

Ground Penetrating Radar (GPR)

Principles of operation

Ground Penetrating Radar (GPR) systems operate by transmitting polarised pulses of electromagnetic energy into the ground and then recording the energy that is reflected back to the surface. The method responds to variations in the electrical properties of subsurface materials (dielectric constant and conductivity) that are a function of material type, moisture content and pore fluid type. Where a contrast in dielectric properties exists between adjacent materials a proportion of the electromagnetic pulse will be reflected back. Subsurface structures are mapped by measuring the amplitude and travel time of this reflected energy. More information is given by Reynolds (2011).

The electromagnetic energy is transmitted via an antenna at a specified central frequency and can be recorded with either the same antenna or a separate antenna (monostatic mode or bistatic mode, respectively). Digital radar systems can also operate with multiple receiving antennae. The frequency of the transmitted energy (antenna frequency) is selected with reference to the size and depth of potential targets, *i.e.* the lower the frequency of the transmitted energy, the greater the depth of penetration, and the higher the frequency, the smaller the size of target than can be resolved. GPR manufacturers produce antennae with a range of frequencies from 25 MHz up to 2.6 GHz. The low-frequency antennae are normally used for geological applications while the high-frequency antennae (> 500 MHz) are used for engineering applications, although most geo-environmental applications utilise the mid range of frequencies (200 MHz to 500 MHz).

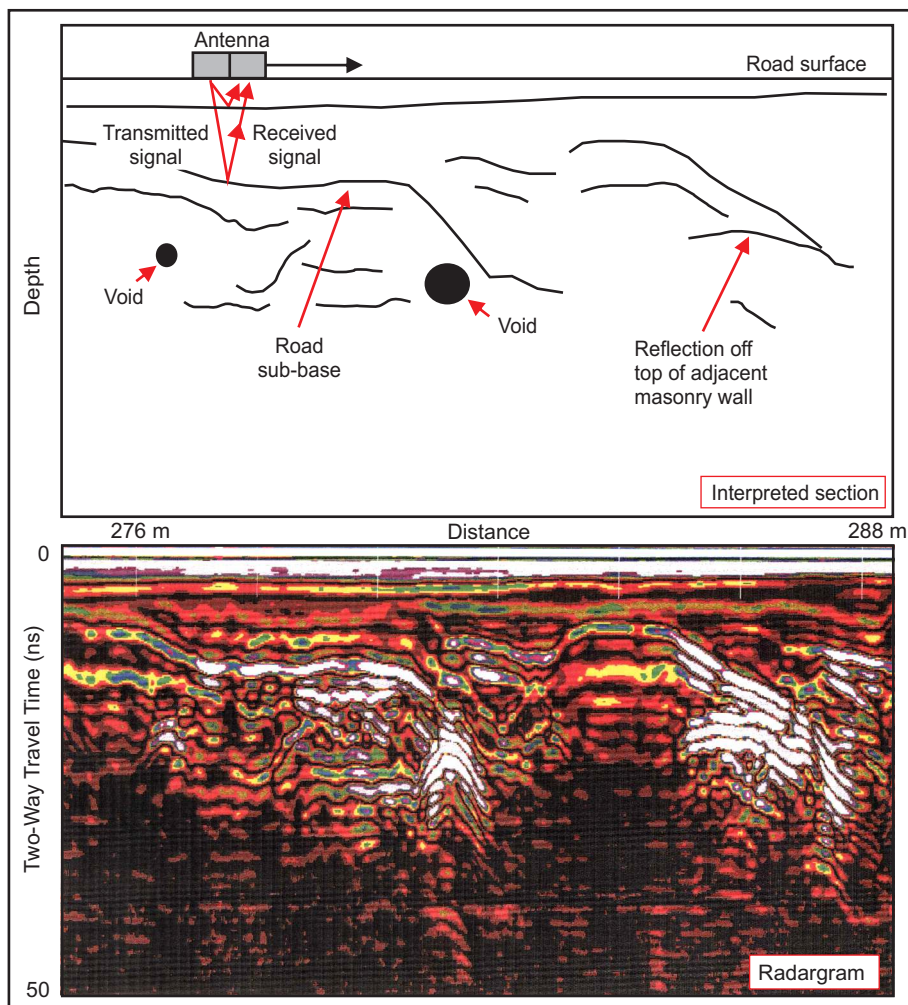


Figure 1: Example radargram from a GPR survey conducted along a road surface. The survey was successful in its aim, which was to locate possible subsurface voids.

The output of a GPR survey is a series of radargrams, analogous to a seismic section, which is a record of the reflected energy displayed in terms of Two-Way Travel Time (TWTT) versus horizontal distance. Two-Way Travel Time is the time taken for the energy to travel from the transmitting antenna to the subsurface reflector and back up to the surface. Radar waves travel at the speed of light (0.2998 m/ns) through air, but their propagation velocity through engineering and geological materials is much slower (c. 0.05-0.14 m/ns). Disruption of reflections from known linear features often indicates anomalous volumes of material (e.g. voids) in the overburden. Usually, radargrams can be interpreted immediately after limited data processing (e.g. filtering and gain application) but, in cases that justify the additional expense of advanced, complex processing, GPR data can be analysed to highlight features that might otherwise remain undetected.

Applications

- Geological and hydrogeological investigations including mapping of bedrock topography, water levels, solution features, glacial structures, soils and aggregates.
- Engineering investigations to evaluate dams, sea walls, tunnels, pavements, road beds, railway embankments, piles, bridge decks, river scour, buildings and monuments.
- Location and evaluation of buried structures including utilities, foundations, reinforcing bars, cavities, tombs, archaeological artefacts, and animal burrows.
- Brownfield site investigations: location of buried engineering structures and underground storage tanks.

Advantages

- Rapid ground coverage afforded by towing the antennae either by hand or from a vehicle.
- High lateral resolution of targets, even for larger surveys.
- The instant graphic display offered by most GPR systems allows on-site interpretation.

Limitations

- Data acquisition may be slow over difficult terrain.
- Depth of penetration is limited in materials with high electrical conductivities, e.g. clays.
- Energy may be reflected and recorded from above-ground features, e.g. walls, canopies, etc. unless antennae are well shielded.
- Artefacts in the near surface (e.g. reinforcing bars, boulders, components of made ground, etc.) may scatter the transmitted energy and complicate the received signal and/or reduce depth of penetration.

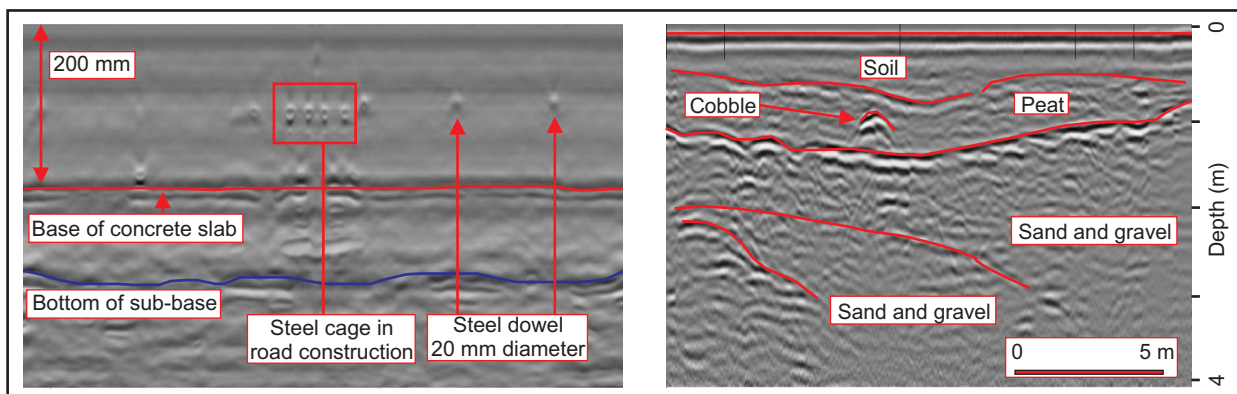


Figure 2: *Left:* Migrated 1.5 GHz radargram revealing steel dowels in concrete. *Right:* unmigrated 100 MHz radargram showing shallow sedimentary deposits in a peat bog.

Reference

Reynolds, J.M. 2011. *An Introduction to Applied and Environmental Geophysics*. John Wiley & Sons Ltd, Chichester, 2nd ed., 712 pp.