Effect of frequencies on the change of electrical impedance in sand dunes of Ouargla region

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Abstract. In this paper, we put the accent on the measurement of real and imaginary parts of electrical impedance and effective loss tangent respectively $z'$, $z''$ and $\tan \delta$ in sand dunes of Ouargla region at a range of frequency intervals between $4.6849 \times 10^{-2}$ Hz and $1.8593 \times 10^{6}$ Hz with AC voltage of 1.000 V using the impedance spectroscopy. The experimental results revealed that the real and imaginary parts of electrical impedance and effective loss tangent have strong frequency dependence. In the frequencies range $(4.6849 \times 10^{-2} - 4.9385 \times 10^{-1})$ Hz $z' < 0$ and $z''$ change between $(4.8118 \times 10^{-2} - 5.0422 \times 10^{1}) \ \Omega$, in the frequencies range $(5.4877 \times 10^{1} - 2.3426 \times 10^{6})$ Hz $z'$ change between $146.04 \ \Omega$ and $4.8193 \ \Omega$ and $z'' < 0$. In high frequencies range $(1.2599 \times 10^{5} - 1.8593 \times 10^{6})$ Hz $z'$ change between $4.5359 \ \Omega$ and $5.0567 \ \Omega$. The effective loss tangent values increase until they reach a peak, in frequencies range between $4.6849 \times 10^{-2}$ Hz and $2.5197 \times 10^{1}$ Hz, but then the remaining frequency the values decrease until they become constant. The nature of impedance electric variation indicated a possibility to knowledge the polarization of sand dunes of Ouargla region and acquaintance the frequencies when the material is passive devices or active devices. It is also possible to know the quality of equivalent electrical circuit, whether it is induction or capacitance.

1. Introduction
Sand is a granular material where grains diameter varies from 0.02 to 2.0 mm [1, 2]. Its chemical composition is quartz (SiO2) and gypsum (CaSO4.2H2O) [1].

Algerian Sahara has huge quantities of sand dunes. These are among the important natural resources that can be exploited in different fields. Sand is known as a raw material used in industry [3, 4]. Sand is used either in its natural form or after various processes to be ready or use [5, 4]. Sand is an excellent filter for removing sediment and bacteria from water [6, 7] and building [8, 9]. Extracted quartz from sand can be used in glass, optics [3, 10, 11] and to extract silicon which is used in semiconductors and nano-industry.

The previous research works in the field of knowledge of sand dunes in Ouargla region have focused on the diagnostic side [1]. The aim of this work is to measure the electrical impedance of the sand dunes in the terms of frequency, and its effect on the variation of electrical Impedance.

2. Material and methods

2.1. Collection of Sand Samples
The original sample has been taken from the sand dunes of Makhearzha area, located south-west of the city of Ouargla. Ouargla is located in the north of the Algerian Sahara where its geographical coordinates are: latitude is 31°57' North, longitude 5°20' East and its mean altitude is 137 m.

![Dunes of Ouargla region](image1.png)

**Figure 1. Dunes of Ouargla region [1]**

### 2.2. Sample Preparation

The sample of sand was grinded by a mechanical machine containing small pellets of agate, an amorphous type of silica stone. These particles collide with each other by the vibrations caused by the device. The material to be grinded between the pellets is a collision case, which causes crushing. The sample grinding lasted about a quarter of an hour and the sand became very smooth.

### 2.3. Spectroscopy Techniques

#### 2.3.1. Impedance spectroscopy (IS)

Measuring the complex impedance provides the complex conductivity as a function of frequency. This technique is known as impedance spectroscopy. The electrical impedance connects several physical parameters such as the complex dielectric constant, electrical conductivity and capacity.

The impedance spectroscopy is a powerful proven method of analysis in research and development of materials. This method is relatively simple and non-destructive. The results can be often correlated with a lot of physical properties of materials [12], dielectric properties [13] and the influences of the composition on the electrical conductivity of solids [13, 14]. It is also used as a method for food quality control and pharmaceutical products [15]. Furthermore, it can contribute to the interpretation of fundamental electrochemical processes, usually due to electrochemical phenomena. This technique is based on the modeling results by equivalent electrical circuits which have the same frequency response as the sample.

The electrical behavior of an electrochemical system can be represented similarly by impedance circuits. Applying a sinusoidal voltage and analyzing the possible system response to obtain information on the various steps involved in the reaction mechanism. All the responses of the system in a very wide frequency range are an impedance diagram.

![Impedance spectroscopy](image2.png)

**Figure 2. Impedance spectroscopy [16]**

#### 2.3.2. Measurement of electrical impedance and effective loss tangent

The complex impedance can be written as follows [17]

\[ z_e = z' - iz^* \]  \hspace{1cm} (1)

Where
\[ z' = \sum \frac{R_i}{1 + \omega^2 R_i^2 C_i^2} \]  
(2)

\[ z'' = \sum \frac{\omega R_i^2 C_i}{1 + \omega^2 R_i^2 C_i^2} \]  
(3)

\(z'\) and \(z''\) are the real and imaginary parts of electrical impedance respectively; where \(\omega\) is the angular frequency, the resistance \(R_i\) represents ionic or electronic conduction mechanisms, while the capacitance \(C_i\) represents the polarizability of the sample from different components labeled \(l\), which are related to the grain, grain boundary or the electrode interface [17].

If \(z'\) is less than zero the material is a passive device, and if it is greater than zero the material is an active device.

When \(z''(0)\) the equivalent electrical circuit is induction, and when \(z''(0)\) the equivalent electrical circuit is capacitance.

The effective loss tangent \(\text{tg}\delta\) can be written as follows [17]

\[ \text{tg}\delta = -\frac{z'(\omega)}{z''(\omega)} \]  
(4)

3. Results and discussion

In their previous studies, the researchers like Mahdadi et all [1], focused only on the study of Ouargla sand dune on the formal (morphologies) side, for this reason we will not be able to compare our results with other results in the same field.

The experimental results showed that the real part values of electrical impedance was negative, in frequencies range between \(4,6849\times10^{-02}\) Hz and \(4,9385\times10^{-01}\) Hz, these values indicate that in these frequencies cited early, the Ouargla sand dunes has taken the active devices class (produces power). The real part of electrical impedance takes the greatest positive value at frequency \(5,4877\times10^{01}\) Hz, but its value begins to decrease until it stabilizes at all remaining frequencies (Figure 3(a)). This change in the real part of electrical impedance values shows that Ouargla region sand dune plays the role of passive devices (consuming energy) in this case.

But the imaginary parts take high positive values whereas the real part is negative which indicate that the equivalent electrical circuit is induction.

In the frequencies range between \(5,4877\times10^{01}\) and \(2,3426\times10^{04}\) the imaginary parts values are negative. In this case the equivalent electrical circuit is capacitance.

In the other frequencies, the imaginary parts increase to reach positive values and finally stabilize (Figure 3. (b)).

Between frequencies \(4,6849\times10^{-02}\) Hz and \(2,5197\times10^{-01}\) Hz. The effective loss tangent values increase until they reach the peak, then they decrease and remain constant (Figure 3. (c)).
4. Conclusion
In the present work, we have mainly reported the electrical impedance, effective loss tangent, and calculate their values in sand dune of Ouargla region, using the Impedance spectroscopy method. The experimental results showed a correlation between real, imaginary parts of electrical impedance and frequency. At low frequencies the values of real parts were negative (The Ouargla sand dunes has been taken the active device class), while the imaginary parts have taken high positive values (The equivalent electrical circuit is inductive). At medium and high frequencies real parts were positive (Ouargla region sand dune plays the role of passive devices) but imaginary parts took negative values (The equivalent electrical circuit is capacitive).

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