CISESS: *Developing Low-cost Microwave Radiometer for Student Training and Supporting JPSS programs*

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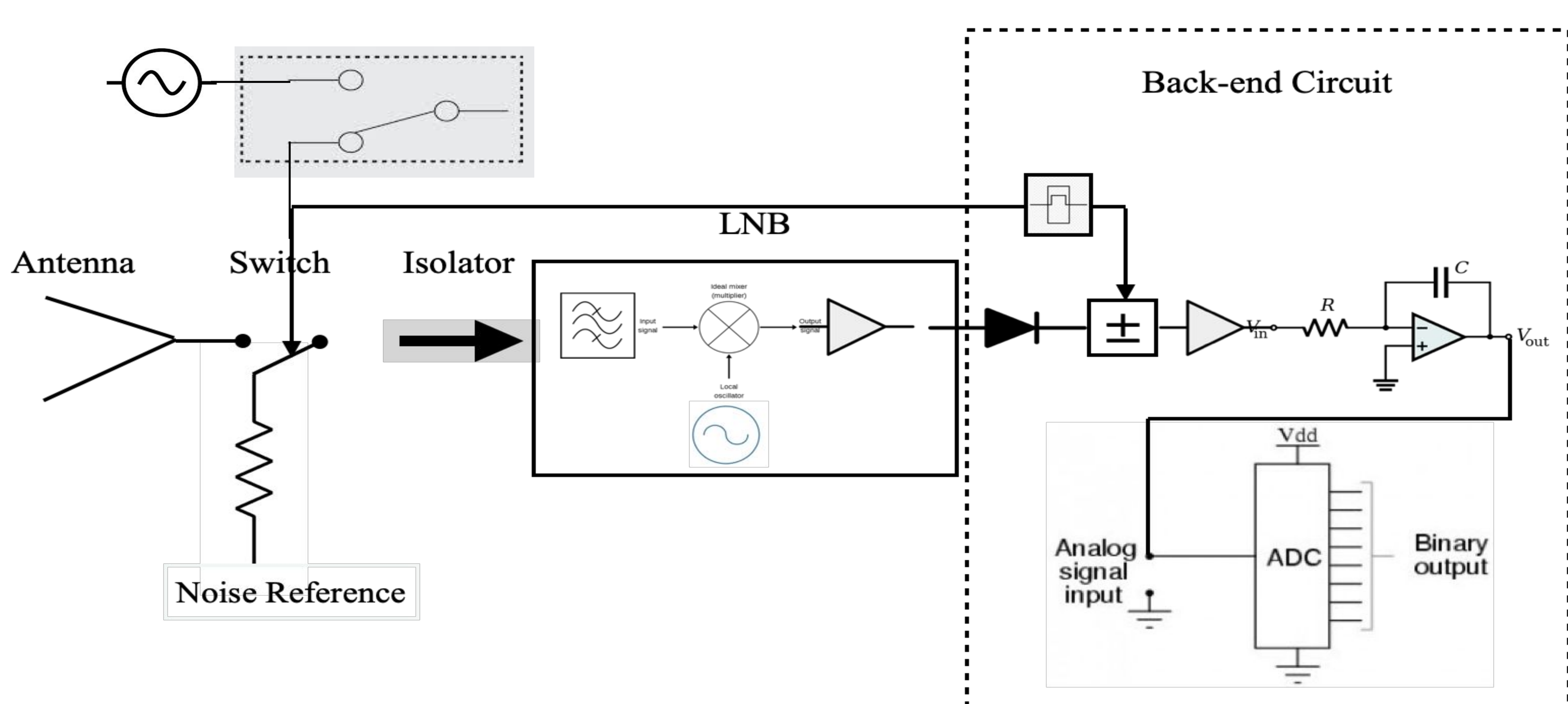
Introduction: A low-cost microwave radiometer operating at Ka band (18~22GHz) is built at the ESSIC/CISESS Remote Sensing Lab for students education and training, it can also be used as a ground observation instrument for in-situ experiments to support the JPSS program. The instrument can be operated under two different detection modes: total power and Dicke-type detection. The instrument is built based on a self-designed digital back-end processing module and from the domestic commercial market with low cost. In 2021 and 2022, we have a total of five students who worked in our Lab, which include three undergraduates and two high school students. Courses were designed to guide the students learning the basic knowledge of microwave remote sensing and being trained with skills required for microwave instrument development.

INSTRUMENT BLOCK DIAGRAM

A dual-mode Ka band radiometer is designed for the fulfillment of the projects goal. The 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.

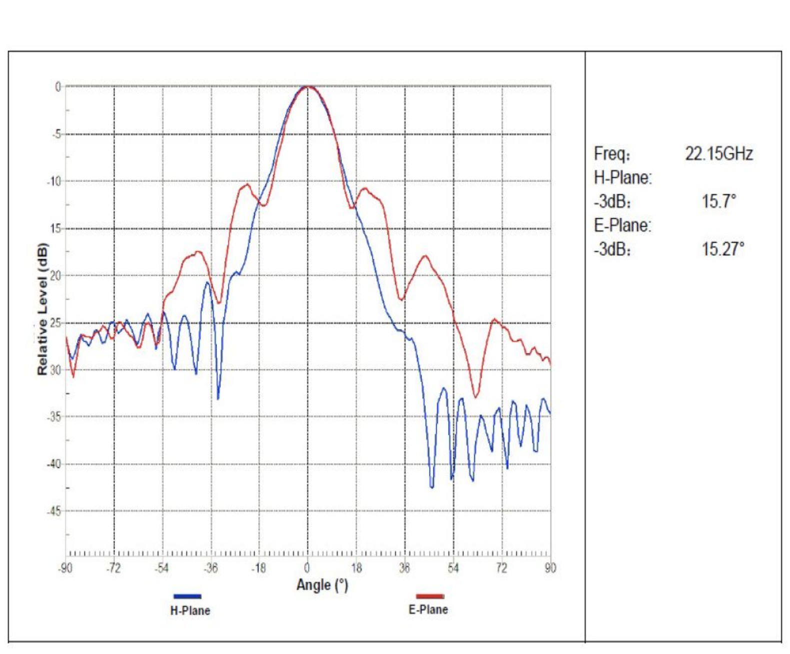


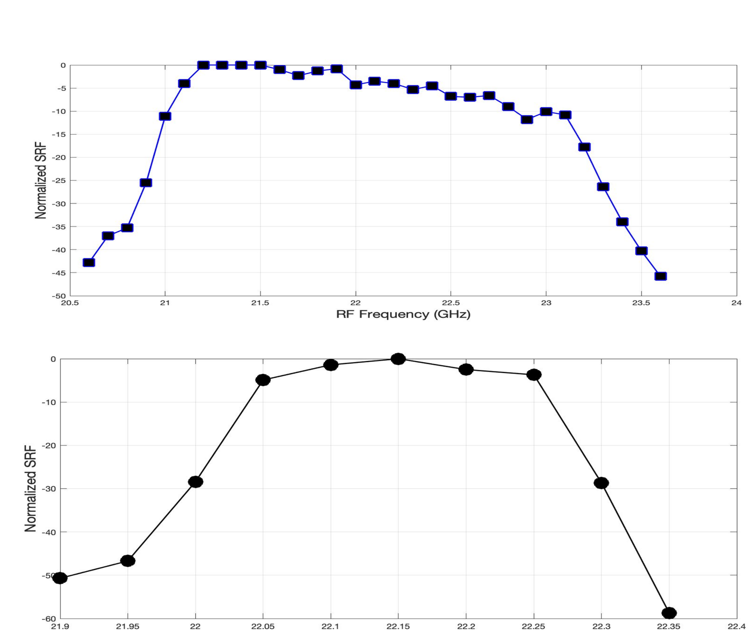
INSTRUMENT CHARACTERISTICS

Instrument Parameter	Designed Value
Center frequency	22.148 GHz
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

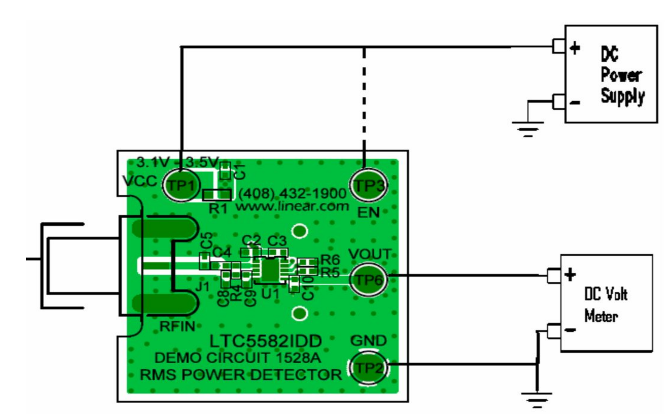
A waveguide horn antenna with gain of 20dB is used to collect the microwave radiation from free space with a frequency range from 17.6 ~26.7 GHz. The 3dB beam width of the antenna is 15.7°. The spectrum response function was measured at two different stages: RF stage before the IF filter and the IF stage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

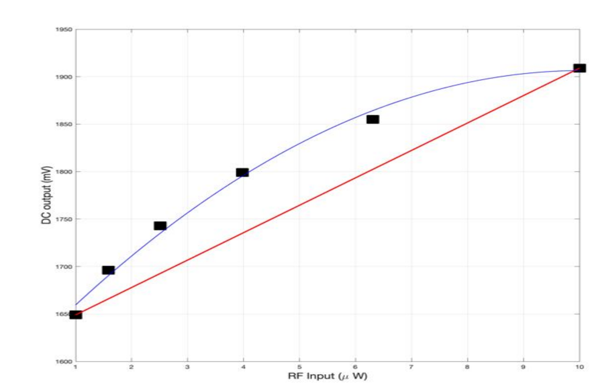




DYNAMIC RANGE AND DETECTOR NONLINEARITY

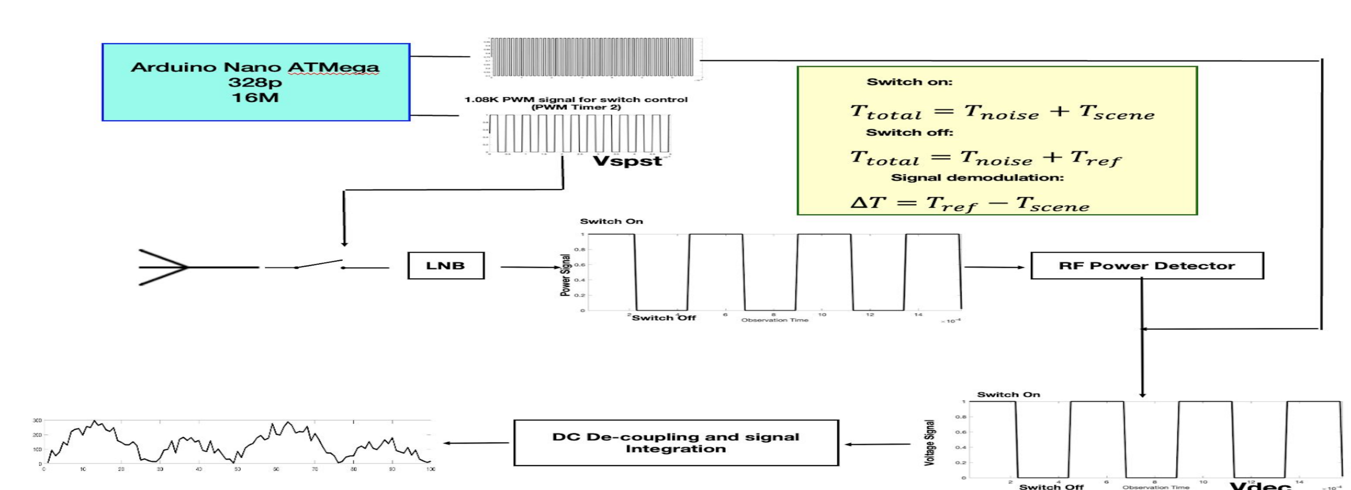
The detector used in the radiometer is built based on LTC5582 IC, which is a wide dynamic range Mean Squared RF power detector, operational from 40MHz to 6GHz. The P-V response curve is measured in the Lab by using calibrated pulse signal source and attenuator and the detector is used to measure the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





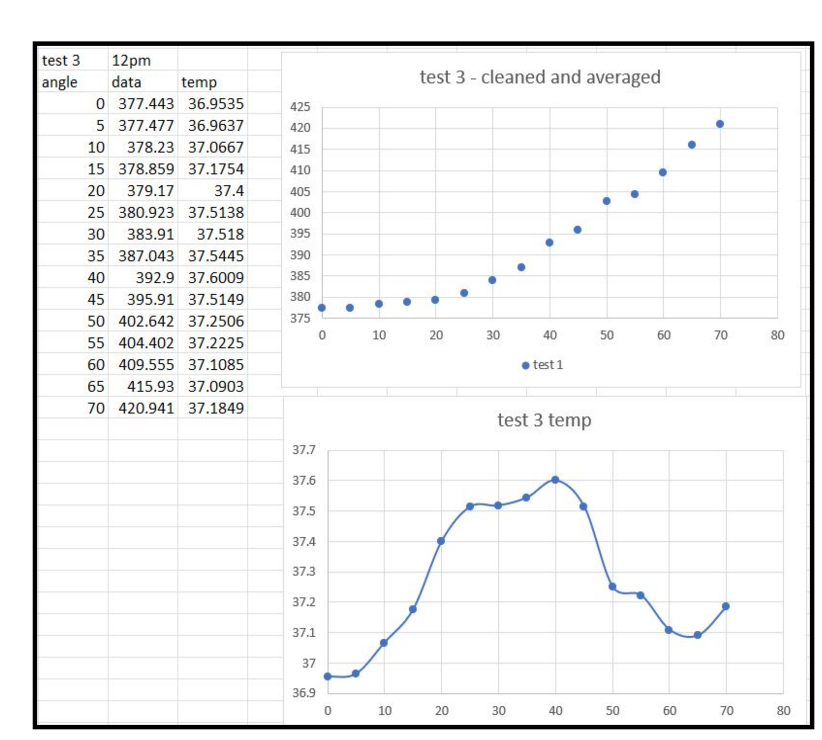
DESIGN AND IMPLEMENTING THE DIGITAL SYNCHRONOUS DETECTOR

Microwave controller ATmega328P was used to generates a PWM signal to control the switch to make the detected signal switch between the scene and the noise reference. The signal then was 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.



INSTRUMENT PERFORMANCE EVALUATION DURING FIELD CAMPAIGN

To test the performance of the instrument, an outdoor experiment was designed to evaluate the instrument under clear sky weather conditions to capture the incoming signals. As shown in the image, the microwave radiometer was mounted on a telescope tripod, so it could be rotated to capture the different signals received at each angle rotation. The data collected shows an exponential growth pattern of the counts collected and we also measured the barometric pressure, temperature, and relative humidity at each angle.



CONCLUSION AND DISCUSSION

Currently we've finished the test and evaluation of the key function modules for the Ka-band radiometer, and an operational instrument product has been built and tested during 2023 summer field campaign. Evaluation results show that the instrument performance meet the expectations.

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