Creating Diversity in 5G via Beam Pattern Jittering

Real Time Signal Processing Challenges for Massive MIMO SDR

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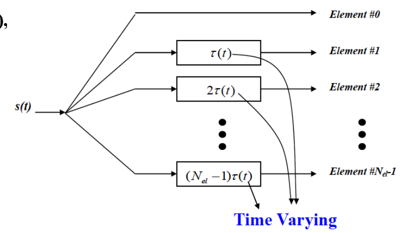
Goals:

- Enhance capacity (*numbers of users or throughput*),
- Increase QoS (probability-of-error performance),
- Reduced Cost

A merger of Directionality AND Transmit Diversity



HOW? Adaptive Antenna Arrays at the BS:

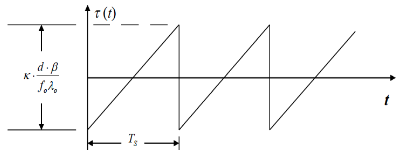
(1) **Proper Phase shifts** ➡ *Directionality* (Spatial Multiplexing)

➡ **Higher Capacity**

(2) ***Moving beam pattern*** ➡ ***Transmit*** *Diversity* (Induced Time Diversity)

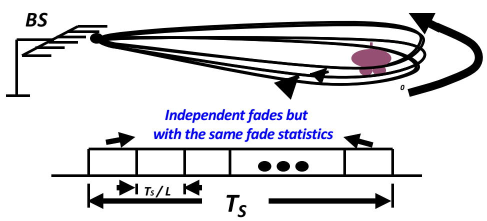
➡ *Improved probability-of-error performance*

(3) ***Low Cost***: *Complexity remains at the BS, Low MS Complexity*

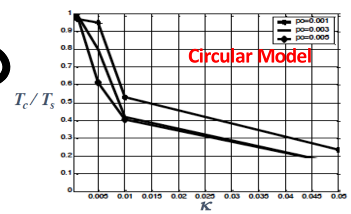


Examples of Beam Pattern Movement:

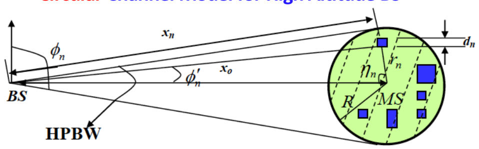
Beam Pattern Oscillation; Beam Pattern Beating



BS-MS distance=500 m, HPBW=28 deg.



Circular Channel Model for High Altitude BS



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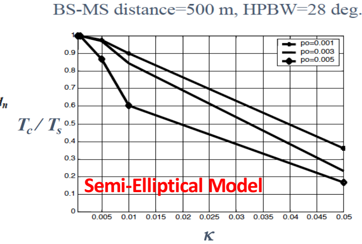
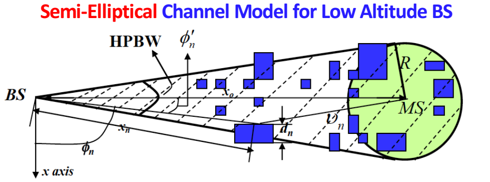


Semi-Elliptical Channel Model for Low Altitude BS



$$h(t,\tau)=\sum_{n=1}^{N(t)}\alpha_n(t)\cdot e^{j\theta_n'(t,\phi_n)}\cdot\delta(\tau-\tau_n)$$

1. HPBW ∈ [0.1rad , 0.5 rad]. $6°$, $28°$

2. $\rho_o \in [1, 5]$ scatterers $/1000m^2$

The control parameter $\kappa \in [\,0.0005\,,\,0.05\,]$:

Antenna pattern movement between 0.05% to 5% of its HPBW.

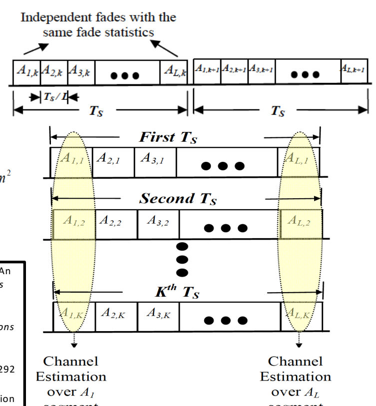
S. A. Zekavat, and C. R. Nassar, "Transmit diversity via oscillating beam pattern adaptive antennas: An evaluation using geometric-based stochastic circular-scenario channel modeling," *IEEE Transactions on Wireless Communications,* vol. 4, no. 3, pp. 1134-1141, July 2004.

S. A. Zekavat, C. R. Nassar and S. Shattil, "Merging multi-carrier CDMA and oscillating-beam smart antenna arrays: Exploiting directionality, transmit diversity and frequency diversity," *IEEE Transactions on communications,* vol. 52, no. 1, pp. 110 – 119, Jan. 2004.

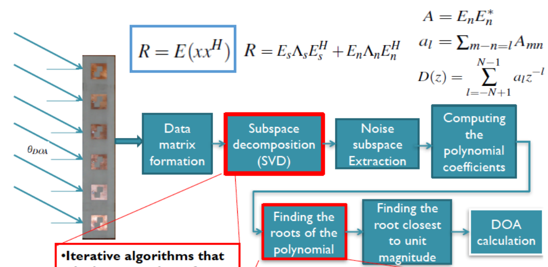
S. A. Zekavat, C. R. Nassar, "Power-azimuth-spectrum modeling for antenna array systems: A geometric-based approach," *IEEE Transactions on Antennas and Propagation*, vol. 51, no. 12, pp. 3292 – 3294, Dec. 2003.

S. A. Zekavat, and C. R. Nassar, "Smart antenna arrays with oscillating beam patterns: Characterization of transmit diversity using semi-elliptic-coverage geometric-based stochastic channel modeling," *IEEE Transactions on Communications*, vol. 50, no. 10, pp. 1549-1556, Oct. 2002.

$A_{l,k}$: The l^{th} time segment within k^{th} symbol time duration. In these segments independent fades are experienced due to BPS.



Real-time implementation of root-MUSIC



- Iterative algorithms that take large number of iterations
- Only offline processing possible for large matrix sizes
- Lack of modular, extendable design for SVD

- Computationally complex
- Absence of simple parallel algorithms
- Lack of modular, extendable design for polynomial rooting

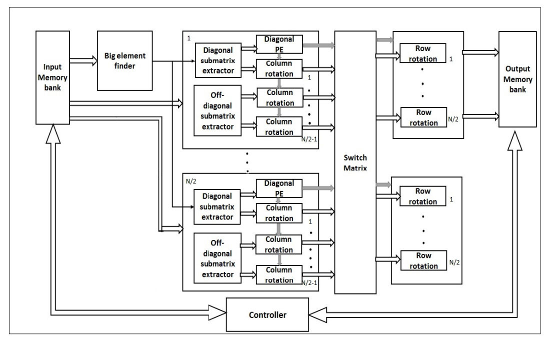
Brent-Luk-Van (BLV) SVD:

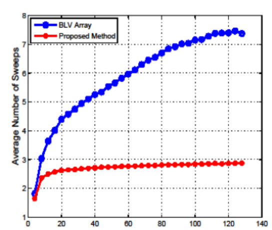
Special purpose CORDIC algorithm → computation reduction → FPGA Implementation

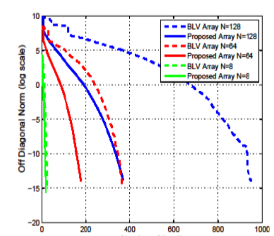
Not Suitable for Large Matrices

Proposed SVD:

- In each iteration target the biggest element and few other big elements
- These set of four big elements need to be row and column exclusive
- No exchange of data between iterations is required.
- We term this as "dynamic ordering" unlike Jacobi methods which follow predefined "fixed ordering"



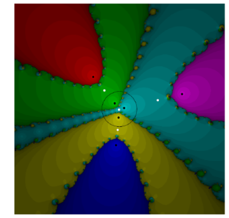




Improvement more Evident as Matrix Size Increases;

M. Athi, S. A. Zekavat, and A. A. Struthers, "Real Time Signal Processing of Massive Sensor Arrays via a Novel Fast Converging SVD Algorithm: Latency, Throughput and Resource Analysis," *IEEE Sensors Journal,* vol. 16, no. 08, pp. 2519-2526, 2016.

Real-time root-MUSIC DOA estimation via Parallel Polynomial Rooting



Newton map :

$$N_p:\mathbb{C}\to\mathbb{C}, z\to z-\frac{p(z)}{p'(z)}$$

Critical points:

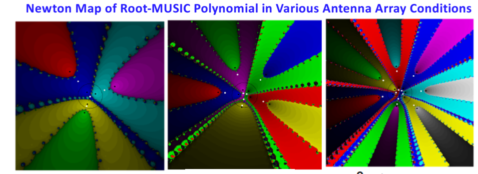
$$N_p'(z)=\frac{p(z)p''(z)}{p'(z)^2}=0$$

Properties:

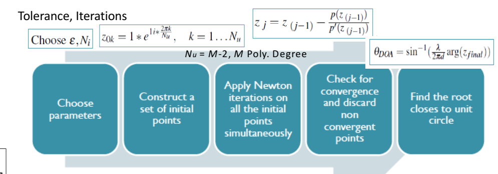
1. Symmetry of Roots across Unit Circle;
2. Access to Infinity= *M*-2

M Poly. Degree

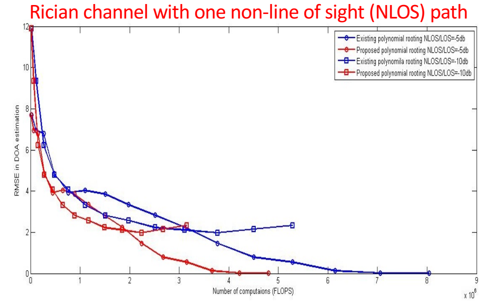
Newton Map of Root-MUSIC Polynomial in Various Antenna Array Conditions



4 antenna elements, degree=6 | 6 antenna elements, degree=10 | 8 antenna arrays, degree=14



Rician channel with one non-line of sight (NLOS) path



Method	Computational Complexity	Parallel Implementation	Comments
Eigenvalue of companion matrix using QR decomposition	$O(d^3)$	None, QR decomposition is inherently sequential	Each QR step is $O(d^2)$
Fast QR based on n[th] root of unity	$O(d^2)$	None, QR decomposition is inherently sequential	Each QR step is $O(d)$
Roots by balanced factorization of polynomial	$O(d\log^5(d)\log B)$	$O(\log^6(d))\log b$ using $O(d\log^{\omega}(d))$ processors	Factorization introduces error
Newton's method for general polynomials	$O(d^2\log^2(d))$	$O(d)$ using $O(d\log^2(d))$ processors	Large set of initial points
Proposed method	$O(d^2)$	$O(d)$ using $O(d)$ processors	Method specific to RM polynomial

M. Athi, and S. A. Zekavat, "A novel parallel polynomial rooting technique for root-MUSIC" proceedings *IEEE PIMRC 2014*, Sept. 02-05 2014, Washington DC.