

# The Radiation Measurement System (RAMS)

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Radiative processes in the atmosphere are at the heart of anthropogenically induced climatic changes. High quality measurements of radiative parameters must be obtained to be able to characterize the way in which the interaction of radiation with the atmosphere results in climatic change and evolution. With the goal of contributing to the above objective we are developing state-of-the-art radiation measuring instruments. We are using the latest technology and extensive heritage from our aircraft and spacecraft systems to achieve the stringent requirements of the Atmospheric Radiation Measurement (ARM) program. The Radiation Measurement System (RAMS) will provide infrared spectral and broadband fluxes and radiances. Furthermore, the RAMS will be an integrated system with central instruments control, real time data processing and display, and the modeling capacity to monitor the progress of the experiments. We also plan to offer, for consideration by the science team, prototype field demonstrations of novel solar multichannel instrumentation (the solar instrumentation is being minimally funded by other sources). The combination of self consistent, infrared (IR) and shortwave radiometers is, in our opinion, crucial to meet the ARM requirements.

## Narrow Spectral Bandpass, Narrow Field of View Multiple Spectral Channels Radiance Radiometer

### Instrument Concept and Description

The instrument design is directed toward obtaining accurate IR radiance measurements by careful choice of materials, components, layout, and, above all, the best available technology, together with a superior approach to the physical problems of IR measurements.

The most important design objectives are to

- a) maximize the signal-to-noise ratio (SNR) by the use of synchronous ac detection, which is made possible by the fast response of the detectors
- b) eliminate the error introduced by infrared emission from the optical components (filters, windows, domes, etc.)
- c) use a detection system insensitive to changes in the responsivity of the detector and amplifier gain and to variations in ambient temperature

- d) ensure the ability of the instrument to remain calibrated under all foreseeable conditions and for long periods of time in order to provide accuracy of the measurements. We achieve this objective by using the Electrically Calibrated Pyroelectric Technology, plus a liquid-nitrogen-cooled blackbody reference that provides the zero radiation signal level. Identical optical elements in the scene and reference optical paths provide a symmetric, self compensating, balanced infrared detection arrangement.

Before we discuss how the design objectives are met, a brief description of the prototype airborne system is in order. The radiometer uses three germanium lenses, an electrically calibrated pyroelectric detector, optical chopping, a null-balanced method of measurement, and a liquid-nitrogen-cooled blackbody surface as a zero-radiation source. A schematic of the system optics for one channel is shown in Figure 1. The two channels are identical except that one is a mirror image of the other, and they may differ in the spectral filtering used. The radiation passes through a 25-mm-diameter objective lens, reflects off the gold-plated surface of the optical chopper, and is then focused on a 25-mm-diameter field lens which images the objective on the detector. During the half-cycle when the optical chopper has rotated out of the path of the scene radiation, a third lens, identical to the objective lens, permits the detector field to be filled by the cold blackbody surface. This lens is also imaged on the detector.

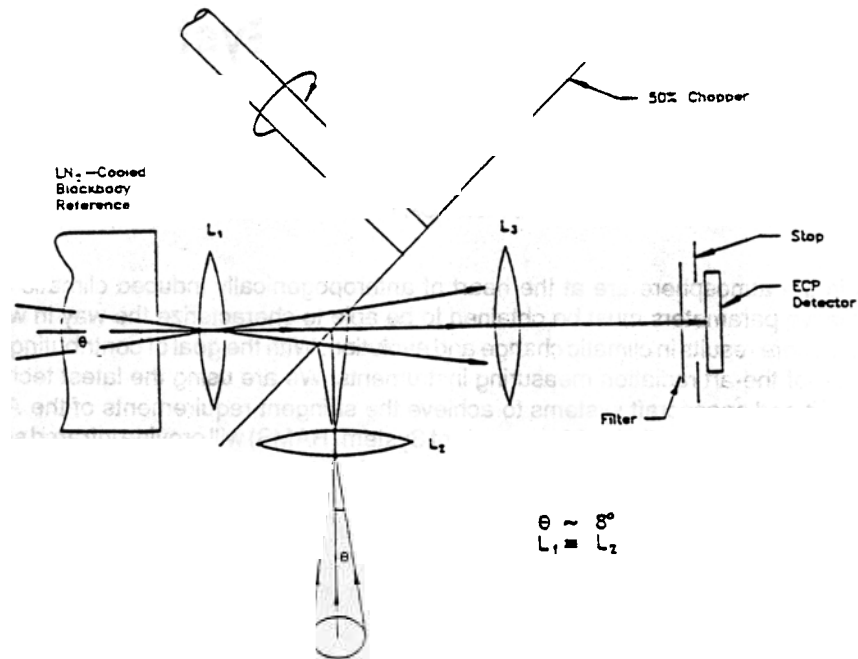


Figure 1. Optics schematic for one channel of the narrow field of view radiometer (NFVOR) infrared radiance radiometer.

Maximizing the SNR (objective a) is achieved by using a lithium tantalate pyroelectric detector, a fast detector that easily permits signal modulation and, therefore, synchronous amplification and detection. Furthermore, as in the case of the broad spectral bandpass radiometers, synchronous amplification is conducive to a large SNR and the rapid acquisition of data which is so important in the case of fast-moving clouds and/or aircraft, as would be the case if this instrumentation were to be used aboard aircraft participating in the ARM program.

Using both optical chopping and the proper location of spectral filters eliminates the error introduced by IR emission from the optical components (objective b). Radiation emitted by any component of the system located between the chopper and the detector produces a dc signal and hence does not contribute to the output signal of the synchronous amplifier. Filters are, therefore, placed between the chopper and the detector.

The key to the operation of the radiometer is the generation of an electrical signal synchronized 180 degrees out of phase with the optical chopper. This signal is fed into the gold-black coating on the detector surface which also serves as a resistive heating element; this gives a thermal

signal in opposition to that resulting from the chopped optical radiation. The amplitude of the electrical drive is then varied until a null is detected at the output of the synchronous amplifier. At this point, the optical power absorbed by the detector is nominally equal to the electrical drive power. The latter is measured and digitally recorded on computer memory. Objective c is clearly fulfilled by the use of this detection method since the null detection is independent of circuitry changes and temperature.

The calibration design (objective d) is met by using identical objective lenses mounted in the same heat sink for viewing both the field radiation and the liquid-nitrogen-cooled blackbody surface. This ensures that the optical path characteristics are the same for the two fields viewed and that radiation emitted by each lens and viewed by the detector is the same. The primary difference between the two optical paths is the presence of the optical chopper when the radiation field to be measured is viewed. Radiation emitted by the chopper is then received by the detector along with the radiation from the atmosphere. This chopper emission is relatively small since the gold-plated chopper has an emissivity less than 0.01 at the operating

temperature. This small contribution is taken care of as discussed in the following calibration section.

## Calibration

The detector is an absolute device and calibration in the usual sense is not required. The fraction of radiation attenuated by the lenses and the filter can be measured and a resultant loss factor applied to the measured signal. Alternatively, the complete radiometer may be calibrated using either a standard source or a standard detector. The later approach has proven superior in our experience with the two-channel aircraft prototype. Figure 2 shows a calibration plot for the NFOVR. Figure 3 shows an example of the high quality of the data obtained during the Stratospheric-Tropospheric Exchange Project (STEP) from the NASA ER-2 aircraft flying over tropical cumulus-nimbus anvils north of Australia. The figure depicts brightness temperatures determined at 6.7 and 10.3  $\mu\text{m}$ . Note the excellent agreement between the 6.7 and 10.3  $\mu\text{m}$  brightness temperatures in the regions where the anvil is optically very thick (black). This agreement is an indication of

the high quality of the data acquired using the proposed measurement approach.

We are continuing with the development of this radiometer by incorporating several additional spectral channels, extending its overall wavelength coverage to 60 microns, and modifying its thermal control system for ground operations.

## Hemispherical Field of View Multiple Spectral Channels Infrared Flux Radiometer

In order to incorporate the advantages of a liquid-nitrogen-cooled blackbody reference for the measurement of infrared hemispherical fluxes, we plan to apply concepts identical to those employed to measure IR radiances with the NFOVR described in the previous section. We will achieve this by developing a new IR hemispherical field of view radiometer (HFOVR), incorporating a novel optical

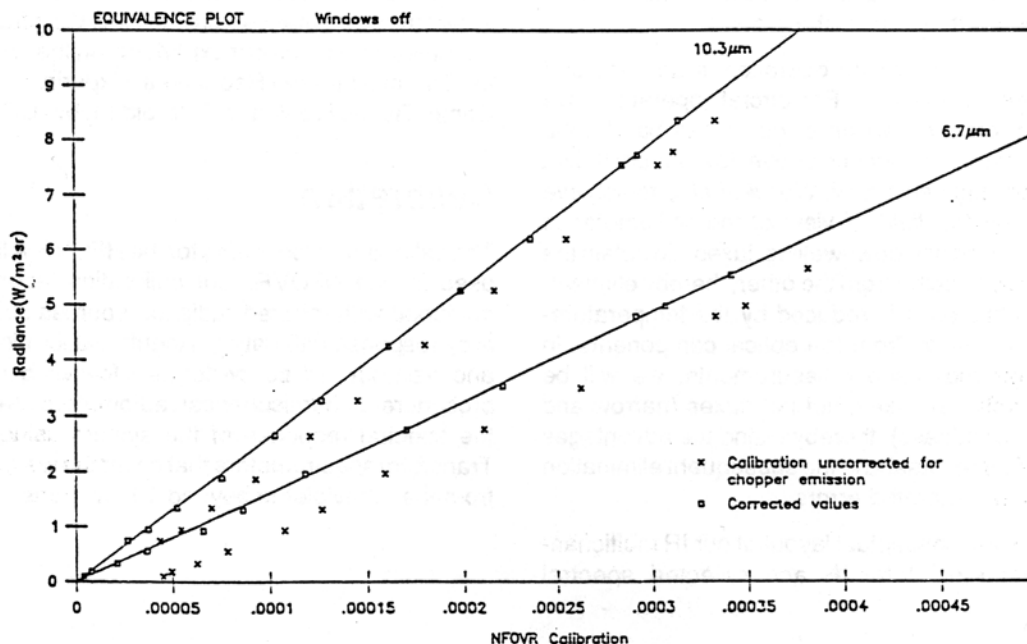
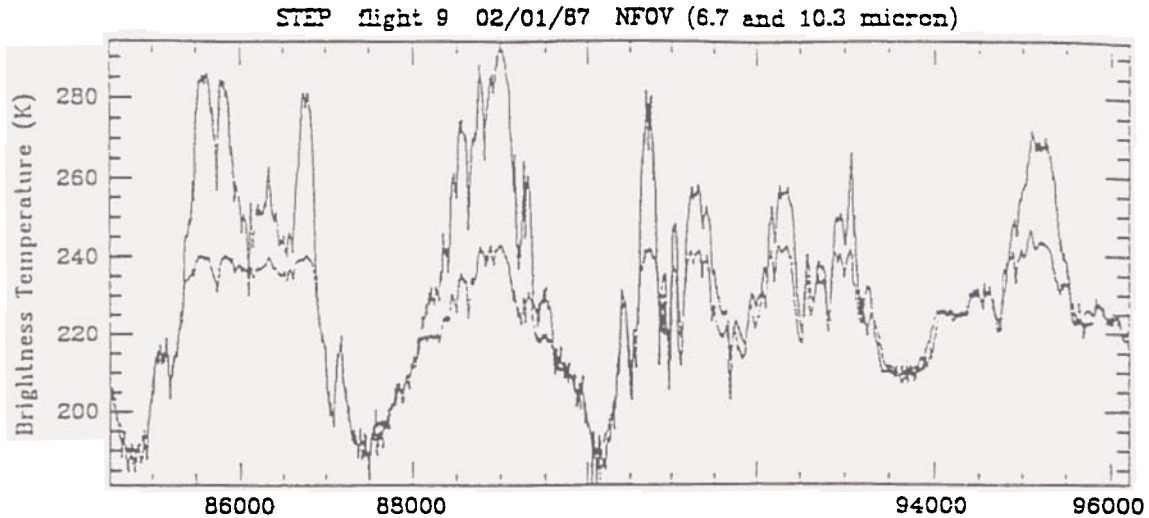


Figure 2. Laboratory calibration plot obtained using a very low temperature calibration blackbody standard source.



system with a hemispherical field of view compatible with IR radiation and with use from the ground.

The compatibility with ground operation is an important element for the new design. For aircraft operations we have used an infrared version of our broad band solar hemispherical system described above, to measure IR Net Fluxes with very high accuracy. We were able to achieve this by reversing the field of view of the radiometer to determine upwelling and downwelling fluxes. To obtain the net flux, one is subtracted from the other, thereby eliminating the systematic error introduced by the temperature-dependent IR emission from the optical components. In the case of ground-based measurements, we will be measuring directional fluxes, not net fluxes (narrow and broad spectral bandpass), thereby losing the advantages of the field of view reversal and the subsequent elimination of instrumentally generated errors.

Figure 4 shows the conceptual layout of our IR multichannel flux radiometer (total IR and selected spectral

bandpasses). Clearly, this instrument benefits to a large extent from inheritance from the NFOVR infrared radiance radiometer and from our experience in the development of the Thermal Infrared Radiometer Experiment of the NASA Comet Rendezvous and Asteroid Flyby (CRAF) Mission.

## Calibration

The calibration procedures for the HFOVR will be the same used for the NFOVR. Our calibration laboratory is well equipped with infrared radiation sources suitable for energy response calibration. Angular calibrations for zenith and azimuth will be performed following our standard procedure for hemispherical radiometers. We will confirm the spectral response of the system using our Fourier Transform spectrometers that cover the wavelength range from the ultraviolet to beyond 100 microns.

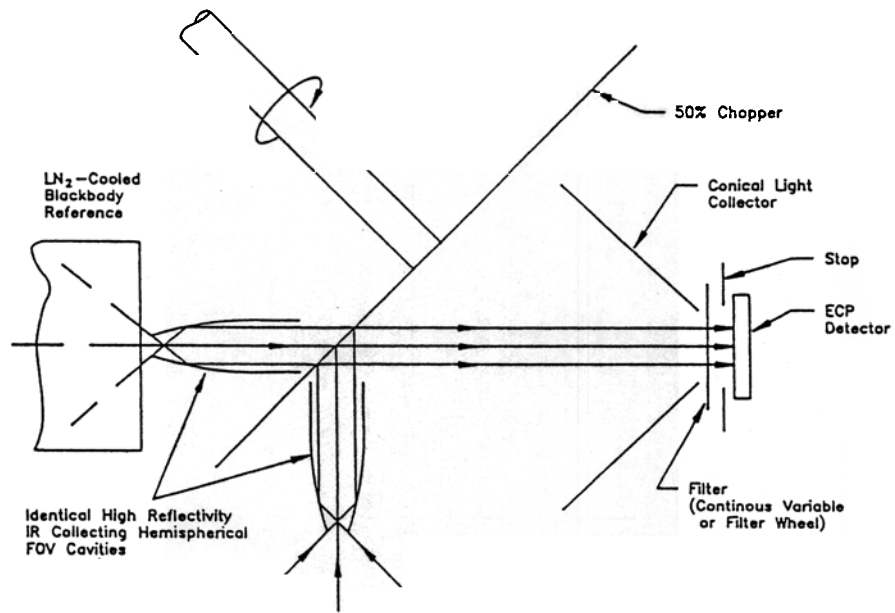


Figure 4. Optical schematic for one channel of the HFOVR IR flux radiometer.