OPTIMIZATION OF SPATIAL FILTERING SENSOR FOR BIOMEDICAL APPLICATIONS

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SUMMARY

Low spatial resolution decreases the effectiveness of conventional biopotential sensors for applications such as electroencephalography (EEG), electrocardiography (ECG), and electromyography (EMG). Blurring by the volume conductors is the primary cause of the low spatial resolution. Significant improvements in SNR, spatial selectivity, and mutual information using tripolar concentric ring biopotential sensors to estimate the Laplacian for ECG and EEG have been reported. We report on a relative comparison of spatial sensitivity between disc, tripolar concentric, and an optimal combination of the electrodes of a tripolar concentric ring biopotential sensor. A planer model of the biological medium was used to calculate the potentials on the biopotential sensor. The optimal combination of the electrode potentials achieved the sharpest spatial filter and selective attenuation of two non-region of interest sources. The Laplacian algorithm had much steeper attenuation than the disc sensor.

BACKGROUND

To improve the spatial resolution of EEG/ECG/EMG researchers have relied on the Laplacian, the second spatial derivative of the scalp potentials. Besio et al.[1-2] has reported on significant improvements in SNR, spatial selectivity, and mutual information using tripolar concentric ring biopotential sensors (TCRBS) (shown in Fig. 1.) to estimate the Laplacian for ECG and EEG. In this report we propose a new method for combining the outputs from the electrodes of a TCRBS to increase the spatial sensitivity.

METHODS

To perform a relative comparison of spatial sensitivity between disc, tripolar concentric, and the optimal combination, a simplified planar model of the head with a single conductivity was used to calculate the potentials on the electrodes of the TCRBS. The electrodes of the TCRBS were divided into 16 and 32 discrete points for the middle and outer rings, respectively with equal arclength between the points. The average was taken of all the discrete potentials as the potential for the electrode. A unity point source was moved from r = 0.0 to 2.0 cm radially from the center of the sensor. The depth of the unity dipole source was 2.0 cm below the surface of the sensor.

Optimal combination of tripolar electrodes

To improve the spatial sensitivity, and thereby the spatial resolution as much as possible, we need to derive an algorithm to combine the three simulated signals to optimize the spatial cutoff. Instead of designing the beamformer to null out sources at specific locations we will attempt to design it so that it is distortionless for a focal point of $r_f = 0$ and minimizes the power out of it at all other locations. This is called the minimum variance distortionless look (MVDL) beamformer [3]. To do so we now let the weights be denoted by wi, where it is always assumed that the focal point is at $r_f = 0$. We then minimized the energy out for all other source locations.

RESULTS/CONCLUSION

The spatial attenuation of the TCRBS was improved by an optimal combination using MVDL on the potentials from the three individual electrodes of the TCRBS. We previously reported that the TCRBS could selectively pass sources beyond the radius of the sensor. [4] We now realized that the TCRBS naturally passes sources directly below the center of the sensor and attenuates all others. In Figs. 2-3 the normalized power is shown. Fig. 2. shows that the MVDL has the sharpest roll off, then the TCRBS Laplacian, followed by the disc sensor, reaching half-power by 0.25, 0.5, and 1.0cm, respectively without noise. When one noise dipole was added at r=1.35cm (bold traces), measuring the power at two radii from the center of the sensor 1.0cm in the +X direction, the TCRBS Laplacian power changes 3.0% due to the noise, disc power changes 17%, while the MVDL is altered minimally in the side lobe. In Fig. 3 two unity dipole noise sources were added at r=0.8cm and r=1.2cm from the center of the sensor. The MVDL was tuned to attenuate sources at those locations. The power for the MVDL did not change, the noise is canceled completely. The TCRBS Laplacian power at 1.0cm increased 22% to 32%. However,

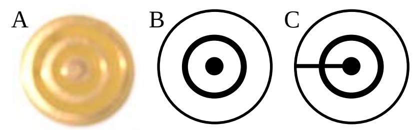

Figure 1: Actual fabricated TCRBS (A) schematic of TCRBS (B), and schematic of virtual disc sensor with all electrodes shorted

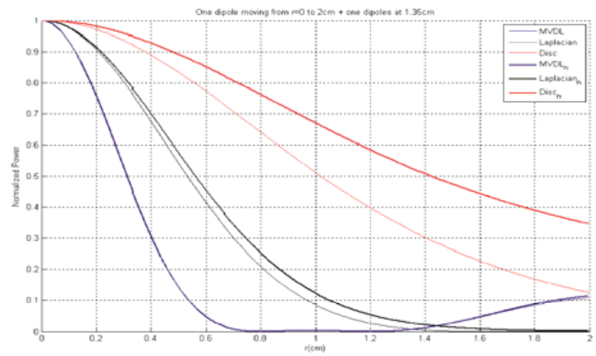

Figure 2: The normalized power calculated for the three sensor configurations (disc – red, TCRBS Laplacian – black, MVDL – blue) with a single radial unity dipole in the z-direction moved from r=0 to r=2.0cm and one noise radial unity dipole in the z-direction at

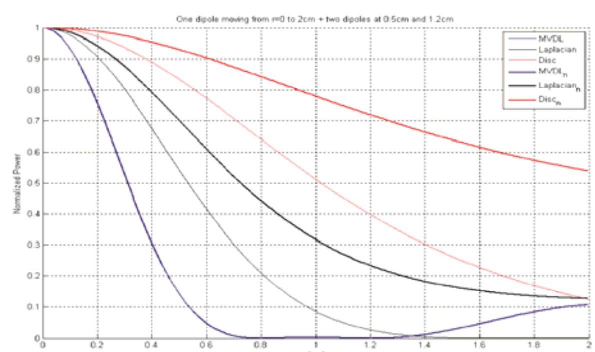

Figure 3: The normalized power calculated for the three sensor configurations (disc – red, TCRBS Laplacian – black, MVDL – blue) with a single radial unity dipole in the z-direction moved from r=0 to r=2.0cm and two noise radial unity dipoles in the z-direction at r=0.8 and r=1.2cm. All dipoles area z= -2.0cm.

the disc power increased to 78% a change of 28%. To put this in perspective 50% of the power would be the -3dB point. In conclusion the MVDL clearly outperforms the other two configurations tested for the steepest radial roll off. Making the TCRBS smaller will also increase the spatial resolution but with the cost of a smaller signal.

REFERENCES

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