EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
Europäische Organisation für astronomische Forschung in der südlichen Hemisphäre

PARANAL/ Instrumentation

VERY LARGE TELESCOPE

Algorithm For Periodic Noise Characterization On Scientific Images

Doc. No.: VLT-xxx-ESO-xxxxx-xxxx

Issue: 1

Date:

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Released:

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CHANGE RECORD

ISSUE	DATE	SECTION/PARA. AFFECTED	REASON/INITIATION DOCUMENTS/REMARKS

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2 List of Abbreviations & Acronyms

This document employs several abbreviations and acronyms to refer concisely to an item, after it has been introduced. The following list is aimed to help the reader in recalling the extended meaning of each short expression:

ATP	Acceptance Test Plan
ATR	Acceptance Test Report
CCS	Central Control Software
CPU	Central Processing Unit
DCS	Detector Control Software
DFS	Data Flow System
ESO	European Southern Observatory
GUI	Graphical User Interface
HW	Hardware
ICS	Instrument Control Software
INS	Instrumentation Software Package
I/O	input/output
ISF	Instrument Summary File
IWS	Instrument Workstation
LAN	Local Area Network
LCC	LCU Common Software
LCU	Local Control Unit
MS	Maintenance Software
N/A	Not Applicable
PAE	Preliminary Acceptance Europe
P2PP	Phase 2 Proposal Preparation
RAM	Random Access Memory
RTAP	Real-Time Application Platform
SW	Software
TBC	To Be Clarified
TBD	To Be Defined
TCS	Telescope Control Software
TIM	Time Interface Module
TRS	Time Reference System
TSF	Template Signature File
VLT	Very Large Telescope
WS	Workstation

3 Introduction

The motivation for this work came from several SciOps inquires regarding the presence of 50Hz noise on the images. After a deep investigation we found that the AC fans of the IRACE heat exchanger were causing the problem. They were replaced by DC ones mitigating significantly the problem. During the investigation an algorithm to characterize periodic noises found on scientific images was implemented in MATLAB. The algorithm goal is to identify frequency and amplitude of periodic noises found on detector images using the Fast Fourier Transform (FFT) as main tool. As a general reference, the ISAAC Hawaii 1k x 1k detector configured on double correlated mode will used in the examples. The algorithm applicability to other detectors and readout modes will be briefly explored on section 6.

4 Algorithm description

4.1 Algorithm concept

The base of this algorithm is to perform a frequency domain analysis across the noise direction, which also normally correspond to the readout direction. In the ISAAC case the 50 Hz noise appear as fuzzy horizontal stripes with a period of about 8 rows in the case of the Hawaii detector. The intensity of the periodic noise is very low, and it is affected by the random noise of the bias level, As a result, the periodic noise signal is not present or strong in every column to be analysed.

For this reason the algorithm takes a FFT of each column to be analysed, as it is shown in figure 1, note that the read out direction is along the rows and the analysis is performed across them. This limit the analysis to Nyquist frequency, given by half the sampling frequency. Since the sampling is determined by the time used by the readout electronics to go from one row to the next, the limiting frequency of this analysis would be the inverse of the time required to read two rows.

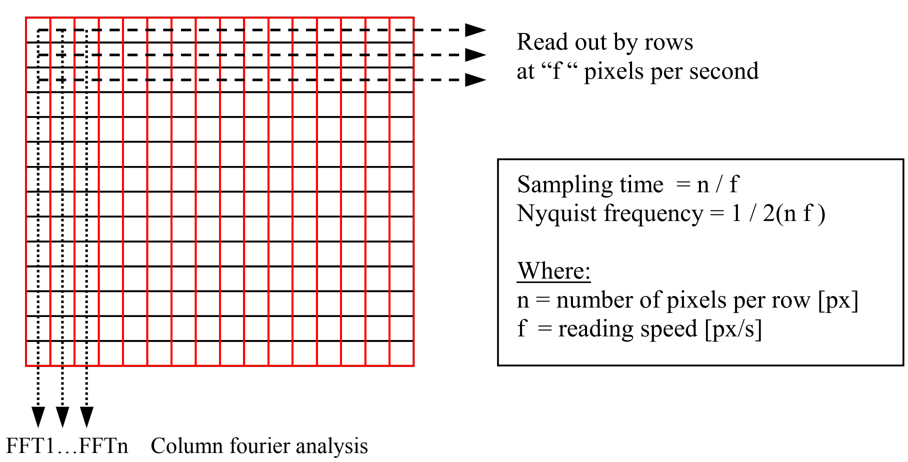

Figure 1. First step: Obtain the FFT of each column.

The next step of the algorithm is to obtain the power spectrum of each FFT, As a result a power spectrum matrix is obtained, This will be shown in following example. finally, the resultant power spectrums are averaged in order to sum up the real noise signal, this process is shown in figure 2. Note that this operation will keep the noise information only because is performed in the frequency domain since is done after compute the FFT. If the columns are averaged in the space domain the noise information would be averaged as well and no useful information would be obtained.

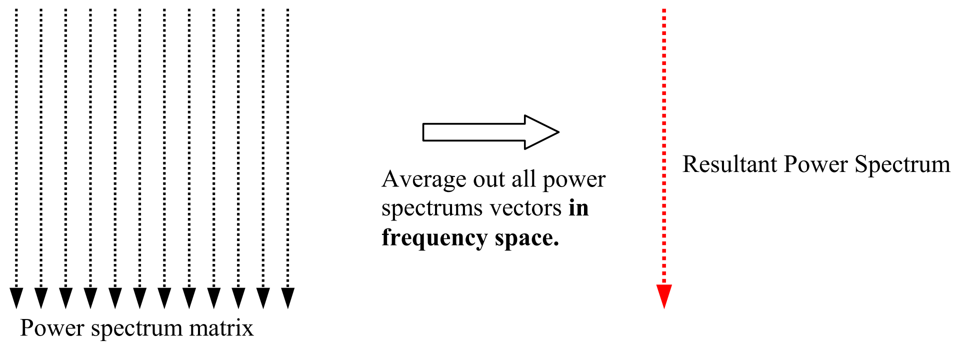

Figure 2. Second step: average out the power spectrum vectors.

4.2 Signal pre processing

In order to obtain good results of the FFT algorithm, it is necessary to pre process the data to be analysed. First, the background the has been subtracted fitting a polynomial to its shape. This also allow to find noise on images with simple and smooth structure on them. Afterwards, hot and dark pixels are removed because they would introduce a strong constant signal on the power spectrum. Finally, a Hanning vector is applied to the data set to mitigate the sampling window effect which is equivalent to multiply the signal by “Rect” function, which would appear as a convolution with a “Sinc” function on the frequency space.

4.3 Validation

To validate the algorithm and the implementation of this tool, a test image has been generated with following parameters:

- Image size: 512 x 512.
- Bias level: 100 ADU.
- Random noise applied: 2%.
- Period of test noise: 8 rows.
- Amplitude of test noise: +/- 1ADU.
- Test noise direction: Along rows.

The image obtained is shown in figure 3a.

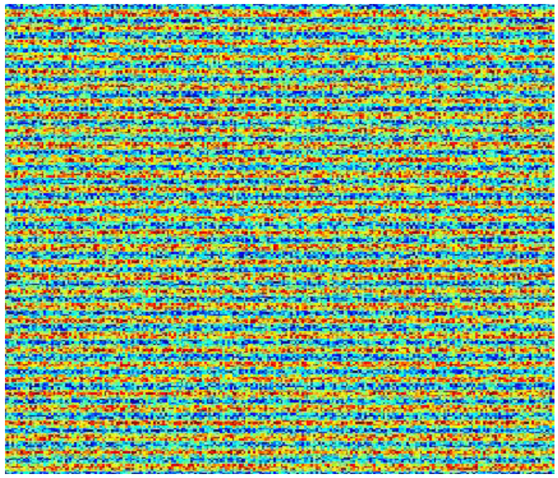

Figure 3a. Fraction of test image generated.

To test the algorithm the simulated readout configuration is defined:

- Simulated readout direction: Horizontal, along rows.
- Simulated readout frequency: 169 Kpixel /s
- Algorithm sampling frequency: 330 Hz (1/(512/169000)).

Considering this parameters the frequency to be found is:

- Noise frequency: 41.25 Hz (330Hz / 8).

The frequency found by the algorithm was 41.25 Hz matching the theory and therefore validating the implementation done. The power spectrum matrix is shown and in figure 3b, and the resultant power spectrum average is shown in Figure 3c. Note that the power spectrum matrix does not present almost any noise, demonstrating the capability of the algorithm to filter out random noise from periodic ones.

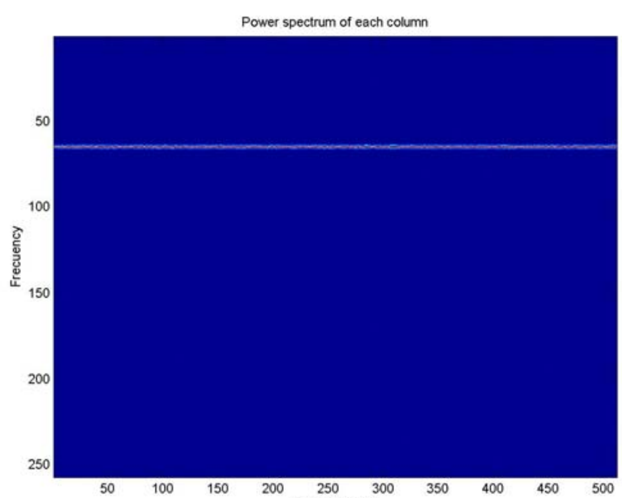

Figure 3b. Power spectrum matrix showing the noise as an horizontal line. **NOTE** that the frequency axis in this plot is in samples, The power spectrum average plot is presented with proper Hz scale.

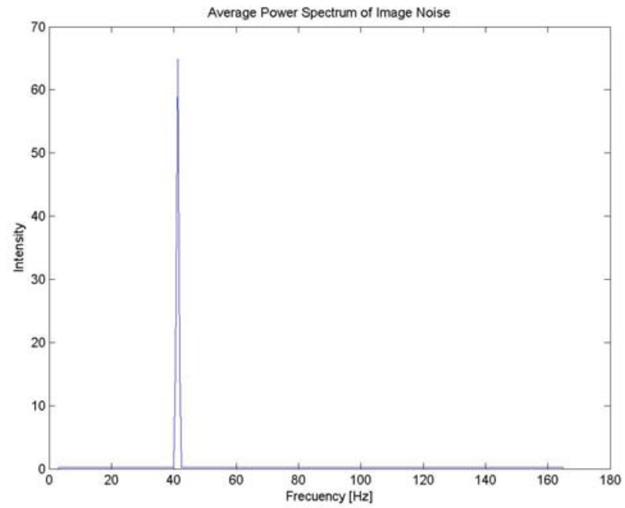

Figure 3c. Average of power spectrum vectors with proper frequency scale. The plot shows that only a 41.25 Hz noise is found as expected.

4.4 Parameters and limitations

The parameters needed to execute this algorithm are the readout speed, the readout and direction. Moreover the size of the array to be analysed should be provided to define the start and end point of the process.

It is important to mention that:

- An incorrect read out speed will affect the resultant frequencies of the noises found.
- An incorrect set of readout direction will analyse the noise components along the row that it is being red and therefore will provide information about higher frequencies.
- The larger the fraction of the array to be analysed the longer will take the analysis but a better data set will be obtained to average it out.

The main limitations of the algorithm are:

- The frequencies are correctly set if the noise pattern is parallel to the readout direction, the larger the angle between both, larger will be the error on the frequency values.
- Noises with frequencies higher than the Nyquist criteria will no be detected.

5 Results

To test the algorithm with real data three different ISAAC images has been analysed, the first one contain an average noise level, the second one is almost completely clean and the third one has strong noise contamination on different frequencies. For each one a fraction of the image will be shown as well as the power spectrum matrix and the resultant average of the power spectrum vectors, which is the useful product of the algorithm where the noise frequencies and their intensities can be easily identified. Note that this plot has the auto scale feature, therefore the strongest signal on each figure will set the vertical plot scale.

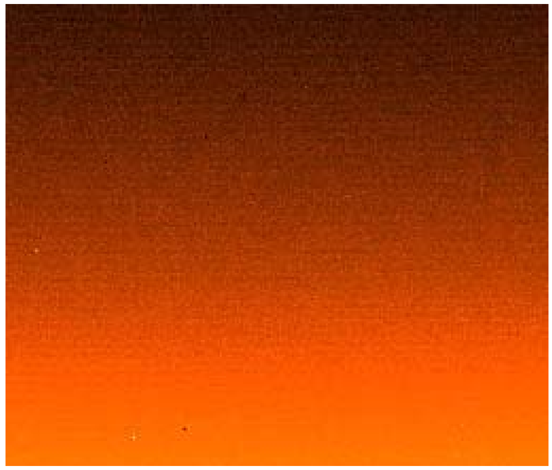

Figure 4a: Normal noise image to be analysed

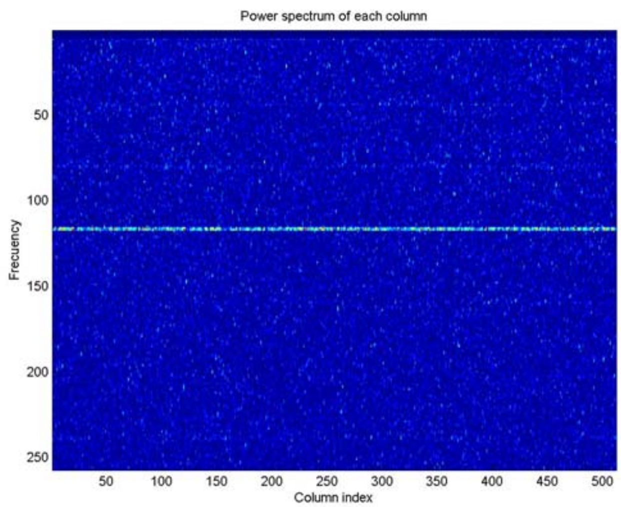

Figure 4b. Matrix of all power spectrum of all the columns.

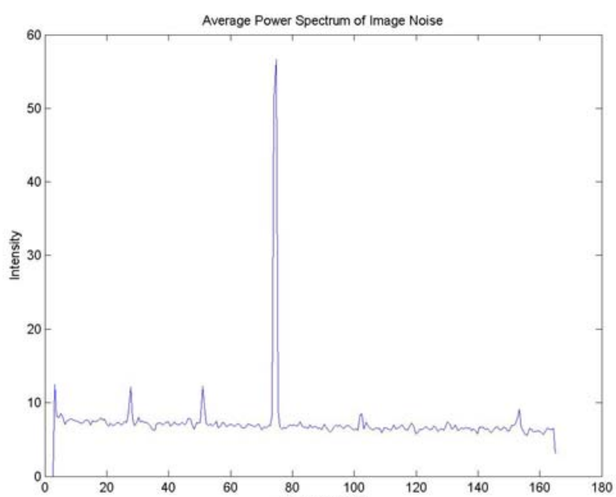

Figure 4c: Average of all power spectrum vectors, note that the small peaks can be barely seen on figure 3b.

Figure 5a. Low noise image of the quadrant to be analysed.

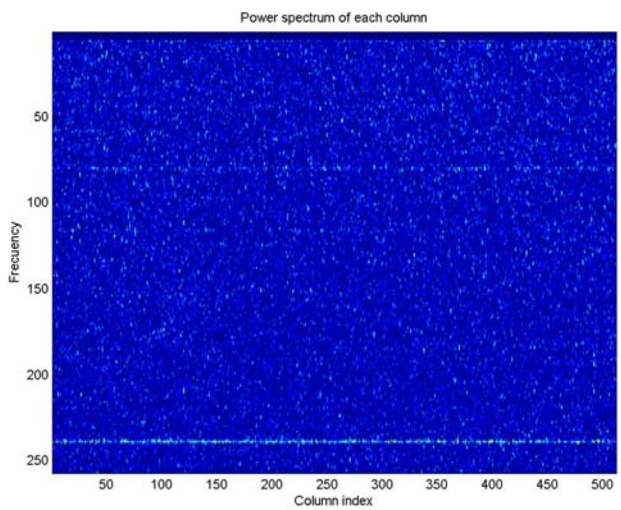

Figure 5b. Matrix of all power spectrum of all the columns.

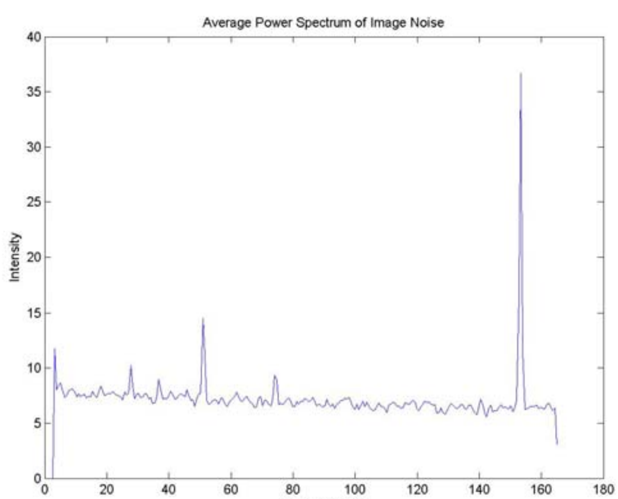

Figure 5c: Average of all power spectrum vectors. Weak noise signal is present

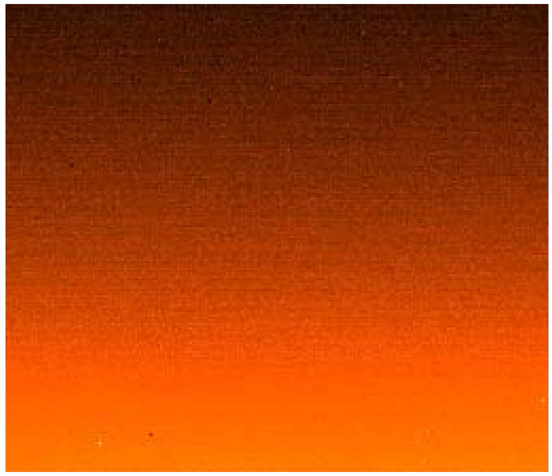

Figure 6a. High noise image of the quadrant to be analysed

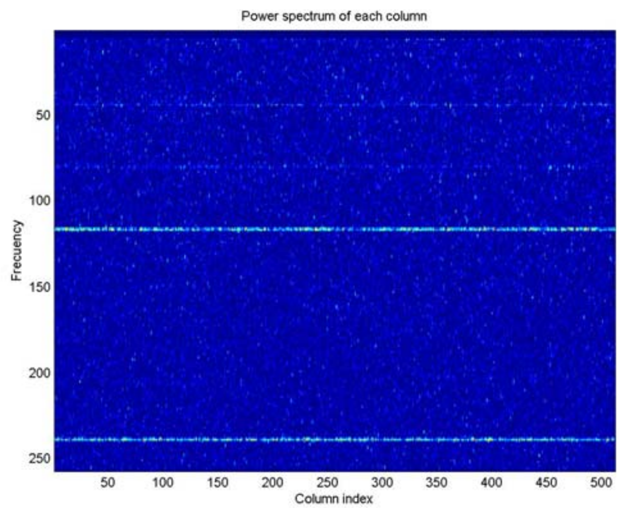

Figure 6b. Matrix of all power spectrum of all the columns.

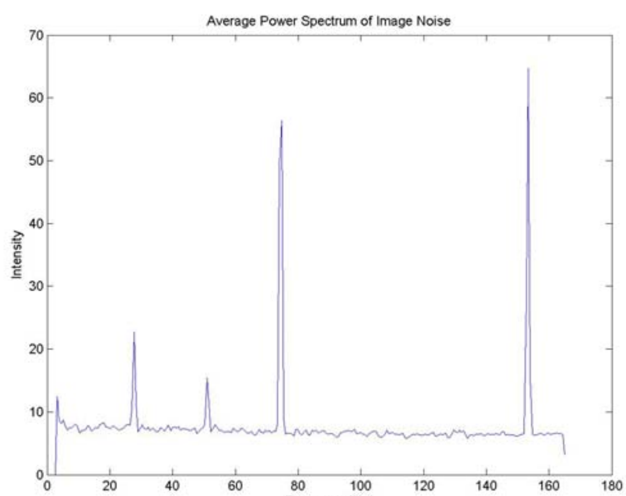

Figure 6c: Average of all power spectrum vectors. Several strong noises are found.

6 Further development

This algorithm can be extended to be used on other detectors, either CCDs or infrared ARRAYS if the readout mode and frequency are known. Some tests has been performed with FORS 2 detector without problems and the MATLAB implementation will be extended to support other detectors and readout modes in the future.