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The Study of Dielectric and Emissivity Measurement of Alkaline Soil at Microwave Frequency

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Abstract

This work presents an analysis of the dielectric and emissivity characteristics of different soils under different moisture conditions, and its impact on plant-soil interactions and for the monitoring of soils by active and passive microwave fields. Soil samples were collected from Jalna district, Maharashtra, India, and characterized physicochemically (pH, EC, organic carbon, and macronutrients N, P, K) as well as electrically based on complex dielectric permittivity for the microwave frequency range of C-, J-, and X-bands. Measurements were conducted in TE10 mode on a waveguide bench and twopoint method was employed for extracting the real (ε') and the imaginary (ε″) permittivity, and subsequently the emissivities for the horizontal and vertical polarization for incidence angles ranging from 0° to 90° were calculated using Fresnel equations. It was found that ε' decreases with increasing frequency, while ε" is greatly affected by ionic content and moisture. The polarization dependence on emissivity trends was correlated with EC and pH. The results present essential dielectric data for alkalinized soils, which has important implications for better soil moisture estimation, satellite calibration and sustainable land management practice in semi-humid climates.

Keywords: *Dielectric constant, Emissivity, Soil, Microwave frequency, Remote sensing, Alkaline soil*

1. INTRODUCTION

Microwave remote sensing has become a useful technique in the monitoring and assessment of soil properties, particularly in agriculture, hydrology and environmental management. Unlike optical sensors, microwaves can pass through clouds and function in a day or night environment. This allows them to be used for continuous monitoring of soil under changing weather conditions. One of the major soil factors detected by microwave characteristic was dielectric parameter, insulation parameters like dielectric constant (ε′), and the dielectric loss (ε″) which played an important role of the resistance relation in the absorb in electromagnetic wave of different soils. These parameters aid in the understanding of the soil's capacity for storing and dissipating electric energy and are related as strongly to vital soil parameters such as moisture content, texture, temperature and salinity.

Yet another remote sensing parameter is the emissivity, associated with the efficiency of the soil in emitting microwave radiation. The emissivity depends on the dielectric constant of the material and on the angle of incidence of the microwave signal. By quantifying and interpreting emissivity, researchers can make more accurate estimates of surface properties, such as soil moisture and temperature. The knowledge of dielectric characteristics and emissivity is important for the development and calibration of space-borne remote sensing algorithms, particularly for sensors in satellite systems such as Sentinel-1, RISAT, as well as other microwave C-band/X-band missions.

The work here considers the context of alkaline soil, typically with high pH and often with excess sodium that can disrupt soil structure and water flow. Soil samples were taken from various sites in the Jalna district, Maharashtra, and their dielectric responses were studied at three standard microwave frequency ranges: Cband (4.785 GHz), J-band (7.6 GHz) and X-band (9.685 GHz). These frequencies are frequently used in remote sensing as they are useful for building region-specific models for the estimation of soil moisture, salinity, and other parameters. The primary goal of the research is to gain an understanding of how alkaline soils behave in this frequency range and how their dielectric and emissivity responses vary with frequency and angle of incidence.

To have more in depth understanding, this work also investigates the soil physicochemical properties viz., pH, electrical conductivity (EC), organic carbon (OC), nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), sodium (Na), and water holding capacity (WHC). These parameters are factors controlling the dielectric response through an effect on the internal soil composition and moisture storage capacity. With consideration to both dielectric and chemical properties, this paper tries to make useful correlations, which can improve the credibility and accuracy of microwave remote sensing on soil. The results of this study will develop to agricultural planning, irrigation schedule, assessing land degradation, and to create soil-specific microwave sensor calibration models, especially for semi-arid and salt-affected areas.

2. LITERATURE REVIEW

Dielectric behaviour of soil at microwave frequencies has been studied by many investigators to acquire an understanding in its interaction with the electromagnetic waves. These works have mainly considered the range from 1 GHz to 18 GHz reflecting L-, C-, X-, and Ku-bands, which are frequently exploited in satellite remote sensing. For instance, Hallikainen et al. (1985) proposed empirical models of wet soil dielectric properties and indicated that it was highly related to soil water content. V. V. Navarkhele et al. (2009) investigated the dielectric properties of black soil with organic and inorganic matter, showing the effect of composition which changes permittivity values. Also, S. S. Deshpande et al. (2015) demonstrated that the salinity showed minor affects on the real part of the dielectric constant (ε') at 5 GHz, however, it had remarkable affect on the imaginary part (ε''), revealing the higher dielectric loss because of the enhanced ionic conductivity.

The dielectric response of soil is affected by the electrolytes, water, texture, and vegetation. The high moisture of soil and high permittivity of water generally lead to a high dielectric constant. This is expected, since sands which have high PSD are high airfield type materials in which the moistening of the airfield also results in reduced permittivity since the humidity lowers the dielectric for the soil-water mixture. Nigara et al. (2015) demonstrated that at low radar frequencies, ε' was sensitive to water and ε'' was related to both moisture and salt content, and therefore ε'' is also beneficial to the detection of salinity. Vegetation also has a role to play as demonstrated by Ashish Itolikar et al. (2020) which showed that there is an effect of surface vegetation on microwave response especially at C-band. And the dielectric constant is also influenced by others, e.g. bulk density, porosity, and temperature, which make the interpretation of remote sensing signal pretty complicated.

The data of the dielectric is widely used in microwave remote sensing, model development of the retrieval of soil moisture, and the calibration of the sensor. It has been adopted in radiative transfer models, and electromagnetic simulations, to retrieve the land surface emissivity and brightness temperature. These soil moisture values are essential inputs for satellite missions such as SMAP, Sentinel-1, RISAT, and Soilscape that have information on global soil moisture conditions. Precise laboratory-based dielectric measurements can be used to calibrate satellite sensors and to improve retrieval accuracies. Additionally, dielectric response of soil aids in the design of the ground and airborne sensors for precision farming and hydrological monitoring, etc. Research such as that of Dhiware et al. (2015) and Ahire et al. (2013) have stressed the relationship of dielectric properties with physicochemical properties such as EC, OC and nutrient contents, and such relationship improves the applicability of dielectric models in field situations.

3. MATERIALS AND METHODS

3.1 Soil Sampling

For the present study, a total ten soil samples were collected from various agricultural fields in the Jalna district of Marathwada region, India. This area is endowed with semi-arid climatic conditions and is rich in black cotton soils and alkaline soils, which is suitable for investigation of soil dielectric properties under microwave frequencies.

Sample No.	Latitude	Longitude	Location
1	19.85942	75.94166	Sample 1
2	19.86076	75.64817	Sample 2

3	19.85159	75.92953	Sample 3
4	20.01811	76.06977	Sample 4
5	19.71071	75.67152	Sample 5
6	19.63571	75.81709	Sample 6
7	20.06713	75.68800	Sample 7
8	19.89677	76.08076	Sample 8
9	19.94890	75.76224	Sample 9
10	19.68070	75.99276	Sample 10

The soil sample collection was conducted with the common surface sampling technique, considered to be the top 0–15 cm soil profile, which is the most critical profile for agricultural and remote sensing applications. The position of each sampling site was recorded in GPS coordinates to maintain traceability of measurements with spatial location. The soil samples were also packaged and transferred in properly labeled clean containers to laboratory for analysis.

In laboratory, the samples were air dried, manually crushed to prevent large aggregates and sieved through a 2 mm tamis to obtain a homogeneous and fine texture. These prepared samples were further used for physicochemical analysis (pH, EC, nutrient content, etc.) as well as microwave dielectric measurements. The numerous sampling locations throughout Jalna provide for a variety of soil textures and compositions, enabling the characterization of the diversity of dielectric and emissivity properties of various soils in the region.

3.2 Physicochemical Characterization

Soil physicochemical properties play a crucial role in analysing the microwave response of soil because they influence its dielectric properties that in turn are responsible for its dielectric behaviour. The laboratory analysis was carried out in each one of the ten soil samples, at different sites of the district Jalna for soil parameters. These findings facilitate the understanding of the microwave interaction involving soil as to why differences occur at different frequencies.

Important parameters measured include soil pH, which lets you know if the soil is acidic or alkaline, as well as electrical conductivity (EC), which can indicate the salinity of the soil. Soils of high EC generally possess more soluble salts which can disturb the dielectric loss. Organic carbon (OC) was also determined, as it represents the partially decomposed amount of plant and animal material in the soil, and affects soil's fertility and structure.

Besides, the macronutrients nitrogen (N), phosphorus (P), and potassium (K) were detected, which are necessary for plant growth, and can indirectly influence soil moisture and structure. In addition, some essential secondary and micronutrients, calcium (Ca), magnesium (Mg), sodium (Na), sulphur (S), iron (Fe), zinc (Zn), copper (Cu), and boron (B) , were also analysed. These factors have a strong impact on soil’s chemical equilibrium and ionic composition that in turn alters the electromagnetic behaviour of soil.

Other physical properties evaluated were water-holding capacity (WHC), which shows how much water the soil can hold, bulk density (AD), and particle density (SD), which are associated with soil compaction. Porosity (PS), void ration (VEP) was determined to study the air and water spaces within soil. These physical parameters are significant as they affect the motion and retention of the water, which is responsible of the dielectric behaviour at the microwave regime.

The Harvesto Soil Testing Kit was used to measure all these parameters; it is a digital measuring instrument commonly used for rapid and precise soil analysis. This portable system provides results for key nutrients and soil parameters based on dry part sample analysis with chemical laboratory reagents and sensors. The soil samples were dried, crushed and sieve to obtain a uniform results. The findings of the detailed analysis are listed in Table 1 and applied to interpret the dielectric constant and the emissivity values observed at X-, J-, C-band frequencies.

This overall analysis of the soil properties enables us to relate the physical and chemical characteristics of the soil to its microwave dielectric response. Such relationships are of importance for satellite-based monitoring of soil and designing advanced remote sensing models for agricultural studies.

3.3 Microwave Dielectric Measurements

For studying the dielectric response of the soil at microwave frequencies, measurements were performed with use of microwave bench setup in the TE_{10} mode. This, standard laboratory technique is used to study the interaction of microwave signals with solid materials (such as soil), Proposed instrumentation consists of a rectangular wave-guide able to propagate the microwave energy, with elements to generate and detect microwave signals.

Using a single mode horn antenna in conjunction with either a Gunn oscillator or a Reflex Klystron, the microwave source was chosen depending on the frequency band needed. These emitters provide a stable and adjustable microwave signal. Dielectric measurements were acquired at three frequency ranges: X-band (9.685 GHz), J-band (7.6 GHz), and C-band (4.785 GHz), typically used for remote sensing.

The dielectric measurements were performed by two-point technique. A short circuited waveguide cell is employed in this technique, and the Voltage Standing Wave Ratio (VSWR) is measured with and without the soil sample loaded. When a microwave signal is transmitted along the waveguide, some portion of the wave is reflected back due to impedance mismatch and produces standing waves. This change in minima in this pattern is due to presence of the soil sample. The dielectric property of the sample can be determined through analyzing the change.

Based on the two-point method analysis, the real part of dielectric constant (ε') and the imaginary part dielectric loss (ε'') were obtained. Where the dissipation tangent ($\tan\delta$) was also calculated from the ratio of ε'' to ε'. This figure provides an indication of the amount of energy the soil loses as heat when the microwave is applied. A larger $\tan\delta$ value represents stronger energy loss, which commonly is related with more moisture or salt.

These are dielectric parameters (ε', ε'' and $\tan\delta$) which give important information for the soil's electromagnetic behaviour. These values at different frequencies are useful to investigate the influence of soil properties such as texture, moisture and salinity on microwave interaction. The data are subsequently employed to compute emissivity, and thus facilitate the interpretation of remote sensing data for agriculture and environment.

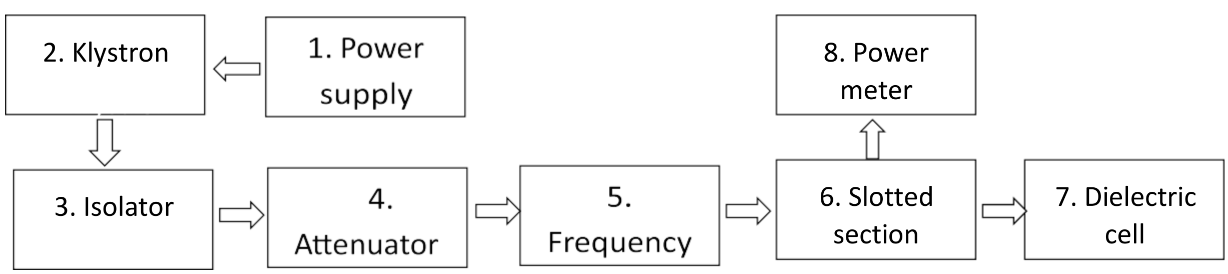


Fig. 1. Block diag. of microwave bench set-up 3.4

Emissivity Estimation

In microwave remote sensing, The microwave emissivity (e) of a surface, such as soil, is a measure of the ability of that surface to radiate microwave energy. It is an important para meter in interpretation of therm al and radiometric measurements. The emissivity is dominated by the complex dielectric constant of the material and angle of incidence and polarization of the impinging wave. We estimated the emissivities of soil samples in this study from the dielectric values (ε' and ε'') derived from the microwave measurement and using the Fresnel reflection equations.

To estimate emissivity, the reflection coefficient (R) is calculated as the first step, which corresponds to the proportion of the incident wave reflected at the soil surface. The remaining part is for emission and transmission. The reflection coefficient is different for the horizontal ($R(\theta,\ H)$) and vertical ($R(\theta,\ V)$) polarizations.

Fresnel Reflection Coefficients: Let θ be the angle of incidence and ε=ε′−jε″ be the complex relative permittivity of the soil. Then, the reflection coefficients for horizontal ($R(\theta,\ H)$) and vertical ($R(\theta,\ V)$) polarizations are given as:

$$R(\theta, H) = \left[\frac{\cos\ \theta - (\epsilon - \sin^2\ \theta)^{1/2}}{\cos\ \theta + (\epsilon - \sin^2\ \theta)^{1/2}}\right]$$

$$R(\theta, V) = \left[\frac{\epsilon \cos\theta - (\epsilon - \sin^2\theta)^{\frac{1}{2}}}{\epsilon \cos\theta + (\epsilon - \sin^2\theta)^{\frac{1}{2}}}\right]$$

Here, the square root is evaluated as a complex quantity due to the presence of ε″. Emissivity Calculation

Once the reflectivity coefficients are determined, the emissivity ($e(\theta, p)$) for both polarizations can be calculated using:

$$e(\theta, p) = [1 - r(\theta, p)]$$

Where $r(\theta,\ p)$ is the reflectivity coefficient, or the square of the magnitude of the Fresnel Reflection Coefficients

Emissivity depends on the angle of incidence. In horizontal polarization, emissivity decreases with the increasing angle and in vertical polarizations, it increases initially and then decreases beyond a critical angle. This tendency is strongly associated with the alignment of the electric field vectors in relation to the surface of the soil, and that is how much reflection and absorption will occur.

In the present work, emissivity was calculated at different incidence angles for each soil sample from its corresponding dielectric constant at several frequencies (X, J and C-bands). The dependencies are also welldemonstrated in the curves for horizontal and vertical polarizations (Figs. 1–10). This work is essential for advancing microwave remote sensing models, particularly for the retrieval of soil moisture, salinity, and roughness from satellite observations.

Based on accurate estimation of emissivity by dielectric measurements and Fresnel equations, this study provides support to improve the reliability of radiative transfer models and to optimize the design, calibration and inversion of remote sensing instruments for environmental monitoring and agriculture.

4. RESULTS AND DISCUSSION

4.1 Dielectric Constant (ε′) and Loss (ε″)

The frequency-dependent nature of the treated alkaline soil was investigated by the measurement of the dielectric constant (ε′) and the dielectric loss (ε″) at three microwave frequencies: X-band (9.685 GHz), J-band (7.6 GHz), and C-band (4.785 GHz). These are important to identify the interaction of soil with the microwave and useful in remote sensing and agricultural monitoring.

The real (ε′) and imaginary (ε″) parts of the complex permittivity correspond to the soil's ability of electric energy storage and the energy dissipation caused by the conductivity loss and other dissipative drafts, respectively. Both these elements were found to be highly frequency dependent. In most cases, ε′ was also maximum at C-band and then decreased at J-band and X-band. This tendency indicates a low to high frequency dielectric constant decline, approaching the dry soil dielectric constant, with most of the moist or ion-abundant soils, where the dielectric polarization mechanisms are less effective at higher frequencies. In contrast, the dielectric loss (ε″) across frequencies and samples was more variable. Some of the samples showed an increase of ε″ with frequency while for the others it decreased, depending on the physico-chemical composition, and in particular, on the moisture and salt content. Soil with higher salinity or ionic content

tends to exhibit higher dielectric loss especially at low frequencies where prevalence of conductivity is apparent.
These frequency-dependent response are summarized in Table 2, using the measured values of ε′ and ε″, respectively, of the ten soil samples at X-, J- and C-bands. It can be noted from the table that the dielectric properties are varying from sample to sample and from frequency to frequency which indicates that the composition of the soil has a great bearing in determining the dielectric response with frequency.
The understanding of these trends is useful for developing frequency-dependent remote sensing applications. As an instance, soils with higher dielectric constants at lower frequencies favour retrieval of soil moisture in case of C-band radar whereas in the case of X-band, greater impact is on surface roughness and vegetation. These ground-truth results are valuable for constructing and calibrating models for microwave remote sensing of soil properties in semi-arid and in salt-affected regions.

Table 2: Measured real (ε′) and imaginary (ε″) parts of the complex dielectric constant for ten soil samples at X-band (9.685 GHz), J-band (7.6 GHz), and C-band (4.785 GHz) microwave frequencies.

sample no.	ε' on X band	ε' on J band	ε' on C band	ε" on X Band	ε" on J Band	ε" on C Band
1	2.864982	3.04164	5.029963	-0.2437	0.600407	0.16777
2	2.986907	3.234043	4.034575	-0.0914	0.446	2.03676
3	3.592028	3.597823	5.116615	-0.0602	0.192767	0.58635
4	3.1978	3.508843	3.65254	1.27572	0.279353	0.23013
5	3.505601	3.508843	3.48668	-0.0292	0.279353	0.44649
6	3.447888	3.812823	4.178555	-0.0698	0.23442	0.42245
7	3.318476	3.88797	4.480877	-0.1203	0.70501	0.859013
8	3.501706	4.043127	4.177585	-0.0338	0.23636	0.422735
9	3.509055	3.509187	4.597693	-0.0267	0.343005	0.716097
10	3.280762	3.435097	4.674025	-0.0274	0.22647	0.52502

4.2 Emissivity Trends

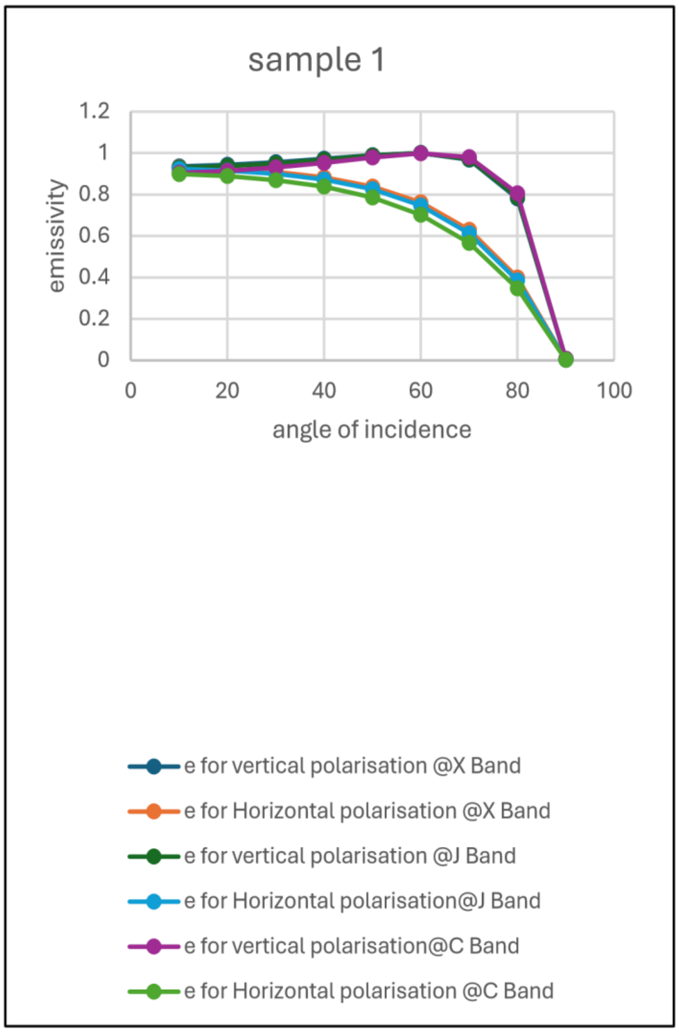
The emissivity of the ten soil samples was characterized in three microwave bands: X-, J-, and C-bands as a function of the incidence angle and polarization. Emissivity Based on the Fresnel formulation, for the HH and VV polarizations, emissivity of the samples was computed and the profiles are plotted in Figures 1-10. These results obviously show the effects of polarization and angle on the emissivity behavior for different soil types.
For all the samples, it is a general trend that the emissivity with H polarized wave decreases monotonically as the angle of incidence increases. On the other hand, ere the amount of vertical polarization emissivity increases, there is a gradual rise, and it then reaches a peak at 60°–70° and decreases drastically. This is observed for all ten figures, meaning that this angular dependence is observed regardless of soil material. The

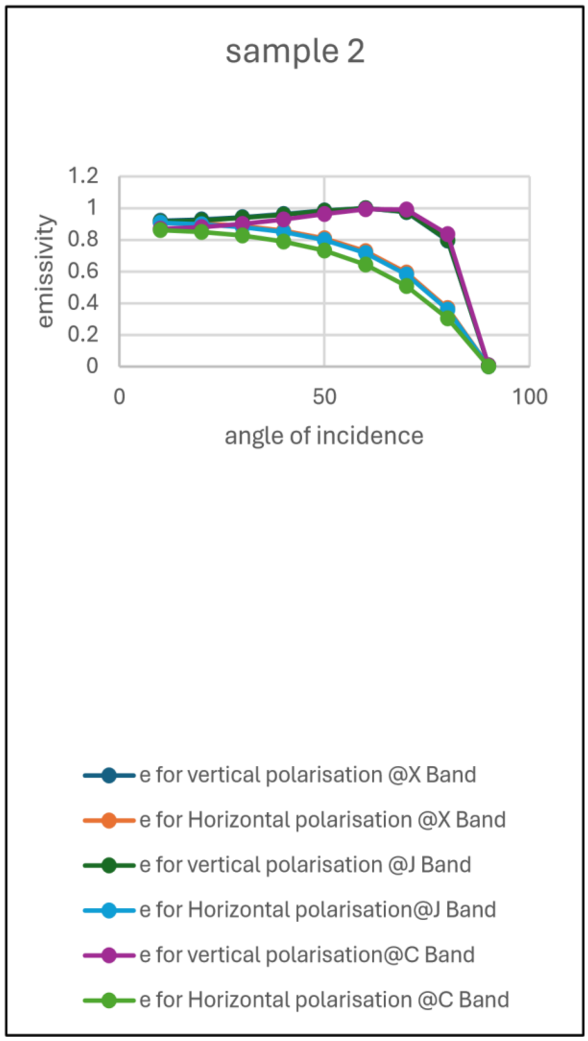
difference between HH and VV polarization could be due to the position of the electric field with respect to the soil surface so that microwave energy are reflected and dielectric loss differently.

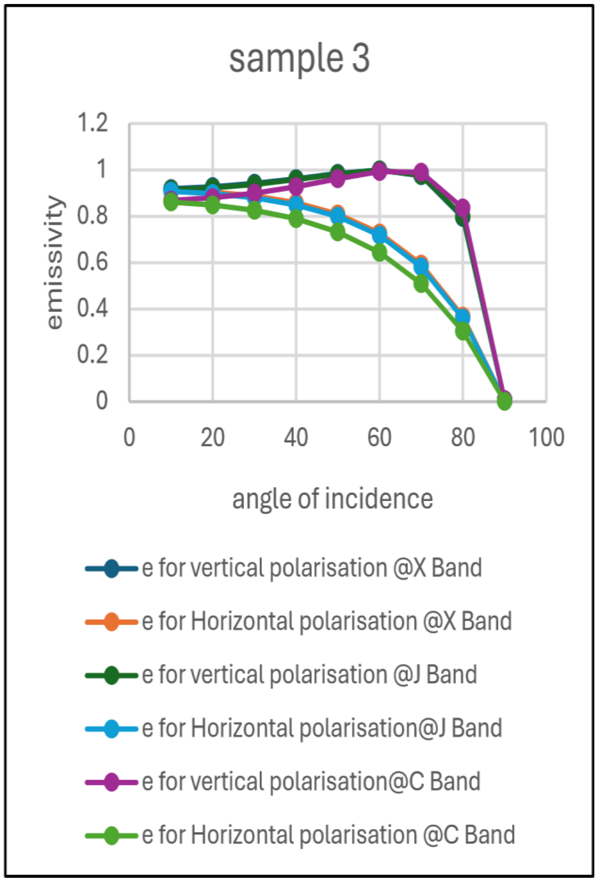
For the sample 1, shown in Figure 1, the corresponding vertical polarization has an emissivity curve profile with large values and keeps them for angles up to 60°, and then it decreases abruptly. The horizontal curve falls more evenly throughout the entire angular spectrum. This tendency is also observed in Figures 3 and 5, where the vertical single emissivity mainly provides higher and more stable emissivity than those on horizontal direction. Those examples demonstrate common aspects of behaviour of soils with moderate dielectric loss, for which the vertical polarization is preferable in the analysis of soil microwave emission.

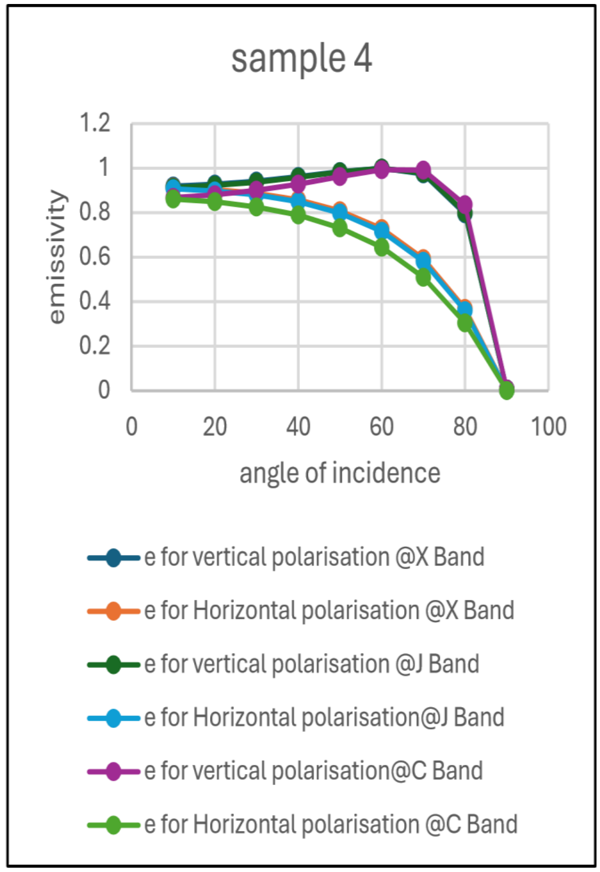
In contrast, Figs.2 and 7 present an opposite trend. In both cases, the vertical polarization is still exhibiting the characteristic oscillation, but the emissivity magnitudes decrease in comparison to the simulations, for all angles, and particularly for horizontal polarization. These trends speak to the higher dielectric losses of these soils, which result in better microwave absorption and lower emissivity overall. The steeper decay of HH emissivity at larger angles may indicate enhanced attenuation and reflection at these samples.

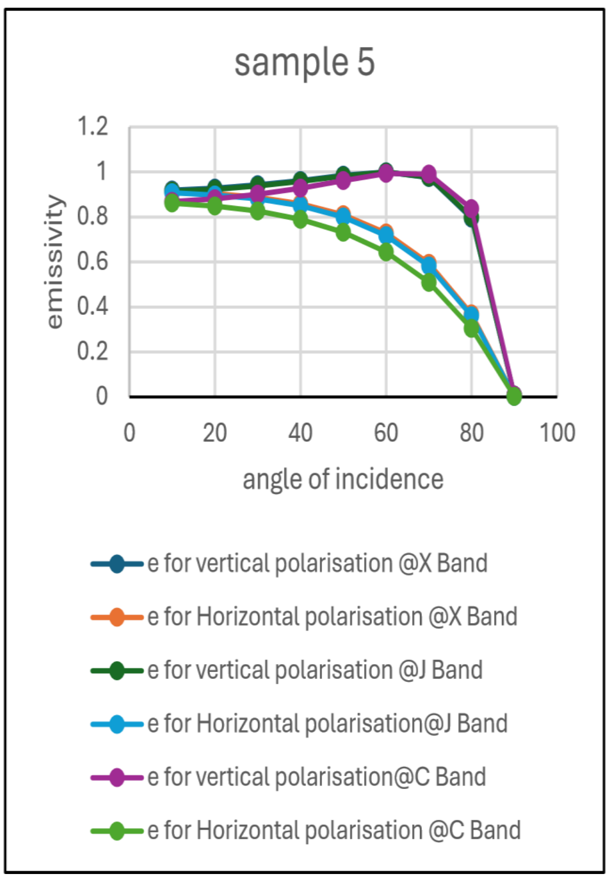
The emissivity plots in Figures 1 to 10 show that, in general, the vertical polarization provides stable and higher emissivity responses than the horizontal polarization. The preferred incident angles for remote sensing use are from 30° to 60°, where emissivity is higher and less sensitive. These angular and polarizationdependent behaviors are important for the designs of microwave radiometric sensors, for the optimization of satellite soil-moisture retrieval algorithms, and for interpreting remotely sensed soil data over semi-arid and alkaline soils.

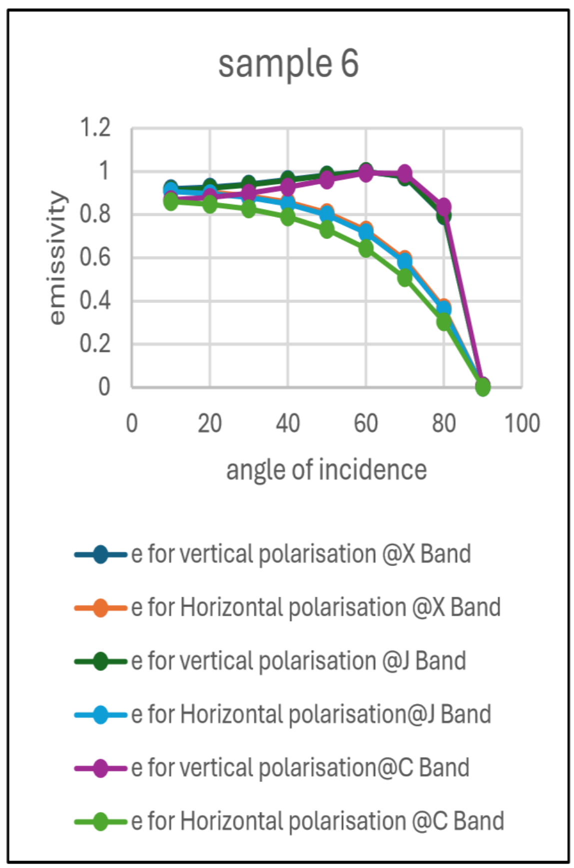


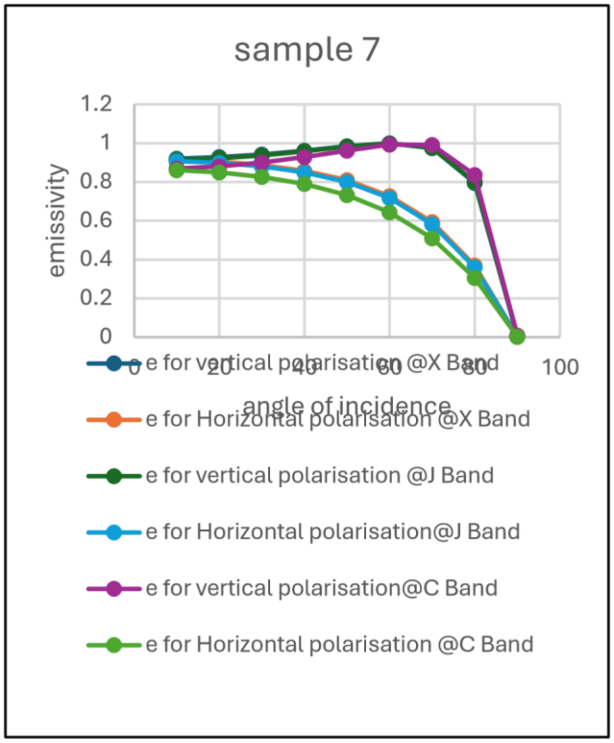


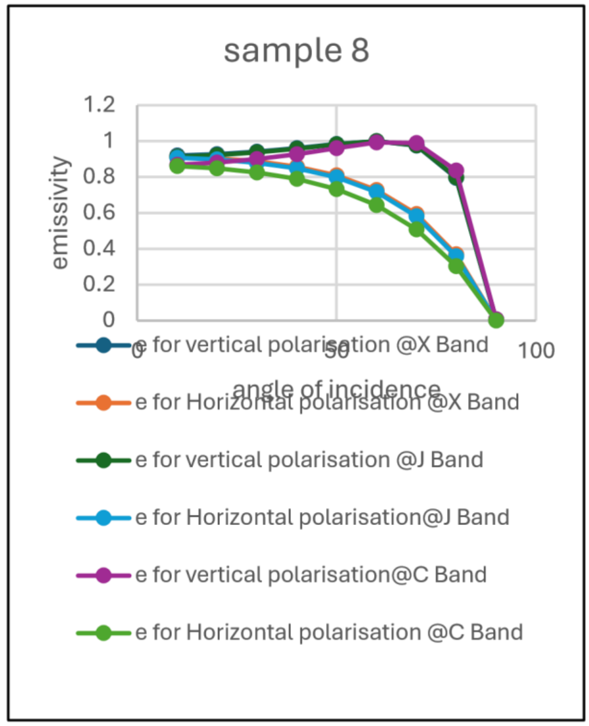

sample 3
emissivity
angle of incidence
e for vertical polarisation @X Band
e for Horizontal polarisation @X Band
e for vertical polarisation @J Band
e for Horizontal polarisation@J Band
e for vertical polarisation@C Band
e for Horizontal polarisation @C Band

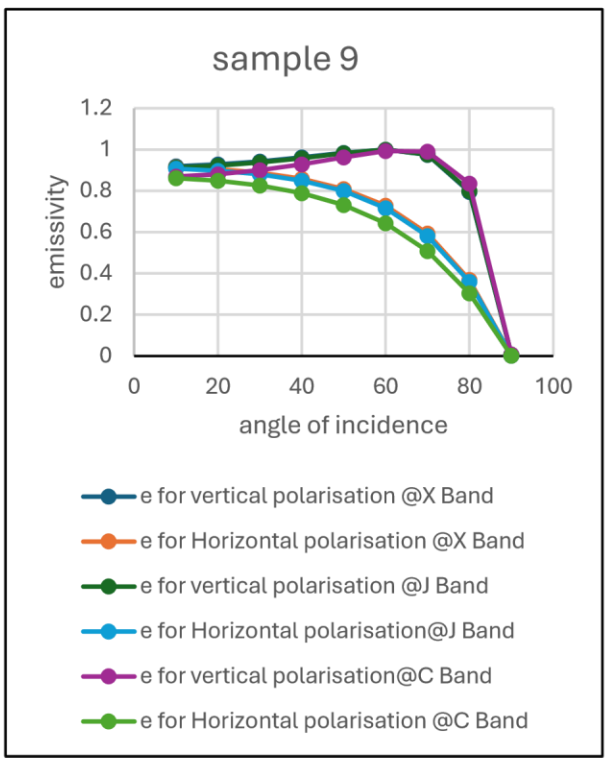

sample 4
emissivity
angle of incidence
e for vertical polarisation @X Band
e for Horizontal polarisation @X Band
e for vertical polarisation @J Band
e for Horizontal polarisation@J Band
e for vertical polarisation@C Band
e for Horizontal polarisation @C Band

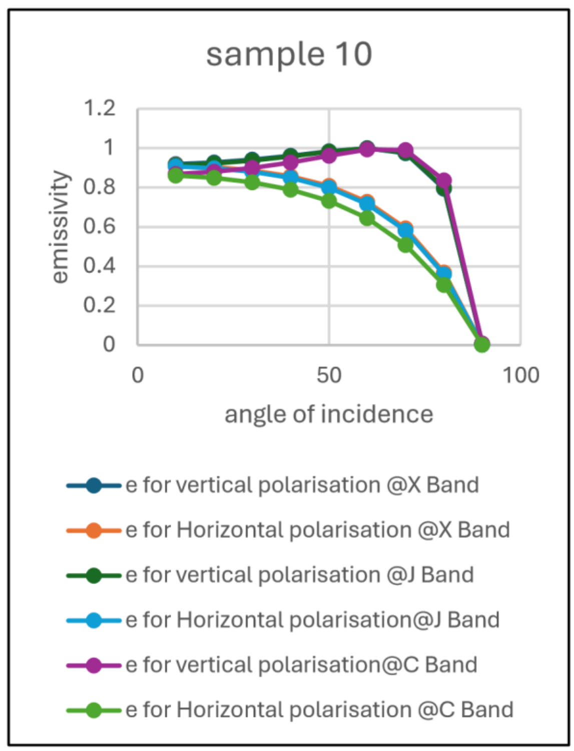

sample 5
emissivity
angle of incidence
e for vertical polarisation @X Band
e for Horizontal polarisation @X Band
e for vertical polarisation @J Band
e for Horizontal polarisation@J Band
e for vertical polarisation@C Band
e for Horizontal polarisation @C Band


sample 6
emissivity
angle of incidence
e for vertical polarisation @X Band
e for Horizontal polarisation @X Band
e for vertical polarisation @J Band
e for Horizontal polarisation@J Band
e for vertical polarisation@C Band
e for Horizontal polarisation @C Band









Figures 1–10: Emissivity variation with angle of incidence (0° to 90°) for ten soil samples at X-, J-, and C-band microwave frequencies under horizontal (HH) and vertical (VV) polarizations.

4.3 Effect of Physicochemical Parameters

The dielectric response of soil, indicated by the real part (ε′) and imaginary part (ε″) of complex permittivity, to a lesser extent of varying magnitude, strongly depends on their physicochemical properties, such as pH, electrical conductivity (EC) and nutrient (N, P, K) content. These factors in turn affect the capacity of the soil to absorb and release electromagnetic energy therefore influencing its interaction with microwave signals at X-, J- and C-bands.

The chemical reactivity and the concentration of ions in the soil solution as available for plants are largely determined by soil pH. Alkaline soils (pH > 7.5), including the ones studied in the present work, are characteristic of the dispersion of clay particles and sodium prevailing cation. This influences ε′ and ε″ by increasing the bound water amount and the ion mobility, and, therefore, the dielectric response of the soil, especially at lower frequencies. A trend of higher ε′ in some of the samples with higher pH may be related to the larger polarization capacities of these soils under an external field.

Soluble salt concentration represented by electrical conductivity (EC) has a direct effect on dielectric loss of ε″. Higher EC of the soils facilitate more ionic conduction leading to higher dielectric losses associated with energy dissipation. For example, the samples with higher EC values tended to show increased ε″ values at the C-band and J-band frequencies. This is due to enhanced microwave absorption by free ions, which leads to more energy loss that is most obvious at horizontal polarization and oblique incidence.

The dielectric behavior is also indirectly influenced by the presence of macro nutrients-nitrogen (N), phosphorous (P), potassium (K). Nitrogen and potassium, frequently found in the form of ions, can contribute to dielectric loss, especially at high levels and under moist conditions. Phosphorus, which is usually lowly mobile, can affect ε′ through its interaction with clay-bound complexes that change the soil matrix and also its actual dielectric storage capacity

Overall the results indicate a positive relationship between both EC and ε″ and a moderate relationship between pH and ε′. Although NPK plays some role and explains some of the dielectric properties variance, its effect is relatively smaller when compared to the salinity and pH factors. These associations demonstrate the intricate relationship between soil chemistry and microwave dielectric properties, and support the integration of physicochemical soil characterization in the modeling and interpretation of remote sensing data.

The correlations would also lead to a deeper understanding of the relationship between electromagnetic properties and the nutrient and salinity-alkalinity composition of the soil. This is particularly important to improve the accuracy of soil moisture retrieval models based on remote sensing and to develop soil specific dielectric libraries used for agricultural and environmental planning.

5. CONCLUSION

In the present study, the alkaline soil samples of Jalna district were analyzed for its dielectric and emissivity response by measuring its microwave characteristics at X- band (9.685 GHz), J- band (7.6 GHz) and C-band (4.785 GHz). The experimental results showed a distinct frequency-dependent response, ε´ tended to decrease with the increase in frequency, which are consistent with theory as well. This reduction indicates that the response of soil dipoles via 1/f noise induced by the antenna is intrinsically bounded with the time derivative at higher frequencies.

In the case of emissivity, dependence on both polarization and angle of incidence was highly appreciable. For all of the samples, vertical polarization possessed a higher and steadier emissivity over mid-range angles (30°–60°), and the emissivity in the horizontal polarization kept decreasing when the deflection angle was increasing. This disparity in response due to polarization emphasizes the general importance of polarization for remote sensing and demonstrates its potential in the retrieval of soil moisture using the vertical polarization.

The results have practical implications. First, the multi-frequency dielectric property characterization can be used to provide key input for the design and calibration of microwave remote sensing sensors, particularly for those in soil moisture retrieval and surface emissivity modeling applications. Second, optimal polarization and angles of incidence bands are mapped for the purpose of increasing the precision in radiative transfer models and also as a way for improving the soil-specific retrieval algorithms applied in satellites like Sentinel1 and SMAP

The broader applicability of the dielectric characterisation in agriculture and remote sensing is stressed within this study. Comprehending the relationship between soil physicochemical properties and ε′, ε″ and emissivity, will help in the accuracy in monitoring soil health, moisture dynamics and salinity- two of the major constituents of sustainable land and water resource management in semi-arid and salt affected areas.

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