SUMMARY

In an aspect of the present disclosure, there is provided a method for determining a bodily characteristic, comprising:

collecting sets of reflected backscatter data for a sequence of ultra-wideband (UWB) pulses transmitted via an UWB sensor comprising an array of transmit (TX) and receive (RX) antenna pairs positioned on a body of a user, and a corresponding calibration measurement from a calibration channel in the UWB sensor;

determining reflection coefficients for each tissue interface based on the sets of reflected backscatter data, the reflection coefficients determined from reflection profiles based upon the reflected backscatter data for that sequence of UWB pulses and the corresponding calibration measurement, the reflection profile associated with a model of tissue layers in the body between the UWB sensor and lung tissue; and

determining a fluid level content of the lung tissue based upon the reflection coefficients.

In another aspect of the present disclosure, there is provided a mobile bodily monitoring system, comprising:

an ultra-wideband (UWB) sensor comprising an array of antennas comprising pairs of transmit (TX) and receive (RX) antennas, and a calibration channel, the UWB sensor configured to be positioned on a body of a user;

a radio frequency (RF) front end comprising a UWB pulse generator coupled to the TX antennas of the array of antennas and a UWB receiver coupled to the RX antennas of the array of antennas, where UWB pulses generated by the UWB pulse generator are sequentially transmitted into the body of the user through the TX antennas and reflected backscatter signals are received through the RX antenna of that pair of TX and RX antennas;

a wireless transmitter configured to communicate data associated with the reflected backscatter and a corresponding calibration measurement from the calibration

channel; and

a computing device configured to receive the data and determine bodily characteristics of the user based upon the reflected backscatter and corresponding calibration measurement.

[0004] Examples of the present disclosure are related to systems, apparatus and methods for mobile bodily monitoring using ultra-wideband radar. In one example, among others, a method for determining a bodily characteristic, comprises collecting sets of reflected backscatter data for a sequence of ultra-wideband (UWB) pulses transmitted via an UWB sensor comprising an array of transmit (TX) and receive (RX) antenna pairs positioned on a body of a user, and a corresponding calibration measurement from a calibration channel in the UWB sensor; determining reflection coefficients for each tissue interface based on the sets of reflected backscatter data, the reflection coefficients determined from reflection profiles based upon the reflected backscatter data for that sequence of UWB pulses and the corresponding calibration measurement, the reflection profile associated with a model of tissue layers in the body between the UWB sensor and lung tissue; and determining a fluid level content of the lung tissue based upon the reflection coefficients.

[0005] In one or more examples, the sets of reflected backscatter data can comprise reflected backscatter data obtained for each of the TX and RX antenna pairs in the UWB sensor that is combined to generate a wideband beamformed signal for each set of reflected backscatter data. The reflection profiles can be determined based upon sparse deconvolution of the wideband beamformed signal of that set of reflected backscatter data using a compensated UWB pulse shape that is based upon the corresponding calibration measurement. The sparse deconvolution of the wideband beamformed signal can be implemented for each of K frequency bands. In various examples, the method can comprise identifying depth of a lung tissue interface at top (inhalation), middle and bottom (exhalation) points in a respiration cycle of the lung tissue based upon the reflection coefficients; and determining the fluid level content of the lung tissue can comprise

determining fluid level content at the top, middle and bottom points in the respiration cycle. In some examples, the method can comprise determining characteristics of tissue layers located between the UWB

sensor and the lung tissue. The characteristics of the tissue layers can comprise location of at least one tissue layer interface or a dielectric property of at least one tissue layer.

[0006] In another example, among others, a mobile bodily monitoring system comprises an ultra-wideband (UWB) sensor comprising an array of antennas comprising pairs of transmit (TX) and receive (RX) antennas, and a calibration channel, the UWB sensor configured to be positioned on a body of a user; a radio frequency (RF) front end comprising a UWB pulse generator coupled to the TX antennas of the array of antennas and a UWB receiver coupled to the RX antennas of the array of antennas, where UWB pulses generated by the UWB pulse generator are sequentially transmitted into the body of the user through the TX antennas and reflected backscatter signals are received through the RX antenna of that pair of TX and RX antennas; a wireless transmitter configured to communicate data associated with the reflected backscatter and a corresponding calibration measurement from the calibration channel; and a computing device configured to receive the data and determine bodily characteristics of the user based upon the reflected backscatter and corresponding calibration measurement.

[0007] In one or more examples, the computing device can be configured to: determine a reflection profile based upon the data associated with the reflected backscatter and the corresponding calibration measurement for the sequence of transmitted UWB pulses, the reflection profile associated with a model of tissue layers in the body between the UWB sensor and a target tissue; determine reflection coefficients based upon the reflection profiles; and determine characteristics of the target tissue from the generated target tissue data. The characteristics of the target tissue can comprise depth of an interface with the target tissue or dielectric properties of the target tissue. The target tissue can be lung tissue. The computing device can be configured to identify a measure of lung fluid content based upon the characteristics of the lung tissue. The computing device can be configured to concurrently identify one or more of heart rate, heart rate variability, respiration rate or tidal volume. The computing device can be configured to identify top and bottom depths of a lung tissue interface over a respiration cycle of the lung tissue. The computing device can be

configured to identify dielectric properties at the top and bottom depths and at an average depth in the respiration cycle of the lung tissue.

[0008] In various examples, a reflection profile can be determined through sparse deconvolution of an averaged wideband backscatter signal based upon the data associated with the reflected backscatter for the sequence of UWB pulses. The computing device can be configured to determine reflection profiles for each of a series of reflected backscatter data sets, each of the reflected backscatter data sets comprising data associated with the reflected backscatter for the sequence of transmitted UWB pulses associated with that set. In some examples, the calibration channel can comprise a temperature calibration loop having a load of known impedance positioned adjacent to the array of antennas. Variations in the transmitted UWB pulses can be compensated for based upon the corresponding calibration measurement. In one or more examples, the mobile bodily monitoring system can comprise digital signal processing (DSP) circuitry configured to obtain and process the reflected backscatter signals and the corresponding calibration measurement for transmission to the computing device. In various examples, the UWB pulses can be transmitted into the body at a rate of about 10,000 per second.

[0009] Other systems, methods, features, and advantages of the present disclosure will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present disclosure, and be protected by the accompanying claims. In addition, all optional and preferred features and modifications of the described examples are usable in all examples of the disclosure taught herein. Furthermore, the individual features of the dependent claims, as well as all optional and preferred features and modifications of the described examples are combinable and interchangeable with one another.