

## A Comprehensive Study of Underground Animals Habitat

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# A Comprehensive Study of Underground Animals Habitat

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**Abstract:** This paper describes a method of studying the natural habitats of underground animals by the example of zokor. The purpose of the research is to find habitation of animals using unmanned aircraft and investigate networks of tunnels and burrows with ground penetrating radar "OKO-2". Geolocation data were processed by techniques developed by the authors.

## 1. Introduction

Zokor is a mole rat rodent which lives underground and borrows tunnels with their powerful front claws. This is a medium-sized rodent with body length of 6 – 11 inches and a tail up to 6.5 inches. Most part of their lives zokors spend underground digging complex multi-level tunnels of 160 – 330 ft length [1]. Zokors are the active object of soil biota, one of the components in biological diversity of land animals. The active observation of zokors' behaviour is performed by trapping and opening their burrows. But, zokors are easily injured when being trapped. Moreover, the natural balance is destroyed by opening the burrows. In that case, the alternative non-destructive technique for underground investigation is supposed to be more efficient.

However, there are some difficulties related to the fact that the animals habitat is quite vast, and the animals don't live in packs or groups, they live individually [2]. The evident signs of the fact that a certain place is occupied by zokors are a large amount of ground piles cast out by the animal in the process of tunneling. Thus, starting the study of these animals a large territory should be covered to find the places with molehills along. So, saving the search time is a quite actual demand for the scientists because the detection of every borrow as well as counting the whole number of zokors are not always successful.

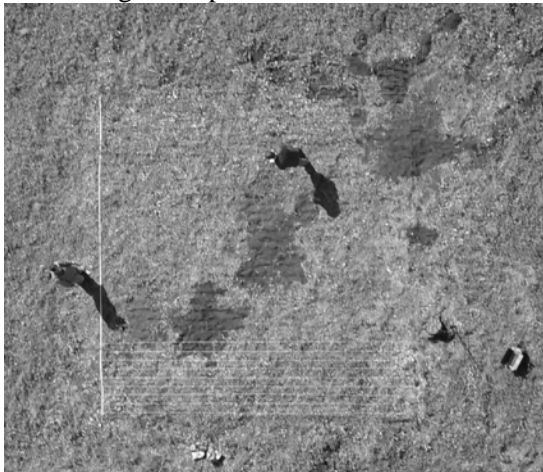
Tomsk State university conducted the summer ground penetrating radar (GPR) research of agricultural fields in Kozhevnikovski district, Tomsk region to detect the zokor habitats.



## 2. Experiments

To define the experimental field, the unmanned aircraft SUPERCAM-250 produced by Finko Ltd, Russia, was used. The aircraft got off the ground at 820 ft over the area, where the zokor habitats were supposed to exist. The area covered by air photographing was about 1.2×1.2 miles. The total time of flight was about 30 min, the identifying the areas inhabited by zokors according to the image analysis took 20 min. So, the 50-min experiment provided the research of the 1.2×1.2miles area, the detection of zokor habitats as well as a preliminary number of animal units. Also, the most suitable area for the GPR investigation was selected. Then, the aircraft was launched again to go on taking images, one of which is presented in figure 1.

Two pieces of the field with evident traces of animal activity – zokors' holes – were sounded. The size of the ground pieces were 4×4 m and 7.5×4 m, respectively. As the ground penetrating



**Figure 1.** The GPR investigation.

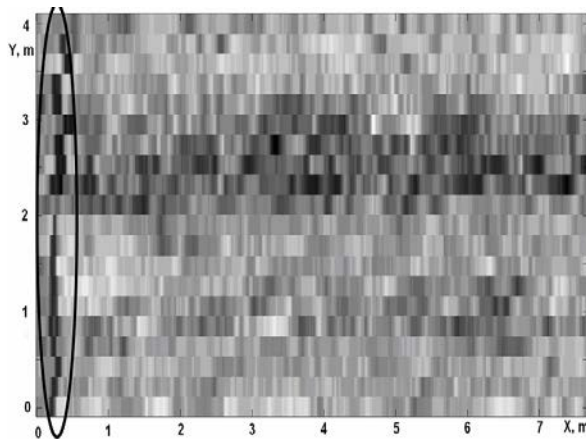
equipment, the radar subsystem OKO-2 with bipolar radiopulses was used. The average pulse frequency in emission band was 1700 MHz. The rated depth of sound penetrating was about 1 m, and the depth resolution was about 3 cm [3]. That resolution should allow us to detect the zokor's tunnels and probably the animals as well.

To obtain the subsurface image, the GPR position on the surface should be precisely recorded. The relative position along the sounding line was provided by GPR tools. A rotation counter attached to a measuring wheel used to monitor linear motion. The crosswise motion to be regulated by ourselves so each piece of ground was marked out before the GPR sounding.

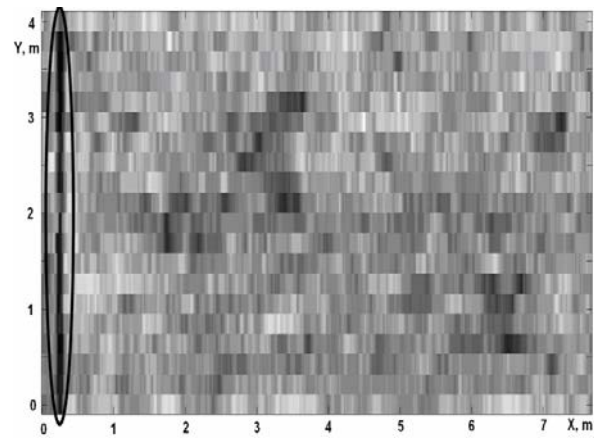
According to the antenna directivity pattern and the radar pulse duration, the longwise and crosswise scanning pitches were defined as 0.022 m and 0.2 m, respectively. The ground marking was performed with nylon cord: firstly, a rectangular of the predefined size was constructed, then, the nylon cord was strained at the defined pitch between the reference points longwise (figure 1). There are a number of possible errors in that approach. One of them is referred to the zero leveling as the GPR was not moved close to the ground. The second one is the need in data adjustment along the GPR trajectory from cross directions. To minimize the errors, a steel tape ruler was placed transversely to the GPR trajectory (figure 1) at the beginning of the trace. As the tape ruler was tightly placed to the ground, it was considered as the zero level and the reference point for the longwise GPR traces as well.

## 3. The GPR data proceeding

There were 21 parallel longwise traces marked out on each piece of ground. The reading of the scattered field was done at 350 points on each trace. To increase the signal-to-noise ratio (SNR), the reading was done 9 times at each point. That corresponded to the three-times increasing the SNR. The row GPR data are presented in figure 2. The figure 2 shows that there are shifts in the zero level signal from the tape ruler (marked with the oval sign) along the GPR trajectory. This shift occurred due to the different initial GPR positions at the cross traces.



**Figure 2.** Row GPR profile of the test ground (the tape ruler position marked with the oval).



**Figure 3.** Row GPR profile of the test ground after the data adjusting (the tape ruler position marked with the oval).

The further data interpreting was possible only when the traces were adjusted against the tape ruler position. To perform the necessary adjustment, an area around the tape ruler was selected, then, the correlation rates were calculated for traces relatively each other. The rates were transformed to the trace shift references. The result of the adjustment is presented in figure 3. There, the signal from the tape ruler is straight across the traces and without essential shifts.

The next processing stage was to perform the focusing. So, the exponential attenuation of radiation when penetrating into the soil should be taken into account. In the test soil, there is a certain quantity of water which causes the signal attenuation. The radiation attenuation will be averaged over the background environment.

The operation sequence is as follows: at every GPR position, time records of scattered signals were transformed into the analytical signal amplitudes.

The analytical signal for the pulse signal was defined as a complex signal  $z(t) = x(t) + iy(t)$ , where the real part was identified with the measured pulse  $x(t)$ , and the imaginary part resulted from the application of the Hilbert transform [4]:

$$y(t) = \frac{1}{\pi} Vp \int_{-\infty}^{\infty} \frac{x(\tau) d\tau}{t - \tau}.$$

The waveform of this signal was evaluated as the complex signal module at each time point. Numerically, this transform was performed using the Fast Fourier Transform (FFT) and the negative frequency muting in the signal band [5]. Then, all the analytical signals obtained were averaged (figure 4). Supposing the exponential signal attenuation, the average ratio should be approximated by the inclined line using the semi-log scale. In figure 4, the corresponding inclined line was drawn using the least square method [6]. The figure 4 shows that deeper than 0.7 m (2.3 ft) the exponential shape was interrupted, and the signal seemed to increase. However, the increase is due to the accumulated intensity of measurement noises. This means that the data at the depth of 0.7 m and deeper are not reliable. So, the attenuation adjustment with renormalization of measured signals to the average exponential decrease provided the alignment of data from all layers in the range from 0 to 0.7 m.

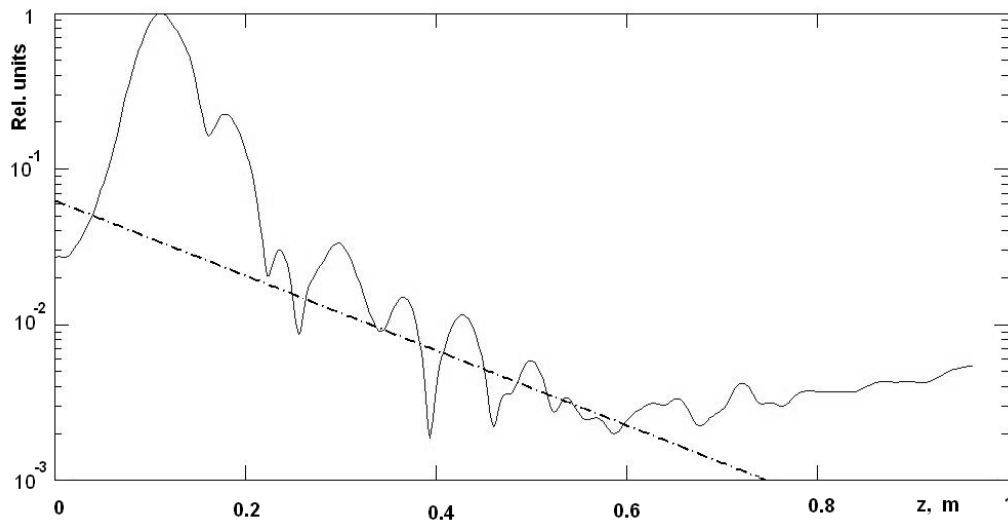


Figure 4. The exponential attenuation of signal.

The last stage in GPR data processing includes the layer-by-layer focusing. The most widely used methods of focusing are the method of diffraction summations and the Stolt migration [7]. Both of them have their advantages and disadvantages as well. The Stolt migration method is faster, as it operates in frequency domain using FFT algorithm. While the method of diffraction summations operates in time domain, but it makes the focusing easier to understand [8].

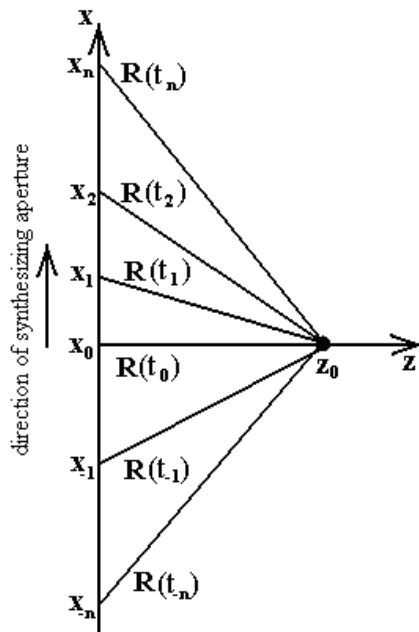


Figure 5. Different travels of reflected signal from the target in different points of sounding system.

As a result of diffraction of each point reflector located in a homogeneous medium is displayed in the form of a hyperbola [7]. In this case the true position of the point scatterer corresponds to the apex of hyperbola. Migration moves reflections to their true positions and mitigates the effect of diffraction, thus increasing spatial resolution and yielding image.

Each reflected pulse travels a distance  $R(t_k)$ , as shown in figure 5, and has a time delay  $\tau_k$ . We can calculate the distance and the time delay by using the Pythagorean theorem:

$$R(t_k) = \sqrt{z_0^2 + (x_0 - x_k)^2}$$

Expressed from this equation  $z_0$  obtain:

$$z_0^2 = R(t_k)^2 - (x_0 - x_k)^2$$

This is a hyperbola equation and  $z_0$ :

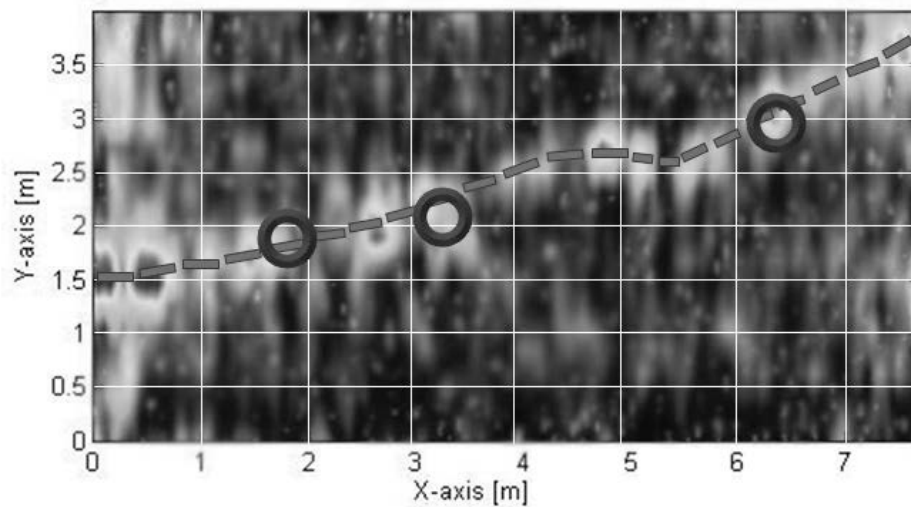
$$z_0 = \sqrt{(t_k c)^2 - (x_0 - x_k)^2}$$

We can obtain in three-dimension case:

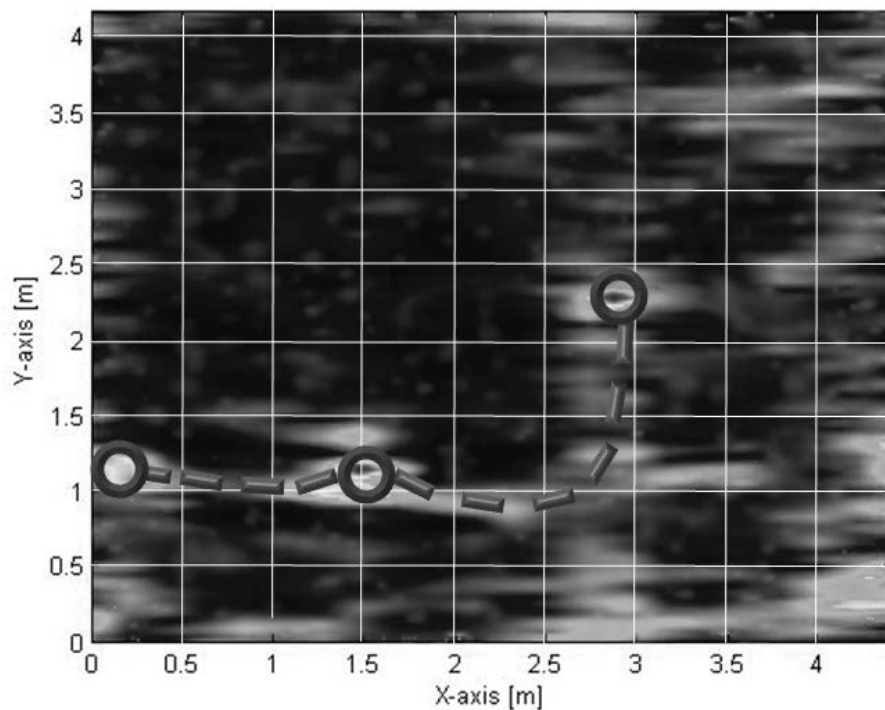
$$z_0 = \sqrt{(t_k c)^2 - (x_0 - x_k)^2 - (y_0 - y_k)^2}$$

The method of diffraction summation is based on the summation of amplitudes along the hyperbolic paths and has the following sequence. 1) Sequent scanning of the test volume points. 2) Calculation of the diffraction hyperbolic curve for each point. 3) Summation of measured signal data along the hyperbolic curve [9].

The results of GPR measurements are presented in figures 6 and 7 for the ground pieces 7.5 x 4 m and 4x4 m, respectively.



**Figure 6.** The GPR crosscut of a horizontal zokor's tunnel at the depth of 12 ft.



**Figure 7.** The GPR crosscut of a horizontal zokor's tunnel at the depth of 12 ft.

The horizontal tunnel is displayed as a dash line. The burrow location observable on the surface is marked with circles.

#### 4. Conclusion

The conducted research demonstrated the opportunity of the GPR application for studying the habitat of underground animals. This is considered to be important and promising direction in geolocation as it prevents the damage caused trapping and opening animal's burrows and helps protect and preserve the animal's natural habitat as well.

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