A Distributed MIMO Radar with Joint Optimal Transmit and Receive Signal Combining

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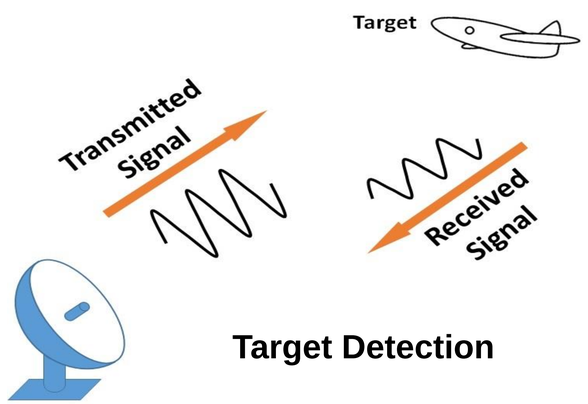
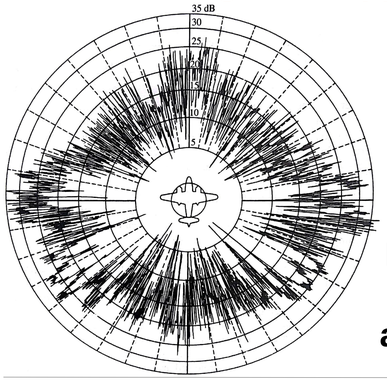
Introduction



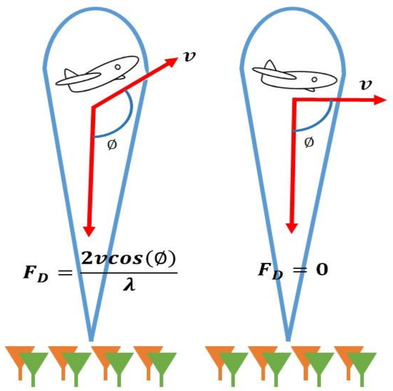
Target Detection

 # Phased Array – Drawbacks
RCS Fading and Doppler Null



B-26 Bomber

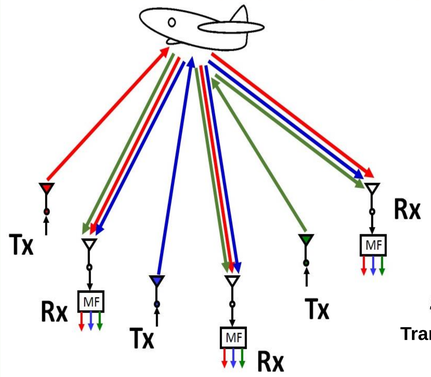
RCS greatly varies with aspect angle



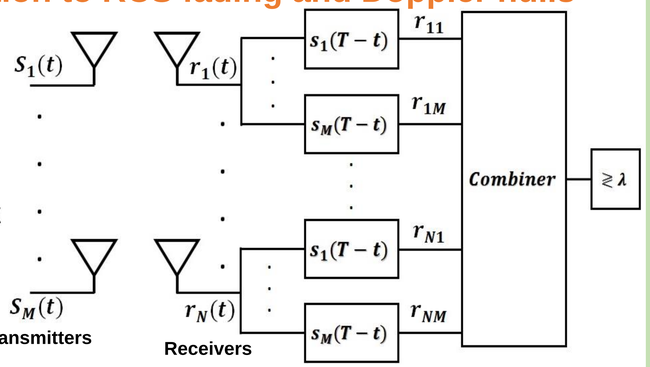
Lack of Doppler: targets moving orthogonal to signal illuminated

MIMO Radar

 # MIMO radar as solution to RCS fading and Doppler nulls



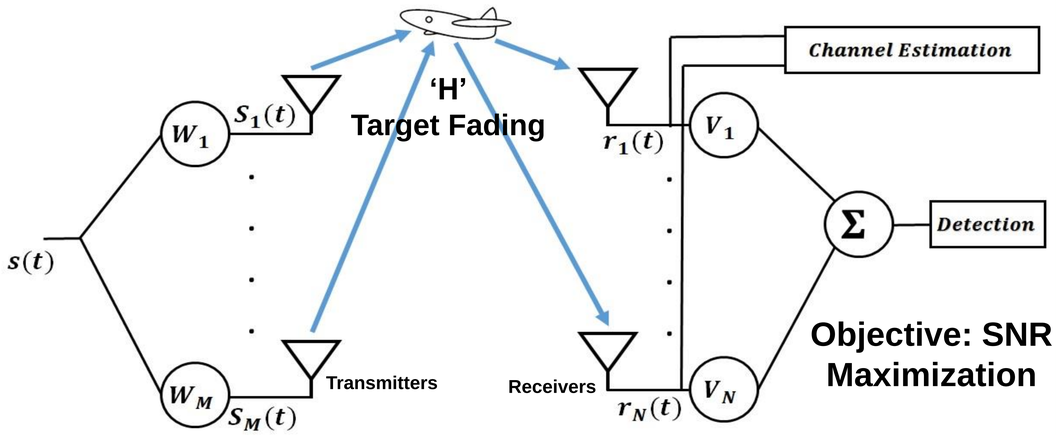
Antenna placement in MIMO radar



MIMO radar block diagram

 # Significant SNR losses in existing combining methods

Proposed Method



Objective: SNR Maximization

Signal model $r(t) = v^{\dagger}\mathbf{H}ws(t-T) + v^{\dagger}n(t)$

SNR maximization $\mathbf{SNR} = \frac{\mathbf{E}\left[\left|v^{\dagger}\mathbf{H}ws(t-T)\right|^2\right]}{\mathbf{E}\left[\left|v^{\dagger}n(t)\right|^2\right]}, \|w\|^2 \le 1, \|v\|^2 \le 1$

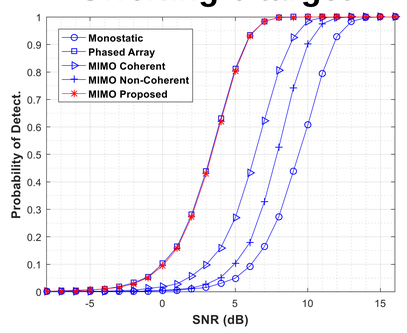
Solution from Lagrange Multiplier w **is** $P\{\mathbf{H}^{\dagger}\mathbf{H}\}$ **and** v **is** $\frac{\mathbf{Hw}}{\|\mathbf{Hw}\|}$

 # Requires the knowledge of Target fading matrix: Estimation

System	Monostatic	PAR	MIMOC	MIMONC	Proposed
SNR	$\frac{E}{\sigma_n^2}$	$MN\frac{E}{\sigma_n^2}$	$N\frac{E}{\sigma_n^2}$	$< N\frac{E}{\sigma_n^2}$	$MN\frac{E}{\sigma_n^2}$

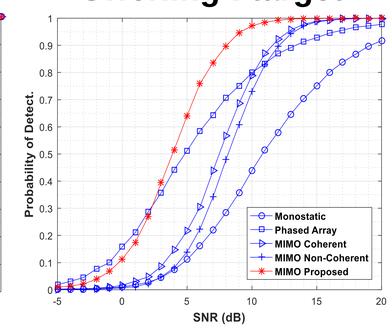
Results

Swerling-0 target



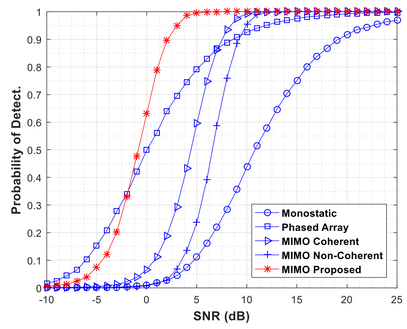
Proposed MIMO: 6dB SNR improvement as PA

Swerling-I target



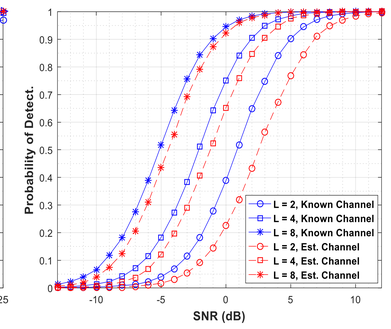
Proposed MIMO: 3.5dB improvement
Outperform phased-array radar at high SNR

3 x 4 System



Proposed MIMO: 5.75dB SNR improvement with increased antennas

With LS Channel Est.



Proposed MIMO: an SNR loss of 1.87 dB, 0.98 dB and 0.61 dB approximately for L = 2, 4, 8 respectively

Conclusions

- The proposed scheme yielding much better result than the existing MIMO radar schemes
- The proposed scheme performs the same as the ideal phased-array radar in case of the non-fluctuating target and performs better than phased-array radar at high SNR in case of fluctuating target
- Approaches optimality with channel estimation
- Future work: moving target detection, tracking, etc.

Publications:

1. A Distributed MIMO Radar with Joint Optimal Transmit and Receive Signal Combining, IEEE Transactions on Aerospace and Electronics Systems (under review).
2. A Study on the Performance of Distributed Phased Array Radar, SPCOM 2020, IISc Bangalore (submitted).

References:

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2. J. Li and P. Stoica, MIMO as a Distributed Radar System. IEEE, 2009.
3. E. Fishler, A. Haimovich, R. S. Blum, L. J. Cimini, D. Chizhik, and R. A. Valenzuela, "Spatial diversity in radars—models and detection performance," IEEE Transactions on Signal Processing, vol. 54, no. 3, pp. 823–838, March 2006.
4. F. Daum and J. Huang, "Mimo radar: Snake oil or good idea?" in 2009 International Waveform Diversity and Design Conference, Feb 2009, pp. 113–117.
5. J. Li and P. Stoica, "The phased array is the maximum snr active array [lecture notes]," IEEE Signal Processing Magazine, vol. 27, no. 2, pp. 143–144, March 2010.