MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886
December 7, 2021

Telephone: 617-715-5533

To: EDGES Group

From: Alan E.E. Rogers
Subject: Simulations on the effects of trees and other scattering structures near antenna

Simulations of scattering are in memos 341, 342, 344, 348, 360 and 371. An analytic approximation for scattering effects is derived and compared with FEKO in memo 360. The approximation is needed for cases for which EM modeling requires a very large compute time. This is needed for possible deployments of EDGES-3 at sites like Johnston Atoll and Ny-Ålesund where trees, buildings and other structures might affect the antenna beam and EM modeling is needed as a check on the level of the effects.

Ground plane	location	Karoo 31S	MRO 27S	Johnston 17N	MARS 79N	peak rms mK
PEC	No scatter	38	38	21	10	
PEC	10m north	745	745	747	645	
PEC	10m west		2367			
PEC	20m north		62			
PEC	20m south		62			
PEC	20m east		237			
PEC	20m west	223	223	223	176	1206 at 05:40
PEC	40m west	44	44	45	33	282 at 05:50
PEC	50m west	39	39	39	16	
PEC	50m east	39	39	39	21	
PEC	50m north	38	38	20	11	
PEC	50m south	38	38	20	11	
Soil 3.5 2e-2	81m west	19	17	8	6	
Soil 3.5 1e-2	No scatter	15	14	6	4	

Table 1. Scattering effects for a 2m diameter tree 6m high with dielectric 10 at various distances and azimuths from an antenna pointing North. The results are the average rms over 1 hour blocks of all GHA in mK with 5-physical terms removed from 55-98 MHz. The peak rms and GHA for 10 minute blocks is given for 2 cases.

Table 1 shows the results of FEKO simulations of the average beam chromaticity over GHA in mK with 5-physical terms removed 55-98 MHz for EDGES-3 at various latitudes. While it looks like the scattering effects of distant objects are reduced with the antenna on flat soil without a ground plane the loss is close to 50% so that with loss correction the rms values are increased by a factor of about 2. The

FEKO simulations in table 1 are for a scatter cross-section of $12m^2$ so if the approximation in equation 7 of memo 360 holds the rms for larger structures will increase with the square root of the cross-section. While equation 7 predicts that the rms will decrease in proportion to the distance an increase in distance also decreases the ripple period and the duration in GHA decreases so that the rms will decrease by more than a factor of two for an increase of distance by a factor of two. The table shows an increase of a factor which is close to the distance squared on the rms which is the average over all GHA. The table shows that objects like average trees and bushes which at a distance of a 100m from the antenna should be of little concern. For distances as short as 10m the elevation of the center of the scattering object with a height of 6m is about 17 degrees which raises the Gscat from about -23 dB to about -1 dB for a factor of about 10 increase using equation 7. On the other hand large objects like a building which is 2 km away and is at an elevation angle of under 2 degrees would need to have a scattering cross-section of 2e4 m^2 to potentially have a significant effect on the antenna beam. Bumps in the ground plane of only 5 cm, over an area of more than $1m^2$, which are studied in memo 362, can have a significant effect on the beam chromaticity.

A check of the effect of the scatter produced by a large bird with scatter cross-section of 0.16 m^2 at a height of 10m west of the antenna produced a beam chromaticity of only 73 mK averaged over GHA with 5-terms removed from 55-98 MHz at the MRO. In addition, such an event would only occur for a small fraction of time so I don't think deployment a site with birds is a concern unless birds perch on the antenna which would change the antenna s11 and have a very large effect on the spectrum but if the perch is infrequent and of short duration the effects would be removed by RFI/rain filter and have little overall impact on long integrations. There were birds present at EDGES-3 deployment in Oregon, described in memo 310, but no evidence that one perched on the antenna but this might be a more serious concern for a deployment on Johnston Atoll.

A pipe for fiber and power, which could be metal, can come out from center over the wire grid and perpendicular to the polarization. Simulation used 1" diameter metal pipe over and not connecting to the wire grid and connected to the antenna pipe as in Figure 1 has no effect on chromaticity for 10x10m and 20x20m wire grid ground planes giving the same rms values as in memo 378 as well the same values rms in the first entry of the table 1 above for the PEC ground plane. An alignment error of 5 degrees perpendicularity increases the chromaticity significantly while a 1 degree error results in less than 1 mK increase in rms.

In summary if the area were the antenna and ground plane are located is flat to within about 5cm out to about 50m from the antenna and are clear of trees out to about 80m from the antenna the effects of scatter should not limit performance. Birds can fly over without significant effect but any significant perching on the antenna or resting on the ground plane within 20m from the antenna could be a problem.

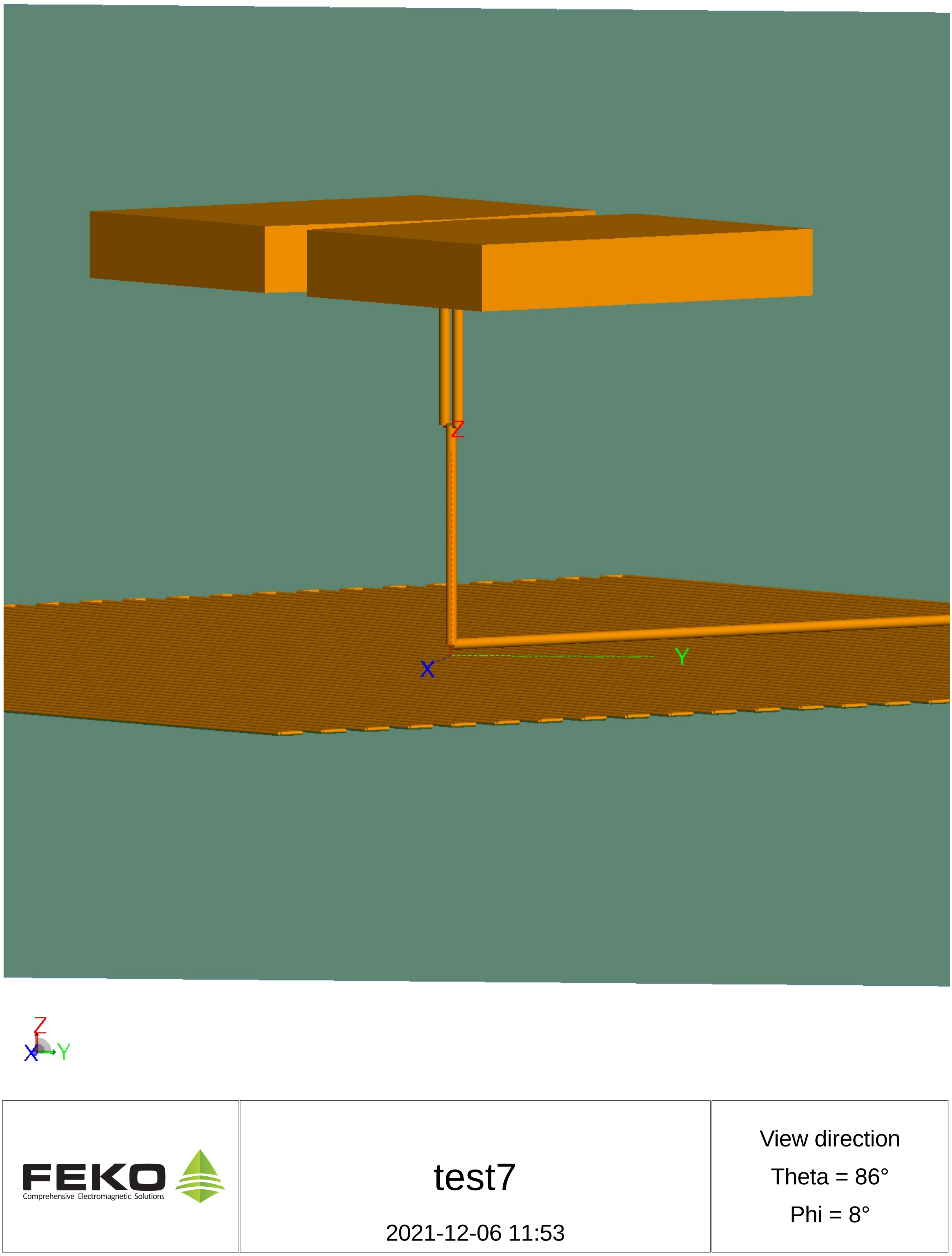

Figure 1. Location of 1” diameter metal pipe used to simulate the effect of the pipe needed for fiber communication and DC power to EDGES-3 antenna. The horizontal section should be perpendicular to the antenna E-field to within 1 degree and whose center is 1” above the ground so as not to be in contact with the wire grid ground plane.