Study of Effect of Potassium Nitrate and Ammonium Sulphate on Dielectric Properties of Soil at X and J-Band Microwave Frequencies

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Abstract: Microwave has prominent role in the present era due to its application in remote sensing. Present investigation is emphasized to explore the impact of potassium nitrate and ammonium sulphate on dielectric traits of soil samples by exposing it to X and J-band microwave frequencies. For this two different soil samples were collected from Jalna and badnapur of Maharashtra. The infinite sample method was employed for the determination of dielectric constant ($\varepsilon'$), dielectric loss ($\varepsilon''$), AC Conductivity and Relaxation Time of the soils. The variation in values of all the parameters of these samples mixed with different concentration of potassium nitrate and ammonium sulphate were then measured at fixed frequency X-band (6 GHz) and J-band (9.86 GHz).

1. Introduction:
For successful interpretation of various remote sensing data it is important to study the dielectric properties of different earth constituent at microwave frequency Microwave electrical properties of material provide information about material characteristics. The natural nutrients found in the soil essential to plant growth, such as nitrogen, phosphorus and potassium, are manufactured synthetically from inorganic material and applied to soil in the form of chemical fertilizers. Although chemical fertilizers improve the growth of plants and increase the yields of fruits and vegetables in a relatively short period of time [1].

The dielectric constant of Indian soils is found to be associated with bulk density of soil and hence on porosity and wilting point of soil P. R. Chaudhari [2]. The speed and height of water movement through capillary action in the soil influenced by the particle size of different soil textures. In general, the capillary water in loamy soil rises relatively quicker and to a greater height compared to clay and sandy soils S. Gharechelou [3]. Soil texture describes the size of the soil particles A. Pandey, [4]. Dielectric properties of soil also influence by Moisture H. C. Chaudhari [5] R. Rajesh Mohan,[6] V. N. Patel,[7] . The dielectric properties of black and red soil exclusively investigated by H.C Chaudhri [8] and revealed that the dielectric properties of soil can be tailored by changing the moisture, temperature, density as well as other physical and chemical properties. At the same time the existence of bound water in soil water mixture significantly affects the electrical properties of soil. It is observed
by Sengwa [9] that the values of $\varepsilon'$ decreases with increase in frequency in low frequency region. Exceedingly high $\varepsilon'$ values were found for clay, siliceous earth and, fuller’s earth at lower frequencies in the 100 Hz to 100 kHz frequency range. Recent reports by Chaudhri and Shinde [10] have explored that the dielectric properties of dry soil at microwave frequency in X-band are function of its chemical constituents and physical traits. A study by Calla [11] have shown that the variability of dielectric constant of dry soil with its physical constituents at different microwave frequencies. To keep the soil productive, it is necessary to replace these nutrients artificially [12][13] The selection of frequency 6 GHz and 9.8 GHz is because of its application to observe the variation in electrical properties and also its application in remote sensing. The selection of potassium nitrate for this work is because the usefulness of potassium nitrate as a reference substance for its suitability like sensitivity, robustness and practicability is proven by [14]. Nitrogen and potassium are important essential macronutrients which play important role in growth and development of vegetable [15].

2. Sample preparation

For preparation of soil samples two samples having black colour and of wide marginal textural difference were collected from Maharashtra. Soils were first sieved by standard sieve and then oven dried to a temperature around 180°C for half hour in order to completely remove any trace of moisture. The soil samples were then prepared by mixing different concentrations of potassium nitrate and ammonium sulphate in 4% distilled water and this mixture is then added to soil. These mixtures were kept in air tight sealing bags and allowed for few hours to facilitate internal drainage. These soil samples were then inserted into the solid dielectric cell for measuring their dielectric properties. Extreme care was taken to expose them to the atmospheric air as little as possible. The concentrations of KNO$_3$ and NH$_4$SO$_4$ were varied over a range from 0 to 12%. Physical and chemical analysis have been done in government agriculture office shahnoorwadi Aurangabad and institute of science Aurangabad

3. Method of measurement of dielectric properties

The infinite sample method was employed to determine the dielectric properties of the fertilized soil samples. An X-band and J-band microwave set-up in the TE$_{10}$ mode with klystron source operating at frequency 9.8 GHz (X-band) and 6 GHz (J-band) respectively. Experiments were performed at room temperatures ranged between 30°C to 35°C. 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 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 were then used in determining the values of shift in minima resulted due to before and after inserting the sample. The dielectric constant $\varepsilon'$, dielectric loss $\varepsilon''$, AC Conductivity and Relaxation Time of the fertilized soil samples were then determined [1]. The soil sample of known volume was placed in sample holder which is on the opposite end of the microwave source. The microwave power was recorded for different slot position of microwave bench. About 95 points were recored for each concentration of KNO$_3$ and NH$_4$SO$_4$. 

Fig 1 Photograph of J-band microwave bench setup for measurement of dielectric constant of Soil
Fig 2 Block diagram of Experimental set up

Table 1 variation of dielectric properties of soil at x and J-band for soil sample 1 for different concentration of KNO3

| KNO3 % | 9.8 GHz | 6 GHz |
|--------|---------|-------|
|        | ε'      | ε''   | ε'    | ε''   |
| 0      | 1.8161  | 0.072 | 2.2261| 1.9432|
| 3      | 2.0352  | 0.0929| 2.2619| 2.1104|
| 6      | 2.0761  | 0.098 | 2.2786| 2.1995|
| 9      | 2.1198  | 0.0973| 2.2944| 2.2924|
| 12     | 2.1642  | 0.1025| 2.4639| 2.354 |

Table 2 variation of dielectric properties of soil at x and J-band for soil sample 2 for different concentration of KNO3

| KNO3 % | 9.8 GHz | 6 GHz |
|--------|---------|-------|
|        | ε'      | ε''   | ε'    | ε''   |
| 0      | 2.1787  | 0.1786| 3.389 | 0.065 |
| 3      | 2.3925  | 0.2246| 4.019 | 0.066 |
| 6      | 2.5119  | 0.2322| 4.162 | 0.066 |
| 9      | 2.5729  | 0.2454| 4.275 | 0.07  |
| 12     | 2.6366  | 0.2594| 4.434 | 0.067 |

Table 3 variation of dielectric properties of soil at x and J-band for soil sample 1 for different concentration of NH₄SO₄
| NH$_4$SO$_4$ % | 9.8 GHz $\varepsilon'$ | 9.8 GHz $\varepsilon''$ | 6 GHz $\varepsilon'$ | 6 GHz $\varepsilon''$ |
|-------------|-----------------|-----------------|-----------------|-----------------|
| 0           | 1.8161          | 0.072           | 2.2261          | 1.9432          |
| 3           | 1.9976          | 0.077           | 2.261           | 2.110           |
| 6           | 2.0761          | 0.098           | 2.334           | 2.185           |
| 9           | 2.1642          | 0.102           | 2.412           | 2.2637          |
| 12          | 2.2586          | 0.114           | 2.463           | 2.354           |

Table 4 variation of dielectric properties of soil at x and J-band for soil sample 2 for different concentration of NH$_4$SO$_4$

| NH$_3$SO$_4$ % | 9.8 GHz $\varepsilon'$ | 9.8 GHz $\varepsilon''$ | 6 GHz $\varepsilon'$ | 6 GHz $\varepsilon''$ |
|-------------|-----------------|-----------------|-----------------|-----------------|
| 0           | 2.1787          | 0.1786          | 3.389           | 0.065           |
| 3           | 2.392           | 0.224           | 4.03            | 0.066           |
| 6           | 2.450           | 0.228           | 4.175           | 0.067           |
| 9           | 2.509           | 0.241           | 4.327           | 0.068           |
| 12          | 2.569           | 0.255           | 4.476           | 0.068           |

Fig 3: Graph of E.C and Relaxation time with Concentration of KNO$_3$ in soil samples 1 on X and J-band
Table 5: Physical and chemical properties of sample 1 and 2

| Soil composition              | Percentage for sample 1 | Percentage for sample 2 |
|-------------------------------|-------------------------|-------------------------|
| Sand                          | 98.175                  | 83.45                   |
| Slit                          | 0.585                   | 6.54                    |
| clay                          | 0.7                     | 10.01                   |
| Water holding capacity(WHC)   | 35                      | 22                      |
| Bulk density                  | 1.157                   | 1.741                   |
| Volumetric water content(VWC) | 27.28                   | 4.55                    |
| Gravimetric water content(GWC)| 17.37                   | 1.833                   |
| Organic carbon (OC)           | 0.33                    | 0.32                    |
| Copper (ppm)                  | 2.96                    | 3.40                    |
| Iron (ppm)                    | 1.86                    | 2.16                    |
| Manganese(ppm)                | 3.14                    | 0.84                    |
| Zinc (ppm)                    | 0.30                    | 1.56                    |
| Phosphorous (kg/ha)           | 21.53                   | 19.35                   |

Fig 4: Graph of E.C and Relaxation time of soil samples 2 with Increasing concentration of KNO₃ on X and J-band
5. Result and discussion:

The physico-chemical analysis report of soil samples is presented in table 3. The experimental observations of the soil with increasing percentage of ammonium sulphate and potassium nitrate are presented in two different frequencies (9.8 GHz and 6 GHz) in table 1, 2, 3 and 4. It was that dielectric constant and dielectric loss decreases as frequency goes on increasing. Polarization of molecule decreases as frequency increases due to lesser rotating time. It was also observed that as we increase the concentration of NH4SO4 KNO3 the dielectric properties increases slowly. The dielectric constant increases slightly greater in case of NH4SO4 as compare to KNO3. The reason may be KNO3 decomposes very slowly as compare to NH4SO4. It is interesting to note that because of higher conductivity sample 2 exhibit a moderate rise in the dielectric loss at lower frequency as compare to sample 1 which show more variation in dielectric loss ion both frequencies. The AC conductivity of both samples was influenced by operating frequency. When ammonium sulphate added to sample 1 the AC conductivity was calculated 0.785 mS/cm⁻¹ (6 GHz) and 6.21 mS/cm⁻¹ (9.86 GHz) and for sample 2 it is 2.281 mS/cm⁻¹ (6 GHz) 13.88 mS/cm⁻¹ for (9.86 GHz). This indicates that ionic conductivity is inversely proportional to the angular frequency (ω). When potassium nitrate added to sample 1 the AC conductivity was calculated 0.797 mS/cm⁻¹ (6 GHz) and 5.59 mS/cm⁻¹ (9.86 GHz).
and for sample 2 it is 2.243 mS/cm\(^{-1}\) (6 GHz) 14.21 mS/cm\(^{-1}\) for (9.86 GHz). This indicates that ionic conductivity is inversely proportional to the angular frequency (\(\omega\)).

6. Conclusion:

From results we can conclude that there is major effect of frequency on dielectric properties of soil and it is also influence by moisture content present in potassium nitrate and ammonium sulphate powder thus changing the dielectric properties of sample. Out of these two chemical ammonium sulphate effects more positively as compare to potassium nitrate on soil dielectric properties. These dielectric parameters are useful for researchers working in the field of agriculture, hydrology and matereology. Emissivity and scattering coefficient can be estimated from these parameters that will provide tools for designing sensors.

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