P2-18 Experiment of a Trail 1-D SAILR System

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1. Introduction

SA (Synthetic Aperture) imaging generally brings about angular resolution with the order of λ /L, where λ is the observing wavelength and L, the SA size, respectively. When SA imaging is applied in the shorter wavelength regions, the finer angular resolution can be attained with a certain SA size though the finer positioning accuracy for the receiving aperture control is required.

A number of fundamental but innovating works have been devoted to the development of SAL (Synthetic Aperture Laser radar), i.e. SA in optical wavelengths. We presented in a previous work[1] the concept and the feasibility of SAILR(Synthetic Aperture Infrared Laser Radar) operated in a wavelength around 10 μm using CO_2 lasers as a transmitting and a local oscillator. The advantages of SA imaging in the 10 μm band were discussed and a processing method was newly proposed there. Based upon the results of the feasibility study, we constructed for trial a 1-D (one-dimensional) SAILR system to demonstrate the proposed concept and the processing method for SAILR imaging. The SAILR system has a single receiving aperture mounted on a linear moving stage with the length of 1 m. The aperture position can be controlled with the accuracy of 1 μm.

We have performed a short-range experiment to verify the fundamental functions of this system, and succeeded in obtaining 1-D SAILR images of model objects consisting of point targets with the theoretically expected resolution. In the following parts of this paper, we put a summarized description about a single aperture SAILR for imaging static objects in Section 2, and show some results of the short-range verification experiment using the trial 1-D system in Section 3.

2. Concept of SAILR for static objects

Figure 1 shows the concept of imaging static objects by a 1-D SAILR with a single receiving aperture. The coordinate system is set as described in the figure, that is, the z axis is directed toward the vicinity of the object, O. The sensing 10 μm-band laser beam is shed on the object. The transmitting point of the sensing wave, T, need not coincide with the origin. The receiving aperture, A, is moved along the x axis over the synthetic aperture length, L, to receive signal waves from the object at each observation point. The interval of the observation points should of course be determined by the sampling theorem for the signal waves.

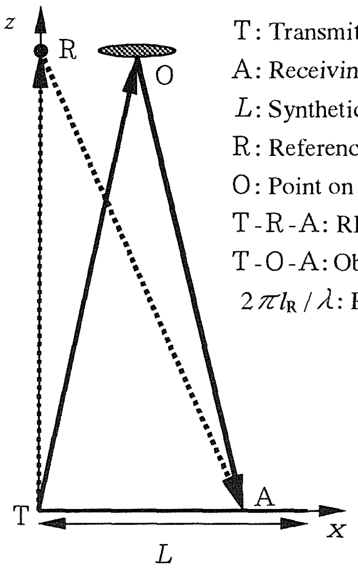

Fig. 1 Concept of 1-D SAILR imaging for static object.

SAILR imaging uses coherent waves, so needs a reference wave to give the phase reference as is the same in other coherent imagers as microwave SAR. The reference wave is split from the sensing wave before transmitted to the object.

The RPT (Reference Point-Target), R in the figure, does not exist actually. The correlation between the response of this imaginary RPT obtained by calculation and the response signal of actual objects gives the object image, as is well known in SAR data processing. In case of SAILR imaging for static objects, we can adjust the phase of the reference wave during data acquisition to adopt a more convenient way, as described below, for imaging process instead of the conventional correlation method.

In the SAILR imaging process adopted, we adjust the phase variation of the reference wave to simulate that of the RPT wave, i.e. an imaginary wave traveling from the transmitting point to the RPT and returning to the receiving aperture (along the path T-R-A in Fig. 1). The block diagram of the SAILR imaging process is shown in Fig. 2. In this method, the output image can be produced by the simple Fourier transform of the correlator output (a

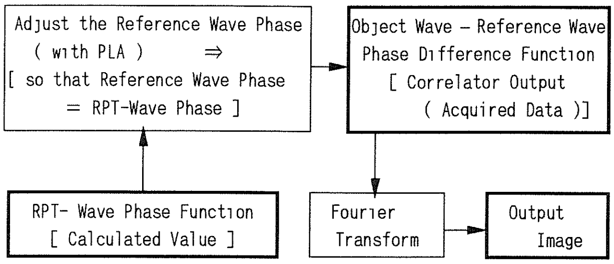

Fig. 2 Block diagram of the SAILR imaging process using PLA.

function of the receiving aperture position, x) obtained as the result of data acquisition.[1]

The phase variation of the RPT wave can be calculated if the path-length of T-R-A is determined, and we can adjust the phase variation of the actual reference wave by expanding and contracting its path-length. For this operation, we used a PLA (Path-Length Adjuster) with a corner-cube reflector mounted on a linear movable stage.

During data acquisition, the position of A moves, and therefore the path-length T-R-A varies, from an observation point to another point. According to this variation, the path-length of the reference wave has to be adjusted with the PLA.

3. Short-range verification experiment

In order to verify the capability of synthetic aperture imaging by the method described above, we constructed a trial 1-D SAILR system for imaging static objects, using two CO_2 lasers as a transmitter and a local oscillator for heterodyne detection. It has a single receiving aperture mounted on a linearly movable stage with the length of 1 m and the position accuracy of 1 μm.

As the first step for confirming the basic functions of the 1-D SAILR and demonstrating its imaging capability, we performed a short-range experiment in the laboratory. The model objects were constituted by specular point targets that reflect the sensing waves. The signal received by the receiving aperture is the superposition of the reflected waves from the constituent point targets. Such model objects have the advantage of making the meaning of results clear, and are sufficient theoretically to verify the function of the system.

Fig. 3 shows a typical result of the experiment for objects consisting of two point targets. The correlator output (relative value) as a function of the position of the receiving aperture in the abscissa (top), and its Fourier transform (bottom) are plotted. As described above, the Fourier transform plot directly gives the 1-D SAILR image. The intense peaks are images of the two specular point targets constituting the model object.

In Fig. 4 is shown the result of numerical

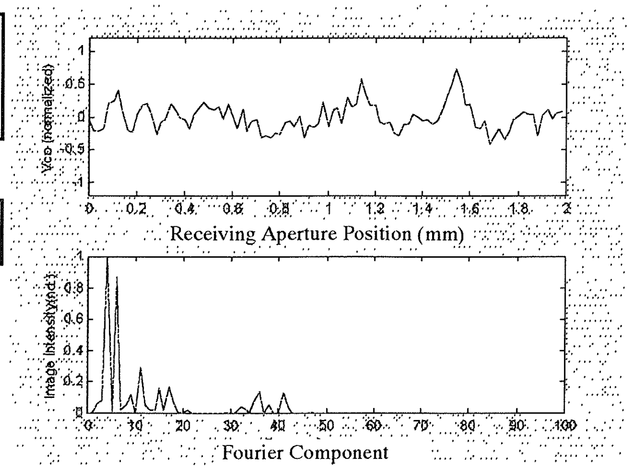

Fig. 3 Typical experimental result for a object consisting of two specular point targets. Correlator output as a function of the receiving aperture position in abscissa (top), and its Fourier transform (bottom) giving the corresponding 1-D image.

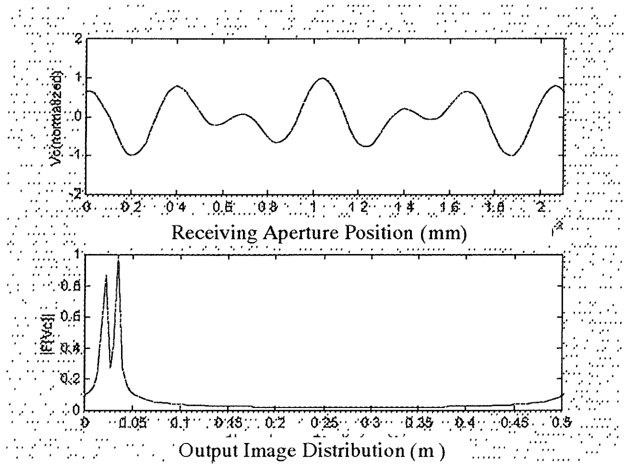

Fig. 4 Simulated result for the same conditions as in Fig. 3. Correlator output function (top), and its Fourier transform (bottom)

simulation in the same conditions as the above experiment. Similarly to Fig. 3, the simulated correlator output function and its Fourier transform are displayed.

4. Conclusions

Compared with this figure, the experimental result shown in Fig. 3 agrees well with this theoretical expectation except inevitably included noises. Our trial 1-D SAILR functions well enough to demonstrate the concept for and data processing method previously proposed.

References

1. S. Yoshikado and T. Aruga, Appl. Opt. 37, 5631-5639 (1998).