Wireless Stethoscope for Anesthesiologists

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UW BME Design

Abstract

Anesthesia providers need to listen to their patients' heartbeat and breathing while administering anesthesia. Manual stethoscopes are the standard method but only allow one provider to listen at a time and can be uncomfortable over an extended time. The manual method is hard to position and secure on the patient's skin. There already exists a rather expensive Bluetooth system, and some antiquated self assembled FM wireless systems, but it would be simpler and far less expensive to have a fully prepackaged commercial system. We have proposed a system with multiple wireless chest pieces that can all be heard from a central transceiver box. This box can connect to a speaker for more than one person to listen, or a headphone jack for private listening. Pediatric anesthesiologists commonly want to be able to compare breath sounds from the right and left chest, so a two microphone capable system is preferred. Resistance to high-frequency electrical signals from the electrosurgery unit is required.

Design Criteria

The client requires a system that will allow him to wirelessly monitor patients' heart beats and breathing before, during, and post surgical procedures that require anesthesia.

- Sound quality should mimic the sounds produced by a conventional acoustic stethoscope
- The sound frequencies that are need to be picked up by the microphone span between 50 Hz and 300 MHz
- Main purpose of monitoring the patient is to determine if airflow is obstructed, therefore capturing trachea and lung noises are crucial (Figures 1 and 2)
- The anesthesiologist would like to be able to switch between multiple chest pieces
- Chest pieces should be able to be securely adhered to the patient during surgery, but offer easy removal post surgery
- The user should be able to output the audio through a speaker system or a wireless headset
- Must be durable, extremely reliable, lightweight, and portable (chest pieces and transmitters are no larger than a deck of cards)
- Battery life must allow for longer surgeries, optimally it will last 20 straight hours plus
- Needs to operate at low voltages to minimize risk to patient and user
- Wireless signal transmission must occur over frequencies that do not interfere with current operating room devices
- Must comply with IACUC and FDA product development and ethics regulations for use in clinical trials

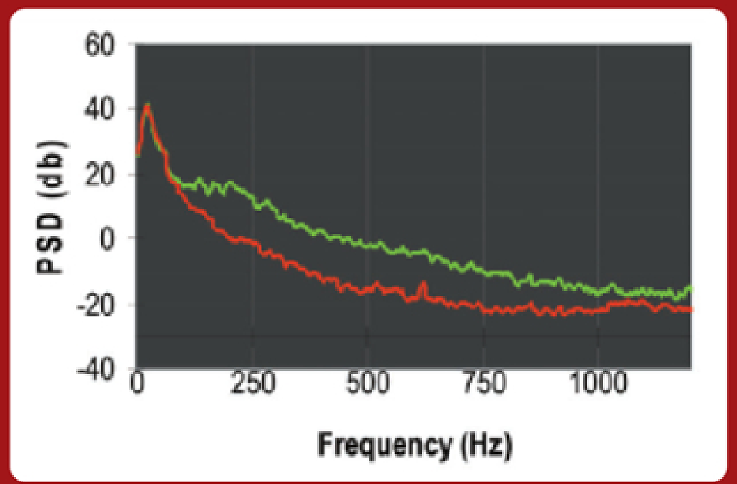

Figure 1 - Trachea Audio Frequency versus Amplitude

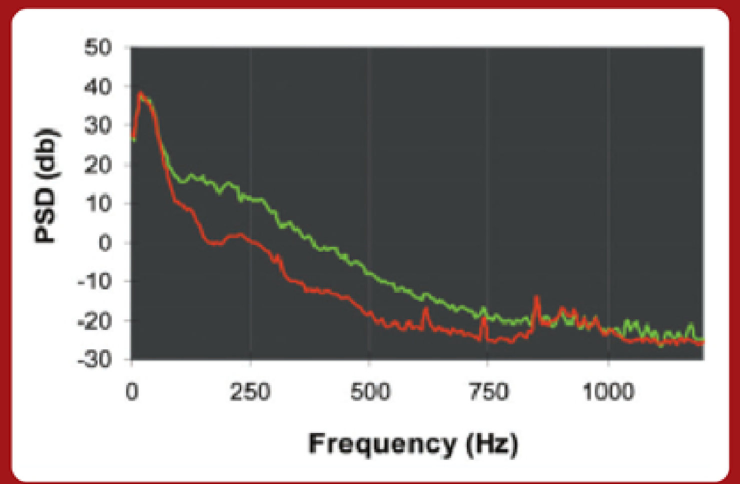

Figure 2 - Lung Audio Frequency versus Amplitude

Previous Designs

First iteration of this device as a BME Design Project occurred in Fall of 2011

- It had a custom manufactured chest piece that a microphone had been inserted in
- A series of passive filters were used to get a clean signal of the desired frequency's pro duced by the stethoscope
- A mixer was used to adjust treble and bass, and the final audio signal was out putted over a conventional speaker system

This device still had drawbacks that needed to be corrected

- The device was not wireless, as the client had originally requested
- The audio produced by the custom built chest piece was different than the audio produced by a traditional chest piece
- The device was extremely crude in appearance and functionality, many aesthetic improve ments needed before it could be placed in an operating room

Background

The acoustic stethoscope has been a crucial medical tool for over 200 years

- Attributed to a French Physician, Rene Laennec, whose first prototype was a rolled up newspaper [1]
- The modern acoustic stethoscope uses a bell and diaphragm chest piece with rubber tubing leading to the two earpieces
- The bell captures lower frequency sounds, while the diaphragm, a small plastic disc, captures higher frequencies [2].

The first electronic Stethoscope was developed in 1961

- Original prototype extremely bulky and cumbersome
- Electrical interference and sensitivity to surrounding noise caused the sounds to be unlike the traditional acoustic model
- The sound quality has been greatly improved through the use of sound transducers, adjustable gain amplifiers, and frequency filters [4]
- Widespread adoption of the technology is still hindered by their expense, wired nature, and the noises only able to be heard by one individual at a time

Transmissions of wireless signals in the operating room has to be regulated

- As most equipment in an operating room is vital to patient health, it is very important that a wireless system not interfere with existing systems
- The proposed system uses very high frequency (VHF) transmission bands, while most operating equipment employs ultra high frequency (UHF) transmission bands. This ensures no interference occurs from

Figure 3 - Final Design

Final Design

A traditional chest piece will be used to ensure that the sound produced is familiar to the user

- The chest piece can be either made of plastic or metal, depending on the surgeries requirements
- 3M makes a torus shaped adhesive that can be employed to fasten the chest piece to the patient
- The sound from a traditional chest piece travels up a rubber tube, this tube will be cut directly after the chest piece and a microphone will be inserted into each chest piece employed, effectively capping the end of the rubber tube to prevent sound loss

Wireless transmission of the audio will be performed using very high frequencies (VHF)

- The microphone employed is a standard lapel microphone used by stage productions
- This microphone is connected to a transmitter by a small gauge wire, allowing the transmitter to be placed in a location that prevents it from obstructing the surgeon
- The transmitter than broadcasts the audio signal using frequencies between 30 to 300 MHz

The audio signal will then be received by a transceiver located away from the patient

- Wireless transmission allows the anesthesiologist to position himself in an unobstructed location near his equipment
- The transceiver works with multiple chest pieces, each chest piece is assigned a certain subset frequency band and switching between them occurs with the touch of a button

Once received by the transceiver, the audio can be listened to using a variety of options

- The output of the transceiver is a 1/4 inch audio jack; we've used an adapter to change this to an 1/8 inch audio jack which is the most commonly used audio jack
- Therefore desktop speakers, capable of reproducing the required frequency range, can easily be connected to the transceiver and used to broadcast the sound
- Alternatively, any commercially available wireless headset could also be connected

Future Work

The device will need to be thoroughly tested in an operating room environment

- Unable to locate a hospital that would allow us to test the equipment currently
- ICUAC and FDA approval will be necessary to allow the sale of this device

A patent could be pursued to ensure rights to the devices novel features

- Wisconsin Alumni Research Foundation will assist in this pursuit
- It must be determined that we aren't infringing on any existing patents

A longer lasting power source would provide increased functionality

- Currently the transmitter runs off of a disposable alkaline 9 volt battery
- Replacing this with a Li-Ion battery would provide a rechargeable option with extended battery life

Improving sound quality would allow for a better user experience

- Lung sounds are the most underrepresented due to their low frequencies, while heart and trachea are up to par
- Replacing the stock microphone with a microphone that specializes in low frequencies could improve this issue
- Physical and electronic filtering methods could be employed to reduce unwanted noise interference

Testing

Frequency Response of Microphone

- Audio signal from microphone was fed into MatLab, ensuring that it was capturing the correct frequencies

Frequency Response of the Entire System

- Microphone was fed audio signals at a wide range of frequencies to determine the systems entire range
- Output was recorded from the speakers, as they are the end point of the audio signal processing
- MatLab verified that there were no major sources of distortion or corruption to the signal

Real World Application Testing

- Chest piece was attached with adhesive to a test patient
- Output of trachea, lung, and heart locations were all listened to and analyzed
- Trachea and heart sounds have great response; however, lung sounds could be improved

Battery Life Verification

- Device was left on for an extended period of time to determine battery
- Device lasted 22 hours, which could be improved by using Li-Ion batteries

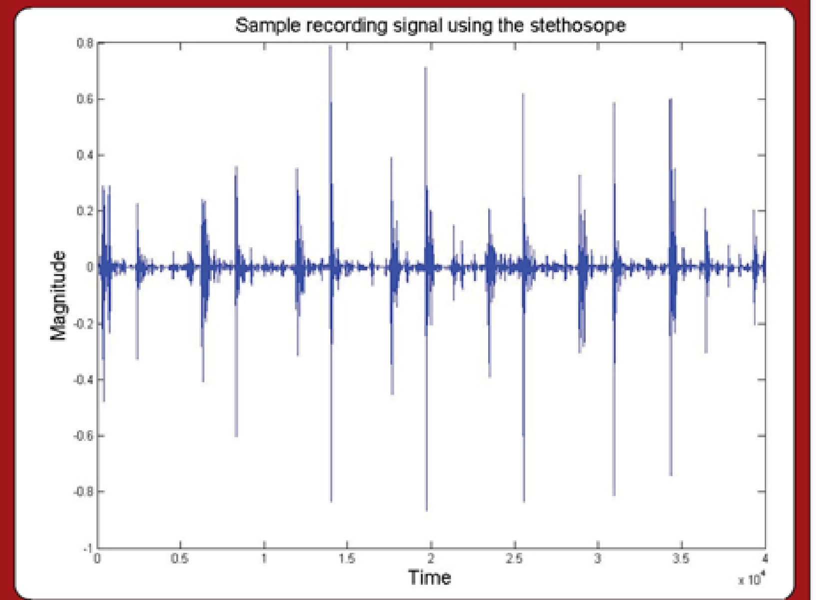

Figure 4 - Output of Prototype Stethoscope in Use

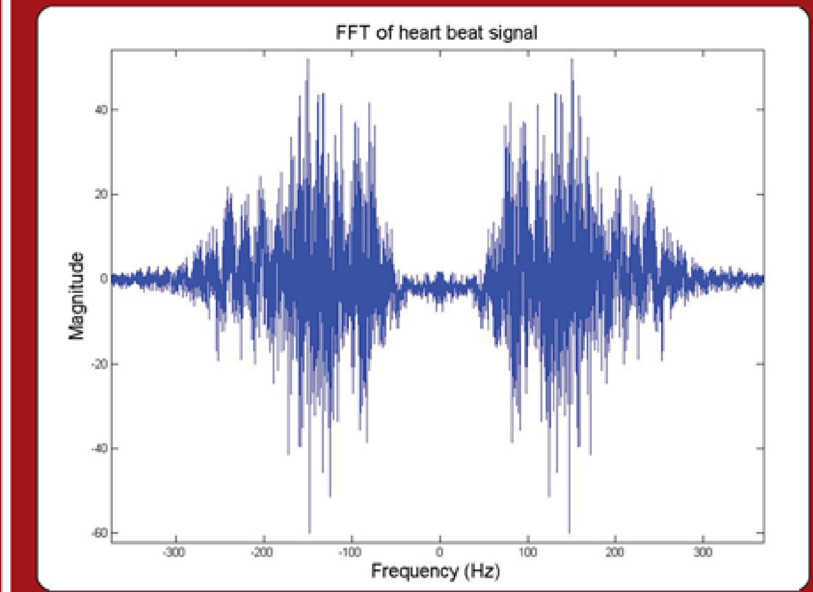

Figure 5 - Fast Fourier Transform of the Device's Heart Beat Recording

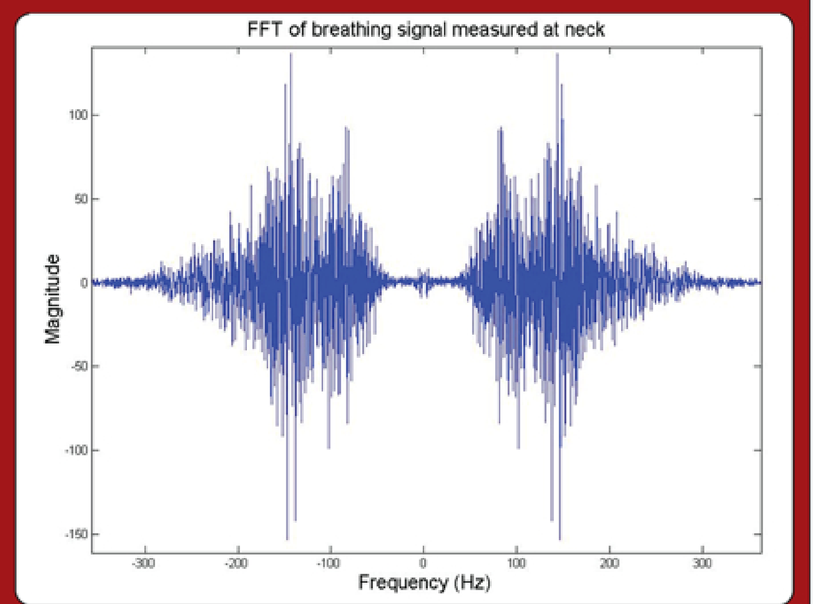

Figure 6 - Fast Fourier Transform of the Device's Trachea Response

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