EDGES MEMO #370

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To: EDGES Group

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Subject: FEKO simulations of ground loss for small ground planes

The ground loss has been studied in memo 258 using a uniform dielectric without conductivity so that the beam can be calculated over 4π so that the fraction below the horizon can be used to estimate the loss. This method avoids the “glitches” in the simulations described in memos 239, 258, 263, 277, 280, 290 and 308. The 5-term residuals are computed using the method described in memo 316 using a fit to the model spectrum from 55 to 95 MHz

$$T_{loss} = 300(f/150)^{-2.55}(1 - loss) + 300(loss)$$

antenna	ground plane size	ground loss at 75 MHz	residual rms K
Lowband diel 3.5	none	40%	0.021
“	0.2x0.2m	40%	0.020
“	0.5x0.5	40%	0.019
“	0.8x0.8m	38%	0.78
“	1x1m	30%	1.84
“	1.5x1.5m	23%	1.44
“	2x2m	18.5%	0.272
“	4x4m	5.9%	0.429
“	8x8m	1.5%	0.138
“	10x10m	1.0%	0.104
midband	8x8m	1.3%	0.082
Lowband diel 6.0	8x8m	1.29%	0.111
Lowband 3.5 2e-3 GF	2x2m	18.6%	0.253
“	4x4m	6.1%	0.095
“	8x8m	1.8%	0.039
Lowband diel 3.5	Low3high 5x5 plus	1.7%	0.232
Lowband 3.5 2e-3 GF	Low3high 5x5 plus	0.9%	0.069
Lowband 80 5 GF	1x1m over seawater	2.5%	0.03
Lowband 3.5 2e-4 GF	4x4m	6.1%	0.344

Table 1. ground loss vs size for uniform soil below ground plane

Figure 1 shows plots of the residuals for 5-terms removed using the method of memo 258 for which the soil has no conductivity and the loss if determined from the fraction of the beam power below the horizon. Figure 2 shows plots of the residuals for 5-terms removed using the for uniform soil with conductivity of 2e-3 S/m using the Green's Function (GF) method in FEKO. In this case there is a small "glitch" at about 78 MHz. It is noted that if the soil conductivity is lowered to 2e-4 as in the last case in Table 1 the loss is in fair agreement with the method of memo 258. This provides some confidence that the GF method provides a reasonably accurate estimate if the glitch is ignored. The results with zero conductivity show that there is a "resonance" for a ground plane size of about 1x1m and Figure 3 shows that this peaks at 1.1x1.1m which corresponds to a ground plane of about half a wavelength at 95 MHz. This peak shifts to 1.0x1.0m with dielectric of 4.5 in Figure 4.

The important aspect of these results are that while the loss is smooth with very small residuals for an antenna on uniform soil without a ground plane the addition of a ground plane of about 0.8x0.8m the loss residuals are large and only decrease to a reasonable level for a ground plane larger than about 8x8m for a low soil conductivity of about 2e-4 whereas a ground plane of 6x6m should result in an acceptable loss if the soil has conductivity of 2e-3 or larger.

In summary if these results are confirmed by more checks on FEKO and the use of another EM software the deployment of a 21-cm system either requires a ground plane larger than 8x8m or the antenna on uniform soil without a ground plane to avoid the effects of significant frequency structure in the ground loss. The results of low3 in memo 285 on the 5.35x5.35m with 4 2x2.5m extensions forming a "plus" shape ground plane, which is large enough to avoid significant frequency structure in the loss, are consistent with this conclusion. The results of EDGES-3 without a ground plane in figure 12 of memo 310 with a rms of about 1 K may be an indication of a non-uniform soil at the site in Oregon. In order for a 21-m system to ensure low residuals without a large ground plane it is essential that a ground penetrating radar (GPR) measurements be made at any potential sites. Another possibility for a small ground or no ground plane in the case of non-uniform soil considered in memo 263 is to place the antenna on an absorber but no specific details have been modeled.

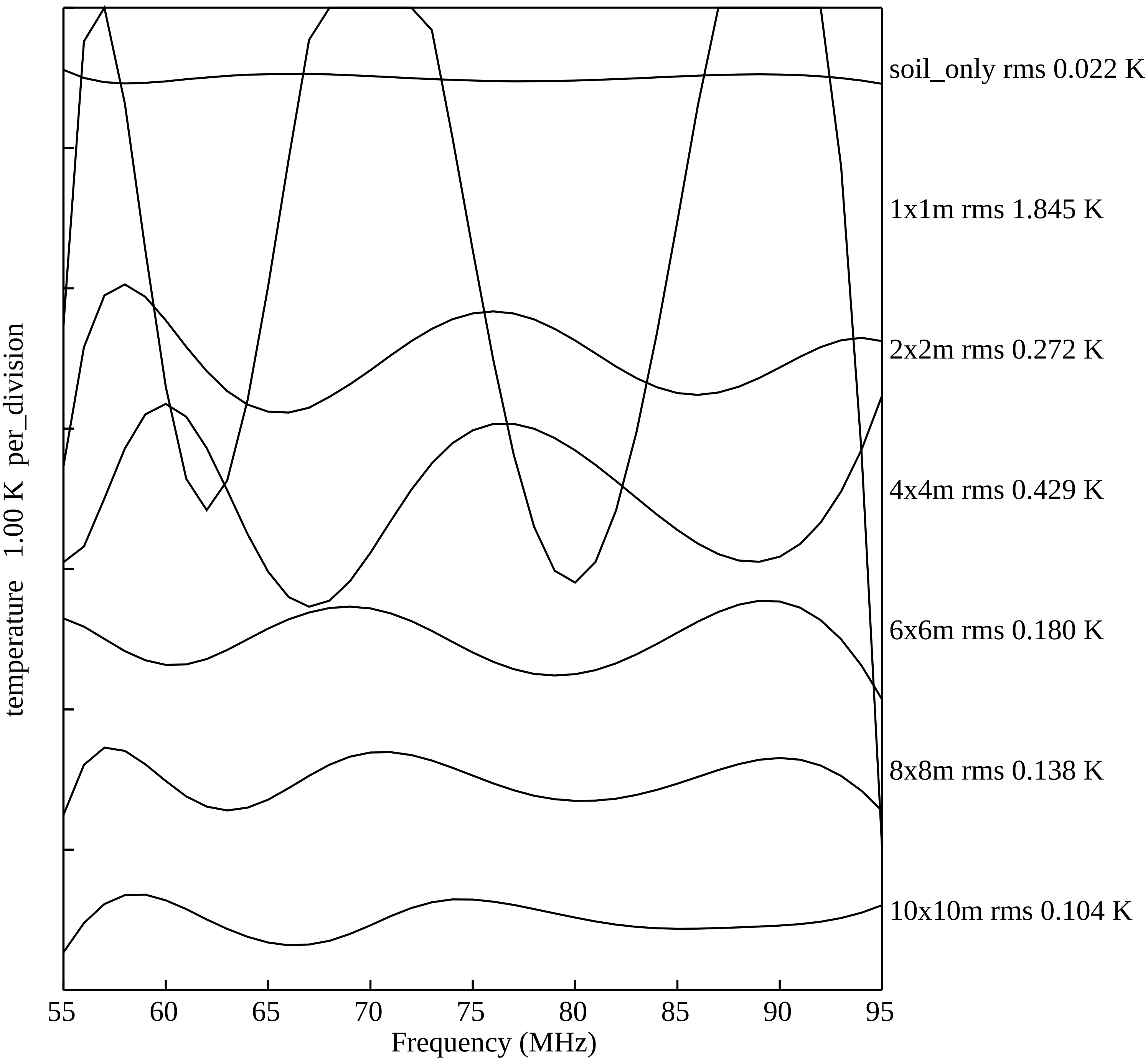

Figure 1. Residuals to 5-term fit to spectrum with loss calculated from beam fraction below the horizon for uniform soil with dielectric 3.5 and zero conductivity.

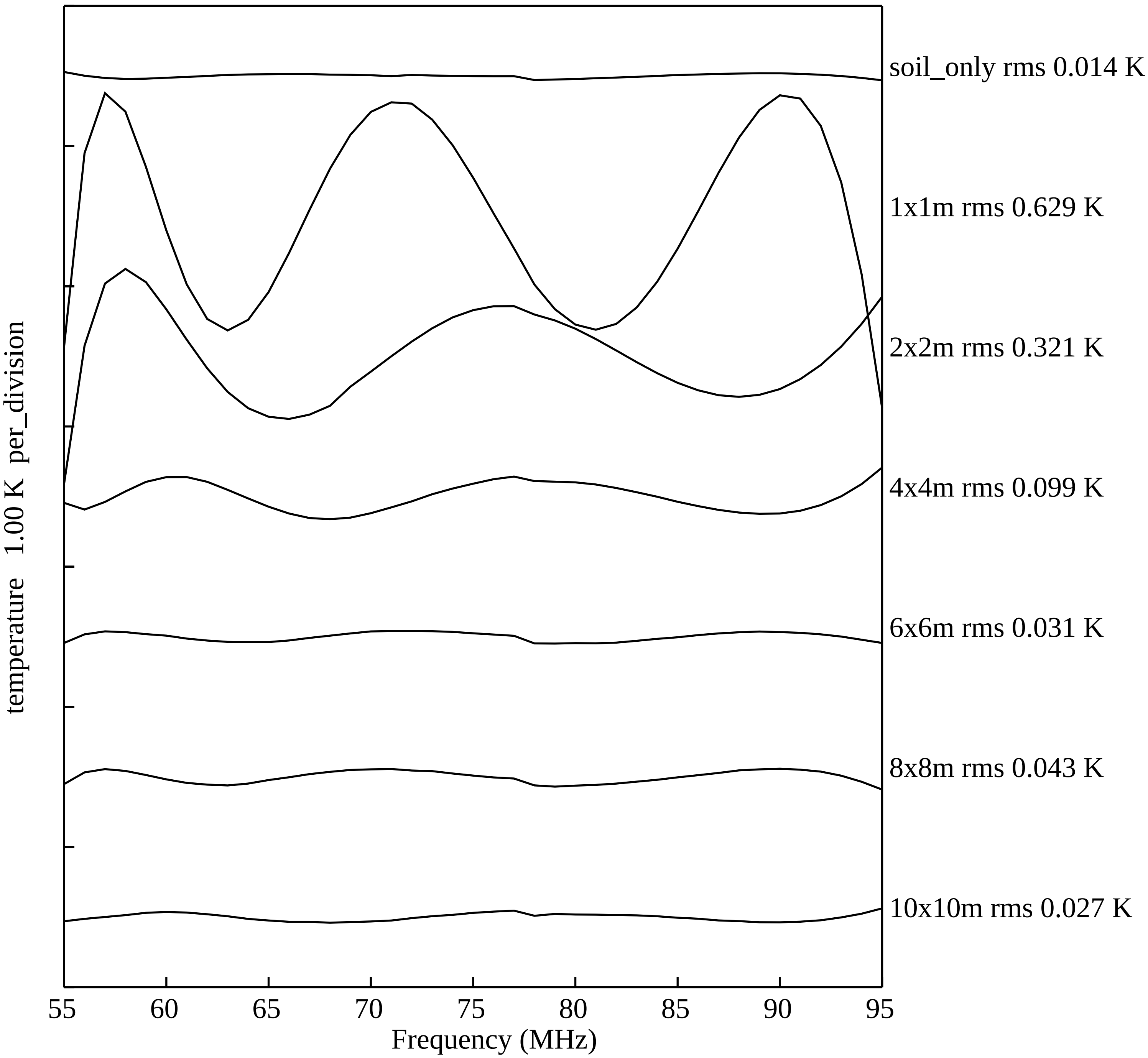

Figure 2. Residuals with loss calculated from beam fraction difference from unity when integrated over the gain above horizon using the GF method with soil dielectric 3.5 and conductivity 2e-3.

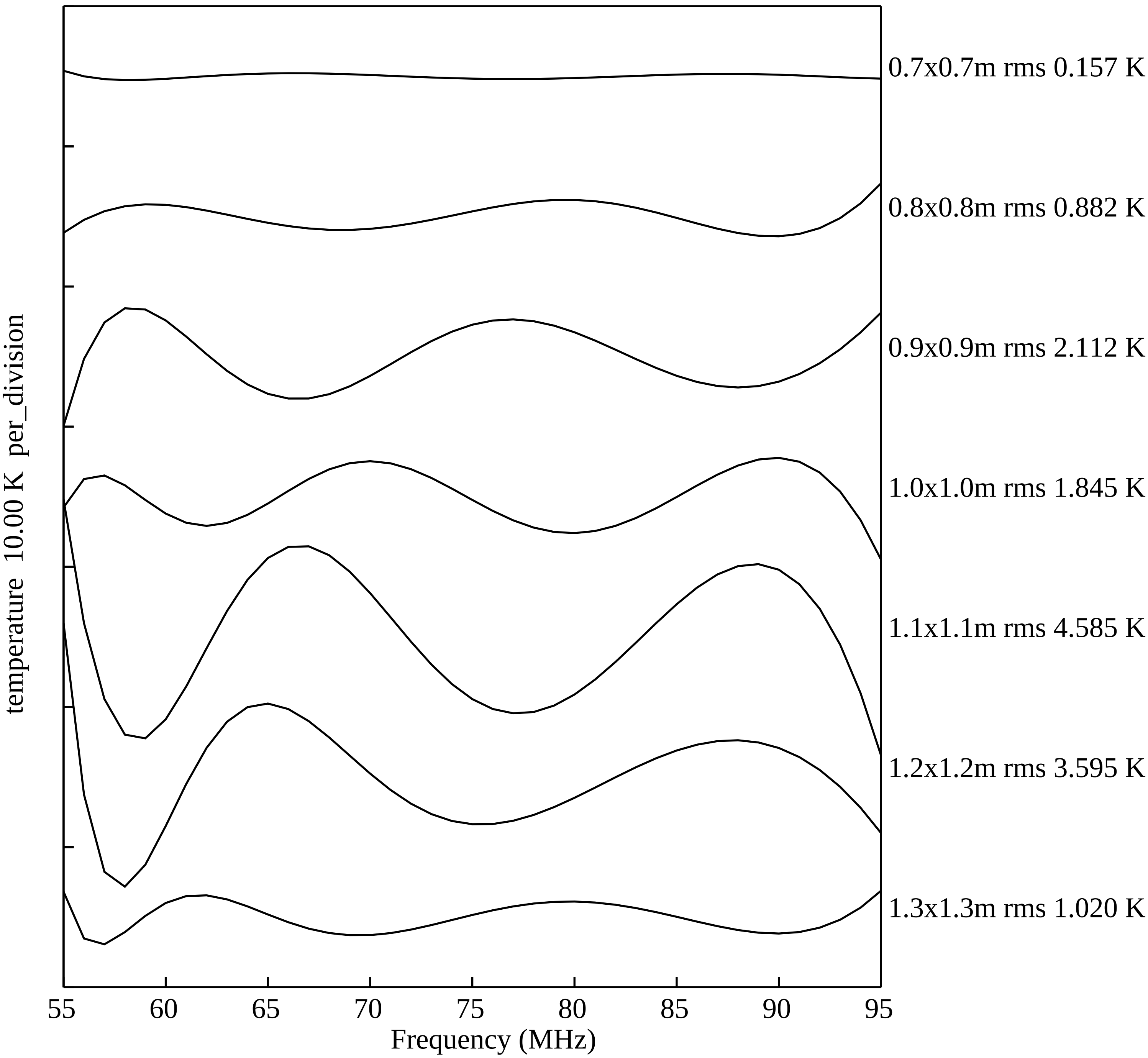

Figure 3. Residuals for loss as in figure 1 for square ground planes from 0.7x0.7m to 1.3x1.3m.

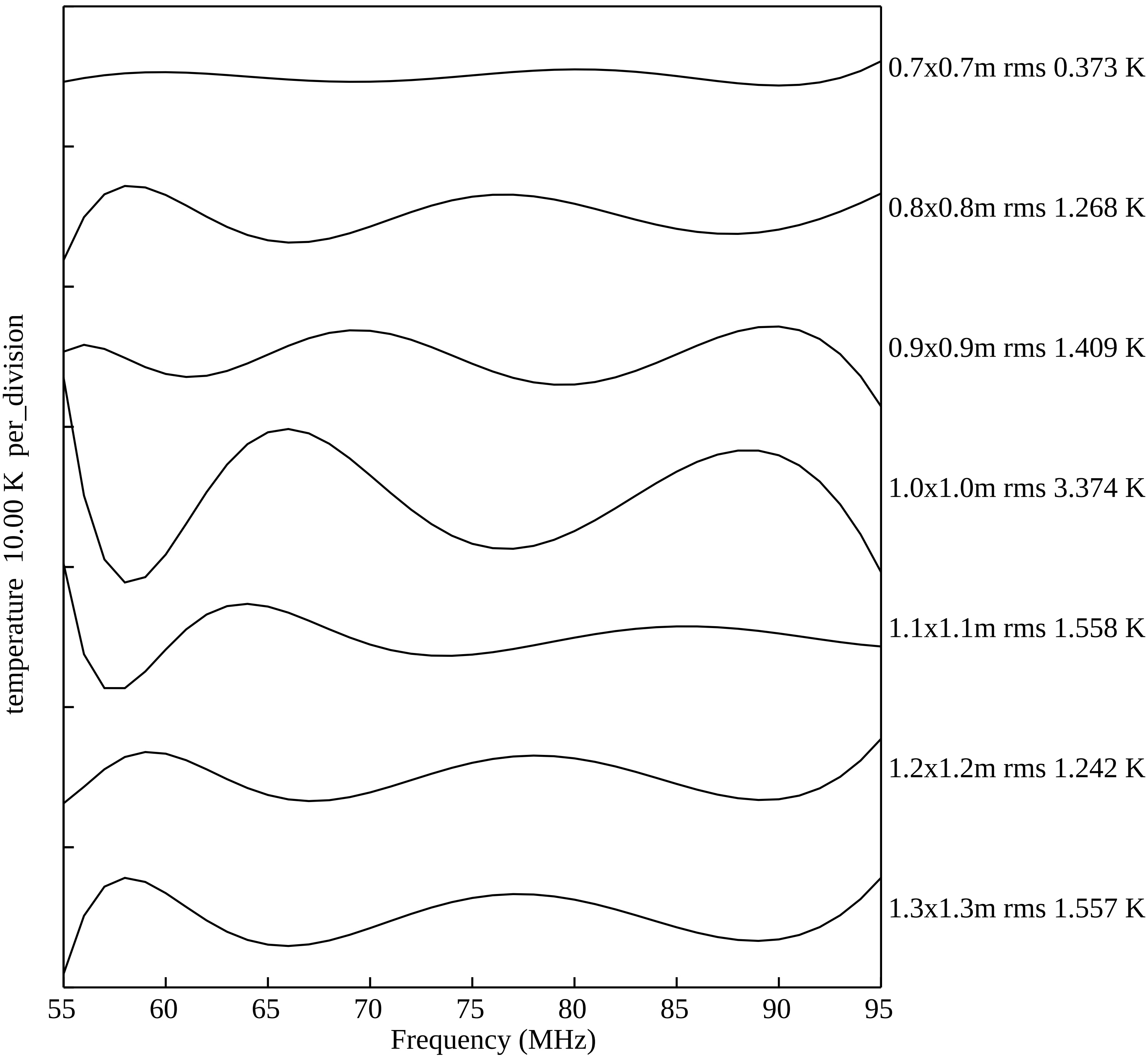

Figure 4. Residuals for loss as in figure 3 with a change in dielectric from 3.5 to 4.5.