Microwave Heartbeat Detection by Suppressing Respiration Component

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***Abstract* – The authors have proposed a non-contact vital sign detection method using a microwave. In general, the body surface movement due to respiration is significantly larger than that of heartbeat, and this obstructs heartbeat detection. In this paper, we propose the microwave heartbeat detection method by suppressing the respiration component. Measurements were carried out in a multi-path environment, and the experimental results showed that the proposed method works well in detecting heartbeat.**

keywords — MIMO; antenna; vital sign

I. INTRODUCTION

Recently, the technology using biological information has been widely used in various fields such as medical, welfare, and security. The biological information is personal physical information like the heartbeat, respiration, and fingerprint pattern. However, most of technologies for measuring biological information, such as the ECG (ElectroCardioGram) have the problem that those have physical and mental burdens on the subject because the probes must be contacted directly to the body for measuring the biological information. On the other hand, the studies on measurement using the microwave have been investigated to solve such problems [1]. The biological activities can be detected by observing a Doppler shift caused by the displacement in a living body surface. However, the body surface movement of respiration is significantly larger than that of heartbeat. The respiration interferes with the detection of heart beat.

In this paper, we propose the microwave heartbeat detection method by suppressing the respiration component. This method estimates the average period of the respiration component from the time-varying channels, and cancels it to detect the heartbeat. An experiment was carried out in an actual multi-path environment to validate the proposed method.

II. HEARTBEAT DETECTION ALGORITHM

In an environment where there is one person, the measured $m \times n$ time-variant MIMO (Multiple-Input Multiple-Output) channel consists of the constant component from the fixed objects and varying component from the subject. The channel matrix is transformed to the vector as,

$$\boldsymbol{h}(t) = [h_{11}(t), h_{12}(t), \cdots, h_{1n}(t), h_{21}(t), \cdots, h_{mn}(t)], \quad (1)$$

where, $h_{ij}(t)$ is the complex channel response, and t represents the time of channel observation. We detect the peak value of the respiration component and calculate the average frequency of the respiration component by Fourier-transformation. When we define average period, τ, which is calculated by this frequency, the channel $\boldsymbol{h}'(t)$ is defined as,

$$\boldsymbol{h}'(t) = [\boldsymbol{h}(t), \boldsymbol{h}(t+\tau), \cdots, \boldsymbol{h}(t+(k-1)\tau)\ ], \quad (2)$$

which represent space-time characteristics with emphasis on the respiration. The correlation matrix $\boldsymbol{R}$ is calculated as,

$$\boldsymbol{R} = \overline{\boldsymbol{h}'(t)\boldsymbol{h}'(t)^H} \quad (0 \le t \le T_d), \quad (3)$$

where, T_d represent the total-period of the observed channel, $\{\cdot\}^H$ means complex conjugate transposition and $\overline{\{\cdot\}}$ means averaging operator. By eigenvalue decomposition of $\boldsymbol{R}$, we calculate eigenvalue, $\boldsymbol{\Lambda}$, and eigenvector, $\boldsymbol{U}$, as,

$$\boldsymbol{\Lambda} = \mathrm{diag}([\lambda_1, \cdots, \lambda_k]), \quad (4)$$

$$\boldsymbol{U} = [\boldsymbol{u}_1, \cdots, \boldsymbol{u}_k], \quad (5)$$

where, the eigenvalues have the relation,

$$\lambda_1 \ge \lambda_2 \ge \cdots \ge \lambda_k, \quad (6)$$

and, the respiration component dominates in larger eigenvalues. Therefore, Eigenvector $\boldsymbol{u}_k$ corresponding to the eigenvalue λ_k can suppress the variation of the respiratory component. The channel $\boldsymbol{h}'(t)$ and eigenvectors $\boldsymbol{u}_k$ are multiplied, and the resulting channel $Y(t)$ is calculated as,

$$Y(t) = \boldsymbol{u}_k^H \boldsymbol{h}'(t). \quad (7)$$

Since the respiratory component is suppressed in $Y(t)$, the heartbeat component can be easily detected.

III. MEASUREMENT CONDITIONS AND EXPERIMENTAL RESULTS

Fig.1 shows experiment environment. The experiment was carried out in a multi-path environment where furniture, such as a shelf or desk were existing. Antenna arrangement is 4×4 MIMO configuration using 4 element patch array antennas for both transmitting and receiving antenna, array element spacing is 0.5 wavelength, and the element spacing of the transmitting and receiving antenna was 1.5 wavelength. Receiving antenna height was $h = 0.85$m, an antenna - target distance was set to $0.5\,\mathrm{m} \le d \le 1.5\,\mathrm{m}$, center frequency was 2.47125GHz, channel measurement time is 90 seconds, and the sampling frequency was set to 6Hz. The movement of living body interferes with the detection of Doppler shift. In order to avoid this, the target was seated right in front of the antenna.

Fig.2 shows vital sign measurement system. Four Transmitting antennas ware switched, where the switching speed is sufficiently fast compared to the Doppler speed of the

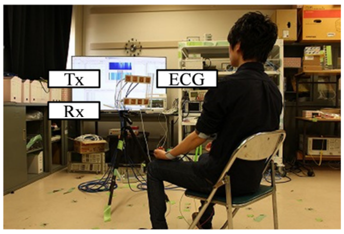


Fig.1 Experiment environment

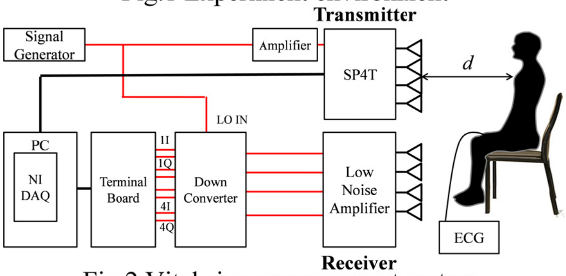


Fig.2 Vital sign measurement system

vital sign. In addition the channel data length was $N = 64$, channel observed time was $T_d = 10$ seconds, generating a channel matrix number was $k = 10$. The experiment was carried out attaching the ECG (Electrocardiogram) to the body for reference.

Fig.3 shows the frequency response matrix versus observation time. From this figure, peak amplitude of respiration component is confirmed around about 0.3Hz. Average period of respiration, τ ,was determined by the calculation from the spectrum peak value.

Fig.4 (a) and (b) show the time responses of the channel without and with respiration component suppression respectively. Here, the distance was set to $d = 0.5$m. In Fig.4 (a), the variation component of the respiration component can be confirmed with approximately 3 second period. However, heartbeat component is interfered by the respiration component. In Fig.4 (b), it is found heartbeat component can be clearly seen with approximately one second period.

Fig.5 (a) and (b) shows the frequency response of the channel without and with respiration component suppression in a target distance $d = 0.5$m respectively. In Fig.5 (a), peak amplitude can be confirmed at 0.35Hz. In Fig.5 (b), peak amplitude can be confirmed in 1.047Hz, where the heartbeat frequency measured by ECG was 1.047Hz. Therefore, in case without suppression, the spectrum of respiration is significantly larger than that of heartbeat and this obstructs heartbeat detection. in case with suppression, the spectrum peak of heartbeat is clearly confirmed. It is confirmed that the proposed method is effective in detecting heartbeat.

IV. Conclusion

This paper proposed the microwave heartbeat detection method by suppressing respiration component. The respiratory component suppression is performed by exploiting space-time signal processing, and this allows the heartbeat detection. The experiment demonstrated that the proposed method works well in detecting heartbeat.

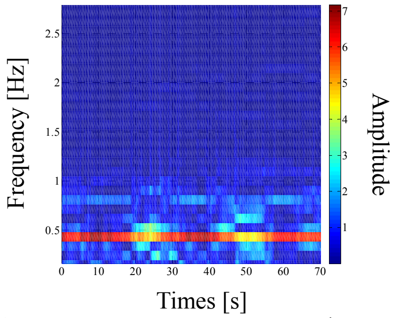
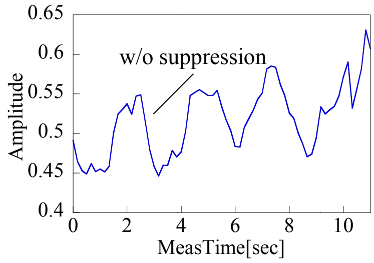
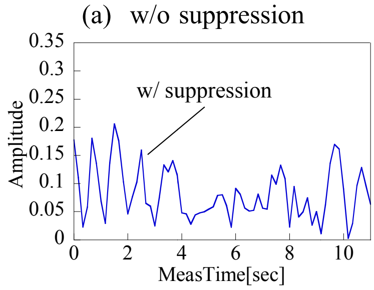


Fig.3 Frequency response versus observation time

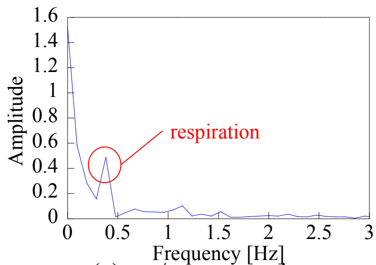


(a) w/o suppression

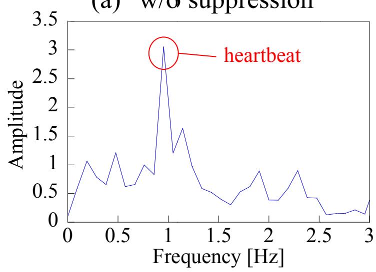


(b) w/ suppression

Fig.4 Time response characteristics of the channel



(a) w/o suppression



(b) w/ suppression

Fig.5 Frequency response characteristics

References

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