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Retraction

Retracted: Exhibition of Dielectric Property Based on Soil Class and Moisture Presence for Bengaluru District

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] S. Kumar, N. Ahalya, V. Singh et al., "Exhibition of Dielectric Property Based on Soil Class and Moisture Presence for Bengaluru District," *Advances in Materials Science and Engineering*, vol. 2023, Article ID 6807204, 9 pages, 2022.

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Research Article

Exhibition of Dielectric Property Based on Soil Class and Moisture Presence for Bengaluru District

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This research examined the dielectric characteristics of soils by utilizing four types of soil (clay-loam, loam, clay, and Frank) in a vector network analyzer (VNA) in the 600–8000 MHz microwave frequency range at ambient temperature (25°C ± 3°C). In this experiment, three observations were performed on the basis of soil moisture contents (dry, 33%, 66%, and 100% field capacities (CC)). Both actual (dielectric constant) and fictional (loss factor) parts of the dielectric characteristics improved with increasing soil moisture; however, the responses were not linear. It was observed that dry soil dielectric characteristics were deficient when compared to wet soil. In conclusion, the dielectric behavior of soil mainly was resolute by the moisture in the soil. Frank soil had considerably lower dielectric characteristics, while the Jain University (JU) clay soil had a far more significant dielectric loss factor.

1. Introduction

There are different applications employed with microwave energy, as shown in Table 1, and there are results of soil treatment with a microwave also mentioned in Table 1. Its significant benefits include quick start-up time, accurate control, and volumetric warming [1].

It causes polar particles to rotate due to the oscillating electromagnetic field created when microwave radiation is also applied to the soil. The intermolecular friction generated by this causes the production of heat. To comprehend soil heating, it is necessary to comprehend the treatment of microwave soil [14].

To use a microwave, the material must absorb microwave energy and then used for heat. The complex permittivity, called the dielectric constant, reflects the materials' ability to store energy and the efficient manner in which they convert energy into heat, known as dielectric loss [2, 20, 25]. Dielectric loss factor (DLF) is dependent on microwave energy absorption. Soil is an intricate combination of water, minerals, ions, and vapors (mainly air), and many types of microorganisms and macroorganisms [26]. There are many ways of classifying soil, based on particle size [20]. Particle size is used to classify soils according to their proportion of sand, silt, and clay. Several scientific investigations have examined the dielectric characteristics of the soil. Particular

Table 1: Applications of microwave energy.

S. no.	Applications	References	Result of soil treatment with microwave	References
1	Food processing	[2–6]	Reduction of weed emergence	[7–11]
2	Textiles and leather processing	[1]	Increased carbon and nitrogen mineralization	[12]
3	Medical application	[13]		
4	Plasma	[15]		
5	Solvent-free chemistry	[16]		
6	Drying of wood	[17, 18]	Greater plant growth	[14]
7	Paper and cardboard	[19]		
8	Pest control	[20]		
9	Enhancing seed germination	[21, 22]		
10	Elimination of perilous waste from dirtied soil	[23, 24]		

studies focus on remotely sensed data, whereas others focus on soil heating [26–28]. However, it appears that there has been limited research on the engineering, technical, and health (ETH)-based microwave frequencies (895/916/923 MHz, 2460 MHz, and 5900 MHz). At high ETH frequencies, the dielectric property of soil becomes significant. Based on prior research (which found that moisture content has an enormous influence on dielectric characteristics [29], expected that moisture presence influence extreme impact over dielectric properties), the dielectric characteristics are fundamental because they influence moisture content directly [30–32]. In addition, the other variables that influence the dielectrics of soil are soil classification, as shown in Table 2, soil composition, and soil compactness.

There is an urgent requirement to examine soil dielectrics through ETH microwave frequencies since the dielectric behavior of most materials changes markedly with frequency.

Many disinfectants and seed deactivators use soil temperatures between 60°C and 120°C; however, microwave heating raises the temperature of hydrocarbon-contaminated soil to levels much higher than 200°C, as discovered by [23].

For a thorough examination of the dielectric characteristics of soil, knowing the consequence of soil organic matter on soil water holding capability should be considered. Studies show that soil organic matter concentrations contribute to warming during microwave treatment when starting at approximately 200°C [33]. The electrical conductivity of soil will also be affected by salinity since it influences the ability of soil to absorb electromagnetic energy through ion conduction. As a result, it impacts the loss factor of wet soil [34]. So, it follows that the primary concerns for soil dielectric property studies revolve around three parameters: frequency (600–8000 MHz), type of soil, and moisture present in the soil.

Different techniques are used for dielectric property measurements [35]. For frequencies between 50 and 100 MHz, the cavity resonator effectively works with trim loss materials. Free space analysis is helpful for significant, level, reedy, and shunt samples, and it can handle great frequencies (1 GHz–100 GHz) and temperatures over 373°C. Due to the nature of the lumped circuit approach, only frequencies below 100 MHz should be used. In contrast, because of the concern about loss, the distributed circuit technique is often not suitable. The transmission line method is most suitable for liquids and solids, but not gases, because of their low permittivity in this frequency range of 20 to 100 GHz [35–37]. To conduct dielectric property testing, a closed-loop coaxial probe is sometimes used with food grains. This particular measuring instrument, a VNA, was often used with this kind of test [38–41]. Based on the soil characteristics, the most frequently used model was dielectric mixing [42]. The semiempirical model was suggested based on soil structure, moistness presence, unpackaged density, and temperature.

Extensive diversity of soil sorts, moistness levels, and frequencies is required to examine soil's dielectric characteristics and identify its heating pattern. To meet the goal of this study, the following tasks were completed: (i) assessed the frequency range (600–8000 MHz) for soil's dielectric properties and (ii) developed a multidynamic mixing model to predict soil dielectrics by combining different mathematical models, according to the results of Debye models.

2. Materials and Methods

2.1. Preparation of Soil Samples. Four soil types were utilized in this investigation to examine the dielectric characteristics of various types of the soil as in Table 1. Ramanagara, situated at 12.9°N, 77.2°E, served as the source for clay loam soil, while the other three soil types were gathered from Jain University in Bengaluru (JU) Karnataka, India: Magadi wheat field loamy soil (12.5°N, 75.2°E), clay soil from Kanakapura rice field (13.5°N, 80.4°E), and sugarcane field Frank soil (13.8°N, 81.4°E). The samples were allowed to dry for one week after collection. The aggregates were broken down to remove unwanted components such as dried roots, grasses, stones, and gravel preceding to be separated using a 1.5 mm soil filter, which results in a better assessment of the dielectric characteristics. To achieve an even distribution of nutrients, the different soils were carefully assorted by using the slicing technique.

2.2. Exploration of Soil Assets. Before they are sent to the laboratory for the complete analysis, samples are dried at 45°C for one day. Table 2 represents the data obtained after the experiment.

Table 2: Experimented data of soil assets.

Soil assets	Analytical method	Type of soil			
		Bangalore	JU loamy	JU clay	JU frank
Structure	Hydrometer and filter study	Clay loam	Loam	Clay	Frank
Sand		48.0	58.2	49.6	84.8
Silt		15.1	24.9	18.2	7.2
Clay		35.6	21.1	33.1	6.7
Field capacity	Gravimetric	66	68	74	18
Organic carbon	Walkley and black	0.74	1.42	0.54	0.75
Electrical conductivity	Walkley and black	1.7	0.8	2.6	0.9
pH	1 : 5 $CaCl_2$	7.6	5.8	7.3	5.4

2.3. Preservation of Soil Dampness. Four types of soil moisture (dry, 33%, 66%, and 100% CC) were maintained. To measure the volume of the soil field, a funnel was employed. The distilled water of 20 ml was then added to the soil to promote germination. A funnel was positioned in a cylinder of the correct volume and left overnight to measure the gravity water in the cylinder. The volume basis CC of the soil was calculated using the equation [43]. After drying, the soil samples were allowed to dry at 100°C for one day altogether. The other moisture content was reached by adding further deionized water to the soil and gently stirring it. To prevent water loss, all of the samples were stored in locked plastic bags at 3°C. Table 3 shows the particulars of the experiment attempting to find out all the variables of dielectric characteristics at once.

Table 3: Details of experiment.

Type of soil	Presence of moisture (CC) (%)	No. of samples observed
Clay loam	33	8
	66	8
	100	8
Loam	33	8
	66	8
	100	8
Clay	33	8
	66	8
	100	8
Loamy Frank	33	8
	66	8
	100	8

2.4. Measurement of Soil Dielectrics. A VNA (N5230 A PNA-L network analyzer) was used to quantify the complex permittivity as in Figure 1. To accurately evaluate the dielectric characteristics of materials, the network analyzer could determine frequencies from 10 to 50 GHz.

The primary portion of the analyzer was linked to an external computer, which in turn was connected to Agilent's related analytical software, which was implemented with an embedded algorithm for calculating permittivity characteristics. The network analyzer was calibrated using three standards before the test. The electrical short was created by a metal sheet that was placed below the probe. A set of standards, such as water or Teflon or ceramic, was used to validate the calibration (the test was conducted to ensure the calibration was correct). The dielectric characteristics of the experimental samples were then tested once they had acquired satisfactory values for the reference samples.

Different soil samples were examined in terms of their dielectric characteristics, with measurements spanning the frequency range of 600 to 8000 MHz. The frequency range used by industries, scientific and medical applications, and other expected usage frequencies, falls within this range. To increase the certainty of the statistics, samples were measured three times, with three replications of the process and three observations in each replication. The results from each replication were combined to give three averages, and this value was used for additional numerical examination. The integrity of the dimensions was protected by placing the soil sample in a 2.8 cm long ampule that had a diameter of 1.5 cm. Every experiment was performed at ambient temperature (25°C ± 3°C).

2.5. Dispersion Deepness and Wavelength. When it comes to dielectric materials, the two most significant factors are the dielectric constant and loss. Microwave treatment controls the warming design of a specific shape. Additional data acquired from the measurement of dielectric characteristics and the depth of the electromagnetic waves in the soil may include the wavelength of the waves [43, 44]. The electromagnetic power density starts decreasing from its surface value to a drop of 36.8% [2, 43].

2.6. Analysis by Cole-Cole. It is often required to conduct a curve-fitting analysis to get the observed complex permittivity. Debye relaxation model and dielectric relaxation time are often used in curve-fitting studies. The complex permittivity of a pure polar substance is given by Debye:

$$\varepsilon = \varepsilon_{\infty} + \frac{\delta_s - \delta_{\infty}}{1 + jw\tau} - j\frac{\sigma}{w\varepsilon_0}. \quad (1)$$

The respective parameters are mentioned in [45]. The Debye equation cannot be simplified because all of the materials are not entirely polar. Consequently, it takes more time for the system to relax, and therefore, the Debye equation shown in (2) is not simplified [46]:

$$\varepsilon = \varepsilon_{\infty} + \frac{\varepsilon_s - \varepsilon_{\infty}}{(1 + jw\tau)^{1-\alpha}} - j\frac{\sigma}{w\varepsilon_0}. \quad (2)$$

Real and fictional dielectric features may be divided into two components, as shown by Cole and Cole in (3) and (4) [46]:

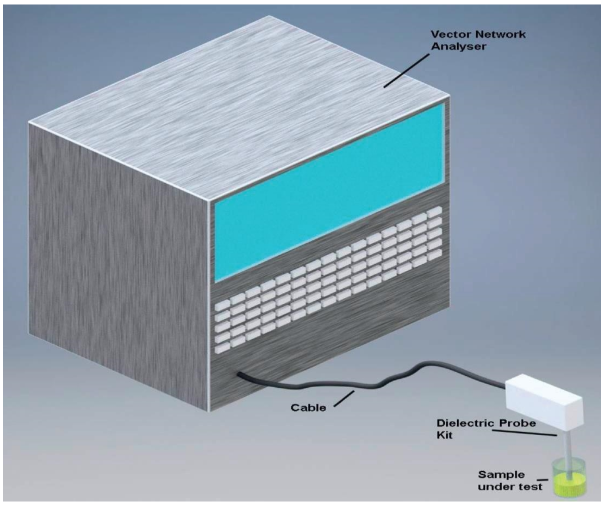

Figure 1: Representation of the vector network analyzer (VNA) (N5230 A PNA-L) with the sample under test.

$$\varepsilon' = \varepsilon_\infty + \frac{(\varepsilon_s - \varepsilon_\infty)\left[1 + (wt)^{1-\alpha}\sin(\alpha\pi/2)\right]}{1 + 2(w\tau)^{1-\alpha}\sin(\alpha\pi/2) + (wt)^{2(1-\alpha)}}, \quad (3)$$

$$\varepsilon'' = \frac{(\varepsilon_s - \varepsilon_\infty)(w\tau)^{1-\alpha}\cos(\alpha\pi/2)}{1 + 2(w\tau)^{1-\alpha}\sin(\alpha\pi/2) + (wt)^{2(1-\alpha)}} + \frac{\sigma}{w\varepsilon_0}. \quad (4)$$

Additionally, it is apparent that the dielectric characteristics of most ordinary ingredients, which include most vegetation, are connected to the moisture presence of the material, which may be either the extent of water in the substance or the percentage of water in the vegetation:

$$\varepsilon(m) = \left[\varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{(1 + jw\tau)^{1-\alpha}} - j\frac{\sigma}{w\varepsilon_0}\right]\cdot F(m). \quad (5)$$

3. Results and Discussion

Figure 2 demonstrates dielectric characteristics of all soil samples at various frequencies and moisture content.

The findings from this study are used to provide a representative sample of the dielectric characteristics of soil concerning frequency, soil type, and moisture, as shown in Table 4.

Dryness often increases as moisture is depleted, and this happens to both the actual (dielectric constant) and fictional (loss factor) properties of the dielectric (i.e., dry, 33%, 66%, and 100% CC).

Soil moisture is the primary determinant of soil dielectric characteristics since dry soil has a limited dielectric capacity. It was reported in [47, 48] that, with increased moisture content, the dielectric value also increases. Inversely related to their sand content and the moistness holding capability, therefore, the CC of soils is proportional to their water-binding capacity. Because of a significant amount of sand (84.8% (Table 2)), the JU loamy Frank's field capacity is lower than that of the other soils (48.0% to 58.2% (Table 2)).

When the frequency lowers, the JU clay soil's dielectric loss factor climbs significantly. The significant difference in ionic conductivity between these soils suggests that this may be linked to it (2.6 dS m^{-1}-Table 2). According to [46], the angular frequency (ω) is inversely proportional to ionic conductivity. Lower frequencies indicate it is more prominent; higher frequencies suggest it is smaller. When frequencies are lower, the dielectric loss factor in Bangalore soil is on the lower side, but when the moisture content is higher, the conductivity of the soil (1.7 dS·m^{-1}) is notable.

Most of the free water component has been leached away by gravity; thus, the remaining moisture is bound to water. The soil dielectric behavior was studied to establish an empirical formula for Debye [32].

Calculated best $F(m)$, which could represent the observed statistics, was

$$F(m) = \mathrm{erf}\left[-c(m - m_0)\right]. \quad (6)$$

As a result, in this research, these soils' dielectric constant and loss factors are defined by modifying (5) and by replacing (6):

$$\varepsilon' = \varepsilon_\infty + \frac{(\varepsilon_s - \varepsilon_\infty)\left[1 + (w\tau)^{1-\alpha}\sin(\alpha\pi/2)\right]}{1 + 2(w\tau)^{1-\alpha}\sin(\alpha\pi/2) + (wt)^{2(1-\alpha)}}\cdot \mathrm{erf}\left[-c(m - m_0)\right], \quad (7)$$

$$\varepsilon'' = \frac{(\varepsilon_s - \varepsilon_\infty)(w\tau)^{1-\alpha}\cos(\alpha\pi/2)}{1 + 2(w\tau)^{1-\alpha}\sin(\alpha\pi/2) + (wt)^{2(1-\alpha)}} + \frac{\sigma}{w\varepsilon_0}\cdot \mathrm{erf}\left[-c(m - m_0)\right]. \quad (8)$$

Figure 3 demonstrates how plot designs change with frequency and moisture content. Table 5 shows all the model equation's parameters for all soil types. JU Frank soil shows fit (r^2) of 0.964, whereas JU loam soil shows 0.995, signifying that the above models accurately represent the dielectric properties of these soils in which they vary by less than 0.2 percentage points over the assessment frequency range and moisture content range that were tested in this study.

What anticipated throughout this research was a more linear response to moisture content. The dielectric probe must be pressed down to establish excellent contact with the soil while making a measurement. Moisture inside soil makes the particles slide together, resulting in a higher bulk

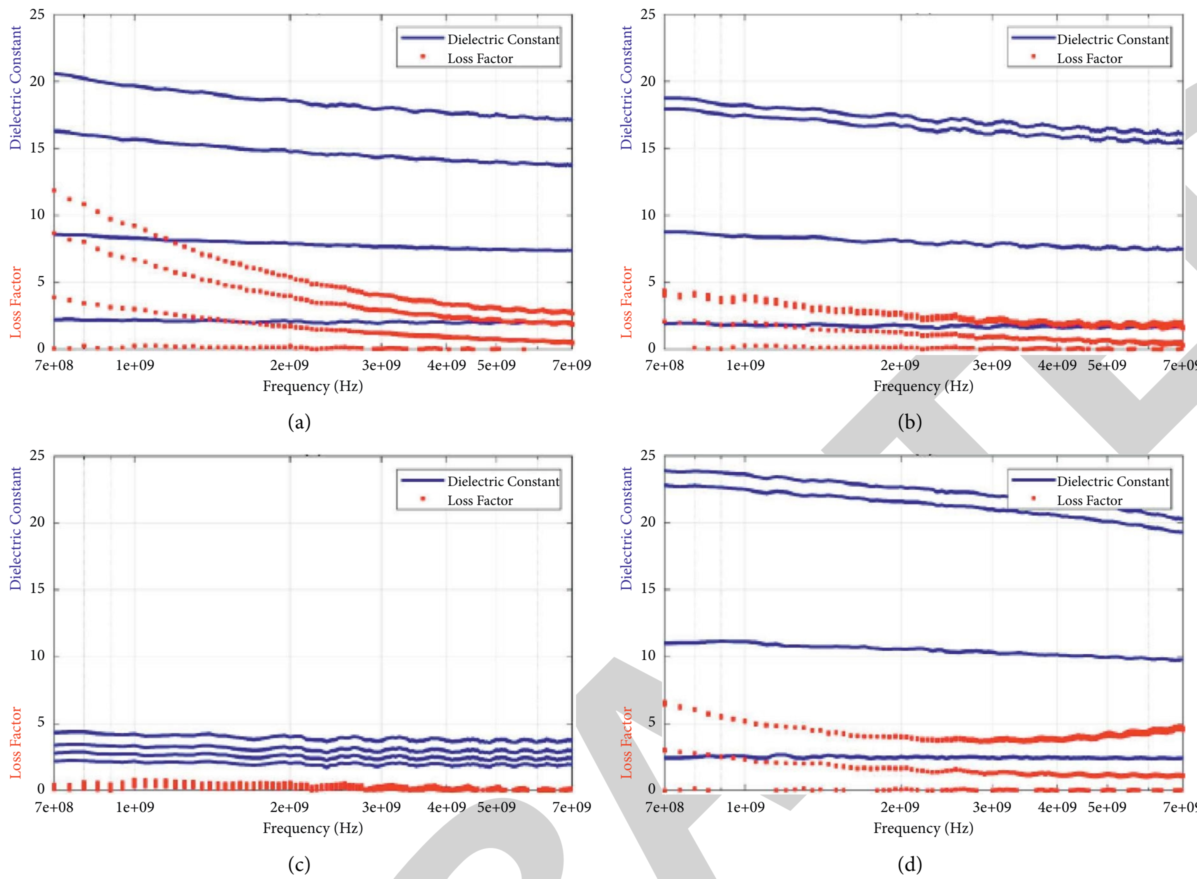

Figure 2: Four soil types were tested for their dielectric characteristics with respect to frequency and moisture presence: (a) JU clay, (b) JU loam, (c) JU frank, and (d) Bangalore clay loam.

Table 4: Information about soil moisture state, frequency, and type of soil in relation to dielectric data.

Type of soil	F (GHz)	Presence of moisture							
		Dry soil		33% CC		66% CC		100% CC	
		Real	Imaginary	Real	Imaginary	Real	Imaginary	Real	Imaginary
JU clay	0.8	2.204	0.059	8.478	3.712	16.301	8.658	20.621	11.760
	0.9	2.155	0.142	8.244	3.057	15.646	6.878	19.688	9.425
	1	2.214	0.262	8.214	3.001	15.594	6.700	19.685	9.215
	2	2.065	0.248	7.869	1.740	14.602	4.010	18.525	5.408
	2.54	1.998	0.147	7.771	1.432	14.513	3.418	18.215	4.652
	3	1.970	0.028	7.689	1.210	14.346	2.930	17.981	4.039
	4	1.999	0.001	7.549	0.909	14.111	2.306	17.621	3.346
	5	2.040	0.019	7.478	0.759	14.008	2.108	17.565	3.009
	5.95	2.019	0.119	7.426	0.621	13.842	1.968	17.354	2.817
	6	1.949	0.129	7.390	0.608	13.806	2.002	17.212	2.858
	7	2.004	0.197	7.385	0.501	13.720	1.868	17.054	2.612
JU loam	0.8	1.902	0.017	8.721	2.078	17.859	4.026	18.687	4.35
	0.9	1.835	0.140	8.425	1.858	17.401	3.546	18.184	3.859
	1	1.859	0.269	8.514	2.051	17.519	3.640	18.210	3.897
	2	1.782	0.205	8.041	1.200	16.539	2.578	17.304	2.718
	2.54	1.673	0.129	7.799	1.100	16.254	2.216	17.017	2.369
	3	1.658	0.058	7.749	0.917	16.073	2.006	16.701	2.217
	4	1.659	0.012	7.642	0.705	15.843	1.725	16.531	1.928
	5	1.728	0.028	7.671	0.667	15.819	1.805	16.538	2.042
	5.95	1.682	0.075	7.515	0.450	15.501	1.611	16.222	1.738
	6	1.612	0.072	7.445	0.463	15.428	1.718	16.100	1.844
	7	1.676	0.148	7.457	0.292	15.354	1.460	15.879	1.658

Table 4: Continued.

Type of soil	F (GHz)	Dry soil		Presence of moisture: 33% CC		Presence of moisture: 66% CC		Presence of moisture: 100% CC	
		Real	Imaginary	Real	Imaginary	Real	Imaginary	Real	Imaginary
JU Frank	0.8	2.185	0.102	2.708	0.114	3.401	0.201	4.309	0.472
	0.9	2.121	0.140	2.268	0.312	3.249	0.316	4.159	0.544
	1	2.109	0.324	2.655	0.408	3.369	0.611	4.241	0.811
	2	2.016	0.249	2.547	0.376	3.152	0.439	4.001	0.526
	2.54	1.871	0.187	2.441	0.287	3.001	0.323	3.818	0.424
	3	1.847	0.057	2.363	0.127	2.915	0.175	3.721	0.255
	4	1.877	0.001	2.383	0.056	2.944	0.087	3.734	0.159
	5	1.989	0.072	2.471	0.146	3.035	0.163	3.815	0.218
	5.95	1.925	0.119	2.423	0.101	2.976	0.101	3.733	0.063
	6	1.819	0.112	2.318	0.108	2.849	0.104	3.618	0.061
	7	1.912	0.215	2.419	0.224	2.950	0.230	3.738	0.217
Bangalore clay loam	0.8	2.445	0.001	11.01	3.001	22.725	6.589	23.715	6.129
	0.9	2.531	0.012	11.12	2.521	22.625	5.428	23.724	5.328
	1	2.551	0.031	11.10	2.324	22.524	5.114	23.621	5.142
	2	2.537	0.092	10.45	1.623	21.432	3.927	22.582	4.024
	2.54	2.402	0.044	10.37	1.474	21.156	3.814	22.213	3.814
	3	2.490	0.009	10.34	1.325	21.012	3.780	22.008	3.798
	4	2.462	0.001	10.10	1.142	20.425	3.798	21.328	3.825
	5	2.426	0.052	9.935	1.273	20.012	4.001	21.168	4.250
	5.95	2.471	0.018	9.914	1.176	19.715	4.121	20.759	4.365
	6	2.401	0.054	9.795	1.021	19.516	4.257	20.473	4.415
	7	2.421	0.039	9.780	1.119	19.173	4.498	20.195	4.625

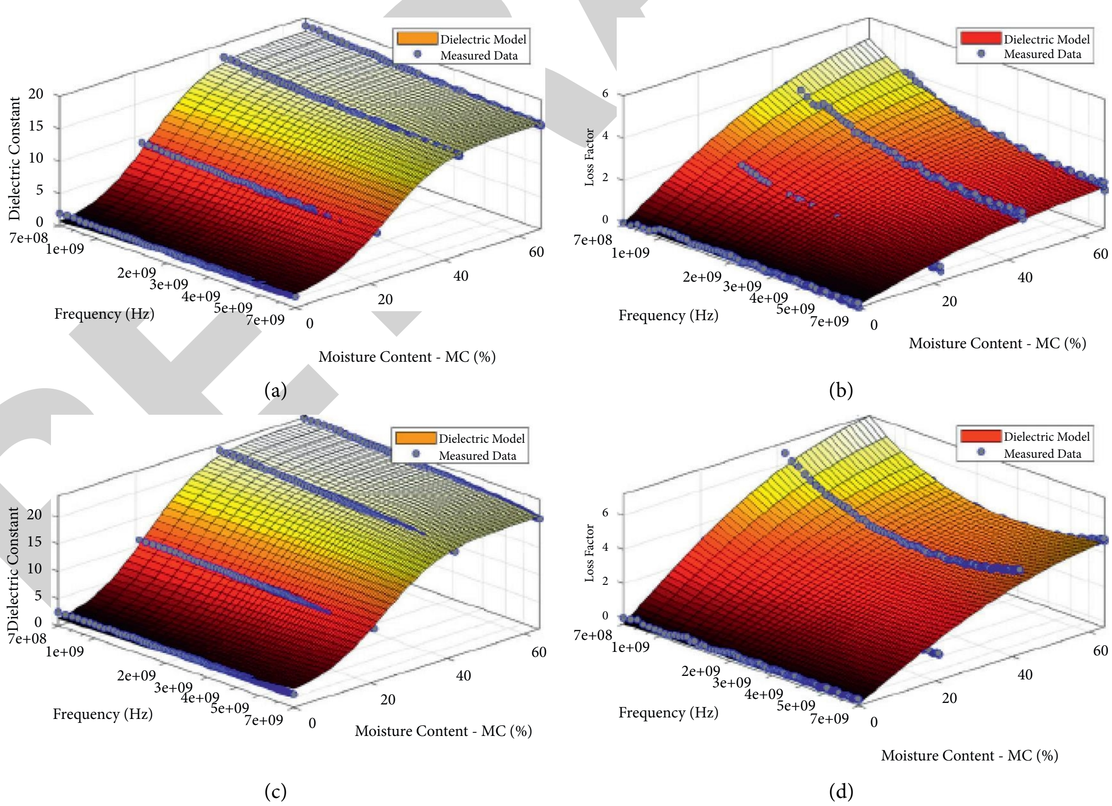

Figure 3: Comparisons between anticipated and observed dielectric characteristics for JU loam soil and Bangalore clay loam soil.

Table 5: List of all four soils investigated and their respective dielectric characteristics were simulated by the parameters utilized.

Parameter utilized	Types of soil			
	JU clay	JU loam	JU frank	Bangalore clay loam
Permittivity at high frequency, ε_∞	8.874	9.102	3.125	9.850
Static permittivity, ε_s	20.250	21.784	4.269	22.112
Alpha, α	0.202	0.652	0.000	0.211
C	2.452	5.102	7.622	6.230
m_0	0.256	0.236	0.117	0.241
r^2	0.993	0.995	0.964	0.995

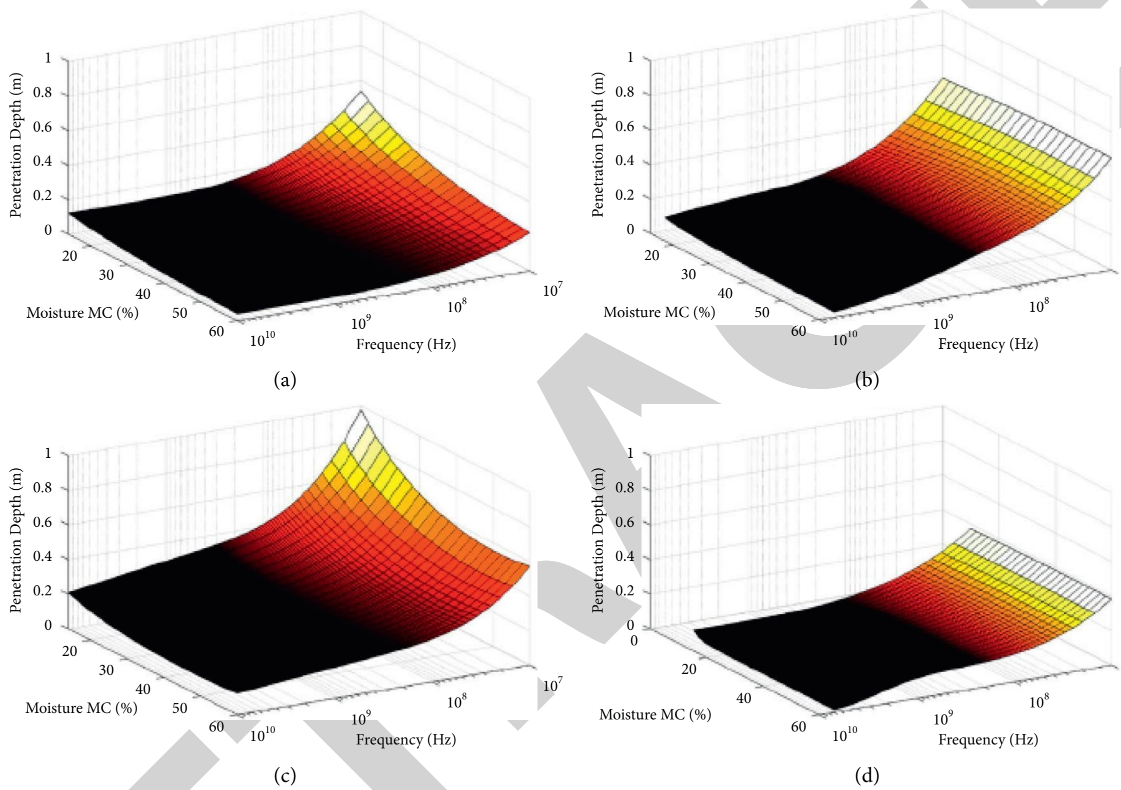

Figure 4: Various depths to which electromagnetic waves can penetrate in contrast to frequency and moisture content for (a) JU clay, (b) JU loam, (c) JU Frank, and (d) Bangalore clay loam soils.

density [49]. This will influence the dielectric characteristics. Optimal soil compaction occurs when the CC is 66%; as a result, the soil compaction measurements made when the test soil had 66% of its total capacity would have been greater than it should have been since the wet soil was under-compacted. It is feasible to calculate the dispersion deepness for electromagnetic waves in various soil types using models for dielectric characteristics, as shown in Figure 4.

Thus, dispersion deepness is related to frequency and moisture content, and as frequency drops, so does penetration. It is more difficult for low-frequency sound waves to reach the ground than for higher-frequency sound waves. Moreover, due to their dielectric characteristics, dry soils enable a greater penetration than wet soils because they have lower levels of electromagnetic field attenuation. While the image in Figure 4 shows soil texture impacts the depth of dispersion of electromagnetic energy, as JU Frank soil (Figure 4(c)) pierces deeper with lower moisture content and a frequency of 107 Hz Bangalore clay loam at similar moisture and frequency.

4. Conclusion

The dielectric behavior of soil was observed by the presence of moisture in the soil. Frank soil had considerably lower dielectric characteristics, while the Jain University (JU) clay soil had a far more significant dielectric loss factor. Several models were created with different frequency and moisture content settings to examine the dielectric characteristics of soils. For the JU Frank soil, the best fit ($r2$) diverges from 0.964 to 0.995 for JU loam soil. The findings shown above indicate that the models used to estimate the dielectric characteristics of these soils in this research were appropriate. To better understand how deep electromagnetic waves travel through soil, a new model was created that models the dielectric characteristics of the soil. In both frequency and moisture content, dispersion falls. For very low frequencies, the depth of the soil penetrates deeper than higher frequencies. As it is the case with wet soils, dry soils too provide better soil dispersion.

Data Availability

The data used to support the findings of this study are included within the article. Further data or information are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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