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SYNTHETIC APERTURE LASER RADAR FOR 10μm-BAND HIGH-RESOLUTION IMAGING

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1. INTRODUCTION

Synthetic aperture radars(SAR) have widely been developed and are now utilized in various practical fields. Most of them are installed in an airplane, or a spacecraft, for side-looking imaging with a wavelength longer than 1 cm.

For infrared wavelengths, aperture syntheses are much more difficult than for radio wavelengths. We have been making a basic study of a synthetic aperture laser radar(SAL) for 10μm-band high-resolution imaging. The concept and the availability of the SAL are presented below.

2. SYSTEM CONFIGURATION

An elementary configuration of the SAL system is illustrated in Fig. 1. Two CO_2 lasers are used for a transmitter(TR.) and a local oscillator (L.O.). Waves reflected by an object (Object waves) are received by a single aperture(A_R) continuously-movable on a linear baseline(Length:L). The received object waves are heterodyne-detected by a HgCdTe detector (D_2), and its IF signal(IF_2) is correlated with a reference signal(IF_1) split from the transmitting wave and detected by another detector(D_1). The correlator output is processed by a data-processor to regenerate an image of the object.

Signal processing algorithm for SAR data is well established, and high-resolution SAR images can be easily obtained owing to parallel processing through array-processors. When we can estimate the object range even approximately, however, a simpler processing method is available. If the reference wave pathlength is controlled so that its phase at the detector D_1 be equal to that of an imaginary wave reflected by a reflector IRR, which is assumed to be placed at a range $R+R_E$, the correlator output is equivalent to that for the interference of the object waves with the imaginary reference wave from IRR(See Fig. 1).

In this case, we can obtain an (one-dimensional) image of the object directly through Fourier-transform of the correlator output. We use a fine delay adjuster(FDA) to optically controll the reference wave pathlength.

3. MAJOR CHARACTERISTICS

The SAL is a kind of interferometer of a single element aperture. Its expected angular resolution is of the

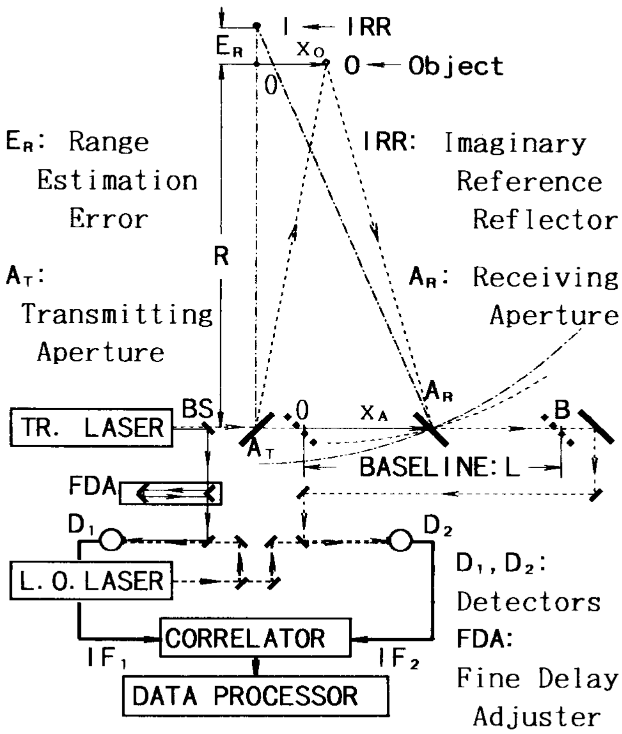

Fig. 1 Schematic diagram of a synthetic aperture (imaging CW) laser radar in an observation configuration. Waves reflected by an object are heterodyne-detected(IF_2), and correlated with a reference wave signal (IF_1) whose phase is controlled by FDA to be equal to that of an imaginary wave from IRR.

order of λ/L (Diffraction limit; λ : observed wavelength). Our system has a baseline of 1 m resulting in an angular resolution limit of about 10 μrad for 10μm-band radiation.

The diameters of transmitting(A_T) and receiving(A_R) apertures are both 10 cm. The field-of-view angle of the A_R is so narrow (about 100 μrad) that we have to adjust its pointing direction during data-acquisition for an object at short ranges.

4. NUMERICAL SIMULATION

We have performed a numerical simulation to investigate the SAL availability. Figure 2 shows a simulated correlator output variation as a function of the A_R position and an one-dimensional image obtained through Fourier-transform of the above correlator output in a case without any range estimation error.

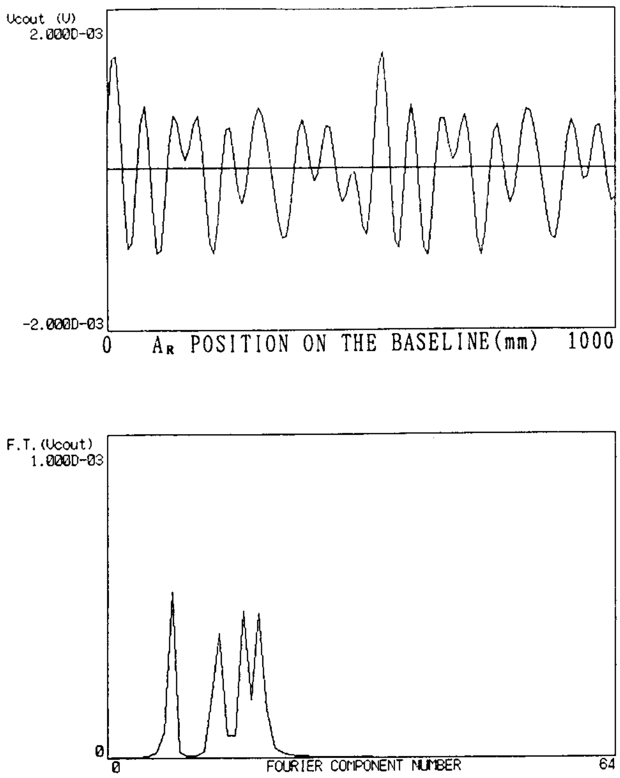

Fig. 2 An example of numerical simulation results. A plot of correlator output(Top) shows a fringe due to the interference of waves from 4 reflectors with the reference wave equivalent to an imaginary wave from IRR. We can obtain an one-dimensional image of the reflectors(Bottom) directly by Fourier-transform of the above correlator output.

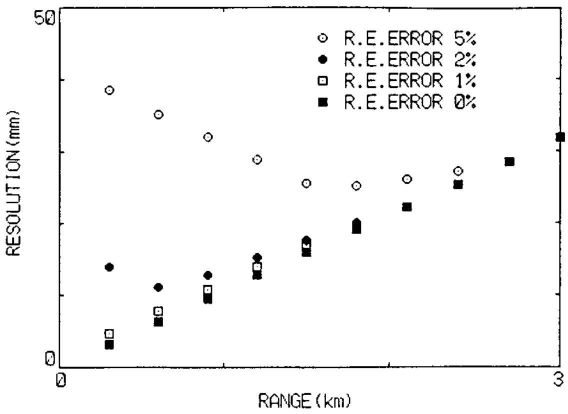

Fig. 3 Relation of object resolution to range(R) shown with variation due to range estimation error(E_R/R) as a parameter(⇒Fig. 1). Errors exceeding 1 % are not realistic.

It is important to study the effect of a range estimation error on object image resolution in the simple processing method described above. We can, however, derive a conclusion from the result shown in Fig. 3 that this effect is not so serious because we can actually get a better estimation than 1 % for object ranges within several to ten kilometers.

5. CONCLUSIONS

We have to take atmospheric turbulence effects into consideration. But we have obtained results pointing that, in conditions of weak or medium turbulence, we can obtain an object image without serious degradation. Consequently, the SAL is available for high-resolution imaging of an object at ranges within several to ten kilometers.