ADVANCED MAGNETOMETERS

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Potassium sub-pT Gradiometers for Earthquake Prediction Research

By Dr. Ivan Hrvoic

Emergence of new supersensitive potassium gradiometers enables a new approach to earthquake prediction research. Gradiometric sensitivities of some 50fT √Hz (10^{-9} relative in the Earth's magnetic field) allow for short base distance gradiometers to replace traditional long base distance and modest sensitivity magnetometers.

It is hoped this will suppress or eliminate parasitic signals like diurnal variations, effects of nearby conductive bodies of earth, salt water and cultural noises. Also, traditionally long term measurements have to be complemented by fast measurement (width bandwidth), as there are reports of such indicators appearing immediately before or during earthquakes.

Development of a Potassium "SuperGradiometer"

GEM Systems has in the past decade in alliance with Professor Alexandrov's group (Magtec and Vavilov State Optical Institute) developed a potassium Supergradiometer. Special sensors of large diameter (13 – 15cm) and wax-coated walls developed by Prof. Alexandrov's team generate ESR spectral lines as narrow as 0.1nT. Fully resolved and well-spaced spectral lines allow for single spectral line operation of the magnetometer with enormous reduction of spontaneous fluctuations of the precession frequency. Passive systems with VCO locked to the spectral line have the best sensitivity.

GEM Systems is now manufacturing 2 Potassium Supergradiometers with 3 sensors each for deployment at the Dead Sea rift by the end of this year. The project is financed (50% of expenses) by the Canadian-Israeli Foundation. On the Israeli side Soreq Nuclear Institute, Geophysical Survey of Israel, Survey of Israel and Isorad participate mainly in gradiometers deployment, data collection, analysis and interpretation.

Field Configuration

The gradiometer sensors will be at the end of 100m (separate) cables spaced 50m apart and connected to a high-resolution magnetic processor. Two gradients will be measured with 1fT/m precision in 2 parallel ways: 1 reading per second, updated 20 times per second (moving average) and a genuine 20 readings per second. The data will be transferred in real time to signal processing station at the Survey of Israel premises.

The gradiometer configuration will be one horizontal gradient (sensors on a plateau above Dead Sea) and one vertical gradiometer at the edge ~~of the~~ plateau. Expected sensitivity of measurement will be about 1fT/m √Hz. The sensors will be buried to minimize their movement. Range comparison of sensitivities of the new and traditional methods show at least one order of magnitude improvement.

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For example, traditional methods could barely detect 1nT anomalies over long term (years). A dipole producing 1nT magnetic field at 10km distance (deepest expected earthquake centers).

DB / dr = - 3 DB / r

will produce about 0.3pT gradient at the same place.

Since the gradiometer sensitivity is 1fT/m we achieve signal to noise ratio of 300: 1 short term. Even with substantially worse long-term stability, we will still have one order of magnitude or better improvement of sensitivity over traditional ways. Main improvements however should some from better reduction of interfering magnetic fields.

The project is very interesting as at this point we only have estimates of long term stability of Potassium magnetometers. The geological fault near Dead Sea is very active with over 20 earthquakes stronger than 2.0 on Richter scale per year thus providing an excellent testing ground. Some years ago Israeli researchers have established radon emanation measurement at the same place and a weak correlation with earthquakes has been found. The project will go on for several years.