A MILLIMETER WAVE RADIOMETER FOR COSMIC BACKGROUND RADIATION MEASUREMENTS

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ABSTRACT

A ground-based radiometer for measuring the cosmic background radiation at a wavelength of 2.1mm is described. The instrument, including black body radiators for calibration, is self-contained and operable in the automatic mode. Output data is punched on paper tape for later computer analysis.

A ground-based radiometer for measuring the cosmic background radiation is in the final stages of construction. The instrument, including black body radiators for calibration, is self-contained and operable in an automatic mode driven by a teletype tape reader. Output data is punched on paper tape for later computer analysis. The basic objective of this work is to measure cosmic radiation at a wavelength of 2.1mm, corresponding to an atmospheric window, to obtain additional experimental evidence concerning the validity of the primeval fireball theory of the formation of the universe. To support this theory the magnitude of the measured radiation must be consistent with that from a black body at a temperature of 2.7K. Field measurements using the radiometer described here are planned during Spring, 1974.

The radiometer shown in Figure 1 consists of the detector, filter, modulator, transition to oversize circular waveguide, a length of circular waveguide and two black body absorbers which can be inserted at either end of the circular waveguide. The apparatus is placed into a liquid helium dewar so that the detector, filter modulator and one absorber are immersed in liquid helium. The other end of the circular waveguide emerges from the top of the dewar by the second absorber. The whole apparatus tilts so that radiation can be collected from the zenith sky and the sky at a maximum of 60° from the zenith. The ambient and liquid helium cooled absorbers provide calibrating sources interspersed with measurements at various sky angles which are required to take atmospheric emission effects into account.

A diagram of the radiometer filter, modulator, and detector is shown in Figure 2. The detector consists of a thin slab of InSb terminating a short section of WR-12 waveguide. These detectors are in continual development but the better ones at the present time have approximate values of 800Ω dc resistance, 5000 v/w responsivity and 7db return loss at the test frequency of 143 GHz. Band pass filtering is a achieved by a mechanically driven cutoff waveguide modulator and a magic tee-cutoff waveguide filter[1]. The combination produces a sharp attenuation at the band edges of 130 and 150 GHz. The effectiveness of the filtering will be tested with a built-in waveguide cutoff attenuator also shown in Figure 2. Calculations, based on a detector noise twice Johnson noise and an overall amplifier plus matching transformer noise figure of 0.5db, indicate a system ΔT of about 2.5K for a one-second integration. System calculations show that random errors in the background measurement can be reduced to the system ΔT with about 100 seconds of integration time distributed over measurements of zenith sky, sky 55° from zenith, and hot and load calibrating terminations. So with hours or days of measurement time the error bars can be reduced to a fraction of a degree.

A block diagram of the Data Acquisition System is shown in Figure 3. A Hewlett-Packard Coupler/Controller system is used which enables a control tape on the teleprinter tape reader to drive the system in an automatic mode. The system is programmed to move calibrating black bodies into position, tilt the radiometer and measure radiometer output and thermometer signals. The data are formatted and coded and punched on paper tape as well as printed on the teleprinter. At a later time the paper tape data can be transmitted to a computer for data reduction via a telephone line.

A photograph of this apparatus is shown in Figure 4. The radiometer, located in the center, is shown with the dewar tilted for measurement of radiation corresponding to a zenith angle of approximately 30°. The antenna output is located near the focal point of the shield so that the sidelobes of the antenna will effectively see the zenith sky temperature. Also shown are the data acquisition equipment located on the left and the detector test set-up located on the right.

References
1. Torgow, E.N. IRE Trans. On Microwave Theory and Techniques, Vol. MTT-7, pp. 163-167, January 1959.

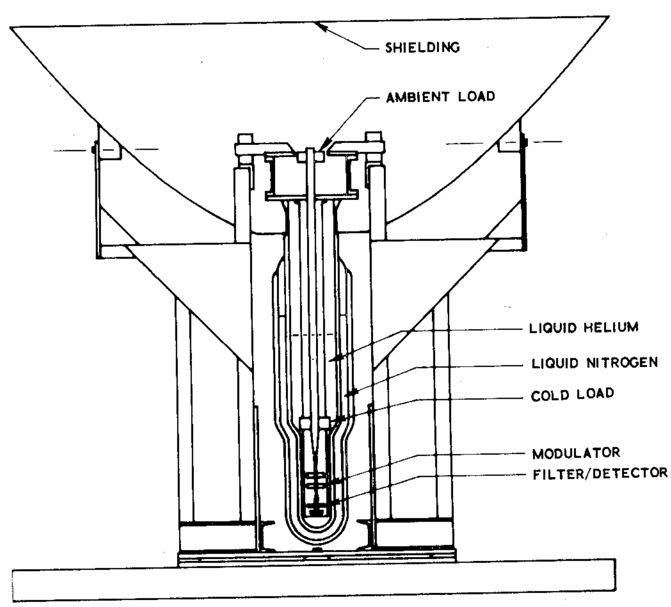

Fig. 1. Diagram of 2mm radiometer showing dewar mount and shielding which can be oriented to various zenith angles.

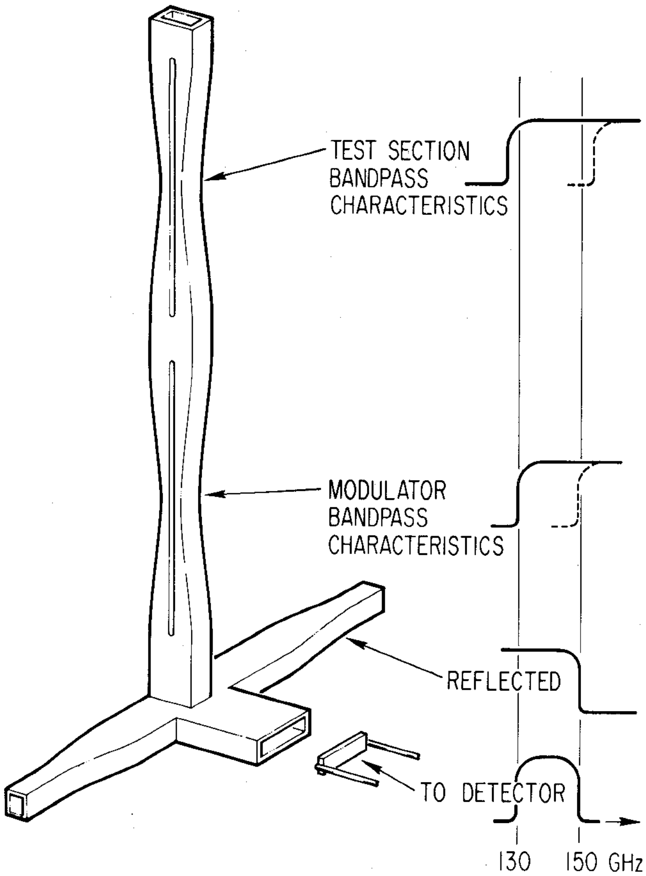

Fig. 2. Diagram of the radiometer detector, filter, modulator, and test section along with appropriate pass band characteristics

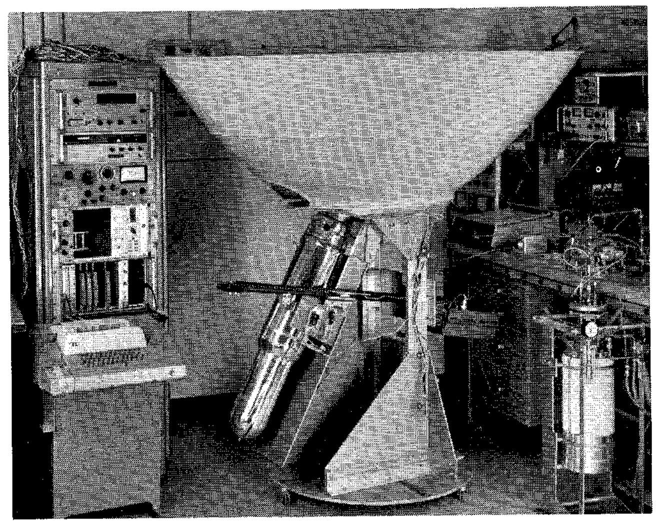

Fig. 4. Photograph of assembled radiometer with associated electronics. Also shown is the bench set-up for detector test.

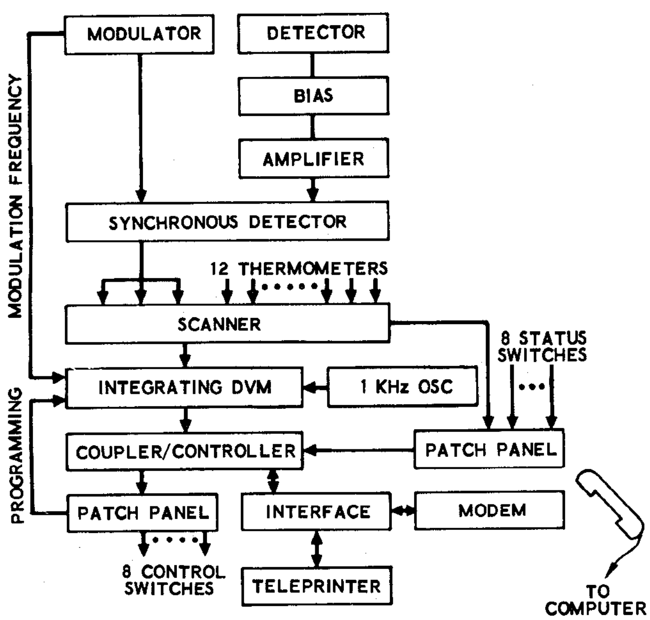

Fig. 3. Block diagram of control and data acquisition system.