HIGH QUALITY IMAGE ACQUSITION METHOD USING DUAL PANCHOMATIC CHANNEL

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ABSTRACT : The Space-borne electro-optical camera system has panchromatic redundant image channel as well as primary channel in order to increase reliability of satellite system. In most case redundant channel never been used during the whole mission period. Staggered array configuration using redundant image channel and new operation mode proposed which operates primary and redundant channel simultaneously. Without new hardware design, fast electronics and system complexity, we can get 1.414 times more fine GSD image of original system or we can get 1.414 times more SNR or High dynamic range imaging mode. In this paper we deal with several image quality improvement methods using dual panchromatic channel.

KEY WORDS: CCD, MTF, SNR, BLOOMING, ARRAY

1. INTRODUCTION

The Space-borne electro-optical camera system has panchromatic redundant image channel as well as primary channel in order to cope with single point failure and increase reliability of satellite system. In most case redundant channel never been used during the whole mission period, because redundant channel has only one purpose of replacing failed primary channel and each channel has no more than 1~2% failure rate for mission time. Additional weight, mass, manufacturing and assembly burdens are in vain only to satisfy reliability number. In order to boost efficiency and utilize potential of whole system, we propose CCD array configuration using redundant image channel and new operation mode which operates primary and redundant channel simultaneously.

2. OPERATION

General space-borne camera system is consisted as Figure 1. The front end is CCD (Charge Coupled Device), which converts input image to electronic signal. Next stage, FPE (Focal Plane Electronics) receives analog electronic signal from CCD output and converts to digital signal. ICSU (Image Compress and Storage Unit) have several functions to get the transmission efficiency and data buffering. Data coding and modulation unit have coder and modulator for encryption and transmission of image data. Finally, antenna radiates electro magnetic wave contains image data to the ground station.

Along the image data flow, each functional block is connected with cross strapped path in order to avoid fault block. But generally, the line between CCD and FPE has only one dedicated path to get the signal integrity. Impedance of the line is controlled and well shielded, because this connection is very critical for the image quality,

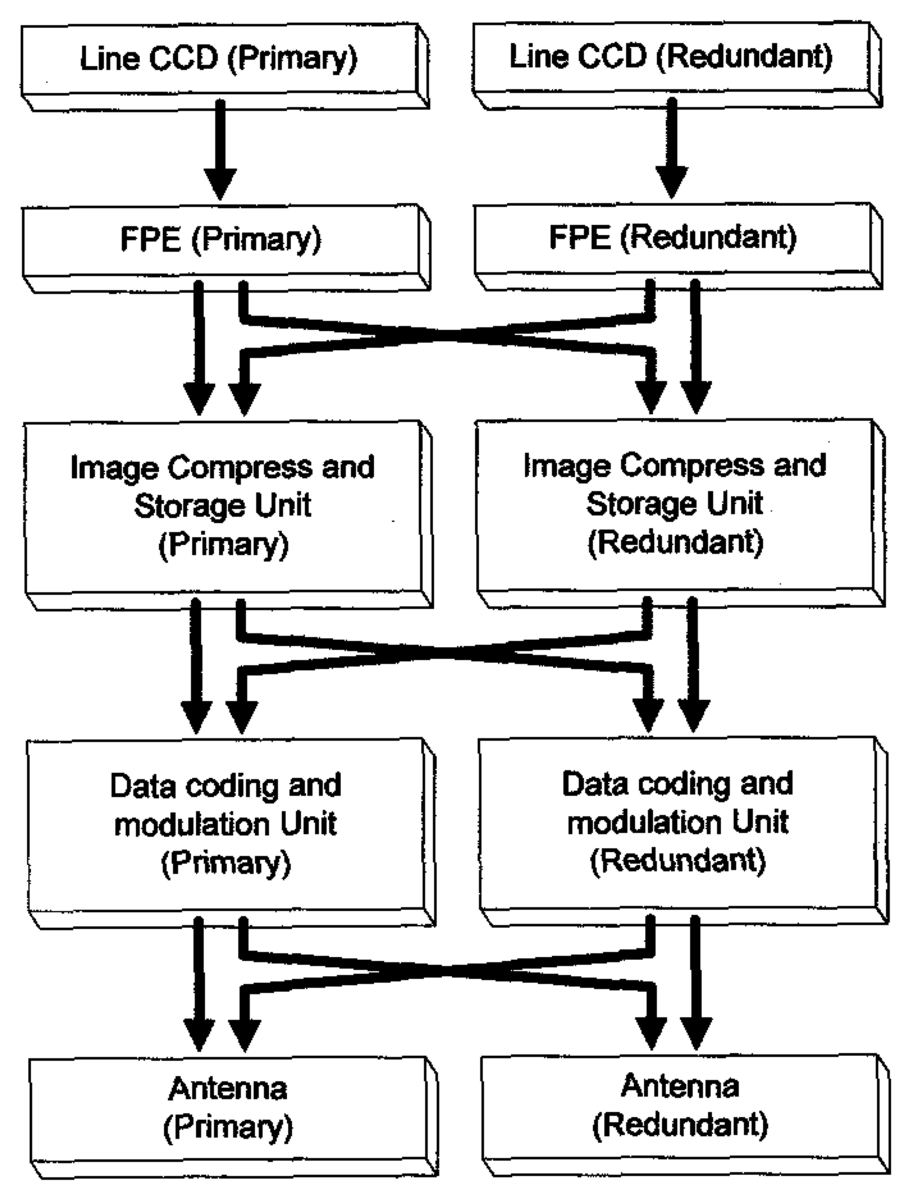

Figure 1. Image data flow

2.1 Conventional operation mode

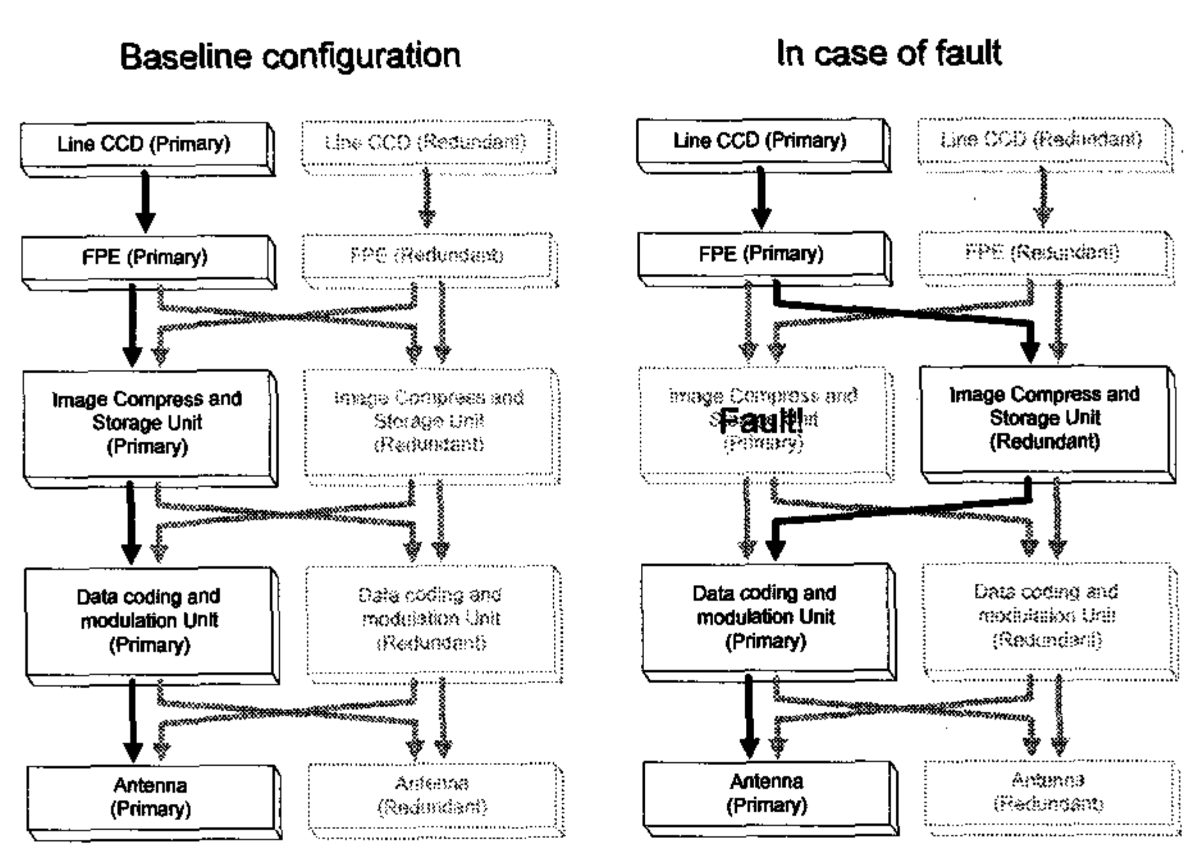

Figure 2. Typical redundant unit usage

At first, connection is established along the primary path. All redundant unit stay in idle status until some problem occurred in primary unit. In most cases they wait until mission ending time and never get the chance to operate. This operation concept can cope with any single fault failure in image chain and improve reliability of payload and entire satellite system but that's all. Mass, volume and manufacturing budgets are in sleep.

2.2 Proposed operation mode

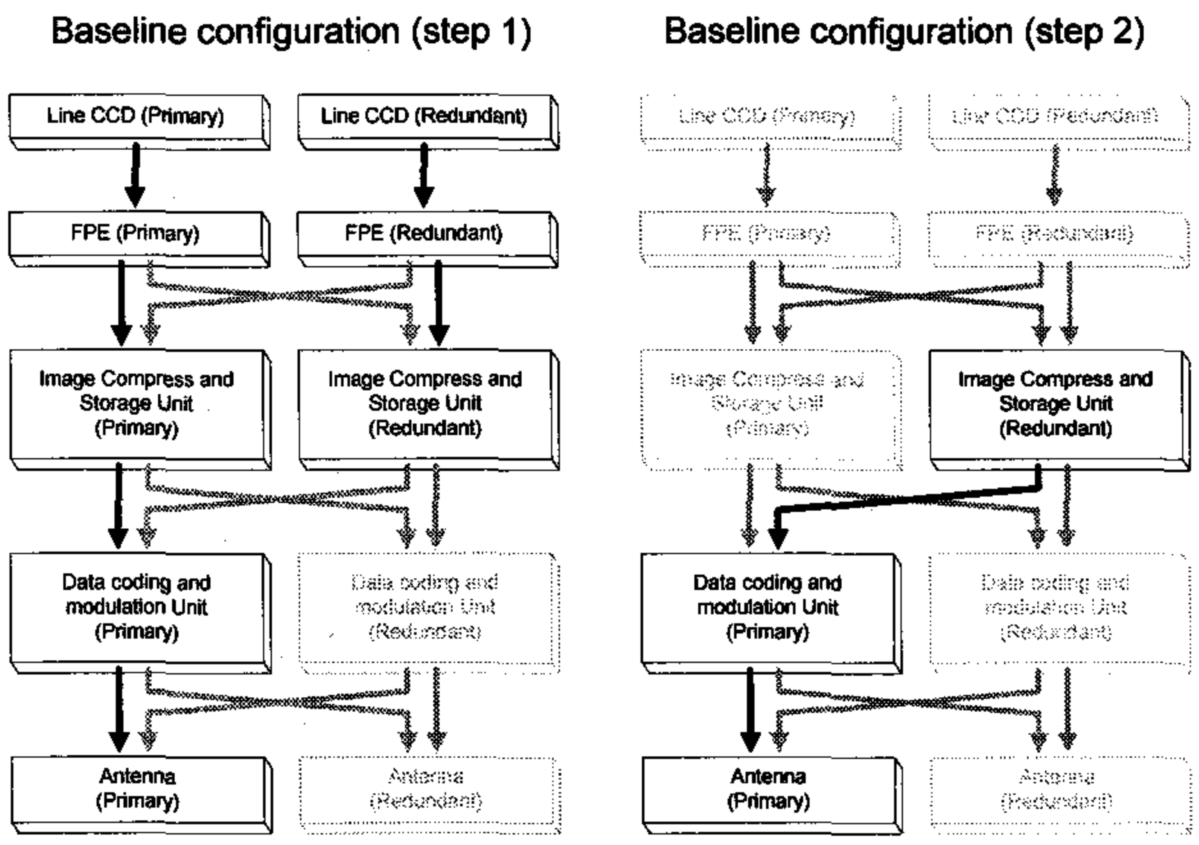

Figure 3. Proposed operation concept

In order to squeeze out all performance potential of imaging system, we can operate both primary and redundant imaging channel concurrently maintaining current redundant scheme and all hardware details. It is possible to get more fidelity by using redundant channel information. Only a few operation tweaks are needed.

The new operation concept is consisted of two steps, the first step is simultaneous imaging. Alike with conventional imaging, image data of primary channel is directly transmitted to the ground. But redundant image channel is not in idle but in operate. During the imaging, both primary and redundant CCD, FPE and ICSU are in operation. Image data of redundant channel is stored in the ICSU. The second step is transmitting redundant image data to ground. In unoccupied time, redundant image information can be transmitted to the ground station. This information attributes to the improvement of the image quality which is already transmitted primary image data by proper post processing. This operation concept does not harm to the coverage of single point failure but widen the liberty of operation and requirement.

3. IMAGE QUALITY IMPROVEMENTS

By concurrent imaging of both channels, primary and redundant, we can get higher quality image than conventional single channel imaging. High resolution, high SNR or high dynamic range imaging mode can be selected by operation or CCD alignment.

3.1 High resolution

Resolution is the most important factor on evaluating image quality. More shaper image provides more visual information.

Using a two lines detector, each line being shifted by 0.5 pixel along the CCD direction and (n+0.5) pixel along scanning direction, each CCD line thus produces conventional images with a 0.5 pixel offset along both row and column directions. Interleaving the two images yields a quincunx sampling which has the twice dense sampling grid.

The quincunx grid generated by two 0.5pixel shifted CCD arrays has sampling frequency 1.414 times higher than original sampling grid and its unit pixel geometry form is rhombic structure rather than rectangular. Figure 5 shows general optical system MTF with conventional sampling and quincunx sampling. In each case pixel MTF is almost same but 1.414 times faster Nyquist frequency makes maximum MTF value outside from the Nyquist frequency 0.22 to 0.12 and aliasing effect is dramatically reduced.

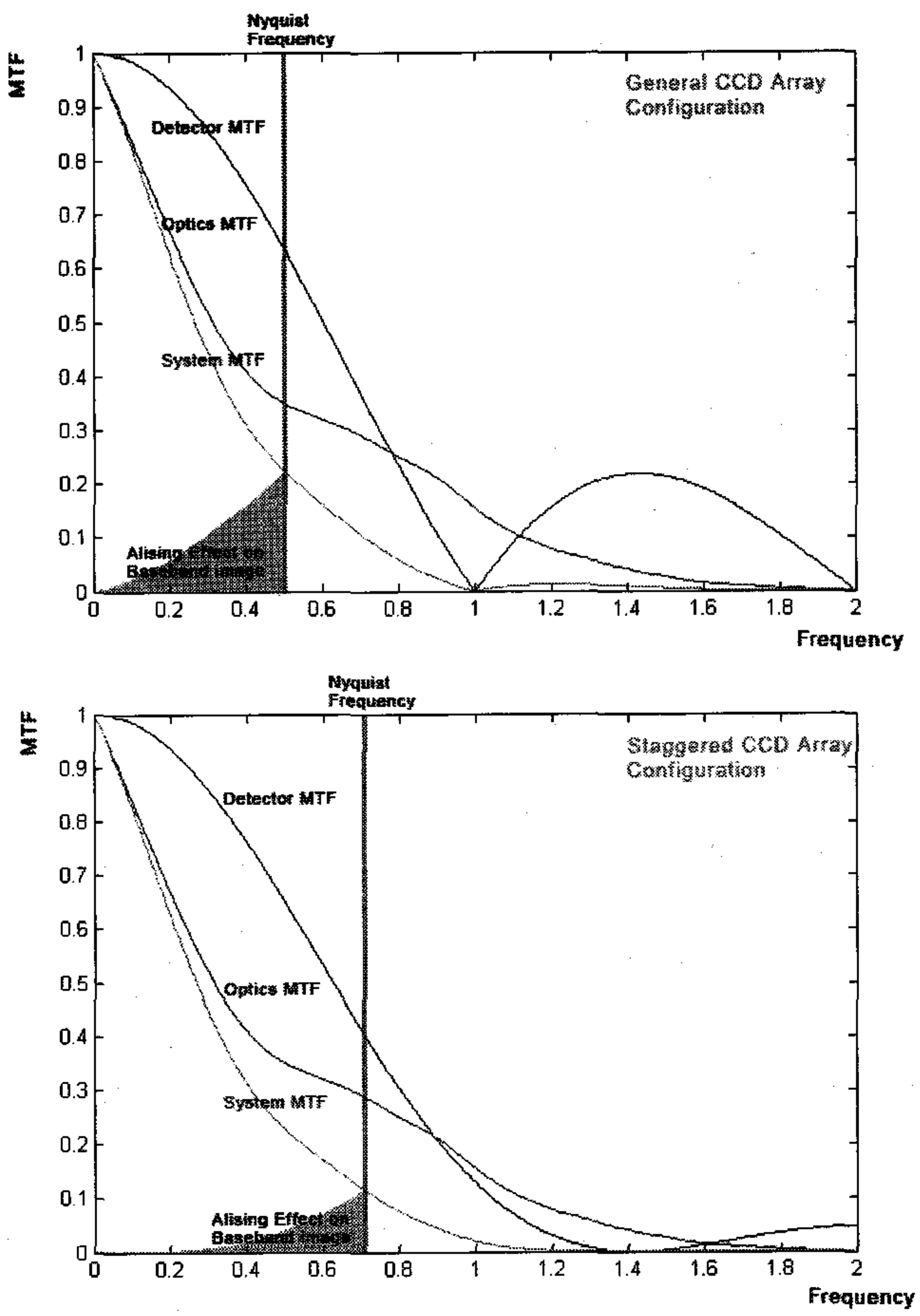

Figure 5. MTF and aliasing comparison

For the best performance in resolution, CCD must be aligned carefully. Each CCD has to make correct quincunx sampling grid.

3.2 High SNR

For the image quality, SNR is also important factor. Higher SNR images give more information than low ones and sometimes it is much more important than resolution factor in point of quality of visual perception. By concurrent imaging, higher SNR images can be acquired. Theoretically, when primary and redundant channels are aligned perfectly in pixel (in case of primary and redundant pixel shows exact same area), 1.414 times SNR improvement is possible. Several operation scenarios are possible. According to interested area, (ex. low light region, medium light region) same TDI or different TDI between primary and redundant channel can be selected.

3.3 High Dynamic range (Anti blooming)

Blooming occurs when the charge in a pixel exceeds the saturation level and the charge start to fill adjacent pixels. Typical CCD sensors are designed to allow easy vertical shifting of the charge and especially TDI (time delayed integration) type CCD which is commonly used in pushbroom type spaceborn imager has very low potential barrier along the vertical line. Excess charge will preferentially flow into nearest vertical neighbours and Blooming therefore produces a characteristic vertical streak.

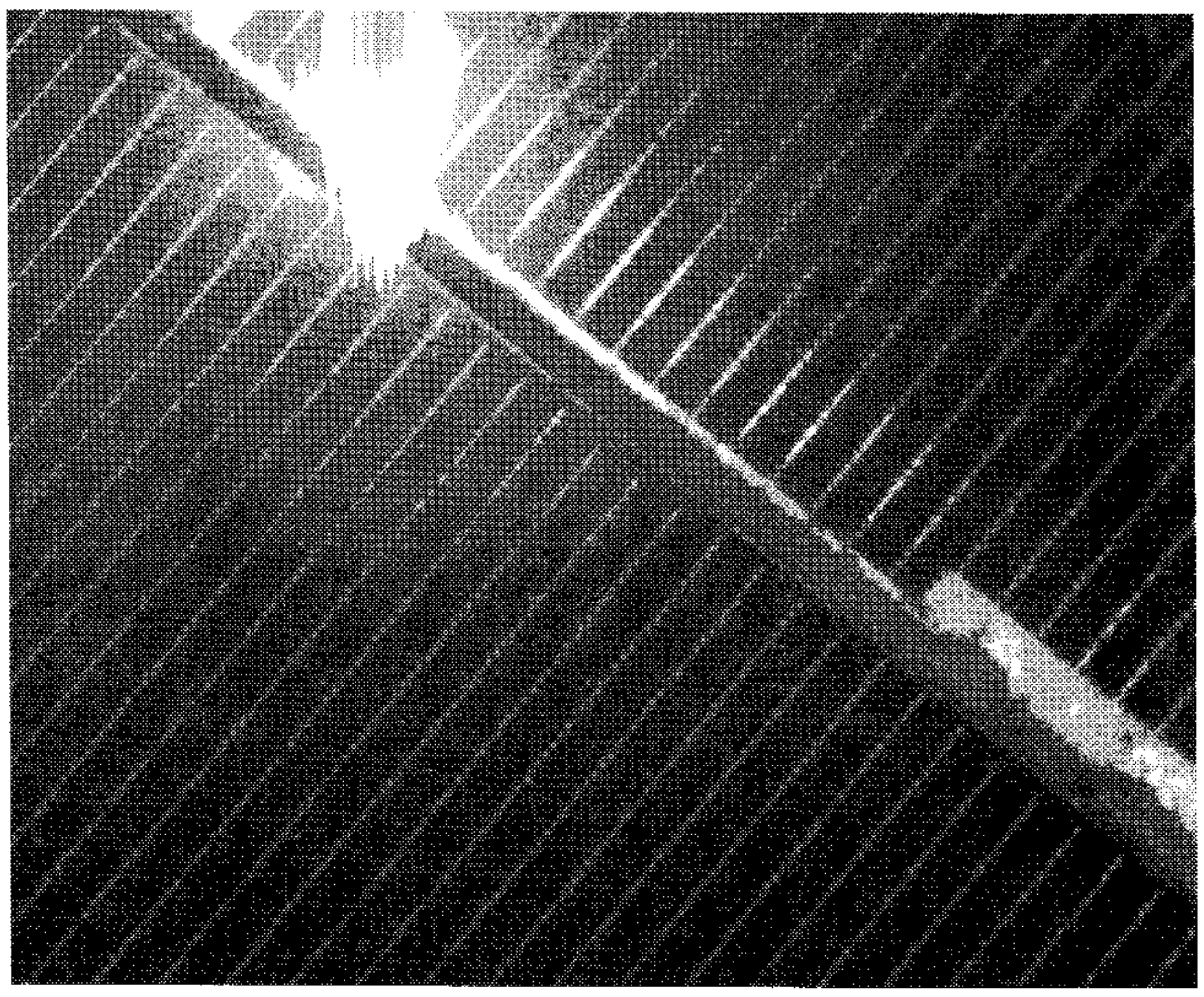

Figure 5. Example of CCD blooming

Blooming can be a nuisance when a strong signal can obscure data from a weak signal of interest especially on an image with a high dynamic range. Anti-blooming structure can help reducing this artifact but it also decreases sensitivity and full well capacity of CCD significantly. Anti blooming structure decreases whole system performance and especially in case of TDI sensor, it is very hard to adapt anti-blooming along the TDI direction. Without any system performance degradation and any hardware modification, only by using different TDI between primary image channel and redundant image channel, we can get anti-blooming function. Operation of CCD with lowered TDI than nominal value does not induce saturated cell and blooming of electrons.

4. PRACTICAL CONSIDERATIONS

In previous chapter, three major improvements using redundant image channel is introduced. As we reviewed, all three improvements can't be achieved in same time. We had to distribute performance resources according to the demands.

CCD alignment is the most important factor for the system performance trade off. N+0.5 pixel alignment is the best solution for spacial performance but the worst for SNR performance. And N pixel alignment is vice versa. Because this parameter can't be changed in orbit we had to choose before launch phase and actually integration phase. There is no satellite operation flexibility. The other point is alignment accuracy. The limitation of alignment accuracy limits and distortion of optical system make hard to exact alignment between primary and redundant channel. To get the best results from primary and redundant CCD array, exact real coordinate of all pixels must be acquired and sophisticatedly ground processed.

Different TDI parameter can be chosen in imaging. To maximize low light level SNR performance, primary channel is operated in norminal TDI parameter and additional redundant TDI parameter should be selected to higher TDI. The information from redundant data has higher SNR in low light region but it may be saturated in some region. So by this method we can improve SNR value of low light region except the region polluted by blooming. If blooming artifact is more critical, we can choose low TDI mode operation of redundant channel. This can be controlled by the ground operation according to the image optimization demands.

5. CONCLUSION

By concurrent operation of both primary and redundant channel, we can get more visual information in several aspects. Without new hardware design, fast electronics and system complexity, we can get 0.707 GSD image of original system and aliasing effect can be minimized. These advantages make ground image correction process more accurate and efficient. We can also get the high SNR images and anti blooming images. Smart operation and ground image processing are very important for the image quality.

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