

# Real-Time Moving Object Tracking Using Multi-Channel UWB ISAR

Se-Yeon Jeon, Jonas Matuzas, Jiwoong Yu, Tae-Yun Lee, and Min-Ho Ka

**Abstract**— Real-time moving object tracking using radar is a technology in high demand because of the penetration properties of radar signals and the advantage in the aspect of security, when compared to conventional optical systems. In this research, an ultra-wideband impulse signal was used to achieve high resolution in inverse synthetic aperture radar images. It is possible to track the position of moving objects in real-time by using one transmitting antenna and multi receiving antenna.

**Keywords**—UWB, ISAR, real time, tracking, multi-channel

## I. Introduction

Inverse Synthetic Aperture Radar (ISAR) is a technology that provides high-resolution images of the targets by observing the target in rotational motion using a stationary sensor platform [1]. High resolution images can be achieved using Ultra-Wide Band (UWB) radar systems [2]. UWB ISAR technology is in high demand for medical, security and military applications. Some research results relating to these applications exist, such as breast cancer imaging [3], indoor human location tracking systems for security purposes [4], and through-wall imaging and tracking systems for military purposes [5].

Another approach to the development of ISAR is the use of the multi-static Multi-Input-Multi-Output (MIMO) technique [6-7]. The MIMO technique is used to improve cross-range resolution.

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In this research, high resolution real-time moving object tracking is implemented using a UWB measurement system with one transmitter and a multi-channel receiver. For the imaging algorithm, a near-field bistatic ISAR is used.

## II. Measurement Setup

### A. UWB Measurement System

The hardware configuration for the multi-channel UWB measurement is shown in Fig. 1. In this work, one transmitting antenna and four receiving antennas were used to obtain the measurement. The antennas were placed in a semi-circle geometry with the transmitting antenna at the center.

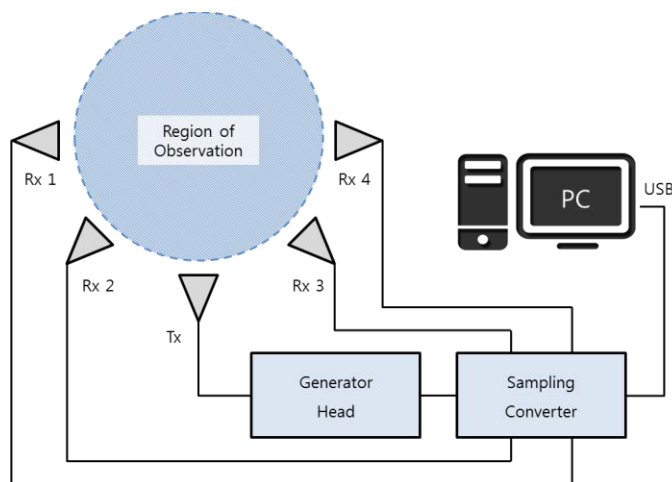


Figure 1. Measurements schema.



Figure 2. Hardware implementation of the measurement system.

The hardware implementation of the measurement system is shown in Fig. 2. The antennas operate in wide frequency bandwidth from 1 GHz to 26 GHz. The generator head generates a monocycle pulse with very short pulse width of less than 100 ps. The generated pulse is radiated to the objects by transmitting antenna and scattered. The scattered signal is received by four receiving antennas, and sampled by sampling converter.

### B. Moving Object Setup

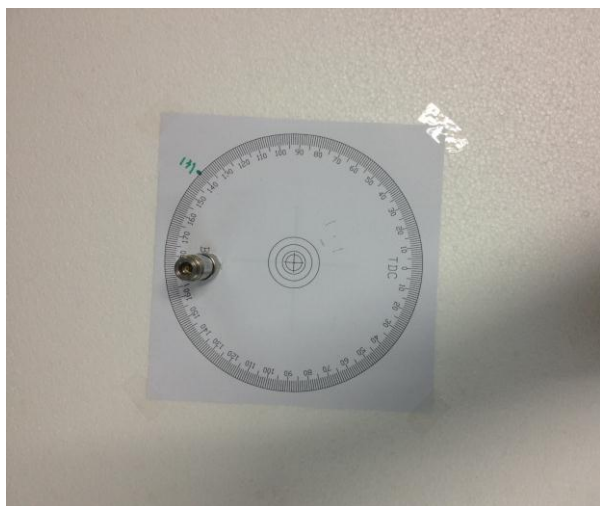
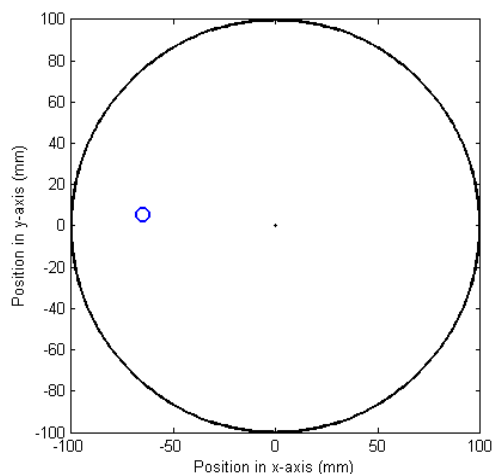


Figure 3. Moving Object Setup.

The moving object used in this study was a cylindrical shaped metal object with a 10 mm radius and height of 50 mm. The center of the black circle in Fig. 3 indicates the center of the region of observation in Fig. 2. The position of the center is set as origin (0 mm, 0 mm). The object is initially positioned at (-64.7 mm, 5.7 mm). The object is in clockwise circular movement with rotation center of (0 mm, 0 mm) and a rotation speed of 4 degree/sec during the measurement.

### C. The Transmitted and Received Signal

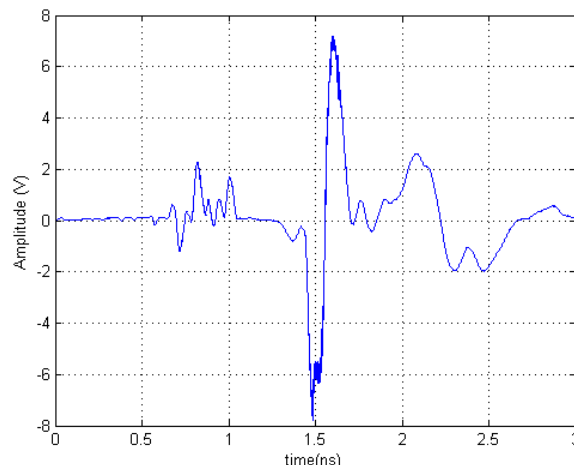


Fig 4. Waveform of the transmitted signal.

The waveform of the transmitted signal generated by the generator head and radiated at the transmitting antenna is shown in Fig 4. The transmitted signal was radiated to the region of observation and reflected by the object. The reflected signals were received by four receiving antennas with different pulse delays. The difference in pulse delays is due to the varying distance between the object and each receiving antenna. The waveform of the received signals at each receiving channel are shown in Fig. 5.

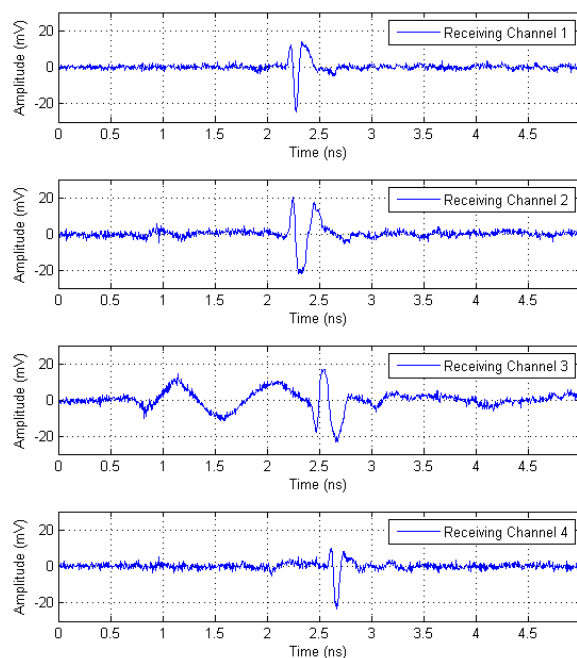


Fig 5. Waveform of the 4-channel received signals.

### III. Signal Processing

#### A. Bistatic Near-Field ISAR

The far-field monostatic ISAR equation is given as (1) and (2) in [8].

$$E(\vec{k}) = \int d\vec{r} \cdot \rho(\vec{r}) \cdot e^{-2j\vec{k} \cdot \vec{r}} \quad \square \square (1)$$

$$\hat{\rho}(\vec{r}) = \int d\vec{k} \cdot E(\vec{k}) \cdot e^{2j\vec{k} \cdot \vec{r}} \quad \square \square (2)$$

$E(k)$  is the measured complex electric field and  $\rho(r)$  is the density function of the object. For near-field bistatic ISAR, equation (1) is changed to (3), and equation (2) is changed to (4).

$$E(\vec{k}) = \int d\vec{r} \cdot \rho(\vec{r}) \cdot e^{-j\vec{k} \cdot (|\vec{r} + \vec{R}_{Tx}| + |\vec{r} + \vec{R}_{Rx}|)} \quad \square (3)$$

$$\hat{\rho}(\vec{r}) = \int d\vec{k} \cdot E(\vec{k}) \cdot e^{j\vec{k} \cdot (|\vec{r} + \vec{R}_{Tx}| + |\vec{r} + \vec{R}_{Rx}|)} \quad \square (4)$$

Fig.6 shows the geometry of near-field bistatic ISAR.

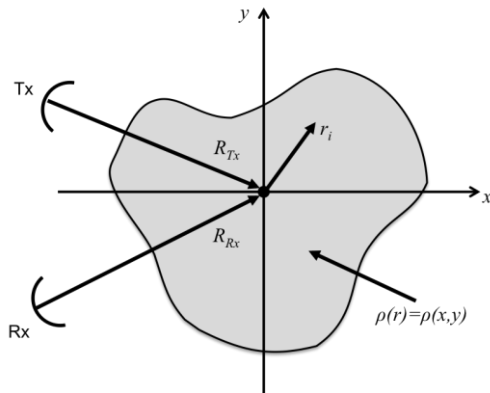


Figure 6. Near-field bistatic ISAR.

The ISAR imaging result of the measured object using equation (4) is shown in Fig. 7.

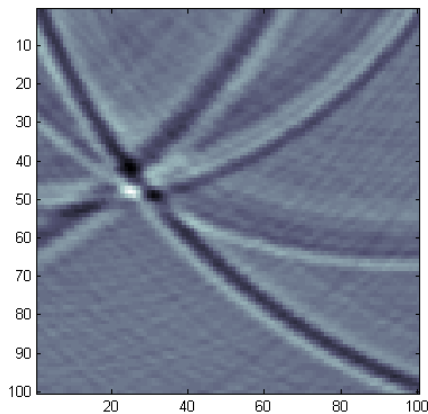


Figure 7. ISAR image of the measured object.

#### B. Moving Object Tracking

By applying a threshold to the ISAR image result in Fig. 7, only the position of the object is imaged, as illustrated in Fig. 8.

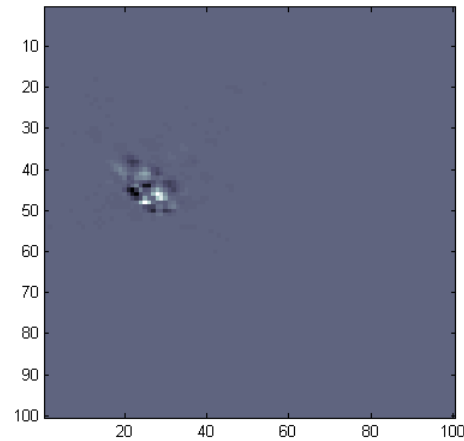


Fig 8. The threshold applied ISAR image.

After applying the threshold, the coordinate of the object position is determined. The result of determining the object position is shown in Fig. 9.

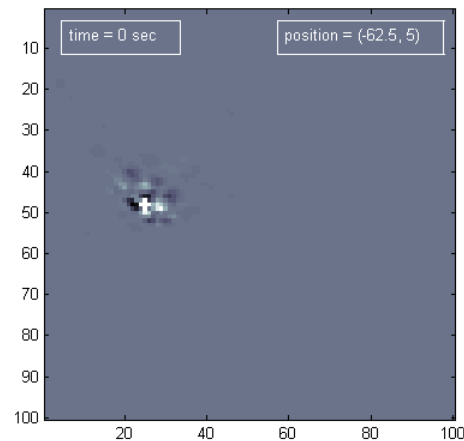


Figure 9. Object position tracking.

## IV. Results

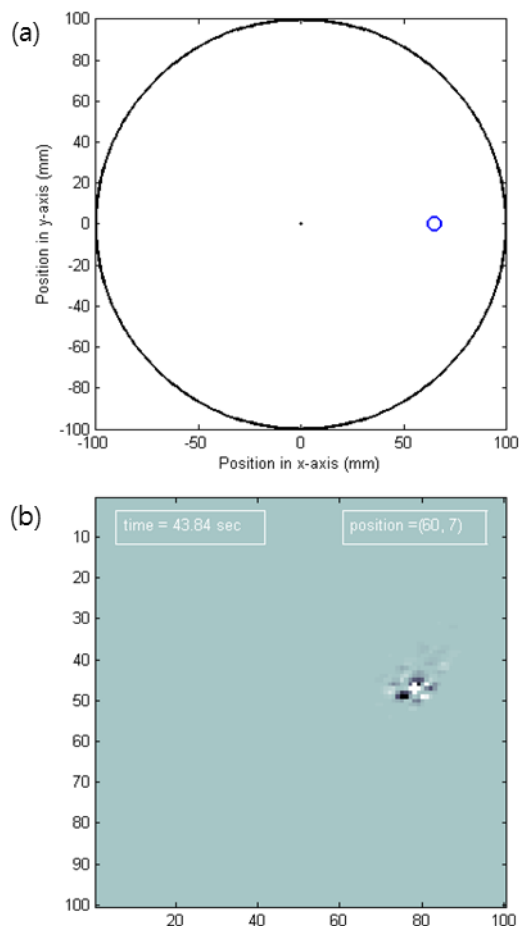


Fig 10. Real-time object position tracking: (a) ideal position of the object, (b) measured position of the object.

The real-time moving object position tracking result is shown in Fig. 10. The 4-channel received signal is measured at  $t=43.84$  seconds. The object moved in a circular motion at a 4 degree/sec angular speed. Therefore the object rotated about 175 degrees from the initial position at  $t=0$ . Fig. 10 shows that the position of the moving object at the measured instant is imaged and determined correctly.

## v. Conclusion

Conventional ISAR technology is mainly used for high resolution imaging. It required many measured signals from various angles, which makes the image results time-consuming to acquire. In this study, the possibility for real-time object tracking using multi-channel UWB ISAR was presented. It has shown that a single moving object position can be imaged and determined using one transmitting antenna and four receiving channels. For further development of this technique, multiple objects and multiple transmitters should be used.

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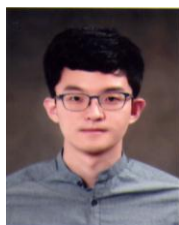
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