EDGES MEMO #342

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

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Telephone: 617-715-5533
Fax: 781-981-0590

To: EDGES Group

From: Alan E.E. Rogers

Subject: Modeling ferrite tiles for reducing reflections from hut

In the current plan for EDGES-3 deployment the electronics hut will be between 30 and 50m east of the antenna. At 30m distance the model from FEKO using the metal hut results in a rms residual of about 1000 mK at GHA = 4 hours for 5 physical terms removed from 52 to 95 MHz. This is reduced to a rms residual of about 100 mK at 50m which is close to the estimate of 47m for the distance of the pad, which has been prepared for EDGES-3, from the face of the hut facing the pad. Figure 1 shows the residuals vs GHA over 24 hours. The simulation is for EDGES-3 on the new pad pointed N-S. The effect of the hut is reduced by more than a factor of ten for the antenna pointed E-W and is shown in Figure 2.

The plan is to cover the face of the hut which points towards the planned antenna location with ferrite tiles. A check can be made using the theoretical performance at normal incidence as follows:

A metal backed ferrite sheet has a reflectivity at normal incidence given by equations

$$z = \sqrt{(\mu/\epsilon)}\tanh((j2\pi f\, d/c)\sqrt{(\epsilon\mu)}) \qquad (1)$$

$$loss = -20\log_{10}(|((z-1)/(z+1))|) \qquad (2)$$

where $\mu$and $\epsilon$are the complex relative permeability and permittivity respectively

f is the frequency in Hz

d is the tile thickness in m

c is the velocity of light = 3e8 m/s

The loss is the loss in dB that a reflected ray would suffer relative to a reflection from PEC without the ferrite.

The negative complex fractions of relative permeability and permittivity are given by the "tan(delta) magnetic" and tan(delta) electric" in FEKOs "DATA FOR DIELECTRIC MEDIA".

Some information on the permeability and permittivity is in the data sheets for ferrite tiles. A starting point given by Sushan Khadka (2017) is to assume $\epsilon = \mu = 60(2-j)$which predicts a loss of 10 dB for a 5 mm thickness at 100 MHz. This loss doubles to 20 dB if the complex permeability and permittivity are doubled. The data sheet gives a relative permeability of 1000 at 0.1 MHz but little information on frequency dependence other than a plot of the expected reflection loss of better than 25 dB in the 50 – 100 MHz range.

A check using FEKO would be more assuring since the results from the formula above and the tile specifications are only for normal incidence. While FEKO is is capable of modeling the tiles the values of complex relative permeability and permittivity are needed. The large values of permeability and permittivity require a very small cuboid mesh size as the wavelength in the ferrite is reduced by the square root of the product of permeability and permittivity. This makes a complete modeling using standard MoM difficult owing to the huge number of very small "mesh" cuboids needed to cover the face of the hut. A limited check can be made by limiting the permeability and permittivity to low values for a comparison with the values from the formula above and checking the ratio with the results for a smaller metal reflector.

Table 1 shows the results of FEKO MoM simulations of EDGES-3 antenna on PEC ground plane with the antenna pointed North with the hut 30m to the east of the antenna.

Reflector 2.4x2.4m	diel	tan(electric)	mu	tan(magnetic)	rms at GHA=4	average rms mK	Expected mK
just face	PEC				1600	295	1600
all hut	All pec				1084	186	1084
just top	Top pec				1255	247	
just face	1	0.4	100	0.5	892	198	634
with hut	1	0.4	100	0.5	764	190	431
with hut	1	4e-4	50	1	596	158	272

Table 1. Simulations of hut reflection for hut 30m east of the EDGES-3 antenna pointed N-S.

What is clear from these simulations is that the reduction expected from the formula for the plane wave reflection, listed in the last column, is not achieved from the FEKO simulation even for single face of the hut and gets worse as additional metal faces, which are not covered with tiles, are included in the simulation. Note the effect of just the top panel which faces edge-on. These effects are also seen in anechoic chambers when there are gaps between tiles are the plane wave solution is only valid for normal incidence over a few wavelengths without gaps.

reflector 2.4x2.4m	diel	tan(electric)	mu	tan(magnetic)	rms at GHA=4hr	average rms mK	expected mK
just face	PEC				430	108	430
with hut	all PEC				95	61	
with hut	1	4e-4	50	1	93	59	108

Table 2. Simulations of hut reflection from hut 40m east of EDGES-3 antenna pointed N-S

The first entry is for a single “free-standing” 2.4x2.4m metal panel shows that attaching sides and top reduces the effects of scattering significantly presumably because the free-standing panel approaches a half-wave resonance at 50 MHz. The encouraging result is that moving the antenna from 30 to 40 m from the hut reduces the affects by a factor greater that the square of the distance in this case.
Table 3 shows a further reduction of more than the square of the distance in going to 50m.

reflector 2.4x2.4m	diel	tan(electric)	mu	tan(magnetic)	max rms mK	avrms mK
face	PEC				207 at 5hr	73
with hut	PEC				150 at 5hr	62
with hut	1	4e-4	50	1	95 ar 5hr	57

Table 3. Simulations of hut reflection from hut 50m east of EDGES-3 antenna pointed N-S

So far the results in the figures and tables are for the standard MoM processing and using 22 Fourier terms to filter the beam results from FEKO. Table 4 shows the simulations for 47m for the different methods and filtering.

	method	filt	gnd	diel tan perm tan	max mK	av mK
hut	MoM/sep	22 fourier	pec	10 1 20 1	100 at 5h	59
hut		26 fourier	pec	10 1 20 1	360 at 3h	85
hut face	MoM/sep	26	pec	10 1 20 1	510 at 3h	100
hut face	MoM/sep	26	pec	120 0.5 120 0.5	490 at 3h	100
hut no diel	MoM/sep	26	pec		800 at 3h	125
hut	MoM/sep	12 poly	pec	120 0.5 120 0.5	130 at 23h	51
hut no diel		12 poly	pec		132 at 23h	49
hut	MoM	26 fourier	pec	1 4e-4 50 1	380 at 4h	90

Table 4. Simulations of reflection from hut 47m east of EDGES-3 antenna pointed N-S

At a distance of more than 40m the effect of the reflections become less significant when the beam results are fit with fewer terms which smooth out the ripples. These results are shown in Table 4. In addition the method of the surface equivalent principle (sep) is used in FEKO as it only requires defining a region so only the surface has to be meshed as opposed to meshing the volume into a very large number of cubes which are known as “cuboids” in FEKO.

Figures 3 and 4 show the simulations for the hut at 47m filtered by 22 Fourier and 12 polynomial terms respectively.

In summary it looks like at 47m the hut reflections should not be a problem even if the ferrite panels only provide a factor of two reduction in the level of the reflections and using the E-W orientation should certainly not have any significant added beam chromaticity from reflections from the electronics hut.

References:

Evaluation of Radio Anechoic Chamber by Sushan Khadka
Helsinki Metropolia University of Applied Sciences Bachelor of Engineering Degree Programme in Electronics Bachelor’s Thesis 27 April 2017

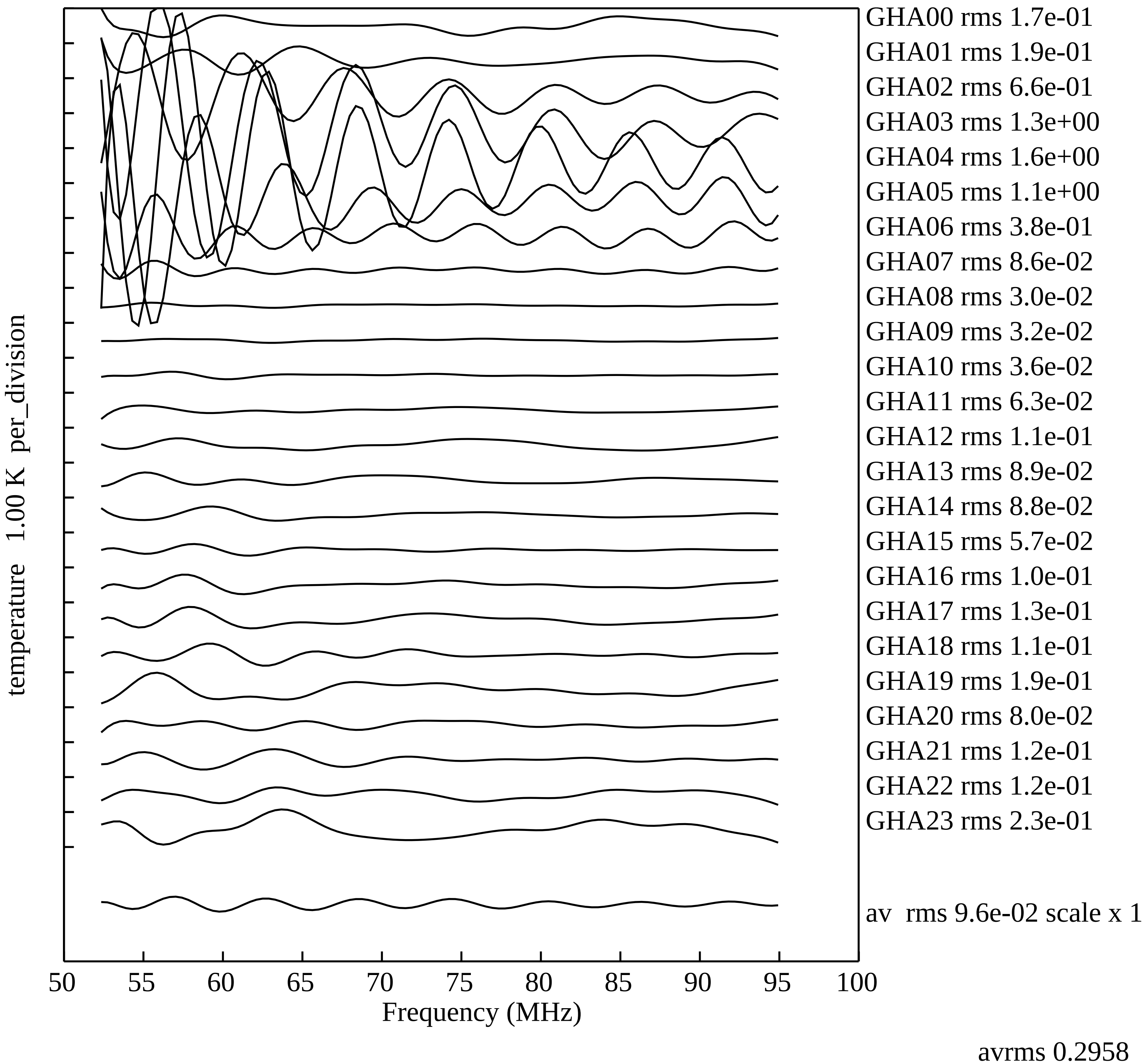

Figure 1. Residuals with 5-physical terms removed for EDGES-3 N-S 30m from hut.

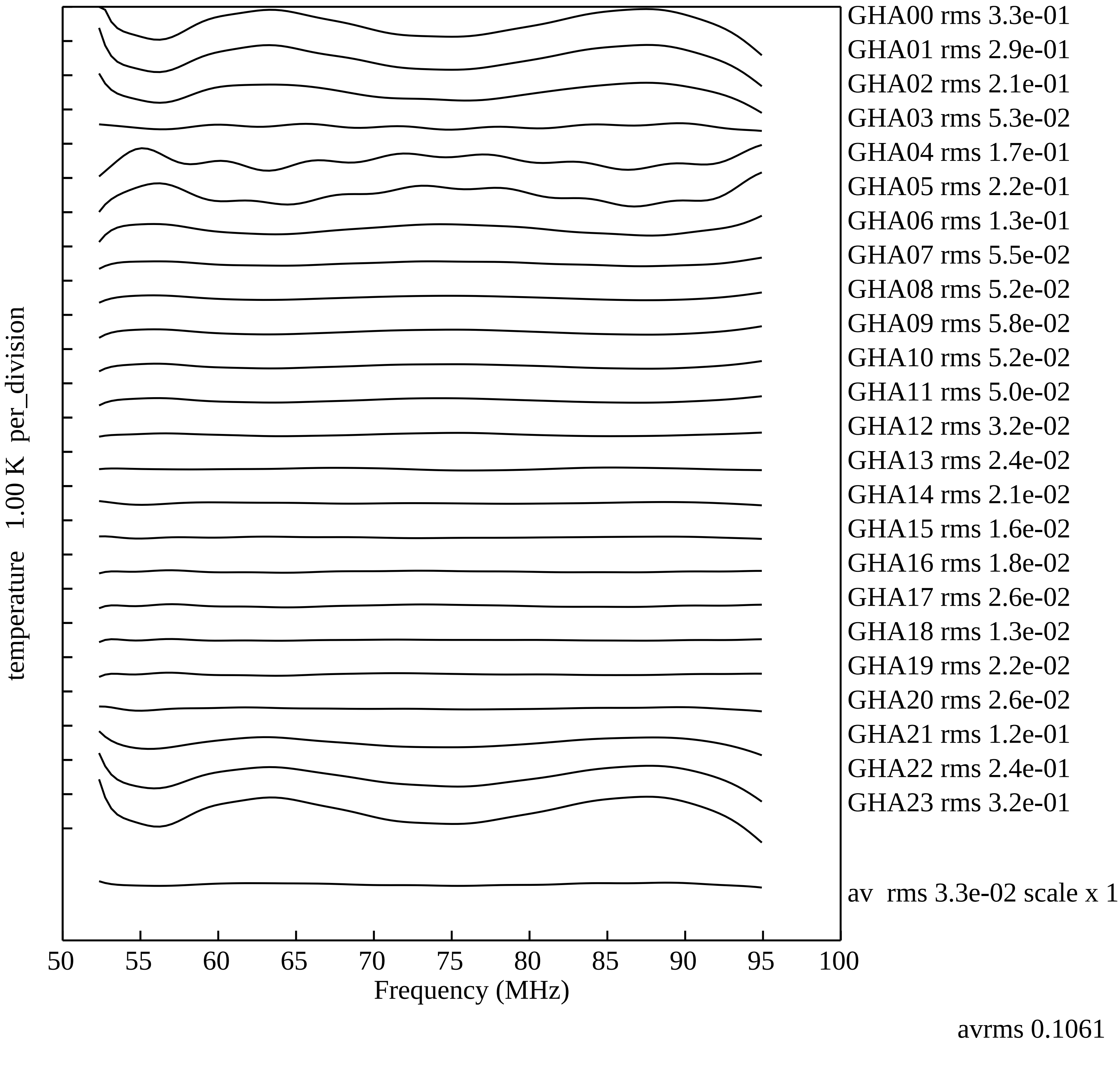

Figure 2. Residuals with 5-physical terms removed for EDGES-3 E-W 30m from hut.

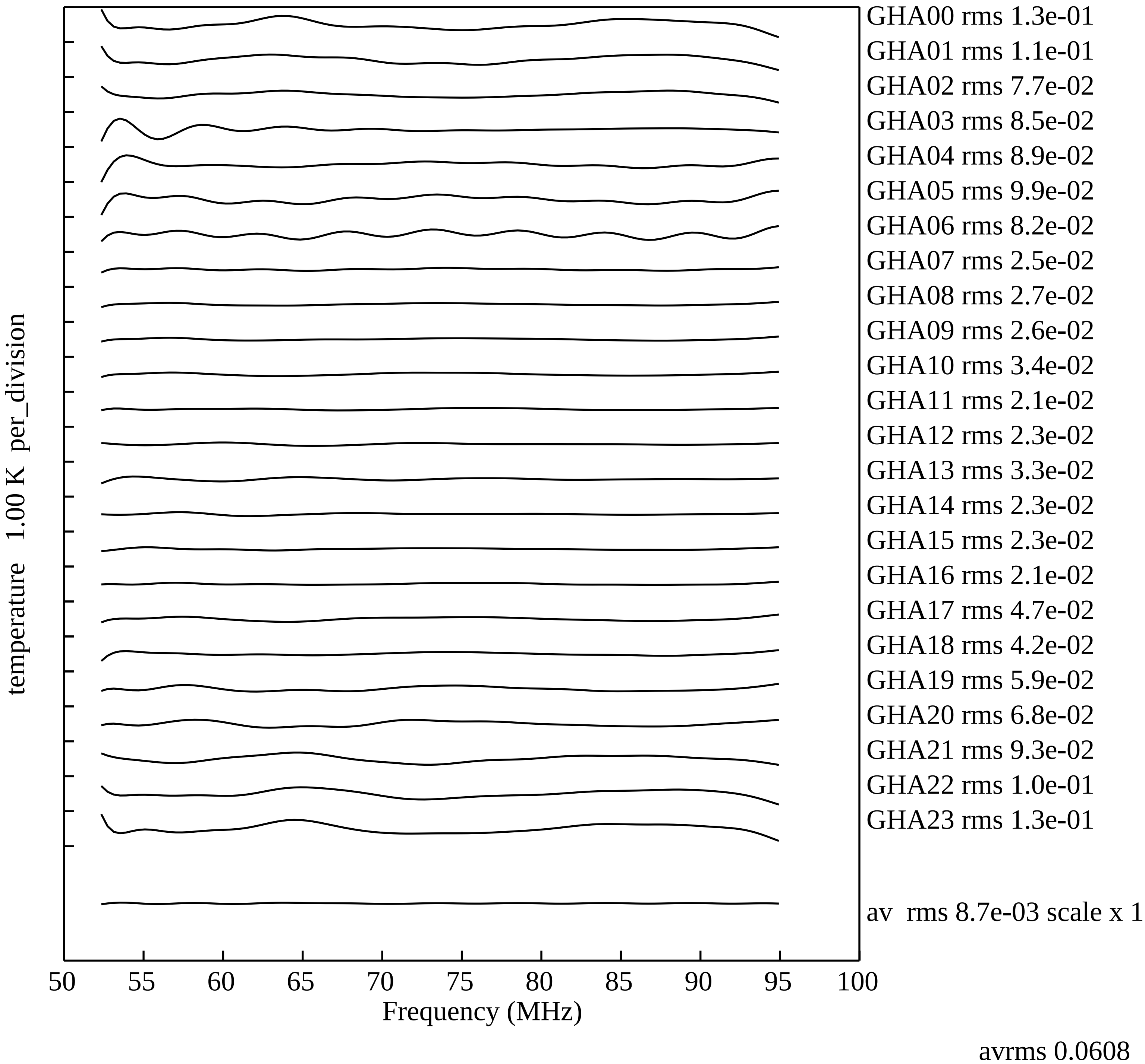

Figure 3. Residuals with 5-physical terms removed for EDGES-3 N-S 47m from hut beam filtered using 22 Fourier terms.

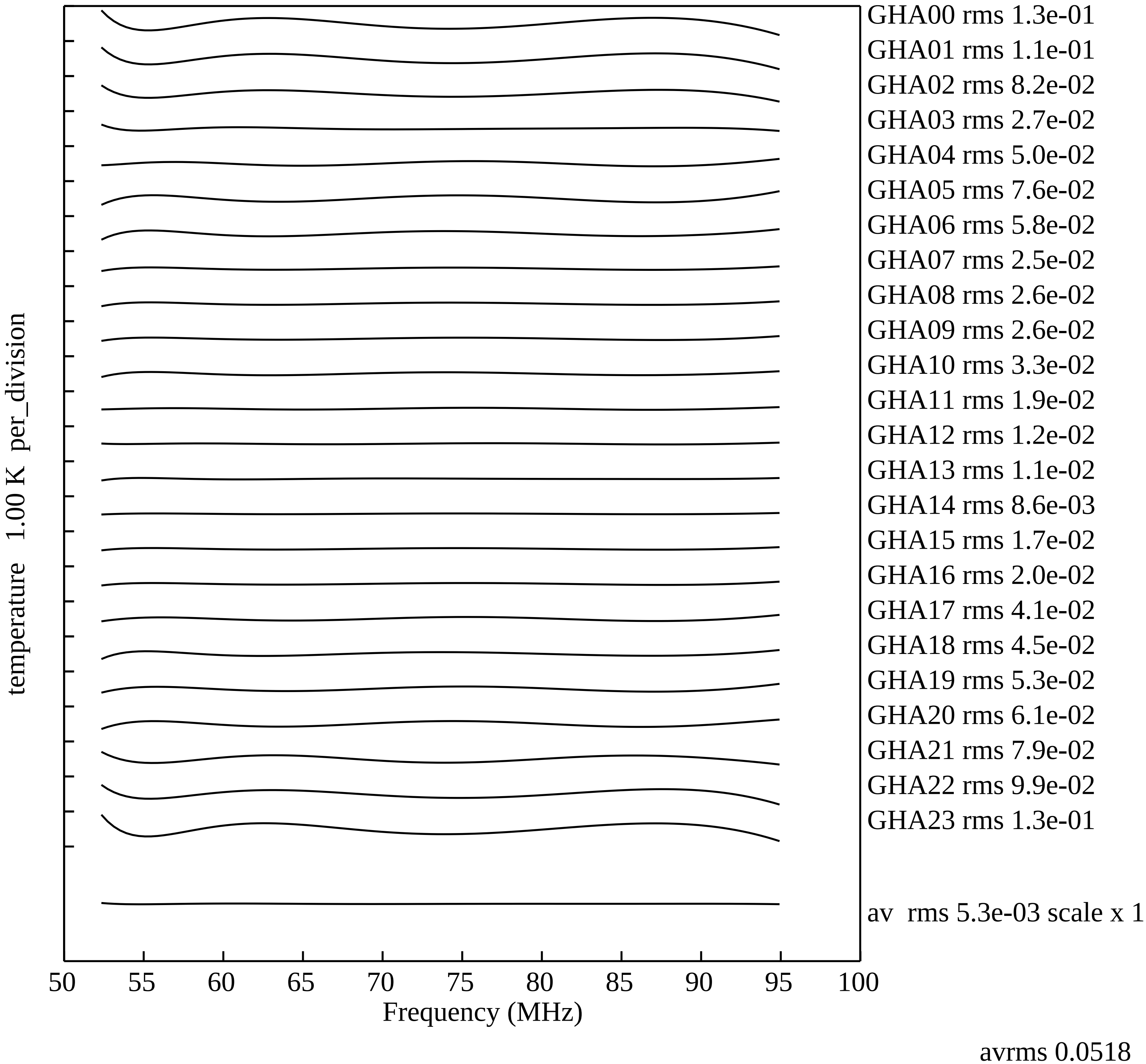

Figure 4. Residuals with 5-physical terms removed for EDGES-3 N-S 47m from hut filtered using 12 polynomial terms. These curves are basically just the beam chromaticity of the EDGES-3 on a PEC ground plane.