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To: EDGES Group
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Subject: Sensitivity of the frequency dependence of beam to ground plane parameters.

Introduction

Memos 186, 187 and 188 discuss the effects of a finite ground plane on the frequency dependence of the beam. In summary the frequency structure observed in the low band spectra is now thought to largely originate from the effect of a finite ground plane. All simulations of the beam chromaticity prior to 2016, were done with the antennas on an infinite ground plane. The ground plane size was determined based on estimates of the ground noise pickup. The loss was estimated using FEKO with finite ground plane on a dielectric ground assumed to have a dielectric constant of 13 (see memo 88) and from the power fraction below with a finite ground plane in free space (see memo 88 and ASU memos 47 and 48. Loss for a 5×5 m ground plane high band was a smooth curve under 4 percent.

After obtaining a few weeks of data from low band it was clear that the systematic trends in the low end of the spectrum were much larger than expected. It's clear that the spectra with 5-terms removed have trends when the Galaxy is up that are similar to those obtained from FEKO simulations with the ground plane over soil assuming a dielectric constant in a range around 3.5.

Effect of ground plane size

While the loss which results from a finite ground plane is approximately inversely proportional to the area the magnitude of the fine frequency structure in the beam is approximately inversely proportional to the size of the ground plane because it depends on the current at the end edge of the ground plane which is proportional to the inverse distance from the antenna.

Size (m)	Shape	rms to 5-term fit mK	
		Peak	Average
5	Square	3000	280
10	Square	1000	250
20	Square	450	180
15	Plus	650	170
30	Plus	230	64
Infinite	Plus	200	21

Table 1. Simulations over range of GHA with band from 51 to 97 MHz.

Table 1 shows the results of FEKO simulations with the blade antenna on a ground plane over an infinite ground with conductivity 10^{-3} S/m and dielectric constant 3.5. The simulation was taken over the full range of Galactic hour angle. Since there is a large variation with GHA the most meaningful quantity is the peak but the average over 24 hours is also given as a measure of performance. There appears to be some advantage in using a “plus sign” shape formed by 5 squares of one third the size listed in the table.

While the best solution would be to use a very large ground plane. At a bare minimum at low band this should be a “plus” made of 5 10×10 m squares which should reduce the beam chromaticity by a factor of at least 3.

Effect of dielectric constant

Figure 1 and 2 show the simulated spectra for a dielectric constant of 3.5 and 4.5 respectively. Note that even this small change effects the shape of the spectra even for times when the Galactic center is below the horizon. The GHA time slots are 4 hour averages which can be compared with the low band spectra in Figure 3 which are uncorrected for beam effects. While applying a beam correction makes a small improvement to the rms the details of the beam correction with 5 terms removed are not known well enough to make a significant improvement.

Effect of small change in size

Figure 4 shows the simulated spectra for a square ground plane 9.8×9.8 m which is closer to the actual size of the low band ground plane.

Figure 5 shows the beam effects for a ground plane 10×10 m on a dielectric of 13. Some of the fine scale is enhanced while the larger is suppressed.

Figure 6 shows the simulated spectra for an infinite ground plane for comparison.

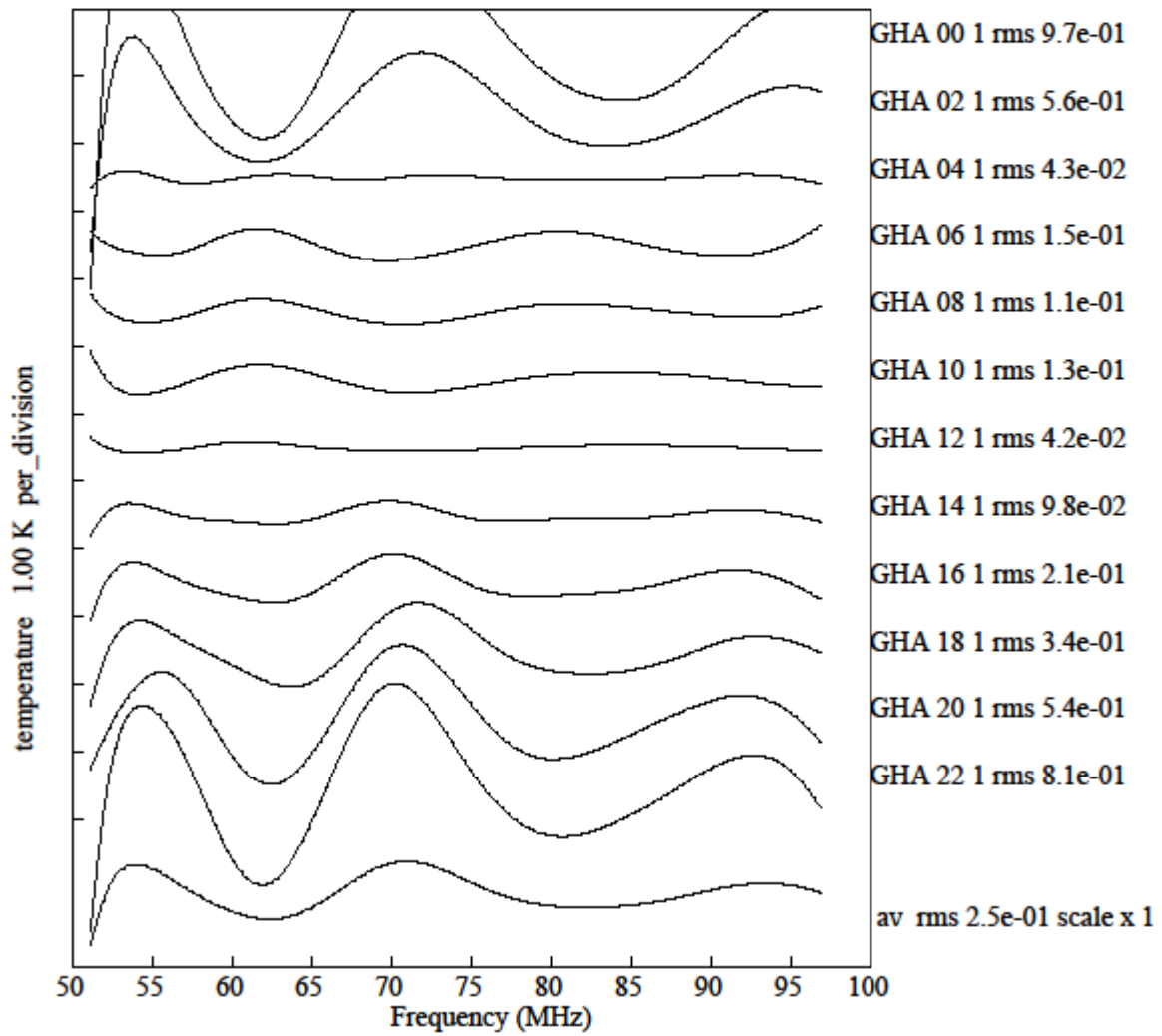


Figure 1. Simulation of beam chromaticity with 5 physical terms removed for $10\text{ m} \times 10\text{ m}$ ground plane.

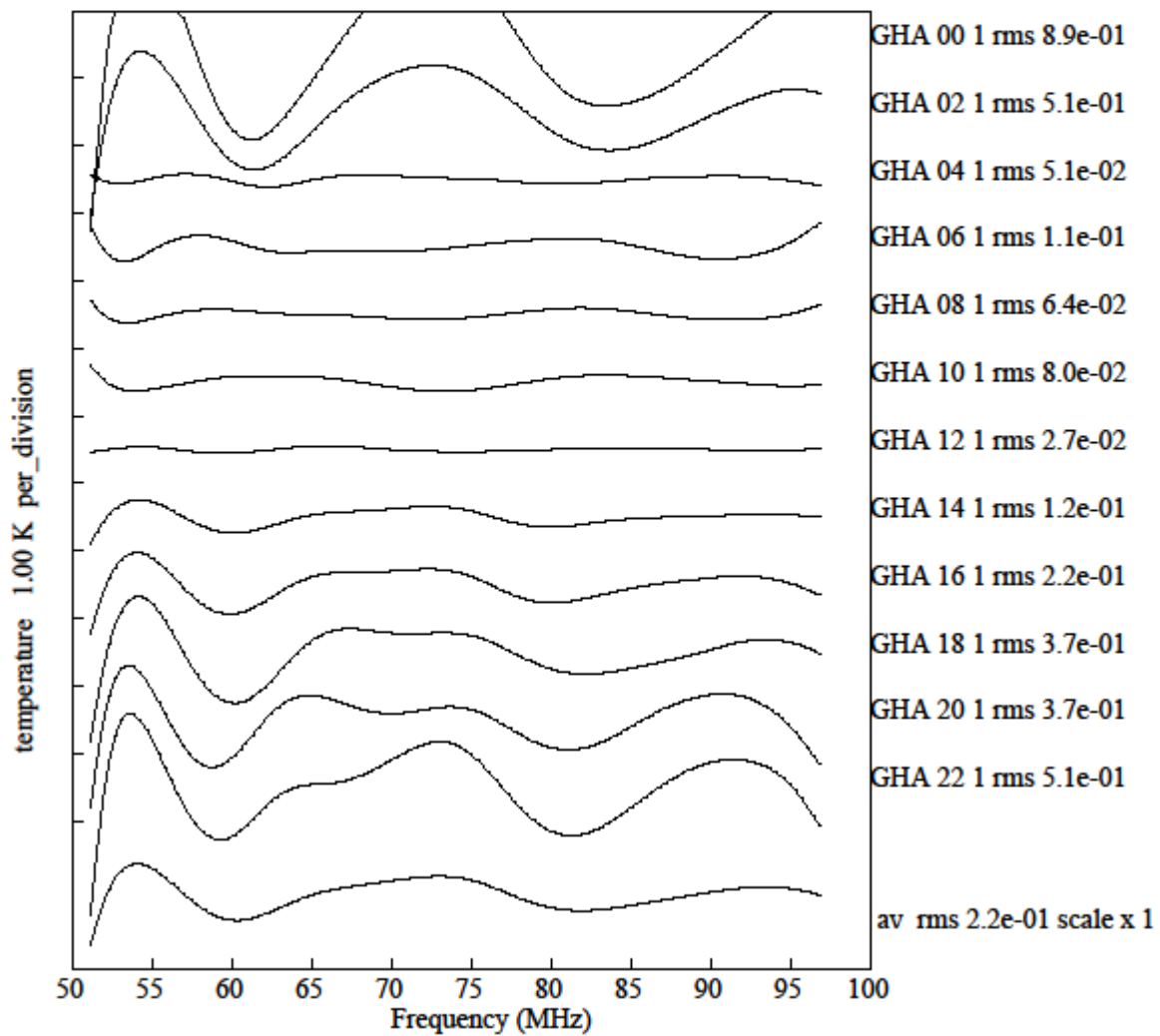


Figure 2. Dielectric constant increased to 4.5.

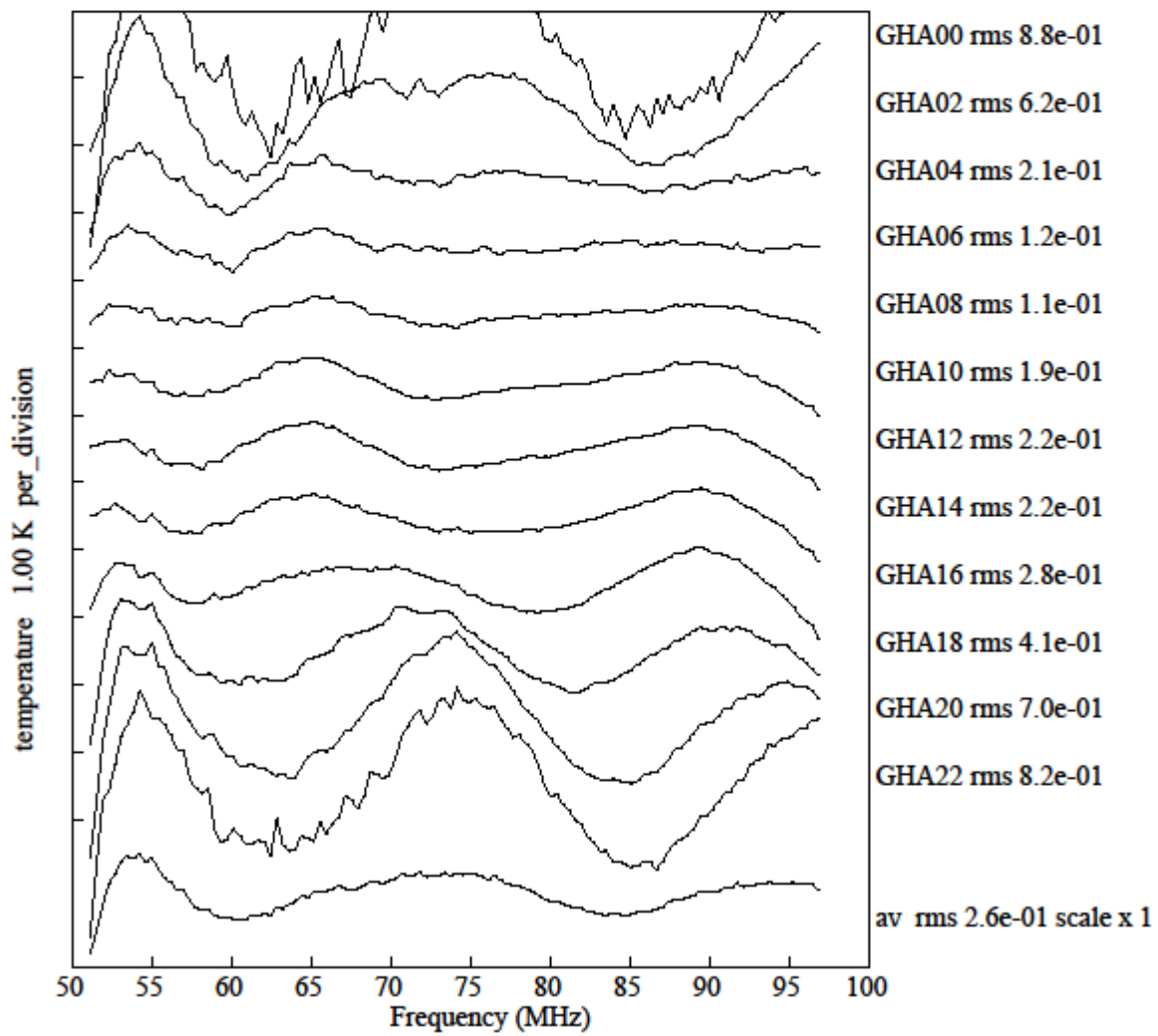


Figure 3. Low band data from 2015.

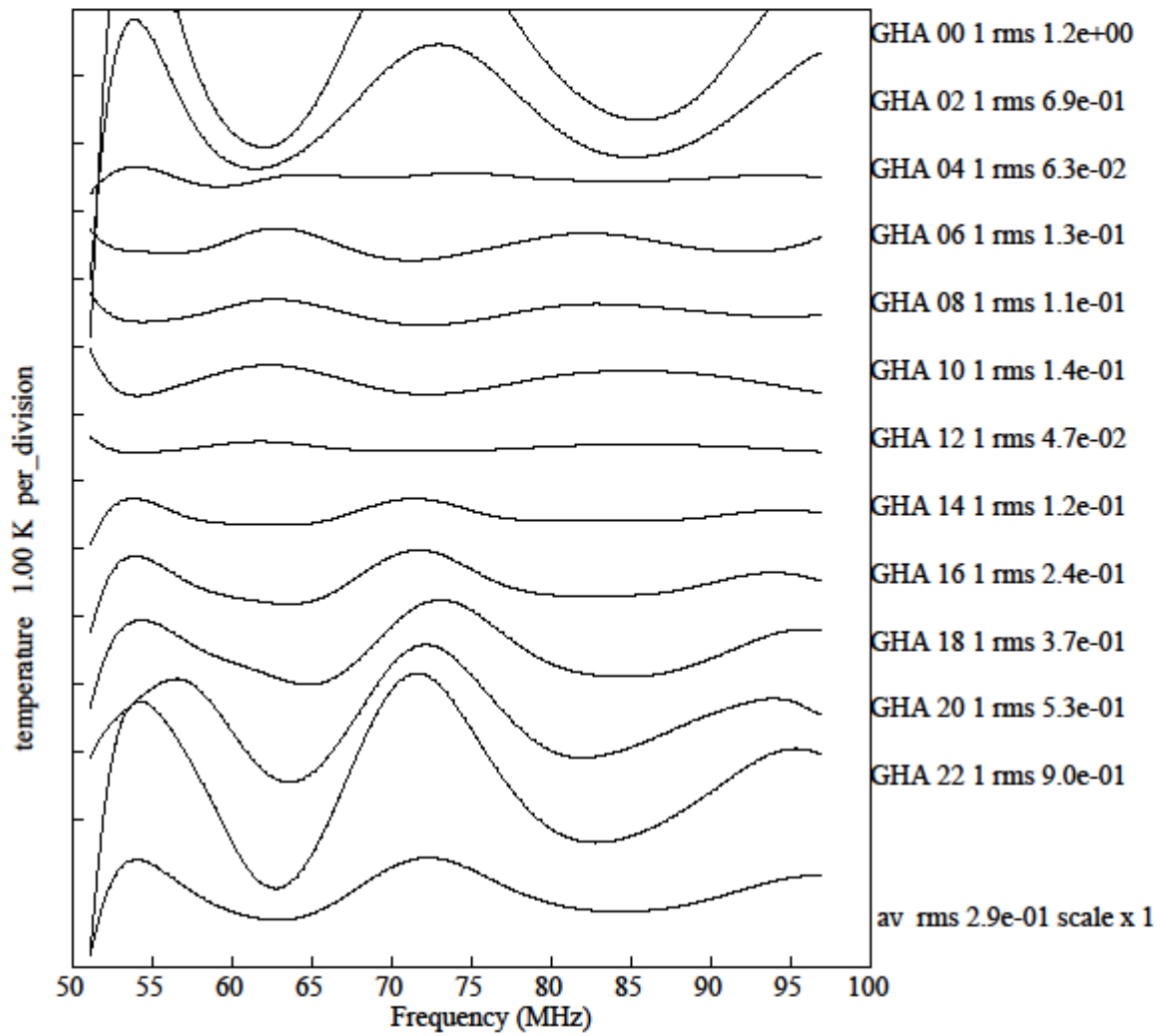


Figure 4. Simulated spectrum for square ground plane of 9.8×9.8 m.

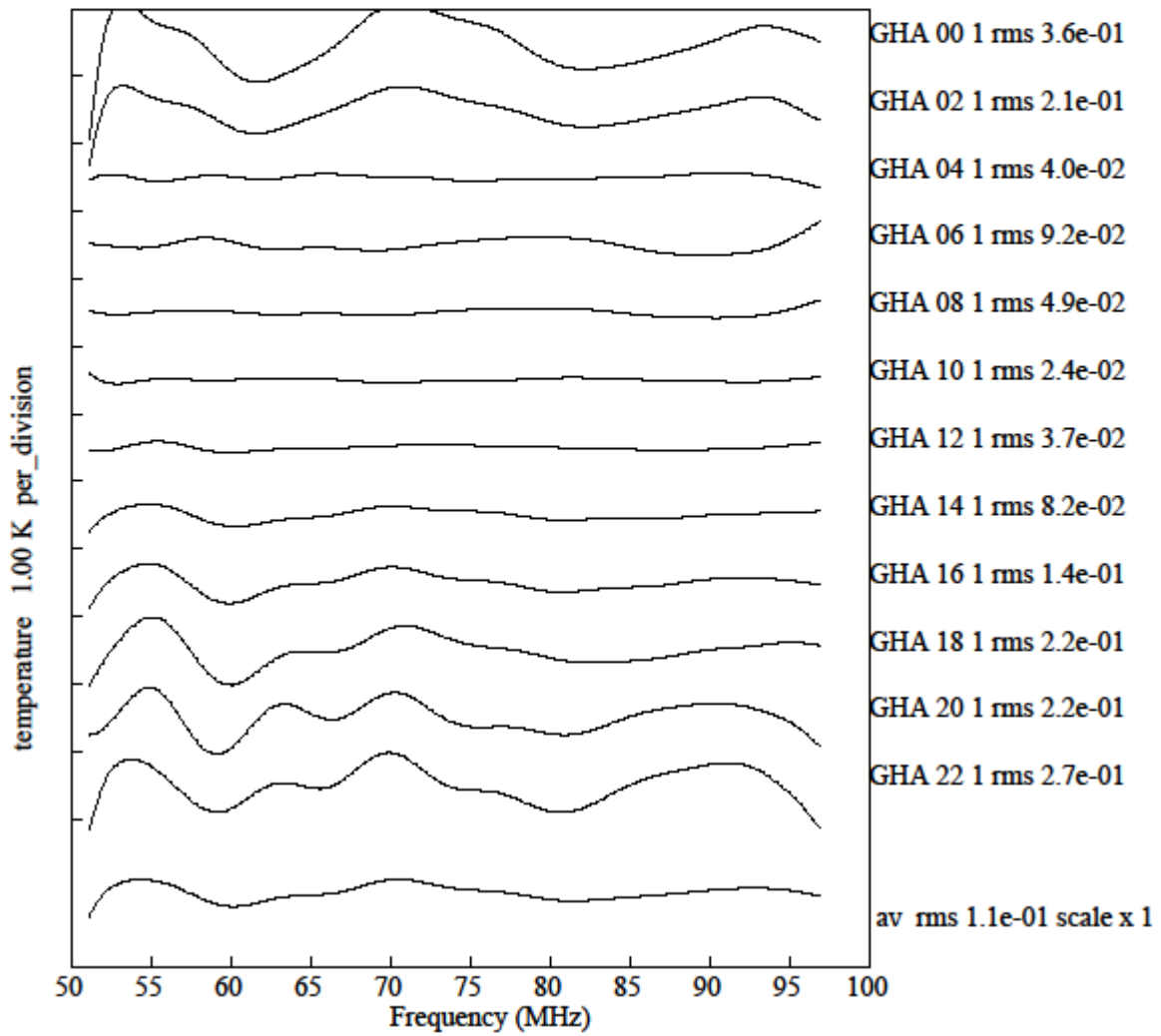


Figure 5. Simulation for 10×10 m ground plane on soil with dielectric constant of 13.

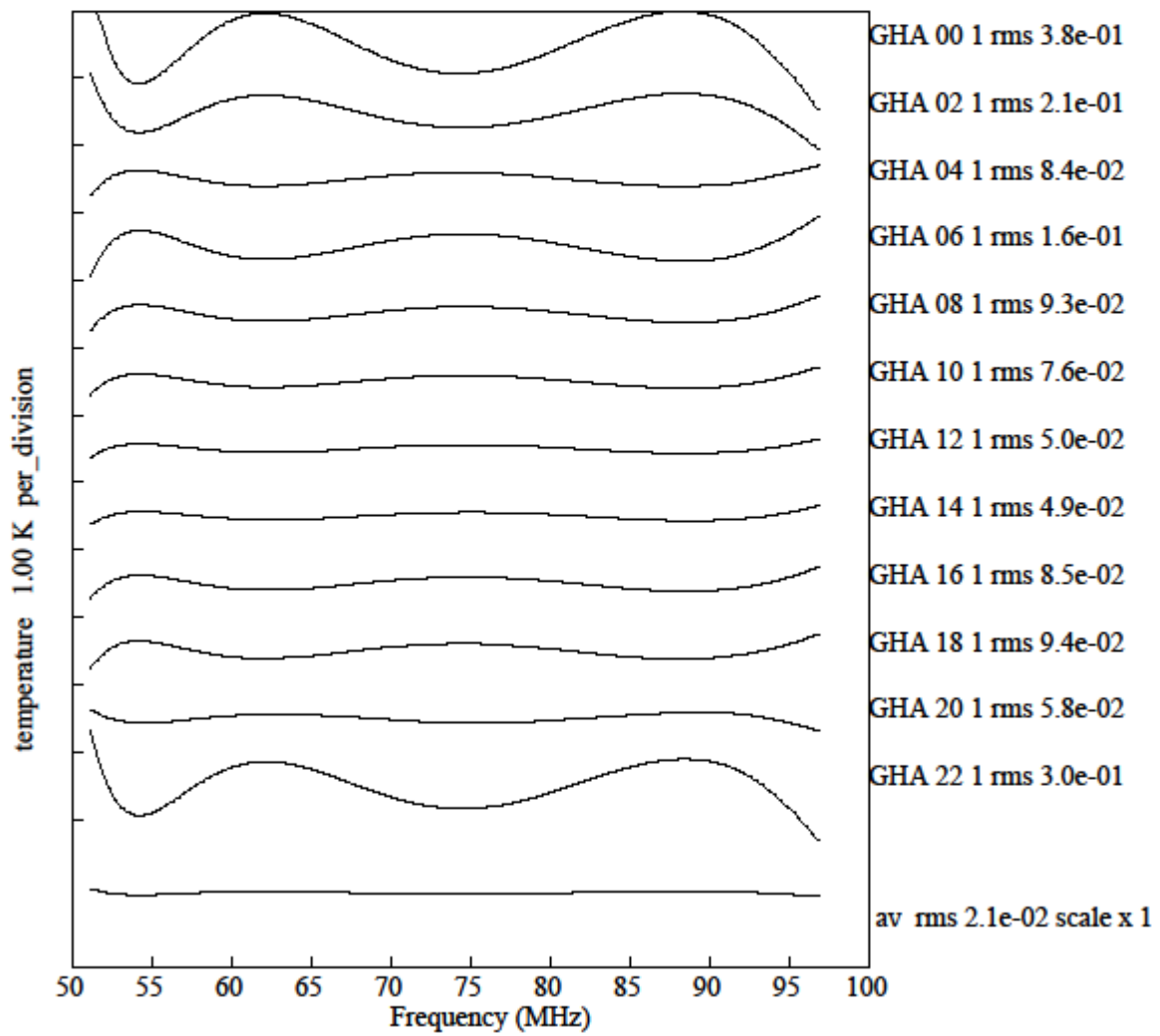


Figure 6. Simulation with infinite ground plane for comparison.