A Study of Passive Aircraft Surveillance Using Signal Delay Profile

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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.**

In this paper, we show the experimental results of aircraft positioning using signal delay profile and we describe the potential of the aircraft surveillance using our proposed method.

***Index Terms*—passive radar system, OFDM, multipath, signal delay**

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. The ASR is composed of a Primary Surveillance Radar (PSR) and a Secondary Surveillance Radar (SSR)[1], [2]. The PSR uses the reflection wave of the scanning signal by the radar system. The SSR treats 1090MHz reply signals with own altitude and ID transmitted from aircraft transponder after receiving 1030 MHz interrogation signal from ground station. The SSR is mainly used in ATM of normal operation. However, 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. Although 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] for reduce oprational and maintenance cost. 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 Television (DTTV), GNSS and cellar.

DTTV is the most expected signal for MSPSR because the transmitters signal is always present and their power is higher than others. Therefore, passive radar systems using DTTV have been intensely studied in the last few years. Various concepts and technologies have been developed and published by research institutions, universities and industries. They are almost discussed on the numerical simulations, and they have attention about how to eliminate unnecessary reflected signals for target ranging[4], [5], [6], [7].

In this paper, we discussed on the aircraft surveillance using the radio wave signal delay profile. We have investigated the scattered powers caused by aircraft using fast numerical simulation[8]. From this study, we have found that the scattered signal caused by aircraft can detected by the commercial antenna but the scattered signal power is very lower than the direct signal ($\sim$-30dB). Therefore, it is necessary to separate the scattered signal from the received wave and various methods were proposed for the scattered signal detection. In our study, we focused on the principle of digital communication system. Japanese DTTV has adopted ISDB-T (Integrated Services Digital Broadcasting - Terrestrial) which is broadcasting format of DTTV constituting the 13 OFDM (Orthogonal Frequency Division Multiplexing) segments transmission band. Consequently, it is easy to derive the received signal delay profiles. We show the experimental results of aircraft positioning using signal delay profile and we describe the potential of the aircraft surveillance using our proposed method.

II. Aircraft Positioning using Delay Profile

In this section, we describe a principle of target positioning using ISDB-T characteristics. Next, we explain some experimental results of target estimation using our proposed techniques.

A. Principle of Target Positioning by Delay Profile

Generally, the principle of PBR is based on the cross correlation of the direct signal from the transmitters using a dedicated channel with the collected signal that possibly includes target echoes by PBR main receiver. When a single bistatic couple is employed, the time difference of arrival (TDOA) provides the TDOA ellipsoid. The target location is calculated by with combining the TDOA ellipsoid of each bistatic couple. TDOA information is most important for the principle of PBR. Because the scattered signal from aircraft is very small, it is difficult for calculation of the cross correlation of the direct signal with the target echos. From this reason, we have focused on the characteristic of digital communication.

One of the characteristic of ISDB-T is a Guard Interval (GI) which is attached a portion of posterior effective symbol to signal heading. In Japanese DTTV, the length of GI is 1/8 effective symbol. Therefore, each signal length is 1008 μs with 126 μs GI length. The intention of GI is absorbing the interference of delayed signal by multipath. Consequently, the delayed signal are detected by using the characteristic of GI. We calculate each delayed signals following;

1) Searching signal head by auto correlation with a longer than the effective symbol length and finding carriers used to estimate the channel status
2) Defining the minimal FFT windows including as many signal delays as possible
3) Searching delayed signal peak and estimating the delay profile

The delay profile is enough information for calculating TDOA ellipsoid.

B. Experimental Results

Figure 1 presents the relative received power versus signal delay profile. Blue and Red line indicate the delay profile with and without moving target passed in front of receiver antenna respectively. We can find that the received power increases at about 8.4 μs. This delay signal is considered to be from the aircraft. We calculated the distance from the receiver to the target.

Figure 2 shows calculated results obtained by the PBR principle. In this figure, there are a source transmitter, a receiver an antenna direction and so on. A elliptical curve indicate a ranging calculated from signal delay with 8.4 μs. The aircraft position can be estimated by the intersection between the antenna direction and the ellipsoidal curve by the signal delay, because we used a directional antenna in this

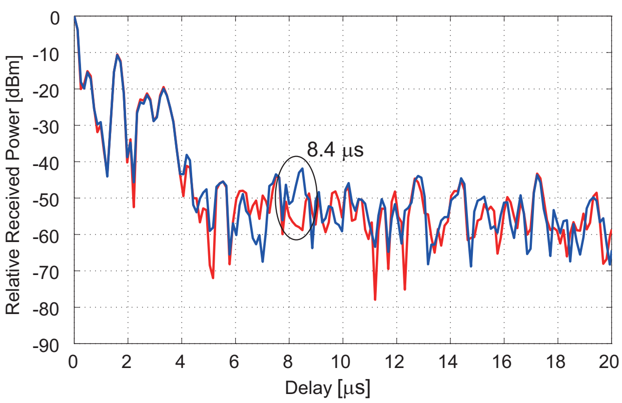

Fig. 1. Delay profile of collected ISDB-T signal in experiments near Sendai airport

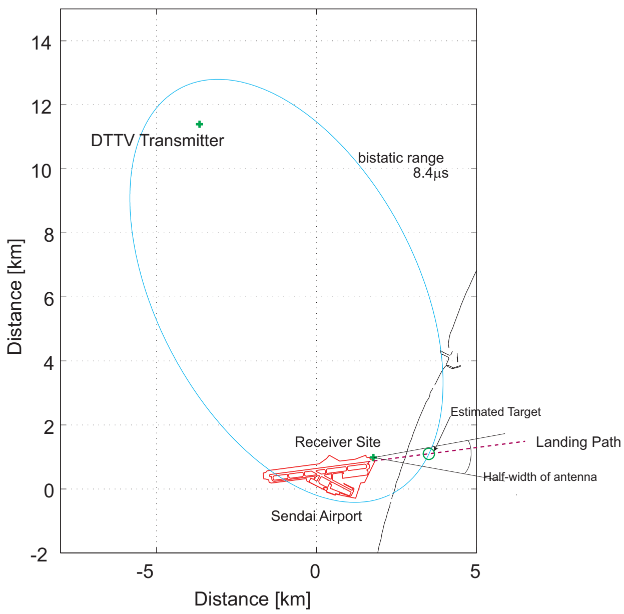

Fig. 2. Calculated aircraft position using delay profile of collected data

experiments. From these experimental results, we have found following:

1) The scattered signal from moving aircraft can be detected by the signal delay profile
2) The received delay signals can be separated by the principle of digital communication system.

III. Summary

In this paper, we have shown that the aircraft positioning by using ISDB-T signal delay profile. From our experimental results, we found that the configured system can detect the scattered wave from target aircraft which passed in front of our receiver antenna. We calculated the bistatic range and estimated the aircraft position using the delayed signals. These results was found that the proposed method have the ability to estimating the aircraft position. We would like to develop new multistatic radar applying these results. There will be our future works.

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