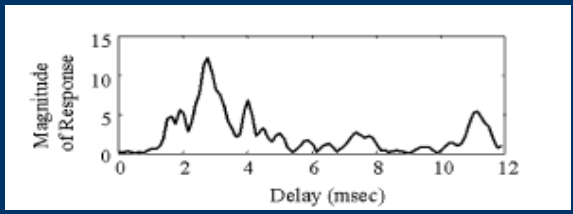
Leveraging Advance Sonar Processing Techniques for Underwater Acoustic Multi-Input Multi-Output Communications

Brian Stein
University of Texas Austin

Problem Statement

- High rate underwater acoustic (UWA) communication difficult to achieve



- low propagation speed (1500m/s)
- constrained bandwidth (~1MHz)

- *Solution*: spatial diversity
  - MIMO: capacity increase with number of antennas
  - Sonar arrays

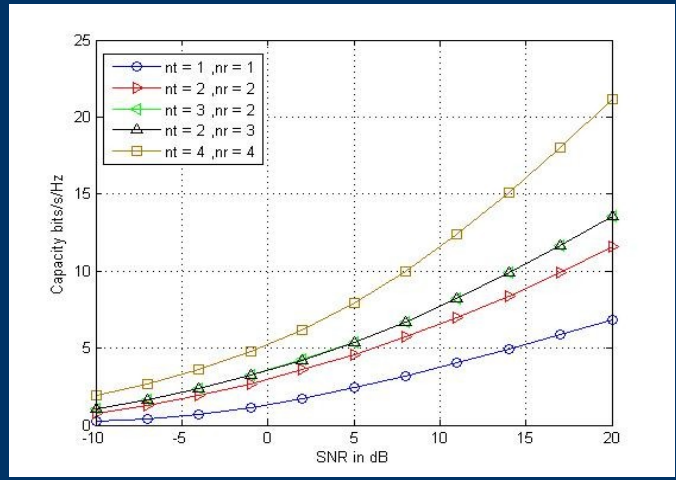


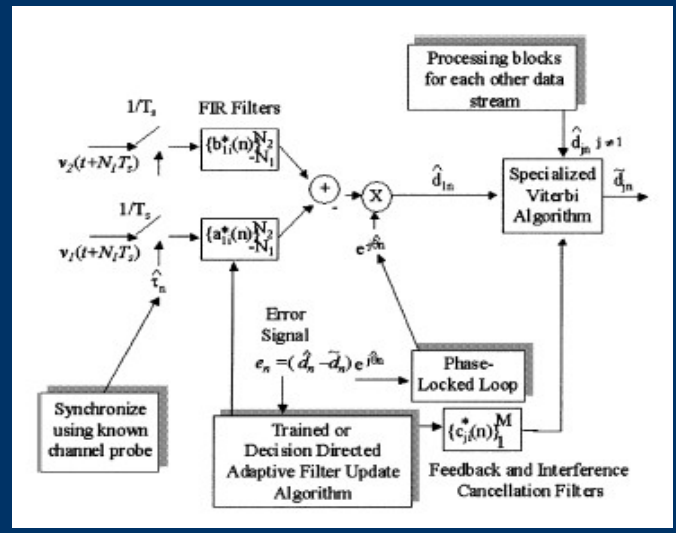
Fig. 1. Theoretical relationship between SNR, number of antennas and capacity.

Key Paper #1 [Kilfoyle et al, 2005]

- Experimental investigation of MIMO in the UWA channel that quantified
  - Improved SNR
  - Increased capacity

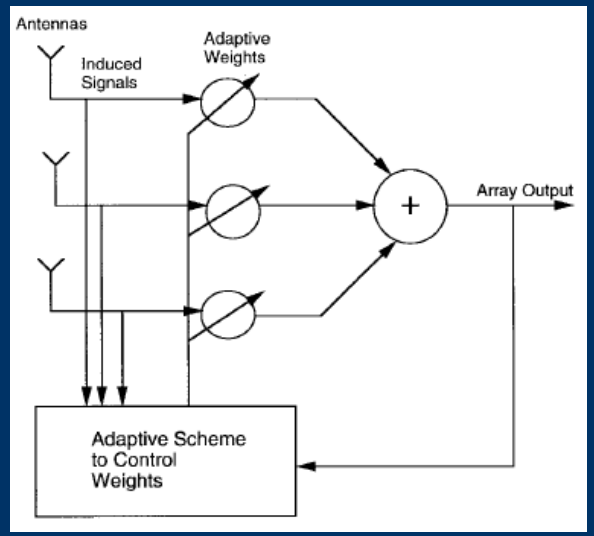
	Sub-Array A bits/sec/Hz	Sub-Array B bits/sec/Hz	SVD-narrowband bits/sec/Hz	SVD-broadband bits/sec/Hz
Conventional	6.7	6.6	6.8	7.0
2 Parallel Channels	9.9	9.5	8.7	8.8
3 Parallel Channels	12.0	11.2	11.4	9.8

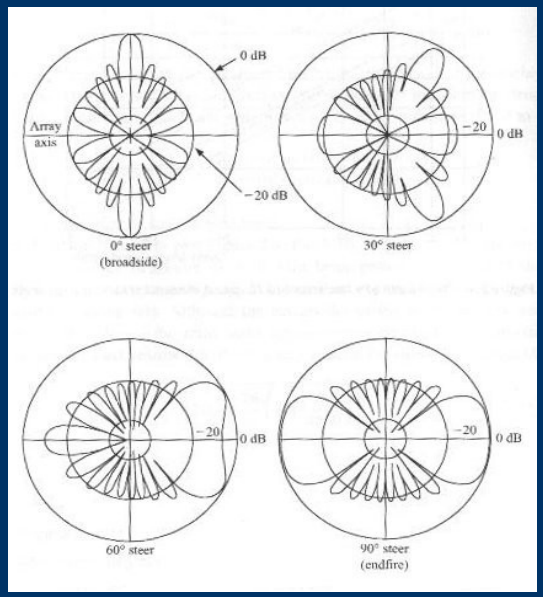
	Sub-Array A SNR (dB)	Sub-Array B SNR (dB)	SVD-narrowband SNR (dB)	SVD-broadband SNR (dB)
Conventional	20.0	19.9	20.3	20.9
2 Parallel Channels	14.2/15.2	13.8/14.4	12.7/13.2	13.9/12.1
3 Parallel Channels	12.4/12.0/10.8	11.2/10.6/10.8	10.5/11.1/11.8	9.9/9.2/8.8



Key Paper #2 [Godara 1997]

- Use of antenna arrays
  - Improved spectrum efficiency
  - Increased channel capacity
  - Extended range coverage
  - Steer beams/nulls toward targets

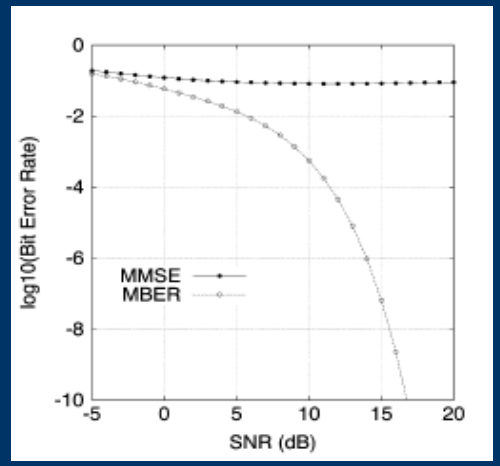


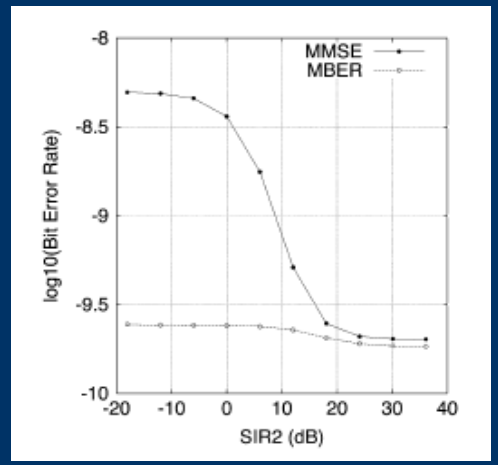


- Array processing techniques with application to wireless comm.
  - *Beamforming*
  - *Null Steering*
  - *Optimal Combining*

Key Paper #3 [Chen et al, 2005]

- Propose an adaptive beamformer for improved communications
  - Bit-error rate (BER) minimization
  - Significant BER improvement over minimum mean-square error





Combining Approaches

- MIMO seeks to utilize multiple, resolvable propagation paths to create parallel communication channels
  - Spatial array filtering provides intuitive solution
    - Eliminate the need for lengthy equalizers
    - Constrain signal power in direction of receiver
- *Future research*
  - Development of receiver architecture
  - Comparison with traditional MIMO system

References

[1] D. B. Kilfoyle, J. C. Preisig, and A. B. Baggeroer, "Spatial modulation experiments in the underwater acoustic channel," *IEEE Journal of Oceanic Engineering*, vol. 30, pp. 406–415, Apr. 2005.

[2] L. C. Godara, "Application of antenna arrays to mobile communications, part I: beamforming and direction-of-arrival considerations," in *Proc. of the IEEE*, vol. 85, pp. 1031–1060, July 1997.

[3] L. C. Godara, "Application of antenna arrays to mobile communications, part II: beamforming and direction-of-arrival considerations," in *Proc. of the IEEE*, vol. 85, pp. 1195–1245, Aug. 1997.

[4] S. Chen, N. N. Ahmad, and L. Hanzo, "Adaptive minimum bit-error rate beamforming," *IEEE Trans. on Wireless Communications*, vol. 4, pp. 341–348, Mar. 2005.

[5] D. B. Kilfoyle and A. B. Baggeroer, "The state of the art in underwater acoustic telemetry," *IEEE Journal of Oceanic Engineering*, vol. 25, pp. 4–27, Jan. 2000.

[6] M. Stojanovic, "Underwater wireless communications: Current achievements and research challenges," *IEEE Journal of Oceanic Engineering Society Newsletter*, pp. 10–13, Spring 2006.