EDGES MEMO #095

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To: EDGES Group

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Subject: EDGES antenna design notes

1] Horizontal planar elements

Mounting a horizontal structure over a ground plane ensures zero gain at the horizon which minimizes the susceptibility to RFI since most RFI arrives from low elevations. Other structures like the horizontal biconical antenna or MWA "shortwide" have almost no response at the horizon.

A minimum at the horizon also reduces the ground noise from terrain and structures or the horizon. In addition changes in the shrubs and ground in the local environment have a negligible effect on antenna S11 with very low gain at the horizon.

2] Wide S11 bandwidth

Biconical, asymptotic conical, fat, droopy, bowtie, bat-wing, foursquare, Fourpoint are all capable of more than a 2:1 bandwidth with less than -10 dB reflection.

3] Constant beam pattern

Another desirable, if not essential, characteristic needed for EDGES is a constant, or very nearly constant beam pattern with frequency. This is difficult to achieve over the same frequency range for which the antenna is well matched.

4] "Fourpoint" dipole

So far EDGES has used the Fourpoint dipole originally developed by Suh at the Virginia Tech Antenna group. This antenna comes closest to meeting the desirable features or near zero gain at the horizon, wide S11 bandwidth and nearly constant beam over an octave. In addition the impedance is close to 50 ohm which simplifies the Roberts balun.

In Table 1 compares several dipoles scaled to a common frequency range of 100 to 190 MHz. In this comparison the ½ and ¼ λ dipoles are 50 cm above a perfect ground plane.

Antenna Type	Zenith gain (dBi)			Gain ellipticity (dB)			Horizon response (dBi)	
	High	Low	Ratio	High	Low	Ratio	High	Low
Fourpoint[1]	7.5	8.5	1.0	4.8	3.4	1.4	-23	-26
MWA[2]	7.4	9.4	2.0	6.5	3.4	3.1	-10	-17
½ λ dipole	6.4	8.2	2.2	2.7	3.4	0.7	None	None
¼ λ dipole	5.9	8.2	2.3	3.2	3.1	0.1	None	None
¼ λ dipole[3]	8.3	8.6	0.3	2.7	2.7	0	None	none

Table 1. Comparison of some wideband dipoles

Only the "short" dipole (¼ λ, 25 cm above the ground plane) has virtually no change in beamshape with frequency as indicated by the zenith gain at 190 and 100 MHz and the azimuth ellipticity of the beam at 45 degree elevation. Only the Fourpoint has been optimized to achieve a S11 reflection below -15 dB over the frequency range. In order to obtain this S11 bandwidth the beam shape constancy had to be compromised by raising the panels above the ground plane by enough to achieve a good match at the low frequency end of the band. Figure 1 shows the difference of the antenna patterns at 190 and 100 MHz for the Fourpoint antenna from FEKO. The power weighted rms difference between the antenna pattern at 190 and 100 MHz is 0.72 dB.

5] Alternate antenna designs

So far no extensive search through parameter space has yet been made to find an antenna with better characteristics than the Fourpoint optimization given in memo 89. A 4:1 bandwidth would allow the full range where the red-shifted 21 cm line is expected to be explored with one antenna and spectrometer. This might still be possible with a tapered ground plane.

6] The effect of surrounding objects

a) Effect on S11

The relative voltage reflection from an object of angular diameter θ and distance d assuming isotropic scattering given by

$$v = G\lambda\theta/(16\pi d)$$

Where G is the gain of the antenna. A change of 0.01 dB at -15 dB reflection corresponds to a relative voltage change of 2×10^{-4}.

[1] EDGES Fourpoint with unshielded Roberts balun
[2] MWA "shortwide" scaled from 120-240 MHz
[3] Short dipole 25 cm above ground plane

A 12 m antenna at a distance of 100 m away from the EDGES antenna at 150 MHz would result in a relative voltage of 5×10^{-6} if it is located in a -10 dBi sidelobe. This would produce a negligible effect on the S11. To get to the 0.01 dB level it would have to be as close as 20 m away.

b) Effect on antenna temperature

The antenna temperature due to isotropic scattering from an object is given by

$$T_{scat}G\theta^2/(4\pi)$$

Where Tscat is the temperature of the scattered radiation which equals its physical temperature for an absorber and equals the average sky temperature for a reflector. A 12 m antenna at 100 m in a -10 dBi side lobe would be expected to contribute about 60 mK for Tscat~500 K so that a distance of 300 m would be needed to bring the contribution to the 5 mK level.

A 1 degree horizon of absorbing terrain results in a noise contribution of 25 mK for the approx. -20 dBi response of EDGES at 1 degree elevation. Locating EDGES in a canyon with a 4° horizon would result in about 1 K which would need to be modeled.

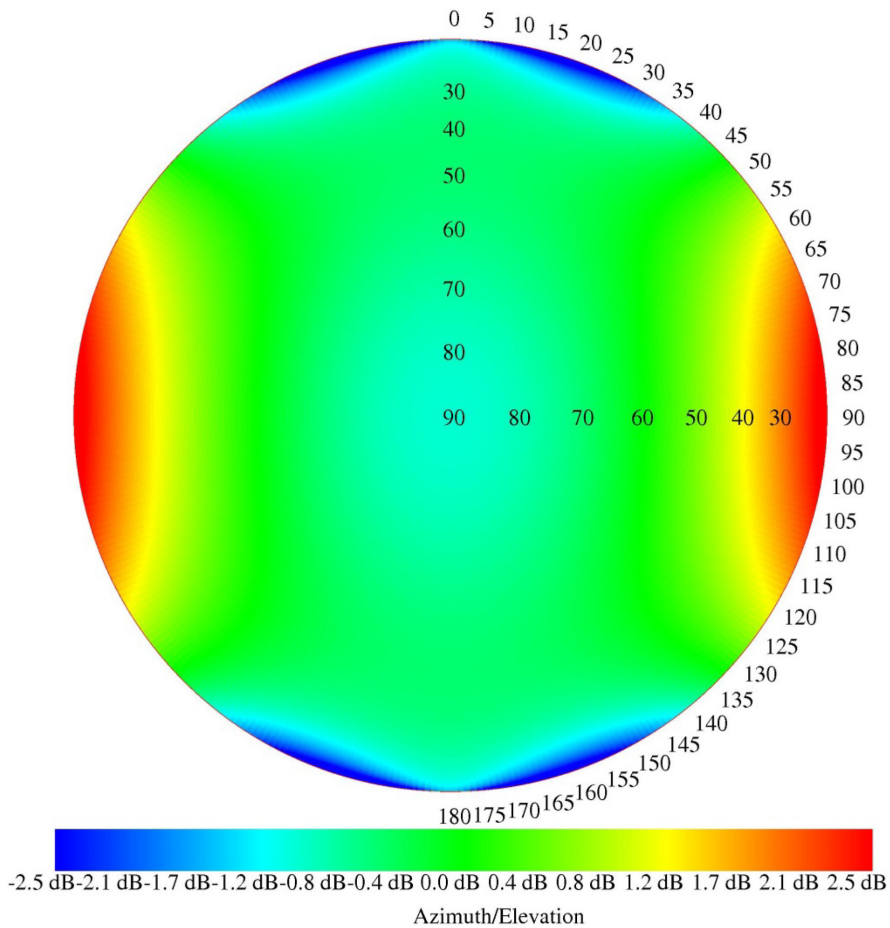

Figure 1. Difference in EDGES beam patterns at 190 and 100 MHz.