Electronic System Group

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Field of study: Biomedical radar sensor and its signal processing, microwave circuits and modules, radio-frequency integrated circuits

Key words: Biomedical radar, noncontact vital-sign sensor, microwave circuits, radio-frequency integrated circuits (RFIC)

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1. The Subject and Aims of Research

The main research interest is design of "microwave circuits and modules" and "radio-frequency integrated circuits (RFIC)", especially for implementation of noncontact vital-sign sensing radar. In addition, considering the radar applications for "various physiological parameter detection", "human tracking", and "automotive safety", our research group also dedicates to develop the digital signal processing algorithm for the acquired radar signals. The educational goal of our laboratory is to cultivate the system integration elites with the technical capabilities of radio-frequency and baseband circuit design and digital signal processing for the next generation.

2. Related Recent Research Topics

(a) 5.8-GHz vital-sign sensing radar [1]: Since the Doppler radar can detect the velocity of the relative motion and object vibration frequency, it has been successfully applied to sense the velocities of vehicles and vital signs of human beings. In our laboratory, a 5.8-GHz Doppler radar module has been developed using off-shelf integrated circuits (ICs) for the human respiration and heartbeat detection as shown in Fig. 1. The key feature of the developed radar module is designing a passive isolation device to achieve that the transmitting and receiving ports can share a single antenna array. Fig. 2 shows the measurement scenario of vital-sign radar and the measured frequency-domain results. The respiration and heartbeat rates of the subject under test are 19/min and 65/min, respectively. The heartbeat rate agrees the result measures by figure pulse oximeter very well. In addition, this Doppler radar earns the 1st place of "2015 IEEE MTT-S High Sensitivity Radar Student Design Competition".

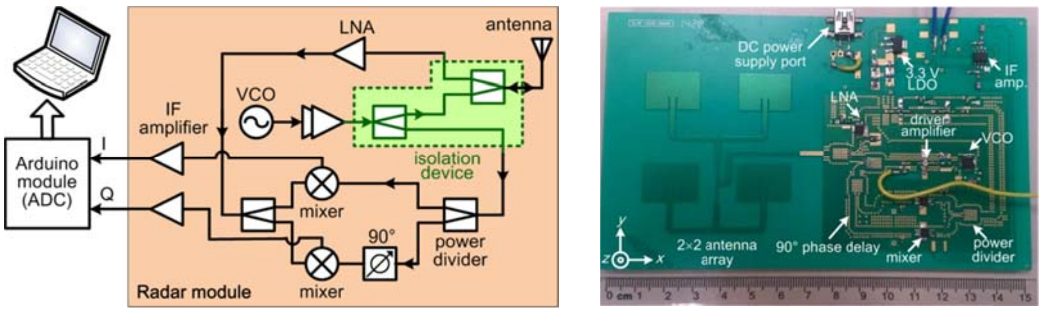

Fig. 1 System block diagram of the 5.8 GHz vital-sign sensing radar (left) and its circuit module photograph (right).

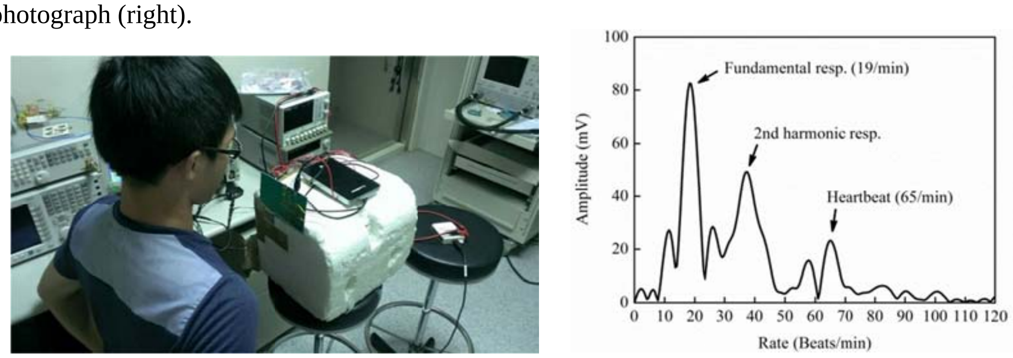

Fig. 2 Measurement scenario of 5.8-GHz vital-sign sensing radar (left) and the measured frequency-domain results (right).

(b) 5.8-GHz spatial-scanning vital-sign sensing radar [2]: Based on the above-mentioned vital-sign radar module, one can extend the system to have the spatial scanning capability as the transmitting and receiving ports are connected with beam canning antennas using the composite right/left-handed transmission lines shown in Fig. 3. Referring to the measured results shown in Fig. 4, when two subjects under test are positioned at azimuth angles of 0° and 26°, respectively, the developed radar can clearly distinguish the respiration and heartbeat vital signs between two human subjects.

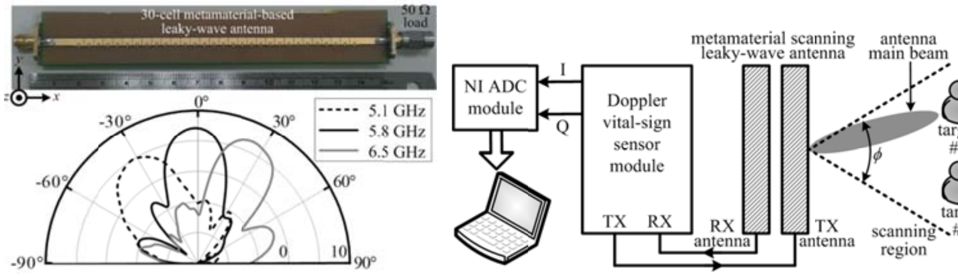

Fig. 3 Beam scanning antenna using composite right/left-handed transmission line (left) and its application scenario in a spatial scanning radar system (right).

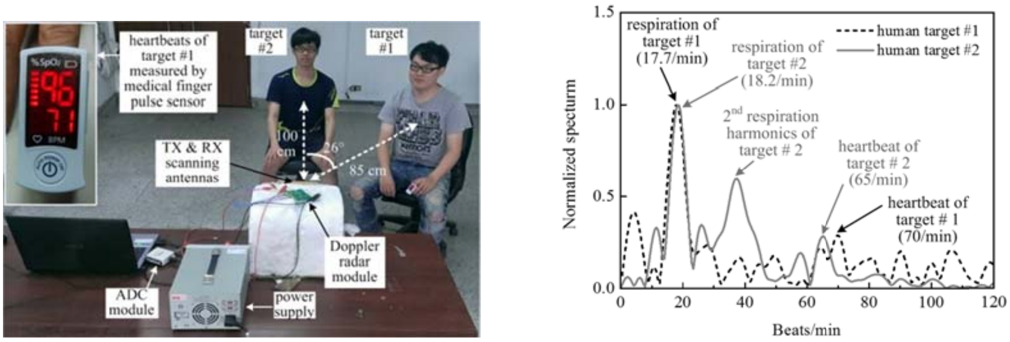

Fig. 4 Measurement scenario of 5.8-GHz vital-sign radar with the spatial scanning capability (left) and measured frequency-domain results (right).

(c) 5.8-GHz CMOS vital-sign sensing radar chip [3]: The vital-sign sensing radar module developed in our laboratory has been successfully employed to detect the respiration and heartbeat rates. However, the module size is large and difficult to be applied in the applications of the home healthcare and Internet of Things (IoT) sensor. Hence, in our laboratory, the TSMC 0.18 μm CMOS technology has been used to develop the radar system on a single chip (SoC). The system block diagram and microphotograph of the radar chip are shown in Fig. 5. It consists of local oscillator (LO), power divider, driver amplifier, mixer, and low-noise amplifier (LNA). Except for the antennas and baseband circuits, all the components are integrated in a single CMOS chip, and then mounted on the print-circuit board (PCB) by the bonding wires for the system evaluation. Fig. 6 shows the system evaluation scenario of the radar chip and the measured frequency-domain results, which agree those measured by the finger pulse oximeter.

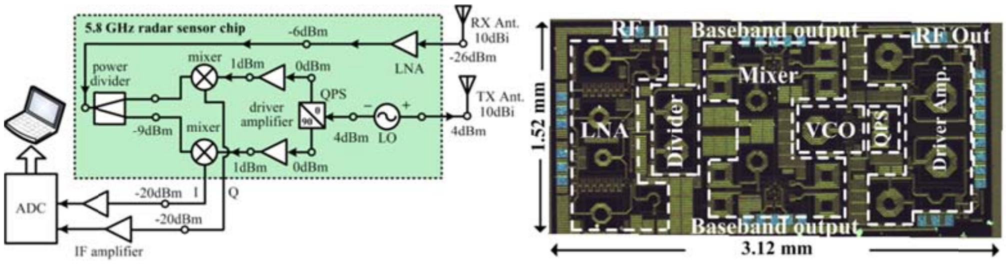

Fig. 5 System block diagram of 5.8-GHz CMOS vital-sign sensing radar chip (left) and its chip microphotograph (right).

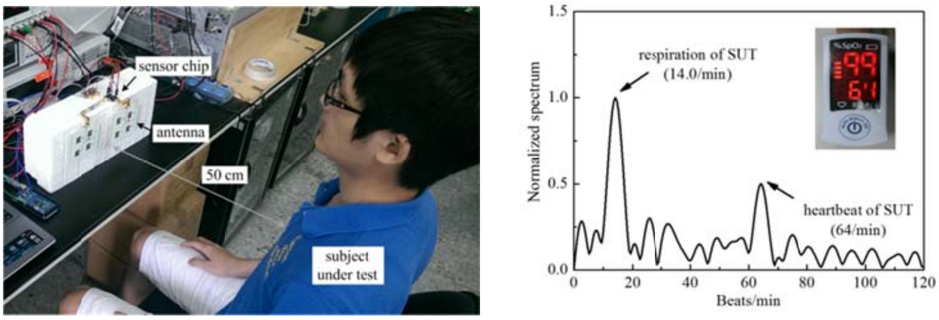

Fig. 6 Measurement scenario of 5.8-GHz CMOS vital-sign sensing radar chip (left) and measured frequency-domain results (right).

(d) 24-GHz vital-sign sensing radar module [4]: In order to increase the radar sensitivity and reduce the module size, in our laboratory, a 24-GHz vital-sign sensing radar module has been developed to satisfy these requirements. This module adopts a 24 GHz radar transceiver chip as a kernel component, and integrates antennas, baseband circuits, microcontroller, and Bluetooth module in a single PCB module. It only occupies a circuit size of 5 cm×10 cm and is approaching to a commercial prototype. Fig. 8 shows the measurement scenario of 24-GHz radar module. The subject under test is sit at a distance of 1.5 m, and his respiration and heartbeat rates are clearly revealed in the frequency-domain results. Moreover, this module has been experimentally verified to detect the vital signs of a new-born infant and the 4-μm vibration at a distance of 1 m away from the radar.

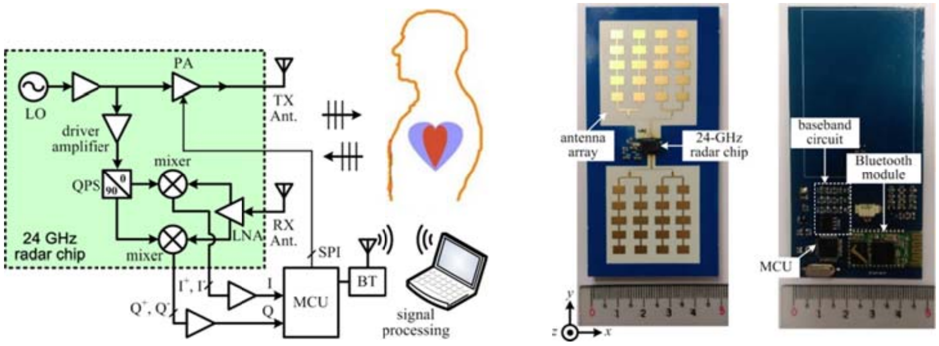

Fig. 7 System block diagram of 24-GHz vital-sign sensing radar module (left) and its circuit module photograph (right).

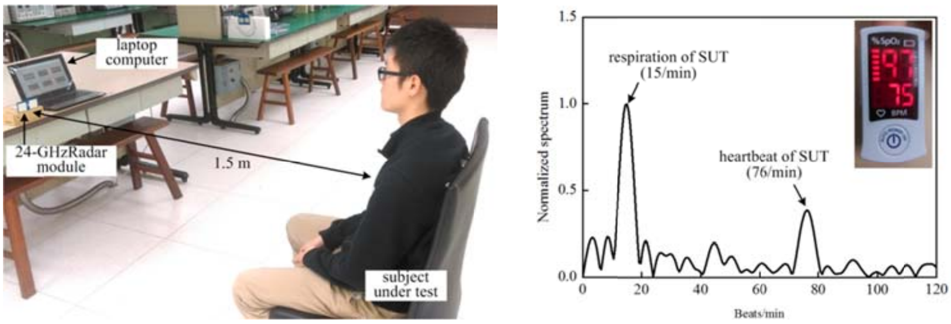

Fig. 8 Measurement scenario of 24-GHz vital-sign sensing radar module (left) and measured frequency-domain results (right).

3. Selected Publications and Projects

[1] C.-H. Chao, T.-W. Hsu, and C.-H. Tseng, "Giving Doppler more bounce: A 5.8 GHz microwave high-sensitivity Doppler radar system," *IEEE Microw. Mag.*, vol. 17, no. 1, pp. 52-57, Jan. 2016.

[2] C.-H. Tseng and C.-H. Chao, "Noncontact vital-sign radar sensor using metamaterial-based scanning leaky-wave antenna," in *IEEE MTT-S Int. Microwave Symp. Dig.*, San Francisco, CA, USA, May 2016.

[3] J.-K. Huang, and C.-H. Tseng, “A 5.8-GHz radar sensor chip in 0.18-μm CMOS for non-contact vital sign detection,” in *Proc. IEEE Int. Symp. Radio-Frequency Integration Tech.*, Taipei, Taiwan, Aug. 2016. (invited paper)

[4] T.-W. Hsu and C.-H. Tseng, “Compact 24-GHz Doppler radar Module for non-contact human vital-sign detection,” in *Proc. International Symp. on Antennas Propag.*, Okinawa, Japan, Oct. 2016.