# ELECTROMAGNETIC AND ULTRASONIC WAVES IN SOILS: REGULARITIES OF THEIR PROPAGATION

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Radio waves and their interaction with soils are of particular importance for soil research and also play an important role in economic activities, as various measuring devices operate on the basis of radio frequency soil sensing. However, soil is an extremely difficult medium for radio waves to pass through due to its chemical, physical and mechanical properties.

We will consider the peculiarities of interaction of electromagnetic and ultrasonic waves with soils, which propagate in soils, attenuate in them and are reflected under certain conditions. We will compare the radio physical constants for both types of waves and find out whether it is advisable to use these types of radio waves for soil research.

Electromagnetic waves can interact with soil at different levels, depending on their frequency and soil properties.

High-frequency electromagnetic waves, such as microwaves and millimeter waves, can leak out to some depth in the soil before being absorbed. This can be used in radar and other applications to investigate soil structure. Low-frequency radio waves can bounce off the ground, creating an echo. This effect is used in radar systems and satellite sensing.

Soil microstructure can affect the scattering of electromagnetic waves. Soil with different properties can scatter waves in different ways, which can be used to determine the composition of the soil or to detect certain characteristics (for example, moisture).

Different types of soil have different effects on electromagnetic waves. For example, wet soil can have a significant impact on wave penetration compared to dry soil. Electromagnetic waves can propagate in the ground, transmitting information or energy through it. This can be used in communication systems or sensor networks, especially in the low frequency bands.

In general, the interaction of electromagnetic waves with the soil depends on the frequency of the waves, their characteristics, and the properties and structure of the soil.

Ultrasonic waves can also interact with the soil. They can penetrate the soil, similar to the way sound waves penetrate different media. The permeability will depend on the physical properties of the soil, such as density, moisture content,

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etc. Ultrasonic waves can reflect off the soil surface, just as sound waves reflect off hard surfaces, for this reason, a study was conducted on the use of ultrasonic waves to detect the depth of the compacted soil layer [1, p. 456–464; 2, p. 48–50; 3, p. 13–15].

The microstructure of the soil can affect the scattering of ultrasonic waves. Different properties of different soil layers can cause different scattering effects. Soil properties can change the frequency and amplitude of ultrasonic waves. For example, wet soil may require more energy to penetrate, and dense soil may affect the speed of wave propagation.

The main radio physical constant for electromagnetic waves is the specific electrical conductivity, which is determined for soils of different structure and temperature conditions using separate specific formulas. Here is a general formula for a sample [4, p. 20].

$$\sigma = \frac{l}{RS}, \tag{1}$$

Where $R$ is the electrical resistivity, $l$ is the length of the soil section in one unit ($l$ =1), $S$ is the cross-sectional area in one unit ($S$=1).

Another radio physical constant for electromagnetic waves is the dielectric constant, which depends on the structure of the soil and is also determined by different formulas, we will give an example of the main formulas. It should be noted that the dielectric constant of a moistened soil system is weakly dependent on the shape and almost independent of the grain radius, but only on the water content (%). Universal formulas for determining the dielectric constant of soil are as follows [4, p. 20].

for some cases when $\varepsilon_2 \gg \varepsilon_1$, then

$$\varepsilon^{(k)} = \varepsilon_1 \frac{n_k - (n_k - 1)p}{p}, \tag{2}$$

for some cases when $\varepsilon_2 \ll \varepsilon_1$, then

$$\varepsilon^{(k)} = \frac{\varepsilon_1 (n_k - 1)p}{n_k - p}, \tag{3}$$

where $\varepsilon_2$ is the dielectric constant of the solid phase, $\varepsilon_1$ is the dielectric constant of the intermediate medium (air, water), $n$ is the concentration of the intermediate medium, and $p$ is the porosity of the system.

For the propagation of ultrasonic waves in soils, we can distinguish two informative constants, namely, the acoustic stiffness of the medium and the acoustic impedance.

The first constant is the acoustic stiffness of the medium, which is calculated by the formula (according to the laws of acoustics):

$$Q_{\text{А.ж.}} = \rho c \omega = \frac{D}{A}, \tag{4}$$

where $\rho$ is the density of the medium, $c$ is the speed of sound, $\omega$ is the frequency of the sound wave. This formula shows the dependence of the sound pressure $D$ on the amplitude of the shear of the medium particles $A$.

The second constant is the wave (or acoustic) resistance of the medium. This constant represents the resistance to the propagation of a sound wave, which is determined by the absorption, refraction and reflection of the sound wave. The acoustic impedance $R_A$ is calculated by the formula (according to the laws of acoustics):

$$R_A = \rho c = \frac{D}{U}, \tag{5}$$

where $\rho$ is the density of the medium (kg/m$^3$), $c$ is the speed of sound in the medium (m/s), $D$ is the amplitude of the sound pressure, and $U$ is the maximum amplitude of the oscillatory speed.

For different soils, the absolute value of the acoustic impedance differs dramatically: the denser the soil, the higher the acoustic impedance.

In acoustic measurement technology, acoustic impedance is an important information parameter, because it determines the property of the medium to conduct acoustic energy, including ultrasound. Thus, reflected waves are bound to occur at the interface between media with different acoustic impedances.

Thus, the radio physical constants by which radio waves are transmitted, attenuated or reflected are different for different types of radio waves. The reflection of electromagnetic waves depends on the greater the dielectric constant of the soil, while in terms of the acoustic conductivity of the soil, only its elasticity, density and inertial properties should be taken into account. The acoustic conductivity of the medium does not depend on other properties. In short, in order for an ultrasonic wave to be reflected from any soil layer, it must be very hard, over-compacted; otherwise, the ultrasonic wave will be attenuated in any type of soil.

The use of electromagnetic and ultrasonic waves for soil investigation can be very useful in various scientific and technical fields.

Different frequencies of electromagnetic waves can be used to determine the physical properties of soils, such as moisture, density, composition, and others. Ultrasonic techniques can help to determine the mechanical properties of soils, such as elasticity and compactness.

Some techniques, such as electromagnetic tomography, can be used to detect anomalies, such as the presence of water or other materials in the soil. Ultrasonic imaging can provide information about the internal structure of the soil.

The use of electromagnetic and ultrasonic waves can be effective in the construction industry to control the quality of soil compaction, detect irregularities in building materials, and more.

Some methods, such as electrical resistivity (electromagnetic waves), can indicate the composition and presence of various substances in the soil. Ultrasonic waves can be used to study the distribution of pores in the soil and other soil characteristics.

However, it should be borne in mind that the effectiveness of these methods may depend on specific soil conditions and properties, as well as on the application. It is also important to consider ethical and environmental aspects when using such technologies.

However, it should be borne in mind that the effectiveness of both ultrasonic and electromagnetic waves can depend on the specific conditions and properties of the soil, as well as the application. It is also important to consider ethical and environmental aspects when using such technologies.

## References:

1. Antypchuk B. O. (2022). Pryimalno-peredavalnyi prystrii vyprominiuvannia, elektronno-obchysliuvalnyi blok ta blok indykatsii operatyvnoi systemy vyznachennia shchilnosti gruntu [Radiation receiving and transmitting device, electronic computing unit and display unit of the operational system for determining the density of the soil]. *Moderní aspekty vědy*: XXIV Díl mezinárodní kolektivní monografie. Česká republika: Mezinárodní Ekonomický Institut s.r.o. pp. 455–466.

2. Antypchuk B. O. (2017). Ultrazvukovyi eksperymentalnyi prystrii – osnovnyi element avtomatyzovanoi systemy keruvannia polozhenniam hruntorozpushuvacha [The ultrasonic experimental device is the main element of the automated system for controlling the position of the soil loosener]. *Konstruiuvannia, vyrobnytstvo ta ekspluatatsiia silskohospodarskykh mashyn*. Kropyvnytskyi: TsNTU, is. 47, part 1, pp. 47–51: il.

3. Myronenko V. H., Antypchuk B. O. (2018). Doslidzhennia prystroiu operatyvnoho vyznachennia hlybyny zaliahannia ushchilnenoho sharu gruntu [Study of the device for operational determination of the depth of the compacted soil layer] *Mekhanizatsiia ta elektryfikatsiia silskoho hospodarstva*. Hlevakha: IMESH, is. 8(107), pp. 12–17: il.

4. Riabchuk O. P., Antypchuk B. O. (2019). Zakonomirnosti rozpovsiudzhennia elektromahnitnykh khvyl v gruntakh [Patterns of propagation of electromagnetic waves in soils]. *Visnyk Zhytomyrskoho ahrotekhnichnoho koledzhu*: zb. nauk. Statei, is. 1, no. 1(1), pp. 17–24.