Space-time adaptive FIR filtering with staggered PRI

Space-Time Adaptive FIR filtering with staggered PRI

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Principle of STAP

clutter spectrum  temporal filter  spatial filter  STAP

Doppler-azimuth spectrum

space-time clutter filter

fast target

slow target

inverse spatial clutter filter

inverse temporal clutter filter

stop band

clutter notch

\cos \phi

\textbf{Principle of STAP}
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The optimum processor

\[ w = \alpha Q^{-1} s(\varphi, \nu) \]

- \( Q \) space-time clutter+noise covariance matrix
- \( s \) space-time steering vector

For large dimensions \( N,M \) not realizable by various reasons (amount of computations, lack of training data, accuracy)
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Azimuth-Doppler Characteristics of a STAP Filter for Sidelooking Array
Subspace STAP techniques

- Space-time transforms (e.g. GSC concepts)
- Spatial transforms (reduction in the spatial dimension)
- FIR filters (reduction in the temporal dimension, => very efficient solution)
- Multi-stage filters
- Frequency dependent spatial processing (for large CPI only)
- Angle-Doppler subgroups (e.g. JDL-GLRT)
- others
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Overlapping subarray processor with space-time FIR filter
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\[
Q = \begin{pmatrix}
Q_{11} & Q_{12} & \cdots & Q_{1M} \\
Q_{21} & Q_{22} & \cdots & Q_{2M} \\
\vdots & \vdots & \ddots & \vdots \\
Q_{M1} & Q_{M2} & \cdots & Q_{MM}
\end{pmatrix}
\]

The space-time clutter+noise covariance matrix

\[
K = Q^{-1} = \begin{pmatrix}
K_{11} & K_{12} & \cdots & K_{1M} \\
K_{21} & K_{22} & \cdots & K_{2M} \\
\vdots & \vdots & \ddots & \vdots \\
K_{M1} & K_{M2} & \cdots & K_{MM}
\end{pmatrix}
\]
and its inverse
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\[ K = Q^{-1} = \begin{pmatrix}
K_{11} & K_{12} & \cdots & K_{1L} \\
K_{21} & K_{22} & \cdots & K_{2L} \\
\vdots & \vdots & \ddots & \vdots \\
K_{L1} & K_{L2} & \cdots & K_{LL}
\end{pmatrix} \]

The north-west \( NL \times NL \) submatrix
\((N \text{ number of antenna elements, } L \text{ temporal filter length})\)

\[ \tilde{K} = \begin{pmatrix}
K_{11} \\
K_{21} \\
\vdots \\
K_{L1}
\end{pmatrix} \]

The LS FIR filter matrix (1. Block column of inverse)

\[ h = \tilde{K}b \]

Further reduction: beamforming
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Fully adaptive processing, constant PRI

FIR filter, 5 taps, constant PRI
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Properties of staggered PRI

- Avoidance of multiple clutter notches (blind velocities)
- Unambiguous target Doppler estimates
- Resistance against spot jammers
- However: no FFT for Doppler filter bank
Matrix scheme for space-time FIR filtering
(K=4, M=5, L=3)
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a. optimum processing, **no staggering**, Nyquist sampling in space & time
b. optimum processor, **staggered PRI**
c. fixed ST FIR filter, **staggered PRI**
d. STAP FIR filter with **variable coefficients**
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Summary

- **Staggered PRI**: avoiding blind velocities (ambiguous) clutter notches, unambiguous estimation of target Doppler, resistance against spot jammers

- The **optimum (LR) STAP processor** can cope with staggered PRI

- The **STAP FIR filter** is a most efficient tool for real-time clutter rejection

- **FIR filters with constant coefficients** are mismatched to staggered echo sequences

- **FIR filters with varying coefficients** (readaptation at every PRI)

- **Loss** compared with constant FIR filter and constant PRI: a few dB