Space Time Processing for Fixed Broadband Wireless

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Essential Attributes of Broad Band Wireless (BWA) Network

- High Speed > 4-5 Mbps
- High QoS / Availability
  - DSL / Cable like
- Low Costs $$$
  - High capacity
  - High coverage
  - CPE and Infrastructure unit costs
- Friendly
  - Easy CPE Install
  - Environmental/Regulatory
- Scalability (Multi-cell)
- Evolution to portability

BWA Network Architecture

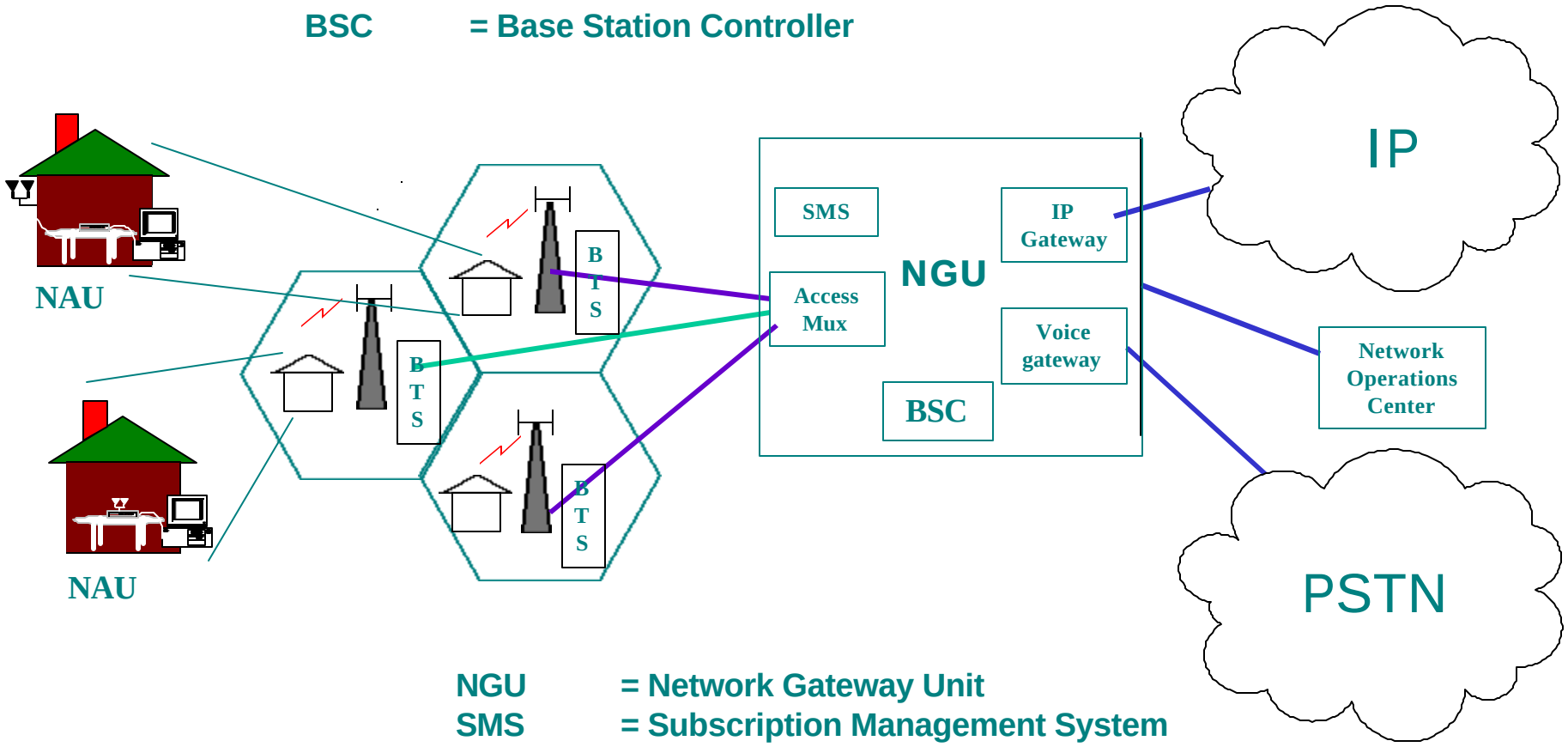
- Multi-cell architecture
- Low BTS antennas (50 - 150 ft)
- Under-the-eave subscriber antennas

- Significant Non-LOS propagation (Rayleigh fading)
- Strong multi-path
- Low Doppler channels

Mobile cellular-like network with all its challenges but with ×50 Speed and ×50 QoS

BWA Network

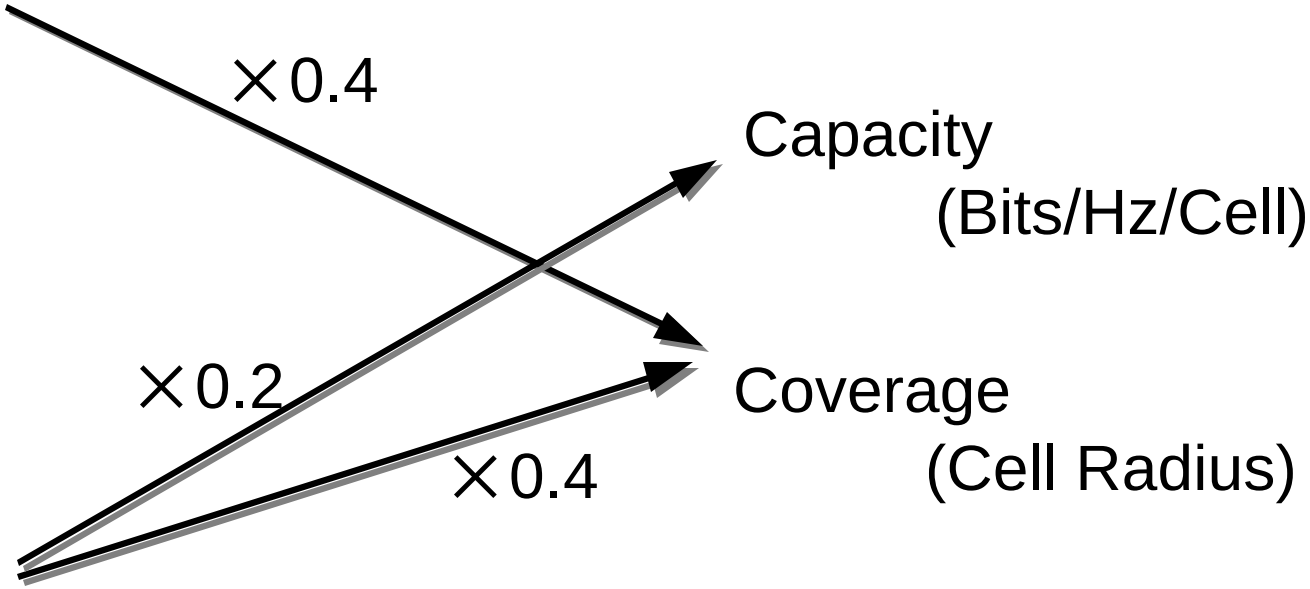
NAU = Network Access Unit
BTS = Base Transceiver Station
BSC = Base Station Controller



NGU = Network Gateway Unit
SMS = Subscription Management System

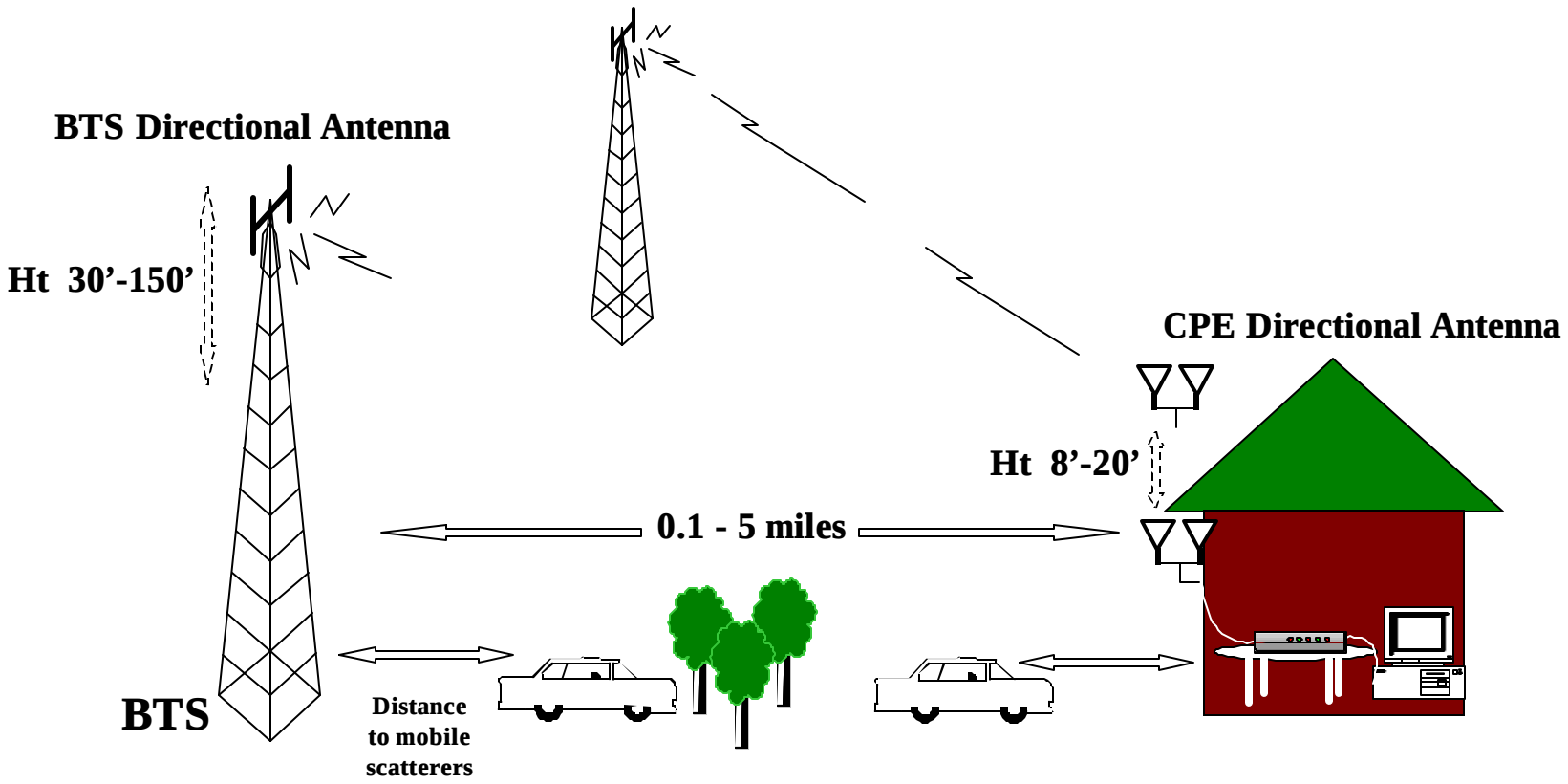
Data Rate & QoS Challenges

- ×50 High Data Rate

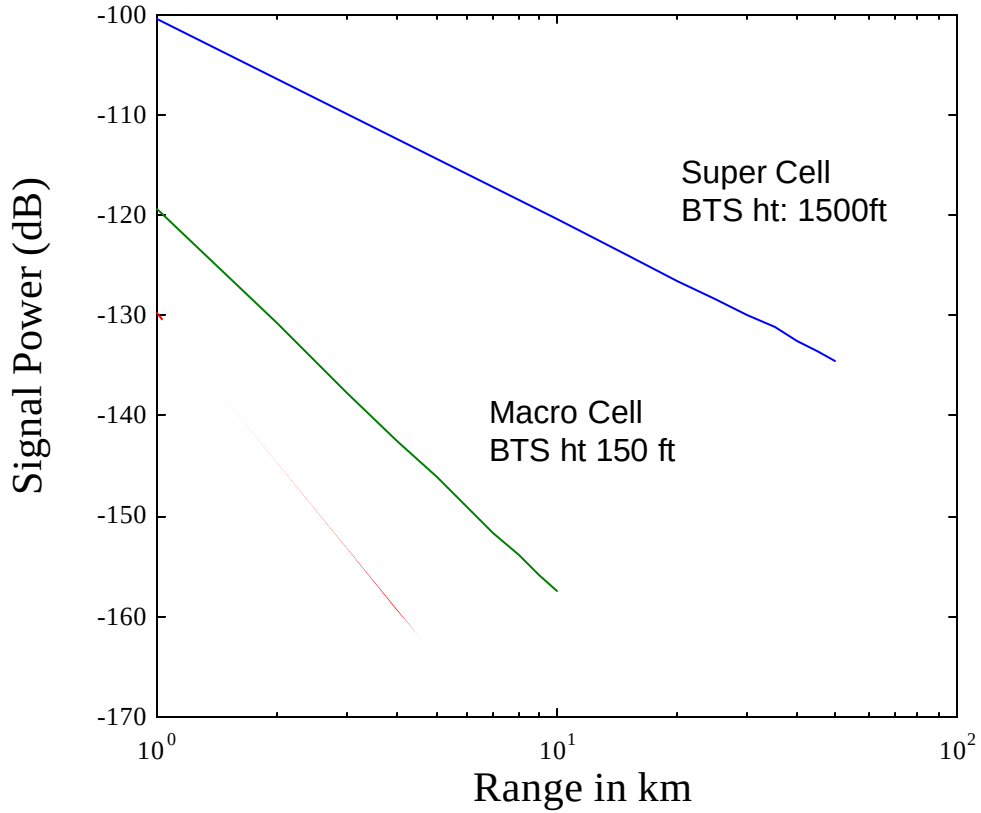


- ×50 QoS
  (0.999 Availability on
  Throughput, Delay, Jitter)

Typical Propagation Scenario



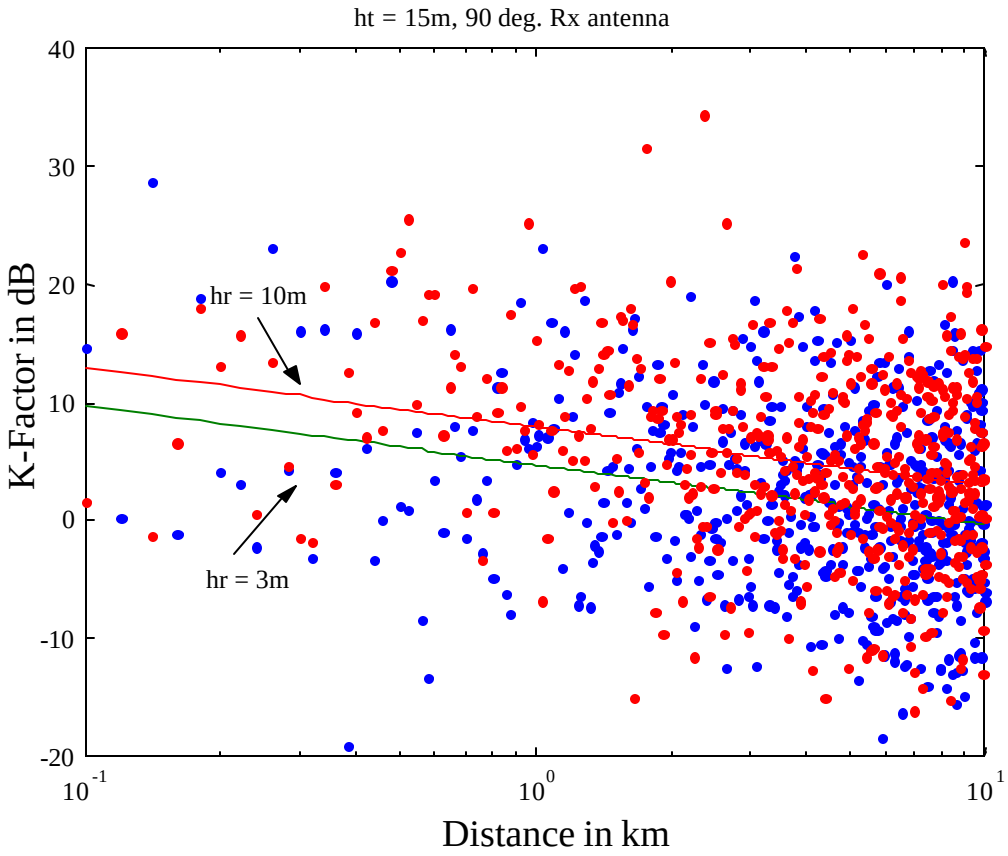
Path Loss (Mean Level)



Super Cell: Free Space model
Macro/Micro Cell: Erceg's model

Frequency: 2.5 GHz
Ant Beamwidth: 90 deg

K-Factor vs. Distance
(Suburban BWA)

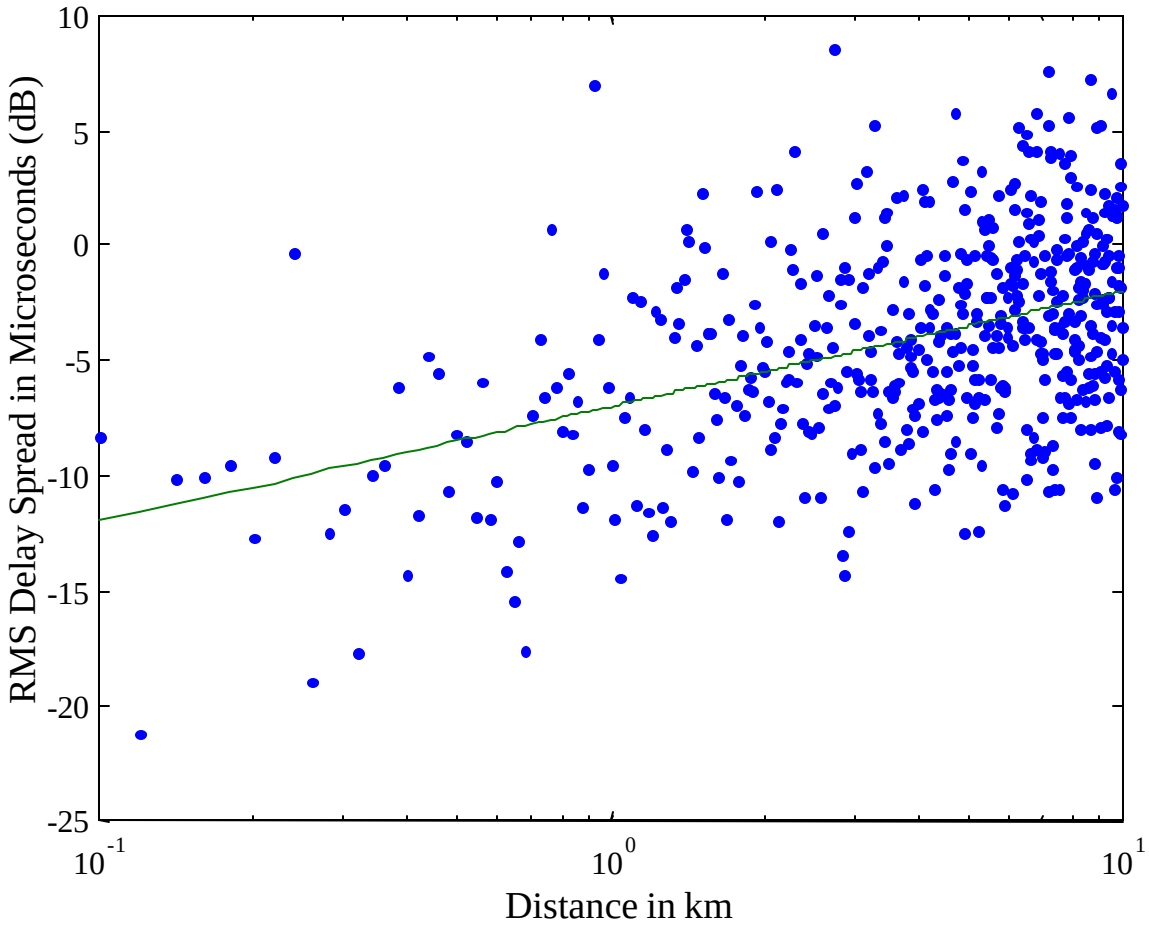


--- hr = 10m
--- hr = 3m

GW and AT&T measured data similar

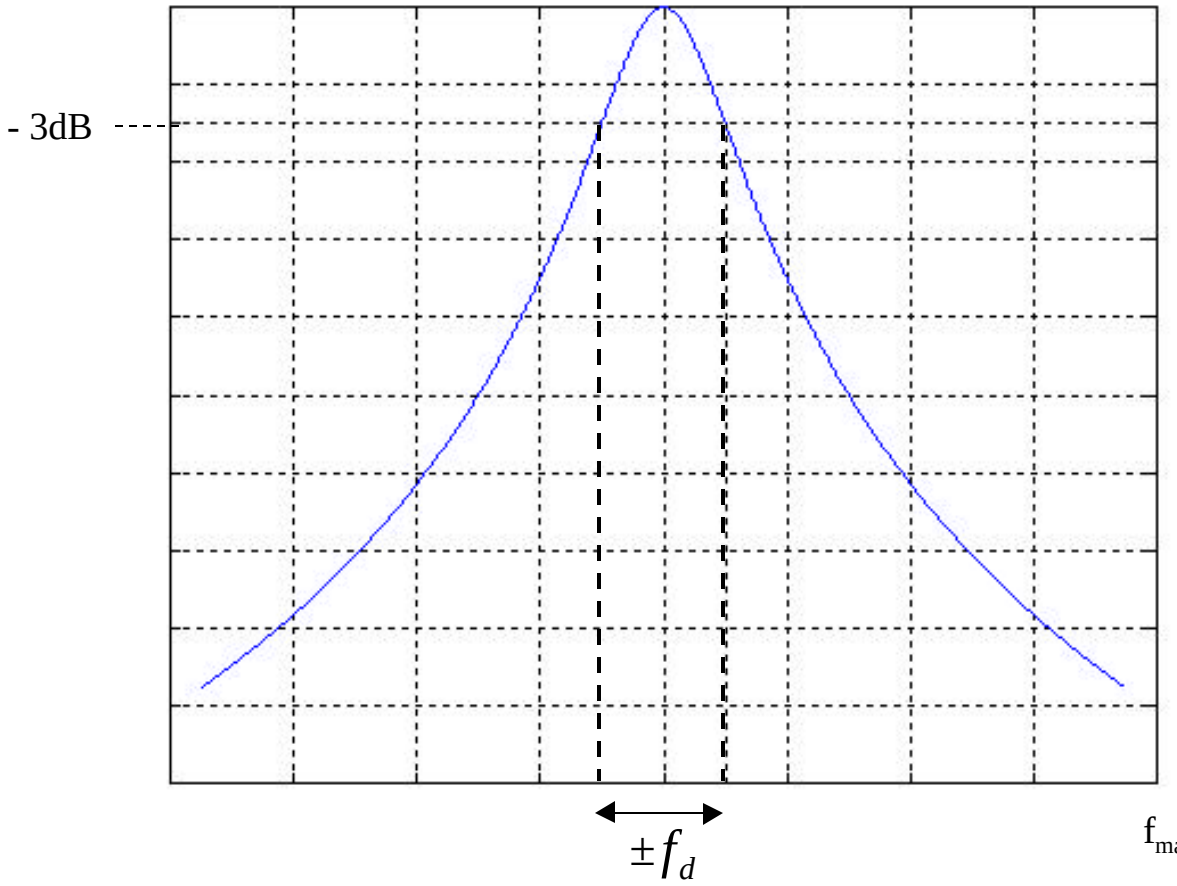
K = 0 is necessary assumption for reliable deployment

RMS Delay Spread vs Distance
(Suburban BWA)



GW experimental data similar

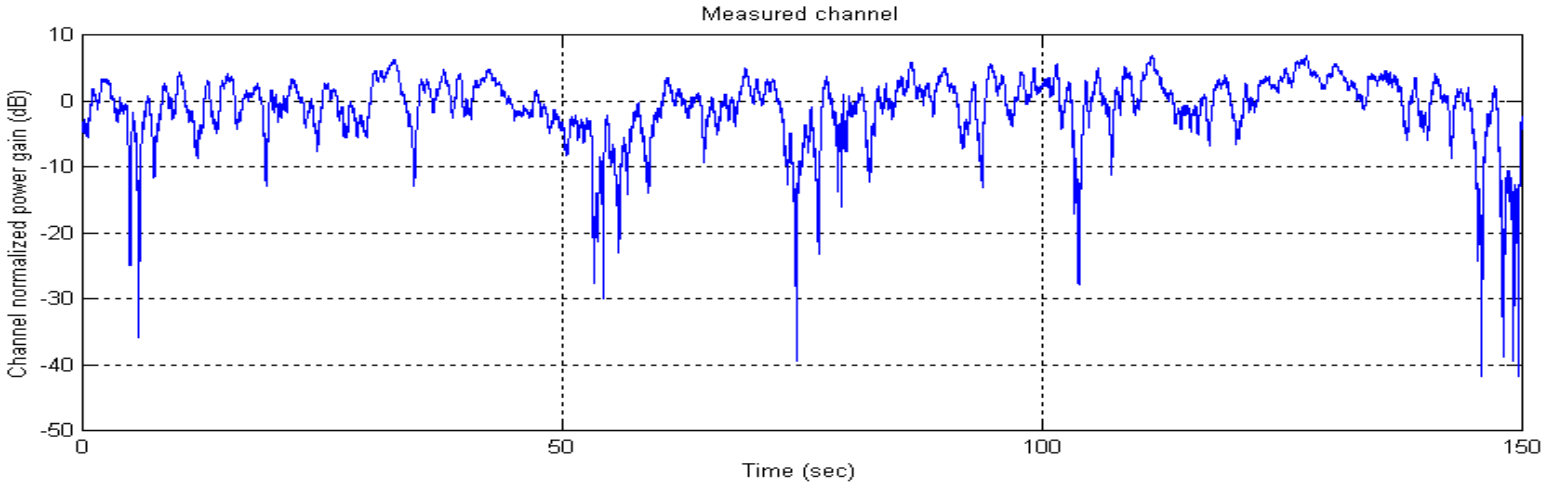
Doppler Spectrum - BWA



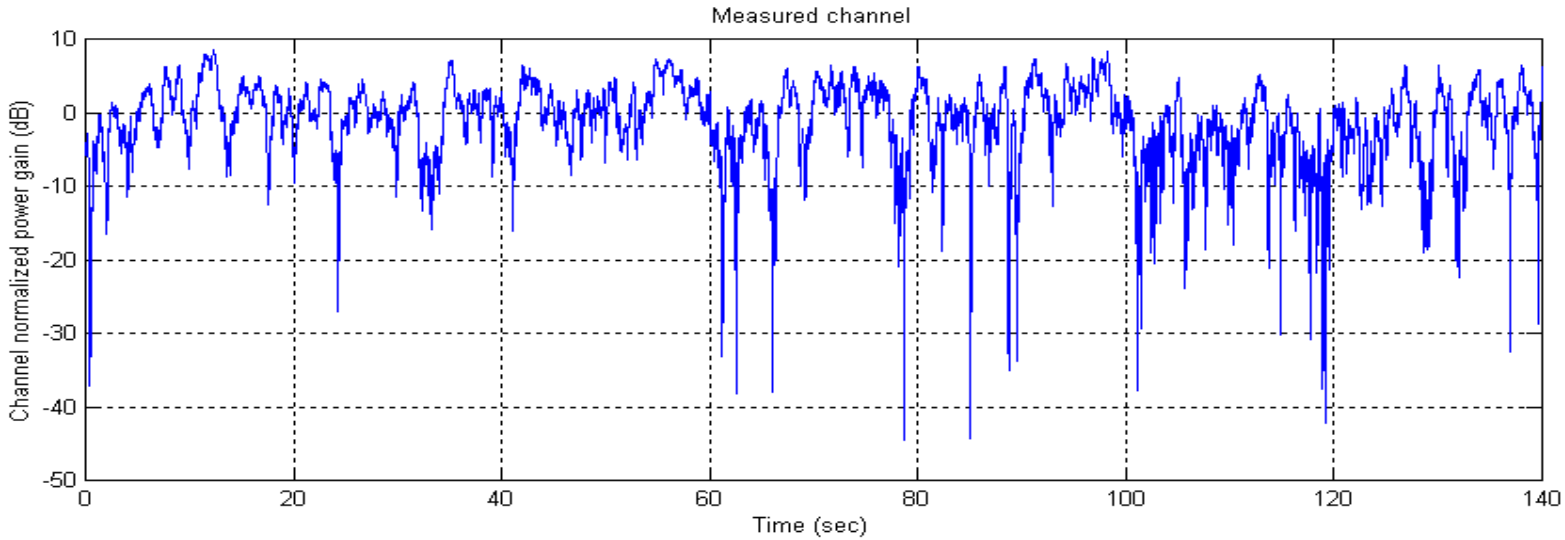
$0.05 \leq f_d \leq 0.5$ Hz

Signal Measurements

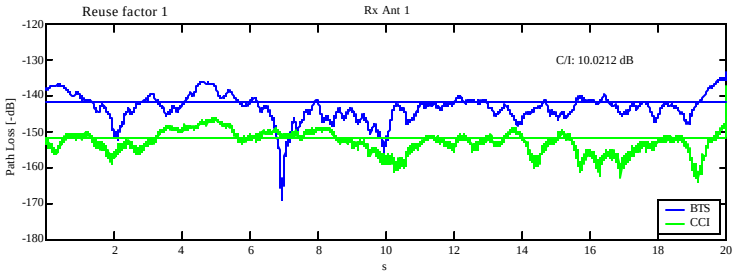
Low Doppler, 0.05 Hz

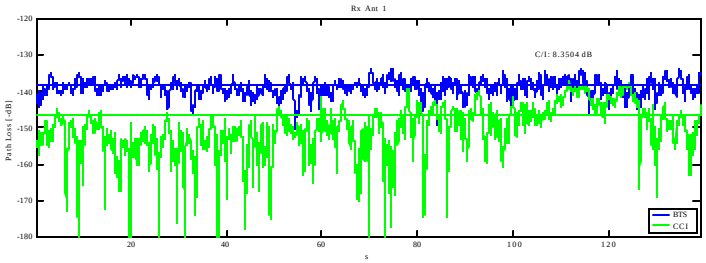


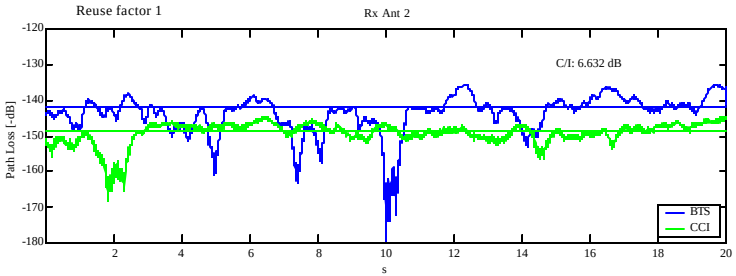
High Doppler, 0.5 Hz

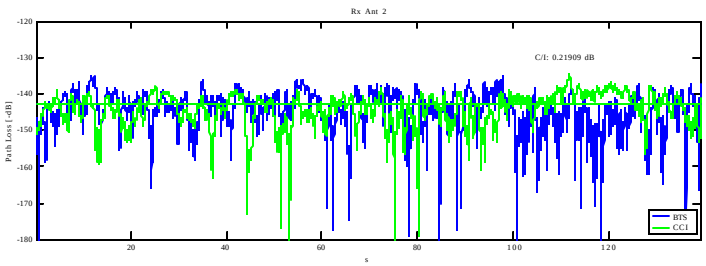


C vs I Measurements

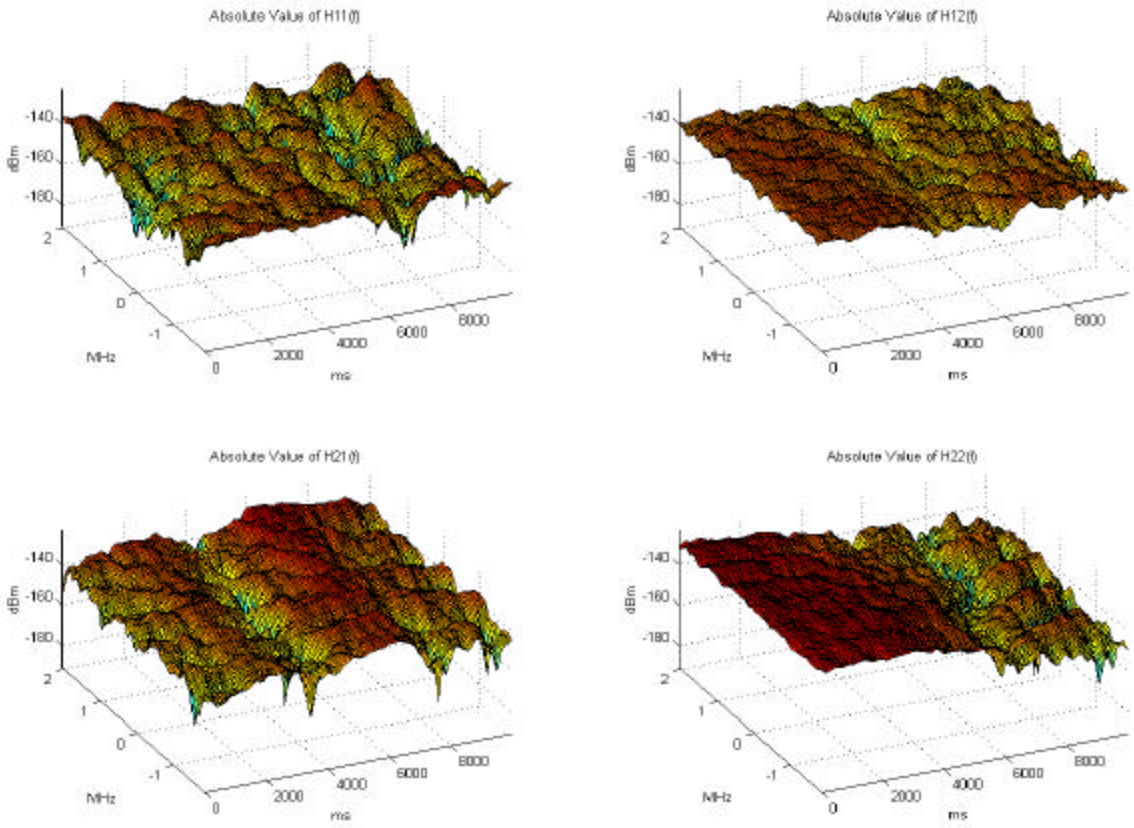


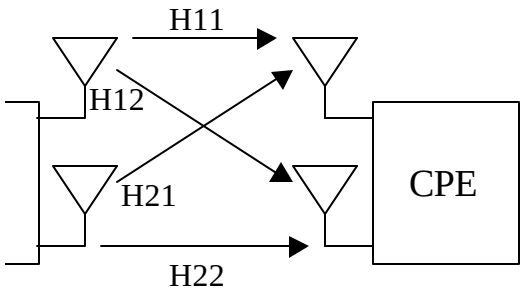




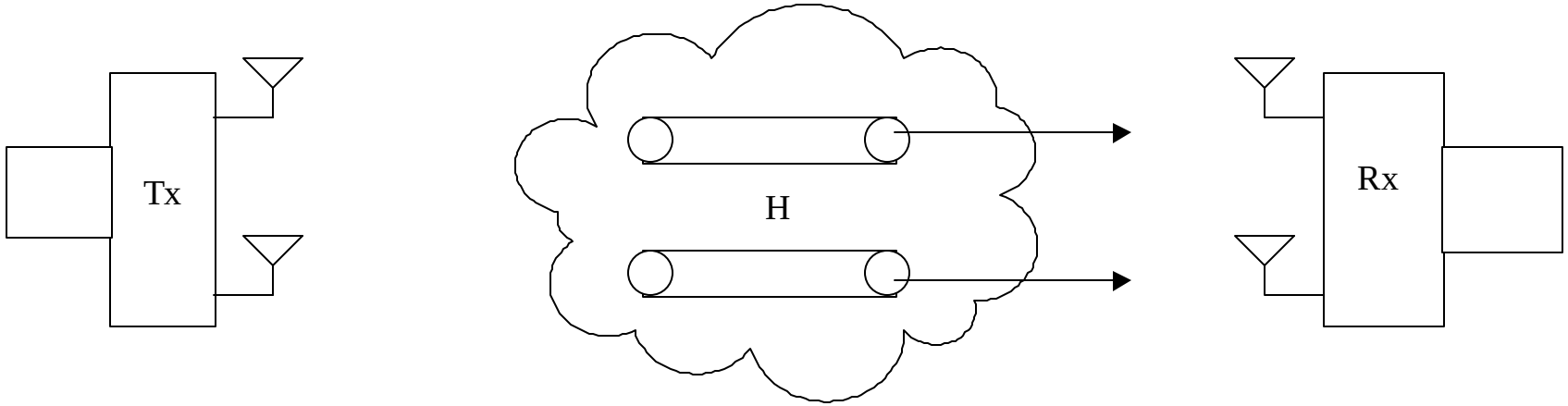


MIMO Measurements





Spatial Multiplexing (SM) Offers Higher Speeds



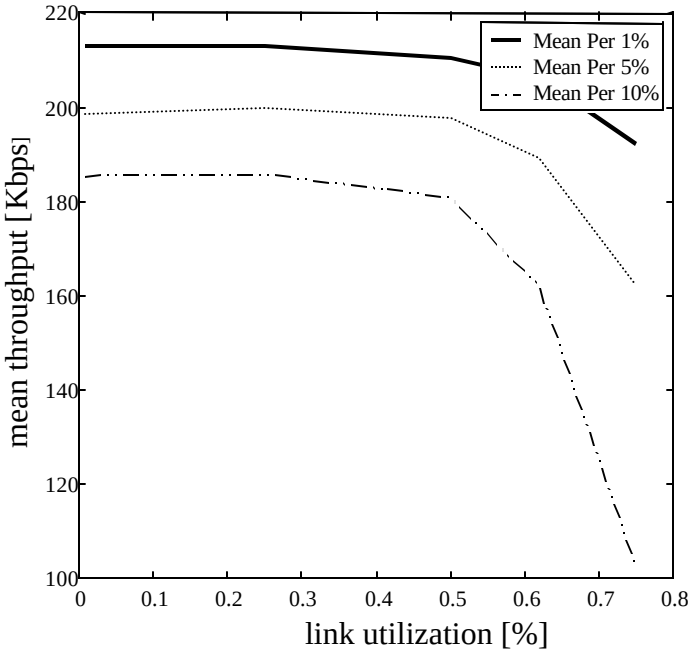
Each Eigen mode of the matrix channel can support a radio link. 11.4 $\Rightarrow$ 1.5 speed up possible in 2 x 3 systems.

Increasing Capacity/Coverage

- Coverage: Lower the C/N needed to close link - improves link budget
- Capacity: Lower C/I needed to close link - improves reuse factor
  - Use diversity, array gain, coding, etc to minimize required C/N or C/I to support a target PER
  - Use RLP and fragmentation to allow higher target PER
  - Use spatial multiplexing to run parallel channels

Throughput vs Utiliz. (vs PER)

Mode 6, Doppler 1Hz, MaxUtil 635 users, small files



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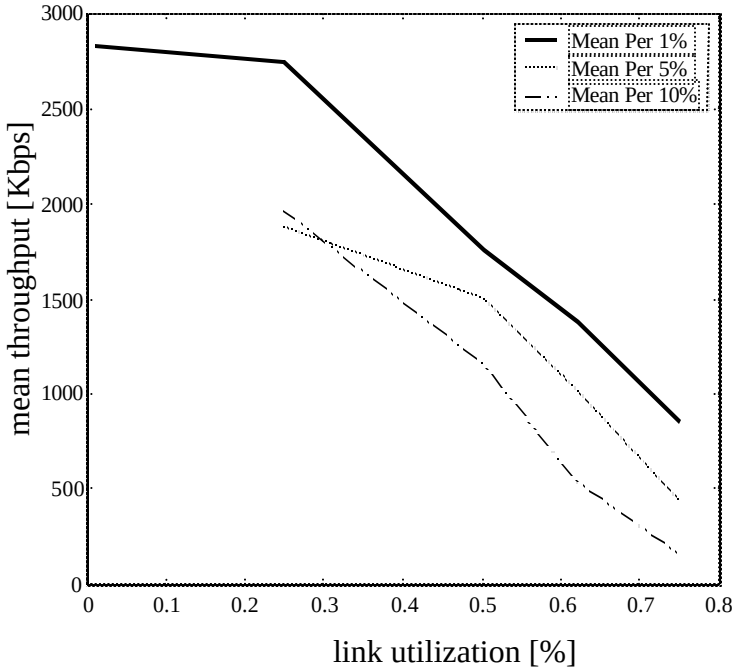


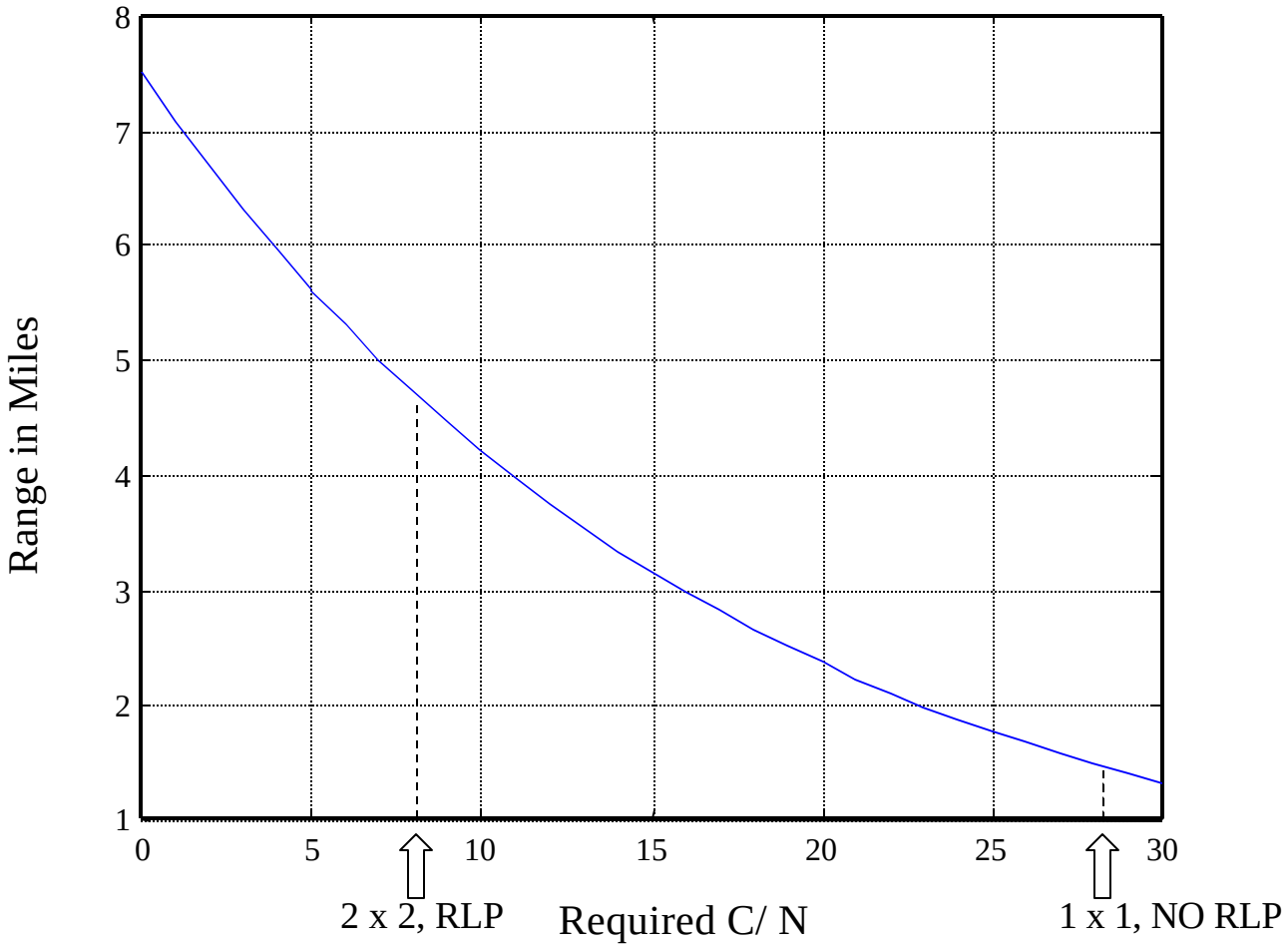
- Throughput = File size/ Mean transfer delay

- TCP windowing algorithm yields the difference in the throughput of ‘small’ and ‘big’ files

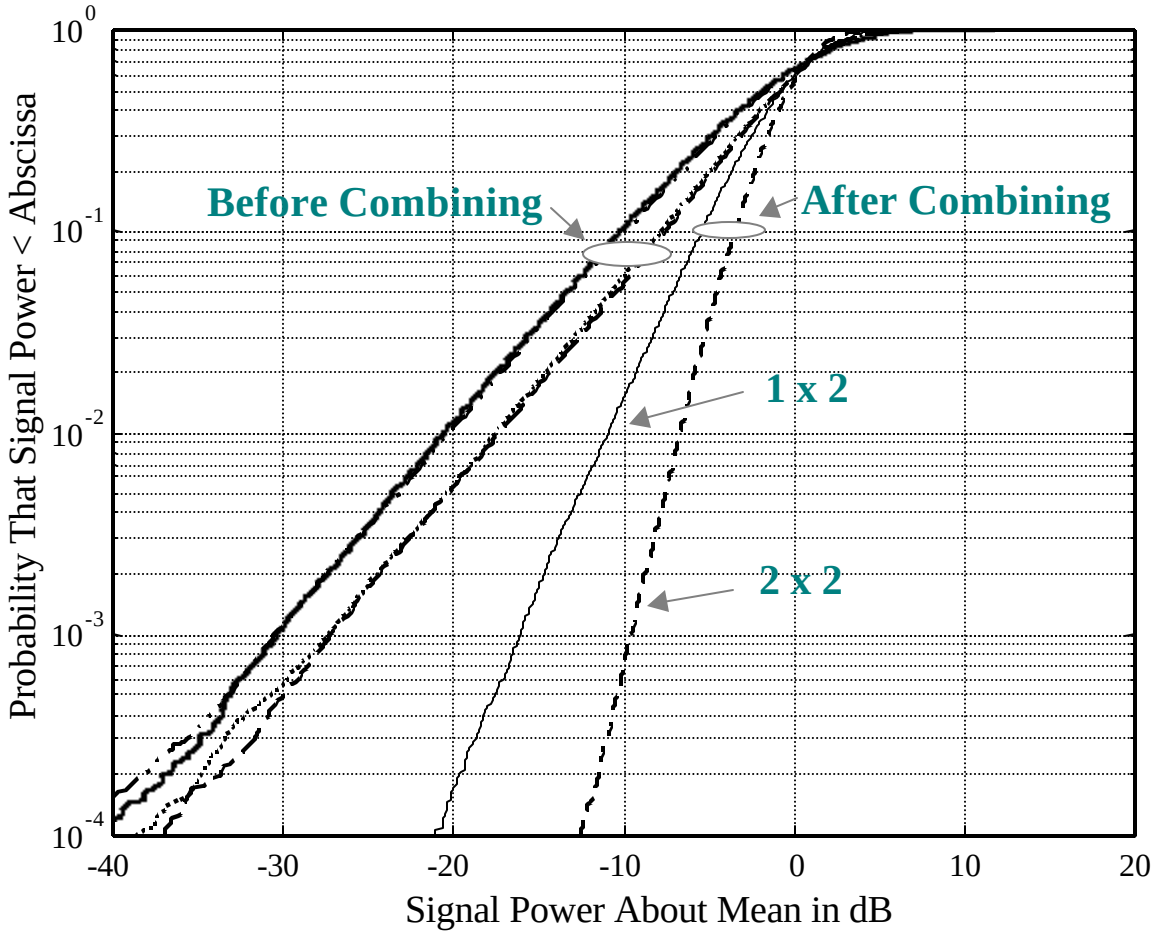
Increasing Coverage

- Diversity is critical (Tx antenna, Rx antenna, frequency, pol)
- Directional CPE antennas
- Forward Error Correction (FEC) & ARQ
- Increase BTS & CPE height

Coverage vs Required C/N



CDF of Tx-Rx Diversity - Measured Data

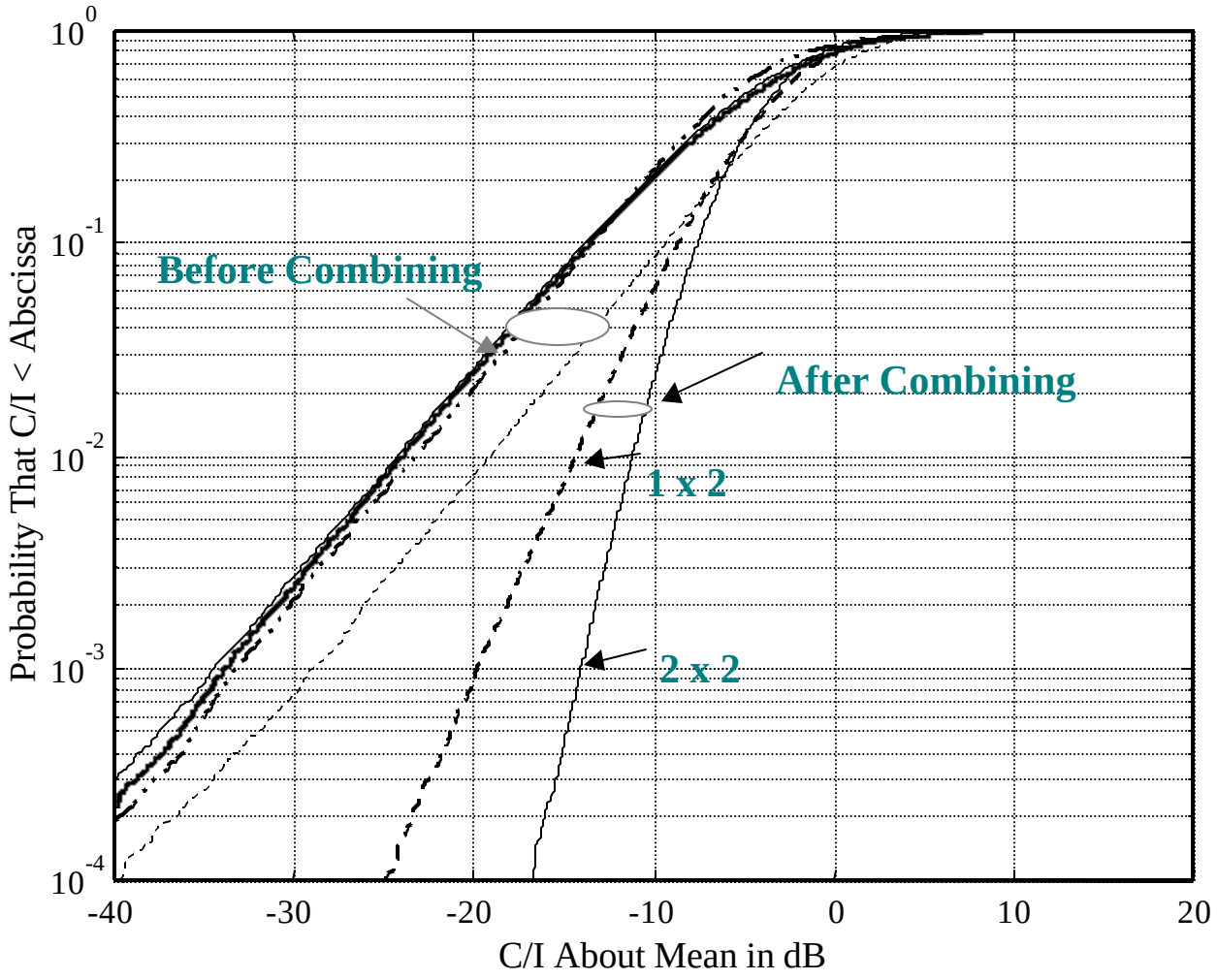


Probability of signal falling 10 dB below mean is 300 times lower with 2 x 2 compared 1 x 1

Increasing Spectrum Efficiency

- Reduce CCI to improve reuse
  - Increase signal diversity
  - Interference averaging
  - Antenna sectorization, beam forming, interference cancellation
- Reduce ACI to improve reuse
  - Careful frequency planning
  - Stringent emission masks, Rx filtering
  - Interference suppression
- Use link adaptation to exploit available C/N or C/I levels
- Use Radio Link Protocol to allow link to use high BER

C/ I After Combining - Measured Data



$\overline{C/I}$ = 10 dB

Probability of C/I falling 15 dB below mean is 300 times lower with 2 x 2 compared to 1 x 1

Conclusion

- Achieving high capacity/coverage in a multi-cell BWA (×50 speed & ×50 QoS compared to mobile cellular) network is a challenging problem.

- Many technologies help improve performance. MIMO antennas are a key leverage.

- Gigabit Wireless is a pioneer of MIMO for BWA networks