**Motorized Surveying with GPS and DUALEM Electromagnetic Induction (EMI) Instruments.**

## Introduction

DUALEM instruments operate through electromagnetic induction and, thus, require no contact with the ground. Non-contacting operation makes DUALEM instruments suitable for surveys using a motor vehicle, which enables efficient coverage of large areas.

Three factors that affect the effectiveness of motorized surveying are the situation of the instrument relative to both the vehicle and the ground, the platform for the instrument, and the positioning of data.

## Situation of the Instrument

The situation of the instrument refers to the distance between the instrument and the vehicle, the orientation of the instrument relative to both the vehicle and the ground and the height of the instrument above the ground.

There are two potential sources of noise from the vehicle, namely the electrical system of the vehicle and EMI in the metal of the vehicle. Both types of noise decrease greatly as the distance increases between the vehicle and the instrument. DUALEM instruments are insensitive to noise away from their 9-kHz operating frequency, so the broadband noise of the electrical system is of less concern than EMI in the metal of the vehicle.

EMI is generally insignificant if the distance between the instrument and any substantial area of metal on the vehicle is at least as large as the transmitter-receiver separation (i.e. 2 m for the DUALEM-2 and 4 m for the DUALEM-4). The distance should be increased where signal levels are very low, such as on deeply frozen ground, or where the application requires high-quality in-phase measurements, such as UXO detection.

Figure 1 shows a DUALEM-4 being towed on a cart behind an all-terrain-vehicle. The distance between the vehicle and the instrument is a little more than the length of the instrument, which is perfectly adequate for the application of measuring conductivity (i.e. quadrature) over moderate ground.

The orientation of the instrument relative to the vehicle is of little importance, but accidental damage to the instrument is usually less likely if the instrument is aligned with the direction of travel (as in figure 1). Most operators prefer orient the instrument with the transmitter closest to the vehicle, and this is clearly advantageous if a data cable, which attached to the connector near the transmitter, extends from the instrument to a logging system on the vehicle.

The instrument should be secured so that the data connector remains vertical on the top of the instrument throughout the surveying.

**Figure 1: DUALEM-4 on a Cart.**

(Photo: Alpha Geoscience Pty. Limited)

The distance from the ground to the mid-height of the instrument should be measured and noted. To maximize signal levels, this ground clearance should be as low as practicable. However, some surveyors of metal or UXO in magnetic ground prefer a ground clearance of as much as 0.5 m, as the effect of magnetic susceptibility on in-phase measurements decreases rapidly with increasing clearance.

## Instrument Platform

Carts and sleds are the prevalent types of platform for DUALEM instruments. The Appendix notes websites that may contain information about sled materials. A comprehensive description of the sled shown in figure 2, as originally designed and built by John Holman, is available from Dualem by request.

**Figure 2: Sled for DUALEM-2.**


(Photo: John Holman, USDA-ARS)

Wherever possible, platform materials should be non-conductive and without magnetic permeability, especially for portions of the platform nearest the transmitter and receivers. Significant perimeters or areas of conductive material are most problematic; for example, inflatable tires that incorporate loops of wire should not be used.
The illustrated cart and sled both use blocks of plastic foam to reduce vibration of the instrument. Protective padding such as the foam not only will help to maintain the service life of the instrument, but will also tend to improve the quality of data.
Some users place a shell around the instrument to provide additional protection from rocks and vegetation. Figure 3 shows a combined shell and sled constructed by the University of Florida for surveying irregular terrain in citrus groves. Foam-rubber sleeves inside the shell and mounts between the shell and the sled insulate the DUALEM-2 from some vibration and shock.

**Figure 3: Sled with Shell for DUALEM-2.**


(Photo: A. Schumann, University of Florida)

A shell can provide additional benefits in sunny conditions. A shell that shades the instrument uniformly will tend to reduce any drift, particularly in perpendicular (PRP) in-phase, that may otherwise occur. In hot weather, a shell that reduces solar heating will extend the operating range of the instrument.

**Positioning of Data**
GPS positions are used routinely for data from motorized surveys. Positions can be assigned to data on the basis of matching time-stamps, or by suitable logging systems.
A typical logging system consists of a hand-held computer with two RS-232 ports, along with software that combines serial DUALEM and GPS input into an integrated file with measurements and positions. DUALEM user manuals

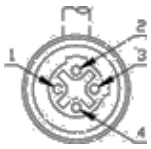
contain specifications for logging systems, and the Appendix contains information about components of systems that may be commercially available.
Where a measurement is made while the instrument is moving through an interval between a starting point and an ending point, the most accurate position for the measurement will lie somewhere between the points. The exact position depends on the time that is required to sense the measured quantity and for the instrument (and logging system) to process the result.
A test of the displacement between the most accurate position and the recorded position for a measurement uses a conductive object on the ground. The object must provide a distinct response to the instrument; an example is a length of wire connecting two metal stakes that have been driven into moist ground. The instrument is passed at survey speed over the object twice, in opposite directions, and the apparent positions of the responses are compared.
Note that the PRP response over a narrow object is asymmetrical, so to compare PRP positions, the orientation of the instrument should be kept consistent relative to the positioning coordinate system. For example, if the passes over the object are from north to south, and then south to north, the transmitter end of the instrument on both passes should be consistently either north or south of the receiver end.

**Summary**

DUALEM instruments are used in motorized surveys to measure conductivity and detect metal over large areas.
For most surveying, the instrument should be at a distance from the motor vehicle equivalent to one transmitter-receiver separation, and at low clearance above the ground. The instrument should be held securely to prevent rotation about its axis during surveying.
The platform for the instrument should be non-responsive to the DUALEM transmitter. The platform should lessen vibration for the instrument, and protect the instrument from mechanical shock and abrasion. In sunny conditions, a covering that provides shade may be beneficial.
Generally, GPS is used to position data. Some displacement between the recorded position and the actual position of measurements may occur, especially at greater speed. Such displacement can be measured by surveying in opposite directions over a small target.

**Appendix: Components of Survey Systems that may be Commercially Available.**

A wide variety of components can be used in a DUALEM/GPS survey system. The following table is provided for the convenience of surveyors who are starting to investigate sources of components. The table lists very few of the components that may be available; components are not necessarily compatible with each other, and much of the information may be inaccurate or outdated. Dualem welcomes comments from surveyors and suppliers.

<table>
<tr><th>Component</th><th>Notes</th></tr>
<tr><td>Sled</td><td>www.emscogroup.com or www.theparisco.com</td></tr>
<tr><td>Data Cable<br>  <br>Figure 4: Dual-keyway micro-style sockets</td><td>For systems where the logging device is beyond the reach of the 2-m cable supplied with the DUALEM instrument, and where the user does not want to extend the cable with a 9-pin-to-9-pin extension. A DUALEM data/power cable has four wires with a dual-keyway micro-style female connector at one end and a DE-9 female connector at the other. Suitable micro-style cordsets are may be found at www.ab.com (e.g. part number 889R-F4AEA-5) and www.turck.com (e.g. part number KB 4T-4). A DUALEM data cable is made as follows:
<table>
<tr><th>Micro Socket</th><th>Wire</th><th>DE-9 Socket</th><th>Function</th></tr>
<tr><td>1</td><td>Red/Black</td><td>2</td><td>DUALEM data Tx / Logger Rx</td></tr>
<tr><td>2</td><td>Red/White</td><td>3</td><td>DUALEM data Rx / Logger Tx</td></tr>
<tr><td>3</td><td>Red</td><td>9</td><td>+ 12 V power</td></tr>
<tr><td>4</td><td>Green</td><td>5</td><td>Ground</td></tr>
</table></td></tr>
<tr><td>Logging Device</td><td>Compaq IPAQ plus Compaq PC-card expansion pack (part number 249708-B21) plus Socket dual-serial PC-card (product number SLO723-116 or SLO703-081). Websites are www.hpshopping.com and www.socketcom.com.</td></tr>
<tr><td>Logging Program</td><td>DLog. Website is www.deltadatasystems.com.</td></tr>
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| Logging System | Trimble TSC1 with AssetSurveyor software. Website is www.trimble.com. |
| Logging/GPS System | Juniper Allegro with bracket-mounted Holux GPS receiver and StarPal HGIS software. Websites are www.junipersys.com and www.starpal.com. |
| USB adapter | Belkin USB PDA Adapter. Website is world.belkin.com. |