Finite Ground Screen Effects Upon Below Horizon Response

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9/5/2014

CST simulations of the full EDGES antenna model using a finite ground plane of various sizes were run on the model of the EDGES antenna deployed in Nov. 2013. This model does not contain any of the current modifications. It is a full model that includes the balun, tall shield, previous top cap design, and a finite solid ground plane with simulation space under the ground plane (see Figs. 1a & 1b).

The ground loss (beam power fraction below the horizon) is computed by

$$Ground\ Loss = \frac{\int_0^{2\pi} d\phi \int_\pi^{\pi/2} \mathrm{Beam} \cdot \sin\theta \, d\theta}{\int_0^{2\pi} d\phi \int_\pi^{0} \mathrm{Beam} \cdot \sin\theta \, d\theta}$$

The additional power picked up from the ground is computed by multiplying the ground loss by 300K.

The ground loss is plotted vs frequency in Fig. 2 for a variety of ground plane sizes ranging from 6' x 6' to 48' x 48'. Six feet corresponds to the wavelength at 164 MHz. The sizes plotted begin at 1λ x 1λ and end at 8λ x 8λ. The values obtained via CST are similar to the values in Alan's memo #88 if one compares the solid ground plane to the finest mesh ground planes of memo #88. Note that memo #88 uses 2m wavelengths (150 MHz).

Comparing the values in memo #88 to the values in this report for the 1λ and 2λ sizes (and remembering that the lambdas differ by ~10%), memo #88 reports losses of 5.5% and 1.5% respectively vs CST values of 5.5% and 1.6% respectively. The CST values quoted are the minimum values along the frequency range. Also, the CST values tend to increase above these levels at the low and high ends of the frequency range (see Fig. 2).

Memo #88 has an entry for 4λ x 4λ (1.5%), but the grid mesh is too coarse and one must extrapolate to a finer mesh result. This extrapolation puts the loss below 0.75%, which would then agree with the CST result. The rule of thumb of 4x reduction in ground loss for a 2x increase in the ground plane generally holds, but breaks down for the 5λ x 5λ size as these results are very similar to the 4λ x 4λ ground plane results. However, the trend towards less structure as seen in the 4λ size does continue with the 5λ size as can be seen in Table 1.

A third order (4 term) polynomial fit of $\log(\nu/\nu_0)^n$ was made and a plot of the residuals are shown in figure 3. Table 1 lists the RMS error for the fits using three different fit variations. Figure 4 shows the S11 curves for the various cases. The 3λ x 3λ ground plane took 10 hrs. to simulate, the 4λ x 4λ took 12 hrs., and the 5λ x 5λ took 27 hrs.

The next phase of simulation will consider a ground plane made by extending the existing solid ground plane with sections of 2m x 5m mesh which are readily available at CSIRO. The ground plane will be extended by 2m on each side in the first case, leaving the corners bare (Fig. 5). The second case will extend the screen by 4m on each side and fill in the corners as depicted in Fig. 6.

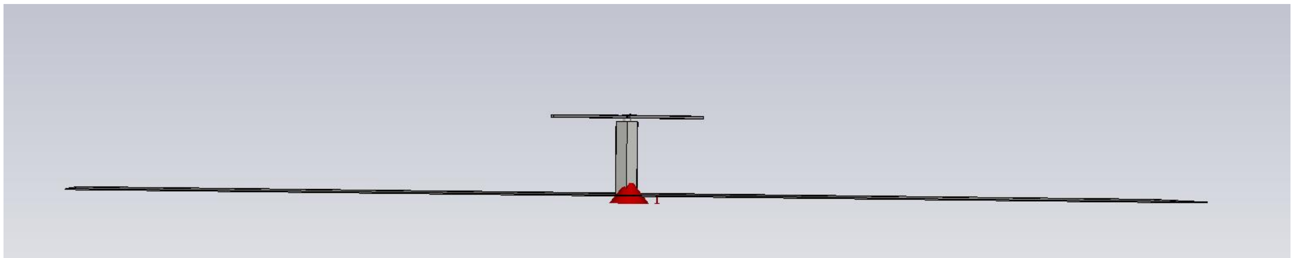

Figure 1a. Antenna model for CST using the parameters and design features of the antenna deployed as of November 2013.

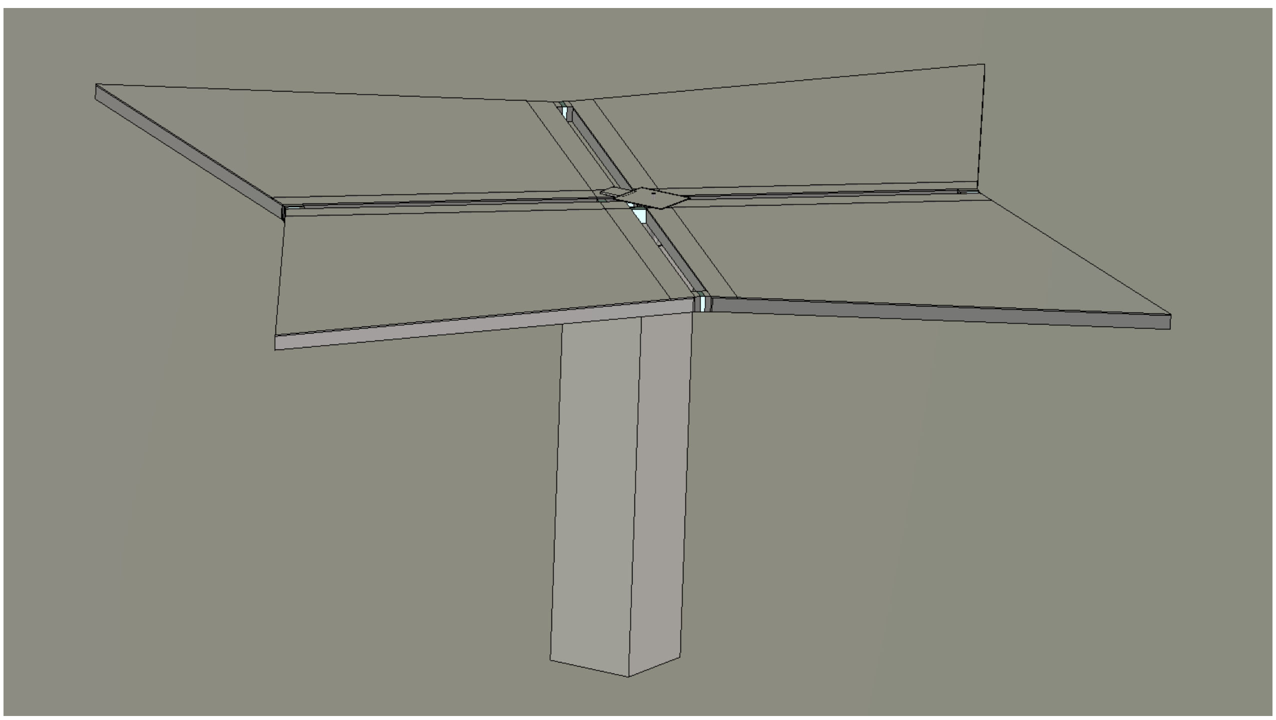

Figure 1b. Closer view showing the shield and top cap design.

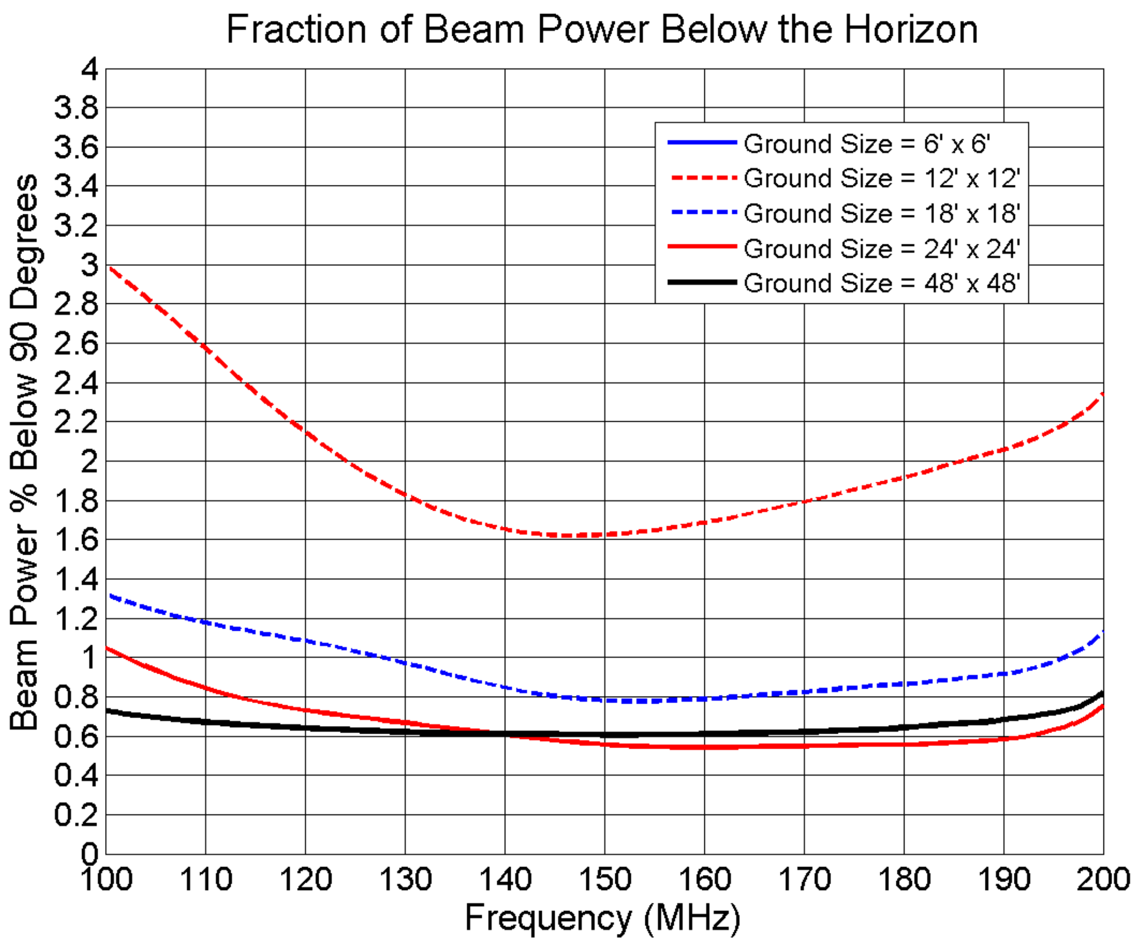

Figure 2. Percentage of the beam below the horizon (theta > 90°) for various sizes of solid ground planes. The 6' x 6' ground plane (1λ x 1λ) and the 12' x 12' ground plane (2λ x 2λ) in general agree with Alan Rogers' memo #88 in that the minimum values are within 10% of the numbers quoted, but the average value and maximum values are higher. The loss at 48'x48' is similar to that at 24'x24', but with a lower frequency dependence.

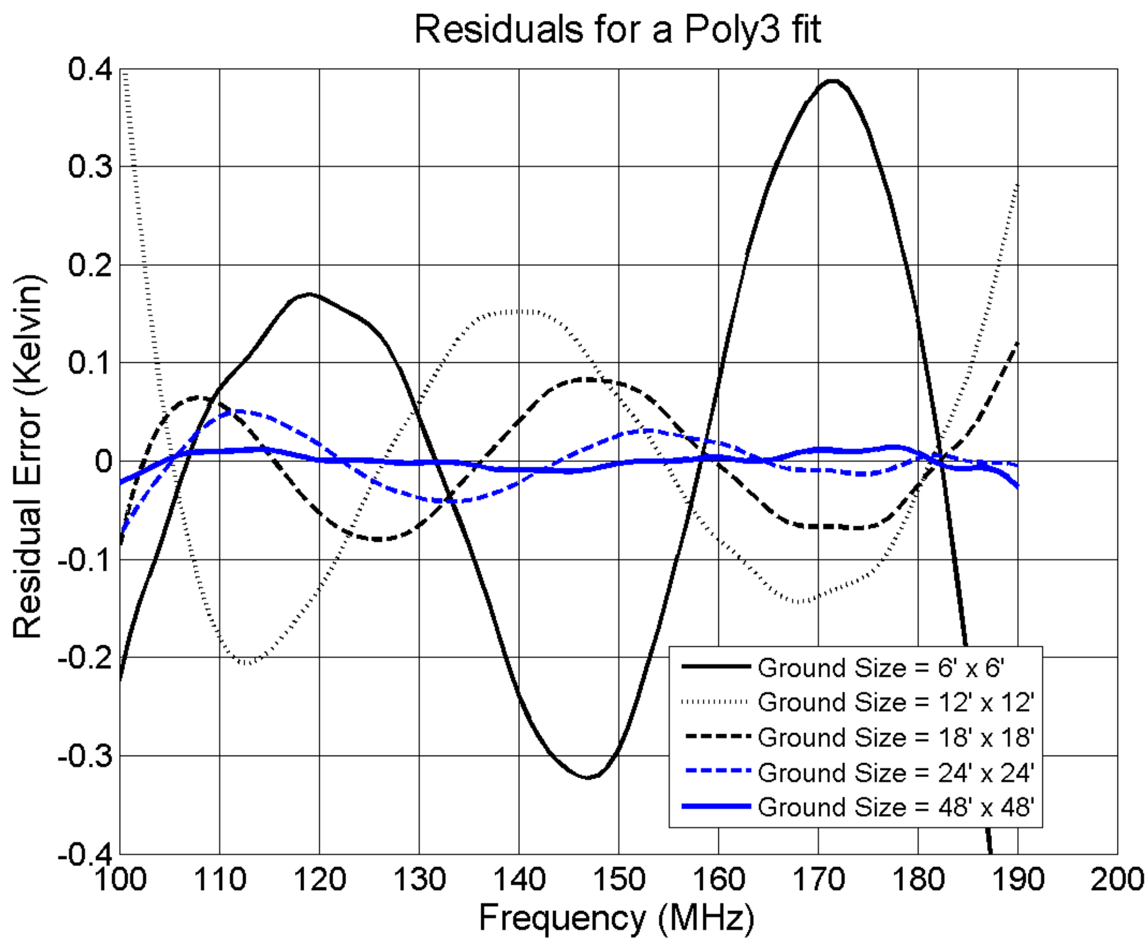

Figure 3. Residuals for a 3rd order polynomial fit to log(frequency). The RMS errors are shown in Table 1 below.

Ground Size	RMS Error (mK) 100-200 MHz Poly3	RMS Error (mK) 100-190 MHz Poly3	RMS Error (mK) 100-190 MHz Poly4
4’x 4’	393	425	472
6’ x 6’	261	231	119
8’ x 8’	138	106	102
10’ x 10’	138	131	98
12’ x 12’	150	137	31
14’ x 14’	114	61	63
16’ x 16’	105	101	37
18’ x 18’	59	56	57
24’ x 24’	49	26	20
48’ x 48’	31	8	3

Table 1. RMS error values of the fit assuming the ground is at 300K. More sizes are shown in the table than the graphs to reduce the clutter in the graphs.

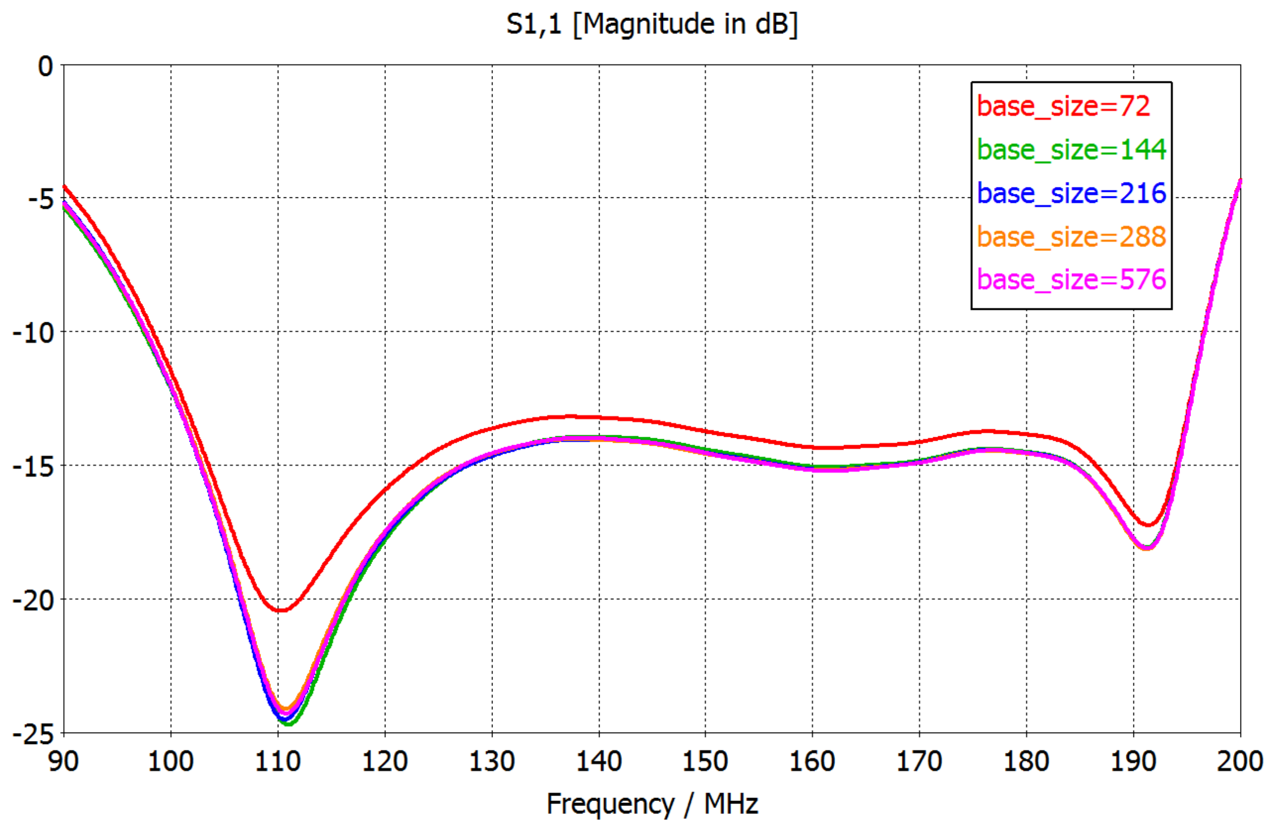

Figure 4. S11 curves for various finite solid ground plane sizes (measured in inches). The curves are in multiples of 6 ft.

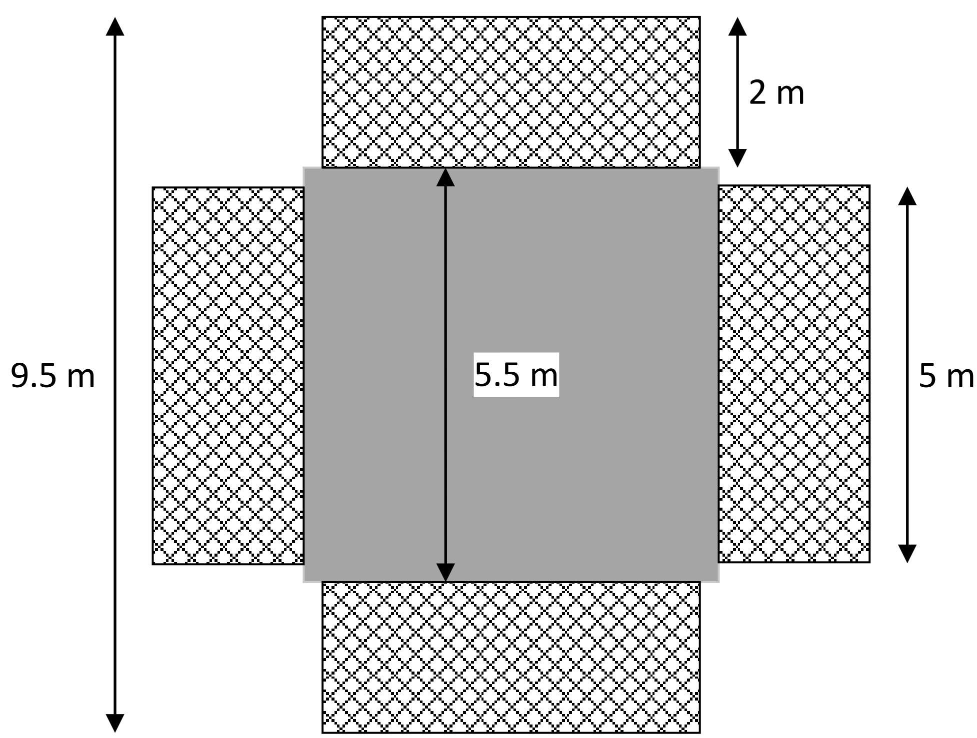

Figure 5. Existing solid ground screen extended using 1 sheet of 2m x 5m mesh per side and leaving the corners bare.

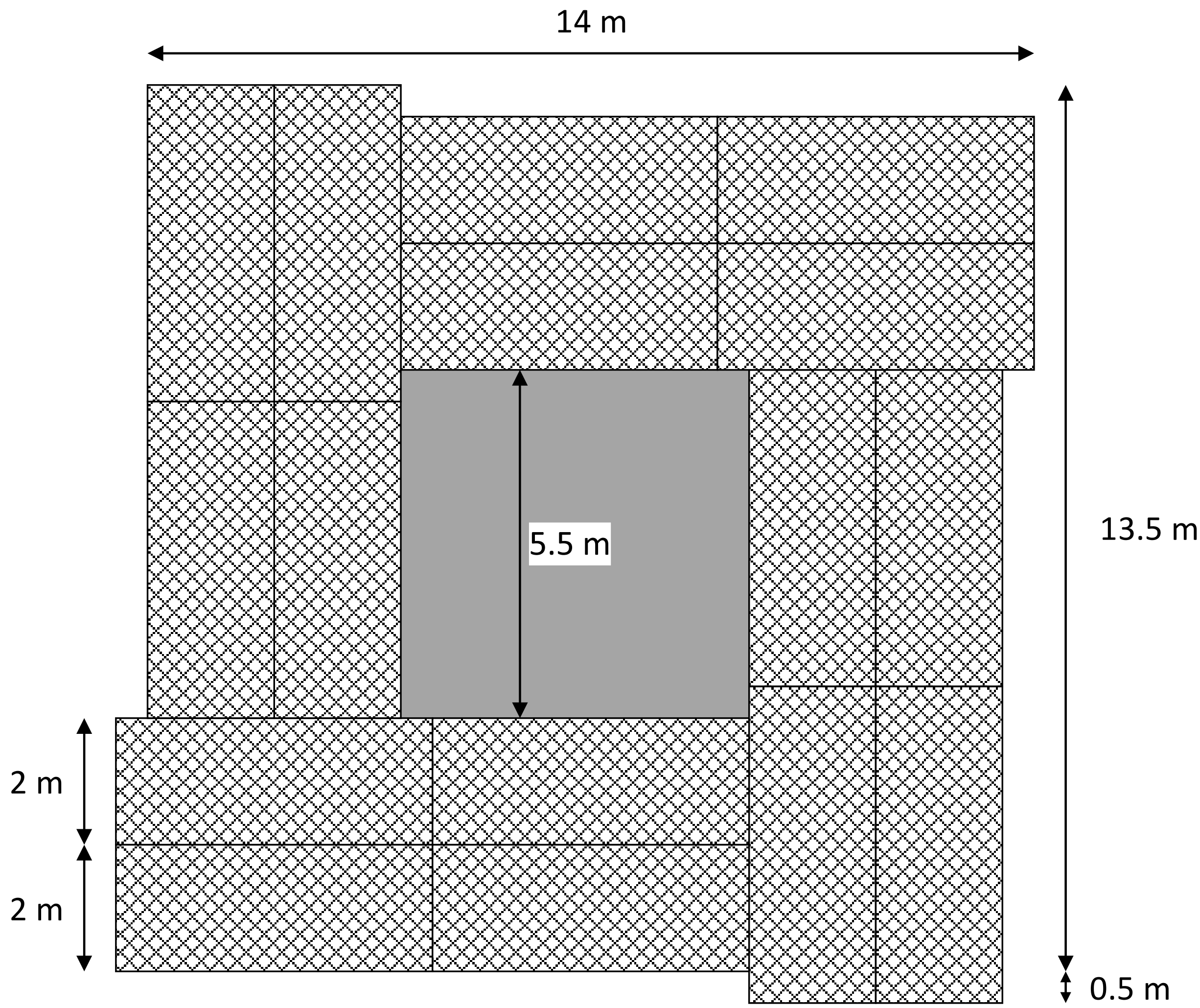

Figure 6. Existing solid ground screen extended using 2 sheets of 2m x 5m mesh per side and filling in the corners.