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J911: The Case for Fast Jammer Detection and Location Using Crowd Sourcing Approaches

Companion Paper is Available for Download at www.gpsexpert.net

Presentation to ICG-10 Working Group A

Logan Scott has 35 years of military and civil GPS systems engineering experience. He is a consultant specializing in radio frequency signal processing and waveform design. At Texas Instruments, he pioneered approaches for building high-performance, jamming-resistant digital receivers. At Omnipoint (now T-Mobile), he developed spectrum sharing techniques that led to a Pioneer's preference award from the FCC. He is a cofounder of Lonestar Aerospace, an advanced decision analytics company located in Texas.

Logan has been an active advocate for improved civil GPS location assurance through test based GPS receiver certification, crowdsourced jammer detection and location, and, by adding robust signal authentication features to civil GPS signals.

Logan is a Fellow of the Institute of Navigation and holds 39 US patents.

J911 System Concept

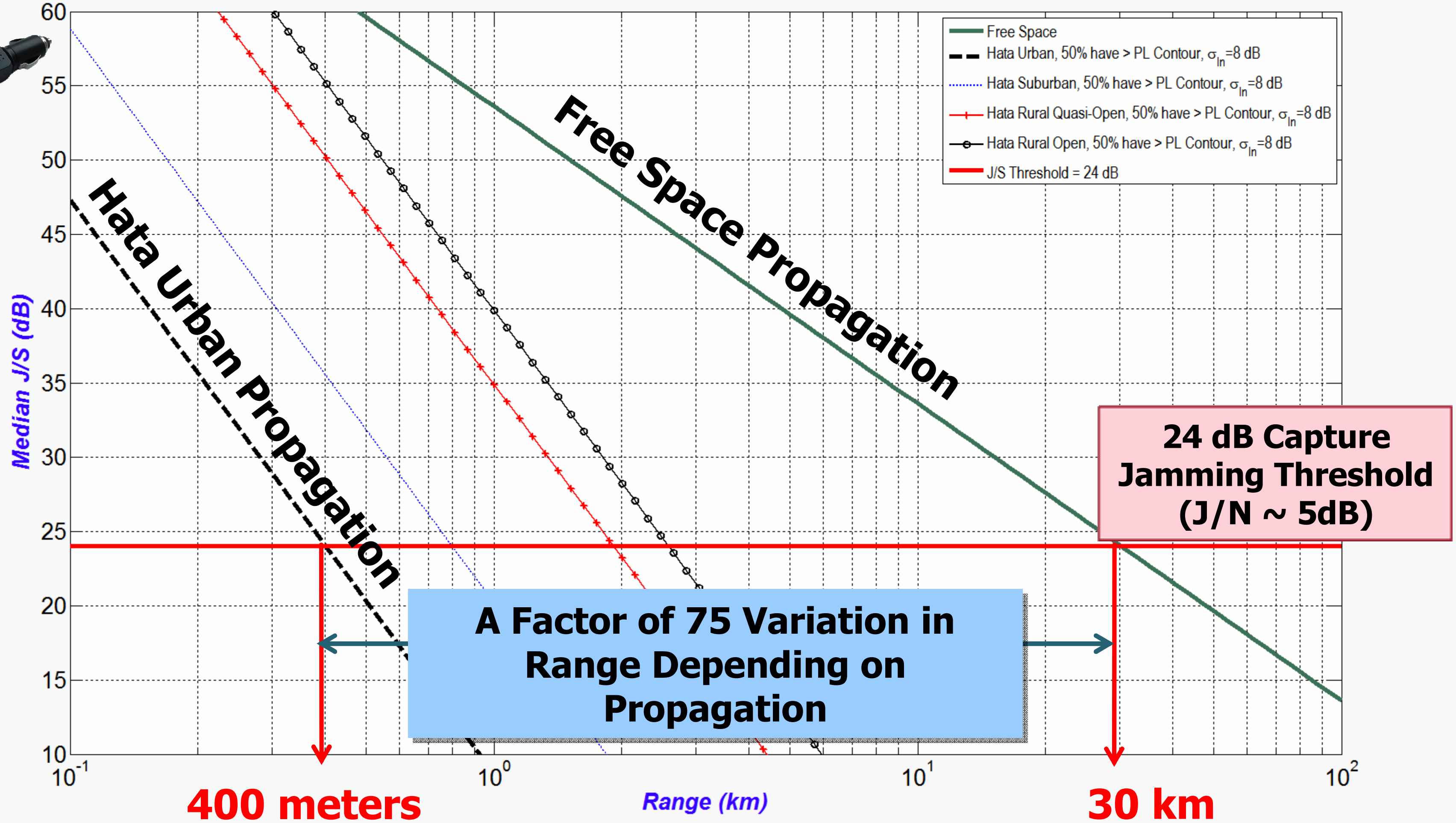
Finding Jammers In a Ground Mobile Environment

The Effective Range Of a Jammer Varies Widely Depending on Propagation & Waveform

Can Also Make Jammers Hard to Find

Nominal GPS Signal: -157 dBW into 0 dBiC

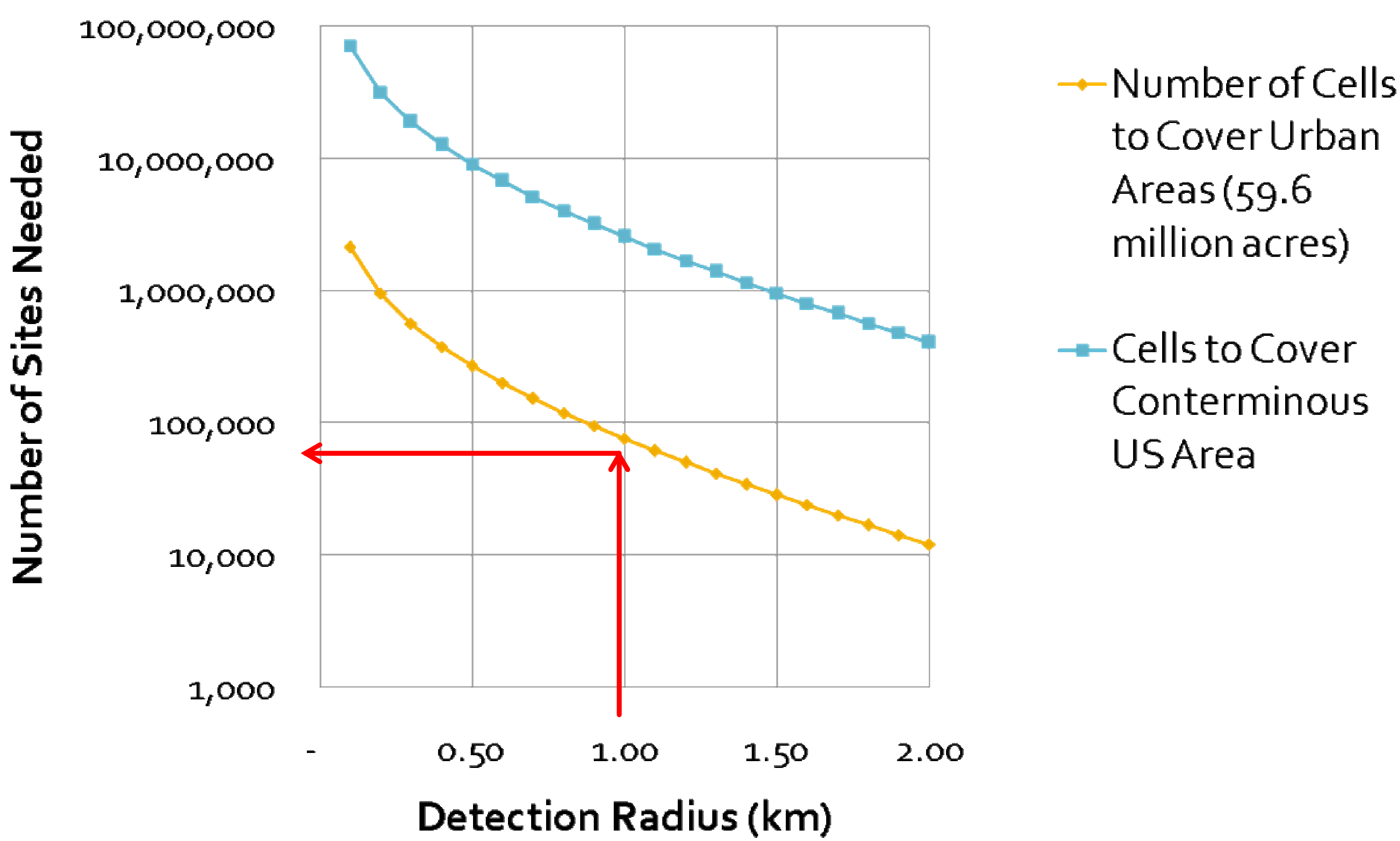
0.2 Watt EIRP Jammer at 5 feet AGL, Victim Receiver at 30 feet AGL with 0 dB Gain Towards Jammer
-157 dBW Signal with 0 dB Gain towards Jammer



J_over_S_for_J911.m

Would Need ~75,000 IDM Receivers to Cover Urban Areas In US Just for Detection (1 km detection range)

Economically Feasible?

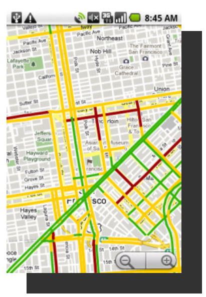


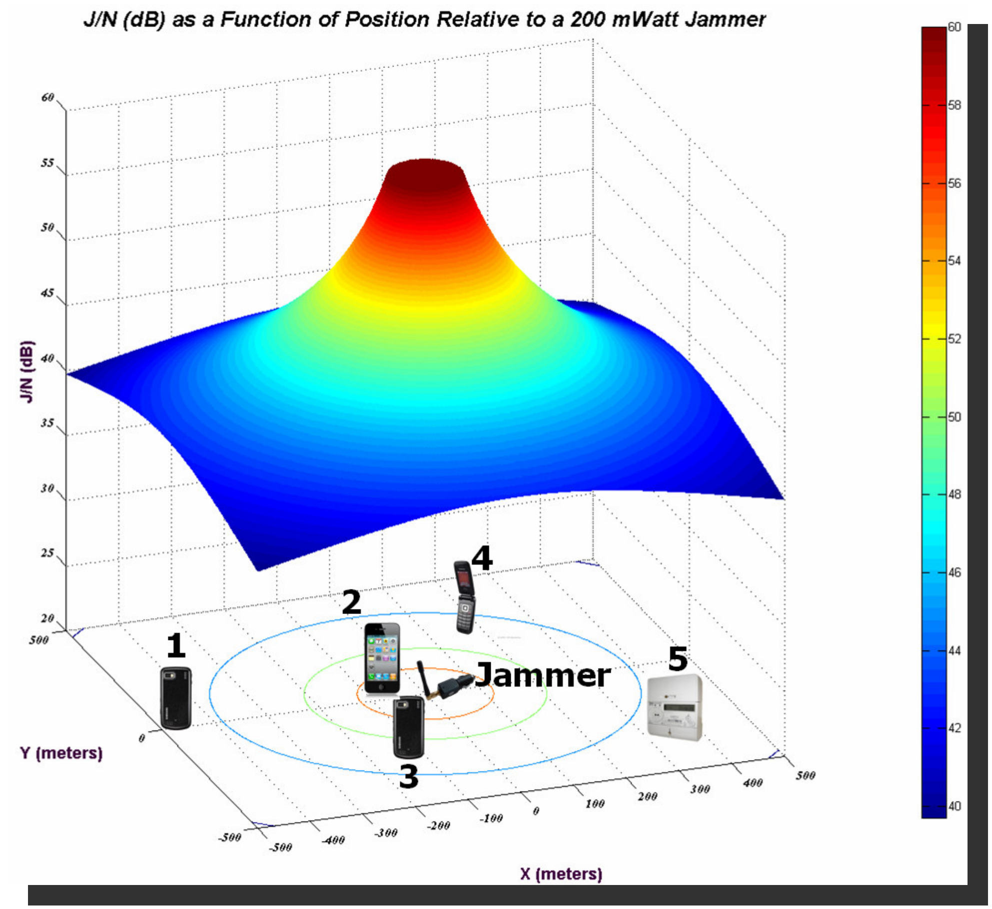
Crowdsourcing for Jammer Detection & Location (J911)

Geographic Coverage Is the Challenge for IDM Systems; Detectable Range May Only Be a Few Hundred Feet and Multipath Effects Can Be Severe

Collaborative Defense

- Devices Report Jamming Parameters & Own Position to J911
- Using Aggregate of Reports, J911 Can Determine Jammer *Position to ~ 40 meters in near real-time*
- J911 Can Report Interference Events to Networked Users (Like Traffic Reports)

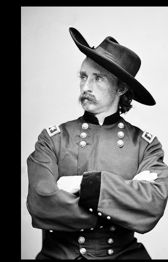


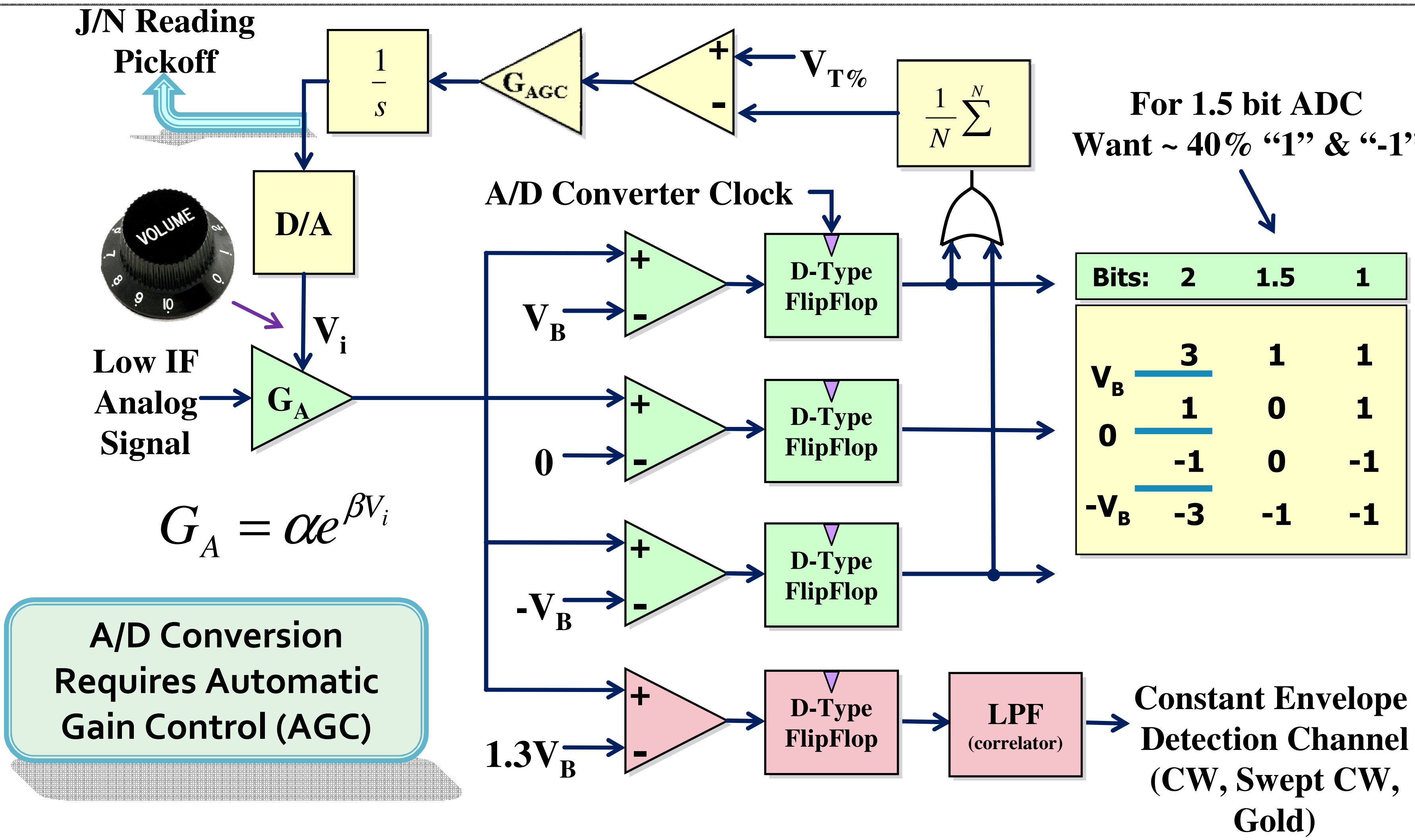


from Logan Scott: J911: *The Case for Fast Jammer Detection and Location Using Crowdsourcing Approaches*, ION-GNSS-2011, September 20-23, 2011

The Receiver is The First Line of Defense

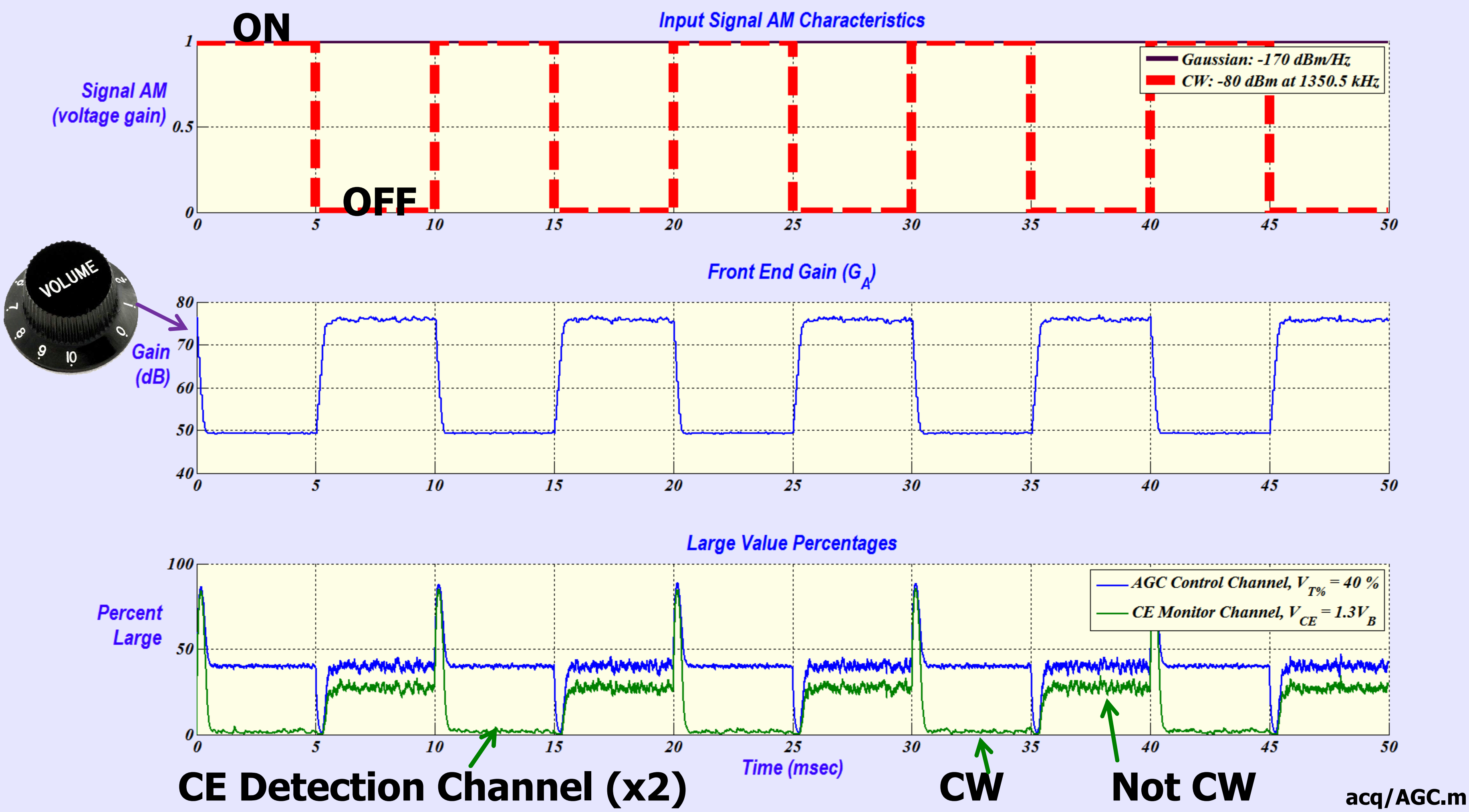
Knowing You Are Jammed (or Spoofed) Is the First Step





A/D Process Can Measure J/N, Pulse Rate & Jammer Type

Pulsed CW at 30 dB J/N (50 dB J/S), 100 Hz PRF



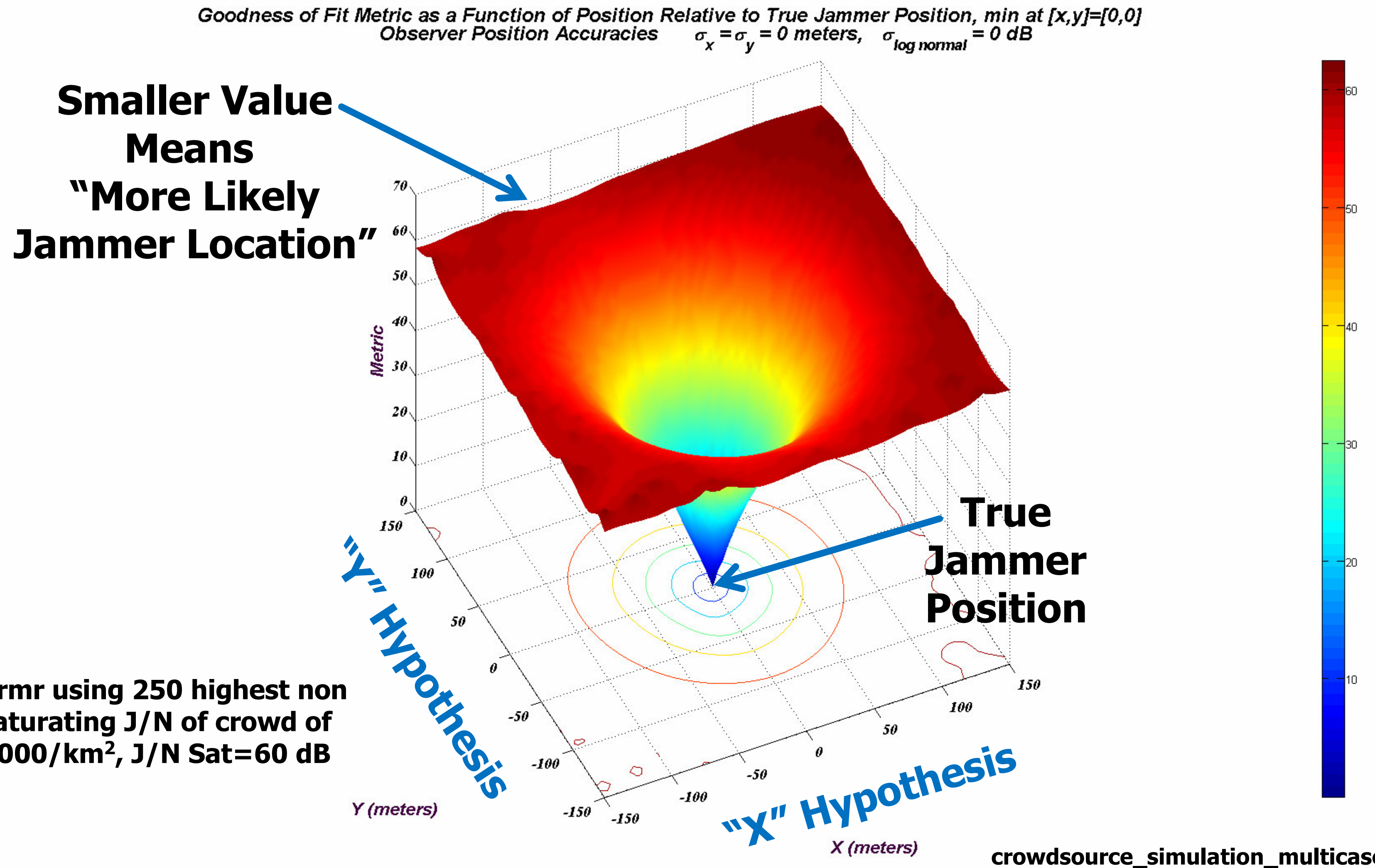
Intelligent Receivers Continuously Assess The Environment
Like Trained Witnesses

- Using Simple Algorithms, Receivers Can Measure Numerous Jammer Parameters
  - Time
  - Apparent C/No(s) (Signal to Noise Ratio)
  - Received Jammer Power (J/N) is Measurable By AGC
  - Jammer Type
    - Gaussian
    - CW
    - Swept FM
    - Gold
  - Pulse Characteristics
    - PRF, Sweep Rate and Duty Factor
  - And Much More…

This Is the Jammer's Signature

- Most Measurements Can Be Accomplished in Less than 1 msec
  - Not a big power impact

Location Metric As A Function Of Position Relative to True Jammer Position
(No Observer Errors)

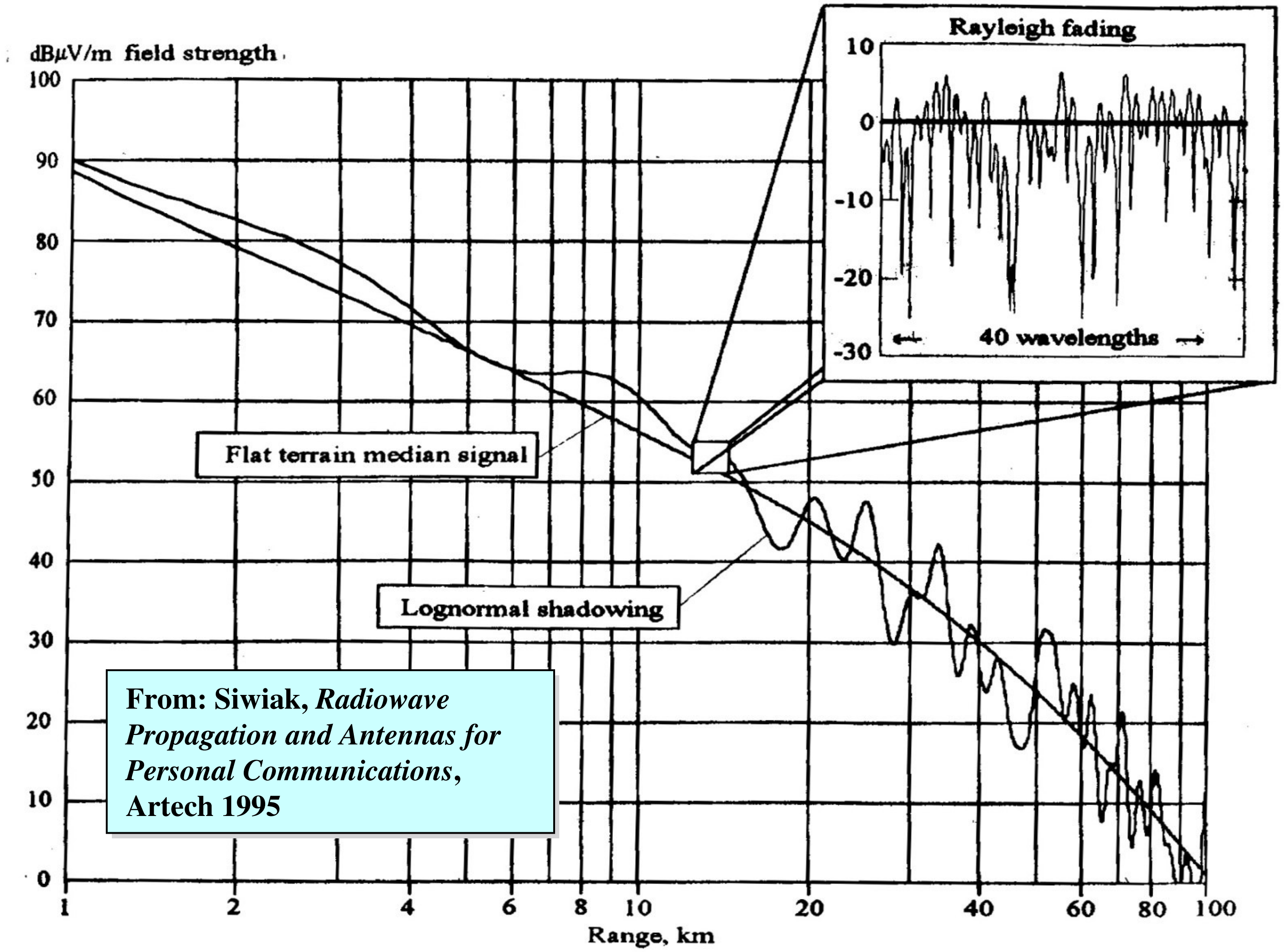


normr using 250 highest non saturating J/N of crowd of 1000/km^2, J/N Sat=60 dB

crowdsource_simulation_multicase.m

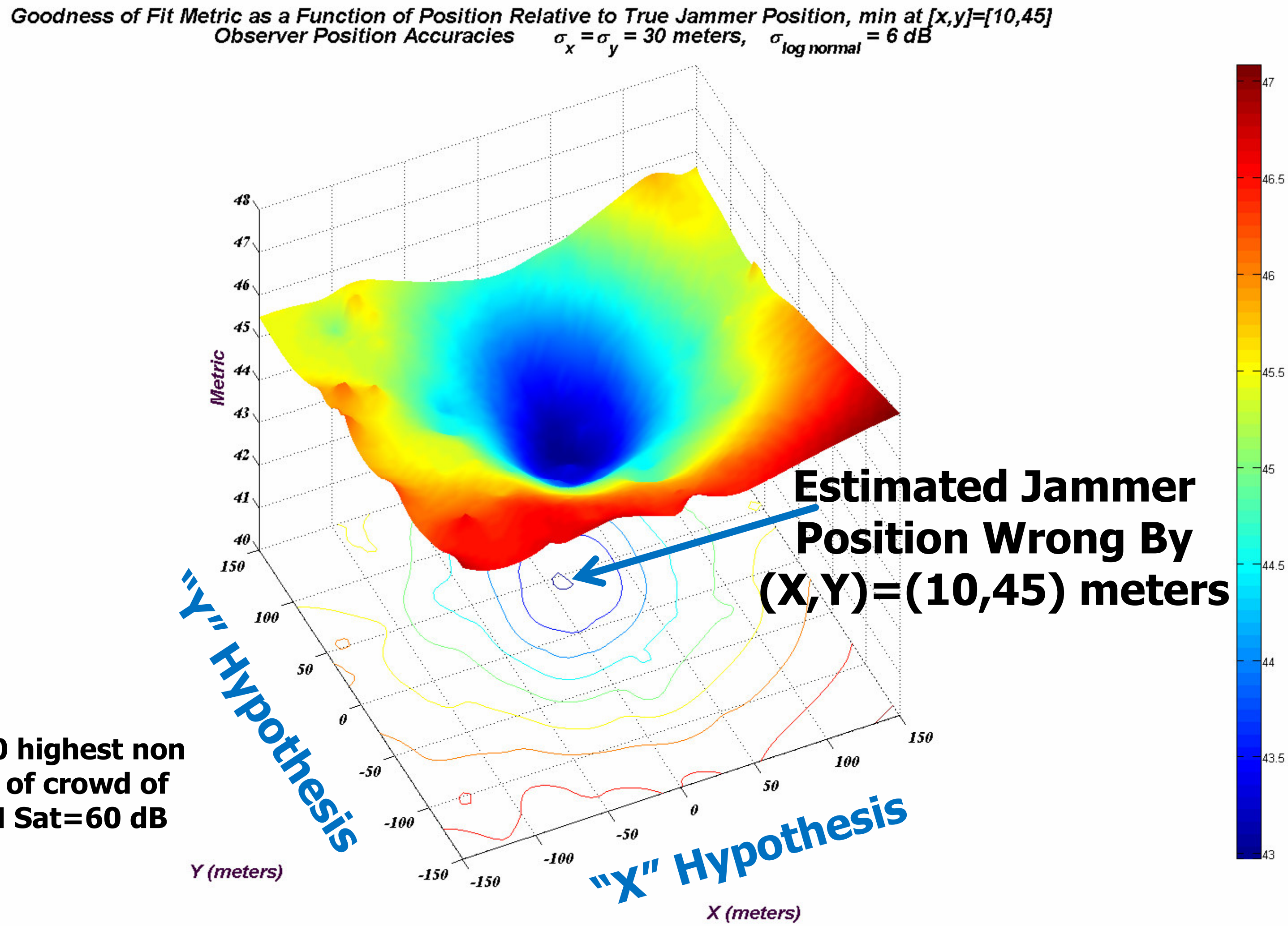
The Ground Mobile Channel

6 to 10 db (1σ) Deviation About Median Signal Strength



From: Siwiak, *Radiowave Propagation and Antennas for Personal Communications*, Artech 1995

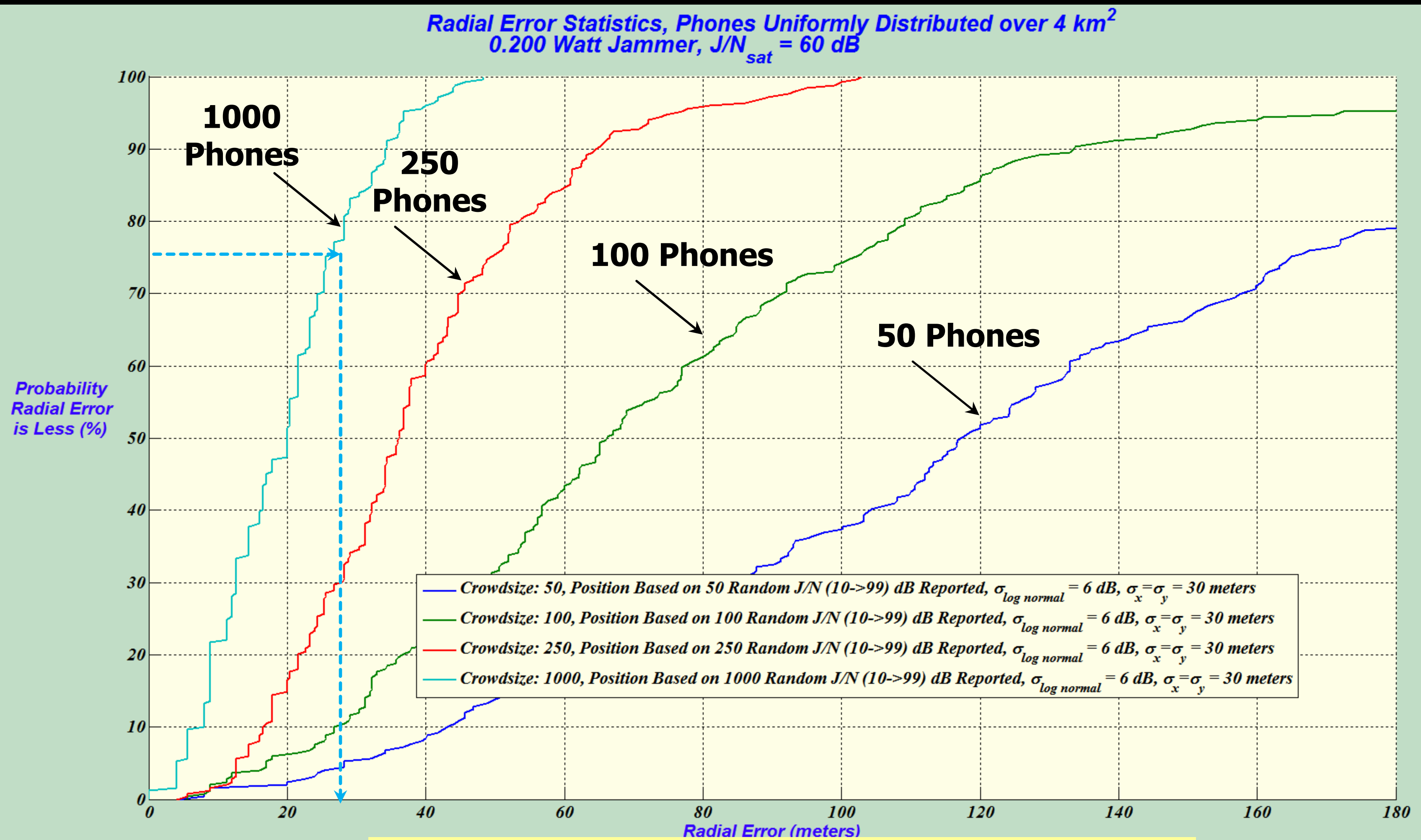
Location Metric As A Function Of Position Relative to True Jammer Position
(Observer Errors: 30 meters 1σ /6 dB 1σ J/N)



normr using 250 highest non saturating J/N of crowd of 1000/km^2, J/N Sat=60 dB

crowdsource_simulation_multicase.m

Radial Error Statistics with Random Selection of [50,100,250,1000] Phones, 200 mW Jammer



$$Radial\ Error = \sqrt{\left(x_{jammer\,estimated} - x_{jammer\,true}\right)^2 + \left(y_{jammer\,estimated} - y_{jammer\,true}\right)^2}$$

Four Phase J911 Implementation Strategy

Nationwide IOC in 5 to 7 years

IOC Could Happen in ~ 5 to 8 Years

Would Also Geolocate Cell Phone Jammers

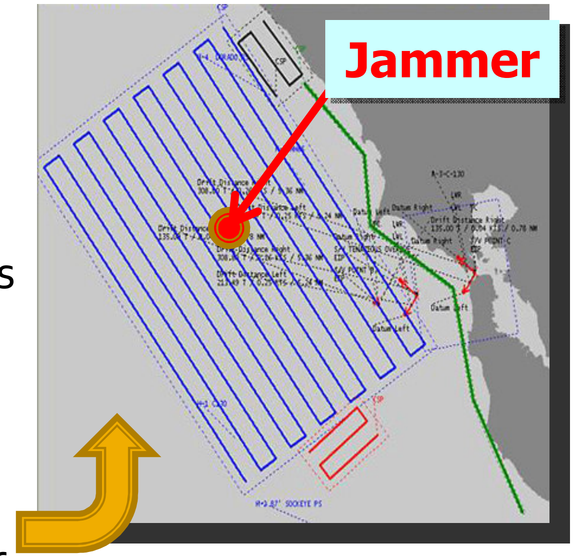
1. **Concept Validation (1 to 2 years)**
   - Prove that J911 Works Using Field Data
2. **FCC Rulemaking (1 to 2 years)**
   - Notice of Proposed Rulemaking (NPRM)
   - Industry Comments
3. **Standards Setting (1 to 2 years)**
   - Standards Bodies have Well Established, Formal Process
   - e.g. http://www.3gpp.org/
4. **Rollout (2 years)**
   - LTE major release updates are on a 2 year cycle
   - Roughly 2 Years to Transition UE to J911 Capable Versions

- Continual J911 PSAP Updates
  - Software Entity -> Easy Updates

Numerous Receiver Vendors Have Told Me:
"We Have the Data But We Have No Place to Send It"

J911 Proof of Concept Field Demonstration Program (1/2)

- **Objectives**
  - Demonstrate J911 jammer locating ability and determine jammer location accuracy statistics using field test data.
  - Characterize propagation channel and J/N (J/S) statistics as a function of range to the jammer in differing environments.
- **Collection Method Does Not Jam GPS**
  - **Setup "Jammer(s)" somewhere in the 1710-1755 MHz band and record georeferenced I/Q data** in a variety of well described environments (e.g. Urban, Suburban, Airborne)
    - Good point space / materials maps desirable
- **Make meta-tagged recordings available to academia and industry**



J911 Proof of Concept Field Demonstration Program (2/2)

- **Database Applications**
  - **J911:** Synthesize grid of cellphone reports with varying accuracy assumptions, reporting densities etc.
    - Apply various processing methodologies to geolocate jammer.
      - e.g. Corrected propagation based on pointspace database vs. generic propagation models
  - **SA:** Develop Improved Situational Awareness Algorithms based on Propagation Impaired View of Jammers
- Stimulate Collaborative Efforts Across Industry and Academia
- **Recruit People to The Problem**

Backup / Additional Results

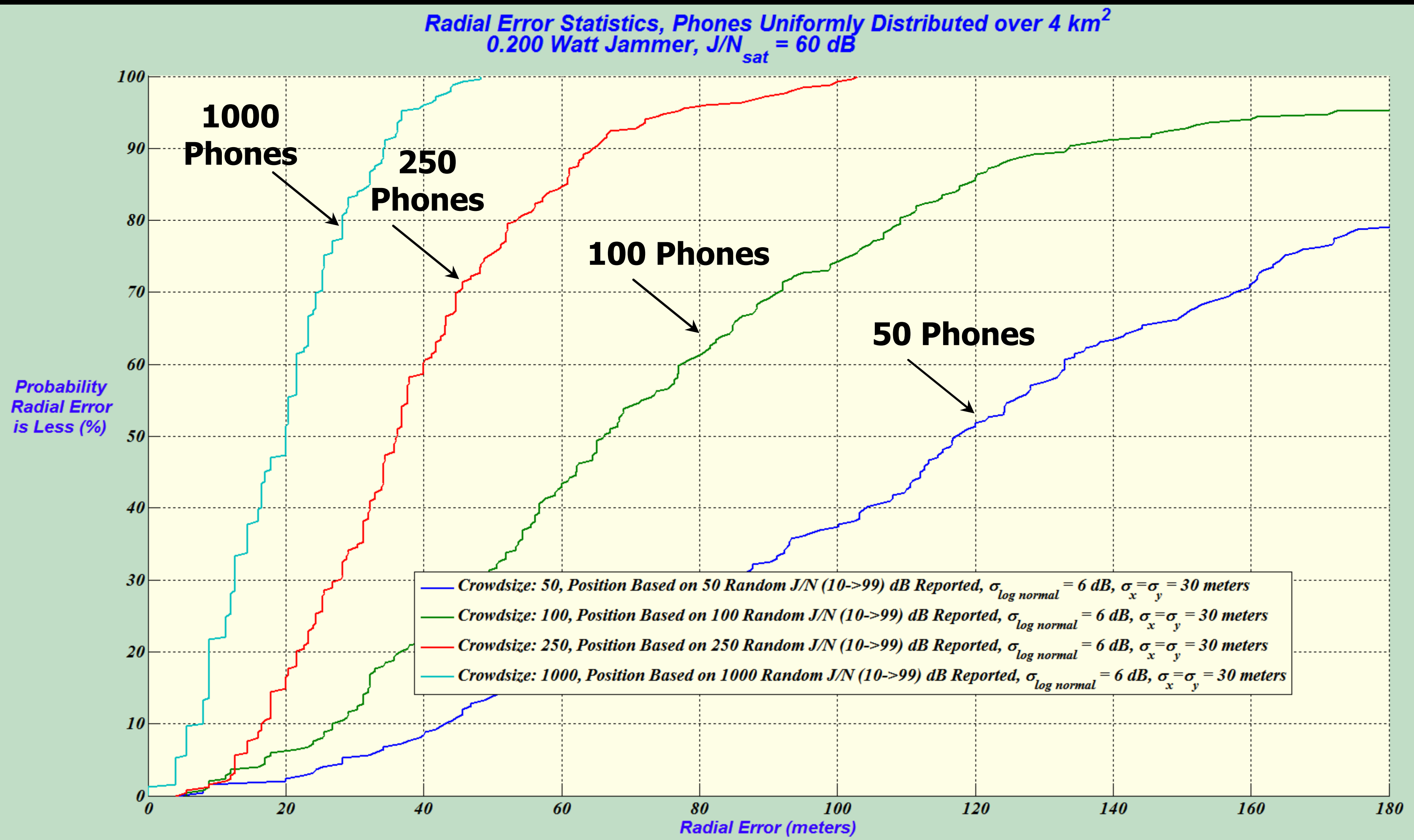
Density of 1000 Phones/km² Is Common in Urban Areas

City	Population (thousands)	Geographic Area (km^2)	Phone Density (Phones/km^2)
Peoria, IL	112.9	115.0	687.4
Portland, ME	62.9	54.9	801.7
Fort Collins, CO	138.7	120.5	805.7
Dallas, TX	1299.5	887.2	1025.3
Portland, OR	582.1	347.9	1171.2
Washington, DC	599.7	159.0	2640.0
Newark, NJ	279.0	61.6	3170.2
New York, NY	8391.9	789.4	7441.5

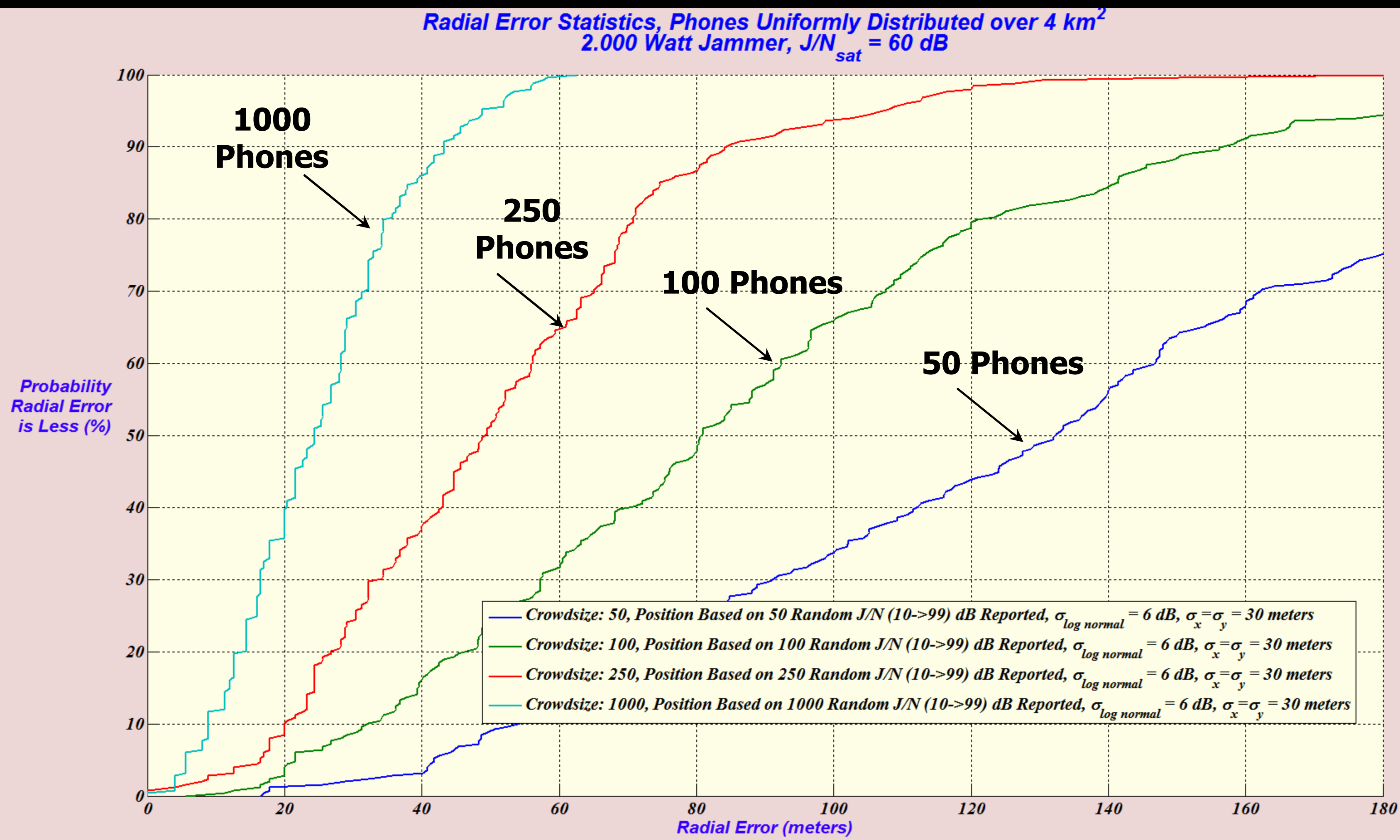
Figure from: The Economist, Jan 27th 2011

Assumes 70% of Population Carries A Cell Phone

Radial Error Statistics with Random Selection of [50,100,250,1000] Phones, 200 mW Jammer

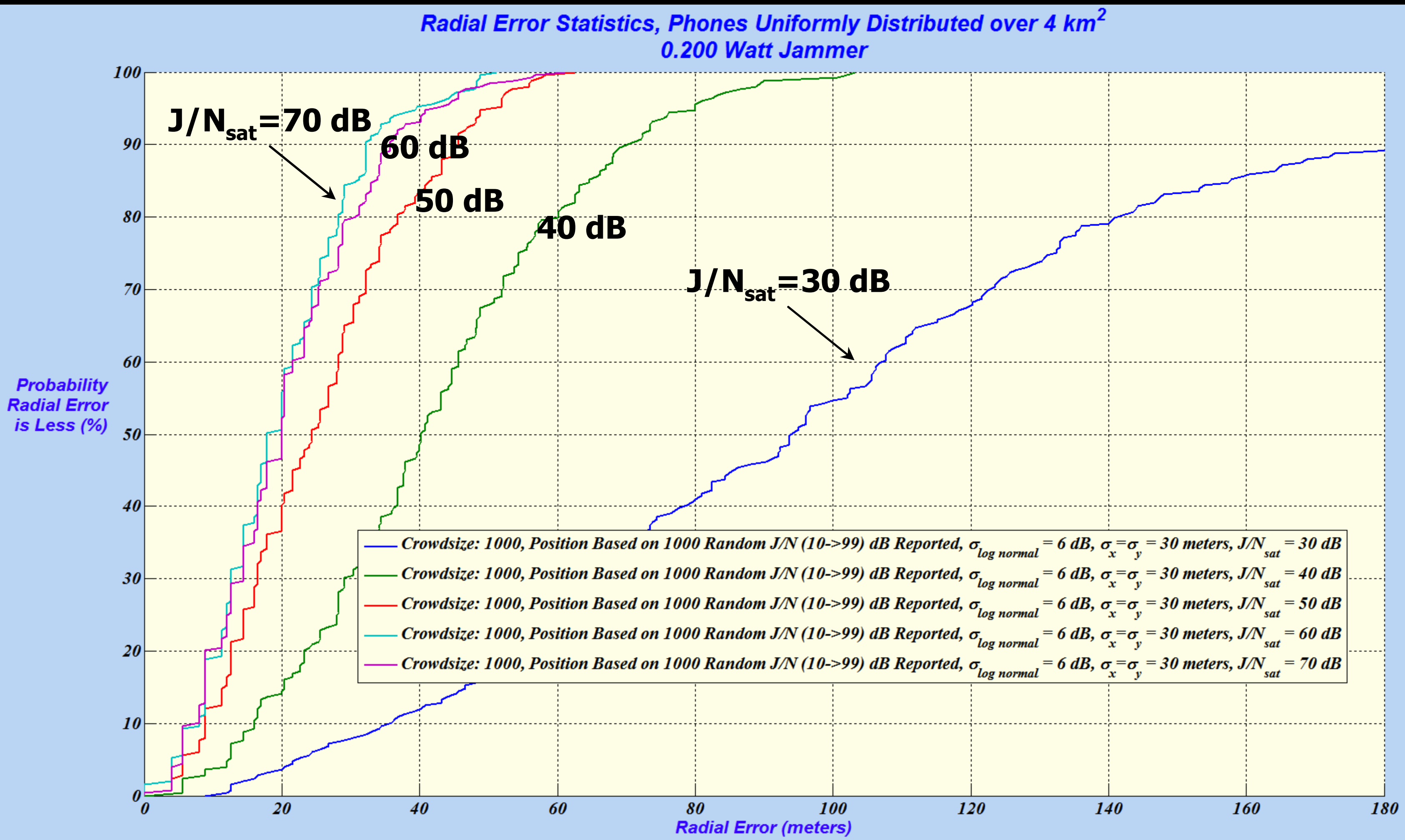


Radial Error Statistics with Random Selection of [50,100,250,1000] Phones, 2000 mW Jammer

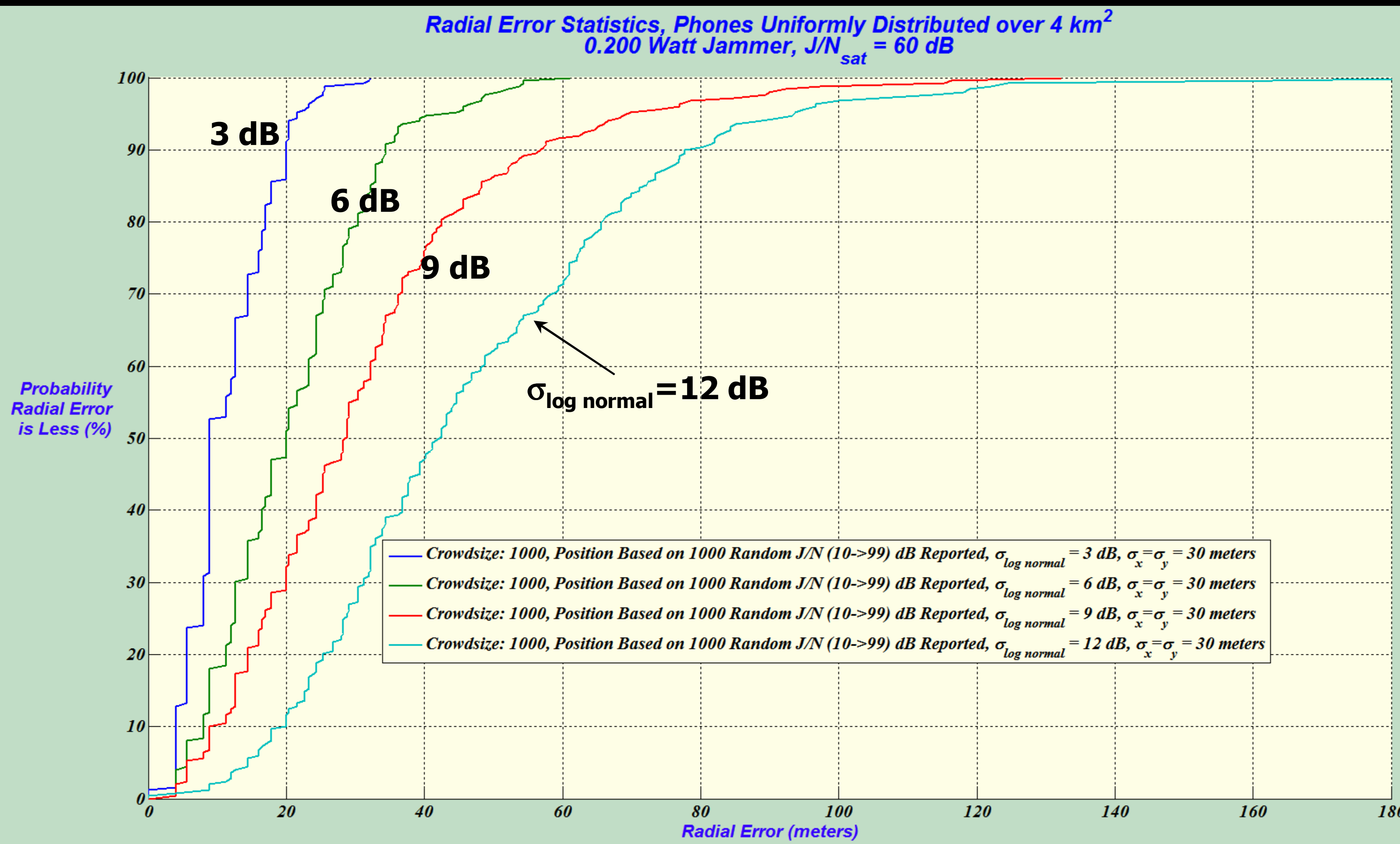


Lower J/N_{sat} Adversely Affects Ability to Determine Jammer Position

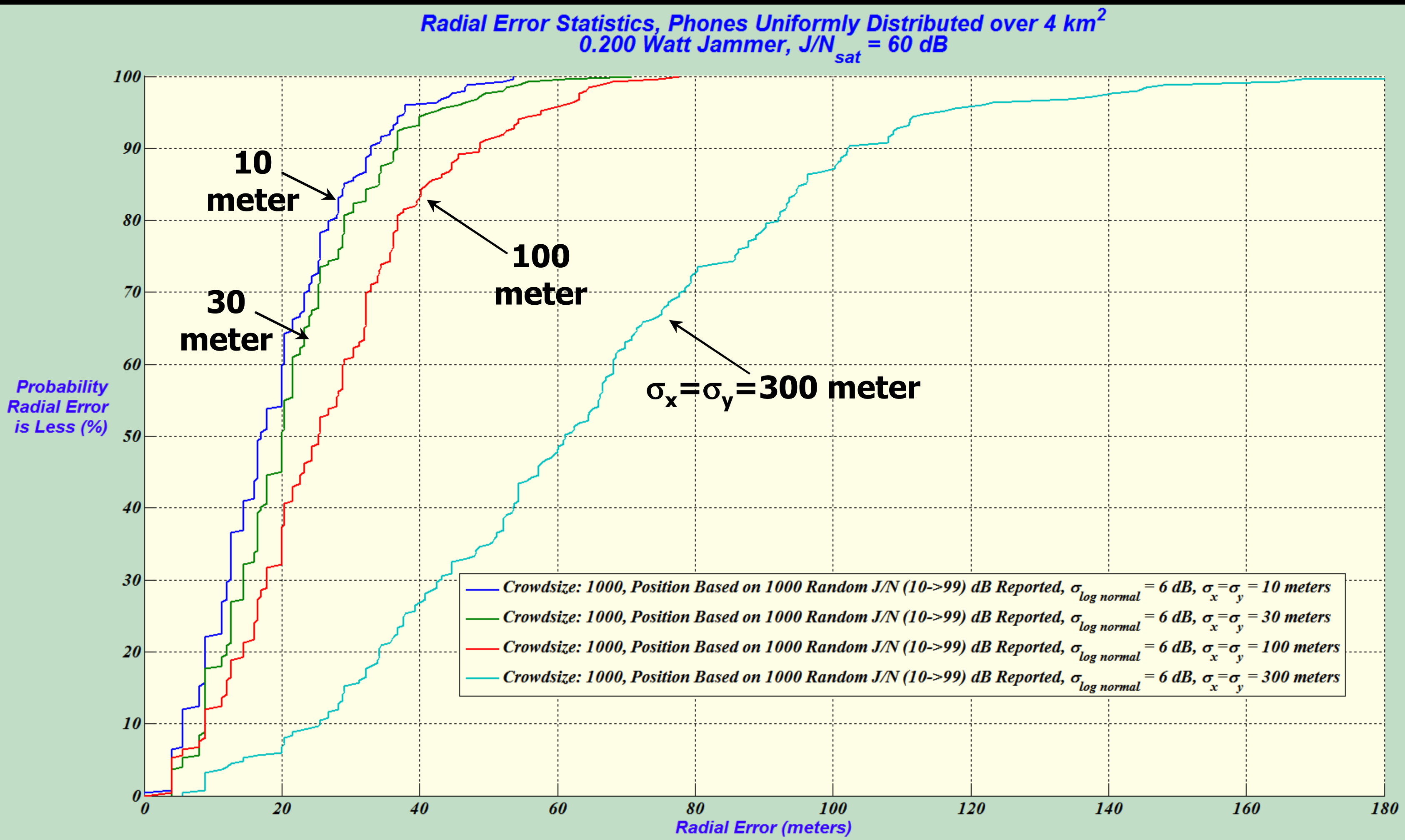
Processing 1000 Randomly Selected Measurements



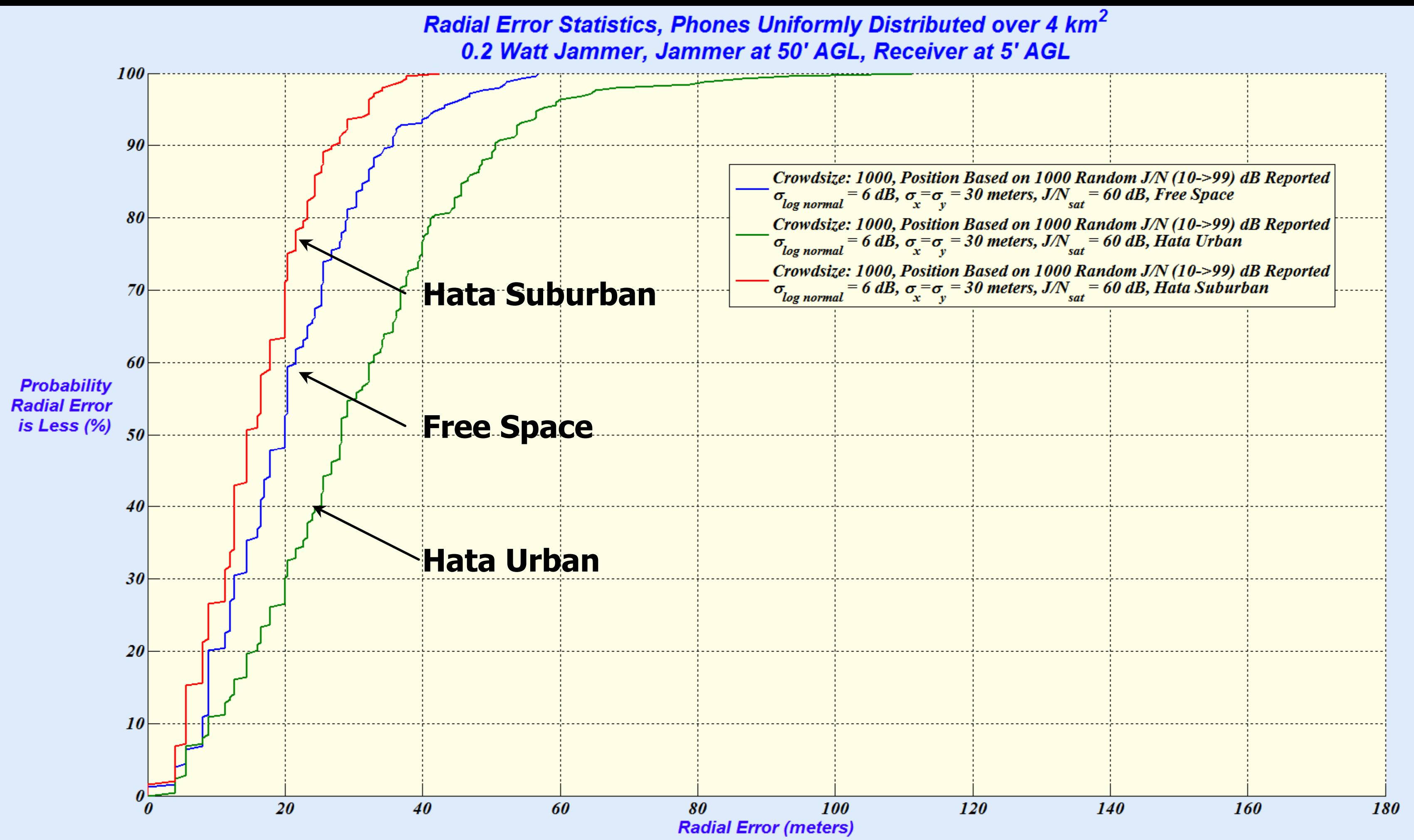
Radial Error Statistics with σ_{log_normal} =[3,6,9,12] dB Random Selection of 1000 Phones



Radial Error Statistics with $\sigma_x = \sigma_x$ =[10, 30, 100,300] meters Random Selection of 1000 Phones

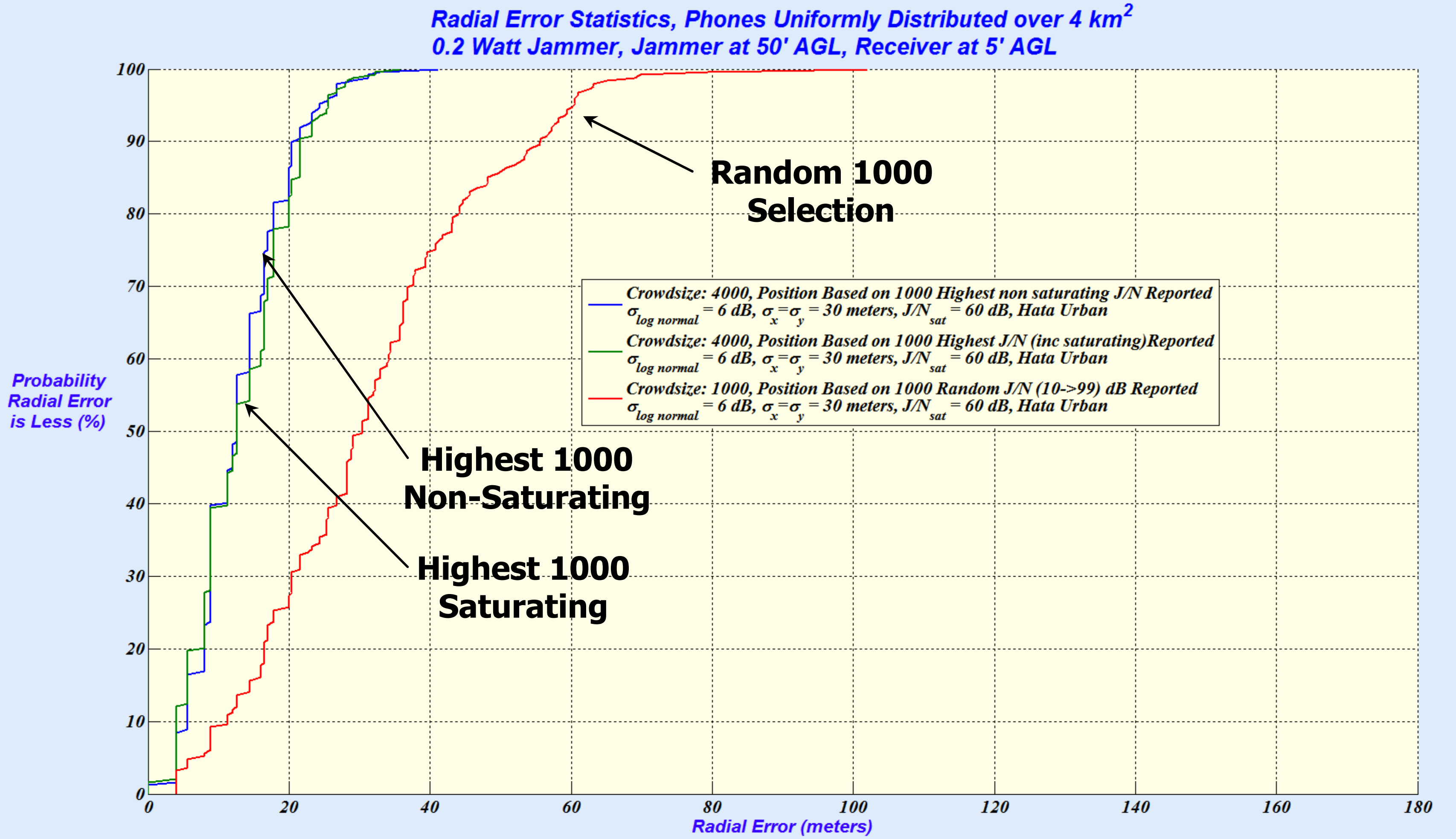


Radial Errors with Different Propagation Models Random Selection of 1000 Phones



Radial Errors with Hata Urban Propagation Models

Highest Non-Saturating, Highest Saturating, Random Selection of 1000 Phones



Hata Urban, 100 to 1000 Phones