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Study on Movement Detection in Care Environment Using Precise Ultrasonic Distance Measurement at 40 kHz – Aiming at Installation in Sensor Network –

40kHz 高精度超音波計測による介護環境での検知　ーセンサネットワークへの実装ー

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1. Introduction

Achieving good care environment will be one of the most important issues in near future. Sensor network is considered to be a promising method to provide such services. We have proposed a novel movement detection using precise ultrasonic distance measurement for elderly and sick people without an invasion of privacy. Sensor nodes which include Tx / Rx ultrasonic transducers transmit and receive ultrasonic CWs (continuous waves) with small amplitude. The data are sent to the center node via network, where all distance information is obtained by IFFT and stored automatically.

Tx transmits CWs at IFFT frequencies and Rx receives them via moving reflection object. Data of relative amplitudes and phases are sent from sensor nodes to center node by means of ZigBee or Z-wave. In the center node, impulse responses are calculated by applying IFFT procedure. The movement information of the object is obtained by subtraction between two impulse responses at different times [1]. We have proposed a new sensor node which includes function of transmitting and receiving ultrasonic CWs. Signals at IFFT frequencies are generated by division / multiplication of the signal from TCXO. We constructed automatic measurement systems with similar performances of both sensor and center nodes. Lock-in amplifier provides Tx signals and X / Y components of Rx signals. PC controls frequency and executes IFFT and subtraction etc., which provides measurement data at 40 kHz.

Fundamental experiments were done with variable distances between Tx and Rx at 40 kHz. Impulse responses and subtraction between two responses were automatically obtained from the developed setup. We can clearly recognize not only the distances but also the movement. However, the sensitivity is very high due to short wavelength. So, we must also investigate lower frequency, 17-20 kHz, to achieve more practical systems [2].

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2. Positioning and movement detection

In our proposal, Tx and Rx transducers in sensor nodes alternately transmit and receive small-amplitude ultrasonic CWs (Fig. 1). The frequencies correspond to those of IFFT with spacing Δf. Relative amplitudes and phases between the transmitted CWs (Fig. 2(a)) and the received CWs (Fig. 2(b)) are measured and are sent to the center node. In the center node, the above data are compensated with intrinsic phase characteristics of the Tx / Rx transducers. Impulse responses which include distance information between the sensor nodes via reflecting objects can be obtained using IFFT. Subtraction between two impulse responses at different times can provide movement information of objects from one point to the other.

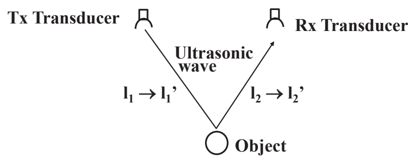
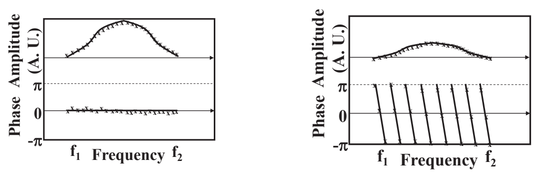


Fig. 1 Transmitting and receiving of ultrasonic CWs reflected from moving object.



(a) Transmitted signals (b) Received signals
Fig. 2 Ultrasonic CWs at IFFT frequencies.

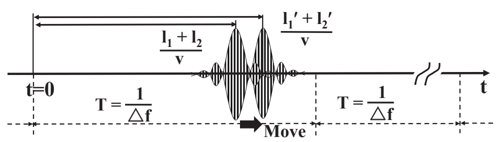


Fig. 3 Impulse response of Fig. 1 by IFFT: Subtraction between two impulse responses corresponds to movement.

3. Automatic measurement systems at 40 kHz

We have proposed ZigBee sensor node which includes ultrasonic Tx and Rx parts as shown in Fig.

3. Relative amplitudes and phases, i.e. X / Y components, of the received CWs to transmitted CWs are obtained by mixing between them. In order to confirm our detection method for moving objects, we developed automatic measurement systems as shown in Fig. 4, which has not only almost same functions as Fig. 3's sensor node but also part of the center node.

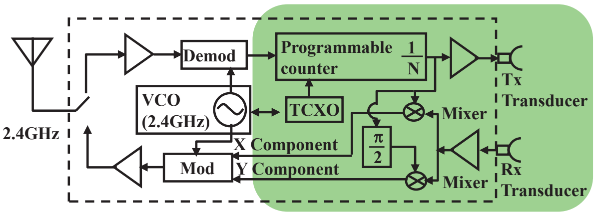


Fig. 3 Proposed block diagram of ZigBee sensor node: Tx frequencies are generated by division / multiplication of TCXO.

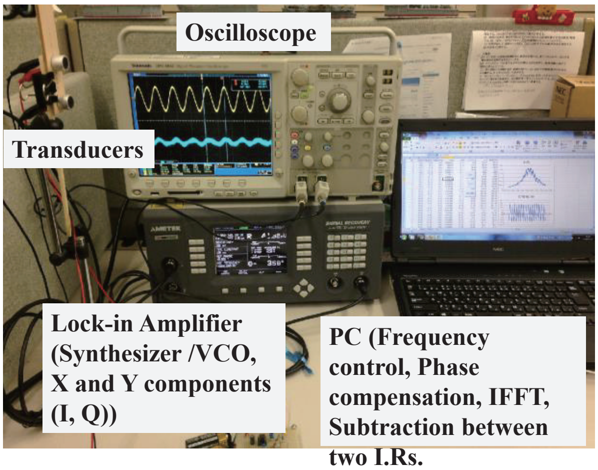
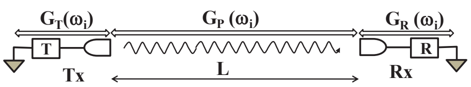
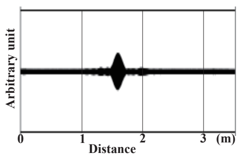


Fig. 4 Automatic measurement systems with almost same functions as Fig. 3's sensor node.

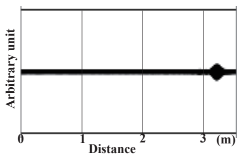
4. Basic experimental results using automatic measurement systems



(a) Experimental setup



(b) L=1.6 m



(c) L=3.2 m

(d) Subtraction between (b) and (c)

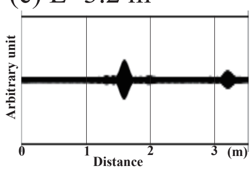
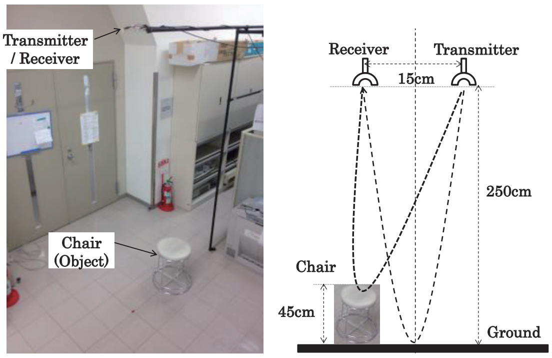


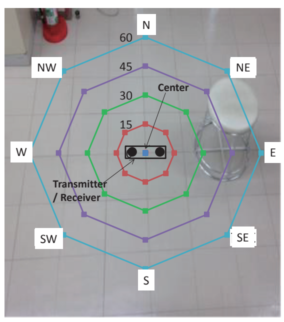
Fig. 5 Distance measurement of L's between Tx and Rx, and movement detection from L=1.6 to 3.2 m.

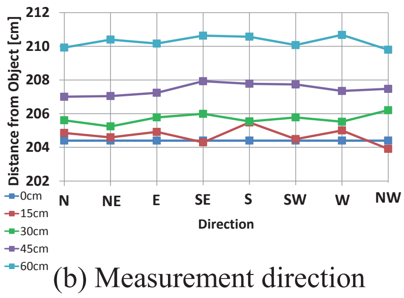
Fundamental experiments of measuring the distance between Tx and Rx (Fig. 5(a)) were done using Fig. 4's automatic measurement systems. As shown in Fig. 5(b) and (c), different distances of L=1.6 m and 3.2 m are measured. Subtraction between (b) and (c) shows clearly the movement from 1.6 to 3.2 m.

In more realistic experiments, Tx and Rx were fixed upward near the room ceiling (Fig. 6(a)). A chair was used as the moving object. It goes around Tx and Rx with different radiuses. Distances were measured at each direction as shown in the left of Fig. 6(b). Measured data are shown in the right of Fig. 6(b), which illustrates distances clearly. We will monitor the movements of the chair next step.



(a) Experimental setup similar to room model





(b) Measurement direction and distance data

Fig. 6 Distance measurement around Tx and Rx using Fig. 4's automatic measurement systems.

5. Conclusion

We proposed new ultrasonic movement detection based on impulse responses, which can be installed in sensor network. Fundamental experiments using developed automatic measurement systems were illustrated. We will investigate 17-20 kHz to reduce excess sensitivity.

References

1. T. Sato, N. Tobita and M. Hikita, in Proc. of USE, Vol.34, pp.117-118, 2013.
2. Y. Kaneda, T. Sato and M. Hikita, in Proc. of USE, Vol.35, pp.43-44, 2014.