Design of 90 GHz Band Radiometer System for Remote Sensing Applications

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ABSTRACT

The 92 GHz radiometer system, which will be used for an atmosphere remote sensing, is presented in this paper. The characteristics of RE and IF module are described. The architecture of radiometer including data acquisition, data storage and digital signal processing using notebook computer are explained and the result of indoor experiment is introduced. The radiometer system is designed as a total power type to obtain the high temperature sensitivity. The effect due to system instability can be removed by the computer compensated calibration method. The system noise figure and total gain of implemented radiometer are 12dB and 56dB, respectively. The short-term stability of 92GHz radiometer is evaluated from the experiment. The difference of the radiometer output voltages for two targets, whose brightness temperature are 120K and 300K, is about 40 mV.

I. INTRODUCTION

Microwave radiometers have been used for a remote monitoring of the earth environment and for a military application. A radiometer system for a military application is designed to measure at the window channels to avoid the attenuation effect due to the atmosphere. The measurement parameters of the radiometer such as a temperature distribution of sea surface, a soil condition, a total water vapor and a cloud liquid water of atmosphere depend on the selection of the frequency channel [1]. For the detection of a water vapor and a cloud liquid water, 22GHz absorption band and 36.5GHz window channel have been selected. Recently 90 호z channel is added to a water vapor radiometer for atmosphere monitoring because the 90GHz channel increases the sensitivity of the radiometer to liquid water, water vapor and significant ice cloud. Also 90GHz millimeter wave radiometer can be used for passive imaging system because of a small size and a high angular resolution compared with microwave radiometer.

In this paper we introduced the 92GHz radiometer system developed for atmospheric monitoring. The characteristics of RF and IF module are tested. We also describe calibration method, brightness temperature measurement and data acquisition for getting high accuracy result.

II. CHARACTERISTICS OF 92GHz RADIOMETER SYSTEM

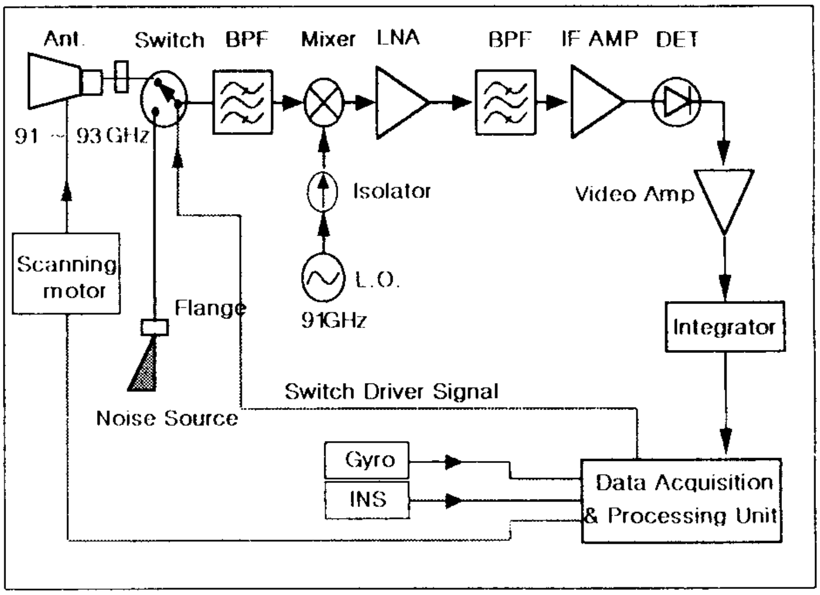

Figure. 1 System block diagram of 92GHz Radiometer

When one design the receiver for radiometer system, the important design parameters are the stability. temperature sensitivity and the spatial resolution. The brightness temperature sensitivity depends mainly on the bandwidth of the receiver and integration time for the total power system [2]. The system gain variation, power supply fluctuation and environmental temperature change cause the instability of the radiometer. The spatial resolution is decided by the beamwidth of the antenna and measurement height. The 92GHz radiometer shown in Fig. 1, is designed as a total power radiometer with computer compensated gain calibration to get high sensitivity with simple structure.

TABLE I Specification of 92GHz Radiometer System

Radiometric observation angle	2 °
System noise temperature	4306 K
Sensitivity	$\Delta T < 0.5$ K
Dynamic range	80 ~ 320 K
Absolute radiometric accuracy	$\delta T < 2$ K
Center frequency	92 GHz
Bandwidth	2 GHz
System type	Single channel Total power

The specification of radiometer is shown in TABLE I. The system noise figure including RF switch is 12dB and the dynamic range of input brightness temperature is from 80K to 320K. The temperature and angular resolution are 0.5K and 2°, respectively. The noise temperature of the system is 4306K and integration time is set to 75ms for achieving 0.5K sensitivity. Radiometer receiver can be divided into antenna, RF module and IF module· and data acquisition part. The function of these parts should be tested before the use of radiometric measurement.

A. *RF module Characteristics*

The reflector antenna with low side-lobe and high main-beam efficiency was used for high performance. The observation angle of antenna is 2 and the SLL(Side Lobe Level) is below 18dB. The RF module of 92GHz receiver is shown in Fig. 2. The noise figure of RF module, which consists of switch, BPF, oscillator and mixer, is less than 12dB. It is very difficult to implement a millimeter-wave radiometer system with a low noise figure because of the difficulty in designing low noise amplifier. Therefore all of the RF components should be designed to achieve a low noise figure.

Figure. 2 RF module for radiometer system.

The band pass filter was designed with low insertion loss and high Q. The optimum structure for getting a good performance is fin line configuration. Generally, metal inserts in fin-line structure are printed on a dielectric substrate which bridges the broad walls of a rectangular waveguide[3]. The implemented BPF was designed using a grounded fin-line structure with alternating metallic bridges ('fin') and large gap over the total height of the rectangular waveguide. A quarter wave length transformer was also used for the efficient transition waveguide-to-fin-line. As a result, the return loss of filter improved about 5dB using this transformer. The experimental data of BPF is 0.8dB insertion loss, 16.8dB return loss, 3GHz bandwidth at 92GHz. in a radiometer system, local oscillator should have the characteristics of low phase noise, good frequency and amplitude stability. So the local oscillator is designed using the gunn diode which satisfies these considerations[4]. The oscillator is composed of Gunn diode, radial resonator, backshort, bias filter and impedance transformer. The output power of oscillator is +12dBm, and the phase noise is -105dBc/Hz at 100kHz offset. Also the designed Gunn diode oscillator has good amplitude stability and frequency stability. To convert RE signal to IF signal, the 92GHz waveguide mixer was designed and implemented using beam-lead shottky diode. The implemented mixer is single balanced crossbar type with good isolation between LO port and RE port[5]. This mixer is made up of LPF, BPF, suspended stripline-to-wavguide transition, and matching network. The measured data of mixer is 8.5dB conversion loss, 5dB bandwidth, 1.3 RE VSWR.

B. *IF Module characteristics including detector*

The IF module consists of IF LNA, BPF, detector and integrator. The IF LNA is used to reduce system noise figure. The total gain of amplifiers is adjusted to a suitable level because detector must be operated in square-law detection region. The noise signal down- converted from RE module is transmitted to IF LNA, BPF and detector in turn. The total input power of detector is adjusted to below -20dBm for the square- law operation. And total power noise signal is converted to voltage signal by detector with voltage sensitivity of 1.7mV/μ.W.

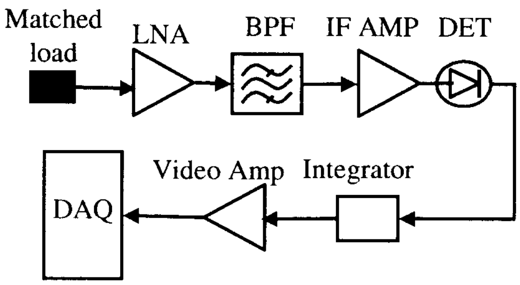

Figure 3. 1.5GHz radiometer for the test of the IF module and DAQ.

The system gain depends on the IF LNA and IF high amplifier because the RE amplifier is not used. The temperature sensitivity is affected by the system gain fluctuation as given by equation (2). Figure (3) shows 1.5GHz radiometer to test the IF module and DAQ. The physical temperature of matched 50Ω load is controlled by the temperature control box and the output voltage of video amp is measured by DAQ.

$$\Delta T = [(\Delta T_N)^2 + (\Delta T_G)^2]^{1/2} \quad (1)$$

$$= T_{SYS}\left[\frac{1}{B\tau} + \left(\frac{\Delta G_S}{G_S}\right)^2\right]^{1/2} \quad (2)$$

The response of IF module including detector is given by Figure (4). When the physical temperature of matched 50Ω load is changed from 230K to 300K, the radiometer output is changed about 380mV. The relation between temperature and output voltage is expressed by the equation V = 0.0055×K + 1.7485.

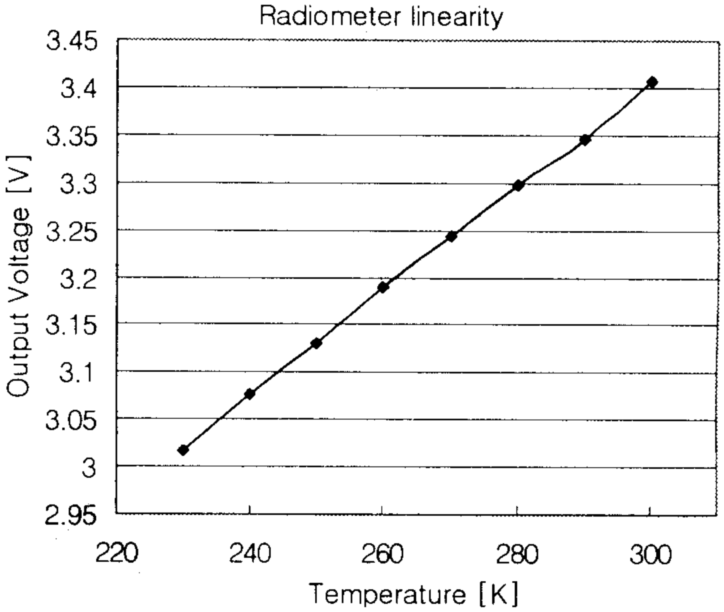

Figure 4.1.5 GHz radiometer response

C. Calibration and Stability Test

Since the radiometer is operated in an unexpected environment, it is very important to maintain a reliable calibration. When square law detector is used, it is assumed that the radiometer output voltage is linearly proportional to the input noise power. The performance of the 92GHz radiometer is tested by use of cold calibration source and precision attenuator. Figure (5) shows the measurement for the test of total radiometer system. Figure (6) shows the change of radiometer output voltage when the attenuation value is varied. The effective brightness temperature can be calculated from the attenuation value by equation (3).

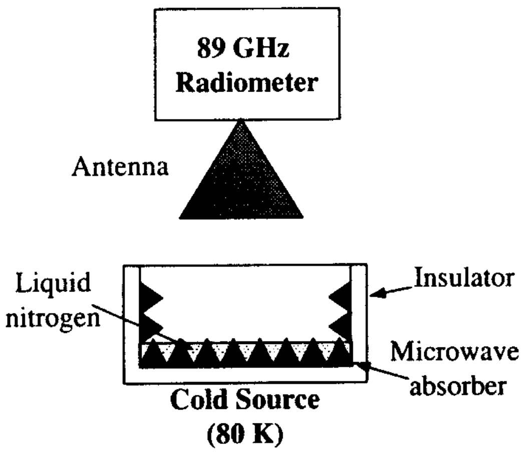

Figure 5. Test of total radiometer system

$$T_{eff} = \frac{T_N}{L} + (1 - \frac{1}{L})T_o \qquad (3)$$

The calibration graph is shown in figure (7). When the brightness temperature of antenna input is changed from 120K to 300K, the radiometer output is changed about 40mV. The relation between temperature and output voltage is expressed by the equation V = 0.0002×K + 3.0019.

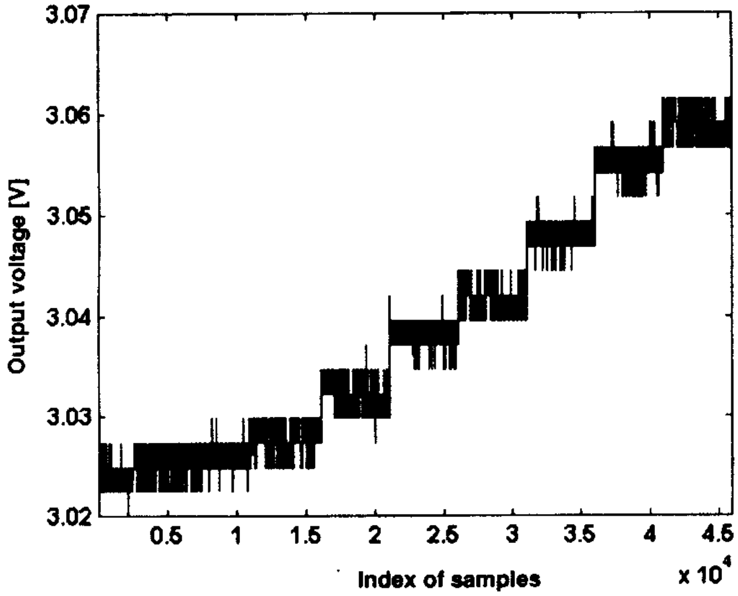

Figure 6. Radiometer output with the variation of attenuator.

For the type of computer compensated gain calibration, the short time stability is more important than long time stability, because the output drift due to gain variation will be compensated during the measurement. The short time stability of the total system is shown by figure (8). During the antenna see the hot source, the output voltage is sampled at 1KHz frequency. The standard deviation is 1.7mV for 10minuets measurement. Therefore it can be said that the designed radiometer system is very stable.

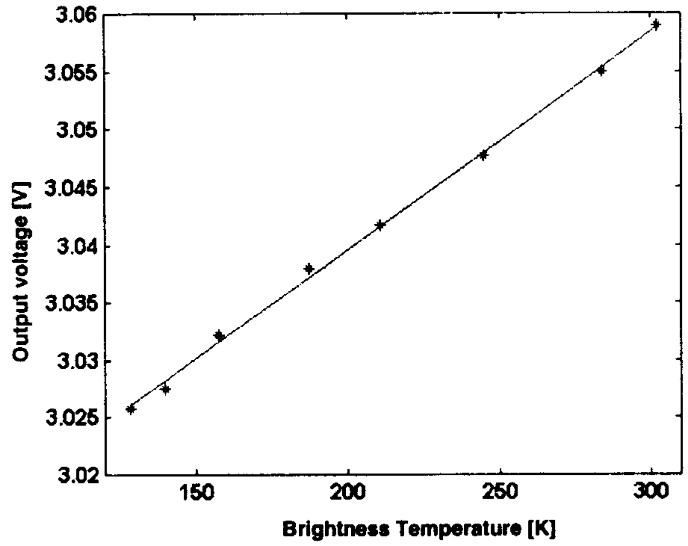

Figure 7. Calibration graph of 89GHz radiometer

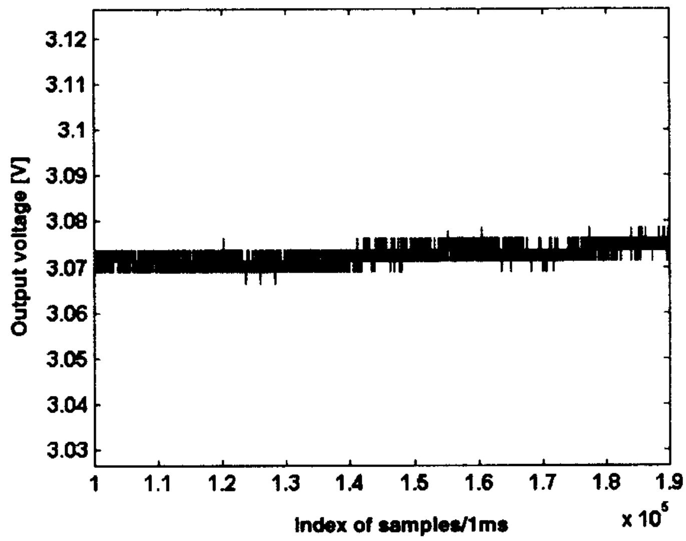

Figure 8. Short time stability test

III. CONCLUSIONS

The millimeter-wave radiometer system of 92GHz has been tested. The RF module and the IF module are examined separately. Through the experimental result of calibration and stability test, it can be concluded that the implemented radiometer system is very stable for short interval. Also the radiometer output voltage is changed in proportional to brightness temperature of input noise in the dynamic range. To obtain better performance of radiometer system, noise figure and stability of the system must be adjusted.

VI. ACKNOWLEDGEMENT

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