EDGES MEMO #077

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Subject: Calibration sensitivity to LNA and antenna parameter errors.

Memo 76 presents a noise wave model for the absolute calibration of EDGES using measurements of the antenna and LNA impedance combined with measurements of the LNA noise parameters using an open cable. In this memo we examine the effect of measurement error or bias on the EDGES spectrum from 50 to 100 MHz.

		atten = 0 dB	atten = 6 dB	
Parameter	Error	rms mK	rms mK	Comments
Antenna refl.	0.01	1452	1406	VNA 0.01 amp. Error
Antenna refl.	1 deg	408	151	VNA 1 deg phase error
Antenna Imp.	0.1%	65	65	Impedance analyzer error
LNA refl.	0.01	1423	646	
LNA refl.	1 deg	481	150	
LNA Imp.	0.1%	66	31	
Balun refl.	0.01	1209	1209	
Balun refl.	1 deg	11	11	
Balun imp.	0.1%	12	12	
T_{LNAU}	1 K	23	5	
T_{LNAC}	1 K	28	28	
ϕ_c	1 deg	58	58	LNA at ambient
ϕ_c	1 DEG	6	6	LNA at 20 K
Attenuation	0.1 dB	1590	585	
Ground loss	%	0	0	
Resistive loss	0.1 Ω	217	217	
T_{amb}	1 K	11	130	

Table 1. rms error in spectrum due to systematic errors in measurements of the antenna, balun and LNA

The errors in table 1 are given after the removal of a constant, slope and a logarithmic scale error. It is noted that error in the measurement of the LNA impedance and uncorrelated LNA noise parameter are reduced when an attenuator is placed between the antenna and the LNA whereas other sources of systematic error are not reduced. It is also noted that reducing the magnitude of the LNA noise waves by cooling the LNA should reduce the systematic error due to fractional errors in the determination of the LNA noise.

The parameter errors in table 1 for measurements of the antenna, balun and LNA reflection coefficients or impedances are those expected for the limits on the accuracy of a network analyzer or an impedance analyzer. The impedance analyzer, in the frequency range below 100 MHz, is capable of an accuracy of 0.1 percent where as the network analyzer is limited to about 0.01 in amplitude and 1 degree of phase.

If we assume the LNA noise wave temperatures are approximately proportional to the absolute temperature and the LNA impedance changes by about 0.05 Ω/K or about 0.1% per K, as indicated from some preliminary measurements, a 1K change in the LNA temperatures results in an rms error of about 30 millikelvin. The largest sources are the uncertainty of the measurements of antenna impedance and the loss between the antenna input of EDGES and the sky. The EDGES balun has a loss of 0.25 dB from 50 to 100 MHz and a temperature coefficient of loss of 0.002 dB/$^\circ C$. The effects of the errors in parameters given in table 1 are obtained from a simulation of EDGES observing a sky temperature. With spectral index of 2.5 and 500 K at 150 MHz. Antenna impedance, LNA impedance, balun loss and noise parameters were measured values. A LNA with perfect match makes little difference. A high impedance LNA increases the sensitivity to antenna impedance errors. A cooled LNA reduces the sensitivity are not significantly changed. A perfect 50 Ω antenna removes all sensitivities.

Table 1 shows that even when using an impedance analyzer to make extremely accurate measurements the absolute calibration may not be good enough to detect an EoR signature of only 100 mK spread out over half of the 50 MHz band. Some performance improvement may be possible by fitting instrumental parameters in addition to the constant, slope and scale factor already used in deriving the numbers in table 1. An example of one such parameter is the function of a constant error in the real part of the antenna impedance.