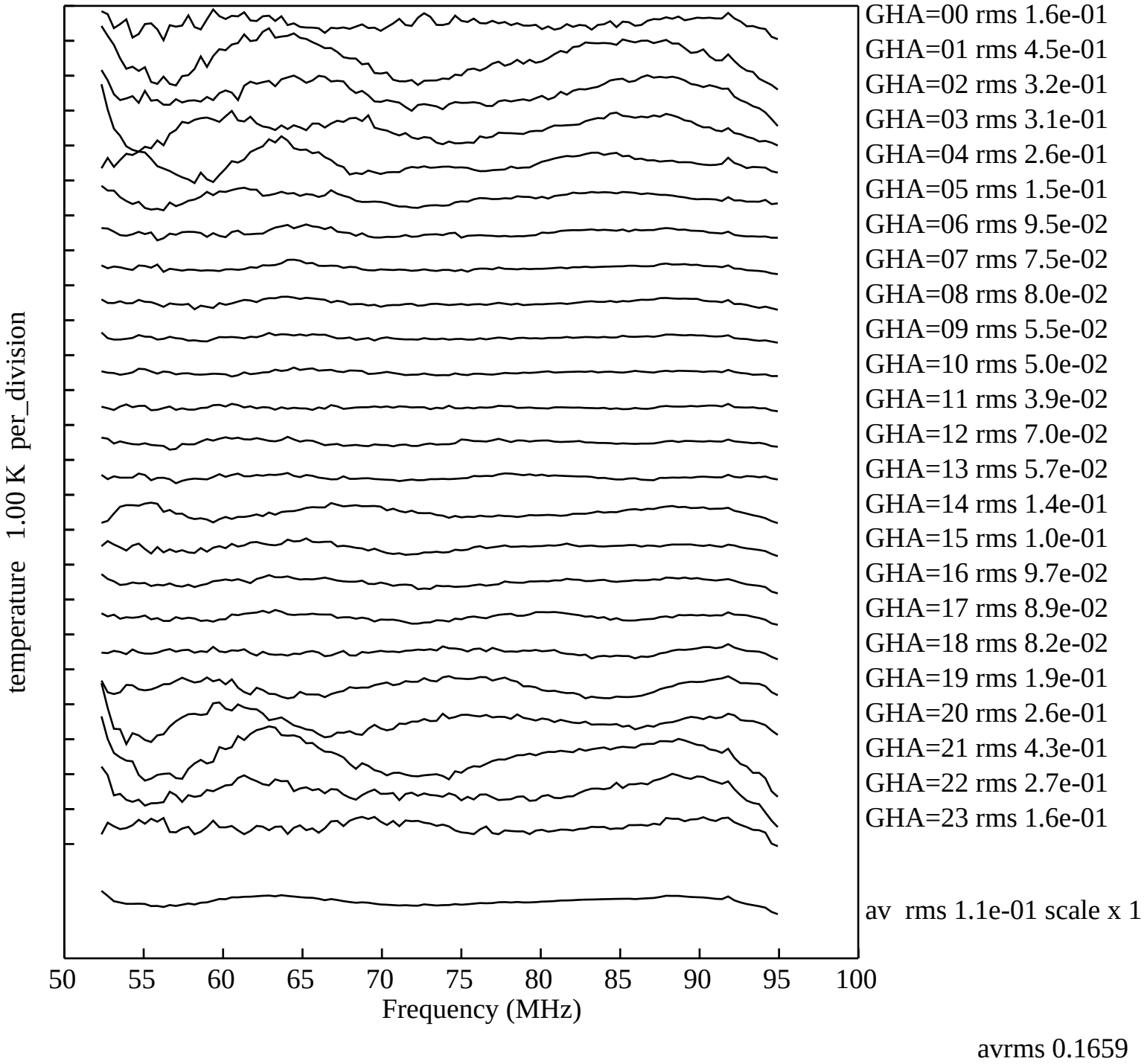


Figure 5. Same as figure 4 but without dielectric cubes.