AN AIRBORNE REMOTE SENSING 4.5 TO 7.2 GIGAHERTZ STEPPED FREQUENCY MICROWAVE RADIOMETER

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ABSTRACT

A microwave stepped frequency radiometer operating from 4.5 to 7.2 gigahertz has been designed, fabricated and flight tested in an airborne remote sensing mission by NASA Langley Research Center. This paper describes the design of this precision microwave Dicke-switched noise feedback radiometer, calibration techniques and presents typical results from remote sensing mission employing this radiometer.

SUMMARY

A broad band microwave stepped frequency radiometer has been designed, developed, fabricated, and flight-tested by NASA Langley Research Center. This radiometer is believed to be the first airborne variable frequency microwave radiometer operating under control of a microprocessor based digital subsystem. It is capable of operation in several different preprogrammed modes or from front panel controls. The digital subsystem provides both radiometer control functions and real-time data processing for real-time display of brighness temperature to the operator. The radiometer has been flown on several NASA remote sensing missions aboard the NASA C-130, CV-990 and C-54 remote sensing aircraft. Measurements of spectral emissions of fresh water ice, salt water ice and coastal waters have been performed on these missions.

This paper describes the basic design and operation of the stepped frequency radiometer. The radiometer antenna, microwave portion and signal processor in the CV-990 configuration are shown in figure 1. The digital subsystem, recorders, thermal controllers and-power supplies are shown in figure 2. The stepped frequency radiometer installed in the NASA C-54 remote sensing aircraft is shown in figure 3.

The radiometer has the capability of operation at frequencies between 4.5 gigahertz and 7.2 gigahertz at bandwidths of 10, 50, 250 or 1000 megahertz with integration times from 0.2 to 20 seconds. The frequency can be varied in incremental steps from approximately 0.2 to 5 times the bandwidth per integration time.

This capability provides the radiometer with many remote sensing applications. The frequency stepping program can be preplanned for different scientific measurements, then altered in flight to avoid RFI problems. This proved extremely valuable during the 1978 ice mission over the Great Lakes on the NASA C-130 remote sensing aircraft. The variable bandwidth and integration time provides the capability to trade spatial resolution on the surface for temperature resolution of the radiometric measurement during an experiment. This enables the experimenter to select one temperature resolution for an ice mission, typically 3° Kelvin, and another for an oceanographic mission, typically 0.3° Kelvin. The temperature resolution of the stepped frequency radiometer can be varied from 0.1° to 3° Kelvin. The frequency stepping capability will allow the radiometer to measure both salinity and physical surface temperature by stepping between two widely spaced frequencies. Also, dispersive geophysical media such as layered fresh water ice can be measured using the frequency stepping capability of the radiometer

The design of the stepped frequency radiometer is a balanced Dicke-switched square-wave correlated radiometer. The radiometer utilizes a closed-loop Type I noise feedback circuit to add noise to the received antenna noise thereby balancing the Dicke reference noise. The microwave portion of the radiometer, including the broad band tunnel-diode low-noise amplifier is maintained in a constant temperature enclosure. The temperature is held constant at the Dicke reference temperature within ± 0.10 Kelvin. A block diagram of the radiometer is shown in figure 4.

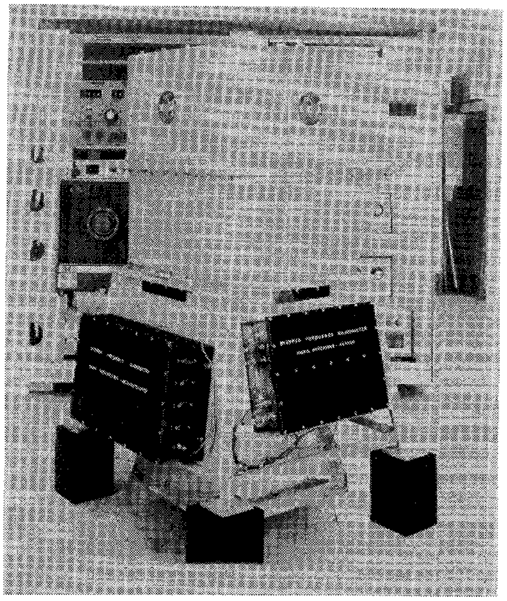
The antenna consists of a corrugated wall broad band horn. The antenna has a polarizing radome to provide for circular polarization. An 11 layer fiberglass/honeycomb sandwich radome is used over the polarizing radome in pressurized aircraft. The feed of the antenna is located within the constant temperature enclosure. The noise injection circuit consists of a solid-state noise diode, isolator, PIN diode switch and 20 dB directional coupler. The Dicke switch is a broad band latching circulator.

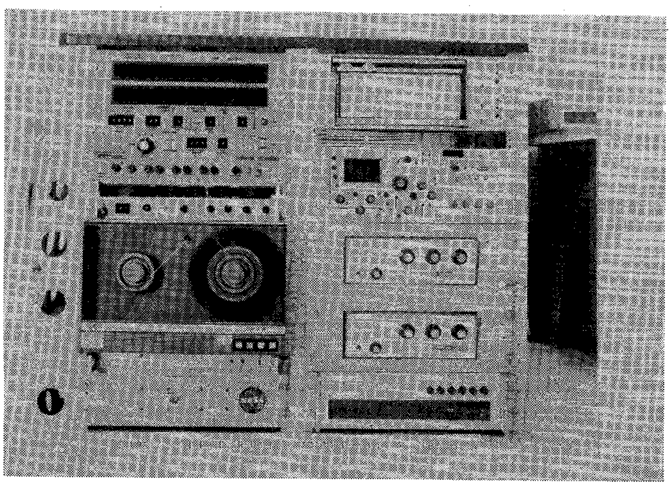
The receiver portion of the radiometer consists of a homodyne mixer, YIG tuned local oscillator and 1 to 1000 megahertz IF amplifier. The frequency of the radiometer is controlled by a eight bit digital word from the digital subsystem that is converted to a 0 to 10 volt dc voltage. This signal controls the voltage tuned microwave oscillator. The frequency can be changed every 200 milliseconds in steps of 16 megahertz or greater from 4018 megahertz to 8098 megahertz. However, the antenna limits the useable frequency range from 4500 megahertz to 7200 megahertz. The bandwidth of the radiometer is selected by the digital subsystem by selecting one of four paths through the filter bank.

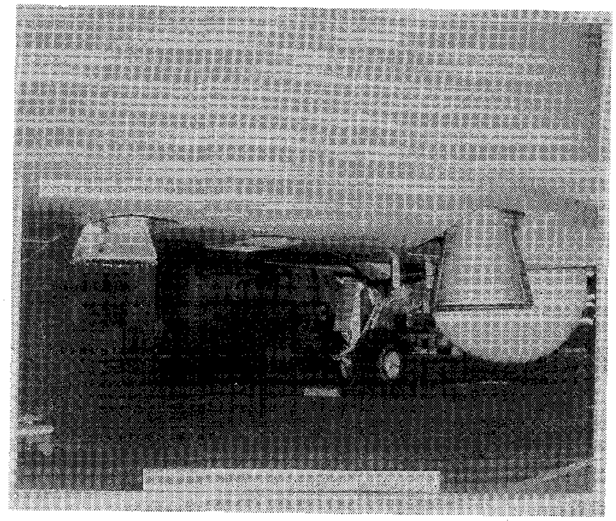
The 1 to 1000 megahertz constant power level noise signal is transformer coupled into a hot-carrier diode square-law detector in the analog signal processor. The detected noise signal is amplified, synchronously detected with the Dicke switching frequency and the resultant error signal is fed to a true integrator. The output of the integrator is filtered to remove the effect of the Dicke switching frequency and used to control the pulse train output of a voltage-to-frequency (V/F) converter.

The V/F converter provides a variable duty cycle 70 microsecond pulse train. The pulse repetition frequency varies from 0 to 10,000 pulses per second linearly with the dc output voltage of the integrator. This pulse train is applied to the noise injection PIN diode switch and controls the number of injected constant amplitude, constant width noise pulses. The digital subsystem measures the duty cycle of the pulse train to determine the noise added to the antenna noise.

The block diagram of the digital subsystem is shown in figure 5. The digital subsystem provides both control functions to the radiometer, data processing of the output signal from the radiometer and physical temperature measurements of several locations in the radiometer. It also provides front panel control functions and real-time displays for the operator. The radiometer data is formatted along with time. temperatures, and other operational data and is recorded on a digital tape recorder. An estimate of the brightness temperature is computed by the microprocessor and displayed to the operator. The integration time of the radiometer is determined by the count periods of the NT and NTAU counters which compute the duty cycle of the radiometer output. The integration time of the closed-loop radiometer noise-feedback is several times faster than the minimum integration time allowed by the digital subsystem.







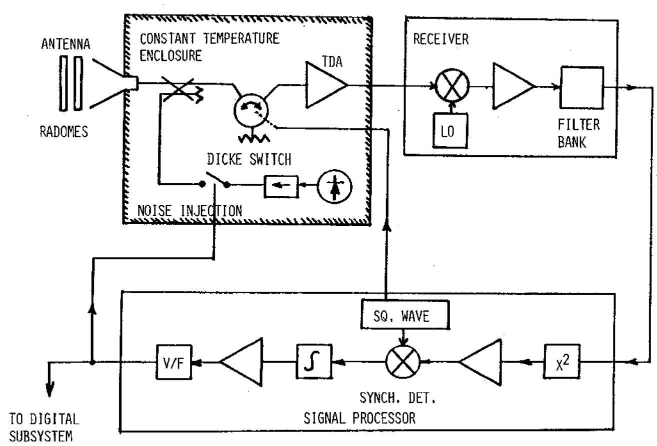


FIGURE 4. STEPPED FREQUENCY RADIOMETER.

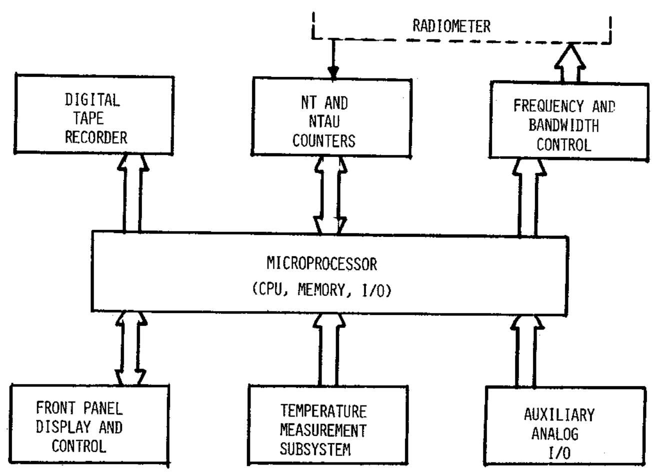


FIGURE 5. DIGITAL SUBSYSTEM.