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IR Instrument Thermal Background Modelling and Radiometric Analysis

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Abstract - *In this paper the thermal modelling IR instruments is carried out along with it's radiometric analysis. The focus in thermal modelling is laid on the instruments focal plane array temperature. For analysis the FPA data sheet is used in which the FPA temperature varies in 28 such datasets. Coefficients are generated and stored. Second part deals with radiometric analysis where SNR is determined after subtracting the dark and then the LTC coefficients are generated. Fitting profile chosen for both thermal modelling and radiometric analysis is same except for order of fitting while for generating LTC coefficients different profile (linear fitting) is chosen.*

Keywords: Radiometric Analysis, Background Modelling, IR Instruments

Introduction

Establishing the relationship between instrument's temperature and dark counts with a set of mathematical equations is termed as the thermal model. The analysis of grating based spectrometer modelling and coefficients of different data sets like FPA (focal plane array) and IIR data set have been carried out. To begin with this modelling the first step is the data dimension reduction which is followed by generating the coefficients of appropriate fitting after analysing the datasets and from there radiometric analysis is carried out. SNR determination is the major purpose of radiometric analysis and after that LTC coefficients are generated.

Figure 1 provides the indication of arrangement of the temperature values of various parts of the instrument. There are 28 such data files, which corresponds to the different FPA temperatures keeping other temperatures values nearly same.

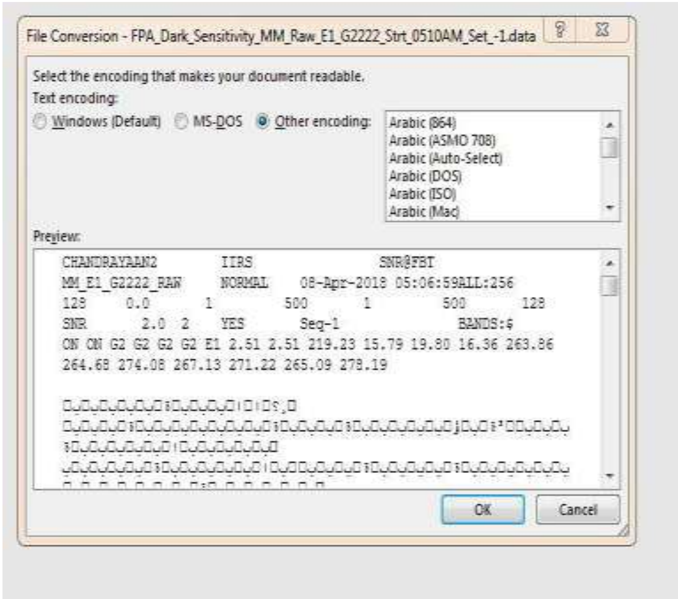

Figure 1: Temperature values of various parts of the instrument are listed in a pre-defined order. FPA temperature marked with an arrow

Here we are trying to determine the relationship of dark current with FPA-temperature (T3).Temperature of FPA is achieved and maintained by Cooler Driver Electronics. Data is recorded just after the cooler drive electronics operation. At this time FPA was at high temperature (~220K). Following is the list of the parts of the instrument for temperature monitoring arranged in the pre-defined order.

T1-Power supply electronics (degC)
T2-FEC electronics (degC)
T3- Focal Plane Array (FPA) (K)
T4, T5, T6 = N.A. (degC) to be ignored
T7-PRT tertiary mirror (K)
T8-PRT spectrometer case (K)
T9-PRT IDCA mount (K)

T10-PRT cooler radiator (K)
T11-PRT Dewar VW (K

T1-T13 are all temperature of different parts of the instrument out of which T3 for FPA is used for thermal background modelling. In raw data individual data sets have about 100 frames. The mean is taken along 100 frames for all 28 data sets. 28 data sets corresponds to the 28 different temperatures of the FPA. Once the data is read it generates a matrix cube of 500*256*28. Which is analysed for developing the thermal background model. For each set mean is taken for all the 500 x 256 pixels, to get 28 points / values of dark counts. Plot and fitting is carried out for these 28 dark count values v/s 28 FPA temperature values. Fitting co-efficients are generated as part of the modelling activity.

Figure 2: Raw Count Image of Dark Measurement

Thermal Background Modelling with respect to FPA Temperature

Figure 3 shows plot of FPA temperature v/s mean data of all pixels for each sets.

x-axis – denotes the FPA temperature and y-axis corresponding mean counts.

As can be seen from the graph upto temperature 156 kelvin the data mean increases almost exponentially and after that from 156 to 220 Kelvin it is constant. This means that saturation has occurred having values above 4000.

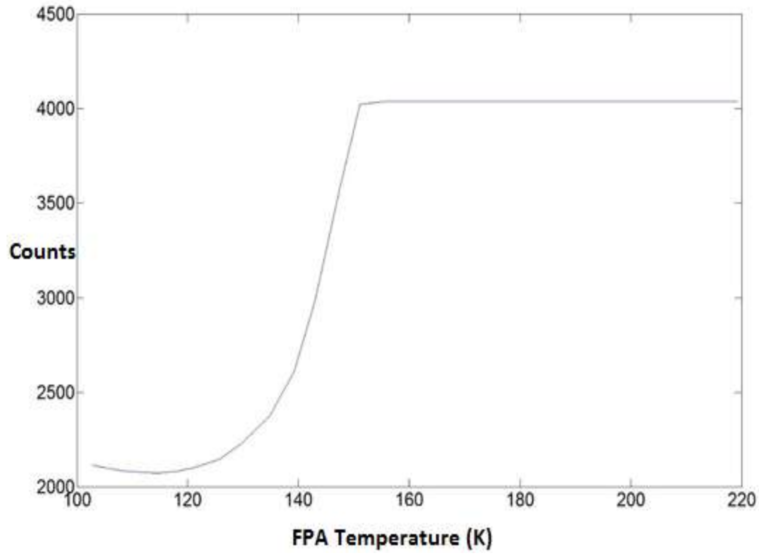

Figure 3: FPA Temperature v/s Dark Counts (Mean of all pixels)

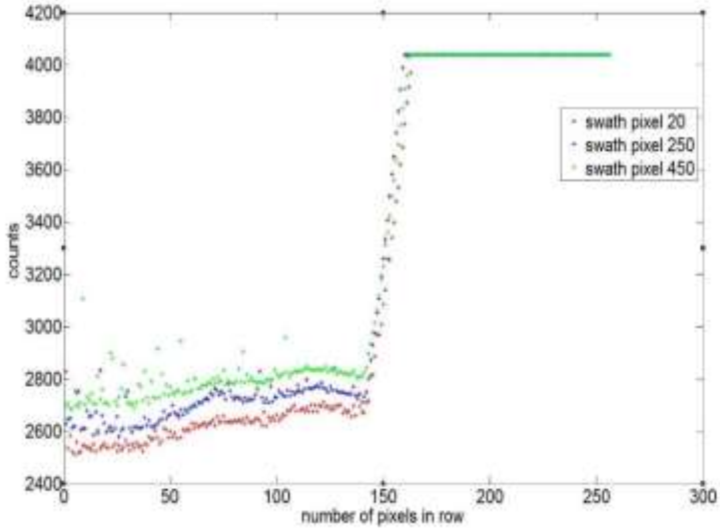

Figure 4: Dark count plot in spectral direction (256 bands) for swath pixels 20, 250 and 450

In figure 4 x-axis – denotes the spectral bands and y-axis corresponding dark counts for swath pixels, namely 20, 250 and 450.

Two curve fitting options are tried namely exponential (of order 2), polynomial (of order 3).Modelling or curve fittings carried out for individual pixels, swath pixels (with mean along spectral bands), spectral pixels (with mean along swath pixels) and mean of all pixels for global of full detector level trend. Results are stored in an excel sheet for final for future use as and when requirement arise. Some examples of modelling used are shown below.

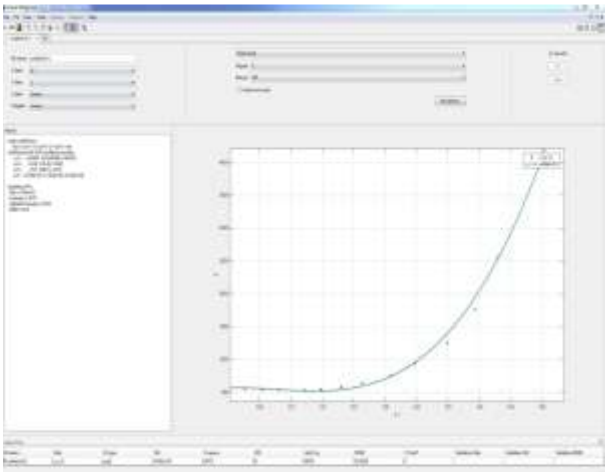

Figure 5: Exponential fitting of order two

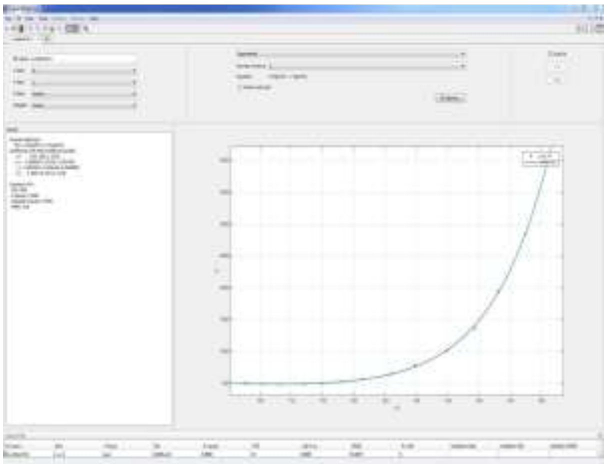

Figure 6: polynomial fitting of order 3

Different fitting options are available for example linear, sinusoid, sum of sines, exponential, polynomial etc. In the preceding two figures exponential and polynomial curve fitting are shown. Here polynomial curve fitting is chosen because of its mathematical simplicity. The fitting curve generates three coefficients p1, p2, p3 and p4 which satisfies the equation, **Dark Counts = $p1x^3+p2x^2+p3x+p4$**, where x is the FPA temperature. The coefficient values are generated for all 500*256 pixels and are stored in an excel sheet. figure 5 and figure

Radiometric Analysis

Radiometric analysis is carried out in terms the instrument output counts response to the input radiance. Also for various data sets of illumination, mean, SD and SNR computation is carried out.

SNR = mean counts / standard deviation (SD) in counts = μ / σ.

Where, $mean, \mu = \frac{1}{n}\sum_{i=1}^{n}(x_i)$ $and\ SD, \sigma = \frac{\mu}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_{i-}\mu)^2}}$

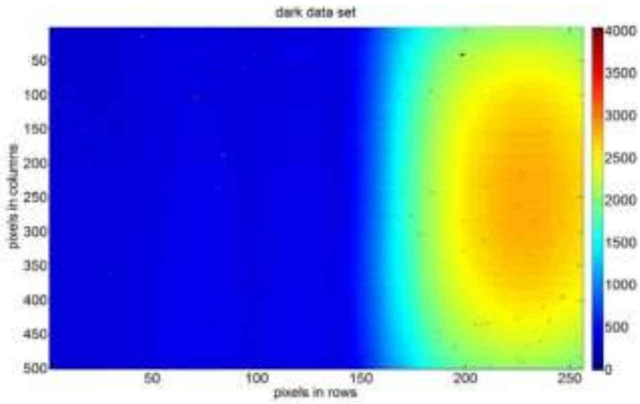

Figure 7: dark count image

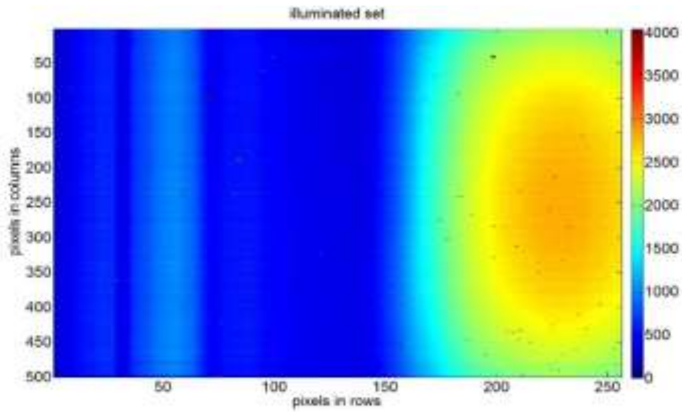

Figure 8: illuminated count image

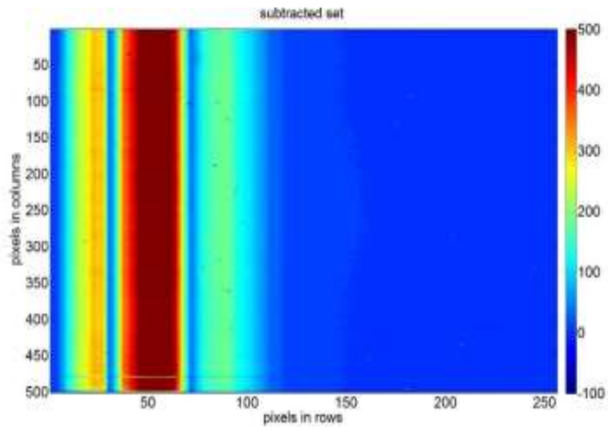

Figure 9: dark subtracted

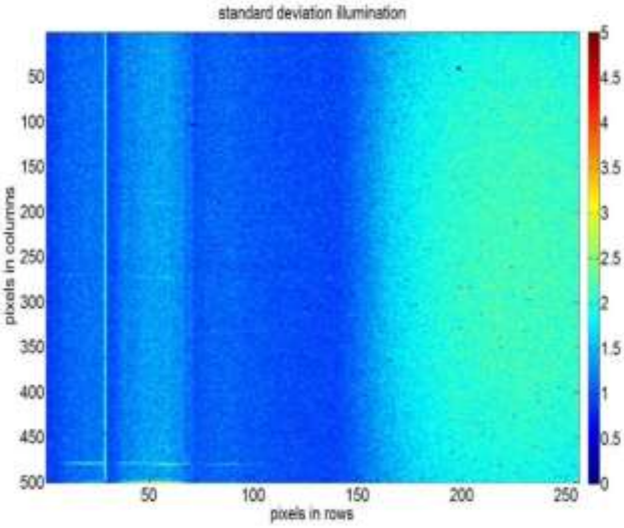

Figure 10: standard deviation image of illumination data

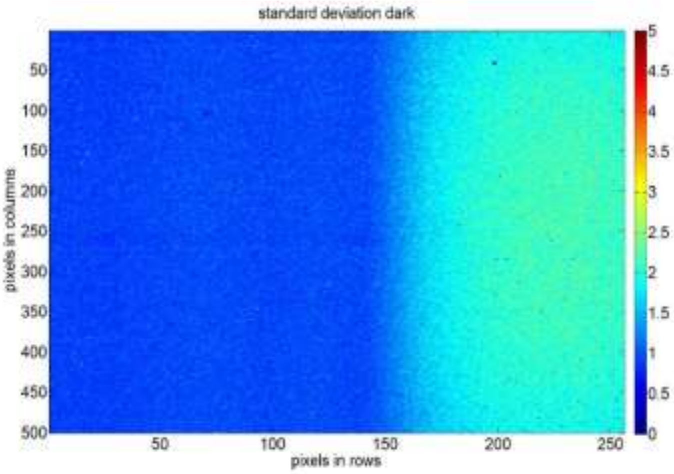

Figure 11: standard deviation image of dark data

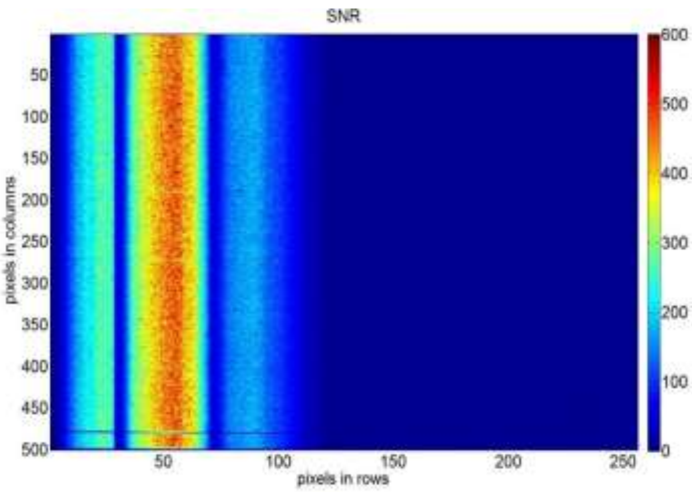

Figure 12: SNR calculated

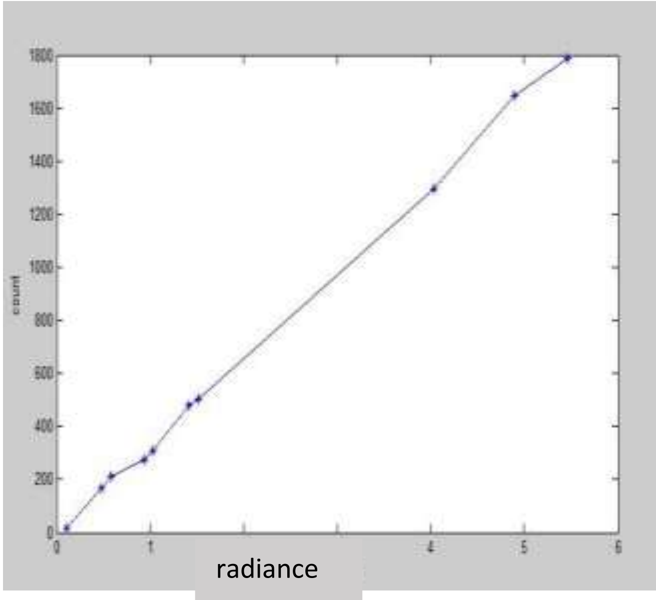

Figure 13: graph of count v/s radiance

Figure 13 depicts a relation a between radians v/s counts. Here there are ten specific points each corresponding to one data sets of which the radiometric analysis is done. Counts at any specific radians value can be determined from this graph. Linear transfer coefficients provides a mathematical relation to determine counts at any radians. Applying fitting tool to the graph of figure 13 coefficients of the transfer functions can be obtained.

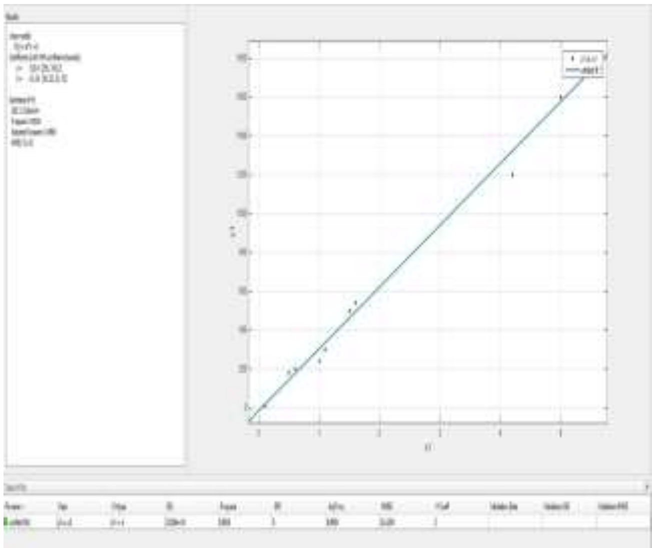

Figure 14: linear curve fitting on radian v/s counts

Above figure shows the linear fitting done on the count v/s radians graph. Linear fitting is chosen for mathematical simplicity. Two coefficients are generated for each dataset and the values are stored in excel sheet for future references. R square values are in the range of 0.9905-0.9987 depicting greater than 99.18% accuracy in fitting. Here the equation that is plotted is **y=a*x+b** where a is the slope and b is constant. The above fitting is for band number 56. For which a=318.6 and b= -15.24. For the whole spectrum a varies from 295 to 342.2 and b varies from -82.23 to 51.75.

Conclusion

Here in this paper thermal background modelling is carried out of Focal Plane Array temperature is carried out. Polynomial fitting of degree 3 is chosen as the best fit for coefficients generated for model and results are stored in excel sheets. Next the SNR is determined for the dark subtracted image for each pixel of the 500*256 pixel matrix and relation between radiance, counts and SNR is determined. Further the radiance v/s counts graph is taken for determining the LTC coefficients. Linear fitting is chosen for this purpose. All of the coefficients generated here can be applied to IR instrument data for correction and determining counts value at specific radiance values.

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