Magnetic field measurements of the human heart at room temperature

December 11 2009

The "most magnetically quiet room on Earth" is on the PTB site in Berlin. Credit: PTB

A new optical sensor developed by the American National Institute of Standards and Technology was successfully tested by the Physikalisch-Technische Bundesanstalt (Germany) in the "magnetically best shielded room on Earth." The sensor does not need advanced cooling and is very small. Its suitability was proven for biomagnetic measurements in the picotesla range. So, magnetocardiographic measurement devices -- to be used as a supplement or an alternative to the ECG -- could become simpler and less expensive.

The "magnetically best shielded room on earth" has the size of an

apartment block and is located on the site of the Physikalisch-Technische Bundesanstalt (PTB), Institute Berlin. Magnetic fields such as that of the earth are kept out here as effective as nowhere else. Such ideal conditions allow to measure the tiny magnetic fields of, e.g., the human heart.

This was the motivation for the American National Institute of Standards and Technology (NIST) to ask PTB to jointly test a newly developed optical magnetic field sensor. It is based on a physical principle very different from SQUIDs, which are usually applied for biomagnetic field measurements. The optical sensor does not need advanced cooling and has the size of a lump of sugar. A high-quality measurement of the human heart signal was demonstrated using this optical sensor. The sensor's suitability was thus proven for biomagnetic measurements in the picotesla range. In future magnetocardiographic measurement devices - to be used as a supplement or an alternative to the ECG - could become simpler and less expensive.

Up until now one had to cool as much as one could for biomagnetic measurements! This was necessary as SQUIDs, superconducting quantum interference devices, work optimally at -269 degrees Celsius and can only then fulfil their purpose of measuring tiny magnetic fields. SQUIDs are the best suited sensors to record the magnetic fields arising during the electrical activity of the human heart. A magnetocardiogram (MCG) can be compiled supplementing a conventional electrocardiogram (ECG). (The same applies to the magnetoencephalogram, MEG, which is a recording of the magnetic field of the brain.) Yet to use SQUIDs requires well-shielded rooms and complicated cooling systems. The latter might become obsolete in the future if the optical magnetometer developed by NIST continues to fulfil expectations.

The optical sensor is a byproduct of the development of miniaturized

atomic clocks, one of NIST's current key research areas. As biomagnetic research is not established at NIST, the scientists turned to their colleagues at PTB in Berlin. PTB is one of the few metrological state institutes in the world with a large scale biomedical research program. The combination of highly advanced equipment such as the magnetically shielded room (BMSR-2) with the experience in testing new sensors on human subjects made PTB the ideal partner for NIST.

Using the optical magnetometer PTB experts measured the magnetic field of the human heart and relaxation curves of magnetic nanoparticles. Both are important routine laboratory measurements normally applying SQUIDs. For a direct comparison of the results, SQUID reference data were recorded simultaneously with the optical magnetometer using the multichannel SQUID device installed in the BMSR-2.

The impressive quality of the data obtained confirms the suitability of these optical micromagnetometers in the picotesla range. This is the range for magnetic field measurements of the heart, but further improvements are needed to measure the even tinier fields of the human brain. Compared to SQUIDs, the optical sensors exhibited - as expected - a significantly higher noise level. The distinct advantage of these sensors lies, however, in their small design (^{3}). this allows them to be installed at a small distance from the magnetic source in order to increase the signal strength. the room temperature operation of the sensor and its small size will allow a much simpler system design compared to other sensor types suitable for this measurement range. the fabrication of the sensor by use of microsystem technology could enable simple and cost-effective mass production. nist plans the development of a multichannel system on the basis of the existing technology. further tests of these sensors at ptb are planned.

Source: Physikalisch-Technische Bundesanstalt