EDGES MEMO #317

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To: EDGES Group

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Subject: Comparison of square circular and perforated ground planes

The current plan for the EDGES-3 installation at the MRO is to extend the 30×30 m perforated ground plane 100 m west of the electronics hut to 48×48 m in order to make further reductions in beam chromaticity and loss.

EDGES ground sizes and shapes has been studied in memos 185, 186, 189 leading to the proposed perforated ground plane in memo #204. The studies show that the loss is approximately inversely proportional to the area and the fine frequency structure in the beam is approximately proportion to the size of the ground and also dependent on the shape. The reflections from the edges of the ground plane are also dependent on the ground dielectric conductivity.

The large ground planes are difficult to simulate because they require a large computation time and high accuracy. Table 1 shows the results of FEKO simulations of large ground planes.

Ground plane	Size m	2e-3	2e-2	Area m^2
Square	30×30	131	92	900
Circular	30	177	92	707
Perforated	30×30	122	92	600
Square	48×48	92	84	2304
Circular	48	95	79	1810
Perforated	48×48	84	77	1536
Hexagonal	30	183		636
Hexagonal	48	88		1629
Perforated A	48.8×48.8	87	86	1440
Perforated B	48.8×48.8	96		1793
PEC	Infinite	74	74	

Table 1. Chromaticity of large ground planes.

The sizes are the largest dimension so the area of the first entry, which is a square is 900 m^2 while the 30 m diameter circular has area of 706.86 m^2. The third column is the average rms residual in mK of 1 hour blocks over 24 hours with 5 linlog polynomial terms removed from 60 to 120 MHz. The soil has dielectric 3.5 ad conductivity 2e-3 S/m. The fourth column is for soil dielectric 3.5 and higher conductivity of 2e-2 S/m. Based on this figure of merit the perforated ground plane is clearly the best with the lowest chromaticity and the smallest area.

The inner section of the 30×30 m and 48×48 m perforated ground plane has inner square sections of 20×20 and 32×32 respectively each with 4 triangles on each side.

Perforated case “A” has 3 9.6×10m triangles per side and these triangles are made from 2 2.4×5m mesh panels and 2 2.4×5m mesh panels cut in half along the diagonal. The inner section to which the triangles are welded is made of 72 2.4×5m mesh panels for a total of 120 mesh panels for the ground plane.

Perforated “B” listed for comparison has 6 4.8×5m triangles per side and has a higher chromaticity and area of panels.

In order to optimize the loss of the ground planes which have 5×5 cm mesh for inner square sections and 10×10 cm mesh for the outer triangular mesh. But since the mesh has significant loss the ground plane under the antenna needs to be solid. From the simulations in memo #316 an estimate of the overall loss for a large ground plane as follows:

1] Loss for solid 2×2 ground plane due to soil outside the 2×2m is 18% at 100 MHz
2] The loss for 20×20 m square of 10×10 cm is 0.45%.

From 1) and 2) the added loss due to 20×20 m section of 5×5 cm mesh is $0.18 \times 0.45/8 \cong 0.1\%$ where the factor 8 is the expected reduction factor in going from 10×10 cm to 5×5 cm mesh.

While direct simulation of the mesh with FEKO is possible the computation time is many days.

A test of the effect of the lack of close contact of the panels to the soil was made and Table 2 shows the results of FEKO simulations of the chromaticity of a 4×4m ground plane made of metal or mesh.

	Soil			
Material	Dielectric	Conductivity	S/m rms mK	Height above soil cm
Solid	3.5	2e-3	447	0
Solid	3.5	2e-2	121	0
Solid	3.5	2e-2	128	2
10×10 cm mesh	3.5	2e-2	162	0
5×5 cm mesh	3.5	2e-2	135	0

Table 2 effect of contact with soil.

For a solid panel there is a small increase in beam chromaticity which is the result of a stronger reflection from the EDGEES of the panel as it is raised above the soil. For a mesh panel there is a small increase in beam chromaticity for a 5×5 cm mesh and a more significant increase for a 10×10 cm mesh. The simulations were done with a small 4×4m ground plane to keep the computation times to under 2 days for the 5×5 cm mesh.

Ground plane	Size	linlog	linpoly	Physical
Perforated	30×30	122	102	134
Perforated A	48.8×48.8	87	60	100
PEC	Infinite	74	42	88

Table 3 Effect of different fitting functions for ground planes oN soil with conductivity 2e-3 S/m.

Table 3 gives the values of the average of the rms residuals for 5 term fits to each of the 24 one hour blocks centered at 0 to 23 hours GHA. The different functions linlog and linpoly are defined in memo 308 and the 5-term physical function is defined in the Nature paper. The different functions give different results but the ratios of improvement for the larger 48.8×48.8 perforated planned for EDGES-3 compared with the existing 30×30 m perforated ground plane are similar.

This study shows that at about 50×50 m the contribution of the ground plane to the beam chromaticity is small for a frequency range down to 60 MHz for a horizontally polarized dipole. A vertically polarized antenna is more sensitive to reflections from the edges of the ground and consequently requires a much larger ground plane. A size larger than 50×50 m takes a long to simulate with FEKO but based on the ripple of about 1000 mK rms it would take a ten fold size increase to 500×500 m ground plane to achieve a chromaticity at 10 mK rms level using a vertically polarized antenna.

The high frequency end of EDGES-3 can be extended from the point where the maximum gain is no longer at the zenith which is at about 120 MHz to about 180 MHz by lowering the antenna from 88 to 58 cm. In this case the frequency range can be extended from 60-120 MHz to 60-180 MHz with low beam chromaticity and S11 below – 6 dB over the full range.

Preliminary tests show that an improvement can be made in bandwidth, chromaticity and S11 using a tapered ground plane under the antenna as suggested by Suh, Virginia Tech. Ph.D. Thesis 2002. Further study is needed to optimize a design for a potential improvement for EDGES-3.