EDGES MEMO #354

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Subject: Tests of instrumental errors on midband data from 2018 and 2020

The midband data from 2018 day 146 to 218 is analyzed in memo 287 in 4 hour blocks of GHA to obtain estimates of the feature center frequency, width and amplitude for a fixed flattening parameter of tau equal to 7 for a frequency range of 55 to 110 MHz. In order to improve the consistency of the feature parameters over GHA the frequency range is extended to cover 55 to 120 MHz. The sensitivity to instrumental errors is checked from the results of applying offsets and changes in filtering the S11 using data averaged over all GHA as in memo 352 which is relatively insensitive to beam correction error. Table 1 shows the results for changes to a reference case averaged over GHA with beam correction applied using the Haslam map with 9-term polynomial filtering of beam correction over 50 to 120 MHz. Figure 1 shows the results of a weighted least squares grid search for the "reference" feature center frequency, width, and amplitude at a fixed flattening parameter of tau equal to 7. Figure 2 shows the antenna S11 from 50 to 120 MHz with 13-term polynomial fit to smooth the S11.

change	amp K	SNR	center	width	rms mK	comments
reference	0.53	37.2	78.9	18.1	31	5-term physical S11 2018_147_16
foreground terms	0.63	30.9	78.5	19.1	43	5-term polynomial
foreground terms	0.55	37.1	78.9	18.3	31	5-term linlog
foreground terms	0.60	51.7	79.3	18.1	34	5-term loglog
foreground terms	0.54	28.3	79.9	21.4	19	6-term linlog
Ant S11 +0.05 dB	0.89	15.4	79.3	19.0	121	
Ant S11 -0.01 dB	0.47	25.9	78.5	18.0	38	sensitive to small offset
Ant S11 +50ps	0.46	31.9	80.5	17.6	36	
Ant S11 -50 ps	0.63	29.3	77.7	18.1	42	
LNA S11 +50ps	0.48	31.9	79.3	17.8	34	
S11 from 147_17	0.72	20.5	75.0	25.2	40	Ant S11 from 2018_147_17
No S11 smoothing	0.46	4.9	79.7	16.1	240	37-term Fourier series interpolation
S11 smoothing	0.58	32.8	78.5	18.8	35	12-term polynomial S11 smoothing
S11 smoothing	0.47	29.3	79.3	17.2	37	14-term polynomial S11 smoothing
with beam correction	0.55	33.2	78.5	18.3	35	Guzman map with 9-term filter
with beam correction	0.54	37.6	78.9	18.2	31	Haslam map with 12-term filter
no beam correction	0.65	20.3	77.3	19.2	56	needs restricted search range
without balun loss	0.63	38.4	79.5	22.1	18	

Table 1. Change in feature search results with changes in S11 and filtering needed for smoothing

These results show the high sensitivity to S11 accuracy with the need for smoothing and the best choice of the specific choice of antenna S11 to get low residuals in the feature search. The midband antenna has relatively high S11 below 65 MHz which makes midband more sensitive to S11 error than the lowband antenna. This sensitivity to S11 at the 0.01 dB level has also been checked using simulated data.

The midband data from 2020 day 54 to 174 is first analyzed by averaging over all GHA as in memo 352 in order to assess the systematic errors in calibration, antenna and LNA S11 errors and loss estimate errors. Figure 3 shows the results of a weighted least squares grid search for feature center frequency, width, and amplitude at a fixed flattening parameter of tau equal to 7. Figure 4 shows the antenna S11 from 60 to 120 MHz with 10-term polynomial fit to smooth out the instrumental ripples in the remote calibration present in VNAs discussed in memos 333 and 351. Figures 3 and 4 are for the "reference" case.

change	amp K	SNR	center	width	rms mK	comments
reference	0.53	28.9	79.5	22.5	20	5-term physical ant S11 from 090_16
foreground terms	0.18	13.9	87.7	10.0	35	5-term polynomial
foreground terms	0.51	25.1	79.5	23.2	22	5-term linlog
foreground terms	0.44	35.2	79.5	23.1	26	5-term loglog
foreground terms	0.54	28.3	79.9	21.4	19	6-term linlog
Ant S11 +0.05 dB	0.20	23.1	86.6	10.0	24	going to 6-terms needed
Ant S11 -0.05 dB	0.58	31.1	79.9	20.7	22	
Ant S11 +50ps	0.58	25.0	79.2	25.0	23	
Ant S11 -50 ps	0.53	28.3	79.9	20.4	23	
LNA S11 +50ps	0.58	26.6	79.2	25.0	22	
S11 from day 89	0.55	35.7	79.9	21.3	19	antenna S11 from 89_16
No S11 smoothing	0.49	5.9	77.6	27.1	84	37-term Fourier series interpolation
S11 smoothing	0.70	23.8	76.8	25.6	32	8-term polynomial S11 smoothing
S11 smoothing	0.44	23.4	80.7	20.7	22	12-term polynomial S11 smoothing
with beam correction	0.42	19.4	80.3	19.4	16	6-term linlog with beam correction
with beam correction	0.52	26.9	79.9	21.3	19	6-term linlog with Guzman map
without balun loss	0.63	38.4	79.5	22.1	18	

Table 2. Changes in feature search results with S11 and smoothing for midband data taken in 2020

In summary the results are very sensitive to S11 smoothing and choice of which S11 data was used. The rms fit to the antenna S11 in Figure 4 is 0.005 dB and 0.036 deg compared with 0.003 dB and 0.021 degrees for data taken for midband in 2018. The poor VNA performance in 2020 was the result of using a VNA with I/Q crosstalk. Another problem with the 2020 data that it is not possible to get reasonable residuals below 64 MHz.

The 2018 data looks better than the 2020 data. A feature search using the data averaged over all GHA can be found which is consistent with the Nature result but does require a choice of which antenna S11 data to use and the best choice of S11 smoothing. The beam correction for the narrower frequency range of the 2020 data is not needed and if used there is not a large difference on which map is used. The 2018 data needs beam correction for an unrestricted search range but it makes very little difference which map is used. For 5 foreground terms the "physical" terms for scale, spectral index, spectral curvature, ionosphere absorption and ionosphere emission give the best results. While the absorption features obtained from the

grid search for the data averaged over GHA from midband data obtained in 2018 and 2020 are consistent with the Nature result the added error introduced from the uncertainties in beam will make it difficult to get results consistent with the Nature result for all 6 separate 4 hour blocks of GHA without applying some constraints especially for the 2020 data which is limited by the antenna S11 data.

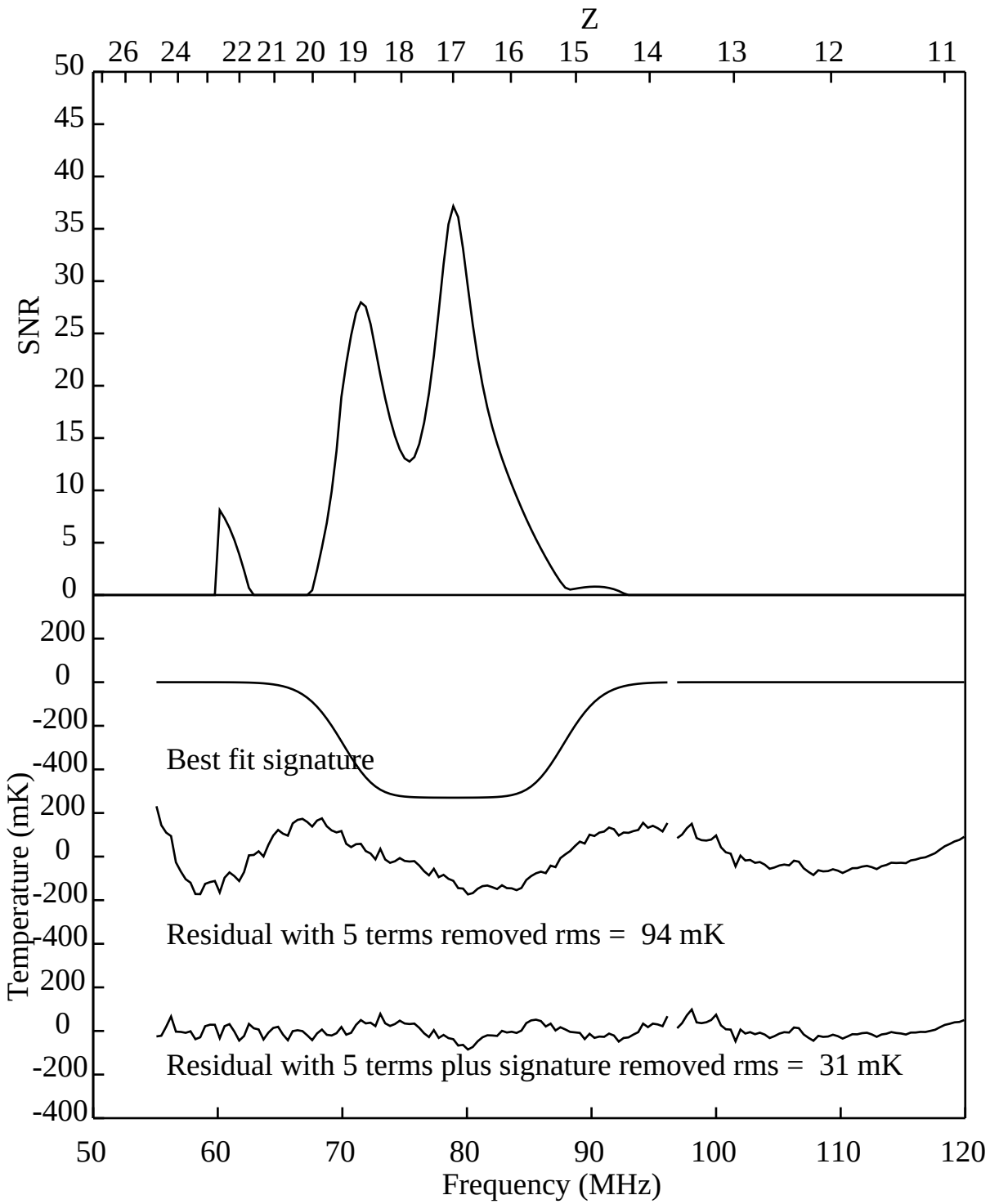

Figure 1. Weighted least squares grid search for feature using midband data from 2018 day 146 to 218 averaged over GHA. This is the “reference” case for the results in table 1.

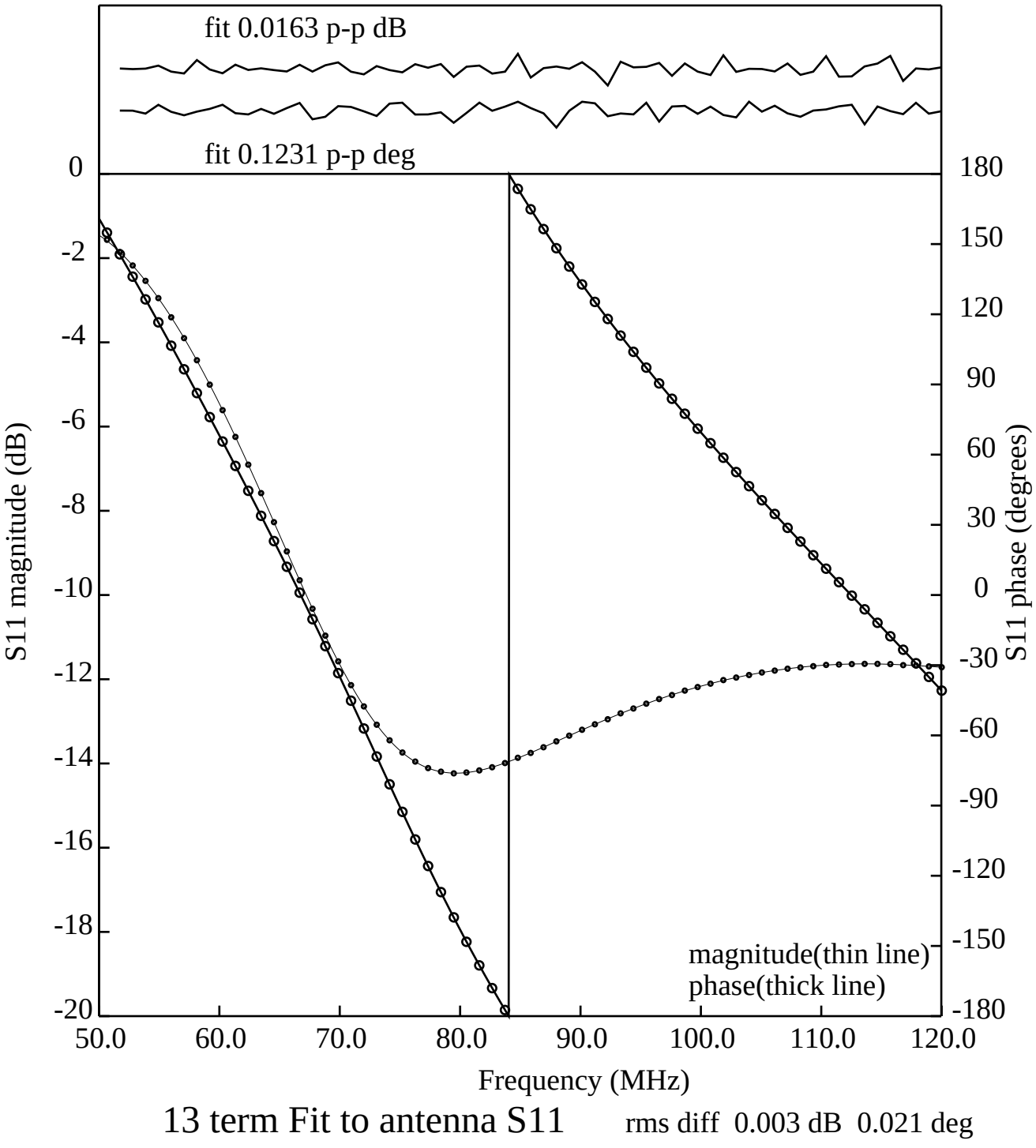

Figure 2. Antenna S11 used for the analysis of the 2018 “reference” case in table 1.

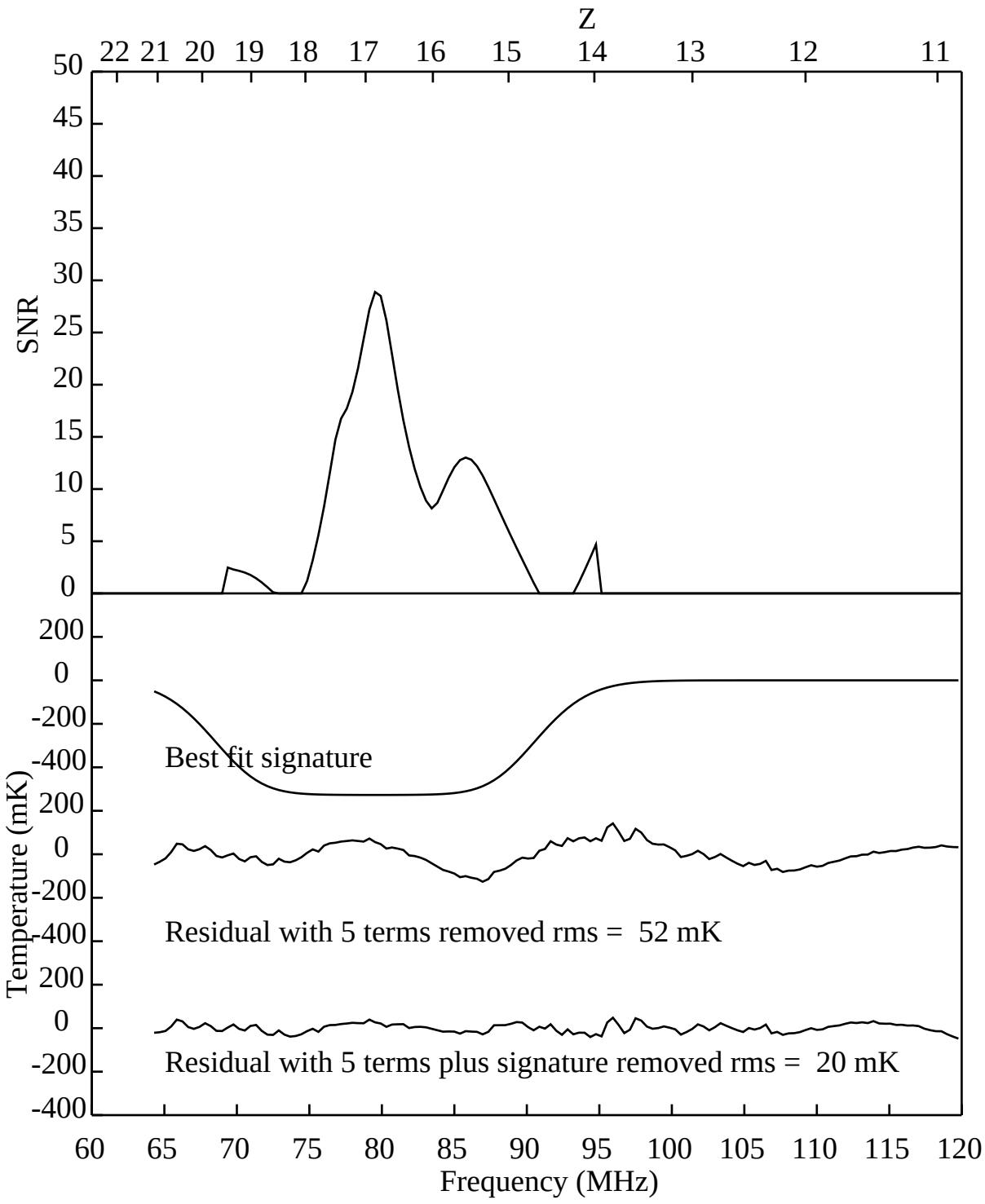

Figure 3. Weighted least squares grid search for feature using midband data from 2020 day 54 to 174 averaged over GHA. This is the “reference” case for the results in table 2.

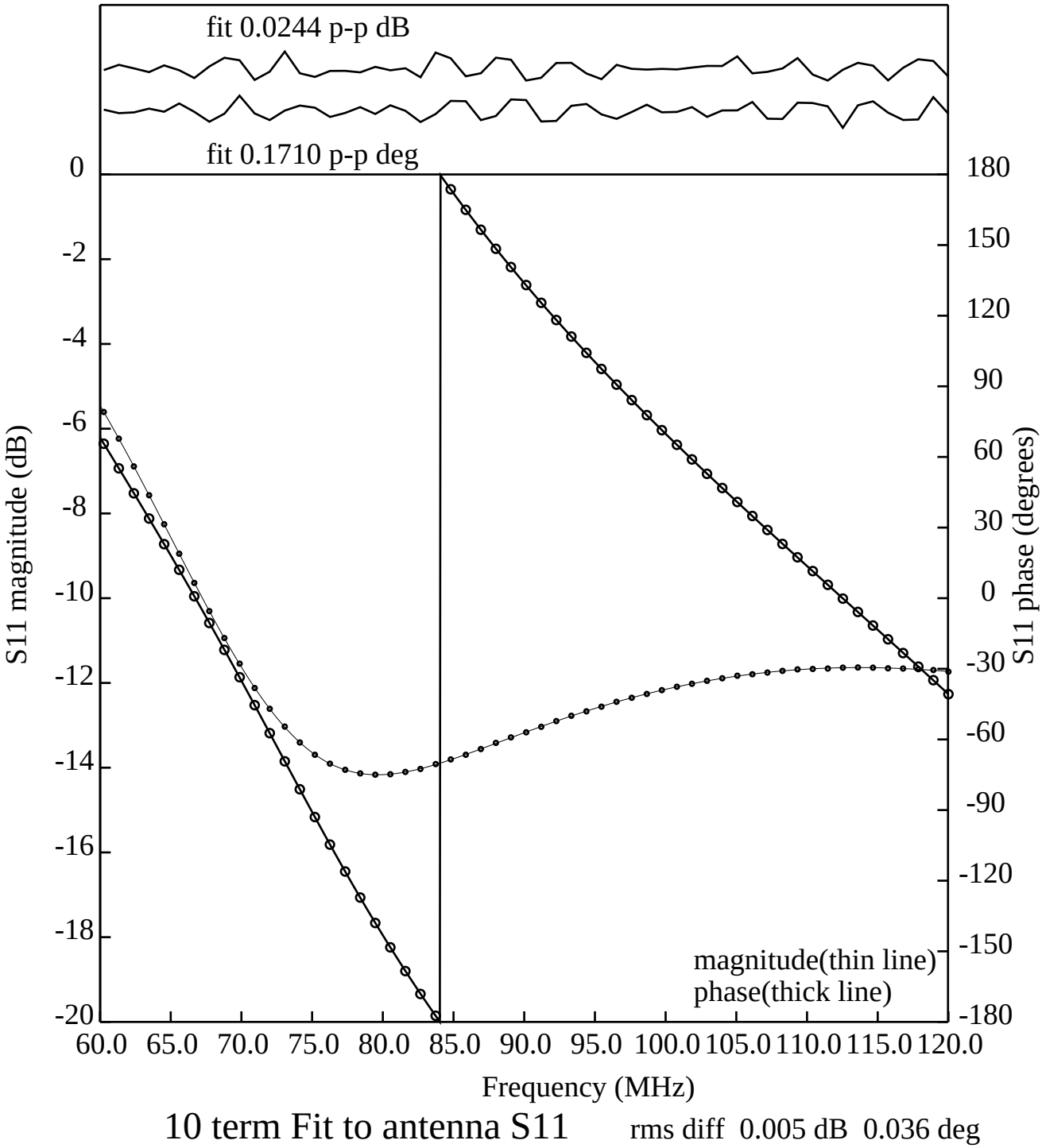

Figure 4. Antenna S11 used for the analysis of the 2020 “reference” case in table 2.