EVLA Memo #233

VLA 4m-band Power Interference AGM-60 Line Filter Test Results

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Abstract

The very low band (4m wavelength) system of the EVLA covers a frequency range of 54-86 MHz with a typical channel resolution of 15.6 kHz. Reaching ~100 mJy sensitivity (~1h integration) and ~25'' of angular resolution enables a wide variety of science study cases such as galactic supernova remnants, radio galaxies and galaxy clusters. Given that most of the high power analog TV channels are absent these days, external narrow-band RFI is not a major concern in this band at this time. However, internal to the array RFI is present and it is self-generated at the antennas with a major contributor identified to be the antenna control units (ACUs), causing a broad-band RFI modulated with 60 Hz and harmonics of from alternate current (AC) power distribution, which is seen across the entire band. Over the course of many years, tests have identified a major contributor to this interference being generated by the AGM 60 unit in each antenna to varying degrees and signals being picked up by the antenna dipoles, including by neighboring antennas. This has the effect that this interference signal correlates and causes high amplitudes in the resulting data products. This renders short baselines unusable for science observing with the 4m-band system and significantly degrades the achievable performance of the overall system. To address this issue, an attempt was made to equip the ACUs with line filters. Here, we present the results and impact of inserting line filters at the AC input and DC output side of the AGM 60 at antenna ea10.

Line Filters

Electronic filters were used and installed in the AGM 60 (Absorbed Glass Mat) - 48V DC power system (Figure 1) part of antenna ea10. The AGM 60 both serves as a rectifier for a three phase AC input to -48V DC and controls/connects to backup batteries to bridge brief power outages. The so-called line filters are usually placed between the utility power input and the internal circuitry of electronic equipment in order to attenuate the radio frequency interference (RFI). We used both AC and DC line filters such as the ones shown below in Figure 2. The total cost including all the box assemblies and cables was estimated to be around $1,000. A more detailed description of the required parts and their cost estimate can be found in Table 1.

Figure 1. AGM-60, the DC power supply.

Testing

The installation of the filters at ea10 took place on 2023/09/06 and the tests were performed at the same date. Prior to and following the filter installation, we took data at 4m-band (under the TSUB0001 program) including auto-correlations of ea10. The array was pointed at zenith and we let the observing script run for about 20-30 minutes before and after installation. We used 256 channels with 15.62 kHz width each span over 54 to 79.99 MHz and 7 spectral windows. Details of the observations can be seen in the log below, Figure 3.

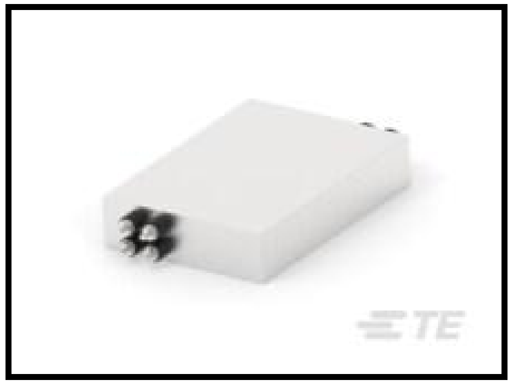

Figure 2. Examples of the AC and DC filters used in this experiment. **Left:** FN7612-32-M4 AC filter, **Right:** 60DCB6F DC filter.

Product	Type	Quantity	Item cost ($)	Total Cost ($)
FN7612-32-M4	AC Line filter	x3	150.32	450.96
60DCB6F	DC Line Filter	x1	256.29	256.29
SMH SY350A-600V	Heavy 2 pole connector	x2	17.60	35.20
4 AWG	Black	x12	1.72	20.64
4 AWG	Red	x12	1.72	20.64
Conductor Cable		x5	1.42	7.10
ASL630P-BK	L6-30 30A 250V Plug	x1	17.99	17.99
FML630R	L6-30 30A 250V Receptacle	x1	25.99	25.99
Enclosure	AC Filter enclosures	x1	22.50	22.50
Enclosure	DC Filter enclosures	x1	33.95	33.95
Miscellaneous	e.g: screws			
Total Estimate				891.26

Table 1. A detailed description of the required parts and their cost estimate per antenna.

```
4band.ms
Observer:                   Dr. Frank Schinzel
Telescope:                  EVLA
Project:                    uid://evla/pdb/1695465
Beginning of Observation: 2023-09-06 16:17:03.000 (ISO) -- 60193.67850694445 (MJD)
Observation length:         1234.0s (0.34 h)
Mean integration time:      2.0 s
Number of correlation
polarization products:      [4]

ROW   ID    NAME          RA            DEC
0     0     Zenith        12h00m00s     86d00m00s

ROW   CHANS          WIDTH[MHz]          REF_FREQ[MHz]
0     256            0.015625            54.0
1     256            0.015625            58.0
2     256            0.015625            62.0
3     256            0.015625            66.0
4     256            0.015625            70.0
5     256            0.015625            74.0
6     256            0.015625            78.0
```

Figure 3. Observations log of the tests taken after installing the line filters at the antenna ea10.

Results

In Figure 4, we present the waterfall plots showing the spectrum of ea10 using auto-correlations. The left plot shows data before the filter installation while the right plot shows data after the line filter installation. The contrast and the scaling are fixed to the same level for both plots in order to be visually directly comparable. It is clearly noticeable that the general power levels in cross-correlations is lower after installation of the filters. The frequency range between 62 MHz to 78 MHz is not dominated anymore by the internal self-generated broad-band interference, which has been filtered out.

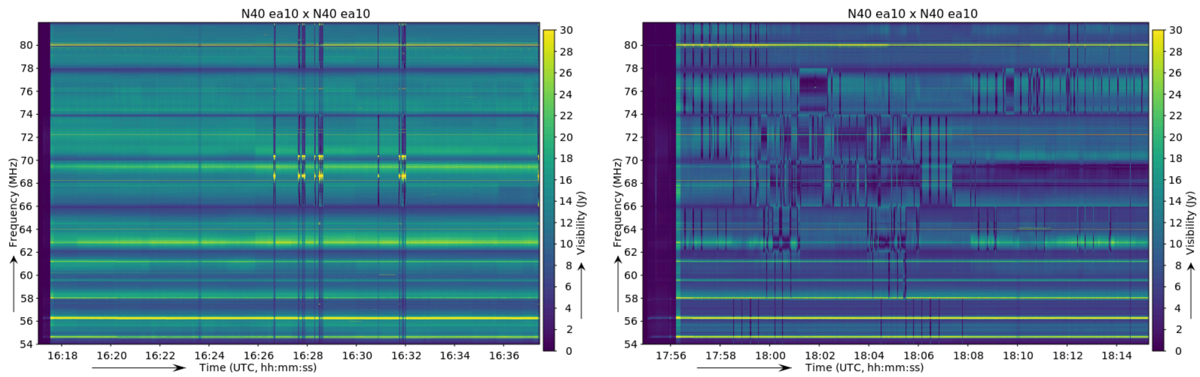

Figure 4. Dynamic spectra of antenna ea10 auto-correlations. Frequency as a function of time, coloured by intensity. **Left:** ea10 auto-correlations before the installation of the line filters. **Right:** ea10 auto-correlations after installing the line filters.

Similarly, we show below in Figures 5 and 6 the cross-correlations between antenna ea10 that hosts the line filters in the AGM 60 and two of the neighbor antennas, ea14 and ea18. We compare the bandpass of the two baselines (ea10&ea14 and ea10&1ea18) before and after the filter installation at ea10. The bandpass spectrum seems to be smoother and frequency-dependent distortions are reduced after the installation of the filters even at only one of the antennas of each baseline. Especially, notice that the cross-correlation power levels have dropped below that of the parallel hand correlation products.

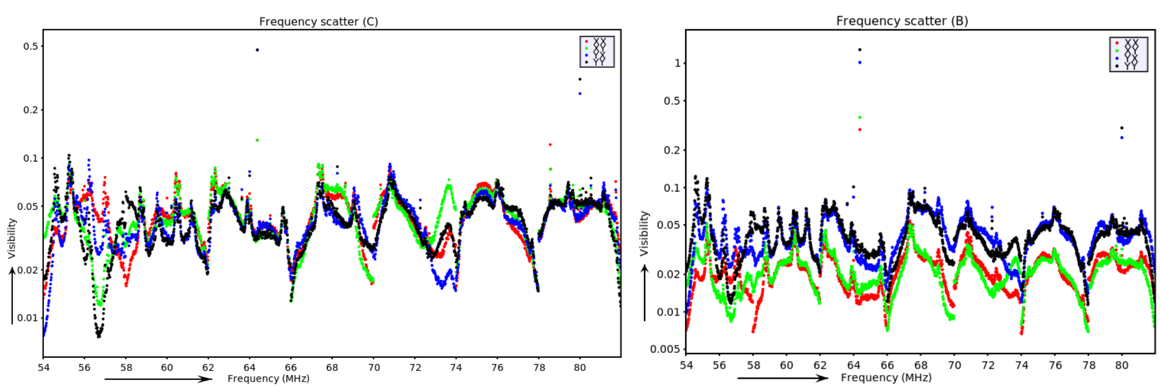

Figure 5. Bandpass spectrum of the baseline consisting of ea10 and ea14. The four correlation products are also plotted, in red is the XX correlation, in black the YY, in green the XY and the YX in blue.
Left: ea10 & ea14 bandpass spectrum before the installation of the line filters. **Right:** ea10 & ea14 bandpass spectrum after installing the line filters.

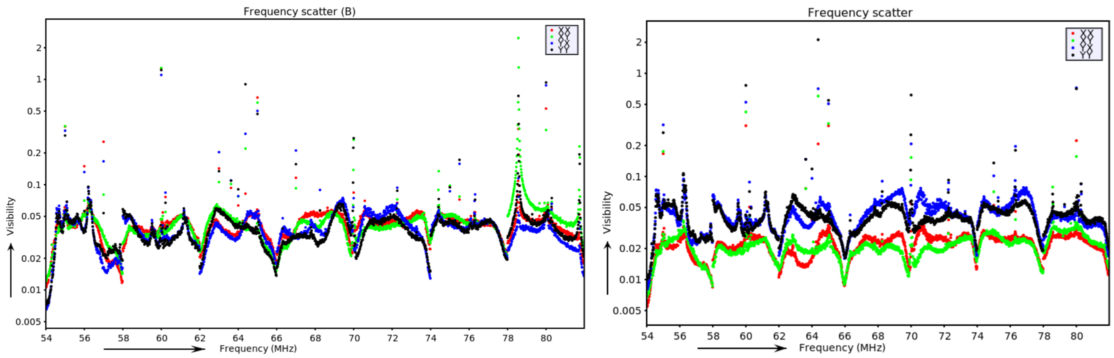

Figure 6. Bandpass spectrum of the baseline consisting of ea10 and ea18. The four correlation products are also plotted, in red is the XX correlation, in black the YY, in green the XY and the YX in blue.
Left: ea10 & ea18 bandpass spectrum before the installation of the line filters. **Right:** ea10 & ea18 bandpass spectrum after installing the line filters.

Figure 7, shows the spectrum caught by the spectrum analyzer at the ea10 in front of the AGM 60 power supply box before the filter installation and after. It is centered at 75MHz. The spectrum got better at the central frequency and it is "free of the frequency dependent distortions, large amplitude ripples, especially below 76 MHz. The spectrum after filter installation is flat and relatively smooth above 40 MHz and the noise floor is up to 20 dB lower.

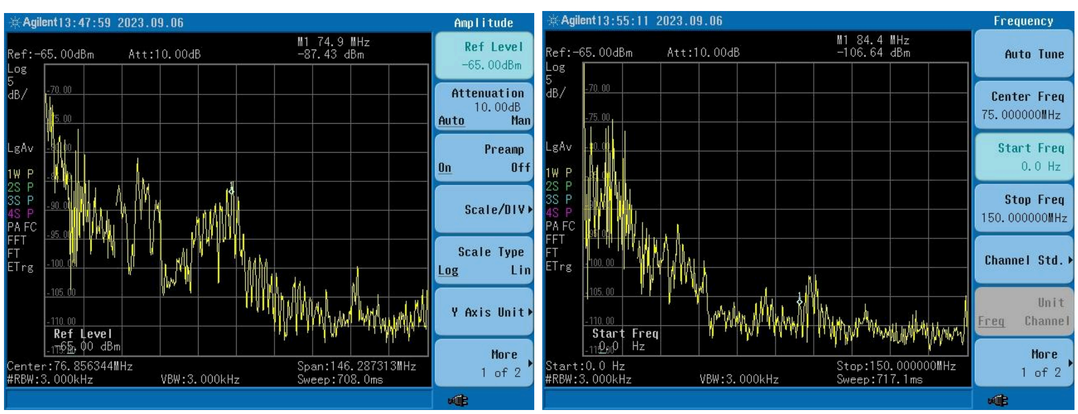

Figure 7. Spectrum was captured from the ea10 using the spectrum analyzer, before (left), and after the filter installation (right). The frequency center is 75MHz.

Summary

We presented the results of successful tests performed at the antenna ea10 using line filters in order to attenuate a significant fraction of broad-band power interference picked up by the low-band dipoles on the VLA antennas and confirm that the identified antenna self-generated interference is due to the AGM 60. Data were taken before and after the installation of the filters and they show an improvement at the 4m band spectrum for both the auto and cross correlations, with a drop of the noise floor at each antenna of around 20 dB. The cost in parts per antenna is estimated to be around ~$1000. Exact cost estimates of each part used are available and they may be useful for a potential future installation to the rest of the VLA antennas.

Acknowledgements

We acknowledge help from operators coordinating the tests and running the scripts. We are grateful to the Front End group for helping us perform those tests by putting everything together and installing the AC-DC line filters.