UWB RADAR HIGH RESOLUTION ISAR IMAGING

Dr. B. Levitas, J. Matuzas

Geozondas JSC, 16 Shevchenkos str., 2009 Vilnius, Lithuania
Phone +370 5 2135404, Fax +370 5 2333816, e-mail: info@geozondas.com

Abstract

In this paper are presented results of high-resolution ISAR imaging using Ultra Wide Band Radar System working in Time Domain. Experiment was done in the ordinary room. Image resolution was 1mm. Results are important for various applications.

Keywords: Radar Imaging, ISAR, Time Jitter, Phase noise.

1. INTRODUCTION

ISAR Imaging [1-2] is used for measurement and modeling the properties of different scattered targets. High resolution images can be achieved using Ultra Wide Band (UWB) Radar System. This system works in Time Domain. Using time windowing it is easy to exclude signal from occasional reflections from the walls, ceilings and from signal leakage in bistatic measurement. These advantages let to do measurements indoor without expansive anechoic chambers.

The measurement schema it is shown in the fig. 1. ISAR Imaging is done turning the object around with positionier and taking signal at every angle.

Our ISAR Imaging measurement was done in ordinary room using UWB Radar System. Some examples of the ISAR imaging are presented in result section. The bandwidth was 0.8-22 GHz, Time window - 3 ns.

UWB Radar System include Pulse Generator (30ps duration), Sampling Converter (DC – 26 GHz), Positionier, Transmitting and Receiving Antennas, Personal Computer. In such configuration system bandwidth is limited with antenna bandwidth. Using pulse drift correction algorithms space resolution can be achieved up to 1mm. These results are interesting for non-destructive control, security, and biomedical applications.

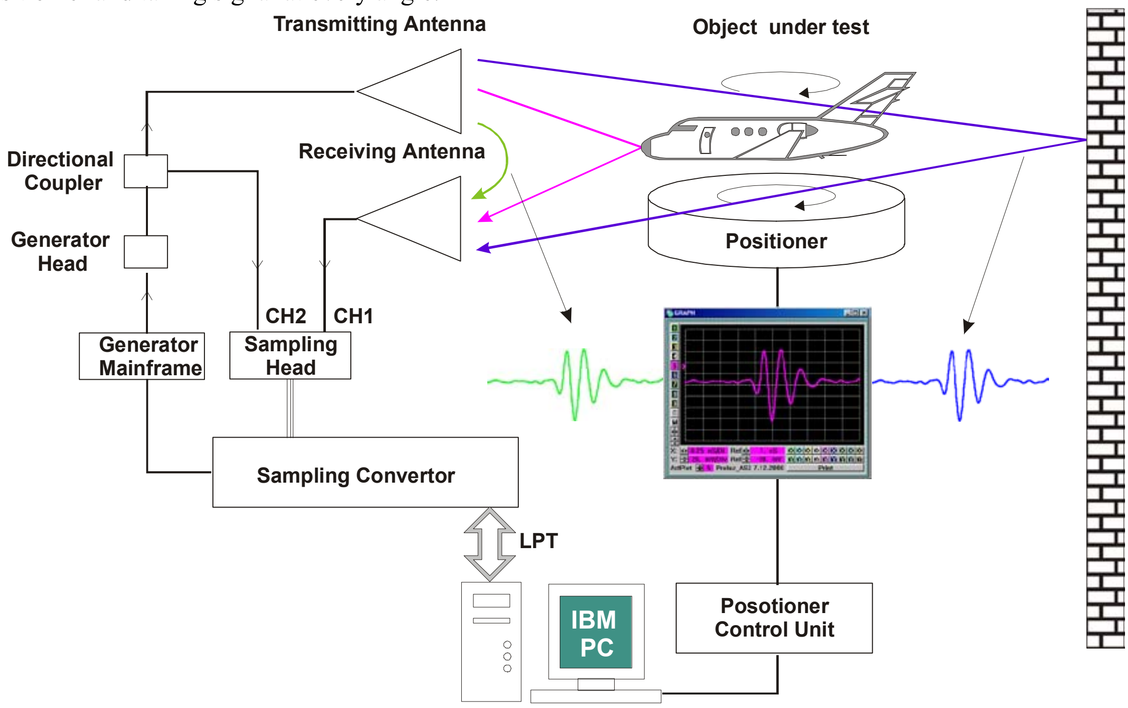

Fig. 1. Measurement schema.

2. THEORETICAL BACKGROUND

2.1 IMAGE FORMATION

To calculate the ISAR image we use formula (1), which is the solution of Helmholtz differential equation [2] for far field:

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

Where $\hat{\rho}(\vec{r})$-the square root of radar cross section (RCS) density. $E(\vec{k})$ Electrical field vector is taken at every angle scattered from the target. $\vec{R}$ -distance from antennas plane to target. $\vec{k}$ -wavelength vector. $\vec{r}$ radius vector pointing at every targets point. A is a frequency independent coefficient.

Representing $\vec{k}$ and $\vec{r}$ in Polar and Cartesian coordinates, we get:

$$\hat{\rho}(x,y) = \int_0^{\pi}\int_{-\infty}^{\infty} E_\theta(\omega)|\omega|e^{2j\omega(x\cos(\theta)+y\sin(\theta))}d\omega d\theta \qquad (2)$$

One integral in (2) can be evaluated using FFT, second integral can be presented by the sum.

2.2 CALIBRATION

Calibration is necessary for correction of errors influenced by equipment. A well-known analytical solution of simple object like metal sphere [3] was used for calibration. We used the optimal filtration formula. Calibrated electric field is:

$$E(\vec{k}) = F(j\omega)\frac{F_T(j\omega)F^*{}_K(j\omega)}{|F_K(j\omega)|^2 + \alpha\max(|F_K(j\omega)|^2)} \qquad (3)$$

$F(j\omega)$ -spectrum of the pulse reflected from the target. $F_T(j\omega)$-theoretical frequency response, the square root of RCS of the calibration object (conducting sphere). $F_K(j\omega)$-spectrum of the pulse reflected from the calibration target.

In the figure 2 is shown procedure of calibration. On the top of the figure is theoretical frequency response of the 5 cm diameter sphere. Second plot is a measured spectrum of the impulse reflected from the sphere. Next plot is relation of above two graphics. On the bottom it is shown the transfer function of the system after calibration witch is close to one up to 22 GHz.

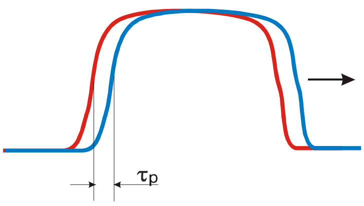

Fig. 3. Pulse drift.

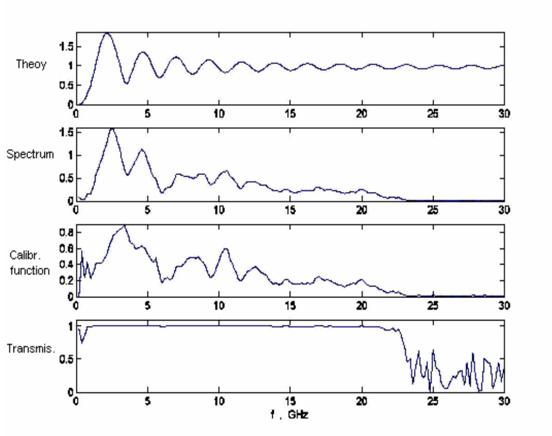

Fig. 2. Procedure of calibration.

2.3 PULSE DRIFT COMPENSATION

For image resolution the main role is playing time jitter and pulse drift (fig. 3). Time shift and space shift is related so:

$$\Delta l = \frac{1}{2}c\Delta\tau \qquad (4)$$

Where is c – speed of light 0.3 mm/ps. Pulse drift can be compensated. In the measurement schema (fig. 1) is shown that the part of the signal form generator goes to second channel. In both channels the pulse drift is the same. Because in the second channel signal is constant, we can evaluate pulse drift by phase difference and use that information for correction to the signal reflected from the object in the first channel. After such procedure phase error becomes significantly smaller. In the figure it is shown phase error dependence on frequency before and after pulse drift correction. Time jitter after phase correction is less then 3 ps that correspond 1 mm in space.

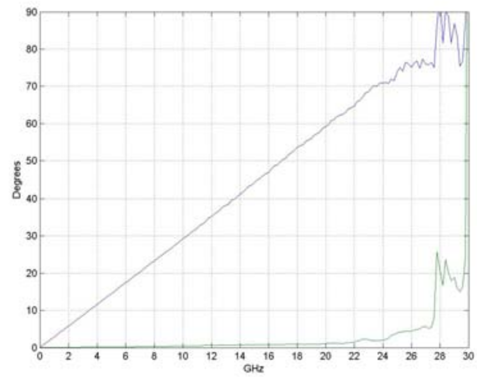

Fig. 4. Phase noise before and after pulse drift correction.

3. EXPERIMENTAL RESULTS

For measurements we used Time Domain equipment produced by Geozondas, Lithuania. It is Sampling Converter SD203T with frequency band 0-26 GHz (fig. 3) and Pulse Generator GZ1105DLP with pulse of duration 30ps (fig. 4). We also used a double rigged horn antennas P6-23M (fig. 1). The frequency band in which the measurements were done is 0.85 - 22 GHz. The bandwidth is restricted by bandwidth of antennas.

Distance between antennas and target was up to 4m. Measurements were made in the room with free space $3 \times 5m^2$ and 2.5m ceilings height. Example of the ISAR imaging is presented in figures 5-8.

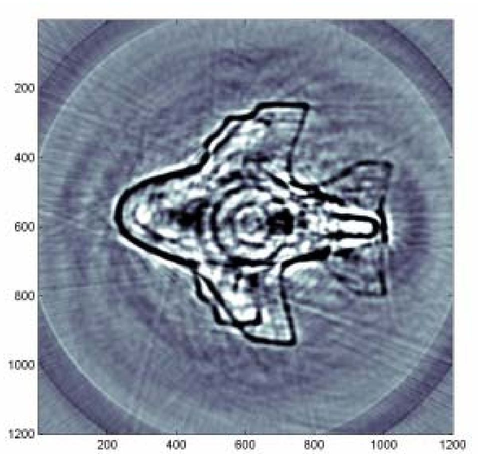

Fig. 5. ISAR Imaging of the metallic plane.

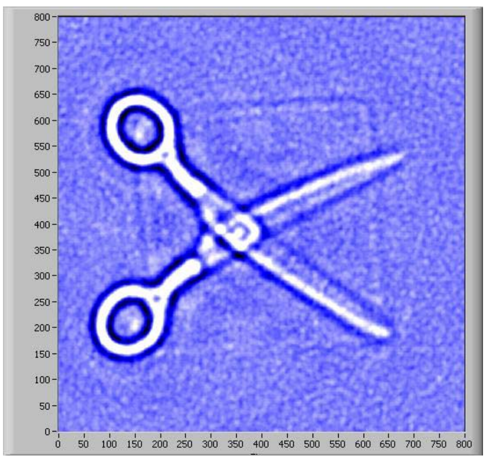

Fig. 6. ISAR Imaging of the scissors.

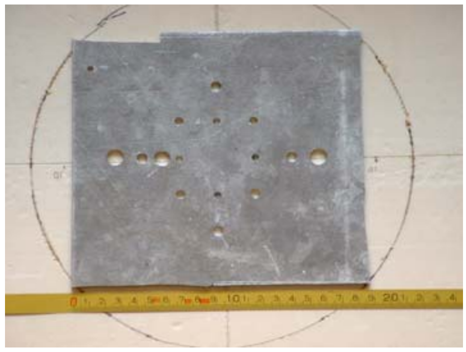

Fig. 7. Photo of the metallic plate with holes.

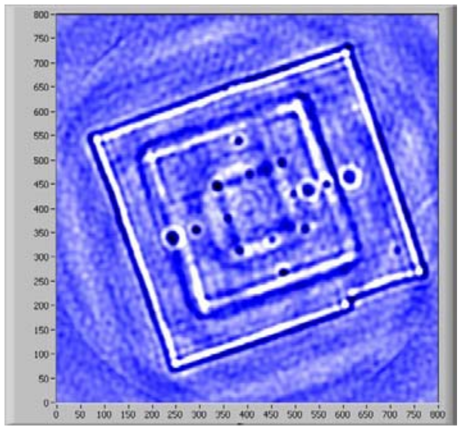

Fig. 8. ISAR Imaging of the metallic plate with holes.

4. CONCLUSIONS

1. The measurements are carried out using the short video pulses. Signal spectrum band is 0.85 ÷ 22 GHz.
2. Time Domain method let to overcome many measurement problems: signal leakage through antennas, occasional reflection from the walls, ceilings of the room. It let to create good quality ISAR Imaging without expensive Anechoic Chamber Imaging.
3. Resolution is less then 1 mm.
4. Time Domain method opens wide possibilities for interesting applications.

5. LITERATURE

1. James D. Taylor. *Ultra-Wideband radar technology*. CRC Press 2001.
2. Roger J. Sullivan. *Microwave Radar Imaging and Advanced Concepts*. Artech House 2000
3. J. A. Stratton. *Electromagnetic Theory*, New York: AcGrow-Hill, 194