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Low Power Overhauser Magnetometer GSM-19L

Presented at the International Association of Geomagnetics and Aeronomy meeting, Uppsala, August 4 to 15, 1997 by Dag Hrvoic, Ivan Hrvoic and Jacek Myzyk

The need for a low power scalar magnetometer is becoming more acute due to very positive developments in automatic magnetic observatories suitable for ocean bottom deployment and various schemes of component measurements with the help of bias coils. While several groups now produce various kinds of bias coils an excellent example are spherical coils developed by a Hungarian group of colleagues.

Power Requirements

Scalar magnetometers are notoriously power hungry. For optically pumped magnetometers the main reason for this is a need for polarizing light produced either by a lamp containing the particular element's vapour or laser. Some alkaline magnetometers must also have a heated cell to achieve the appropriate density of the element atoms. None of those magnetometers are suitable for efficient (sporadic) operation on demand.

Proton magnetometers in the other hand need a strong DC magnetic field for polarization. Although suitable for a sequential mode of operation, it needs 100Ws or more of energy per reading. There are 2 exceptions in this group of magnetometers:

• The He 3 optically pumped nuclear magnetometer needs relatively high power for polarization, but then the polarization lasts for hours (transversal relaxation time constant may be as high as 36 hr). Nevertheless the He 3 is an expensive and relatively complicated magnetometer.

• Overhauser effect magnetometers, variations of proton magnetometers offer the best possibilities for miliwat operation, relative simplicity and reasonable costs. Overhauser magnetometer uses free radicals as a source of free electrons for polarization of protons. In the electron-proton coupled systems electron resonant lines need to be saturated. The saturation virtually transfers large electron thermal equilibrium polarization to the protons.

To achieve higher gain in polarization of protons free radicals with large zero field splitting are favoured. Their electrons have a higher thermal equilibrium polarization.

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Free Radicals

Currently, nitroxide free radicals that offer large proton polarizations are in use. Nitrogen has local magnetic field of some 16 Gauss in which the “free electron dwells. The electron resonance frequency is thus shifted to some 60 MHz (from about 1.4MHz in a field of 0.5G and the absence of zero field splitting). The amount of polarization is in general proportional to the resonance frequency ratio of electrons and protons.

At GEM Systems we currently use a nitroxide free radical that seems to be perfectly stable. It has 2 ESR lines at 58.8 and 60.7 MHz of about 0.35 G width. For good polarization one of the lines (but not both) must be at least partially saturated.

RF Resonator

We use a very high quality RF resonator – in principle a piece of shorted coaxial cable with the liquid between its conductors, tuned to the polarization frequency. We need about 0.3W of RF power for full saturation of the ESR line. This power is somewhat high because the shorted coaxial cable RF resonator is modified to be an isotropic sensor in order to avoid malfunctioning in case of uncontrolled deployment. The sensor is of somewhat higher volume (0.251) than our standard sensor (0.171) and requires some more power.

The resonator is tuned to 50-ohm cable that connects to an efficient C- class RF power source. Total DC power of polarization is some 0.7 to 0.8W and we need about 2 seconds for sufficient polarization. The electronics consist of low noise amplifier, comparator and microprocessor based hardware and readings. A large memory of 8 M bytes is fully nonvolatile RAM, sufficient for about 1 million readings.

A precise time base is necessary for good absolute accuracy of the magnetometer so a 1ppm TCXO is used. The communications are organized as a simple RS 232 ASCII link.

All the electronics consume a considerable amount of power – about 26mA at 12V but most of it can be switched off between readings. With this kind of operation we were able to keep the average power at 48mW for the first GSM-19L magnetometer deployed off Japan (I believe the next paper is about this system) and down to 40mW by just optimizing the RF consumption for the Geostar deployment.

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Future Optimization

A relatively simple improvement that we plan to introduce will reduce the power to some 32mW for 1 reading per minute. Further reductions are possible if we return a standard sensor instead of the isotropic one. In the automatic observatory, the orientation of the sensor obviously shall not be a problem. The system is very suitable for various component measurements since it can produce a reading in 0.2 seconds or a full 5 intervals needed for dIdD or vector measurements in 1 sec. In continuous operation with up to 5 readings per second the power is some 1.2W. With some effort the 1W barrier could be broken. Bias Coil power needs to be added to this.

I would also like to mention that we are currently searching for new free radicals completely different from nitroxides with huge zero field splitting that may lead to further improvement of this system. We are also in possession of a free radical with substantially narrower ESR lines (0.125G) but its stability apparently is not perfect. It is therefore not suitable for long-term deployment.

Recently I was informed about attempts of another group of researchers in Denmark to achieve low power operation of a novel Overhauser magnetometer. They use a very narrow ESR line free radical without zero field splitting. To achieve sufficient gain they need to put the sensor in some 22G field while polarizing. They have, reportedly, achieved similar levels of operating powers using water as a solvent.

LOW POWER OVERHAUSER MAGNETOMETER						
Mode of Operation	**Rate of Reading Model GSM-19L**	**Battery Capacity for 550,000 reading**			**Rate of Reading Model GSM-19LF**	**Battery Capacity for 550,000 reading**
	1 min.		10 sec.		1 sec.	
External trigger	8.5 mW	6.4Ah	50mW	6.4Ah	300mW	3.8Ah
± 5 ppm clock internal trigger	8.5 mW	6.4Ah	50mW	6.4Ah	300mW	3.8Ah
1 ppm clock internal trigger	38 mW	29Ah	80mW	10.2Ah	300mW	3.8Ah