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Dielectric Properties of Yavatmal Saline Soil At 5.2 GHz

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ABSTRACT

The dielectric properties, both ε', (real part) and ε'' (imaginary part) of complex dielectric constant are measured for Yavatmal saline soil at 5 GHz. The study also includes measurement of dielectric properties for various percentages of moisture contents, The Shorted waveguide technique is used for dielectric measurements using automated C-Band microwave bench set up. The least square fitting technique is used to calculate dielectric constant, ε', and dielectric loss, ε'', and errors in their measurements. From measured dielectric properties, emissivity and brightness temperature are theoretically calculated at different angles of incidence of moisture-contented soils using Fresnel equations. The laboratory data obtained are useful for the interpretation of data in remote sensing applications, particularly in agriculture.

Keywords **Saline soil, Dielectric properties, 5 GHz microwave frequency, Brightness temperature, Emissivity. Alkalinity; Videography; Remote sensing; Hyperspectral; Microwave; Image classification; Modelling; Monitoring remote sensing, ERDAS, arid region, Landsat satellite .**

INTRODUCTION

Soil salinity caused by natural or human-induced processes is a major environmental hazard. Nearly 22% of all irrigated land is salt-affected, and this proportion tends to increase in spite of considerable efforts dedicated to land reclamation. This requires careful monitoring of the soil salinity status and variation to curb degradation trends, and secure sustainable land use and management. Multitemporal optical and microwave remote sensing can significantly contribute to detecting temporal changes of salt-related surface features. Airborne geophysics and ground-based electromagnetic induction meters, combined with ground data, have shown potential for mapping depth of salinity occurrence. Constraints on the use of remote sensing data for mapping salt-affected areas. Results of various remote sensing image techniques of (TM) data were used to show the spectral classes and the corresponding areas of the different land uses covering the region, and to delineate and map those areas that are salt-affected, and finally to monitor the temporal changes in salinity in terms of its severity and real extent for the period under investigation. Results of the study have indicated that a serious salinity problem exists and it is getting worse. Moreover, it calls for an urgent salinity management program to control the spread of salinity and to reclaim the damaged areas to be used for economic agriculture.

Agriculture productivity is affected badly due to salinity in soil. The agriculture pattern of cash crops is day-by-day becoming popular for obvious reasons. More and more irrigation facilities are used to increase yield of cash crops. However many agriculture land, it is found that excessive of water for cash crop like sugarcane, cotton is resulting into production of water logging areas ultimately causing the increase in salinity of soil. Inappropriate cropping systems, reduction in crop diversity, inadequate post-harvest infrastructure are other major areas of concern. Hence, mapping and monitoring of soil are highly important and usually done by microwave Remote Sensing.

Remote sensing (Eugene A. Sharkov, 2003; Ulaby et al., 1986) usually refers to the technology of acquiring information about the earth's surface (atmosphere, land, vegetation, forest and ocean) using sensors onboard airborne (aircraft, balloons) or space-borne (satellites, space shuttles) platforms. The electromagnetic radiation is used as an information carrier in Remote Sensing. Remote sensing employs passive and/or active sensors. Passive sensors are those, which sense natural radiations, either reflected or emitted from the earth. On the other hand, the sensors, which produce their own electromagnetic radiation, are called active sensors (e.g. LIDAR, RADAR). In passive microwave, remote sensing the radiometer measures the emissivity of soil, whereas in active remote sensing the radar measures the back-scattering coefficient of the soil, both factors depend on dielectric properties of soil. The complex dielectric constant is a measure of the electric properties of the surface. It consists of two parts: the real part, known as the dielectric constant (ε') and is a measure of the ability of a material to be polarized and store energy. The imaginary part (ε'') is a measure of the ability of the material to dissipate stored energy into heat. The two are related by the expression:

$$\varepsilon * = \varepsilon' - j\varepsilon''$$

Where $\varepsilon *$ is complex dielectric constant.

The measurement of these parameters is significant for remote sensing applications.

MATERIAL AND METHOD

The soil sample is collected from location latitude 24^0 38' 41" N longitude 77^0 70' 37" E, Yatmal District Near lake which is in Maharashtra. The pH of the collected soil sample is 9.8 hence it is saline in nature. The saline soil sample dry and different percentage of moisture contain 5% - 30% are prepared. Dielectric measurements of all these samples are done at 5.2 GHz at room temperature.

Experimental set-up

The C-Band microwave bench setup (Von Hipple A.R., 1954) consisting of a low power microwave source VTO, isolator, coaxial-waveguide adapter, attenuator, SS tuner, slotted section and solid dielectric cell. The Block diagram of the setup is shown in figure 1.

Microwave generated by VTO are propagated through passive components of rectangular wavelength to the dielectric cell with perfect reflector at closed end. The source is tuned to give 5.2 GHz frequency by applying tuning voltage of 7 volts. The attenuator is used to keep the desired power in waveguide assembly of the bench. A slotted section with a tunable probe containing 1N23 detector with the square law characteristics has been used to measure power (current) along the slotted line. The detector is connected to a micro ammeter and to the PC to read and record the measured power. The probe sits on slot line such that the tip of the tunable probe is penetrated and it can be moved forwarded and backward along the slot line section. The depth of the tip is adjusted for its critical position to get a symmetrical standing wave pattern. The empty dielectric cell is connected to the other end of the microwave bench. The bench is tuned for symmetrical standing wave pattern in the slot line. The dielectric sample under consideration (soil sample) is inserted in the dielectric cell with a constant compaction. The probe is transverse along the slot line at equal intervals and the probe positions are recorded with corresponding power (current). This data is acquired and store in file using microcontroller interface system. This data makes use of α and β as fitting parameters, where α = attenuation factor, β=phase shift constant.

The data is stored for soil samples of different thickness. The dielectric properties of the solid material can be calculated for best fit of parameters. The guided wavelength, λ_g is measured from the minima of the standing wave pattern

$$\beta = \frac{2\pi}{\lambda_g}$$

The free space wavelength in determined using the relation

$$\frac{1}{\lambda_0^2} = \frac{1}{\lambda_g^2} + \frac{1}{\lambda_c^2}$$

Where$\lambda_c^2 = 2a = 2 * 4.73\ cm = 9.46\ cm$, ‘a’ being the broader side of the C-band rectangular wave-guide.

The real and imaginary parts of the complex dielectric constant are calculated using the relations

$$\varepsilon' = \lambda_0^2 \left(\frac{1}{\lambda_c^2} + \frac{(\alpha^2 - \beta^2)}{4\pi^2} \right)$$

$$\varepsilon'' = \frac{\lambda_0^2 \alpha\beta}{2\pi^2}$$

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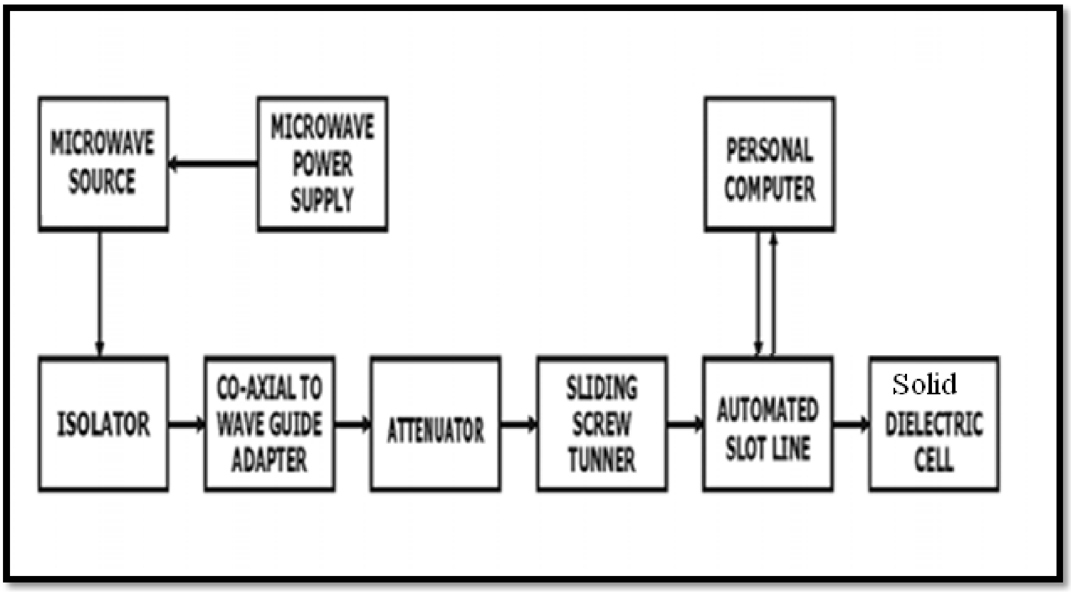
A source code for computing dielectric constant has been developed. The numbers of data files, for different thickness of samples are combined to get single input data, which can be used, in the source code for calculating dielectric constant and loss. Experimentally calculated dielectric constant ε' and loss ε" with error in measurement in both Δε', Δε" are tabulated.

Figure 1 Block diagram of a C-band microwave bench



Brightness temperature and emissivity

Passive microwave remote sensing is based on the measurement of thermal radiation in the centimeter wave band of the electromagnetic spectrum T_b. This radiation is determined largely by the physical temperature and the emissivity of the radiating body and can be approximated by

$$T_{b(p)} \approx e_{s(p)} T$$

Where T_b observed brightness temperature; T physical temperature of the emitting layer;
P refers to vertical or horizontal polarization; es smooth-surface emissivity. This emissivity is further defined as

$$e_{s(p)} = (1 - R_{s(p)})$$

Where Rs is the smooth-surface reflectivity. For a homogeneous soil with a smooth surface, the reflectivity at vertical and horizontal polarizations, RsV and RsH, are given by the Fresnel expressions

$$R_{sV} = \left| \frac{K \ \cos\cos u - \sqrt{K - \sin^2 u}}{K \ \cos\cos u + \sqrt{K - \sin^2 u}} \right|^2$$

$$R_{sH} = \left| \frac{\cos\cos u - \sqrt{K - \sin^2 u}}{\cos\cos u + \sqrt{K - \sin^2 u}} \right|^2$$

Where u is the incidence angles and k is the absolute value of the soil bulk dielectric constant, which is a measure of the response of the soil to an electromagnetic wave and is largely determined by the volumetric soil water content. Emissivity and Brightness temperature for different angle of incidence for 5% saline soil for different percentage of water content is calculated using Fresnel equations.

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RESULT AND CONCULSION

The dielectric properties of dry Yatmal saline soil are studied at 5.2 GHz at room temperature. Table 1 shows details of dielectric constant ε' and loss ε'' and error in measurement in both Δε', Δε''.

Dielectric properties of dryYatmal saline soil are measured as a function of moisture contents shown in table 1. The sample was oven dried and considered at a level of 0% moisture. Then a desired weight of distilled water is added to achieve different moisture content levels. The variations of moisture content up 5% to 30% are studied at 5 GHz. The response to the dielectric constant ε' is sensitive to moisture for saline soil , as soon as 5% moisture is added significant increase in dielectric constant is found, which remain increasing with addition of more moisture content in figure 2.

Higher is the magnitude of humidity, the stronger the effect of salinity on the imaginary part. Since ε'' is proportional to the conductivity, increase in soil moisture content increases conductivity. Thus, behavior of the increase in ε'' with increase in moisture content is seen in table 1. Similar trend is obtained by other workers (Wang. Jet al., 1978, 1980; Y. Lasne et al., 2008).and (Yueru Wu, Weizhen Wang, Shaojie Zhao, and Suhua Liu in *IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING,* VOL. 53, NO. 1)

Figure 4. Plotted for emissivity against the angle of incidence for saline soil sample at 5 %, 15%, 25 %, 30 %, moisture content. Decrease in emissivity values at normal incidence is seen with increase in moisture contain in saline soil. Reductions in emissivity values for horizontal polarization are seen; as angle of incidence increases. The curve for horizontal polarization shows a decrease in emissivity at a slow rate initially up to 20°, and above this angle, the emissivity reduces faster as the angle of incidence increases. The curve for vertical polarization shows a gradual increase in emissivity initially, which becomes faster as the angle of incidence 30°. For moisture content saline soil of 5%, 15 %, 25 %, 30% the emissivity curve changes for vertical polarization at 70°, 73°, 80°, 82°, respectively, instead of increase in the emissivity decreasing trends from these angles are found.

Table 1 Dielectric constant ε’, dielectric loss ε'', error in dielectric constant Δε' and loss Δε'' for different moisture content Yatmal saline soil samples at 5.2 GHz..

Sr No.	Moisture Percentage %	AP(2) Factor	Dielectric Constant ε'	Error In Dielectric constant Δε'	Dielectric loss ε''	Error in Dielectric loss Δε''
1	0	0.108	8.3832	3.3294 E002	1.8958 E002	6.8096 E002
2	5	9.50 E-002	9.2782	5.4843 E002	2.2499 E002	2.3585 E002
3	10	8.70 E-002	11.9628	4.5858 E002	5.7945 E002	5.5232 E002
4	15	7.50E-002	13.7464	2.9577 E002	1.6248 E002	1.8746 E002
5	20	6.70E-002	16.8401	2.2844 E002	2.3789 E002	2.2871 E002
6	25	5.69E-002	19.3618	6.3234 E002	6.2195 E002	5.1574 E002
7	30	5.19E-002	23.6040	4.2601 E002	3.1121 E002	6.97 E002

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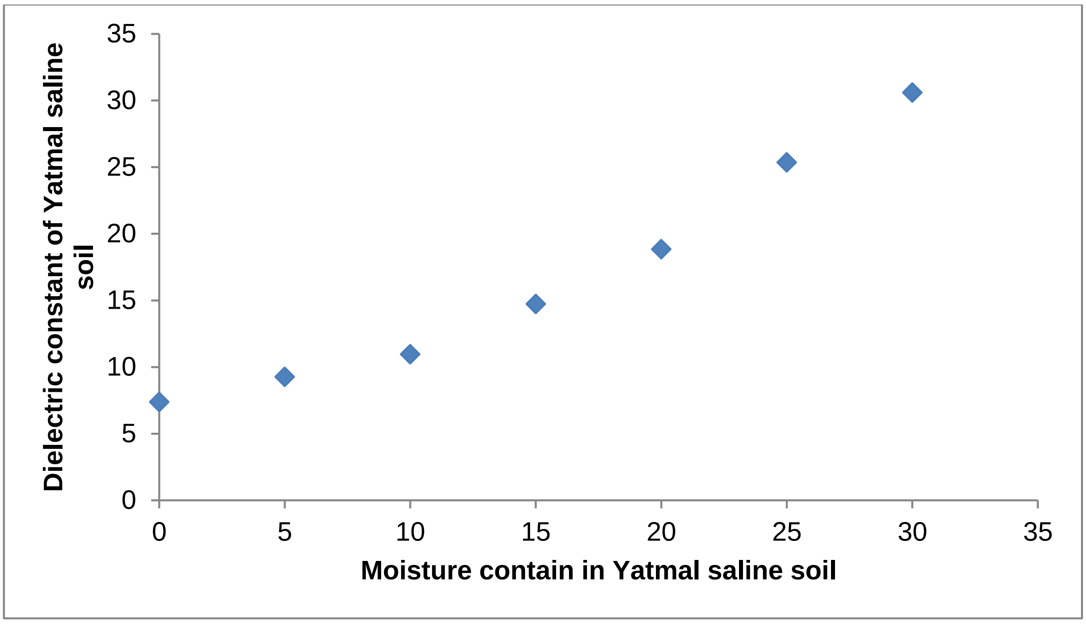

Figure 2 Variations of dielectric constant Versus Moisture% contain of Yavatmal saline soil.

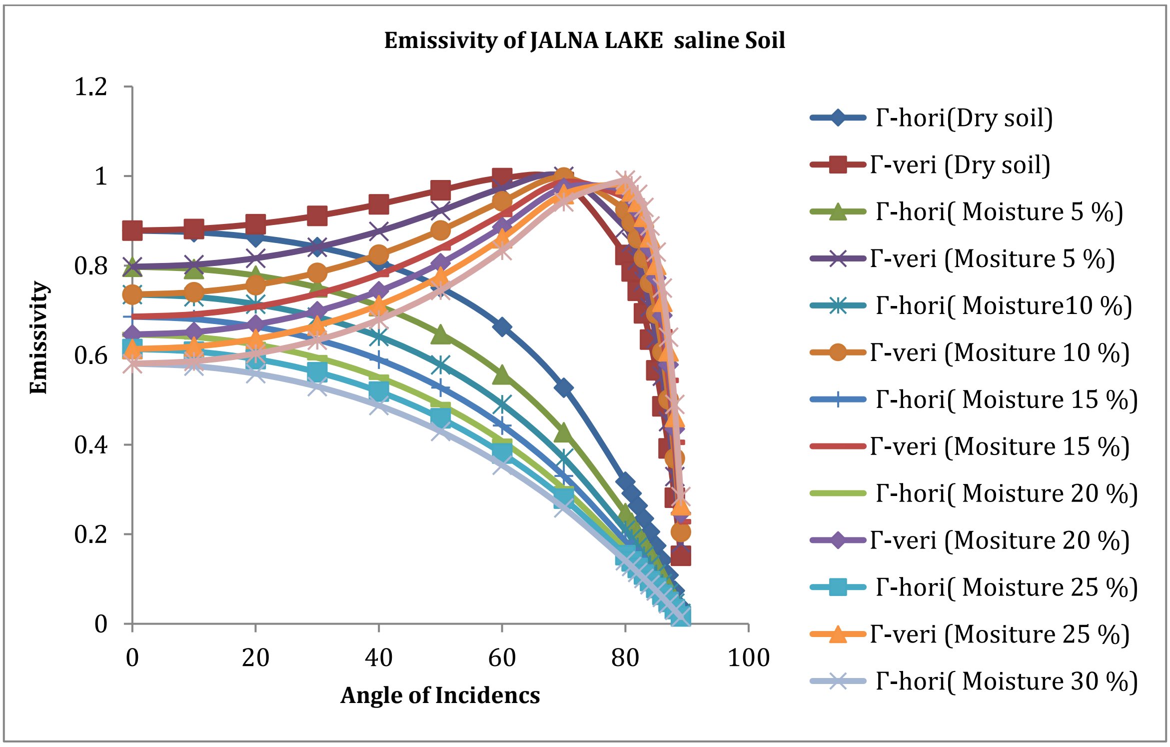

Figure 3 Emissivity Variations Yavatmal of saline soil**.**

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