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Post-amplification Module (PAM) Attenuation and Status

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ABSTRACT

This document summarizes the work to adjust the antenna autocorrelation power and query the status of PAM and SNAP.

1. INTRODUCTION

Ideally, antennas in the HERA array should have the correct auto-correlation power level. Analog systems require certain input power ranges to achieve the anticipated performance. This memo describes the work to adjust the antenna power to the designed value, and how the status of the system is queried.

The post-amplification module (PAM) has a tunable attenuator with a 16 dB dynamic range. Each antenna has two PAM attenuation values to adjust for two polarizations. The attenuation setting on PAM can be adjusted remotely and is our main tool to bring the antenna power to the designed value. This document describes how the operation is performed in detail.

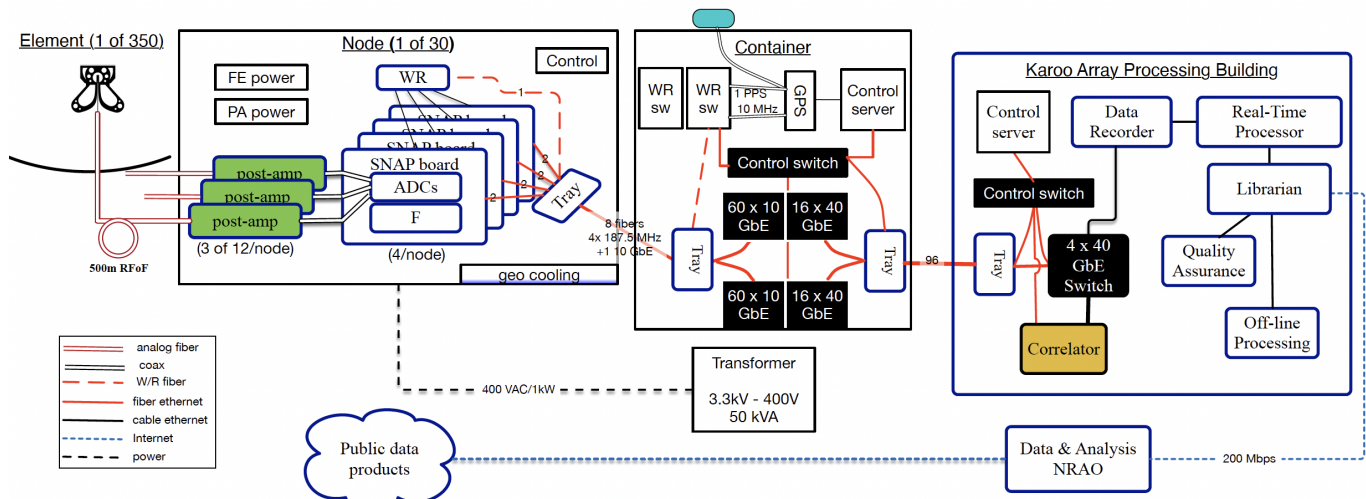


Figure 1. HERA system (DeBoer et al. 2017). The post-amplification module (PAM) and Smart Networked Analog-Digital Processor (SNAP) board are shown in the box on the left.

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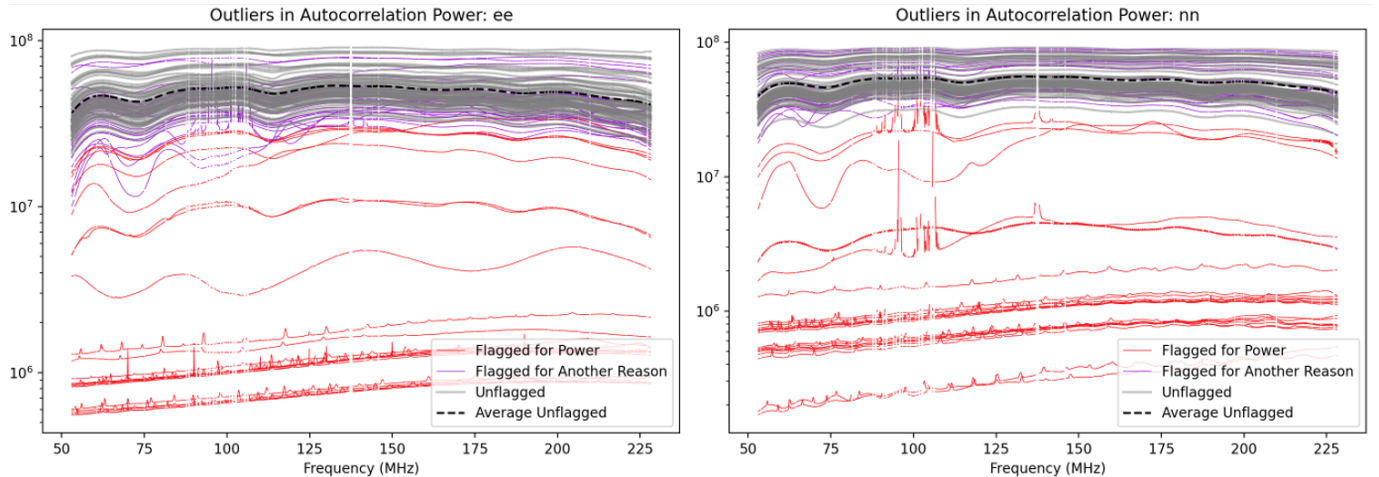


Figure 2. Antenna autocorrelation spectra before adjustment. The two panels show the East-West (ee) polarization and the North-south (nn) polarization. The antenna power spreads across one order-of-magnitude before PAM attenuation adjustment. Also seen are some autocorrelation bandpass with abnormal shape, those are the antpols in non-ideal operation conditions. Color coding of the lines is shown in the legend.

During site work, the status of the array needs to be closely monitored to guide the site operations. We introduce the way we query the status of PAM and Smart Networked Analog-Digital Processor (SNAP) boards.

2. ADJUSTING ANTENNA POWER

HERA has 350 antennas, each antenna has two polarizations. In principle, there are 700 attenuation values to be adjusted. We coin the term *antpol* to specify a certain antenna and its specific polarization.

2.1. Automatic Adjustment

The raw data are spectrum for each antpol, we use the median to represent the power level. This power level is compared with an *absolute target value* to calculate a desired attenuation adjust. Then we can query the related PAM for the current attenuation setting. The current setting plus the desired change is the target we are adjusting the attenuation to. However, the target attenuation is not always within the 0–15 attenuation range. In those cases, we set the attenuation to the closest end (0 or 15). This operation is automated via a script which makes the adjustment for all antpols¹. The script runs within minutes to change hundreds of antpols.

The automatic script adjusts most of the antpols to the desired power level. However, using the median to represent overall spectrum power level introduces errors, especially when the overall spectral shapes are significantly different. Figure 2 shows the ensemble of autocorrelation spectra. Most of them have similar spectral shape while a small fraction does not (mainly at the bottom of Figure 2). In addition, the target attenuation value can be outside the 0–15 attenuation range. The above two situations are signs of instrument malfunctioning which will be discussed in a separate memo.

¹ GitHub Link to the script: https://github.com/HERA-Team/HERA_Commissioning/blob/master/scripts/snaphead/setting_pam_attenuation.py

```
#####
[Antenna? 107
107 e
107 e from 11 to 10
[Take action? (y/n): y
2022-11-07 17:33:30,411 - hera_corr_f.hera_corr - INFO - Setting PAM for (107,e)
2022-11-07 17:33:30,449 - hera_corr_f.hera_corr - INFO - Commanding (107,e) PAM atten=10 dB in redis
Action taken.
107 n
107 n from 10 to 9
[Take action? (y/n): y
2022-11-07 17:33:32,031 - hera_corr_f.hera_corr - INFO - Setting PAM for (107,n)
2022-11-07 17:33:32,067 - hera_corr_f.hera_corr - INFO - Commanding (107,n) PAM atten=9 dB in redis
Action taken.

#####
[Antenna? 97
97 e
19 attenuation is requested.
97 e from 15 to 15
Action NOT taken.
97 n
97 n from 9 to 9
Action NOT taken.

#####
[Antenna? 205
205 e
19 attenuation is requested.
205 e from 15 to 15
Action NOT taken.
205 n
205 n from 12 to 10
[Take action? (y/n): y
2022-11-07 17:33:42,591 - hera_corr_f.hera_corr - INFO - Setting PAM for (205,n)
2022-11-07 17:33:42,629 - hera_corr_f.hera_corr - INFO - Commanding (205,n) PAM atten=10 dB in redis
Action taken.
```

Figure 3. Manual Adjustment Command Line Example. Above shows the interactive adjustment process on Antenna 107, 97, 205. After one specific antenna number is entered, the program provides the proposed adjustment. The observer gives the command to take the action or not.

2.2. Manual Adjustment

Given the complexity of the system, human interventions are needed to inspect and adjust the malfunctioning antpols. In this step, a human observer manually looks at one spectrum and decide whether the median-based adjustment should be applied or not.

In practice, the observer inspects the daily notebook `antenna_classification_summary`² to pick out the outlier antpols. Then, another script³ is run which interacts with the observer in selecting the antpols and deciding whether to perform the adjustment or not. A short example of the command line interface is shown in Figure 3.

This step also catches some nonlinear effect of the analog system. To calculate the desired attenuation adjustment, we assume a linear system response. When the system operated outside the optimal dynamic range, the response is frequently nonlinear, which means more than one adjustment is need to get the target power level. In the manual step, we adjust the attenuation multiple times if necessary.

² Link to the folder: https://github.com/HERA-Team/H6C_Notebooks/tree/main/antenna_classification_summary

³ GitHub Link: https://github.com/HERA-Team/HERA_Commissioning/blob/master/scripts/snaphead/individual_pam_attenuation_setting.py

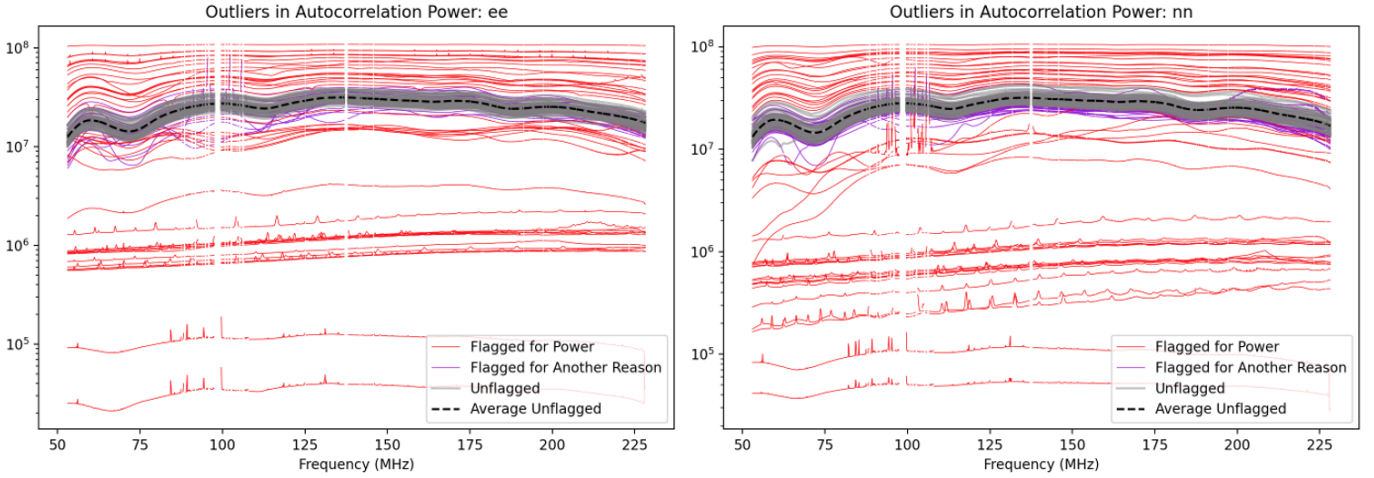


Figure 4. Autocorrelations after adjustment. Compared to Figure 2, spectra are brought together to a much narrower range. The outliers are either from abnormal spectral shapes or out of the 0–15 attenuation is needed. Color coding of the lines is shown in the legend.

Table 1. Attenuation Adjustment Recording Example

antpol	current	target	action
130n	15	15	n
130e	13	13	n
137n	6	10	y
137e	9	15	y
136n	15	15	n
136e	15	15	n
135n	15	13	y
135e	13	14	y
...

NOTE—The recordings are automatically generated when an adjustment operation is performed. They are all stored in the `HERA_commissioning` GitHub repository at this [link](#).

After the two rounds of adjustment, most of the autocorrelation spectra are at the target power level, except for the outliers as described above. Figure 4 shows the after-adjustment spectra in 2022-08. For future reference, operations on PAM attenuators are recorded and pushed to the `hera-commissioning` GitHub repository, with one example of the recordings shown in Table 1.

Table 2. PAM and SNAP Status Example

host	ant	pol	pam	att	pwr	snap	med	slope	rms
heraNode1Snap3	15	n	on	13	-19.658	on	7.363	0.137	3.678
heraNode1Snap3	15	e	on	12	-16.490	on	6.694	0.136	5.794
heraNode1Snap3	16	n	on	15	-19.877	on	8.856	0.156	3.963
heraNode1Snap3	16	e	on	14	-16.545	on	7.789	0.177	6.04
heraNode10Snap0	93	n	on	13	-18.866	off	N/A	N/A	N/A
...

NOTE—The recordings are automatically generated when the query python script is run. Meaning of each column is explained in the main text. The recordings are stored in the `HERA_commissioning` GitHub repository at this [link](#).

3. PAM AND SNAP STATUS

To assist the site work, a script is written to quickly assess the status of PAMs and SNAPs. The script runs on `hera-snap-head` for direct communication with the instrument. The script loops through SNAPs and look into all the antpols within each snap.

For each antpol, the PAM is queried of its on/off status. If the PAM is on, the attenuation setting and the PAM power is queried. Then the SNAP is queried. If it is on, the median of the spectrum is measured. Then, the slope of the spectrum is measured, defined as the difference between the median of the first and second half of the spectrum. Finally, the ADC root-mean-square (RMS) is measured from the SNAP. All the measurements are recorded as shown in Table 2.

APPENDIX

A. SITE COMPUTERS

Site computers operate the instrument and perform preliminary analysis of the raw data. The primary on-site analysis machine is `qmaster`. Closer to the instrument, HERA has three computers where one can `ssh` from `qmaster`. The three computers are:

1. `hera-node-head`: powering the correlator nodes on/off
2. `hera-snap-head`: controlling the PAMs and SNAPs
3. `hera-corr-head`: controlling the correlator

In this memo, we only use the `hera-snap-head` to communicate with PAMs and SNAPs.

REFERENCES

- DeBoer, D. R., Parsons, A. R., Aguirre, J. E., et al. 2017, *PASP*, 129, 045001, doi: [10.1088/1538-3873/129/974/045001](https://doi.org/10.1088/1538-3873/129/974/045001)