



Near-Field Line-of-Sight Communication with Massive Movable Antennas

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Brief Summary

Optimal antenna placement in near-field LoS wirelss communications for SE maximization.

■ **Closed-form** and **Greedy** approximation schemes are provided.

► **Closed-form** [1]: Transform SE maximization to an **Electrostatic Equilibrium**

► **Greedy** [2]: Approximation via **Leja sequence**

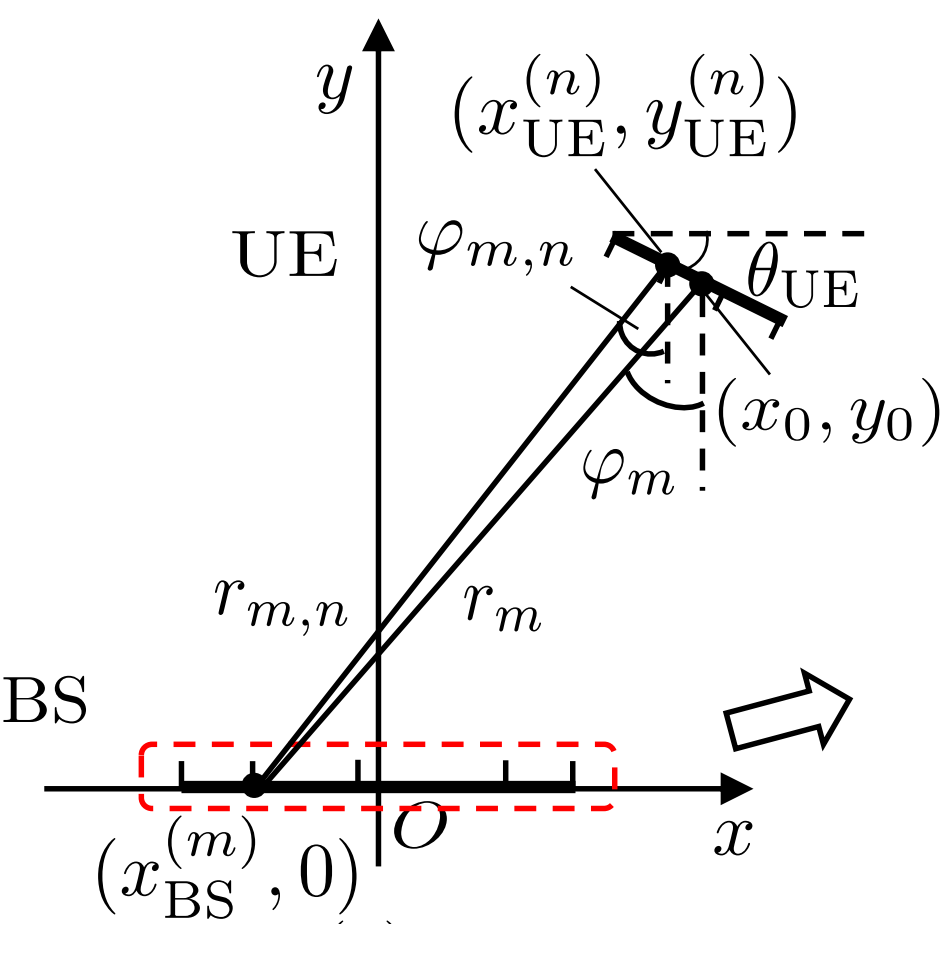
■ **~10%** SE gain over ULA, **35×** lower execution time reduction over CVX.

1. Motivations

- **Near-field** channel geometry provides higher **spatial DoF**.
- Conventional **ULA cannot** fully utilize the additional DoF.
- **Position Reconfigurable Antennas (MA / FAS / PASS)** reshape the channel, at the cost of high computational complexity under numerical optimization framework.

Goal: Place M movable antennas *efficiently* so the channel matrix excites the maximum number of orthogonal modes.

2. System Model



■ Antenna position (ascending order):

$$-\frac{A}{2} = x_{BS}^{(1)} < x_{BS}^{(2)} < \dots < x_{BS}^{(M)} = \frac{A}{2},$$

■ Near-field channel model:

$$\mathbf{H}_x[n, m] = \frac{e^{jkr_{m,n}}}{r_{m,n}},$$

■ SE maximization problem:

$$\begin{aligned} \max_{\mathbf{x}} \quad & R_x = \log_2 \det \left(\mathbf{I}_N + \frac{\rho}{M} \mathbf{H}_x \mathbf{H}_x^H \right) \\ \mathcal{P}_1 : \text{ s.t. } \quad & x_{BS}^{(M)} = -x_{BS}^{(1)} = \frac{A}{2}, \\ & x_{BS}^{(m+1)} - x_{BS}^{(m)} > 0, \end{aligned}$$

3. Problem Formulation

■ Antenna positions in **angular** domain

$$s_m = \sin(\varphi_m - \theta_{UE}) = \sin \left(\arctan \left(\frac{x_{BS}^{(m)} - x_0}{y_0} \right) - \theta_{UE} \right),$$

■ SE maximization problem is transformed into a **Weighted Fekete Problem (WFP)** [3]

$$\begin{aligned} \mathcal{P}_2 : \quad & \max_s \quad 2 \sum_{1 \leq i < j \leq M} \log_2(s_j - s_i) + \sum_{m=1}^M \log_2(1 - \tilde{s}_m^2) \\ \text{ s.t. } \quad & s_{\min} = s_1 < s_2 < \dots < s_M = s_{\max}, \\ & \tilde{s} = \sin(\arcsin s + \theta_{UE}). \end{aligned}$$

Convex problem with lots of variables.

4. Greedy Solution

WFP has a famous sub-optimal solution: **Leja Sequence**

■ Define objectives according to $\mathcal{P}_2$

$$J_D(s) = 2 \sum_{i=1}^{m-1} \log_2 |s_i^* - s|, \quad J_W(s) = \log_2(1 - \sin^2(\arcsin s + \theta_{UE})).$$

■ Greedy Algorithm:

Greedy Antenna Position Design

Input: M , spacing thresholds ϵ , aperture A , UE position (x_0, y_0) and rotation θ_{UE} .

Output: Positions $\{x_{BS}^{(m)}\}_{m=1}^M$ of antennas.

1: Fix endpoints s_1^*, s_M^* at the aperture boundaries

2: **for** $m = 3, \dots, M$ **do**

3: Update the feasible region

$$S_m = \{s \in \mathbb{R} \mid s_1 < s < s_M\} \setminus \bigcup_{i=1}^{m-1} B_\epsilon,$$

4: Determine the m -th position over S_m

$$s_m^* = \arg \max_{s \in S_m} (J_D(s) + J_W(s))$$

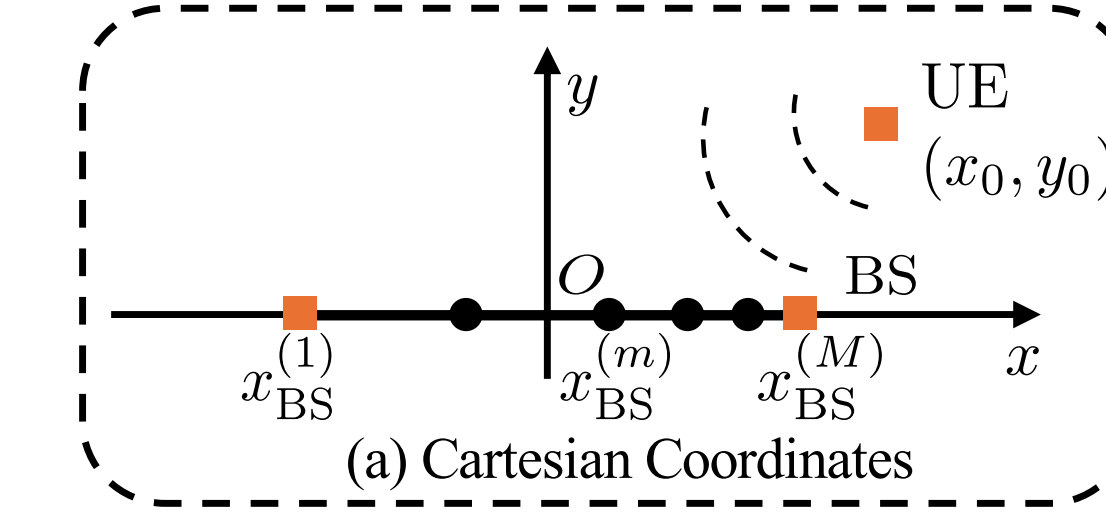
5: **end for**

6: Angular positions $\{s_m^*\}_{m=1}^M$ to coordinates $\{x_{BS}^{(m)}\}_{m=1}^M$.

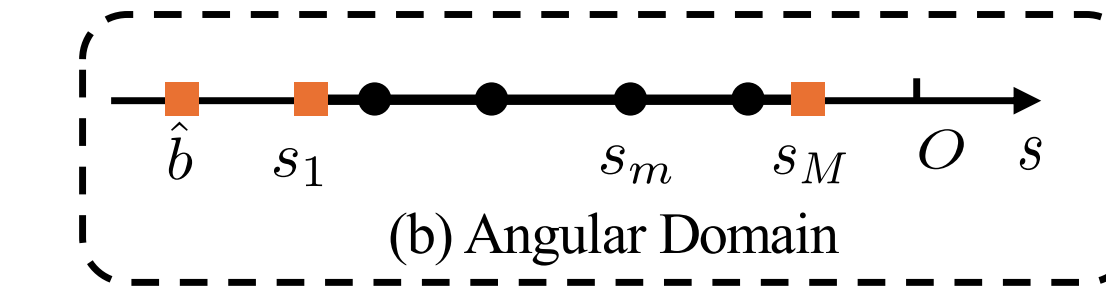
■ Execution time table:

Methods	Computational Complexity ($\mathcal{O}$)	Ave. Exec. Time (ms)	
		$M = 16$	$M = 128$
AS	$MG^2(N^3 + M^2N^2)$	47.4	3.38×10^3
Prop. CVX	$\sim M^{4.5}$	6.42×10^3	3.47×10^5
Prop. Greedy	GM^2	2.19	94.1

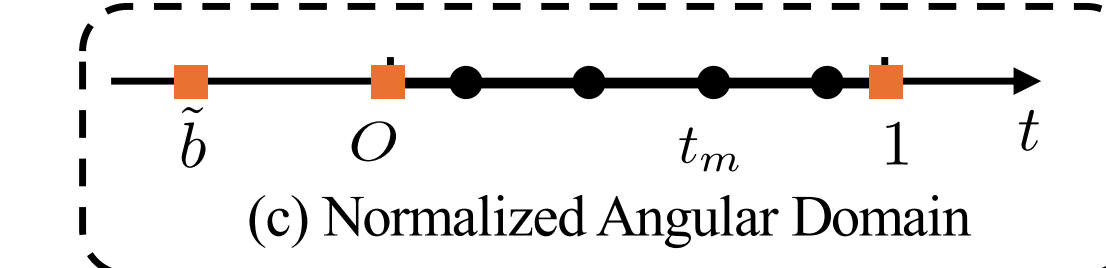
5. Closed-form Solution



$$x_{BS}^{(m)} \Rightarrow s_m \quad s_m \Rightarrow x_{BS}^{(m)}$$



$$\text{Normalization } s_m \Rightarrow t_m \quad \text{Denormalization } t_m \Rightarrow s_m$$



■ First order optimal condition ($\mathcal{P}_2$)

$$\sum_{i=1, i \neq m}^M \frac{2}{s_m - s_i} = \underbrace{\frac{b}{a - b(s_m - s_0)}}_{\text{external force}}$$

internal force

■ Normalized angular domain t

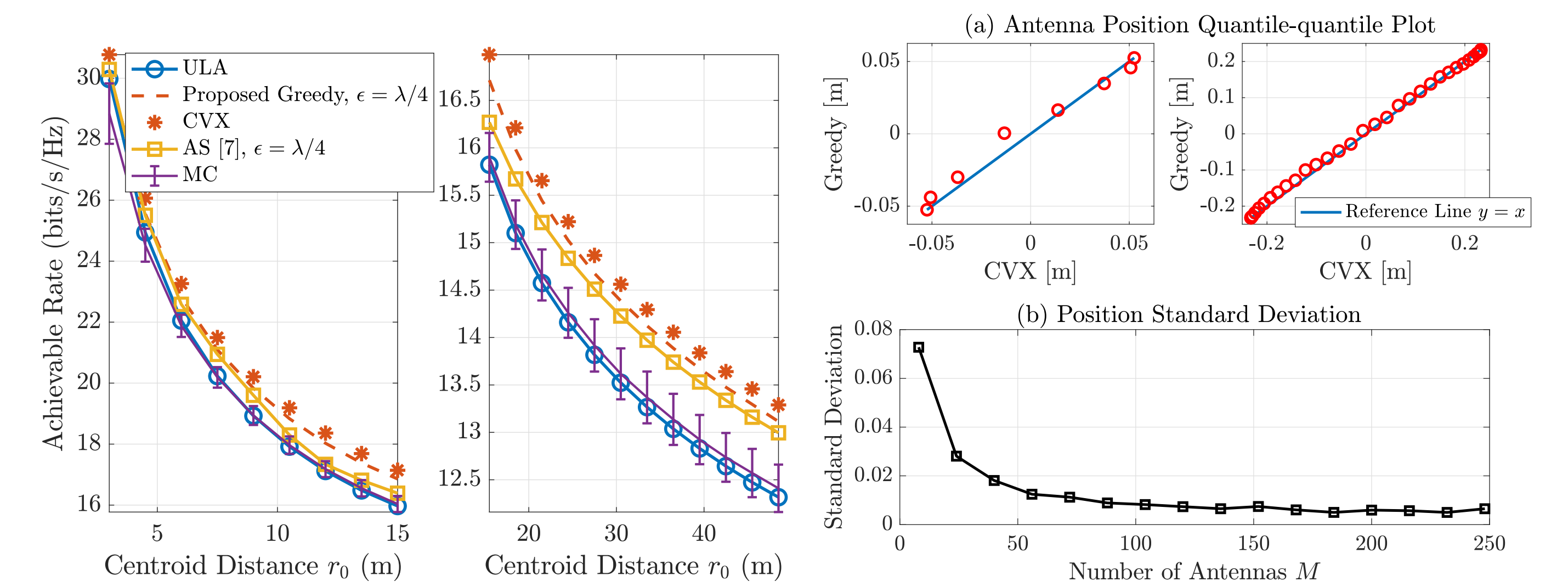
$$\sum_{i=1, i \neq m}^M \frac{2}{t_m - t_i} = -\frac{1}{t_m - \tilde{b}},$$

where $0 = t_1 < \dots < t_M = 1$.

Closed-form solution can be obtained by solving a two-step EVD operation.

Physical analogy: M charges on an interval, mutually repelling yet pulled by an external charge (UE). Optimal positions are the *equilibrium* positions.

6. Numerical Results



(a) Rate vs. distance.

(b) Greedy $\rightarrow$ CVX convergence.

Observations: Antenna elements are dense at the edges while sparse at the center.

References

- [1] S. Liu, X. Yu, S. Song, and K. B. Letaief, "Near-field communication with movable antennas: An electrostatic equilibrium perspective," *IEEE Trans. Wireless Commun.*, vol. 25, pp. 16 024–16 039, 2026.
- [2] S. Liu and X. Yu, "Near-field line-of-sight communication with massive movable antennas," in *IEEE International Conference on Communications (ICC'26)*, to appear, Glasgow, Scotland, UK, 2026, pp. 1–6.
- [3] E. B. Saff and V. Totik, *Logarithmic Potentials with External Fields*. Springer Cham, 2024.