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# Dielectric response of sandstones of Rajasthan in the frequency range 200 MHz-20 GHz

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***Abstract***- Dielectric response (ε', ε'') of nine different dry and water saturated sandstone samples of Rajasthan were measured in the frequency range 200MHz-20GHz. Result has been presented in the form of variation with frequency which showed characteristics features. The change observed in dielectric characteristic with water saturated sample is interpreted as existence of water molecules in free space of sandstones samples. The mechanisms that influence the dielectric values of sandstone are strongly dependent on the frequency of electromagnetic field. The ac conductivity, bulk density and porosity were also measured for dry and water saturated sandstone samples.

***Keywords****: dielectric constant, ac conductivity, sandstone, frequency, water saturated*

## I. INTRODUCTION

Dielectric behaviour of sandstone and rock samples are important in the field of mining, planning ground penetrating radar (GPR) [1-3], microwave remote sensing [4-12], calibration of time domain reflectrometer (TDR) [13-15], investigation of individual contribution, induced polarization and detection in pollutants in ground water. Several studies [16-25] have been reported in the literature on the dielectric properties of rocks. Their measurements are either at MHz or lower frequency or at one or very few microwave frequencies.

In this work we reported the variation in dielectric constant, ac conductivity and loss tangent for dry and wet sandstone samples in frequency range 200MHz-20GHz at room temperature (300.15K). These parameter are related with water contain, chemical properties and physical properties like frequency, density, porosity, size of the sandstone particles, temperature and electrochemical interaction [16,17,20,22]. It is difficult to confirm the accurate contribution of each chemical and physical quantity to reported ε 'and ε'' but in all parameter water saturation and frequency part are most dominate the dielectric response.

## II. EXPERIMENTAL

### (a) Sample collection and preparation

Nine sandstone samples were collected from open mining area of desert region of Rajasthan.

- Nagaur (Khatu Khurd 27.1563° N, 74.3499° E)
- Nagaur (badi khatu 27.1161° N, 74.3302° E)
- Nagaur (badi khatu 27.1161° N, 74.3302° E)
- Jodhpur ( Soorsagar 26.3098° N, 73.0048° E)
- Jodhpur ( Rohila Kalan 26.2303° N, 72.8604° E)
- Jodhpur ( Rohila Kalan 26.2303° N, 72.8604° E)
- Jodhpur( Balsamand 26.3357° N, 73.0329° E)
- Kota (Rawatbhata24.9306° N, 75.5909° E)
- Jaisalmer( Jethwai 26.9805° N, 70.9190° E)

 

Each sample was cut by a diamond wheel cutter and was polished to get fine surface for proper probe contact. Three samples were prepared from a same piece of the original sandstone rock and are shown in figure 1. Samples were fully dried using oven for 7-8 hour at a temperature of $90^0$c for measurement and wet samples were saturated with distilled water for seven days. Before measurements water on surface of the sample was removed using soft tissue paper.


Figure: 1 - sandstone samples of Rajasthan

**(a) Analysis of physical and chemical properties**

The physical and chemical properties of the sandstone samples were measured at "Moni's Grosam Engineering Lab" Jodhpur. They are presented in table 1 & 2 respectively.

**(b) Measurement Method**

The measurement were carried out using Anritsu Shockline Vector Network Analyzer [26], (VNA) Model No.-MS46322A along with SPEAG DAK dielectric assessment kit at Microwave Research Laboratory, Department of Physics, School of Sciences, Gujarat University, Ahmedabad, India. It is used to measure the dielectric parameters like dielectric constant, dielectric loss, loss tangent, etc. for dry and water saturated samples. For calibration we use two liquids HPLC water and Methanol to nullify the measurement error. Dry and wet samples are gently brought into contact with the probe tip. Sweep is commanded to Anritsu Shockline VNA through DAK software. Dielectric constant, dielectric loss, loss tangent and electrical conductivity have been carried out by this software.

## III. RESULTS AND DISCUSSION

The variation in dielectric constant at different frequencies for dry and wet sandstone samples for Nagaur, Jodhpur, Kota and Jaisalmer region are shown in figure 2 - 4 respectively. The values of dielectric constant of dry sandstone samples of Nagaur region varies from 3.80 to 1.41 and for wet samples varies from 6.90 to 2.57. The values of dielectric constant of dry sandstone samples of Jodhpur region varies from 4.71 to 1.49 and for wet samples varies from 6.63 to 2.32. The values of dielectric constant of dry sandstone samples of Kota region varies from 3.98 to 1.69 and for wet samples varies from 4.78 to 3.57.The values of dielectric constant of dry sandstone samples of Jaisalmer region varies from 7.32 to 4.19 and for wet samples varies from 7.95 to 6.25. From these graphs it is clear that the values of dielectric constant of sandstone samples for four district of Rajasthan are shown same variation.

The value of dielectric constant of dry sandstone sample of Jaisalmer is obtained higher (7.32) at frequency 200 MHz while for Jodhpur sample dielectric constant value is lower (2.41) at frequency 200 MHz. The value of dielectric constant wet sandstone sample of Jaisalmer is obtained higher (7.95) at frequency 200 MHz while for Jodhpur sample dielectric constant value is lower (4.58) at frequency 200 MHz. In general the value of dielectric constant for dry sandstone samples of all district decreases with increase in frequency from 200 MHz to 10000 MHz after that its values slightly increases and remains almost constant. The same variation in dielectric constant of all wet samples of four districts is obtained only the difference is that the value of dielectric constant is greater than the dry sample.

The variation in ac conductivity at different frequencies for dry and wet sandstone samples of Nagaur, Jodhpur, Kota and Jaisalmer region are shown in figure 5 to 7 respectively. The values of ac conductivity of dry sandstone samples of Nagaur region varies from 0.141 to 0.009 and for wet samples varies from 1.231 to 0.038. The values of ac conductivity of dry sandstone samples of Jodhpur region varies from 0.177 to 0.004 and for wet samples varies from 1.167 to 0.038.The values of ac conductivity of dry sandstone samples of Kota region varies from 0.208 to 0.010 and for wet samples varies from 0.609 to

 

0.040.The values of ac conductivity of dry sandstone samples of Jaisalmer region varies from 0.469 to 0.014 and for wet samples varies from 1.003 to 0.043.

The value of ac conductivity dry sandstone sample of Jaisalmer is obtained higher (0.469) at frequency 20000 MHz while for Nagaur sample ac conductivity value is lower (0.126) at frequency 20000 MHz. The value of ac conductivity wet sandstone sample of Nagaur is obtained higher (1.231) at frequency 20000 MHz while for Jodhpur sample ac conductivity value is lower (0.366) at frequency 20000 MHz.

The value of ac conductivity for dry sandstone sample of Nagaur increases with frequency up to 4000 MHz after that it decreases up to 9000 MHz and then it increases continuously up to 20000 MHz. The value of ac conductivity for dry sandstone sample of Jodhpur increases with frequency up to 5000 MHz after that it decreases up to 10000 MHz and then it increases continuously up to 20000 MHz and the value of ac conductivity for dry sandstone sample of Kota and Jaisalmer increases with frequency up to 4000 MHz after that it decreases up to 11000 MHz and then it show irregular variation in ac conductivity but for all wet sandstone sample of four district it increases continuously with frequency. The increase in ac conductivity is more at higher frequency region.

The variation in loss tangent with frequency for dry and wet sandstone samples of for Nagaur, Jodhpur, Kota and Jaisalmer region are shown in figure 8 to 10 respectively. The values of loss tangent of dry sandstone samples of Nagaur region varies from 0.294 to 0.010 and for wet samples varies from 0.749 to 0.090. The values of loss tangent of dry sandstone samples of Jodhpur region varies from 0.260 to 0.001 and for wet samples varies from 0.762 to 0.047.The values of loss tangent of dry sandstone samples of Kota region varies from 0.232 to 0.030 and for wet samples varies from 0.756 to 0.083.The values of loss tangent of dry sandstone samples of Jaisalmer region varies from 0.175 to 0.001 and for wet samples varies from 0.486 to 0.074.

The trend of loss tangent for dry sandstone sample of four district shows zig-zag variation with increase in frequency while for wet sample it decreases with increase in frequency from 200 MHz to 5000 MHz after that its value increases with

The variation in dielectric constant of dry rock and mineral samples at microwave frequencies is mainly due to variation in sample density and also due to the change in chemical composition of sample. The real part of dielectric permittivity dry geological sample remains almost frequency independent in the microwave region. The value of dielectric constant of Nagaur and Jodhpur region are same & also related with their density. The computed average values of density reduced permittivity $(\varepsilon'_{dr}) = (\varepsilon')^{1/d}$ of Nagaur and Jodhpur sandstone sample were found 1.28 and 1.39. The values of density reduced permittivity of Jaisalmer sandstone is higher than the other sandstone sample ($\varepsilon'_{dr}$ =1.74). Some sandstone sample show the enhancement in dielectric constant is proportional to water absorption in the sample and hence dielectric constant is proportional to porosity. The irregular variation in $\varepsilon''$ values is observed with increase in sample porosity. There is no directed convincing correlation between ε" values and bulk density of dry sandstone sample. The increase in percentage of $Fe_2O_3$ and $Al_2O_3$ ($\varepsilon'$ >12) in chemical composition of sandstone sample increases the $\varepsilon'$ values at frequency 200 MHz. The value $\varepsilon'$ of Jaisalmer sandstone sample is higher in comparison to other sandstone sample.

## IV. CONCLUSION

The variation in dielectric constant of dry sandstone samples of Nagaur, Kota, Jaisalmer and Jodhpur, shows same pattern but different values of dielectric constant with frequency. This indicates that apart from water content in the sandstone samples, chemical composition physical properties and its grain geometries also affect the dielectric constant ($\varepsilon'$) of the sandstone sample.

At low frequency dielectric constant of dry samples higher and it decreases with increase in frequency i.e. dry rock and mineral material show dielectric dispersion in low frequency region. In geological materials the low frequency dispersion is believed due to polarization associated with charge build up at grain boundaries or grain imperfection. At high frequency region it shows almost constant trend i.e. in microwave region the value of dielectric constant of dry rock and mineral samples are almost independent of the frequency. Similar response was found for wet samples with higher values of dielectric constant. At low frequency region ac conductivity of wet sample is small and constant but at microwave region ac conductivity is abruptly rises.

 

**Table 1: Physical Properties of Sandstone samples of different region of Rajasthan**

| S. No. | Location (Region) | Color | WA (%) | Porosity (%) | Density (gm/cc) |
|---|---|---|---|---|---|
| 62 | Nagaur (badi khatu 27.1161°N,74.3302°E) | Light Rainbow | 3.16 | 7.33 | 2.85 |
| 64 | Nagaur (badi khatu 27.1161° N, 74.3302° E) | Teakwood (yellow) | 7.16 | 14.13 | 1.91 |
| 75 | Nagaur (Khatu Khurd 27.1563° N, 74.3499° E) | Dark Rainbow | 3.58 | 7.74 | 2.20 |
| 70 | Jodhpur (Soorsagar 26.3098° N, 73.0048° E) | Pink | 3.47 | 8.08 | 2.42 |
| 71 | Jodhpur (Rohila Kalan 26.2303° N, 72.8604° E) | Beige Pink | 2.63 | 5.92 | 2.31 |
| 74 | Jodhpur (Rohila Kalan 26.2303° N, 72.8604° E) | Pink | 3.16 | 7.33 | 2.35 |
| 63 | Jodhpur (Balsamand 26.3357° N, 73.0329° E) | Red | 2.34 | 5.72 | 2.60 |
| 67 | Kota (Rawatbhata 24.9306° N, 75.5909° E) | Grey | 2.93 | 7.01 | 2.47 |
| 72 | Jaisalmer (Jethwai 26.9805° N, 70.9190° E) | Yellow | 3.32 | 8.15 | 2.60 |

**Table 2: Chemical Properties of Sandstone samples of different region of Rajasthan**

| S.No. | Location (Region) | $CaCo_3$ | $MgCo_3$ | $SiO_2$ | LOI | $Fe_2O_3$ | $Al_2O_3$ | $Mno_2$ |
|---|---|---|---|---|---|---|---|---|
| 62 | Nagaur (badi khatu 27.1161°N,74.3302°E) | 1.4 | 3.84 | 86.01 | 1.85 | 1.67 | 1.18 | 1.1 |
| 64 | Nagaur (badi khatu 27.1161° N, 74.3302° E) | 1.18 | 6.32 | 83.18 | 2.89 | 1.07 | 1.41 | 0.1 |
| 75 | Nagaur (Khatu Khurd 27.1563° N, 74.3499° E) | 5.14 | 4.98 | 80.04 | 1.44 | 1.14 | 0.63 | - |
| 70 | Jodhpur (Soorsagar 26.3098° N, 73.0048° E) | 0.84 | 1.07 | 89.41 | 0.98 | 1.70 | 1.97 | 0.07 |
| 71 | Jodhpur (Rohila Kalan 26.2303° N, 72.8604° E) | 3.1 | 2.18 | 84.68 | 0.90 | 1.55 | 0.63 | 0.08 |
| 74 | Jodhpur (Rohila Kalan 26.2303° N, 72.8604° E) | 1.44 | 1.78 | 88.72 | 1.60 | 1.68 | 1.07 | - |
| 63 | Jodhpur (Balsamand 26.3357° N, 73.0329° E) | 1.47 | 2.84 | 87.08 | 1.05 | 1.94 | 1.80 | - |
| 67 | Kota (Rawatbhata 24.9306° N, 75.5909° E) | 1.32 | 4.32 | 85.60 | 1.84 | 1.79 | 1.60 | 4.32 |
| 72 | Jaisalmer (Jethwai 26.9805° N, 70.9190° E) | 4.18 | 3.68 | 76.71 | 1.4 | 4.1 | 1.68 | - |

 

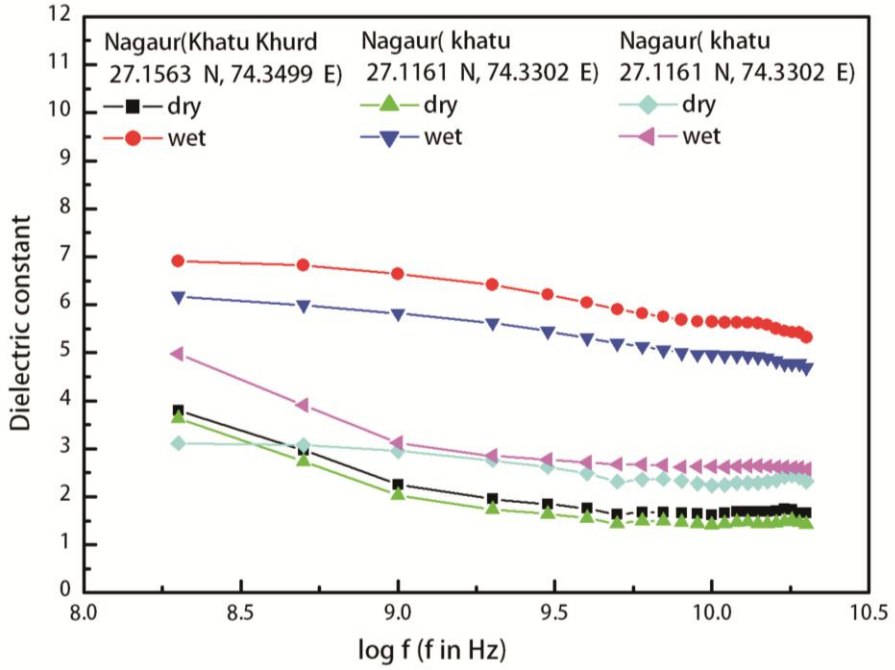


Figure:-2 Dielectric constant with frequency for dry and wet sandstone samples of Nagaur region

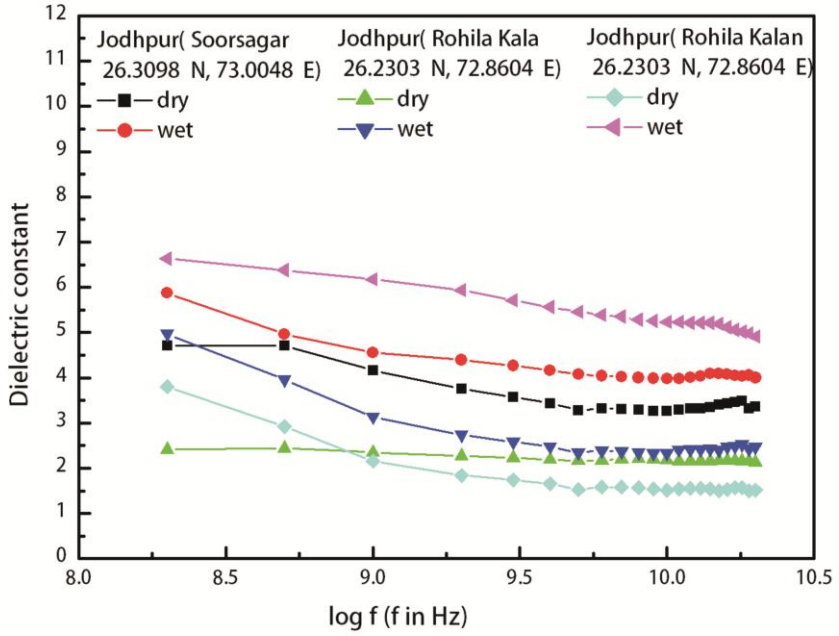


Figure:-3 Dielectric constant with frequency for dry and wet sandstone samples of Jodhpur region

 

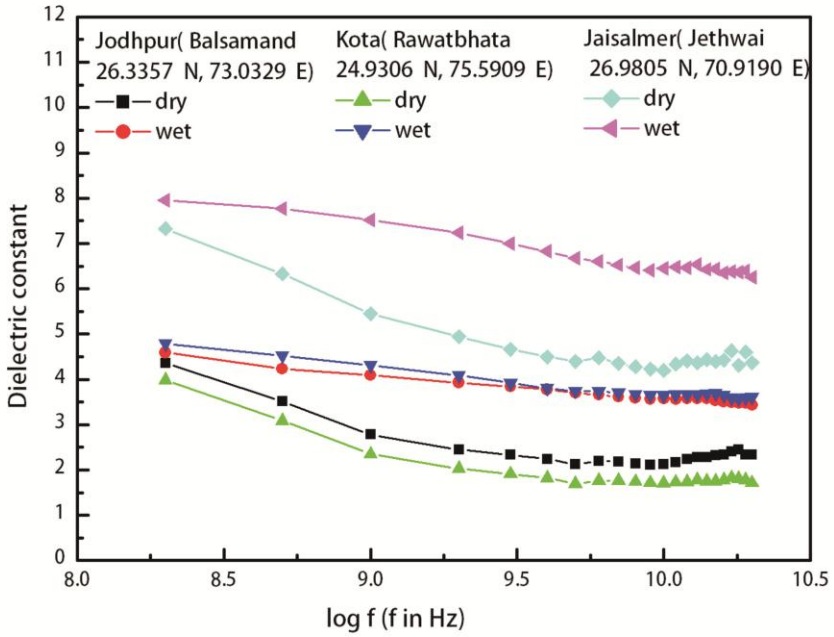


Figure:-4 Dielectric constant with frequency for dry and wet sandstone samples of Jodhpur, Kota and Jaisalmer region

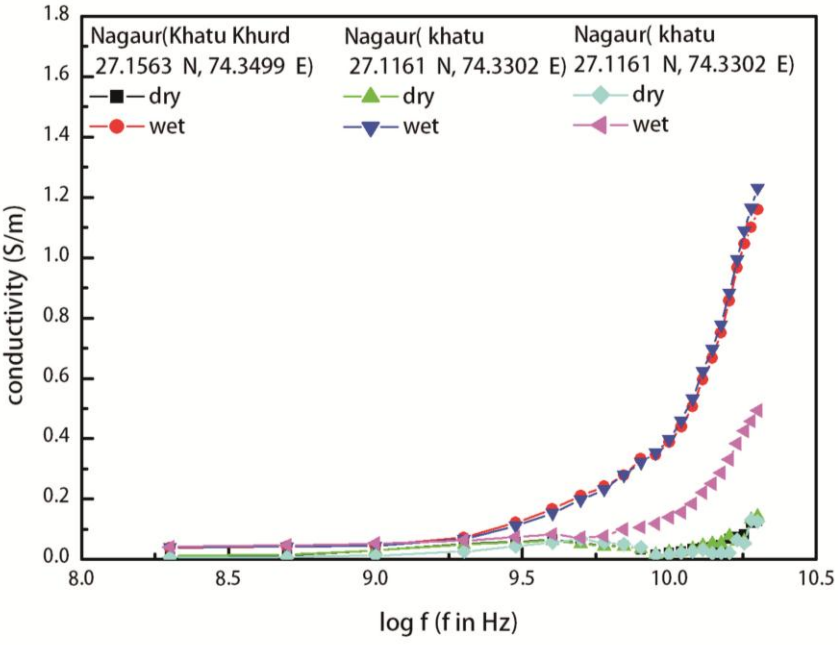


Figure: - 5 AC Conductivity with frequency for dry and wet sandstone samples of Nagaur region

 

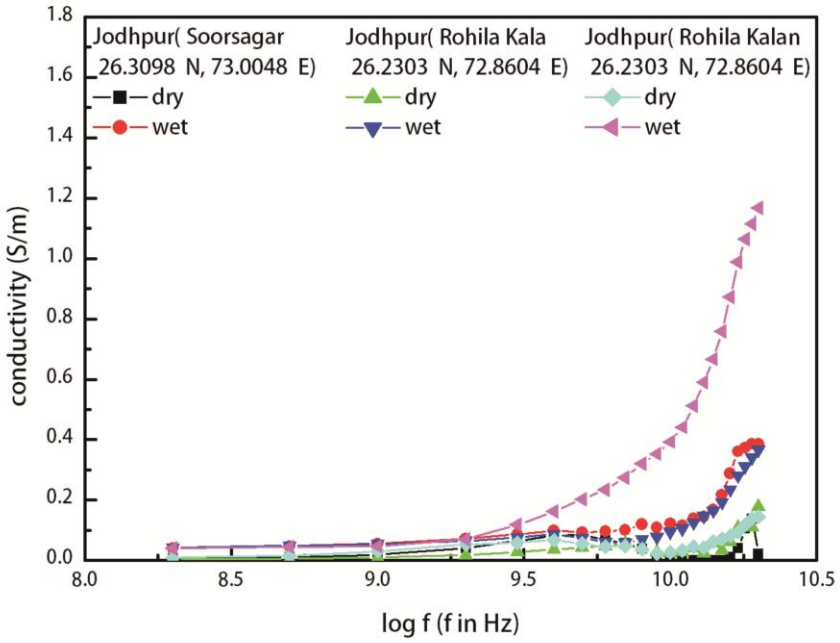


Figure: - 6 AC Conductivity with frequency for dry and wet sandstone samples of Jodhpur region

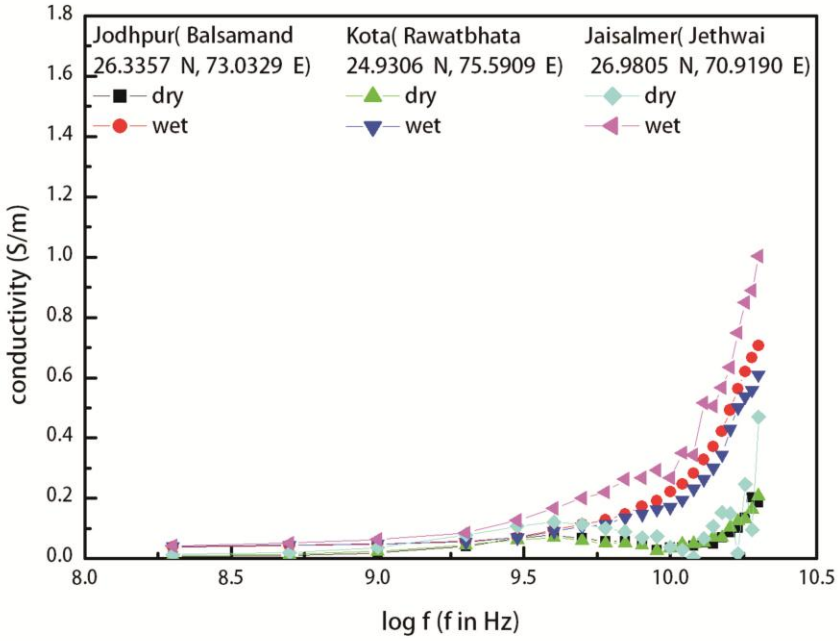


Figure:- 7 AC Conductivity with frequency for dry and wet sandstone samples of Jodhpur, Kota and Jaisalmer region

 

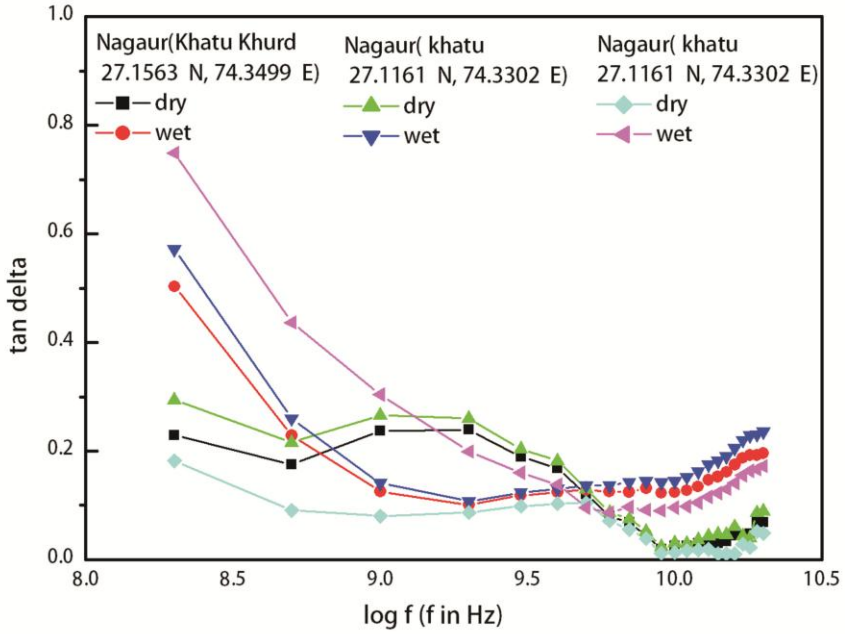


Figure: - 8 Loss Tangent with frequency for dry and wet sandstone samples of Nagaur region

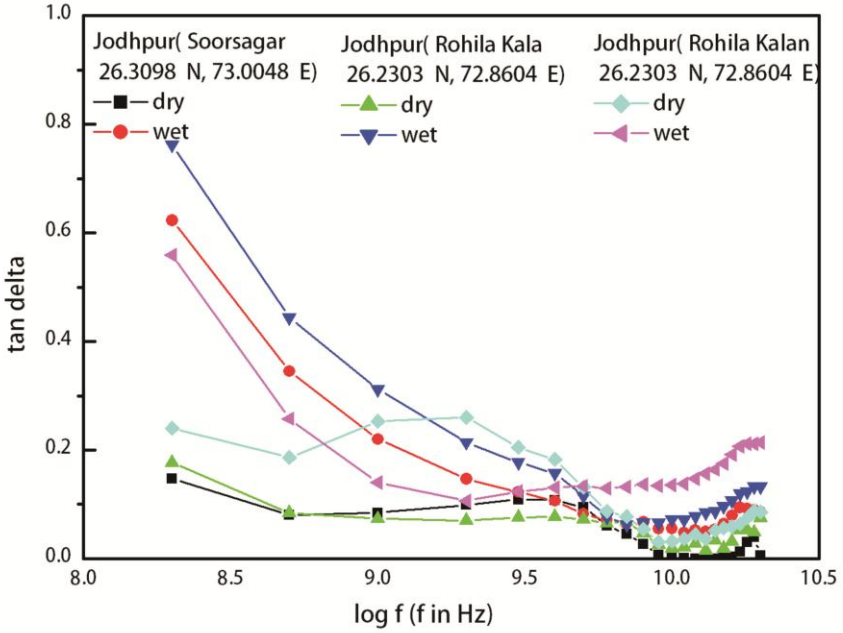


Figure: - 9 Loss Tangent with frequency for dry and wet sandstone samples of Jodhpur region

 

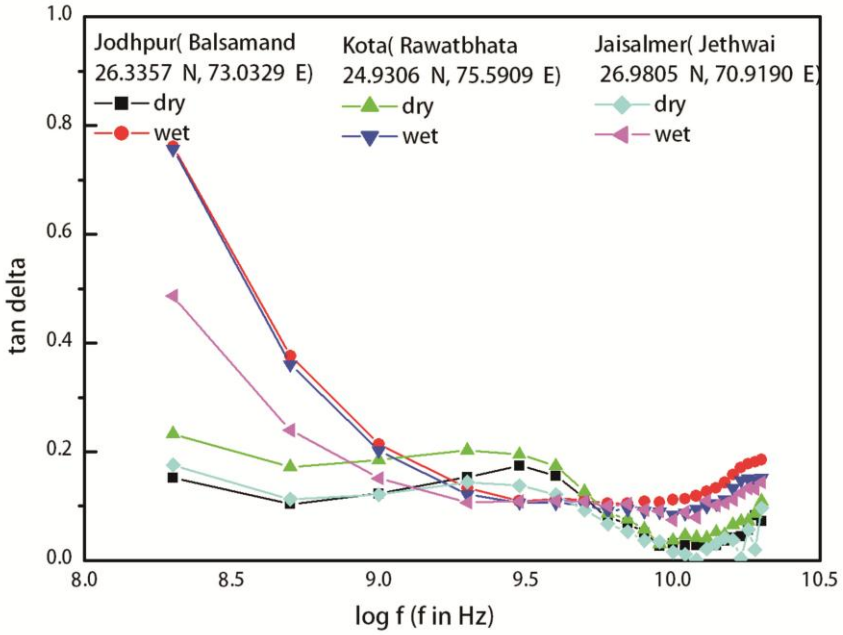


Figure: - 10 Loss Tangent with frequency for dry and wet sandstone samples of Jodhpur, Kota and Jaisalmer region

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