EDGES MEMO #391

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

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Telephone: 617-715-5533

To: EDGES Group

From: Alan E.E. Rogers

Subject: The effects of a raised ground plane

The disadvantages of a raised antenna was first discussed in memo 4. In this memo the effects on the propagation loss vs antenna height were studied using propagation modeling. The figure in memo 4 shows that for horizontal polarization the path loss for low angle RFI is decreased by about 10 dB for a 1 meter height of the antenna bringing the path loss closer to that of vertical polarization. In addition to the increased sensitivity to RFI coming from the horizon raising the height of the ground plane increases the strength of the reflections from the edges of the ground plane. This is illustrated in Figure 5 of memo 384 which shows the increased beam chromaticity for a 20m circular ground plane as it is raised from the ground into free space. The effects of raising the 30x30m ground plane used by EDGES at the MRO are also large and in practice a construction a large raised ground plane made of welded mesh would be a very significant engineering project. However a raised wire grid which was known as a “counterpoise” ground in the very early days of radio may actually be quite straightforward as there is only a sag of about 5mm for a 18 awg wire over 40 meters with 60 pound tension. Several studies have analyzed effects of the ground plane height needed to reduce the level of multipath

Scire-Scappuzzo, Francesca, and Sergey N. Makarov. "A low-multipath wideband GPS antenna with cutoff or non-cutoff corrugated ground plane." *IEEE transactions on antennas and propagation* 57, no. 1 (2009): 33-46.
Counselman, Charles CIII. "Multipath-rejecting GPS antennas." *Proceedings of the IEEE* 87, no. 1 (1999): 86-91
James Johnson, John Braun, Chris Rocken, Teresa VanHove.
“The Role of Multipath in Antenna Height Tests at Table Mountain”,UNAVCO July, 1995

needed for high accuracy geodesy.

A study of raised ground planes is needed because at some potential sites for global 21-cm systems a raised ground plane might be requiired for environmental reasons or the high cost of leveling. While there are disadvantages of a raised ground plane this study looks at looks at whether it might be less sensitive to the layered ground in the arctic.

Using the FEKO model for a 20m diameter circular ground plane elevated 1.5m off the ground with dielectric 3.5 and conductivity 2e-2 an rms beam chromaticity over 24 hour of GHA in 1 hour blocks of about 700 mK with 5 foreground terms removed is obtained which is about 7 times larger than for the rms of about 122 mK 30x30m ground plane at the MRO also shown in Figure 5 of memo 384.

Given that a raised ground plane might be required for environmental reasons at some sites a search is made for ground planes with a much lower chromaticity than the circular ground plane. Table 1 below shows some comparisons of different ground planes all over a ground with dielectric 3.5 and conductivity of 2e-2 S/m:

Ground plane	hgt m	avrms1	avrms2	freq	amp	width	rms1	rms2	rms3
30x30m no beam correction	0	75	53	78.1	0.53	19.3	49	4	4
30x30m no beam correction	1.5	321	310	78.1	0.57	19.7	51	5	10
20m diam circle with beam corr.	0	253	237	77.7	0.44	18.7	51	20	21
20m diam circle with beam corr.	1.5	473	459	78.1	0.45	17.3	63	27	33
20m diam circle no beam corr.	0	479	471	72.5	1.48	28.8	87	17	90
20m diam circle no beam corr.	0.5	1050	1045	73.1	2.55	27.8	169	64	179
20m diam circle no beam corr.	1.5	895	893	71.9	1.74	27.3	129	41	120
20m diam circle no beam corr.	space	801	795	78.5	0.58	14.3	111	43	90
30x15m wire grid no beam corr.	1.5	238	232	78.1	0.65	19.7	64	29	31
30x15m wire grid with beam corr.	1.5	153	138	78.2	0.59	19.4	58	19	21
40x20m wire grid no beam corr.	1.5	156	147	78.1	0.53	19.2	51	3	3
40x20m wire grid no beam corr.	1.2	165	156	78.1	0.54	19.2	52	4	4
40x20m wire grid with beam corr.	1.2	94	78	77.7	0.46	19.4	45	10	13
40x20m rectangle no beam corr.	1.2	138	127	77.7	0.57	18.4	64	9	18

Table 1. Simulations using the Haslam map scaled by spectral index of -2.5 from 408 to 50-100 MHz to generate simulated data and then processed to obtain the "chromaticity" with 5-physical terms 55-95 MHz for the foreground removed. When processed with beam correction the Guzman map scaled from 45 MHz is used since using the Haslam map again would yield a perfect reconstruction of the Nature feature when added to the map. Simulations used an EDGES low 2 or EDGES-3 antenna either of which give almost exactly the same results as the chromaticity is dominated by the ground plane.

The average of the rms residuals of each 1 hour block of GHA over all 24 hours is avrms1 and avrms2 with and without adding the Nature feature to the sky model respectively. The average of all 24 blocks after removing a 5 physical terms for the foreground is rms1 and rms2 are the averages before and after after a grid search for the feature using a fixed value of tau = 7. The columns labeled freq, amp and width are the best fit parameters obtained from the least squares absorption grid search. The best results were obtained for an azimuth of 135 degrees. rms3 is the rms without adding the Nature feature and should be less than rms1 but in some cases with very large systematics it is larger than rms1. For example with the 20m circular ground plane 50 cm off the ground rms3 is 179 mK compared with 169 mK for rms1.

The cases of the 30x30m ground plane require no beam correction to obtain the Nature feature with low residuals even when the ground plane is elevated. The 20m diameter circular ground plane only reproduces the Nature feature which is added to the Haslam map when beam correction using the Guzman map is applied. In this case the beam correction uses the Guzman map to assess the need for a very accurate sky map with sufficient resolution to beam correct data with a poor ground plane. See memo 386 for a discussion on the differences in resolution between the Haslam and Guzman maps. All of the simulations in Table 1 are done for a latitude of -26.7 degrees.

The 40x20m wire grid gives the best results for a given area of ground plane when raised by 1.5m or 1.2m. An even larger wire grid would result in lower beam chromaticity. It is also found that a 1.2m raised ground plane is about a factor of two more sensitive to the scattering from an object at 30m from the antenna than the same ground plane on the ground.

Tests of GPS accuracy vs antenna height has been studied by Haystack geodesy group and can be found in https://kb.unavco.org/kb/assets/186/tblmtn.pdf

Another important question is how much is the sensitivity to the ground dielectric and conductivity along with a layered ground reduced by raising the ground plane.

Ground plane	hgt m	avrms1	avrms2	freq	amp	width	rms1	rms2
1 40x20m no beam correction	1.2	189	182	77.7	0.58	18.5	64	9
2 40x20m no beam correction	0.01	160	151	77.7	0.57	19.1	65	6
3 40x20m no beam correction	1.2	160	151	78.1	0.55	19.2	52	4
4 40x20m no beam correction	0.01	139	128	77.7	0.55	19.0	56	5
5 40x20m no beam correction	1.2	165	156	78.1	0.54	19.2	52	4
6 40x20m no beam correction	0.5	154	144	78.1	0.58	19.1	57	7
7 40x20m no beam correction	0.2	127	116	78.1	0.57	19.0	56	6
8 40x20m no beam correction	0.01	121	110	77.7	0.54	18.9	56	5

Table 2. Simulations with soil with 0.5m layer of soil with dielectric 3.5 1e-4 S/m over dielectric 20 2e-2 S/m down to minus infinity. Entries 3 and 4 are for soil with dielectric 3.5 1e-4 S/m down to minus infinity and entries 5, 6, 7 and 8 are for soil dielectric 3.5 2e-2 S/m down to minus infinity.

Comparing the results in Table 2 with those in Table 1 shows that there is still sensitivity to the soil with an elevated antenna as avrms1 increases from 160 to 189 mK with a layered soil. The chromaticity is also shown for low conductivity soil without a layer of high conductivity below which still shows an increase in chromaticity with height.

Another test for an elevated ground plane is to see is adding an absorbing sheet under the wire grid is useful. In table 2 the performance of a 20x10m wire grid elevated by 1.2m over a layered soil is tested for which the top layer down to 50 cm below has dielectric 3.5 and 1e-4 conductivity S/m and bottom layer has dielectric 20 conductivity 1e-2 S/m.

Ground plane	hgt m	avrms1	avrms2	freq	amp	width	rms1	rms2
1 20x10m no beam correction	1.2	632	644	77.7	0.67	19.3	66	13
2 20x10 plus sheet	1.2	732	738	77.7	0.20	16.9	31	15
3 20x10 plus sheet on the ground	1.2	774	783	77.7	0.77	20.7	61	10
4 20x10m plus 30x15m sheet	1.2	302	299	77.7	1.38	24.3	89	29
5 20x10m plus 40x20m sheet	1.2	218	212	77.4	0.52	16.8	76	21

Table 3. Simulations of a raised ground plane with added absorbing sheet which in cases 4 and 5 is extended to 30x15m and 40x20m respectively. The sheet used in the simulations had a conductivity of 24 S/m and a thickness of 1.6mm as in memo 388. All cases are with no beam correction.
Table 3 shows that adding an absorbing sheet as in memo 388 is only useful if the absorber extends beyond the the edges of the ground plane but it is more effective to just increase the size of the wire grid to cover the same area.

Ground plane	hgt m	avrms1	avrms2	freq	amp	width	rms1	rms2
1 50x25m no beam correction	0.2	80	68	78.1	0.50	19.1	49	4

Table 4. Performance of a 50x25m wire grid 20 cm off the ground

A ground plane with the performance shown in Table 4 is close to the 30x30m mesh at the MRO shown in table 1 can be achieved with a 50x25m wire grid 20 cm off the ground.

In summary raising a 30x15m ground plane, which is 450 square meters, increases the chromaticity by a factor of about five but by a smaller factor when the soil has a reflective layer and by smaller factors for larger ground planes. Typically the chromaticity factor reaches a maximum of about five at a height of about 0.5m and then decreases to a factor of about four in free space. The chromaticity of a 20m diameter circular ground increases by smaller factors but it has an unacceptably large chromaticity on the ground. The results of these simulations show that if a raised ground plane is required the amount it is raised should be as small as possible and its size should be as large as needed to obtain an acceptably low beam chromaticity. The chromaticity of a 40x20m wire grid, which is 800 square meters, comes within a factor of two of that obtained by the 30x30m welded mesh ground plane at the MRO if it is raised by less than 20 cm. A ground plane with the performance equivalent to the 30x30m mesh at the MRO can be achieved with a 50x25m wire grid 20 cm off the ground.