Variation of Physical Parameters of Soil from Nasik Region with Dielectric Constant at X Band Frequency

M.D.Dhiware[1], S. B. Nahire[2], Sushant Deshmukh[3]

[1] G.M.D. Arts, B.W. Commerce and Science College, Sinnar, Nasik, Maharashtra, India
[2] Arts, Science and Commerce College, Ozar (Mig) Nashik, Mahashtra, India
[3] J.E.S. College, Jalana, Maharashtra, India

Abstract: The Real and Imaginary parts (ε & ε") of the Complex Dielectric Permittivity (ε*) of soil have been determined experimentally using an automated X-band microwave set-up in the TE10 mode with Reflex Klystron source operating at frequency 9.5 GHz . It has been observed that the effect of physical parameters in the soil is more pronounced in the dielectric loss as compared to dielectric constant. The microwave conductivity, relaxation time, emissivity (e) and tangent loss of soil were also calculated from the measured value of complex dielectric permittivity. Soil samples were analyzed for physical and chemical properties for the status of available micro nutrients. These parameters have great importance in remote sensing of soil moisture using microwave signals.

Keyword: Dielectric constant, tangent loss, relaxation time, , microwave conductivity

1.0 Introduction:

Soil is a thin layer that covers earth's rocky surface. Soil is an intimate mixture of organic and inorganic materials, water and air. Productive soils are necessary for agriculture to supply the world with sufficient food. Now a day's soil contamination has become a severe environmental problem. Soil is a heterogeneous body. Therefore, it is not possible to collect a soil sample which would be representative of the heterogeneous land. So, first of all the heterogeneity of the land is minimized by dividing the land into smaller units. It is, therefore, important that samples are representative of the soil for the area under investigation. Unless this is ensured, sampling may be the greater source of error in the whole process.

The measurement of complex dielectric constant and complex permeability is required not only for scientific but also for industrial applications.[1] When microwaves are incident on the surface of the earth, part of the energy is reflected, part is transmitted through the surface and rest is absorbed. The distribution of the incident energy in these proportions is defined in terms of dielectric properties. The complex dielectric permittivity is the fundamental electrical property which describes these interactions, which is mathematically expressed as

$$\varepsilon^{*} = \varepsilon' - \varepsilon''$$

Where

ε' - dieectric costsnt and

ε'' - dielectric loss

The measurement of dielectric constant of soil as a function of moisture content has been carried out over a wide frequency range in the past several years using soils of widely different texture structures (Wang & Schmugge 1980).[2]

Over the past few decades, the Earth's surface has witnessed major changes in land use. These changes are likely to continue, driven by demographic pressure or by climate change. In this context, monitoring tools are needed for maintaining a sustainable ecological status, improving soil conservation and water resource management. Floods, excess runoff, soil erosion, and related contamination and disequilibrium of the water and carbon cycles are, among others, key issues that are controlled and influenced by soil surface characteristics. The implementation of sustainable agricultural, hydrological, and environmental management requires an improved understanding of the soil, at increasingly finer scales. Conventional soil sampling and laboratory analyses cannot efficiently provide this information, because they are slow, expensive, and could not retrieve all temporal and spatial variability's. Indian agriculture occupies an eminent position in global cultivation of rice, wheat, sugarcane, pulses and vegetables. Soil testing is the only way to determine the 5available nutrient status in soil and the only way we can develop specific fertilizer recommendations. Soil is the medium for plant growth. Its physical, chemical and biological properties determine the degree of workability, suitability to specific crop varieties, physical and chemical capacities as well as productivity. The physical capacities of a soil are influenced by the size,

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proportion, arrangement and composition of the soil particles. The physical and biological properties of soils need careful study because they give mechanical support to plants. The ideal soil for agricultural use is loam, which combines good aeration and drainage properties of large particles, with the nutrient-retention ability of clay particles. The soil texture depends upon the percentage of clay, silt and sand particles in the soil.

2.0 Study Area

In Nasik district, season-wise crops are taken i.e. in rainy season- cotton, soya bean, in winter- wheat and in summer-onion. The maximum temperature of Nasik District in summer is 42.5°C and the minimum in winter is less than 5°C. The humidity range is from 43% to 62%..The average rainfall of Nasik District is 1161mm.The major soil is of shallow red (536.7 ha), medium red/black (170.3 ha) and deep black (101.9 ha). The geographical area of Nasik District is 15.63 lakh hectares and cultivated area is 8.09 lakh hectares. The Nasik district is famous for grapes and onion..

2.1 Materials and methods

Soil samples were collected from 10 to 15 cm depth layer at different points on the experimental site. Soil samples were taken from agricultural land and after removing the surface organic materials and fine roots all the samples mixed thoroughly to make one composite sample. The soil samples were then brought to laboratory in rigid containers to avoid atmospheric changes and breaking the soil aggregates. Prior to the analysis, each soil sample was passed through a 5 mm sieve. The collected soil samples mixed thoroughly to make one composite mixture and crushed well before the analysis. The texture analysis of both the soil samples was completed with the help of mechanical sieves. The soil samples are kept in a closed container for proper settling over several hours. The physical properties of soil play an important role to improve the life and quality of soil, since they are related with the water holding capacity, water conducting ability, aeration, water retention, productive capacity, structure and plant nutriments. The choices of measurement technique, equipment, and sample holder design depend upon the dielectric materials to be measured, and the frequency or frequency range of interest [3].

2.0 Methods

The measurement of dielectric properties has gained importance because it can be used for monitoring the specific properties of materials undergoing physical or chemical changes. Methods of measuring the dielectric properties of granular and powdered materials at microwave frequencies and the factors affecting the dielectric properties of materials, such as frequency, moisture content, temperature, and bulk density, were reviewed by Nelson S. O. [4,5]. There are basically four methods for measuring the dielectric constant of materials at microwave frequencies, viz.,

(i) Waveguide- cell method (Transmission line method)
(ii) Free space transmission method
(iii) Cavity resonance method.
(iv) Network analyzer and dielectric probe method

These dielectric property measurement techniques can be categorized as reflection or transmission types using resonant or non-resonant systems, with open or closed structures for sensing the properties of material samples [6]. Waveguide and coaxial line transmission measurements represent closed structures while the free-space transmission measurements represent open-structure techniques. According to Nelson S.O. [7], resonant structures can include either closed resonant cavities or open resonant structures operated as two-port devices for transmission measurements or as one-port devices for reflection measurements. A general comparison/review of the microwave dielectric measurement techniques has been made by several investigators [8-13]. These four methods are briefly described below.

2.2 Waveguide- cell method (Transmission line method)

Early efforts to characterize the dielectric properties of materials were made at the Massachusetts Institute of Technology [14]. The values of ε' and ε" were derived from transmission line theory, which indicated that these properties could be determined by measuring the phase and amplitude of a reflected microwave signal from a sample material placed against the end of a short-circuited waveguide.

This method gives data for a wide range ranging from 500 MHz-110 GHz using waveguides of different dimensions. For a waveguide structure, rectangular samples that fit into the dimensions of the waveguide at the frequency being measured are required. For coaxial lines, an annular sample needs to be fabricated. The method can be used for solid, liquid and semi-liquid samples. The thickness of the sample should be approximately one-quarter of the wavelength of the energy that has penetrated the sample. This technique is easy to use and its analysis can be done manually as well as with the help of suitable computer programs. Since the shift in wavelength is related to the dielectric constant, a guess must first be made as to the magnitude of the constant. Dielectric sample holder design for a particular material of interest is an important aspect of the measurement technique. The overall equipment cost is low and it can provide fairly good accuracy.

In present study the waveguide cell method is used to determine the dielectric properties of these soil samples. An automated X-band microwave set-up in the TE10 mode with Klystron source operating at frequency 9 GHz. PC-Based slotted line control is used for this purpose. The solid dielectric cell with soil sample is connected to the opposite end of the source. The signal generated from the microwave source is allowed to incident on the soil sample. The soil sample reflects part of the incident signal from its front surface. The reflected wave combined with incident wave to give a standing wave pattern. These standing wave patterns are then used in determining the values of shift in minima resulted due to before and after inserting the sample. Experiments were performed at room temperatures ranged between 30-40oC. The dielectric constant ε', dielectric loss ε" emissivity (e) and a.c. conductivity (σ) of these soil samples are then determined.

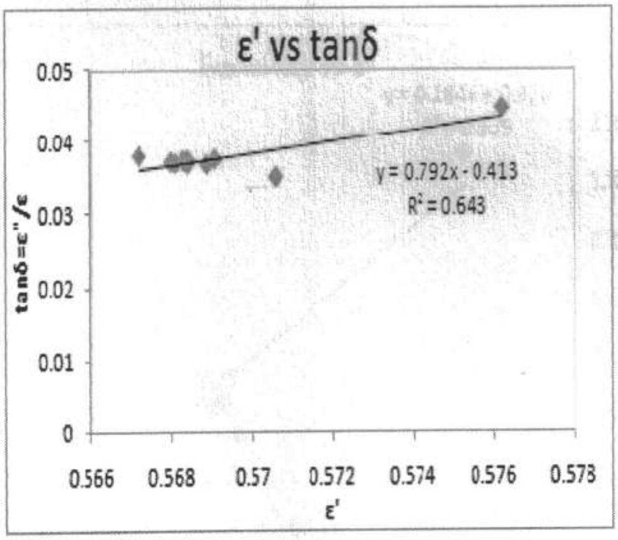
3.0 Results and Discussion

The electrical properties of soil samples are listed in Table 1.Tangent loss, ac conductivity, relaxation time and emissivity are calculated and reported in the following table. Tangent loss of soil samples has high degree positive correlation with dielectric constant. The relaxation time (Ґ) is proportional to dielectric constant. It has strong positive correlation with dielectric constant. Similarly relaxation time and emissivity also has strong positive correlation with dielectric constant.

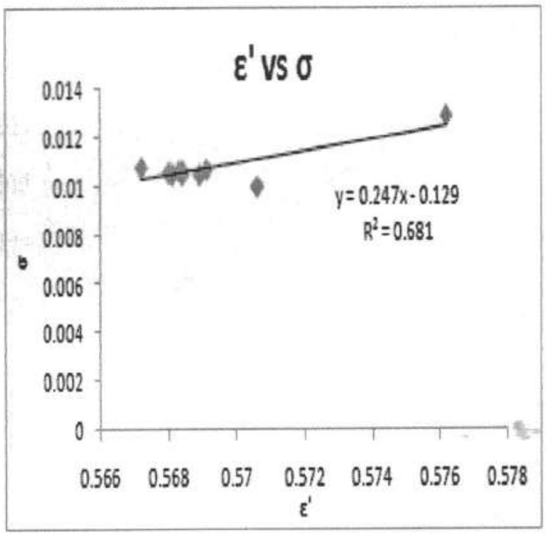
TABLE NO. 1:

Specification	ε'	ε"	tanδ=ε"/ε'	σ=ωεοε"	Ґ=ε"ωε'	Emissivity
Sample 1	0.568	0.02112	0.037177	0.0105624	2.12E-13	0.9802672
Sample 2	0.5672	0.02156	0.038015	0.0107847	2.16E-13	0.980166
Sample 3	0.5762	0.02575	0.044689	0.01288	2.63E-13	0.9812422
Sample 4	0.5689	0.02097	0.036859	0.0104881	2.11E-13	0.9803721
Sample 5	0.5684	0.0213	0.037465	0.010652	2.14E-13	0.9803157
Sample 6	0.5684	0.02097	0.036894	0.0104889	2.11E-13	0.9803116
Sample 7	0.5681	0.02101	0.036979	0.0105082	2.11E-13	0.9802793
Sample 8	0.5706	0.02	0.035051	0.0100035	2.02E-13	0.9805765
Sample 9	0.5683	0.02125	0.037395	0.0106308	2.14E-13	0.9803076
Sample 10	0.5691	0.02138	0.037568	0.0106937	2.15E-13	0.9803962

Graphical Representation



Graph (1) Dielectric constant verses Tangent loss



Graph (2) Dielectric constant verses Conductivity

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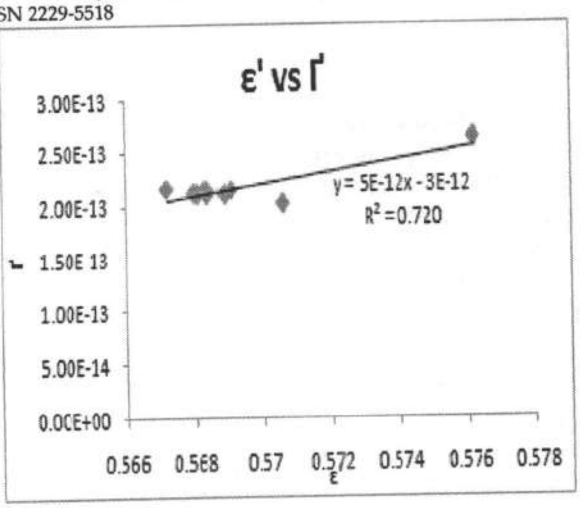
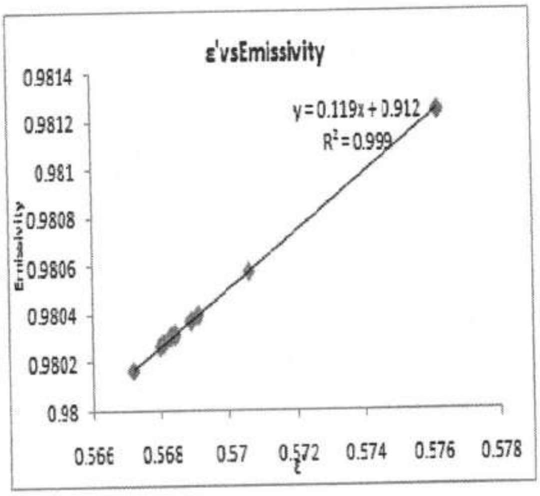
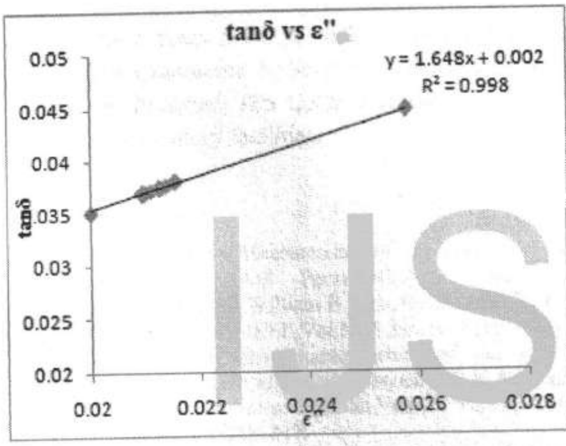


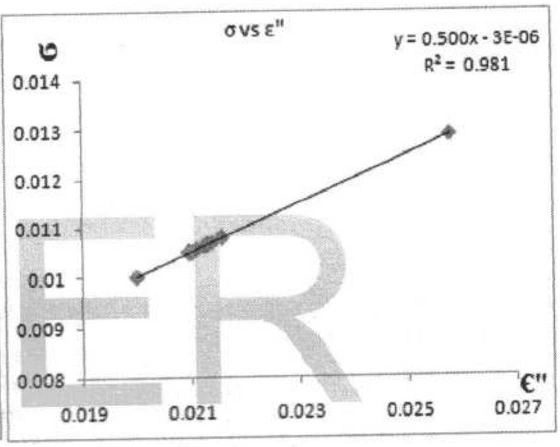
Graph (3) Dielectric constant verses Relaxation time



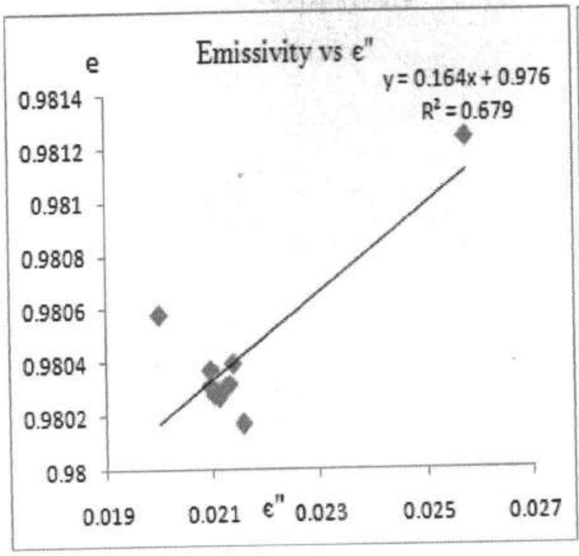
Graph (4) Dielectric constant verses Emissivity



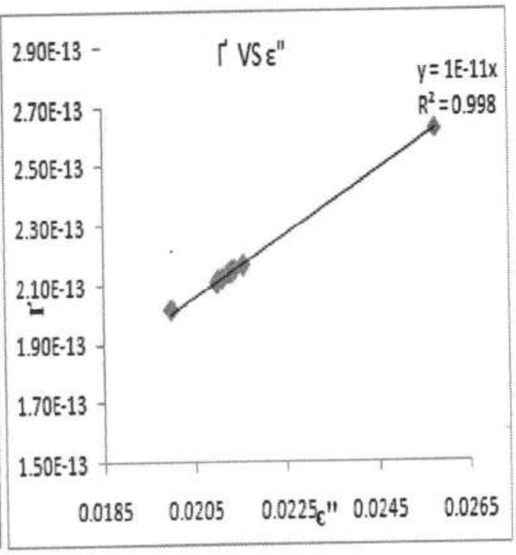
Graph (5) Tangent loss verses Dielectric loss



Graph (6) Conductivity verses Dielectric loss



Graph (7) Emissivity verses Dielectric loss



Graph (8) Relaxation time verses Dielectric loss

4.0 Conclusion-

Electrical a.c. conductivity, tangent loss and relaxation time are estimated from calculated dielectric constant and dielectric loss. Electrical a.c. conductivity, tangent loss and relaxation time and emissivity has strong positive correlation with dielectric constant. It is useful for the researchers working in the field of microwave remote sensing. Especially, by knowing the correlation coefficient of various soil properties with dielectric loss help to understand and analyze the satellite data and also for agriculture scientists. The results are in good agreement with the work reported by earlier researchers.

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