EDGES MEMO #313

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To: EDGES Group

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Subject: Optimization of EDGES-3 antenna

The EDGES-3 prototype antenna was initially tested at Haystack as described in memo #302. Following this initial test the pipe lengths were reduced from 20.5" to 13.5". The results of the S11 with the new pipe length are shown in Figure 1 of memo 306 but this test was made on a small wire grid ground plane. A better test was made during the test deployment in Oregon and is shown in Figure 10 of memo #310. Further improvements in the S11 should be possible based on a multi-dimensional grid search using FEKO to optimize the pipe length, the separation of the boxes and the height above the ground plane. The optimization was also made using an increase in the height of the boxes from 12 cm to 15.11 cm to accommodate thermal insulation inside the boxes when the air circulation proposed in memo #312 is needed.

Figure 1 shows the optimum S11 from FEKO using the following parameters for the antenna on an infinite PEC ground plane

Box length at center	73.4 cm
Box width	95.3 cm
Box height	15.11 cm
Box length reduction at sides	6.6 cm
Pipe diameter	2.54 cm
Pipe separation	2.54 cm
Pipe length	34 cm
Height of bottom of box above ground plane	88 cm
Gap between boxes	3.6 cm

Other tests and checks

1] Beam chromaticity on PEC ground plane: 74 mk average rms of 1 hour blocks over 24 hours GHA at latitude 27 degree south 5 terms removed 60-100 MHz.
2] Sensitivity to antenna tilt: 8 degrees doubles beam chromaticity while 2 degrees result in about 10% increase and a 1 degree tilt of the antenna or ground plane has a negligible effect on beam chromaticity.
3] It was checked that the S11 optimization has a negligible effect on the beam chromaticity.

4] The resistive loss of the antenna including the shorted transmission line formed by the pipes is estimated to be at the level of 0.01% using the skin effect loss calculated by FEKO. It also has been checked that this small loss is without resonant structure.

Comparison with EDGES-2 antenna

Figures 2 and 3 show the S11 for the midband and lowband respectively. The EDGES-3 antenna has a frequency range of acceptably low S11 that covers most of range of the lowband and midband. This is achieved via the combination of the thicker structure and the impedance of the shorted parallel pipe transmission line that is also used to carry DC power and fiber optics as well as air circulation if needed. Table 1 shows the beam chromatism for each antenna on a PEC ground plane and 30×30 m ground plane with 5-term LINLOG polynomial removed.

Antenna	PEC	30×30 m
Low	187	191
Mid	88	98
Box	74	100

Table 1 Average rms residuals with 5-term LINLOG 60 to 120 MHz removed.

Comparisons of the beam chromaticity and S11 for the planar elliptical dipole show that with optimization it is possible to get the beam chromaticity down to a level close to that of the rms values given in Table 1 for the EDGES antennas.

Comparison of the beam chromaticity using FEKO for a conical log spiral, similar to that of BIGHORNS shown by Sokolowski et al. at the RRI CMB spectral distortion workshop July 2016, shows that the rms residuals are limited to the 1 K level despite attempts to optimize the design. The problem appears to be while the beam is relatively constant with frequency there is fine structure in the beam and a significant horizon response in all the models I have tested with FEKO on a PEC ground plane. Another illustration of the complexity of the beam at the level of 1 part in 1000 is that the residuals to a 5-term look different for a rotation of the antenna in azimuth by only 5 degrees owing to the lack of smoothness in the antenna beam.

Comparison of the beam chromaticity for an inverted cone monopole antenna over a 2 m metal ground plane 10 cm above a lake with conductivity 2e-3 S/m had a much lower rms of 17 mK in comparison with EDGES antenna results in Table 1. This antenna is not electrically small and has a vertical height of 1.14 m and S11 below -12 dB from 60 to 130 MHz which better than the EDGES-3 antenna. This vertically polarized antenna has a very low chromaticity. While the beam chromaticity is small the antenna has 45% loss and this loss may have significant chromaticity. This needs further study because FEKO exhibits glitches see ASU memo #153. An upper limit of the loss without glitches can be obtained for soil without conductivity as discussed in memo 258. In this case FEKO can calculate the beam directivity over 4π Steradians and the loss obtained from the fraction below the horizon. Figure 4 and 5 show the loss and beam chromaticity of EDGES-3 using this method.

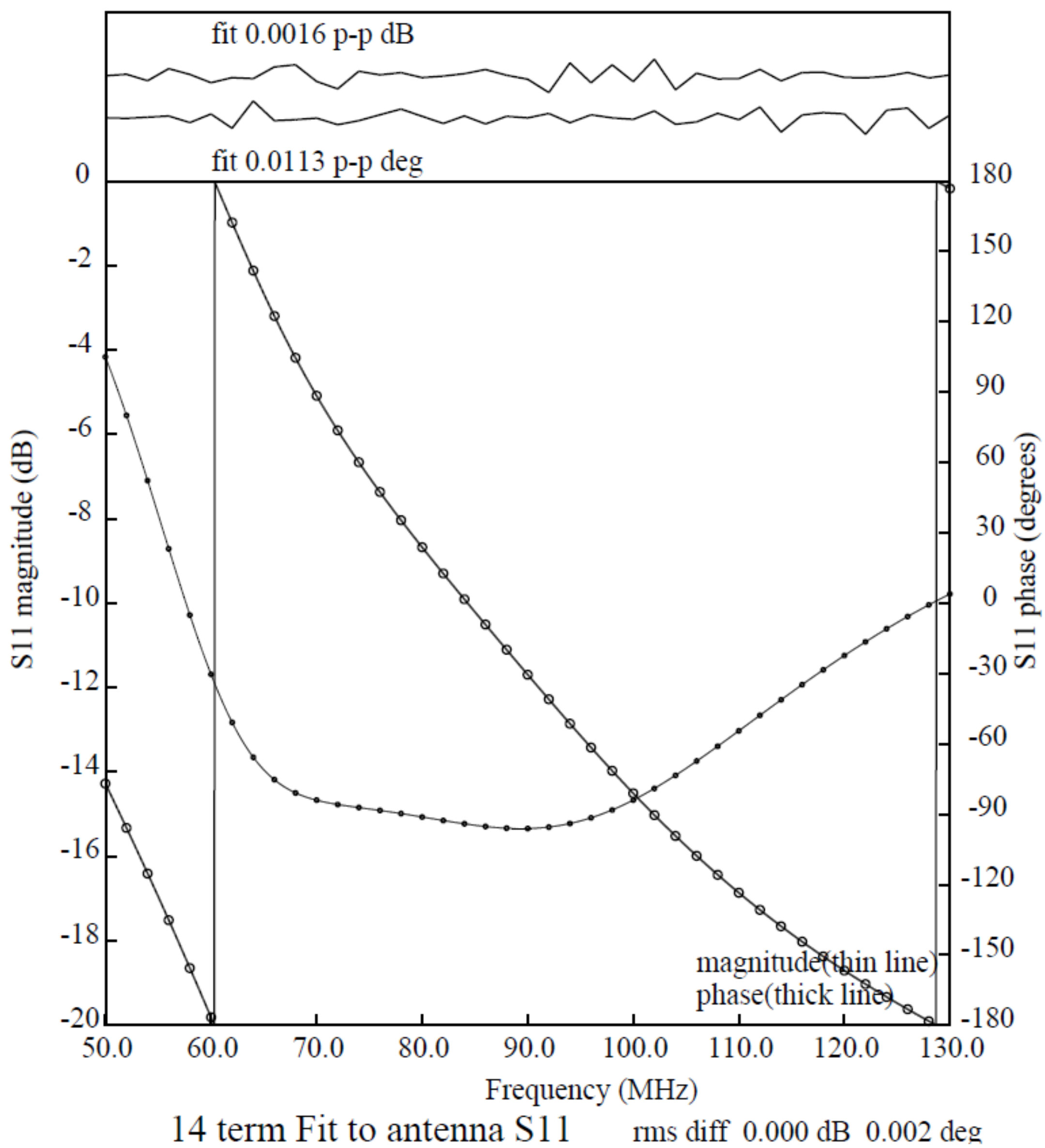

Figure 1. Optimized S11 of EDGES-3 from FEKO

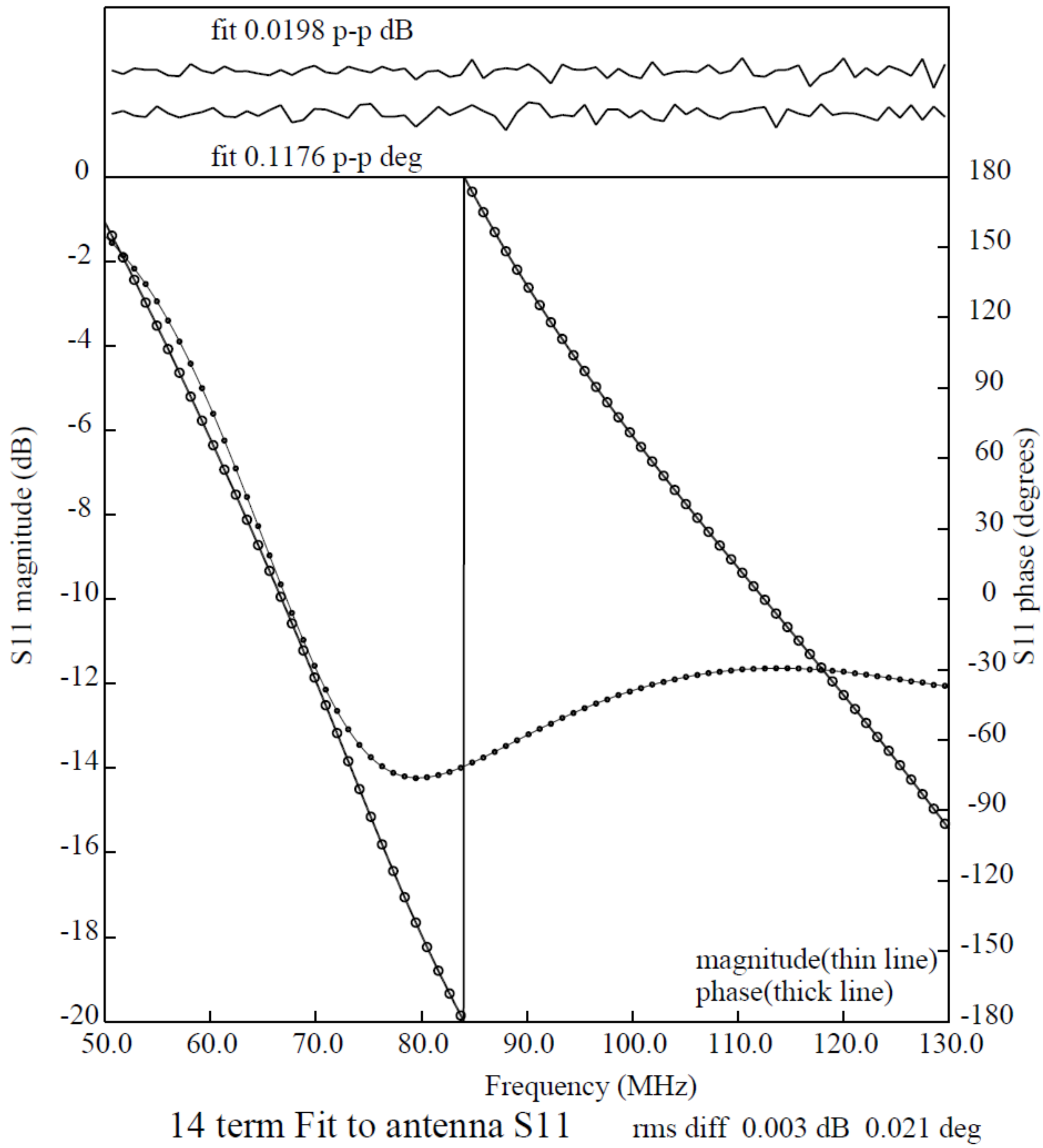

Figure 2. Midband S11 from the MRO

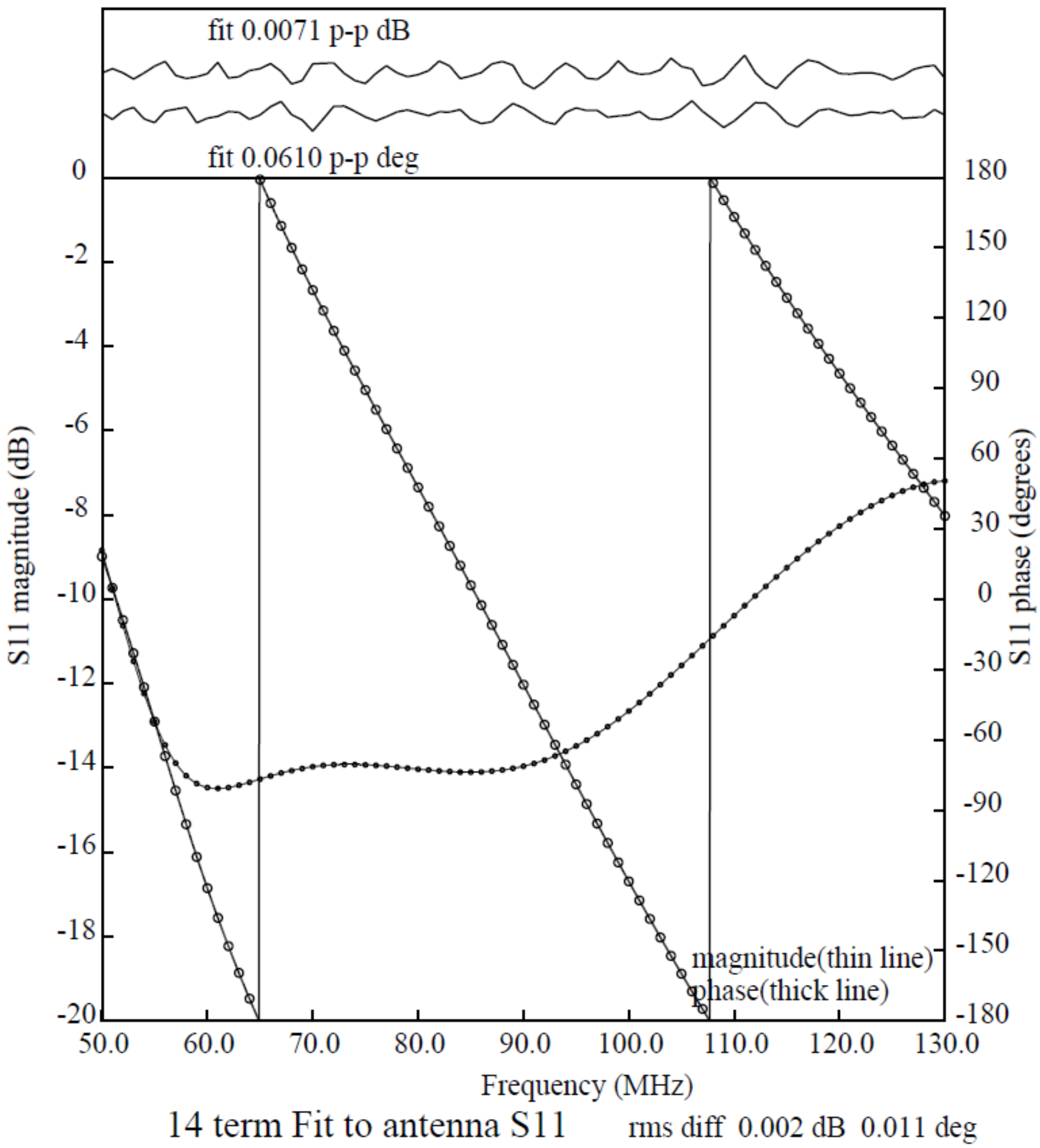

Figure 3. Lowband S11 from the MRO

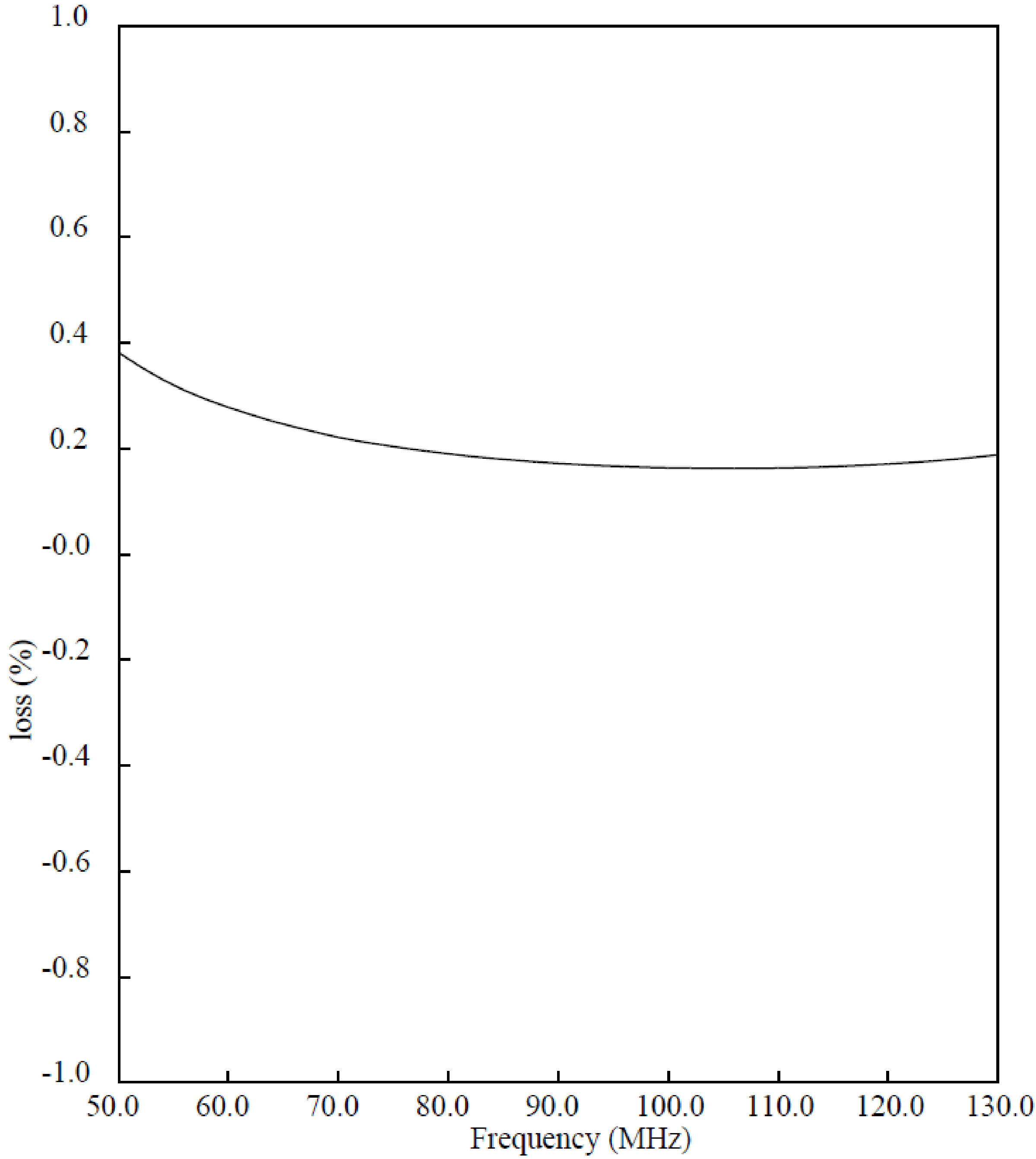

Figure 4. Loss estimate for EDGES-3 on the 30×30 m ground plane for non conductive soil with dielectric 3.5.

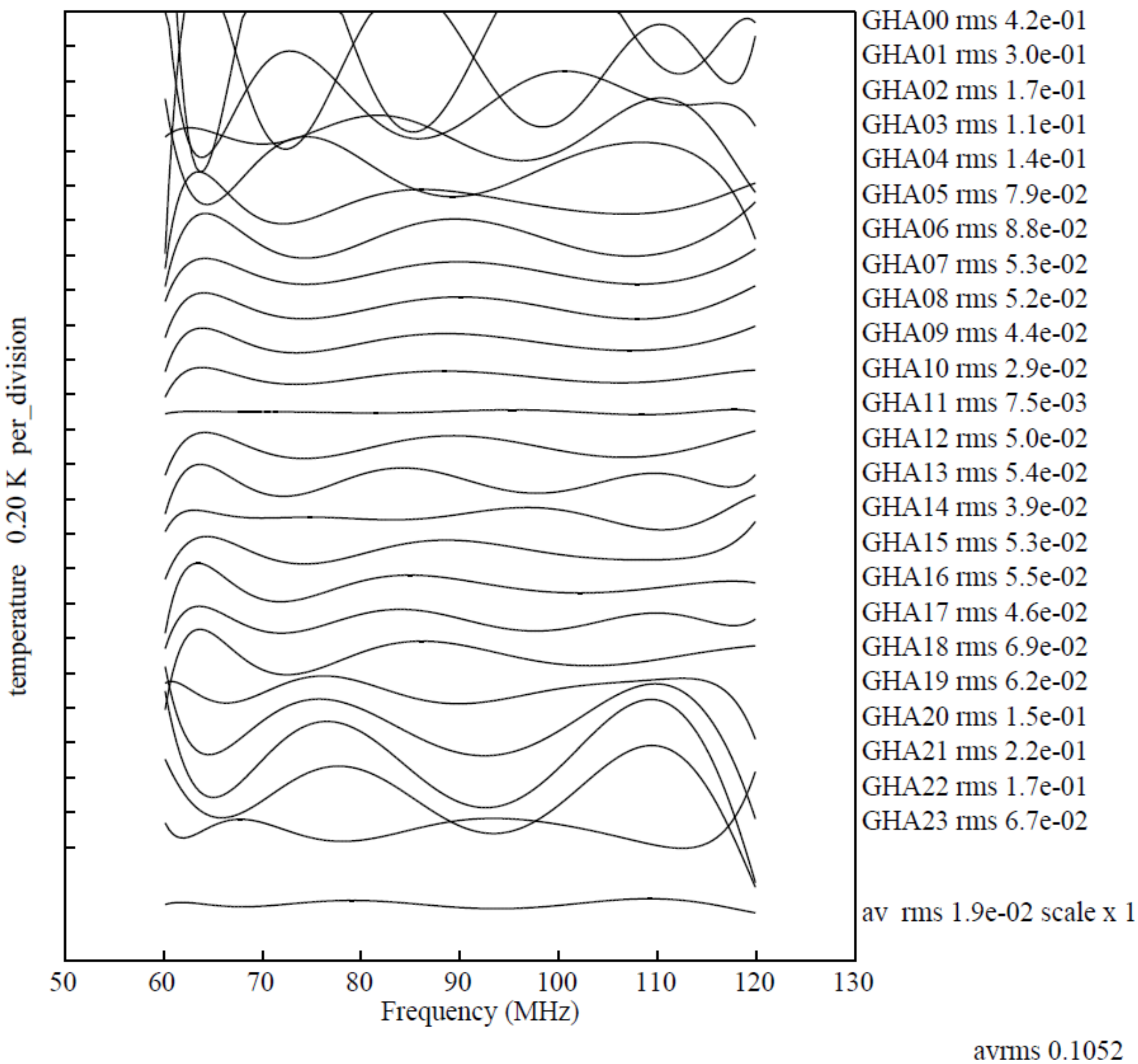

Figure 5. Beam chromaticity with 5-terms removed for EDGES-3 on 30×30 m ground plane at the MRO.