EDGES MEMO #295

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To: EDGES Group

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Subject: Simulations of chromaticity effects of non-uniform soil.

The beam chromaticity is strongly influenced by the non-uniformity of the soil especially when the ground plane is small or when there is no ground plane below the antenna. This is discussed in memos 231, 263, 279, 280 and 294. In addition, the effects of poor connections in the ground plane over non uniform soil is of great concern and are discussed by Bradley et al in https://arxiv.org/abs/1810.09015 and in memo 283.

A key questions for future deployments of EDGES is whether a sufficiently uniform soil can be found for deployment without a ground plane or whether a large ground plane will always be required. Some simulations of the effects of a layer of rock are given in memo #294 but the case of a sharp transition from soil to rock is extreme and areas of earth where the soil is very deep can be found but given the extreme sensitivity to the ground without a ground plane the soil may not be uniform enough. One possibility considered at the EDGES workshop in August 2018 was placing the antenna over a lake but this would require very calm conditions to avoid changes in the antenna S11 as the distance between the antenna and the surface varies.

Table 1 shows the results of FEKO simulations of the beam chromaticity from 2 hour blocks over all GHA at the latitude of Oregon. The chromaticity is given as the average rms residual for linlog terms removed over frequency range of 60 – 120 MHz. These results show that in order to get the average rms residual under 100 mK the soil has to be uniform at a level of about 30% in dielectric and conductivity down to 10 m or the rock needs to be uniform to 30% and no deeper than 20 cm.

Rock	Soil		Rock		rms
Depth	dielectric	S/m	dielectric	S/m	mK
5 m	3.5	1e-5	8.5	2e-2	2300
5 m	3.5	2e-3	8.5	2e-2	2550
5 m	3.5	2e-3	8.5	2e-3	1653
5 m	3.5	2e-3	4.0	2e-3	238
5 m	3.5	2e-3	3.5	2e-2	2354
5 m	3.5	2e-3	3.5	3e-3	132
10 m	3.5	2e-3	3.5	3e-3	30
10 m	3.5	2e-3	8.5	2e-2	83
2 m	3.5	2e-3	8.5	2e-2	7285
1 m	3.5	2e-3	8.5	2e-2	1372
0.5 m	3.5	2e-3	8.5	2e-2	628
0.25 m	3.5	2e-3	8.5	2e-2	100
0.12 m	3.5	2e-3	8.5	2e-2	29

Table 1. Beam chromaticity for various soil conditions for antenna without ground plane.

This is equivalent to a Ground Penetrating Radar (GPR) return of under 0.3 ns delay with no echoes with longer delay or no echoes at all. From another perspective, the ground effects on the beam are similar to the reflections measured by a GPR. A mK out of 3000 k can be produced by a reflection -90 dB of the total ground plane reflections for a delayed reflection since the relative voltage level is 3×10^{-5}. This level is close to the dynamic range of a GPR which is limited by surface ground scatter so solids with any detected echoes over 12 cm depth may not be acceptable. Looking through examples of GPR echoes on the web I have not yet seen any without some subsurface echoes hence find it unlikely that any location will have an acceptably uniform layer of solid for EDGES-3 deployment without a ground plane.

Most GPR operate at 200 MHz and are limited in sensitivity to a depth of about 4 m. The sensitivity increases to about 8 m as the frequency is reduced to 100 MHz. Figures 3A and B on pages 6 66 and 67 of the book on GPR (see reference below) show how a reflection due to the ground water layer is clearly detected at 100 MHz and is not detected at 225 MHz. The detection of deep layers for EDGES operation down to 50 MHz may be difficult with a standard GPR. Looking at typical ground reflection plots in the book emphasizes that a ground plane will be needed.

An introduction to GPR is in “Stratigraphic Analyses Using GPR” edited by Gregory S. Baker and Harry M. Jol. The Geological Society of America special paper 432, 2007.