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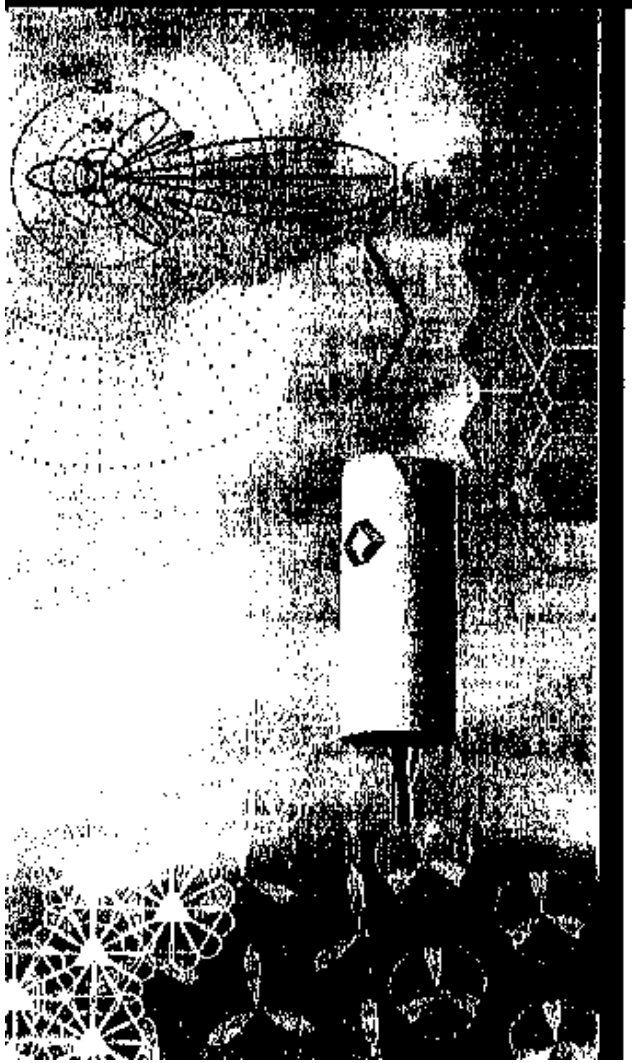

Practical Applications of Smart Antennas to Wireless Networks

by

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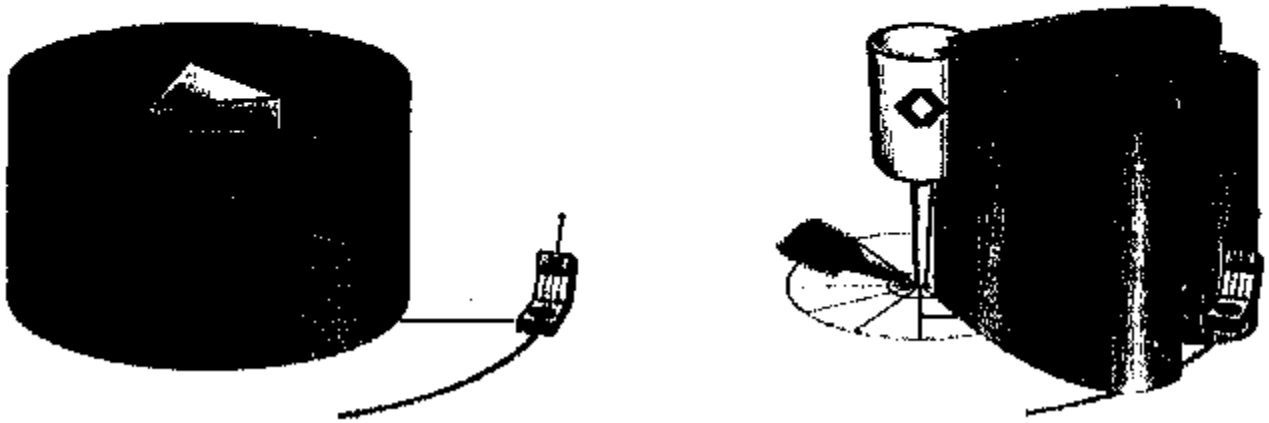
Advantages of Smart Antennas

- More efficient use of licensed RF spectrum
- Greater capacity from existing cell sites
- Broader, more consistent coverage
- Few cell sites required
- Reduction in antenna and tower siting issues
- Cleared spectrum for digital service
- Reduces transmit power

High Gain Antennas Extend Range

Increased RF sensitivity

- **Up to 11 dB over Omni**
- **Up to 6 dB over 3-Sector**



High gain, directive antennas increase cell site range by over 40%. They improve in-building penetration and close coverage gaps experienced by 0.6W phones.

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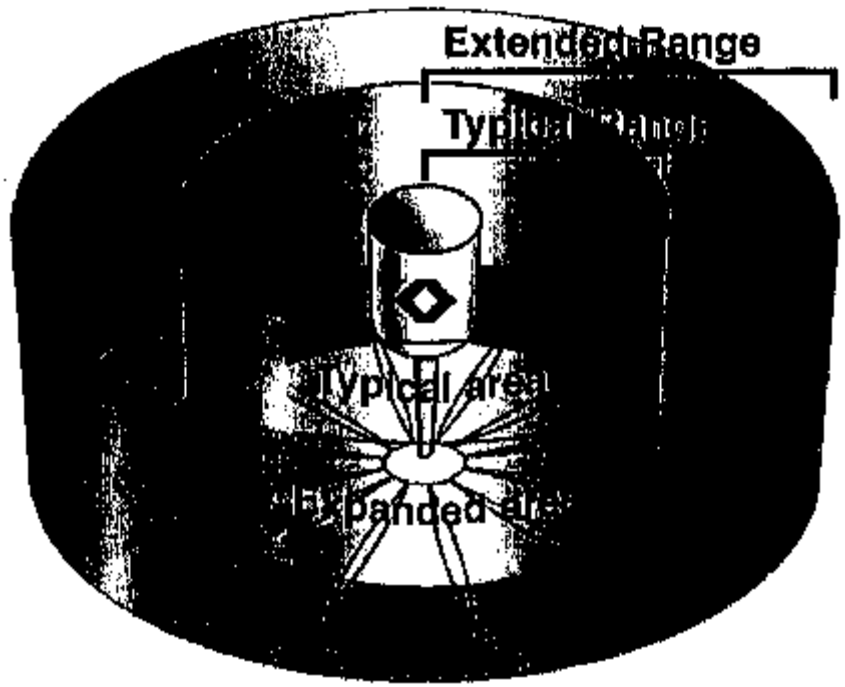
Expanded Footprint, Few Cell Sites



Smart antennas can double a cell's footprint, thereby reducing the number of cells needed to cover an area. This helps avoid antenna and tower siting issues.

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Propagation Loss

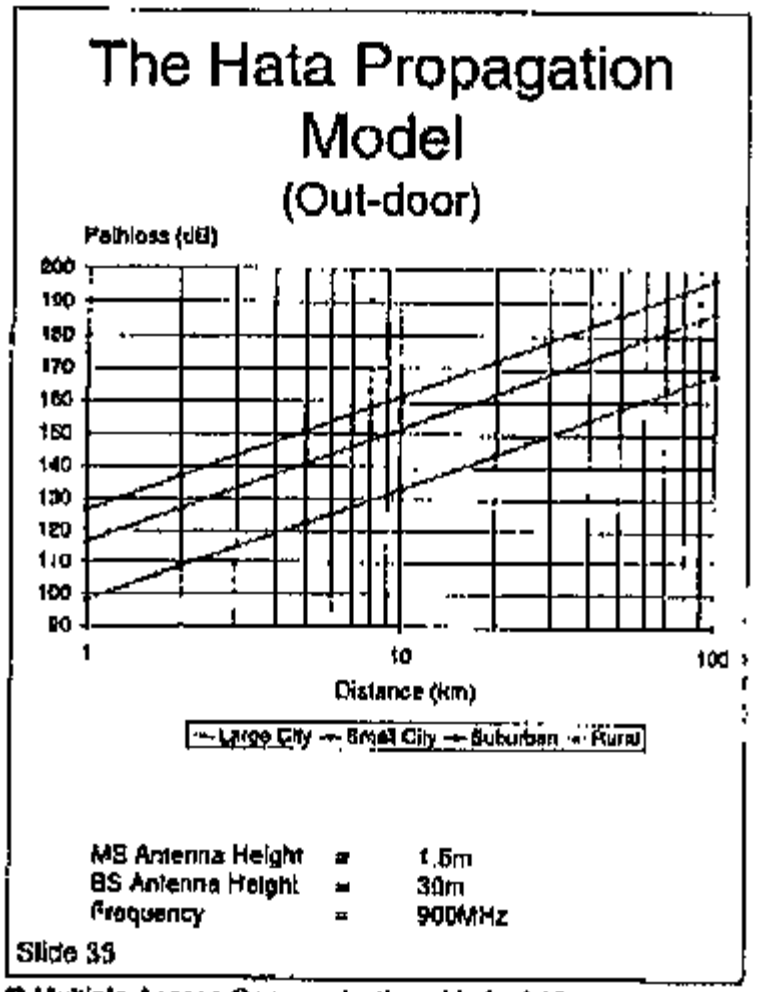
Hata Model

$$L = L_o + S \log d$$

L_o *and* S = **Functions of the frequency, antenna height and area (e.g. urban, suburban, rural, etc.**

d = **The distance between transmitter and receiver**

The Hata Propagation Model



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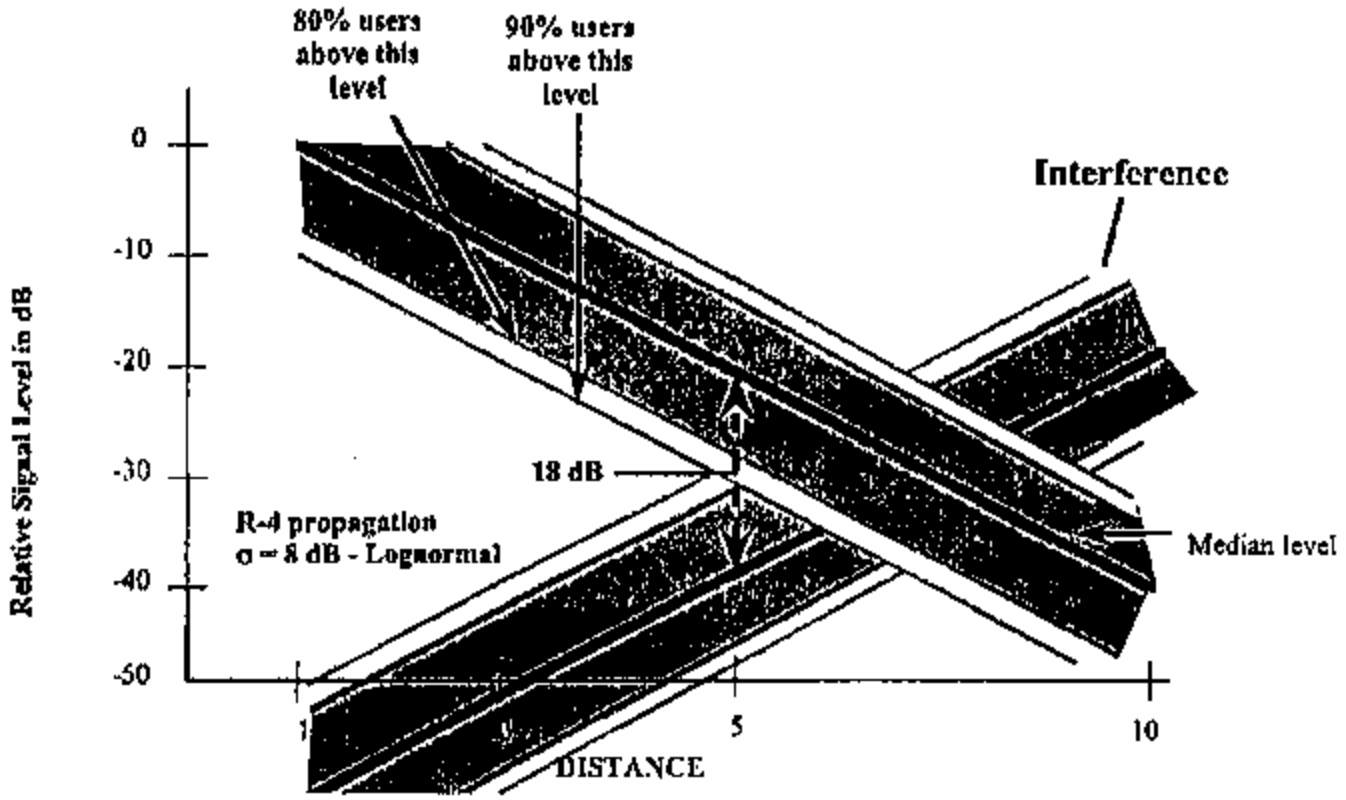
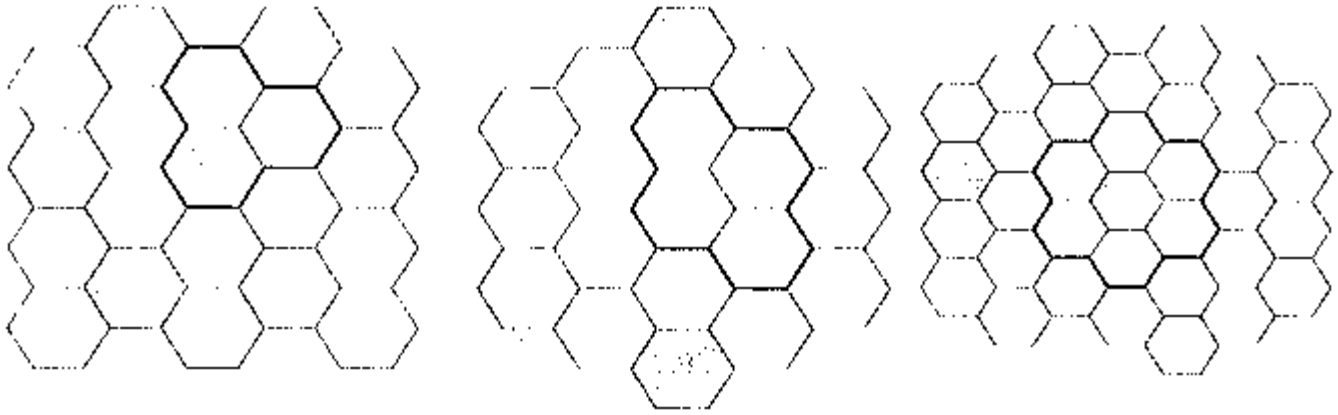
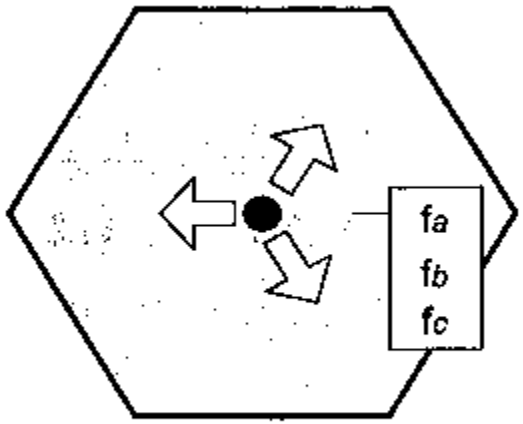
Propagation in Mobile Radio



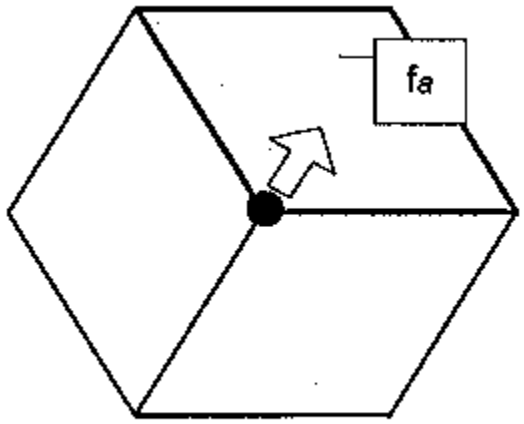
Reuse Patterns (N=3, 4 and 7)



Sectorization



omni trunking



3-sector trunking

Reduces interference but reduces capacity because few channels are available to handle peak demand.

Channel Usage Efficiency

Erlang B Formula

$$P_B = \frac{a^n / n!}{\sum_{k=0}^{n} a^k / k!}$$

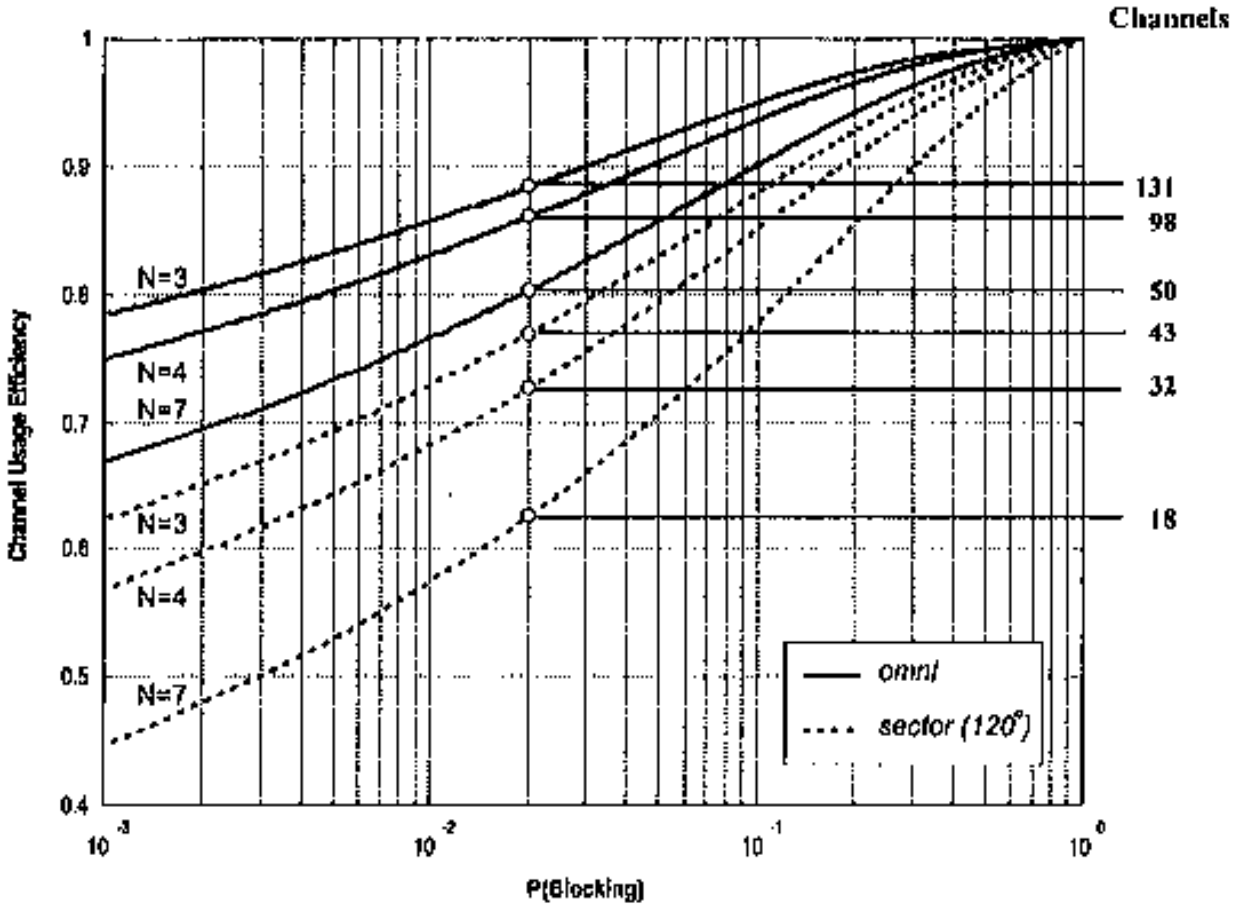
a= Offered traffic in Erlang (I Erlang corresponds to one circuit occupied during one hour)

n= The number of available channels

Channel Usage Efficiency (or loading factor)

$$\eta = a(1 - P_B) / n$$

Channel Usage Efficiency versus Blocking Probability



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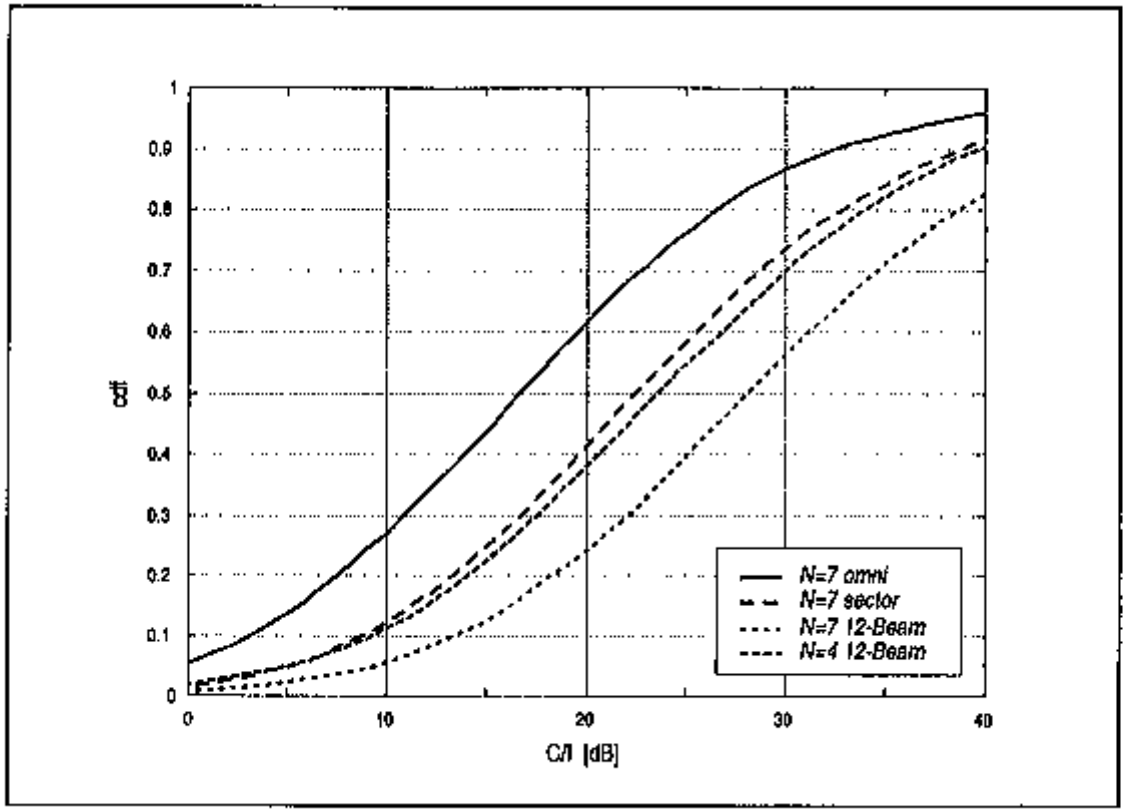
Performance of Switched Beam

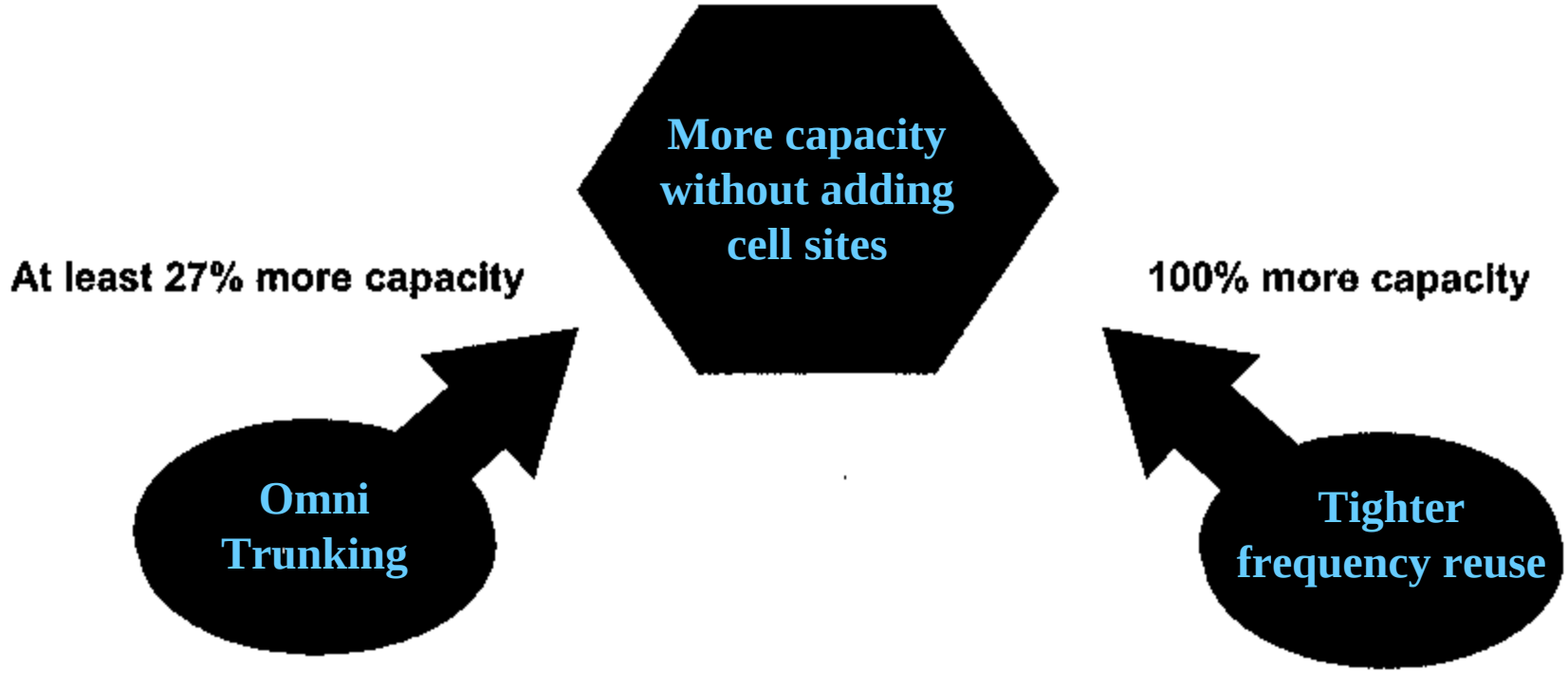


Propagation Path Slope = 3.5

Standard Deviation = 8 dB

The performance of switched beam either can be used to improve the C/I or to migrate from N=7 to N=4.

Increased Capacity from Existing Network

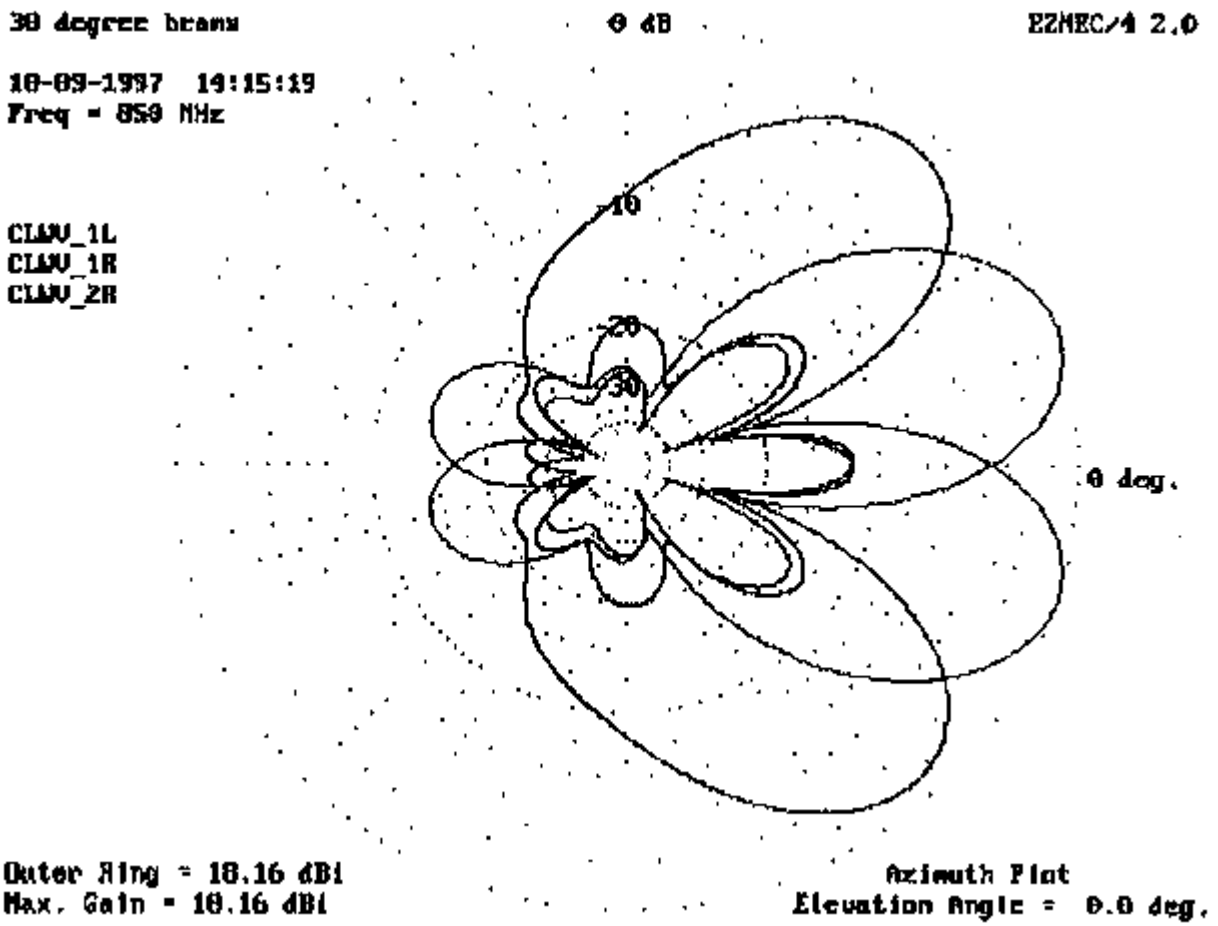


By increasing capacity, smart antennas clear RF spectrum for the introduction of digital service and minimize the need for new cell sites.

System Description

- 12 fixed 30-degree beams
- Analog and CDMA operate independently with the same antennas
  - unlocks analog and CDMA sector definitions
  - ability to optimize each system independently
- Analog operation
  - two best beams based on a combination of signal strength and SAT/DSAT are connected to the radio
  - switch matrix updates beam assignments every 1.5 seconds
- CDMA operation
  - supports three variable sector sizes Tx and Rx
  - facilitates load balancing which increases capacity

Pattern for 30 Degree Bandwidth Antenna



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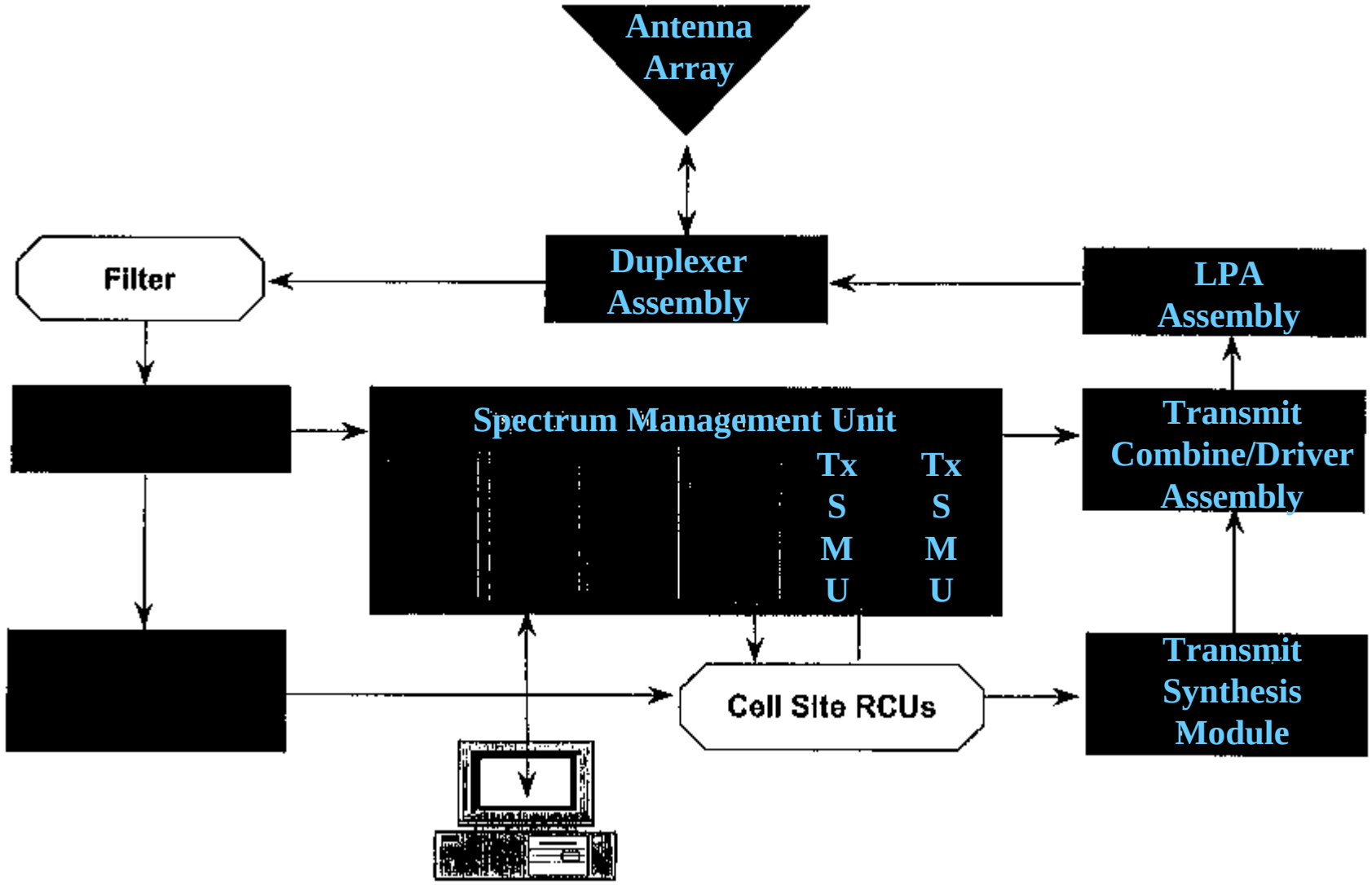
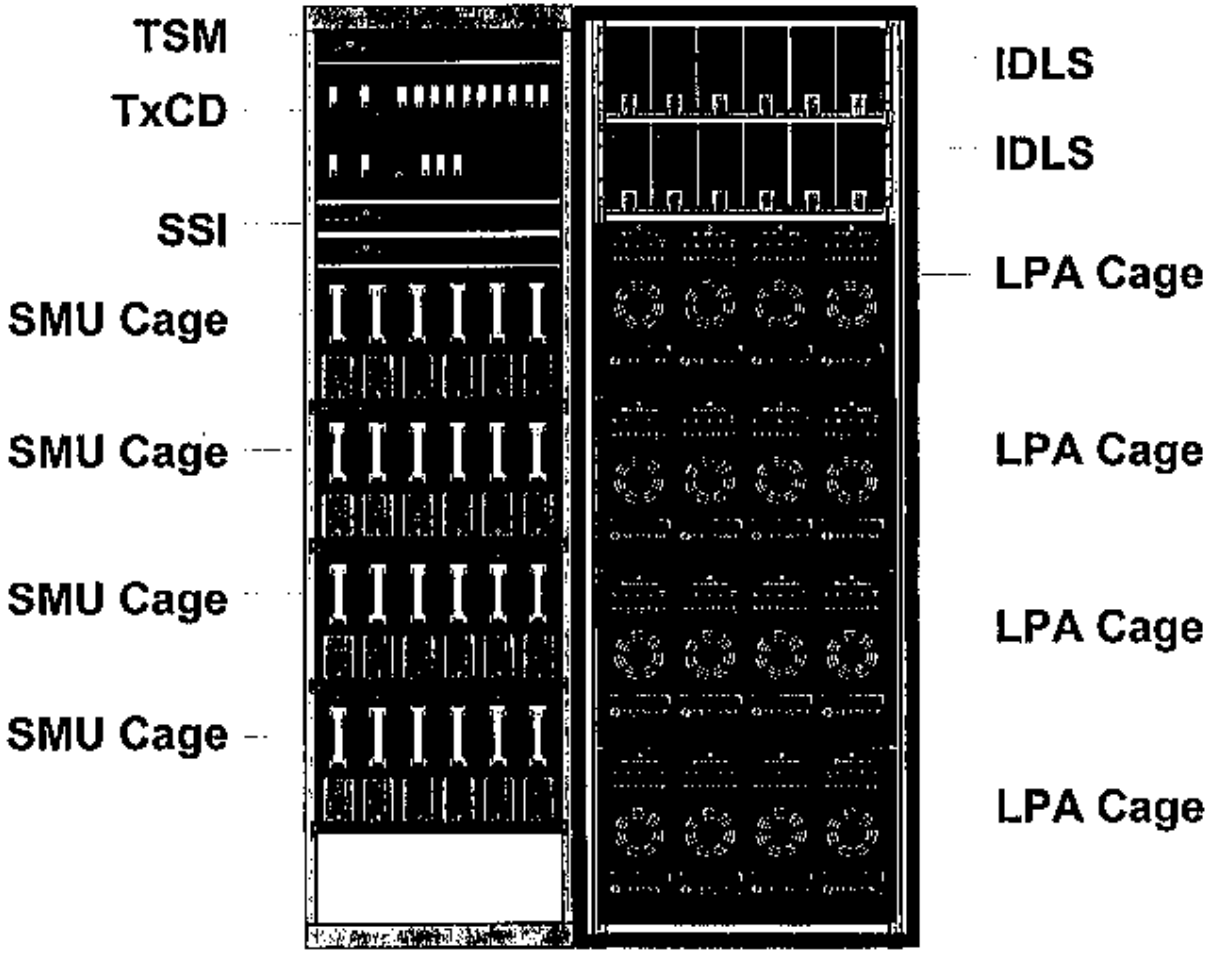
System Block Diagram



System Block Diagram



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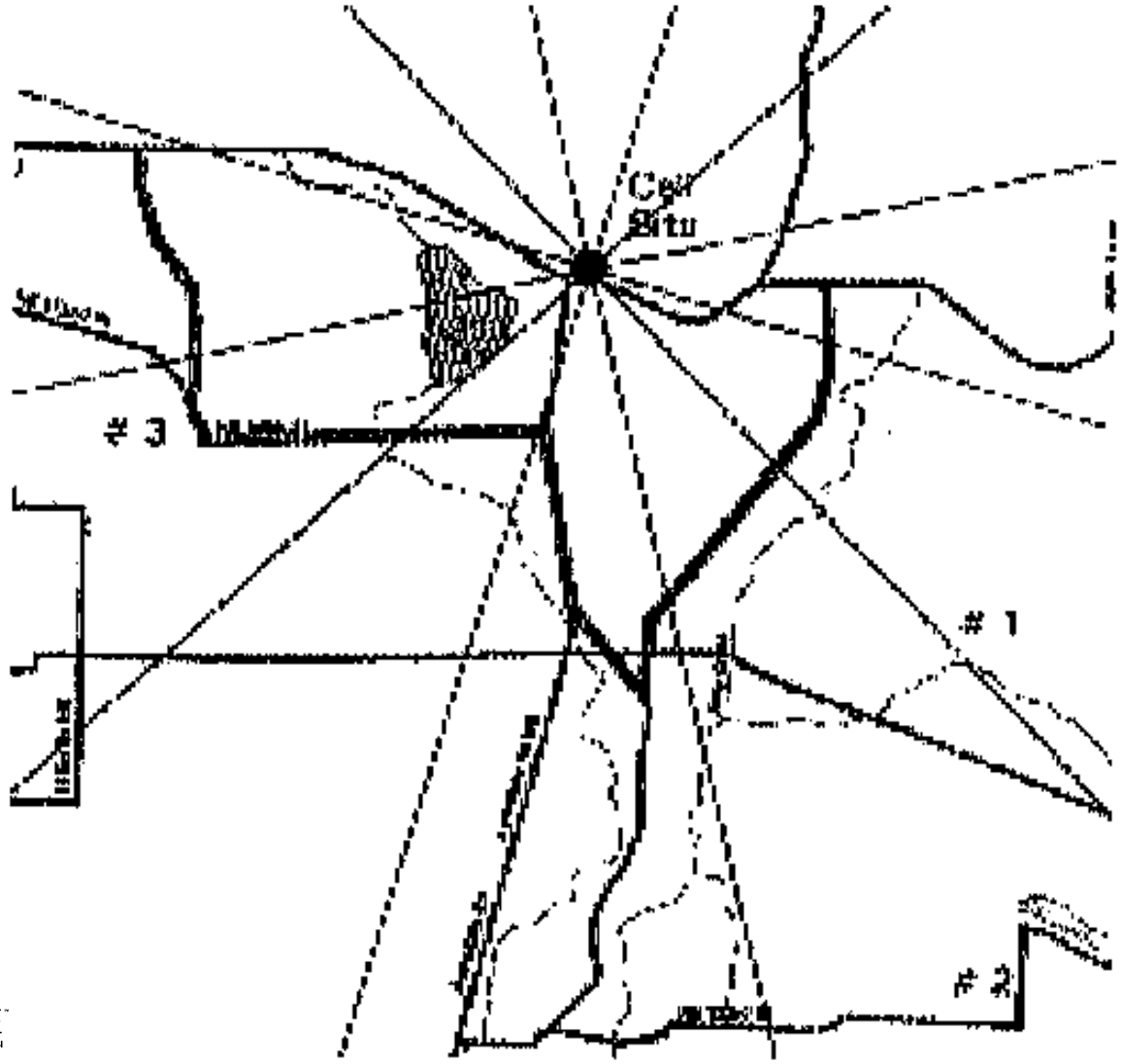
Drive Routes: Omni



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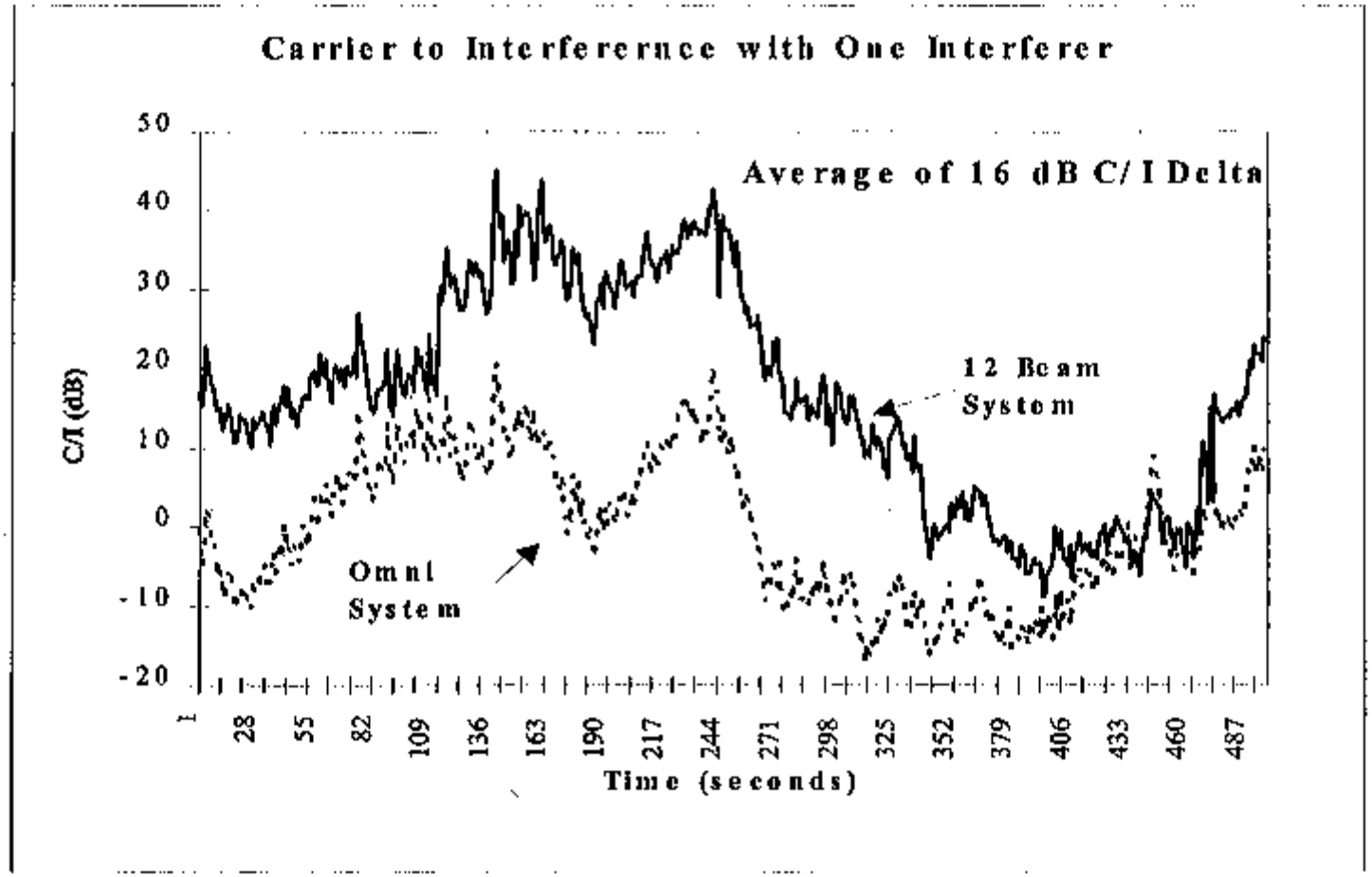
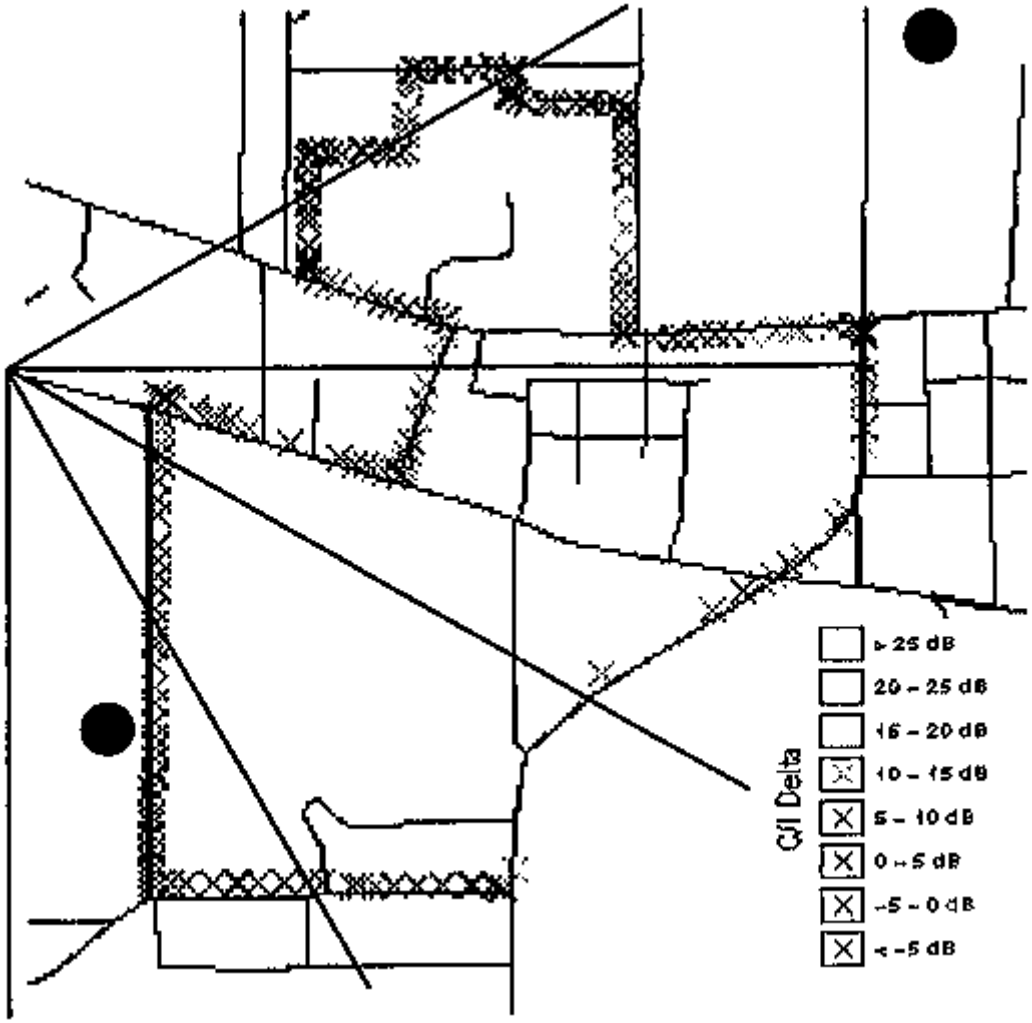
C/I Improvement: 12 Beam Over Omni



SpotLight vs. OMNI C/I Testing Results
Two Interferers

Env.	Veg.	Loc.	Original Antenna	SpotLight Antenna	C/I ↑
Sub-urban	Medium	Flat	omni	30° multibeam	13.5 dB
Sub-urban	Medium	Flat	omni	30° multibeam	11.5 dB
Sub-urban	Medium	Flat	omni	30° multibeam	13.0 dB
Rural	Light	Flat	omni	30° multibeam	10.0 dB

C/I Improvement: 12 Beam versus 3 Sector



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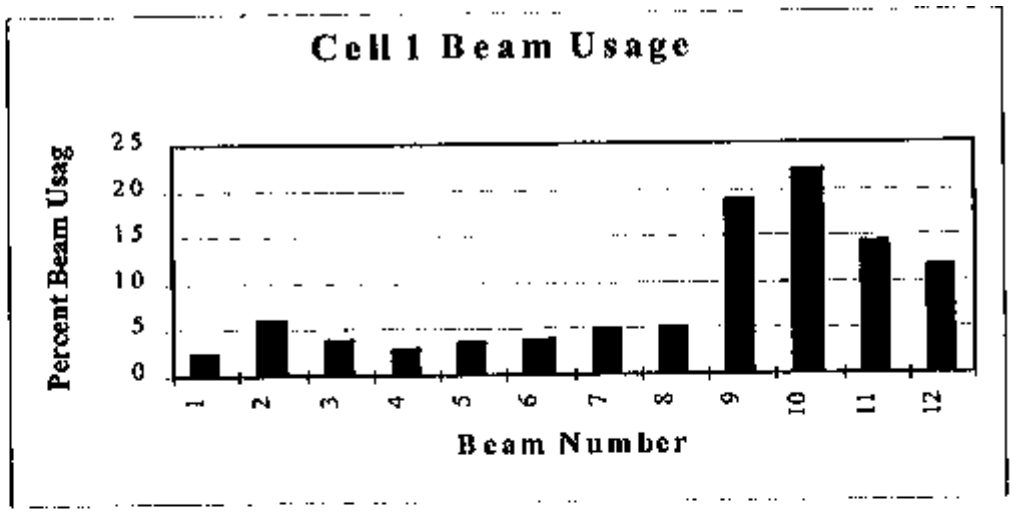
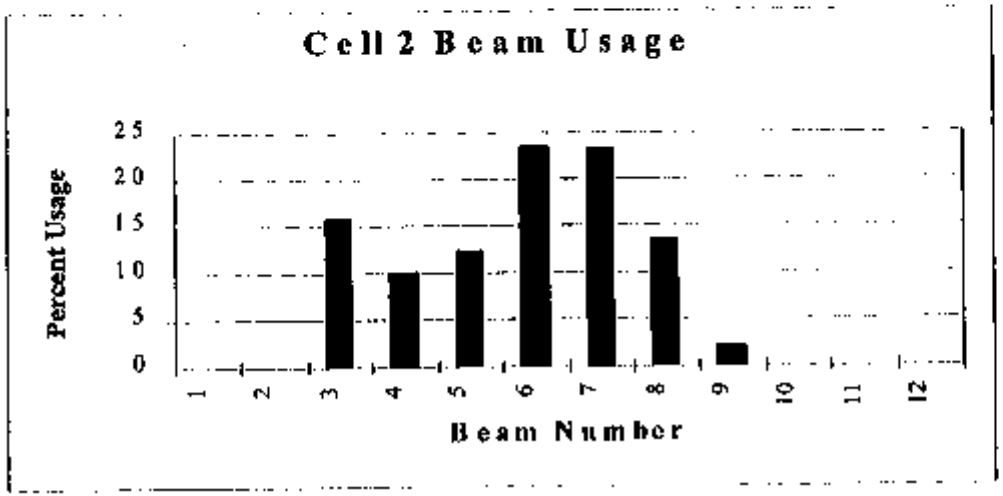
SpotLight vs. Sector C/I Testing Results
Two Interferers

Env.	Veg.	Loc.	Original Antenna	SpotLight Antenna	C/I ↑
Sub-urban	Light	Hill Top	60° sector	15° multibeam	7.3 dB
Sub-urban	Light	Hill Top	120° sector	30° multibeam	7.0 dB
Sub-urban	Medium	Flat	120° sector	30° multibeam	8.6 dB
Sub-urban	Medium	Flat	120° sector	30° multibeam	8.0 dB
Sub-urban	Medium	Flat	120° sector	30° multibeam	7.6 dB

Beam Usage





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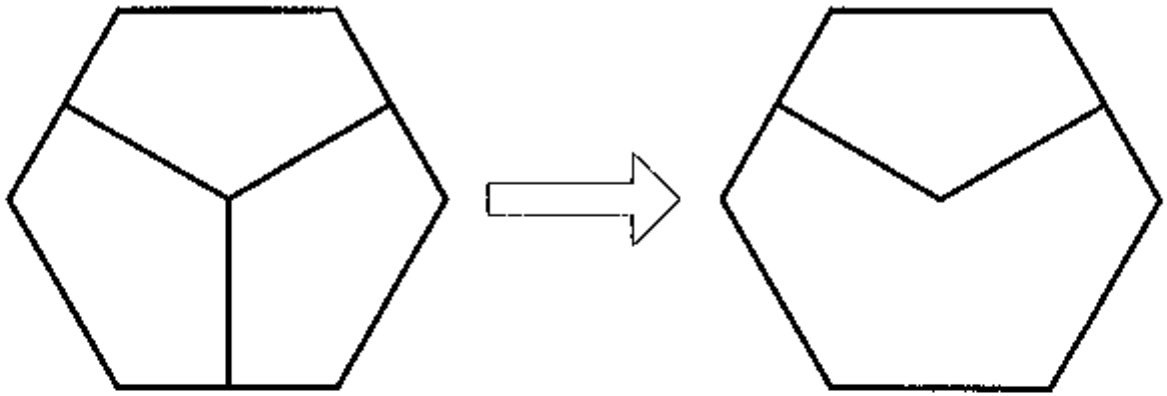
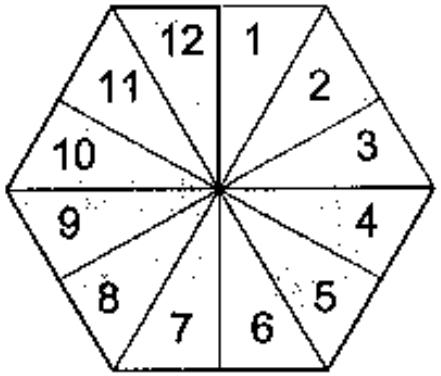
Sector Combining

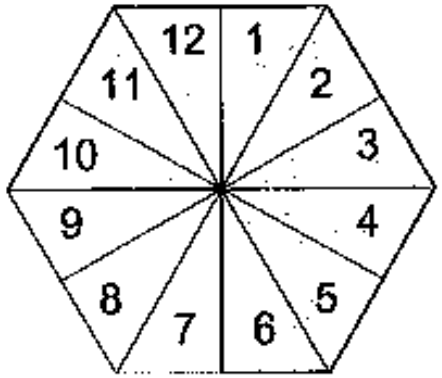


System Setup	Seizues Denied (Service Busy)	% Handoff Completions	Seizures Assigned
Thee Sector System	169.56	96.54	8652.89
Two Sector System	82.36	96.45	9262.27

Frequency Planning with Non-standard sectors



Cell A



Cell B

Conclusions

- Average 7.6 dB C/I improvement over sector system with two interferers
- Interference reduction allows a capacity increase of 100%
- Customer cell and sector sizes provide the ability to uniformly distribute traffic across sectors
  - Sector combining reduces blocking while usage increases
  - Aggressive Frequency Reuse is possible with degrading network quality