A Novel Magnetic Gradiometer: Description, Design Issues and Trial Results

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Magnetic Gradients

Experiments using two rigidly mounted TMI sensors have been made since 1954

Gradient measurements are not a function of the Earth's magnetic field

- Calculation of grids is more rigorous
- Diurnal variations are not a factor

Remnant magnetisation can differ from Earth's magnetic field

- Complex signals from discreet bodies are more easily resolved
- Koenigsberger Ratio (remnant : induced) can be computed

Inverse model solutions are more unique using gradients

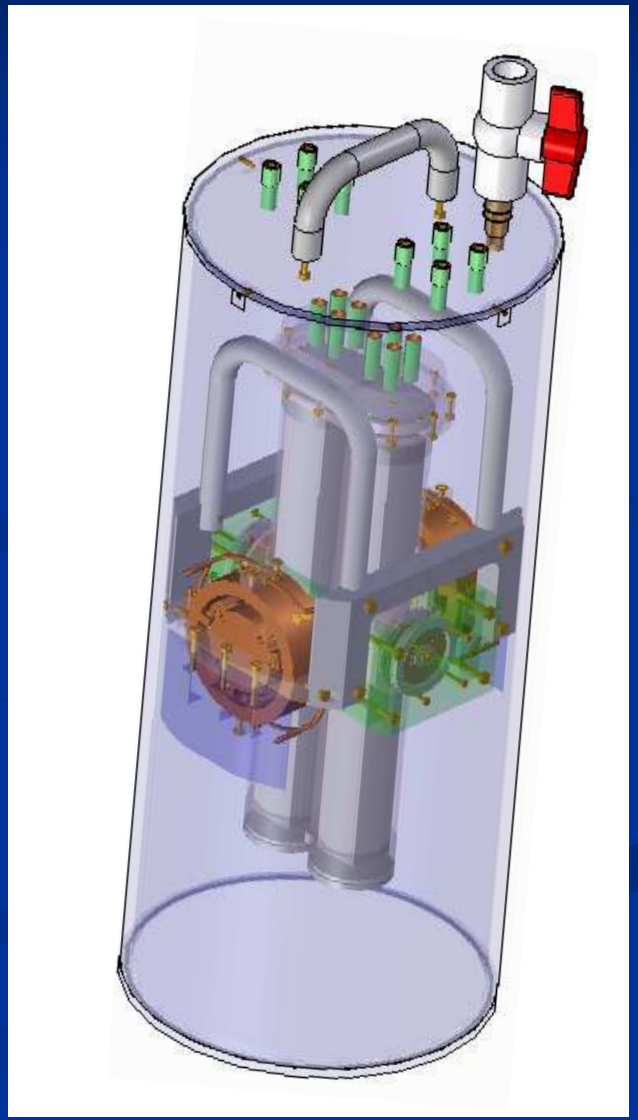
Higher frequency information can be obtained using gradients

- Airborne surveys can be flown lower
- Smaller objects can be detected

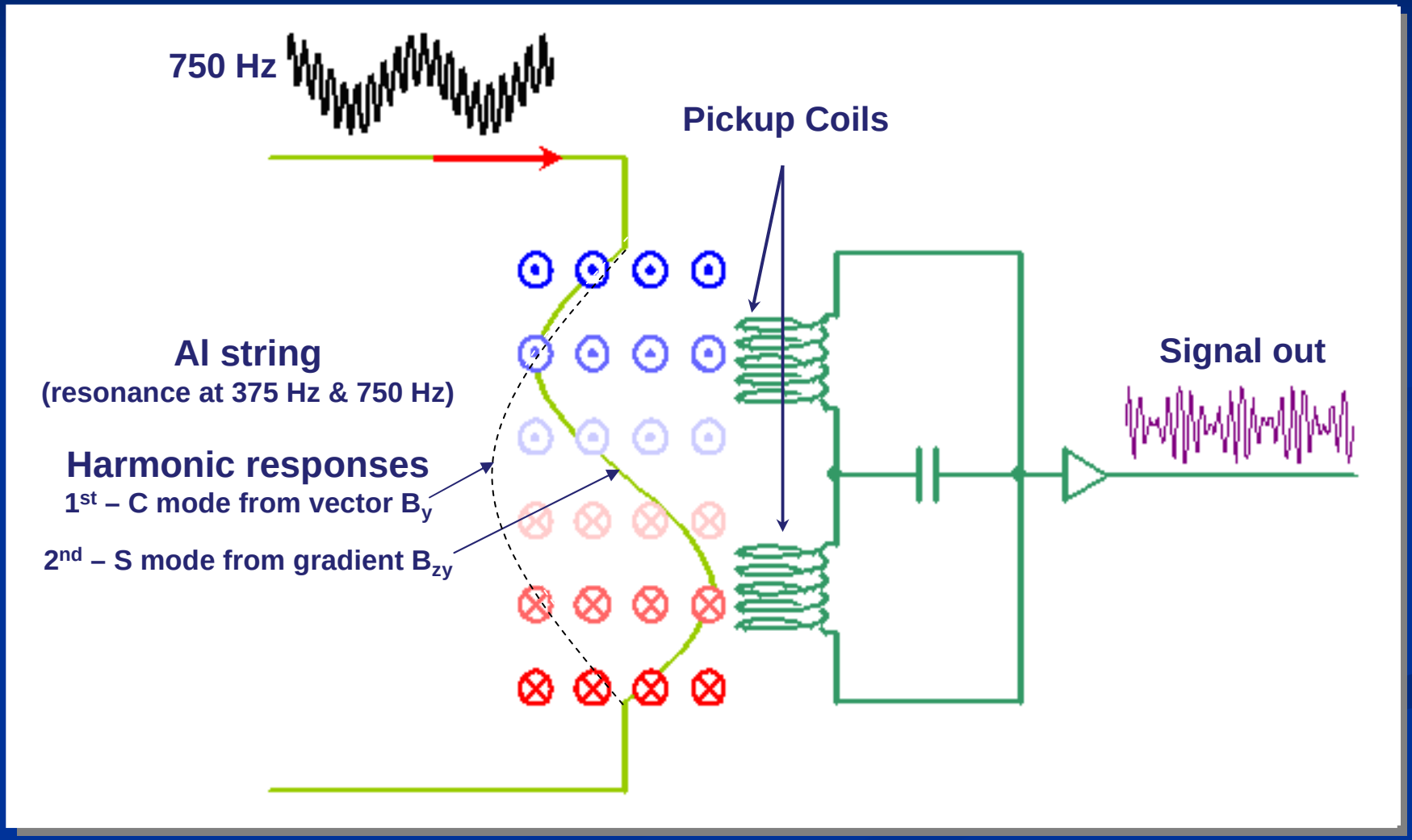
Components of the Gravitec Magnetic Gradiometer

The Magnetic Gradiometer comprises the following components:

- A string under tension with 750 Hz AC signal
- Inductive pick-ups at ¼ and ¾ positions to measure string deflection
- A plastic rigid frame with feedback wire – increases linearity, provides real-time calibration
- Anti-vibration suspension
- Anti-acoustic noise vacuum flask



Principle of Operation



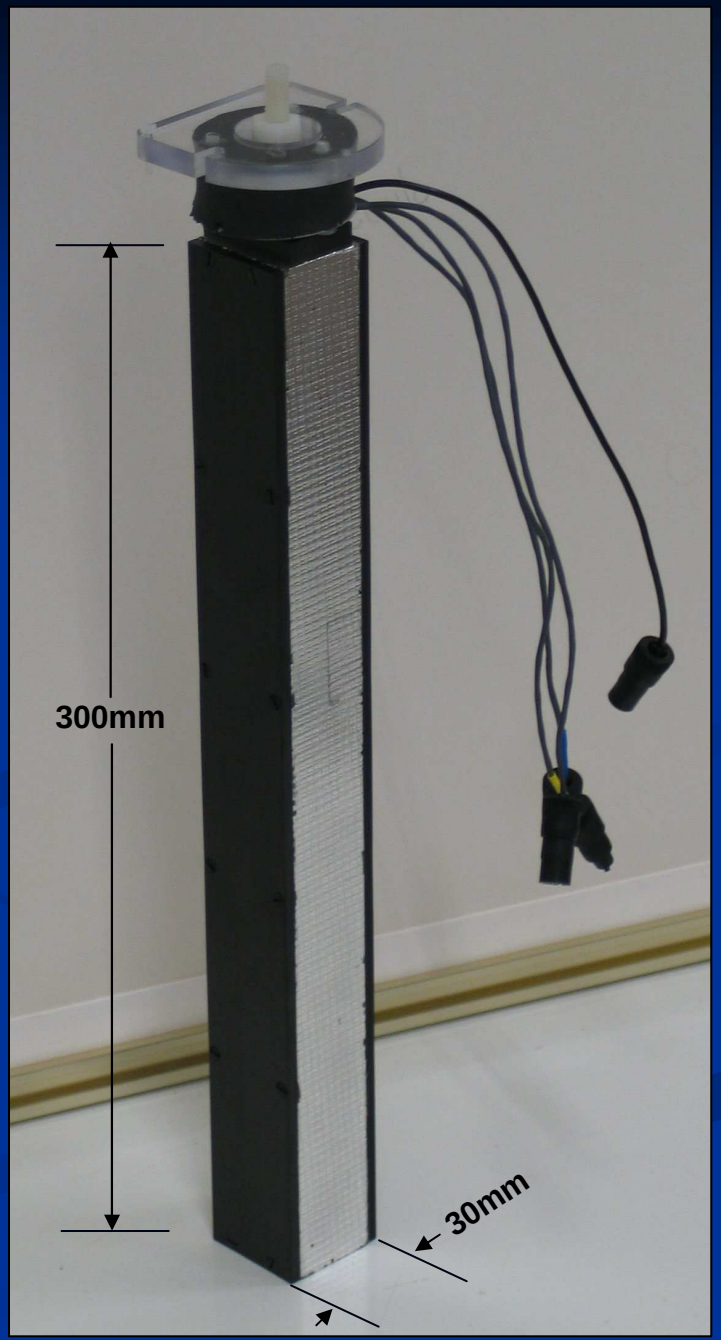
Magnetic Gradient Sensor Technologies

- **IPHT, Germany – 2 SQUID magnetometers rigidly fixed (2 cm apart) to derive gradients**
- **Fluxgates, various – 2 fluxgate magnetometers mounted up to 1 m apart to derive gradients**
- **CSIRO, Sydney – 2 SQUID magnetometers mounted at 180° on two sides of a cylinder and rotated**
- **Wingtip, various – 2 Cs vapour total field magnetometers mounted at each end of a heli-mounted boom of aeroplane wingtips to derive gradients**

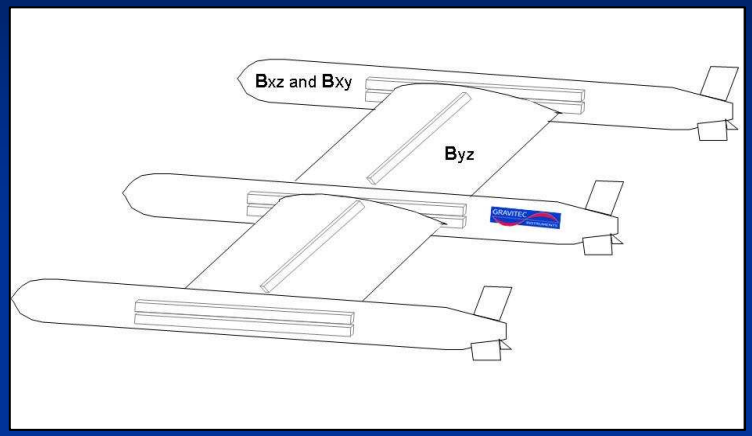
String Magnetic Gradiometer

Construction

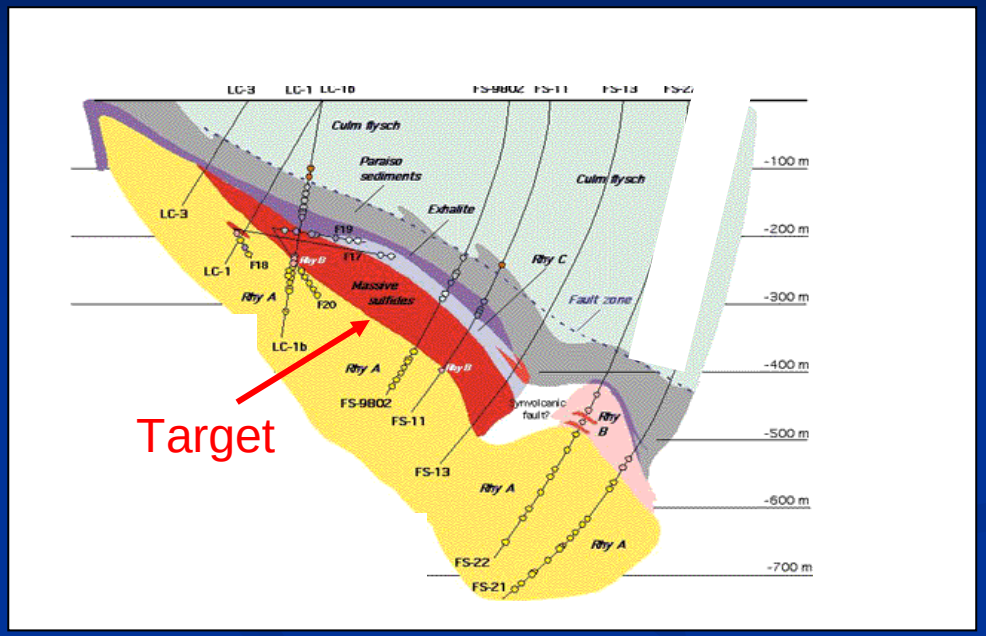
- Manufactured from Torlon plastic
  - Lightweight
  - Non-ferrous
  - Identical thermal expansion to Al
- Low power consumption
- No moving parts
- Small physical size
- Direct gradient measurement



Magnetic Gradiometer Applications



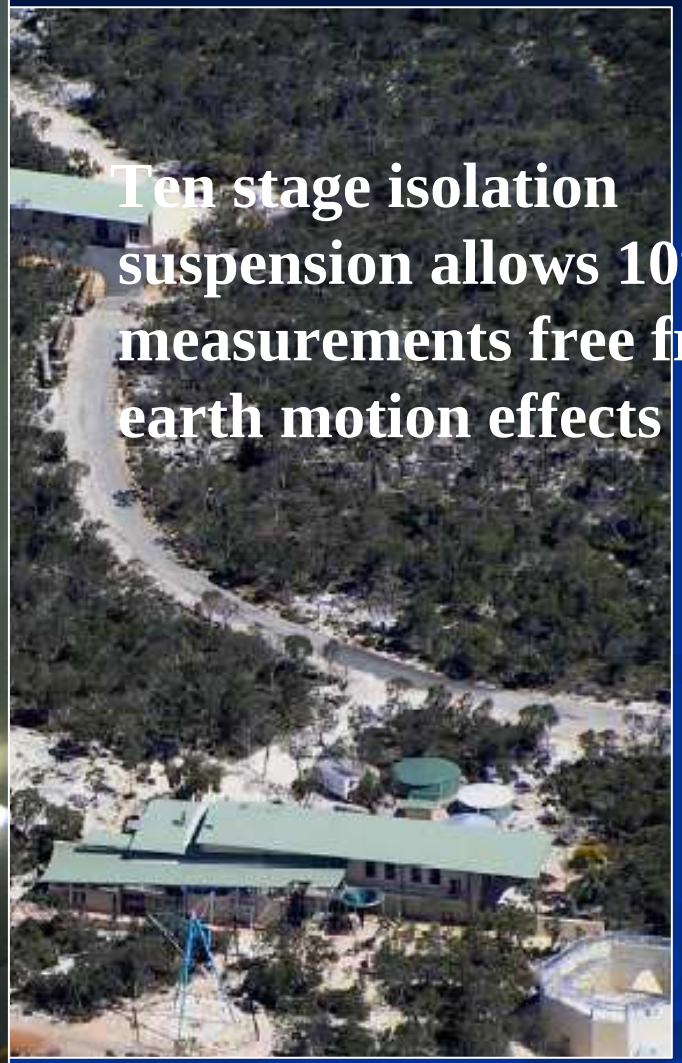
Sub-sea cable detection



Geometric information from magnetic ore deposits

(from drill holes or airborne)

Unexploded ordnance detection



Ten stage isolation suspension allows 10^{-25} m measurements free from earth motion effects

The Australian International Gravitational Research Centre

Technology transfer for gradiometer vibration isolation

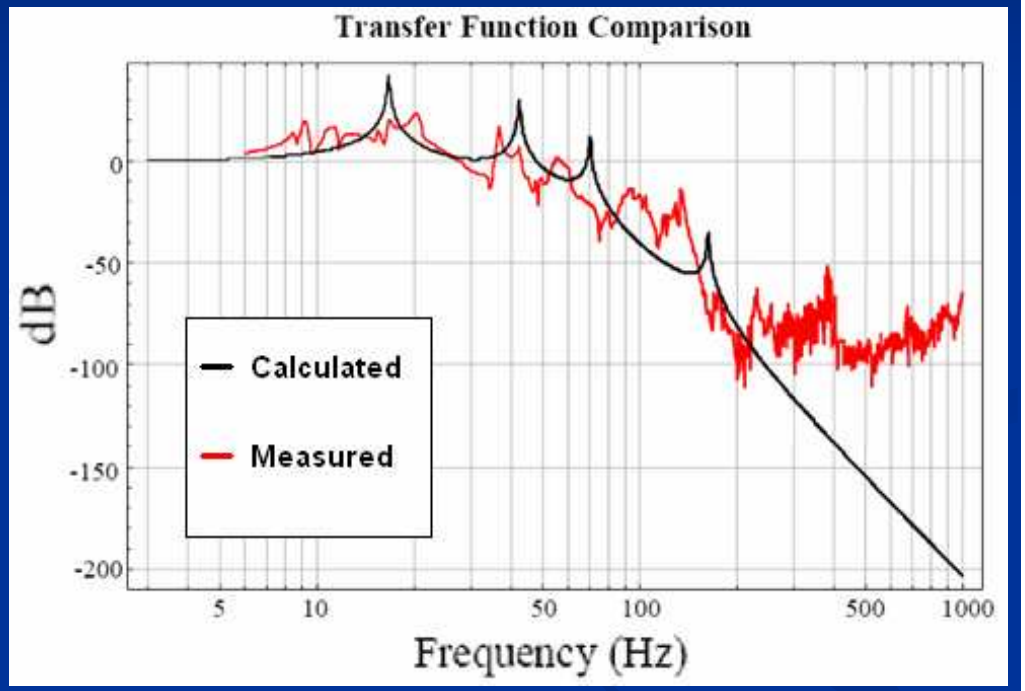
UWA AIGRC Anti-vibration Suspension

Stinger - vertical sensor housing

UWA custom designed 4 stage

Subject to significant vibrations

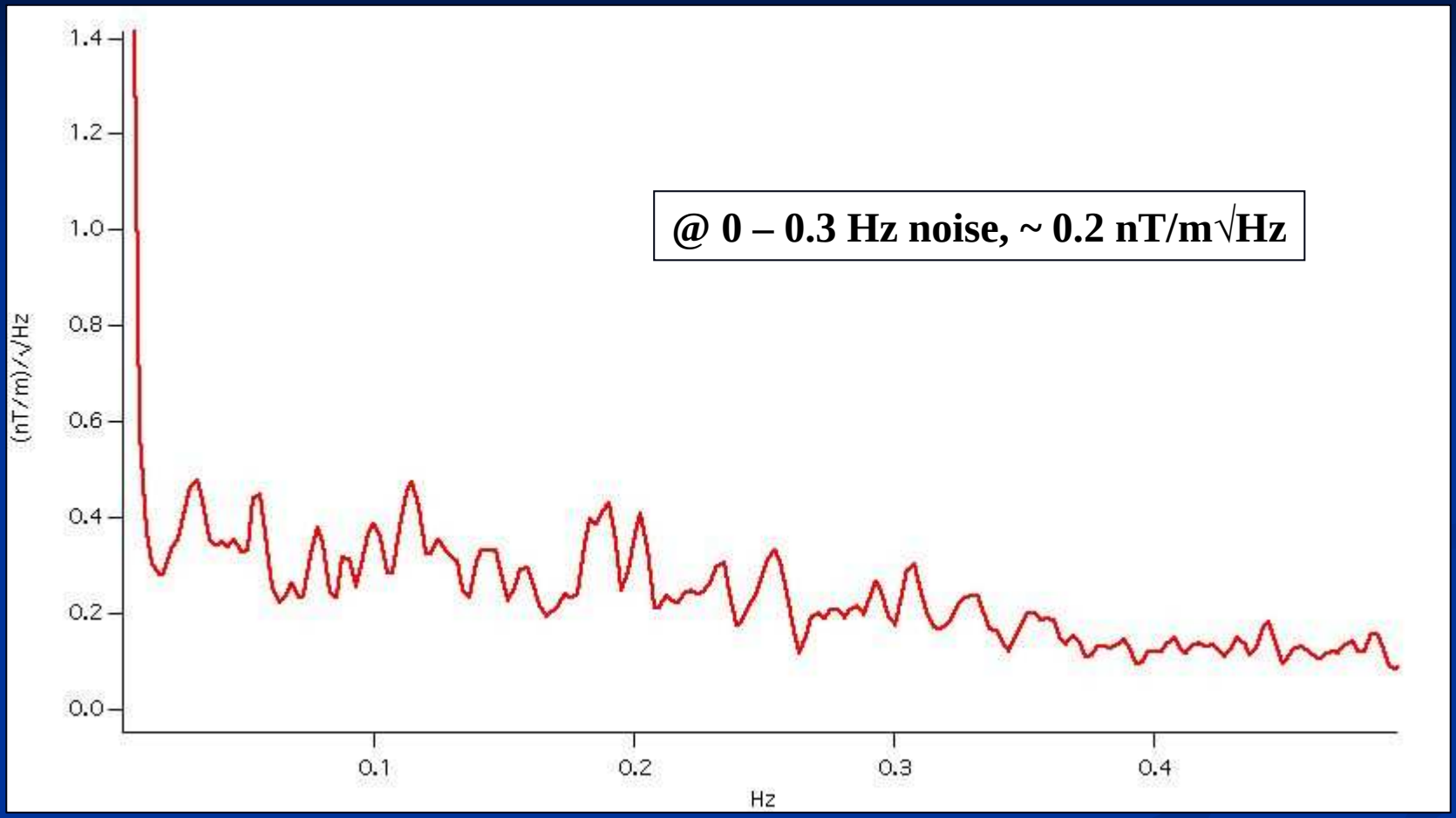
up to 0.5 G



Mechanical isolator provides

> 100dB isolation from vibration noise

Noise Measurements

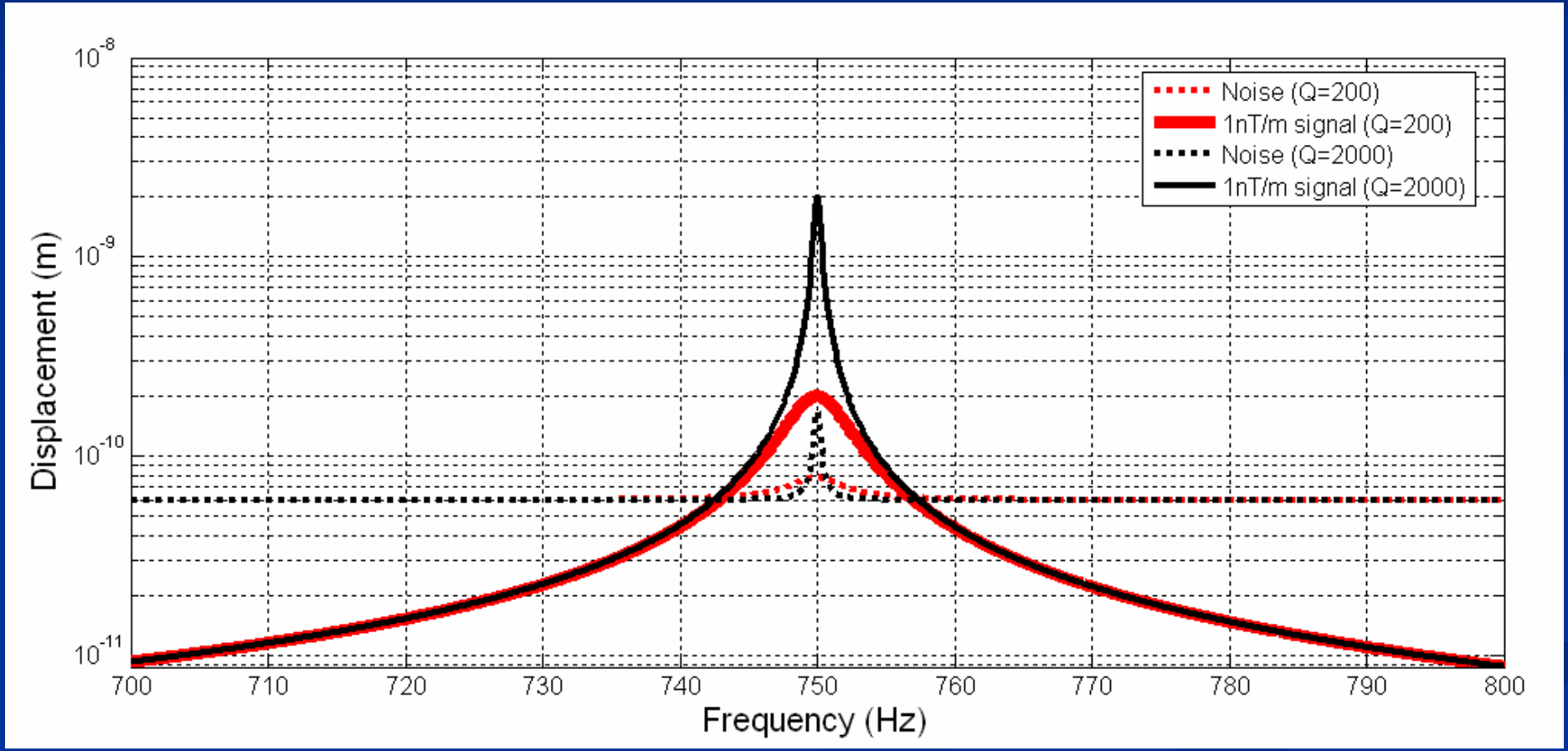


@ 0 – 0.3 Hz noise, ~ 0.2 nT/m√Hz

Laboratory noise test

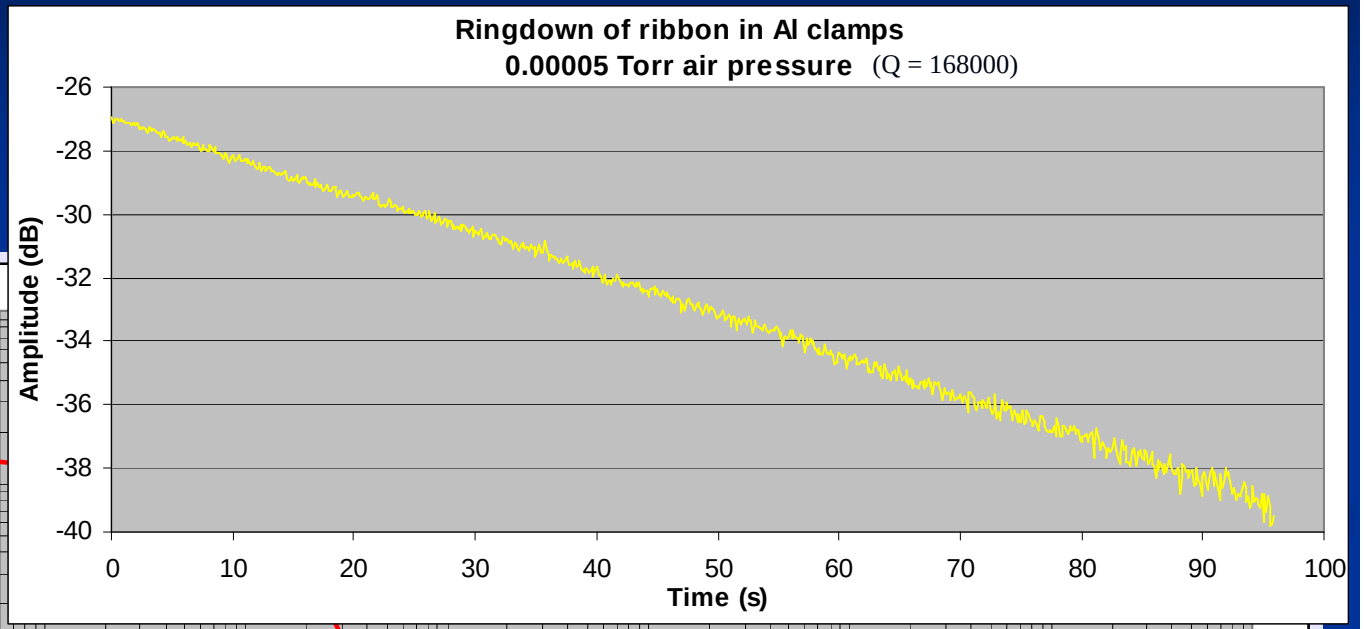
- **No temperature stabilisation**
- **No RF shielding**
- **Room Temperature**

Effect of Ribbon Q Factor

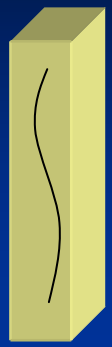


Effect of Ribbon Q Factor

Vacuum increases Q effectively



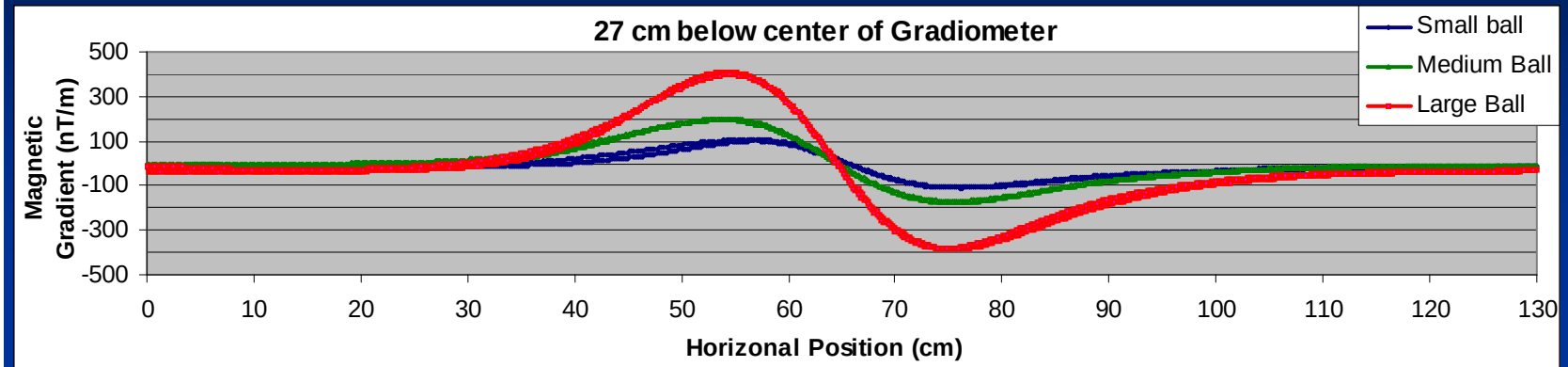
Simulated “Fly-over” Test

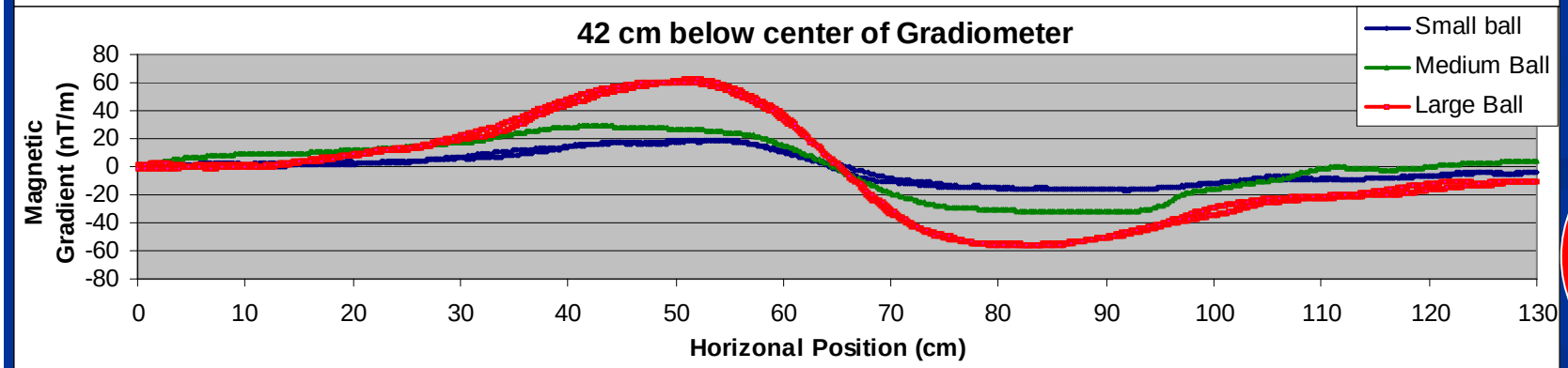


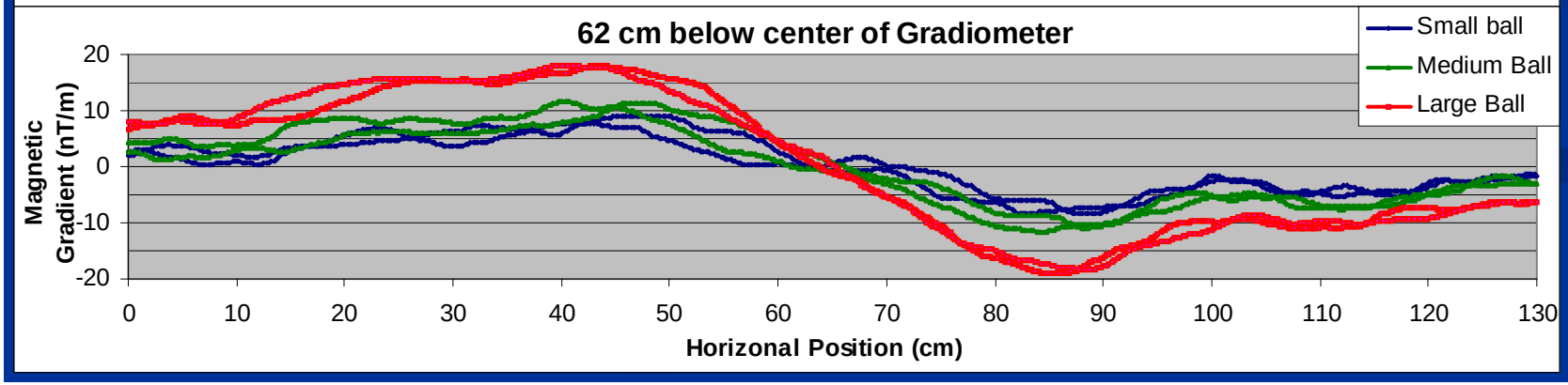
To simulate an airborne survey, steel ball bearings were moved past and under the magnetic gradiometer.

Various sizes of balls were used at various distances to test the instrument sensitivity

Simulated "Fly-over" Test







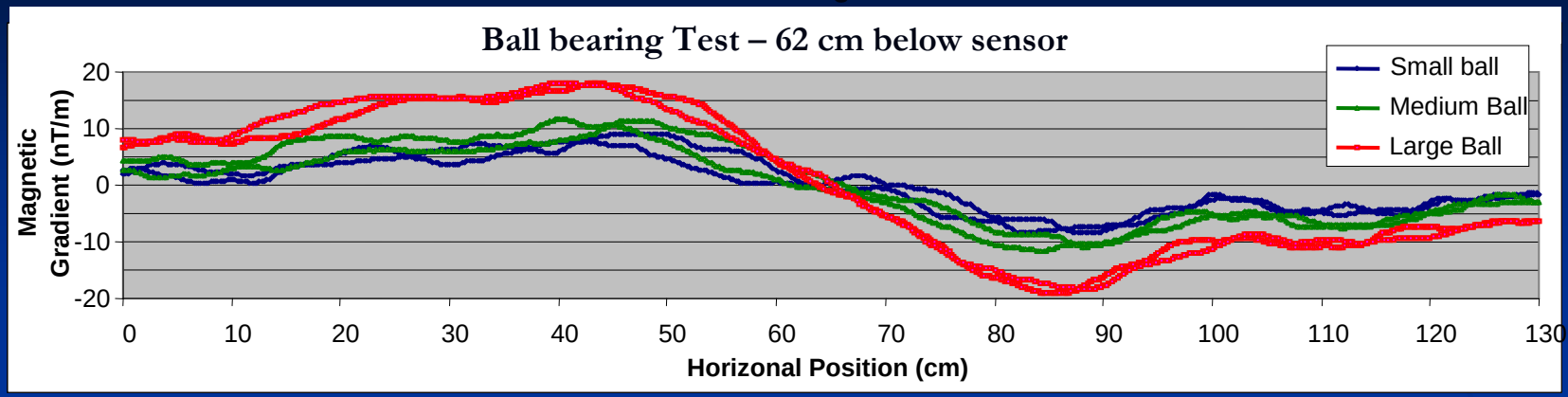
67g

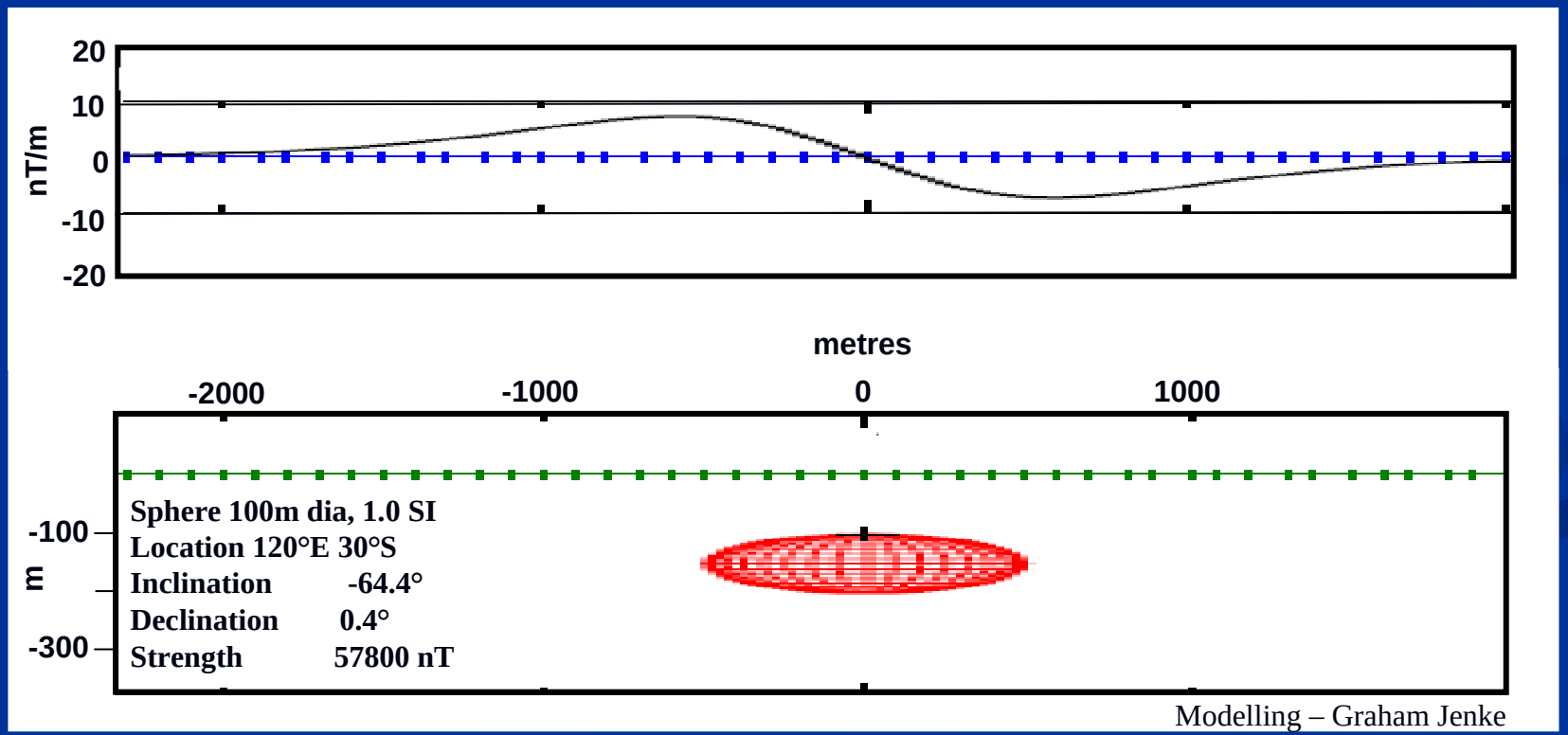
110g

226g

k ≈ 3 SI

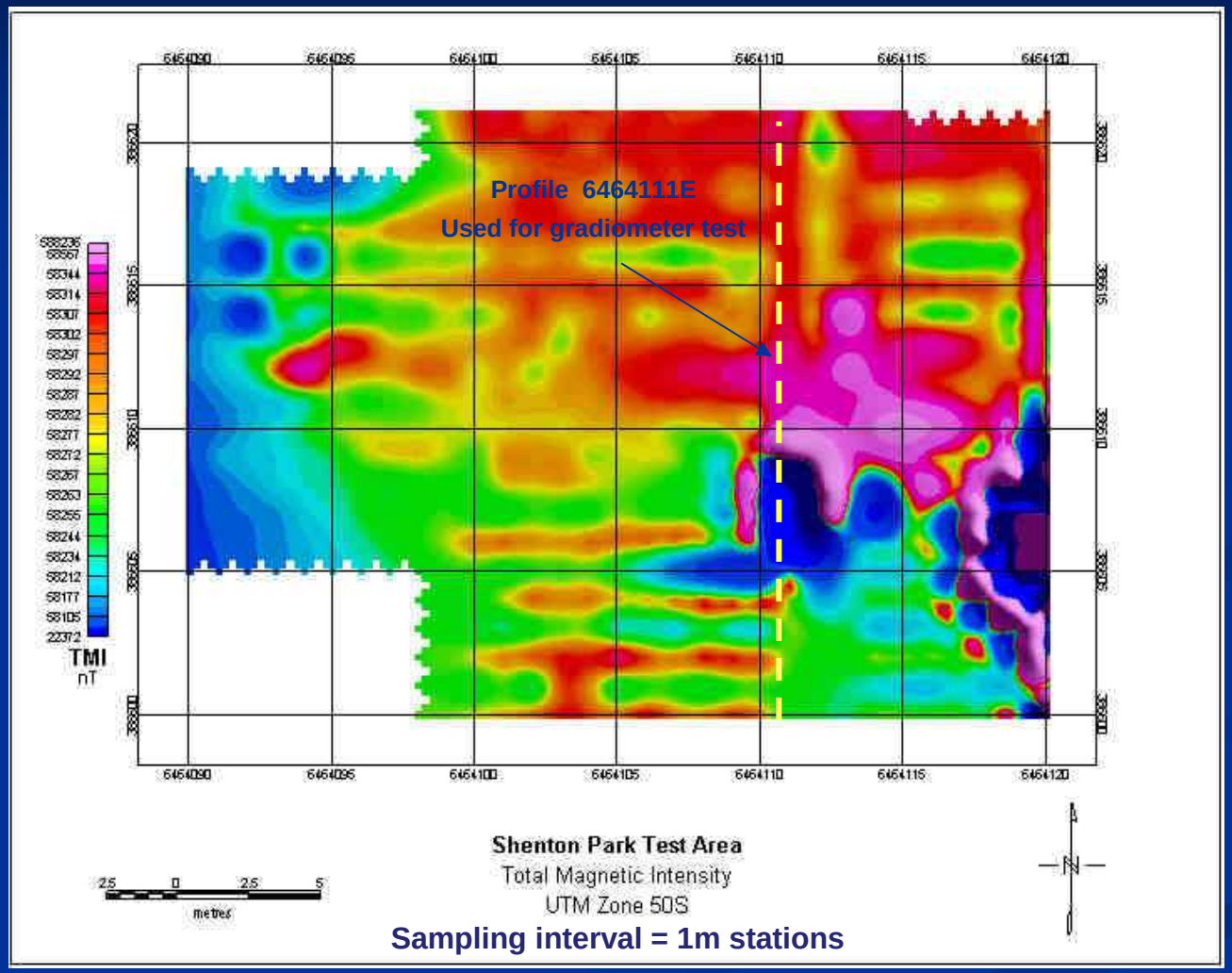
Simulated "Fly-over" Test





Modelling – Graham Jenke

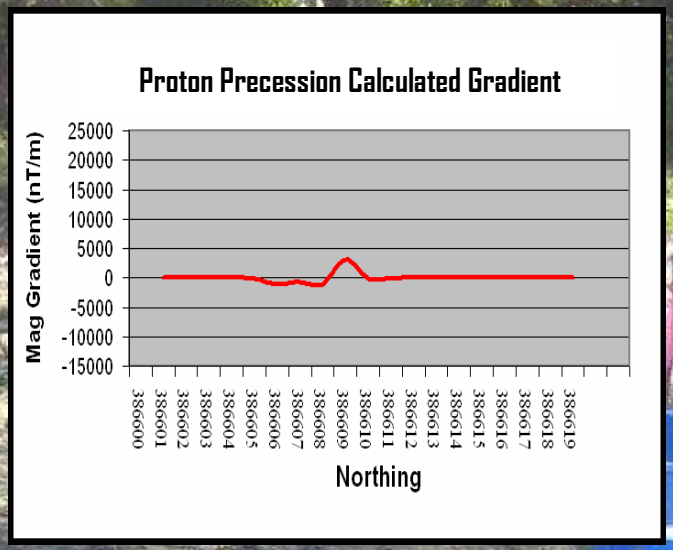
High Gradient Field Test

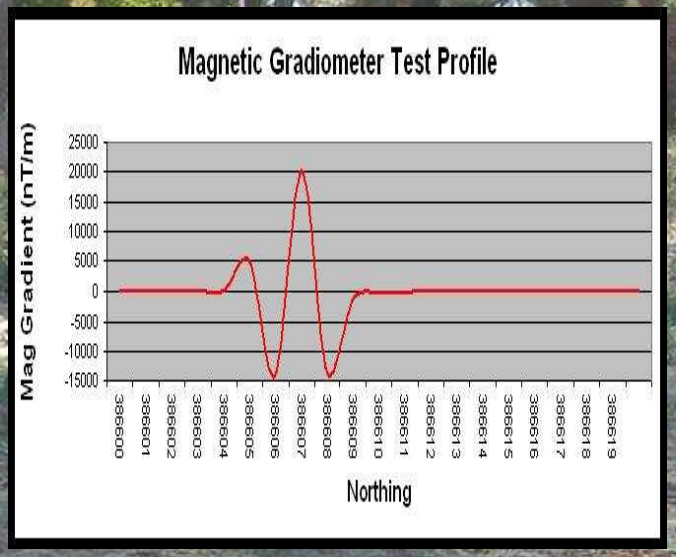


Total Magnetic Intensity, measured at 1 m AGL, displayed as a colour image

Data were used to calculate gradients for comparison with gradiometer data

High Gradient Field Test





Gradient calculated from the TMI profile

Magnetic Gradiometer survey over same profile

Gradiometer copes easily with high gradients up to >20,000 nT/m.

Conclusions

- An absolute magnetic gradiometer has been designed, built and field tested
- Device measures the magnetic gradient directly
- Current sensitivity in field conditions is ~0.2 nT/m (target – 0.02 nT/m)
- Ability exists to provide high spatial resolution full tensor data for detailed modelling of magnetic targets
- Applications in mining, telecommunications, defence and research