A Method for Eliminating False Detection Results in FM-radio-based Passive Bistatic Radar

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***Abstract*—When estimating the position and velocity of a target using an FM-radio-based passive bistatic radar (PBR), false detection results caused by sidelobes may appear due to the structure of the FM radio signal. Since such false detections can degrade the target detection performance of PBR, a sidelobe mitigation method is required. In this paper, we analyze the sidelobe generation pattern using the main channel of the FM radio signal and then propose an algorithm to remove the false detection results on the FDOA axis. Through the simulations, we verify the effectiveness of the proposed method.**

Keywords—Passive Bistatic Radar; Bistatic range; FDOA; Sidelobe;

I. INTRODUCTION

FM (frequency modulation) radio-based passive bistatic radar (PBR) is a passive radar that estimates the position and velocity of a target. PBR estimates target information by using a reference signal which is a received signal directly from the transmitter, and a target echo signal which is a reflected signal from the target [1]. PBR derives a cross-ambiguity function (CAF) with the reference signal and the target echo signal to estimates the position and velocity of the target by applying constant false alarm rate (CFAR) detection [2]. From the CFAR detection results, the bistatic range and frequency difference of arrival (FDOA) of the target can be estimated, and the position and velocity of the target are finally obtained from the estimated results [1].

However, due to the structure of the FM radio signal, several sidelobes may occur at the FDOA axis of the CAF, which yields false detection result as well as the detection result of the target. Since the false detection results degrade the target detection performance of the PBR, a method to eliminate the false detection results is required.

There have been research results for the elimination of false detections [3, 4]. Sidelobe mitigation method by mismatched filtering is using modified form of mismatched filtering algorithm to reduce the sidelobe level in CAF [3]. In this case, there is a disadvantage that the amplitude of the target as well as the sidelobe is reduced. Side peak identification (SPI) method uses property that sidelobes of the same bistatic range occur symmetrically in Doppler dimension [4]. However, this method cannot eliminate false detection results if detection results caused by sidelobes do not appear symmetrically in FDOA axis.

In this paper, a new false detection elimination method is proposed. The proposed method uses characteristics that sidelobes appearing in the CAF are located at the multiple of the harmonic frequency from the mainlobe on the FDOA axis. Therefore, if we estimate the harmonic frequency, we can separate the false detection results from the target detection result by grouping the detection results with the multiple of the FDOA interval equal to estimated harmonic frequency. By removing the separated false detection results, we can finally get the detection results without false detection.

II. FALSE DETECTION REMOVAL METHOD

In order to remove the false detection, we propose a PBR system as shown in Fig. 1. As shown in Fig. 1, the proposed method has two steps. The first step is to extract harmonic frequency from the main channel of the FM radio signal. The second step is to classify the detection results of each target into groups using the harmonic frequency extracted in step 1 and remove the false detection results by separating false detections from target detection result.

A. Harmony frequency extraction [4]

The FM radio signal is modulated by stereo modulation, which uses the sum and difference of the sound channels L and R (left and right). The main channel is generated from the sum of L and R, while the subchannel is defined by difference of L and R. A 19 kHz pilot signal can be also used to distinguish the main channel and subchannel when demodulating the FM stereo radio signal. The spectrum structure of this FM stereo radio signal is shown in Fig. 2.

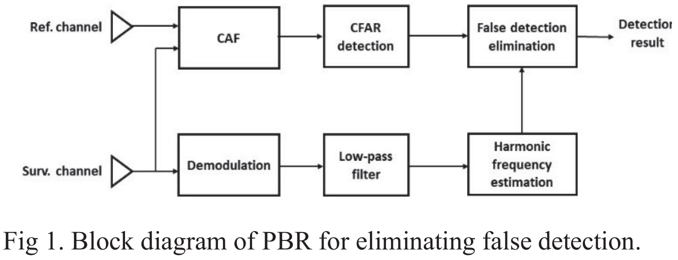

Fig 1. Block diagram of PBR for eliminating false detection.

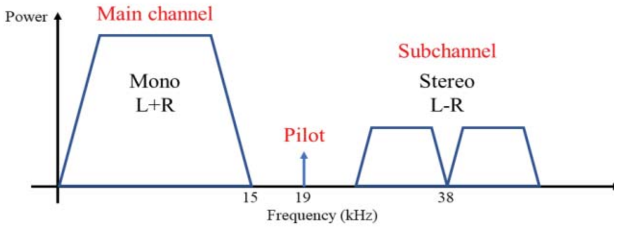

Fig 2. Spectrum of the stereo modulated FM radio signal.

The message signal of the FM stereo signal is written as

$$A(\tau) = 0.9 \times \{[L(\tau) + R(\tau)] + [L(\tau) - R(\tau)]\, cos(4\pi f_p \tau)\} + 0.1 \times cos\,(2\pi f_p \tau) \qquad (1)$$

where the pilot carrier frequency $f_p = 19$ kHz. Then, the baseband of FM stereo signal can be expressed as

$$S(t) = exp\left\{j2\pi k_f \int_0^t A(\tau)d\tau\right\}. \qquad (2)$$

Define $S_1(t) = \int_0^t L(\tau) + R(\tau)d\tau$, $S_2(\tau) = L(\tau) - R(\tau)$ and substitute Eq. (1) into Eq. (2), we get

$$\begin{aligned} S(t) &= exp\{j[m_1 S_1(t) + 9m_2 S_2(t)\, sin(4\pi f_p t) \\ &\quad + 2m_2\, sin(2\pi f_p t)]\} \\ &= exp\{jm_1 S_1(t)\} \times exp\{j9m_2 S_2(t)\, sin(4\pi f_p t)\} \\ &\quad \times exp\{j2m_2\, sin(2\pi f_p t)\} \qquad (3) \end{aligned}$$

where $m_1 = 1.8\pi k_f$ and $m_2 = 0.1 \times k_f/2f_p$.

The first, second, and third terms of Eq. (3) are created by the main channel, subchannel, and pilot, respectively. The detection result generated by the main channel is formed around the zero frequency, while the detection result generated by the subchannel and the pilot is repeated at f_p and $2f_p$, respectively. Since PBR generally estimates FDOA from -300 Hz to 300 Hz [5], only harmonic component included in main channel ($S_1(t)$) occurs as sidelobes in the FDOA axis. Therefore, the proposed method removes the false detection result after extracting the harmonic component of the main channel through YIN, a simple and efficient fundamental frequency estimation algorithm [6].

B. Grouping and removing detection result

The method to remove the false detection results on the FDOA axis is as follows:

1) Among the detection results of applying CFAR detection to the CAF, detection results located within grouping range from distance of harmonic frequency or multiple of harmonic frequency to the FDOA axis are classified in the same group.
2) In the same way, all detection results are grouped into the corresponding group.
3) Detection results are eliminated except those with the highest CAF power in the group.

The above method eliminates the false detection results formed around the target in the FDOA axis.

III. SIMULATION RESULTS

The sound sources listed in Table 1 were used to generate an FM stereo signal with a carrier frequency of 94.1 MHz. Target echo signal generated by reflection on two targets are used for simulation. The bistatic range of each target was set to 28.9 km and 59.5 km, and the FDOA was set to 34.7 Hz and -93.6 Hz. Grouping range was set to ±3 Hz. Fig. 3, 4, and 5 show the results of the simulation after generating the FM signal using the first sound source and setting the false alarm rate to 10^{-12}. Fig. 3 shows the spectrum of the main channel. As can be seen from the peak value of the spectrum, it can be clearly seen that the signal of the main channel has a harmonic component of 41.1 Hz. When YIN is applied to the main channel signal, the estimated fundamental frequency was 41.1 Hz, which is the same as peak value of the spectrum. Fig. 4 shows the results of applying CFAR detection to the CAF. Detection results of the sidelobes are appeared at the distance of harmonic frequency or a multiple of harmonic frequency from the target detection results. In Fig. 5, all of the false detection results were eliminated by using the harmonic frequency which was extracted from the main channel signal.

Fig. 6 shows the total number of detection results before and after removal using the sound sources as seen in Table 1. The simulations were conducted with an average of 100 times. There were 4 to 10 false detection results exist in the CFAR detection result. After applying the proposed method, most of the false detection results were eliminated.

Table 1. Sound sources used for simulation

Source No.	Artist - Title	Section (sec)
1	Coldplay – Everglow	4 ~ 5
2		5 ~ 6
3	Sia – Chandelier	1 ~ 2
4		12 ~ 13
5	Maroon 5 – Girls like you	14 ~ 15
6		37 ~ 38

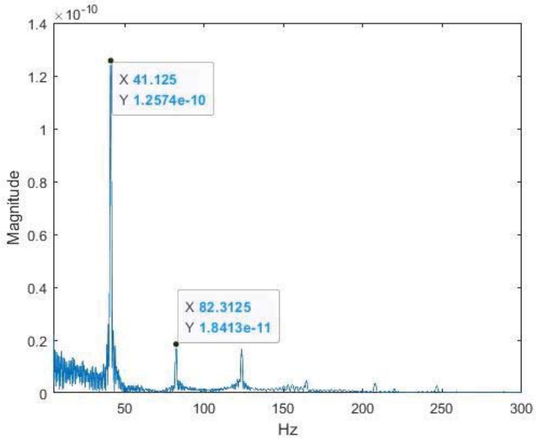

Fig 3. Spectrum of the received main channel signal.

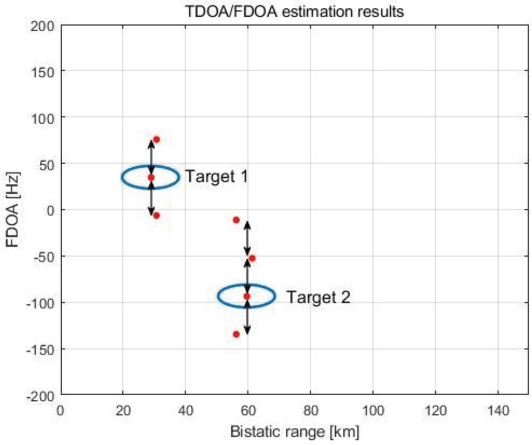

Fig 4. The result of applying CFAR detection to the CAF.

IV. CONCLUSION

In this paper, we proposed a new removing method of false detection results in FM-radio-based PBR systems and verified its performance through the simulations. The proposed method consists of the first step of estimating a harmonic frequency in the main channel of an FM radio signal and the second step of eliminating false detection results using the estimated harmonic frequency. It is expected that the proposed method can be effectively used to improve the target detection performance of the FM-radio-based PBR system.

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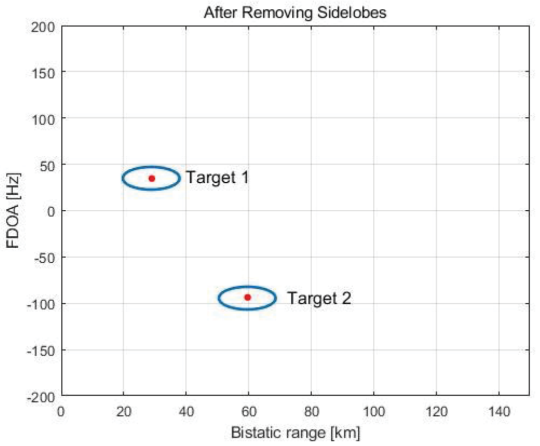

Fig 5. Detection result after eliminating false detections.

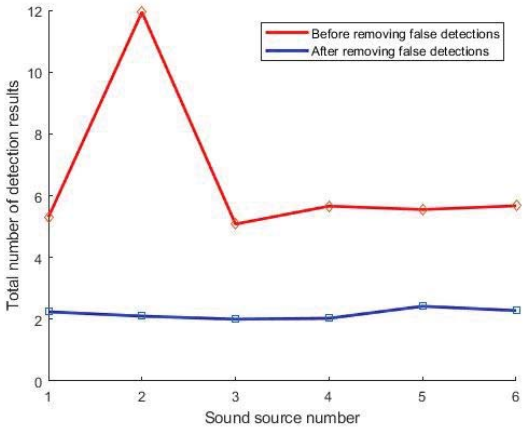

Fig 6. Comparison of the total number of detection results for different sound sources.

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