Abstract

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“STUDY OF COMPLEX PERMITTIVITY OF SOLIDS AND LIQUIDS AT MILLIMETER WAVELENGTHS”

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Study of Complex Permittivity of Solids and Liquids at Millimeter Wavelengths

Knowledge of the low and high frequency dielectric properties of materials is of essential interest, particularly for solids and liquids, which have device applications for e.g. semiconductor and liquid crystals. Quite recently a strong interest has also risen in the dielectric response of biological substances in the microwave frequency range. [1]

The dielectric property of the material is one of the factors that determine how the material interacts with an electromagnetic field. It is a complex quantity consists of a real part (dielectric permittivity) and an imaginary part (dielectric loss). The knowledge of the dielectric properties of the materials and their frequency and temperature dependence is of great importance in various areas of science and engineering in both basic and applied research. Dielectric properties can be often related to a physical parameter of interest. It has been demonstrated that properties such as moisture content [2], bacterial content [3], mechanical stress [4], and other seemingly unrelated parameters are related to the dielectric properties of the material [5]. An accurate measurement of these properties provides scientist and engineers with valuable information that allows them to properly incorporate the material into its intended applications or to monitor a process for improved quality controlled [6]. The permittivity is a fundamental property of the material and is independent of measurement technique. Measurement techniques typically involve placing the material in an appropriate sample holder and determining the permittivity from the measurements on the
sample holder. There are other different techniques where this relationship is not straight forward have been employed. One of these techniques is a transmission line waveguide method. This technique has attracted much attention because of its applicability to nondestructive testing over a relatively broad frequency range [7].

Dielectric phenomena play a fundamental role in many areas of modern science and technology. The dielectric spectroscopy technique occupies a special place among the numerous modern methods used in physics and chemical analysis of materials because of the extremely wide range of times ($10^3$-$10^{12}$) available with this technique to track the time evolution of dynamic process in molecular systems. Although it does not possess the selectivity of NMR and ESR methods, it can offer important and sometimes unique information about the dynamic and structural properties of molecular systems and complements these other techniques. Dielectric spectroscopy is essentially sensitive to intermolecular interactions and able to monitor cooperative processes. It provides a link between the investigation, via -molecular spectroscopy of the properties of the individual constituent of the complex material and the characterization of its bulk properties. The recent successful developments of the time domain spectroscopy and broadband dielectric spectroscopy methods have radically changed the attitudes towards dielectric spectroscopy, making it an effective tool for solids and liquids investigation on macroscopic and microscopic levels.

The measurement of dielectric properties of several agriculture, environmental, and food processes is need for the society. Microwave measurements and dielectric properties of materials are finding increasing applications, as new electro-technology is adapted for the use in the agriculture
and food processing industries. The interest in dielectric properties of materials has historically been associated with the design of electrical equipment, where various dielectrics are used for insulating conductor and other components of electrical equipment. The measurement of dielectric properties is not an end onto itself. Rather, these properties are intermediary vehicle for understanding, explaining, and empirically rating certain physical-chemical properties of materials [8].

If we apply potential difference across piece of material, some or no electric current flows through it. If the material piece contains free electron as in case of copper they move one end to another end and current generated in piece. On the other hand if the material piece contains no free electrons as in case of ebonite no electric current at result. Such material producing no current on application of potential difference is known as insulators. In an insulator the electrons are tightly bound to the atoms, therefore there are no free electrons or very less. In spite of non-conducting nature of insulators they have an important behavior in presence of electric field. In the presence of electric field the insulator piece develops a dipole property. The insulators with such property are called as dielectrics [9].

The development and application of high frequency current technology in the past decades increased the demand for dielectric materials. In particular, the suitability of the use of dielectrics in electronic circuits design for high frequency became a factor of paramount importance. In an external driving field, the motion of the particles present in the material (molecule, ions, atomic nuclei and electrons) needs characteristic time to build up an equilibrium polarization. If the
electric field strength is varies sufficiently fast, the polarization will lag behind the changing field. The dielectric properties of materials in time-dependent fields will therefore deviate characteristically from the corresponding equilibrium properties in study fields. Physicists use the dielectric relaxation measurements and chemists as a spectroscopic method to study molecular motion and to thus enable statements to be made on short-range specific interaction [15, 16].

Chapter I give the introductory information and describe the objective of the present work. Our increasing interest is to study the physical properties of different solid and liquid samples. The physical properties are like dielectric permittivity, dielectric loss, and loss tangent of solids, which are useful in microwave remote sensing for both active and passive. It is also possible to measure the water content from the dielectric permittivity measurement of soil. The soil moisture, which is estimated from dielectric permittivity, is needed for management purposes; irrigation schedules and fertigation can be planned more efficiently if we have the knowledge of soil water content.

Chapter II describes the experimental aspects of the experimental setup consisting of microwave X band. This chapter also consists of experimental methods like, transmission line theory, wave guide theory, resonance and non-resonance experimental theories, the basics equations for low and high loss dielectric materials and the experimental setup of microwave X-band. It also consists of theory of components used in the experimental setup. The information regarding Agilent Technology made microwave power meter, which is used for the measurement of power, frequency and for the tuning purpose. One mechanical
instrument designed for pressing the soil to remove the soil air and discontinuities in the samples is given in this chapter.

Chapter III consists of dielectric measurement of different solid samples at two different wavelengths/ frequencies. The solids samples are green, cream, brown, black, dark brown granites. The experimental observations of these solids show that the dielectric properties of all granite samples are different and decreases with increase in frequency.

Chapter IV gives the physical, chemical analysis of three different color soil samples.

Chapter V gives the measurement of water content and soil water interaction in terms of dielectric properties of three soil samples for two different wavelengths/ frequencies. The Robert-Von Hipple method and least squares fit program of Sobhanadri are used to measure the dielectric permittivity, loss and water content. The results show that the measurement of soil dielectric permittivity is very sensitive to volumetric water content. It is also show that at lower percent of water content there is slow increase in dielectric permittivity whereas it increases sharply at higher water content and becomes constant at certain value of water content in soil. It is interesting to observe that these variations have been found to be strongly dependent on texture of soils. The value of dielectric permittivity decreases with presence of excessive water due to ionic effect.

Chapter VI consists of the density dependent dielectric properties of three soil samples for two different wavelengths/ frequencies. The results show that as
density increases the dielectric properties of soils are also increases i.e. the dielectric properties are depends on density of the material.

Chapter VII consists of dielectric parameter study of binary mixtures using FDR technique i.e. at microwave X-band. The dielectric parameters study involves the study of interaction of N, N-dimethyl formamide with methyl isobutyl ketone, N, N-dimethyl formamide with Ethyl methyl ketone and N, N-dimethyl formamide with n-propanol. The study of these binary mixtures has been conducted for two different wavelengths / frequencies and at room temperature 32°C. The results show that there is decrease in dielectric permittivity with increasing percentage volume of N, N-dimethyl formamide and deceases with increasing frequency.

Chapter VIII gives the conclusion of the present thesis.