

Req. PACS InvNtt Calibration Files and Noise Analysis

- A. History

Version	Date	Author(s)	Change description
1.0	2009 Sep 11	D. T. Frayer	First issue

- B. Summary

The MADmap software requires accurate noise calibration files for mapping. The inverse time-time correlation noise (InvNtt) calibration data are computed from the power spectrum per detector. InvNtt calibration files are produced for each band (Blue, Green, and Red) and for 10 Hz and 5 Hz (parallel mode) data. Default offset files are also produced. Basic noise analysis is carried out. The detector drifts are the dominant noise component. We find little excess noise correlated over the entire array or per 16×16 module.

- C. Data

Table 1: Data

OBSID	Description
1342182424	OD97 PVPhotBol_1111A_nStd_bluDrctNomiBias_DarkField
1342182427	OD97 PVPhotBol_1111A_nStd_grnDrctNomiBias_DarkField

- D. Data Processing

- D.1. Lev0 to Lev1 Processing

We used the low-frequency noise measurements taken in OD97 with the nominal bias settings using the default direct mode (Table 1). The “tm-files” were used, and the data were extracted and reduce using `hcss.dp.pacs-1.2.912`. After decompression the following pipeline modules were run.

- `frames = addObcp2Frames(frames,seq)`
- `frames = findBlocks(frames, calTree=calTree)`
- `frames = photFlagBadPixels(frames)`
- `frames = photFlagSaturation(frames)`
- `frames = photConvDigit2Volts(frames)`
- `frames = photCorrectCrosstalk(frames)`
- `frames = photMMTDeglitching(frames,scales=4,nsigma=5)`

In addition to the deglitching parameters given above (which have been used by CEA), we also carried out power-spectrum analysis without deglitching and for less aggressive parameters used previously for the M51

data (scales=2 and nsigma=8). All data were saved using FitsArchive and analysis was carried out using specialized scripts written in IDL.

- D.2. Derivation of Power Spectrum

The power spectrum for each band as a function of deglitching parameters was derived for each detector over a 3 hr period (108k 10Hz samples). The power spectrum (PS) is computed simply as

$$PS = (abs(FFT(data)))^2 \quad (1)$$

where *FFT* is the Fourier transform. We did not perform “hanning” smoothing as done by CEA (e.g., *hann* = *hanning(npts, alpha = 0.5)* and *power* = *power * 8/3*). We confirm that the PS shape was very similar with or without the hanning smoothing, and the application of the InvNtt results are independent of the normalization of the PS.

To improve the derivation of the PS for individual detectors, the data were broken up into independent chunks to average the results over time. The PS was computed for different size chunks of data (1×108000 samples, 2×54000 samples, 4×27000 samples, 10×10800 samples, 30×3600 samples, 100×1080 samples, 300×360 samples, and 1000×108 samples). The power spectrum solutions were spliced together and fitted in IDL using CURVEFIT (which was found to be more robust than SVDFIT) adopting the following function:

$$PS = B1(1 + (B2/\nu) + (B3/\nu)^\alpha) \quad (2)$$

The index α was derived for the array average and kept constant for the fitting of individual detectors. If one attempts to fit α for each detector many of the solutions become unphysical. It was more robust to leave α constant while fitting each of the coefficients. We used an average α value of 1.8, 1.7, and 1.6 for the Blue, Green, and Red arrays, respectively. If the fits for parameter *B3* were unphysical, then the detector was fitted only with $PS = B1(1 + B2/\nu)$.

- D.3. Derivation of InvNtt Files

For the application of MADmap method, the noise is assumed to be Gaussian, “piece-wise stationary”, and “circulant”. Under these assumptions, the noise depends only on the time difference between two samples. Correlated noise between detectors is not accounted for in the current method. The InvNtt file represents the first row of the time-time noise covariance matrix which is given by the inverse Fourier transform of the power spectrum (see PACS MADmap Users Manual Documentation for additional information).

The InvNtt vector is computed as

$$InvNtt = FFT^{-1}(1/PS). \quad (3)$$

The InvNtt vector was computed for each detector. The scaling of the InvNtt data is not important. We

normalized the data to the first sample. The InvNtt file approaches near zero fairly quickly (10-30 samples) and slowly converges to zero exactly for infinite time. We subtracted the value of last sample used in the calibration file (101) from the vector to force the last sample to be zero.

- E. Results

- E.1. Power Spectrum Analysis

As reported by Marc Sauvage, the power spectrum depends on the deglitching. To look at the average properties of the array and to improve statistics, we derived the array averaged power spectrum by taking the median over the array for each frequency in the power spectrum. Figures 1, 2,&3 show the average PS for the Blue, Green, and Red arrays as a function of the deglitching parameters. Deglitching at $\sigma = 5$ instead of $\sigma = 8$ changed the PS only slightly. Without any deglitching, the PS is significantly higher at high frequencies. Figure 4 shows the array average PS for each band for the the adopted deglitching parameters of nscales=4 and sigma=5. At low frequencies, the blue array has the steepest PS. The red band has the shallowest PS.

Figures 5 –13 show the histograms of the parameter fits (B1, B2, B3) based on equation 2 for the blue, green, and red bands. There are a wide range of solutions for the individual detectors. In particular, there is a fairly long tail of solutions at high frequencies for parameter B2. Figures 14–16 show the images of these parameters along with the OFFSET images for the blue, green, and red array for comparison.

- E.2. InvNtt and Offset Calibration Files

We derived InvNtt files per band. We produced an array average calibration file by taking the median value across the array for each sample and derived the files per detector. Detectors with badly defined PS were given the median InvNtt solution. The files were made for 10 Hz and binned to produce initial 5 Hz files (for parallel-mode data). The application of these calibration files are undergoing testing with real data. While making the InvNtt file, we also computed “nominal” offset files which could be used by the DP system. These files are simply the median value per detector for these dark field data. The following calibration files were made available to the NHSC-PACS team for further testing and inclusion within the PACS-DP system:

- DP_InvNtt_blue_od97_10Hz_avg.fits (median for all detectors)
- DP_InvNtt_blue_od97_10Hz.fits (per detector fit)
- DP_InvNtt_blue_od97_5Hz_avg.fits (median for all detectors)
- DP_InvNtt_blue_od97_5Hz.fits (per detector fit)
- DP_InvNtt_green_od97_10Hz_avg.fits (median for all detectors)
- DP_InvNtt_green_od97_10Hz.fits (per detector fit)
- DP_InvNtt_green_od97_5Hz_avg.fits (median for all detectors)
- DP_InvNtt_green_od97_5Hz.fits (per detector fit)
- DP_InvNtt_red_od97_10Hz_avg.fits (median for all detectors)
- DP_InvNtt_red_od97_10Hz.fits (per detector fit)
- DP_InvNtt_red_od97_5Hz_avg.fits (median for all detectors)

- DP_InvNtt_red_od97_5Hz.fits (per detector fit)
- off_blue_od97.fits (Blue offset)
- off_green_od97.fits (Green offset)
- off_red_od97.fits (Red offset)

As needed for individual data sets, users can carry out more or less aggressive MADmap processing by the modification of the first index of the InvNtt calibration file (to match the effective noise level in their data). An example of doing this within the DP system is given below:

- #update InvNtt calfile
- fa = FitsArchive(reader=FitsArchive.STANDARD_READER)
- invntt = fa.load("InvNttMED_Rm51.fits")
- dat = invntt["PrimaryImage"].data
- #get current calfile
- calTree = getCalTree()
- prod = calTree.photometer.invnttRed
- #Change effective noise level as needed
- dat[:,0]=dat[:,0]/1.3
- prod.set("Contents", ArrayDataset(Double2d(dat)))
- calTree.photometer.invnttRed = prod

- E.3. Offsets and Noise Analysis

MADmap does not correct for correlated noise, so it is natural to ask how important is correlated noise for PACS. If the detectors are all going up and down together (e.g., due to global temperature changes) or if individual modules go up and down together, then one could expect significant correlated noise. To empirically quantify these possible effects, we computed the noise in the data cubes for different reduction methods.

1. No offset correction
2. Constant offset correction for entire 3 hr data cube
3. 1000 sample high-pass time filter
4. 100 sample high-pass time filter
5. 30 sample high-pass time filter
6. 10 sample high-pass time filter
7. 10 sample high-pass filter and subtracting the median across the array for each frame.

8. 10 sample high-pass filter and subtracting the median for each 16×16 module for each frame and module.

The noise measurements as a function of the time filter are shown in Table 2 for each of the bands. To quantify possible array-based and module-based correlated noise, we compare methods 6, 7, & 8 listed above. These tests were carried out over the entire blue array for 10,000 frames (sufficient statistics). With only the high-pass filter (10 frames), we derive an rms of $195.057 \mu\text{V}$. By also subtracting the median of the array for each frame, the noise is only 0.006% lower (rms of $195.046 \mu\text{V}$), and by subtracting the median of every module of each frame the noise is lowered by 0.04% (rms of $194.972 \mu\text{V}$). Therefore, we find no strong contribution of “correlated” noise across the entire array or as a function of module as a function of time for these data. This does not mean that correlated noise is not an issue. One can see intermittent fringing in some PACS data, so correlated noise does exist. Systematic correlated noise should be removed when possible.

Table 2: Noise Levels as Function of Time Filter

Method	Blue σ [mV]	Green σ [mV]	Red σ [mV]
No Offset	42.9	41.4	40.0
Offset	0.151	0.102	0.122
1000 frame filter	0.0258	0.0253	0.0492
100 frame filter	0.0212	0.0207	0.0385
30 frame filter	0.0196	0.0191	0.0338
10 frame filter	0.0186	0.0181	0.0306

Table 2 Notes: Computed one σ standard deviation after clipping at 5σ . To expedite the high-pass filter calculations only 10,000 frames were used, and the calculation was made only for the detectors in the first 16×16 module.

- F. Discussion

The InvNtt calibration files needed for MADmap processing were made from the low-frequency noise data from OD97. These calibration files were delivered to the NHSC-PACS team for further testing and inclusion within the PACS-DP system. This report gives the basic methodology for producing these files.

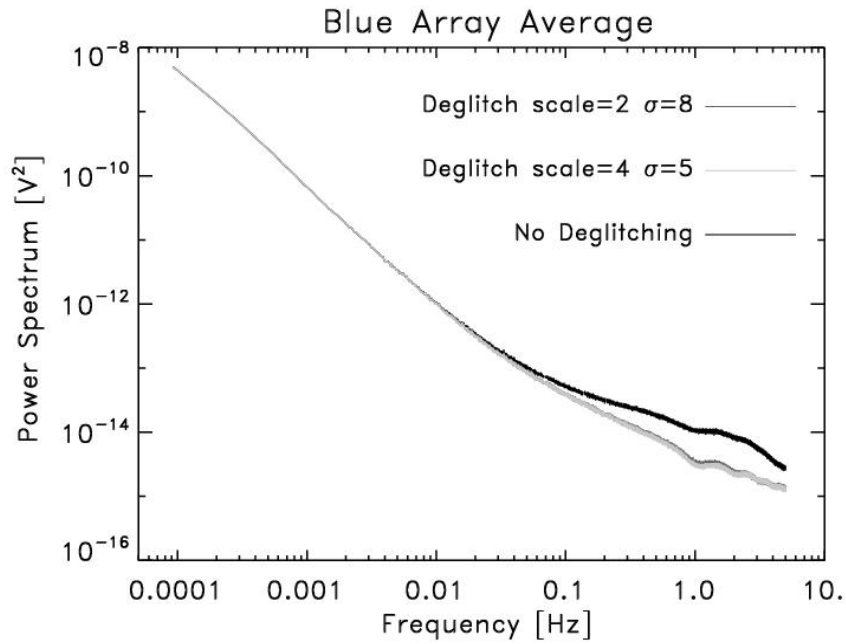


Figure 1: The average power spectrum for the blue array as a function of deglitching.

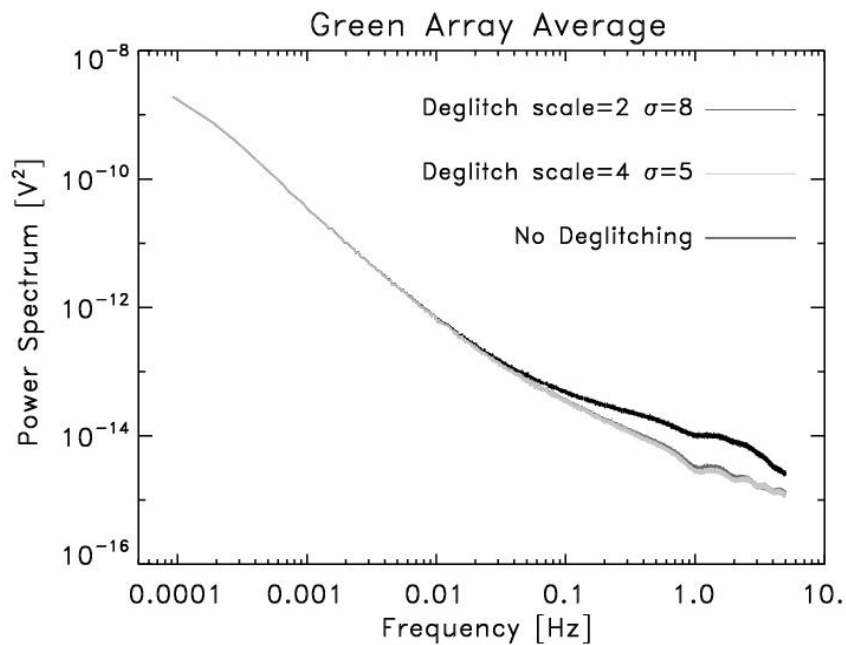


Figure 2: The average power spectrum for the green array as a function of deglitching.

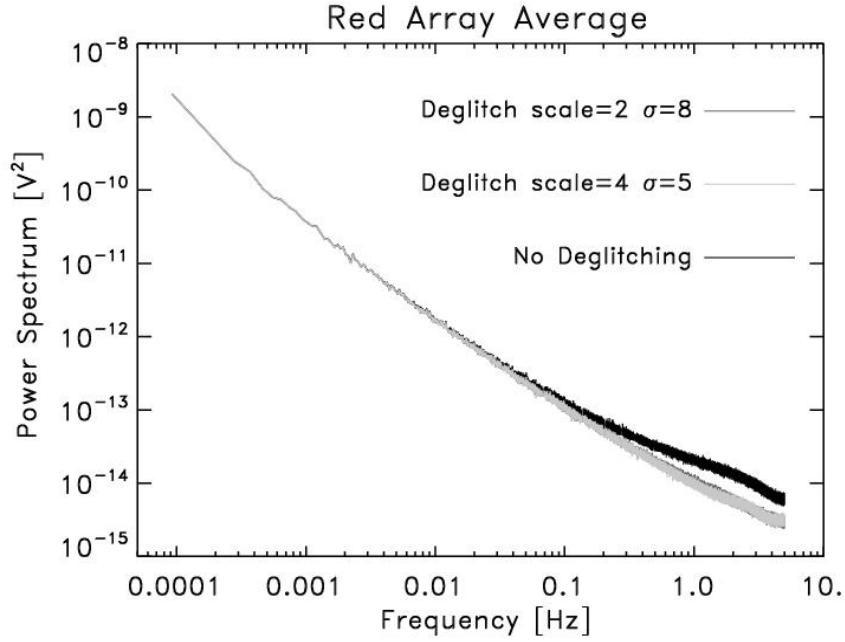


Figure 3: The average power spectrum for the red array as a function of deglitching.

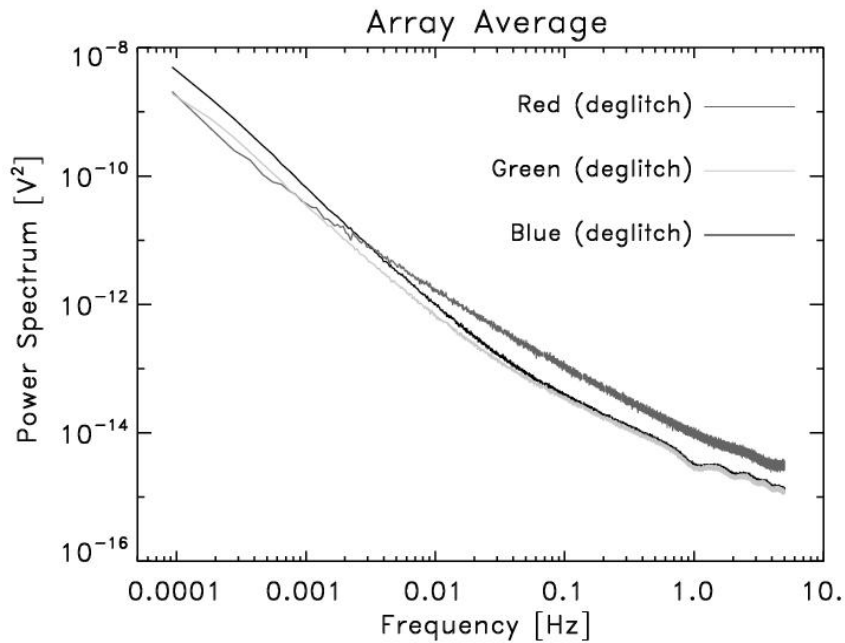


Figure 4: The average power spectrum for the blue, green, and red arrays for the deglitching parameters of nscales=4 and sigma=5.

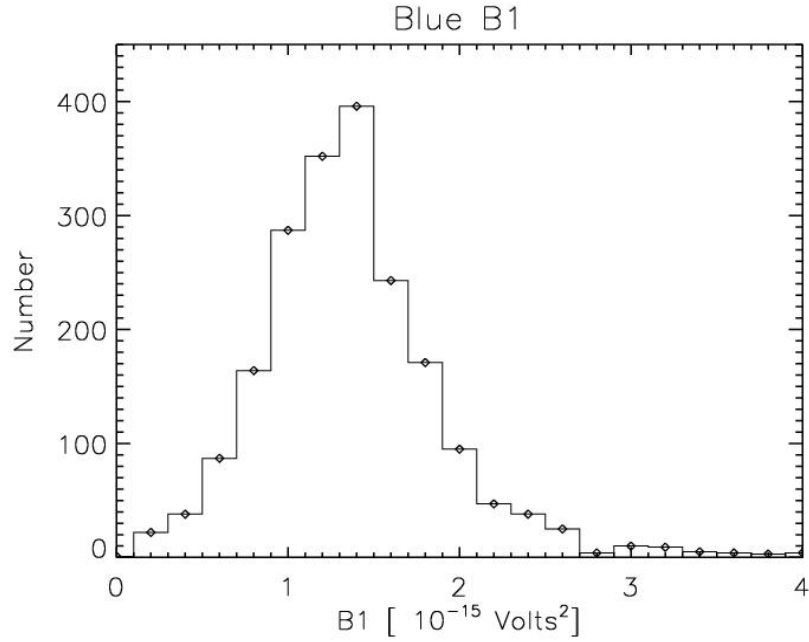


Figure 5: The histogram for the blue array for parameter B1 (equation 2).

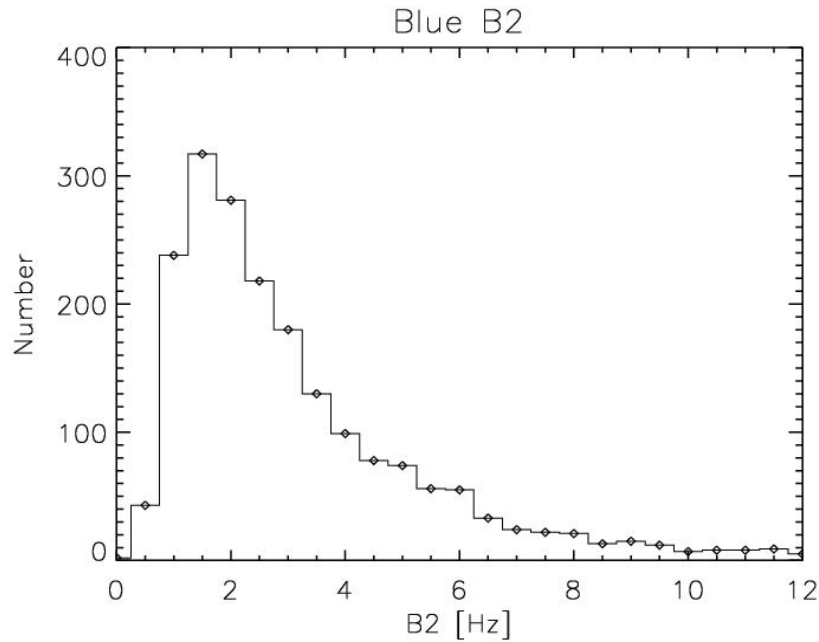


Figure 6: The histogram for the blue array for parameter B2 (equation 2).

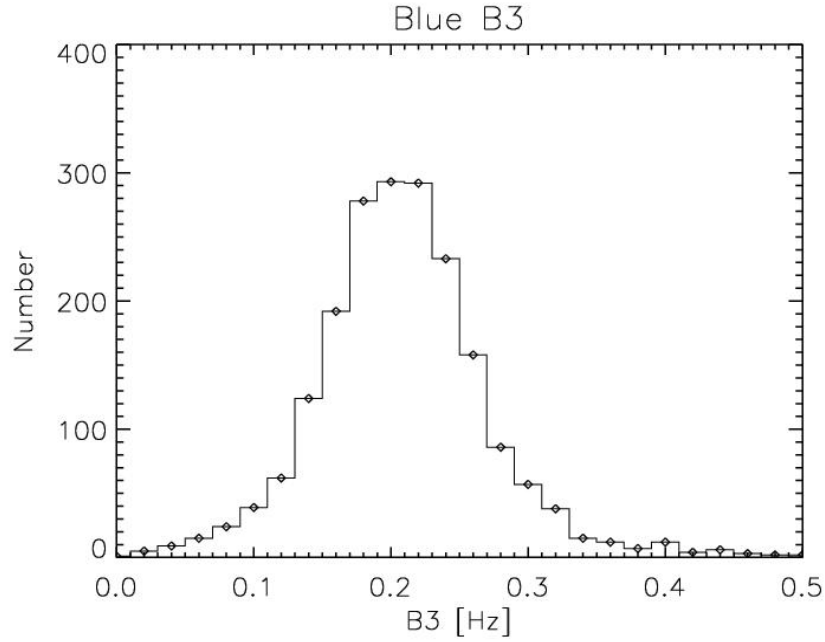


Figure 7: The histogram for the blue array for parameter B3 (equation 2).

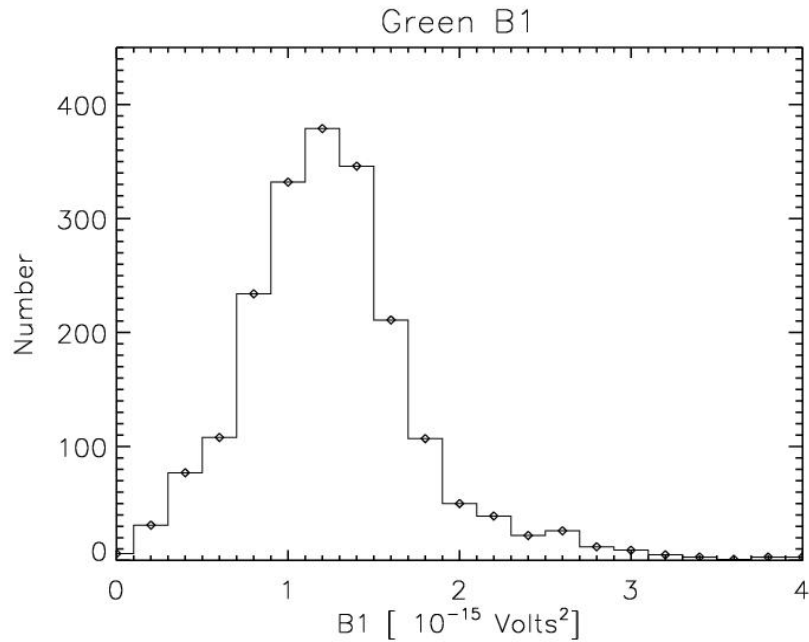


Figure 8: The histogram for the green array for parameter B1 (equation 2).

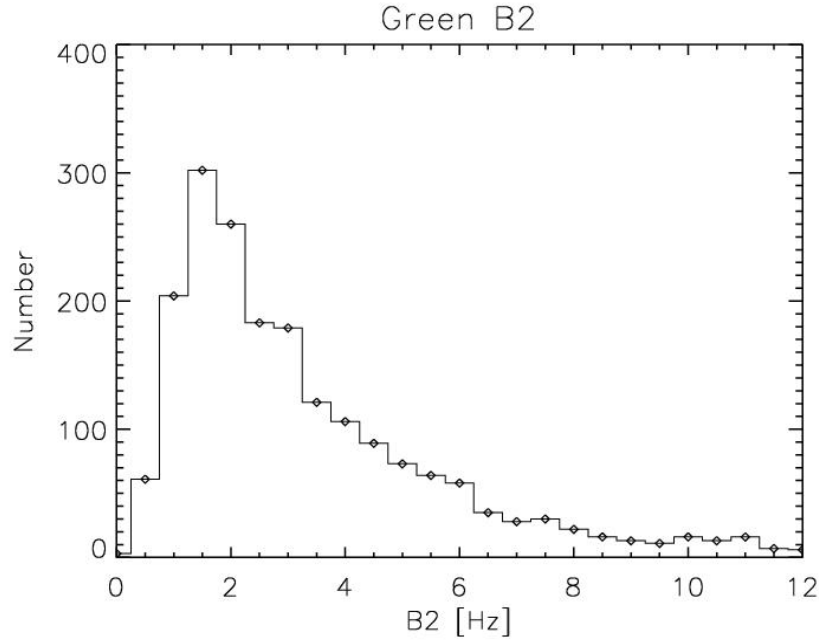


Figure 9: The histogram for the green array for parameter B2 (equation 2).

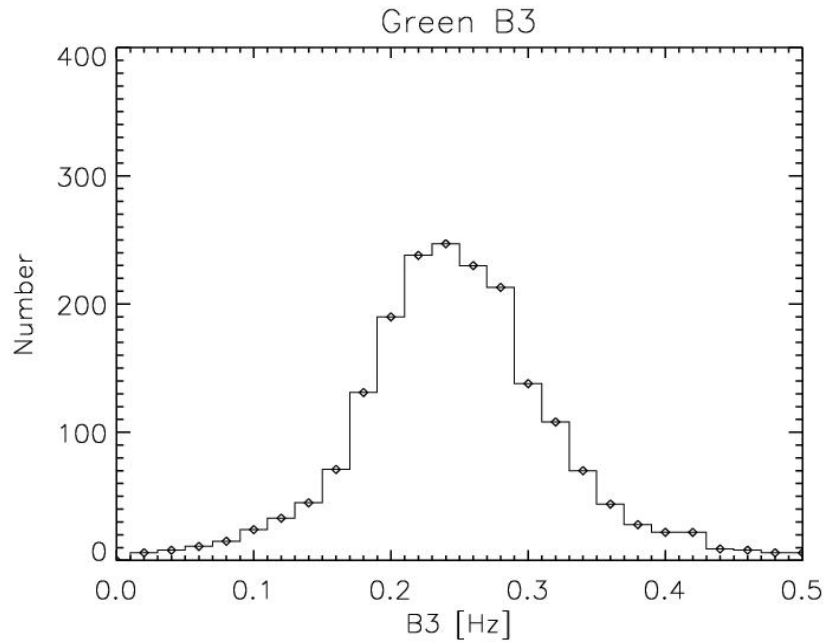


Figure 10: The histogram for the green array for parameter B3 (equation 2).

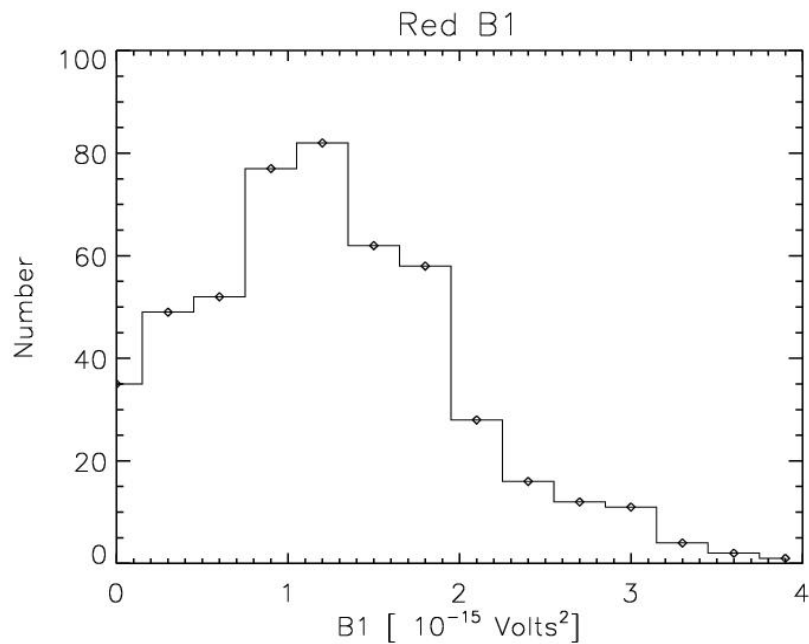


Figure 11: The histogram for the red array for parameter B1 (equation 2).

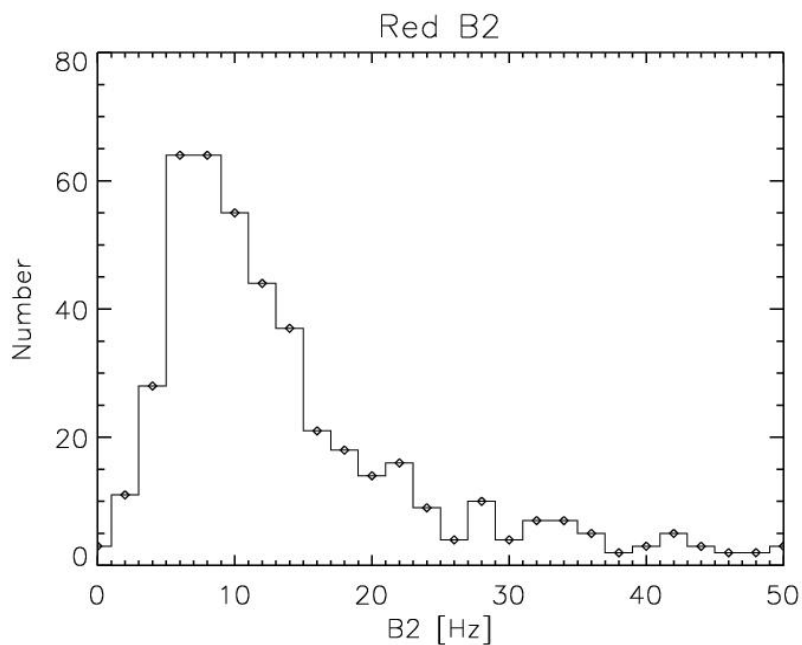


Figure 12: The histogram for the red array for parameter B2 (equation 2).

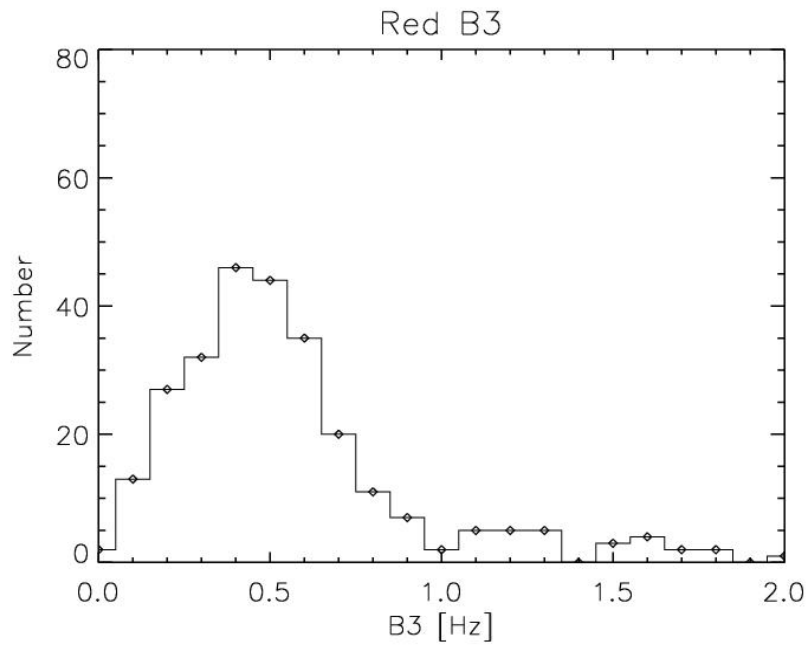


Figure 13: The histogram for the blue array for parameter B3 (equation 2).

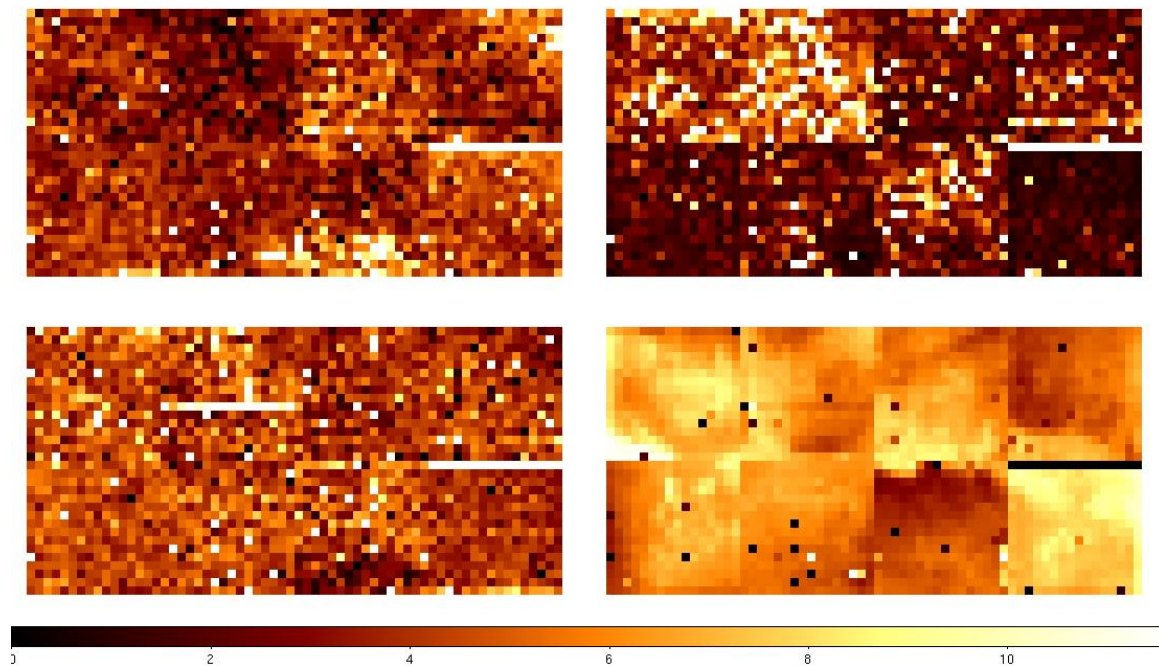


Figure 14: The images of the parameters B1 (top left), B2 (top right), and B3 (bottom left) and the offset (bottom right) values for the blue array

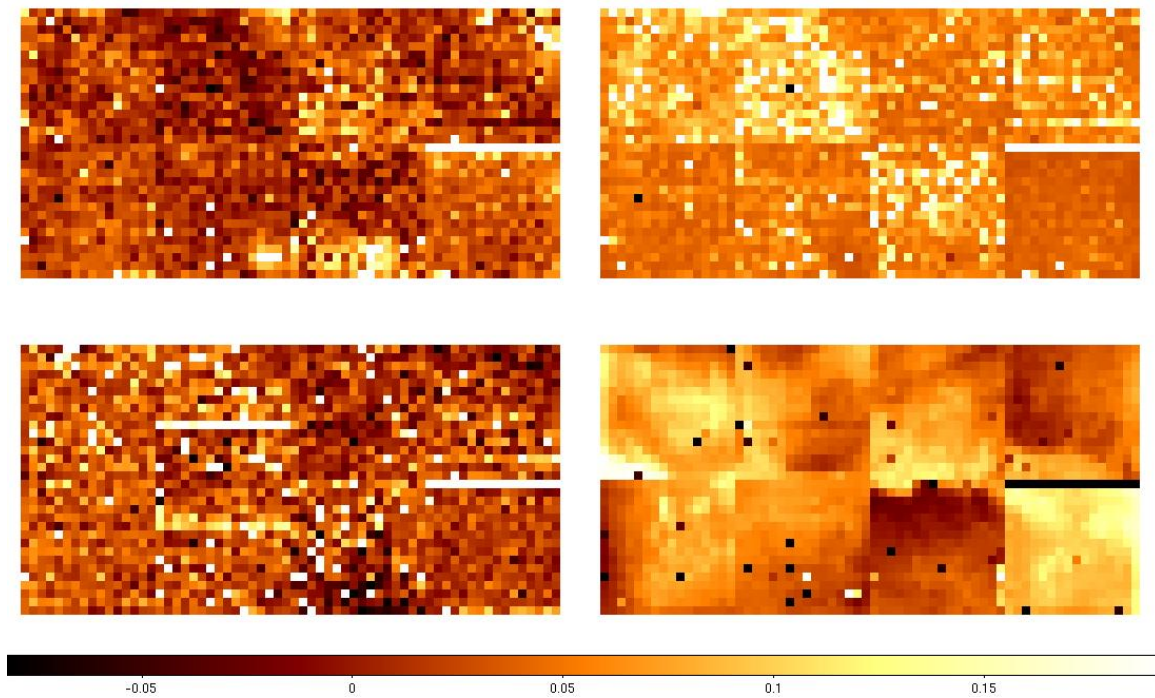


Figure 15: The images of the parameters B1 (top left), B2 (top right), and B3 (bottom left) and the offset (bottom right) values for the green array

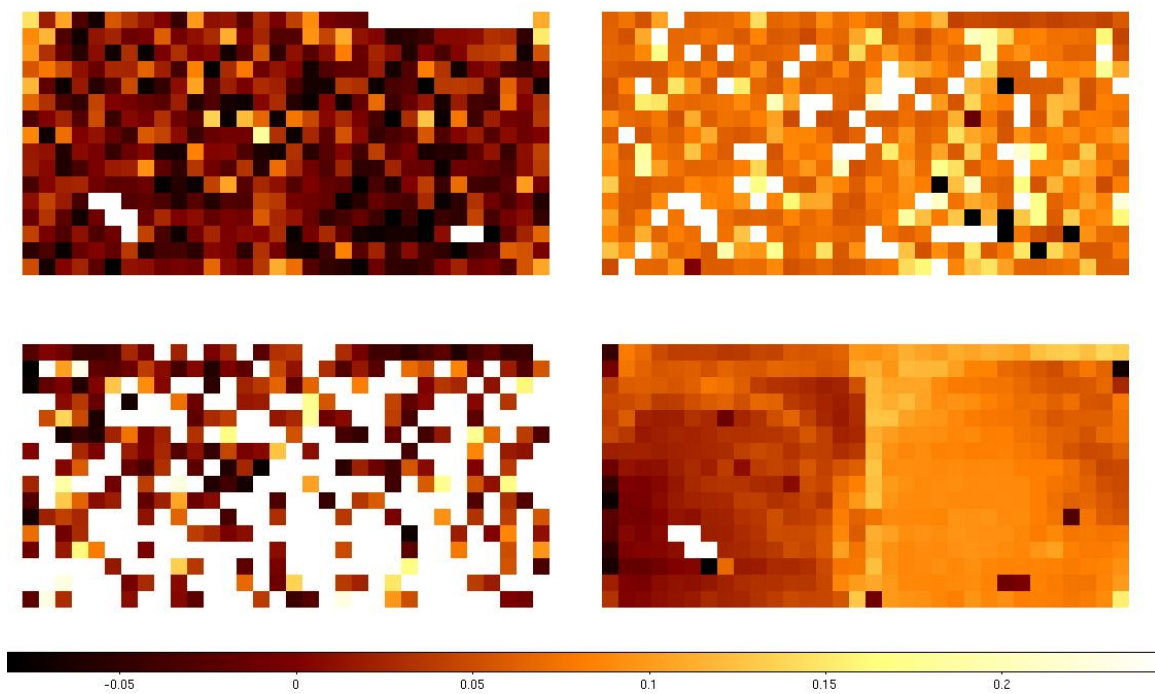


Figure 16: The images of the parameters B1 (top left), B2 (top right), and B3 (bottom left) and the offset (bottom right) values for the red array