System for Control, Data Collection and Processing in 8 mm Portable Microwave Radiometer-Scatterometer

LI Yi, FANG Zhen-He, ZHANG Jun
Shanghai Institute of Electronic Physics, School of Communication and Information Engineering, Shanghai University, Shanghai 201800, China

Abstract In this paper we describe a system used to control, collect and process data in an 8 mm portable microwave radiometer-scatterometer. We focus on hardware and software design of the system based on a PIC16F874 chip. The system has been successfully used in an 8 mm portable microwave radiometer-scatterometer. Compared with other similar systems, the system modularization, miniaturization and intelligentization are improved so as to meet portable instrument requirements.

Key words radiometer, scatterometer, data collection, data processing.

1 Introduction

Radiometer and scatterometer are two main types of important remote sensing instruments. The former is a passive remote sensing instrument, only with receiver. It can be used to measure object brightness temperature $T_{Bp}$. The latter is an active remote sensing instrument having both receiver and transmitter, with which object backscattering coefficient $\sigma^0$ can be measured$^{[1]}$.

In this paper, an 8 mm portable microwave radiometer-scatterometer is described, which combines both bireference temperature digital demodulation radiometer and noise scatterometer in one instrument so that one can simultaneously make passive and active measurements of microwave spectra of ground objects. The radiometer receiver measures signals reflected from objects. The output results are; object brightness temperature $T_{Bp}$ in V or H polarization, and backscattering coefficient $\sigma^0$ in VV, HH, VH or HV polarization. The block diagram of the instrument is shown in Fig. 1$^{[1]}$.

Due to different working modes, the system of control, data collection and processing has to be specially designed. The design criterion is to let the instrument work flexibly and automatically in different modes.

2 Working Principle of the System

The instrument can work in three modes: radiometer mode, scatterometer mode and combined measurement. Object radiation can be measured in radiometer mode, and backscattering coefficient in scatterometer mode.

In radiometer mode, the microwave receiver receives signals from the antenna and a reference load in turn. Then the signals are transformed into digital
pulses based on the amplitude of received signals. The pulses are then sent to CPU via 6N137 opto-coupler and demodulated to deduce object brightness temperature. The object brightness temperature can be calculated by following formula:

$$T_a = \frac{N_a - N_{ol}}{N_{oh} - N_{ol}} (T_{oh} - T_{ol}) + T_{ol}$$  \hspace{1cm} (1)

where

- $T_a$: object brightness temperature,
- $T_{ol}$: low reference temperature,
- $T_{oh}$: high reference temperature,
- $N_a$: counter value of antenna temperature,
- $N_{ol}$: counter value of low reference temperature,
- $N_{oh}$: counter value of high reference temperature.

The scatterometer mode differs from the radiometer mode as explained in the following.

Firstly, the solid state noise generator is turned on and a noise signal is emitted from transmitting antenna, which is turned off in radiometer mode. Secondly, the microwave receiver alternately receives signals from the antenna and a calibration attenuator. These signals are fed into CPU through the same path. The backscattering coefficient $\sigma_b^\theta$ of object may be calculated with Eq. (2).

$$\sigma_b^\theta(a_i) = \left(\frac{P_r}{P_t}\right)_{db} - K_{db} - I(a_i, H)_{db}$$  \hspace{1cm} (2)

where

- $a_i$: incident angle,
- $H$: setting altitude of antenna,
- $I(a_i, H)_{db}$: irradiation integral (it is the function of incident angle and antenna altitude).

$$K_{db} = \left[\frac{\lambda^2 G_r G_t}{(4 \pi)^3}\right]_{db} = -31 \text{ db}$$

$\lambda$: operational wavelength (8 mm),

$G_r$: receiving antenna gain,

$G_t$: transmitting antenna gain,

$P_r$: received power,

$P_t$: transmitted power.

In the combination mode, more object features may be obtained by data fusion, which cannot be obtained in radiometer or scatterometer mode alone.

3 Hardware Design

The hardware block diagram is shown in Fig. 2.

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Compared to other similar systems\cite{4,3}, the system has three distinct properties: modularization, miniaturization and intelligentization. Because switches, temperature sensing and motor driver are all made into different modules, the task of development becomes clearer. Stability and robustness are improved. Having introduced a LSIC chip PIC16F874 as CPU, the number of peripheral circuits, hence the overall size, are reduced, while similar instrument using 8031 usually take more space.

The hardware is composed of several units: PIC16F874, switching board, temperature sensing board, V/F convertor, step motor and serial communication unit.

The center of hardware is PIC16F874, which contains 10-bit A/D module, RAM, FLASH RAM and E²PROM. So it does not require other peripheral circuits. The whole system is small in size, consumes less power than other similar equipment and may be operated in real time.

The switching board contains all switches, including DICKE switch, load switch, etc. Switch control