

## Comparing Cesium and Potassium magnetometers

From Ross Johnson, vice president, magnetics, and Ken Smith, senior electronics engineer, Geometrics

Geometrics staff of engineers and physicists have reviewed the article *Development of a high sensitivity potassium magnetometer for near surface geophysical mapping* published in the May issue of *First Break*. We have found the article contains inaccuracies and some theoretical misstatements that we feel should be addressed. To that end we offer the following comments:

1. Equation (4) (on page 83) is incorrect in that the author has ignored the effect of bandwidth on system performance. It is not the total noise that is of concern but the noise density (typically in nanovolts per root Hz) that is at issue. Components in the noise that are far from the Larmor frequency are easily filtered out in the electronics. However, there is no way to effectively remove noise that is very near the Larmor frequency. This is why, in spite of its much narrower line width, the performance of the Potassium is not better than that of a Cesium magnetometer. We can verify this through direct comparison of published specifications.

2. The Cesium magnetometer is capable of 0.0004nT/√Hz- RMS. It should be noted that there are several Cesium magnetometer array installations using high performance counting systems wherein low noise data is being collected at 100Hz or 120Hz on up to 7 or 8 sensors simultaneously (Naval Research Labs and Oakridge National Labs MTADS systems). All statements referring to a maximum of 10Hz sample rate and low sensitivity specifications (0.05nT) are in error.

3. The article claims that the potassium magnetometer has 'very high sensitivity' and yet by its own published specifications, it is no more sensitive

than Cesium products already on the market. Both Scintrex of Canada and Geometrics in the USA make Cesium magnetometers which have better performance than the numbers shown at the top of page 84. Our published specifications as listed previously support our position.

4. On page 83 the authors claim that the better gradient tolerance of a Cesium magnetometer requires a trade off in sensitivity. This is not the case since the Cesium magnetometers have higher sensitivities than the Potassium magnetometers.

5. The authors present a misleading supposition that five point averaging is used in commercial high sensitivity Cesium magnetometers. There are only two commercial manufacturers, Geometrics and Scintrex. Neither the Scintrex Cesium magnetometers nor the those from Geometrics employ a five point averaging technique.

6. On page 84, the author states there are 14 of spectral lines for Cesium which is incorrect. The correct number is eight.

7. The authors state that a heading error of 1 to 2nT would obscure the geological signals. Magnetometer heading error specifications refer to the entire 'signal' as the sensor is rotated through 360° in a homogenous field. During actual survey, the heading error variation would be expected to be in the range of 0.1nT along track. Slowly varying signals of 0.1nT will not obscure the geological signal. In addition, heading errors from the platform itself (aircraft) are always much larger than the heading error of the sensors and require that heading compensation be applied to the entire fixed wing installation regardless of magnetometer type.

In conclusion, we feel that while the article under discussion was interesting and well written, it contains significant inaccuracies which could lead the reader to misunderstand and underestimate the performance of competitive products.

### Response from authors

Dr. Ivan Hrvoic, GEM Advanced Magnetometers

In response to Messrs. Smith and Johnson, we would like to state firstly that we welcome their comments. We also thank *First Break* for the opportunity to reply. As per the comments of Smith and Johnson (SJ), we have tried to keep our responses short and in sequence.

1. Equation (4) (on page 83 of the EAGE article) assumes unit bandwidth (1 Hz). We thought that this was self-evident; however, we welcome the chance to clarify. SJ also raised the issue of bandwidth. In this context, the influence of bandwidth is known and is the same for all methods of measurement. We do not see any advantage in terms of Cesium or Potassium sensitivity.

2. As far as we know, the only scalar magnetometer (besides Potassium) that exceeds 1pT / √Hz/2 sensitivity is the laser pumped Helium 4 system from Polatomic Systems. They reported 0.5 pT / Hz<sup>1/2</sup>. If SJ have achieved this benchmark with the physics of Cesium, we congratulate them. Our main point of discussion really relates to equation (4) and *Technical Report M-TR91* written by Kenneth Smith. On page 3, he states, 'This would cause all [Cesium] sensors to have a 5 nT heading error. To prevent this we split the polarizer along its diameter and make one-side right handed and the other left handed polar-



ization. This prevents this heading error at the cost of much lower signal level'. This statement supports the one in our paper on Potassium methods in talking about trade-offs. Here, Smith indicated that lower heading error was traded for lower sensitivity. Addressing another SJ issue, we selected a 10 Hz sample rate as a standard of comparison for the convenience of readers. It is not a maximum as our own higher sampling rates illustrate. In stating a 0.05 nT sensitivity at 10 readings per second, the reader may wish to refer to the last page of *Portable Cesium Magnetometer / Gradiometer Model G-858*.

3. The maximum sensitivity of Potassium magnetometers/gradiometers is theoretically some  $5 \text{ fT} / \div \text{ Hz}$  (E.

Alexandrov, private communication). We have so far achieved about  $50 \text{ fT}$  or  $0.05 \text{ pT} / \text{ Hz}^{1/2}$  (Model GSMP-20S 'Supergradiometer'). No other scalar magnetometer approaches this value, although this sensitivity is impractical (i.e. too high) for any non-stationary fieldwork.

4. See point 2 above.

5. Since SJ state bandwidth of 2Hz at sampling rate of 10 x per second, one can only conclude there must be a deliberate narrowing of the Nyquist bandwidth to allow for 'over sampling'.

6. There are 14 spectral lines according to Breit-Rabi formulas and they are split in 2 lumps. The stronger one has eight lines and the weaker one (with six lines) is located about 1kHz

away. If we consider operating at the stronger lump, we agree with SJ. Our approach in the paper was to be as complete as possible in describing the physics.

7. Strictly speaking, heading error complicates processing and analysis of data. SJ take the position that the sensor is fixed during the survey so that there is no influence of heading error (which may or may not be practical in the field). Potassium is free from this effect.

We would like to conclude by thanking Messrs. Smith and Johnson for their interest. Objective discussions and clarifications can only contribute to the user's awareness of the intricacies of technologies. Ultimately, this will help in choosing the most appropriate tools for their work.