Comparison of different coil positions for ventilation monitoring with contact-less magnetic impedance measurements

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Abstract. For monitoring the health status of individuals, proper monitoring of ventilation is desirable. Therefore, a continuous measurement technique is an advantage for many patients since it allows personal home care scenarios. As an example, monitoring of elderly people at home could enable them to live in their familiar environment on their own with the safety of a continuous monitoring. Therefore, a measurement technique without the restriction of mobility is required. Since it is possible to monitor ventilation with magnetic impedance measurements without conductive contact, this technique is well suited for the mentioned scenario. Integrated in a chair, a person’s health state could be monitored in many situations, e.g. during meals, while watching TV or reading a book. In this paper, we compare different positions of coil arrays for a magnetic impedance measurement system integrated in a chair in order to monitor ventilation continuously. For limiting the costs and technical complexity of the magnetic impedance measurement system, we have a focus on coil configurations with one RF channel. To limit the needed space and thickness of the array in the backrest, planar gradiometer coil setups are investigated. All measurements will be performed with a new developed portable magnetic impedance measurement system and a standard office chair.

1. Introduction

One application for magnetic impedance measurements is monitoring vital parameters [1]. Both ventilation and heart activity influences the local impedance distribution over the time. This is a reaction of well conductive blood transport or poor conductive air shift in the human chest. Therefore, it is possible to monitor ventilation or perfusion by measuring the changing eddy currents. In this article we focus on ventilation monitoring. The benefit of this technology is the complete contact-free measurement setup. Necessary coils can be easily integrated in a bed or in chairs. With this setup monitoring in a day-to-day basis is applicable without the need of cables that could limit the users mobility. For example over night monitoring during sleep phases or monitoring bus drivers and pilots could help to reduce accidents or alarm paramedics just in time. For the mentioned scenario, a magnetic impedance measurement device is needed as well as a coil setup designed for this special application. In our work, we focus on a coil array with only one RF channel and two coils (one for the excitation signal and two as a planar gradiometer). To reduce the needed size we test three different planar coil arrays at different positions in the backrest of a chair and determine which position or array is best suited for continuous ventilation monitoring. In the literature, a similar monitoring setup with only one RF coil was presented.
2. Measurements

2.1. Portable Impedance Measurement System

For a complete chair-integrated measurement setup a small and lightweight portable magnetic impedance measurement device is needed. First investigations regarding this scenario were done with the Multi-Channel-Simultaneous-Magnetic-Impedance-Tomography-System (MUSIMITOS), presented in [5]. However, due to size and weight of the device, we decided that it is not adequate for a chair-integrated measurement solution. Thus, we reduced the number of excitation channels (now one) and the number of measurement channels (now two) and implemented the software IQ-demodulation and the control functions for the DDS on a Blackfin DSP from Analog Devices Inc. The new developed device called “Portable-Impedance-Measurement-System (PIMS)” (see [6], system overview in figure 1 and foto in figure 2) is now battery driven and fits into a 10 inch housing. Another group uses the same concept together with NI PXI-5105 ADCs [8]. To expand the scenario, data visualisation was done on a notebook computer via a common PC Network to show the data from more than one measurement device on one screen. This is ideal for situations in which all passengers in a bus or plane should be monitored. To validate the measured data, a flow or pulse reference sensor can be attached to the device. Some first measurements for estimation ventilation with this device are presented in [7].

2.2. Coil configurations

As measurement coils we used three planar gradiometer configurations (see figure 3). The diameter of the measurement and excitation coils are $D_s = D_m = 35\text{mm}$. The distance between them varies for each gradiometer. For the coil configuration 1 we used 25 mm, for 2 40 mm and for 3 10 mm. This leads to a tradeoff between coil diameter and size of the complete coil arrays. All coils are maid of FR4 PCB on two layers. This makes the gradiometers very thin. They are driven with symmetrical amplifiers, placed on the backrest very close to the coils, and are connected via short cables.

2.3. Setup

Together with the portable magnetic impedance measurement system we used the three coil configurations described above and a common office chair as a test scenario. For each of the
coil configurations we measured changes in the magnetic impedance caused by respiration at four different positions on the backrest of the office chair and the flow signal from a differential pressure sensor together with a breathing mask as a reference. The positions of the coils are shown in figure 4. Assuming that it is a symmetrical problem, only one side of the chair was investigated. Due to ethical reasons we performed the measurement on one male volunteer of our project group. The candidate was in the age of 28 and healthy. We advised him to breath as normal as he could and in the same way for all measurements.

2.4. Results
Compared to the results in [7] the actual investigated measurement scenario is more ill posed. In this approach the measurement coils are not in front of the person. By measuring from the backside the spine covers the lung and decreases the reinduced fields. This fact also reduces the SNR. Hence it is necessary to verify the HF respiration signal measured with the magnetic impedance method and the flow signal again. A sample for this test is presented in figure 5.

for coil 1 on position 1. As shown in this example, breath strokes correspond well. However, this was not the case for all measurements. Only for coil configuration number one, the MIT respiration signal correlates with the flow reference signal. The results for these measurements are presented in figure 6. For coil configuration 2, the measurement position two and three are the only one for which the measured data represents respiration. For the other two positions the data contains noise and artefacts (see figure 7 for details). With coil setup number three it was
not possible to detect any respiration signal with the magnetic impedance measurements. The

![Figure 7. Measurement results for all 4 positions with coil configuration 2](image1.png)

![Figure 8. Measurement results for all 4 positions with coil configuration 3](image2.png)

data plotted in figure 8 is only noise. In total only 50% of the respiration could be monitored. As shown in the figures, the amplitude of the signal depends on position and coil configuration and contain drift movements.

3. Conclusion

As presented, the dimensions of a planar coil configuration and the position at the backrest are both important for proper respiration detection using magnetic impedance measurements. However, it is possible to detect respiration with a thin planar gradiometer from behind the patient. Since these measurements are the result of a data acquisition with only one volunteer, it is necessary to investigate the scenario with more volunteers within an clinical trial. For the future, measurements with other types of coil configurations are also planned in order to further improve the monitoring results. With saline solution it would be possible to evaluate drifts and noise and give a perform index of the system.

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