ISAR IMAGING OF AN AIRCRAFT TARGET USING ISDB-T DIGITAL TV BASED PASSIVE BISTATIC RADAR

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1. INTRODUCTION

Passive bistatic radars (PBRs) exploit existing transmitters such as TV broadcasts, radio broadcasts, Global Navigation Satellite System (GNSS), etc., as the source of illumination [1]. PBR is consisted of two receivers, with one antenna pointed at the source and the other at the target, and the target range is determined by correlating the signal scattered by the target with the signal directly arrived at the receiver (Fig.1). Since PBR does not transmit any waveform, it consumes lower power, and no frequency allocation is required. More thorough discussions about the advantages and the limitations of PBR can be found in [1].

The authors are investigating the target imaging capability of PBR. Some theoretical works on Inverse Synthetic Aperture Radar (ISAR) based on PBR have been reported [2, 3]; however, no experimental work, to the best of authors' knowledge, has been published. We have conducted a field experiment exploiting terrestrial digital TV broadcast to assess the feasibility of passive ISAR observation. The wide and flat spectrum of the OFDM signal and the small gap between the channels enables us to obtain high range resolution of up to several meters by exploiting multiple physical channels. Therefore, modest resolution ISAR imaging is expected to be possible.

In this paper, PBR based ISAR algorithm is briefly explained, and the first example of observed PBR based ISAR image of an aircraft target is shown.

2. THE METHOD

To obtain high cross-range resolution, the target needs to be observed for sufficient length of time. To save the memory size the receiver is operated in an intermittent way as shown in Fig.2. We call the continuing receiver operating duration "pulse width" and the interval between the pulses "pulse repetition interval (PRI)."

Fig. 3 shows the flow chart of the algorithm. Range compression corresponds to the correlation of the direct wave signal $s_{dn}(t)$ and the scattered wave signal $s_{sn}(t)$ to obtain the range profile $x_n(\tau)$ as in Eq.1.

$$x_n(\tau) = \int_{t_n - T_0/2+\tau}^{t_n+T_0/2} s_{sn}(t) \cdot s_{dn}^{*}(t-\tau)\, dt \qquad (n = 0, \cdots, N-1) \tag{1}$$

The range compression is applied to each pulse and N range profiles are obtained. We set the pulse width T_0 sufficiently small so that the expected Doppler shift in the scattered signal caused by the target motion can be neglected. The range compression is implemented using FFT, and the range profile is substituted by the circular correlation function. The clutter suppression is moving target indication (MTI) and is implemented as follows:

$$\tilde{x}_n(\tau) = x_n(\tau) - \frac{1}{N}\sum_{n=0}^{N-1} x_n(\tau) \qquad (n = 0, \cdots, N-1) \tag{2}$$

The following range migration compensation, phase compensation and cross range compression are basically the same as the conventional ISAR processing [4].

3. EXPERIMENTAL RESULTS

Field experiment was conducted in October 2009 near Tokyo International Airport. Fig.4 shows the geometry. The receiver is located about 10.5km apart from the digital TV broadcasting tower – Tokyo tower – and about 12km apart from the airport. The arriving and departing airplanes, whose flight paths are about 5 – 10km away from the receiver, are observed. One Yagi-Uda antenna is pointed at Tokyo tower to receive the direct wave, and to obtain the better gain for the scattered wave, an array of three Yagi-Uda antennas are pointed at the flight path. Table.1 shows the observation parameters. The signal of six physical channels with bandwidth of 5.57MHz, i.e., the signal with the total bandwidth of approximately 36MHz is received, which realizes the transmitter-to-target-to-receiver range resolution of 8.3m. The received signal is amplified, down converted and sampled at the rate of 100MHz. The pulse width is set to be 0.8msec and 50 pulses are obtained at PRI of 100msec; that is, the observation time was 5 seconds, which realizes the Doppler frequency resolution of 0.2Hz.

Fig.5 shows an example of the observed data. The target in this case was Boeing 777-300. Fig.5 (a) shows the spectrum of the digital TV signal. The horizontal and the vertical axes represent the frequency and the intensity, respectively. The six channels employed in the experiment are between the magenta lines. Fig.5 (b) shows the the range-hit map after the background clutter suppression. The horizontal and the vertical axes represent the pulse number and the range, respectively. One can observe that the range of the scattered signal from the aircraft migrates from 5.5km to 6.5km. Fig.5 (c) shows the signal after range migration compensation. The target signal is successfully aligned on the same range cell after the process. Fig.5 (d) shows the final ISAR image. The horizontal and the vertical axes represent the Doppler frequency and the range, respectively. It can be seen that the target signal extends about 120m in range direction and approximately 1.2Hz in Doppler frequency. Considering the bistatic angle of 68 degree, the target size is roughly estimated to be 73 m($=120/(2\cos 34^\circ)$), which agrees well with the size of Boeing 777-300, which is 73.9m length and 60.9m width.

4. CONCLUSION

The potential of the passive ISAR imaging has been investigated and validated by the field experiment. A modest resolution ISAR imaging is feasible by exploiting terrestrial digital TV broadcast as the transmitter.

5. REFERENCES

[1] N.J. Willis and H.D. Griffiths, “Advances in Bistatic Radar,” Scitech publishing Inc., 2007

[2] M.Cetin and A.D. Lanterman, “Region-Enhanced Passive Radar Imaging,” *IEE Proceedings. Radar, Sonar and Navigation*, Vol.152, No.3, pp.185--194, Jun. 2005

[3] Y. Wu, D.C. Munson,Jr, “Wide-angle ISAR passive imaging using smoothed pseudo Wigner-Ville distribution,” *Proc. IEEE Radar Conf., 2001.* pp.363--368, May, 2001

[4] D.R. Wehner, “High Resolution Radar Second Edition,” Artech House, Inc. 1995

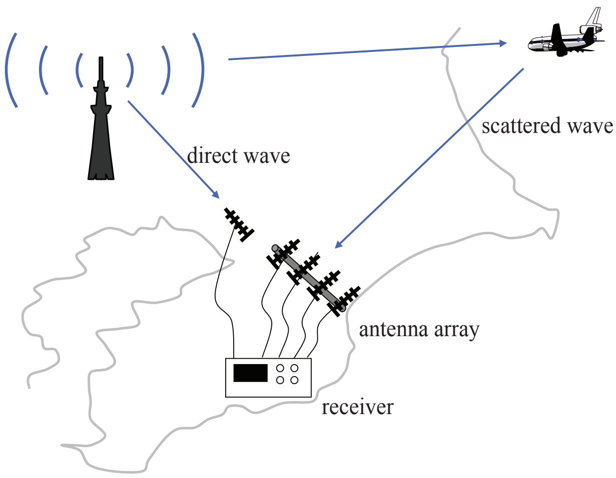


Fig.1 The concept of passive radar

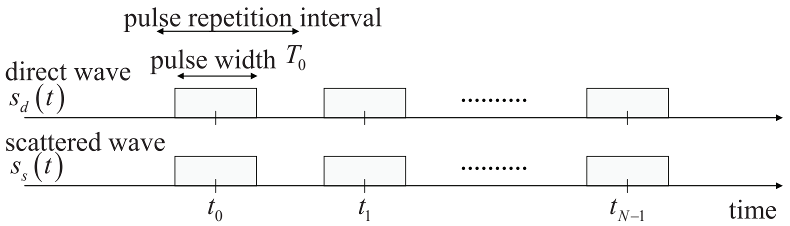


Fig.2 “Pulsed” operation of the receiver

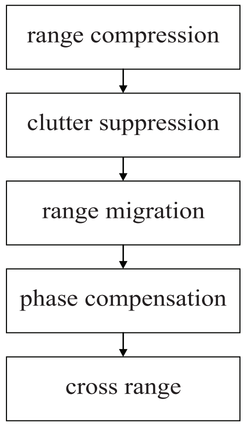


Fig.3 ISAR processing

Table 1. Observation Parameters

Parameters	Value
Frequency Band (21ch – 26ch)	512—560MHz
Equivalent Radiation Power	48kW
Direct wave path length	10.5km
Receive antenna gain	10.65dB
A/D sampling frequency	100MHz
Pulse width	0.8msec
PRI	100msec
The number of pulses	50

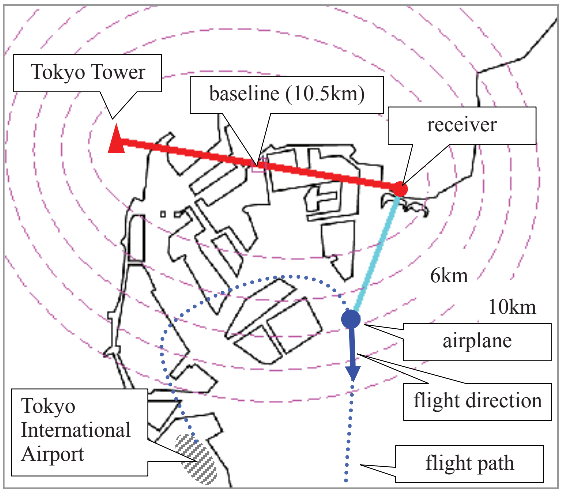
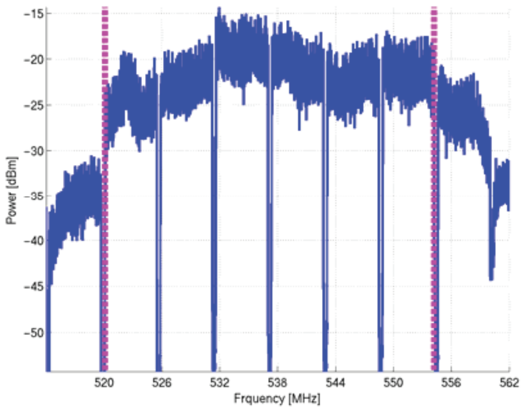
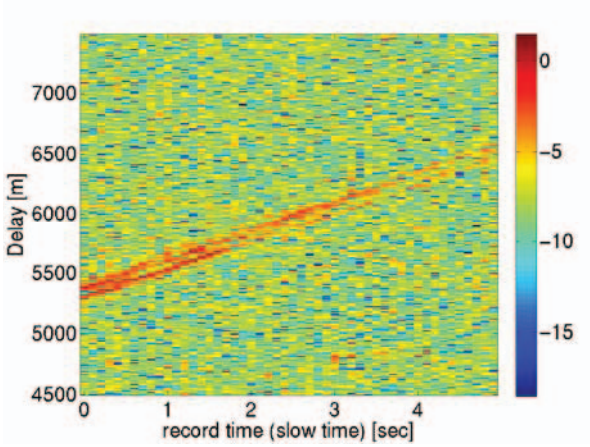


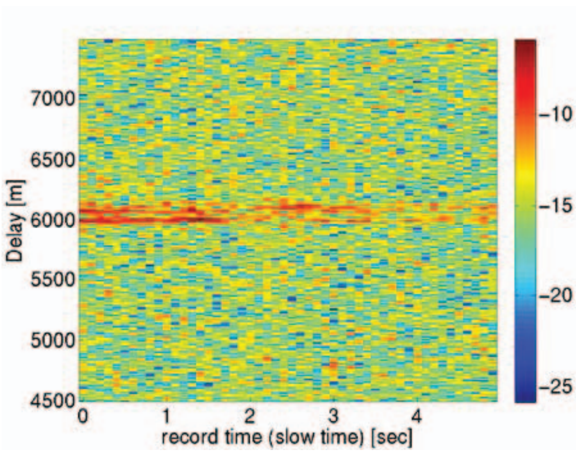
Fig.4 Geometry



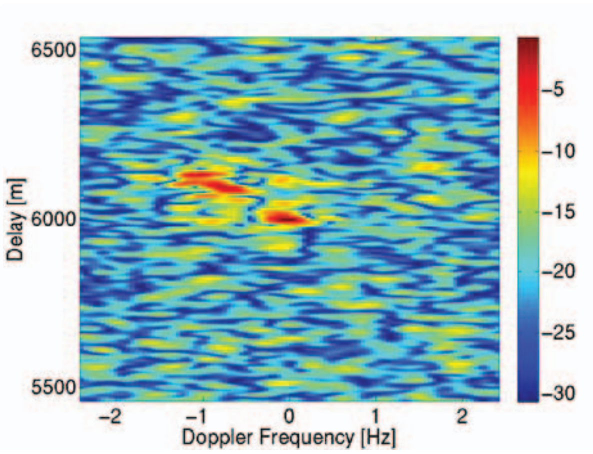
(a) Spectrum of the Digital TV signal



(b)range compressed signal



(c) range migration compensated signal



(d) ISAR image

Fig.5 Experimental results