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Variation of Electrical Parameters of Soil With Moisture and Salinity over Frequency Range From 20 HZ TO 2 MHZ

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ABSTRACT

Measurements of electrical properties like dielectric constant, dielectric loss, conductivity, tanδ, electric modulus (M^*)and complex impedance (Z^*)for various moisture contents and saline contents of soilhave been carried out usingPrecision LCR meter(Agilent make E-4980A)operating in the frequency range from 20 Hz to 2 MHz.Measurements were carried out by adding (i) double distilled water and (ii) saline water of 20,000 ppm, in various proportions, inPalanpur district sandy soil.It has been observed that dielectric constantϵ' and dielectric lossϵ" increase with increase in the moisture contents in the soil over the frequency range from 20 Hz to 2 MHz.The value of tanδ peak and conductivity increase with increase in moisture in the soil. The variation oftanδ and conductivity with frequencyhave also been discussed. The electric modulus values M' and M" are found to increase with increase in frequency, but decrease with increase in water content and saline watercontent in the soil at given frequency. The complex impedance plane plots (Z", Z') have been plotted over the given frequency range, for various moisture, and saline moisture and analysed. The Z" minimum values separating the bulk material and electrode polarization are observed to decrease towards lower frequencies with increase in water contents in the soil.

KEYWORD

Complex Dielectric Constant,Soil, Moisture content, Saline content, Precision LCR meter

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INTRODUCTION

Moisture plays and important role in soil which affects land fertility, growth and yield. The electrical properties provide very useful information for agriculture, meteorology, hydrology and other application[1]. Mainly, dielectric permittivity is very strong function of volumetric soils moisture. Curtis have been measured moisture effects on dielectric properties of soils at 100 MHz[2].

Complex permittivity of moist soil over 10 Hz to 5 MHz frequency range was measured by *Bobrov et al*[3] using LCR meter.The electrical properties of Palanpur district sandy soil with fertilizer for various concentration over 20 Hz to 2 MHz frequency range was measured by *Gadani et al*[4]. It has been observed that the complex permittivity decreases with increase in frequency from 10kHz to 2 MHzrange.

MATERIALS AND METHOD

(I) Sample preparation

The soil sample was collected from the Palanpur district. Stones and gravels were removed from the soil sample and then soil sample was oven dried.The texture structure of Palanpur district soil shows 82% sand, 16% silt, 1% clay content which belongs to sandy soil. The dry density of the soil is 1.59 g/cm^3. The wilting point (WP) and transition moisture (Wt) have been calculated using the Wang and Schmugge Model[6] as

$$WP = 0.06774 - 0.00064 \times Sand + 0.00478 \times Clay \quad ...(1)$$

$$Wt = 0.49 \times WP + 0.165 \quad ...(2)$$

Where, Sand and clay stand for the sand and clay contents in percent of dry weight of the soil.

(II) Preparation of soil sample for various moisture contents

Distilled water wasadded to the soil in different proportions and allowed to saturate for 24hrs. Gravimetric moisture and volumetric moisture content were calculated using,

$$Wm = \frac{\text{weight of wet soil} - \text{weight of dry soil}}{\text{weight of dry soil}} \quad ...(3)$$

Hence, the volumetric moisture content was determined as

$$Wv = Wm \times \rho_b \quad ...(4)$$

Where, ρ_b= dry bulk density of the soil.

(III) Preparation of soil sample for various saline water contents

The saline water solution of 20000 PPM was prepared by adding 20 gm NaCl (AR grade) in the 1 litre distilled water. Saline water was added to the soil in different proportions and then allowed to saturate for 24hrs.The gravimetric moisture and volumetric moisture content in the soil sample were calculated using Eqs.(3) and (4), respectively.

(IV) Experimental set up and Measurement

Experimental setup and methodology as discussed by *Gadani et al*[4] has been followed to obtain electrical properties.

A precision LCR meter (Agilent make E-4980A) was used for the measurements in the frequency range from 20 Hz to 2 MHz. A standard four terminal probe (Agilent 16089A) with Kelvin clip leads was connected to the LCR meter.The open and short circuit compensation of the coaxial capacitor was carried out to eliminate the effect of stray capacitance during the evaluation of frequency dependant values of complex dielectric constant. The coaxial capacitor was calibrated using liquids of known dielectric constant, like carbon tetrachloride, benzene and 1-propanol (AR grad) as represented by *Gadani et al*[4].

The dielectric constant of each sample was calculated using

$$\epsilon' = 2.1012\,(C_P - C_O) + 1.0177 \qquad \ldots (5)$$

RESULTS AND DISCUSSION

Dielectric behaviour of sample:

The variation of dielectric constant and dielectric loss of Palanpur sandy soil with different proportions of moisture contents over the frequency range from 20 Hz to 2 MHz is shown in Fig. (1).

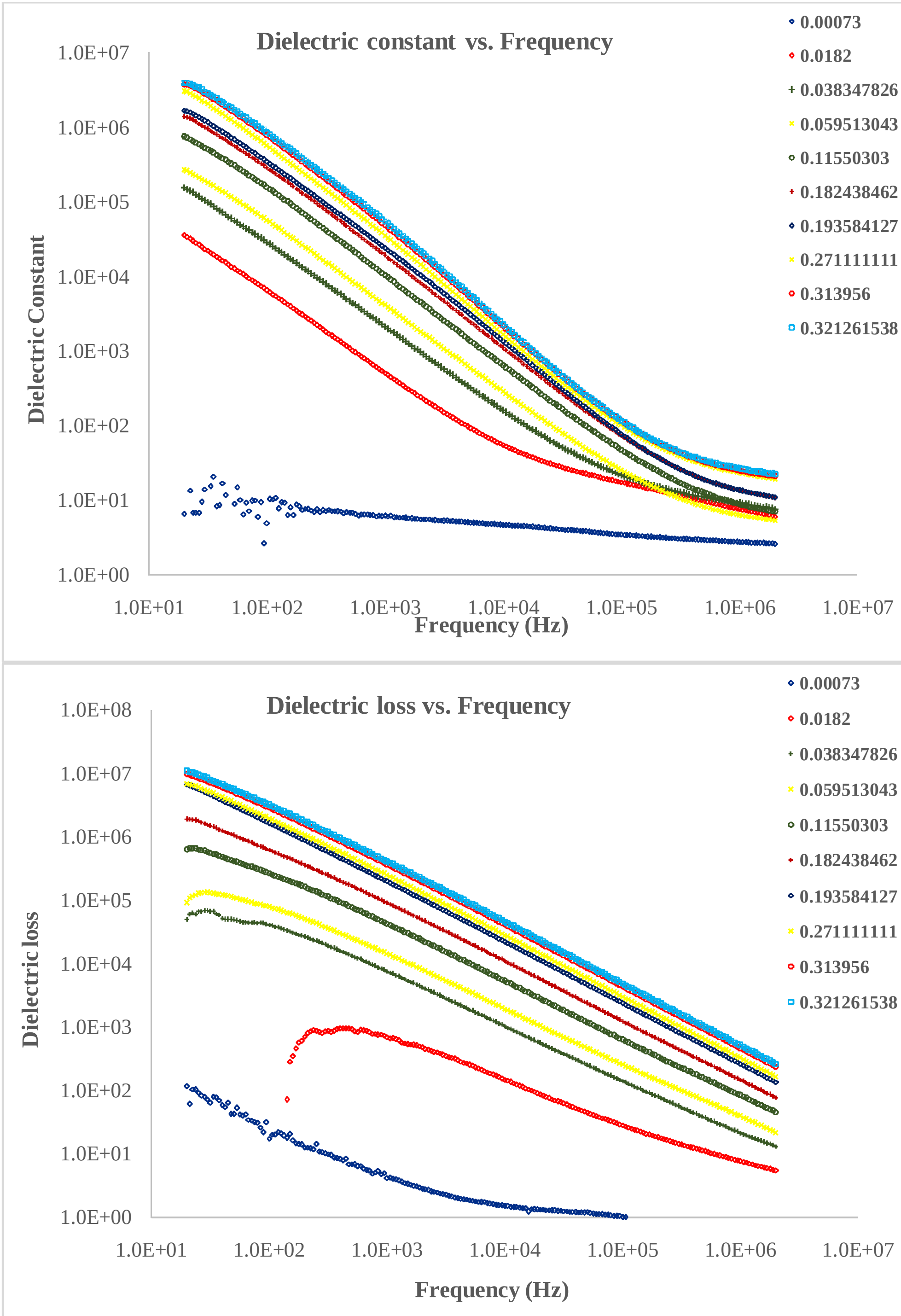


Fig. 1- Measured values of (a) dielectric constant and (b) dielectric loss of Palanpur districtsandy soil for various moisture contents in the soil with frequency.

It can be observed from Fig.(1) that the dielectric constant and dielectric loss of the moist soil decrease with increase in frequency from 20 Hz to 2 MHz.For dryer soil (Wv = 0.00073 cm^3/cm^3), the dielectric constant and dielectric loss values are small compared to moist soil and decrease slowly with increase in frequency.

The variation in the values of dielectric constant and dielectric loss with frequency for different the saline water content is shown in Fig. (2).

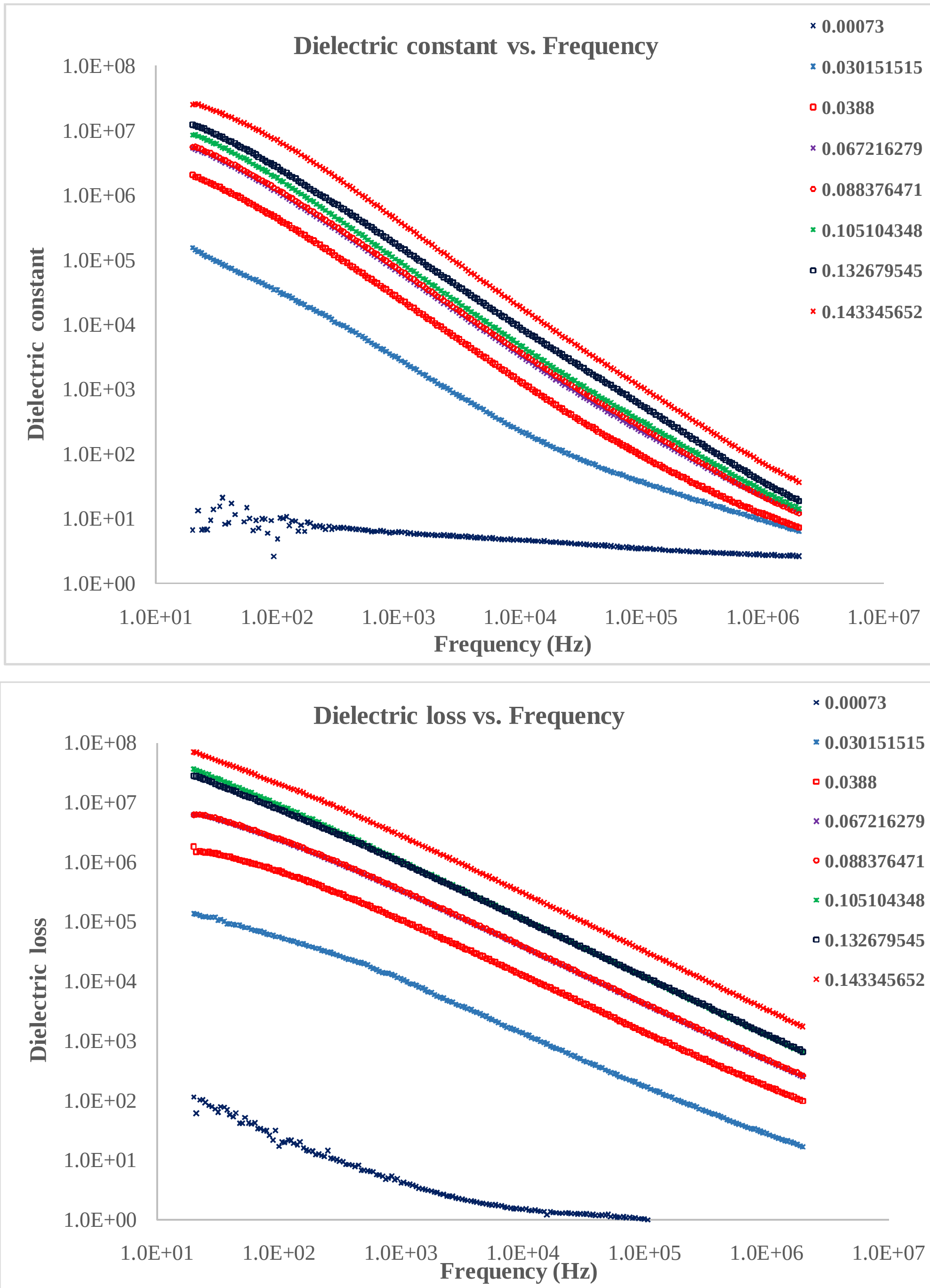


Fig. 2- Measured values of (a) dielectric constant and (b) dielectric loss of Palanpur district sandy soil for various saline water contents in the soil with frequency.

The dielectric constant and dielectric loss of soil with the saline water content soil decreases with increase infrequency.

The enhancement in dielectric constant and dielectric loss values of wet soil is due to electro chemical polarization[7]. This arises due to increase in surface charge carrier density in the presence of water molecules in the pore spaces of sandy soil.The logarithmic slope of frequency dependent ϵ' value of wet soil is close to -1 for the frequency below ~ 100 kHz, which indicates the leakiness of the EDL capacitances (blocking layers) to moving charges. Above 100 kHz, the slope decreases from -1, but does not approach 0. The decrease in slope of frequency dependent ϵ' values for wet soil, suggests decrease in charge movement through the layers.

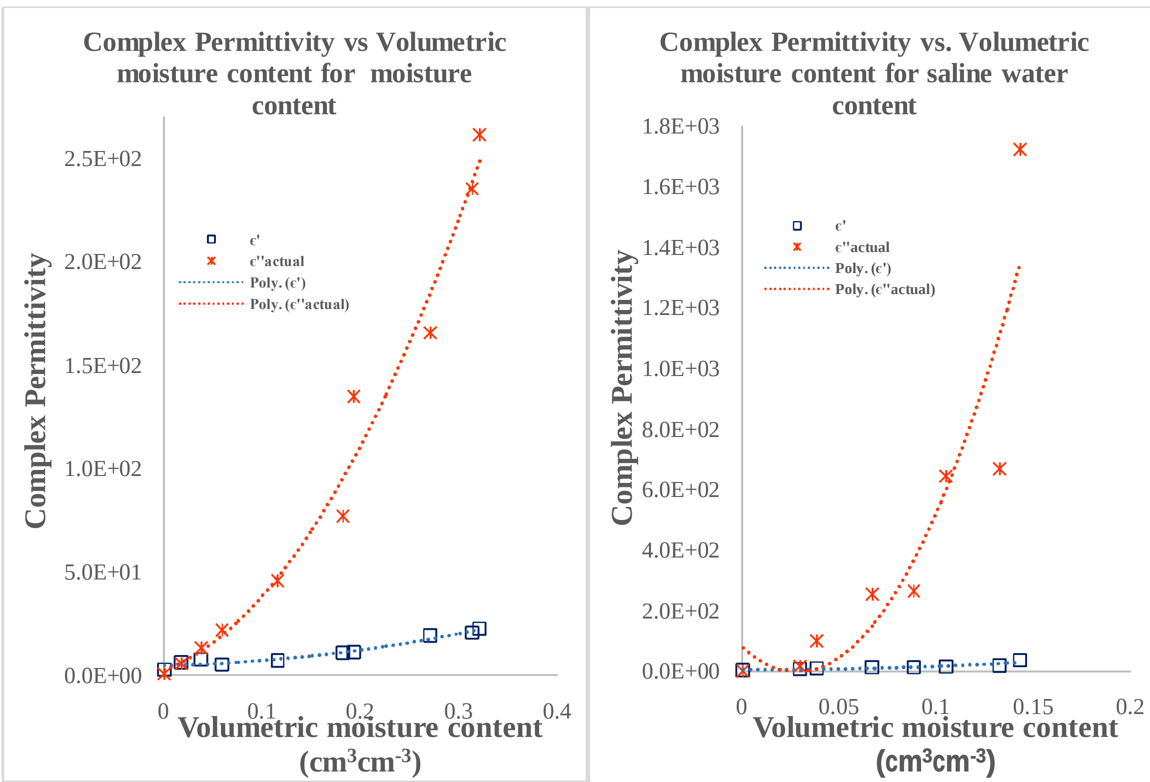


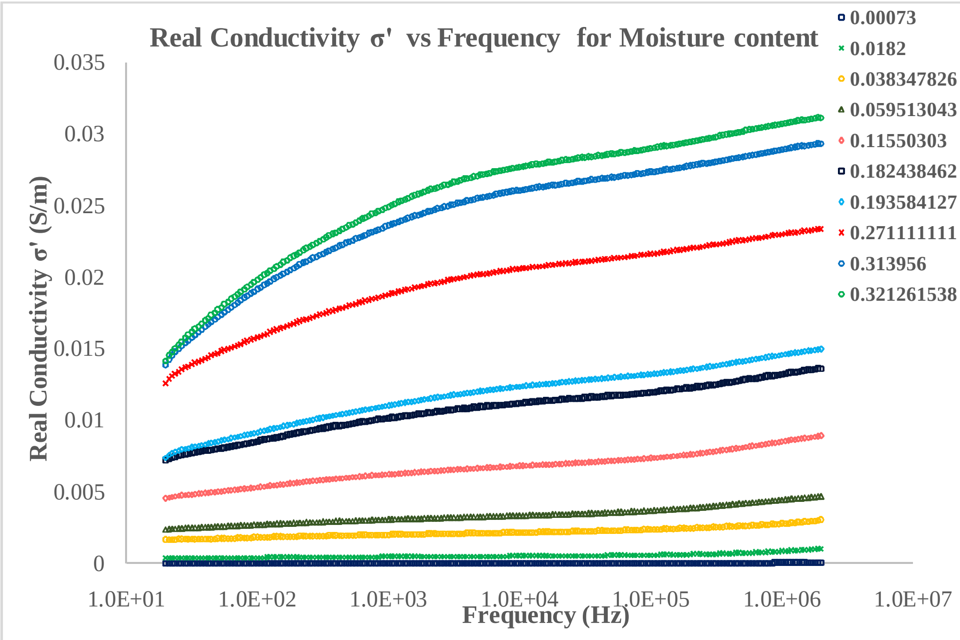
Fig.3- Measured values of (a) dielectric constant and (b) dielectric loss of Palanpur district sandy soil with Volumetric moisture content.

The measured value of the dielectric constant and dielectric loss of the moist soil and saline water content soil sample at 2 MHz frerquency has also been plotted agaist volumetric moisture in cm^3 cm^{-3}as shown in Fig.(3).It is observed that the dielectric constant and dielectric loss increase with increase in the moisture content in the soil. Further, dielectric loss increase slowly up to the transition moisture, after which it increases rapidly, but the dielectric constant increases slowly with volumetric moisture content Wv.

It can be seen from these plots that at 2 MHz measurement and moisture content in the soil, the dielectric loss values follow the trend as;

$\epsilon''_{20,000\ ppm} > \epsilon''_{doble\ distilled\ water}$

Conductivity:



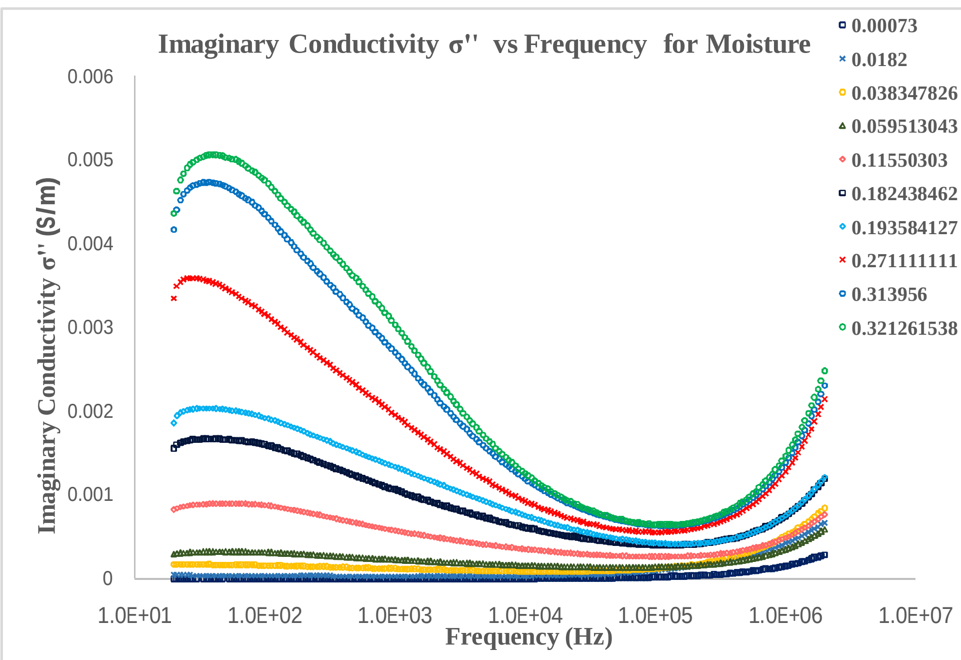
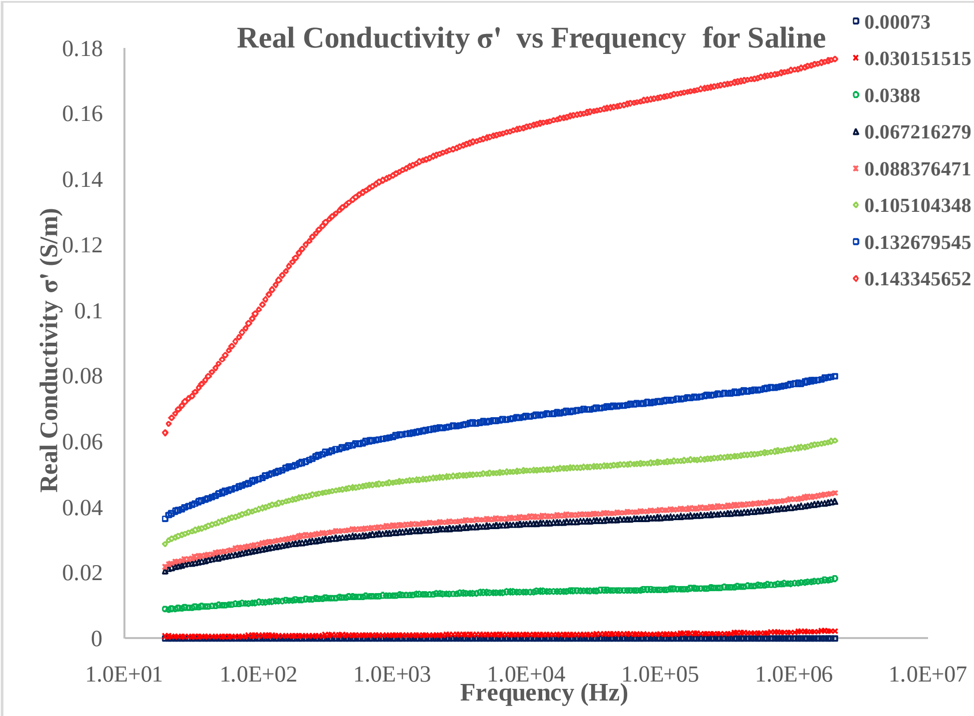


Fig.4 (a) Real (b) Imaginary values of Conductivity for variation with Frequency for various moisture content in the soil



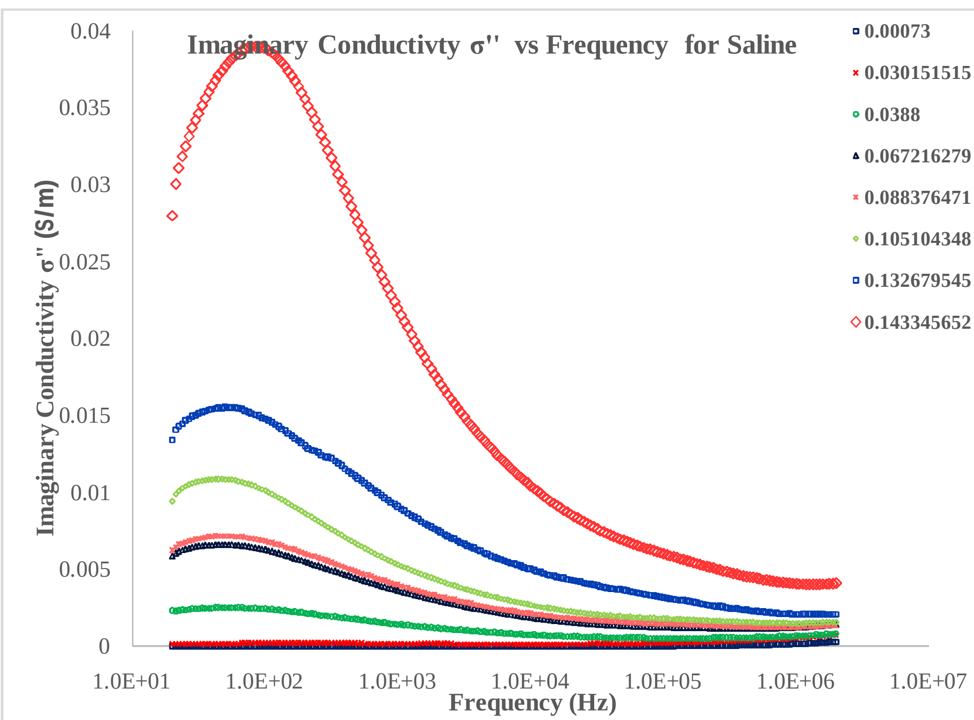
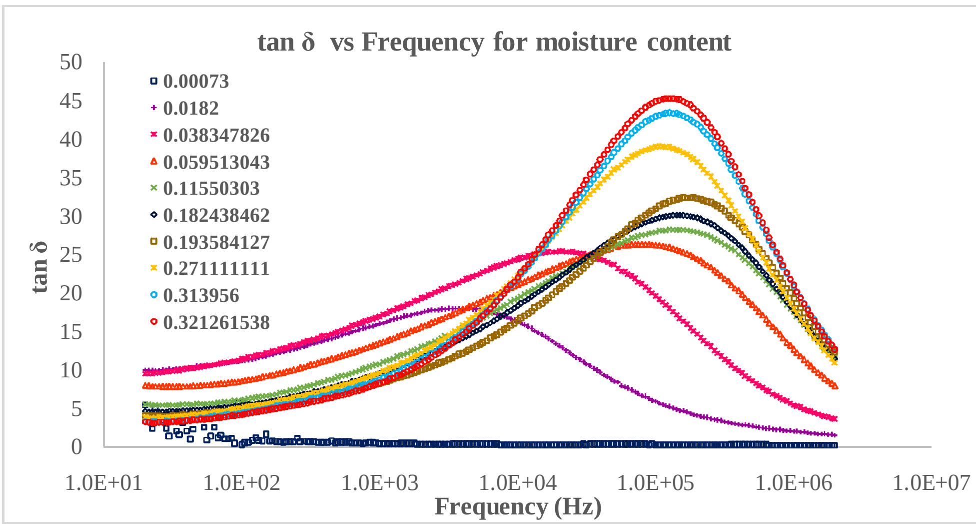


Fig.5 (a) Real (b) Imaginary values of Conductivity for variation with Frequency for various saline water content in the soil

The variation of realconductivity for various proportions distilled water and saline water content (20,000 ppm) in the soil with frequency is shown in Fig.(4)& Fig.(5). It has been observed that the conductiviy increase with increase in frequncy from 20 Hz to 2 MHz and also increase with the moisture content in the soil. It has been observed that the conductivity of the soil is small for lower frequency and increase with increase in frequency and also increase with increase in moisture content, Similar observation were observed by other researchers*Gadani et al*[4],*Sengwa et a*[8,9], *levitskaya and sternberg*[10], *Bobrove et al*[3].

tanδ:



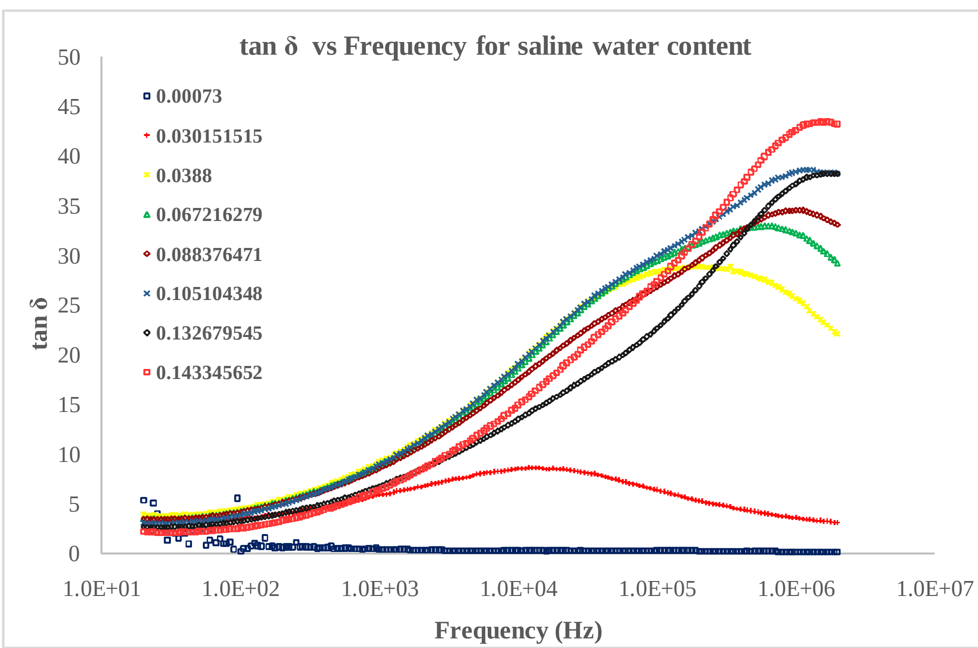


Fig.6 Calculated values of tan δ of Palanpur district sandy soil for various moisture content and saline water content with frequency

The variation of tan δ of the Palanpur sandy soil for various moisture content and saline content in the frequency range from 20 Hz to 2MHz is shown in Fig.(6). It has been observed that the tan δ peak value increases with increase in the moisture in the soil.

The frequency dependant tan δ peak values of the soil for different moisture and saline water content has peak corrospond to the electro polarization frequency[13]. The value of relaxation frequency separates the bulk material and the electro surface polarization phenomena in the low frequency dielectric dispersion[11].

Complex impedance:

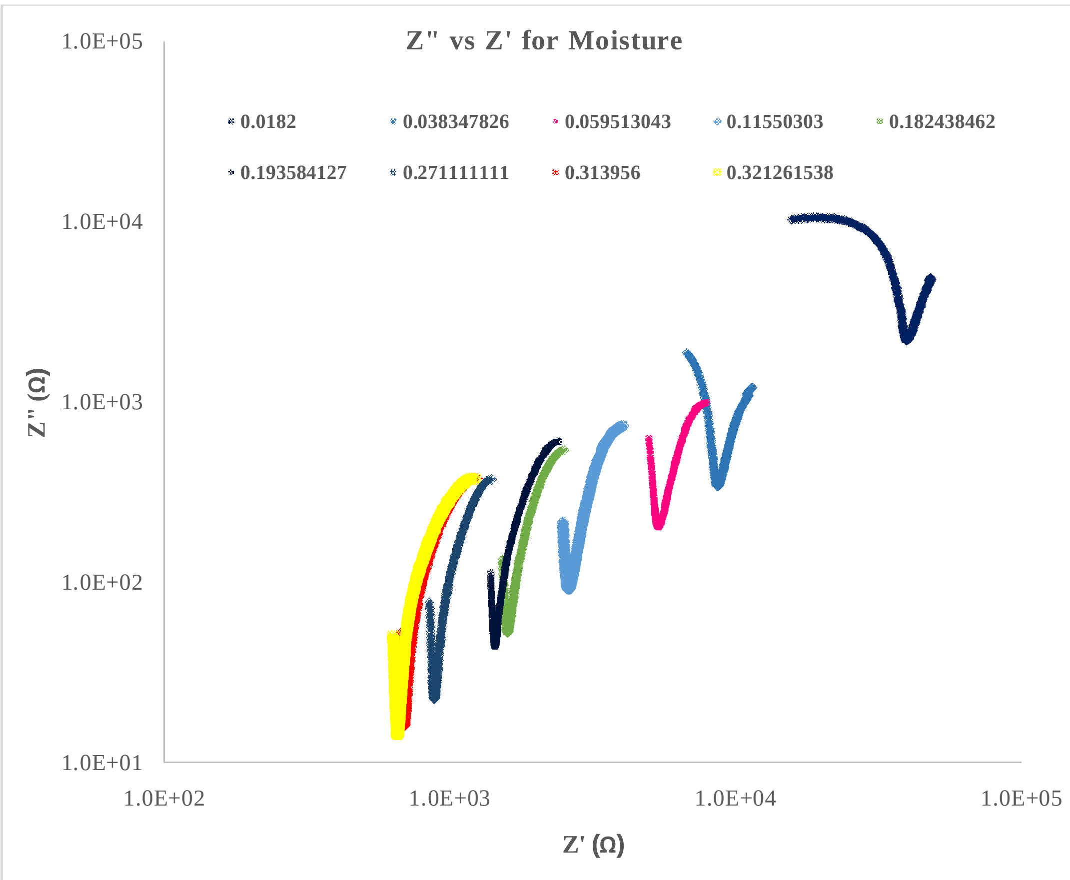


Fig.8 Plot of Z" against Z' for various moisture content in the Palanpur district sandy soil

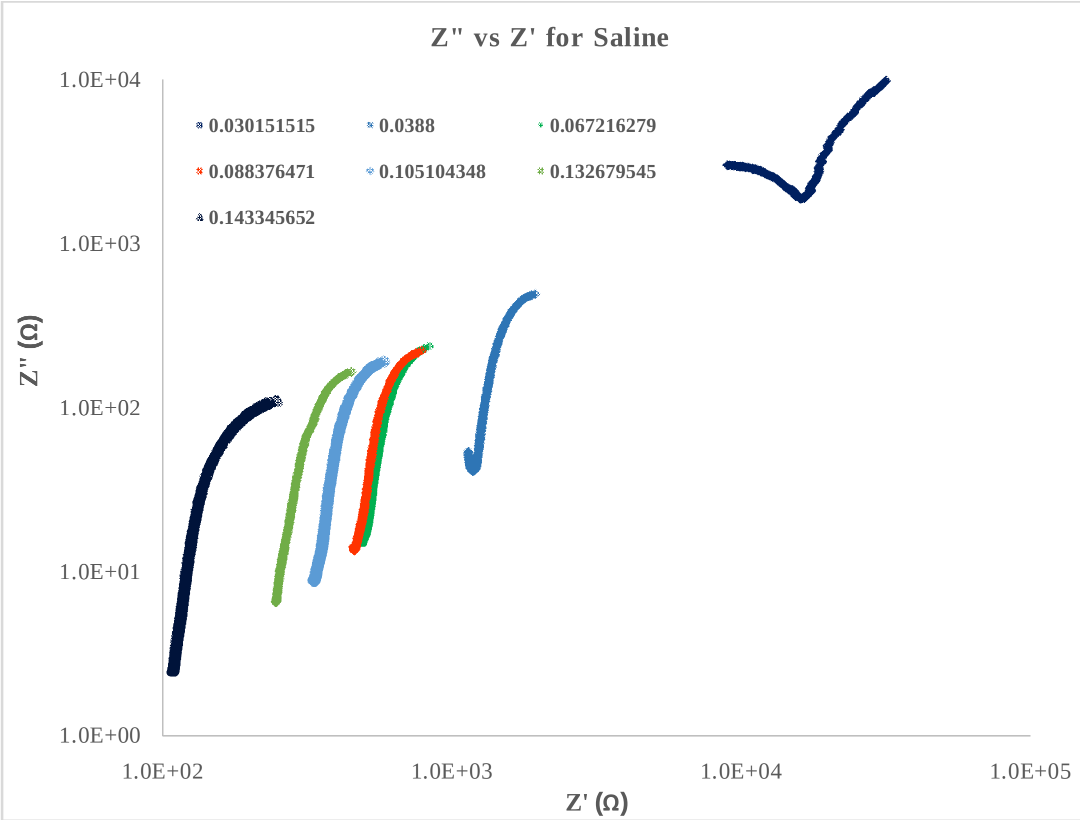
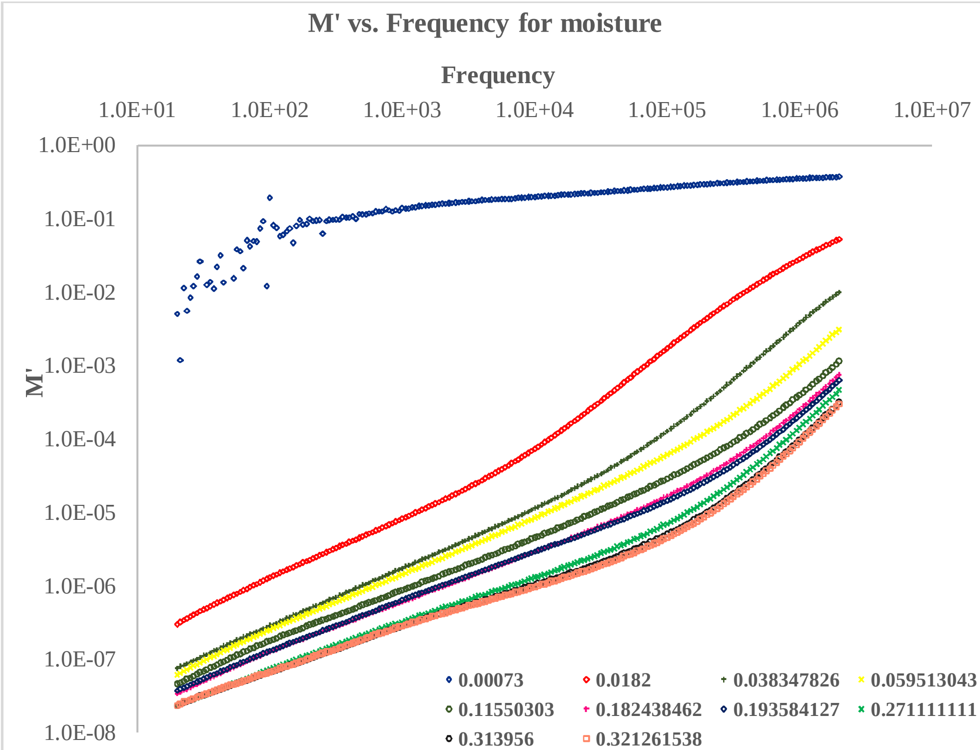


Fig.9Plot of Z” against Z’ for various saline water content in the Palanpur district sandy soil

The plot of Z” against Z’ over the given frequency range, moisture and saline moisture contents in the soil have been plotted in Fig.(8) and Fig.(9). The value of the experimental points going from right to left side on the complex impedance plane plot of Palanpur sandy soil. The Z” minimum values shift from right to left side with increase in moisture and saline content which represents that the conductivity increases with increase in moisture contents in the soil. For saline soil, the Z” decrease more rapidly with increase in moisture content due to additional conductivity by the presence of sodium salts. For pure water as moisture content, the complex impedance Z” vs. Z’ has two arcs. It is seperated by some minimum value of Z”. The arc on the left side of $Z”_{min}$ corrosponds to the bulk material effect and right side of $Z”_{min}$ corrosponds to the elecrode surface polarization.

Electric modulus:



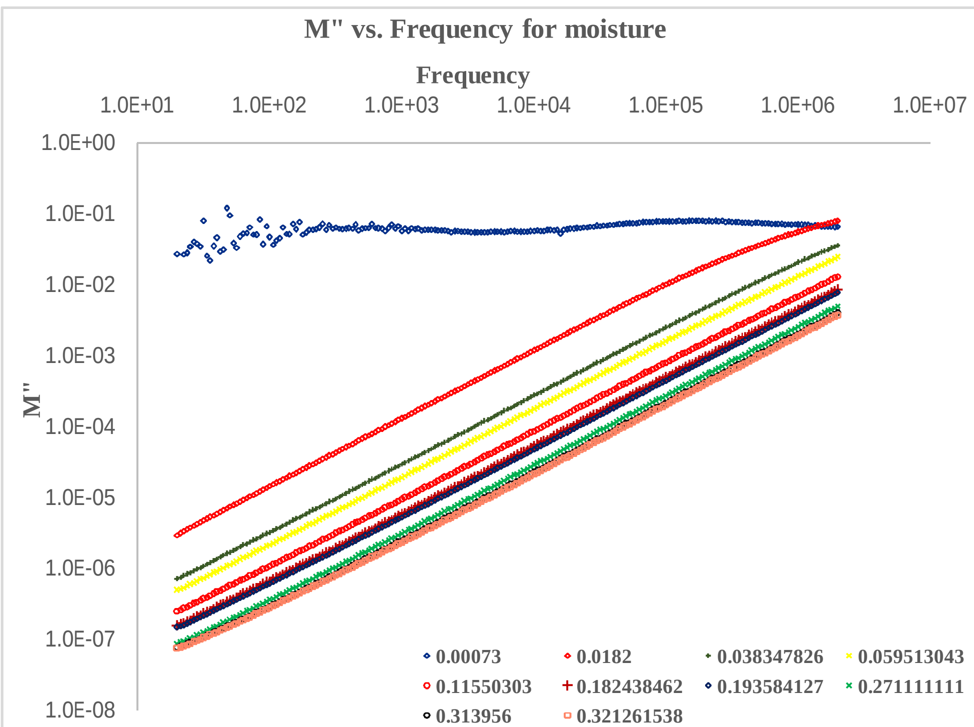
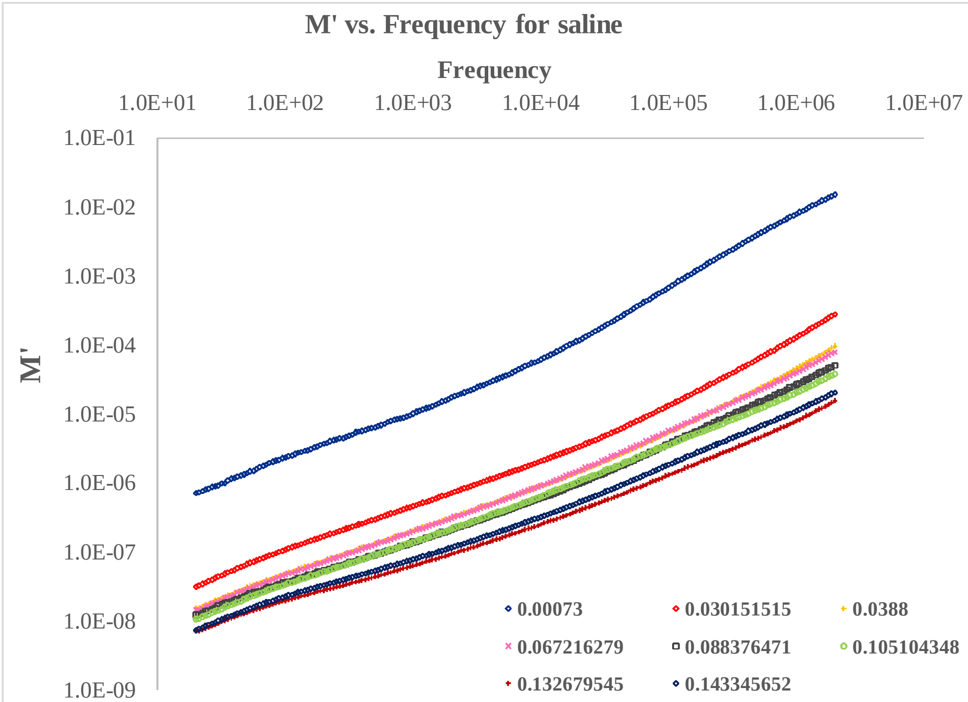


Fig.10 Plot of M' and M" against Frequency for various moisture content



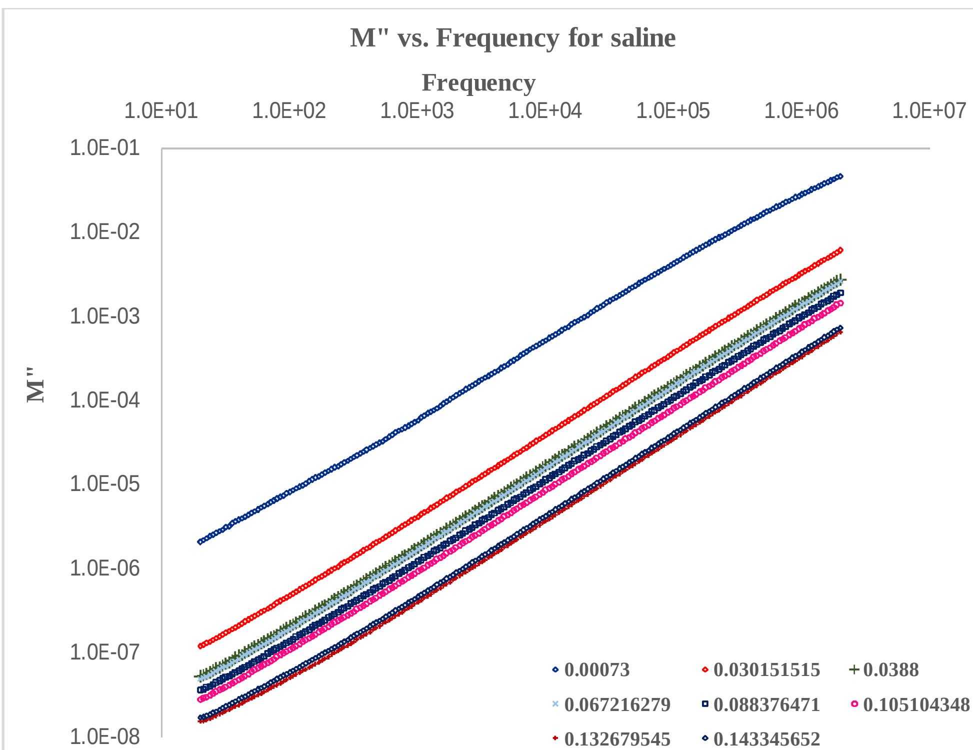


Fig.11 Plot of M’ and M” against Frequency for various saline water content

The variation of the evaluated values of M' and M" against frequency of soil with different proportions. Is shown in Fig.(10) and Fig.(11) The value of M' and M" decrease with increase in moisture content but increase with increase in frequency.

CONCLUSION

It has been observed that the complex permittivity increases with increase in moisture contents in the soil but decreases with increase in frequency. Similar, behaviour of complex permittivity for saline water content in the soil has been observed.

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