Proton Precession Magnetometers

Sometimes called the "grandfather" of magnetometers, proton precession units serve an important function for earth science professionals seeking inexpensive solutions for low-sensitivity fieldwork or academic. Major applications include:

- Locating buried ferrous containers (ex. contaminant waste drums) in environmental surveys.
- Locating and tracing buried pipelines in utility-type surveys.
- Locating abandoned wells for de-commissioning and sealing.
- Geologic mapping.
- Teaching of geophysical methods.

Other applications, such as mineral exploration surveys, UXO, archaeology and other surveys not listed may be better performed with Overhauser or Optically Pumped Potassium systems.

Proton precession has limitations, such as order of magnitude lower sensitivity than Overhauser and two orders of magnitude lower sensitivity than Potassium. Other limitations include low sampling rates, high power consumption, and additional weight.

However, precession methods are still viable in many applications. GEM's proton precession system has particular advantages as described elsewhere in this document.

Principles

The method is based on the spin of protons in a magnetic field according to the Larmor equation.

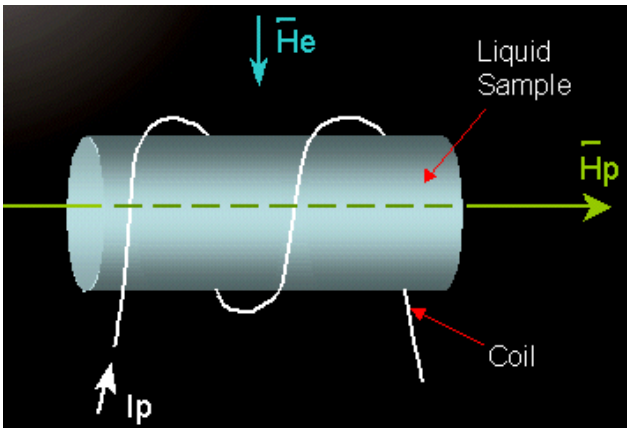
$$\vec{\omega} = \gamma \vec{B}$$

$\vec{\omega}$ angular frequency of precession

γ gyromagnetic constant – much higher for electrons than protons

$\vec{B}$ magnetic induction

Typically, a sensor bottle containing a fluid with a large number of protons (such as kerosene) is subjected to a large direct current in a coil wound around the bottle. The current creates a corresponding induced field in a direction perpendicular to the earth's magnetic field.



The current is then shut off and the protons precess with a frequency that is proportional to the magnetic induction. With GEM, an advanced frequency counting algorithm is used to determine

the magnetic intensity with an accuracy that is unmatched by other systems.

When choosing a proton precession system, we recommend that you carefully consider the system specifications on an equivalent footing to ensure that you are obtaining the maximum value for your investment. The following table compares specifications for different manufacturers.

Note that manufacturers are not named explicitly as GEM's practice is to maintain integrity and ethical practice in its customer-focused communications.

Specification	**GEM GSM-19T Family**	**Other 1**	**Other 2**
Configuration Options	15	10	2
Cycle Time	999 to 0.5 sec	2, 1, 0.5 sec	999 to 1.5 sec
Environmental	-40 to 60 ° Celsius	-40 to 60 ° Celsius	-20 to 50 ° Celsius
Gradient Tolerance	7,000 nT/m	?	1000 nT/m
Magnetic Readings	299,593	140,000	5,700
Operating Range	10, 000 to 120,000 nT	20,000 to 110,000 nT	20,000 to 90,000 nT
Power	12 V @ 0.62 A	12 V @ 0.65 A	9 – 1.5 "D" Cell Batteries
Sensitivity	0.1 nT @ 1 sec	0.1 nT @ 2 sec	0.1 nT @ ? sec
Weight (Console/Sensor)	3.2 Kg	3.45 Kg	4.5 Kg
Special Capabilities			
Automatic Grid Setup	Yes	No	No
Integrated GPS	Yes	No	No
Internet Upgrades	Yes	No	No
Simultaneous Grad	Yes	Yes	No
Warranty	2 Years	1 Year	1 Year
Waypoint Navigation	Yes	No	No
Waypoint Programming	Yes	No	No

Configuration Options

GEM has 15 configurations that are constructed from 5 basic building blocks, including mag, grad, vlf, mag/vlf, and grad/vlf. Each of these building blocks can be augmented with GPS and / or "Walking" mode.

The "Walking" mode is a mode that simulates the high-density coverage provided in airborne surveys. The operator advances to a station and takes a reading. When the data is dumped from the unit, the system automatically interpolates intervening values.

Cycle Time

Cycle time is an important parameter as it controls survey efficiency. GEM has a basic mode (GSM-19T) that cycles from 999 to 3 seconds – this mode requires the operator to stop to take a measurement.

Alternately, an enhanced version (GSM-19TW) enables the operator to acquire data much faster in "Walking" mode.

Environmental

The test of an instrumentation system is its robustness in temperature extremes. The GSM-19T proton precession unit has been used around the world.

It is fully experienced in environmentally challenging settings, ranging from harsh polar climates to the steaming jungles of equatorial countries to dry deserts.

Gradient Tolerance

Gradient tolerance is key when operating in areas where magnetic fields vary rapidly (either due to geology or to the presence of cultural objects or ferrous debris).

Comparative tolerance is especially high for GEM's system. Note that where *very* high gradients are encountered, it may be desirable to consider Overhauser or Optically Pumped Potassium instruments.

Magnetic Readings

In 2001, the v6.0 system was launched. It includes standard 4 Mbyte memory that can be upgraded in 4 Mbyte increments to a maximum of 32 Mbytes.

When choosing your magnetometer, gradiometer or base station solution, it is important to make sure that you will have enough memory to make it through a day's surveying without interruption. The GSM-19T is designed with this objective in mind.

Operating Range

Operating range should be sufficient to enable you to take readings wherever you are operating. GEM's proton precession is the highest rated system.

Please note that precession systems may still have problems in equatorial regions due to the inherent physics. To learn about advantages of Overhauser, access:

www.gemsys.on.ca/Quantum/Exploration/Prospecting%20in%20Low%20Magnetic%20Latitudes.htm

Power Consumption

High power consumption is one of the limitations of proton precession systems. In fact, about 99% of the DC current applied for polarization is dissipated as heat energy. This high power need is one of the reasons that systems are heavier than Overhauser instruments (i.e. more batteries are required).

However, proton precession systems will still perform well for many applications; GEM offers the lowest power consumption available; meaning that field time is prolonged as long as possible.

Sensitivity

Sensitivity is a statistical value indicating relative uncertainty of repetitive readings of the same magnetic field intensity. It is defined as r.m.s. (root - mean - square) value per square root of a unit of bandwidth ($Hz^{1/2}$). For example, a sensitivity of 1 pT / $Hz^{1/2}$ means 1 pT r.m.s. (about 3 - 4 pT peak-to-peak depending on the character of the noise) will be a scatter of readings about any "etalon" (fixed value) of the applied magnetic field per 1 Hz of measurement bandwidth.

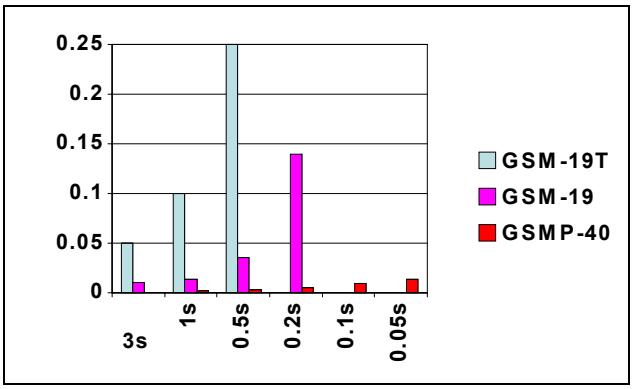
The sensitivity of quantum units is determined by the signal-to-noise ratio obtainable from its sensor, the spectral line width on which it operates and on the gyromagnetic constant, in accordance with the following equation:

$$\Delta B = k \Gamma / \gamma_n S_n$$

where k is a constant of proportionality, Γ is the spectral line width, γ_n is the gyromagnetic constant and S_n is the signal-to-noise ratio.

Any well-designed magnetometer's readings will eventually be limited by a noise level that cannot practically be suppressed any further: Sensor thermal noise is typically the limiting factor in the case of Proton and Overhauser magnetometers.

The following diagram shows the sensitivity of GEM's proton (GSM-19T), Overhauser (GSM-19) and potassium (GSMP-40) systems. Each system has its own characteristic "sensitivity" envelope defined by sample interval.



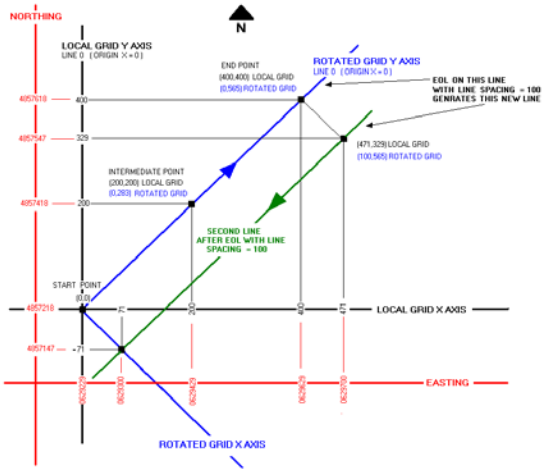
Note that the proton sensitivity at 0.5 seconds is 0.5 nT, and is cut-off at 0.25 nT for illustrative purposes.

Weight

Proton precession weight is primarily a function of battery weight– a reflection of the high power consumption for DC polarization.

Automatic Grid Setup

The automatic grid setup capability delivers efficiency in defining your survey. To use this option, you access the corresponding menu and enter the starting and finishing points of your first line, and a direction (clockwise or counter clockwise).



The system then automatically generates a survey grid of 500 lines. You can use as many or as few lines as required to complete your survey.

Integrated / External GPS

With precise GPS positioning comes the ability to significantly speed up surveys and to acquire reliable information for decision-making.

Integrated GPS is an attractive option in GEM's proton precession systems – minimizing the potential for damage to GPS components and minimizing the physical size of units for reduced shipping costs. Where sub-metre resolution is required, GEM also provides an external GPS with on-board corrections for real-time DGPS using WAAS or subscription services.

Internet Upgrades

Imagine that your manufacturer has the ability to deliver the latest technology to your magnetometer via periodic web updates. Now envision the money you will save – no shipping costs to have the latest modifications or to add functionality to your unit. GEM provides these benefits as a standard feature in all its proton precession magnetometers.

Simultaneous Gradiometer

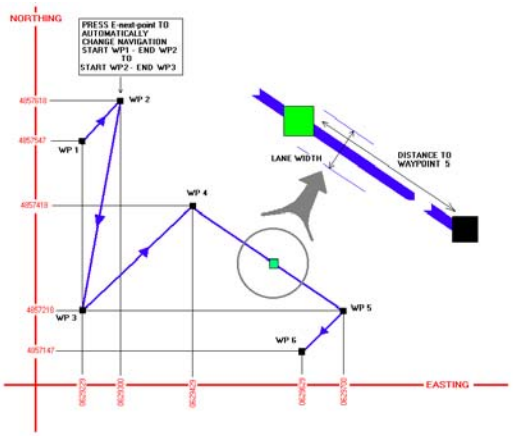
Gradiometer configurations deliver a number of advantages for near surface and deeper work, including resolution of shallower targets as well as the ability to acquire data without performing diurnal surveys (other benefits are described in [www.gemsys.ca/Quantum/Technology/Gradiometer%20Advantages.htm)](www.gemsys.ca/Quantum/Technology/Gradiometer%20Advantages.htm).

It's important, however, to have sensors recording at exactly the same time – particularly if the system is to be used for diurnal corrections or in areas of high

magnetic gradients. This capability is provided in all GEM systems, including proton precession, Overhauser and potassium.

Waypoint Navigation

Waypoint navigation delivers several functions. These include the ability to enter a set of waypoints for use in GPS surveying mode, and lane guidance. The system guides you to each waypoint - keeping you within a user-defined lane.



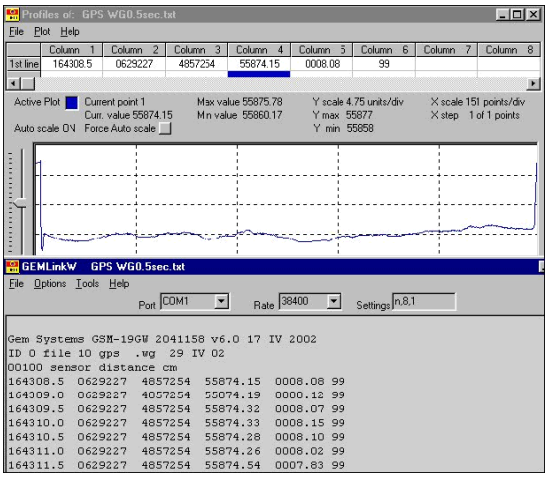
The main benefits lie in survey efficiency and tight survey control for as accurate positioning as possible. You also have the ability to perform surveys along lines that are non-parallel – a useful capability for environmental-type or non-standard, roving surveys.

Waypoint Programming

This option enables you to enter waypoints from either keyboard or download from your personal computer for maximum efficiency.

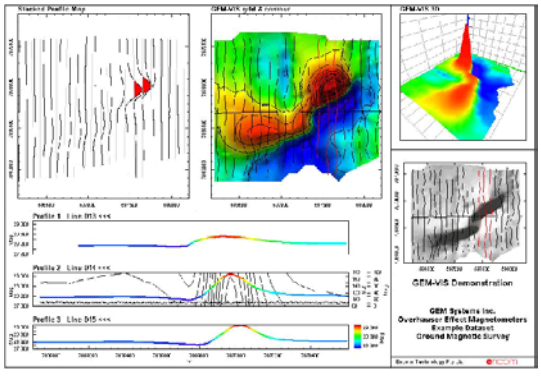
GEMLinkW Software

No system is complete without software for downloading and correcting your data, and GEM provides you with the proven GEMLinkW software for this purpose.



GEM-VIS Software

GEM-VIS is an optional package developed by a major commercial software house for GEM's users. It enables rapid quality control and analysis with easy visualization of profiles and stacked plots as well as 2D and 3D grids.



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