



Smart Antenna Technology

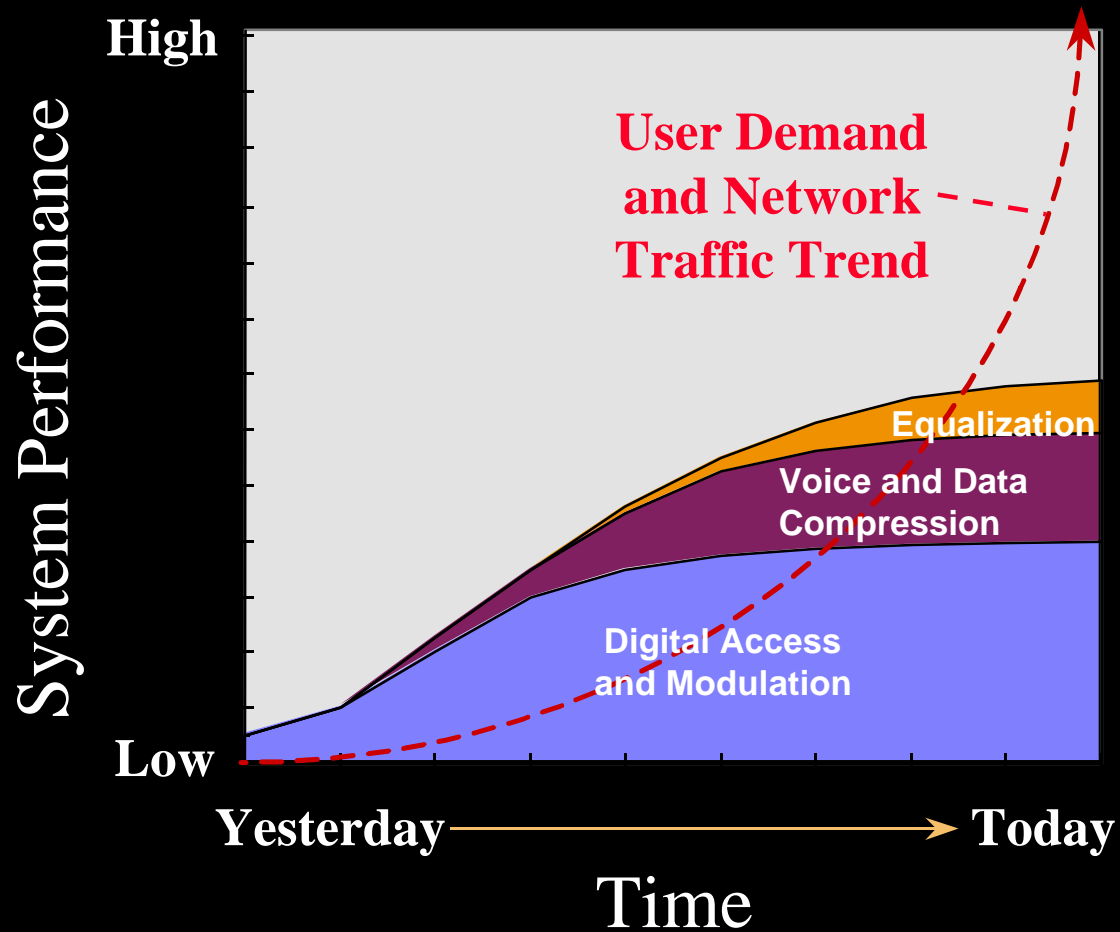
- Past, Present, and Future

Dr. Richard Roy

ITS ART Symposium - 9-11 September 1998



Why Does Anyone Need ... Smart Antenna Systems ?





Wireless Communication Systems

The Real Need ...

- Capacity (bits/sec/Hz/sq-km)
 - More links per unit-area
 - High quality per link
- $C_i = W_i \log_2(1 + P_i/N)$



Wireless Communication Systems A Real Solution ...

- $C_i = W_i \log_2(1 + P_i/N)$
- Smart antenna technology
 - Increases P_i/N for all i (better signal quality for all users)
 - Increases the simultaneous number of users (range of i)



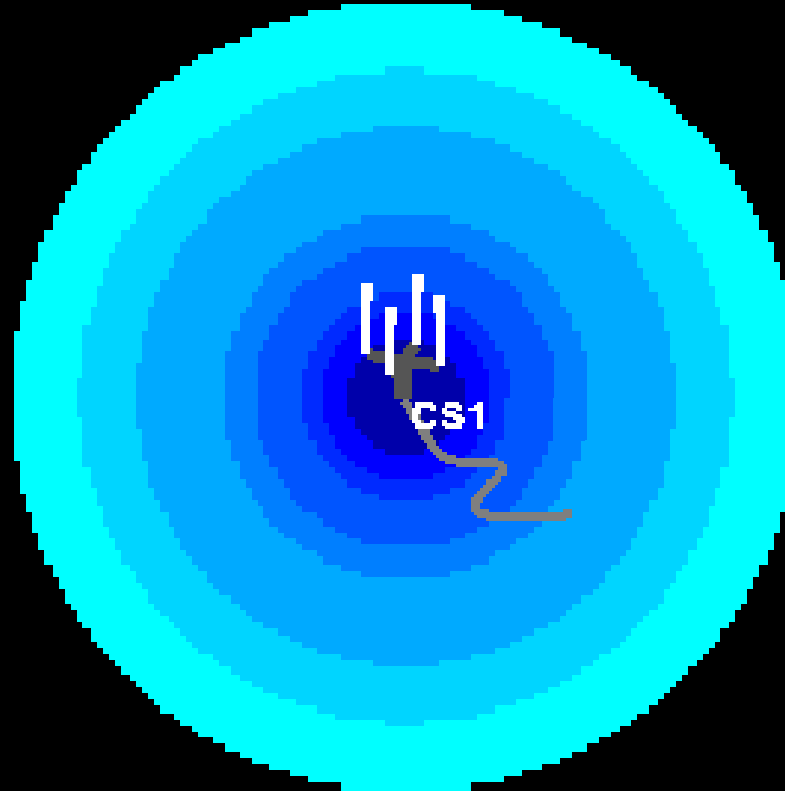
Why Smart Antennas?

The real challenges ...

- Maxwell's equations are simply stated, but ...
- Electromagnetic propagation in the real world is rather complex
- The real world is constantly changing
- Power control is the issue - temporal AND spatial

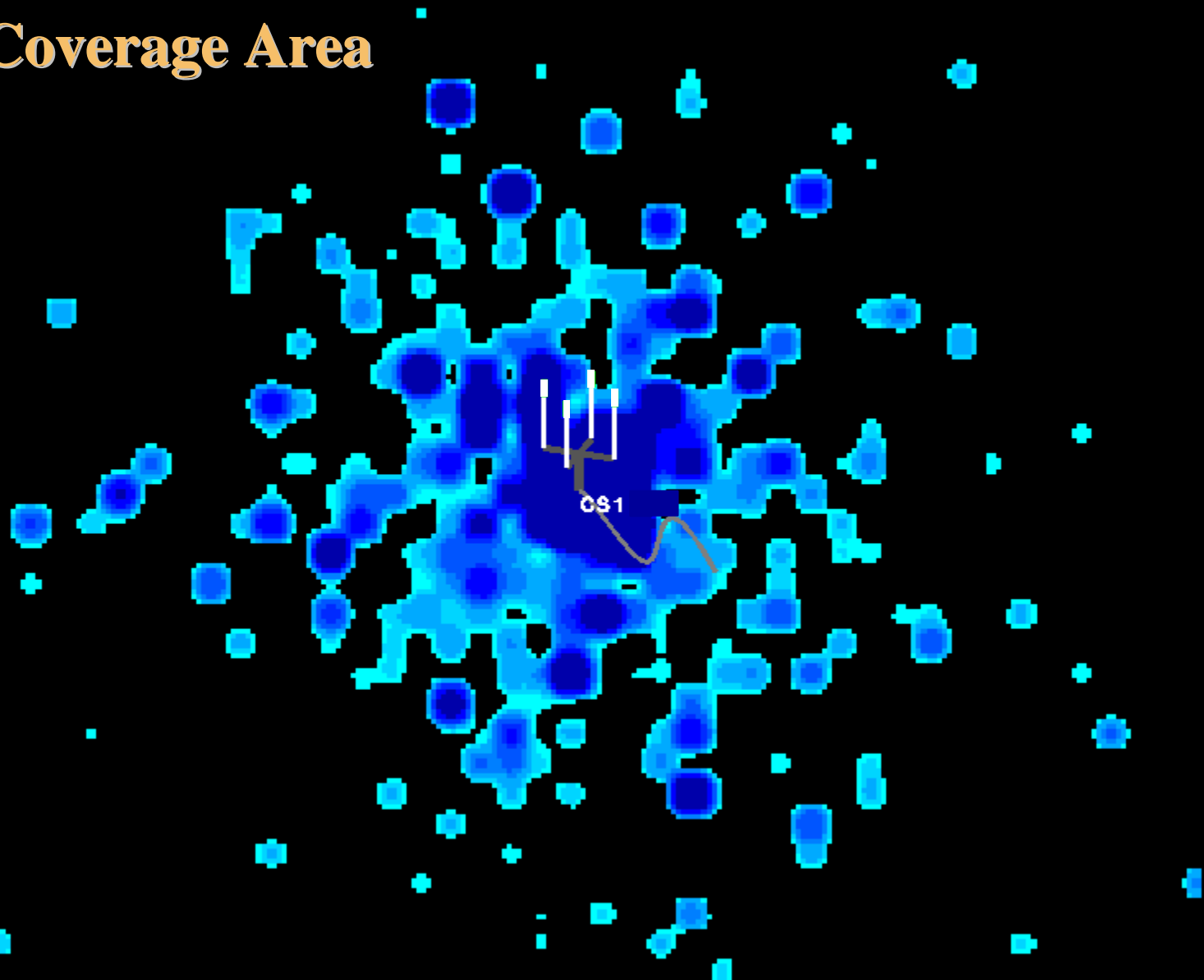
Ideal RF Environment

Coverage Area



Outer Space Cell

Real RF Environment Coverage Area



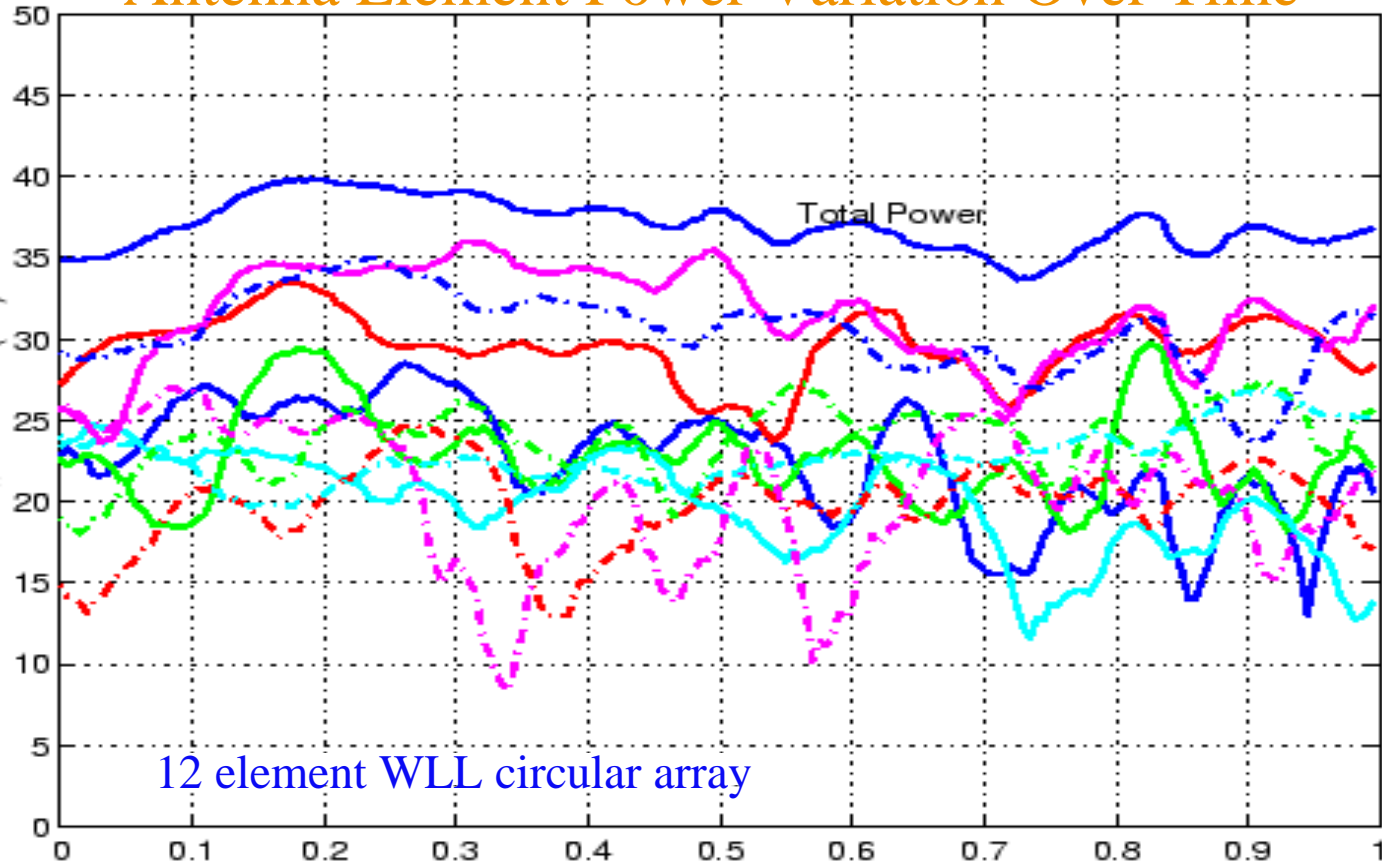
Urban Cell

Wireless Communication Systems

The Need for Adaptivity ...

Relative Power (dB)

Antenna Element Power Variation Over Time



12 element WLL circular array

Time (sec)

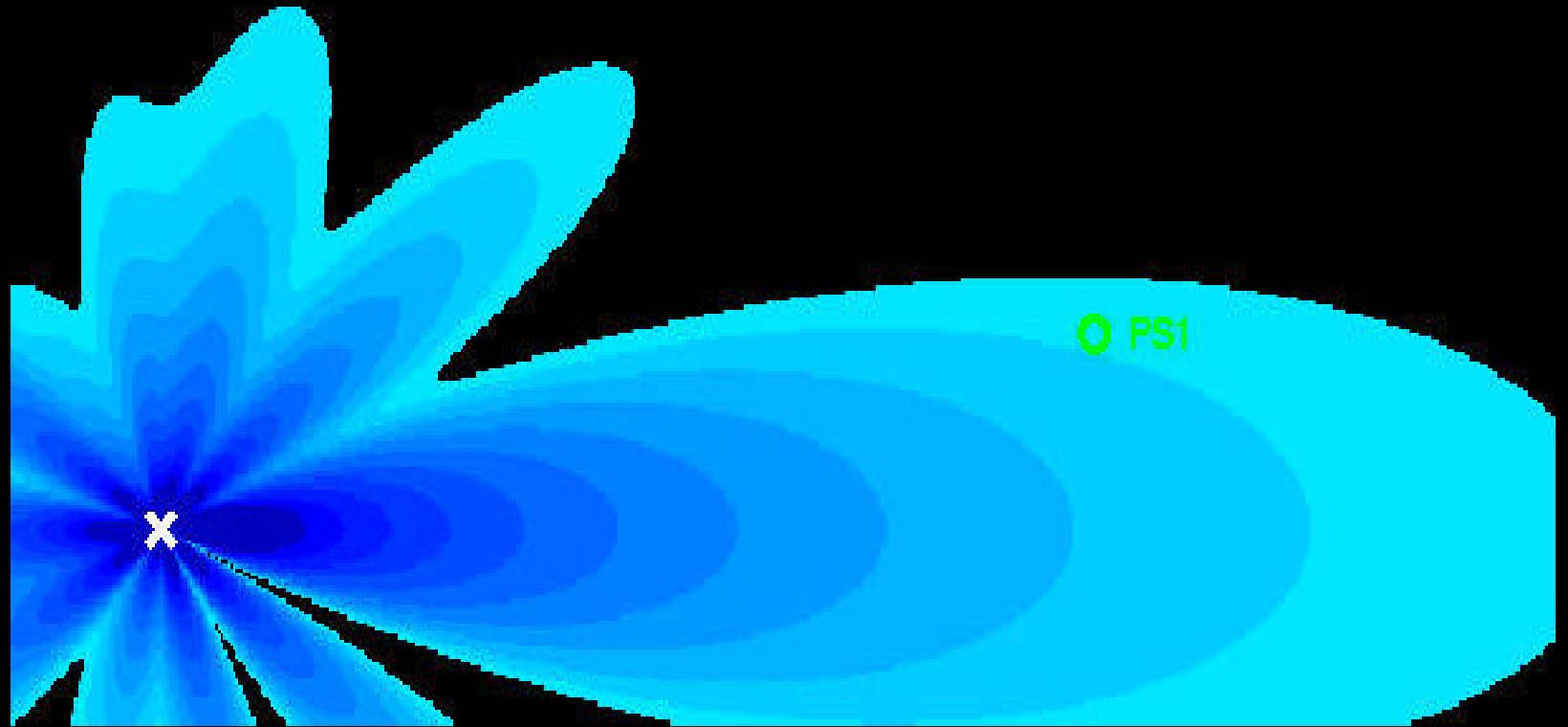


Smart Antenna Technology Precursors - Past and Present

- Sectorization
- Microcells
- Diversity
- Common theme: more (spatially distributed) antennas provide increased ability to control power

Ideal RF Environment

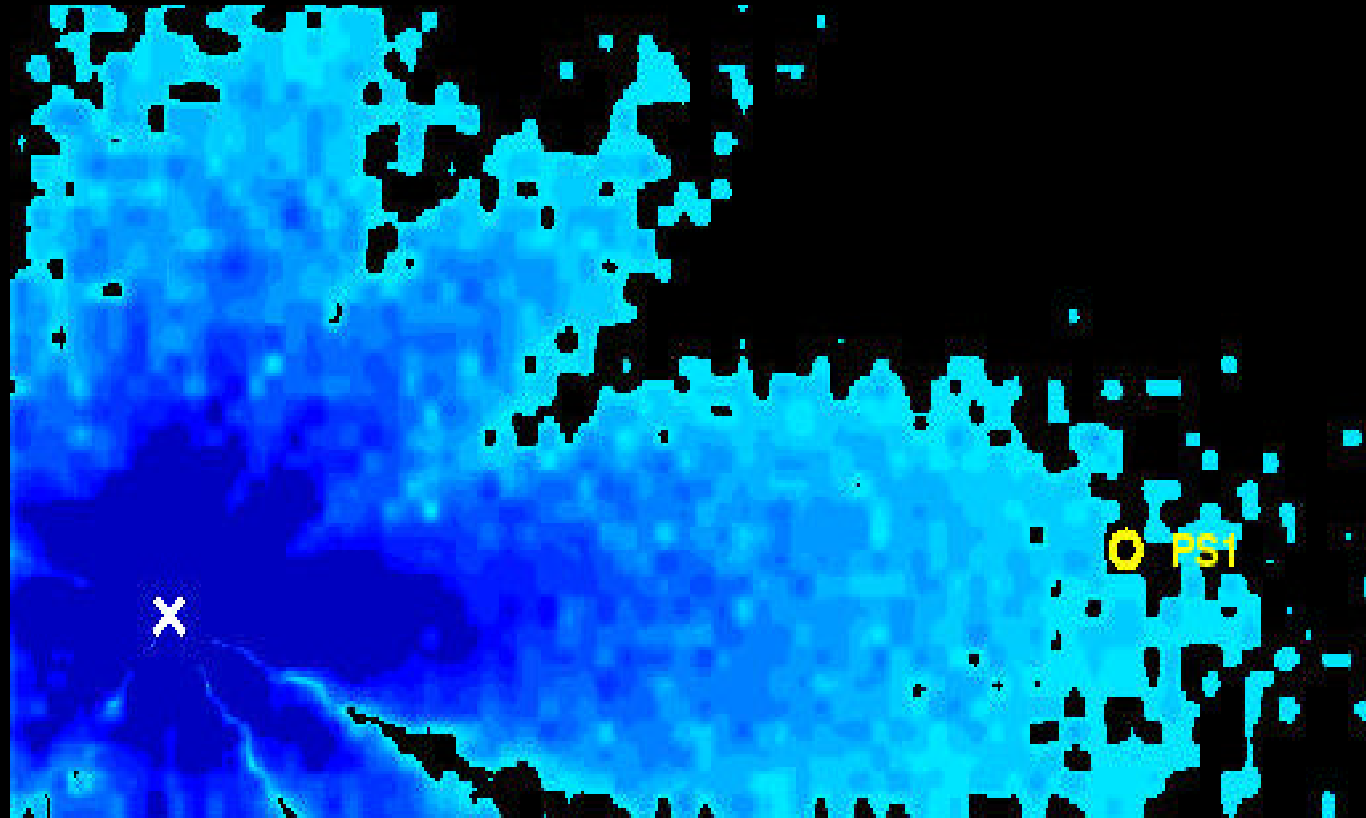
Directional Antenna Coverage Area



Outer Space Cell

Real RF Environment

Directional Antenna Coverage Area



Suburban Cell

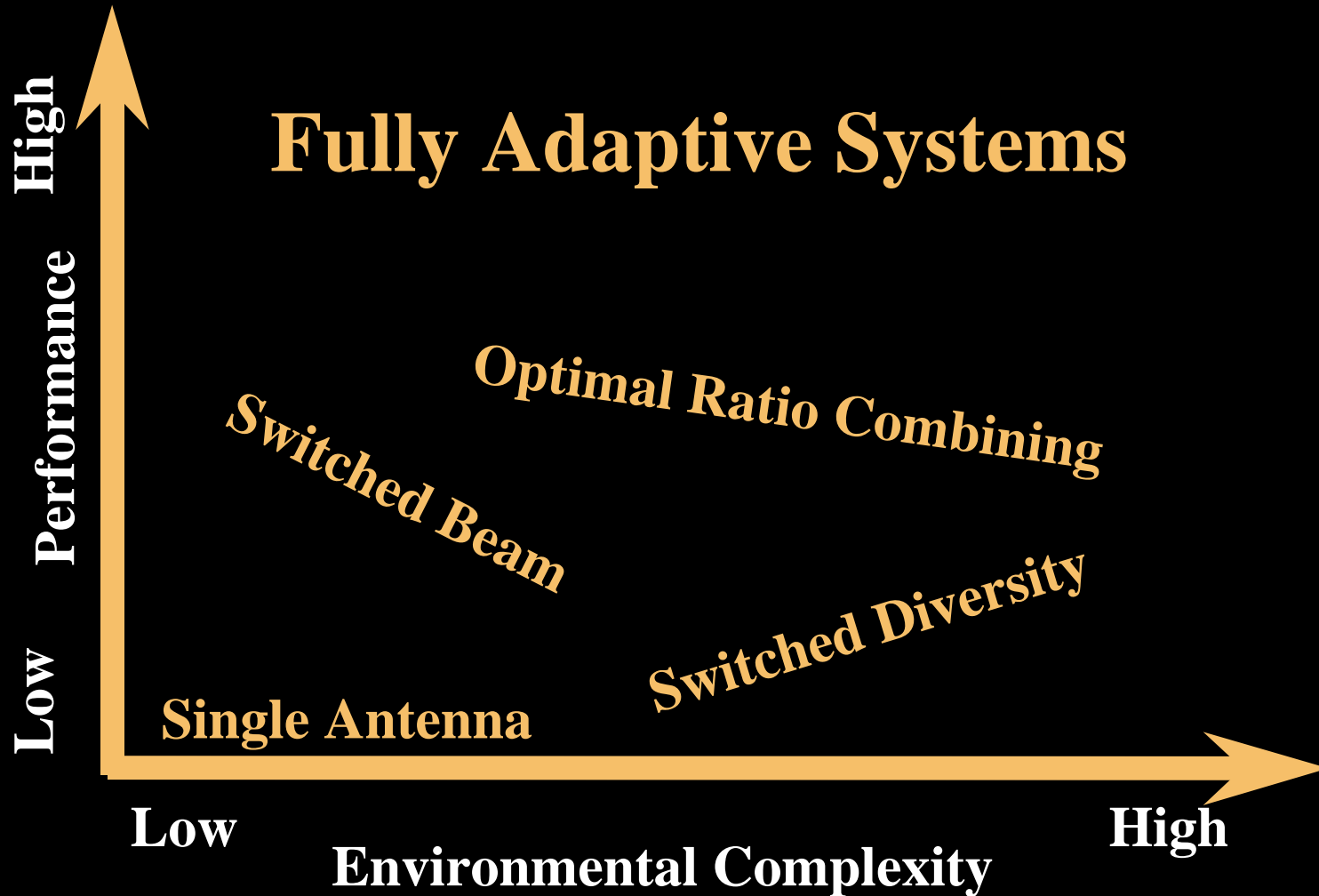
Real RF Environment

System Engineering and Frequency Reuse

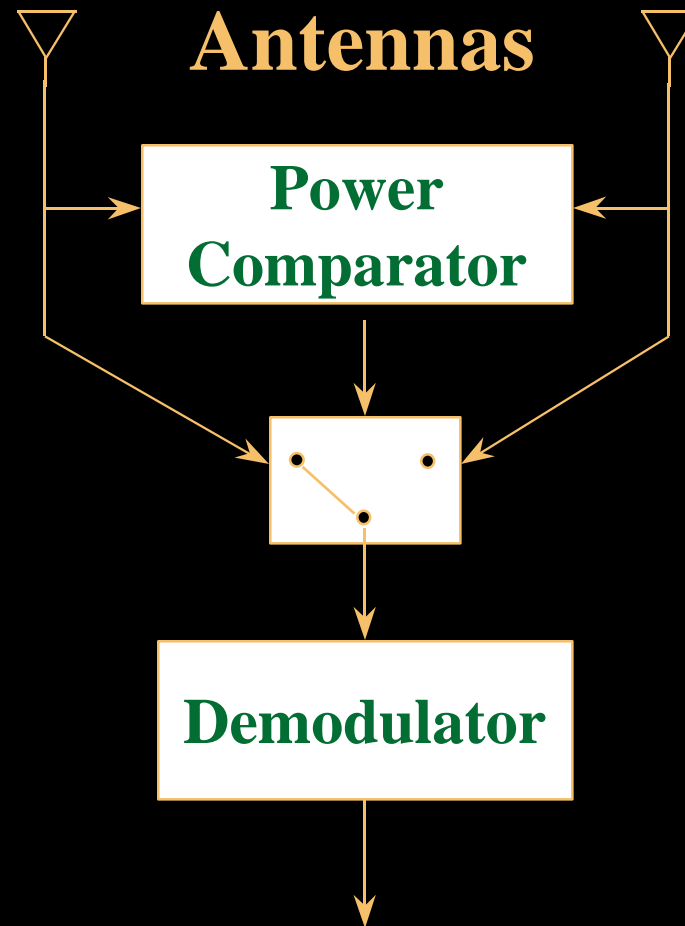


Trading Coverage for Capacity

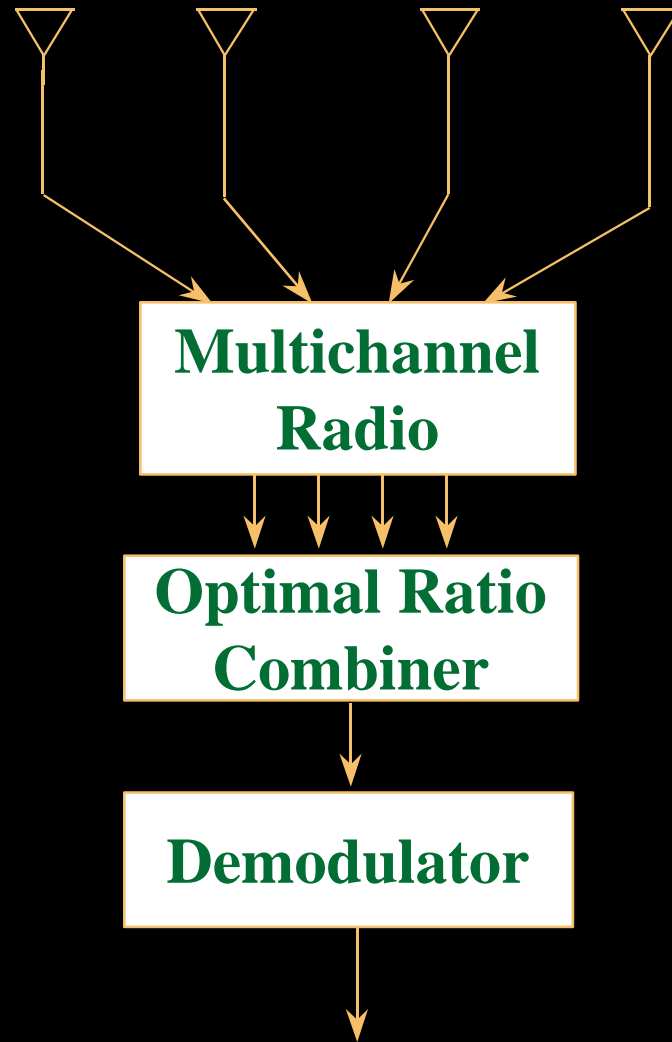
Smart Antenna Technology Road to the Future ...



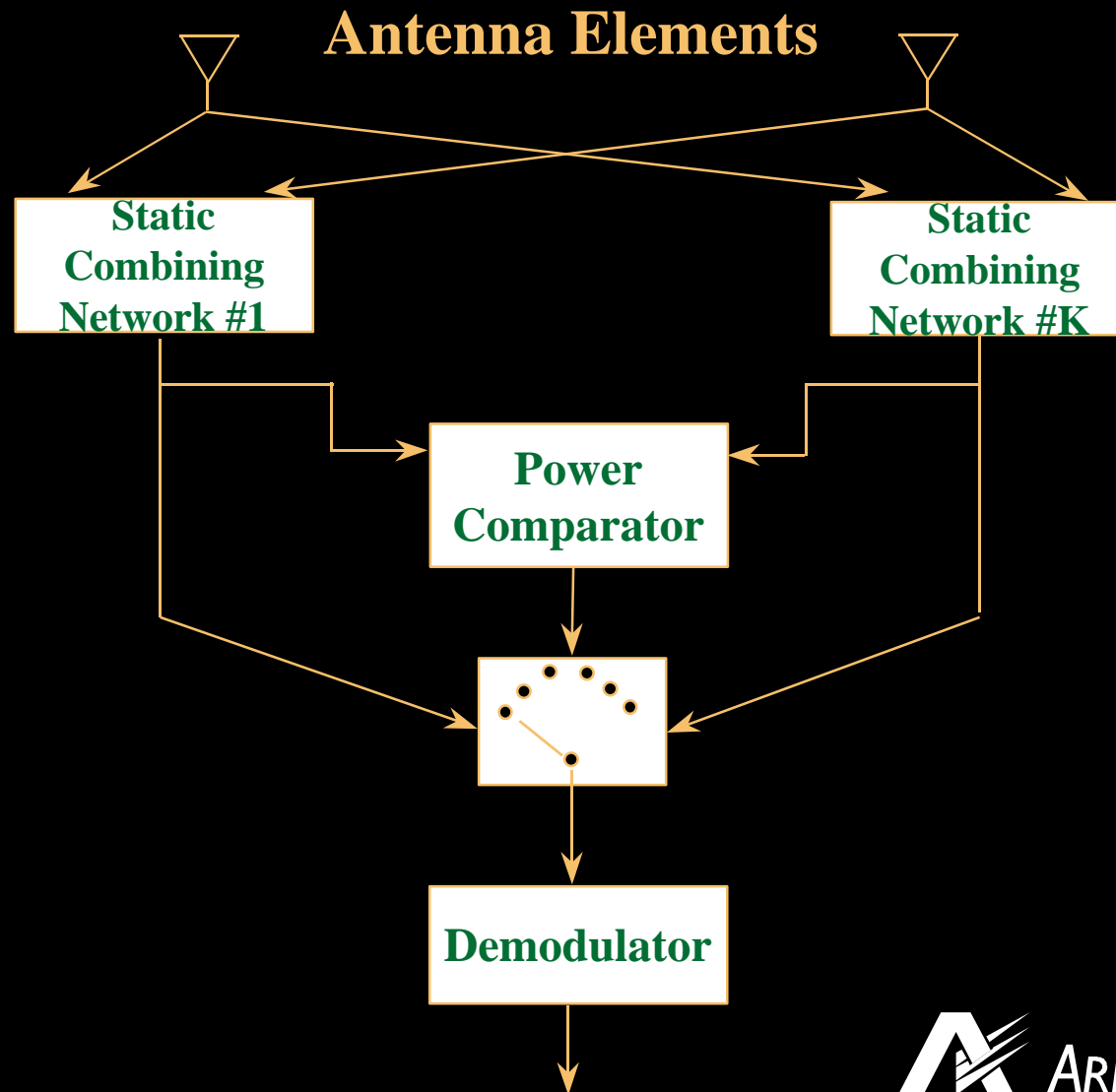
Selection Diversity



Optimal Ratio Combining Antennas



Switched Beam Systems





Past and Present Smart Antenna Systems Commonalities ...

- Increased number of antennas of differing types
- Relatively simple signal processing (based on detection of signal power)
- Limited use of temporal properties
- Provide a discrete set of fixed alternatives from which the best alternative is chosen



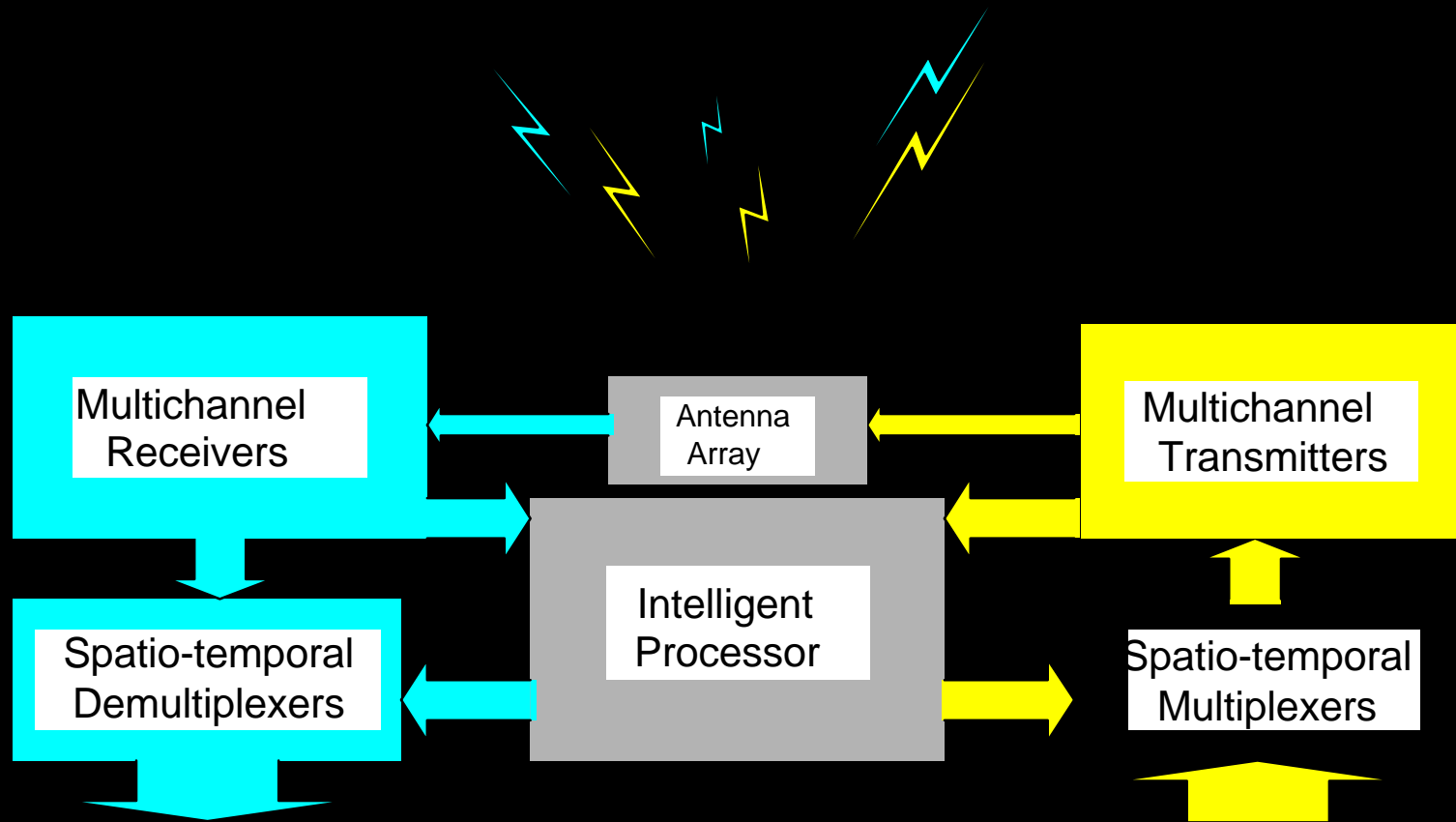
Smart Antenna Technology


The Future ...

- **Multiple antennas**
- **Digital signal processing hardware**
- **Spatio-temporal signal processing software**

Smart Antenna Technology


Basic Architecture of Future Systems





Smart Antenna Technology Algorithms of the Future ...

- **Analyze the RF environment**
 - **Estimate how signals are transformed as they propagate between (multiple antennas at) base stations and subscriber units**
- **Use analysis results to communicate intelligently**
 - **Allocate resources to maximize the number of high quality communication links that can be established simultaneously**



Smart Antenna Technology

Algorithms of the Future ...

- **Selectively receive multiple cochannel signals from subscribers**
 - **Optimally reconstruct signals from each subscriber**
 - **Reject interference from noncooperative sources**
- **Selectively transmit multiple cochannel signals to subscribers**
 - **Ensure high quality signals throughout the network**
 - **Minimize transmitted power required to accomplish this goal**



Smart Antenna Systems

Factors Affecting Algorithms ...

- **MOBILITY:** high / low / portable / fixed
- **RF ENV TYPE:** urban / suburban / rural
- **RF ENV VARIABILITY:** low ... high
- **MULTIPLE ACCESS:** FDMA / TDMA / CDMA
- **DUPLEX METHOD:** TDD / FDD
- **MODULATION:** FM / BPSK / DQPSK / GMSK ...
- **CONNECTION TYPE:** circuit (voice) / packet (data)
- **PROTOCOL:** training sequences / power ctl / feedback
- ...



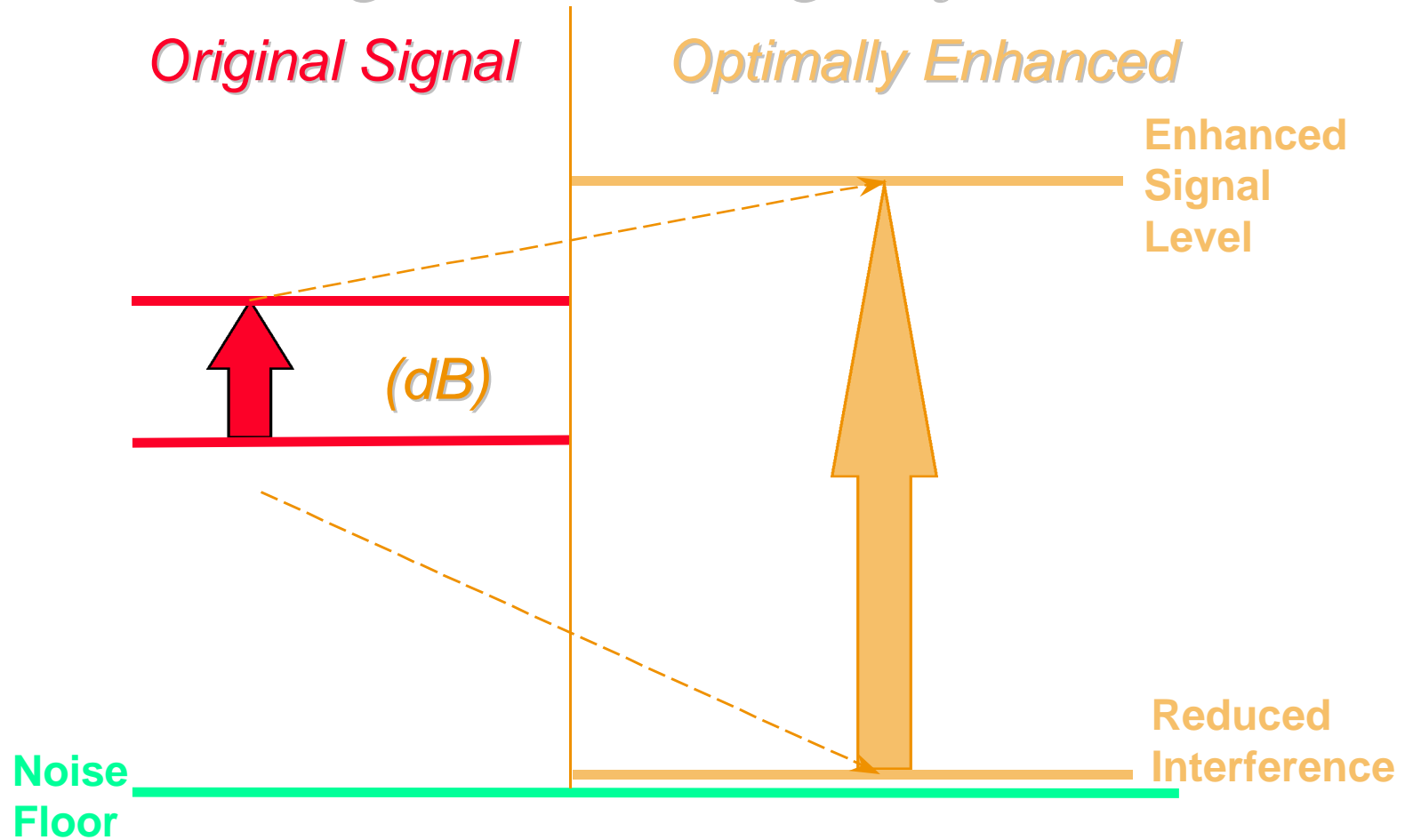
Future Smart Antenna Systems Commonalities ???

- Increased number of antennas of differing types
- Spatio-temporal signal processing of varying complexity for exploiting various amounts of information present
- Increasing appreciation of the system identification and optimal control aspect of the wireless communication problem
- Designed from the outset with smart antenna technology in mind



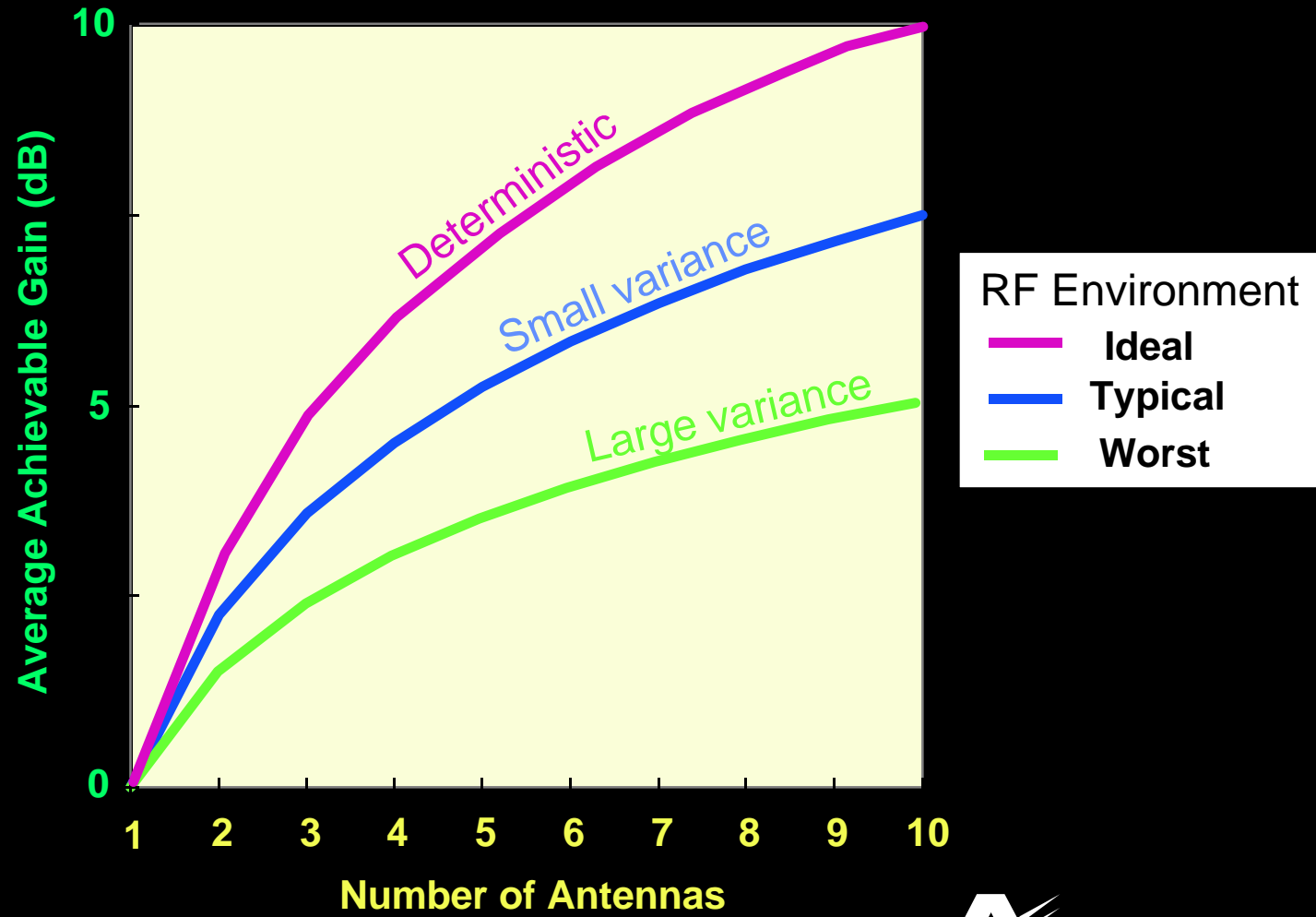
Future Smart Antenna Systems

Common Signal Processing Objectives



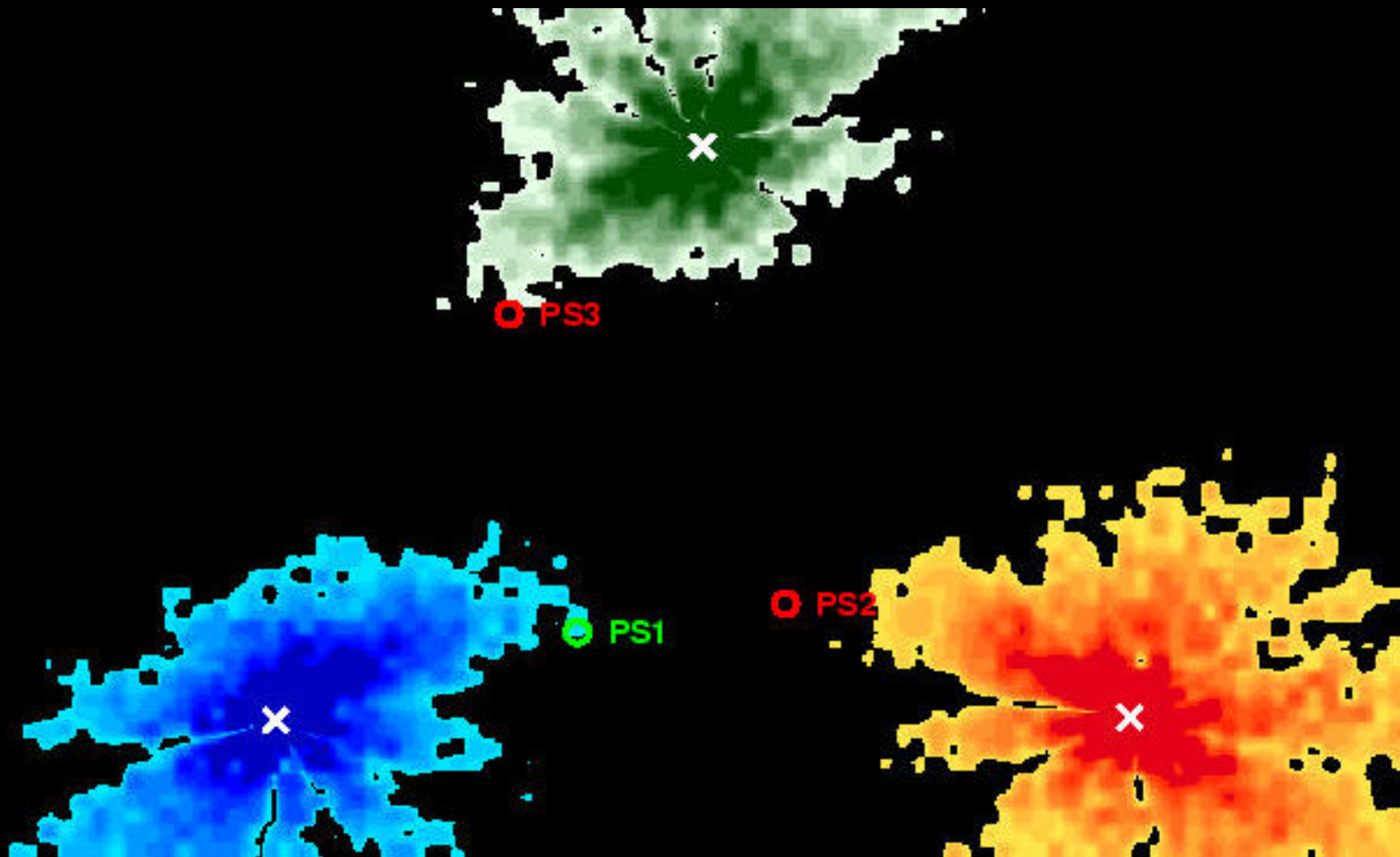
Future Smart Antenna Systems

Transmit Power Efficiency Limitations



Fixed-Sector Wireless System

Sample Suburban Deployment



Cochannel Interference Prohibits Intercell Reuse

Smart Antenna Wireless System

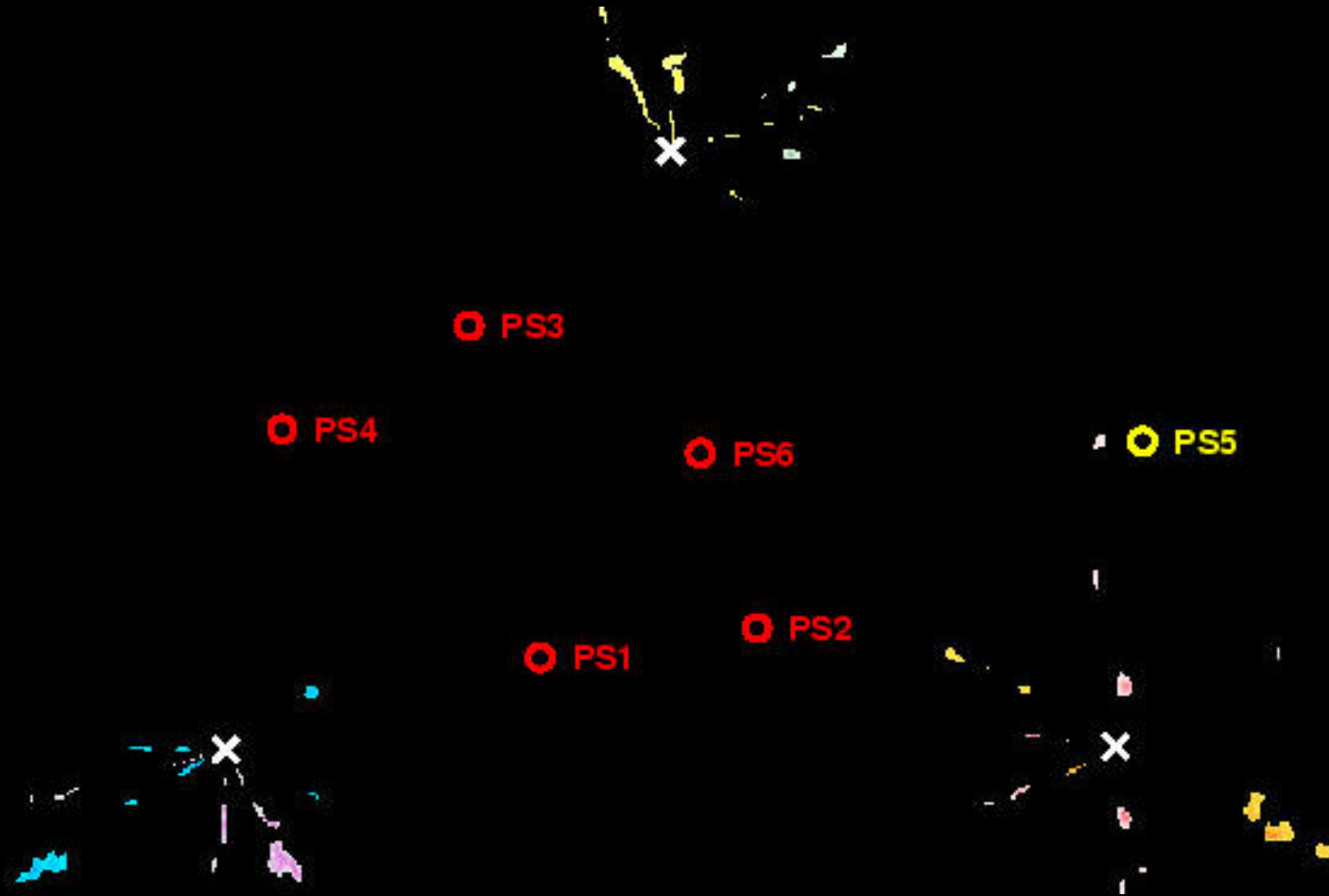
Sample Suburban Deployment



Spatial Selectivity Permits Intercell Reuse

Fixed-Sector Wireless System

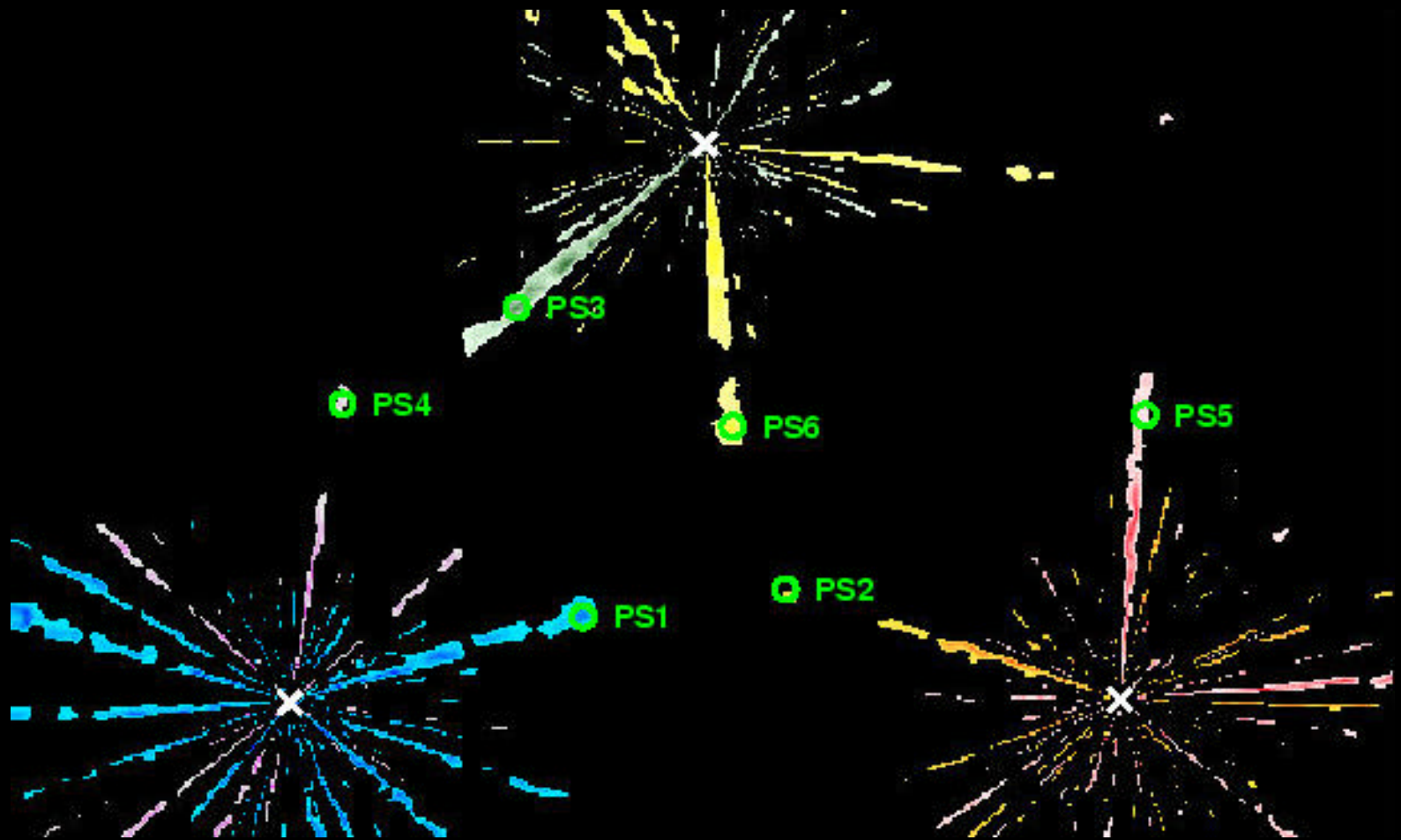
Sample Suburban Deployment



Cochannel Interference Prohibits Intercell and Intracell Reuse

Smart Antenna Wireless System

Sample Suburban Deployment



Spatial Selectivity Permits Intercell AND Intracell Reuse



Smart Antenna Technology

What lies ahead ...

- Substantial increases in signal processing power (at decreasing costs) ...
- Improvements in spatio-temporal multi-user algorithms ...
- Advent of protocols designed with smart antenna technology in mind ...
- All point to a very bright future for smart antenna technology!