SPREAD SPECTRUM CODED WAVEFORMS IN ULTRASOUND IMAGING

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This patent document claims the priority of U.S. provisional application No. 61/553,137 entitled "SPREAD SPECTRUM CODED WAVEFORMS IN ULTRASOUND IMAGING" filed on October 28, 2011, which is incorporated by reference as part of this document.

TECHNICAL FIELD

[0002] This patent document relates to ultrasound imaging.

BACKGROUND

[0003] Ultrasound imaging is an imaging modality that employs the properties of sound waves traveling through a medium to render a visual image. Ultrasound imaging has been used as an imaging modality for decades in a variety of biomedical fields to view internal structures and functions of animals and humans. Ultrasound waves used in biomedical imaging may operate in different frequencies, e.g., between 1 and 20 MHz, or even higher frequencies. Some factors including inadequate spatial resolution and tissue differentiation can lead to less than desirable image quality using conventional techniques of ultrasound imaging, which can limit its use for many clinical applications.

SUMMARY

[0004] Techniques, systems, and apparatuses are disclosed for ultrasound imaging using spread spectrum, coherent, frequency- and/or phase-coded waveforms that can exhibit wide instantaneous bandwidth.

[0005] In one aspect of the disclosed technology, a method of creating an image from an acoustic waveform in an acoustic imaging device includes setting a transmit/receive switch in the acoustic imaging device into a transmit mode to transmit an acoustic waveform toward a target, in transmitting the acoustic waveform, synthesizing, in one or more waveform synthesizers, a plurality of substantially orthogonal coded waveforms that form a composite waveform as the transmitted acoustic waveform toward the target, in which each coded waveform corresponds to a distinct frequency band and the coded waveforms include at least one of frequency-coded

waveforms or phase-coded waveforms, setting the transmit/receive switch in the acoustic imaging device into a receive mode to receive a returned acoustic waveform that returns from at least part of the target, converting the received returned acoustic waveform from analog format to digital format as a received composite waveform comprising information of the target, and processing the received composite waveform to produce an image of at least part of the target.

[0006] In another aspect, an acoustic waveform imaging system is provided to include waveform generation unit comprising one or more waveform synthesizers coupled to a waveform generator, wherein the waveform generation unit synthesizes a composite waveform comprising a plurality of substantially orthogonal coded waveforms corresponding to frequency bands that are generated by the one or more waveform synthesizers according to waveform information provided by the waveform generator, the coded waveforms including at least one of frequency-coded waveforms or phase-coded waveforms; a transmit/receive switching unit that switches between a transmit mode and a receive mode; an array of transducer elements in communication with the transmit/receive switching unit that transmits an acoustic waveform based on the composite waveform toward a target and receives a returned acoustic waveform returned from at least part of the target; an array of analog to digital (A/D) converters to convert the received returned acoustic waveform received by the array of transducer elements from analog format to digital format as a received composite waveform comprising information comprising information of the target; a controller unit in communication with the waveform generation unit and the array of A/D converters comprising a processing unit that processes the received composite waveform to produce an image of at least part of the target; and a user interface unit in communication with the controller unit.

[0007] In another aspect, a method of creating an image from an acoustic waveform is provided to include setting a transmit/receive switch into transmit mode; selecting a mode of operation from a plurality of operating modes; synthesizing, in one or more waveform synthesizers, a plurality of substantially orthogonal coded waveforms that form a composite waveform, wherein each coded waveform corresponds to a distinct frequency band, the coded waveforms including at least one of frequency-coded waveforms or phase-coded waveforms; transmitting an acoustic waveform based on the composite waveform toward a target; setting the transmit/receive switch into receive mode; receiving a returned acoustic waveform returned from at least part of the target; converting the received returned acoustic waveform from analog

CLAIMS

What is claimed is:

1. A method of creating an image from an acoustic waveform in an acoustic imaging device, comprising:

setting a transmit/receive switch in the acoustic imaging device into a transmit mode to transmit an acoustic waveform toward a target;

in transmitting the acoustic waveform, synthesizing, in one or more waveform synthesizers, a plurality of substantially orthogonal coded waveforms that form a composite waveform as the transmitted acoustic waveform toward the target, wherein each coded waveform corresponds to a distinct frequency band, the coded waveforms including at least one of frequency-coded waveforms or phase-coded waveforms;

setting the transmit/receive switch in the acoustic imaging device into a receive mode to receive a returned acoustic waveform that returns from at least part of the target;

converting the received returned acoustic waveform from analog format to digital format as a received composite waveform comprising information of the target; and

processing the received composite waveform to produce an image of at least part of the target.

2. The method of claim 1, wherein the synthesizing the frequency-coded waveforms includes selecting two or more carrier frequencies corresponding to the frequency bands, and determining one or more amplitudes and a time-bandwidth product parameter of each waveform of the coded waveforms.

3. The method of claim 1, wherein the synthesizing the phase-coded waveforms includes determining a time-bandwidth product parameter and a phase parameter of each waveform of the coded waveforms.

4. The method of claim 3, wherein the phase parameter is determined from a set of a pseudo-random numbers.

produce an image of at least part of the target; and

a user interface unit in communication with the controller unit.

21. The acoustic waveform imaging system of claim 20, wherein the user interface unit comprises a display that displays the image.

22. The acoustic waveform imaging system of claim 20, wherein the waveform generation unit further comprises one or more amplifiers configured between the transmit/receive switching unit and the one or more waveform synthesizers that modifies the composite waveform.

23. The acoustic waveform imaging system of claim 20, further comprising an array of one or more pre-amplifiers configured between the transmit/receive switching unit and the array of ~~at least one~~ A/D converters that modifies the received returned acoustic waveform.

24. The acoustic waveform imaging system of claim 20, wherein the processing unit comprises a digital signal processor (DSP).

25. The acoustic waveform imaging system of claim 20, wherein the controller unit further comprises a master clock that synchronizes time in at least one of the elements of the acoustic waveform imaging system.

26. The acoustic waveform imaging system of claim 20, wherein the user interface unit further comprises one or more user interface devices in communication with the controller unit that receives input from a user.

27. The acoustic waveform imaging system of claim 26, wherein the input includes a mode of operation.

28. The acoustic waveform imaging system of claim 27, wherein the mode of operation includes at least one of ATS-Mode (Artificial Tissue Staining Mode) for imaging biological tissue that enables image color coding based on at least one feature of one or more measured properties that are obtained from the returned acoustic waveform.

29. The acoustic waveform imaging system of claim 27, wherein the mode of operation includes at least one of CAD-Mode (Computer Aided Diagnostic Mode) for imaging biological

tissue that uses one or more algorithmic classifiers to classify biological tissue types using at least one feature of one or more measured properties that are obtained from the returned acoustic waveform.

30. The acoustic waveform imaging system of claim 29, wherein the user interface unit comprises a display that displays a color coded image of the biological tissue based on the classified biological tissue types.

31. The acoustic waveform imaging system of claim 20, wherein the array of transducer elements is partitioned into two or more subarrays such that at least one of the two or more subarrays is individually amplitude weighted and at least one of the two or more subarrays is individually phase weighted for at least one frequency band of the frequency bands corresponding to the transmitted acoustic waveform and combined, thereby providing enhanced cross-range resolution.

32. The acoustic waveform imaging system of claim 20, wherein the array of transducer elements is partitioned into two or more subarrays such that at least one of the two or more subarrays is individually amplitude weighted and at least one of the two or more subarrays is individually phase weighted for at least one frequency band of the frequency bands corresponding to the received returned acoustic waveform and combined, thereby providing enhanced cross-range resolution.

33. A method of creating an image from an acoustic waveform, comprising:

setting a transmit/receive switch into transmit mode;

selecting a mode of operation from a plurality of operating modes;

synthesizing, in one or more waveform synthesizers, a plurality of substantially orthogonal coded waveforms that form a composite waveform, wherein each coded waveform corresponds to a distinct frequency band, the coded waveforms including at least one of frequency-coded waveforms or phase-coded waveforms;

transmitting an acoustic waveform based on the composite waveform toward a target;

setting the transmit/receive switch into receive mode;

receiving a returned acoustic waveform returned from at least part of the target;

converting the received returned acoustic waveform from analog format to digital format