NASA Technical Memorandum 108515

Enhancement of High-Speed Infrared Array Electronics

(Center Director's Discretionary Fund Final Report Project Number 93–03)

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DEFINITIONS OF ABBREVIATIONS

BIB	blocked-impurity-band
IRT	infrared telescope facility
IR	infrared
VME	Versa Module Europe
OSCIR	observatory spectrometer camera for the infrared

TECHNICAL MEMORANDUM

ENHANCEMENT OF HIGH-SPEED INFRARED ARRAY ELECTRONICS
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INTRODUCTION

The Space Sciences Laboratory and the Astrionics Laboratory developed an advanced infrared (IR) spectroscopic camera for observations of astrophysical sources, atmospheric phenomena, and the shuttle and other satellites. The camera utilized an Aerojet (BIB) 20- by 64-pixel array. Because of the high thermal background at these IR wavelengths, the state-of-the-art detector must be read out very rapidly to prevent detector saturation. The signal-to-noise level is very critical to such measurements. It is crucial to amplify small signal sources without introducing noise. The objective of the Center Director's Discretionary Fund (CDDF) task was to specify, design, and integrate a low-noise, high-frequency preamplifier into the detector system. The entire system was tested at the IRT facility on Monte Kea in Hawaii.

DESCRIPTION

A general description of the system, from an engineering standpoint, is warranted before a discussion of the preamplifier design (fig. 1). The MSFC/UCSD spectrometer-camera (OSCIR) was developed for use at the focal plane of ground-based telescopes. The system consists of a detector dewar, preamp, digital signal processor box, and display and control computer.

The detector dewar contains the infrared detector, IR optics, and cryogen tanks for helium and nitrogen. The detector is an array of 20 by 64 pixels. It is cooled to liquid helium temperature (4 K) with a cold finger from a helium dewar. The optics can be adjusted to select either imaging or spectrometer measurements. The outputs from the detector exit the dewar via a connector next to the optical window. The preamplifier is directly mounted to the dewar. Twenty output coaxes feed the preamp, which drives cables connected to the DSP/analog electronic box.

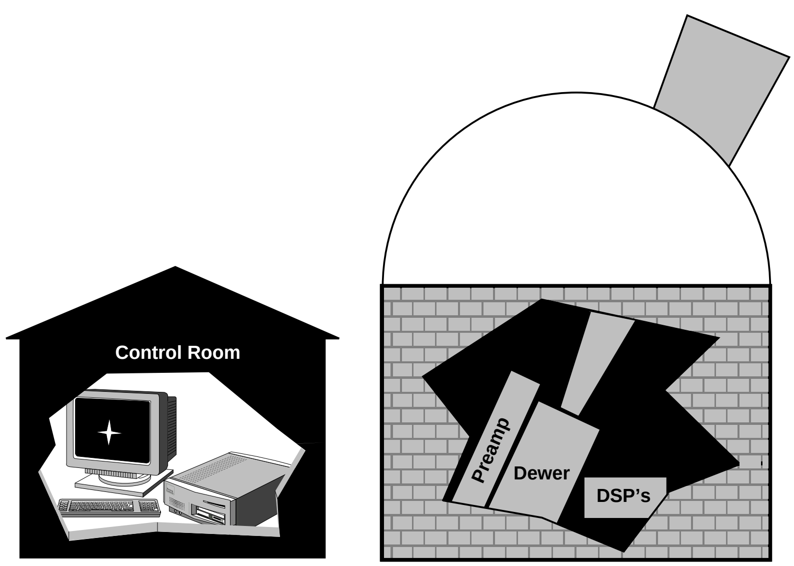

Figure 1. Preamplifier design.

The electronics box consists of a 6U VME rack with five processing cards. Each card digitizes four analog inputs by multiplexing the input lines to a central analog-to-digital converter operating at 2 MHz. One of the DSP boards acts as the central controller and synchronizes the timing for the detector and other DSP processing boards. An 80486 processor board acts as the slot 1 controller for the VME bus. This processor board is the master controller for the data acquisition system and reads the digitized image data from the bank of DSP processors. The data are stored on a read/write optical disk via an optical cable to the operator's console. The system is configured so that the operator can remotely control the operation of the system. The operator controls the system from a remote computer console, which is linked to the telescope/camera via a local area network.

The driving force in the design of the detector system is the elimination of unwanted infrared emissions and other noise sources. The telescope itself is a strong emitter of infrared radiation. Its infrared signal is fairly constant over time. The sky, in general, is also a strong source and rapidly fluctuates. These sources of "noise" can be partially eliminated by the way data are collected. "Nodding" is a procedure in which the entire telescope is slightly moved back and forth every 10 s. "Chopping" is a method in which a small mirror inside the detector housing is moved every 0.1 s (10 Hz). The mirror movement causes one image of the object of interest to be taken and the next is of the background sky close to the object. By taking four images, two in each node position, the sky and telescope noise can be greatly reduced by adding together the object images and subtracting off the sky images. A "noise-less" image of the target remains. This can be expressed as:

Object Image = Object Image 1 + Object Image 2 – Sky Image 1 – Sky Image 2 .

These techniques for noise reduction can only be useful if the processed data are good. Assuming the detector itself is as good as can be made from the technology available, i.e., it converts the infrared energy into electrical efficiently, the electronics that convert the electrical energy to image data must also be efficient and noiseless. The voltage levels from the detector itself are low, approximately 1 V. To convert these signals to digital data, it is necessary to have as much resolution as possible. But with low-level signals, that is difficult to obtain. Gain is introduced to increase the signal level. If the signal is amplified by ten, all signals, whether noise or wanted signals, are amplified. If noise is introduced between the detector and the amplifier, it too will be amplified. A preamplifier is placed close to the detector to boost the signal level. This amplifier has to work on low-level signals, introduce minimal noise, and be stable.

The noise level that can be tolerated was determined from the noise level generated from the unit cell (pixel) of the detector. A noise level of 30 μV per unit-cell output is generated by the unit cell. The rest of the electronics, preamplifier, amplifier, a/d converter, etc., must not introduce anymore than the 30 μV of additional noise. After determination of the noise margins, a study was done of available off-the-shelf amplifiers. The PolyCom Development Corporation had an amplifier that was being developed for the another telescope project in Hawaii. The amplifier had 96 input channels that where multiplexed to 24 output channels. Initial analysis of the circuit design determined the component selection, and amplifier/multiplexer design could not produce the low-noise amplification desired. The operational amplifiers used in their design produced more noise than allowed and were not fast enough. The amplifier also had a programmable gain section whose configuration and component selection could produce different gains between the 96 input channels. After a redesign, the initial input operational amplifiers where changed and the programmable gain section was eliminated. This led to an amplifier that at least looked good on paper.

The PolyCom amplifier was incorporated into the system and full-up system tests were performed in the laboratory. After the system verification tests, the entire system was shipped to the IRT facility in Hawaii for engineering tests on the telescope. The overall system performed well, but noise problems and detector timing problems limited the amount of astronomical data that was gathered. The noise problems seem to come from the preamplifier section, but a thorough analysis has not been done since the lead scientist and the entire system left the Government.

CONCLUSION

The design of the entire IR spectrometer-camera system was a learning experience. Everything, from the mounting of the detector chip to the layout of the controllers system console, was new. The state-of-the-art IR detector promises to increase understanding of IR sources, whether it be astronomical or manmade. The entire system worked as it was designed with the exception of the noise problems. In every new technology there are periods of refinement where adjustments are made after the first tests are performed. This system is no exception. The preamplifier problems, once tested and understood, could be modified to yield the desired results.

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