A Study of Direction Finding Method for Passive Airport Surveillance Radar

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***Abstract*—The current Air Traffic Management (ATM) uses various radio equipment. The radar is the one of important system and the recent ATM uses a combination of several radar systems. However, the conventional Primary Surveillance Radar have a high cost of maintenance and operation. Recently, Multi-Static Primary Surveillance Radar (MSPSR) has attracted interest from the civil aviation research field. The MSPSR is classified into passive bistatic radar (PBR).**

In this paper, we discussed receiver side direction finding method (DF) for the passive PSR system. This method is required for MSPSR. We show the DF method based on interferometer and experimental results, and we discussed the potential of DF for the passive PSR system.

***Index Terms*—direction finding, passive radar system, interferometer**

I. Introduction

The current Air Traffic Management (ATM) uses various radio equipment. In particular, the radar is an important system for detecting the position of the aircraft. And the recent ATM system uses a combination of several radar systems. The Airport Surveillance Radar (ASR) is medium range surveillance radar used to control aircraft in the vicinity of an airport. In general, both a Primary Surveillance Radar (PSR) and a Secondary Surveillance Radar (SSR) are employed in the ASR [1], [2]. The SSR is mainly used in ATM of normal operation, but the PSR is important radar as an independent surveillance system of transponder. The conventional PSR is a transmitter unit combined with a receiver. The receiver can obtain transmitted time in advance, it easily computes the aircraft position by using the round-trip time of emitted signals. However, reflected waves from aircraft are too small, and high transmission power is required for detecting aircraft. It results in a high cost of maintenance and operation. Recently, Multi-Static Primary Surveillance Radar (MSPSR) has attracted interest from the civil aviation research field [3]. The MSPSR is classified into passive bi-static radar (PBR), and is worked by combining some transmitter or some receivers. The MSPSR system is to use not just the conventional PSR signals, but also other radio waves, such as digital terrestrial broadcasting, GNSS and cellar. From this, MSPSR have the possibility to reduce maintenance and operation cost of PSR system.

Electronic Navigation Research Institute (ENRI) started the feasibility study of the passive surveillance system to be conventional PSR enhancement. In this study, we have already succeeded the detecting aircraft target using the passive PSR receiver system. This PSR receiver processes reflected signals by synchronizing the PSR rotating cycle for signal direction finding, and it operates by computing delay time between direct wave and reflected waves. The distance from receiver to target is estimated by the elliptical positioning method. Therefore, the target position is calculated from the PSR beam angle and the elliptical range [4]. The synchronizing the PSR rotating cycle is an important function of prototype passive PSR receiver.

In this paper, we discussed receiver side direction finding (DF) method for passive PSR system. It is possible to calculate the target position just received signals without the PSR rotation information. Thus, it is required technique for the next step of the passive PSR system which use omni-direction transmitter signals. First, we show DF method based on interferometer technique and experimental results. Finally, we discuss the potential of the DF method for passive PSR system.

II. Direction Finding Using Interferometer

The principle of the interferometer direction finding technique is to calculate the phase difference between the EM waves received by a pair of spatially separated broadband antennas [5]. The simplest radio interferometer consists of two separate antennas. Let us consider two broadband separated horizontally above the ground with a distance d, as shown in Fig. 1. The received signal, which originates from a common source, by the antennas 1 and 2 are $r_1(t)$ and $r_2(t)$, respectively. These signals are digitized at time interval Δt

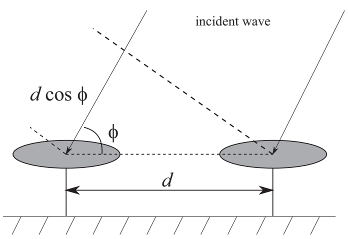

Fig. 1. The simplest radio interferometer. The angle of incidence against the baseline could be estimated.

and expressed following discrete time series.

$$r_i[m] = r_i(m\Delta t), (i = 1, 2; m = 0, 1, \cdots, N-1) \quad (1)$$

The discrete fourier transform is applied to r_i as,

$$R_i[m] = \sum_{n-0}^{N-1} r_i[n] \exp\left(-j\frac{2\pi mn}{N}\right), (i = 1, 2) \quad (2)$$

The phase difference (θ_{12}) signals r_1 and r_2 for each frequency components is given by

$$\theta_{12}[m] = \tan^{-1}\frac{\mathrm{Im}R_1[m]}{\mathrm{Re}R_1[m]} - \tan^{-1}\frac{\mathrm{Im}R_2[m]}{\mathrm{Re}R_2[m]} \quad (3)$$

The angle of incidence $\phi[m]$ defined in Fig. 1 can be interpreted with $\theta_{12}[m]$ by

$$\phi[m] = \cos^{-1}\frac{c\theta_{12}[m]}{2\pi f d} \quad (4)$$

where c is the speed of light in vacuum.

III. Experimental Results

We investigated electromagnetic environment in the Sendai airport area by using a PSR with 2.84 GHz. Figure 2 shows a field map around the Sendai airport. The Sendai airport is located in a rural area, and there are a terminal building and a control tower at the airport. Around the airport, the northern and western part is an agricultural area and the eastern part is the Pacific Ocean. In this experiment, we used biconical antennas with absolute gain 3.9dBi and waveform recorder which consists of NI PXIe-6553E. We installed these equipment at east end of the airport. We put biconical antennas with a separation of 1m on the experimental vehicle roof. And we were aligned antenna baseline with the direction of the PSR site.

Figure 3 shows the DF process of recorded data. The calculated signal is a short pulse of PSR. In this case, the PSR beam angle was directed to the airport terminal building. At first we calculated Fourier spectrum. Then the phase differences between antennas 1-2. The calculated phase differences include fringe ambiguity. Fig. 3 illustrated by pseudo phase differences in the high frequency with $\theta_{12} \pm 2\pi$. We can remove the ambiguity using the feature that the phase differences should be linear dependence with frequency. And the angles of incidence against the baseline for each Fourier component are calculated. From these calculations, the incident angle of PSR short pulse is estimated to $\sim$ 70 degrees, and this result is consistent with the experimental environments (Fig. 2).

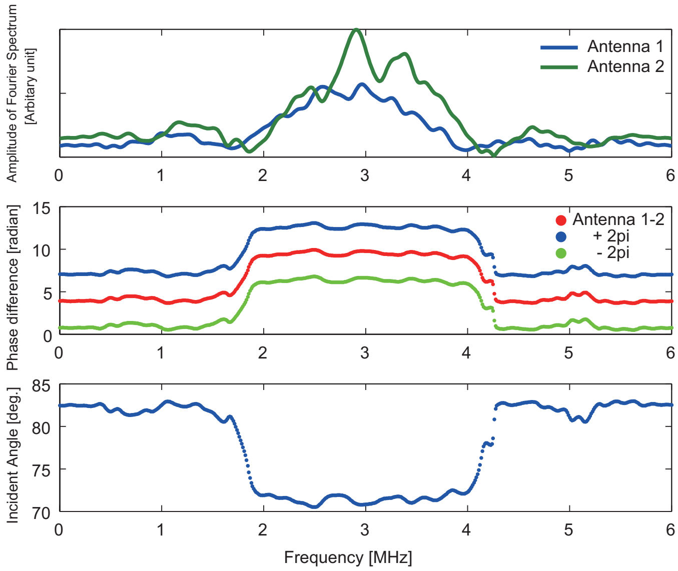

Fig. 3. DF process of Sendai airport experimental results. The amplitude, the phase differences and the angle of incidence for each Fourier component.

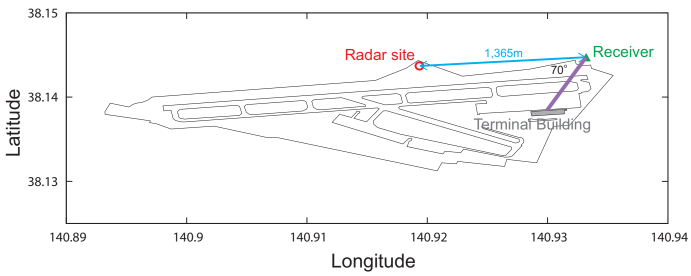

Fig. 2. Sendai Airport. Experimental environment.

IV. Summary

In this paper, we have shown that the DF using a reflected wave from the terminal building which have large RCS (Radar Cross Section) is possible. However the PSR system is detection radar of the aircraft whose RCS is smaller than a building, it is necessary to show the possibility of DF for a smaller object. The proposed DF method in this paper does not depend signal strength and detection accuracy. It uses the phase differences in frequency component. Is is important that they picked up a signal for DF calculation include the reflected wave from aircraft and the passive PSR system using the PSR rotation information have already developed[4]. From these results, a passive PSR system without the PSR information, is possible to calculate the object position. We would like to develop the independent new passive system of above information.

References

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