Laboratory Validation of Dielectric Properties of Earth Resources

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Abstract

The information about dielectric properties of earth resources at MW frequencies is very significant from Remote Sensing Application point of view as these parameters are closely related to the emissivity, brightness temperature as well as the back scattering coefficient of various earth surfaces. Laboratory validation of these parameters provides fundamental information for RS applications. Measurement of the dielectric properties of several materials of geophysical interest is done in the C-Band MW Laboratory of J. E. S. College, Jalna. A brief account of the work is presented in this paper.

***Key Words**: Dielectric properties of soil, Water and ocean; C-band MW RS applications; Geophysical materials*

Introduction

A RESPOND proposal of the author(MLK),with the inspiration of the other author(SCM) submitted to ISRO for measurement of dielectric properties of earth resources at C-band MW frequency (5 GHz), submitted in late 1980s resulted into establishment of a C-Band Microwave Laboratory at J. E. S. College, Jalna, Maharashtra, in 1992. This laboratory was the off-shoot of the microwave research group led by the author (SCM) in the Physics Department of Dr. B. A. M. University, Aurangabad. Since then the C-band MW Laboratory of J. E. S. College is involved in measurement of dielectric properties of earth resources; Land, Water and Ocean, for over past 20 years, even after completion of the initial RESPOND project, now under the headship of the author (SKP).

Objectives

The objective of establishing the C-band MW Laboratory was to develop a strong centre for laboratory validation of measurement of dielectric properties , dielectric constant (ε') and dielectric loss (ε"), of various earth resources , significant for MW Remote Sensing Applications at C-Band, in accordance with the goals of ISRO in 1990s for launching a RS satellites in the forthcoming 21^{st} century.

Experimental Setup and Methodology

A C-band MW bench setup is used to accomplish the objectives of the RESPOND project. The MW bench consisting of a low power (10 mW) MW source (VTO 8430/8490 of Avantek), an isolator, co-axial to WG adaptor, s.s. tuner, attenuator, a slot-line section and a dielectric cell (for liquid or solid) with a perfect reflector at the back end of the cell is used to measure dielectric properties of any material which can be suitably filled in the rectangular cavity of the dielectric cell. It is like any standard MW bench used to adopt the Von Hipple method (1954) for this purpose. The usual MW bench setup is converted to an automated bench with a facility of acquiring and storing the data in a file and reducing the same for computation of dielectric properties of the earth resource materials. Certain mechanical modifications are done in the existing bench for moving the probe sitting on the slotted section in forward and reverse directions by using a stepper motor and limit switches. An auxiliary fabricated structure is used to hold the liquid dielectric cell and control the movement of the plunger in the cell with the help of another stepper motor. These motors are interfaced with a PC. The paper of automation was published in proceedings of NCMMT (2004).

The normally incident microwaves from the source pass through the sample (solid or liquid) of soil, rock, water etc. and are reflected back from the perfect reflector in contact with the sample material at the far end of the sample. These waves form a perfect standing pattern in the slot line when the bench is perfectly tuned. The data of the probe position in the slot-line and corresponding microwave power is used to plot the standing wave pattern using a microcontroller based PC interface. These patterns are obtained when the cell is empty i.e. not filled with the dielectric material and that obtained by filling the rectangular cavity of the cell with solid or liquid material. The shift in the minima of the standing waves due to the dielectric material in the cell is used to calculate dielectric properties of the material. In case of solid materials like soil, rock etc., the data is acquired for three different thicknesses of the sample (say 1.0, 2.0, 3.0 cm) where as the thickness of the liquid sample is changed in steps of

0.25 mm. The data of the empty cell and that when it is filled with dielectric material is fitted for least squares of microwave parameters α, β, P0 and δ (α = attenuation factor, β = propagation constant, P_0=maximum microwave power and δ=phase factor) to calculate the optimum value of dielectric constant (ε') and dielectric loss (ε") of the material along with the error factors Δε' and Δε" in the measurement of these values, using a software developed for this purpose. The dielectric properties of the material are calculated using the standard formulae given in textbooks, literature and several papers and thesis.

Results and Discussion

The work pertaining to the laboratory validation of the dielectric constant (ε') and dielectric loss (ε") of soils of different regions varying in texture depending on percentage of sand, silt and clay and moisture (0-30%) is carried out in the C-band MW Laboratory of J.E.S.College in past 20 years. These properties of saline soil samples from several regions of the country are also measured in the laboratory. Measurements for a variety of natural water types like rain water, lake water, river water and sea water in different parts of the ocean around the Indian subcontinent have been done in the laboratory during past two decades. The onboard facilities of ORV Sagar Kanya of National Centre for Antarctic and Ocean Research (NCAOR), Goa were used by participating the cruises in different periods like pre- and post-monsoon. Measurement of dielectric properties of a variety of ice and few soil samples of Antarctica was done by carrying the bench to Antarctica during XXII Scientific Expedition in 2003. Few Antarctic rock samples were brought to India and dielectric measurements of these samples were done in the lab after cutting them appropriately for inserting in the cavity of solid dielectric cell. The work on sodic soil and vegetation material is also in progress. Most of the work on soil, natural water and ocean is submitted to Dr.B.A.M.University , Aurangabad as the doctoral work of V.V.Navarkhele (water and electrolytic solutions , 1996), R.S.Agrawal (soil, 2000), A.G.Murugkar (sea wate r, 2003), P.G.Kulkarni (soil, 2006), A.S.Joshi (pre- and post-monsoon sea water, 2012), S.S.Deshpande (saline soil, 2012). The work on metal contamination of soil done by R.S. Wahul (2008) was submitted for dissertation of M.Phil.Work of Ashish Itolikar (vegetation) is in progress.

Summary and Conclusions

Summary and conclusions are given in the respective thesis and papers.

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