Development of a Low-cost Microwave Radiometer (for JPSS support and Student Education)

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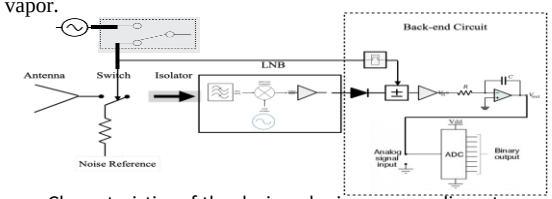
EARTH SYSTEM SCIENCE INTERDISCIPLINARY CENTER

Introduction: **A low-cost microwave radiometer operating at Ka band (18~22GHz) is built at the ESSIC/CISESS Remote Sensing Lab It can also be used as ground observation instrument for in-situ experiment to support the JPSS program, as well as being an instructional instrument for student training. The instrument can be operated under two different detection mode: total power and Dicke-type detection. The instrument is built based on a self-designed digital back-end processing module from the domestic commercial market at low cost. Following the results of our initial models from 2021 and 2022 (shown top right) we have devised two new models since, the first of which (see c.) was used to calibrate the instrument with real-time brightness temperature data. Currently, we are working on a new model, (see d.) which can both perform the previous experiments autonomously, and can also be flown as a drone payload to allow ground-coverage scans.**

INSTRUMENT INTRODUCTION

The dual-mode Ka-band radiometer can be operated to switch between the total-power mode and the Dicke-type mode, to take the advantage of the high sensitivity of total power detection and the high stability of the Dicke detection. Operating in the 22 GHz range, the instrument can be used to sense levels of atmospheric water vapor.

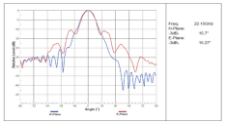


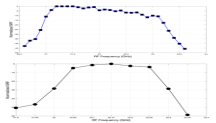
Characteristics of the designed microwave radiometer

Instrument Parameter	Designed Value
Center frequency	22.148 GHz (Water Vapor)
Band width	200MHz
sensitivity	Total-Power Mode: 0.43K Dicke Mode: 0.86K
Beam width	15.7°
Dynamic Range	3 K ~ 313 K

ANTENNA PATTERN AND RECEIVER SRF

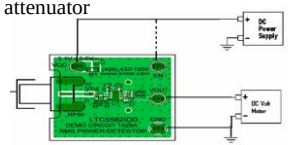
A waveguide horn antenna with gain of 20dB is used to collect the microwave radiation from free space with frequency range from 17.6 ~26.7 GHz. The 3dB beam width of the antenna is 15.7o. The spectrum response function was measured at two different stages: RF stage before the IF filter and the IF stage after the filter.

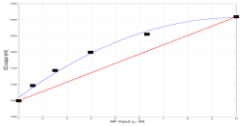




DYNAMIC RANGE AND DETECTOR NONLINEARITY

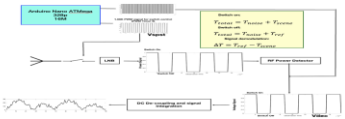
The detector used in the radiometer is build based on LTC5582 IC, which is a wide dynamic range Mean Squared RF power detector, operational from 40MHz to 6GHz. The P-V response curve is measured in the Lab by using calibrated pulse signal source and attenuator

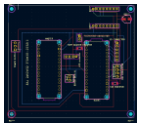




DESIGN AND IMPLEMENTING THE DIGITAL SYNCHRONOUS DETECTOR

ATmega328P microcontroller is used to generate a PWM signal to control the switch to make the detected signal switch between the scene and the noise reference. The signal is then sampled by a synchronous analog-to-digital conversion (ADC) module that makes AD conversion one at a time across all analog pins in the microcontroller.



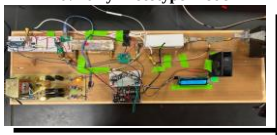


Single-board PCB design for use in rotation (auto sweep) model

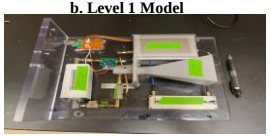
System Integration and the Preliminary Test Results for the Prototype Instrument

The progression of our prototype models is shown below. A series of system level tests were designed to evaluate the performance of the instrument.

a. Early Prototype Model

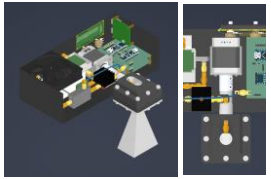


b. Level 1 Model

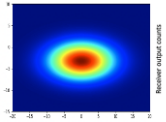


c. 2nd Gen tripod mounted sweep Model

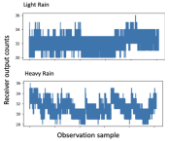
d. 3rd Gen Rotation (Auto Sweep) Model



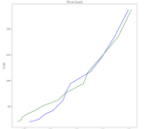
System Performance and Calibratrion Tests



Calibrated, fixed source validation test results



Rainfall test results (counts)



Sweep Calibration test results (Radiance Temp vs. Device counts)

Interns preparing sweep calibration test

Conclusion and Discussion

Currently we've finished the test and evaluation of the key function modules for the Ka-band radiometer, and a prototype instrument has been built and tested by using the calibrated signal source. We have then since calibrated the instrument using results from our 2023 field campaign, and are currently working on a model that will perform scanning sweeps autonomously via a motor system

References

Niels Skou and David Le Vine, Microwave Radiometer Systems Design and analysis, second edition, Artech house, 2005

Norman C. Grody, Microwave Radiometry-Construction, Measurement and Analysis, 2022