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A lightweight clutter suppression algorithm for passive bistatic radar

Key words: Passive bistatic radar; Clutter suppression; Extensive cancellation algorithm; Computational complexity; Space complexity

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Motivation

In passive bistatic radar, the computational efficiency of clutter suppression algorithms remains low, due to continuous increases in bandwidth for potential illuminators of opportunity and the use of multi-source detection frameworks.

Main idea

1. The construction of the reference signal subspace matrix within the ECA framework is adjusted to simplify the computational aspects.
2. A dimension-expanding technique is introduced to streamline the clutter estimation.
3. Overall, the proposed method replaces the computation-intensive aspects of the original ECA with fast Fourier transform (FFT) and inverse FFT operations, and eliminates the construction of the memory-intensive signal subspace.

Method

We introduce a lightweight ECA called ECA-L. ECA-L works through circular convolutions and circular matrix processing, leveraging fast Fourier transforms (FFTs) and inverse FFTs (IFFTs) to fundamentally reshape the construction of reference subspaces and large-scale matrix computations. This transformation yields an order-of-magnitude reduction in both computational workload and storage space requirement compared to the traditional ECA, while retaining high performance.

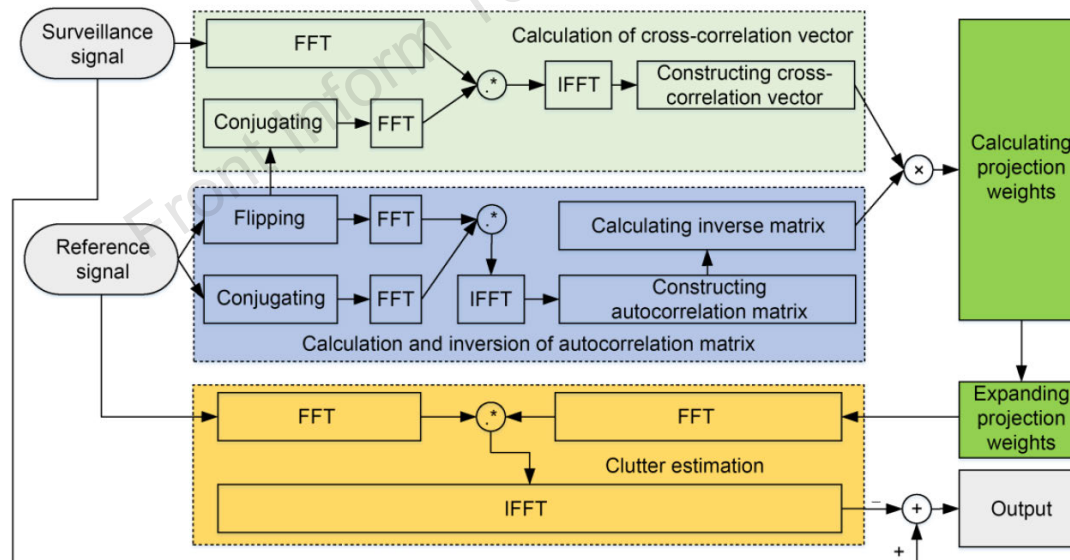


Fig. 2 Flowchart of the proposed ECA-L (FFT: fast Fourier transform; IFFT: inverse FFT)

Major results

- Comparison of clutter suppression performance of ECA, ECA-B (across different batches), and ECA-L based on simulation data

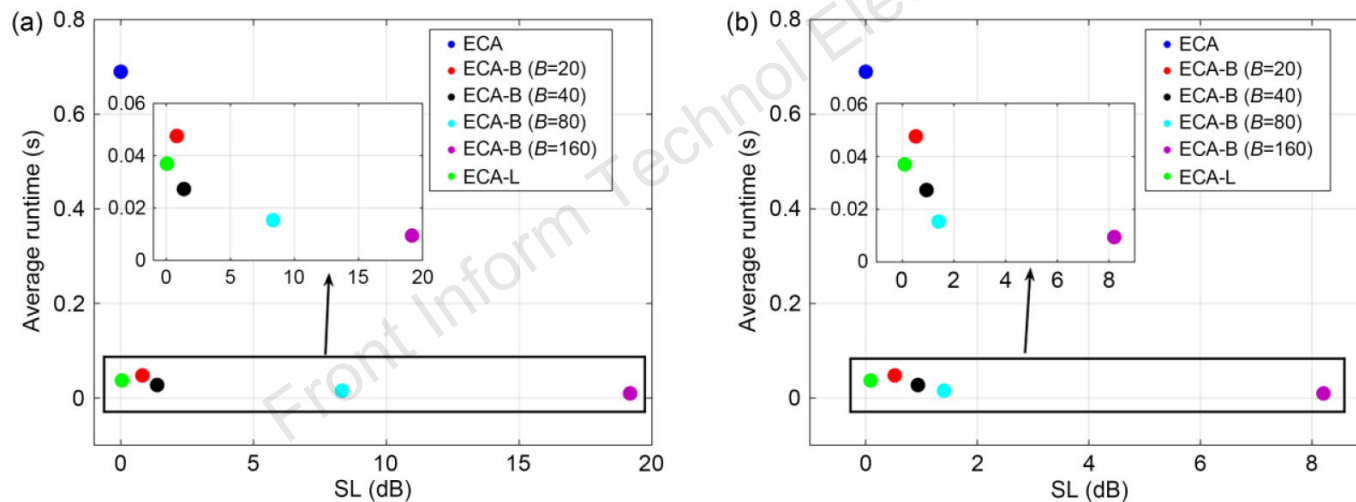


Fig. 4 Comparison of the signal-to-noise ratio loss (SL) of the two targets and average runtime for ECA, ECA-B, and ECA-L: (a) SLs of target A and average runtime for the three methods; (b) SLs of target B and average runtime for the three methods

Major results (Cont'd)

- Comparison of clutter suppression performance of ECA, ECA-B (across different batches), and ECA-L based on real data

Table 5 Comparison of average SL, average runtime, and allocated storage space for ECA, ECA-B, and ECA-L based on FM field data

Algorithm	Average SL (dB)	Average runtime (s)	Allocated storage space (MB)
ECA	0.00	1.122	660
ECA-B ($B=20$)	0.66	0.075	672
ECA-B ($B=40$)	0.96	0.039	685
ECA-B ($B=80$)	1.30	0.023	711
ECA-B ($B=160$)	2.36	0.015	762
ECA-L	0.01	0.067	50

SL: signal-to-noise ratio loss; FM: frequency modulation

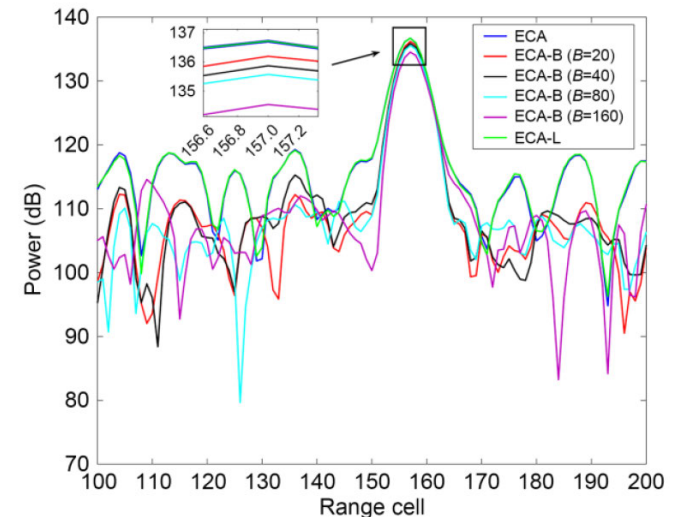


Fig. 7 Doppler dimensional profiles of the range-Doppler (RD) results of the strongest target for ECA, ECA-B, and ECA-L

Major results (Cont'd)

- Comparison of clutter suppression performance of ECA, ECA-B (across different batches), and ECA-L based on real data

Table 6 Comparison of SL, average runtime, and allocated storage space for ECA, ECA-B, and ECA-L based on DTMB field data

Algorithm	SL (dB)	Average runtime (s)	Allocated storage space (GB)
ECA	0	19.162	6.44
ECA-B ($B=20$)	3.49	0.719	6.57
ECA-B ($B=40$)	12.89	0.348	6.59
ECA-B ($B=80$)	23.89	0.184	6.63
ECA-B ($B=160$)	35.00	0.102	6.71
ECA-L	0	0.269	0.13

SL: signal-to-noise ratio loss; DTMB: digital television terrestrial multimedia broadcasting

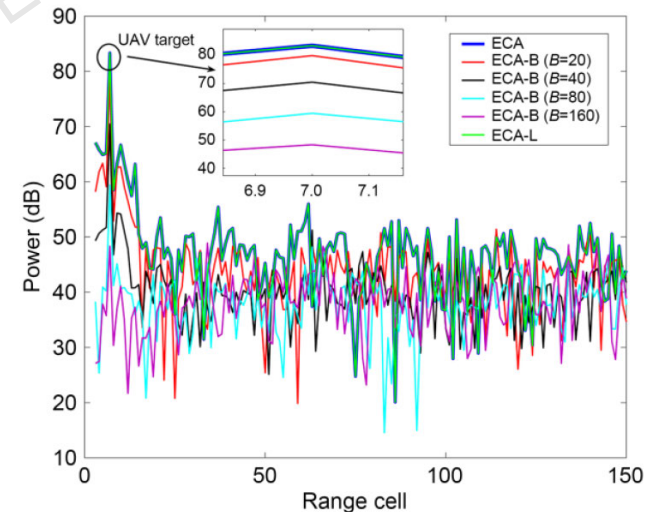


Fig. 8 Doppler dimensional profiles of the range-Doppler (RD) results of the UAV target for ECA, ECA-B, and ECA-L

Major results (Cont'd)

- Comparison of clutter suppression performance of ECA, ECA-B (across different batches), and ECA-L based on real data

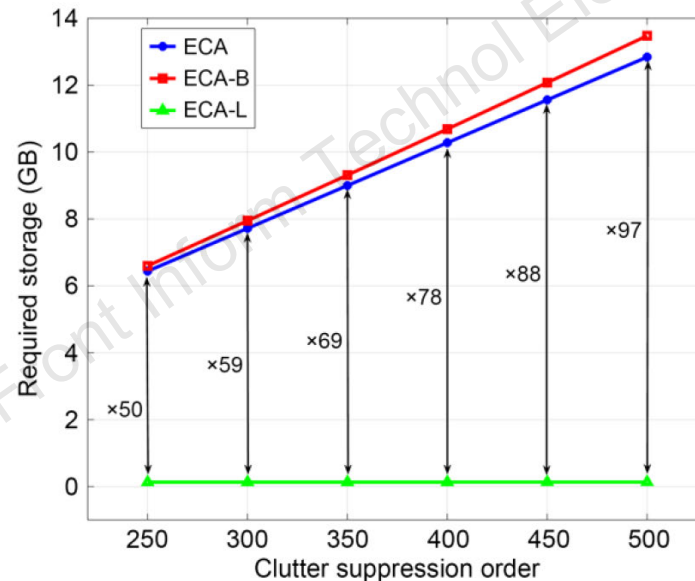


Fig. 9 Variations in storage resource requirements with clutter suppression order for ECA, ECA-B, and ECA-L

Conclusions

1. Differing from mainstream batch processing methods like ECA-B and its variants (which necessitate dividing the signal and reduce the accuracy), the proposed ECA-L streamlines computations through FFT and IFFT operations and eliminates the need to divide the signal. Additionally, it dispenses with the requirement for constructing the reference subspace.
2. ECA-L markedly improves computational efficiency compared to the traditional ECA, while maintaining comparable clutter suppression performance to ECA.
3. The effectiveness of the proposed method was validated through both simulation and field data results, providing a valuable demonstration of its utility for PBR applications.



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