



Spectral Ground Penetrating Radar in Landslide Studies - The next-generation solution for near-surface imaging

Artur Marciniak¹, Zygmunt Trześniowski², Mariusz Majdański¹, Roman Prykhodchenko², Sebastian Uhlemann³, Adrian Flores-Orozco⁴, Szymon Oryński¹, Justyna Cader-Marciniak⁵, Paweł Rzońca², and Sebastian Kowalczyk⁶

¹Institute of Geophysics Polish Academy of Sciences, Warsaw, Poland

²Widmo Spectral Technologies, Kraków, Poland

³University of Bremen, Bremen, Germany

⁴TU Wien, Wien, Austria

⁵Mineral and Energy Economy Research Institute, Polish Academy of Sciences, Kraków, Poland

⁶University of Warsaw, Warsaw, Poland

Imaging of the shallow near-surface, and any processes associated with it, is particularly important considering the interaction of this zone with human life. Climate change is considerably changing the properties and processes of the shallow subsurface, leading to an increase in triggering conditions of natural hazards, such as landslides. Hence, it is particularly important to have an accurate understanding of the evolution of subsurface properties and their temporal changes to assess the dynamic hazard conditions. One of the key problems to be solved are the physical limitations and resolution owing to classical geophysical methods such as refraction tomography, surface wave analysis or electrical resistivity tomography. On the other hand, more advanced methods such as the use of fiber-optic seismic are expensive in terms of acquisition and processing.

Here we present Spectral Ground Penetrating Radar (SGPR) data compared to classical geophysical techniques. The latest developments on SGPR significantly shift the possibilities of ground imaging by using a frequency modulated continuous electromagnetic wave (FMCW) in place of the impulse usually used in GPR technology. These novel devices and methodology represent a huge leap in subsurface imaging resolution, while also providing interpretation capabilities for results previously used primarily in seismic reflection methods in wider industrial approach. In addition, new visualization capabilities based on a number of physical parameters unique to this method are also under development.

An example of the application of this method is a time-lapse study of a landslide under significant anthropogenic influence in Ciśiec (Silesian voivodeship, Poland). This landslide poses high risk to the community, where accurate monitoring is crucial to ensure the safety of people and infrastructure. At the same time this site is a large-scale model of a landslide where triggering factors can be estimated and are representative to this part of the Outhern Carpathians. The SGPR

method proved particularly useful in characterizing the 10-30 m zone, where other geophysical methods give limited or low-resolution information. This allowed very accurate imaging of slip planes and zones of compaction, further distinguishing structures not visible on other geophysical methods and which were not recognized in previous studies since 2018.

The results presented here demonstrate the usefulness of the SGPR methodology, especially in environments where other geoelectric and electromagnetic methods cannot be used or give limited results, and where seismic methods are expensive. Landslides are just one example of the application of this novel methodology, allowing both single and time-lapse measurements to be carried out quickly, cost-effectively and with unprecedented resolution.