Progress Toward a Full Uncertainty Propagation Machinery for EDGES: II

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Description

This report describes the progress toward a full uncertainty propagation procedure for EDGES. It explores aspects not described in the previous report, available at:
`http://loco.lab.asu.edu/memos/edges_reports/report_20150212.pdf`
For a general description of the pipeline, please read that document.

The main purpose of this document is to explore the effect of the phase of the antenna S11. Three cases are compared. In all cases, the magnitude is -15 dB, completely flat in frequency in the range 100 to 200 MHz. The phases are different, and shown in Figure 1. The black trace corresponds to the steepest phase, the blue trace is the intermediate case, and the red trace is the extreme case of zero phase across the frequency range.

Figure 2 shows the scale, offset, and noise wave parameters obtained during calibration of the receiver. The scale and offset are modeled with 6th degree polynomials, and the noise wave parameters are modeled with 3rd degree polynomials.

Figures 3 through 30 show the isolated effect of each source uncertainty, for the three cases of antenna phase. The color of the traces correspond to those in Figure 1. The 1σ bounds are obtained after removing a 4-term Log-Poly model from 2000 MC realizations of calibrated antenna temperature.

Figures 29 and 30 show the impact of systematic uncertainty in the magnitude and phase of the antenna S11 itself.

Finally, the combined effect of all the uncertainties is presented in Figure 31, and Figure 32 shows the effect of only the systematic uncertainty (S11, and physical temperature of the ambient load, hot load, and open cable).

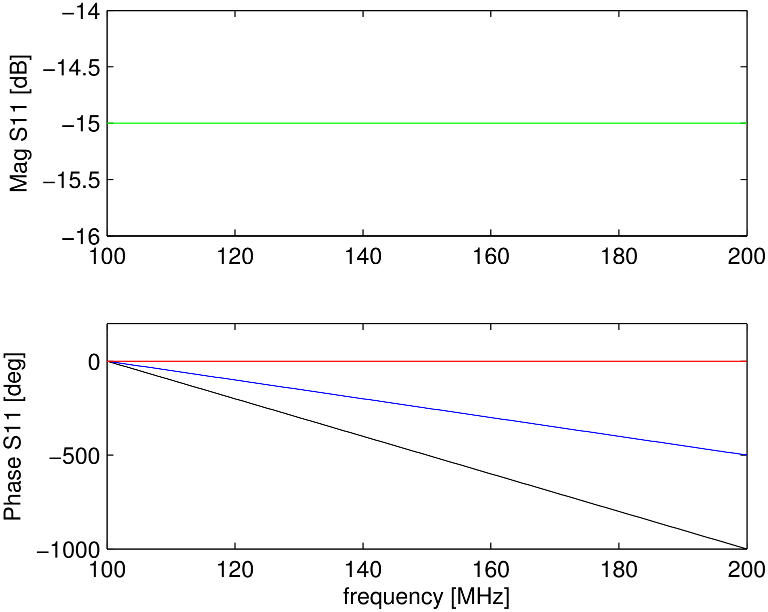
Results

The plots from Figure 3 onward show a clear dependence of the uncertainty level and shape, on the phase of the antenna S11. The steeper the phase in the 100-200 MHz range, the more ripples that appear. The cases of highest sensitivity to the antenna phase are:

- Physical Temp. of Open Cable
- Spectrum of Open Cable
- S11 of LNA
- S11 of Open Cable
- S11 of Antenna

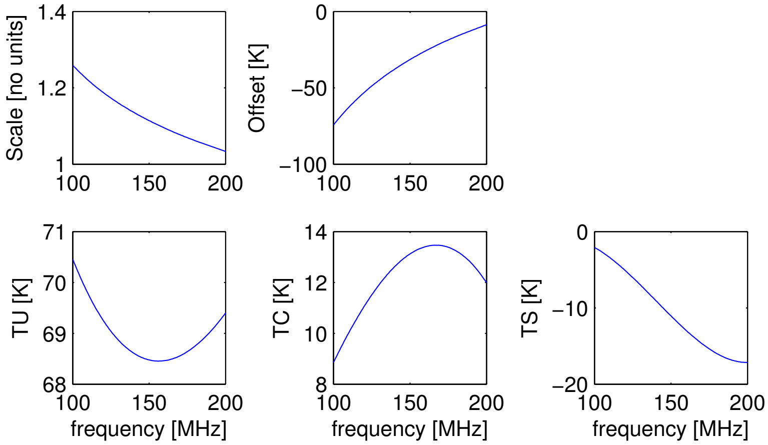
The uncertainty due to the sources listed above can be significantly reduced by reducing the antenna delay.

Even for zero antenna delay, there is residual ripples in the shape of the uncertainties due to the modeling of the other quantities, and the covariance between their parameters. Understanding this structure at a deeper level requires more investigation.



−14
−14.5
−15
−15.5
−16
Mag S11 [dB]
100
120
140
160
180
200
0
−500
−1000
Phase S11 [deg]
100
120
140
160
180
200
frequency [MHz]

Figure : (1)



Scale [no units]
1.4
1.2
1
100
150
200
Offset [K]
0
−50
−100
TU [K]
71
70
69
68
frequency [MHz]
TC [K]
14
12
10
8
TS [K]
0
−10
−20

Figure : (2)

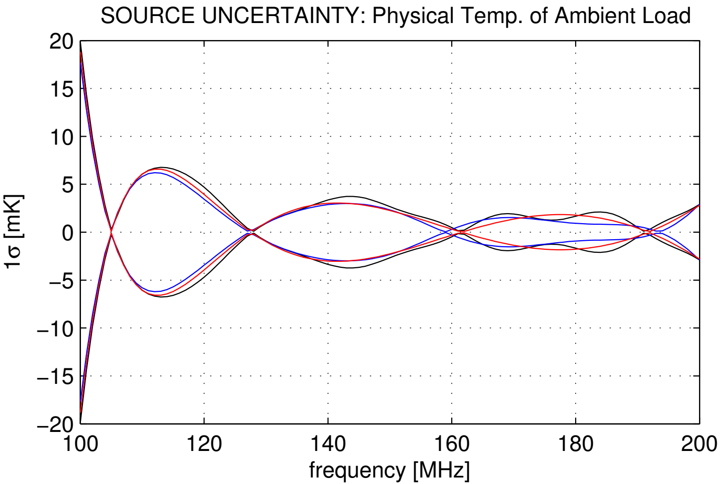
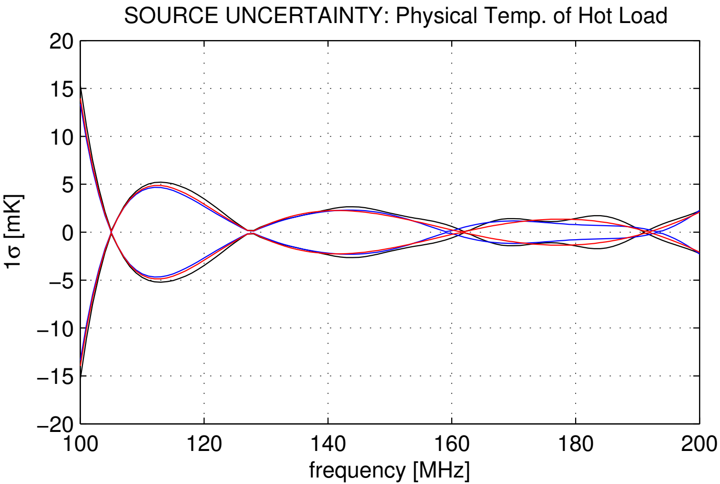

SOURCE UNCERTAINTY: Physical Temp. of Ambient Load
20
15
10
5
0
−5
−10
−15
−20
100
120
140
160
180
200
frequency [MHz]
1σ [mK]

Figure : (3)



SOURCE UNCERTAINTY: Physical Temp. of Hot Load
20
15
10
5
0
–5
–10
–15
–20
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (4)

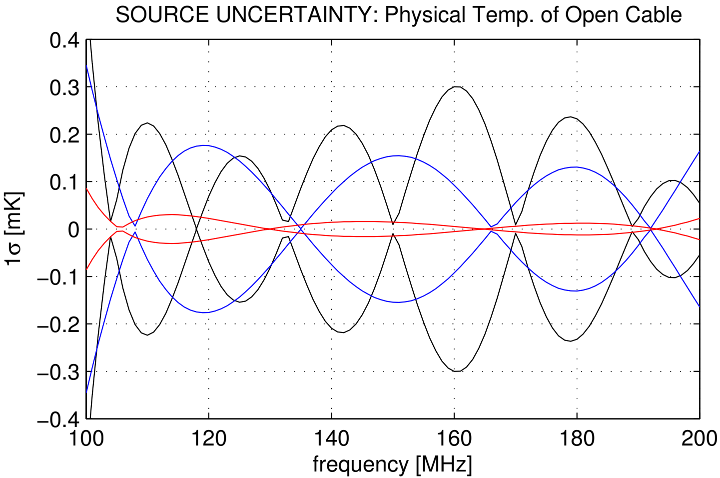

SOURCE UNCERTAINTY: Physical Temp. of Open Cable
1σ [mK]
frequency [MHz]
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
100
120
140
160
180
200

Figure : (5)

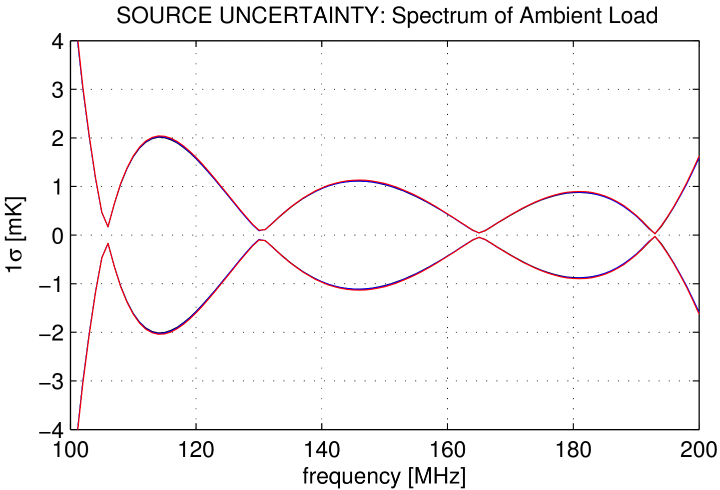
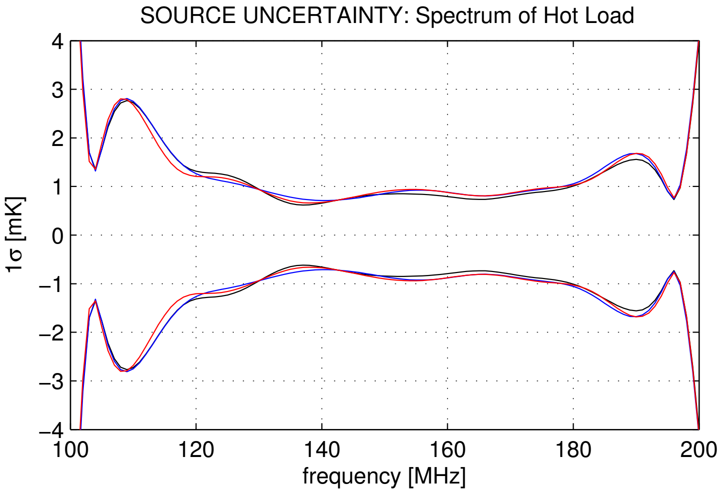

SOURCE UNCERTAINTY: Spectrum of Ambient Load
1σ [mK]
4
3
2
1
0
−1
−2
−3
−4
100
120
140
160
180
200
frequency [MHz]

Figure : (6)



SOURCE UNCERTAINTY: Spectrum of Hot Load
4
3
2
1
0
–1
–2
–3
–4
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (7)

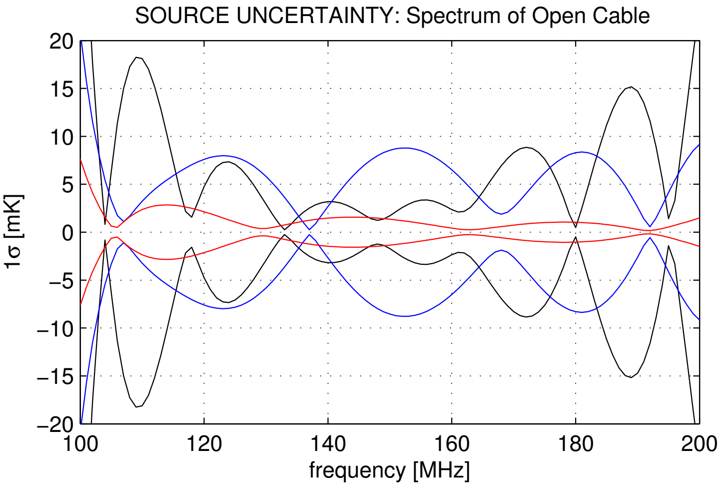

SOURCE UNCERTAINTY: Spectrum of Open Cable
20
15
10
5
0
−5
−10
−15
−20
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (8)

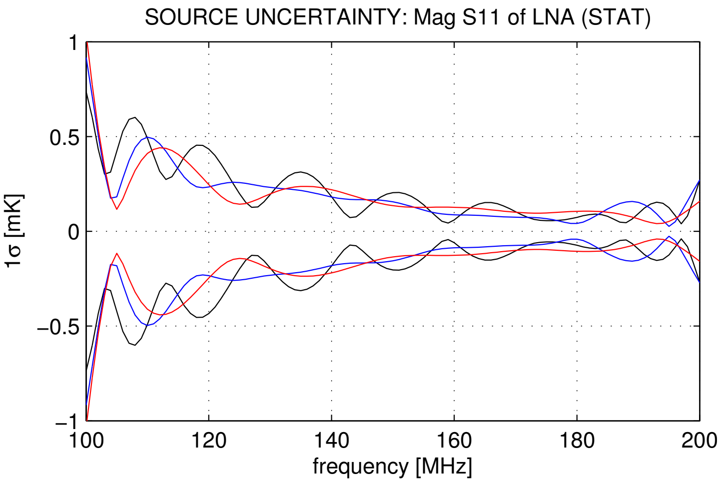

SOURCE UNCERTAINTY: Mag S11 of LNA (STAT)
1σ [mK]
1
0.5
0
−0.5
−1
100
120
140
160
180
200
frequency [MHz]

Figure : (9)

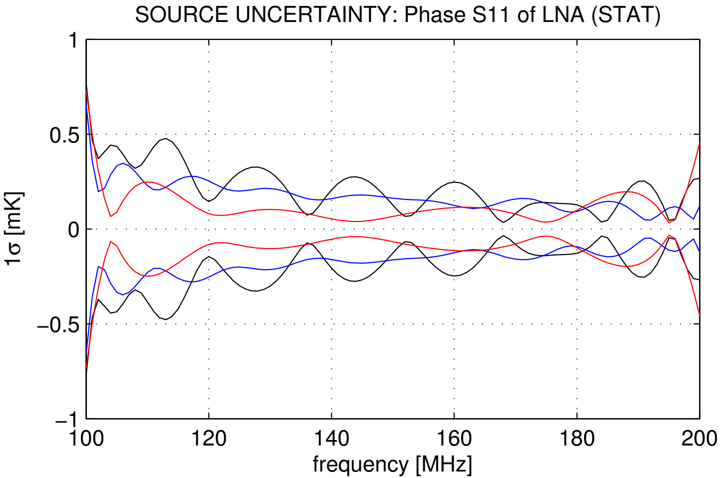

SOURCE UNCERTAINTY: Phase S11 of LNA (STAT)
1σ [mK]
1
0.5
0
−0.5
−1
100
120
140
160
180
200
frequency [MHz]

Figure : (10)

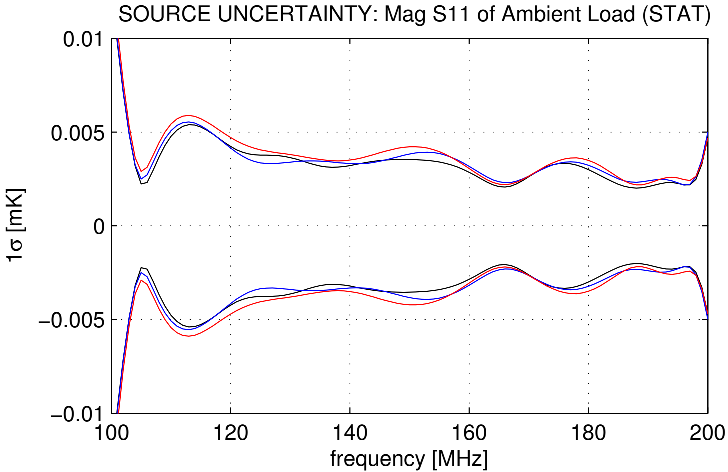

SOURCE UNCERTAINTY: Mag S11 of Ambient Load (STAT)
0.01
0.005
0
−0.005
−0.01
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (11)

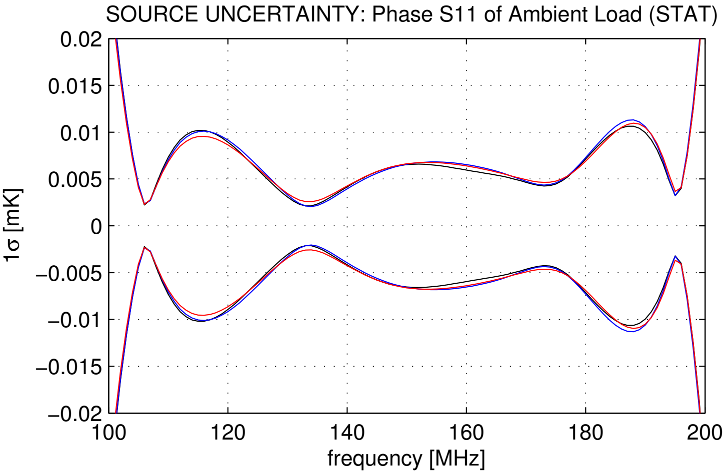

SOURCE UNCERTAINTY: Phase S11 of Ambient Load (STAT)
0.02
0.015
0.01
0.005
0
−0.005
−0.01
−0.015
−0.02
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (12)

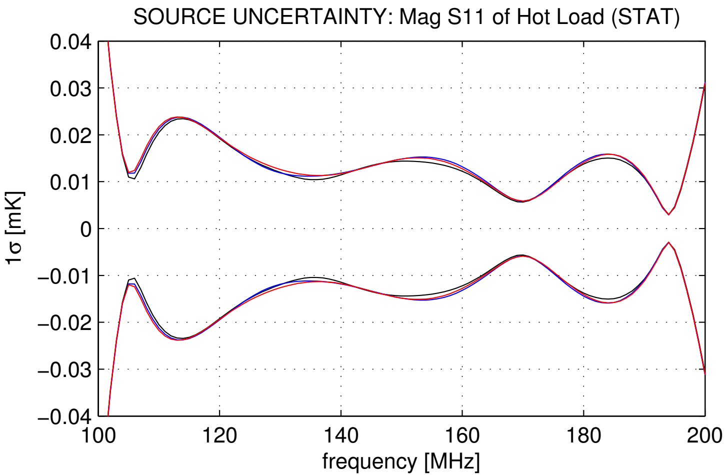

SOURCE UNCERTAINTY: Mag S11 of Hot Load (STAT)
0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (13)

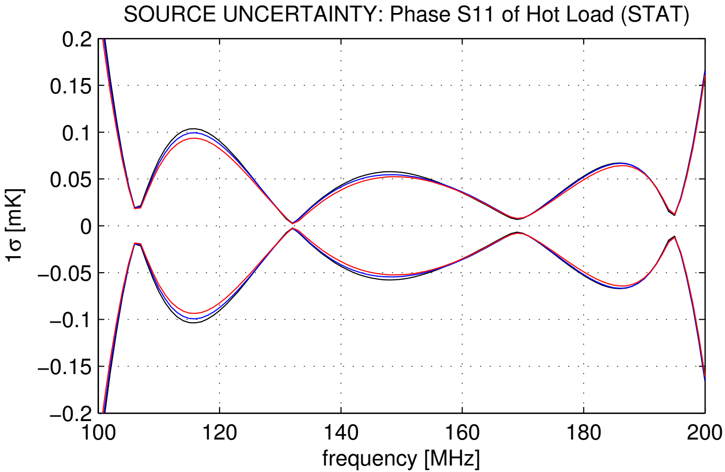

SOURCE UNCERTAINTY: Phase S11 of Hot Load (STAT)
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (14)

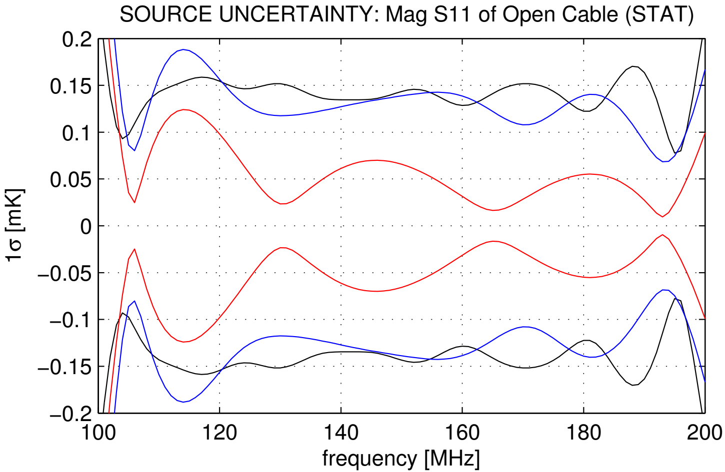

SOURCE UNCERTAINTY: Mag S11 of Open Cable (STAT)
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (15)

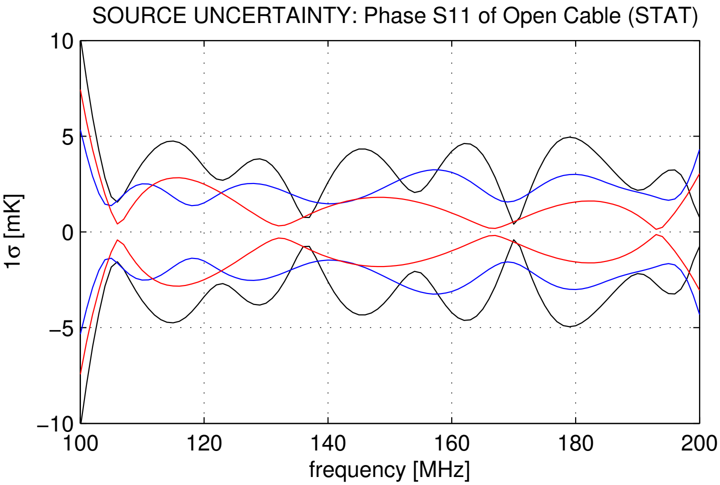

SOURCE UNCERTAINTY: Phase S11 of Open Cable (STAT)
10
5
0
−5
−10
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (16)

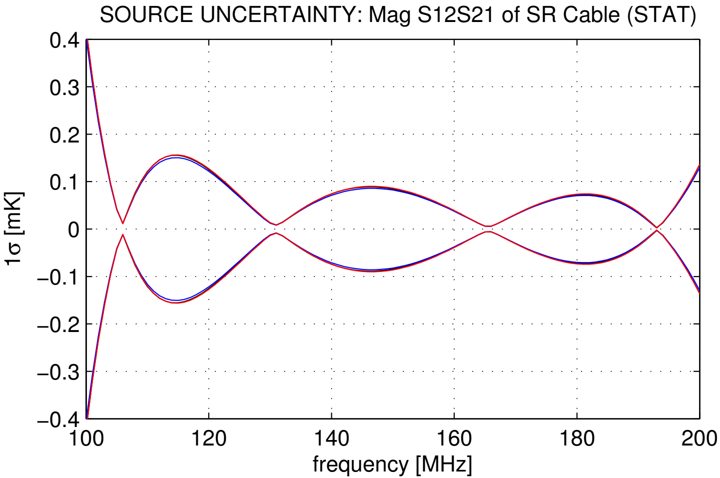
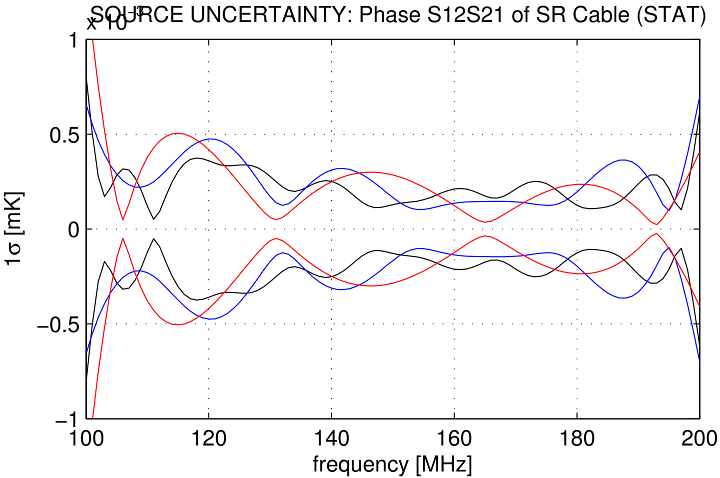

SOURCE UNCERTAINTY: Mag S12S21 of SR Cable (STAT)
0.4
0.3
0.2
0.1
0
–0.1
–0.2
–0.3
–0.4
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (17)



SOURCE UNCERTAINTY: Phase S12S21 of SR Cable (STAT)
x 10^-3
1
0.5
0
–0.5
–1
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (18)

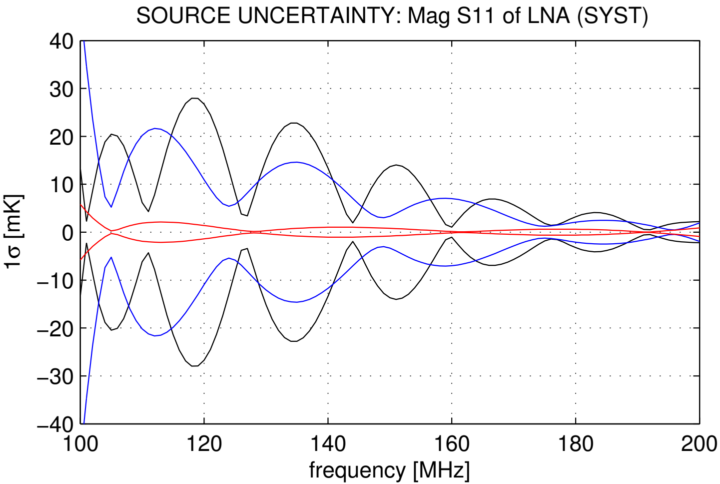

SOURCE UNCERTAINTY: Mag S11 of LNA (SYST)
40
30
20
10
0
−10
−20
−30
−40
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (19)

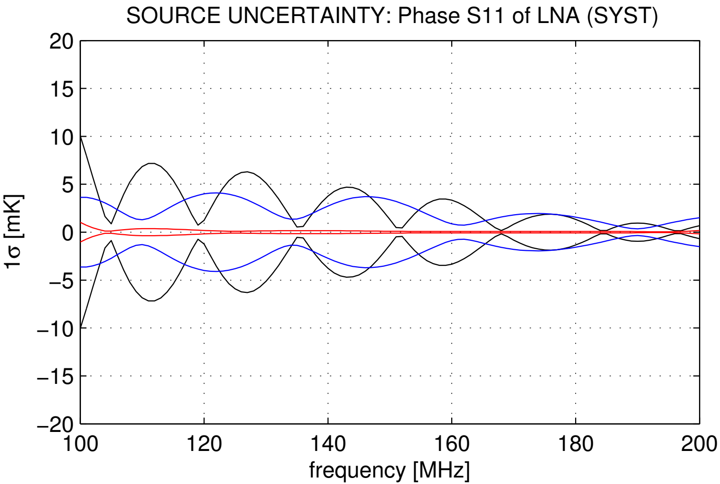

SOURCE UNCERTAINTY: Phase S11 of LNA (SYST)
20
15
10
5
0
−5
−10
−15
−20
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (20)

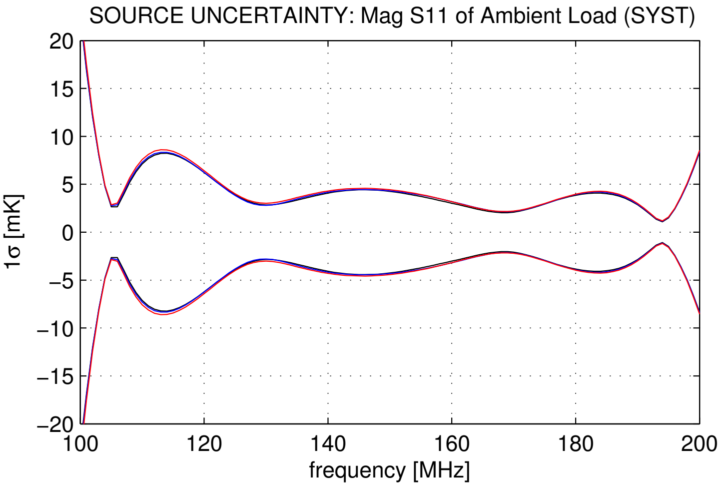

SOURCE UNCERTAINTY: Mag S11 of Ambient Load (SYST)
20
15
10
5
0
−5
−10
−15
−20
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (21)

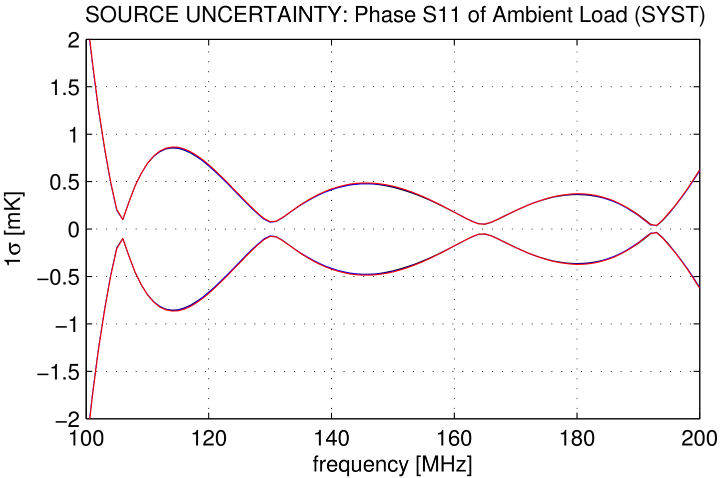

SOURCE UNCERTAINTY: Phase S11 of Ambient Load (SYST)
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (22)

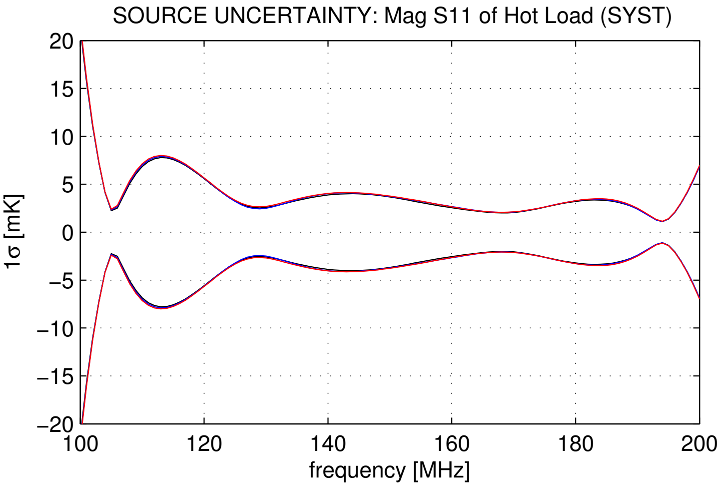

SOURCE UNCERTAINTY: Mag S11 of Hot Load (SYST)
20
15
10
5
0
–5
–10
–15
–20
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (23)

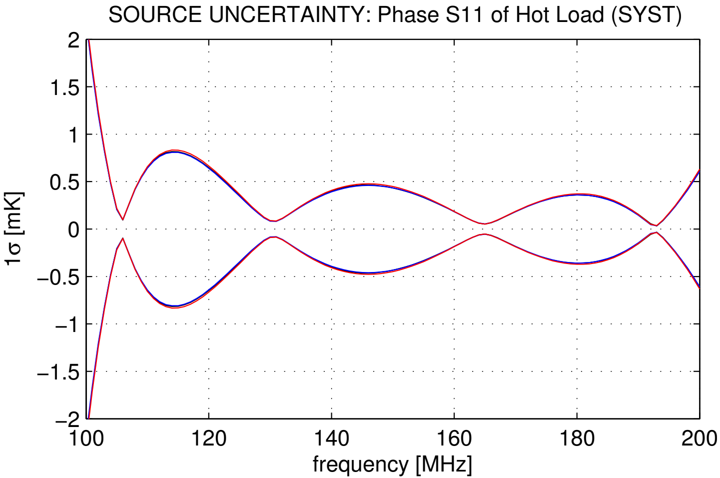

SOURCE UNCERTAINTY: Phase S11 of Hot Load (SYST)
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (24)

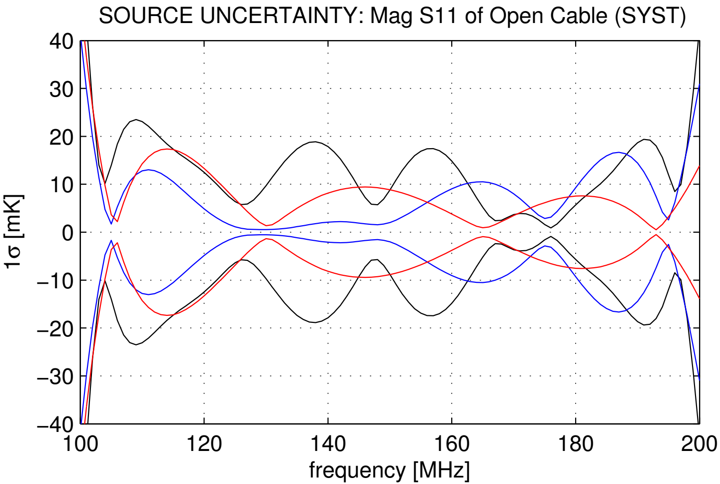

SOURCE UNCERTAINTY: Mag S11 of Open Cable (SYST)
40
30
20
10
0
−10
−20
−30
−40
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (25)

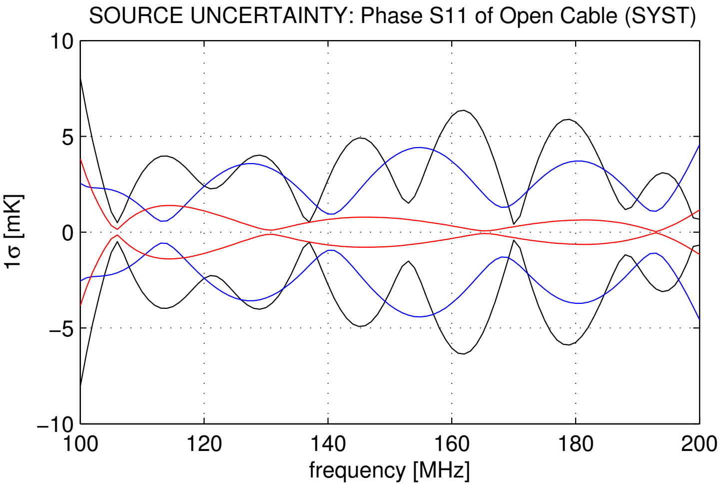

SOURCE UNCERTAINTY: Phase S11 of Open Cable (SYST)
10
5
0
–5
–10
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (26)

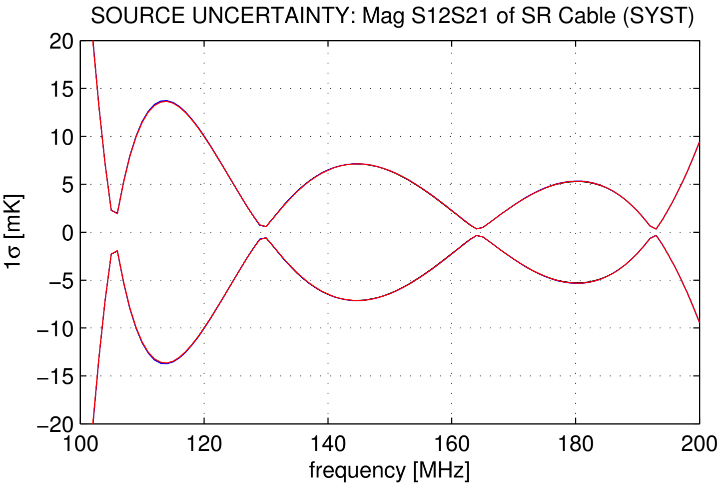

SOURCE UNCERTAINTY: Mag S12S21 of SR Cable (SYST)
1σ [mK]
frequency [MHz]
20
15
10
5
0
−5
−10
−15
−20
100
120
140
160
180
200

Figure : (27)

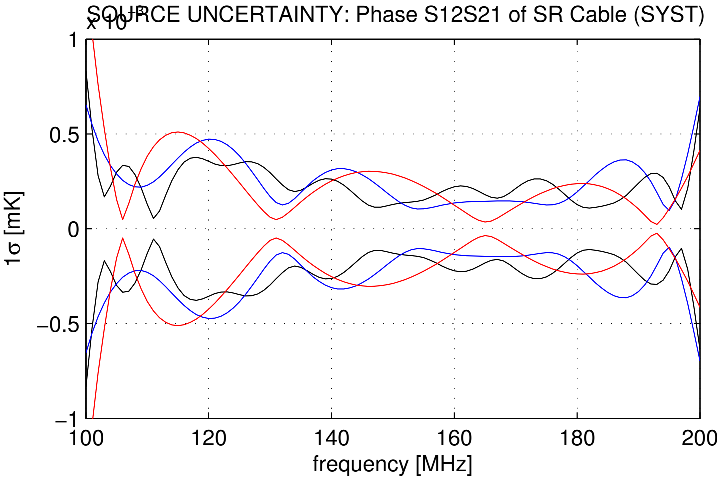

SOURCE UNCERTAINTY: Phase S12S21 of SR Cable (SYST)
x 10^-3
1
0.5
0
−0.5
−1
100
120
140
160
180
200
frequency [MHz]
1σ [mK]

Figure : (28)

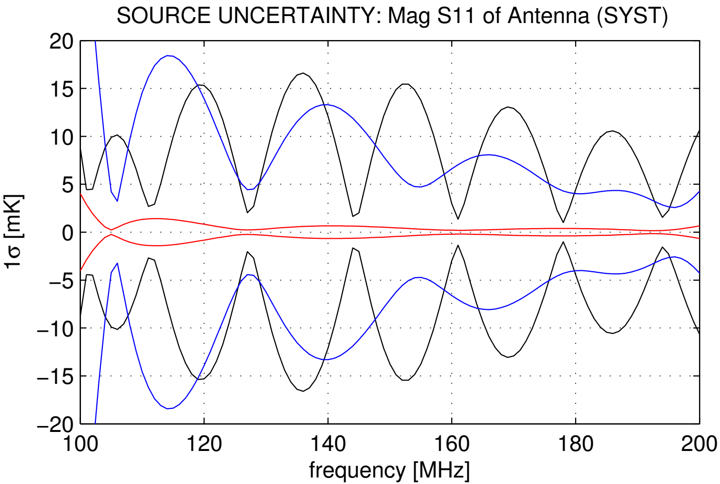

SOURCE UNCERTAINTY: Mag S11 of Antenna (SYST)
20
15
10
5
0
−5
−10
−15
−20
100
120
140
160
180
200
frequency [MHz]
1σ [mK]

Figure : (29)

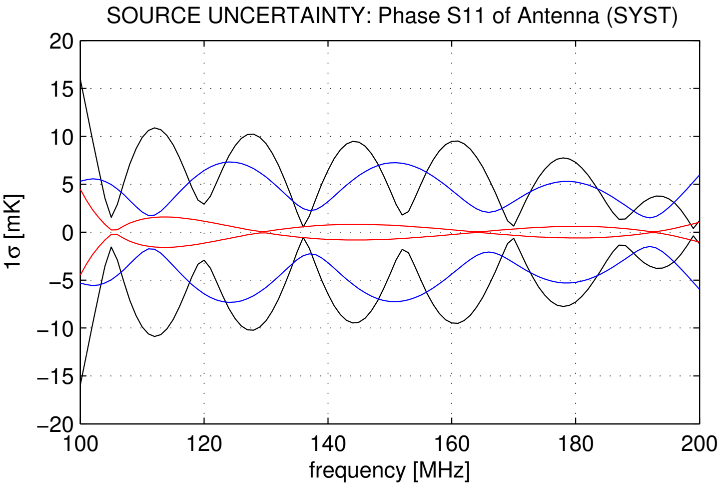

SOURCE UNCERTAINTY: Phase S11 of Antenna (SYST)
20
15
10
5
0
−5
−10
−15
−20
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (30)

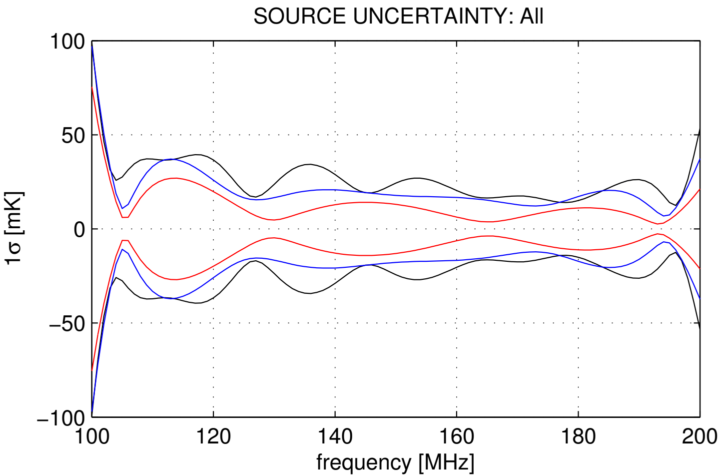

SOURCE UNCERTAINTY: All
100
50
0
−50
−100
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (31)

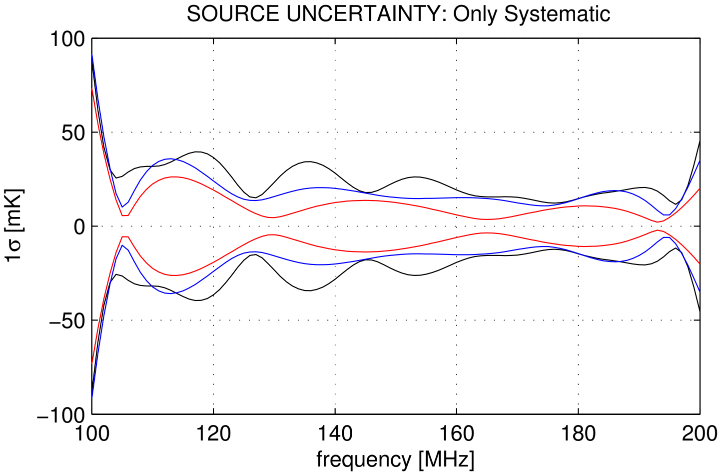

SOURCE UNCERTAINTY: Only Systematic
100
50
0
−50
−100
1σ [mK]
100
120
140
160
180
200
frequency [MHz]

Figure : (32)