International Journal of Advances in Electronics Engineering– IJAEE
Volume 5 : Issue 1 [ISSN : 2278-215X]
Publication Date : 30 April, 2015

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.

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.

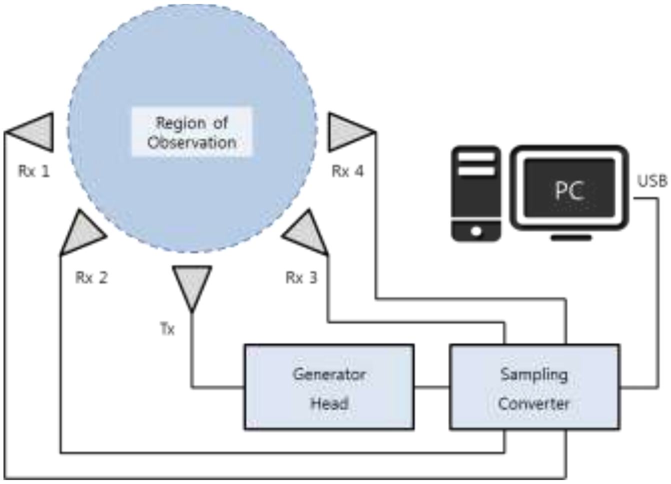

Figure 1. Measurements schema.

Figure 2. Hardware implementation of the measurement system.

Se-Yeon Jeon
School of Integrated Technology, Yonsei Institute of Convergence Technology, Yonsei University, Republic of Korea

Jonas Matuzas
Center for Physical Science and Technology at Vilnius, Lithuania,
Geozondas JSC, Lithuania.

Jiwoong Yu
School of Integrated Technology, Yonsei Institute of Convergence Technology, Yonsei University, Republic of Korea

Tae-Yun Lee
School of Integrated Technology, Yonsei Institute of Convergence Technology, Yonsei University, Republic of Korea

Min-Ho Ka
School of Integrated Technology, Yonsei Institute of Convergence Technology, Yonsei University, Republic of Korea

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*

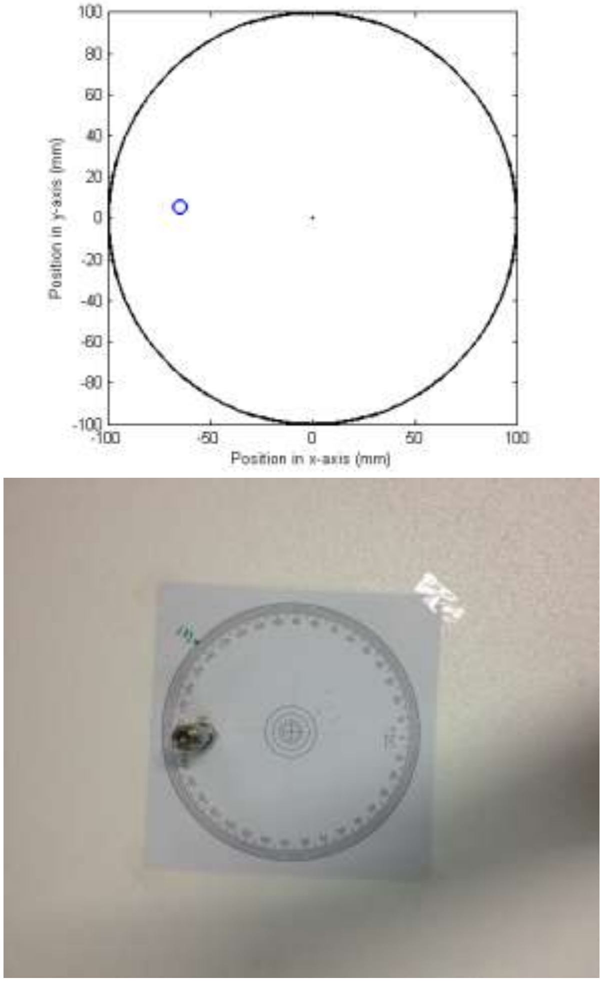

Figure 3. Moving Object Setup.

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 was 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*

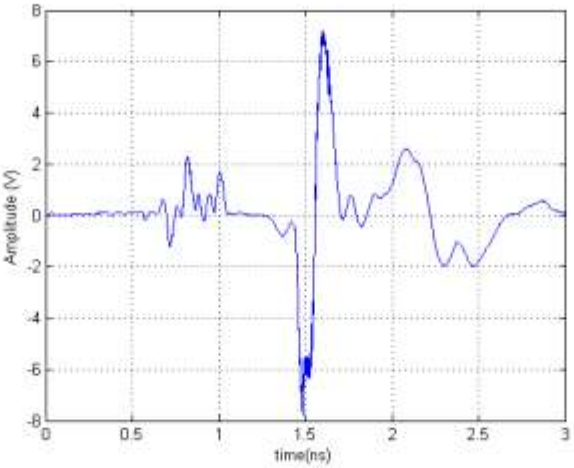

Fig 4. Waveform of the transmitted signal.

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.

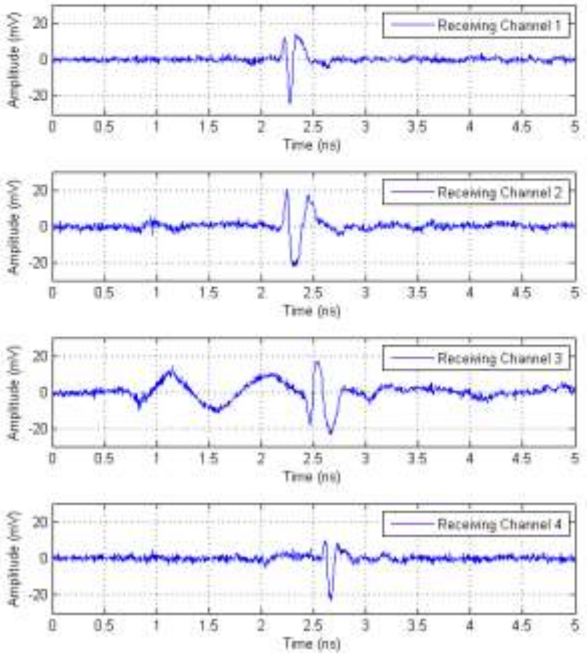

Fig 5. Waveform of the 4-channel received signals.

III. Signal Processing

A. Bistatic Near-Field ISAR

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

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

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

E(k) is the measured complex electric field and *ρ(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).

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

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

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

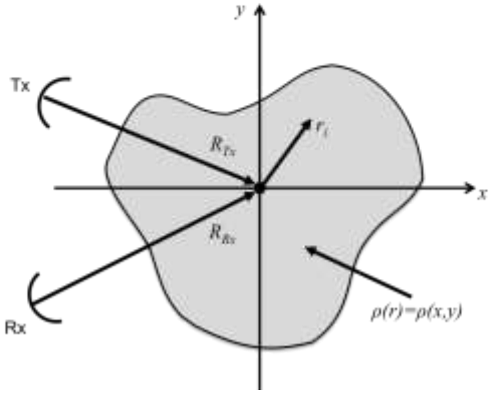

Figure 6. Near-field bistatic ISAR.

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

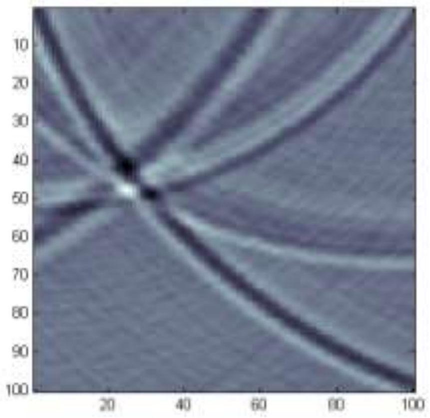

Figure 7. ISAR image of the measured object.

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.

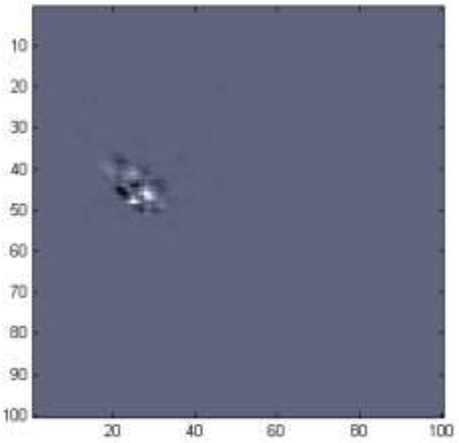

Fig 8. The threshold applied ISAR image.

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

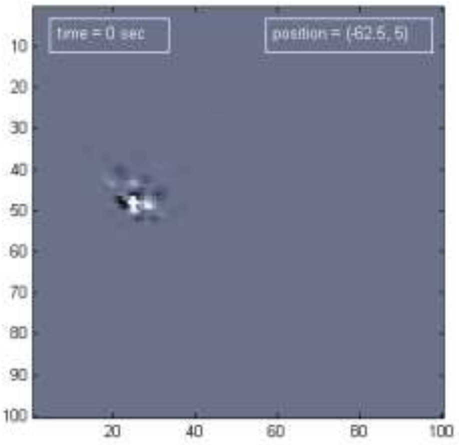

Figure 9. Object position tracking.

IV. Results

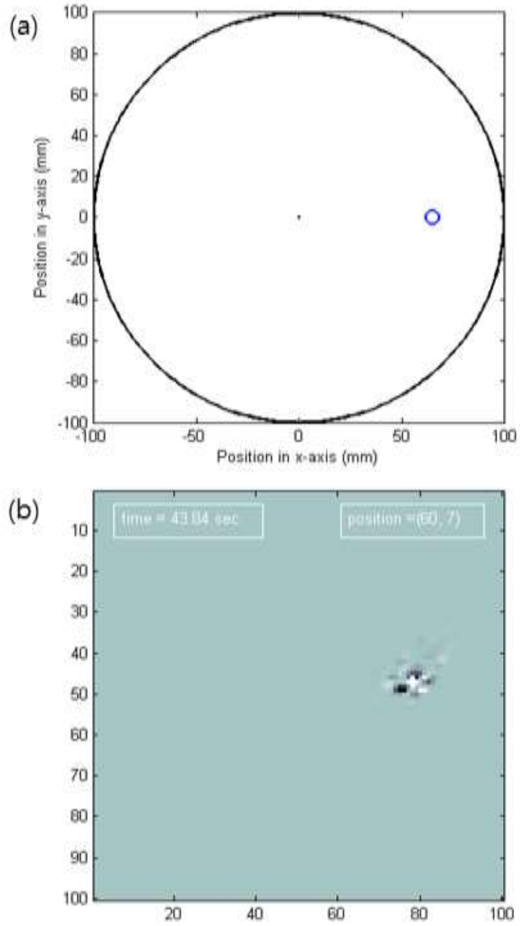

Fig 10. Real-time object position tracking: (a) ideal position of the object, (b) measured position of the object.

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.

Acknowledgment

"This research was supported by the MSIP(Ministry of Science, ICT and Future Planning), Korea, under the “IT Consilience Creative Program” (NIPA-2014-H0201-14-1002) supervised by the NIPA(National IT Industry Promotion Agency)

"The authors gratefully acknowledge the support from Electronic Warfare Research Center at Gwangju Institute of Science and Technology (GIST), originally funded by Defense Acquisition Program Administration (DAPA) and Agency for Defense Development (ADD).”

References

[1] Walker, Jack L. "Range-Doppler imaging of rotating objects." Aerospace and Electronic Systems, IEEE Transactions on 1 (1980): 23-52.

[2] Levitas, B., and J. Matuzas. "UWB radar high resolution ISAR imaging." Second International Workshop Ultrawideband and Ultrashort Impulse Signals. 2004..

[3] Khor, Wee Chang, et al. "An ultra wideband microwave imaging system for breast cancer detection." IEICE transactions on communications 90.9 (2007): 2376-2381.

[4] Yarovoy, A. G., et al. "UWB radar for human being detection." Aerospace and Electronic Systems Magazine, IEEE 21.3 (2006): 10-14..

[5] Li, Jing, et al. "Through-wall detection of human being's movement by UWB radar." Geoscience and Remote Sensing Letters, IEEE 9.6 (2012): 1079-1083.

[6] Pastina, Debora, Marta Bucciarelli, and Pierfrancesco Lombardo. "Multistatic and MIMO distributed ISAR for enhanced cross-range resolution of rotating targets." Geoscience and Remote Sensing, IEEE Transactions on 48.8 (2010): 3300-3317.

[7] Zhu, Yutao, Yi Su, and Wenxian Yu. "An ISAR imaging method based on MIMO technique." Geoscience and Remote Sensing, IEEE Transactions on 48.8 (2010): 3290-3299.

[8] Sullivan, R. J. (2000). Microwave radar: Imaging and advanced concepts(Book). Norwood, MA: Artech House, Inc, 2000.

About Authors

Se-Yeon Jeon received her bachelor of Science degrees in IT Convergence Technology from Yonsei University, Seoul, Korea. She is currently a Ph.D candidate at the School of Integrated Technology, Yonsei University and a researcher at Yonsei Institute of Convergence Technology since 2014. Her research focuses on the development of microwave sensors, electromagnetic wave signal processing, SAR, and ISAR.

Jonas Matuzas is a PhD candidate at the Center for Physical Science and Technology in Vilnius , Lithuania. He received his Master degree at Vilnius University, Faculty of Physics in 2003. He currently works in JSC "Geozondas", in Lithuania on SAR, ISAR, MIMO, tracking and breath detection.

Jiwoong Yu is a PhD candidate at the School of Integrated Technology, Yonsei University, Korea. He received his Master degree from the Department of Astronomy at Yonsei University in 2011. His research focuses on the SAR, ISAR, and signal processing.

Tae-Yun Lee received his Bachelor of Science degree in Earth System Science from Yonsei University, Seoul, Korea. He is currently a Ph.D candidate at the School of Integrated Technology, Yonsei University and a researcher at Yonsei Institute of Convergence Technology since 2012. His research focuses on the development for microwave sensors, electromagnetic wave signal processing, and inverse synthetic aperture radars.

Min-Ho Ka received the B.S. and M.S. degrees in Electronic Engineering from Yonsei University, Seoul, Korea in 1989 and 1991, respectively, and the Ph.D. degree in Radio Engineering from Moscow Power Engineering Institute (MPEI), Russia in 1997. From 1997 to 2000, he was with the Agency for Defense Development (ADD), Ministry of Defense, Republic of Korea for the development of microwave imaging sensors, Spaceborne and Airborne Synthetic Aperture Radars. He worked at Korea Polytechnic University as a Professor, Head of the Department of Electronic Engineering, Dean of Planning Office and Deputy Director of the Korea-Russia Industrial Technology Cooperation Centre from 2002 to 2010. He is currently Associate Professor in the School of Integrated Technology and Yonsei Institute of Convergence Technology, Yonsei University from 2011. His research area is system design and development for microwave sensors, spaceborne and airborne synthetic aperture radars.