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Application Note 259 ECG Averaging in the MRI using the ECG100C-MRI amplifier

This application note is concerned with the possibility of performing high-resolution ECG measurements in the MRI, during EPI. High-resolution ECG recordings are possible in the noisy MRI environment if signal averaging is performed. However, for signal averaging to be performed on ECG data, it's important to be able to reliably identify locations of QRS complexes on the ECG data record.

By using the BIOPAC ECG100C-MRI amplifier, it's possible to directly employ the "Locate ECG Complex Boundaries" in the Acq*Knowledge* **Analysis** menu to reliably locate component waves in the ECG data record, during EPI.

The BIOPAC ECG100C-MRI amplifier can be used to collect electrocardiogram (ECG) data from a subject, in the MRI, during EPI sequencing. The ECG100C-MRI will nearly entirely reject EPI interference to record the ECG manifested at the electrode recording locations. The EPI artifact rejection capability is typically on the order of 40dB, as referenced to the artifact typically present on an ECG waveform not treated with artifact rejection. Figures 1 and 2 illustrate the large difference in signal quality obtained between the two amplifiers.

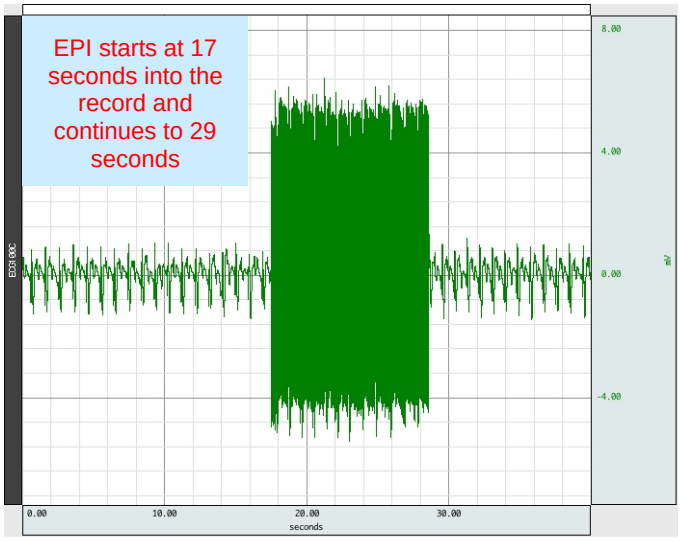

Figure 1: EPI Artifact using ECG100C amplifier with no artifact rejection.

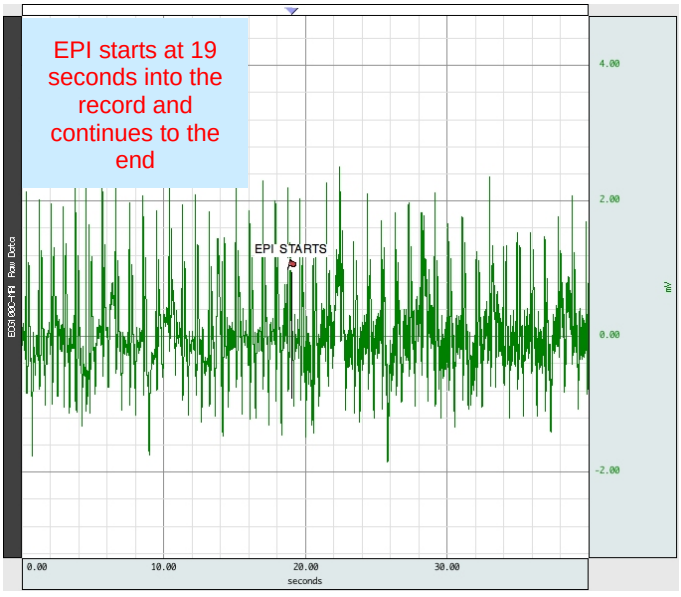

Figure 2: EPI Artifact using ECG100C-MRI amplifier with artifact rejection.

To perform ECG signal averaging in the MRI, employ the ECG100C-MRI amplifier (with appropriate accessories) to collect the desired vector, via a MP150 System with Acq*Knowledge*. After the data is collected, using a sampling rate of not less than 1000 Hz, duplicate the data.

Perform an FFT on the duplicated data (on the portion of the data impacted by EPI) to obtain the following result, as shown in Figure 3. Note that EPI manifests as an 18 Hz fundamental + associated harmonics.

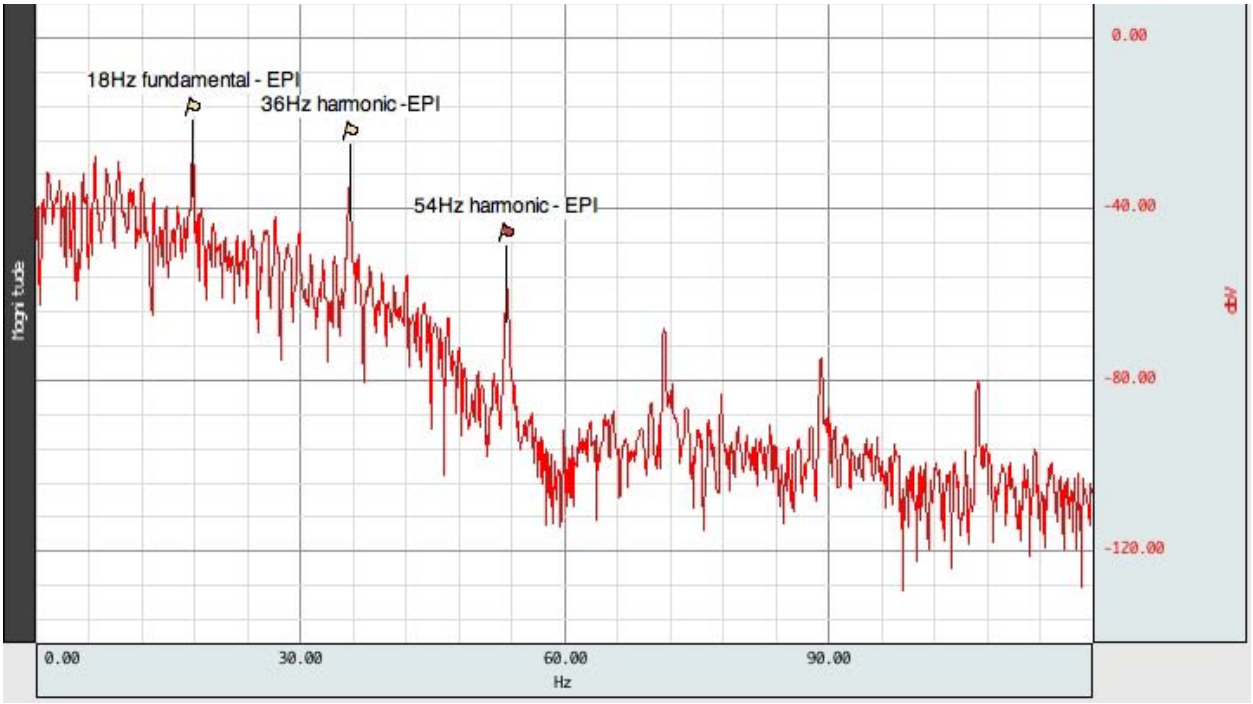

Figure 3: FFT result of ECG100C-MRI raw data, performed during EPI sequence

To remove the EPI artifact

1. Perform a Comb Band Stop Filter (CBSF) operation on the duplicated channel data.
    - The CBSF function is found under “Digital Filters” under the **Transform** menu. The CBSF is set to a fundamental of 18 Hz with a Q of 20. This filter will remove very narrow slices of the ECG spectra to extract the artifact while minimally impacting the source data.
2. Employ “Locate ECG Complex Boundaries” to locate the component waves in both ECG data records.
    - This function is found under the **Analysis** menu. In this example, CH1 is the raw ECG100C-MRI data and CH2 is the CBSF ECG100C-MRI data.

Figures 4 and 5 illustrate the performance of the “Locate ECG Complex Boundaries” function for the two data channels. Note that the function is able to correctly identify the location of the QRS peak in both cases.

The case in Figure 4 is sampled ECG, collected in the MRI, during “quiet” periods—meaning EPI operation is not in effect.

The case in Figure 5 is sampled ECG, collected in the MRI, during EPI operation. Note the presence of EPI artifact in the top channel of Figure 5. The bottom channel in Figure 5 has had the residual EPI artifact removed, via the use of a CBSF.

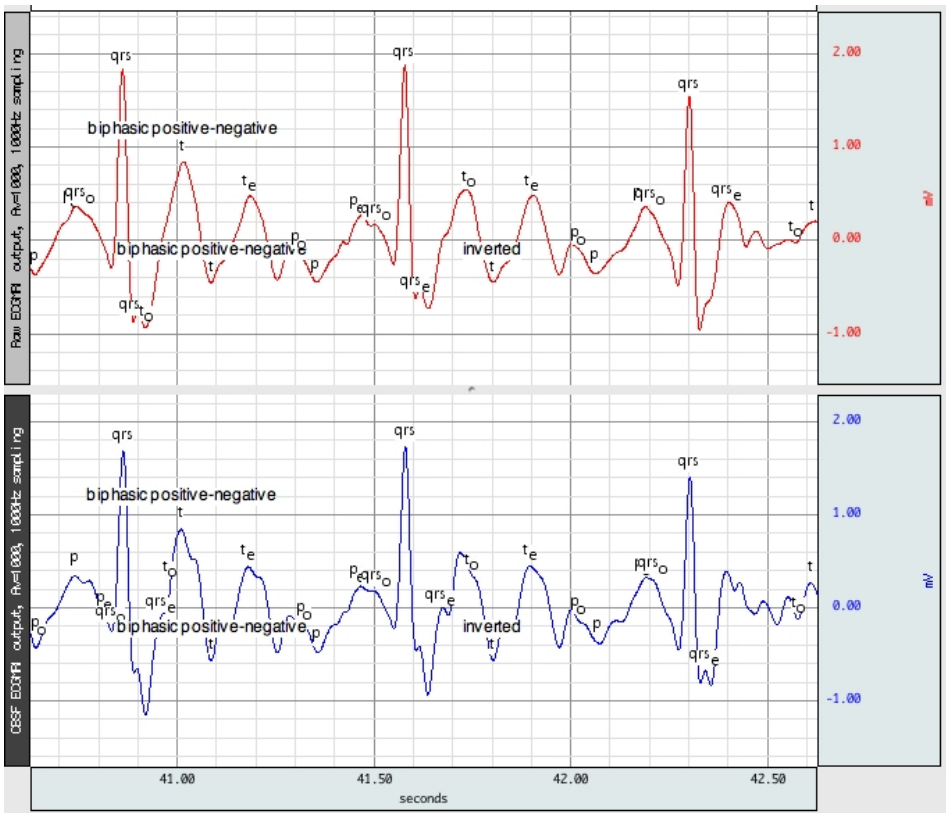

Figure 4: The result of the Acq*Knowledge* Analysis "Locate ECG Complex Boundaries" function, during "quiet" segment

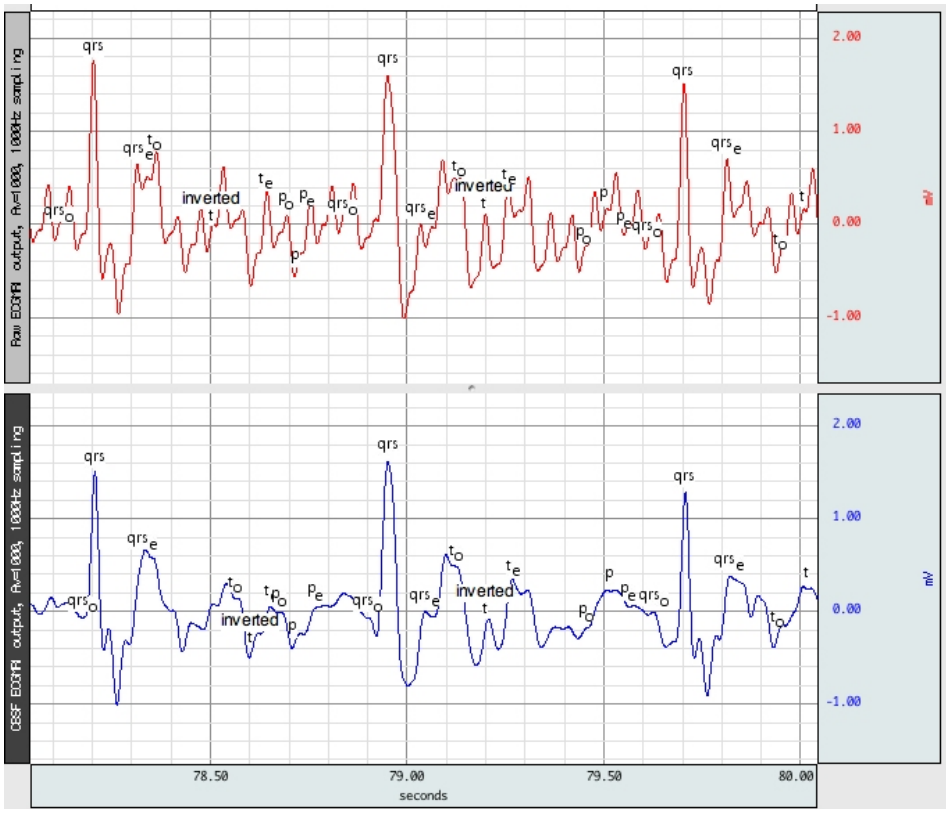

Figure 5: The result of the Acq*Knowledge* Analysis "Locate ECG Complex Boundaries" function, during EPI segment.

The following two graphs, Figure 6 and Figure 7, show the result of performing signal averaging on the ECG data, when the averaging is synchronized to the qrs peak location. Note that the waveforms appear pretty similar, except that the data in CH2 (blue), has a lack of EPI artifact.

Signal averaging was performed via the “Find Cycle” function in Acq*Knowledge* **Analysis**. Cycles are located via “events” and the Start and End event are set to “QRS Peak”, located on the relevant channel (CH1 or CH2). The selection time was set to Starting event -0.5 seconds to Starting event + 0.5 seconds. This setting provides a 1 second averaged “window,” with the QRS centered in the middle. Averaging is performed on the relevant channel (CH1 or CH2) and, in this case, the entire data record was used to obtain the average.

The data indicates a high resolution ECG performed during EPI. The unusual shape of the ECG complex is a consequence of magneto-hydrodynamic effects acting upon the heart.

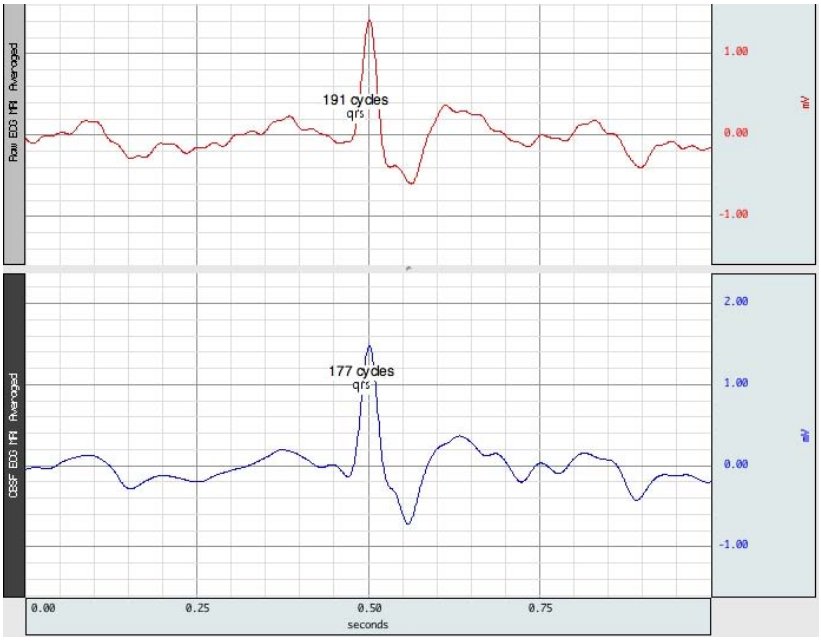

Figure 6: Averaged ECG data, during EPI

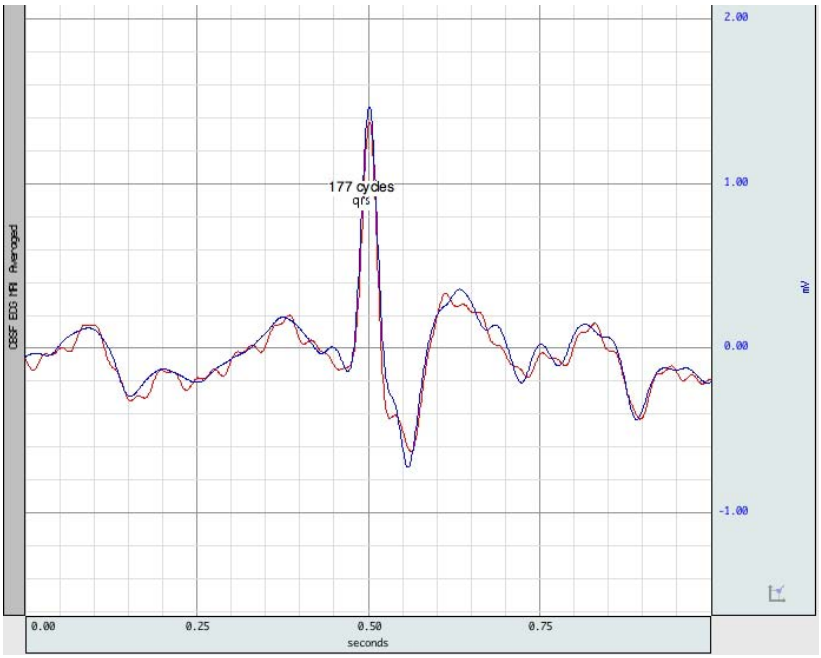

Figure 7: Averaged ECG data, during EPI, overlapped