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Robust mismatched filtering algorithm for passive bistatic radar using worst-case performance optimization

Key words: Passive bistatic radar; Range sidelobes; Low signal-to-noise ratio; Mismatched filtering; Worst-case performance optimization

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Motivation

- The available broadcasters and communication transmissions in passive bistatic radar are not designed for radars, and the time-varying character of the signal results in high-level ambiguity range sidelobes. These sidelobes have influence on extracting the parameters of the target.
- The commonly used method for range sidelobes suppression is mismatched filtering. However, this method requires a high SNR reference signal. When a low SNR reference signal occurs, the performance of the mismatched filter degrades sharply.

Main idea

- By considering the error between the observed and the true reference signals, the optimal filter weights of the mismatched filter are obtained by minimizing the total energy of the range ambiguity sidelobes and the energy loss in the main lobe.
- Because the difference between the observed and the true reference signals is considered, range ambiguity sidelobe suppression can be achieved when a low SNR reference signal is given.

Method

1. Robust mismatched filtering algorithm

   New cost function:

$$\min_{w} \sum_{k} c\boldsymbol{w}^{\mathrm{H}}\boldsymbol{S}(k)\boldsymbol{S}^{\mathrm{H}}(k)\boldsymbol{w} \ \text{ s.t. } |\boldsymbol{w}^{\mathrm{H}}\boldsymbol{a}| \geq 1, \ \boldsymbol{a} \in \boldsymbol{A}(\varepsilon), \tag{13}$$

   Optimal solution:

$$\boldsymbol{w} = -\lambda\left[\sum_{k} c\boldsymbol{S}(k)\boldsymbol{S}^{\mathrm{H}}(k) - \lambda\boldsymbol{s}_{\mathrm{ref}}(k)\boldsymbol{s}_{\mathrm{ref}}^{\mathrm{H}}(k) + \lambda\varepsilon^{2}\boldsymbol{I}_{N}\right]^{-1}\boldsymbol{s}_{\mathrm{ref}}(k). \tag{24}$$

2. Experimental setup

Table 1 Simulation parameters of the three target echoes

Signal	SNR (dB)	Range (km)	Doppler frequency (Hz)
Target 1	−23	60.00	−192
Target 2	−30	90.00	166
Target 3	−15	26.25	243

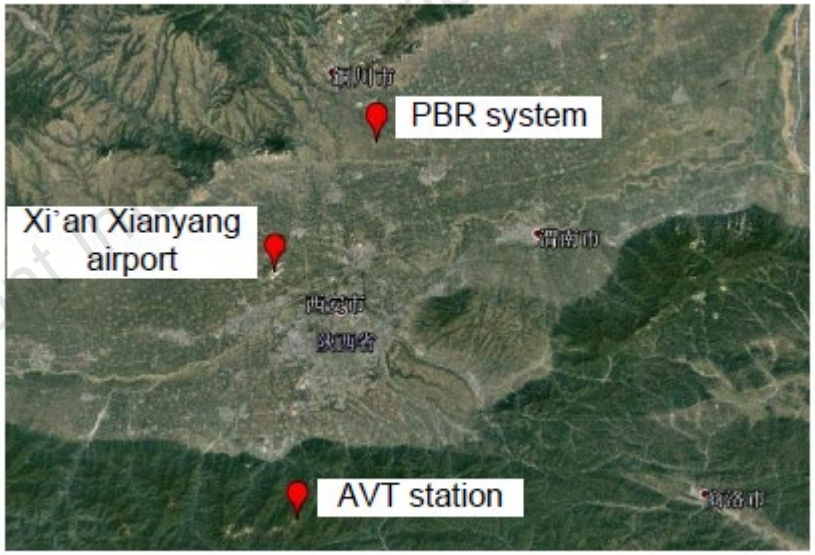
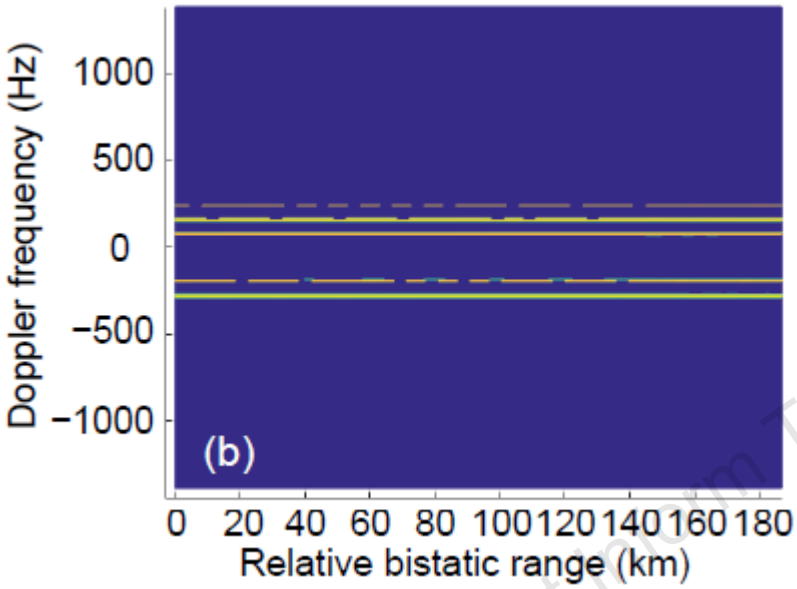
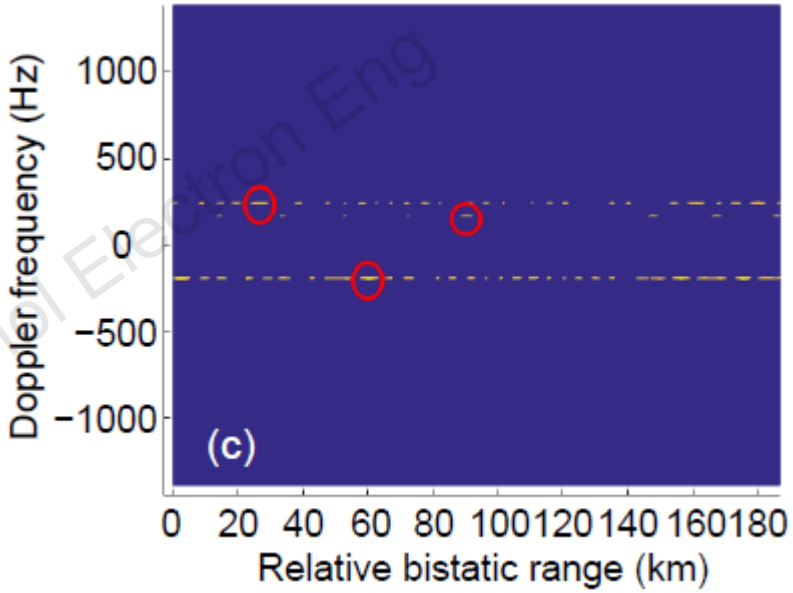


Fig. 8 Positions of the PBR system and ATV station

Major results (simulations)





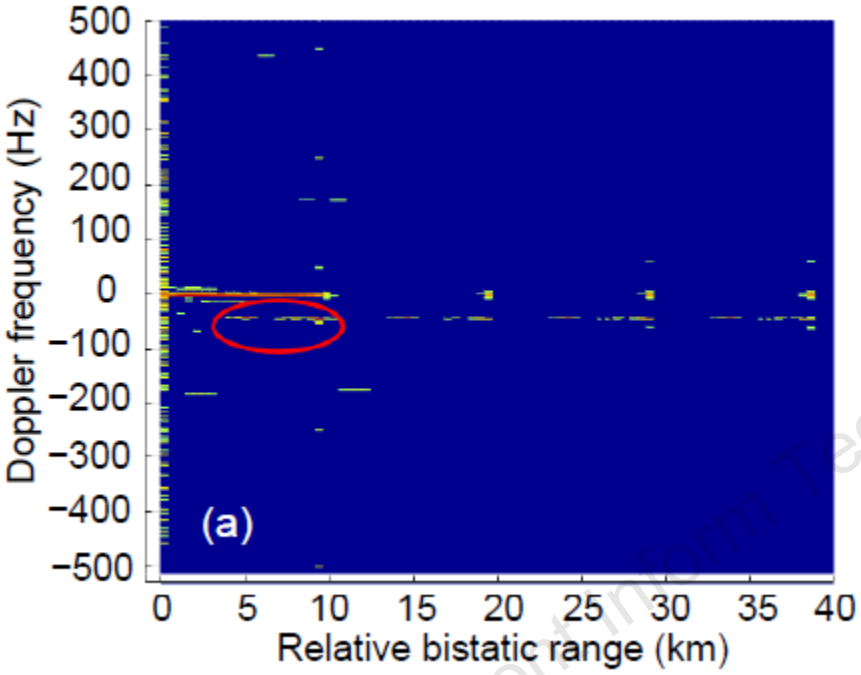
Original mismatched filtering algorithm

The main lobe of the targets cannot be distinguished by the original mismatched filtering algorithm due to the low energy level in the reference signal.

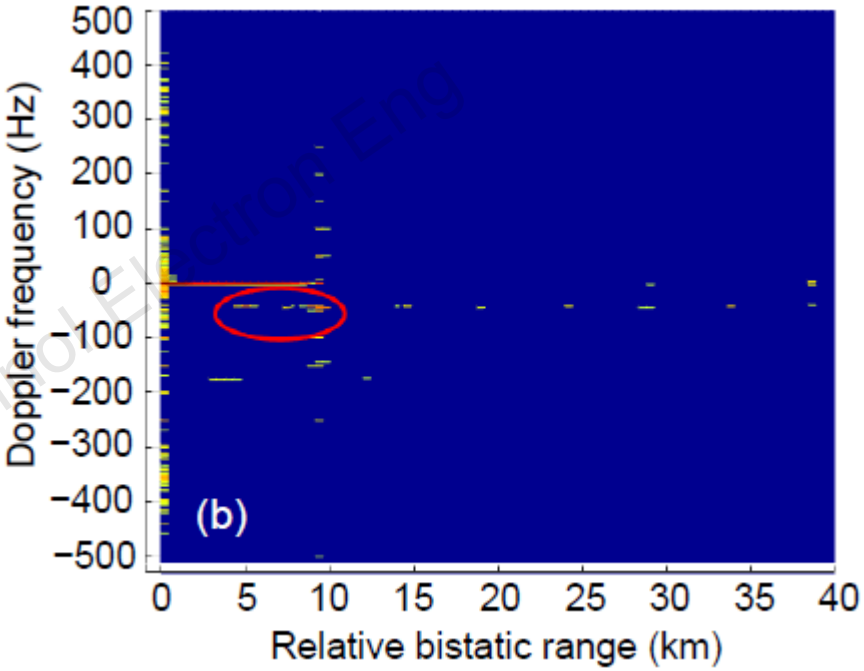
Robust mismatched filtering algorithm

The main lobe of the three simulated targets is distinguished by the robust mismatched filtering algorithm since the low SNR in the reference signal is considered.

Major results (real data)



Original mismatched filtering algorithm



Robust mismatched filtering algorithm

The outputs of the original mismatched filtering algorithm contain more ambiguity range sidelobes.

The ambiguity range sidelobes are better suppressed by applying the proposed mismatched filtering algorithm.

Conclusions

- Ambiguity sidelobes suppression problem in a PBR system is studied when a low SNR reference signal is given.
- Using worst-case performance optimization, the robust mismatched filter weights are acquired by minimizing the total energy of the ambiguity range sidelobes.
- Simulation results demonstrated that the proposed method has better sidelobes suppression performance when a low SNR reference signal is given.
- Application results based on continuous real data verified the effectiveness of the proposed mismatched filtering method.