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Subject: Effects of tilts and sky maps on beam correction for different antennas and ground planes

The sensitivity to beam models is simulated for low2-45 for changes in antenna tilts and site coordinates to account for the tilts in the ground plane. The results are in table 1 below:

Beam model	Ground plane	Sky model	change	Avrms mK
Low2_45	PEC	Haslam	180 deg rotation	0.7
Low2_45	PEC	Haslam	+1 deg in lat	2.3
Low2_45	PEC	Haslam	+1 deg in long	3.7
Low2_45	PEC	Haslam	Gusman	28.4
Low2_45	30x30 3.5 2e-2	Haslam	180 deg rotation	11.2
Low2_45	30x30 3.5 2e-2	Haslam	+1 deg in lat	16.3
Low2_45	30x30 3.5 2e-2	Haslam	+1 deg in long	17.6
Low2_45	30x30 3.5 2e-2	Haslam	Guzman	64.8
Low2_45	PEC 1deg roll	Haslam	180 deg rotation	67.2
Low2_45	PEC 1deg roll	Haslam	+1 deg in lat	2.7
Low2_45	PEC 1deg roll	Haslam	Guzman	32.3
Low2_45	PEC 1deg tilt	Haslam	180 deg rotation	29.8
Low2-45	PEC 1deg tilt	Haslam	+1deg in lat	1.9
Low2_45	PEC 1deg tilt	Haslam	Guzman	28.8
Low2_45	30x30 1 tilt+roll	Haslam	180 deg rotation	72.3
Low2_45	30x30 1 tilt+roll	Haslam	+1deg in lat	18.7
Low2_45	30x30 1 tilt+roll	Haslam	Guzman	65.3
Low2_45	30x30 1 tilt+roll	Haslam	diff. without tilt+roll	38.8
EDGES-3	48x48	Haslam	Guzman	44.3
EDGES-3	infinite PEC	Haslam	Guzman	8.0
Small monopole on very	large gnd or lake	Haslam	Guzman	3.5

Table 1. The results of simulated data for different antennas on different ground planes processed with a 180 degree rotation, an offset in site coordinate and a change in sky map. In all cases 5 physical terms are used from 52 to 95 MHz. The average rms is the average of the rms differences for GHA = 0 to 23 hours in one hour steps. See memo 343 for details of antenna tilt and roll.

Table 1 shows that the rms residual with 5 physical terms removed is not significantly dependent on the sky map when the ground plane is infinite PEC and there is no tilt or roll. The sensitivity is significant for the 30x30m ground plane and significantly reduced for a 48x48m ground plane. The change with 180 degree rotation is a measure of the asymmetry in the beam.

antenna	Ground plane	change	Av1 rms mK	Av2 rms mK
Low2_45	PEC	Tilt of 1deg	15.5	13.5
Low2_45	PEC	Roll of 1deg	34.0	27.7
Low2_45	30x30 3.5 2e-2	Tilt and roll 1deg	35.0	29.2
Low2_45	30x30 3.5 2e-2	Roll 1deg	43.2	35.6
Low2_45	30x30 3.5 2e-2	Tilt 1deg	17.1	12.8
Low2_45	30x30 3.5	Soil 4e-2 to 1e-3	85.8	45.6
Low2_45	30x30 3.5 4e-2	+1 deg in lat	14.5	5.7
Low2_45	30x30 3.5 1e-3	+1 deg in lat	28.0	11.5
Low2_45	30x30 3.5 1e-3	+1 deg in long	22.7	9.4
low2_45_halfsize	PEC	Tilt and/or roll 1deg	< 1	< 1
Low full or half size	soil or metal	+5 cm bump	~ 30	~ 20

Table 2. Dependence of the average rms to uncertainties in the antenna and ground plane. For Av1 rms the Haslam map is used for simulated spectra and processing with the indicated change while the Guzman map is used for Av2 rms.

The FEKO simulation of antenna "roll" is surprisingly sensitive to the mesh of the antenna with a jump in the results with a small change in numerical value. The sensitivity of antenna roll is surprisingly large and results in a residual of about 30 mK per degree of roll. When the antenna is electrically small on a PEC ground plane the effects of tilt and roll become insignificant but the effects of scatter due to a change in soil and other sources are still similar as discussed in memos 340 and 348. The effects of roll are largest at the rise and set of the galactic center at GHA 20 and 04 hours with sign reversal between rise and set.

The last entry in table 2 is the effect of a bump of 5 cm over area of 2.5x2.5m at a distance centered 5m from the center of the antenna which as discussed in memo 337 has an effect which is largely independent of whether antenna is full size or electrically small or the ground plane is metal or soil.

The larger change in residual for a change in soil using the Haslam map than when using the Guzman map is due to the higher angular resolution of the Haslam map as discussed in memo 345. In a similar manner the fine structure in the beam makes the effect of a change in latitude and longitude of 1 deg more significant for soil whose effects are due the reflections from the edges of the ground plane which is some distance from the antenna so that change from 4e-2 to 1e-3 S/m and is twice as sensitive when using the higher angular resolution of the Haslam map.

The simulations show that a very accurate beam is needed. The beams are complex with a lot of structure in azimuth and elevation and frequency owing to scattering from the edges on the ground plane. While there is also a significant dependence on the sky map the major concern is that details of the ground plane are currently not well enough known for accurate beam correction. In addition, it also may be difficult to get sufficient accuracy from the EM modeling of the beam. With fine meshing and a lot of fine detail the compute time in FEKO also becomes a limiting factor. Tilt and roll also contribute to beam complexity and to an increased dependence on the sky map accuracy. Another difficulty is that FEKO beam calculations tilting and rolling the ground plane and the soil underneath is not practical so that the tilt and roll of the ground plane has to be modeled by tilting and rolling the antenna and moving the effective location in latitude and longitude.

In summary we need a large level ground plane to produce a very smooth beam and avoid a beam which is very difficult to model accurately and requires an accurate high resolution sky map for accurate beam correction.