Electrical impedance

Electrical impedance is an extension of the term electrical resistance to situations where an alternating current passes through an area. The simplest view of impedance is that it is the resistance to an alternating current. The base unit of impedance is ohm *Ω*, usually denoted by the letter **Z**. If the impedance is connected to a voltage *U* and a current *I* flows through it, its value is given the Ohm's law:

$$Z = \frac{U}{I}$$

Impedance of electrical elements

Essential electrical elements are **resistor**, **capacitor** a **inductor**. The primary property of a resistor is electrical resistance, the primary property of a capacitor is capacitance, and the primary property of an inductor is inductance. These are of course only ideal models, to emphasize this fact, only these particular terms are used and not the technical names officially given: resistor, capacitor and coil.

When calculating impedance, the frequency *f* is usually not used, but the circular frequency *ω* determined by the relation:

$$\omega = 2\pi \cdot f$$

Impedance of the resistor

The impedance of the resistor itself is called resistance, denoted *R*. The resistance value does not depend on the frequency.

Impedance of the capacitor

Impedance of the capacitor is called **capacitance**, normally denoted by X_C. The capacitance is inversely proportional to the capacitance *C* of the capacitor ind inversely proportional to the frequency *f* of the applied voltage:

$$X_C = \frac{1}{\omega C}$$

Impedance of the inductor

Impedance of the inductor is called **inductance**, usually denoted by X_L. Inductance is directly proportional to the inductance *L* of the inductor and directly proportional to the frequency *f* of the current flowing through the inductor:

$$X_L = \omega L$$

Impedance of series connection of resistor and capacitor

Addition of impedances is not done easily, for the impedance *Z* of the series connection of the resistor *R* and capacitor *C* goes:

$$Z = \sqrt{R^2 + \frac{1}{(\omega C)^2}}$$

Impedance of parallel connection of resistor and capacitor

The relation for the impedance *Z* of a resistor and capacitor in parallel connection has a rather complex form, but it is worth noticing because the parallel connection of a resistor and capacitor is a frequently used model for a tissue impedance:

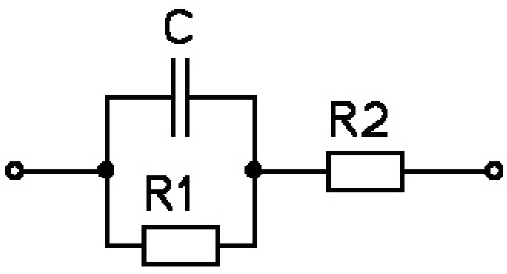
$$Z = \frac{\sqrt{R^2 + \omega^2 C^2 R^4}}{\omega^2 C^2 R^2 + 1}$$

Electrical impedance of tissues

__ **Electrical impedance of tissues** characterizes the passive electrical properties of the organism and tissues. This means that it describes the behavior of an organism as a consumer of electrical energy when it is connected to a source of alternating electrical voltage.

Model of electrical impedance

As an example, a simple model, which consists of the parallel connection of resistor R1, capacitor C and resistor R2 connected to them in series, can be used:



It is not complicated to express the dependence of the impedance of the model as a function of the resistance of both resistors, the capacity of the capacitor and the frequency of the applied voltage. However, the resulting relation would look rather complicated.

Nevertheless, by analyzing the problem, the impedance behavior as a function of frequency can be easily estimated. For direct current, the capacitor behaves like an open conductor, so the resulting model is formed only by the series connection of resistors R1 and R2. For very high frequency, the capacitor will behave almost like a short circuit. It will bridge the resistor R1 and only the resistor R2 will contribute to the impedance. Somewhat less obvious is that the impedance will decrease gradually, with no local maximum anywhere.

Capacitor C models the total capacitance in tissues, especially the capacitance of cell membranes. Capacitance of the cell membranes can be considerable, the area capacitance of a cell membrane is $1\ \mu F \cdot cm^{-2}$. However, for example, the capacity of planar fibrous structures also contributes to the capacity, so the capacity in the model can not be equated with the capacity of cell membranes. Resistor R1 models the electrical conductivity of body fluids, especially extracellular fluids. Nonetheless, even the intracellular fluid is not completely without the influence on the value of the parameter R1. Resistor R2 corresponds to skin resistance, but the conductivity of body fluids also has an effect on it.

A more detailed analysis takes into account, for example, the following phenomena:

- body fluids are a conductor of the 2nd type, i.e. conductivity is not independent of current density and frequency
- the polarization of macromolecules takes place differently at different frequencies, i.e. the permittivity of the medium is not independent of frequency
- the structure of the tissue is similar to a suspension of dielectric beads with a conductive core in a conductive medium rather than a homogeneous medium
- conductive blood flows through the tissues
- the conductance of the cell membranes of excitable cells changes according to their state

Models build on the basis of these assumptions are quite complicated, while their utility is not significantly higher than the utility of the model above.

Utilization of tissue electrical impedance

Bioimpedance analysis

Electrical impedance of the tissue is influenced, among other things, by the composition and arrangement of the tissue. Knowledge of electrical impedance can thus be used to obtain information about body composition. Impedance information is used in the following cases:

- total body fat analysis (bioimpedance scale)

- assessment of dehydration and body fluid dynamics

Tomography systems

More or less experimentally, methods are used which, after placing numerous electrodes on patient's body, would computationally reconstruct the conductivity distribution of individual segments inside the body, so-called electroimpedance tomography. This methodology encounters difficulties mainly in two areas. The first area of difficulty is the need to use relatively low currents, i.e. relatively high sensitivity to interference. The second area of difficulty is that the methods of mathematical reconstructions are quite demanding, among other things, for the reason that it is absolutely impossible to use the idea of a “current beam”. The following applications may be encountered:

- electroimpedance tomography of the breast – offered as an alternative or supplement to mammography
- electroimpedance tomography of the chest – early detection of pulmonary edema in patients on intensive care beds

Links

Related articles

- Electrical impedance/NMgr
- Conduction of electric current through the body
- Current measurement
- Resistance measurement
- Voltage measurement

Source

- KUBATOVA, Senta. *Biofot* [online]. [cit. 2011-01-31]. <https://uloz.to/!CM6zAi6z/biofot-doc>.