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Research Article

Study of Dielectric Constant and Dielectric Loss of some Igneous Rocks at Frequencies in X - band under Ambient Atmospheric Conditions

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Abstract: Microwave remote sensing of rock requires the study of dielectric parameters like dielectric constant and dielectric loss of rocks. In this paper dielectric constant of five igneous rock samples Rhyolite, Granite, Tholeiite Basalt, Dolerite Dyke, Basalt Ferro have been measured at three microwave frequencies 9.32 GHz, 9.72 GHz and 10.25 GHz of X-band by using waveguide cell method, under ambient atmospheric conditions. Dielectric loss was then calculated from dielectric constant for all rock samples. The result shows that the dielectric constant of igneous rocks under ambient atmospheric conditions decreases with increase in frequency. Loss factor for basic rock samples are greater than that for acidic rock samples at a fixed frequency.

Keywords: Dielectric constant, igneous rocks, microwave frequency.

INTRODUCTION

The study of earth's surface is important for remote sensing applications. Its image is a function of geometric forms and dielectric properties like dielectric constant and dielectric loss of the objects on the earth. Minerals and rocks are the most widespread objects on the earth surface; hence, their properties are fundamental significance in microwave remote sensing. Several studies have been reported in the literature on the dielectric properties of rocks [1-6], but in most of these studies, the reported experimental measurements had been made either at MHz or lower frequencies, or at one or very few microwave frequencies. The dielectric properties of rocks are primarily a function of frequency, temperature, moisture content and depending on rock petrology and electrochemical interactions[1]. Above 1 MHz frequency there is small variation in dielectric constant of dry rocks. In microwave frequency region most of the dry rocks have almost frequency independent values of dielectric constant[2]. Under atmospheric conditions rocks absorbing minute amount of moisture from the atmosphere. Due to absorption of moisture there is variation in dielectric constant of the rock. The measurements of dielectric constant and of rocks in microwave region under ambient atmospheric conditions have remained the subject of investigation.

It was observed that by controlling the variation of moisture content in the rock samples, the dielectric constant of rocks is a function of frequency in microwave region. In the present paper, dielectric constant of five igneous rock samples was measured at three microwave frequencies of X - band region from 8 GHz to 12 GHz.

EXPERIMENTAL DETAILS

Sample Preparation: We have measured the dielectric constant of five igneous rock samples viz Rhyolite, Granite, Tholeiite Basalt, Dolerite Dyke, Basalt Ferro at microwave frequencies 9.32 GHz, 9.72 GHz and 10.25 GHz. Samples shaped according to the dimension of rectangular waveguide i.e. with cross section 2.286 cm. x 1.016 cm.

Dielectric constant and loss factor measurement at microwave frequency: To avoid the variation in moisture content of rock samples, each sample exposed to same treatment in its preparation and was measured under same atmospheric conditions. Also all measurements were made at room temperature about 35^0 C and for three different lengths of each sample. The average value of dielectric constant was taken as true value of dielectric constant. The X-band microwave test bench equipped with Gunn Oscillator was used to measure dielectric constant of rock samples under study. For accurate measurement of dielectric constant, width at twice minima method was used Lance [7]. Following steps followed in this method.

(i) The frequency of source was determined by taking micrometer reading of cavity resonator.

(ii) The guide wavelength, λ_g, was measured by short circuiting waveguide section.

(iii) The distance, ΔX, shown in **figure 1** was measured by width at twice minima method.

(iv) The position of minima without sample 'A' was recorded **(figure 1).**

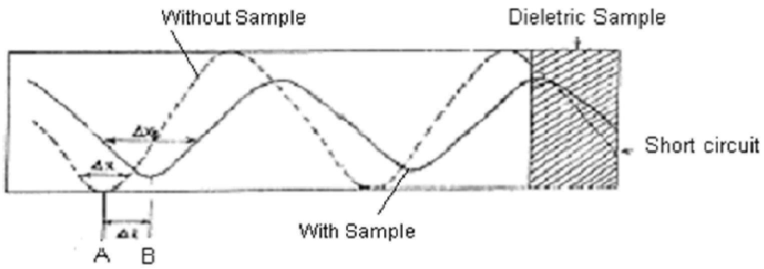

Figure 1: Standing waves in the waveguide with and without sample

(v) Rock sample was then introduced in the waveguide touching the short-circuit end.

(vi) The distance, ΔXs, was measured.

(vii) The position of minimum 'B' of standing wave pattern occurring with sample was recorded **(figure 1).**

(viii) Shift in minima Δlwas calculated. The dielectric constant calculated by using the formula given in equation (1).

Dielectric constant: Dielectric constant (ε') given by the following formula

$$\varepsilon' = (X\lambda_o/2\pi d)^2 + (\lambda_o/\lambda_c)^2 \qquad (1)$$

where, λ_o is the free space wavelength (= 3.03 cm), λ_c the cutoff wavelength (= 4.582 cm), d the thickness of the sample and X the multivalued function and its value was chosen from the tables of (tanX/X) given by Von Hippel[6].

Loss tangent (tan δ): The loss tangent calculated using the formula Lance [7]

$$\tan\delta = \{|DXs - DX|/\varepsilon' d\}\,(\lambda_o/\lambda_g)^2 \qquad (2)$$

Loss factor or Dielectric Loss (ε''): The loss factor, **ε''**, is determined from the following formula

$$\varepsilon'' = \varepsilon' \tan\delta \qquad (3)$$

RESULTS AND DISCUSSION

Variation of Dielectric Constant of rock samples with Microwave frequencies in X – band region: Table 1 summarizes the values of dielectric constant for five rock samples at three frequencies 9.32 GHz, 9.72 GHz and 10.25 GHz.

Table-1: Dielectric Constant of rock samples at three frequencies.

Frequency (ω) in GHz	Dielectric constant (ε')				
	Acidic Rocks			Basic Rocks	
	Rhyolite	Granite	Dolerite Dyke	Tholeiite Basalt	Basalt Ferro
9.32	2.26	2.06	2.23	2.27	2.16
9.72	1.85	2.03	2.03	2.11	2.13
10.25	1.46	1.96	1.74	1.83	2.05

Fig. 2 shows variation of dielectric constant with frequency for all rock samples. This indicates that the dielectric constant decreases slightly with increase in frequency. This is because, as frequency increases the dipoles of the molecules tend to orient randomly. At high frequencies, the dipole cannot follow the field and remains randomly oriented. As a result, the field cannot induce dipole moment. So that the relative permittivity i.e. dielectric constant of the material remains unchanged, Kasap[3].

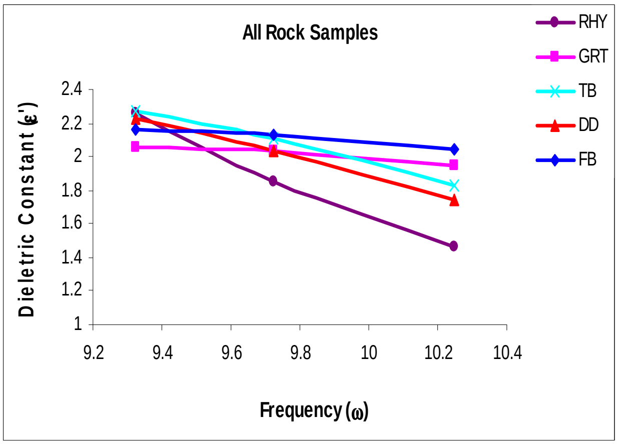

Figure 2: Variation of Dielectric Constant with Frequency for all rock samples

Fig. 3 shows variation of dielectric constant with frequency for acidic rocks, Rhyolite (RHY) and Granite (GRT). It is observed that in Rhyolite the dielectric constant of decreases with increase in frequency with relatively high rate while in case of Granite the dielectric constant decreases with slow rate. This may happen because of high density of Granite than Rhyolite, dipoles in Granite cannot respond instantaneously to the changes in the applied electric field i.e. frequency.

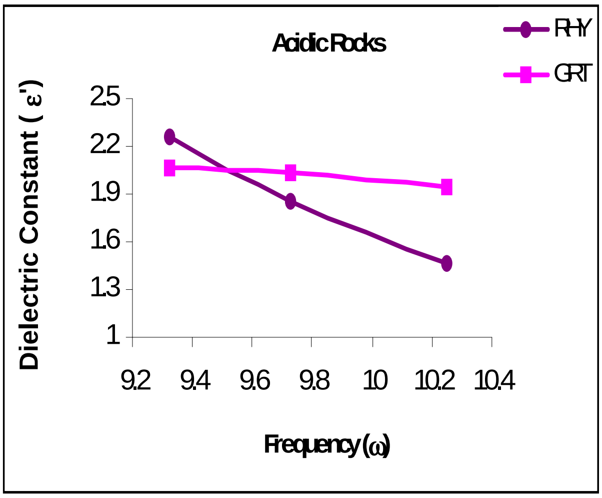

Figure 3: Variation of Dielectric Constant with Frequency for acidic rock samples

Fig. 4 shows variation of dielectric constant with frequency for basic rocks Tholeiite Basalt (TB), Dolerite Dyke (DD) and Ferro Basalt (FB). In all rocks it is observed that dielectric constant decreases with frequency. Here also because of high density of Ferro Basalt, the change in dielectric constant is very slow as compared to Tholeiite Basalt and Dolerite Dyke. Chung et al. [2] and Ulaby et al.[4] reported that the dielectric properties of igneous rocks and volcanic rocks are sensitive to frequency in microwave region.

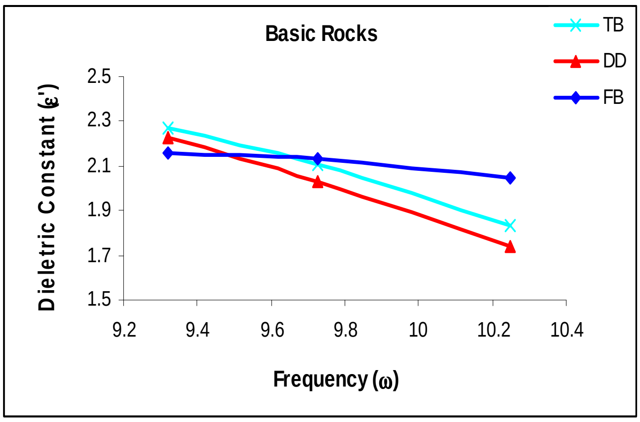

Figure 4: Variation of Dielectric Constant with Frequency for basic rock samples

Variation of Dielectric Loss of rock samples with Microwave frequencies in X – band region: An ideal dielectric releases all its stored energy to the external circuit when the electric field is removed, but practical dielectrics dissipate some of energy as heat. The loss factor is a measure of the portion of stored energy, which gets converted to heat. Its value always falls between 0 and 1. Loss factor is affected by several factors like frequency, moisture content and temperature. In the study of dielectric properties of rocks by Ulaby et al. [4], they showed that the chemical composition and crystal structure are presumed to be important determinants of dielectric loss. The investigations by the authors, of dielectric constant of Limestones, Marbles and Indian Granites Sengwa and Soni[8-10] also favorthe results of Ulaby et al. [4], at microwave frequencies. Sengwa and Soni[10] studied the dielectric behavior of minerals at microwave frequencies. They reported that the presence of Na_2O and K_2O in fuller earth leads to the large value of loss factor. **Table 2** gives values of loss factors of five rock samples at three frequencies, 9.323 GHz, 9.725 GHz, and 10.25 GHz.

Table-2. Loss factor of rock samples at three frequencies.

Frequency (ω) in GHz	Loss Factor (ε'')				
	Acidic Rocks		Basic Rocks		
	Rhyolite	Granite	Dolerite Dyke	Tholeiite Basalt	Basalt Ferro
9.32	0.011726	0.0113159	0.02535957	0.026369522	0.034632
9.72	0.0179809	0.0243933	0.07556294	0.067756279	0.029791
10.25	0.0392381	0.0432431	0.02973225	0.108001993	0.05833

From **Fig. 5** it is observed that, the values of loss factor for basic rock samples are in general greater than that for acidic rock samples at a fixed frequency. In acidic igneous rock samples, Rhyolite (RHY) and Granite (GRT), the loss factor increases with frequency. But no concrete conclusion can be drawn about basic rock samples. In Tholeiite Basalt (TB), the loss factor increases with frequency. In case of Ferro Basalt (FB) initially the loss factor decreases and then increases with frequency. While in case of Dolerite Dyke (DD) initially the value of loss factor increases and then decreases with frequency.

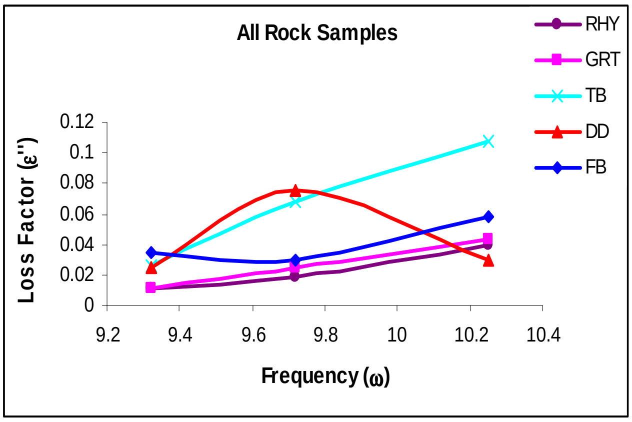

Figure 5: Variation of Dielectric Loss with Frequency for all rock samples

The study of rocks is much important and useful for us. The present work has much future scopes. The study of rocks in powder form of different grain size is much important and can reveal much more about the interior dielectric properties of rock. Also the comparison of dielectric constant of rocks along with their density and chemical composition can reveal much more information about dielectric properties. All these study can be helpful in further knowledge of usefulness of rocks.

CONCLUSIONS

Following conclusions are made from graphs

- The dielectric constant decreases slightly as frequency increases within the range for acidic as well as basic rock samples.
- In Rhyolite the dielectric constant decreases with increase in frequency with relatively high rate.

- In Basalt Ferro and Dolerite Dyke rocks, the dielectric constant decreases with increase in frequency with moderate rate.
- In Granite, the dielectric constant decreases with relatively high rate for lower frequencies up to 9.3 GHz and afterwards decreases slowly with frequency.
- The values of loss factor for basic rock samples are greater than that for acidic rock samples at a fixed frequency.
- In acidic igneous rock samples, Rhyolite and Granite, the loss factor increases with frequency while no conclusion can be made for basic rock samples.

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