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Role of Moisture Content and Dielectric Constant in Soil

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Abstract - In this research paper it has been described that the role of moisture content and dielectric constant in soil. It has been seen that dielectric constant increases when water content increases. There are a relation between microwave dielectric constants and soil properties. It has been also seen that soil properties effect microwave dielectric constants. There are a lot of effects viz, water effect, texture effects, bulk density effects, organic matter content, soil water temperature, salinity effects, soil structure effects etc. but role of moisture content plays pivotal role in microwave remote sensing. It has been also seen that microwave remote sensing has the potential for widespread use in soil moisture.

Keywords: dielectric, soil properties, organic matter content, remote sensing.

1. INTRODUCTION

In India, Chhattisgarh is located in the central part of India, between the **latitudes of 17° 46'N - 24° 5' N** and the **longitudes of 80° 15' E - 84° 20' E**. Its proximate position with the Tropic of Cancer has a major influence on its climate. It is landlocked by the states of Maharashtra and Madhya Pradesh on the west, Uttar Pradesh on the north, Jharkhand on the north-east, Orissa on the east, and Andhra Pradesh on the south. Climate of Chhattisgarh is sub tropical**[1]**. Chhattisgarh comes under the hot Torrid Zone and probably that's why the state observes tropical type of climate. Though weather varies from region to region, it's warm in most of the places. Like any other part of India, Chhattisgarh enjoys three seasons, summers, winters, and monsoons. During summers (April-June), the temperature sometimes goes up to **45°C** (max) **.** Late in the month of June, Monsoons (July-September) arrive in the state as a respite from the scorching heat. Chhattisgarh receives pretty decent amount of **rainfall with an average of 1292mm**. The elevated regions in the north and south observe moderate climate round the year. In October, cool breeze envelops the entire state as if heralding the arrival of winters. The winter season (November-February) doesn't necessarily mean wearing loads of woolens in Chhattisgarh. At this time, the temperature even drops **down to 10°C.** Light woolens are usually enough to deal with winters in the state, however, heavy woolens are required in hilly areas. Otherwise, light cotton clothing is best for most of the time.

This state is also known as bowl of rice in Chhattisgarh. The northern and southern regions of the state are hilly, whereas the central region is a fertile plain. About 40% of the state's area is covered by forests. Dense forest affects the propagation such as amarkantak region dense forest, Achanakmar, Baster district, Gariyaband. According to partition of soil it has been devided into six parts i.e.

- Highland: jammu kasmir,Sikkim, HP,ArunachalPradesh;
- Humidsubtropical:Punjab,HP,UttaraKhand, Chhattisgarh,NDL,UttarPradesh,
- MP,Bihar,Assom,Meghalaya,Nagaland,Manipur,Tripura,Mizoram;
- Tropical wet and dry: WB, Odissa, Andhra Pradesh, MH,Karnataka, TN,Chhattisgarh;
- Arid: Rajasthan,Gujarat Semiarid: Gujarat, Rajasthan,NDL; Haryana,Punjab,MH,Karnataka, TN;
- Ttropical wet: Goa, Kerala,Karnataka, Lakshadweep, Andaman & Nicobar

Fig. 1.

Fig. 2.

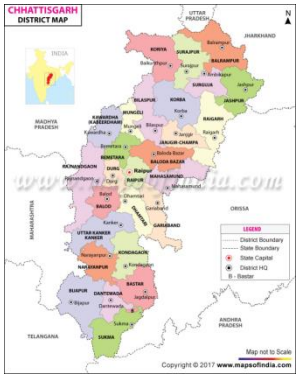


Fig. 3. Chhattisgarh State

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. 'Dielectric properties of soils with organic and inorganic matter at J-band microwave frequency' has been observed by H.C.Chaudhary**[9]** and found that due to soil parameters variation of organic and inorganic matter, these are very useful in agriculture.

2. THEORETICAL CONSIDERATION:

The parameter of soil affects the production of grains. There are a lot of parameters but moisture content is the very very important. In the laboratory the properties of dry and fertilized soil are utilized for study which is very useful in agriculture **[8]**. Now a days a lot of concerned researchers have found out update technology, model and techniques between soil moisture and dielectric properties **[7]**. Climate also affects the agriculture. There are different methods of measurement of dielectric constant of soil at microwave frequencies. They are as follows **[2] [6]**:-

- Approximation model
- Automatic measurement system
- Cavity Method
- Cavity perturbation technique
- Coaxial probe method
- Colloid dielectric probe
- Data processing techniques
- Dielectric spectroscopy technique
- Digital elevation model approach
- Dobson model
- Elmake model 7200
- Empirical mixing model
- Empirical model
- Four component dielectric mixing model
- Free space Method
- Geometric optics model
- Gravimetric method for water content measurements using soil science
- Hewlett-Packard model 8540
- HP Network analyser (HP 8510-C) & HP dielectric probe(85070 M) employing coaxial probe method
- Infinite sample Method
- Keysight 85070E dielectric probe
- Micro strip transmission line
- Model generation
- MVA (multiple view angle) approach
- Open – structure technique
- Open ended coaxial probe
- Passive optic technique

- Perturbation model
- Physical optic model
- Physical soil model
- RADAR approach
- Resonator model
- Roberts & Von Hipple experimental technique A sensing technique
- Semi empirical model
- Six – port reflectometer
- Soil testing kit (model-161)
- SSM inversion method
- Stern- Gouy double – layer model
- TDR(Time Domain Reflectometry) for measuring soil water content
- THEORETICAL MODEL/ TECHNIQUE/ ICTP, Priesta
- Transmission Method
- Two point method
- Vector Network Analyser
- Wang and Schmugge model
- Waveguide cell Method

There are several factors to influence the climate but sand dust particles, rain, water vapour attenuation, cyclones, soil erosion, fog, smoke, smog, fly ash, forest, mountain, latitude. Altitude, nearness from sea, desert, ocean currents, soil. So the role of soil in agriculture is very important. In India there are a lot of pioneers who are really torch bearer for beginners researcher in the field of dielectric behaviour of soil. Some names are given as:

- ASSOM…….M.C.Borah
- CHHATTISGARH…S.K.Shrivastava,Dr.S.K.Patel.,Dr,.Samir-bajpai,Dr.U.K.Dewangan
- Gujarat…P.R.Choudhary,ManabChkravarty,V.K.Shrivastava
- J&K…Waseem-Hasan,H.S.Bali,NIT,Hazarathbal
- KARNATAKA……Chetan-Bohra,Vivek-Ranjan
- KERALA…….Rajesh Mohan, S.Mridula, P.Mohanan, Binu Paul
- MAHARASHTRA..H.C.Choudhary,V.J.Sinde,D.V.Ahire, V.V.NavarkheleA.K.Kapre,A.A.Shaikh,Dodha, V.Ahire,
- MP……..J.P.Shukla,
- ODISHA……..T.Panda,B.B.Kar
- PUNJAB…….S.N.Jha,RajeevSharma,,(CIP HET),Ludhiyana
- UK…P.Mishra,D.Singh,IIT,Roorkee
- Rajasthan...O.P.N.Calla,V.K.Gupta,R.A.Jangid, AnilKumar, Vivek-Yadav,SudipSaran(CEERI)
- UP……Jitendra-Behari,DevendraSingh
- WB…….P.K.Paul,R.Mishra,

Besides the properties of soil colour of soil is very important. India is the country of villages. There are several types soil in India. Recently V.V. Navarkhele found that the colour of soil does not matter the agricultural productivity**[10]**. Further he has also explained that due to higher percentage of calcium carbonate, the white soil is used for construction and other applications where calcium carbonate is used.

2.1 Sand Dust particles:

It has been found the relation ,[3],

$$R = \frac{A+\frac{B}{Z_t}-Z_1\left(c+\frac{D}{Z_t}\right)}{A+\frac{B}{Z_t}+Z_1\left(c+\frac{D}{Z_t}\right)}$$

Eq. (1)

$$T = \frac{2}{A+\frac{B}{Z_t}-Z_1\left(c+\frac{D}{Z_t}\right)}$$

Eq.(2)

Where,

R = Reflection Coefficients

T = Transmission Coefficients

Z_1 = Impedance of 1-space

Z_t = Impedance of Transmission

A = Layer

B = Layer

C = Layer

D = Layer

In general total power dissipated (Pabs) is determined by using the concepts of energy balance. For the general case the absorbed power can be obtained by the reaction**[3]**.

$$P_{abs} = P_{in}[1 - (|T|^2 + |R|^2)]$$

Eq.(3)

With the help of equation (1) and (2) it may be obtained as:

$$P_{abs} = P_{in}\left[1-\left(\left|\frac{2}{A+\frac{B}{Z_t}-Z_1\left(c+\frac{D}{Z_t}\right)}\right|^2+\left|\frac{A+\frac{B}{Z_t}-Z_1\left(c+\frac{D}{Z_t}\right)}{A+\frac{B}{Z_t}+Z_1\left(c+\frac{D}{Z_t}\right)}\right|^2\right)\right] \quad \text{Eq.(4)}$$

Now it has been observed that the value of transmission coefficient decreases with increasing frequency where as the reflection coefficient increases with increasing frequency. Further the loss due to absorption is found to increase with increasing frequency. For zero visibility the medium is completely packed with sand, dust particles.

2.2 Rain:

Rain causes attenuation in microwaves propagation through the process absorption and scattering. The rain attenuates the upper spectrum and frequencies suffer strong impairment as the rain drop parameter approaches the size of operating wave length. In tropical countries like India, a great diversity of climatic conditions has been witnessed in the recent past, useful for all ranges of rain fall rate as well as frequencies **[5]**.

The change in the amplitude and phase of incident wave due to the rain drops is mainly because of scattering and absorption of wave by drops. The phenomena of scattering and absorption depend on the shape of particle and size of rain drops. For small rain drops compared to the wavelengths, the attenuation due to absorption is small. That is the main attenuation is small and unimportant at longer wavelength then under such condition Rayleigh scattering approximation has got in limited use for prediction of attenuation through rain drops.

With increase in rain rate, attenuation in radio link communication is increased which shows adverse affect at microwave and mill metric frequencies, since EM waves are most affected by scattering and absorption phenomena. Rayleigh and Mie scattering are the main cause of attenuation at higher attitude of the atmosphere.

2.3Water Vapor attenuation:

In addition to absorption by molecular oxygen, molecules of water vapor also interact with electromagnetic radiation in the microwave and millimeter wave regions**[4]**. A important consideration is that the water vapor being the only green house gas whose concentration is highly variable in space and time in the atmosphere. The IPCC fourth [5] assessment report says that a further warming of about 0.1^0C per decade would be expected even if the aerosols had been kept constant. This report also says that in order to reduce the level of existing uncertainties, the modeling of nature society interaction is urgently required on a long term basis taking into account non linear changes in climate systems.

2.4 Cyclones:

Cyclones also affect the electromagnetic wave. Geophysical parameters derived from advanced microwave sounding unit (AMSU) measurements like surface pressure, upper troposphere warm core, gradient winds and cloud liquid water are demonstrated for the monitoring of the intensity of recently formed tropical cyclone in the Bay of Bengal. The cyclone affects the constant area. Recently the disaster of Gopalpur (Odisa) had been controlled as well as monitored by the help of updated technology.

2.5 Soil Erosion:

The information on soil erosion such as quantification of erosions soil loss and soil conservation prioritization of watersheds/sub watersheds provides vital inputs for sustainable agricultural management with respect to soil conservation. Remote sensing and GIS techniques are being effectively used in India for preparation of soil erosion inventories by integration of physiographic, layers and use of ancillary data of agro-met and soil physic-chemical Properties **[6].**

2.6 Fog:

Fog can be formed in variety of ways depending mostly on the condensation mechanism. Generally it can be encountered the type of fog, which is formed by the cooling of land after sunset by thermal radiation in calm and clear sky. The cool ground produces condensation in the nearby area by conduction of heat. This type of fog mostly prevails at night and does not lost long after sunrise. It generally occurs in autumn and winter. Attenuation due to fog in the millimeter wave band is mainly caused by absorption and scattering which in turn

depends on the extent of the fog density (Visibility) and its index of refraction. According to Gibbins (1988), the fog density is given in terms of visibility V(km) by **[4]**

$$M = \left(\frac{0.024}{V}\right)^{1.54} gm^{-3}$$

Eq.(5)

2.7 Smoke, Smog & fly Ash:-

It affects attenuation for zero visibility the medium is completely packed with sand, dust, smoke, smog and fly ash particles. Any lossy dielectric medium will have the complex permittivity,

$$\epsilon = \epsilon \left(1 - \frac{j\sigma}{\omega\epsilon}\right)^2$$

Eq.(6)

Where the symbols have usual meanings.

The imaginary part of which is a function of conductivity and frequency. It has been found that increasing visibility the reflection coefficient decreases where as transmission coefficient increases for all values of frequency.

2.8 Forest and Mountain:

It has been found that the forest, mountain, ice, etc affect the attenuation of electromagnetic waves; Chhattisgarh covers a large area regarding dense forest.

Various studies carried out in microwave propagation under climatic zone of subtropical India. It has been found that sand dust, fog, rain, fly ash affect the microwave remote sensing.

3. RESULT AND DISCUSSION

Dielectric constant of soils increases as moisture content increases rapidly[4]. It has been seen that partition of soil it has been devided into six parts i.e. highland: jammu kasmir,Sikkim, HP,Arunachal Pradesh ; humid subtropical: Punjab,HP,UttaraKhand,Chhattisgarh,NDL,UttarPradesh,MP,Bihar,Assom, Meghalaya,Nagaland,Manipur,Tripura,Mizoram; tropical wet and dry: WB, Odissa, Andhra Pradesh, MH,Karnataka, TN,Chhattisgarh; arid: Rajasthan,Gujarat ;Semiarid: Gujarat, Rajasthan,NDL; Haryana,Punjab,MH,Karnataka, TN; tropical wet: Goa, Kerala,Karnataka, Lakshdeep, Andman & Nicobar. There are eight states including Chhattisgarh are humid subtropical and tropical wet and dry. Laboratory studies of dielectric properties of soils with varied moisture, texture, temperature density, as well as othere chemical and physical properties of solids are very important in correlating remotely sensed data with actual field conditions and in distinguishing targets having identical dielectrics properties [6].

Fig.4.

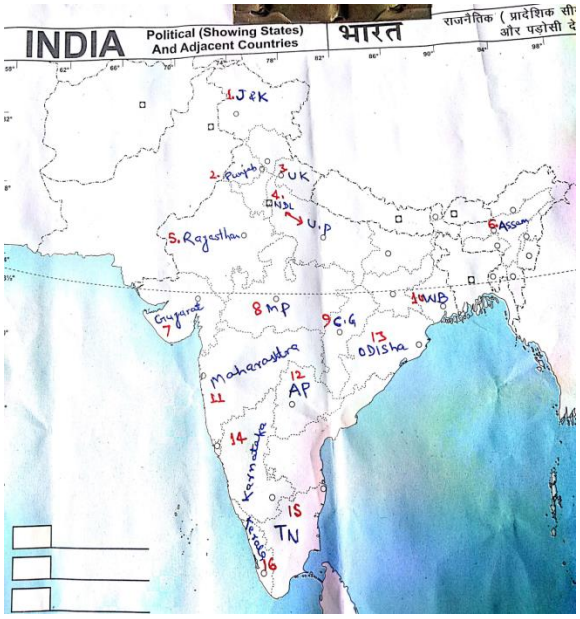
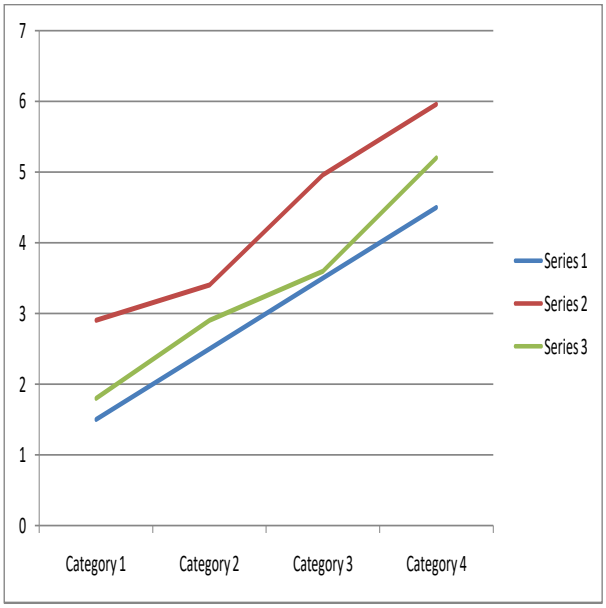


Fig. 5.



X-axis , % of water content

Y-axis , Dielectric Constant

Fig. 5.

4. CONCLUSIONS:

The dielectric constants of soils are strongly dependent on soil moisture and soil texture. Physical and chemical properties show remarkable variation in dielectric properties these dielectric properties can be used to predict the soil fertility and health. Dialectic constant of soil are strongly dependent on soil moisture and soil texture. Moisture is soil significantly affect the dielectric properties of soil. Dielectric constants of solid particles, like sand, silt, and clay present in storms are essential in the estimation of total attenuation due to sand and dust storms in microwave communications.Such study of soil in also useful in microwave remote sensing and agriculture in order to increase its productivity.

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