Effects of Internal Switch measurements on the Antenna S11 modeling.
Case: EDGES low-band 1 & 2

Nivedita Mahesh, Steven Murray
ASU

01/04/2022

Introduction

The findings presented in this memo are an extension of the Low2-45 deg data processing using the edges-collaboration pipeline. The latter is done to perform an additional test of the new open-source pipeline and to cross-check the low2-45 processing results of Alan's pipeline. For this exercise, the results of MIT memo#352 are used to compare various stages of the analysis.

Low2-45 antenna S11

One of the diagnostic points for comparing the two pipelines and analysis is the antenna S11 modeling. The antenna S11 measurement used by both the pipelines is from the day: 2020_080_23_03_01, and the filtering/modeling is done using a 10-term polynomial. The modeled/filtered S11 from Alan's pipeline is obtained from Alan via an email dated 11/27/2021. This is compared against the modeled and filtered S11 measurement using the edges-analysis code (Fig.1). The maximum difference in the magnitude of the S11 from both the pipelines is of the order of 5×10^{-3} in log-scale. Since we are using the same S11 measurement and filtering polynomial, we should see only machine level differences between the two curves of the order of 10^{-6} or lower.

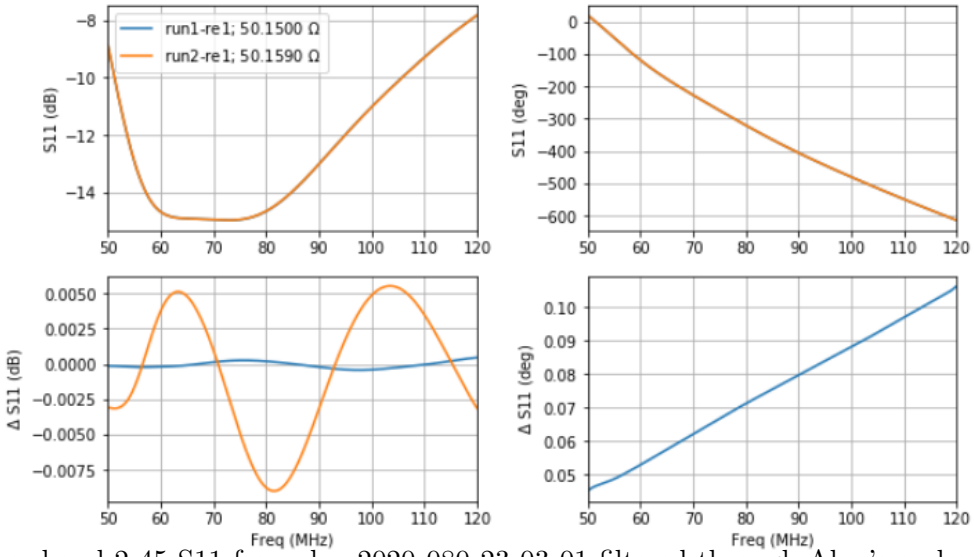

Figure 1: Lowband-2-45 S11 from day 2020_080_23_03_01 filtered through Alan's and edges-analysis codes respectively. [top] Magnitude of the S11 in dB from both codes. [second] Difference, taken in dB, between the two filtered S11s. [Third] Phase of the S11 in deg. [bottom] Difference in the phase.

Low1 antenna S11

We carried out a similar comparison between the pipeline's results of the lowband1 antenna S11 modeling and filtering. The antenna measurement was taken from day: 2015_342_03_14(2015_12_07). Again a 10-term polynomial was used by both the pipelines for filtering.

The file (S11_blade_low_band_2015_342_03_14.txt) from Alan was obtained on 08/18/2021. The comparison between the two S11s is shown in Fig.2. The discrepancy for the lowband1 S11 is higher and of the order of 5×10^{-2}.

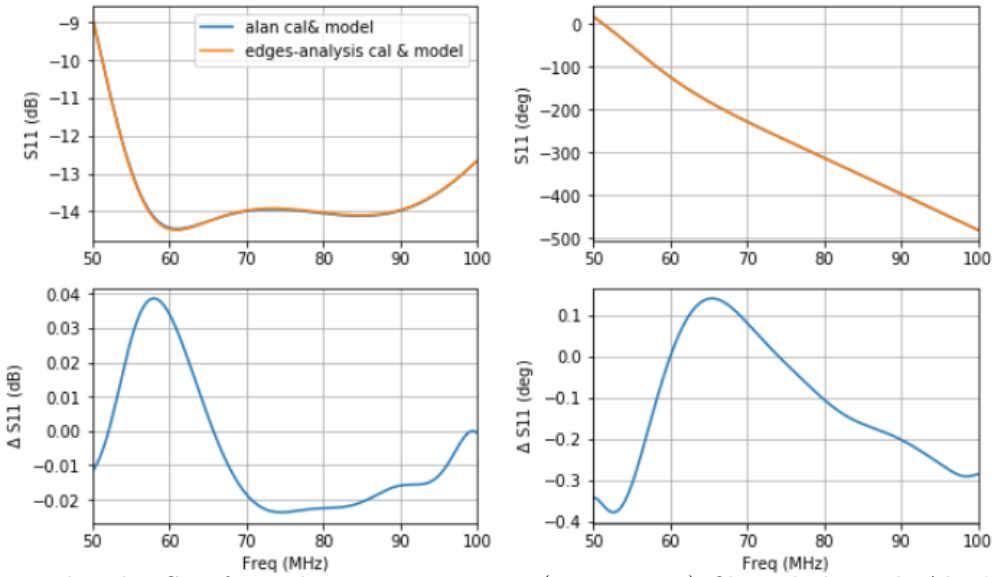

Figure 2: Lowband-1 S11 from day 2015_342_03_14(2015_12_07) filtered through Alan's and edges-analysis codes respectively. [top] Magnitude of the S11 in dB from both codes. [second] Difference, taken in dB, between the two filtered S11s. [Third] Phase of the S11 in deg. [bottom] Difference in the phase.

Analysis

Before modeling the antenna S11, the S11 is corrected/calibrated for the S11 of the internal switch in each pipeline. The possible differences could be in that step. The internal switch S11 used for low2-45 processing is in the Receiver02_2019_12 measurement folder. Both pipelines used the same receiver internal switch measurement date. However, there were discrepancies in the calibrator resistance value and the run number used.

In the Receiver02_2019_12 folder there are two measurement runs for the internal switch S11 and two repeats with each measurement run. Additionally, the male calibrator's resistance is noted in the folder and is shown in figure.3. For the run in Fig. 1, I used the run2 of the internal switch S11 measurement and the corresponding male calibrator resistance of 50.1590 Ω. I calibrated the antenna S11 using various combinations of the internal switch measurement runs and calibrator resistance values.

```
measurements:
  resistance_m:
    01: 50.1515
    02: 50.1590
  resistance_f:
    01: 49.9953
    02: 49.9954
```

Figure 3: Snapshot of the definition.yml file in the Receiver02_2019_12 measurement folder. It records the male calibrator's resistance values for the two internal switch runs.

As seen in Fig 4, the first run of the internal switch S11 and the male resistance value of 50.1500 Ω results in the lowest residuals. **This was verified and confirmed with both Alan and Raul that they indeed used the first measurement run and a resistance value of 50.1500 Ω.** It is a little concerning that within the same run number (1), the two repeats of the measurements result in a significant change in the antenna S11 (compare orange and purple curves).

Propagating the antenna S11 effects to the Processed data.

We noted that the various choices of internal switch S11 measurement runs and the changes in male calibrator resistance values considerably changes the magnitude of the antenna S11. Next we will see how these changes in the antenna S11 affects the final calibrated spectra. So I take two cases of the antenna S11:

- Internal Switch S11 run1 & 50.1500 Ω (orange curve in fig. 4)
- Internal Switch S11 run2 & 50.1590 Ω (green curve in fig. 4)

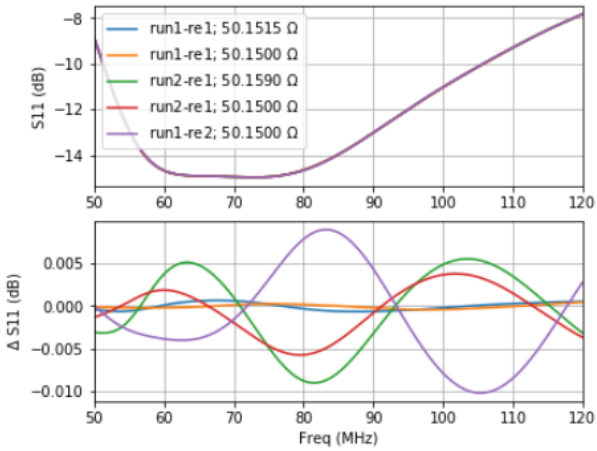

Figure 4: lowband2-45 S11 filtered through edges-analysis. [top] S11 magnitude for varying runs of the internal switches and choices of the male load resistance values. [Bottom] Difference between each of the S11 calculated with edges-analysis with respect to the S11 obtained from Alan.

Lowband2-45 data between days 2020-058 and 2021-021 are processed through edges-analysis. All the settings between the two runs are kept the same except for the internal switch choices. In fig 5 I compared the 6to18hr averaged spectra between the two cases. The fourth subplot shows the absolute differences between the spectra. The fifth plot indicates that this difference is just smooth enough for the linlog to absorb it.

Notes

The main findings from this study are:

- The Antenna S11 modeling and filtering is extremely sensitive to the choice of the internal switch measurement run and the value/precision of the calibrator's resistance.
- To be investigated - How much do these changes in the antenna S11 modeling affect the residuals of the data. The changes in the antenna S11 residuals have a slow varying component with frequency. Might not affect the signal detection?
- It is essential to measure and note the calibrator resistance's value up to the 4^{th} decimal point.
- Using the same measurement run and the calibrator Resistance value, we did get the differences between edges-analysis' and Alan's filtered S11 down to 10^{-4} in dB.
- To further reduce the differences, we will need to compare the two codes carefully.

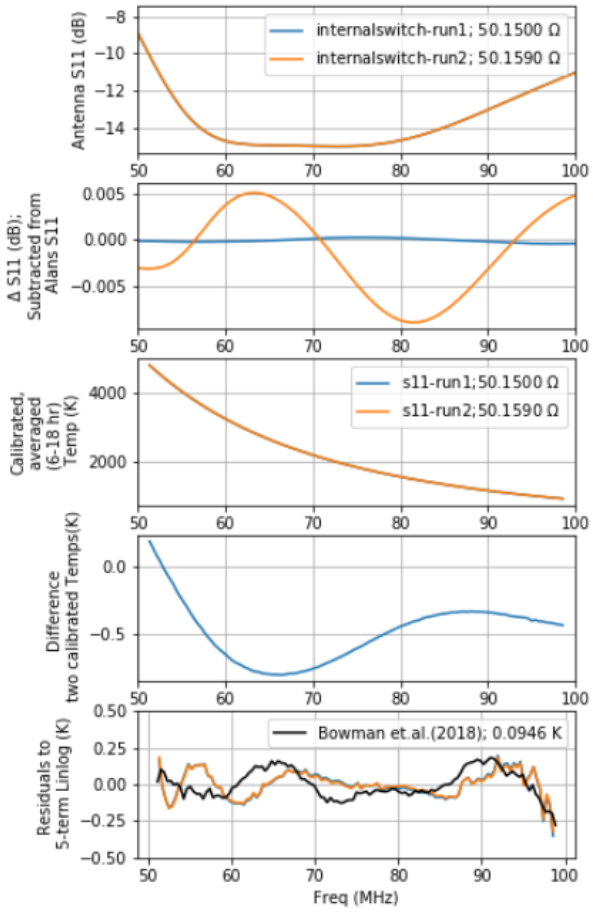

Figure 5: Plot summarizing the effect of the antenna S11 changes on the final calibrated spectra and residuals. Two antenna S11s are chosen for this plot. The differences between them are the internal switch measurement run and the male calibrator resistance. [top] lowband2-45 S11 magnitude for the two runs. [Second] Difference between each of the S11 calculated with edges-analysis with respect to the S11 obtained from Alan. [Third] Calibrated and processed lowband2 data (2020-058 to 2021-021) through edges analysis with the two antenna S11 choices. [Fourth] Difference between the two calibrated spectra. [Fifth] Residuals of the two spectra to a 5 term linlog model. Also shown for reference are the residuals of the Bowman et.al.(2018) spectra to a 5 term Linlog model.