Design and Development of a Ground-based Microwave Radiometer System

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Abstract— This paper presents the design and development of a ground-based microwave radiometer system (MWR) for the offshore oil platform. It will be used to provide long time series of geophysical parameters such as the sea-surface temperature, the near-surface wind speed and the sea ice type. The ground-based MWR is a five-frequency, dual-polarized microwave radiometer which is a total power type microwave radiometer based on a heterodyne receiver. It operates at 6.8 GHz, 10.7 GHz, 18.7 GHz, 23.8 GHz and 37 GHz, respectively.

The scanning mode adopts circular scan in a vertical plane. During each period, two-point calibration is performed to calibrate the receiver gain and noise. The antenna beam directs different angles and the blackbody used in calibration to obtain measurement data and calibration data.

The ground-based MWR consists of three units: antenna and receiver unit, electronic unit and power supply unit. Antenna and receiver unit collects emission from the atmosphere. It is constructed with several RF components, which include voltage-controlled oscillator, high power amplifier, directional coupler, RF switch, band-pass filter, isolators, detectors and mixers. The received signal is down-converted by the double side band mixer to Intermediate Frequency, and then the IF signals are down-converted to Low Frequency by the detector and integrator. The electronic unit digitizes the LF signal, controls the scanning mechanism and measures physical temperature of the hot target for calibration, and takes charge of communication with a remote computer. The power supply unit performs DC/DC conversion, distributes the DC lines to various sub assemblies and switches.

In paper, the basic principle and technical specifications of microwave radiometer will be briefly introduced, and the block diagram and detail design parameters of the proposed system will be described. The system followed radiometer electronics design and achieved exacting stability and high accuracy requirements.

1. INTRODUCTION

In the past few decades, microwave remote sensing has become an important tool for monitoring the atmosphere and the earth surface. Microwave radiometers as an important part of microwave remote sensing, can be used to retrieve the profile of the atmospheric and sea-surface temperature, the near-surface wind speed, water vapor density, the liquid-water content of clouds and rain and the sea ice type. It can also be used to monitor the snow-water content and the spatial distribution of soil-moisture content, which are important factors for hydrology, agriculture and meteorology.

The main purpose of this ground-based MWR is for ocean research and atmosphere research and it enables high absolutely accuracy. It includes five frequencies, 6.8 GHz, 10.7 GHz, 18.7 GHz, 23.8 GHz and 37 GHz, and each frequency band is monitored by vertical polarized and horizontal polarized wave. The ground-based MWR scans the land surface by mechanically rotating the antenna and acquires radiance data of the land surface. It allows observation of everyday changes of earth’s environment and it is expected to contribute to the study of the earth’s environmental system.

The basic principle of microwave remote sensing by MWR and the technical specifications of the ground-based MWR are described, the block diagram, general system design and detail design are also presented in paper.

2. SYSTEM CONTENT AND TECHNICAL SPECIFICATION

As the moisture in the atmosphere could attenuate the microwave radiation from the earth surface, the brightness temperature retrieved from the observation data represents the information of atmospheric temperature and humidity etc. The principle of atmospheric microwave remote sensing is
to measure atmospheric molecular rot-vib absorption spectrum which is broadened by atmospheric pressure effect, and therefore complete the retrieval of temperature and humidity profiles. The ground-based MWR operates at 6.8 GHz, 10.7 GHz, 18.7 GHz, 23.8 GHz and 37 GHz to retrieve the profile of the atmospheric and sea-surface temperature, the near-surface wind speed, water vapor density and so on.

2.1. General System Design

The ground-based WMR is a total power type microwave radiometer based on a heterodyne receiver. The system consists of three units: antenna and receiver unit, electronic unit and power supply unit. The functional block diagram of the ground-based MWR with five receivers is shown in Fig. 1.

The system performs two-point calibration periodically to calibrate the receiver gain and noise by means of noise injection. And the input of the receiver switches automatically between the antenna unit and the calibration unit. The noise source is a microwave absorber inside the MWR and the physical temperature of which could be real-time measured accurately by temperature transducer. The noise source couples with the matched microwave load in the cases of power on and off to make the calibration unit obtain different brightness temperature. So the accuracy of the ground-based MWR is dependent upon the accuracy with the quality of the noise source and other components in the noise injection circuitry.

The received signal is focused upon the antenna feed, and then it is down-converted by the double side band mixer to Intermediate Frequency signal. It is sent to the electronic unit after processing by the amplifiers, low pass filters and directors. The five receivers are installed on the side of one cylinder which could rotate automatically; the observed angle of the ground-based MWR could be changed by changing the rotation angle of the cylinder.

2.2. Technical Specification

The technical specifications are introduced below.

- Operating frequency: 6.8 GHz, 10.7 GHz, 18.7 GHz, 23.8 GHz, 37 GHz
- Receiver type: Total power receiver
- Polarization mode: V, H
- Bandwidth: 100 MHz ~ 500 MHz
- Integration time: 200 ms, 500 ms, 1000 ms (Optional)
- Brightness temperature range: 90 K ~ 400 K
- Brightness temperature resolution: 0.2 K
- Brightness temperature accuracy: 0.5 K

![Functional block diagram of the proposed system.](image-url)
3. DETAILED SYSTEM DESIGN

The ground-based MWR consists of three units: antenna and receiver unit, electronic unit and power supply unit. The receivers could be grouped into two separate units, the low-frequency unit and the high-frequency unit, both of which collect data from up to ten radiometer data channels. They are only identified by their frequency and channel names. The electronic unit is also able to measure up to 25 temperatures of the PT100 sensors to regulate the physical temperature inside the receivers.

3.1. Antenna and Receiver Unit

The construction of the antenna and receiver unit is illustrated in Fig. 2. Five conical corrugated horns are used in the antenna unit as feeds, they can offer a nearly circularly symmetric radiation pattern in a quite wide bandwidth and very low cross-polarization. Considering the actual measurement of sea-surface, the antenna apertures are sealed by dielectric lens to shorten the length of the antennas and avoid the corrosion of salt spray.

The receivers of the proposed radiometer system are used in pairs: H and V polarization. Hence, it is practical to construct them as dual receiver units: a pairs of receivers for one frequency. The orthogonal mode transducer (OMT), input calibration switches, couplers and noise sources are also presented in the design.

The low-frequency receivers consist of three receivers operating at 6.8, 10.7, 18.7 GHz; and the high-frequency receivers operating at 23.8 and 37 GHz adopted waveguide technology, all of which are super-heterodyne receivers with separate horizontal and vertical channels, giving a total of ten channels. The received signal is down-converted by the single side band mixer to Intermediate Frequency, and then the IF signals are sent to the detector. The analog signal needs to be integrated by the integrator at a certain time interval. The maximum signal output level from the integrator is in the order of scores of mill volts, and a sensitive low frequency amplifier is used before the signal can be properly digitized.

The performance of the receivers are strongly dependent on their physical temperature, in order to achieve the desired radiometric sensitivity, the measurement of the inside temperatures are very important for the calibration. Each receiver has five temperature sensors placed at different locations, and the measurement system is implemented using platinum resistive thermometer Pt100 connected to five high-accuracy instrumentation amplifiers, the analog signals output from the Instrumentation amplifiers and the low frequency amplifiers are all sent to the electronic unit.

3.2. Electronic Unit

The system controlling and the real time data processing are performed by this unit. The construction of the electronic unit is illustrated in Fig. 3.
The analog signal output from the receiver unit is digitized by AD converter, and then sent to Xilinx Virtex-IV FPGA. The electronic unit will also feed back the AGC voltage to the receiver unit by analyzing the received data. At the same time, the electronic unit contains the scanning mechanism control and the power control of the electronic unit itself and the radiometer receivers, which are implemented by six 24 volts DC power input relays.

Interfacing the radiometer to the remote computer is accomplished by the protocol of RS485 interface. Ten-channel observation data and twenty-five-channel temperature data will be transmitted to the remote computer after each period.

3.3. Power Supply Unit
The power supply is composed of DC/DC converter of the secondary power supply and the power distributor, which will distribute the DC lines to various sub assemblies and switches. The power supply includes +5 V and +12 V for receivers, +12 V and −12 V for the Detectors and Integrators, +24 V for the relays and +27 V for the noise sources.

4. CONCLUSION
The design of a dual-polarized, multi-frequency ground-based microwave radiometer system is presented, and the practical performance is well accordance with the technical requirement. This radiometer system can be used as a tool for continuously monitoring the atmosphere and the earth surface, and plays an important role in the observation of earth environment.

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REFERENCES


