EDGES MEMO #433

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November 6, 2023

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To: EDGES group
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Subject: Simulations of an impedance analyzer compared with a VNA for EDGES S11 measurements

A comparison of “benchtop” Impedance and Vector analyzers has been made by Masahiro Horibe in a paper entitled “Performance comparisons between impedance analyzers and vector network analyzers for impedance measurement below 100 MHz frequency”. This shows that for low frequencies an impedance analyzer may provide higher accuracy than a VNA at low frequencies. A “handheld” impedance analyzer covering frequencies up to 300 MHz is available from LBA technology. The data sheet for the LBA TE3000 lists an accuracy of +/- 0.2 percent in amplitude and +/- 0.2 degrees of phase in the measurement of an impedance of 50 ohms with an increase in rms error in amplitude and phase by a factor of about 10 for impedance down to 10 ohms or up to 1000 ohms. The EDGES-3 antenna and LNA have impedance close to 50 ohms so I have used the LBA TE3000 accuracy at 50 ohms to make a simulation as follows:

1] Simulate sky noise data using an EDGES-3 calibration and antenna S11 to simulate sky noise data from the WA using the Haslam map with the Nature 218 feature added.
2] The antenna S11 data is converted to impedance and a constant amplitude and phase along with a Gaussian amplitude and phase for which the “srand” state can be changed for each GHA data block.
3] The impedance is then converted back to S11 and the simulated data is then processed.

Table 1 below shows the results of the simulations for 1 hour blocks of data from 8 to 16 hr GHA using 5 physical terms from 55 to 100 MHz. amp and phase are constant errors and Gamp and Gphase are errors with a Gaussian distribution over frequency with different “srand” initialization for each hour. Case A is zero error, case B the last test simulation of impedance errors and case C is for a VNA with fractional errors and noise in the magnitude and phase of the S11 of 1e-3 which corresponds to a vector fractional accuracy of 1.4e-3.

case	center MHz	SNR	sig K	width MHz	rmsin mk	rms mk	amp percent	phase deg	Gamp percent	Gphase deg
A	78.1	inf	0.50	19.0	71	0	0	0	0	0
	78.1	180	0.53	18.9	78	5	0.2	0	0	0
	78.1	180	0.53	18.8	78	5	0	0.2	0	0
	77.7	37	0.47	20.9	57	16	0	0	0.2	0
	78.9	34	0.51	17.1	93	28	0	0	0	0.2
	78.1	119	0.57	18.8	84	8	0.2	0.2	0	0
	71.9	28	0.97	29.9	88	31	0.2	0.2	0.2	0.2
	78.5	51	0.52	18.3	83	17	0.2	0.2	0.1	0.1
	78.5	38	0.45	18.5	72	20	0.2	-0.2	0.1	0.1
	78.5	37	0.45	18.4	72	20	-0.2	0.2	0.1	0.1
B	78.5	25	0.38	16.6	63	24	-0.2	-0.2	0.1	0.1
C	77.0	25	0.66	20.9	82	33	-0.1	-0.36	0.1	0.36

Table 1. Results of a absorption grid search with antenna S11 errors

Figure 1 shows the the residuals prior to fitting an absorption for each GHA and Figure 2 shows the absorption fit. Both figures are for case B of table 1.

These simulations show that the specified error in the LBA TE3000 is good enough to justify acquiring this impedance analyzer for further tests as long as the noise can be reduced to under 0.1% in amplitude and 0.1 degrees of phase. The average power consumption of the LBA TE3000 is about 7.5w and is expected to be less sensitive to temperature changes than a VNA but there is no information on the temperature sensitivity in the datasheet. Having a low "warm-up" is important for remote deployments of EDGES. Tests of a handheld VNA are described in memo 263 and amelioration of warm-up drift by rapid switching of the VNA from device to SOL calibration is described in memo 411.

References:

Horibe, M., 2017, June. Performance comparisons between impedance analyzers and vector network analyzers for impedance measurement below 100 MHz frequency. In *2017 89th ARFTG Microwave Measurement Conference (ARFTG)* (pp. 1-4). IEEE.

https://www.lbagroup.com/products/te3000-lf-vhf-portable-precision-rf-impedance-network-analyzer

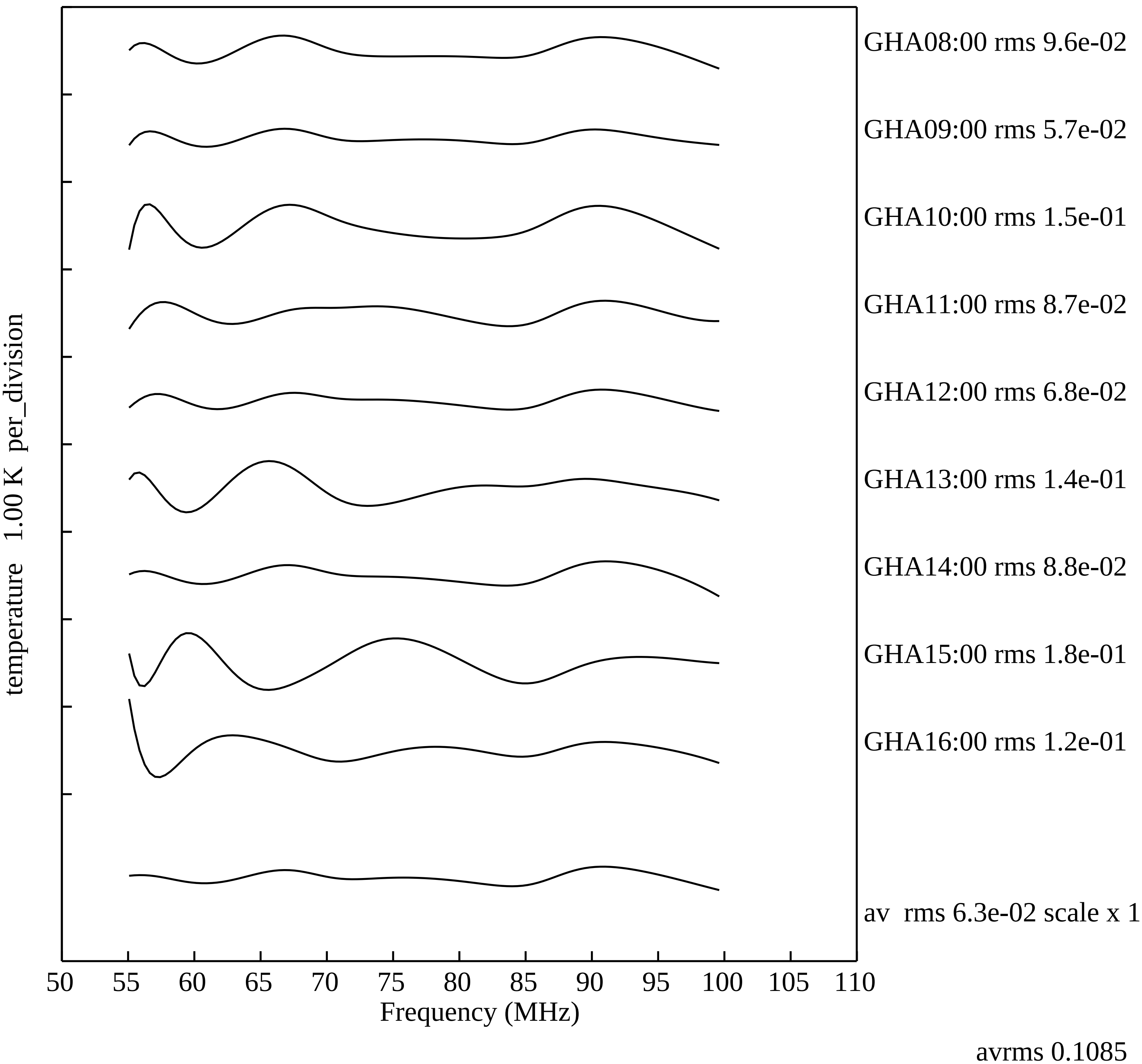

Figure 1. Residuals with 5 physical terms removed for the simulation of case B in table 1.

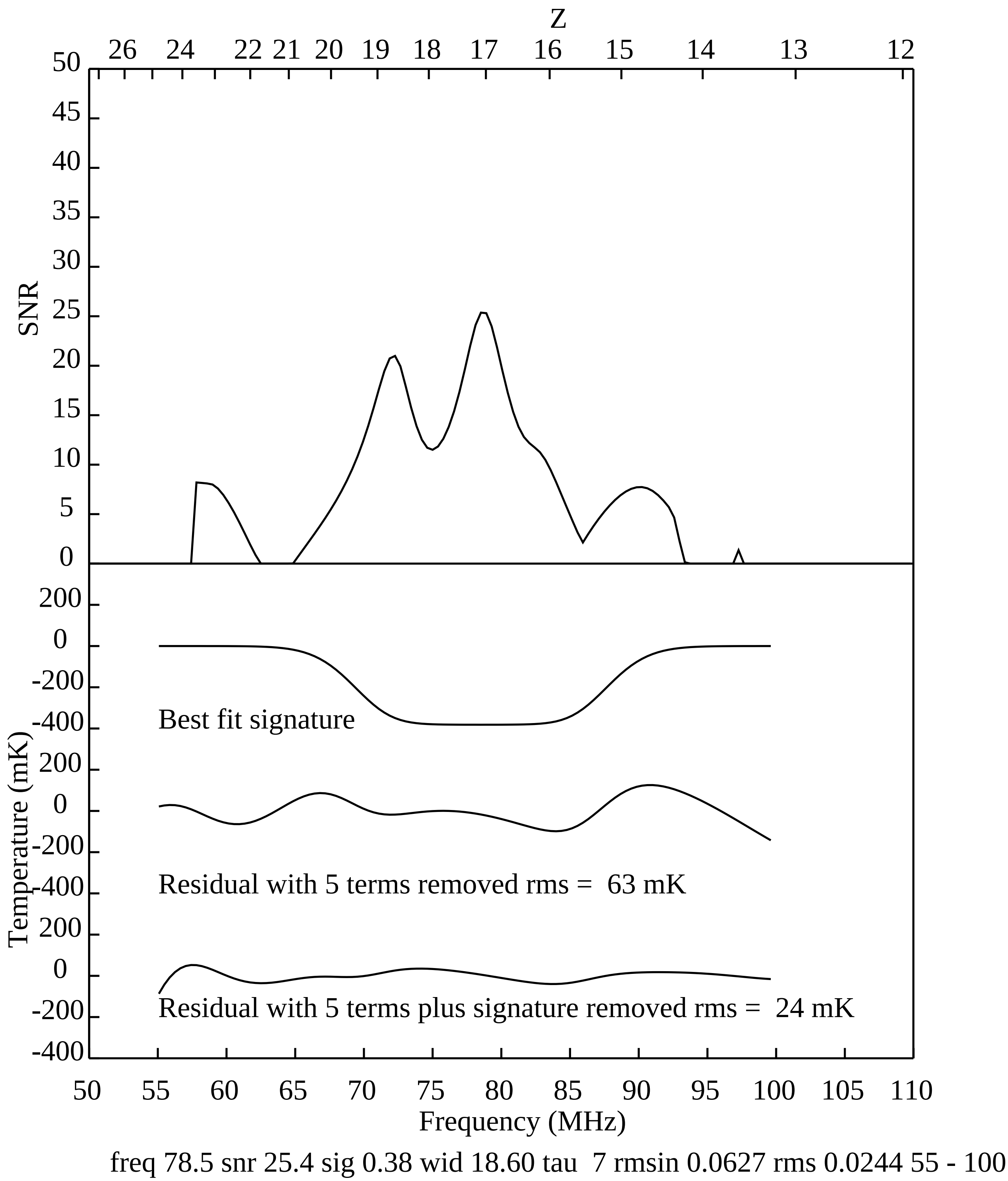

Figure 2. Grid search for case B the best fit absorption for a flattening parameter of tau = 7.