

Microwave Dielectric Behaviour of Soil in Chhattisgarh: A Review

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Abstract: In this paper an attempt has been made to review microwave dielectric behaviour of soil in Chhattisgarh. Soils are complex mixture of minerals, water, air, organic matter, and countless organisms that are the decaying remains of once-living things. The properties of soil such as physical properties, chemical properties, geographic properties are really important in production of agriculture. To perform dielectric constant microwave test bench generally used. The parameter of soil affects the production of grains. It has been observed that the dielectric constants are strongly dependent on moisture content. Dielectric constant decreases with increasing percentage of sand. Dielectric constant increases with increasing percentage of silt. Dielectric constant increases slowly with increasing conc. Fertilized soil. There are a lot of parameters but moisture content is the very important. In the laboratory the properties of soil are utilized for study which is very useful in agriculture.

Keywords: Soil, minerals, DC, MRS, agriculture, minerals.

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I. Introduction:

Remote sensing is the sensing of an object or phenomena from a remote distance, signal, sensor, sensing or the component of remote sensing. Soil has different properties as physical, chemical and Geographical. In physical properties, Soil texture (sand, silt and clay), bulk density, WHC, particle density, porosity, volume expansion, wetting point, transition moisture, water content, dielectric constant exist. Now in chemical properties pH, EC, OC, Heavy metals viz Fe, Pb, Mn, Zn, Cr, Micro nutrients metals viz Fe, Mn, Zn, Cu and macro nutrients N, P, K, Le, Mg further Geographical properties is denoted by LALA, i.e. Latitude, Altitude, Longitude, average rain fall. Recently new term is introduced in concerned research is hydrolic pressure. Soil is the unconsolidated or loose covering of fine rock particles that covers the surface of the earth. High yielding crop cultivars were highly responsive to fertilizers. Soil characterization in relation to evaluation of fertility status of an area or region is an important aspect in context of sustainable agricultural production. Really soil is the unconsolidated material on the immediate surface of the earth that serves as a natural medium for the growth of land, plants and has been subjected to and influenced by genetic and environment factors of parent material, climate (including moisture and temperature effects), macro and micro organisms and topography, acting over a period of time and producing a product that differs from material from which it has derived all the properties and characteristics. The pH of a soil refers to how acidic or alkaline the soil is. Eighteen elements, called nutrients, are essential for plant growth. They are classified as macro- and micro-nutrients, based on the quantity required. As they grow, plants extract nutrients they need from the soil. Unless these nutrients are replenished, plants will eventually cease to grow. In nature, nutrients are returned to the soil when plants die and decay. When cultivated plants are harvested, nutrients that the plants extracted from the soil are taken away. To keep the soil productive, it is necessary to replace these nutrients artificially. Patel et al. showed variation of electrical parameters of soil with moisture and salinity over frequency[1]. Sahu Vijay et al. analyzed dielectric behaviour of soil in agriculture with reference to pond area [2]. Shrivastava Rajesh et al. illustrated the study of microwave dielectric characteristics of soil in north east Chhattisgarh [3]. Kumar Shashi Ranjan et al. worked on review and analysis of microwave remote sensing behavior of soil in India[4]. Patel Lakhpati et al. role of moisture content and dielectric constant in soil[5]. Patel Lakhpati et al. showed significance of dielectric behaviour of flood affected Soil in agriculture, with special reference to Bihar and Chhattisgarh[6]. The importance of soil as a natural body derives in large part from its role as an interface between the words of rock (the lithosphere), air (the atmosphere), water (the hydrosphere), and living things (the biosphere). Environments where, all four of these worlds interact are often the most complex and productive an earth. An estuary, where, shallow waters must the land and air, is an example of such an

environment. Except in the case of organic soils, most of a soils solid framework consists of mineral particles. The larger soil particles, which include stones, gravel and coarse sands are generally rock fragments of various kinds. The mineral particles present in soils are extremely variable in size. Excluding, for the moment, the larger rock fragments such as stones and gravel, soil particles range in size over four orders of magnitude: from 2.0 millimeters (mm) to smaller than 0.0002 mm in diameter. Sand particles are probably most familiar to us. Individual sand particles are large enough (2.0 to 0.05 mm) to be seen by the naked eye and feel gritty when rubbed between the fingers. Sand particles do not adhere to one another; therefore, sands do not feel sticky. Silt particles are somewhat smaller (0.05 to 0.0002 mm). Silt particles are too small to see without a microscope or to feel individually, so silt feels smooth but not sticky, even when wet. The small class of mineral particles are the clays (<0.002 mm), which adhere together to form a sticky mass when wet and hard clods when dry. The smaller particles (<0.001mm) of clay (and similar-sized organic particles) have colloidal properties and can be seen only with the aid of an electron microscope. Because of their extremely small size, colloidal particles possess a tremendous amount of surface area per unit mass. Since the surfaces of soil colloids (both mineral and organic) exhibit electromagnetic changes that attract positive and negative ions as well as water, the fraction of the soil is the seat of most of the soils chemical and physical activity. The proportion of particles, in these different size ranges is called soil texture. Terms such as sandy loam, silty clay and clay loam are used to identify the soil texture. Texture has a profound influence on many soil properties, and it affects the suitability of a soil for most uses. Sand, silt and clay particles can be thought of as the building blocks from which soil is constructed. The manner in which these building blocks are arranged together is called soil structure. Soil organic matter consists of a wide range of organic (carbonaceous) substances, carbonaceous remains of organism that once occupied the soil and organic compounds produced by current and past metabolism in the soil. Also water is of vital importance in the ecological functioning of soil. The presence of water in soils is essential for the survival and growth of plants and other soil organism. The soil solution contains small but significant quantities of soluble inorganic compounds, some of which supply elements that are essential for plant growth. There are eighteen essential elements i.e. Carbon (CO₂), Hydrogen (H₂O), Oxygen (O₂, H₂O), Nitrogen (NO₃⁻, NH₄⁺), Phosphorus (H₂PO₄⁻, HPO₄²⁻), Potassium (K⁺), Calcium (Ca²⁺), Magnesium (Mg²⁺), Sulfur (SO₄²⁻), Iron (Fe²⁺), Manganise (Mn²⁺), Boron (HBO₃), Zinc (Zn²⁺), Cupper (Cu²⁺), Chlorine (Cl⁻), Cobalt (Co²⁺), Molybdenum (MoO₄²⁻) and Nickel (Ni²⁺).

Approximately half of the volume of the soil consists of pore spaces of varying sizes which are filled with either water or air, when water enters the soil, it displaces air from some of the pores, and the air content of a soil is therefore inversely related to its water content. A soil moisture regime (SMR) is the presence or absence of either water saturated conditions or plant-available soil water. The water is present or absent during specified periods in the year in what is termed the control section of the soil. The upper boundary of the SMR control section is the depth that 2.5 cm of water will penetrate within 24 hours when added to a dry soil. The lower boundary is the depth that 7.5 cm of water will penetrate. The control section ranges from 10 to 30 cm for soils high in fine particles (clay) and from 30 to 90 cm for sandy soils, several moisture regime classes are used to characterize soils. There are five category i.e. aquic, udic, ustic, aridic, xeric, clearly the soils is really plays pivotal role in microwave remote sensing behaviour of soil. And understanding of the principles that govern the attraction of water for soil solids and for dissolved ions can help maximize the positive impacts while minimizing the less-desirable once. The water molecule has a polar structure that results in electrostatic attraction of water to both soluble cations and soil solids. These attractive forces tend to reduce the potential energy level of soil water below that of pure water. The extent of their reduction called soil water potential Ψ has a profound influence on a number of soil properties, but especially on the movement of soil water and its uptake by plants. It has been seen that soil aeration and soil temperature critically affect the quality of solids. Soils with extremely wet moisture regimes are unique with respect to their morphology and chemistry. Soil water exerts a major influence over both soil aeration and soil temperature. It competes with soil air for the occupancy of soil pores and interferes with the diffusion of gases into and out of the soil. Soil water also resists changes in soil temperature by virtue of its high specific heat and its high energy requirement for evaporation. The complex structures, enormous surface area (both internal and external), and tremendous numbers of charges of soil colloids combine to make these tiniest of soil particles the seats of chemical and physical activity in soils. The physical activity of the colloids, their absorption of water, swelling, shrinking, and cohesion is very important. It has been also seen that the chemical activity of the colloids activity that results largely from the charges on or near colloid surfaces. These charged sites attract ions and molecules of opposite charge from the soil solution. The negative sites on the colloids attract positive ions (cations) such as Ca²⁺, Cu²⁺, K⁺, Al³⁺ and others. Positive sites on the colloids attract negative anions such as Cl⁻, SO₄²⁻, NO₃⁻ or HPO₄²⁻.

In agricultural production the role of land irrigation soil, fertilizer is very important. The annual rain is from 800 mm to 1700 mm. The crops are dependent on monsoon. Rice paddy is main crops. On the basis of physical characteristics soil is divided in four parts i.e. Bhatta, Matasi, Dorsa and Knhar. The geographical area is 13790 thousand hectare in relation to land, for agriculture 346 thousand hectare is available. for rice paddy the

area is 300.4 thousand hectares. A lot of properties are related with properties i.e. texture, bulk density, particle density, maximum water holding capacity, porosity, moisture, hydraulic conductivity, colour, pH, electron conductivity, organic carbon, calcium carbonate, available nitrogen, available phosphorous, available potassium, available iron, available manganese, available zinc, available copper, NPK fertilizers, dielectric constant, dielectric loss, tangent loss, microwave conductivity, relaxation time, emissivity, LALA (Latitude, Altitude, Longitude, average rainfall), complex dielectric constant, phase factor.

II. Theoretical Consideration

From the point of view of the environment, soil moisture is a key parameter. One of the primary resources upon which man depends for his existence is soil moisture. It plays an important role in the interactions between the land surface and the atmosphere, as well as ground water storage. Surface soil is important for its role on the continental watercycle, more specifically on the partition of precipitation between surface runoff and infiltration [5] and in partitioning the incoming radiation between latent and sensible heat flux. The energy from the former is radiated into the atmosphere, while the latter (sensible heat) processes the convective heats. Moisture near the soil surface is a primary factor in determining runoff, infiltration, redistribution, storage and drainage. Soil moisture also plays a vital role in the functioning of ecosystems. Surface soil moisture is a basic component of meteorological cycles and in the determination of agricultural crop yield. It is important in industrial and mining processes. While significant amount of effort have gone into predictive modelling of these processes, few models utilize or even estimate soil moisture. This arises mainly due to the non availability of the wide coverage of measurements data, necessary as an input to the dynamic models. Remote sensing techniques offer an alternative means of fulfilling this gap for rapid measurement of the moisture status near the soil surface over extended areas. The technique can also be used to measure soil moisture quantitatively on bare and short vegetated surfaces. Basic to the soil moisture information is the knowledge of its permittivity (Dielectric Constant). Therefore, corresponding to a given soil moisture depth profile, a value of permittivity exists which influences the interaction of an electromagnetic wave at the air soil interface as well as the wave propagation properties inside the soil medium. Two techniques have generally been adopted for estimation of soil moisture. One depends directly on experimental measurement while the other on theoretical computations based on measured soil moisture and soil temperature profiles. The soil moisture at any given depth is correlated to the soil moisture at other depths. Therefore, it is difficult to identify experimentally the soil layer to which the radiometer is responding by simply correlating measured brightness temperature to the average soil moisture within different soil layers. Knowledge of the spatial distribution of soil moisture is critical when assessing crop yields and surface energy balance besides many other related parameters. Information about the variability of soil moisture is essential in designing measurement systems and descriptions of the land-atmosphere surface interactions and related hydrologic phenomena [7]. As a result, theoretical models have been used to predict the weighting as to how much energy is emitted by individual soil layer. These weighting functions may be applied to soil moisture profiles to determine the depth of penetration and to predict average soil moisture over this depth. The soil moisture parameters show variability in depth, i.e. as the soil goes from dry to moist, the depth over which the soil moisture parameters correspond decreases. Variation in slope and curvature, upslope contributing area and relative elevation all affect the distribution of soil moisture near the land surface. In arid environment, soil moisture varies as a result of water flow path, radiative effects and heterogeneity in soil type and vegetation. A parameter called equivalent soil moisture is defined, as a weighted integral of the soil moisture profile times the thermal microwave emission profile. It has been shown that the depths from which energy originates can extend approximately to 20 cm at 1.4 GHz for dry soil. For wet soil at this frequency the depth only extends to a couple of centimetres. However, Newton predicted that the near surface layers (0.2 cm) had a dominant effect on the emission that could escape from the soil volume.

In the field of agriculture the requirement of soil water content is highly variable, e.g. one time survey results are needed for finding out the soil moisture storage, available water capacity and moisture retention characteristics, but repeated monitoring of soil moisture is required. This becomes essential to determine levels of soil moisture deficit and extent of soil water depletion by crops, which are dependent upon environmental conditions. A major challenge for measurement, monitoring and modelling of soil water is the extent of variability of soil water in both time and space. The profile of soil water content also varies because of variable conditions such as dry surface with moist lower layer, moist surface with dry lower layer or the soil surface being covered by vegetation/crops or any combination of these.

Radio brightness is sensitive to soil moisture in agricultural land due to the dominant influence of liquid water upon microwave emissivity. To be of practical use in climatic modelling, crop forecasting or estimation rain water runoff potential, radio brightness-derived estimates of soil moisture represent the integrated moisture content of the soil from its surface through the root zone. The radio brightness, an indicative of thermal inertia is an estimate of soil moisture where, vegetation is short or sparse.

Soil Moisture Parameters

With the knowledge of soil bulk density ρ_b and soil particle density ρ_p , we can determine other soil water content parameters. For example, mass of water content m_g can be defined as

$$m_g = \frac{\text{Mass of water}}{\text{Mass of dry soil}} = \frac{m_w}{m_s} = \frac{\rho_w b}{\rho_p c} \dots (1)$$

Where, ρ_w is the density of water, b the equivalent depth of water and c the equivalent depth filled with solids. In practice m_g is measured by taking a sample in the field and measuring the mass of the sample before and after drying. The difference in the before m_{s+w} and after m_s measurements give the mass of water. However, knowledge of m_g does not provide sufficient information to tell the equivalent depth of water in the field without knowing the water content on a volume basis. Consequently m_v is defined as:

$$m_v = \frac{\text{Volume of water}}{\text{Bulk volume of soil}} = \frac{b}{D} \dots (2)$$

and is simply the ratio of the equivalent depth of water to the equivalent depth of the soil made of solid D . Thus, if 360 mm of water is found in 1000 mm of soil, $m_v = 0.36$. This measurement is the most useful expression of soil water content because of the simple and straightforward relation to other parameters of interest. Thus, using Eq. (2) the equivalent depth of water is defined as:

$$b = m_v D \dots (3)$$

These concepts also allow for porosity relations to be expressed in a fairly simple way. The total porosity of the soil is expressed as

$$P = \frac{\text{Total pore volume}}{\text{Bulk volume of soil}} = \frac{(a+b)A}{DA} = \frac{a+b}{D} \dots (4)$$

Where, a is the air space and A the area. The value of P may vary between 0.3 and 0.6 (30 and 60%).

It is thus obvious that for a saturated soil all of the pore volume would be filled with water m_v (saturated) = P . The pore volume filled with air is given as

$$P_a = \frac{\text{air pore volume}}{\text{Bulk volume of soil}} = \frac{aA}{DA} = \frac{a}{D} \dots (5)$$

Another parameter often used is relative saturation m_{vr} , the ratio of m_v to its saturated volume m_{vs} , given as

$$m_{vr} = \frac{bA}{(a+b)A} = \frac{b}{a+b} = \frac{m_v}{m_{vs}} \dots (6)$$

In practice, measurements of wet mass, dry soil mass, and bulk volume are made from which m_g , m_v and ρ_b are calculated. If ρ_b is known for the soil, the other parameters can be calculated from the above relations. Another fallout from the above equation is

$$m_g = \frac{m_{s+w} - m_s}{m_s} \dots (7)$$

Where, m_{s+w} is the mass of the wet soil and m_s the mass of the dry soil. This equation eliminates the need of finding the mass of water and depends only on the basic data.

A knowledge of m_v is generally sought as it is convenient to convert it to m_g using the relation

$$m_v = \frac{\rho_b}{\rho_w} m_g \dots (8)$$

Which requires knowledge of ρ_b alone. It is common to measure ρ_b once in the season and to assume that it does not change with time. This assumption is valid for many soils except the top soil.

Soil Moisture Measurements

Relative use of electromagnetic spectrum (frequency dependence) is classified as follows:

Visible And Infrared (0.3 – 3 μm) Electromagnetic Spectrum

Reflected radiation in the visible region of the electromagnetic spectrum has been demonstrated to have excellent correlation with moisture content, but limited to the top few millimetres of the soil surface. At these wavelengths, the penetration is small and because of cloud cover, the sensitivity rapidly decreases within first few millimetres of the soil surface. In addition, the electromagnetic interaction mode with different dry and wet soil varies widely. Major sources causing uncertainty are surface roughness and surface cover. Therefore, establishing a relationship between the two demands a priori knowledge of soil characteristics.

Thermal Infrared Method

Thermal emitted radiation from surface = $e\sigma T^4$, where, emissivity $e \sim 0.94$, σ the Stefan's constant and T the absolute temperature measurements in the thermal infrared region (10 – 12 μm) have also been shown to correlate well with the surface moisture content of bare soil where, the soil is non-uniform and a fair estimate of soil moisture matrix potential can still be obtained. While this technique appears to offer sensing of moisture at a greater depth than the visible spectrum measurement, it has limitations due to the presence of slightest amounts of vegetation. In addition, both optical reflectance and thermal emission models for estimation of soil moisture

requires knowledge of the solar radiation, (irradiance and isolation) which is not always available. In this method, the thermally emitted radiation from the surface is measured and related to soil moisture content.

Diurnal range of surface temperature is dependent upon the following:

Internal factors: Thermal conductivity K and heat capacity C

External factor: Meteorological parameters

Thermal inertia (TI): $(KC)^{1/2}$

Since K and C increase with increases in moisture content and hence thermal inertia increases.

Soil surface temperature and moisture represent the products of energy balance between the land and the atmosphere. They, in turn, also control the infrared and microwave emission.

Physical Basis of Soil Moisture Measurement Using Microwaves

Dielectric Behaviour of Wet Soils

Dielectric Constant (ϵ') of dry soil is essentially independent of temperature and frequency. The imaginary part ϵ'' is < 0.05 . Wet soil behaviour is, however, very complex. Over the past two decades, a number of studies have been carried out to determine the dielectric behaviour of soil-water. A wet soil medium is a mixture of soil particles, air pockets and liquid water. The water contained in the soil is usually divided into two fractions, viz. Bound water and free water. The relative fractions of bound and free water are related to the particle size distribution (or soil texture). These, in turn, are dependent upon the bulk soil density and the shape of the water inclusions.

Bound Water Layer

Bound water refers to water molecules that are contained in the first few molecular layers surrounding the soil influence of meteoric and osmotic forces. Bound water molecules are absorbed on the surface of particles and the dipoles are, therefore, constrained. Surface of particles offers the bonding site. Within a soil volume two physical parameters that describe the surface area are the specific surface area and the bulk density of soil. The matrix forces acting on a water molecule decrease rapidly with increasing distance from soil particles and, therefore, water molecules that are located several molecular layers away from the soil are able to move within the soil medium with relative ease and hence, are referred to as free water. Dividing the water into bound and free fractions is an approximation of the actual distribution of water molecules in the soil medium. This is based on a somewhat arbitrary criterion for describing the transition between bound and free water layers. The amount of water contained in the molecular layer adjoining the soil particles is directly proportional to the total surface area of the soil particles. This in turn, is a function of the size distribution and mineralogy of the soil particles.

In a dry soil, adsorbed cations are tightly held by negatively charged particle surface composed predominantly of clay. When water is slowly introduced into the system, salt precipitates go into the solution, and the adsorbed cations partially diffuse into the solution adjacent to the particle surfaces. The electrostatic field defined by the particles, however, inhibits this diffusion and results in a charge distribution described by the well known Boltzman and Poisson formulations. Given the large surface charge densities commonly present in soils, cation distribution defined by the double layer model can increase the ion concentration in the bulk solution by an order of magnitude or more relative to the one, measured for a solution extracted from a saturated soil paste. The Stern-Gouy double layer model accounts for the effects of the surface-charge density, type of action adsorbed, and salinity of the bulk soil solution upon the distribution of ions as a function of distance from particle surfaces. Assuming that the surface charge σ is uniformly distributed for soil it is related to its cation exchange capacity (CEC) and its specific surface by the relation

$$\sigma = CEC A_V e \times 10^{-9} / A_s, ESU. cm^{-2} \quad \dots (9)$$

Where, e is electronic charge and A_V is the number of charges per equivalent. Since A_s is dominated by the clay fraction, the surface charge density can be treated as being both constant and non-pH dependent.

In general, a soil medium is considered electromagnetically a four component dielectric mixture consisting of air, bulk soil, bound water and free water. Due to the intensity of the forces acting upon it, a bound water molecule interacts with an incident electromagnetic wave in much the same way that it does when it is in the form of ice, thereby, exhibiting a dielectric dispersion spectrum that is very different from that of free water. The complex dielectric constants of bound and free water are functions of the electromagnetic frequency, physical temperature T and salinity S . Hence, the dielectric constant of the soil mixture is, in general, a function of temperature and salinity and the total volumetric water content.

It is apparent from soil composition that its dielectric constant changes with applied frequency. An alternation electric field of appropriate frequency give rise to dielectric dispersion. The characteristics orientation motions of the dipoles result in a frequency variation of the dielectric constant, and the consequent appearance of dielectric loss. When the direction of the field changes sufficiently fast, the molecular force

impeding the dipole orientation dominate, and the dipoles unable to follow the changes. At these frequencies, the orientations of the permanent dipoles no longer contribute to the dielectric constant. Moreover, in a certain frequency band a phase lag between the field and the dipole orientation develops, and energy is drawn from the electrical source by the material and is dissipated as heat. This phenomenon is described by a complex representation of the dielectric constant

$$\varepsilon = \varepsilon' - j\varepsilon'' \quad \dots (10)$$

Where, imaginary part ε'' is known as dielectric loss, $\varepsilon''/\varepsilon' = \tan \delta$ is the loss tangent, and δ the loss angle.

Dielectric constant of water is based described by the modified Debye's equation

$$\varepsilon = \varepsilon_\infty + (\varepsilon_s - \varepsilon_\infty)(1 + j\omega\tau) \quad \dots (11)$$

Which is component form reduce to

$$\varepsilon' = \varepsilon_\infty + (\varepsilon_s - \varepsilon_\infty)/(1 + \omega^2\tau^2) \quad \dots (12)$$

$$\varepsilon'' = (\varepsilon_s - \varepsilon_\infty)\omega\tau/(1 + \omega^2\tau^2) \quad \dots (13)$$

where, ε_s is the static dielectric constant, ε_∞ is high frequency limit of dielectric constant, ω the applied angular frequency ($2\pi f$) and τ the relaxation time (time required for the water molecule to align itself with an applied field).

An isolated water molecule possesses a permanent dipole moment. If an electric field is applied, the molecule will orient itself such that its dipole moment is aligned with the field. The orientation response to an infinitely fast step variation of applied electric field is characterized by an exponential function of the form $\exp(-t/\tau)$ with time constant τ . This time constant is called the relaxation time and is governed by the interaction of the H_2O molecule with its environment and by the temperature T. If the water molecule is under the influence of nonelectrical forces, such as physical forces, its response to an applied electrical field is impeded by these forces which has the equivalent effect of increasing the relaxation time τ . This accounts for the fact that τ of a bound water molecule is much longer than that of a free water molecule.

Many forms of modified Debye's equations have been proposed to better describe the dielectric behaviour of water. Among them Cole-Cole equation is most widely used and it most accurate

$$\varepsilon = \varepsilon_\infty + (\varepsilon_s - \varepsilon_\infty)/[1 + (j\omega\tau)^{1-\alpha}] \quad \dots (14)$$

Values of ε_s and τ decrease with increase in temperature T. Values of ε_∞ and α are more or less constant for a system.

A still more accurate relationship for free water is given as

$$\varepsilon = n^2 \frac{(\varepsilon_s - \varepsilon_\infty)}{1 + (j\omega\tau_1)^{1-\alpha}} + \frac{(\varepsilon_\infty - n^2)}{1 + j\omega\tau_2} \quad \dots (15)$$

$$n^2 = 1.8$$

$$\varepsilon_s = 295.68 - 1.2283 \times T + 2.094 \times 10^{-3}T^2 - 1.41 \times 10^{-6}T^3$$

$$\tau_1 = 5.62 \times 10^{-15} \exp(3.01 \times 10^{-20}/KT).$$

where, τ_2 can be determined with the knowledge of initial parameters, T is the temperature in degree Kelvin and K the Boltzmann's constant ($= 1.3806 \times 10^{-23} J/K$), α is known as spread of relaxation ε_s and ε_∞ , τ , α are unique properties of a particular system.

$$\varepsilon_s(T) = 88.045 - 0.4147 T + 6.295 \times 10^{-4}T^2 + 1.075 \times 10^{-5}T^{-3} \dots (16)$$

While the relaxation time of pure water is given by,

$$2\pi\tau(T) = 1.1109 \times 10^{-10} - 3.824 \times 10^{-12}T + 6.938 \times 10^{-14}T^2 - 5.096 \times 10^{-16}T^3 \quad \dots (17)$$

High value of dielectric constant for free water is due to the fact that the water molecular dipoles are free to rotate at microwave frequencies. The dielectric properties of bound water are presumed to lie somewhere, between those of ice and liquid water. In several cases, bound water cannot be expelled from a material completely by heat without breaking its structural composition. Hence, in certain cases, we can only determine the total free water and not the total water content.

Relaxation time of bound water τ_{bw} depends on the thickness h (cm) of the film covering soil particles. This dependence has the form

$$\tau_{bw}(+27^0C) = \left[-4.9648 \times 10^{24}h^2 - 3.0867 \times 10^{11} \ln(h) - \frac{7.5092 \times 10^3}{h} + 3.9121 \times 10^{18}h - 5.2036 \times 10^{12} \right] \dots (18)$$

Here it is assumed that $\tau_{bw} = \tau_w$ at the water film thickness of 10 diameters of water molecule, i.e. h_{10} (water molecule diameter is $2.8 \times 10^{-8} cm$).

Relaxation time of bound water τ_{bw} molecules differs from relaxation time of free water τ_w and ice τ_c , where, $\tau_w < \tau_{bw} < \tau_c$. The τ_{bw} decreases with the number of monomolecular layers of water covering the particles and does not differ τ_w at film thickness of 10 monomolecular layers.

Bulk Density Effects

It has been demonstrated that for a given soil at given gravimetric moisture content m_g the measured dielectric constant ϵ is proportional to the soil packing density ρ . Assuming the soil to be homogeneous, the randomly dispersed mixture of solids, liquids and air along with all inclusions, is much smaller than the wavelength. The dependence of ϵ on ρ is explained by the direct dependence of ρ on soil and water volume fractions. For swelling clay the specific volume ($= 1/\rho$) increases linearly with the gravimetric water content .

Moisture, Texture And Frequency Dependence

At any given moisture content and at all given frequencies, ϵ' is found to be roughly proportional to the sand content. The effect of soil texture decreases with frequency. As is the characteristics of many dielectric materials, the real part of the dielectric constant decreases with increasing frequency.

The variation of ϵ_{soil} with soil type is reflected in the shape of brightness temperature curves. For even dried soil ϵ_{soil} is approximately the same for all soil types and depends on the bulk density only. The variation of ϵ_{soil} with increasing m_v can be divided into two parts: (i) between $m_v = 0$ and a transition moisture level m_t and (ii) $m_v \geq m_t$. The transition moisture, which is a constant for a given type of soil composition and varies between 0.03 for sands and 0.10 for clays, represents the boundary between the bound water and the free water molecules . Between the transition moisture levels, most of the water molecules in the soil water mixture are considered to be at least partially bound to the soil particles by the influence of both matric and osmotic forces. Hence, the effective dielectric constant of these partially bound water molecules is much smaller than that of free water, consequently the dielectric constant of the mixture increases only slowly with increasing m_v . Beyond $m_v = m_t$ the water molecules are considered to be free particles with a dielectric constant much larger than that of soil, thereby exercising a strong influence on the dielectric constant of the mixture. The transition moisture m_t depends on the soil particle surface area per unit volume, and hence a function of soil type.

Salinity Dependence

Below 10 GHz ionic conductivity of saline water may have a marked effect on the loss factor. Consequently, high soil salinity may significantly influence the dielectric properties of wet soil. Minute concentrations of an electrolyte usually impart considerable conductivity to a liquid medium. Apart from its conductivity, the electrolyte would be expected influence the dielectric properties of wet soil. Minute concentrations of an electrolyte usually impart considerable conductivity to a liquid medium. Apart from its conductivity, the electrolyte would be expected to influence the dielectric properties in two ways. First, its ions may associate producing an ion pair or similar solute species of appreciable dipole moment; such solute species will make their own contribution to the dielectric polarization and dispersion. Secondly, the ions or their aggregates in the medium can influence the solvent's molecular interactions due to their strong localized electric fields. In the limit, solvent molecules may be firmly bonded to the ions and hence, give new character of molecules in solution. Some ions markedly change the geometrical pattern to molecular interactions present in water.

The dielectric loss ϵ'' , however, is a parameter which describes the motions of electric charge (conduction phenomena). Conduction can arise from an actual charge transport (i.e. ionic conduction in electrolytes). Thus, observed dielectric loss is made of two terms, viz. The loss due to lag of polarization and the conductive loss

$$\epsilon'_{obs} = \epsilon'_{pol} + 2\sigma/f \dots(19)$$

The second term is inversely proportional to f . Hence, at microwave region, its contribution to the total dielectric loss can be safely neglected. This relative insensitivity of ϵ' to ionic content of absorbed water is an important advantage of using microwaves. Also, the loss of dry material is usually small in this region. However, at lower frequencies, this contribution cannot be neglected. Shape and size of granules influence the relaxation frequency of a mixture. Since many shapes and sizes are usually present in complicated systems like wet soil, a large in relaxation time is to be expected.

Soil conductivities, even when the soil is waterlogged, are much lower, being in the general range of 10^{-2} S/m as compared to ≈ 5 S/m for sea water. Sandy and gravel soils have conductivities closer to 10^{-5} S/m and granite rocks can have as low as 10^{-4} S/m. Moreover, temperature variation of σ and ϵ are significant above 50°C . The exact form of dielectric dependence of soil on salinity is, however, not well understood.

Temperature Dependence

It is observed that above 0°C , ϵ'_{soil} and ϵ''_{soil} exhibit a much weaker dependence on temperature as reported by several workers. They observed that at temperatures well below freezing point (0°C), ϵ'_{soil} and ϵ''_{soil} exhibit a much weaker dependence on frequency compared to their dependence above 0°C .

For bare fields the correlation is high between the brightness temperature and the soil moisture of upto 25%. For those fields with moisture content greater than 25%, the response seems to be more variable. Surface

roughness effect is more pronounced for moist fields. In a model developed the difference in observed brightness temperatures between medium rough ($h=0.3$) and rough field is only 6 K for dry fields (soil moisture ~0%) but ~27K for wet fields (soil moisture~25%). In general, data for bare fields agree well with theoretical values with an average roughness value of $h=0.5$.

For vegetated fields, the sensitivity to soil moisture is still strong. The response at nadir and horizontal polarization are similar. The general trend is that for drier fields there is a slight decrease in brightness response, which is attributed to the vegetation as compared to the bare fields. The general increase in brightness temperature is by the vegetation canopy acting as an additional thermal emitting layer. Typically, for moist fields, the vegetation canopy produces an increase in brightness temperature of about 15 K. The increase is greater for wet fields due to their lower surface emissivity's and consequently higher surface reflectivity. Using the IR observation and assuming an isothermal layer between the surface and vegetation, emissivity is defined as $e = T_B/T$. The increase in signature due to vegetation is also compensated by the smoother surfaces under the vegetation relative to the furrow irrigated fields which would produce overall lower emissivities. As a result, for drier fields the brightness temperature responses over vegetated fields are similar to, or in some cases, lower than those over bare fields. For vertical polarization, the vegetation effect is more pronounced such that the response is less sensitive to the background soil moisture content.

Special Class Of Soil

Vertisol

The vertisol, an important class of soils, have the characteristic property of changing their bulk density in response to water content. The water management of these soils is particularly important .

The vertisols are known by a variety of names such as black soils, black earths, cracking clays or swelling clays. These have a high cationic exchange capacity ($\sim 70 \text{ meq}/100\text{g}$) and have a high specific area ($\sim 6000 \text{ m}^2/\text{g}$). This then permits these to have a high retention capacity of water and makes it important for semiarid regions. When dry, these would shrink and increase in volume when wet. These authors performed the dielectric constant for the following soils: sandy loam (19% clay, 55% sand $P_b(1.34 - 1.76)$, ($CEC = 10 \text{ meq}/100\text{g}$); oxisol (62% clay, 19% sand $P_b(0.97 - 1.29)$, ($CEC = 10 \text{ meq}/100\text{g}$) and vertisol (70% clay, 14% sand $P_b(0.57 - 1.09)$, ($CEC = 68 \text{ meq}/100\text{g}$). The regression for the vertisol at 12 GHz is

$$\epsilon' = 2.79 + 2.90 m_v + 36.12 m_v^2 (r^2 = 0.932) \dots (20)$$

$$\epsilon'' = 0.020 - 1.46 m_v + 36.47 m_v^2 (r^2 = 0.861) \dots (21)$$

where, m_v is volumetric water content.

In a similar manner, shows the characteristics of the oxisol and the vertisol. The regression for the vertisol at 4 GHz are

$$\epsilon' = 3.44 - 12.78 m_v + 109.65 m_v^2 (r^2 = 0.958) \dots (22)$$

$$\epsilon'' = 0.32 - 3.63 m_v + 34.00 m_v^2 (r^2 = 0.96) \dots (23)$$

Density Effects

The dry bulk density of soils is not usually of concern of soil moisture measurement. A characteristics of vertisol is that the specific volume ($= 1/P_b$) increases linearly with gravimetric water content m_g and can be express as

$$\frac{1}{P_b} = 1.57 m_g + 0.88 (r^2 = 0.790) \dots (24)$$

III. Result And Discussion

Soil plays pivotal role in agriculture. As a primary motivation to pursue research on the correlation between dielectric properties , physical, chemical properties ; it is essential to determine the quality of agricultural products and food materials so as to meet the consumers' expectations that are growing quickly. The dielectric characterization applications in agriculture have been collected along with their techniques and measurements. Indian agriculture occupies an eminent position in global cultivation of rice, wheat, sugarcane, pulses, and vegetables. There are a lot of parameter to affect agriculture product but physical properties, chemical properties, and electrical properties plays pivotal role. It has been found that dielectric constant of moist sandy soil exponentially increases with percentage water content [8]. Again it has been seen that dielectric constant slowly increases with fertilized soil [9].

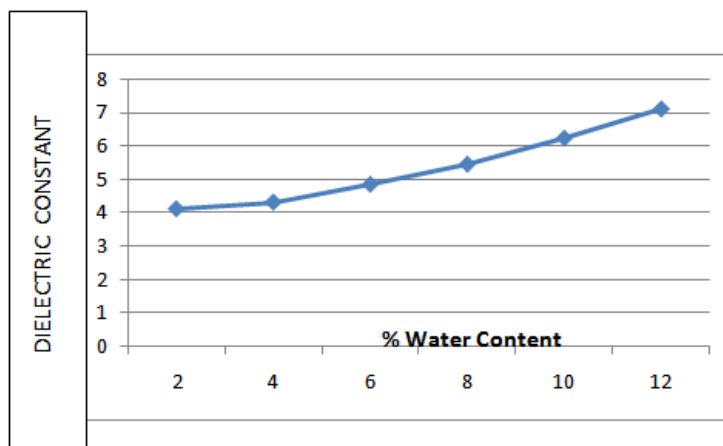


Fig. Variation of dielectric constant with percentage water content for moist sandy soil.

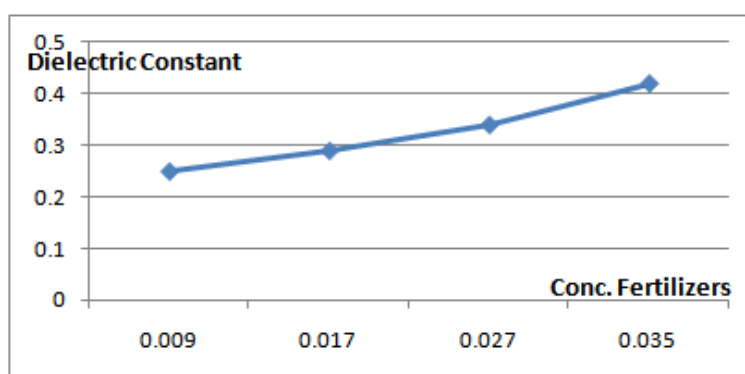


Fig. Variation of dielectric constant with fertilizer content

IV. Conclusions

The dielectric constants are strongly dependent on moisture content. Dielectric constant decreases with increasing percentage of sand. Dielectric constant increases with increasing percentage of silt. Dielectric constant increases slowly with increasing conc. Fertilized soil.

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