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, a reflection profile associated with a model of tissue layers in the body between the UWB sensor and lung tissue;

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

wherein the sets of reflected backscatter data 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; and

wherein the reflection profiles are 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, wherein the compensated UWB pulse shape is compensated for temperature changes.

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 a 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;

wherein the computing device is 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, a 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;

wherein the characteristics of the target tissue comprise depth of an interface with the target tissue or dielectric properties of the target tissue;

wherein the target tissue is lung tissue;

wherein the reflection profile is 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, using a compensated UWB pulse shape that is based upon the corresponding calibration measurement wherein the compensated UWB pulse shape is compensated for temperature changes.

[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

CLAIMS

Therefore, at least the following is claimed:

1. 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, a reflection profile associated with a model of tissue layers in the body between the UWB sensor and lung tissue;

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

wherein the sets of reflected backscatter data 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; and

wherein the reflection profiles are 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, wherein the compensated UWB pulse shape is compensated for temperature changes.

2. The method of claim 1, wherein the sparse deconvolution of the wideband beamformed signal is implemented for each of K frequency bands.

3. The method of any of claims 1-2, comprising:

identifying depth of a lung tissue interface at top, middle and bottom points in a respiration cycle of the lung tissue based upon the reflection coefficients; and

where determining the fluid level content of the lung tissue comprises determining fluid level content at the top, middle and bottom points in the respiration cycle.

4. The method of any of claims 1-2, comprising determining characteristics of tissue layers located between the UWB sensor and the lung tissue.

5. The method of claim 4, wherein the characteristics of the tissue layers comprise location of at least one tissue layer interface or a dielectric property of at least one tissue layer.

6. 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 a 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;

wherein the computing device is 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, a 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;

wherein the characteristics of the target tissue comprise depth of an interface with the target tissue or dielectric properties of the target tissue;

wherein the target tissue is lung tissue;

wherein the reflection profile is 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, using a compensated UWB pulse shape that is based upon the corresponding calibration measurement wherein the compensated UWB pulse shape is compensated for temperature changes.

7. The mobile bodily monitoring system of claim 6, wherein the computing device is configured to identify a measure of lung fluid content based upon the characteristics of the lung tissue.

8. The mobile bodily monitoring system of claim 7, wherein the computing device is configured to concurrently identify one or more of heart rate, heart rate variability, respiration rate or tidal volume.

9. The mobile bodily monitoring system of claim 6, wherein the computing device is configured to identify top and bottom depths of a lung tissue interface over a respiration cycle of the lung tissue.

10. The mobile bodily monitoring system of claim 9, wherein the computing device is configured to identify dielectric properties at the top and bottom depths and at an average depth in the respiration cycle of the lung tissue.

11. The mobile bodily monitoring system of any of claims 7-10, wherein the computing device is 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.

12. The mobile bodily monitoring system of claim 6, wherein the calibration channel comprises a temperature calibration loop having a load of known impedance positioned adjacent to the array of antennas.

13. The mobile bodily monitoring system of claim 12, wherein variations in the transmitted UWB pulses are compensated for based upon the corresponding calibration measurement.

14. The mobile bodily monitoring system of claim 6, comprising 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.

15. The mobile bodily monitoring system of claim 6, wherein the UWB pulses are transmitted into the body at a rate of about 10,000 per second.