EDGES MEMO #331

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To: EDGES group

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Subject: Tests of antenna S11 measurements

In EDGES 2 the antenna S11 is measured by first measuring a Short, Open and Load (SOL internal) internal to the receiver in the lab using a VNA which is calibrated using commercial SOL whose offset delays are known and load resistance has been measured[1]. The lab VNA uses SOL measurements as the calibrated SOL are manually attached to the receiver input, which defines the reference plane for antenna S11, in sequence to obtain the S11 of the internal SOL which are selected by the internal switch. Then in the field the antenna, which is connected receiver input is measured with a VNA located in the hut and connected via a long cable to the receiver using the internal SOL, whose S11 values are known from the lab calibration, remotely selected by the internal switch.

The accuracy of the antenna S11 measurement depends critically on the accuracy of the lab measurements of the internal SOL and performance of the VNA in the hut. Since the remote measurements of the antenna and internal SOL are obtained in sequence the VNA must remain perfectly stable and repeatable between these measurements. Another critical factor is that the field measurements are made with a different frequency spacing than the lab measurements and the lab measurements have to be fit with a polynomial or Fourier series in order to match the frequency spacing of the antenna measurements. In practice the polynomial fitting is also needed to reduce the noise in the S11 measurements but enough terms in the polynomial are needed to avoid smoothing out real structure in the antenna S11. Also to minimize the structure a delay is taken out before fitting and put back after fitting.

In order to test the performance and the effects of fitting a calibrated antenna spectrum is simulated vs GHA with smoothing with polynomials of 14 down to 9 terms. 14 terms is normally enough to just remove the noise in the S11 but fewer terms are needed to remove any systematic ripple in the S11 that is sometimes present. Caution is needed in going to fewer than 12 terms as this may remove some real structure in the antenna S11. This is especially true below 55 MHz for lowband and below 65 MHz for midband.

Figure 1 shows a simulation using antenna S11 from lowband 2016/2017 fitted with a large number of Fourier terms as a reference smoothed with a 12 term polynomial changes the calibrated spectrum vs GHA and Figure 3 shows how the calibrated spectrum at GHA = 12 hour changes with the number of terms. Figures 2 and 4 show the corresponding results for lowband2 2020 antenna S11. The poor performance of the 2020 lowband2 measurements of antenna S11 is clear from Figures 2 and 4 and some

[1] Monsalve, R.A., Rogers, A.E.E., Mozdzen, T.J., and Bowman, J.D. (2016). One-port direct/reverse method for characterizing VNA calibration standards. IEEE Transactions on Microwave Theory and Techniques 64(8): 2631–2639

software changes are being implemented to determine the cause. This emphasizes the need for tests of the accuracy of the S11 measurement system.

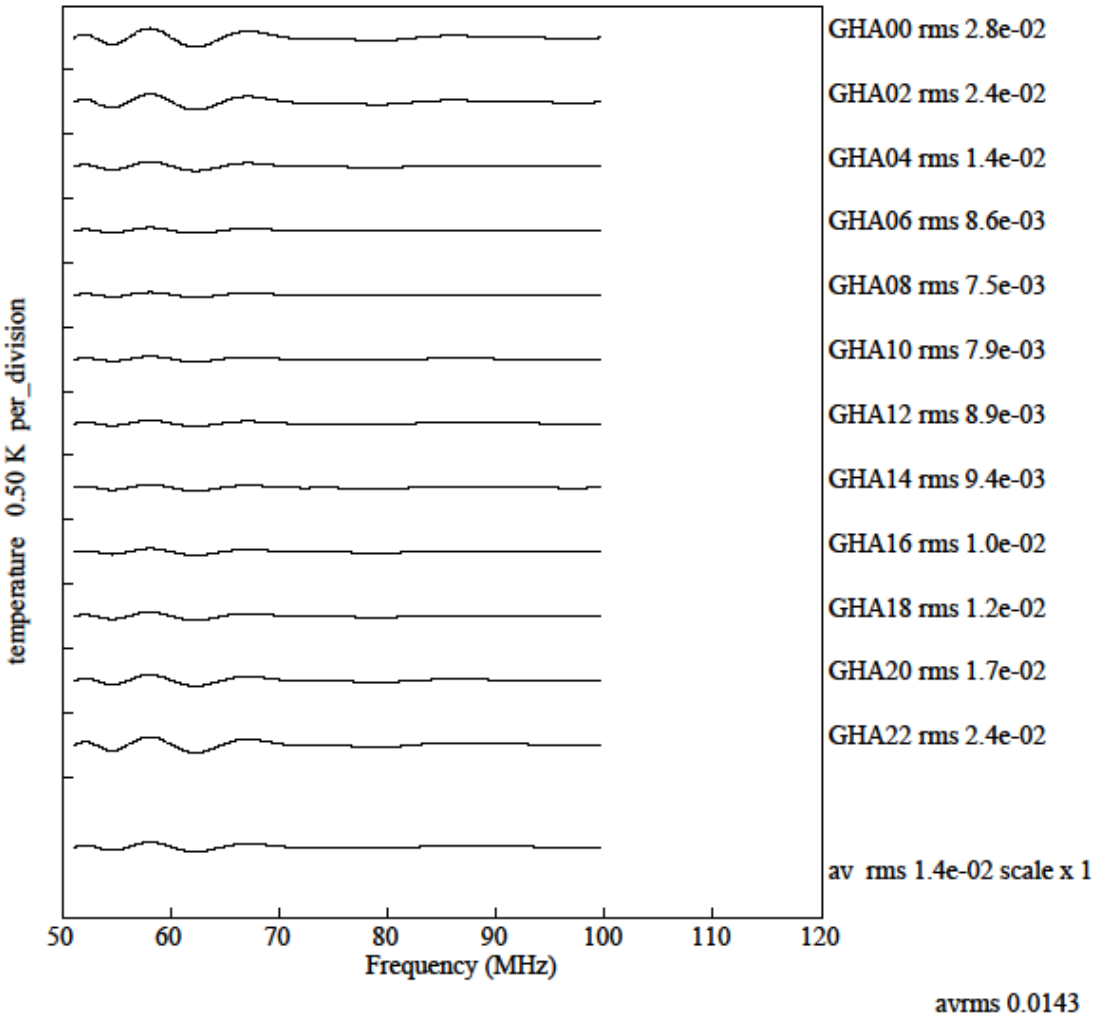

Figure 1. Simulated residuals for lowband 2016/2017 data for a change from a Fourier fit to 12 polynomial terms with 5 physical terms removed

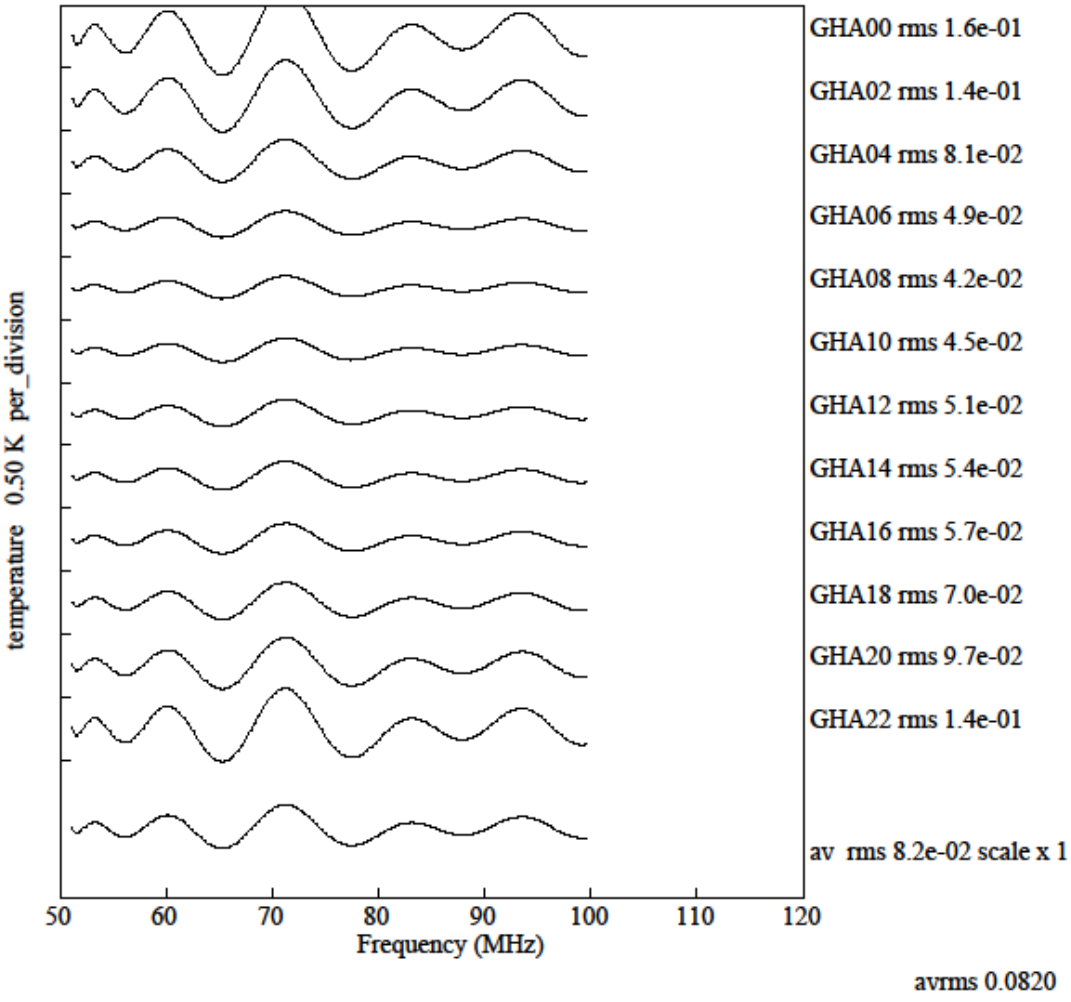

Figure 2 Simulated residuals for lowband2 2020 data using S11 calibration from 2020_087_23_03_01 vs GHA

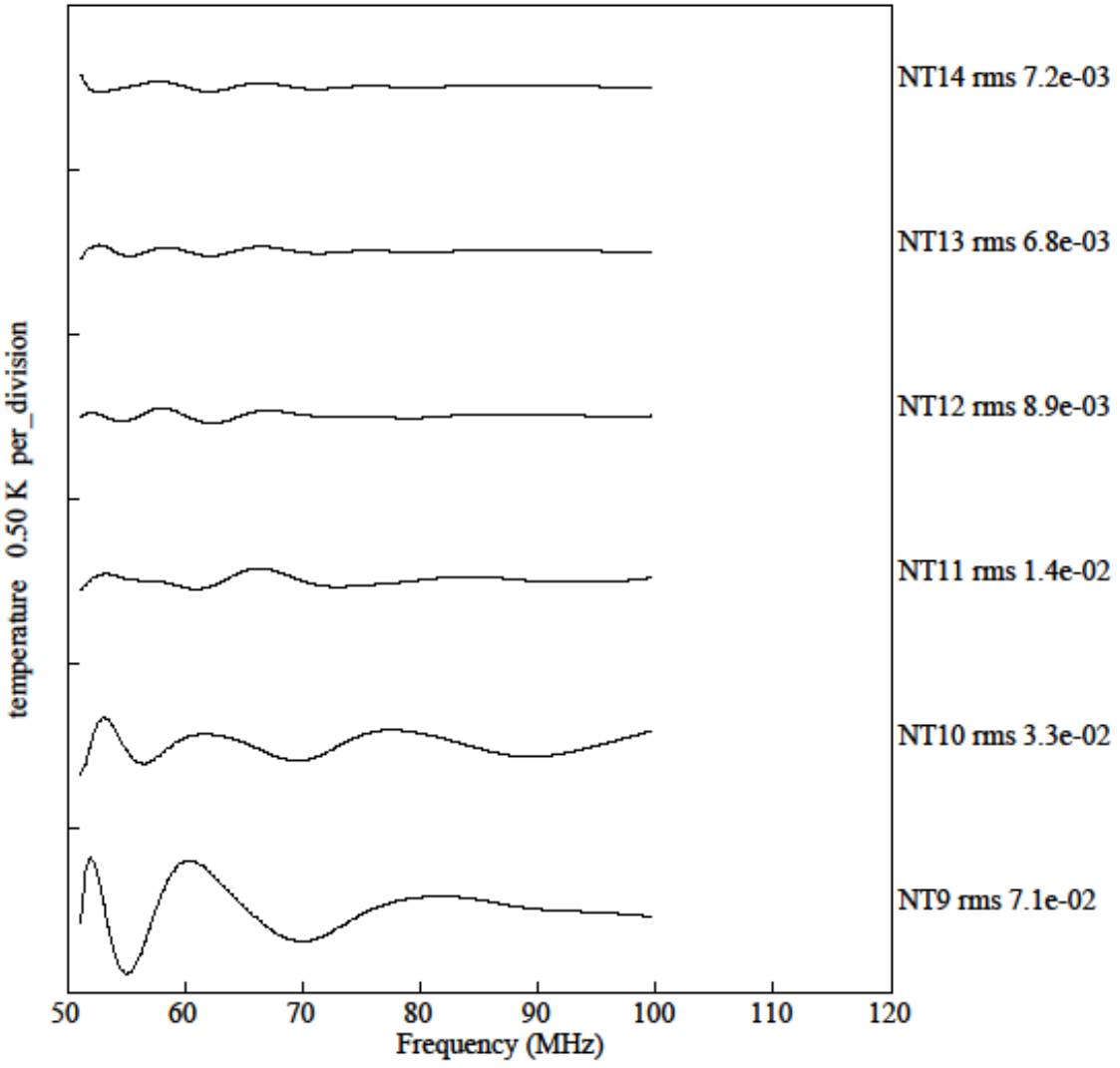

Figure 3. Simulated residuals for lowband 2016/2017 S11 at GHA = 12 hours vs number of terms in the smoothing filter.

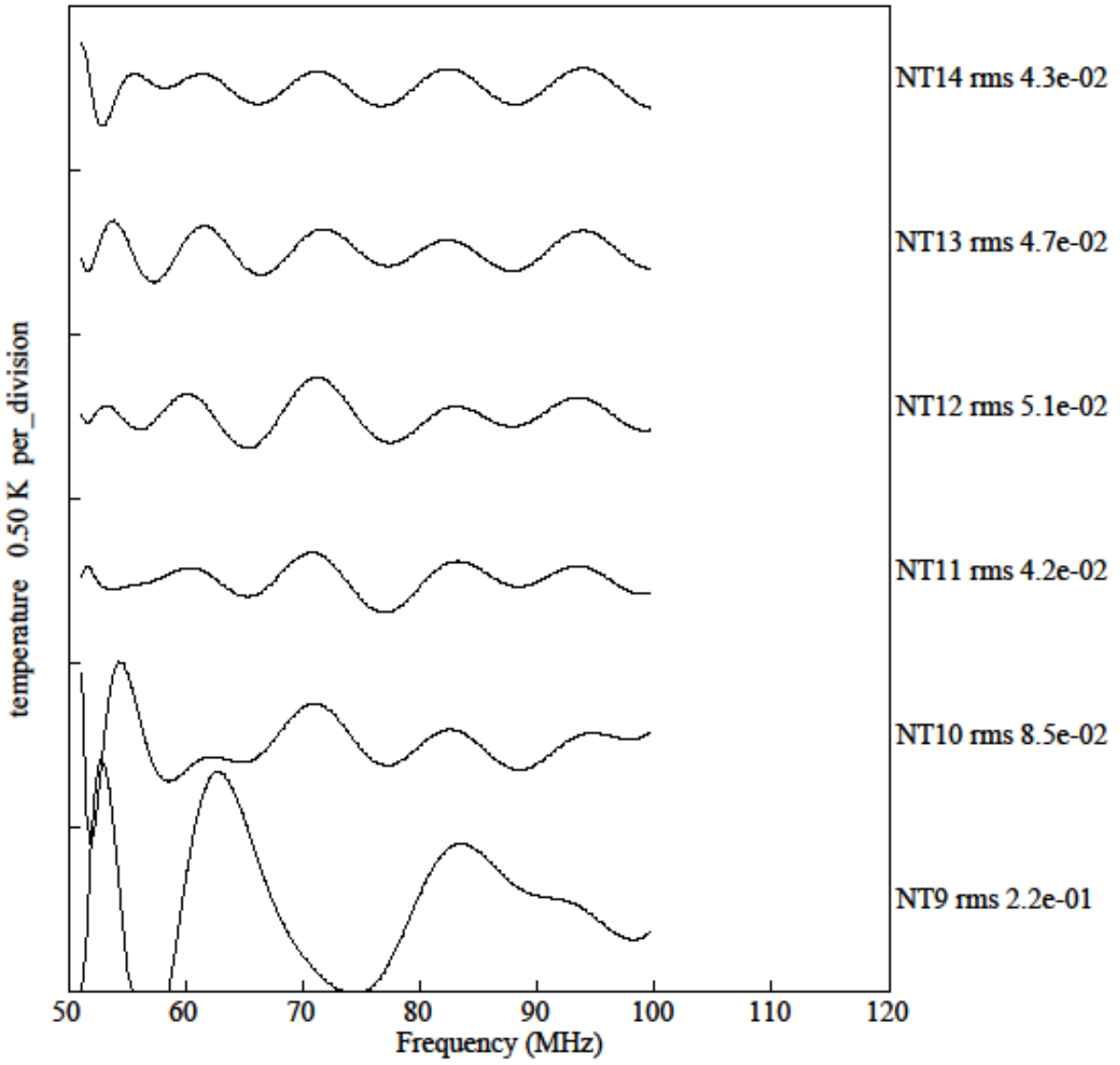

Figure 4. Simulated residuals for lowband2 2020 S11 at GHA = 12 hours vs number of terms in the smoothing filter.