Archaeologia Polona, vol. 53: 2015, pp. 631-635

First results from a new ground-coupled multi-element GPR array

Neil Linford[a], Paul Linford[a] and Andy Payne[a]

KEY-WORDS: ground penetrating radar, ground-coupled array, multi-channel, continuous wave stepped frequency

The 3D-Radar GeoScope continuous wave stepped frequency (CWSF) GPR system was originally introduced with a multi-element, air-launched antenna array. Whilst this system could certainly produce high resolution results over archaeological targets, there was some debate over the suitability of an air-coupled antenna for all site conditions, particularly where

[a] Historic England, Remote Sensing Geophysics Team, Fort Cumberland, Eastney, Portsmouth, United Kingdom

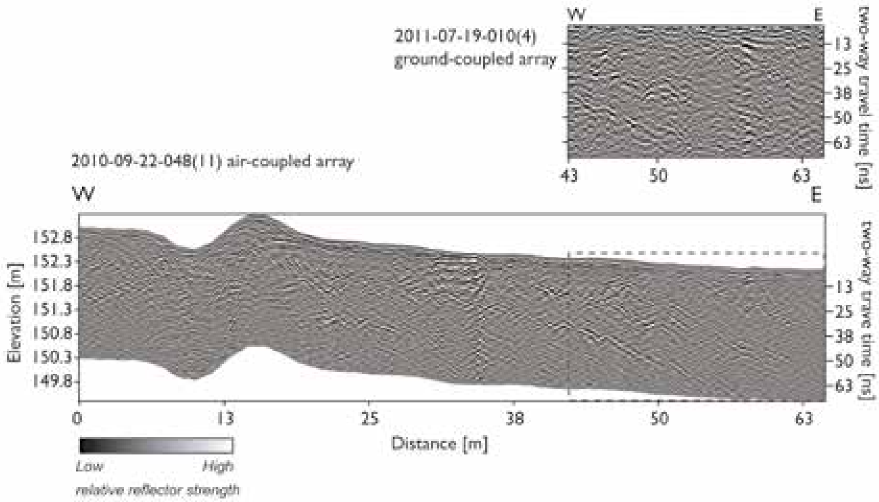

Fig. 1. Topographically corrected GPR profile through the ditch and bank at Stonehenge, collected with an air-coupled V1821 antenna. The inset shows comparative data collected from 43 m with a prototype ground-coupled G0605 antenna

a conductive surface layer, typical of many archaeological sites in the UK, could impede the transfer of energy into the ground (Leckebusch 2011). In addition, to obtain the best quality results from the air-coupled data, alternative data processing routines were required to cope with the strong reflections from the ground surface and varying velocity between the air and subsurface (Sala and Linford 2012).

The English Heritage (now Historic England) Geophysics Team first had an opportunity to test the GeoScope system with a ground-coupled array during a survey at Stonehenge, Wiltshire, in September 2010 (Linford *et al.* 2012; Field *et al.* 2014). Here, most of the survey was conducted over open ground, where our air-coupled V1821 array could operate without impediment. However, to extend the survey into the stone circle required a narrower, hand-operated system to pass between the upright stones. 3D-Radar kindly loaned an early prototype ground-coupled G0605 antenna for this survey, compatible with the Mk III GeoScope console, which combined five individual antenna elements spaced 0.075 m apart within a 0.6 m wide housing, providing highly complementary data that could be readily integrated with overlapping areas collected with the air-coupled array. On further analysis, the ground-coupled array was found to have produced, perhaps as expected, data with a greater signal-to-noise ratio evident in the later returns, beyond ~50 ns, with longer "tails" to hyperbolic point reflectors (Fig. 1). Some very minor discontinuities in the linear reflectors and surface "ringing" could, perhaps, be attributed to a loss of coupling with the prototype antenna over the uneven ground surface that might, potentially, be worse for a wider ground-coupled antenna array.

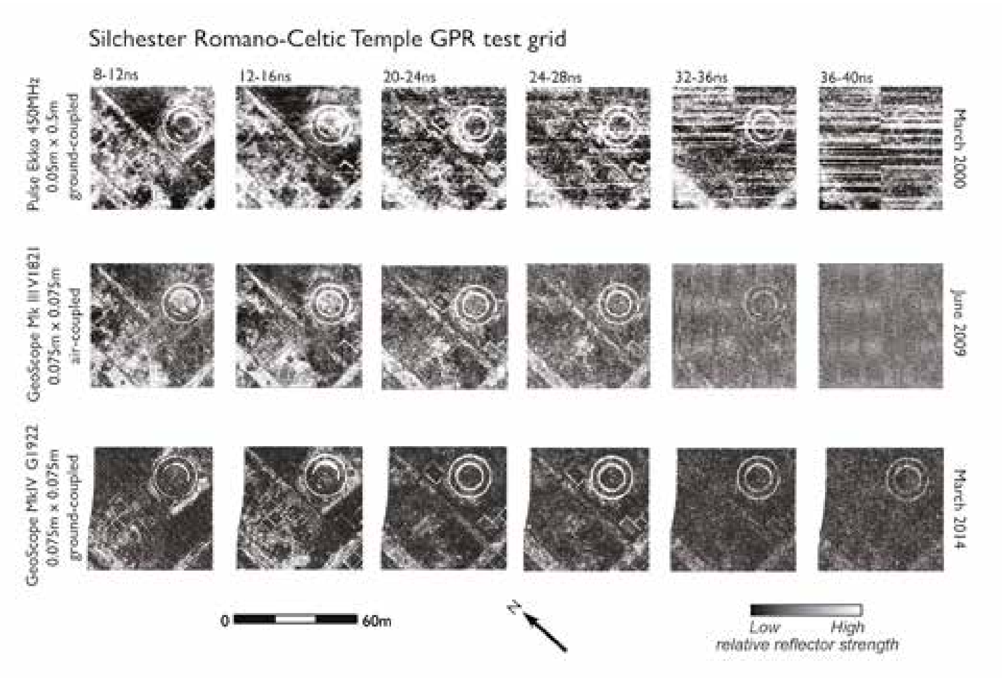

Fig. 2. Extracted data from a 60 m x 60 m square over the Romano–Celtic temple at Silchester, Hampshire, UK. Results from the G1922 pre-production prototype array (bottom row) combine a high signal-to-noise ratio similar to the PulseEkko 1000 single-channel 450 MHz centre frequency ground-coupled antenna (top row), but with higher spatial resolution. The depth of penetration is greater than in the case of the V1821 air-coupled array (middle row)

It was of great interest, therefore, to test a full-width 22 channel G1922 version of the ground-coupled antenna, which became available in March 2014 for use with the MkIV GeoScope console, offering faster acquisition across a wider frequency bandwidth (60MHz to 3GHz) and the same 0.075 m spacing between the individual elements in the array. Field tests over the Roman remains at Silchester corroborated the results from the earlier prototype, demonstrating an increased depth of penetration at the site compared to the previous air-coupled array (Fig. 2). Whilst the comparative ground-coupled data set shown in Fig. 2, collected with a single-channel PulseEkko 1000 using a 450 MHz centre frequency antenna at a lower crossline spatial of 0.5 m, has suffered some loss of coupling along individual lines evident in the later returns, this does not appear to have affected data collected with the new G1922 array. This could suggest that a suitably mounted wider antenna array can offer a good compromise between manoeuvrability and stability over typically uneven surface conditions.

Field tests have been conducted over a range of sites, including further Roman villa sites, formal post-medieval garden remains and a medieval farmstead, to assess the response of the ground-coupled antenna to more challenging site conditions, particularly through water-saturated soils (Linford 2015; Linford and Payne 2015). Results collected over the medieval

Fig. 3. Amplitude time slice between 8.4 and 9.6 ns (0.46 m to 0.53 m) from over the medieval settlement at Catridge Farm, Lacock, Wiltshire, UK. Despite the presence of water-saturated soils, the ground-coupled GPR array produced useful results to complement the analytic earthwork and magnetic surveys

farmstead at Catridge Farm, Lacock, Wiltshire, UK, proved to be of interest as they corroborated and enhanced the existing analytical earthwork plan and magnetic data over this low-lying site with heavily water-saturated soils (Fig. 3). The GPR survey could also be conducted very rapidly, creating minimum interference for the landowner of this busy working stud farm.

Finally, results from a full production DXG1820 version of the antenna will be presented with a further optimisation of the individual element design to aid the recovery of weak return signals. Again, this has proved useful over sites where the presence of water-saturated soils may have compromised the use of an air-coupled antenna array or potentially restricted the depth of signal penetration. Comparison with earth resistance results over a complex of Roman buildings found close to the modern shore line at Warblington, Havant, Hampshire, UK, demonstrates the often complementary nature of the two techniques and the ability of the GPR to extract greater detail from areas of rubble destruction deposits.

REFERENCES

Field, D., Linford, N., Barber, M., Anderson-Whymark, H., Bowden, M., Topping, P., Linford, P., Abbott, M., Bryan, P., Cunliffe, D., Hardie, C., Martin, L., Payne, A., Pearson, T., Small, F., Smith, N., Soutar, S. and Winton, H. 2014. Analytical Surveys of Stonehenge and its Immediate Environs, 2009–2013: Part 1 – the Landscape and Earthworks'. *Proceedings of the Prehistoric Society* 79: 1-32.

Leckebusch, J. 2011. Comparison of a stepped-frequency continuous wave and a pulsed GPR system. *Archaeological Prospection* 18 (1): 15-25.

Linford, N. 2015. West Dean Villa, West Tytherley, Hampshire. Report On Geophysical Survey, July 2014. *English Heritage Research Reports Series* 2/2015.

Linford, N., Linford, P. and Payne, A. 2012. Stonehenge Monument Field And Barrows, Wiltshire, Report On Geophysical Surveys, September 2010, April And July 2011. *English Heritage Research Reports Series* 34/2012.

Linford, N. and Payne, A. 2015. Wrest Park, Silsoe, Bedfordshire, Report On Geophysical Survey, November 2014. *English Heritage Research Reports Series* 1/2015.

Sala, J. and Linford, N. 2012. Processing stepped frequency continuous wave GPR systems to obtain maximum value from archaeological data sets. *Near Surface Geophysics* 10 (1): 3-10.