Constant modulus waveform design for radar with Doppler tolerance based on local ambiguity function template matching

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Introduction

- The phase-coded signal has a large compression ratio, and is a pulse compression signal with a large time width and a large bandwidth. However, it has Doppler sensitivity. This problem not only seriously affects the target detection performance of radar, but also limits the application range of phase-coded waveform.
- Ambiguity function (AF) is a vital indicator to evaluate the performance of the transmit waveform in radar systems. Its volume invariance hinders the designed sequence from reaching the ideal state over the entire AF region.

Objective

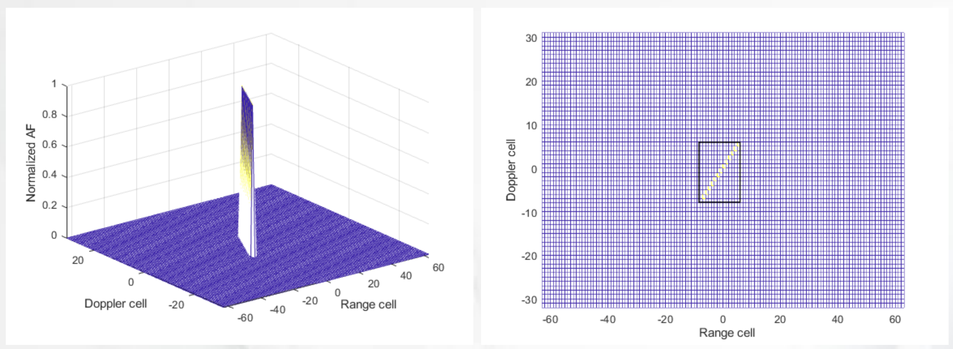
- Design the phase-coded waveform with Doppler tolerance.
- Design the AF over the range-Doppler bins of interest.

Method

- A method for designing the phase-coded waveform with Doppler tolerance under constant modulus (CM) constraint is considered.
- The variance between the ideal local ambiguity function (LAF) and the real one is used as the objective function to establish an optimization problem
- A template matching sequence optimization (TMSO) algorithm is proposed. By introducing an auxiliary variable, in each iteration, the original problem can be transformed into two subproblems with closed-form solutions.

Results

The expected results of locally optimized AF



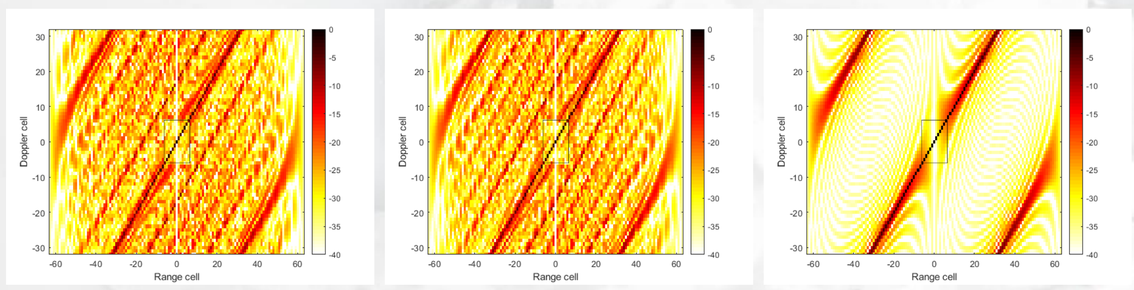
(a) (b)

Fig. 1. The expected results of locally optimized AF: (a)3D-AF; (b)2D-AF.

From Fig. 1:

1. In the region of interest, the ideal LAF exhibits a very narrow sloping ridge with a slope of 1, which has the advantage of Doppler tolerance.
2. In the following, the ideal LAF is exploited as a template to optimize the waveform so that the designed waveform has the ideal performance.

Performance comparison of different algorithms



(a) (b) (c)

Fig. 2. The AFs obtained by CIAFS algorithm, UniAFSIM algorithm and the proposed algorithm: (a) CIAFS; (b) UniAFSIM; (c) Proposed.

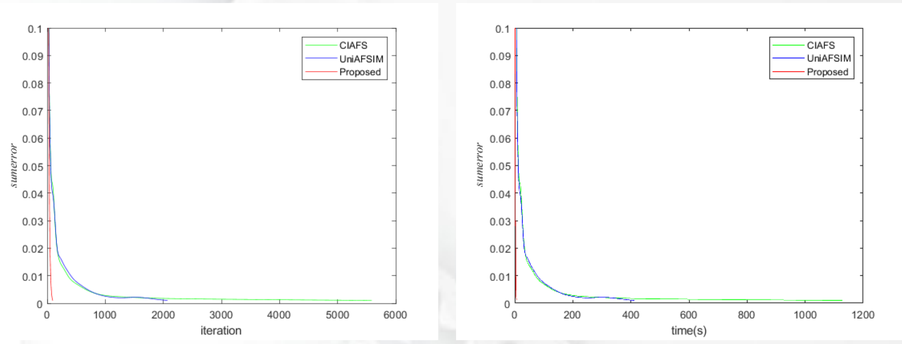
Table I
PERFORMANCE COMPARISON FOR DIFFERENT ALGORITHMS

	CIAFS	UniAFSIM	Proposed
PSL (dB)	-18.52	-19.44	-21.24
Lossmain (dB)	7.708	7.121	0.864

From Fig. 2 and Table I:

1. The AFs obtained by the three algorithms can all exhibit a sloping ridge shape similar to the template.
2. The AF obtained by the proposed algorithm has lower peak sidelobe level (PSL), smaller main lobe loss and more concentrated energy in the specified region.

Comparison of convergence rates of different algorithms



(a) (b)

Fig. 3. The relationship between the *sumerror* and the number of iterations, CPU running time: (a) The *sumerror* versus iterations; (b) The *sumerror* versus time.

Table II
CONVERGENCE SPEED COMPARISON FOR DIFFERENT ALGORITHMS

Algorithms	Iterations number	Runtime(s)	The minimum *sumerror*
CIAFS	5589	1130	9.999e-4
UniAFSIM	2072	412.8	9.991e-4
Proposed	96	6.102	9.665e-4

From Fig. 3 and Table II:

1. The time and number of iterations required by the proposed algorithm to achieve the same stop criterion are two orders of magnitude less than those of the CIAFS algorithm and the UniAFSIM algorithm.
2. The proposed algorithm has advantages in convergence speed compared with the reference algorithms, which is due to the alternate iteration of the two closed-form solutions in the proposed algorithm accelerates the convergence speed.

Conclusion

1. A method for designing waveform with Doppler tolerance based on template matching is proposed.
2. The minimization problem is established by using the variance between the LAF and the template as the objective function and imposing CM constraint.
3. To solve the established non-convex quartic problem, a TMSO algorithm is proposed.
4. Simulation experiments show that the waveform designed by this method is Doppler tolerant, and the execution efficiency is superior to the existing algorithms.

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