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CAR-BORNE IMAGING RADAR SYSTEM

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1. INTRODUCTION

Under bad driving conditions such as heavy rain, heavy snowfall, and fog, drivers can not adequately see the road, often resulting in traffic accidents. A car-borne imaging radar can provide an all-weather driving system. It is necessary that such a radar satisfies a number of requirements. It must 1)use a wave which can transmit through rain, snowfall, and fog, 2)have real-time imaging, and 3)retain high resolution over a short range.

It is well known, that there is little attenuation for micro-wave transmission in snow, rain, or fog. While conventional imaging radars are both short-pulse and real-aperture, it is difficult to reconstruct images of targeted objects over a short range. Holographic radars, however, have good resolution in such a situation[1]. In this paper, we propose a technique for a front-looking radar which is based on holographic-radar principle. The proposed technique consists of a car-borne imaging radar using micro-waves.

Fig.1 shows the essential elements of the car-borne imaging radar. These include the antennas, a data processing unit, and a display unit. Both transmit and receive antennas are mounted at the front of the car. The received signal is detected by a coherent detector and then processed to reconstruct images of detected objects by a processing unit. The reconstructed images are consequently displayed on a CRT which is housed in the dashboard.

2. PRINCIPLE OF HOLOGRAPHIC RADAR

Fig.2 shows a simplified diagram of the geometry of the car-borne imaging radar. The car runs along a track direction z at velocity v. The received signal which is reflected from object g(xo,zo) can be written as

$$u(x,t,f) = \int_0^{\infty} \int_{-l/2}^{l/2} g(x_0,z_0)\, e^{j\frac{2\pi f}{c} r} dx_0 dz_0 \qquad (1)$$

where r is the distance between the target and the antenna, and can be expressed as

$$r = \sqrt{(z_0-vt)^2+(x-x_0)^2}.$$

t is time, f is transmitting frequency, and c is the velocity of the electromagnetic waves. It is assumed that the sweep frequency is less than center frequency f_o, and r is within the distance in which the Fresnel approximation is applicable. In such a case, the following approximation can be obtained.

$$u(x,t,f) = \int_0^{\infty} e^{-j\frac{2\pi f}{c}z_0} \int_{-l/2}^{l/2} g(x_0,z_0)\, e^{j\frac{2\pi f}{c}\left(vt-\frac{(x-x_0)^2}{2(z_0-vt)}\right)} dx_0 dz_0 \qquad (2)$$

Eq.(2) shows that the rate of changing phase with respect to the frequency is proportional to the radar-target range and is independent of the target azimuth. As a result, the range compression can be performed by a Fourier transform of received signal u(x,t,f) with respect to the frequency. The rate of changing phase with respect to both the time t and the x-direction is associated with the target azimuth. While it is possible to ascertain the target azimuth by scanning with the antenna in the x-direction, the scanning time is long for real time imaging.

3. RECONSTRUCTION OF RADAR IMAGE

To reduce the sensing time, we propose a azimuth compression technique. The method use the rate of changing phase with respect to time. The technique is similar to the doppler sharpening technique, utilized by an airborne ground map radar[2]. The doppler ground map radar scans fo the side of the aircraft, but our proposed technique scans to the front of the car.

The phase function of Eq.(2) with respect to time t is expressed as follows.

$$\phi(t) = -\frac{\pi f(x-x_0)^2}{c(z_0-vt)} \qquad (3)$$

The Eq.(3) shows that the rate of changing phase with respect to time is not proportional to the target azimuth. It is possible to modify the phase by sampling the data at durations which are inverse to the time t. As a result of the correction, the rate can be made proportional to the target azimuth $(x-xo)^2$. We can thus carry out an azimuth compression by performing a Fourier transform.

The data received is reconstructed by using the process as shown in Fig.3. A range compression can then be performed by a Fourier transform of the signal received with respect to the frequency f. Data processed by the range compression includes changes in phase corresponding to the range azimuth. Azimuth compression can be performed by phase correction and a Fourier transform. However, the reconstructed image is symmetrical about the z-axis, due to the fact that the term $(x-xo)^2$ in Eq.(3) is symmetrical about x. It is possible to overcome the problem this creates by synthesizing the reconstructed images obtained by two or three spatially separated receiving antennas.

4. SIMULATION RESULT

Computer simulations of the proposed technique were carried out utilizing the parameters as shown in Table 1. Fig.3 shows the simulated receiving signal data where the radar-target range zo was 15m. In Fig.4, the reconstructed image obtained by using the proposed technique is shown. It seems that the technique has good resolution over a short range.

Table1 Simulation parameters

Parameter	Value
Frequency	10.0 - 10.5GHz
Duration of sampling	0.2sec
Velocity of car	36km/h
Number of samples with respect to time	512
Number of samples with respect to frequency	512
Range resolution	30cm
Azimuth resolution	40cm (@zo=15m)

5. CONCLUSIONS

In this paper, we propose a technique for a car-borne imaging radar which is based on holographic-radar principle. The computer simulations show that the proposed technique can be viably applied to a front-looking radar. Since the image reconstruction is done by performing two Fourier transforms and one phase correction, there are obvious advantages in utilizing a digital processor for real-time image reconstruction.

ACKNOWLEDGMENTS

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REFERRENCE

1) Y.SAKAMOTO, and Y.AOKI:"Three-Dimensional Imaging of Objects in Accumulated Snow using Multi-Frequency Holography", IEEE, Tran. on Geoscience and Remote Sensing, Vol.27,No.4,pp.430-436 (1988)

2) C.WU,K.Y.LIU and M.JIN:"Modeling and a Correlation Algorithm for Spaceborne SAR Signals,"IEEE, Tran. on Aerospace and Electronic Systems, Vol.18,No.5,pp.563-575(1982)

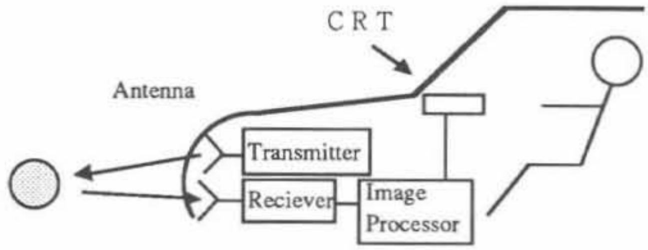

Fig.1 Block diagram of a car-borne imaging radar

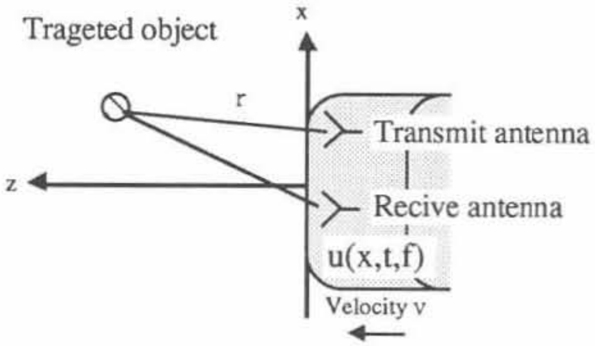

Fig.2 Geomtrical configration

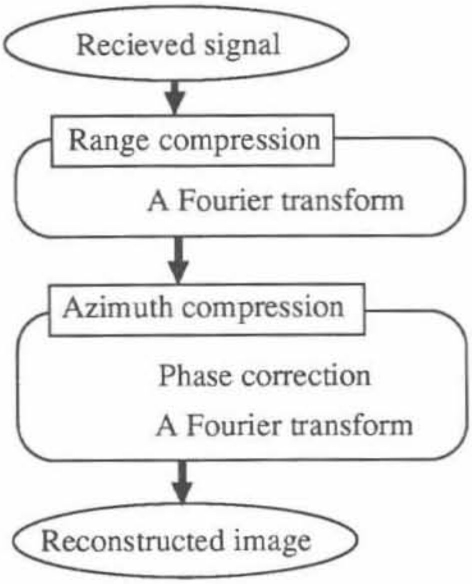

Fig.3 Flow of processing of radar data

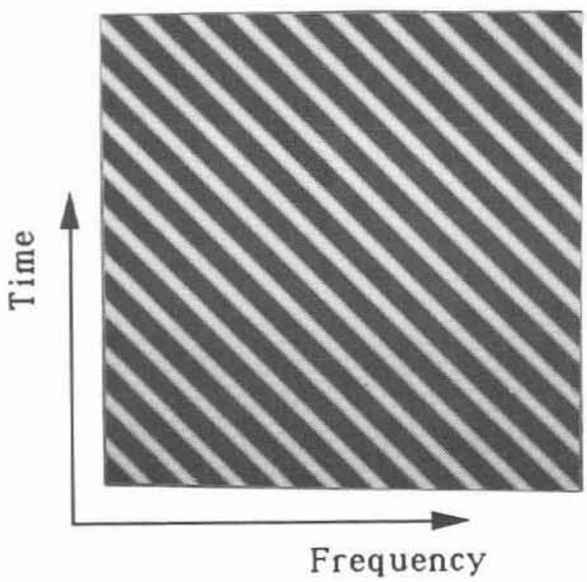

Fig.4 Received signal

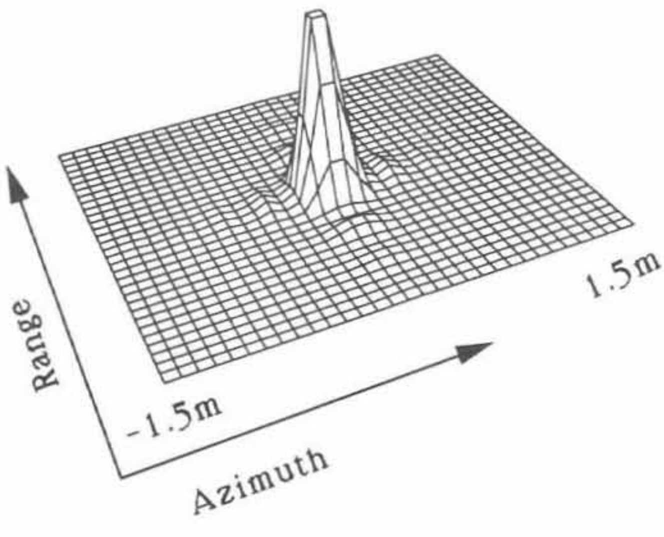

Fig.5 Reconstructed image