Theme Name	Microwave and millimeter wave radar imaging technology, which can work even under bad weather and bad visibility, using the Doppler velocity and multiple scattering waves.
Organization Name	University of Electro-Communications Graduate School of Informatic and Engineering Associate Professor Shouhei Kidera
Technical Field	IT, Manufacturing

Overview

Under the severe environments such as dust, darkness, high concentration of gas, and strong backlight, those deteriorate the performance of ordinary cameras or sensors for detecting victims, obstacles and so on.

This study is to detect the target objects and obstacles exactly in real time even under the bad environments by combining the unique technology called as Range Points Migration (RPM) method and the estimation technology of Doppler velocity on the human body into UWB radar. Finally, we developed a new technology. Since this technology has deep penetration performance, it can be utilized for rescue / resource exploration robots, on-vehicle sensor, etc.

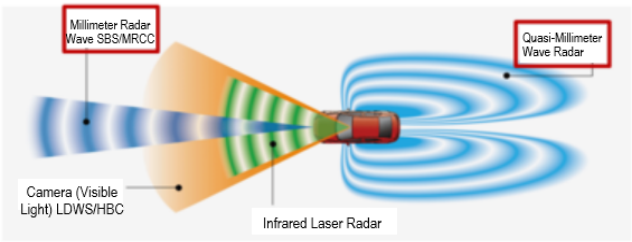
We welcome companies that are willing to develop commercial products utilizing this technology.

Simplified diagram

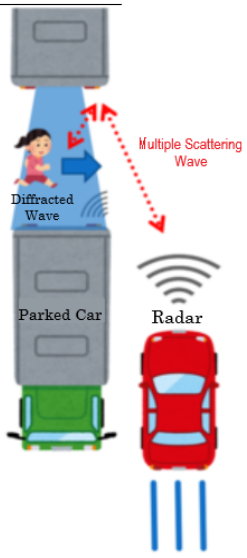
Microwave and millimeter wave sensors (wavelength: 10mm-100mm)

Automatic Drive:
increasing demand of sensors for obstacle avoidance / ambient environment monitoring
→ **all-time / all-weather** radar is essential
(workable **under dust, dense fog, night, bad weather**)
→ decrease traffic accidents by imaging and detecting invisible targets with diffracted wave and multiple scattering wave

Issues : Low Resolution Capability & Accuracy
: cm level + Difficulty for Human Body Detection



i.e. Sensor Integration for Automatic Drive



Imaging of Blind Spot by Diffracted Wave and Multiple Scattering Wave

Background

Under the severe environments such as dust, darkness, high concentration of gas, and strong backlight, those deteriorate the performance of optical cameras or sensors for detecting persons who need rescue or resources.

This study is to detect the target objects and obstacles exactly in real time even under the bad environment by combining the unique technology called as Range Points Migration (RPM) method and the estimation technology of Doppler velocity on the human body into UWB radar. Then, we developed a new technology which achieved the objective. Since this technology has a high permeability, it can be utilized for rescue / resource exploration robots, on-vehicle sensors, and so on. Also, the long wavelength radar can observe objects in blind points due to its diffraction even under bad visibility, so it can be utilized for on-vehicle radar, for example.

We welcome companies that are willing to develop commercial products utilizing this technology.

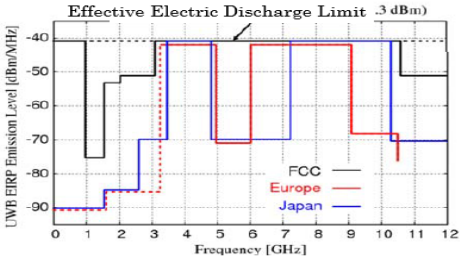
Technical Content

We are studying radar measurement technology using ultra-wideband UWB band. Compared with the preexisting radar, UWB pulse has a characteristic that the range resolution capability is higher at several centimeters to several millimeters. For example, when 3 GHz band is used, the range resolution capability becomes 5 cm.

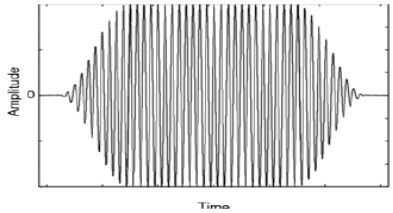
Ultra-Wide-Band (UWB) Signal

UWB (Ultra-Wide-Band) Signal: Recently it is available with low electric power in the space of various

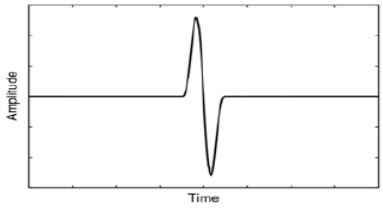
Definition of UWB Signal
- Fractional Band Width 25% or higher
- 10dB Band 500MHz or higher
(FCC, 2002)



Preexisting Radar Pulse
Distance Resolution Capability: 1.5m
(Band Range: 100MHz)



UWB Pulse
Distance Resolution Capability: 5cm
(Band Range: 3GHz)



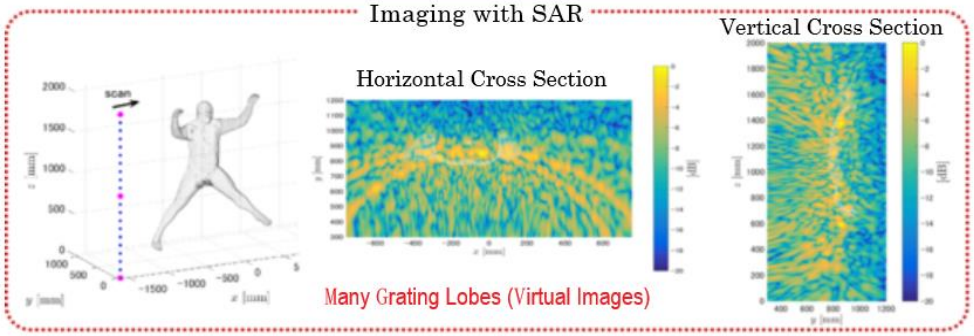
UWB Radar : **High Distance Resolution Capability** (Several cm～Several mm)
Available under severe environments such as dust, darkness, high concentration of gas, strong backlight

In imaging technology using radar, “Synthetic Aperture Radar (SAR)" was used as a conventional technology. When 100% monocycle pulse is used in the fractional band width, the accuracy is improved to 1/100 wavelength compared with the central wavelength and the resolution capability becomes 1/10 at high resolution ratio, consequently ultra-high-speed computer processing can be realized.

Preexisting Image Analysis Method

Length of Microwave and Millimeter Wave : 10mm-100mm

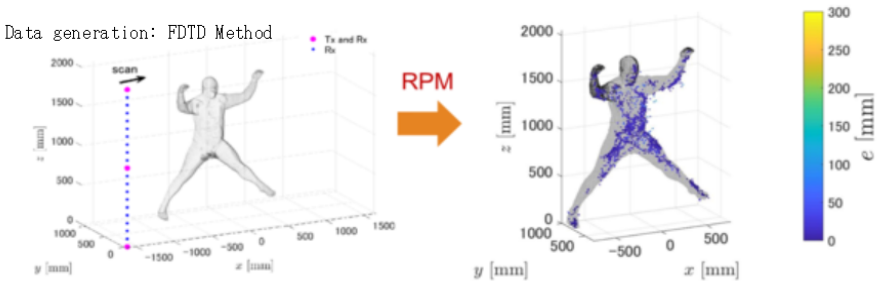
Preexisting Imaging Method: SAR (Synthetic Aperture Radar)
Principle : Image-formation process to reflex point
・Space Resolution Capability : Almost Same as Wavelength (Diffraction Limit)
・Many Grating Lobes (Virtual Images) Generation by Coherent



Unique Visualization Method (RPM Method)

Proposed Method: RPM (Range Points Migration)
Principle : Mapping on Observed Range Point as Reflection Point
(Statistical Approach by Kernel Density Estimation)
→ Almost Solved Joint Problem of Distance and Direction

Major Performances ・Accuracy : 1/100 wavelength ・Resolution Capability : 1/10 wavelength
・High-speed Processing (3 dimension : a few minutes)

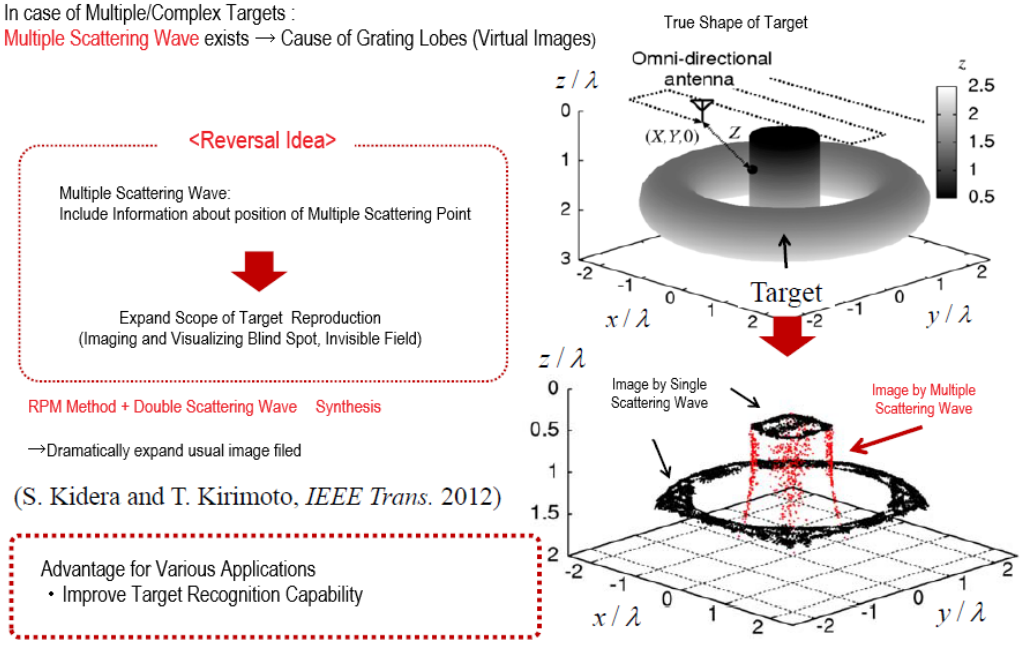


In addition, if the target objects are multiple and more complex inside of room, multiplex scattering waves occur by reflexing on the walls and it causes many grating lobes (ghost images) as well as deterioration of the measurement accuracy.

The conventional method has been focusing on decreasing virtual images but it's not enough. Then, we developed a new method to reproduce shadow areas that could not be reproduced in the past by focusing on the fact that the multiple scattering wave includes information about the shape of target object, which is not included in the single scattering wave.

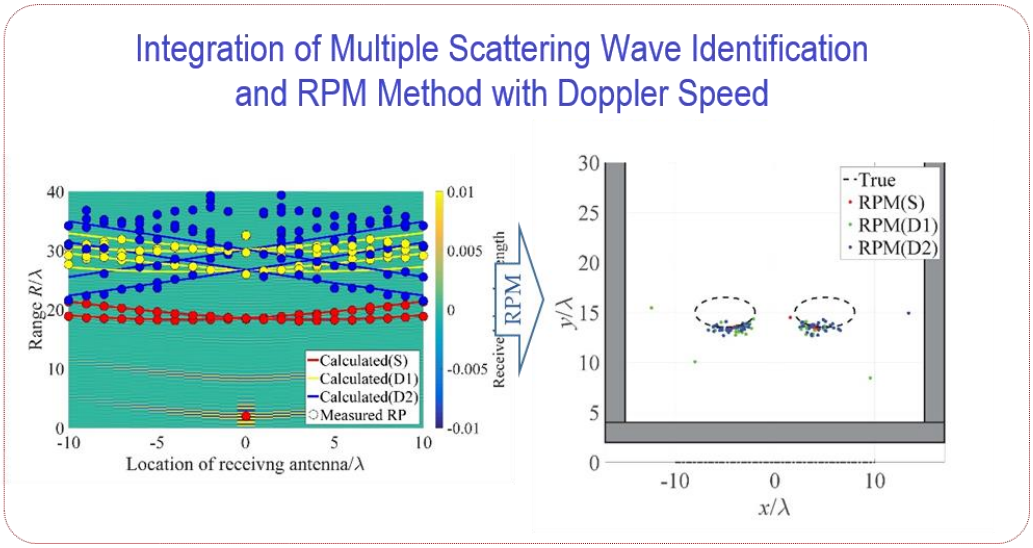
Concretely, the new method, called as "Double Scattering Wave Synthesis", enables high-speed and highly accurate estimation for areas (shadow areas) that could not be found in the single scattering wave.

Imaging of Shadow Area by Multiple Scattering Wave



The above technology visualizes the targets in the situation given information on how many times each signal of multiple scattering wave has been reflected. In general, it is difficult to estimate the reflection frequency of multiple scattering waves only by reflection wave system. For more effective estimations, we have been studying the solution to discriminate the frequency of multiple scattering waves for estimating the images of targets, using the Doppler velocity. The following diagram indicates that many multiple scattering waves occurs between human body of target and each wall if the human body is surrounded by walls. The frequency of multiple

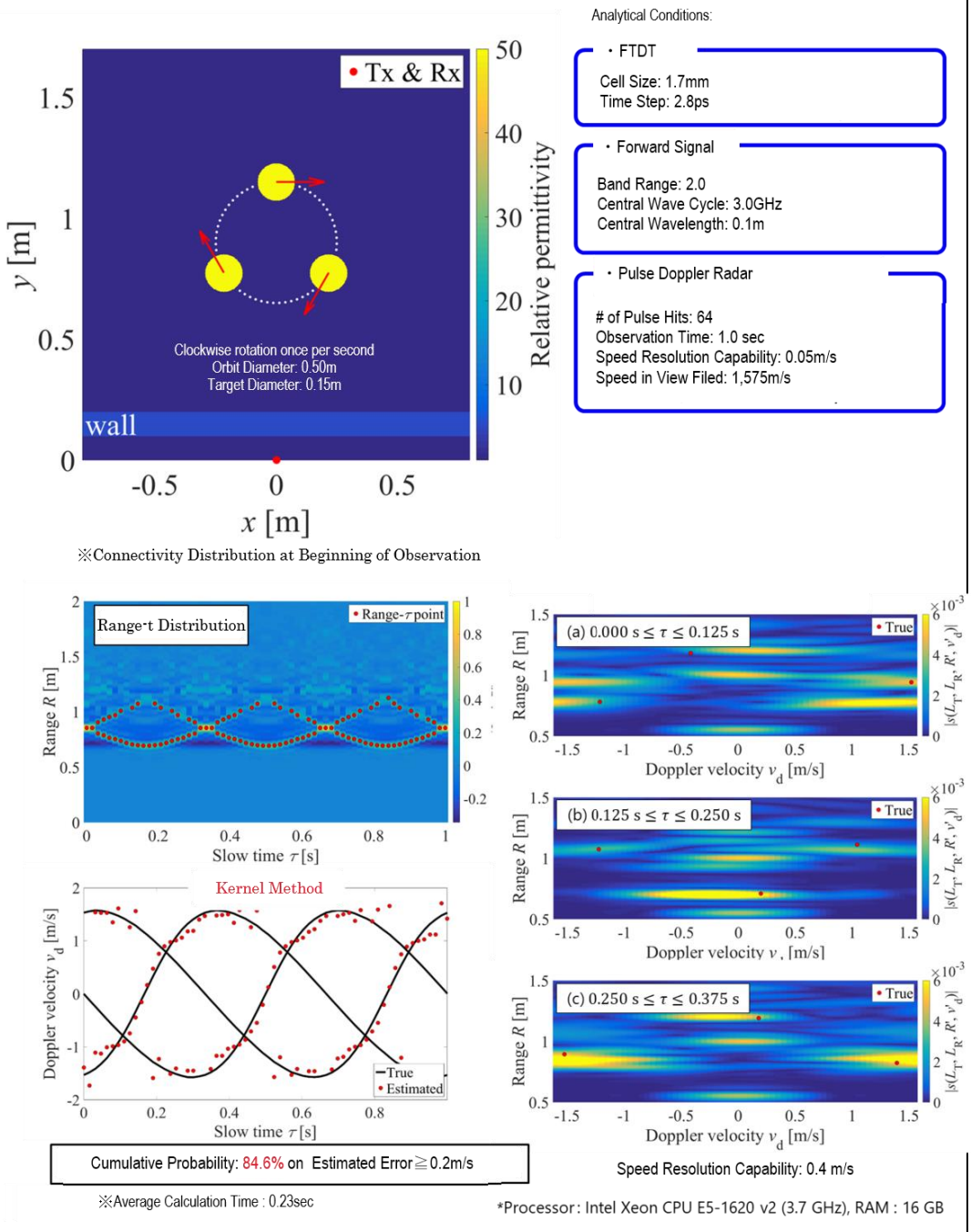
scattering waves is identified through transmission channel by estimating the velocity and vector from the human body in RPM image. It reduces the ghost images and increases the reconstruction area. This technology is especially promising as a basic platform for automatic driving sensors, etc. to detect somebody rushing, jumping into the narrow aperture size.



Moreover, this technology succeeded to improve the accuracy of detection by discriminating between human body and other objects. Since the surface of human body is always shaking, this technology catches the information of such shaking and utilizes it as a signal to process for human specific imaging. On the other hand, the motion speed of each part on shaking human body is about 0.1 m / s called as micro Doppler and it is necessary to estimate the Doppler speed on high-resolution capability.

However, in the conventional method based on Fourier transform, it is difficult to obtain enough Doppler velocity resolution in the low-frequency band in microwave frequency range. In our laboratory, we substantially solved the trade-off issue of Fourier transform between temporal and Doppler velocity resolutions which conflict each other and propose Doppler speed estimation method based on weighted kernel density (WKD) estimation by expanding the principal of RPM method. In the following diagrams indicate the case that 3 circular targets are rotating, and Doppler speed varies as time goes. In this case, the conventional method, STFT (Short Time Fourier Transform) shows that both time resolution capability and Doppler speed resolution capability are insufficient since the time resolution capability is influenced by the time window width.

In contrast, WKD method enables to estimate Doppler speed in each time achieving high resolution capability with high accuracy. This result proves that it substantially solved the conventional trade-off issue between time resolution capability and speed resolution capability.

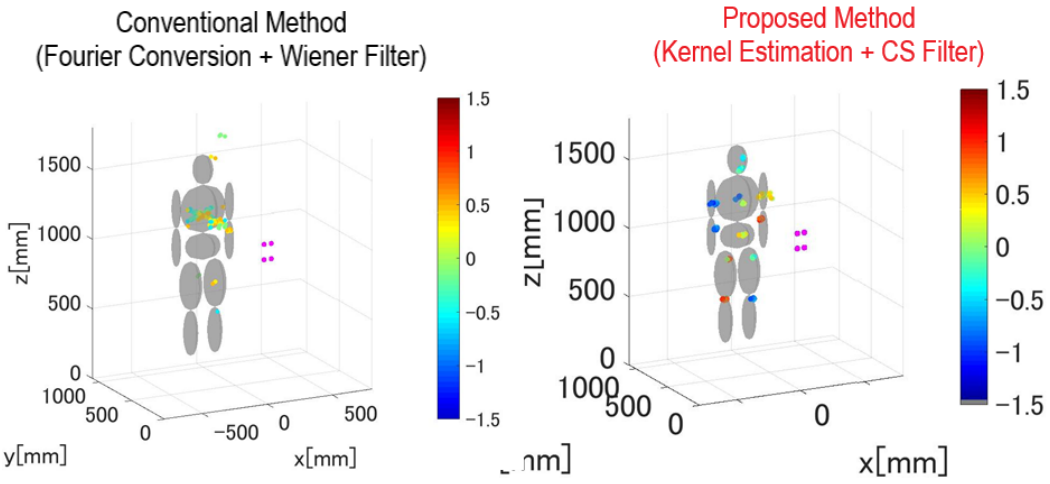


This method has advantages to other methods such as Radon conversion as shown in the following table.

	STFT	Radon Parameter	Kernel Method
Doppler Speed Resolution Capability	Wavelength /Observation Time	Wavelength /Observation Time	No Lower Limit
Velocity Resolution Capability	Observation Time (PRI×Number of Hits)	Observation Time (PRI×Number of Hits)	PRI
Tracking Process & Adjustment	Unnesessary	Necessary	Unnesessary
Noise Tolerance	Coherent Integral Processing	Coherent Integral Processing	In-Coherent Integral Processing
Accuracy	Lower Limit:Doppler Speed Resolution Capability/2	Lower Limit:Doppler Speed Resolution Capability/2	No Lower Limit (Determined by SNR)
Calculation Speed	Very fast	Slow	Fast
RW Correspondence	No Available	Available	Available

Particularly, this technology well fits with Compressed Sensing (CS) filter which is an ultra-resolution distance estimation method.

In our study, it is possible to obtain more detailed human body motion by incorporating WKD method and and CS filter, which is a unique signal processing technology.



Error within 10mm: 3.47%
RMSE: 543mm
Processing Time: 1.2s*

Error within 10mm: 74.3%
RMSE: 11.2mm
Processing Time: 1,600s*

*CPU: Intel ® Xeon ® 2.40GHz Processor

Strengths of the Technology and Know-How (Novelty, Superiority, Utility)

Autonomous robot which can work under the dangerous or harmful environments for human being, such as in disaster scene or space (g) is useful for a wide range of applications (rescue assistance, resource exploration, disaster recovery, etc.) and there is a big social and industrial demand.

A typical 3-dimensional distance sensor, TOF (Time of Flight) Camera (Infrared Pulse) can realize the distance imaging for 30 frames per second, but the error sensitivity to light environment is so high and the estimated error is deteriorated to around 10cm within 2-3m range of measurement.

On the other hand, the laser radar called as infrared laser has high accuracy of distance measurement and is usable even in night, but it is difficult to apply it under bad weather, and the accuracy of speed measurement is not enough.

In contrast, millimeter-wave radar technology is workable under the bad measurement environments such as dust, high concentration of gas, strong backlight, high temperature, high pressure, ultra-low pressure and its distance measurement capability (a few mm) can be maintained even in long-distance filed. Also, it can measure the target object positioned several meters to 10 meters far away.

In-vehicle sensor comparison

	Optical Camera	Infrared Laser(LiDAR)	Millimeter-Wabe Lader
Wavelength Band	300-700 nm	760 nm	1mm – 10mm
Cost	○	○	△
Distance Measurement Capability	×	○	○
Speed Measurement Capability	×	△	○
Space Resolution Capability	○	○	△
Detection Capability under Bad Visibility	×	Night ：○ Bad Weather ：×	Night ：○ Bad Weather ：○
Detedtion Distance	Short Distance (Several m)	Short Distance (Several m)	Biforcal (Several m Several 10 m)

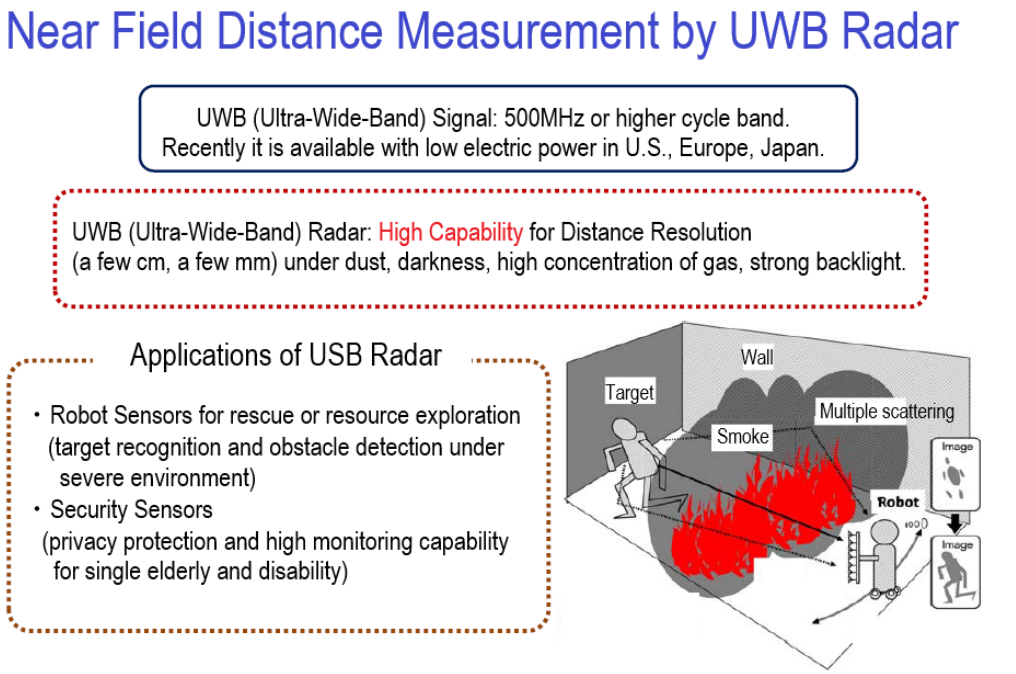
Image of Collaborative Companies

We welcome disaster resource and exploration related apparatus manufacturers, robot makers, radar makers who are willing to commercialize and populate our new apparatus. Since we have knowledges about radar, tomography, microwave imaging technology, and electromagnetic field analysis is in our laboratory, it is possible to cooperate with any companies without those knowledges.

Utilization of Technologies and Know-How (Images)

UWB radar is workable even under the bad conditions such as dust, darkness, high concentration of gas, and strong backlight.

There is a possibility to apply this technology to sensors of disaster resource and exploration related apparatus and so on.



3-dimensional imaging is possible by using the dual-scattering wave synthesis technology as described previously.

In addition, it can be utilized for resource exploration of buried objects, metals underground optimizing its characteristic of penetration ability. For more information. It can also be used for on-vehicle radar and so on.

Flow of Technology and Know-How Application

You are interested in this technology, please feel free to contact us. We will provide a detailed explanation about UWB radar using demonstration apparatus and technology contents.

Description of the Technical Terms

【 UWB (Ultra-Wideband) 】

UWB is defined as wide frequency band with more than 500 MHz or more than 20% fractional bandwidth. Since the data transmitted to each cycle band has small intensity at noise level, so it does not cause confusions with other radio equipment using the same cycle band, and the electric power consumption is small. UWB has 3 functions such as position measurement, radar, and radio communication as a unique radio application technology.

【 Radar 】

Radar is as an acronym for RAdio Detection And Ranging and is an apparatus that clarifies the distance and direction of object by sending radio wave toward the object and measuring the reflected radio wave. Radar is used for recognizing and indicating the positions of aircrafts / ships, measuring rainfall cloud quantity, speed of movement as well as detecting obstacles by measuring the distance between objects with radio wave.

【 Autonomous Robot for Rescue in Disaster 】

Autonomous Robot for Rescue in Disaster is designed for the objective to rescue victims by disasters such as earthquake, flood. The major projects currently ongoing have objectives to explore victims and they focus on specific movement mechanism to move in destroyed buildings or debris and sensors technology to find victims.