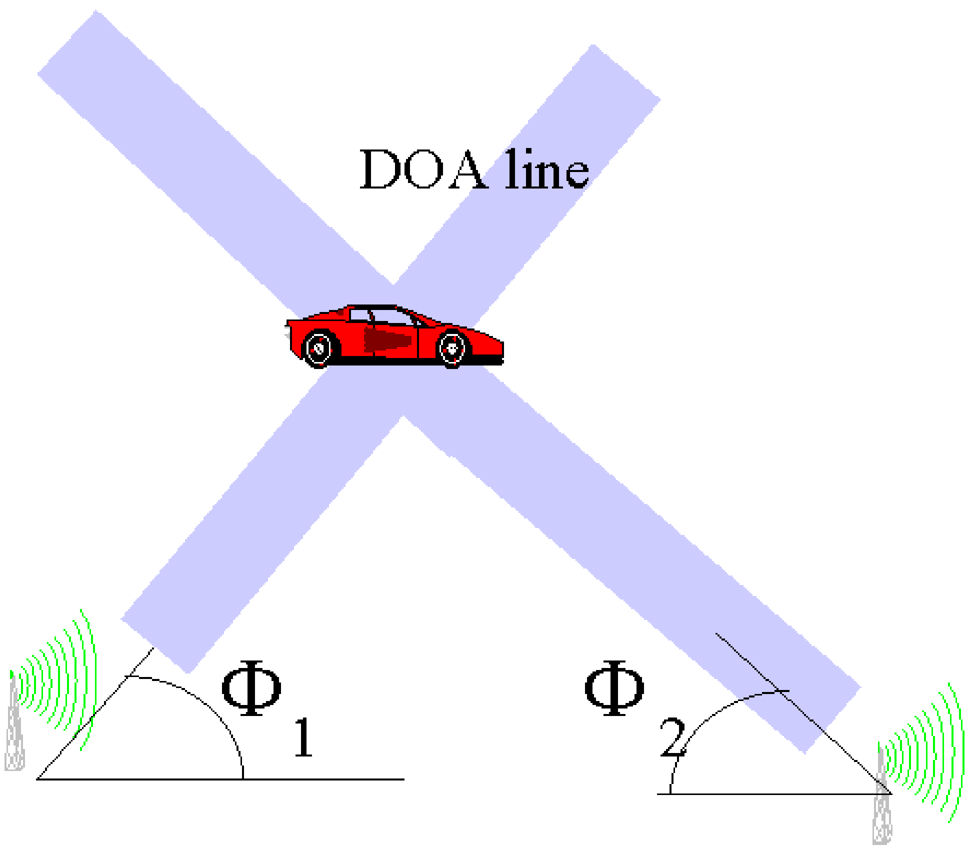
Mobile Localization

- Safety
  - ☞ Wireless E911 (FCC mandate by 2001)
  - ☞ Emergency roadside service
- Tracking
  - ☞ Fleet management for trucks
  - ☞ Tracking children
- Billing
  - ☞ Location sensitive billing
  - ☞ Neighborhood cordless
- Information
  - ☞ Mobile yellow pages
  - ☞ Driving directions

System Requirements

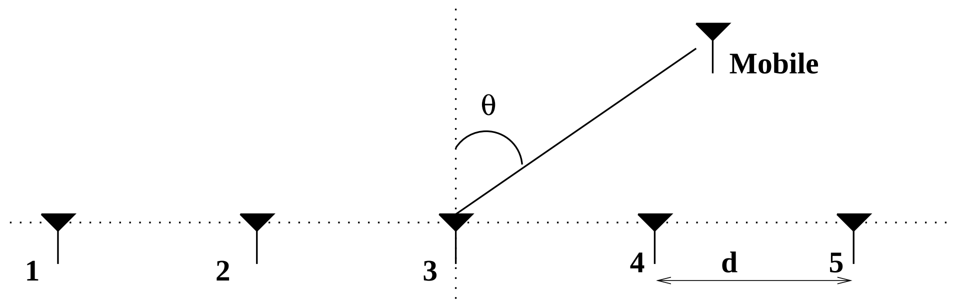
- Mobile user requests its location
- Infrastructure-based solution
  - ☞ Support existing mobile phones
  - ☞ No additional cost to mobile phones
- Compatibility with different standards
  - ☞ Advanced Mobile Phone Service (AMPS)
  - ☞ Code Division Multiple Access (CDMA)
  - ☞ Global System for Mobile (GSM)
- Solutions at basestation
  - ☞ Single antenna
  - ☞ Antenna array (usually linear but sometimes triangular or circular)

Location Based on Direction of Arrival (DOA)



Two-site visibility

Direction of Arrival Estimation



- Sampling in space

  Delay $\underset{\text{Assumption}}{\overset{\text{Narrowband}}{\Longrightarrow}}$ Phase Shift

$$\mathbf{a}(\theta) = [1 \quad e^{j2\pi f \frac{d}{c} \sin\theta} \quad \ldots \quad e^{j2\pi f \frac{4d}{c} \sin\theta}]^T$$

  For P paths,

$$\mathbf{A} = [\mathbf{a}(\theta_1) \;\; \mathbf{a}(\theta_2) \;\; \ldots \;\; \mathbf{a}(\theta_P)]$$

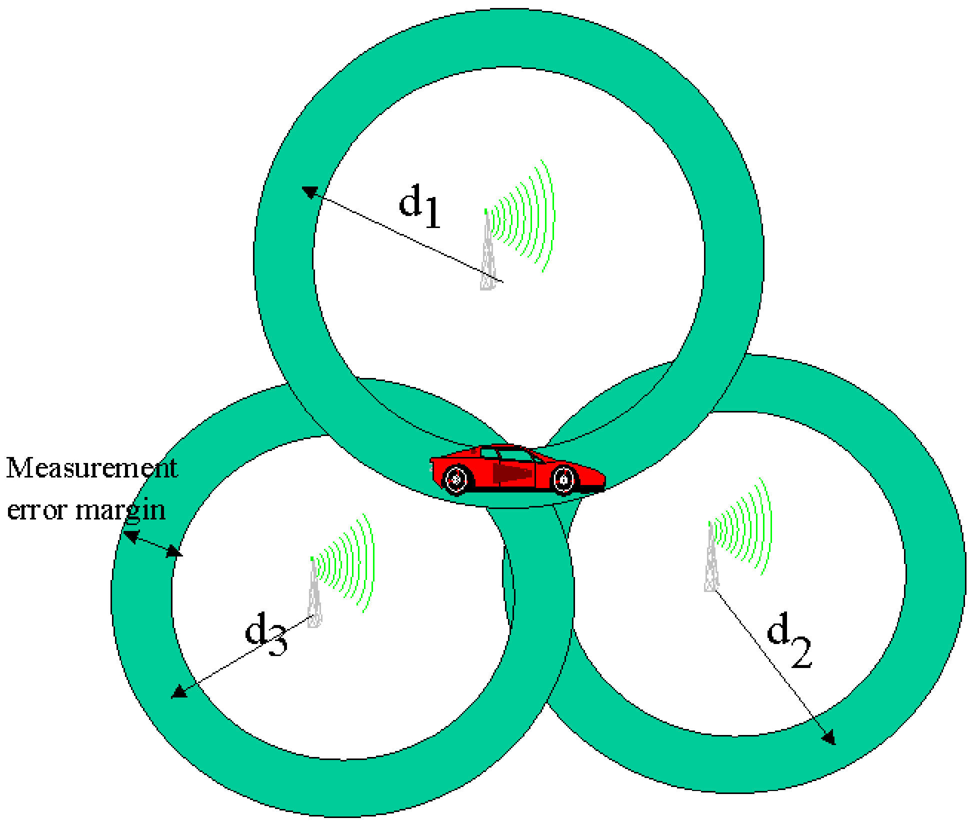
  $\mathbf{A}$ is a Vandermonde matrix

- Estimate θ_i using *Estimation of Signal Parameters using Rotationl Invariance Techniques (ESPRIT)*

Disadvantages of Using Direction of Arrival

- Few antenna elements at basestation (usually 4)
- Extremely sensitive to array calibration
  - ☞ Geometry of sensor layout
  - ☞ Mutual coupling of antenna elements
- No line-of-sight in urban environments
- Failure in absence of fading

Location Based on Time of Arrival (TOA)



Three-site visibility required

Time of Arrival Estimation

- Received signal $\longrightarrow$ Sum of delayed versions of transmitted signal

$$\mathbf{S}(t) = [s(t-\tau_1) \;\; s(t-\tau_2) \;\; s(t-\tau_3) \;\; \ldots \;\; s(t-\tau_P)]^T$$

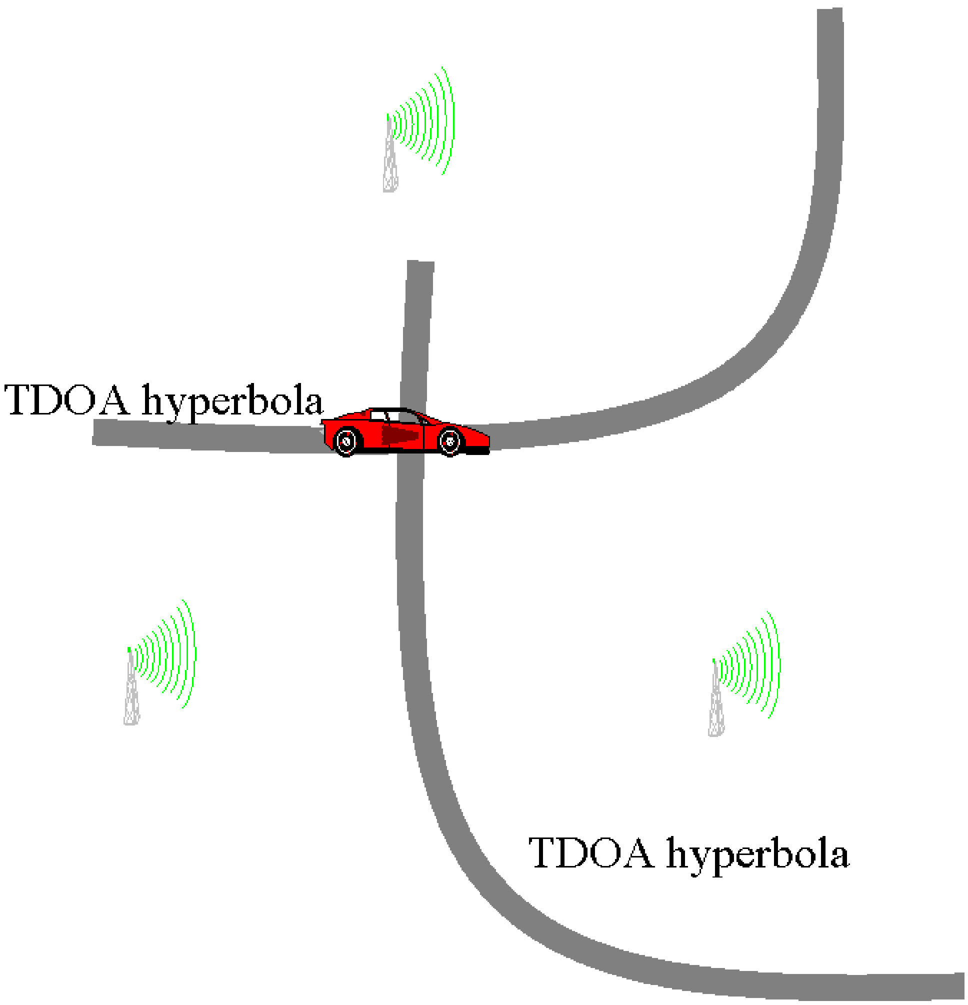
$$\text{Delay } \tau_m \quad \underset{\text{Fourier Transform}}{\overset{\text{Discrete}}{\Longrightarrow}} \quad \text{Phase Shift } \; e^{j2\pi f \tau_m}$$

$$\hat{\mathbf{S}} = [e^{j2\pi f \tau_1} \;\; e^{j2\pi f \tau_2} \;\; \ldots \;\; e^{j2\pi f \tau_P}]^T \;\; \hat{s}(f)$$

where $\hat{s}(f) = \mathcal{F}\{s(t)\}$

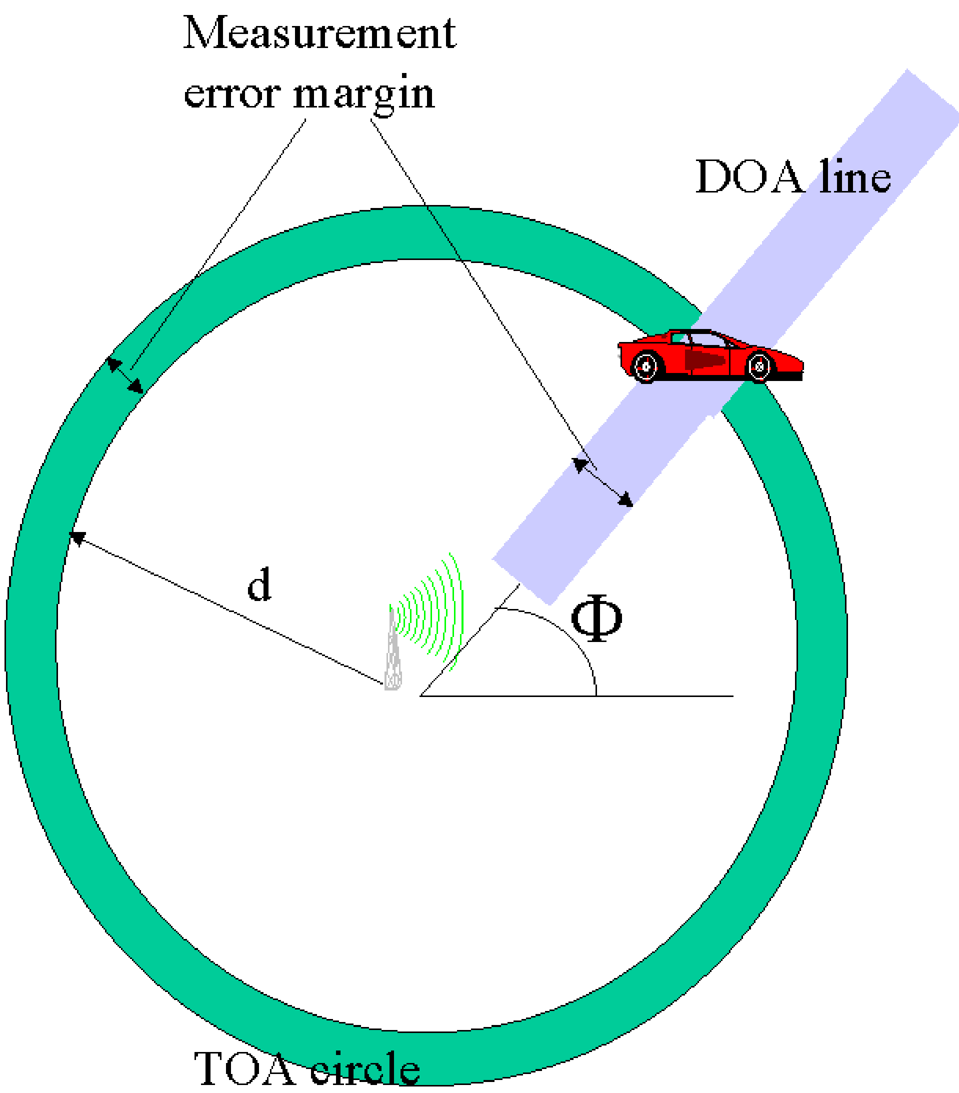
- Estimate time delays $\{\tau_i\}$ using ESPRIT

Location Based on
Time Difference of Arrival (TDOA)



Three-site visibility required

Location Based on a Combination of DOA and TOA

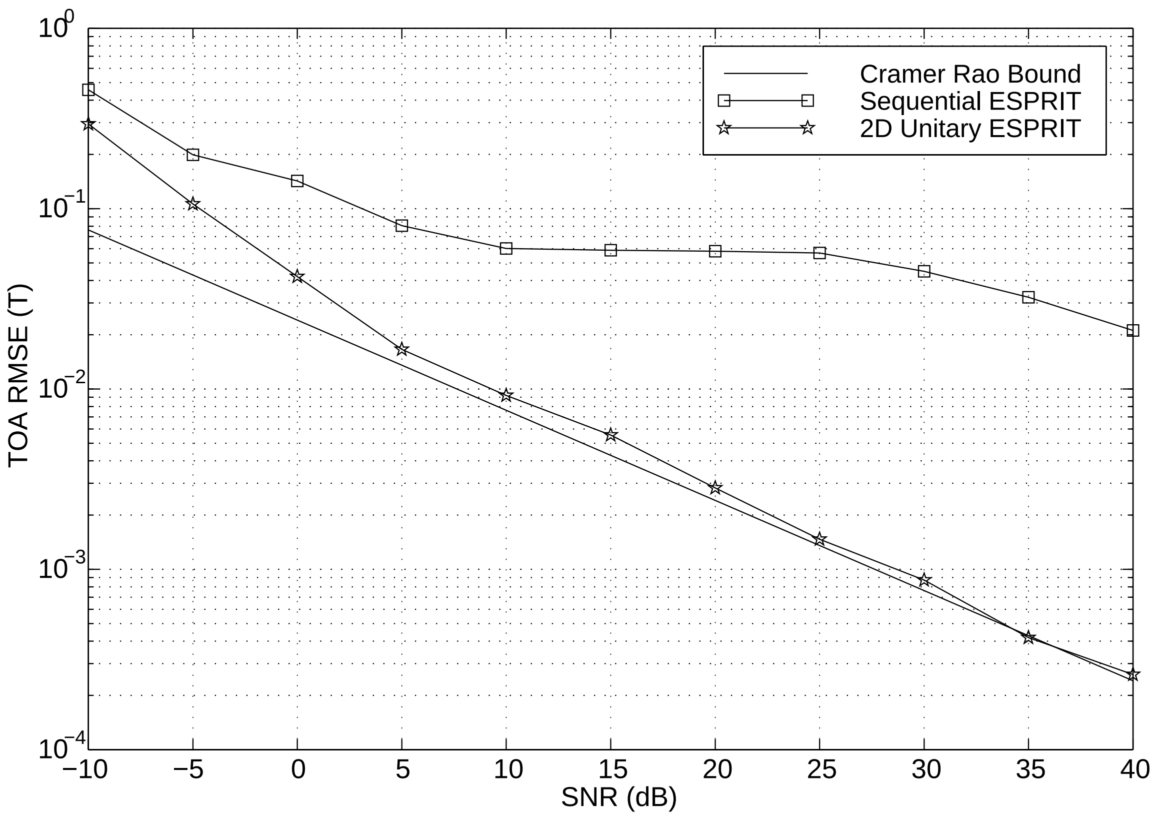


Single-site visibility (35-40% of the cases)

Joint Angle and Delay Estimation (JADE)

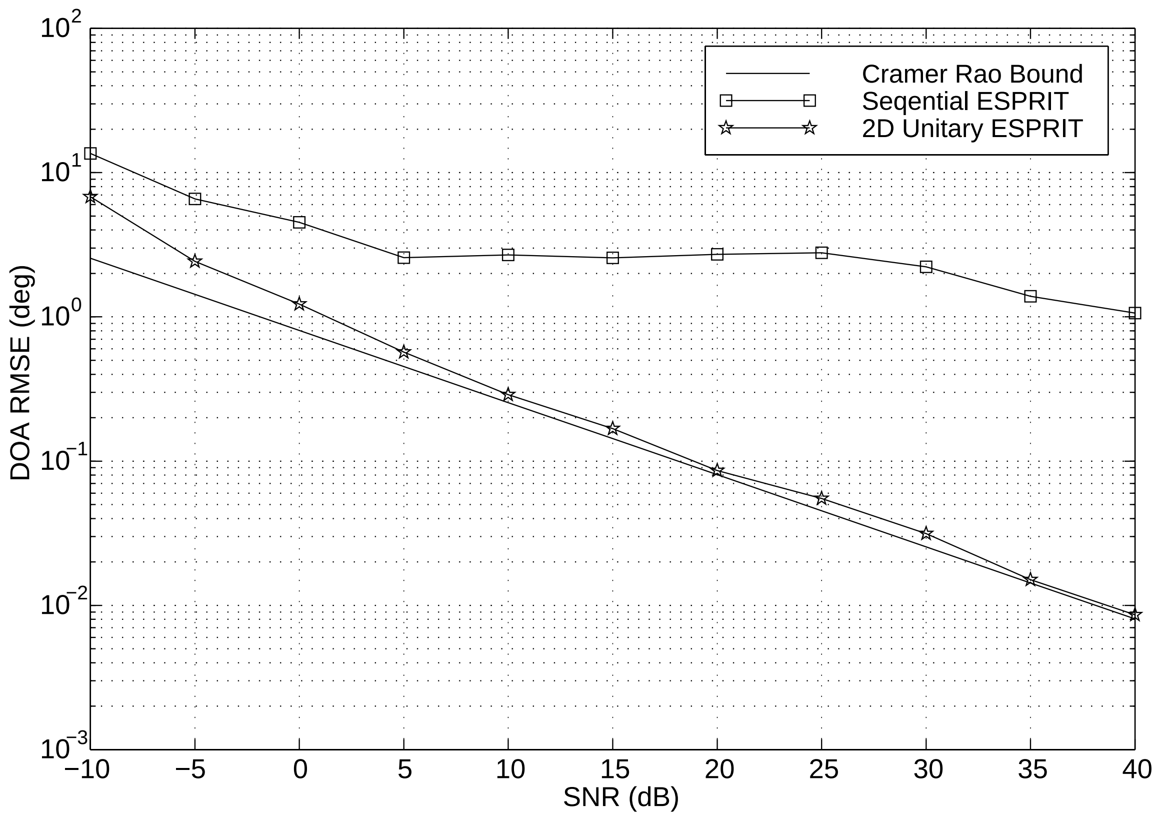
- 1-D ESPRIT
  - ☞ Sequential estimation of DOAs and TOAs
  - ☞ Classification problem
- JADE - ESPRIT
  - ☞ Joint estimation of DOAs and TOAs
  - ☞ Automatic pairing of DOAs and TOAs for each user
- Form a 2-D Vandermonde matrix
  - ☞ Angle-of-arrival along columns
  - ☞ Time-of-arrival along rows
- Large number of time samples $\rightarrow$ better accuracy
- Works in both fading and non-fading environment

Simulation Results



Root mean square TOA error vs. SNR at the basestation

Simulation Results



Root mean square DOA error vs. SNR at the basestation