Noninvasive Life Signal Detecting Systems and Their Analyses

Jung-Min Park · Dong-Hyuk Choi · Seong-Ook Park

Abstract

Wireless life signal detecting system is implemented with using the mechanism of Doppler Effect. This system can measure the respiration and heart rates with the periodic movement of skin and muscle near the heart. The system is consisted of antenna, RF transmitter, receiver, and display part. We did use two operating frequencies at 1.9 GHz and 10 GHz. Firstly, the link budget about detecting system is analyzed and the signal detected from the system is compared with electrocardiogram(ECG) of monitor which is using for patient monitoring in hospital. Secondly, the detection of vital sign is also performed according to the different distances, and including behind the wall.

Key words : Wireless System, Life Signal, Doppler Effect, Heat Rate, Respiration.

Ⅰ. Introduction

Recently, the world trend in medical area is to pursuit remote healthcare system. With this tendency, the parts of remote sensing technology have been studied by many laboratory members. The study about the wireless detection of respiration and heart rate has been started from 1975[1],[2].

The remote medical sensing instrument using RF system is profitable in cost aspects compared with expensive medical instruments. Because the sensing system is easy to handle, even ordinary person who is not instructed about usage of the instruments can use it.

Two systems are considered in this research. Each system is made up of antenna, RF-transceiver, and A/D converter. The transceiver for sensing both heart rates and respiration can be consisted of one or two parts. If it is consisted of two separate parts, the antennas used on the experiment must have also two. But if the transmitter and receiver part are integrated into one, so just one antenna is required on this system. In this paper, we use the identical transceiver which is consisted of coupler, attenuator, LNA, circulator, and mixer. The baseband section is composed of amplifiers, filters, and A/D conversion part.

The principle of operation for this sensing system, based on the Doppler theory, is very simple. If the target has velocity toward the direction of the radar, the reflected signal on the surface of moving target is shifted in frequency in proportional to the velocity of target toward the direction of the radar. The shifted frequency is given

$$f_s = \frac{2f_0 v}{c} \qquad (1)$$

where f_0 is transmitted frequency from antenna, c is the velocity of light, and v is the velocity of target toward the direction of the radar[3],[4]. Then the received frequency is $f_0 \pm f_s$. The shifted frequency is extracted from mixer after compared with reference signal(f_0). If the surface of moving target is the skin near heart, heart rates and respiration will be detected by its periodic back and forth movement. In this paper, we analyze the systems and show detecting results which are sensed in the several different distances and behind the wall.

Ⅱ. Operation Principle of the Systems

The block diagram of the sensing system, shown in Fig. 1, is similar to homodyne radio. The reflected signal from the object is mixed with the reference signal of transmitter to produce an output signal with its magnitude proportional to the phase difference between them.

The dielectric constant and conductivity of each medium near the heart is listed in Table 1 at each frequency.

As shown in Table 1, since the skin and muscle has a high dielectric constant, the penetration depth of radiated signal is rapidly attenuated in the outer tissue, and the other power reflected from the motion of the

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Table 1. The dielectric constant and conductivity of skin and muscle at 1.9 GHz and 10 GHz[5].

Frequencies	Dielectric Constant		Conductivity (S/m)	
	Skin	Muscle	Skin	Muscle
1.9 GHz	38.714	53.418	1.2245	1.3963
10 GHz	31.29	42.764	8.0138	10.626

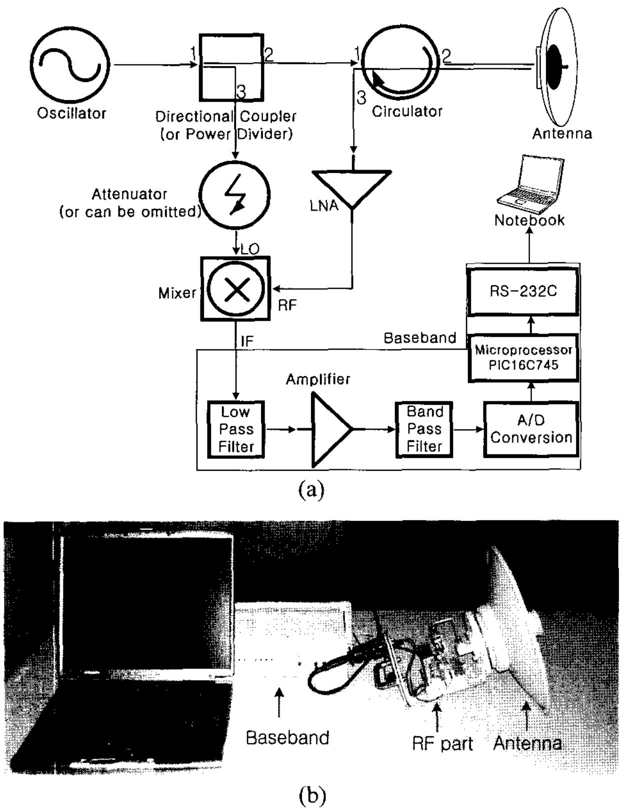

Fig. 1. (a) The block diagram of non-invasive life signal detecting system used at 1.9 GHz and 10 GHz, (b) The real manufactured system.

object is measured with this remote sensing system[6]. The received signal(1～6 dBm at 1.9 GHz with the microstrip antenna, －23～－19 dBm at 10 GHz with the parabolic antenna) is properly amplified by LNA for signal's entering into the mixer, and then filtered by band-pass filter for obtaining the IF signal and monitoring the wave information within 0.6～3.3 Hz(for heart rate), 0.33～0.5 Hz(for respiration)[7].

2-1 The Link Budget Analysis at 1.9 GHz System

The magnitude of source power used in this experiment is 16 dBm. The signal passing 6 dB coupler from port 1 to port 3 is 10 dBm. It is attenuated by 3 dB in attenuator. To extract the shifted frequency, the power of reference signal entering in mixer is 7 dBm. Because the insertion loss of coupler is 1.4 dB, the other signal passing coupler from port 1 to port 2 is 14.6 dBm. It passes circulator which has the insertion loss, 0.28 dB, from port 1 to port 2. The input power of antenna is about 14.3 dBm. The antenna of this system is directional microstrip antenna for PCS repeater. Antenna gain is about 7 dBi.

The backscattered signal power received by the antenna is about －25～－20 dBm. The low noise amplifier's gain is 30 dB and the maximum noise figure is 1.2 dB, respectively.

2-2 The Llink Budget Analysis at 10 GHz System

The magnitude of source power used in this experiment is 11 dBm. Instead of coupler in Fig. 1, power divider is used in this system. And the attenuator is omitted. The signal passed by power divider from port 1 to port 3 is 8 dBm. It is used as the reference signal entered to mixer which is about 7 dBm for extracting the shifted frequency. The other signal passing coupler from port 1 to port 2 is also about 8 dBm. It passes circulator which has the insertion loss 0.3 dB from port 1 to port 2. The input power of antenna is about 7 dBm. The antenna used in the system is the parabolic antenna. Antenna gain is about 27 dBi, and bandwidth is 1 % centered 10 GHz. The power of signal received by antenna is about －23 dBm～－19 dBm. The low noise amplifier's gain is 8 dB and the maximum noise figure is 2 dB.

Ⅲ. The Measured Results

In this paper, all measured data is performed at 1.9 GHz and 10 GHz, respectively.

3-1 The Measured Results at 1.9 GHz System

Fig. 2 shows heart rates and respiration waveform measured at 0.5 m-distance between the system and the vibrating target. In this experiment, we use the system configuration of Fig. 1(a).

Fig. 2(a), and (b) stand for heart rates, and respiration, respectively. The measured results in the 1.9 GHz system are introduced only in 0.5 m-distance. If we install this system in the PCS set, 1.9 GHz vital sign detection system can be used by the portable instrument.

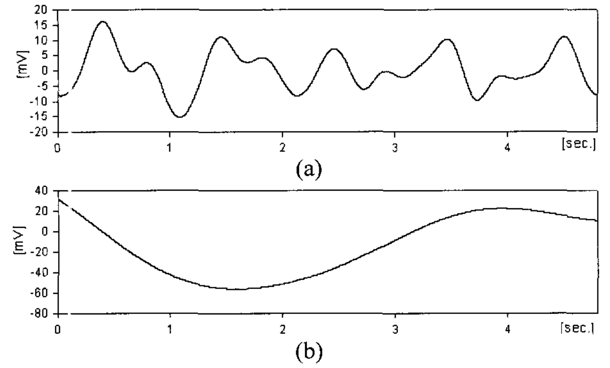

Fig. 2. (a) Heart rates and (b) respiration signals at 0.5 m, 1.9 GHz.

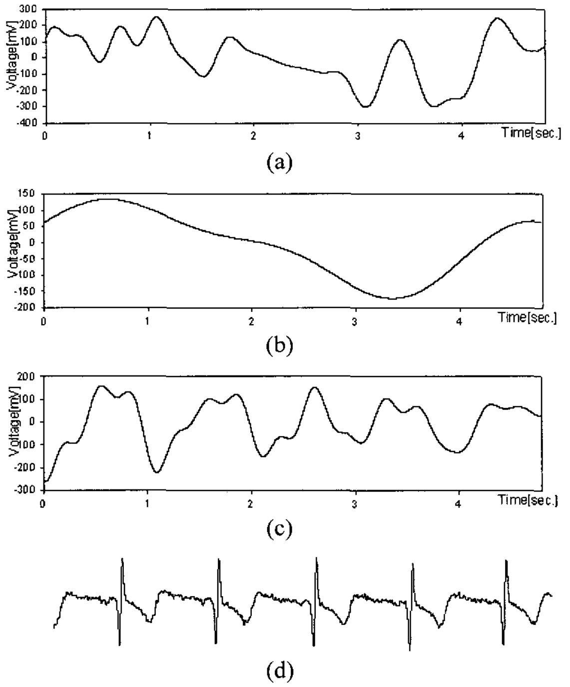

Fig. 3. Waveforms at 0.5 m, 10 GHz. (a) Measured signal after 0.03～3.3 Hz band pass filter, (b) 0.03～0.5 Hz filtering for respiration, (c) 0.6～3.3 Hz filtering for heart rates, (d) Electrocardiogram(ECG) signal.

3-2 The Measured Results at 10 GHz System

In Fig. 3, the first waveform (a), compounded with respiration and heart rates information, is the filtered signal in 0.03～3.3 Hz. As shown in Fig. 3(b) and (c), we can obtain the respiration and heart rate through re-filtering signal within 0.03～0.5 Hz and 0.6～3.3 Hz, respectively. By comparing heart rates(c) with ECG signal(d)'s peak position, we can verify that this system is implemented correctly. The period of ECG's peak time is consistent with heat rates.

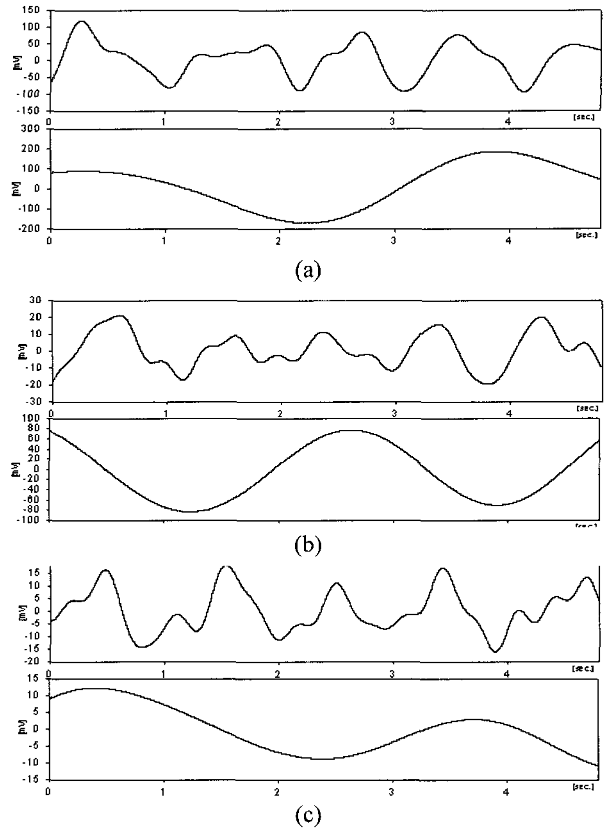

Fig. 4. The heart rates and respiration waveforms at (a) 1 m, (b) 3 m, (c) 5 m at 10 GHz.

In Fig. 4, (a) is stands for the detected heart rates and respiration at 1m-distance. The (b) and (c) indicate vital signs detected from 3 m and 5 m, respectively. Fig. 4 shows that as long as the distance is, detected signal become weak by attenuation of signal power according to the distance.

But, we can find successfully the information of the heart rates and respiration in these results, and detect the signal up to 10m-distance. It can be better if we use higher source power, antenna which has high gain and directivity.

3－3 The Measurement about a Human behind the Wall at 10 GHz

Finally, we take an experiment whether this system can detect vital sign of a human behind the wall (marble) with 10 cm thickness. Right and left sides of the wall are attached the absorber to prevent the unwanted scattering signals.

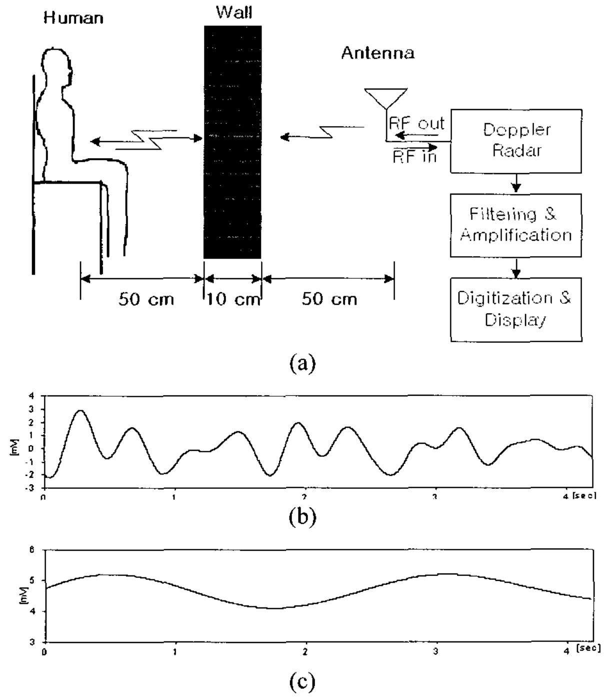

Fig. 5. (a) A human measuring picture behind the wall (b) The heart rates and (c) respiration waveforms measuring a human in 10 GHz behind the wall.

We also obtain the signal of heart rates and respiration in the situation shown in Fig. 5. Although the magnitude of waveform is smaller than none wall case, we can note that totally waveform is similar to the former case.

From these results, we are convinced that the vital sign of a person behind the wall can be detected with the remote sensing system. And this system will be applied to determine the survival of buried person, or to observe an invader.

Ⅳ. Conclusions

We have detected heart rates and respiration in various cases clearly, and all results of this paper are detected by using peak search. We make the decision that 10 GHz system is better than 1.9 GHz system to detect far distance, because of short skin depth in the body according to the short wavelength. Using the remote sensing system, we get the agreeable results that heart rates are 0.9～1.6 Hz(54～96 beats/min.) and the respiration is 0.2～0.3 Hz(12～18 breaths/min). The wireless vital sign (heart rates and respiration) detecting system has many applications such as remote medical examination, portable vital sign sensing within PCS phone, decision either life or death of buried person, observation of invader, and etc.

The work presented in this paper was carried out during the authors affiliation at Digital Media Lab.

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