Output of the 802.16 AAS Ad Hoc

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Purpose:
AAS Ad-hoc Report

Output of the 802.16 AAS Ad Hoc

March 11-15, 2002

Randall Schwartz, Chairman

Goals of the AAS Ad-hoc

- **Reply to AAS PHY and MAC comments from Finland meeting**
- **Present data demonstrating the comparative performance of AAS with Mode C and other Modes.**
- **Flesh out text of the Mode C PHY and MAC sections**
- **Propose structure for adding AAS to other modes**

Participants in the Ad Hoc

- BeamReach
- Raze
- Conexant
- Harris
- WiLAN
- Runcom
- Intersil
- Marvel
- Vectrad
- IOSpan
- Hexagon
- Transcom
- TI
- Arraycom
- WPI

Actions of the Ad Hoc

- Conference calls held to review goals of the ad hoc, set action plan of the ad hoc, review results of the ad hoc
- Call made for inputs to both MAC and PHY text
- Call for simulation testing of all modes

Actions Taken

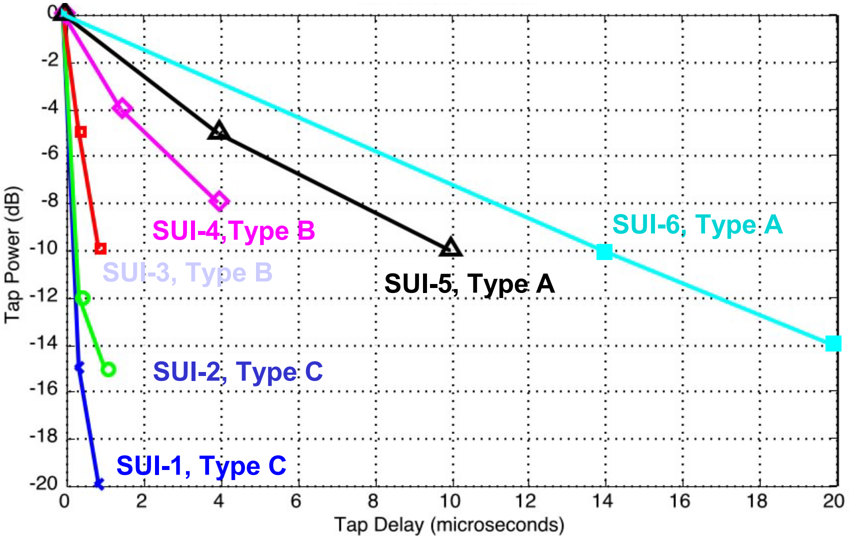
- Test simulation undertaken for comparison of Mode B vs. Mode C for implementation of adaptive antenna system
- Capacity analysis performed comparing diversity techniques with adaptive antenna arrays
- White paper written outlining the performance gains using adaptive antenna arrays
- Review and update of PHY text in document
- Review and update of MAC text in document
- Review comments from last meeting

IEEE 802.16 Channel Models

- **Models are the outcome of the IEEE 802.16 working group's efforts to define channel models in the 2 to 11 GHz bands for evaluation of physical layer design considerations.**
- **Based in part on Stanford University Interim (SUI) channel models**
- **SUI models intended to model typical conditions in the continental U.S. They encompass three terrain types:**
    - A: hilly with moderate-to-heavy tree densities
    - B: intermediate path loss conditions
    - C: mostly flat terrain with light tree densities
- **Models include rms delay spread, based on a 3-tap delay line. The gain associated with each tap is characterized by a Ricean or Rayleigh distribution and Doppler frequency.**
- **Models are based on the following scenario: cell radius equal to 7 km, base station antenna height equal to 30 m, and 90% cell coverage with 99.9% reliability at each location covered.**

IEEE 802.16 Channel Models

Power Delay Profiles



SUI-1, Type C (flat, light trees), τ_{rms} = 0.111, K=3.3

SUI-2, Type C (flat, light trees)

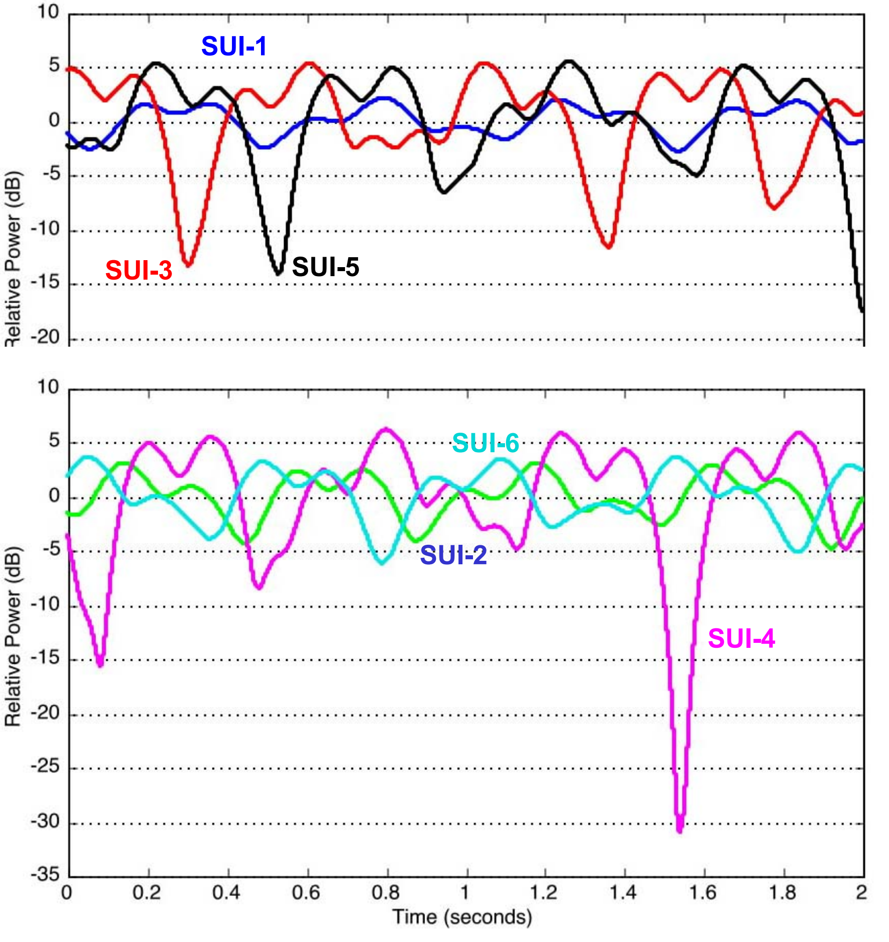
SUI-3, Type B (intermediate) , τ_{rms} = 0.26, K=0.5

SUI-4,Type B (intermediate)

SUI-5, Type A (hilly, moderate trees) , τ_{rms} = 2.8, K=1.0

SUI-6, Type A (hilly, moderate trees)

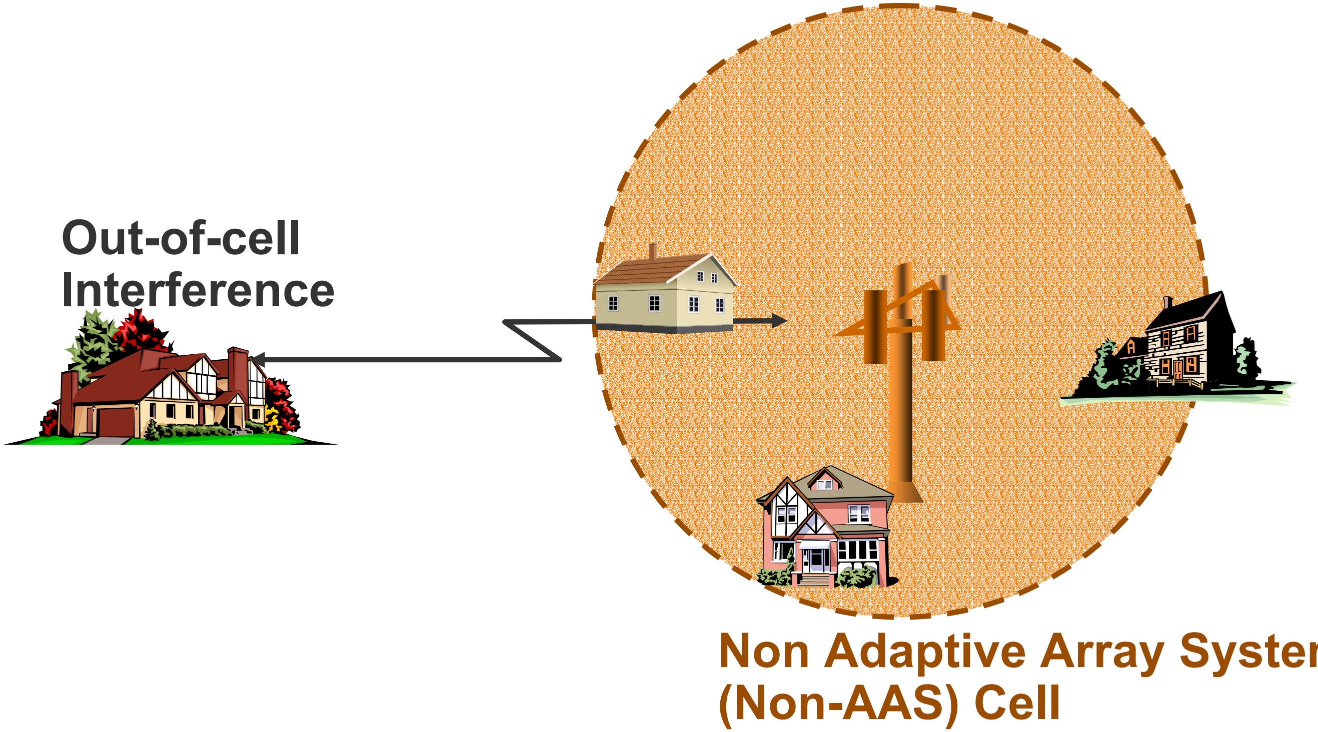
Sample Fading Envelope



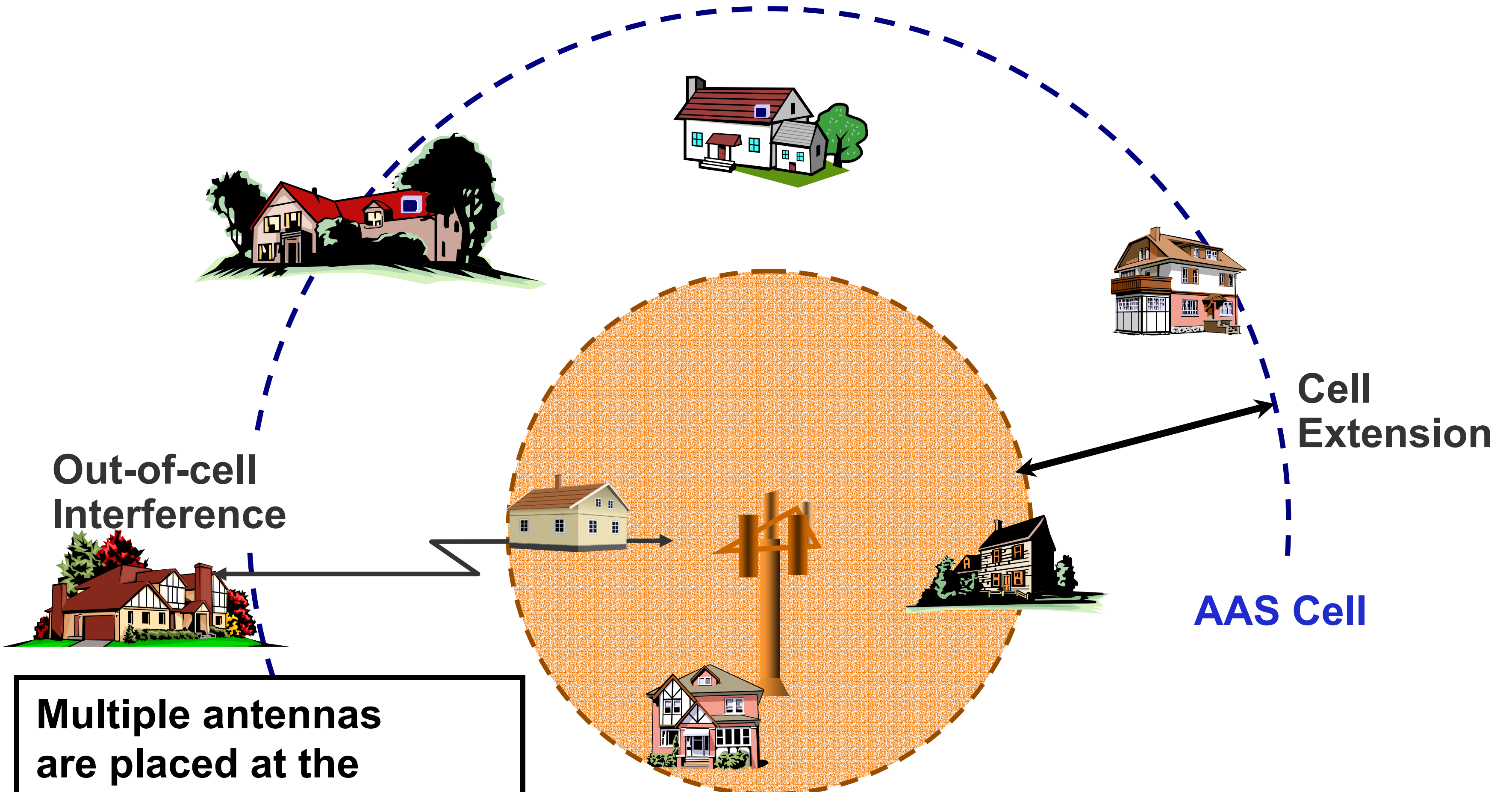
Adaptive Antenna Arrays

- **Attributes**
  - Increased signal power through beamforming gain
  - Reduced interference through null steering
  - Spectral reuse through spatial multiple access
  - Robustness to multipath fading through spatial diversity
- **Benefits**
  - Higher data rates (improved system capacity, spectral efficiency)
  - Increased cell radius
  - Increased coverage
  - Increased link reliability, or lower multipath fade margin

Without Adaptive Antenna Array



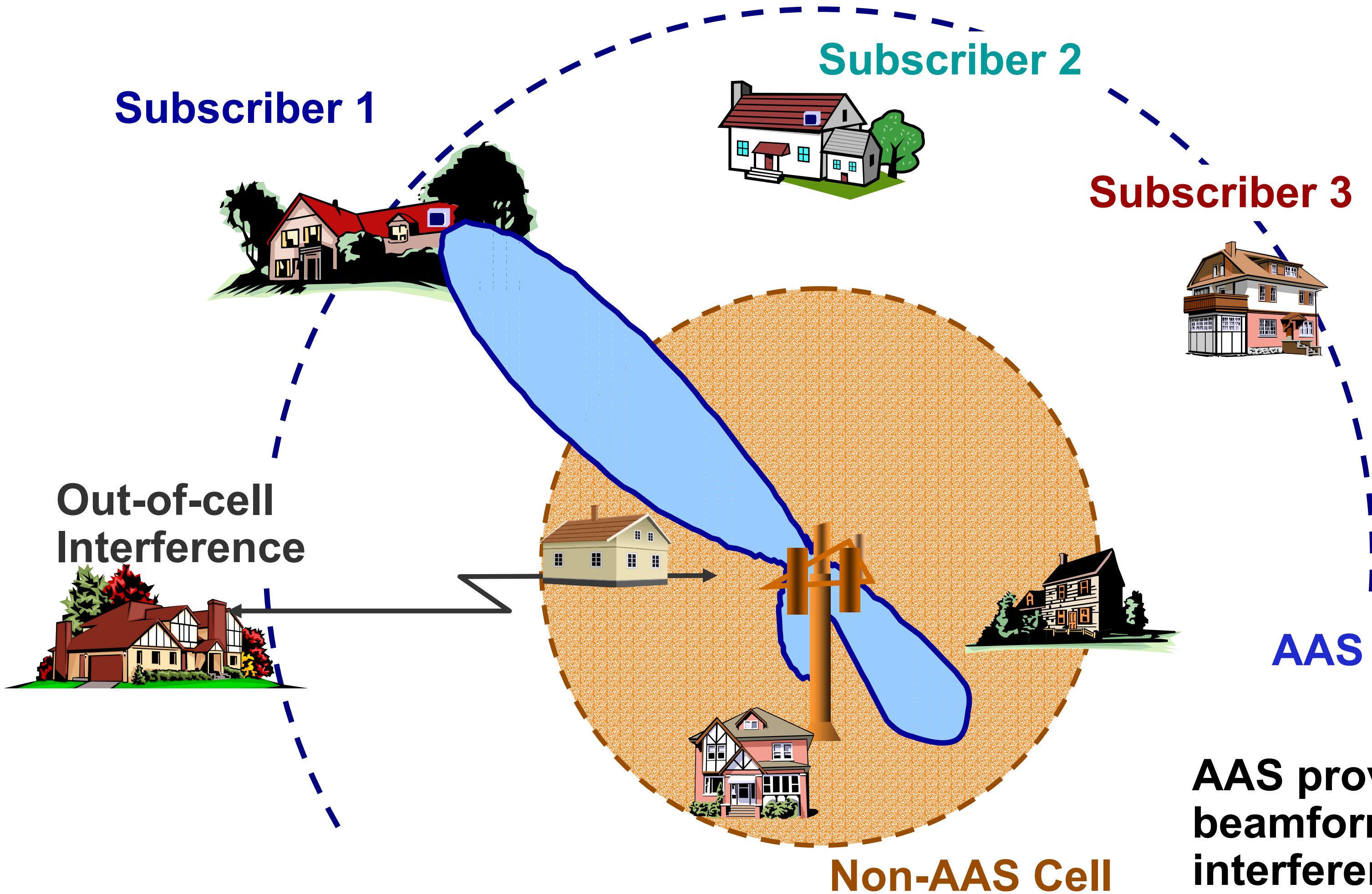
Desired Coverage



Multiple antennas are placed at the Base Station

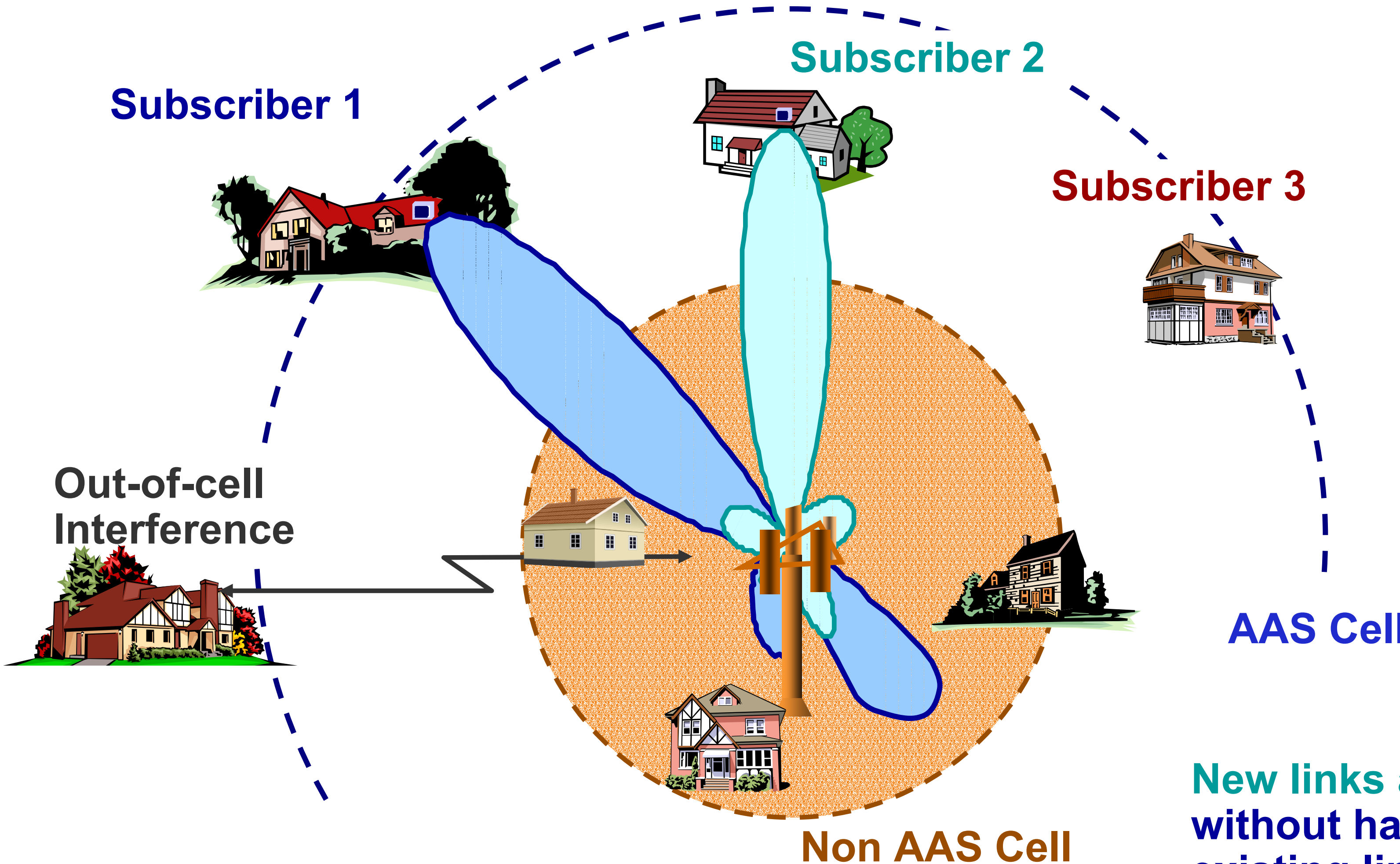
Single antenna at the Subscriber Station

With Adaptive Antenna Array



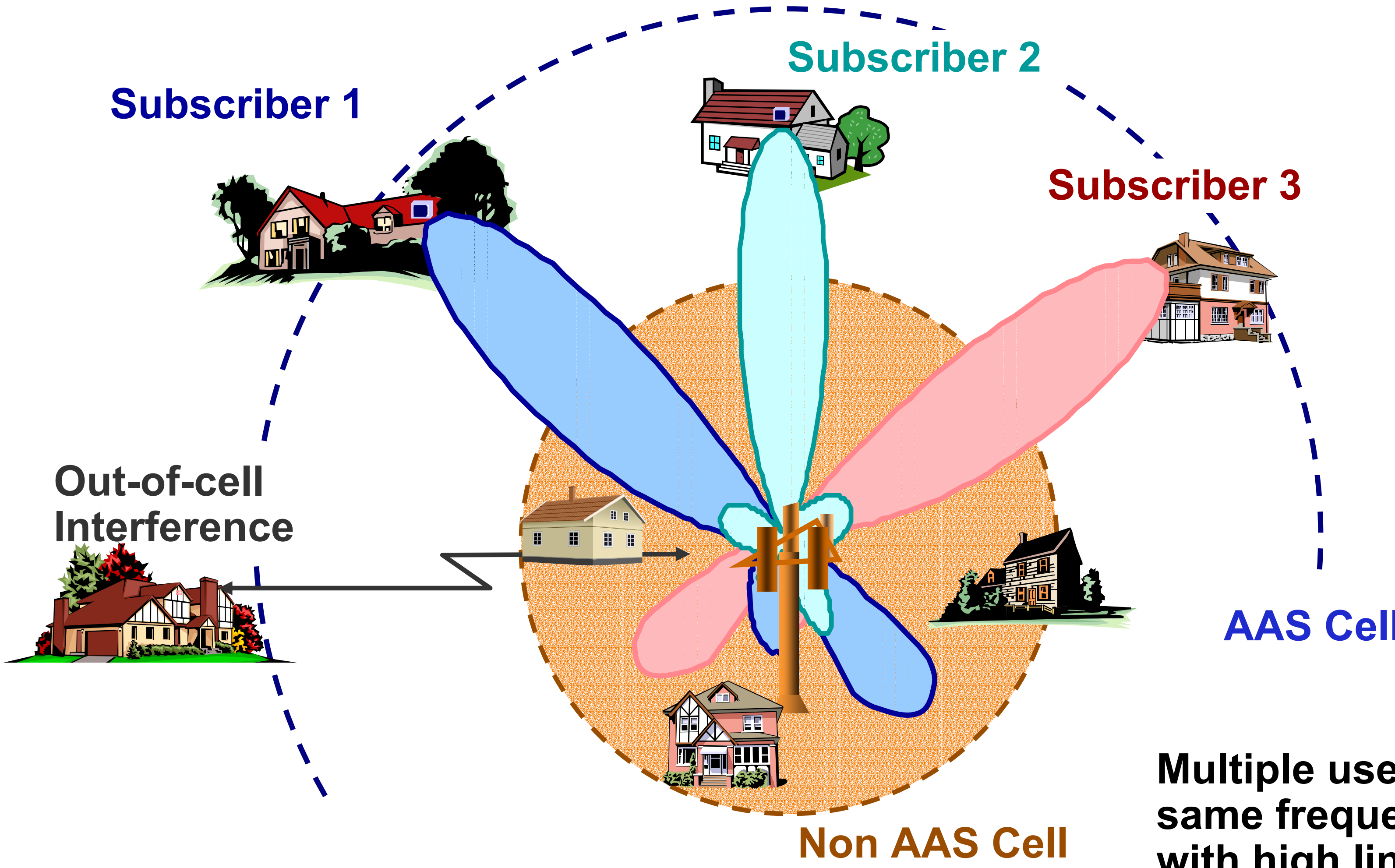
AAS provides beamforming gain, interference rejection, and multipath isolation

With Adaptive Antenna Array



New links acquired without harm to existing links

With Adaptive Antenna Array



Multiple users on the same frequency (each with high link quality)

AAS Gains

- 🗐 **Signal Gain – large (Implementation/Mode dependent)**
- 🗐 **Interference Rejection – Deep nulls (40 to 80 dB)**
- 🗐◆● **Diversity Gain – 20+ dB in Rayleigh fading**
- 🗐 **Link Capacity (bps/Hz) – log2(M)**
- 🗐 **System Capacity – 15 dB**
  (multiple access and interference limited)

🗐 **Provided by adaptive antenna arrays**
◆ **Provided by space-time block codes**
● **Provided by diversity processing**

Implementation Details

- **Nomenclature**
  - OFDMA subchannel = 48 data carriers
  - M = number of antennas
  - S = number of symbols based on time-bandwidth product considerations
    - S = 2 x adaptive degrees of freedom
  - C = complexity (floating point operations)
  - OFDMA symbol duration is on the order of 0.1 to 1.0 ms
- **Option 1: Compute single beamforming weight per subchannel**
  - S = 2 x M
  - C = order $(M)^3$
  - Overhead is S tones per frame
  - Example: M = 8, S = 16; Overhead contained within one OFDMA symbol, so overhead is 2 to 20% in a 5 ms frame
- **Option 2: Compute beamforming weight for each individual tone within a subchannel (i.e., 48 beamforming weights)**
  - S = 2 x M for each carrier => 2 x 48 x M
  - C = order $(48M)^3$
  - Example: M = 8, S = 48 x 16, Overhead requires 16 OFDMA symbols, so overhead is 32 to 320% in a 5 ms frame

Implementation Summary

- **Given 48 data tone subchannel (OFDMA)**

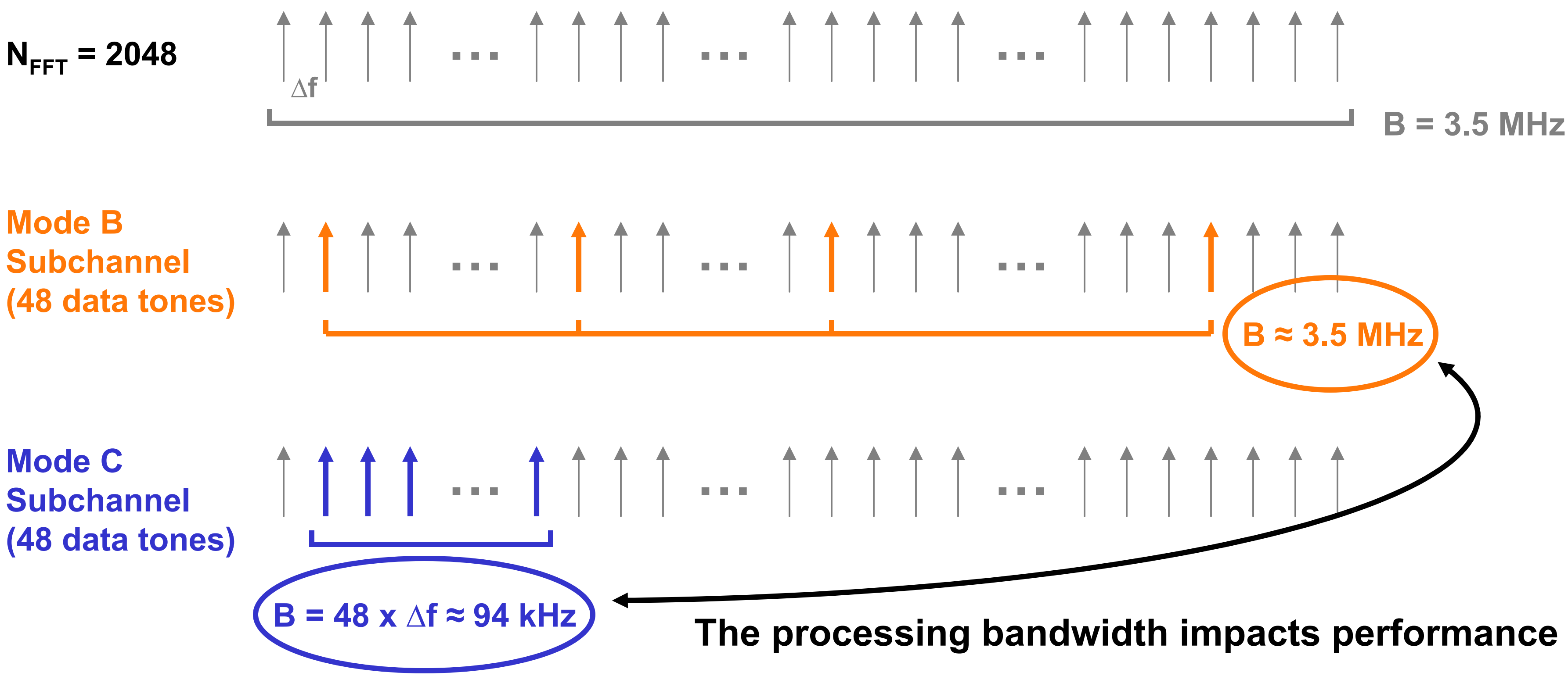
Achievable

- **Option 1: Compute single beamforming weight per subchannel**
  - Reasonable complexity
  - Weight training overhead is 2% to 20% in a 5 ms frame
- **Option 2: Compute beamforming weight for each individual tone within a subchannel (i.e., 48 beamforming weights)**
  - Complexity is up to $(48)^3$ times greater to achieve similar performance
  - Weight training overhead is 32% to 320% in a 5 ms frame

Not practical

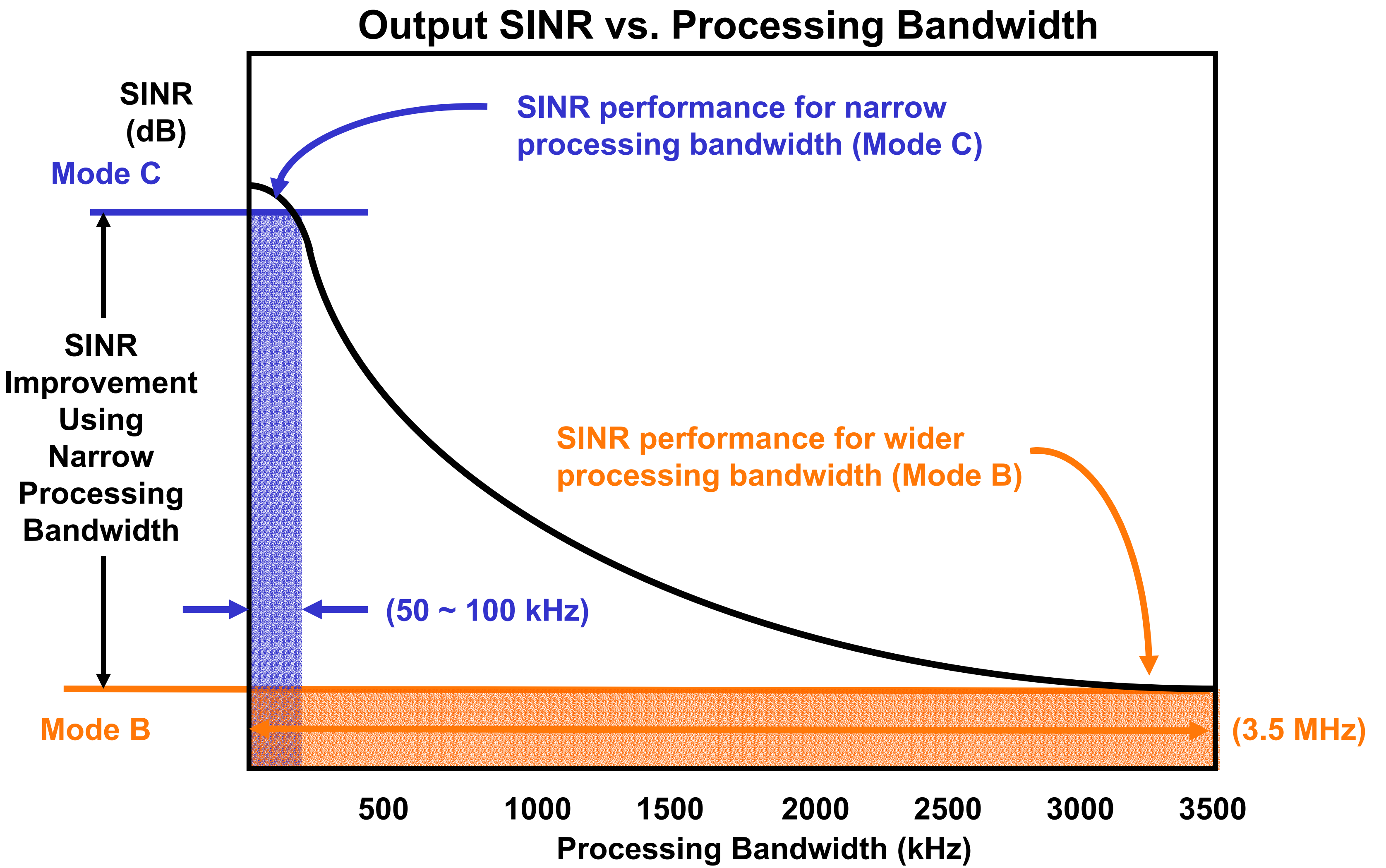
Single Beamforming Weight Per Subchannel

Consider (for example) BW = 3.5 MHz, N_{FFT} = 2048, Δf = 1.95 kHz

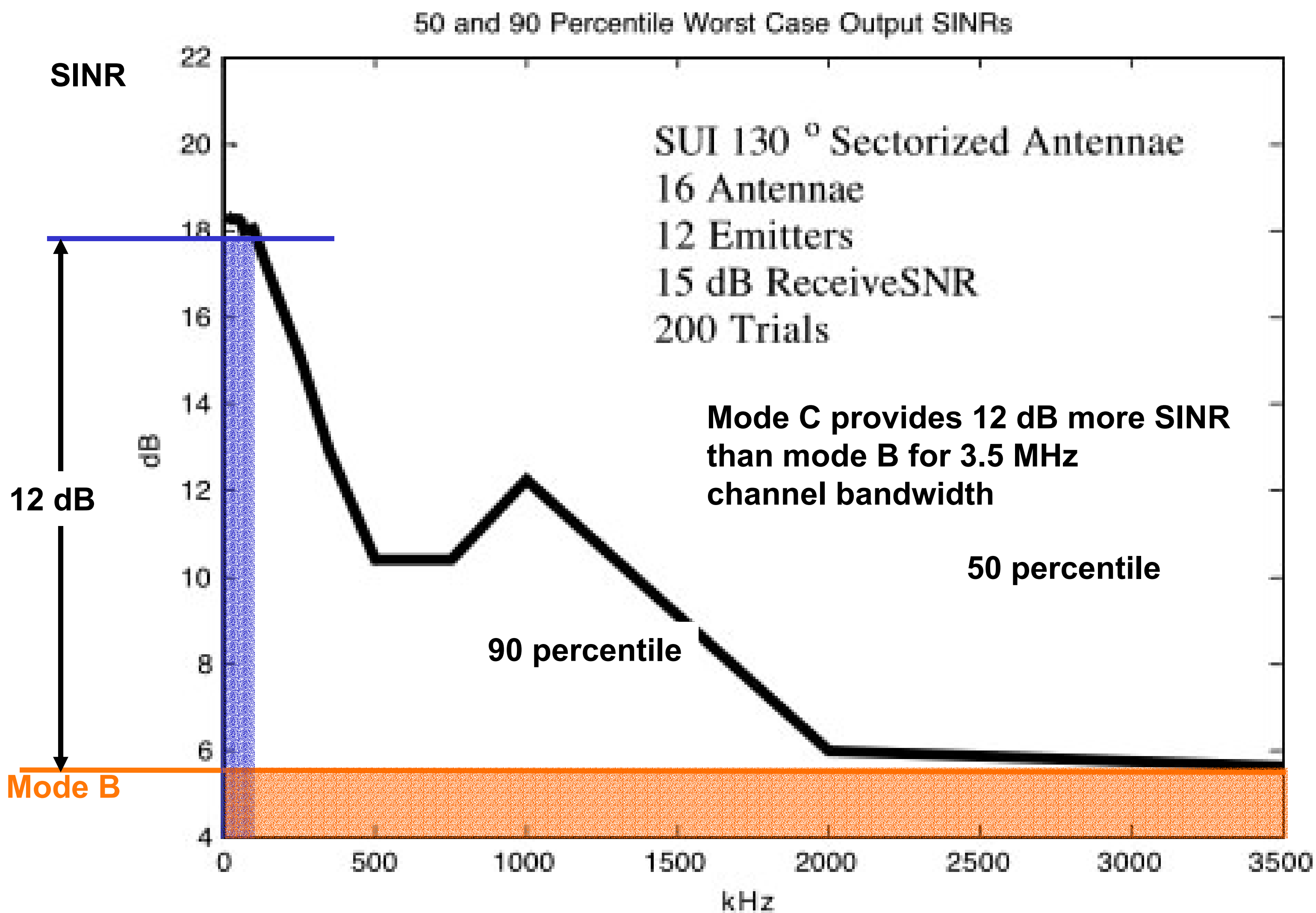


In the analysis, all other factors (coding, FFT size, channel bandwidth) are identical

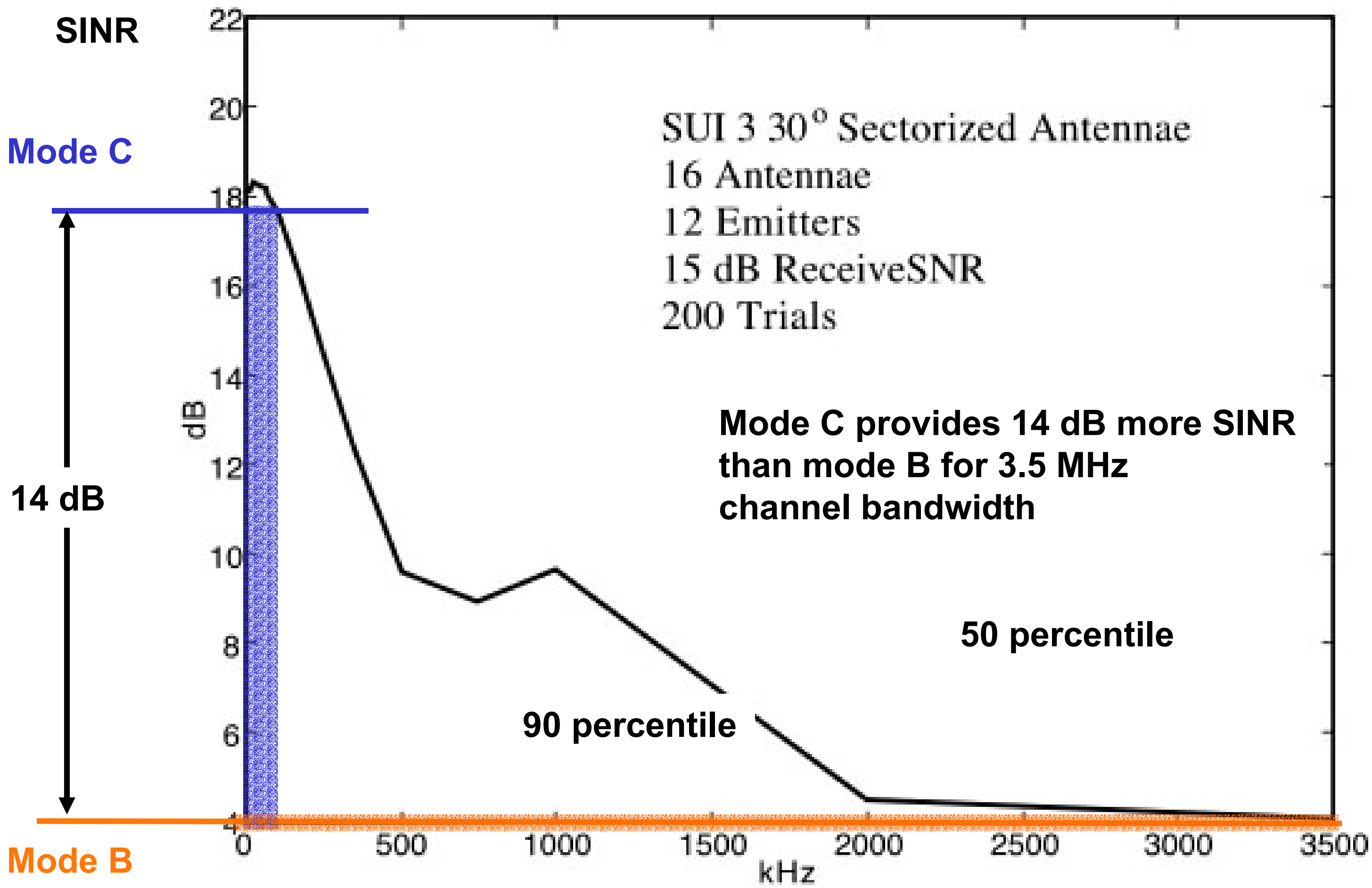
Impact of Processing Bandwidth (Mode C vs. Mode B)



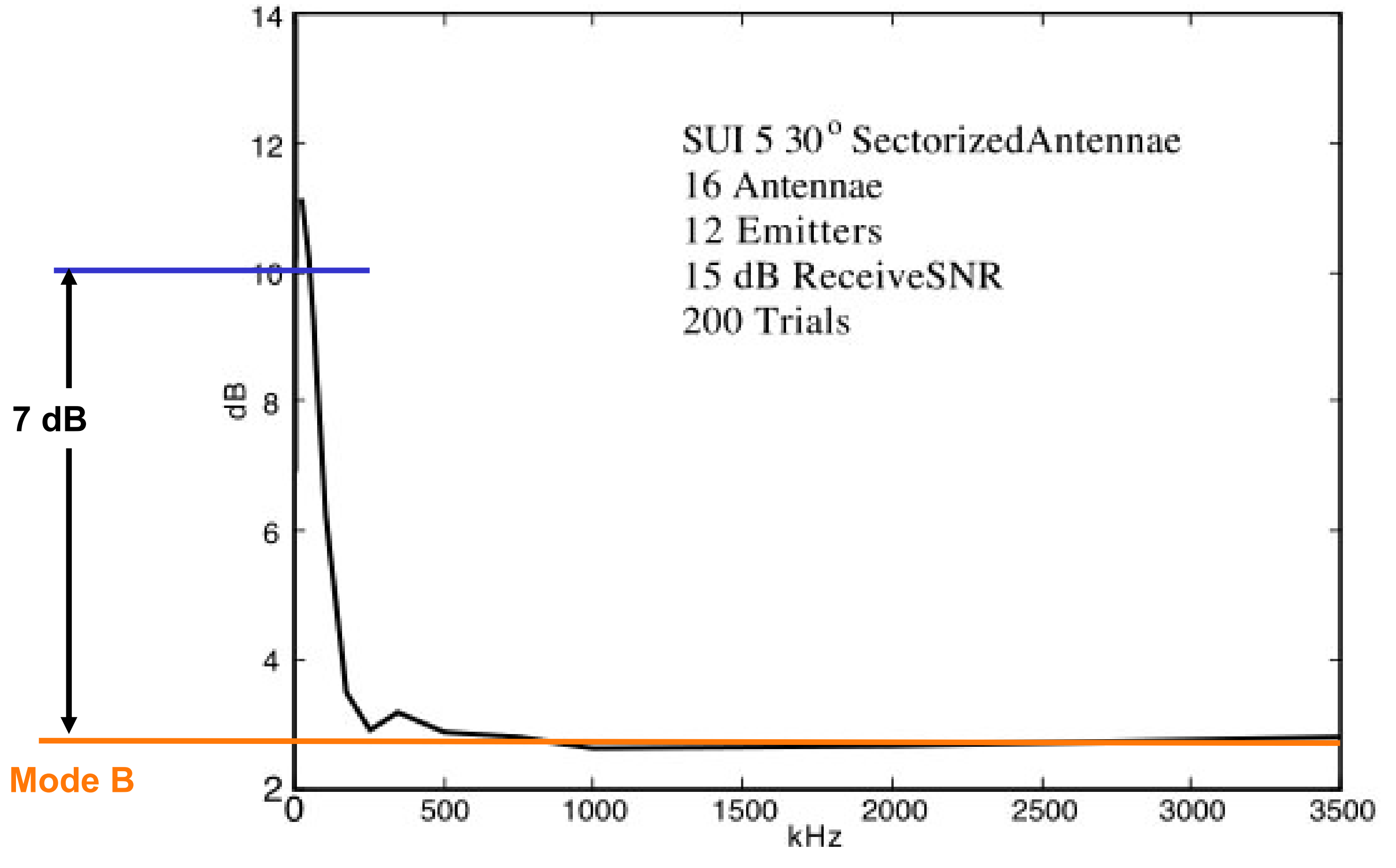
SUI-1


50 and 90 Percentile Worst Case Output SINRs
SINR
22
20
18
16
14
12
10
8
6
4
dB
0
500
1000
1500
2000
2500
3000
3500
kHz
SUI 130 ° Sectorized Antennae
16 Antennae
12 Emitters
15 dB ReceiveSNR
200 Trials
Mode C provides 12 dB more SINR
than mode B for 3.5 MHz
channel bandwidth
50 percentile
90 percentile
12 dB
Mode B

SUI-3

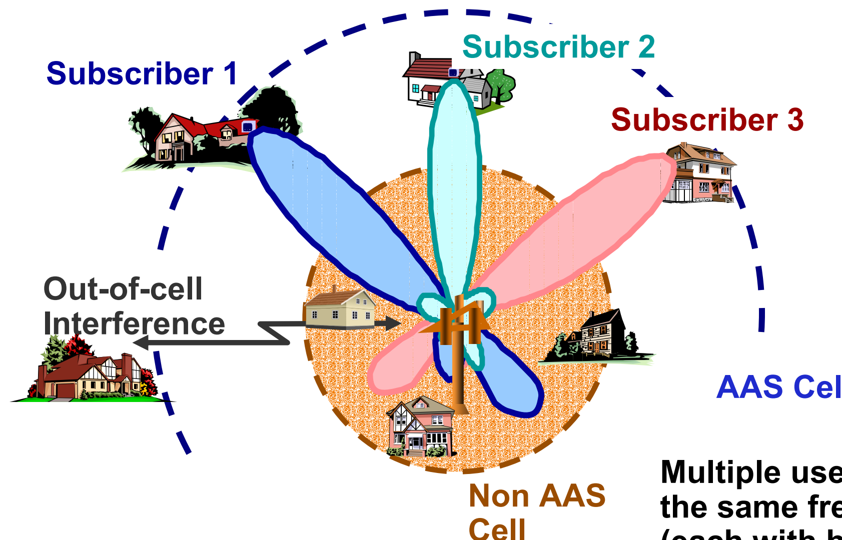

SINR
Mode C
14 dB
Mode B
22
20
18
16
14
12
10
8
6
4
dB
0
500
1000
1500
2000
2500
3000
3500
kHz
SUI 3 30° Sectorized Antennae
16 Antennae
12 Emitters
15 dB ReceiveSNR
200 Trials
Mode C provides 14 dB more SINR
than mode B for 3.5 MHz
channel bandwidth
50 percentile
90 percentile

SUI-5


SUI 5 30° SectorizedAntennae
16 Antennae
12 Emitters
15 dB ReceiveSNR
200 Trials
dB
kHz
14
12
10
8
6
4
2
0
500
1000
1500
2000
2500
3000
3500
7 dB
Mode B

MAC Support for AAS

- **Objectives**
  - Allow evolution toward AAS for range and capacity improvement
  - Support co-existance of AAS and non-AAS subscriber stations
  - Support multiple PHY modes
  - Exploit available MAC mechanisms
- **Main Issue is Lack of Broadcast Capability**
  - AAS extends cell coverage beyond broadcast range
  - Spatial multiplexing increases system capacity through frequency reuse by simultaneous P-to-P links



Multiple users on the same frequency (each with high link quality)

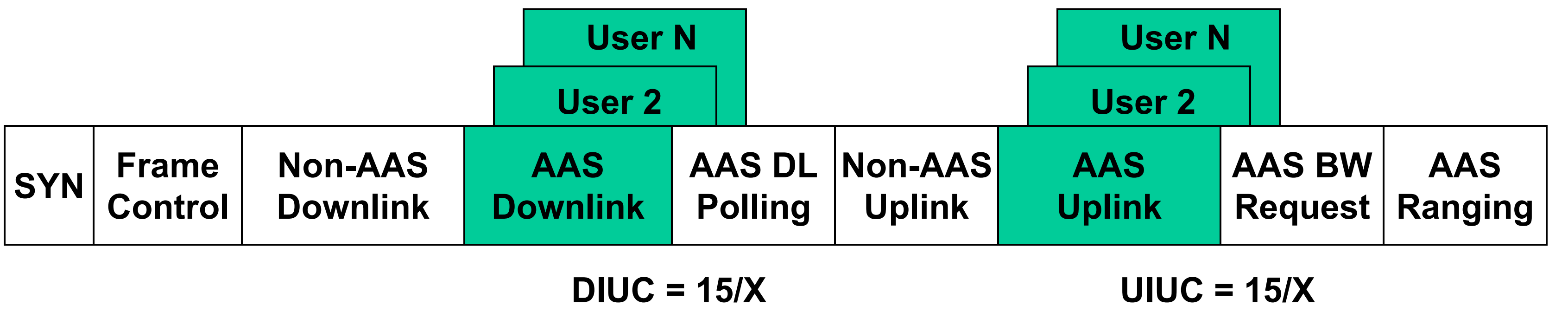
Current Solution (6.2.7.7)

Frame Control	Non-AAS Downlink	AAS Downlink	Non-AAS Uplink	AAS Uplink

- **AAS parts are distinguished by special DIUC and UIUC**
- **AAS boundary is defined by DL/UL MAPS**
  - "standard" broadcast MAPS for non-AAS subscriber stations
  - "private" (unicast) MAPS for AAS subscriber stations
    - Use the same format, but contains only information for a designated subscriber station

Additional AAS Detail

This figure illustrates the current text



Network Entry and Initiation

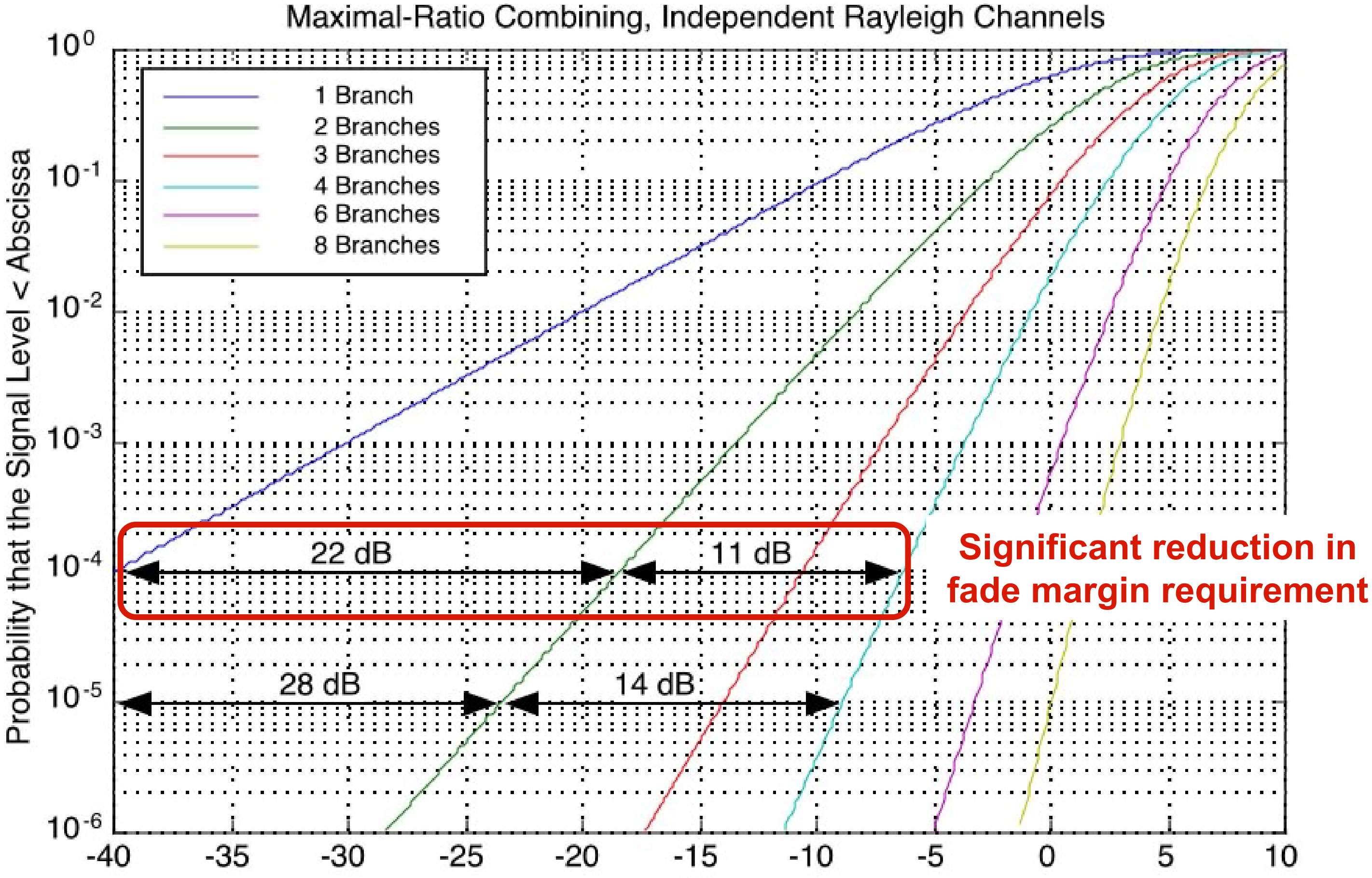
- **Network Entry**
  - Subscriber station uses the same SYN sequence for frequency and time synchronization
  - AAS ranging and BW request interval have a known relationship with SYN
- **Downlink Initiation**
  - Subscriber station transmits its unique code to BS. BS detects it and forms a beam using the unique code. This establishes a link. BS then sends a private map.
- **Uplink Initiation**
  - DL polling channel has a known relationship with SYN
  - BS transmits a unique code in the DL polling channel. SS detects it and sends its unique code in the BW request channel. The subsequent steps are the same as downlink initiation.

Conclusions

- Results assume 2k FFT for OFDMA (Mode B and C)
- Mode C provides 12-16 db improved performance for the implementation of adaptive antenna solutions vs. Mode B for single weighting coefficient implementations.
- Mode B can reach performance levels near Mode C if a scheme of individual weightings are used. But the computation burden would be significant.
- MAC should be able to send message to identify an AAS mode. Would need implementation for each PHY mode. Should allow initialization in AAS or non-AAS mode
- PHY for AAS modes can be implemented with minimum additional updates, as proposed.

Reduced Fade Margin

- Spatial diversity means the required fade margin is reduced, and this excess gain can be applied to higher data rates, increased range, or to support indoor installations



Probability Distribution of SNR (dB) for M-Branch MRC