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Measurement of Survivor Location for Rescue Radar System by using Two Dimensional Array Antenna

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Abstract **—** Authors have studied a radar system with two dimensional array antennas to find survivors accidentally buried in rubble from the top under noisy environment. This paper concentrates on the two issues to improve the survivor-detection abilities. One is a method for the measurement of three dimensional location of each antennas by using ARToolkit. The other is a method for the reduction of impulsive noise in the received signals. Experimental results showed the feasibility of those methods.

Keywords: *Rescue system, GPR radar, Measurement of survivor location, Augmented reality*

I. Introduction

A rescue radar system with two dimensional array antennas has been proposed to identify the existence and location of survivors confined in rubble by an earthquake or other disaster. Conventional CW radar unit with individual antennas detects their respiration based on time variation of the received signals to identify survivors in rubble within a few meters radius of the antennas[1], [2]. We developed the Radar system which consist of 5 antennas[3]. This system detects respiratory variation from a low SNR by utilizing the properties of the variation and 5 antennas information. We proposed the rescue radar system with two dimensional array antennas which extends the radar system of 5 antennas[4]. This system detected the respiration of a survivor 3 meters below the antennas located on the top of rubble.

Thus it is important to measures the three dimensional location of the antennas before starting the search process. Also a reduction of impulsive noises in the signals received by antennas is required in actual rescue environment. This paper shows the discussion on the ARToolkit 3D measurement of the array antennas and the impulsive noise reduction in the signals from the targets.

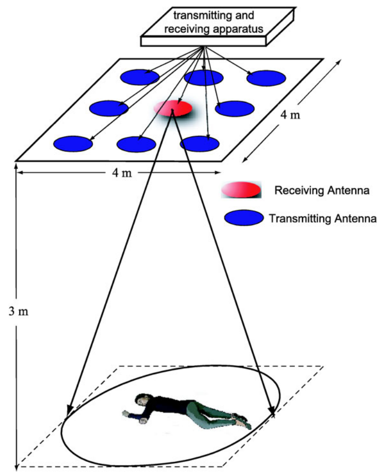

Fig. 1. Schematic illustration of searching survivor using rescue radar system with 2D array antennas.

II. Detection of respiratory variation by radar

Radar detects the object by transmitting microwaves and receiving the reflected waves from the object. In this paper, we detect the respiratory of a survivor from the signals received by array antennas. Fig.1 shows the outline of this system.

III. Radar system with array antennas

A. Specification of the radar system

Radar of proposed system can switch between Continuous wave(CW) radar and pulse radar. Therefore, we utilize the CW radar to detect the presence of the survivor. When the survivor exists, we utilize the pulse radar to measure the three dimensional location of the survivor.

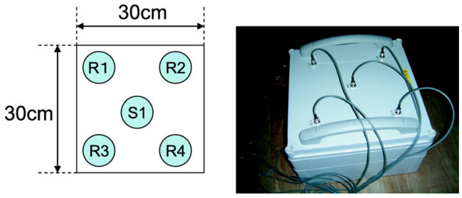

Fig. 2. Module which consists of 5 antennas.

B. Forty five antennas divided into nine modules of five antennas

In this study the detection capability is improved by use of forty five antennas, however it is difficult for an actual rescue scene to locate all the antennas at the appropriate position within a few minutes. Then, as a module with antennas of a minimum number considered the portability of this system, we compose module with five antennas, which is one transmitting antenna and four receiving antennas.

Fig.2 shows the each module of this system. It is 30cm in length and breadth and one transmitting antenna, four receiving antennas. From R1 to R4 show the receiving antennas and S1 shows the transmitting antenna. Antennas are spiral antennas that have a wide band in which they center on 1.2GHz. Signals received by four antennas are sampled about 50psec period and A/D is done and it is accumulated in the memory of the same personal computer.

C. Array antennas configuration

We utilize modules described above to compose the array antennas that can detect the presence of the survivor and measure the location of the survivor. However the accuracy will go up by utilizing a number of modules, we use 9 modules, minimum number of module, to detect the minimum performance. By installing the 9 module as Fig.3, we can measure the horizontal location. First, we transmit microwave of 1.2GHz from module No.5 and receive the reflected waves from inside the shielding platform by an antenna in each module. The received signals include subject respiratory information under the array, because the CW radar detects all the moving objects under the antennas. The sampling speed of the data in nine modules are so faster compared with respiration variation, we can obtain the same data with respiration variation.

IV. Proposed Method

Fig.4 shows the flow of the proposed method. In the place that is not the disaster scene, special characteristics data of the phase and of receiving antennas are obtained beforehand by utilizing the vibrating object. These data are utilized to measure the location survivors by pulse radar. Then in the place of disaster scene, first the presence of the survivor is detected by CW radar. If the survivor exists, the three dimensional location of survivor is measured by pulse radar. In that time, it utilizes the data gotten by vibrating object beforehand. To utilize the data beforehand, the location of

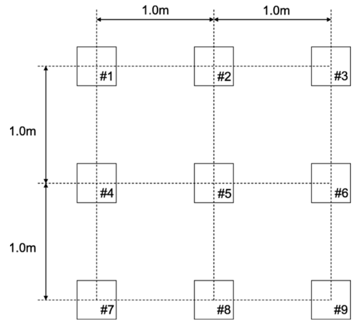

Fig. 3. Arrangement plan of the array antennas.

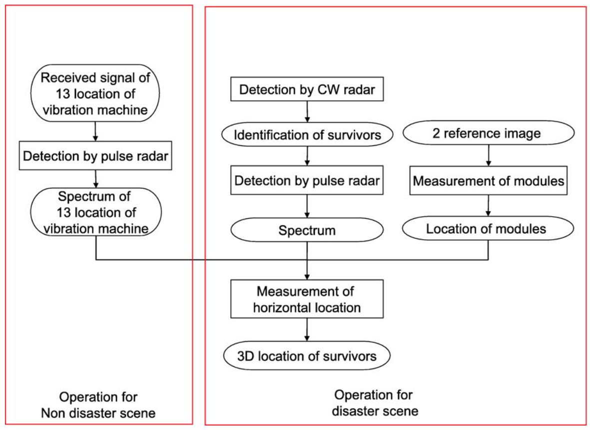

Fig. 4. Flowchart of signal processing of this system.

module is measured by camera. The location information is utilized to measure the 3 dimensional location of the survivor.

A. Detection of the presence of the survivor by CW radar

We utilize electromagnetic radiation survivor inquiry device Life Detector[5] to process the signal of CW radar. CW radar radiate continuous wave, therefore it detects the moving by canceling the reflected wave from the statistic object and extracting the reflected wave from moving object. Then, fourier transform of the obtained signal is done. If the amplitude of the respiration frequency is the most highest, it determines the presence of the survivor.

B. Reference data by using vibrating object

Array antennas usually detect the location of the object by utilizing the phase and strength of the receiving signal of modules. However the received shape of wave in each module changes by the distance from transmitting antenna and distance from the object. The amplitude of the received wave also changes by the characteristics of receiving antenna and attenuating by the rubble. Therefore, we obtain data when the vibration object exists in various positions beforehand. Then we calculate the correlation coefficient between the data beforehand and the data obtained now. By the value of correlation coefficient, the location of the survivor is measured. We utilize the data beforehand as same vibration object, however the data is obtained at different place. Therefore we

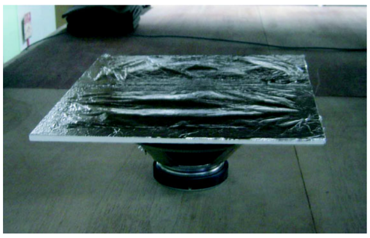

Fig. 5. Vibrating object.

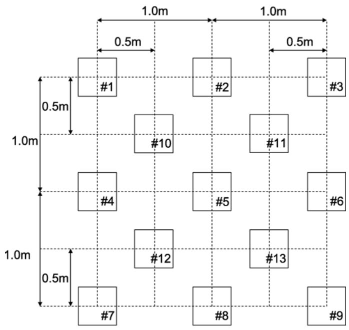

Fig. 6. Arrangement of the nine modules for the reference data by using the vibrating object.

need same vibrating period object. Then, we used a speaker connected with polystyrofoam plate with aluminum foil as the vibrating object. Fig.5 shows the vibrating object of speaker. This object can change the frequency by changing the input frequency. Therefore it can move in various frequency.

We put the vibrating object of speaker on the first floor of tower structure platform. The place where we put the vibrating object is shown at Fig.6. We obtain nine module data for 13 different places. Details of tower structure platform are described at section V.A. These data are utilized for measuring the location by pulse radar.

C. Measurement of the location of modules

When this rescue system is utilized in real scene, modules may not be installed at planate. Therefore, we measure the location of the modules by using a single camera and ARToolkit[6]. ARToolkit is a kind of planar markers to estimate the geometrical relationship between the camera and the marker.

Therefore we install the marker on each module as shown in Fig.7. Then the relationship among the markers on the modules are estimated by the method of vision based registration using multiplane[7]. Fig.8 shows the method overview. From two reference images, a projective space is constructed for the parameters which represent the relationship from each marker to the projective space. By integrating the parameters through the projective space, the relationship between each marker plane is calculated.

D. Measurement of location of the survivor by pulse radar adapting the noise cut

Signal processing to receiving signal is first done in each module, and then signal processing to 9 modules is done. Fig.9

Fig. 7. AR markers installed on each modules.

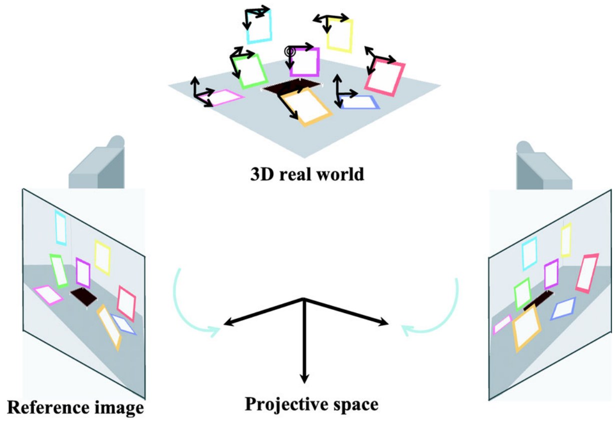

Fig. 8. Method overview of measurement of the location of modules.

shows the signal processing to each module.

We remove the impulsive noise from outside. The impulsive noise comes at small amount of time but the influence is huge. Therefore we detect the impulsive noise by calculate the difference between the wave and the average wave of before-after. $f_k(i)$ is the wave pattern of No.k scan. For all i points, we calculate the equation below.

$$G_k(i) = |f_k(i)| - 0.5|f_{k-1}(i) + f_{k+1}(i)| \qquad (1)$$

Then, if $f_k(i) > a$ and $g_k(i) > b$, a, b are the threshold values which are obtained by experiment, we put the $0.5(f_{k-1}(i) + f_{k+1}(i))$ to that points. By this algorithm, we cut out the impulsive noise and also preserve the wave pattern if point i is not influenced by impulsive noise.

We perform quadrature detection to each receiving signal and cut off the discarded bounds. Then, MTI filter, which reduces average value of 8 to 16 seconds, is used to remove the reflection element from the geostationary object. After performing FFT to 1 minute of data, we multiple the spectrums of 4 received signals and calculate the absolute value. Then, we visually display the vertical axis as the range direction and the horizontal axis as the frequency spectrum. This signal processing corresponds to cross-correlation coefficient if it operates in the time domain. Thus, this processing and correlation coefficient of 4 signal spectrum are equivalent. By this processing, the depth distance and frequency of respiration variation are obtained. The purpose of this system is to detect the respiration variation. Therefore the frequency range of

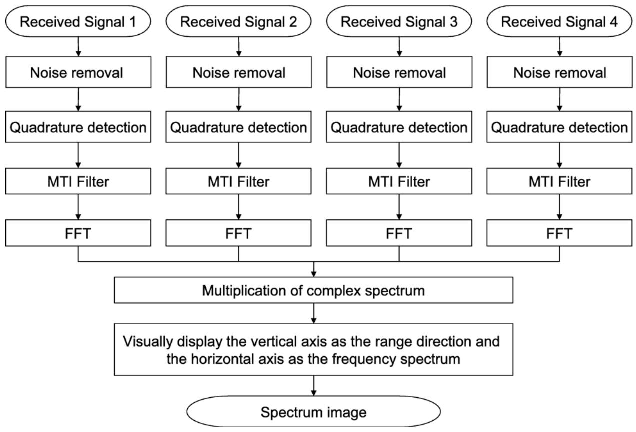

Fig. 9. Flowchart of signal processing of each module.

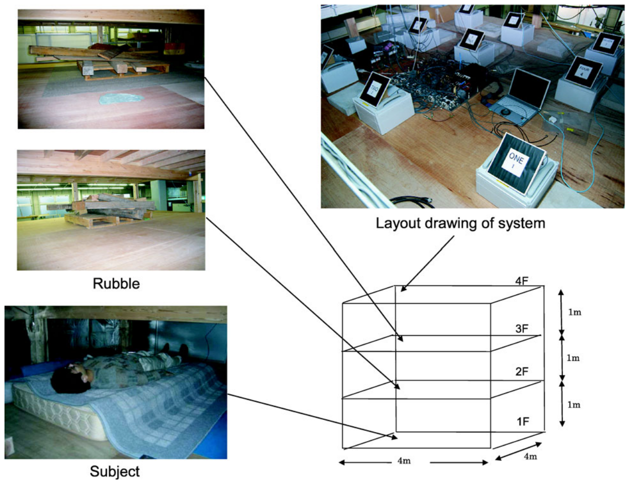

Fig. 10. Tower structure platform.

0.1Hz or less that is outside the range and that is the range of the noise is cut off. By using the information of modules, the horizontal location of the survivor is measured[4].

V. Experiment and Deliberation

A. Experimental environment

Fig.10 shows the tower structure platform which is utilized. A couple of volunteers helped the experiments as a human subject. The subject lies with one's head back on the first or second floor of the tower and breathes normally. We transmit the microwave from the antenna which is put on the top of the tower to beneath. Fig.3 shows the location of the module on the top of the tower. The location of the survivor is arbitrarily-located. Then, to prevent the microwave being interfered by the outside environment, we cover the tower structure platform by electric reflective sheet as shown in Fig.11.

B. Detection of the presence of the survivor by CW radar

We put the additional concrete which is 10 cm thick under each module, and then we measure whether this system can detect the respiration variation of survivor who exists 3 meters beneath the antenna. We measure the change by the passage of time of two different situations when the subject exists beneath the module No.5 and none is there. Each figure shows the six period results of 50 seconds. Fig.12 shows every data when the subject exists shows the peak is in the frequency range of respiration variation of 0.2Hz to 0.5Hz. The spectrum obtained by the experiments without a subject is shown in Fig.13. The highest peak frequency is zero. Also this peak value is much higher than the values in the frequency range of human respiration as shown in Fig.12. By the difference of peak frequency, we can detect the presence of subject. The result shows that we confirm CW radar can detect the presence of the survivor.

Fig. 11. Shield for tower structure.

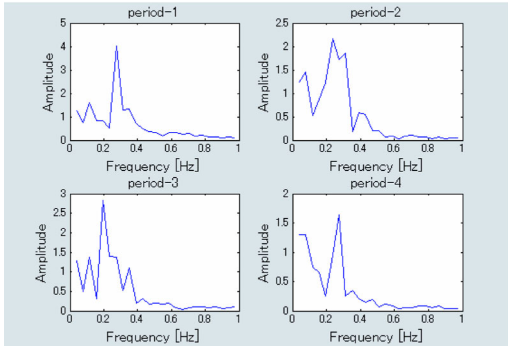

Fig. 12. Spectrum obtained by the experiments with a human subject three meters below the module No.5. Microwave of 1.2GHz is transmitted from an antenna in the module No.5. Reflected waves are received by an antenna in the module No.5. Measurement time for each spectrum is 50 seconds.

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C. Measurement of location of module

We examine this system can measure the positional relationship of modules. We utilize 4 AR-markers to check the minimum performance. 4 AR-markers are installed to irregular surface. Fig.14 shows the location of markers. 4 markers are

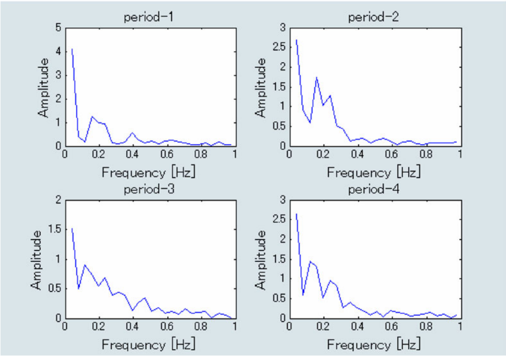

Fig. 13. Spectrum obtained by the experiments without a subject. Measurement time for each spectrum is 50 seconds. Pulses are transmitted from an antenna in module No.5 and the reflected waves are recieved by an antenna in module No.5.

Fig. 14. The disposition of 4 markers. 4 markers are installed uneven to each other.

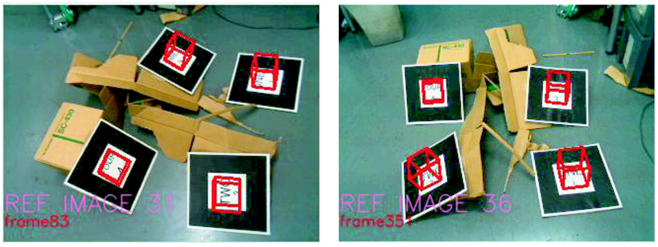

Fig. 15. 2 reference images are utilized to calculate the positional relationship. The red cubes are drawn on the markers

installed uneven to each other. Then, we take 2 reference images from different direction and construct projective space and draw cube on the markers by the reference images as shown in Fig.15.

Fig.16 shows the result of measuring the positional relationship of modules. Green cube is projected by integrating the parameters computed from only each marker. On the other hand, yellow cube is projected by introducing the parameters computed from all the markers via the projective space. In this result image, the red cube, the green cube and the yellow cube almost correspond to each other. This means that the position and pose of each marker can be estimated by using the other markers. Therefore, the positional relationship between each module is measured accurately.

Fig. 16. The disposition of 4 markers. 4 markers are installed at different direction and uneven to each other.

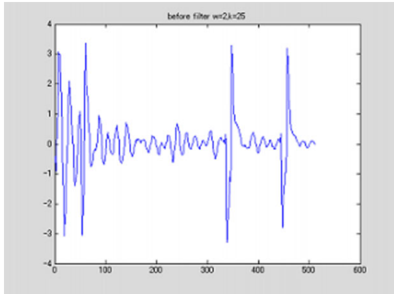

Fig. 17. The wave pattern when impulsive noise come.

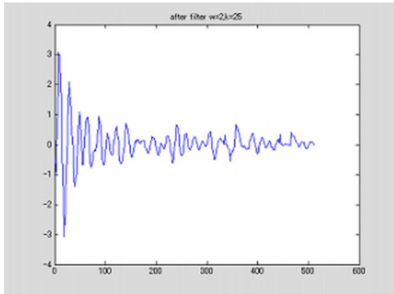

Fig. 18. The wave pattern after removing impulsive noise.

D. Effectiveness of noise removal

We consider the influence of impulsive noise. Fig.17 is the wave pattern when noise come. Two strong signals are detected at between 300 and 500. They are the impulsive noise. If we cut out the impulsive noise, the wave pattern becomes the wave pattern shown at Fig.18. Strong noise is disappeared and the influence of impulsive noise decreases.

Fig.19 is the result when we skip the noise removal. And Fig.20 is the result when we do not skip the noise removal. These figures show the amplitude by color. In Fig.19, there is noise line at 3m and 3.5m, and the radar system cannot find the survivor. In Fig.20, there is no noise line. Fig.20 shows that red that is strong signal is detected within the breath frequency range of 0.2 to 0.5Hz and at depth 3 meters. This result shows that the pulse radar can detect the respiration variation of the survivor when removing the impulsive noise.

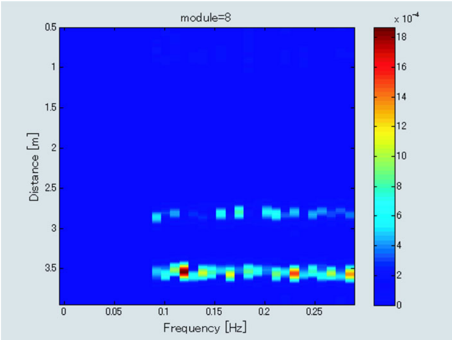

Fig. 19. The result when we skip the noise removal. Two dimensional maps of spectrum to distance from an antenna for a human subject three meters below the module No.5. Pulses are transmitted from an antenna in module No.5. Reflected waves are received in module No.8

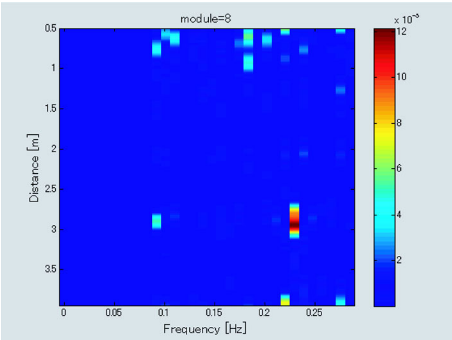

Fig. 20. The result when we remove the impulsive noise. Two dimensional maps of spectrum to distance from an antenna for a human subject three meters below the module No.5. Pulses are transmitted from an antenna in module No.5. Reflected waves are received in module No.8

VI. Conclusion

In this paper, we discussed on the two issues to improve the survivor detection abilities by using rescue radar system with two dimensional array antennas. One is a method for measurement of three dimensional location of each antennas by using ARToolkit with cameras. The other is a method for an impulsive noise reduction in the received signals. The experiments by using radar system showed the feasibility of the proposed algorithm.

The experiments by using AR markers showed that this system can measure the positional relationship of the array antennas by utilizing camera and markers.

The experiments by using pulse radar system showed that we can detect the respiration of the subject by removing the impulsive noises from the received signals.

VII. Future works

In this experimental environment, 9 modules is installed at planate. Therefore, in the above experiment, we do not need to use the location information. Our future work is to utilize the new experimental environment which is planned construction shown at Fig.21. At that experimental environment, location of the modules cannot be installed at planate and we have to utilize the location of information of modules. And we add the

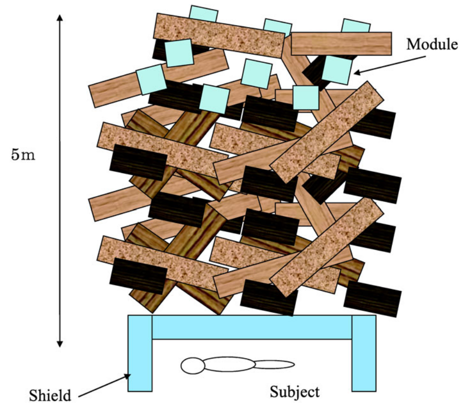

Fig. 21. Future experimental environment. Modules are installed uneven to each other, the amount of rubble increases, and the lenght between antennas and subject extends to 5 meters

rubble much more and extend the length between antenna and subject to 5 meters to adapt to the real earth quake situation.

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