A tunable auscultation system includes a heart sound acquirer for sensing heart sounds from at least one chest location of the patient. An initial conditioner then conditions the heart sounds through pre-amplification and anti-aliasing. The heart sounds are transduced into electrical signals by a signal processor. The electric heart signals are then tuned by an analysis tool. The analysis includes an interaction tuner, a processing tuner and an output tuner. The interaction tuner includes a preset tuning selector and a dynamic range tuning selector. The processing tuner includes a band pass filter and an algorithmic extraction engine which applies extraction algorithms to the electric heart signals, segments them and extracts signals of interest. Signals of interest may be correlated to specific pathologies. The output tuner includes a signal strength indicator, a diagnosis indicator, an overlapping cardiac cycle display and a display configuration engine. A display module provides output.
FIG. 2
Signal Processor

FIG. 3
START

RETRIEVE HEART SOUNDS FROM INPUT BUFFER

DISPLAY OR PLAYBACK MODE?

SELECT FILTER MODE

FILTER SIGNALS

STORE IN OUTPUT BUFFER

VIDEO DISPLAY

SELECT FILTER MODE

FILTER SIGNALS

DAC

AUDIO PLAYBACK

STOP

FIG. 4
Start

Playback Order from Keypad

Normal Playback?

Device in Bell Mode?

Select Audio Filter for Bell Mode

Select Audio Filter for Diaphragm Mode

Display Bell waveform, Low Frequency waveform, and High Frequency waveform; Display moving “Play” cursor; Playback Heart Sound Signal in Bell Mode

Display Diaphragm waveform, Low Frequency waveform, and High Frequency waveform; Display moving “Play” cursor; Playback Heart Sound Signal in Diaphragm Mode

Stop

FIG. 5
FIG. 19
FIG. 21

FILTER MODULE

ALGORITHMIC EXTRACTION ENGINE
FIG. 22

- AUDIO INPUT/OUTPUT DEVICE
- SOUND SEPARATOR
- FREQUENCY INDICATOR
- OUTPUT DRIVER
- VIDEO DISPLAY
- WAVEFORM DIFFERENTIATOR
- DIAGNOSIS INDICATOR
- SIGNAL STRENGTH INDICATOR
FIG. 23
FROM STEP 2306

NOISE REDUCTION

BAND PASS FILTRATION

VARIABLE GAIN CONTROL

TO STEP 2312

FIG. 24
FROM STEP 2306

USER SELECTED?

YES → USER SELECTED TUNING

NO → AUTOMATIC TUNING

TO STEP 2312

FIG. 25
FROM STEP 2502

BAND PASS FILTRATION

EXTRACTION?

YES

APPLY EXTRACTION ALGORITHMS

NO

SEGMENT INCOMING SIGNAL

EXTRACT SIGNALS OF INTEREST

TO STEP 2312

FIG. 26
FROM STEP 2502

USE PRESETS?

YES

USER SELECT PRESET FREQUENCY FILTER

NO

USER SELECT CONTINUOUS FREQUENCY RANGE FILTER

USER SELECTION FEEDBACK

TO STEP 2312

FIG. 27
FROM STEP 2312

DISPLAY RAW SIGNAL

DISPLAY FILTERED SIGNAL

DISPLAY DIAGNOSIS INDICATION

DISPLAY ENERGY CONTENT IN CHOSEN BAND

DISPLAY DIAGNOSIS LOCATION

DISPLAY OVERLAPPING SIGNALS

END

FIG. 28
SYSTEMS AND METHODS FOR TUNING, ANALYSIS AND DISPLAY OF HEART SOUNDS

CROSS REFERENCE TO RELATED APPLICATIONS


BACKGROUND OF THE INVENTION

[0002] This invention relates generally to medical electronic devices for analysis of auscultatory cardiac sounds. More particularly, this invention relates to a method for transducing, intelligently filtering, recording, analyzing and audiovisual representation of heart sounds at the point of care, in humans, to enable differential diagnosis.

[0003] Auscultatory sounds have long been one of the primary inputs to aid in the detection of various physiological conditions. For instance the stethoscope is the first tool used by a clinician to monitor heart sounds to detect and diagnose the condition of a subject’s heart. Auscultation itself is extremely limited by a number of factors. It is extremely subjective and largely depends on the clinician’s expertise in listening to the heart sounds and is compounded by the fact that certain components of the heart sounds are beyond the gamut of the human ear. In addition, auscultation relies on correctly determining which of the primary heart sounds correspond to the systolic and diastolic phases of the heart. This is made more difficult when conditions such as ectopic beats, atrial fibrillation, atrial flutter, tachycardia and various other rhythmic disorders occur.

[0004] A number of improvements have been developed to circumvent such bottlenecks, ranging from relatively noise-free electronic auscultation, to complex computer algorithms that can analyze the cardiac sounds, calculate various numerical values like heart rate, ascertain the heart sounds phases etc. For example, algorithms are available that allow heart sounds in electronic format to be visualized on a personal computer screen and analyzed.

[0005] Accordingly, personal computer (PC) based auscultatory devices like the Acoustic Cardioscan from Zargis Medical Corporation of Stamford, Conn., and software packages like the Veteran Phonocardiogram monitor from Biosignetics Corporation of Exeter, N.H., are capable of a wide range of operations and manipulations of heart sounds offline. However, the above described PC based platforms suffer from the following shortcomings and bottlenecks. These PC based systems call for a separate data gathering device to record heart sounds in the format that can be processed by the PC based algorithm. In addition, there is a critical time delay between the time the clinician auscultates the subject and the time the clinician applies the PC based analysis to the recorded heart sounds. There are also portability issues associated with the PC based system setup.

[0006] Currently, handheld auscultatory devices have been developed in an attempt to circumvent some of the above described problems with PC based computer systems. These handheld devices do incorporate the data gathering mechanism in the device itself, obviating the need for separate data gathering. Handheld devices sold under the brand names Cadiscope (from Caditec AG Medical Instruments of Switzerland) and the Visual Stethoscope (from MC21 Meditech Group) are instances of such handheld auscultatory devices. However, handheld devices have their own shortcomings. For example, some handheld devices are designed such that the chest piece is housed in the device itself thereby rendering sterilization processes difficult, or at least call for involved and expensive methods of cleaning. Further, the mere display of the heart sounds or ECG signals, in addition to the audio of the heart sounds is insufficient for the user to ascertain the condition of the heart.

[0007] Particularly, there is a long felt and unmet need for the ability for such handheld auscultatory devices to dynamically alter the various filters used in processing the heart sounds. Such filtering, or ‘tuning’ may include user selection of filters, preset bands of filters and intelligent filtering.

[0008] It is therefore apparent that an urgent need exists for an improved auscultatory device that is easy to use, accurate, portable, cost-effective, tunable and easy to sterilize and maintain.

SUMMARY OF THE INVENTION

[0009] To achieve the foregoing and in accordance with the present invention, a method and system of tuning, analyzing and displaying heart sounds is provided. Such an auscultation system is useful for a clinician to efficiently and cost-effectively auscultate patients.

[0010] In some embodiments, the tunable auscultation system includes a heart sound transducer for sensing heart sounds from at least one chest location of the patient. The heart sounds are then passed through a circuit which precondition the signal. The pre-conditioning circuit consists of a pre-amplifier and an anti-aliasing filter.

[0011] These heart sounds are then sent to an analysis tool which performs a set of filtering processes. This tuning includes extracting pathology information.

[0012] The analysis tool is able to filter the frequencies of the heart sounds. The analysis tool is able to take in user input, perform intelligent tuning, and provide appropriate user feedback.

[0013] The user of the device is able to input a desired filter combination, consisting of either preset filter setups, e.g. low, medium, high, emphasize a certain feature such as S1 or S2, bell, diaphragm and various other settings whose frequencies are well known, or the user can set the center frequency and filter bandwidth as they desire, with or without the device providing guidance.

[0014] The intelligent tuning section consists of an algorithm that analyzes the signal, segments it into its various component parts, and extracts the segments of interest. The segments of interest can then be used by the algorithm to determine whether there is an underlying pathology. The intelligent tuning section can then pass this determination to the output section for user interaction.

[0015] The output of the stethoscope can consist of a signal strength indicator, a diagnosis indicator, the phonocardiogram and various methods of displaying a processed version of the phonocardiogram. The diagnosis indicator utilizes the information produced by the intelligent tuning section.

[0016] These and other features of the present invention will be described in more detail below in the detailed description of the invention and in conjunction with the following figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In order that the present invention may be more clearly ascertained, one embodiment will now be described, by way of example, with reference to the accompanying drawings, in which:
FIG. 1 is a block diagram showing one embodiment of an auscultation device for analyzing and displaying heart sounds in accordance with the present invention; FIG. 2 is a block diagram illustrating a heart sound signal acquirer for the auscultation device of FIG. 1; FIG. 3 is a block diagram illustrating a heart sound signal conditioner for the auscultation device of FIG. 1; FIG. 4 is a flow diagram illustrating heart sound signal decomposition for the auscultation device of FIG. 1; FIG. 5 is a flow diagram illustrating heart sound signal playback for the auscultation device of FIG. 1; FIGS. 6-10 show screenshots illustrating the various functions of the auscultation device of FIG. 1; FIGS. 11A & 11B are isometric and top views, respectively, of another embodiment of a heart sound signal acquirer for the auscultation device of FIG. 1; FIGS. 12A & 12B show an isometric and two side views of another embodiment of the auscultation device of FIG. 1; FIGS. 13 and 14 illustrate two additional embodiments of the auscultation device of FIG. 1; FIGS. 15 and 16 show embodiments of the auscultation device of FIG. 1 wherein the heart sound signal acquirer is attached directly to the main body of the auscultation device; FIG. 17 shows a functional block diagram of a tunable auscultation device for analyzing and displaying heart sounds in accordance with one embodiment of the present invention; FIG. 18 shows a functional block diagram of a transducer in accordance with the tunable auscultation device of FIG. 17; FIG. 19 shows a functional block diagram of an analysis tool in accordance with the tunable auscultation device of FIG. 17; FIG. 20 shows a functional block diagram of an interaction tuner in accordance with the tunable auscultation device of FIG. 17; FIG. 21 shows a functional block diagram of a processing tuner in accordance with the tunable auscultation device of FIG. 17; FIG. 22 shows a functional block diagram of an output tuner in accordance with the tunable auscultation device of FIG. 17; FIG. 23 shows a flow diagram illustrating tuning analysis of heart sounds for the tunable auscultation device of FIG. 17; FIG. 24 shows a flow diagram illustrating standard processing of heart sounds for the tunable auscultation device of FIG. 17; FIG. 25 shows a flow diagram illustrating signal tuning of heart sounds for the tunable auscultation device of FIG. 17; FIG. 26 shows a flow diagram illustrating automatic tuning of heart sounds for the tunable auscultation device of FIG. 17; FIG. 27 shows a flow diagram illustrating user selected tuning of heart sounds for the tunable auscultation device of FIG. 17; FIG. 28 shows a flow diagram illustrating visual output of tuning analysis of heart sounds for the tunable auscultation device of FIG. 17; FIG. 29A shows a frontal schematic diagram of tunable auscultation device for analyzing and displaying heart sounds in accordance with one embodiment of the present invention; and FIG. 29B shows a skewed schematic diagram of tunable auscultation device for analyzing and displaying heart sounds in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

I. Auscultation Device

The present invention will now be described in detail with reference to several embodiments thereof as illustrated in the accompanying drawings. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art, that the present invention may be practiced without some or all of these specific details. In other instances, well known process steps and/or structures have not been described in detail in order to not unnecessarily obscure the present invention. The features and advantages of the present invention may be better understood with reference to the drawings and discussions that follow.

To facilitate discussion, FIG. 1 is a block diagram showing one embodiment of an Auscultation Device 100 for analyzing and displaying heart sounds in accordance with the present invention. Device 100 includes heart sound signal acquirer 110, signal conditioner 120, signal processor 130, memory 140, user interface 150, video display 160 and audio input/output device 170.

Memory 140 can be fixed or removable memory, and combinations thereof. Examples of suitable technologies for memory 140 include solid-state memory such as flash memory, or a hard disk drive.

User interface 150 can be a keypad, a keyboard, a thumbwheel, a joystick, and combinations thereof. Video display 160 can be an LCD screen, or can be an LED display or a miniature plasma screen. It is also possible to combine video display 160 with user interface 150 by use of technologies such as a touch screen. Contrast and brightness control capability can also be added to display 160.

Audio input/output (I/O) device 170 includes a microphone, and speakers, earphones or headphones, any of which can be internal or external with respect to device 100. It is also possible to use wireless audio I/O devices such as a Bluetooth-based headset. Volume control of device 170 can also be provided.

FIG. 2 is a block diagram illustrating heart sound signal acquirer 110 in greater detail. Acquirer 110 includes an acoustic sensor 210 and a preamplifier 215 which are coupled to signal conditioner 120. In this embodiment, sensor 210 is a unidirectional microphone housed in a chest piece assembly. Preamplifier 215 is solid-state and pre-amplifies the heart sounds before the signal conditioner 120.

FIG. 3 is a detailed block diagram illustrating heart sound signal conditioner 120 which includes an input buffer 310, one or more band pass filters(s) 320, a variable gain amplifier 330, a gain controller 340 and an output buffer 350. Output buffer 350 is coupled to signal processor 130 which in turn is coupled to gain controller 340.

In some embodiments, filter 320 is a pass band filter which limits the analysis of the heart sound signal to frequencies less than the maximum expected in a heart sound, thereby ensuring that all frequencies of the heart sounds are faithfully captured and at the same time eliminating noise sources that typically exist beyond the pass band of filter 320. Variable gain amplifier 330 of signal conditioner 120 serves to vary the signal gain based on a user-selectable input parameter, and also serves to ensure enhanced signal quality and improved
signal to noise ratio. The conditioned heart sound signal after filtering and amplification is then provided to signal processor 350 via output buffer 350.

II. Heart Sound Analysis

[0050] FIG. 4 is a flow diagram illustrating an exemplary “Decomposition” of heart sound signals by one embodiment of signal processor 350. In step 405, heart sound signals are retrieved from input buffer 310. Using the appropriate key sequence on user interface 150, the user can select Visual Display mode and/or Audio Playback mode as shown in step 410.

[0051] Multiple sets of filters of different frequencies pass bands pertain to a plurality of modes of operation. These modes include “Bell” mode, a “Diaphragm” mode, a low, medium and high filtration or additional frequency band pass preset. The bell and diaphragm operational modes emulate the respective functions of a combined Bell/Diaphragm head found in traditional acoustic (non-electronic) stethoscopes that many experienced clinicians are accustomed to using. The other filtration presets may be of particular use for identification of particular pathologies or sounds of interest. Depending on the user selection between audio playback mode and visual display mode, the pertinent set of audio or video filters is enabled.

[0052] Each of the normal and pathological heart sounds will have characteristic frequency content. These can be ordered on a continuum, for example like an analog radio dial from low to high. The user of the device can then dial through these bands in turn while listening to a subject’s heart sounds, and observe its features. This may also be used in an educational setting as students are shown how to differentiate between features which sound similar but by separating into appropriate frequency bands, the various features can be extracted.

[0053] As shown in step 415, the user’s visual analysis of the decomposed heart sounds is based on the filter mode selected through user interface 150.

[0054] For example, FIG. 9 illustrates a “Diaphragm” Visual Display mode, the composite heart sound signal which is between 60-600 Hertz is also decomposed into two component frequency ranges, a low frequency component between 60-250 Hertz and a high frequency component between 250-600 Hertz. The low frequency components highlighting the S1, S2, medium frequency murmurs (prominent) and low frequency murmurs (suppressed). The high frequency components highlighting the medium frequency murmurs and high frequency murmurs.

[0055] In some embodiments, the frequencies captured in “Bell” mode include the complete range of Bell frequencies. Similarly, the frequencies captured in “Diaphragm” mode include the complete range of the Diaphragm frequencies. Other customized decomposition modes with user definable component frequency ranges are also possible.

[0056] As discussed above, display 160, e.g., an LCD display, provides the visual representation of the heart sounds to the user by storing the waveforms in output buffer 350 prior to visual display (steps 440, 445). Meanwhile audio output device 170, e.g., a set of headphones, provides an auditory representation of the same heart sounds to the user by a digital-to-analog conversion (DAC) prior to audio playback (steps 470, 475). Preferably, both visual and auditory representations of the heart sounds as experienced by the user are synchronized.

[0057] In some embodiment, the sensor head has two opposing sensors (not shown), i.e., a Bell-side sensor and a Diaphragm-side sensor, like a traditional acoustic stethoscope. Accordingly, instead of the user manually selecting the Decomposition mode, device 100 automatically selects a default decomposition mode by sensing whether the Bell side sensor or the Diaphragm side sensor of the sensor head is touching the chest wall of the patient and hence is generating a stronger heart sound signal. The heart sounds are then analyzed by the corresponding Bell or Diaphragm filters which may also be automatically selected by processor 130. The user may be able to select additional filter modes, such as high/medium/low, etc. Selection of another filter mode may override the default filter selection in these embodiments.

[0058] In yet another embodiment illustrated by the isometric and top views of FIGS. 11A and 11B, respectively, heart signal acquirer 1110 also includes a selector switch 1115 which the user can use to select from two or more pre-determined modes, e.g., a “Bell” mode, a “Diaphragm” mode, low, medium and high modes, using a finger of the same hand that is holding the signal acquirer 1110 against the chest wall of the patient. While an exemplary two-position slider switch assembly 1115, 1116 is shown, it is understood that other selector switches are also possible, including push button switches, rocker switches, rotary switches, dials, touch screen input or voice operated switches. Switch 1115 can be located on the top or on the side of signal acquirer 1110.

[0059] Referring now to FIG. 5, which is a flow diagram illustrating heart sound signal audio playback as facilitated by the user inputting the “Playback” command using user interface 150, such as a keypad (step 510). In the Playback function, the user can select “Normal” playback or “Stereophonic” playback (steps 520, 530). The user can also select “Bell” mode or “Diaphragm” mode (steps 550, 570). In step 560, when Bell mode has been selected, display 160 such as an LCD screen, shows the composite Bell waveform as well as the respective component low frequency and the high frequency waveforms. Similarly, in step 580, when Diaphragm mode has been selected, display 160 such as an LCD screen, shows the composite Diaphragm waveform as well as the respective component low frequency and the high frequency waveforms.

[0060] As shown in FIG. 10, a vertical “Play” cursor scrolls across the three waveforms on display 160 synchronously with the audio playback described above, thereby ensuring that the user can visually see on display 160 what he/she is hearing via audio output device 170.

[0061] The user is able to ascertain pathologic heart conditions using device 100 because most conditions can be associated with their respective characteristic frequencies and amplitude durations. For example, under the right conditions, mitral value regurgitation can be diagnosed with approximately 60% certainty.

[0062] In some embodiments, the heart sound signals acquired by auscultation device 100 may be stored. For storage, the user selects the “Save” function by pressing keys on user interface 150, causing device 100 to download the heart sound signal, and associated patient identification and any annotation into a removable or an external memory device. In some embodiment, the patient ID and annotations can be added using voice recordings thereby minimizing the need for additional keystrokes. The local memory of device 100 can now be freed up for recording new heart sound signals.

[0063] In some embodiments, speech recognition technology known to one skilled in the art can be incorporated into device 100, enabling a textual record of the patient identification and annotations to be included instead or in addition to an audio recording. Speech recognition capability can also be used to activate the various functions of device 100, thereby resulting in a user-friendly and relatively hands-free auscultation device. Accuracy and/or efficiency of speech recogni-
tion can be increased by limiting the vocabulary and/or training the synthesizer to recognize the user's vocal characteristics.

[0064] It is also possible to incorporate speech synthesis capability into device 100 so as to enhance the ease of use with prompts, instructions and/or feedback. For example, device 100 can ask a user whether device 100 should be sensing in “Bell”, “Diaphragm”, or other filter preset mode, or to inform the user that an invalid command/mode has been selected.

[0065] Having described several of the functions of auscultation device 100 in detail, FIG. 6-10 are now used to illustrate a typical sequence of the various functions that a user may activate while using auscultation device 100 to diagnose the heart sounds of a patient.

[0066] In one embodiment as shown in FIG. 6, a heart sound signal acquirer 110, e.g., a microphone embedded in a chest piece, and audio input device 170, e.g., earphones, are electrically coupled to signal processor 130 of device 100. The user turns device 100 on by pressing the “Function Select” key 1054. FIG. 7 shows device 100 during the “Power On” cycle, while FIG. 6 shows battery level 1011 upon completion of the “Power On” which enables the user to keep track of the power needs of device 100.

[0067] To conserve power, device 100 goes into a sleep mode if there are no key presses after a timeout period, e.g., after two minutes. While in this sleep mode, any key press causes device 100 to return to the last state of operation.

[0068] The user pre-selects a suitable duration of heart diagnosis, e.g., X seconds, of heart sound signals to be acquired. As illustrated by FIG. 8, device 100 displays function “Acquire” 1013 and enables the user to make a voice recording of the associated patient information including patient ID. The user places chest piece 110 on the patient’s chest which causes device 100 to output the heart sound 1064 on video display 160 as shown in FIG. 8.

[0069] Together with the user’s training and experience, the “Original” heart sound 1064 enables the user to interpret the graphical representation of the complete heart waveforms, thereby providing the user with a general idea of the condition of the patient’s heart. Note that device 100 initially displays the default audio volume level as an adjustable “Speaker” icon 1012, the default signal gain level as a “Gain” icon 1016, and the default zoom as a “Percentage” icon 1015 on video display 160.

[0070] At process 400, the user selects “Bell” or “Diaphragm” mode by pressing “Mode Select” key 1053, thereby causing device 100 to indicate the appropriate mode, in this example, “Diaphragm” 1014, on video display 160. When the user presses “Function Select” key 1052 to activate the “Decompose” function, which is followed by a lapse of X seconds, original heart sound 1067, and decomposed low frequency heart sound 1066 and high frequency heart sound 1065 are displayed by device 100. The decomposed heart sounds 1065, 1066 enable the user to identify the various heart sound phases and also to detect the presence of heart murmurs.

[0071] By manipulating the “Play/Pause” key 1059 as shown in step 500, the user causes device 100 to playback and/or record the heart sound signal, and also enables the user to select between “Normal” and “Stereophonic” playback modes.

[0072] FIG. 10 depicts device 100 during playback of the heart sounds, as indicated by “Playback” mode 1017 on display 160. Note vertical line cursor 1073 scrolls across display 160 during playback, synchronizing the video display with the audio playback of the heart sounds, and enabling the user to visually observing on display 160 what he or she is hearing on audio output device 170.

[0073] After playback, the user has the option of saving the heart sounds in memory 140 for future analysis before initiating a new recording by pressing “Home” key 1051. The user can now initiate a new heart sound recording by pressing Function Select key 1054.

[0074] FIG. 12A illustrates another embodiment 1200 in which heart sound acquirer 1210 and display 1260 are both coupled to audio input device 1270. FIG. 12B shows side views of the “open” and “close” positions, respectively, of device 1200. The “power-on” function of device 1200 can be activated by sliding open device 1200 which simultaneously exposes user interface 1250. Conversely, sliding close device 1200 conceals user interface 1250 and powers-down device 1200.

[0075] FIG. 13 is an isometric view of an additional embodiment of device 100. Device 1300 includes a display 1360 which can be a touch-screen large enough to incorporate all or a portion of the user interface for device 1300. It is possible for device 1300 to be worn like a watch on the wrist of the user by adding a wrist strap.

[0076] FIG. 14 is an isometric view of yet another embodiment of device 100. Device 1400 is a compact version with display 1460 supported by audio input device 1470. In addition, display 1460 of device 1400 can be conveniently flipped open resulting in a hands-free display capability. In this embodiment, heart sound acquirer 1410 is attached to display 1460.

[0077] Other modifications to device 100 are also possible. As shown in FIGS. 15, 16, it is also possible to incorporate sensors 1510, 1610 with devices 1500, 1600, respectively, resulting in very compact auscultation system designs. In addition to displaying the heart sounds, it is also possible for device 100 to generate gating signals based on S1 or S2 for heart imaging systems. When tuned to appropriate frequencies, device 100 can also be used to sense and record lung sounds, including the higher frequency ranges associated with pulmonary problems such as wheezing.

III. Tunable Auscultation Device

[0078] Whereas FIGS. 1-16 illustrated an Auscultation Device 100 in general terms, the following FIGS. 17-29B will illustrate embodiments of a Tunable Auscultation Device in more detail. As previously noted, a Tunable Auscultation Device may be user tunable, preset tunable and automatically tunable. The advantage of such Tunable Auscultation Device embodiments is enhanced visualizations of heart sounds for diagnosis.

[0079] Intelligent tuning may have two purposes. The first includes removing noise not associated with the cardiac cycle. For example, removing all breathing or movement related sounds. Additionally, ambient noises may be eliminated. The Auscultation Device may identify sounds not related to the cardiac cycle and remove, via intelligent filtering, those ‘non-signal’ sounds. Secondly, and more importantly, intelligent tuning may be implemented to suggest or automatically focus on in heart sound features indicative of a particular pathology.

[0080] FIG. 17 shows a functional block diagram of a Tunable Auscultation Device 1700 for analyzing and displaying heart sounds in accordance with one embodiment of the present invention. In some embodiments, the Tunable Auscultation Device 1700 includes a Transducer 1702 coupled to an Analysis Tool 1704. The Analysis Tool 1704 may, in some embodiments, be a part of the Signal Processor 130. The User Interface 150 may be coupled to the Analysis Tool 1704,
thereby enabling user interaction and configuration in select tuning processes. Also, an External Input 1710 may couple to the Analysis Tool 1704. External Input 1710 may provide input from additional devices, such as ECG data, data from a peripheral pulse detector, or other suitable sensory devices.

In some embodiments, the Analysis Tool 1704 couples to a Display Module 1706 and Playback Module 1708. In some alternate embodiments, the Display Module 1706 and Playback Module 1708 may be combined into a single component; however, for the sake of clarity, these two modules are illustrated separately.

The Transducer 1702 is configured to acquire, and condition heart sounds. This conditioning may include pre-amplifying and perform anti-aliasing functions on the incoming heart sounds. The conditioned heart signals may then be presented to the Analysis Tool 1704 where specialized analysis may be performed. It is at the Analysis Tool 1704 that signal tuning may occur. Tuning may include filtering the heart signals, as well as performing data extraction from the signals, as will be explained in more detail below. The resulting tuned heart signals, and extracted data, may then be displayed by the Display Module 1706. Likewise, the Playback Module 1708 may, in some embodiments, be configured to playback the tuned heart signals and extracted data on demand at a later time.

The components of the Tunable Auscultation Device 1700 may be physically housed within a single device, such as a handheld Tunable Auscultation Device 1700. Alternatively, each component of the Tunable Auscultation Device 1700 may be separate physical entities which share heart signal data via wired, or wireless, data transfer.

Fig. 18 shows a functional block diagram of the Transducer 1702 in accordance with the Tunable Auscultation Device 1700. The Transducer 1702 is composed, in some embodiments, of three main components, the Acoustic Sensor 210, the Preamplifier 215 and an Anti-Aliasing Filter 1804. The Acoustic Sensor 210 couples to the Preamplifier 215 to form the Heart Sound Signal Acquirer 110. The Preamplifier 215 then couples to the Anti-Aliasing Filter 1804. The Preamplifier 215 in conjunction with the Anti-Aliasing Filter 1804 comprises an Initial Signal Conditioner 1802.

The Acoustic Sensor 210 may include a traditional microphone, or may include a piezo sensor. The signals from the Acoustic Sensor 210 may then be sent to the Preamplifier 215 where pre-amplification occurs. The pre-amplified signal may then be sent to the Anti-Aliasing Filter 1804 where the signal is antialiasing. As is well known by those skilled in the art, anti-aliasing is a technique of minimizing the distortion artifacts, known as aliasing, when representing a high-resolution signal at a lower resolution. This technique may remove the out-of-band component of the input signal prior to sampling with an analog-to-digital converter.

Output from the Anti-Aliasing Filter 1804 may be digitized and displayed through the Display Module 1706. Signal from the Anti-Aliasing Filter 1804 may be subjected to Digital Signal Processing (DSP) 1806a, 1806b, 1806c, 1806d, and 1806e and displayed as External Signal Out 1808. Raw Signal Display 1810, Filtered Signal Display 1812, Audio Filtered Signal 1814 and Additional Display 1816, respectively.

One or more Digital Signal Processing (DSP) 1806a, 1806b, 1806c, 1806d and 1806e may perform filtering operations. Such filtering can be as simple as band-pass filters implemented as digital filters by defining the filter coefficients. However, the Digital Signal Processing (DSP) 1806a, 1806b, 1806c, 1806d and 1806e may also be much more sophisticated, such as wavelets, time-frequency analysis tools, or any other suitable analysis. Filters may be manually chosen by user operation, or the Tunable Auscultation Device 1700 may select filter bands based on an analysis of the input signal energy and contents.

External Signal Out 1808 may include, in some embodiments, a wired signal out. Additionally, the External Signal Out 1808 may be stored on an external memory, such as a flash card. Moreover, the External Signal Out 1808 may be wirelessly transmitted via Bluetooth, or any other suitable methodology, for external device reading. In the case of wireless transmission of the data, encryption may be utilized to ensure patient privacy and health data confidentiality.

The Raw Signal Display 1810 may display the heart sound signal in the native form, or may display conditioned heart signals. Raw Signal Display 1810 may include audio as well as visual display. Raw Signal Display 1810 may be of particular use when viewed in comparison to the Filtered Signal Display 1812.

In some embodiments, more than one Filtered Signal Display 1812 may be displayed as is desired. For example the physician may desire to display both a user selected Filtered Signal Display 1812 alongside an automatic Filtered Signal Display 1812.

Audio Filtered Signal 1814 may be played to the physician over a speaker or headphone style device. Additional Display 1816 is also contemplated as additional display methods become practical or desired.

Fig. 19 shows a functional block diagram of the Analysis Tool 1704 of the Tunable Auscultation Device 1700. The Analysis Tool 1704 may include an User Input Module 1902, a Intelligent Tuner 1904 and an Output Module 1906. The User Input Module 1902 may couple to the Intelligent Tuner 1904 and Output Module 1906. Likewise, the Intelligent Tuner 1904 may be coupled to the Output Module 1906.

The User Input Module 1902 may enable user tuning of the heart signals. The Intelligent Tuner 1904 may filter and perform data extraction on the heart signals. The Output Module 1906 may provide diagnosis, signal strength and frequency indication.

Fig. 20 shows a functional block diagram of the User Input Module 1902 of the Tunable Auscultation Device 1700. The User Input Module 1902 may include a Dynamic Range Selector 2002, a Preset Range Selector 2004 and a Feedback Module 2006. The Dynamic Range Selector 2002 may couple to the Preset Range Selector 2004 and Feedback Module 2006. Likewise the Preset Range Selector 2004 may be coupled to the Feedback Module 2006.

The Dynamic Range Selector 2002 may include, in some embodiments, a thumbwheel, dial, or other variable frequency range selector. The Preset Range Selector 2004 may include a set of selectors, such as buttons, enabled to set filtering to a preset frequency range. The frequency range presets may be pre-configured to provide appropriate filtering to identify particular disease states. Additionally, in some embodiments, the presets may be configurable by the physician.

The Feedback Module 2006 may provide the physician feedback as to frequency ranges selected, as well as suggested frequency domains or frequency presets.

Fig. 21 shows a functional block diagram of the Intelligent Tuner 1904 of the Tunable Auscultation Device 1700. The Intelligent Tuner 1904 includes a Filter Module 2102 coupled to an Algorithmic Extraction Engine 2104. The Filter Module 2102 may include a filter bank of band pass filters capable of filtering incoming sounds. The Algorithmic Extraction Engine 2104 may include exclusion algorithms configured to segment the incoming heart sound signals into constituent parts. These segments may then be analyzed and
data of interest may be extracted. Such extractions may include specific disease and pathology indicia. 0098 Tuning may be temporal based. For example, the Tunable Auscultation Device 1700 may identify S1 and S2. The Tunable Auscultation Device 1700 may then identify sounds outside of where the S1 and S2 occur within the cycle. For example, if there is a sound existent in either the systolic or diastolic phase outside of the S1 and S2, the Tunable Auscultation Device 1700 can indicate to the user a possible murmur/S3/S4. Murmurs, for example, typically are sounds that occur between S1 and S2 or between S2 and S1. S3 and S4 occur at a given location within the cardiac cycle as well. The Tunable Auscultation Device 1700 may identify, via the temporal locations of those sounds, and indicate to the user that they may want to select a frequency band that emphasizes those particular sounds 0099 Likewise, tuning may be frequency based. The extraction algorithms may identify the various frequency bands that define particular pathologies. The relative energy of these bands may also be identified. From this information, the Tunable Auscultation Device 1700 may detect that a particular pathology exists. For example, in a normal, healthy heart, the frequency band 300-800 Hz may contain x % of energy. If the Tunable Auscultation Device 1700 detects that the energy in the band is above x % by a certain amount, it may indicate to the user/physician that pathology y might be present, and that the user may want to choose the appropriate frequency band to listen in more closely. 0100 Moreover, tuning may be a combination of all of the above. Where the Tunable Auscultation Device 1700 may clean up superfluous noise, look at the temporal and frequency signatures and, suggest to the user that they may want to listen to one or more particular frequency bands to determine whether certain pathologies are present. 0101 FIG. 22 shows a functional block diagram of the Output Module 1906 of the Tunable Auscultation Device 1700. The Output Module 1906 includes a Signal Separator 2204 coupled to the Audio Input/Output Device 170. Frequency Indicator 2206 and Output Driver 2208. The Output Driver 2208 in turn couples to a Waveform Differentiator 2210, a Signal Strength Indicator 2214 and a Diagnosis Indicator 2216. The Waveform Differentiator 2210 couples to the Video Display 160. 0102 The Audio Input/Output Device 170, the Frequency Indicator 2206, the Video Display 160, the Diagnosis Indicator 2216 and the Signal Strength Indicator 2214 in turn comprise the Display Module 1706. 0103 The Sound Separator 2204 may provide raw and tuned heart sound signals to the Audio Input/Output Device 170 for audio output via a speaker or headphones. The Sound Separator 2204 may additionally drive the Frequency Indicator 2206, which may provide information on actual frequency ranges in conjunction audio output via a speaker or headphones. 0104 The Output Driver 2208 drives the Waveform Differentiator 2210, Signal Strength Indicator 2214 and Diagnosis Indicator 2216. The Signal Strength Indicator 2214 may provide a visual indication of signal strength of the heart signal. The Signal Strength Indicator 2214 may provide all signal strength indicia in some embodiments. Additionally, in some embodiments, the Signal Strength Indicator 2214 may provide signal strength by frequency range. Moreover, in some embodiments, the signal strength indicator may measure total signal strength and use this value to calibrate the relative signal strengths at particular frequencies. In some alternate embodiments, the physician may calibrate the base signal strength level for computing the signal strength by frequency range. The Signal Strength Indicator 2214 may provide strength indication via visual cues, such as LED lights, color "heat mapping", LCD graphics, or other appropriate means. 0105 The Diagnosis Indicator 2216 may utilize extracted information gained from the Algorithmic Extraction Engine 2104 via the Output Driver 2208 in order to provide a diagnosis. In some embodiments, the physician might input into the Tunable Auscultation Device 1700 that the patient may have a certain pathology. For example, patients with an artificial valve, prior medical diagnosis's, heart failure or operations may have their data inputted to provide for better diagnosis filtering. Additionally, information such as patient age, sex, ethnicity and body type may be inputted. 0106 The Tunable Auscultation Device 1700 may then examine the temporal and frequency content of the heart sounds, and indicates a diagnosis. In some embodiments, the Tunable Auscultation Device 1700 may provide a statistical rating of the diagnosis, dependent upon the likelihood of a correct diagnosis. For example, the Diagnosis Indicator 2216 may provide a 'positive', 'negative' or 'borderline' diagnosis. In some alternate embodiments, the Diagnosis Indicator 2216 may provide a percentile rank of assurance of the veracity of the diagnosis 0107 Also, in some embodiments, the Diagnosis Indicator 2216 may provide suggested positional data regarding the location of possible pathologies. Such a function may be combined to include the aforementioned statistical rating of the likelihood of a correct diagnosis. In such embodiments, the Diagnosis Indicator 2216 may provide a graphical display where location on the display corresponds to location in the patient. Degree of shading on this graphical display may then designate relative signal strength, or likelihood of positive diagnosis. 0108 The Waveform Differentiator 2210 may be configured to separate the tuned heart signal by waveform, or by cardiac cycle. The Waveform Differentiator 2210 may then couple to the Video Display 160 for display of multiple wave cycles. Showing multiple overlapped cycles enables the physician to detect if an event within a cardiac cycle is a one-off, irregular or regularly occurring heart sound. 0109 FIG. 23 shows a flow diagram illustrating analysis of heart sounds for the Tunable Auscultation Device 1700, shown generally at 2300. The process begins and progresses to step 2302 where the heart sounds are acquired. Heart sound acquisition is enabled by the Acoustic Sensor 210 of the Transducer 1702. The process then progresses to step 2304 where the heart sounds are conditioned by the Initial Signal Conditioner 1802. Conditioning of heart sounds includes pre-amplification and anti-aliasing by the Preamplifier 215 and Anti-Aliasing Filter 1804, respectively. As previously noted, the Preamplifier 215 and Anti-Aliasing Filter 1804 comprise the Initial Signal Conditioner 1802. In some embodiments, after conditioning of the heart signal, it may be digitized for subsequent analysis. 0110 The process then progresses to step 2306 where an inquiry is made as to whether tuning will be performed. If tuning is desired the process then progresses to step 2310 where signal tuning is completed. The process then progresses to step 2312 where the tuned audio signal is output. Lastly, at step 2314, the tuned signal is visually output. The process then ends. 0111 Otherwise, if at step 2306 tuning is not desired, the process then progresses to step 2308 where standard processing occurs. The process then progresses to step 2312 where the standard non-tuned audio signal is output. Lastly, at step 2314, the tuned signal is visually output. The process then ends.
Output of the audio signal may include the output of the raw audio signal, as well as the tuned, or otherwise processed signal. Likewise, the output of the video data may include the raw signal as well as tuned, or otherwise processed signal. Additionally, the video output may include diagnosis indication, diagnosis location, signal strength, frequency indication, and multiple wave cycle display.

FIG. 24 shows a flow diagram illustrating standard processing of heart sounds, shown generally at 2308. The process begins from step 2306 of FIG. 23. The process then progresses to step 2402 where the signal undergoes noise reduction. Then, at 2404, the signal is filtered. The process then progresses to step 2406 where the signal passes through a variable gain control. The process then concludes by progressing to step 2312 of FIG. 23.

As previously noted, the Filter 320 may include a pass band filter which limits the analysis of the heart sound signal to frequencies expected in heart sounds, thereby ensuring that all frequencies of the heart sounds are faithfully captured and, at the same time, eliminating noise sources that typically exist beyond the pass band filter of Filter 320. The Variable Gain Amplifier 330 of Signal Conditioner 120 serves to vary the gain based on a selectable variable parameter, and also serves to ensure enhanced signal quality and improved signal to noise ratio.

FIG. 25 shows a flow diagram illustrating signal tuning of heart sounds for the Tunable Auscultation Device 1700, shown generally at 2310. The process begins from step 2306 of FIG. 23. The process then progresses to step 2502 where an inquiry is made as to whether the user selects the tuning. If the user desires user selected tuning, the process then progresses to step 2506 where user selected tuning is performed. The process then concludes by progressing to step 2312 of FIG. 23.

User Selected Filtering may, in some embodiments, be further classified as Presets and Continuous. For the continuous filter the user may specify frequency limits. These limits may be varied continuously with, say, a thumbwheel and with a feedback mechanism as described. Moreover, in some embodiments, the user may specify a center frequency and varying the bandwidth in a continuous fashion via similar mechanism as suggested above.

Otherwise, if at step 2502 user selected tuning is not desired, the process then progresses to step 2504 where automatic tuning is performed. The process then concludes by progressing to step 2312 of FIG. 23.

FIG. 26 shows a flow diagram illustrating automatic tuning of heart sounds for the Tunable Auscultation Device 1700, shown generally at 2504. The process begins from step 2502 of FIG. 25. The process then progresses to step 2602 where band pass filteration is performed. Again, band pass filteration may include a pass band filter which limits the analysis of the heart sound signal to frequencies within those present within heart sounds, thereby ensuring that all frequencies of the heart sounds are faithfully captured and, at the same time, eliminating noise sources that typically exist beyond the pass band of Filter 320. Additionally, for the band pass filtration of step 2602, additional pass bands may be utilized. For example, multiple stepwise pass bands may be applied to the heart sound signals. Each band pass may then be independently analyzed for content and bands of interest may then be displayed.

The process then progresses to step 2604 where an inquiry is made as to whether an extraction is desired. If no extraction is desired, then the process then concludes by progressing to step 2312 of FIG. 23.

Otherwise, if at step 2604 an extraction is desired, then the process may proceed to step 2606 where automatic algorithms are applied. The extraction algorithms may segment the incoming signal at step 2608. Then, at step 2610, the segments may each be analyzed for waveforms that would interest a physician. In this way pathologies and diagnoses may be generated. For example, a high frequency murmur may be identified in a low heart rate. At higher heart rates (e.g. tachycardia), the duration of the murmur will be less. In these situations, a simple filter typically loses the signal; however, by segmenting the heart signals by a time-frequency extraction algorithm, such indicia of murmur pathology may be extracted for a positive diagnosis.

Additionally, in some embodiments, extraction may include a simple homing directly into the strongest signal component automatically. For such an extraction a band pass filter with an appropriate pass band may be swept across the signal in a continuous fashion. Once a maximum output of the desired region is established, the band pass filter may then be centered around that frequency and the pass band is continuously adjusted until an optimum signal to noise is established—the noise power being estimated with a wide band filter setting. This optimum frequency location and band width may then be used to display a filtered signal. This process can be repeated serially or simultaneously for multiple frequency regions, each corresponding to a particular set of pathologies or indications.

After extraction the process then concludes by progressing to step 2312 of FIG. 23.

FIG. 27 shows a flow diagram illustrating user selected tuning of heart sounds for the Tunable Auscultation Device 1700, shown generally at 2506. The process begins from step 2502 of FIG. 25. The process then progresses to step 2702 where an inquiry is made as to whether to use presets. If preset usage is desired the process then progresses to step 2706 where the user selects a preset frequency filter. Such presets may be physician configurable, or may be pre-configured to filter for common pathologies. Selection of presets may be enabled by a button array, or other suitable methodology. The process then progresses to step 2708 where feedback is provided to the user selection. Such feedback may include indication of the frequency chosen, as well as suggested frequency ranges. These suggested frequency ranges may be statistically driven dependent upon patient profile, or may be generated via behind-the-scenes extraction algorithms. The process then concludes by progressing to step 2312 of FIG. 23.

Else, if no user presets are desired at step 2702, the process then progresses to step 2704 where the user manually selects the frequency range. This may be enabled via thumbwheel or dial, which allows the frequency range selection to be continuous. The process then progresses to step 2708 where feedback is provided to the user selection. Again, such feedback may include indication of the frequency chosen, as well as suggested frequency ranges, in the manner discussed above. The process then concludes by progressing to step 2312 of FIG. 23.

FIG. 28 shows a flow diagram illustrating visual output of tuning analysis of heart sounds for the Tunable Auscultation Device 1700, shown generally at 2314. The process begins from step 2312 of FIG. 23. The process then progresses to step 2802 where raw signal is displayed. For purposes of this application, ‘display’ includes both audio and visual display. Then, at step 2804, the filtered signal is displayed. The user may choose to display either the raw signal or the filtered signal independently, or together in order to facilitate comparison.

At step 2806 the energy content in a chosen band may be displayed. As previously noted, energy content may be given for the entire heart signal, or for a particular fre-
quency band. Energy content for a frequency band may be given in a raw form, such as in recorded decibels (dB), or may be calibrated for relative energy content. In some embodiments, the calibration may utilize the overall signal strength to provide a base signal level. In some embodiments, the physician may manually configure the base signal level for the calibration. Energy content may be displayed in any suitable manner. For example a tri-color LED may be utilized, where energy content is displayed in terms of positive, negative or borderline. Another example would include graphical bars on a LCD, or equivalent display.

At step 2808 a diagnosis indication may be displayed. As previously mentioned, pathologies may be identified through extraction analysis utilizing extraction algorithms. A diagnosis may then be displayed for these pathologies. In some embodiments, the diagnosis may include a simple ‘positive’, ‘negative’ or ‘borderline’ indication. In yet another embodiment, the diagnosis indicator may provide a statistical likelihood of the correctness of the diagnosis. This indication may include a percentile rating, color coding or other acceptable means.

At step 2810 the diagnosis location may be displayed. By moving the Tunable Auscultation Device 1700 to different locations on the patient a positional map of the sensed pathology may be generated. By inclusion of accelerometers within the Tunable Auscultation Device 1700, movement and position of the Tunable Auscultation Device 1700 may be determined. This positional data may then be cross referenced by the extraction data to generate a diagnosis location map. In some embodiments, the Tunable Auscultation Device 1700 may omit accelerometers or other location sensing components. In such embodiments the physician may be required to move the Tunable Auscultation Device 1700 in a predetermined pattern in order to link the sensed heart sound to a location. The diagnosis location map may then be utilized to generate the display of diagnosis location. Such a display may include a shaded display indicating the strength of a suspected pathology.

At step 2812 overlapping signals may be displayed. The heart signal may be divided into cardiac cycles, and subsequent cycles may be displayed in tandem. By displaying multiple cycles the physician may be able to determine if a detected event is one-off, irregular or regularly occurring. The process then ends.

FIG. 29A shows a frontal schematic diagram of a Handheld Tunable Auscultation Device 2900 for analyzing and displaying heart sounds. A Handle 2902 couples to the Chest Piece 2904. The Chest Piece 2904 is placed upon the patient, and includes the Transducer 1702. The Handle 2902 may also include a Control Interface 2906. In some embodiments, the Handle 2902 may couple to a wired tubing (not shown). The wired tubing may couple the Handheld Tunable Auscultation Device 2900 to additional diagnostic machinery, headphones and storage devices. The wired tubing may also include speakers, volume controls and a freeze control. In some embodiments, the wired tubing may be omitted in favor of wireless, such as Bluetooth, IR or radio transmission.

The Control Interface 2906 may include an Annunciator 2908, Power Control 2910, Modality Control 2912, Tuning Control 2914 and Wireless Indicator 2916. The Annunciator 2908 may include a LED array, LCD screen or other appropriate display type. The Power Control 2910 may control both wireless connectivity as well as Handheld Tunable Auscultation Device 2900 power options. For example, a prolonged ‘press and hold’ of the Power Control 2910 may power cycle the Handheld Tunable Auscultation Device 2900, while a simple press of the Power Control 2910 may cycle the wireless power.
4. The method of claim 1 wherein tuning the electric heart signals includes at least one of interaction tuning, processing tuning and output tuning.

5. The method of claim 4 wherein interaction tuning includes at least one of selecting preset tuning and selecting dynamic range tuning.

6. The method of claim 4 wherein processing tuning includes at least one of band pass filtering and information extracting.

7. The method of claim 6 wherein the information extracting includes applying extraction algorithms to the conditioned electric heart signals, segmenting the conditioned electric heart signals, and extracting signals of interest.

8. The method of claim 6 wherein the extracted signals of interest are correlated to the pathology information.

9. The method of claim 8 wherein output tuning includes at least one of indicating signal strength, indicating diagnosis, displaying overlapping cardiac cycle and configuring display.

10. The method of claim 4 wherein the indicating diagnosis utilizes the pathology information.

11. A tunable auscultation system useful in association with a patient, the system comprising:
   a heart sound acquisition configured to sense heart sounds from at least one chest location of the patient;
   a signal processor configured to transduce the heart sounds into electrical signals;
   an analyzer configured to tune the electric heart signals, wherein the tuning of the electric heart signals includes extracting useful pathology information; and
   a display module configured to display at least one of the conditioned electrical heart signals, the tuned electric heart signals and the extracted pathology information.

12. The tunable auscultation system of claim 11 wherein the analysis tool is configured to filter frequencies of the electrical signals.

13. The tunable auscultation system of claim 11 further comprising an initial conditioner configured to condition the heart sounds, and wherein the initial conditioner includes a pre-amplifier configured to pre-amplify the heart sounds and an anti-aliasing filter configured to anti-alias the heart sounds, and wherein the initial conditioner performs noise reduction.

14. The tunable auscultation system of claim 11 wherein the analysis tool includes at least one of an interaction tuner, a processing tuner and an output tuner.

15. The tunable auscultation system of claim 14 wherein the interaction tuner includes at least one of a preset tuning selector and a dynamic range tuning selector.

16. The tunable auscultation system of claim 14 wherein the processing tuner includes at least one of a band pass filter and an algorithmic extraction engine.

17. The tunable auscultation system of claim 16 wherein the algorithmic extraction engine is configured to apply extraction algorithms to the electric heart signals, segment the electric heart signals, and extract signals of interest.

18. The tunable auscultation system of claim 16 wherein the algorithmic extraction engine is further configured to correlate the extracted signals of interest to the pathology information.

19. The tunable auscultation system of claim 18 wherein the output tuner includes at least one of a signal strength indicator, a diagnosis indicator, an overlapping cardiac cycle display and a display configuration engine.

20. The tunable auscultation system of claim 14 wherein the diagnosis indicator utilizes the pathology information.

21. A method for diagnosing and displaying heart related pathologies of a patient, the method comprising:
   sensing heart sounds from at least one chest location of the patient;
   transducing the heart sounds into electrical signals;
   receiving user pathology selection;
   selectively filtering the electrical signal for pathological markers, wherein the selective filtering utilizes the user pathology selection;
   generating a diagnosis by analyzing the pathological markers; and
   displaying the diagnosis.