Comparative analysis of some magnetic sensors

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Abstract

This paper shows the results of a comparative analysis of 5 magnetometer in order to evaluate the performance of the new Marine Magnetics SeaSPY Overhauser probe. The test was performed at INGV Geomagnetic Observatory in Preturo(L'Aquila, Italy). Both qualitative and quantitative analysis has been carried out.

Introduction

On 12-15 February 2008 a comparative validation test of the SeaSpy's sensor was performed at the INGV Geomagnetic Observatory in Preturo (L'Aquila) ((42°23' N, 13°19'E, 682 m asl) (Meloni et al, 2007). This site was set as optimal for testing purposes because of its intrinsic features : the very low environmental / anthropic noise (< 0.1 nT), the availability of reliable observatory magnetometers (to be used as reference) and a safe instrumental hosting facility.

In order to achieve reliable and accurate results four magnetometers have been simultaneously operated : the SeaSPY sensor, the G880 (Geometrics) cesium magnetometer, the three sensors SeaQuest probe (Marine Magnetics) and a fluxgate probe provided by Billingley. The probes were placed inside the hosting facility with a separation of 2 m, selected both to avoid electronic interference and assure the same recording. More quantitative constraints to data were provided by artificial signaling induced by iron tools moved simultaneously in proximity of all sensors. The comparative analysis of sensors' response gives better insight on sensor behavior in high gradient scenarios.

SeaSpy specifications

The SeaSpy sensor is a next generation marine magnetometer provided with an omnidirectional Overhauser sensor. The compact design (124 x 12,7 cm), lightweight (in air 16 kg / in water 2 kg) and the overall accuracy (0.2 nT) make the SeaSPY a unique tool for magnetic prospecting, notably when operating in tangled circumstances. The technical specifications of the SeaSPY marine magnetometer are reported in table.1

Time Domain Analysis

As time domain analysis was performed. From the full recordings a subset was extracted in the time span from 16:06:45 to 07:37:56; the sampling rate of all probes was set to 1Hz; 55870 samples were collected for each probe. These datasets form a large and consistent base used for testing purposes.

Qualitative aspects

The qualitative approach underscore a similarity among the five signals simultaneously recorded (fig. 3). During the recording period any human interference have been avoided.

Quantitative analysis

In order to check the similarity of the recorded data a correlation analysis was perfomed.

This analysis was performed using the corrcoef routine provided by Matlab (Hogg and Craig,1995). This routine returns a matrix R of correlation coefficients calculated from an input matrix X whose rows are observations and whose columns are variables. The (i,j)th element of the matrix R is related to the covariance matrix C by

$$R(i,j) = \frac{C(i,j)}{\sqrt{C(i,i)C(j,j)}} \qquad (1.0)$$

Results a reported in table 2.

Since the correlation values do not drop below 0.9988, the correlation analysis underscores a complete similarity of the signals provided by the five sensors.

Frequency Domain Analysis

Overview

In order to have a deeper look at sensors behavior a spectral analysis of the collected time series (Warner 1998) was carried out. The first step of this test was a spectrogram analysis which provides the reader with information concerning the variability of frequency components versus time. More precise insight can be achieved by a power spectral density plot (PSD) which compares the behavior of the tested probes as function of the frequency. The latter analysis shows a difference between the Overhauser and caesium vapor probes. The caesium sensor appears to gives better response then the Overhauser probes at frequencies larger than 0.5 Hz. Using this frequency a statistical analysis of high frequency signals was performed.

Spectrograms

Spectrogram analysis (STFT, short-time Fourier transform) was also performed to check frequency variability versus time. The time-dependent Fourier transform is the discrete-time Fourier transform for a sequence, computed using a sliding window. Since the recording are discrete the data were split into overlapping frames , then each subset has been Fourier transformed, and the complex result is added to a matrix, which records magnitude and phase for each point in time and frequency. This can be expressed as:

The above reported analysis shows a substantial similarity of all sensor during the test.

PSD Analysis

A standard FFT algorithm have been applied to the five magnetograms in order to provide the PSD plot (fig. 5). The PSD was computed using the Burg method (e.g Marple, 1987). As it clearly appears the four Overhauser sensor are almost identical while the cesium vapour sensor shows a quite different behavior. In order to get a deeper insight of high frequency variations a statistical test was performed.

High frequencies analysis

Relying on the PSD plot a target frequency of about 0.2 Hz has been defines. At this frequency the Overhauser's PSD are larger that the corresponding G880 spectrum. This means that the hoverhauser probes give better response at frequencies larger than 0.2 Hz than the Ceasium sensor. In order to explore this fuature an high frequency analysis was performed.

A set of running average filters was applied to the data to extract the short wavelength variations as difference between the original and filtered data. The dataset obtained was statistically evaluated. This test aims to verify and compare the distribution of the high frequency signal component, which is the most relevant feature of the probes under evaluation.

The statistical parameter of the population distribution are reported in table 3, which summarize the high frequency analysis.

Conclusions

After the above reported analysis it is possible state that the four Overhauser probes are almost identical each other. The results of the test are consistent with the SeaSPY calibration test performed by NRC-GSC in 2003 (Calibration certificate 03-04-25)

References

Hogg, R. V., Craig, A. T. (1995) Introduction to Mathematical Statistics, 5th ed. New York: Macmillan, pp. 338 and 400.

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Meloni. A, L. Cafarella, P. De Michelis, De Santis A., Di Mauro D., Dominici G., Lepidi S., Palangio P., Tozzi R And Zirizzotti A. (2007) Systematic Magnetic Observations in Italy PUBLS. INST. GEOPHYS. POL. ACAD. SC., C-99 (398),

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TABLES and FIGURES

Table 1 : SeaSpy characteristics

Absolute Accuracy :	0.2nT	Power Consumption :	1W standby, 3W maximum
Sensor Sensitivity :	0.01nT	Timebase stability :	1ppm, -45ºC to +60ºC
Counter Sensitivity :	0.001nT	Range :	18,000nT to 120,000nT
Resolution :	0.001nT	Gradient Tolerance :	Over 10,000nT/m
Dead Zone :	NONE	Sampling Range :	4Hz – 0.1Hz
Heading Error :	NONE	External Trigger :	By RS-232
Temperature Drift :	NONE	Communications :	RS-232, 9600bps
Operating Temp :	-45ºC +60ºC	Power Supply :	15VDC-35VDC or 100-240VAC

Table 2 : Correlation coefficients

	1	2	3	4	5
1	1.0000	1.0000	1.0000	0.9998	0.9998
2	1.0000	1.0000	1.0000	0.9998	0.9998
3	1.0000	1.0000	1.0000	0.9998	0.9998
4	0.9998	0.9998	0.9998	1.0000	1.0000
5	0.9998	0.9998	0.9998	1.0000	1.0000

Table 3 : Results of high frequency analysis

Filter len.	SeaQST1	SeaQST2	SeaQST3	SeaSPY	G880	
10	0. 6085 0. 0206	0. 6306 0. 0221	0. 5559 0. 0215	0. 5185 0. 0195	0. 4254 0. 0135	Mean (10^{-5}) Std
8	0.4077 0.0188	0.4224 0.0203	0.3187 0.0197	0.2866 0.0176	0.2052 0.0109	Mean (10^{-5}) Std
6	0. 2705 0. 0170	0. 1730 0. 0185	0. 2512 0. 0179	0. 1174 0. 0156	0. 0732 0. 0084	Mean (10^{-5}) Std
4	0. 1161 0. 0151	0. 0920 0. 0165	0. 1699 0. 0159	0. 0240 0. 0136	0. 0152 0. 0060	Mean (10^{-5}) Std

Figure 1 : The INGV geomagnetic observatory at Preturo

Figure 2 : The SeaSPY Magnetometer : tow cable head and probe

Figure 3 : Raw magnetograms of the five simultaneous recording sensors

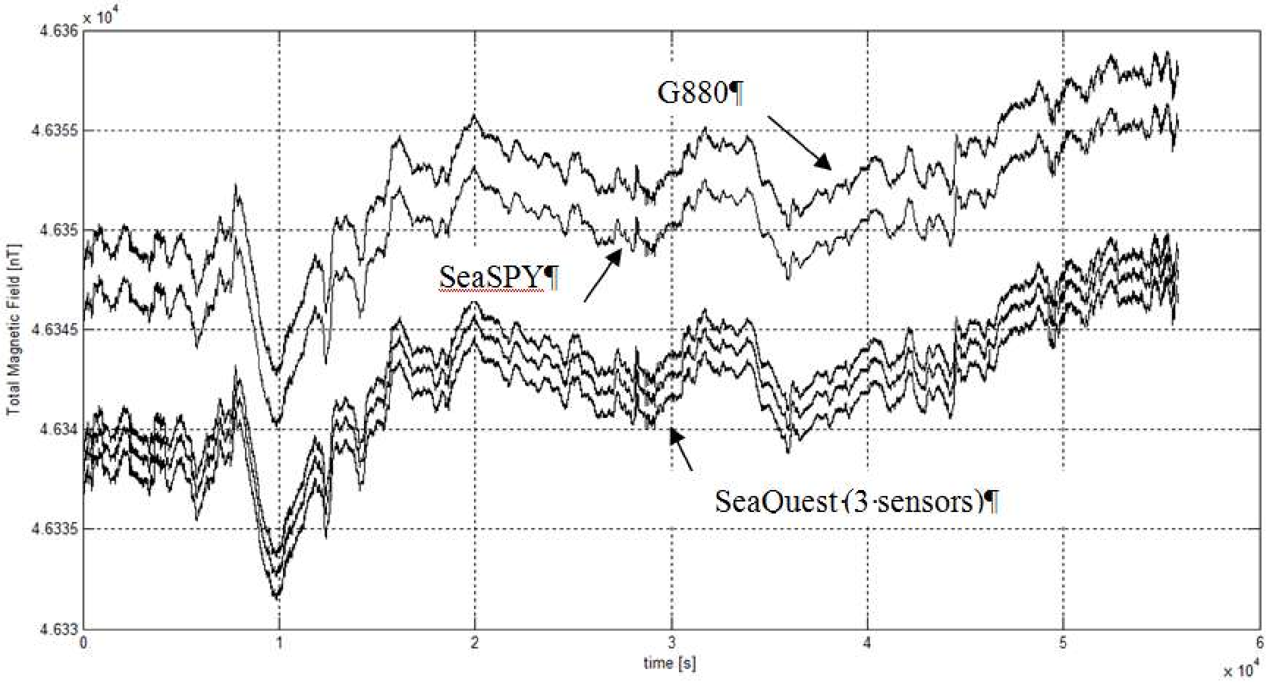

Figure 4 : Spectrograms of the tested sensors

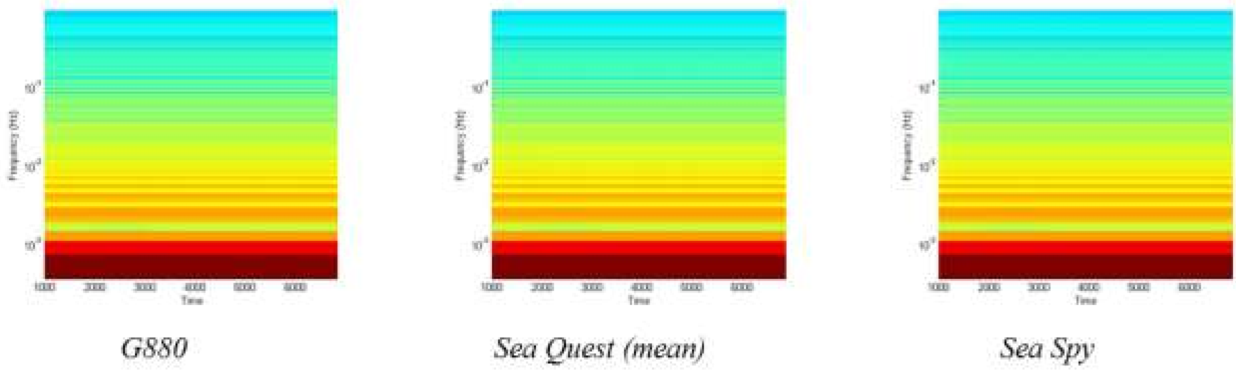

Figure 5 : PSD plot