Color Spectrographic Respiratory Monitoring from the External Ear Canal: Some Preliminary Results

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April 2012

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Introduction The need for simple and reliable means of respiratory monitoring has existed since the time of Hippocrates. This need has become especially strong in recent years with the increased use of opioids such as morphine for acute pain management. Despite this, no simple and reliable method of continuous respiratory monitoring has come into routine clinical use. In this preliminary report we describe the use of color spectrographic analysis of breathing sounds recorded from the external ear canal as a candidate technology to meet this need.

Implementation A miniature electret microphone was modified with the addition of an adapter to allow it to be placed comfortably in the external ear canal. The amplified signal was then connected to a real-time color spectrogram program (spectrogram16.exe) running on a laptop PC. Figure 1 shows the modified microphone, while Figure 2 shows the microphone *in situ*. Figures 3 and 4 shows an alternate design employing an ear clip.

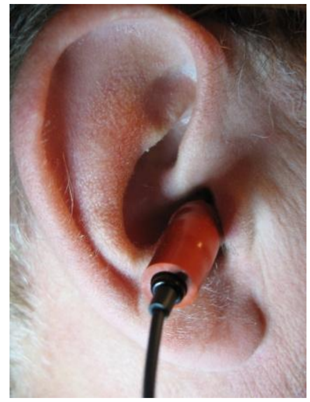
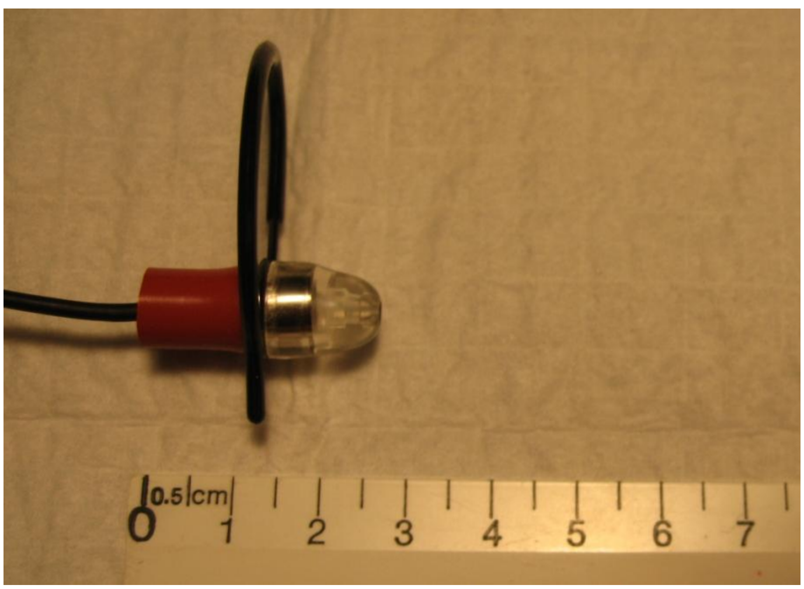


Figure 1 (left). The modified electret microphone, with ear adapter.

Figure 2 (right). The modified electret microphone *in situ*.



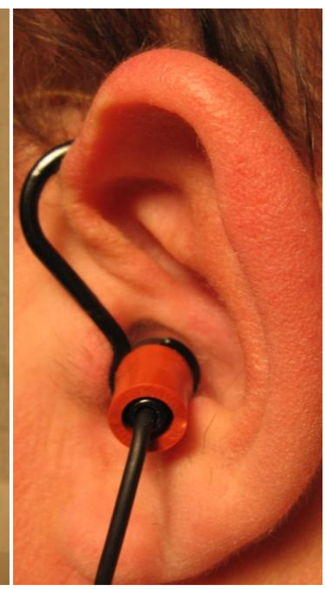


Figure 3 (left). Another modified electret microphone, with ear clip.

Figure4 (right). The electret microphone in Figure 3, shown *in situ*.

Spectrogram Program Setup. Figures 5 and 6 below show the setup used.

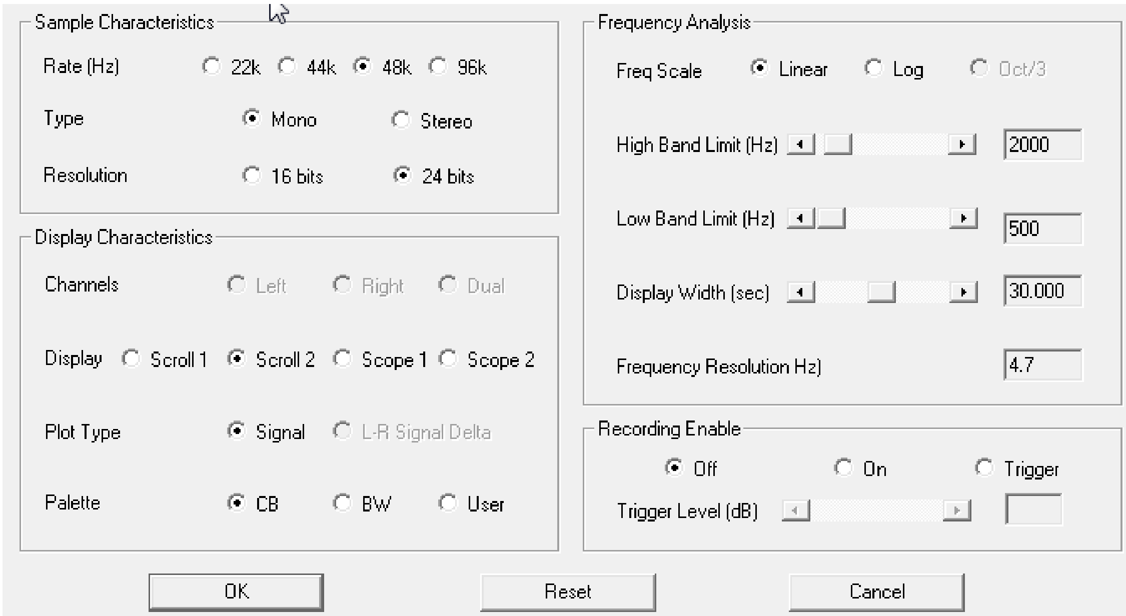


Figure 5. Spectrogram setup parameters used.

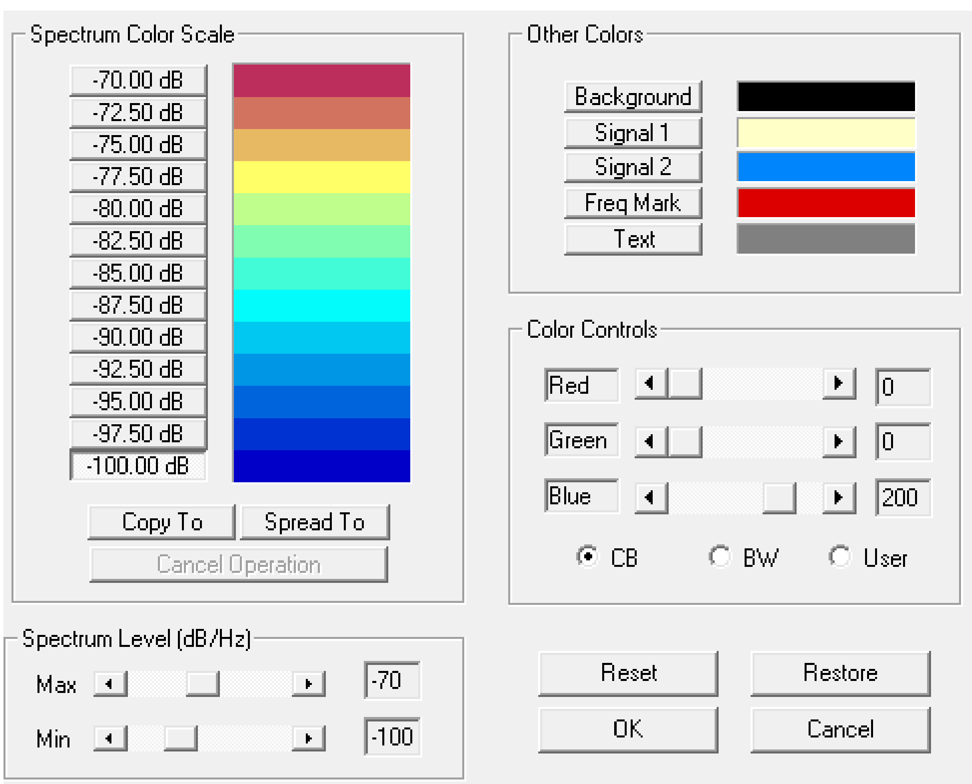


Figure 6. Spectrogram setup for the color arrangement.

Sample Results The figures below shows sample results obtained with nasal and oral breathing by the author on January 3, 2009. The transducer was that shown in Figure 1, placed in the left ear. The time span of each panel is 30 seconds. The range of frequencies displayed was 500 Hz to 2000 Hz. The highest frequency components of the signal are at the top, with the lowest at the bottom. Red areas indicate strongest signal levels, while blue areas are the weakest nonzero signal points (Figure 6):

BLACK < BLUE < GREEN < YELLOW < RED

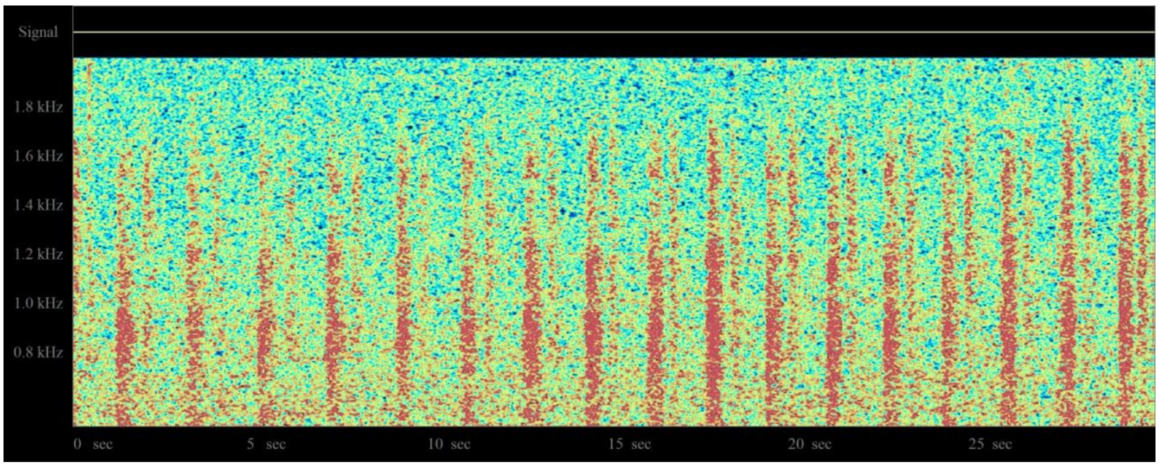


Figure 7. Results for 30 seconds of nasal breathing. Inspiration is more evident than expiration.

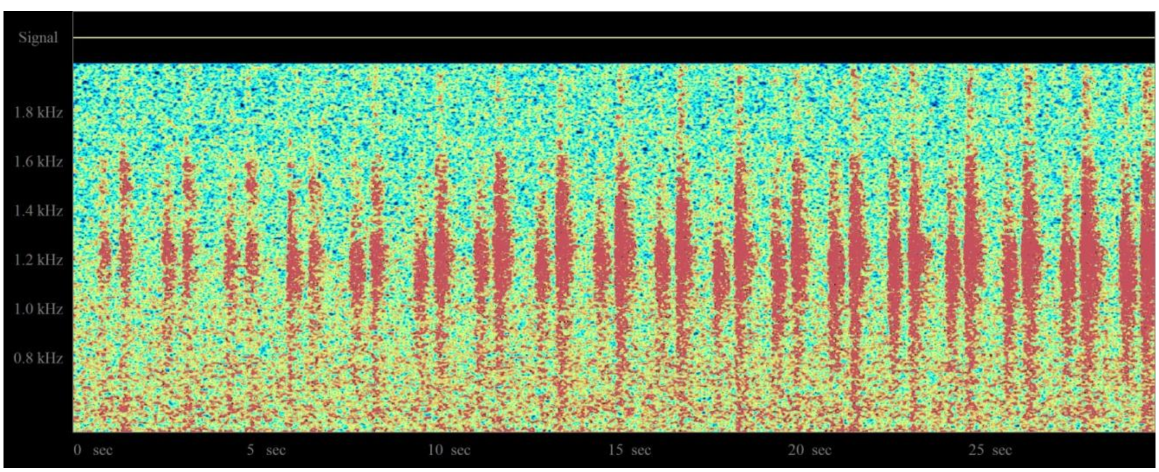


Figure 8. Results for 30 seconds of mouth breathing. Expiration is somewhat more evident than inspiration.

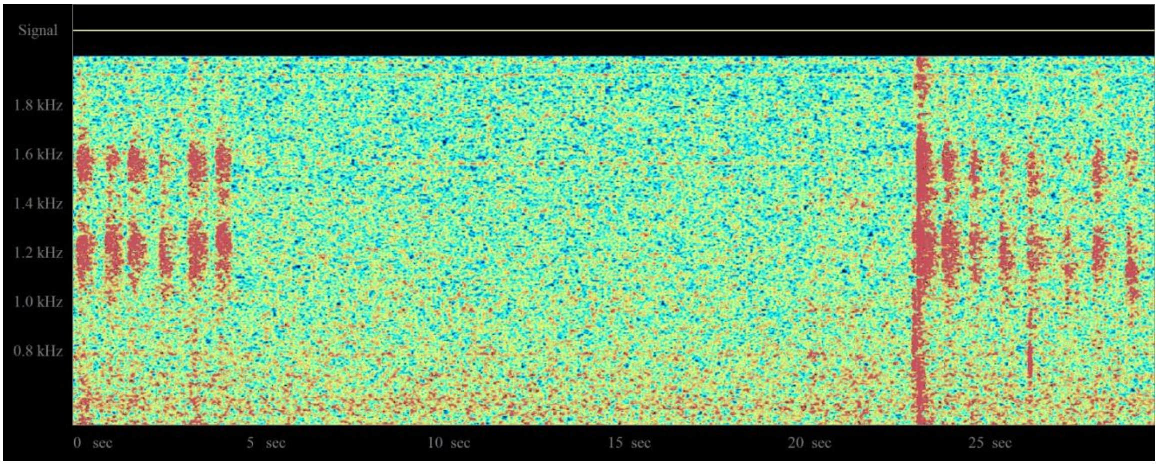


Figure 9. Results showing a 30 second period of mouth breathing interrupted by a period of deliberate apnea (breath holding). Notice the larger than usual inspiration following the apnea period.

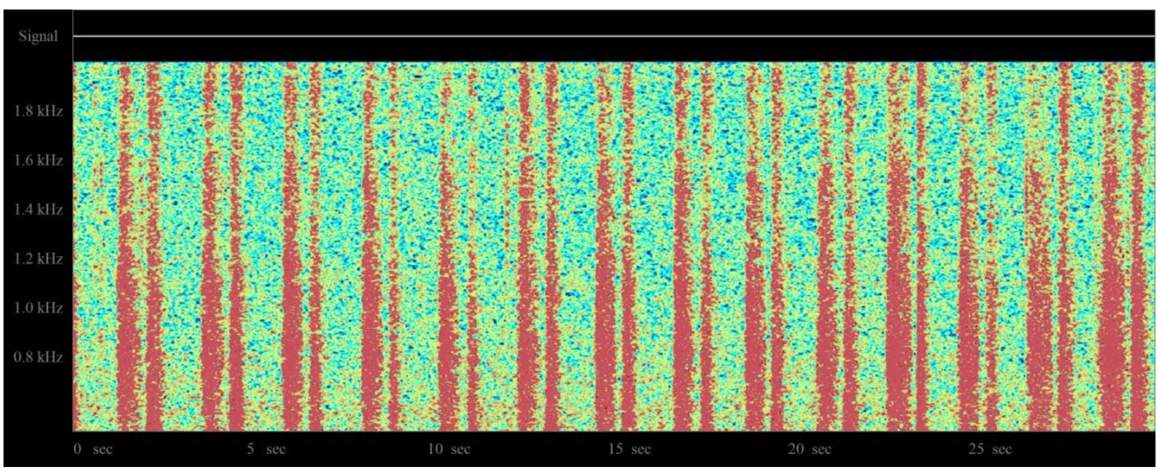


Figure 10. Results showing a 30 second period of nasal breathing with the transducer arranged so as to abut on the nasolabial groove (rather than being placed in the ear). Both inspiration and expiration are strongly apparent in this setting.

Discussion While the results presented here are preliminary in nature, it is hoped that the real-time display of color spectrogram breathing patterns locally or at a central monitoring station may turn out to be a useful means of respiratory monitoring in patients at increased risk of respiratory depression.