**International Journal of Science and Research (IJSR)**
**ISSN: 2319-7064**
**SJIF (2019): 7.583**

# Investigation of Moisture Content in Soil using Dielectric Constant Measurement Method

**Dr. Manisha Dhiware**

Dept. of Physics, K. V. N. Naik Art's, Commerce and Science College, Nasik, SPPU, Pune India 422 002
Correspondence address: *manishasalunke73[at]gmail.com*

**Abstract:** ***Microwave techniques for the measurement of soil moisture content are based on the fact that the dielectric properties of water and the soil particles are dissimilar. An attempt has been made for determining the relation between moisture content and dielectric constant by simple estimation of dielectric constant measurement from microwave signal. Electrical properties of soils have been measured using an automated X-band microwave set-up in the TE10 mode with Reflex Klystron source operating at frequency operating at 9.56 GHz. In this present work, authors made an attempt to present soil moisture measurement by estimation of emissivity i.e. the ratio of energy radiated by an object to absorbing the body of same physical temperature. A strategic method of measuring dielectric constant using a microwave signal is used in this research work. The measurement of the dielectric constant of the soils collected from the specific regions and analysis of results has been reported. This method is simple and can further be used for the identification of soil moisture and agricultural applications.***

**Keywords:** Dielectric constant, Microwave frequency, Emissivity

## 1. Introduction

Soil compaction is the main form of soil degradation which alters the extent and configuration of the pore space. In compacted layers, water, nutrients, and airflow towards the plant roots are also restricted. Soil water content is a soil physical state variable which is defined as the water contained in the unsaturated soil zone. Knowledge of soil water content (SWC) is hereby essential as it represents a key variable in many hydrological, climatologically, and environmental processes. The standard reference method to determine SWC is the gravimetric technique, which consists of extracting soil samples from the field. The samples are then weighted before and after drying in an oven at 105˚C for 24 hours to derive their water content. The amount of water in the soil is classically expressed as volumetric (m3 of water per m3 of soil) or gravimetric (g of water per g of soil) water content. The gravimetric method is the only direct measurement technique but several indirect techniques are also available to measure SWC [1, 2]. Local indirect methods include mainly electromagnetic sensors, namely time domain reflectometry (TDR) [3, 4, 5] and capacitance sensors [6, 7, 8,]. The TDR measurement principle is based on the propagation velocity of guided electromagnetic waves along a probe through the soil, which is dependent on the soil electromagnetic properties.

At microwave frequencies, the real part of the complex numbers representing the dielectric constant are air, K = 1, soil, K = 4 and water, K = 80. These large contrasts in K make it possible to measure soil moisture. As this much significant difference in dielectric constant lies in soil and water, it makes possible to measure soil moisture using microwaves. Because of water molecules absorbed into the surfaces of particles and restrained dipoles, the bounded water has a lower dielectric constant than free water confined to the aperture spaces [9, 10]. Several researchers have used active microwave sensors in order to test the capability of such equipment to measure the soil surface water content [11, 12, 13], and monitor the water budget at a field or regional scale [14, 15].

## 2. Experimental Method

### A. Study Area

Soil samples were collected from ten different agricultural land of Igatpuri Tehsil, Nasik, Maharashtra. Igatpuri is a town and a Hill Station Igatpuri is surrounded by the highest peaks in Sahyaadri i.e. Western Ghats council in Nashik District in the Indian state of Maharashtra. Soil samples were collected in the depth of 0-20cm from desired location. The details of the land are given in Table no.1 below.

| Sample No. | Survey No. | Area | Latitude | Longitude |
|---|---|---|---|---|
| 1 | 35 | Deole | 19°72"39' | 73°65"11' |
| 2 | 53 | Take(Ghoti) | 19°70"42' | 73°61"09' |
| 3 | 7477 | Talegaon | 19°68"73' | 73°55"92' |
| 4 | 350/3 | Alwand | 19°71"59' | 73°60"86' |
| 5 | 572 | Khambale | 19°74"06' | 73°63"78' |
| 6 | 118 | Senvad | 19°77"82' | 73°67"31' |
| 7 | 54 | Wadiwarhe | 19°86"13' | 73°67"87' |
| 8 | 375 | Morambi | 19°85"10' | 73°65"52' |
| 9 | 316/B | Kushegaon | 19°86"42' | 73°57"87' |
| 10 | 29 | Wanjole | 19°83"60' | 73°56"66' |

### B. Soil Sampling

Soil samples are collected from different locations of agricultural land at the depth of ranging between 0-20 cm. in zigzag pattern across the one site areas. Five pits were dug for each sample. A composite sample of about 3 to 4 Kg representing one site was taken after thorough mixing of all above soil samples. This procedure was repeated while preparing composite samples representing all ten sites covering Western Ghat of Maharashtra. These topsoil samples are first sieved by gyrator sieve shaker (size 425 μm) to remove the coarser particles. The sieved out fine particles are then dried in the hot air oven to a temperature around 110$^o$C for about 24 hours in order to completely remove any trace of moisture. Such dry sample is then called as oven dry or dry base sample when compared with wet samples. The Physical and chemical properties of the soil are measured at soil analysis laboratory.

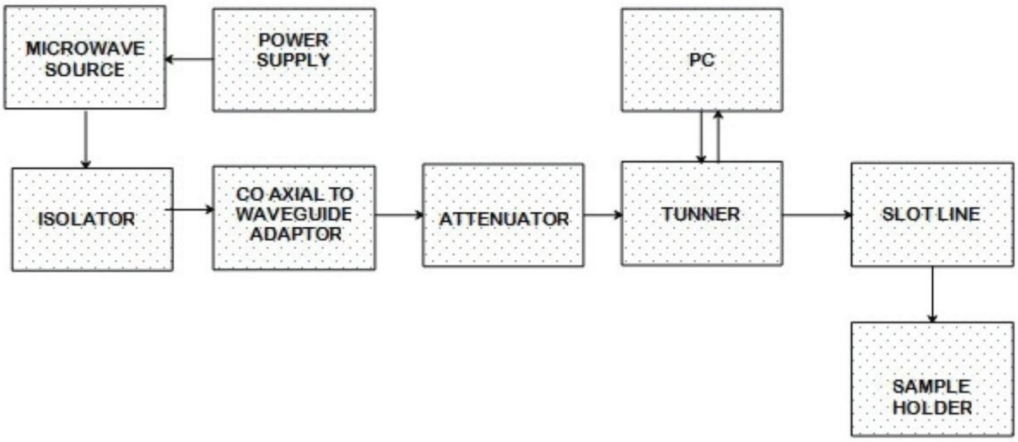
**C. Measurement of Dielectric Constant of dry Soil Samples:**

The waveguide cell method is used to determine the dielectric properties of the dry soil samples. X-band microwave bench set-up for measurement of dielectric constant of soil samples is used. An automated X-band microwave set-up in the $TE_{10}$ mode with Reflex Klystron source operating at frequency 9 .56 GHz is used for measuring dielectric constants .PC-based slotted line control and data acquisition system is used for this purpose. The solid dielectric cell with soil sample is connected to the opposite end of the source. The signal generated from the microwave source is allowed to incident on the soil sample. The sample reflects part of the incident signal from its front surface. The reflected wave combined with incident wave to give a standing wave pattern. These standing wave patterns are then used in determining the values of shift in minima resulted due to before and after inserting the sample. Experiments were performed at room temperatures ranged between 25° -35° C. The dielectric constant ε' of the soils is then determined from the following relation:

$$\varepsilon' = \frac{\beta_r + \left(\lambda_g / 2a\right)^2}{1 + \left(\lambda_g / 2a\right)^2}$$

$$\varepsilon' = \frac{\beta_r}{1 + \left(\lambda_g / 2a\right)^2}$$

**Schematic diagram of X band microwave bench set up**




The sample holder for X band measurements was fabricated from the standard waveguides available. At the one end of the sample holder a metallic flange was connected, so that it can be connected to the main line and the other end was shorted. Length of X band is 3 cm. Initially, with no dielectric in short circuited line the position of the first minimum $D_R$ in the slotted line was measured. Now the soil sample of certain length ($l\epsilon$) having certain moisture content was placed in the sample holder, such that the sample touches the short circuited end. Now the position of the first minimum D on the slotted line and the corresponding VSWR, r were measured. This procedure was repeated for another soil sample of same moisture content for another soil sample length ($l\epsilon'$).Now the propagation constant (in the empty waveguide) is calculated as

$$k = \frac{2\Pi}{\lambda g}$$

where $\lambda g$ = 2x (distance between successive minima with empty short circuited waveguide sample holder).

**Table 2:** Gives details of Physical characteristics of soil samples.

| Sample No. | Bulk Density (gmcm-1) | Particle Density (gmcm-1) | Water holding capacity (%) | Sand (%) | Silt (%) | Clay (%) | Textural Class |
|---|---|---|---|---|---|---|---|
| 1 | 1.22 | 2.63 | 48 | 47.22 | 37.45 | 15.33 | Loam |
| 2 | 1.29 | 2.47 | 39 | 52.5 | 31.75 | 15.75 | Sandy Loam |
| 3 | 1.42 | 2.42 | 46 | 57.75 | 26 | 16.25 | Sandy Loam |
| 4 | 1.21 | 2.46 | 44 | 47.82 | 45.1 | 7.08 | Loam |
| 5 | 1.2 | 2.22 | 48 | 48.25 | 38.75 | 13 | Loam |
| 6 | 1.21 | 2.3 | 41 | 73.82 | 22.58 | 3.6 | Loamy Sand |
| 7 | 1.17 | 2.16 | 47 | 42.25 | 40.25 | 17.5 | Loam |
| 8 | 1.21 | 2.17 | 45 | 41 | 34.25 | 24.75 | Loam |
| 9 | 1.2 | 2.16 | 48 | 67.77 | 13 | 19.23 | Sandy Loam |
| 10 | 1.29 | 2.04 | 42 | 64.05 | 21.93 | 14.02 | Sandy Loam |

The mineral fraction of soil contains particles of widely varying sizes, shapes and chemical compositions. The properties of soil are mainly classified into three groups i) Physical ii) Chemical & iii) Electrical. The electrical properties of material are mainly the permittivity and permeability. The table no.3 gives details of electric characteristics of soil sample.

**Table 3:** Electrical Properties of Igatpuri

| Sample no. | Mean | | $\tan\delta=\varepsilon''/\varepsilon'$ | $\sigma=\omega\varepsilon_0\varepsilon''$ | $\Gamma=\varepsilon''\omega\varepsilon'$ | Emissivity |
|---|---|---|---|---|---|---|
| | ε' | ε" | | | | |
| 1 | 0.43935 | 0.027480 | 0.0625469 | 0.013592823 | 674803007 | 0.95888624 |
| 2 | 0.43815 | 0.026405 | 0.0602647 | 0.013061080 | 646634152 | 0.95861996 |
| 3 | 0.48170 | 0.035335 | 0.0733548 | 0.017478253 | 951330438 | 0.96738169 |
| 4 | 0.48225 | 0.039815 | 0.0825609 | 0.019694259 | 1073170205 | 0.96748130 |
| 5 | 0.43825 | 0.026465 | 0.0603879 | 0.013090759 | 648251415 | 0.95864221 |
| 6 | 0.42825 | 0.025910 | 0.0605020 | 0.012816231 | 620175257 | 0.95636432 |
| 7 | 0.43925 | 0.027360 | 0.0622880 | 0.013533465 | 671703349 | 0.95886411 |
| 8 | 0.43690 | 0.026410 | 0.0604486 | 0.013063553 | 644911463 | 0.95834097 |
| 9 | 0.48010 | 0.034760 | 0.0724016 | 0.017193832 | 932741122 | 0.96709044 |
| 10 | 0.48250 | 0.039615 | 0.0821036 | 0.019595330 | 1068332962 | 0.96752650 |

## 3. Result and Discussion

For moisture content below transition moisture in the soil, most water molecules are tightly bound to the soil particles. It is difficult to polarize these bound water molecules and the bulk of water shows a smaller dielectric constant ' ∈ than that of free water [16]. The present values of dielectric constant are in good agreement with the values reported by other authors. From fig.1 to fig. 4, it is observed that dielectric constant increases with increase in moisture content slowly up to transition moisture then it increases rapidly with increase in moisture content. The result shows the change in the electrical properties of soil before and after the addition of water.

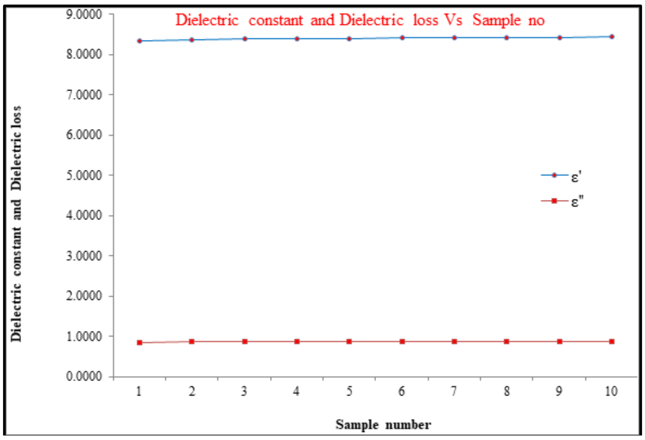



**Figure 1:** Variation of dielectric constant and loss of Dry soil

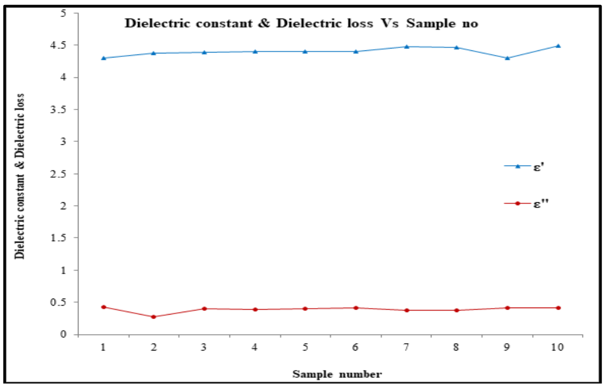



**Figure 2:** Variation of dielectric constant and loss of soil with 5 % moisture content

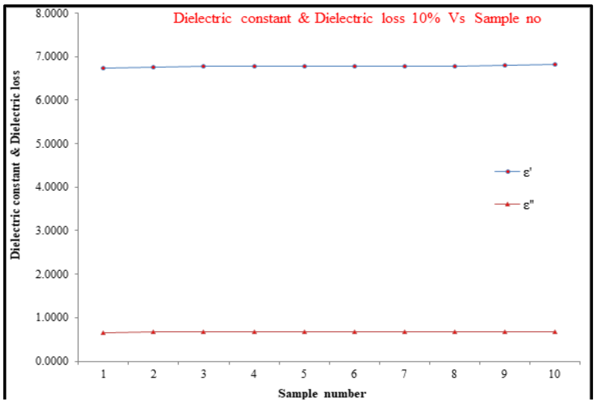



**Figure 3:** Variation of dielectric constant and loss of soil with 10 % moisture content

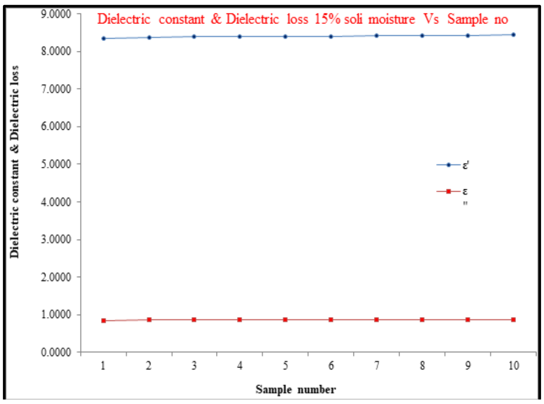



**Figure 4:** Variation of dielectric constant and loss of soil with 30% moisture content

Table 4 shows that the ranges and means of physical, chemical properties of soils collected from Igatpuri tehsil.

**Table 4: Ranges** and means of physical, chemical properties of soils collected from Igatpuri tehsil

| Properties | Unit | Range | Mean |
|---|---|---|---|
| **pH** | -- | 7.1 – 8.5 | 7.30 |
| **Clay** | % | 13 - 50 | 18.4 |
| **Calcium Carbonate** | % | 1 - 3 | 1.5 |
| **Nitrogen** | Kg $ha^{-1}$ | 110 - 158 | 134 |
| **Potassium** | Kg $ha^{-1}$ | 210- 407 | 308 |
| **Copper** | ppm | 2.69 – 7.84 | 5.26 |
| **Iron** | ppm | 6.5 – 12.34 | 9.42 |
| **Manganese** | ppm | 10.69 – 11.77 | 11.23 |
| **Dielectric Constant** | -- | 0.4285 – 0.4825 | 0.4555 |

**Table 5:** Relation between Dielectric constant and crops of Igatpuri Tehsil

| Sample No. | Name of the farmer | Area | Previous crop | New crop | Dielectric constant | Favourable Crop |
|---|---|---|---|---|---|---|
| 1 | Kondaji Khandu Tokade | Deole | Masur, Harbhara | Rice | 0.43935 | Grapes |
| 2 | Dinanath Pandurang Bhagat | Take (Ghoti) | Rice, Grapes | Rice | 0.43815 | Grapes |
| 3 | Gopal Dharma Jagtap | Talegaon | Rice | Rice | 0.48170 | Rice |
| 4 | Arun Haribhau Jadhav | Alwand | Rice | Rice | 0.48225 | Rice |
| 5 | Nivrutti Namdeo Chaudhari | Khambale | Brijal, Grapes | Rice | 0.43825 | Grapes |
| 6 | Shravan Savliram Potkule | Senvad | Rice | Rice | 0.42825 | Grapes |
| 7 | Dashrath Muralidhar Malunjkar | Wadiwarhe | Groundnut, Soyabean | Grapes, | 0.43925 | Grapes |
| 8 | Kailas Thakaji Mate | Morambi | Rice | Rice, Tomato | 0.43690 | Grapes |
| 9 | Santu Rama Sarai | Kushegaon | Wheat,Brinjal,Cucumber | Rice | 0.48010 | Rice |
| 10 | Trimbak Kishan Mahale | Wanjole | Onion | Rice | 0.48250 | Rice |

## 4. Conclusion

Rice can be cultivated under a variety of climatic and soil conditions. Rice comes up well in different soil types. It is observed that soil pH in the range of 7.1–8.5, the range of clay 13-50%, calcium carbonate 1-3%, Nitrogen 110-158 kg $ha^{-1}$, copper2.69-7.84 ppm, iron 6.5-12.34 ppm and manganese range10.69-11.77 ppm and dielectric constant 0.439 is suitable for grapes, and 0.482 is suitable for rice and soyabean crops.

The results have importance not only for better understanding of soil physics but also microwave remote sensing application. The measurement is very sensitive to volumetric water content. The dielectric constant of Western Ghat of Maharashtra soil is dependent on the texture of soil i.e. the percent content of sand, slit and clay.

## References

[1] Wagner, W., Bloschl, G., Pampaloni, P., Calvet, J. C., Bizzarri, B., Wigneron, J. P., and Kerr, Y. 2007. Operational readiness of microwave remote sensing of soil moisture for hydrologic applications. Nordic Hydrology, 38(1):1–20.

[2] Robinson, D. A., Binley, A., Crook, N., Day-Lewis, F. D., Ferre, T. P. A., Grauch, V. J. S., Knight, R., Knoll, M., Lakshmi, V., Miller, R., Nyquist, J., Pellerin, L., Singha, K., and Slater, L. 2008a. Advancing process-based watershed hydrological research using near-surface geophysics: a vision for, and review of, electrical and magnetic geophysical methods. Hydrological Processes, 22(18):3604–3635.
[3] Noborio, K. 2001. Measurement of soil water content and electrical conductivity bytime domain reflectometry: a review. Computers and Electronics in Agriculture, 31:213–237.
[4] Topp, G. C., Davis, J. L., and Annan, A. P. 2003. The early development of TDRfor soil measurements. Vadose Zone Journal, 2(4):492–499.
[5] Robinson, D. A., Jones, S. B., Wraith, J. M., Or, D., and Friedman, S. P. 2003. Areview of advances in dielectric and electrical conductivity measurement in soilsusing time domain reflectometry. Vadose Zone Journal, 2:444–475.
[6] Dean, T. J., Bell, J. P., and Baty, A. J. B. 1987. Soil-moisture measurement byan improved capacitance technique.1. Sensor design and performance. Journal ofHydrology, 93(1-2):67–78.
[7] Rosenbaum, U., Huisman, J. A., Weuthen, A., Vereecken, H., and Bogena, H. R.2010. Sensor-to-sensor variability of the ECH(2)O EC-5, TE, and 5TE sensors indielectric liquids. Vadose Zone Journal, 9(1):181–186.
[8] Mittelbach, H., Casini, F., Lehner, I., Teuling, A. J., and Seneviratne, S. I. 2011. Soilmoisture monitoring for climate research: Evaluation of a low-cost sensor in theframework of the Swiss Soil Moisture Experiment (SwissSMEX) campaign. Journalof Geophysical Research-Atmospheres, 116:11.
[9] K. Ouchi, "Recent Trend and Advance of Synthetic Aperture Radar with Selected Topics," Remote Sensing, vol. 5, pp. 716-807, 2013.
[10] J. P. Walker, et al., "Active Microwave Remote Sensing for Soil Moisture Measurement: A Field Evaluation using ERS-2, " Hydrological Processes, vol. 18, pp. 1975-97, 2004.
[11] Ulaby F T, Batlivala P P, Dobson M C 1978 Microwave backscatter dependence on surfaceroughness, soil moisture and soil texture: Part 1 - Bare soil. IEEE Trans. Geosci. Remote SensingGE-16:286-295.
[12] Le Toan T, Pausader M, Flonzat G, Flutir A 1981 Soil moisture content and microwave backscatterin the 1.5-9 GHz region. Int. Geosci. Remote Sensing Symposium (IGARSS '81) Digest (IEEE)
[13] Jackson T J, O'Neill P E 1985 Aircraft scatterometer observation of soil moisture on rangelandwatersheds. Int. J, Remote Sensing 6:1135-1152.
[14] Bernard K, Vanclin M, Vidal-Madjar D 1981 Possible use of active microwave remote sensing datafor prediction of regional evaporation by numerical simulation of soil water movement, theunsaturated zone. Water Resour. Res. 17:1603-1610.
[15] Pervot L, Bernard R, Taconet D, Vidal-Madjar D 1984 Evaporation of bare soil evaluated using asoil water transfer model and remotely sensed surface soil moisture data. Water Resour. Res. 20:311-316.