EDGES MEMO #434

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To: EDGES group
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Subject: FEKO tests of using RF switched rods to extend the low frequency coverage of EDGES-3

The use of adding rods to broaden the bandwidth of the EDGES-3 antenna is suggested in memo 410. FEKO is used to study the possibility that the rods can remain in place and be connected and disconnected with latched RF open/short switches. With switching, the rods can remain in place and be activated by an autonomous EDGES system.

The switching could be accomplished using Teledyne CCR-33S80 latched SPDT switches. These switches, two of which are already used in EDGES-3, have a very low contact resistance and a very high isolation. Being latched they only take a very small amount of power when being opened or closed. To minimize the complexity of the design I have chosen to use only a rod on each end of the antenna boxes to effectively extend the length of the antenna to provide better S11 at the low end of the 40-140 MHz band when the latched switches connect the rods to the antenna boxes.

The following tests are made using FEKO simulations:

a) A test with open switches shows that the rods have little or no effect on the antenna S11 and beam chromaticity without any rods in place.

b) A test with closed switches shows that the antenna S11 and beam chromaticity are very close to being the same as having the rods directly connected to the antenna boxes.

While these tests work the challenge is to find a design that truly leads to a better overall performance in measuring the 21-cm absorption profile.

A comparison of the beam chromaticity using 5-physical terms is made for various frequency scans is made in table 1.

antenna	55-95 MHz	50-100 MHz	50-120 MHz	60-100 MHz	60-130 MHz	70-130 MHz
EDGES-3	30 mK	92 mK	274 mK	22 mK	132 mK	65 mK
scaled by 1.2	41 mK	126 mK	538 mK	30 mK	804 mK	442 mK
scaled by 0.8	10 mK	32 mK	117 mK	9 mK	86 mK	33 mK
added rods	31 mK	92 mK	286 mK	24 mK	134 mK	66 mK
7cm added to box	35 mK	105 mK	322 mK	27 mK	156 mK	78 mK

Table 1. Average rms residuals with 5 physical terms removed for 24 1hr blocks over GHA at the WA

An EW orientation on an infinite PEC ground plane was used. What this table shows is that reducing the antenna size is needed to obtain a reasonable beam chromaticity and a scale factor of 0.8 gives the same antenna S11 for frequencies that are higher by a factor of 25% and this results in an unacceptably high S11 below 70 MHz. The last test in table 1 is for an antenna with antenna boxes increased in length by 7 cm and leaving other dimensions unchanged.

While adding rods to the current EDGES-3 antenna does make a small increase in beam chromaticity it achieves an antenna S11 that is improved the low end of the EDGES band as listed in table 2. However it is found that just scaling up the length of the antenna boxes by a factor of 1.1 achieves a slightly better improvement in S11 with only slightly higher beam chromaticity.

antenna	54 MHz	56 MHz	58 MHz	60 MHz
EDGES-3	-7.1 dB	-8.4 dB	-9.9 dB	-11.5 dB
EDGES-3 plus rods	-9.0 dB	-10.6 dB	-11.8 dB	-12.6 dB
7cm added to box length	-10.0 dB	-11.4 dB	-12.3 dB	-12.6 dB

Table 2. Low end antenna S11 with added rods

Figure 1 shows the full range of S11 for an EDGES-3 antenna with increased box length from 73.4 to 80.4 cm.

The next test simulates sky noise data with the Nature feature added to the sky and the simulated data processed with some instrumental errors applied. The sensitivity S11 errors is summarized in the figure in memo 368. These results are with perfect beam correction and no noise is added so that rms2, which is the rms after fitting an absorption, is entirely due to receiver systematics from antenna S11 error.

antenna	center MHz	snr	amp K	width MHz	rmsin mK	rms2 mK	freq range MHz	offset dB	delay ps
EDGES-3	77.7	34	0.41	19.8	37	10	60-100	-0.1	0
scaled by 0.8	90.2	21	0.87	17.0	95	41	60-100	-0.1	0
scaled by 1.2	78.1	101	0.46	19.1	43	4	60-100	-0.1	0
with rods	77.7	49	0.44	19.5	39	8	60-100	-0.1	0
with 7cm added	77.7	53	0.44	19.5	39	7	60-100	-0.1	0
EDGES-3	80.1	23	0.92	19.6	177	85	55-120	0.1	0
with rods	79.7	27	0.77	19.2	142	61	55-120	0.1	0
with 7cm added	79.3	28	0.78	19.3	137	56	55-120	0.1	0
EDGES-3	79.7	24	0.58	18.6	111	56	55-130	0.05	0
EDGES-3	79.7	40	0.68	20.2	95	31	55-130	0	30
with 7cm added	79.3	33	0.53	18.5	94	36	55-130	0.05	0
with 7cm added	76.6	40	0.69	20.1	97	32	55-130	0	30
with 12cm added	78.9	45	0.52	18.6	87	26	55-130	0.05	
with 12cm added	77.0	40	0.69	20.1	98	32	55-130	0	30
EDGES-3	57.0	20	1.67	10.0	208	126	52-140	0.05	0
with 7cm added	80.1	24	0.73	19.9	156	84	52-140	0.05	0
with rods	80.1	22	0.75	20.0	163	91	52-140	0.05	0

Table 3. Grid search for absorption for simulated data from 1 hour data at 12hr GHA at MRO

Increasing the length of the antenna boxes by 7 cm gives about the same improvement as the more complex addition of rods suggested in memo 410. It would be possible to make a much larger increase in bandwidth by using multiple scaled antennas as the “SAFARI” project being developed by Bang Nhan and Richard Bradley as discussed in memo 426.

Figure 2 shows a plot of the result for the second to last entry in table 3. This case is also shown without beam correction in figure 3 using 7 loglog terms to get reasonable agreement with the Nature feature. This case emphasizes the problem of the antenna being too large in wavelengths to obtain low

beam chromaticity at the high end of the band and consequently limits the bandwidth that can be obtained with a single antenna. One solution to this problem is to make the antenna electrically small but now the limitation is noise due to the low efficiency and the increased S11 accuracy needed with a poor match as was the case for getting only a marginal confirmation of the Nature result using high band data in memo 275. The use of a cone under the EDGES-3 was studied in memo 323 to get a frequency coverage of 60-180 MHz but the non-planar structure of the cone results in vertical currents that introduce some vertical polarization which increases scattering effects. Some tests were made with planar disks instead of a cone but resonances were introduced.

In summary if we are limited by VNA accuracy or other receiver systematics an increase in box length of 7 to 12 cm would reduce this sensitivity at the low end of the band with little increase in beam chromaticity. More optimization simulations are needed as a reduction of the box height, if it can be accommodated by the new electronics, will also make a small additional improvement.

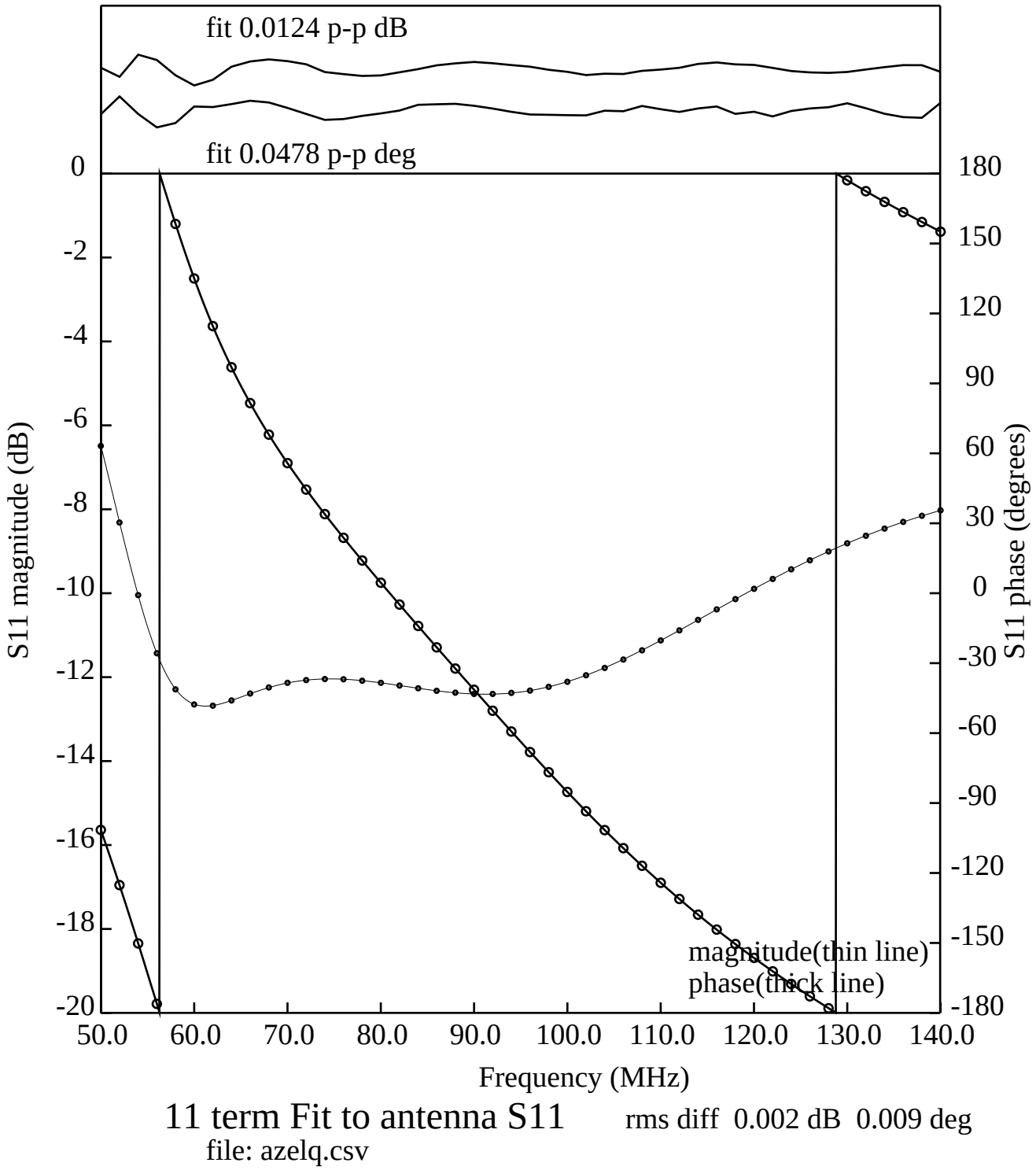

Figure 1. S11 for the EDGES-3 antenna with box length increased from 73.4 to 80.4 cm.

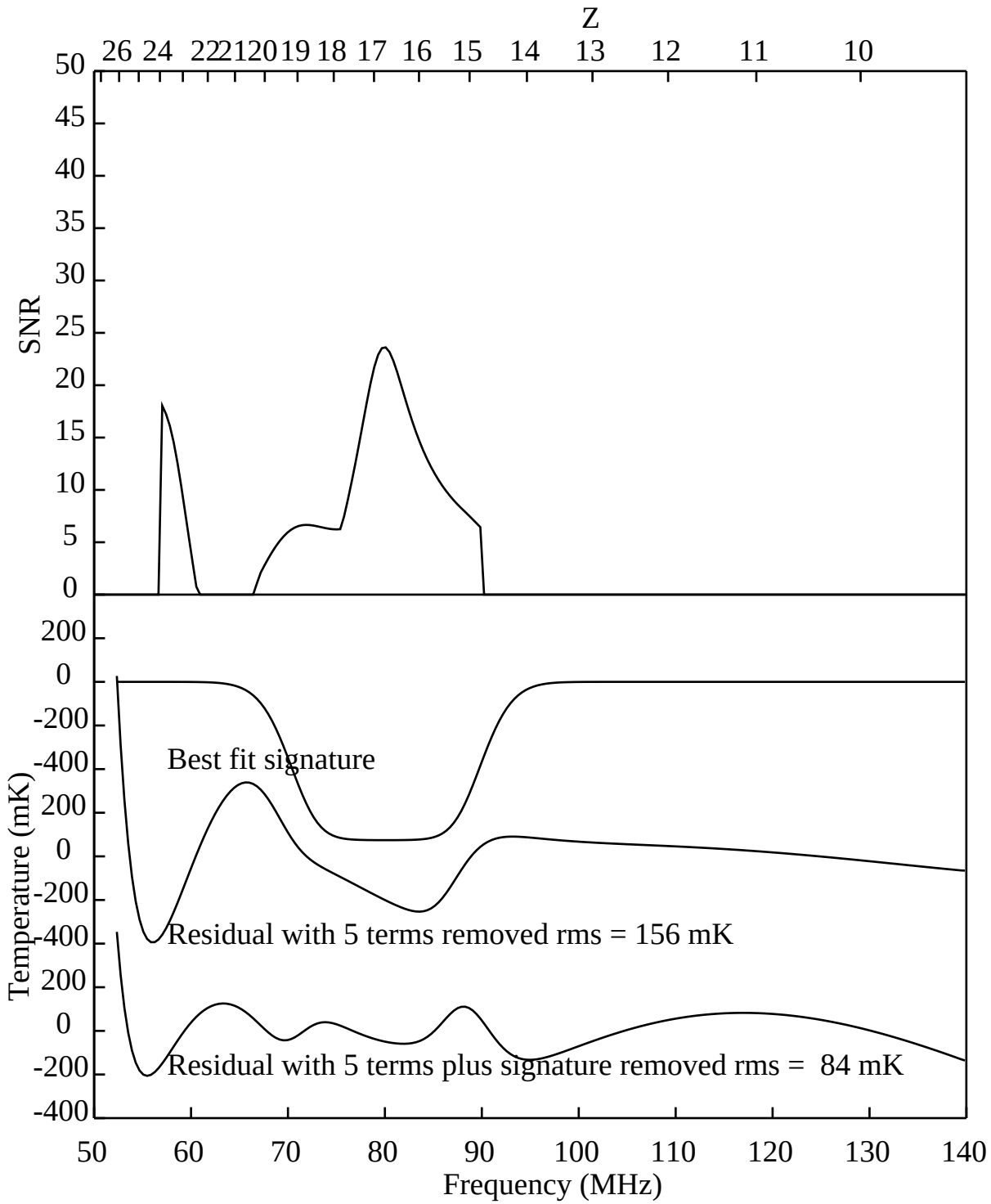

Figure 2. Grid search plots for case of increased box length with a 0.05 dB offset in antenna S11.

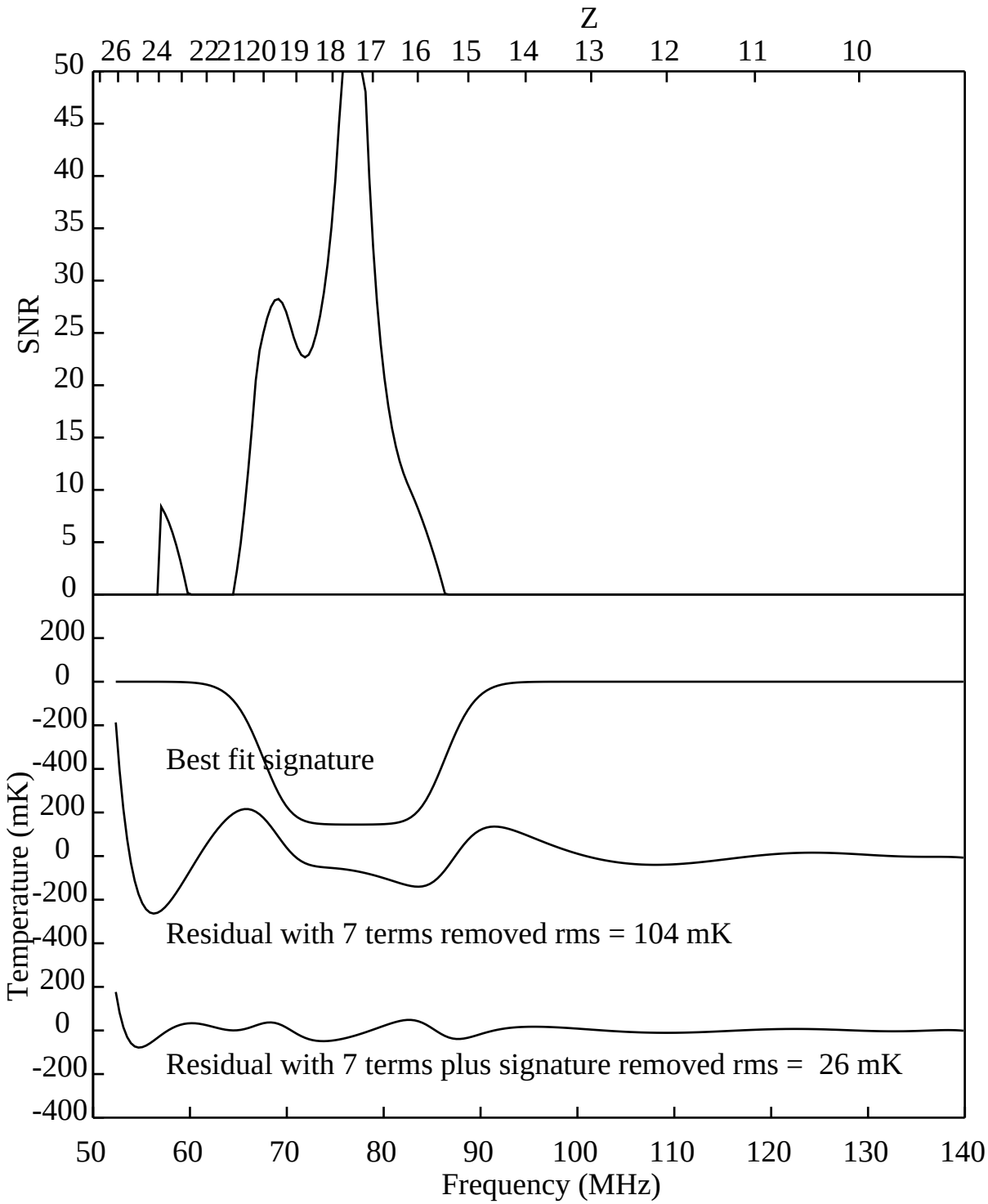

Figure 3. Grid search plots for case in figure 2 without beam correction in addition to 0.05 dB offset.