# Finding water using a pulsed radar

**Gordon Stove, Adrok, Scotland gstove@adrokgroup.com**

Currently we live in a global water crisis, nearly one third of the population live in countries where the availability of water is a constraint on human activity. More than 840,000 people die every year from lack of availability of clean water. The water crisis also has economic implications. For example, Brazil who extracts 60-70% of their energy from hydro-electric dams forced consumers to cut their energy consumption by 10% in 2015 and 20% in 2001 which in turn has a negative effect on the entire GDP (Costas, 2015).

Many believe there is a deficiency in long term and medium-term planning of the water budget, and there is much to be done to find alternative water supplies. The main problems can be summed up in two points:

i. Demand is increasing (increasing populations is putting major strain on already producing reservoirs. According to the United Nations, water use has grown at more than twice the rate of population increases in the last century.)
ii. Supply is decreasing (The amount of available water is effectively shrinking with contamination and pollution, deforestation and irrigation.)

Climate change is also influencing the water crisis, the US alone is expected to see an increase in "mega-droughts" this century placing already strained areas under more pressure to find new water sources.

Some of the problem lies with finding new reservoirs, tracking aquafers, and monitoring the movement of water within aquafers. Where does the water come from? Where does the water go? Where is the water stored?

Shallow and deep groundwater can be a major environmental obstacle for any geophysical surveying technique, especially radio waves. Ground penetrating radar (GPR) is a mature technology with applications in many areas; see Daniels (2004) for an overview. Almost all applications are restricted to imaging the subsurface to a rather shallow depth: large losses of signal occur when propagating through materials with free ions. These conductive losses are determined by the soil conductivity. However, in environments where these losses are low, the depth penetration of GPR increases dramatically, allowing imaging up to depths of several kilometres, for example, through the polar ice on Mars (Jordan et al., 2009; and Orosei et al., 2018) and Antarctica (Berthelier et al., 2005).

To extend the depth range of conventional GPR surveys, a radar-based imaging technology has been developed that measures atomic dielectric resonance (ADR) in the subsurface. ADR technology measures subsurface (i) dielectric permittivity; (ii) spectral (energy, frequency and phase); and (iii) material resonance, from ground level without physically boring the ground. ADR is a patented investigative technique (Stove, 2005) which involves the measurement and interpretation of resonant energy responses of natural or synthetic materials to the interaction of pulsed electromagnetic radio waves from materials which permit the applied energy to pass through the material. The technology can be trained on known geology to build up a reference database, which is then used to classify data collected at new locations.

ADR measurements can be presented in outputs resembling: (i) stratigraphy (like seismic imagery); (ii) information on rock characteristics (like well logs); and (iii) rock petrography (like cores).

**Fundamentals of ADR Technology**

ADR technology is based on the principle that different materials reflect and absorb electromagnetic radiation (radio waves) at specific frequencies and energy levels. The ADR geophysical system transmits a pulse of electromagnetic energy containing a multispectral wave packet that resonates and interacts with the subsurface materials. The reflections from the subsurface are recorded as a time-domain trace and provide information about the location and composition of the materials encountered (Stove and van den Doel, 2015).

ADR technology finds applications in a variety of different fields, including mineral, oil, and gas exploration, as well as water discovery and geotechnical purposes. The field survey equipment (Figure 1) consists of one transmitting antenna and one receiving antenna, the antennas gimbal platform, the receiver control unit, the transmitter control unit, and the data acquisition computer. Data acquisition is relatively quick as the ADR Scanner and equipment are small and mobile.

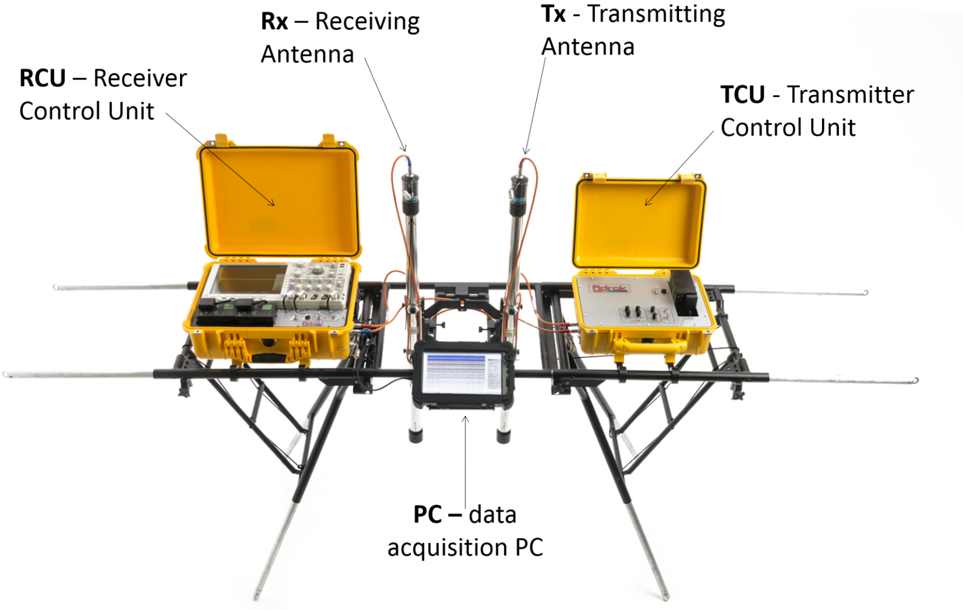


**Figure 1. ADR field equipment, the "ADR Scanner".**

The ADR signal generator produces a broadband pulse that is fed to the transmitting antenna. The transmitting antenna conditions the signal into the desired wave packet using dielectric lenses and mirrors so that the transmitter and receiver appear to have much longer chambers than their actual physical size (Stove et al., 2012). Once the signal has been sent to the transmitting antenna, a signal is sent to the receiving control unit to synchronise collection of the subsurface reflection data which is detected by the receiving antenna from different subsurface rock layers and mineral structures. The receiving control unit collects the signal from the receiving antenna and converts it into a form that can be read and stored on the data logging computer (Stove and van den Doel, 2015).

This paper discusses fieldwork using the ADR system to find subsurface water aquifers in Scotland and in the Great Artesian Basin (Australia).

Theoretical results, as well as those from field experiments and surveys, suggest that the exploration depth of pulsed radar can be increased significantly by including a low frequency component. Data suggests the high losses of Ground Penetrating Radar (GPR) in the 10 - 1000 MHz range are due to polarization effects, rather than conductivity losses (van den Doel et al, 2014). Measurements of limestone conductivity indicate that the skin depth for the low-frequency component of an ADR wave packet could achieve much greater skin depth than possible by GPR. If these results hold for other rock types, deeply penetrating radar scanning can potentially become an attractive geophysical exploration technique in selective environments where there is no highly conductive near-surface layer, or where this layer is thin enough to penetrate.

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