EM61 electro-magnetic metal detection

The Geonics EM61 instrument utilises time-domain Electro-Magnetic (EM) phenomena to locate shallowly buried metallic objects (*e.g.* UXO) in a maximum depth range of 5 cm to 5 m. The system comprises three square coils of 1 m side. Coincident horizontal transmitter (T_x) and receiver (R_x) coils are mounted 40 cm beneath a second horizontal receiver coil (Figure 1). The system is either carried or trolley mounted, at a constant height of 45 cm above the ground. The EM61 is capable of detecting a single 55 gallon steel drum at 3 m burial depth and offers better multiple target discrimination within the depth range than contemporary techniques such as magnetometry. The instrument also exhibits high cultural noise rejection, enabling surveying in regions crossed by fences, power lines, *etc*. More information about EM techniques is given by Reynolds (2011).

Principle of operation

Continuous field electromagnetic instruments observe changes in a secondary electromagnetic field with respect to a much stronger primary. This limits the available signal-to-noise ratio (SNR) and resolution. Transient systems record the time-domain effect of secondary field decay in the interval between switched pulses of the primary (Figure 2). The secondary field is generated through creation of eddy currents when the primary field is abruptly terminated, or by electrical polarisation of the target. Values of secondary field strength are accurate to ±1 mV and typically range from background noise levels of a few milli-volts to signals of several volts. Signal repetition rate is approximately 150 s^{-1}; stacking of multiple signals can be advantageous. The standard EM61 instrument records only a single reading per receiver coil, although customised models can make up to six observations per coil, allowing more detailed analysis of decay curve parameters (McNeill & Bosnar 1996, Saunders *et al.*, 2000). Use of dual receiver coils facilitates correction for near-surface effects and also provides information for quantitative interpretation of decay curves (see below).The secondary electric field strength, rate of decay and decay rate variation are characteristic of the causative conductive body; field strengths generated by objects composed of ferrous metals are approximately an order of magnitude stronger than those due to non-ferrous metals.

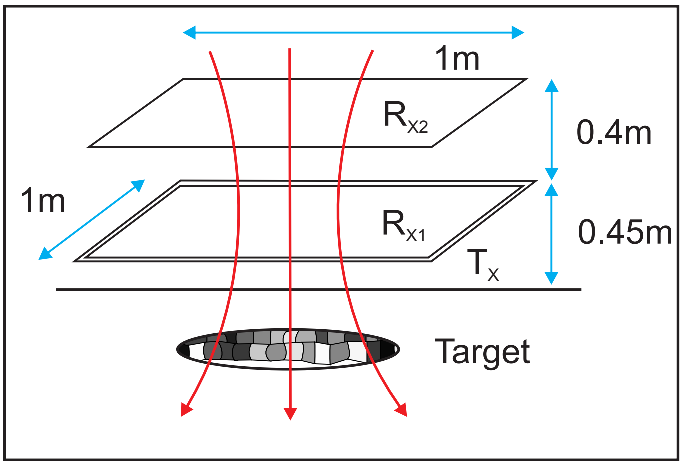

Figure 1: *Left:* Coil configuration of original EM61 Mk 1 showing orientation of magnetic field relative to target. *Right:* Geonics EM61 Mk 2 operated in trolley mode. The coincident coils T_X and R_{X1} are located in the lower quadrangle, whilst the upper quadrangle houses R_{X2}. Survey positioning data are acquired using a GPS antenna mounted above the coils.

Deployment

For location of UXO, the survey grid would typically comprise multiple nodes at 75 cm spacing. First-pass data are contoured and anomalous regions subsequently re-surveyed at closer intervals to provide precise x,y target co-ordinates. Example acquisition rates for UXO location are 5 minutes per 40 m line at 10 cm grid spacing (Pellerin *et al.*, 1997) and one day for a complete 10 line-km survey at 20 cm grid spacing (Geonics, 1996).

Interpretation

Basic interpretation involves contouring of voltage data from channel 1, channel 2, and the difference between channels. The difference between channels provides information on deeper anomalies with near-surface effects removed. Peak amplitude location indicates the x,y co-ordinates of the target centre. Examples of data interpretation and system capability are provided by Hoekstra (1996), *e.g.* detection of a 17.5 cm diameter rocket at 1.8 m depth.

More advanced interpretation procedures using approximations to simple shapes have been developed (*e.g.* McNeill & Bosnar, 1996). These techniques require multiple time gate recordings and non-standard modification of the EM61 instrument. This approach can provide additional information on target composition, structure, depth and orientation, but its use is far more labour intensive.

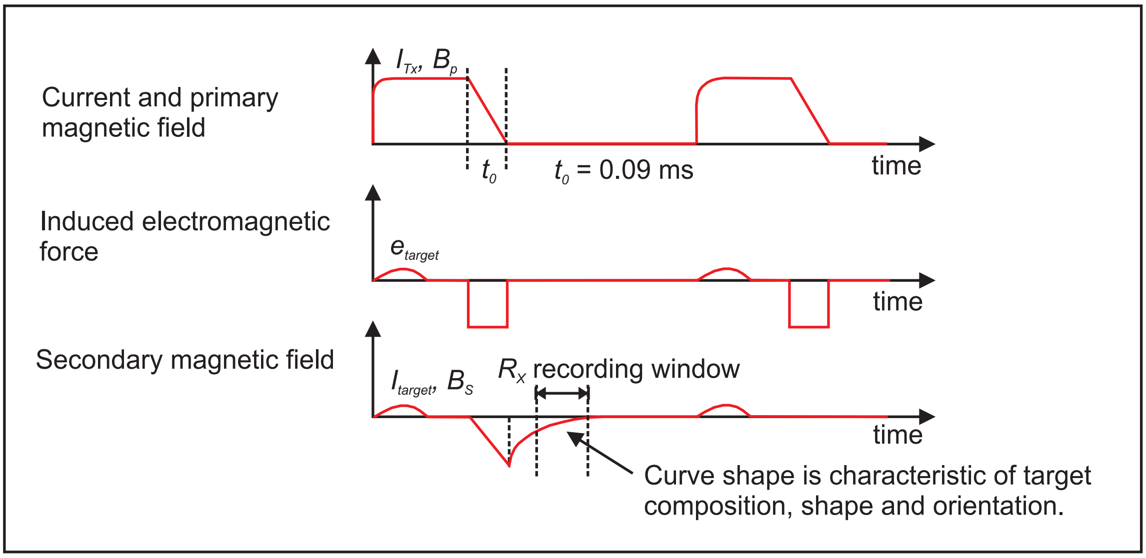

Figure 2: EM61 waveforms demonstrating relationship of primary magnetic field B_p to generation and decay of secondary magnetic field B_S. Reproduced from McNeill and Bosner, 1996.

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