CALIBRATION OF MICROWAVE RADIOMETERS: AN OVERVIEW

Andreas Colliander[1], Darren McKague[2]

1) Jet Propulsion Laboratory, California Institute of Technology

2) University of Michigan

INTRODUCTION

This paper describes 1) the progress of the work of the IEEE Geoscience and Remote Sensing Society (GRSS) Instrumentation and Future Technologies Technical Committee (IFT-TC) Microwave Radiometer Working Group and 2) an overview of the calibration issues of microwave radiometers as an introduction to a dedicated session.

IEEE GRSS IFT-TC MICROWAVE RADIOMETER WORKING GROUP

The Microwave Radiometer Working Group (MRWG) of the IEEE GRSS IFT-TC addresses issues related to passive remote sensing in the microwave, millimeter wave and sub-millimeter wave portions of the electromagnetic spectrum [1].

One of the currently on-going actions of the working group is to summarize the current state-of-the-art and future trends of microwave radiometry for remote sensing in a white paper. A special session was organized in the 11th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment, MicroRad 2010, on current interesting technologies in order to increase the awareness of the community of these technologies and to gather relevant material for the white paper. The session included papers on digital radiometry, high-frequency limb sounder technology, high-frequency miniaturized LNA and receiver development, and an image construction technique for a rotating synthetic aperture interferometric radiometer. These papers cut through the spectrum of relevant new technologies: application of digital techniques for the benefit of microwave radiometry, increasing performance at higher frequencies, and maturing of synthetic aperture interferometric radiometry, which is strongly emphasized by the recent launch of ESA's SMOS satellite. This paper summarizes the novel developments in the field of microwave radiometry addressed in MicroRad 2010.

Furthermore, this paper opens another Working Group session. This session complements the MicroRad 2010 session by devoting itself to the calibration issues of microwave radiometers.

CALIBRATION OF MICROWAVE RADIOMETERS

The calibration of microwave radiometers is paramount to their performance and the receiver-system design goes hand in hand with calibration-system design. The calibration process is defined as [2]: "a set of operations that establish, under specified conditions, the relationship between sets of values of quantities indicated by a measuring instrument or measuring system and the corresponding values realized by standards." In the traditional case a radiometer system is assumed to have linear response to input stimulus and the calibration is established by linearly interpolating between the responses observed from two targets with different brightness temperature levels [3]. The targets may be simple emitters of known power level. However, the operating frequency of the radiometer dictates many parameters of these loads as they need to be proportional to, among others, wavelength, antenna beam width and antenna aperture [4].

The same basic principle can be applied to all radiometers. However, more sophisticated radiometers, such as polarimetric radiometers, may require additional design and hardware to implement suitable targets [5]. The measurement of third and fourth Stokes parameter includes knowledge of the phase which can also be solved separately through different methods including internal and external loads [6], [7].

Depending on the system architecture, components and required accuracy the calibration interval may pose a problem with respect to the deployment parameters of the observing system. Such may be the situation with, for example, airborne or spaceborne systems where there may be limited access to external calibration targets. This kind of situation invokes a need for a compromise: partial calibrations, using internal calibration targets, more frequently and the full end-to-end calibrations less frequently, or even only at the time of manufacturing. The optimum strategy depends on deployment conditions and performance requirements. Internal calibration loads are usually matched loads, noise diodes, or more recently active cold loads. The active cold loads were developed already in the early 1980's [9], but development of critical technologies has made them really attractive only recently and they are becoming part of the standard trade-off in radiometer design process [8], [10].

Additionally, the system may be able to utilize natural external targets, the brightness temperature of which is known. Several targets have been identified and used in many practical applications. Usually they are the sky [11], water surfaces [12] or homogeneous land surfaces [13]. The suitability of a given target depends mainly on the operating frequency, which dictates the penetration depth of the measurements, and on the stability of the target brightness temperature. Space-borne radiometers in particular benefit from the use of natural targets as they potentially provide very reliable end-to-end references [14].

The calibration of synthetic aperture interferometric radiometers is generally a more complicated issue than that of conventional radiometers [15]. However, the problem can be reduced to components of amplitude and phase calibration. The former is basically the same as the conventional radiometer calibration and the latter is equivalent with polarimetric phase calibration. Additionally, there are issues related to the decorrelation of the signal as a function of baseline length. In general, problems usually arise due to the complexity introduced by the number of receivers in the instrument. Significant progress has been made on the calibration of these instruments over the past two decades since the inception of the idea of synthetic aperture interferometric radiometers [16]: for example, phase and amplitude calibration using a noise injection network has been developed [17], [18] and very beneficial utilization of a cold homogeneous targets has been established [19]. Moreover, they have also been applied to a spaceborne instrument [20].

It is expected that the most notable development in the near future will take place for the calibration of synthetic aperture interferometric radiometers and digital radiometers. The papers in the session are a selection of topics that are currently pushing the envelope in the calibration of microwave radiometers.

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