Improving underground mining safety through finite-difference time-domain modelling of through-the-Earth radio signals

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Through-the-Earth (TTE) radio has been proposed as a means of emergency communications in variety of underground settings, including mining operations. There are a variety of ways to transmit a signal, including induction (current-carrying loops akin to those in electromagnetic (EM) methods); placing electrodes in the ground (such as in the DCIP/resistivity methods); seismic pulses; and even coupling to elongated metallic objects such as railway tracks. A modelling tool using the finite-difference time-domain (FDTD) method has been created to simulate inductive TTE radio transmissions in the very low frequency (VLF) range. A major advantage of the FDTD method is that it can model several frequencies of interest at once—the TTE radio signal spans a frequency range of up to 2 kHz. The straightforward discretization used in FDTD permits easy modelling of inhomogeneous geologic media. Forward modelling can answer multiple questions to optimize deployment to a potential site. For example, what is optimal frequency to use for a certain position? In some cases, such as when the receiver is directly below the transmitter, the solution is intuitive—lower frequencies will be less attenuated. In contrast, at certain lateral displacements, we may see an increase in signal with higher frequency. Another example is the position of nulls. At certain distances from the transmitter, there exist zones of very low signal (nulls); how do they get affected by different conductivity distributions? A final example: how far can the signal be received when propagating laterally along a mine level? A caveat about forward modelling is that it is only as reliable as the conductivity information used to build the model. To improve the reliability of the modelling, a method to determine the conductivity structure of a mine overburden using TTE radio transmissions has been developed. By measuring the transmitter current at the surface and the magnetic field received underground, an apparent conductivity for the overburden can be determined. In addition, by taking measurements at several underground locations, a more sophisticated conductivity model can be resolved by using the FDTD tool to minimize the difference between the observed and computed signal attenuation. The poster will feature a case study from the Safety Research Coal Mine, located in Bruceton, PA, near Pittsburgh.