Propagation Modeling of Millimetre-Wave Channels for Fixed Broadband Wireless Access

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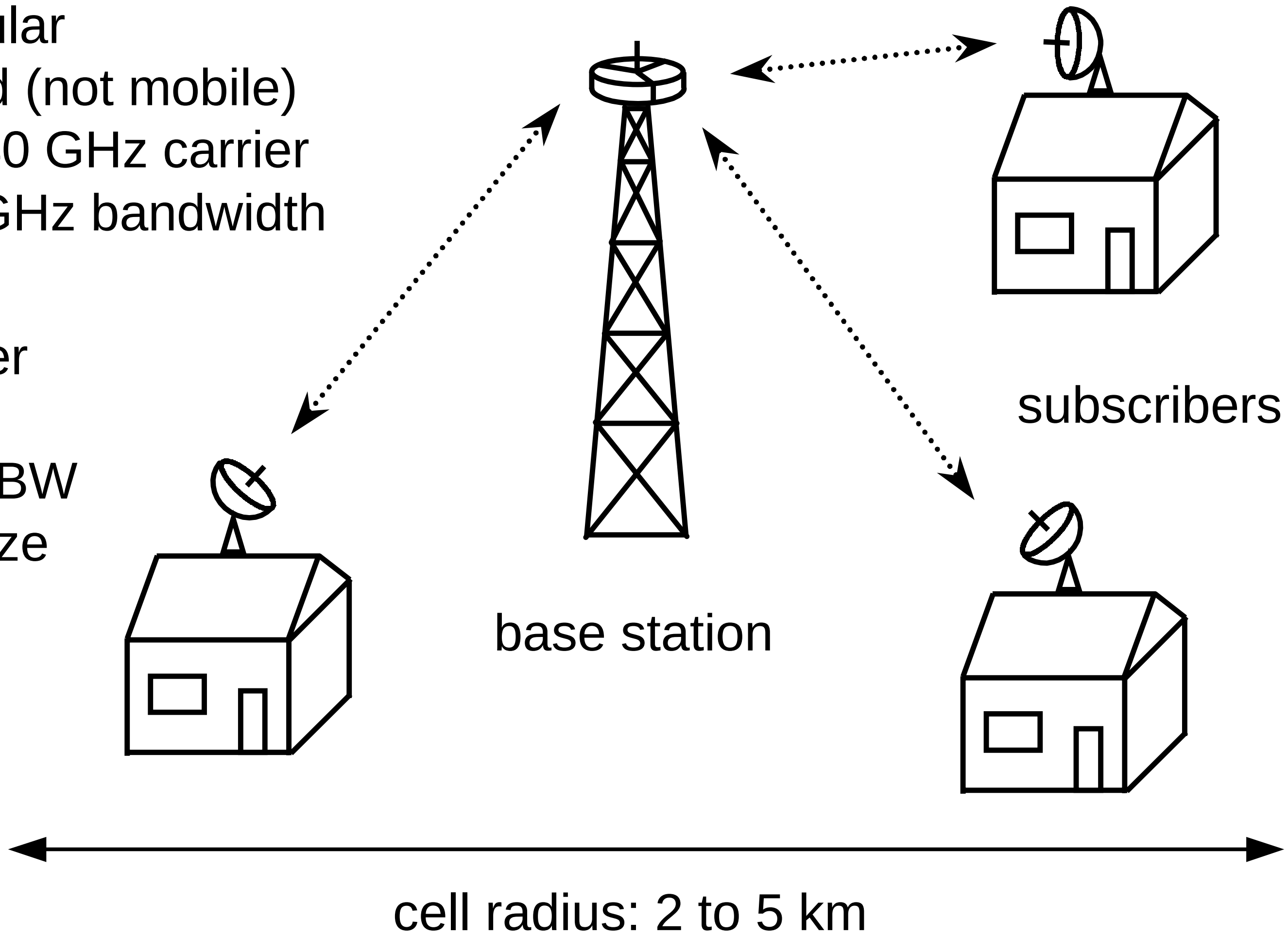
outline

- one type of fixed BWA: LMDS
    - analysis / issues similar for MMDS
- coverage problem in suburban areas
- investigate:
    - several methods for increasing coverage
    - emphasis on non-LOS links
- ray tracer developed:
    - allows fast simulation of large areas (km^2)
- analysis: multiple scenarios
- conclusions:
    - effectiveness of each method
    - proposed ways to achieve high coverage

LMDS (LMCS)

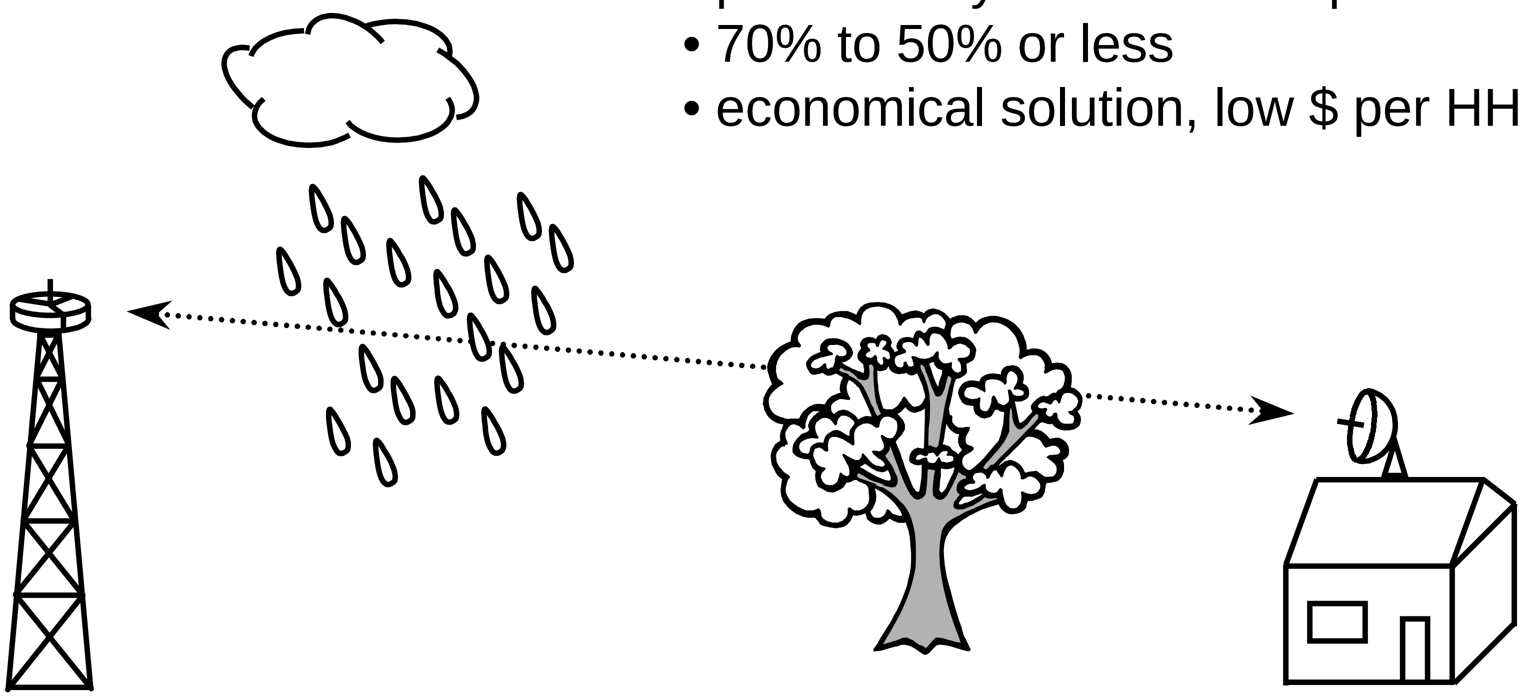
- BWA
- terrestrial
- cellular
- fixed (not mobile)
- 28/40 GHz carrier
- ≈1 GHz bandwidth

subscriber
antenna:
- narrow BW
- small size



coverage problem

- mm-waves: quasi-optical
- attenuation by trees, buildings and rain
- present-day clear LOS requirement
- 70% to 50% or less
- economical solution, low $ per HH



goals

evaluate several techniques for increasing coverage in suburban areas, either:

1) given a strict requirement for clear LOS, or
   - (minimal channel impairments)
   - (long-term link quality is more certain)

2) allowing the use of non-LOS links
   - (reflected)
   - (obstructed by trees and/or buildings)
   - (increased channel impairments)
   - (long-term link quality is less certain)

increasing coverage

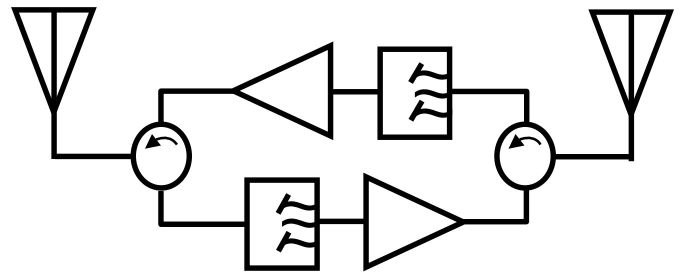
(1) increase number/percentage of available clear paths:
- ↑ base station and/or subscriber antenna heights
- ↓ cell radii
- ensure macrodiversity (cell overlap)
- reflections, natural or artificial reflectors

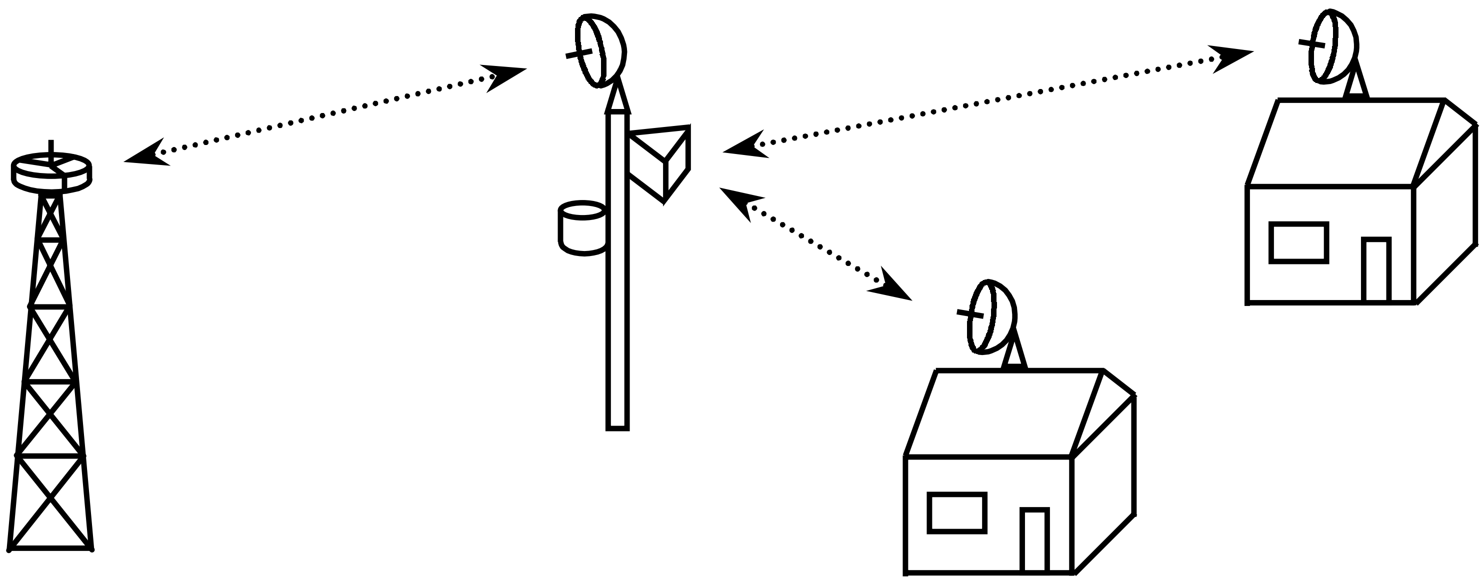
(2) increase MTPL (maximum tolerable path loss):
- ↑ EIRP: antenna gains, Tx power
- ↓ receiver noise figures
- trade-off system capacity and/or receiver complexity:
  (adaptive) modulation, coding

(3) use simple repeaters:
- boost signal in shadowed areas

repeaters

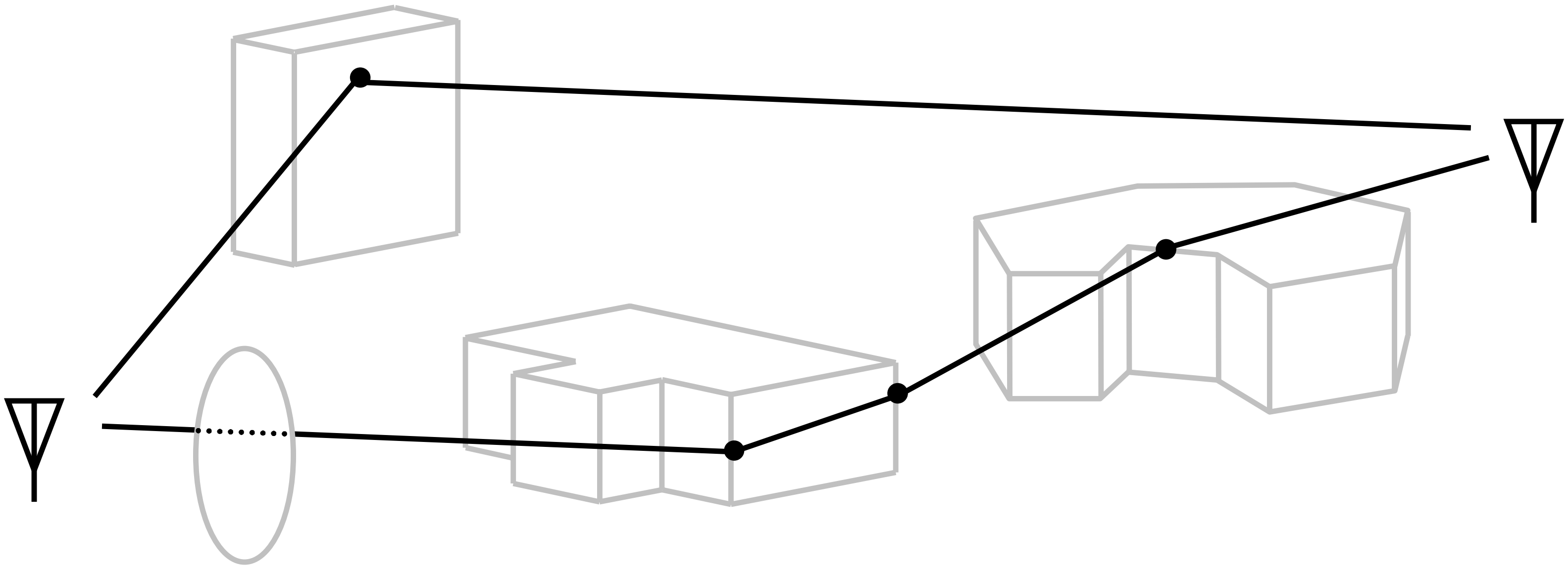
- non-regenerative (analog)
- bidirectional
- wideband
- increase coverage both ways
  (↑ # of paths, MTPL)



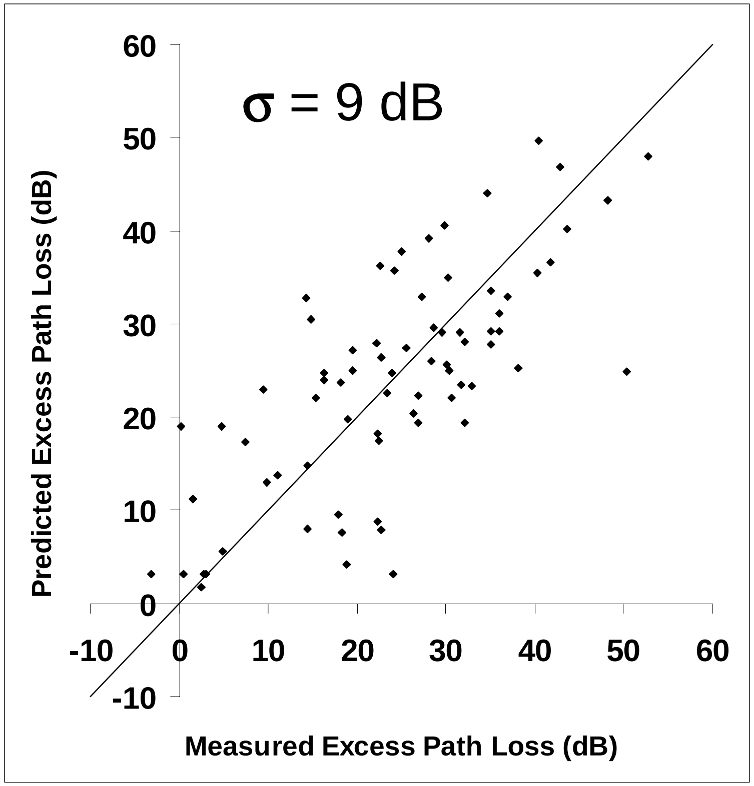


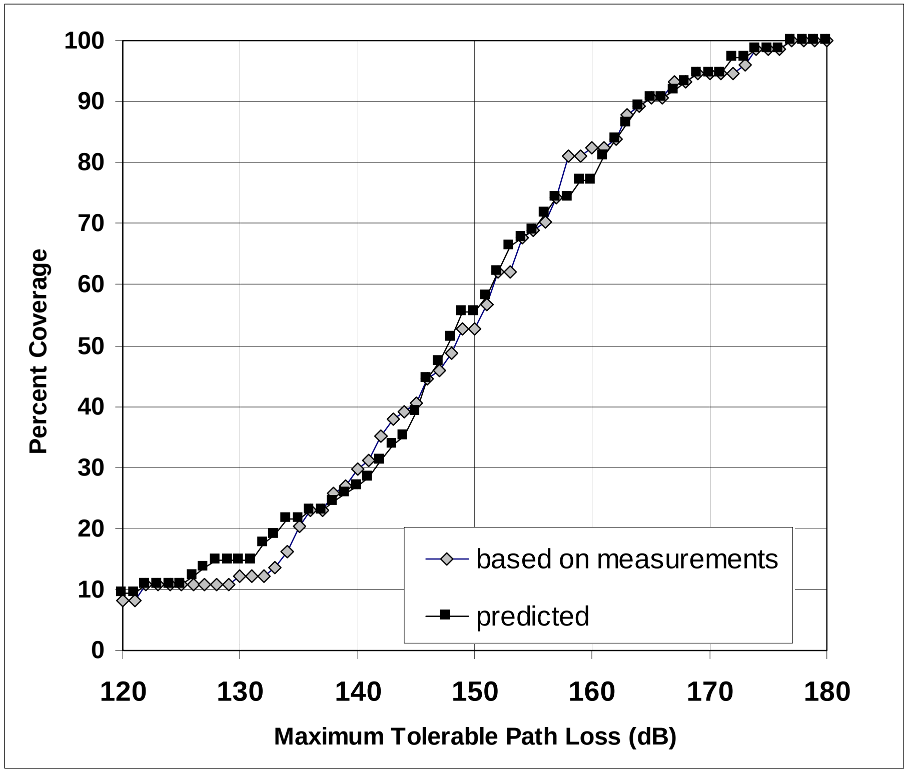
propagation simulator

- developed to determine relative importance of each method
- both deterministic and empirical aspects
- detailed terrain database, polygons
- complexity, accuracy between existing 3D and 2D models
- least-loss path: recursive process, blocking obstacles only
- first order reflections: building walls, tall or nearby only



field measurements





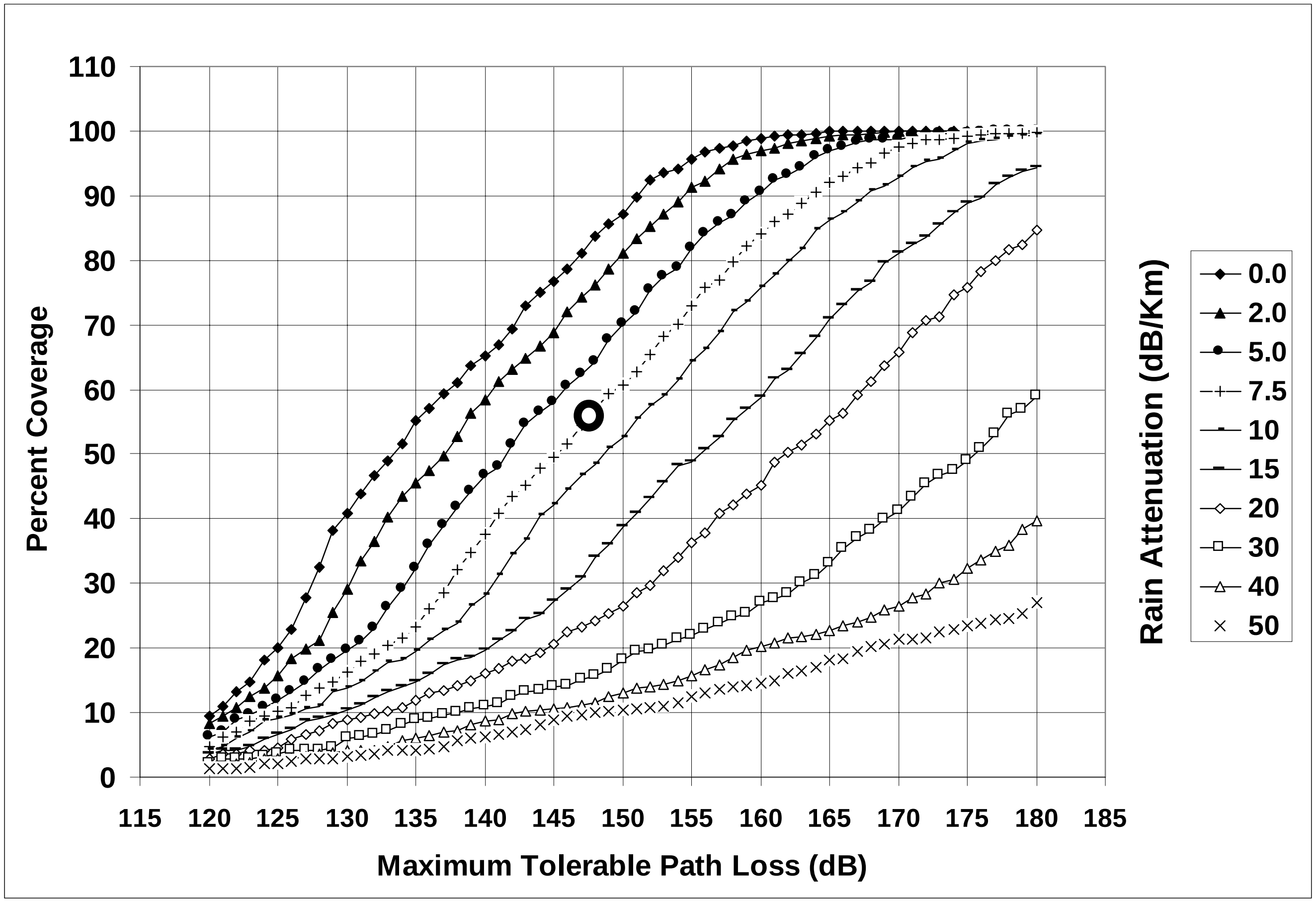
- field measurements used during development: guide, validate
- good agreement
- new measurements required to complete validation

baseline simulation

- 28 GHz
- 4 cells, 3 km cell radius
- terrain database of typical Ottawa suburb
- 500 random buildings (subscriber sites)
- subscriber antennas 0.5 meter above rooftop
- multiple rooftop locations were evaluated
- base station antennas 40 meters above ground

Path loss computed for all predicted paths between each subscriber rooftop location and the four nearest base stations.

baseline coverage

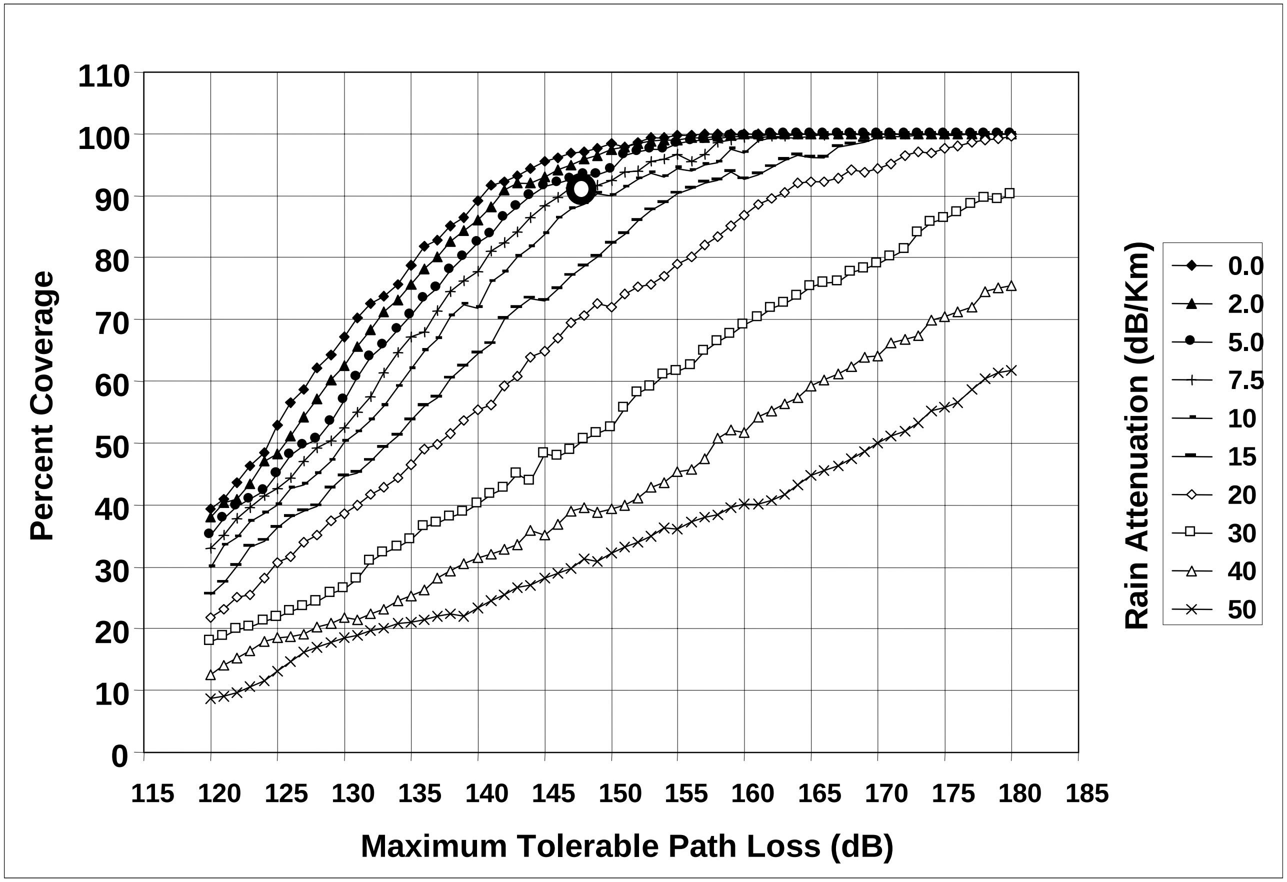


based on selection of single strongest signal

present-day w/ 5 dB fading margin

99.99% availability

repeater coverage



1 repeater per km^2

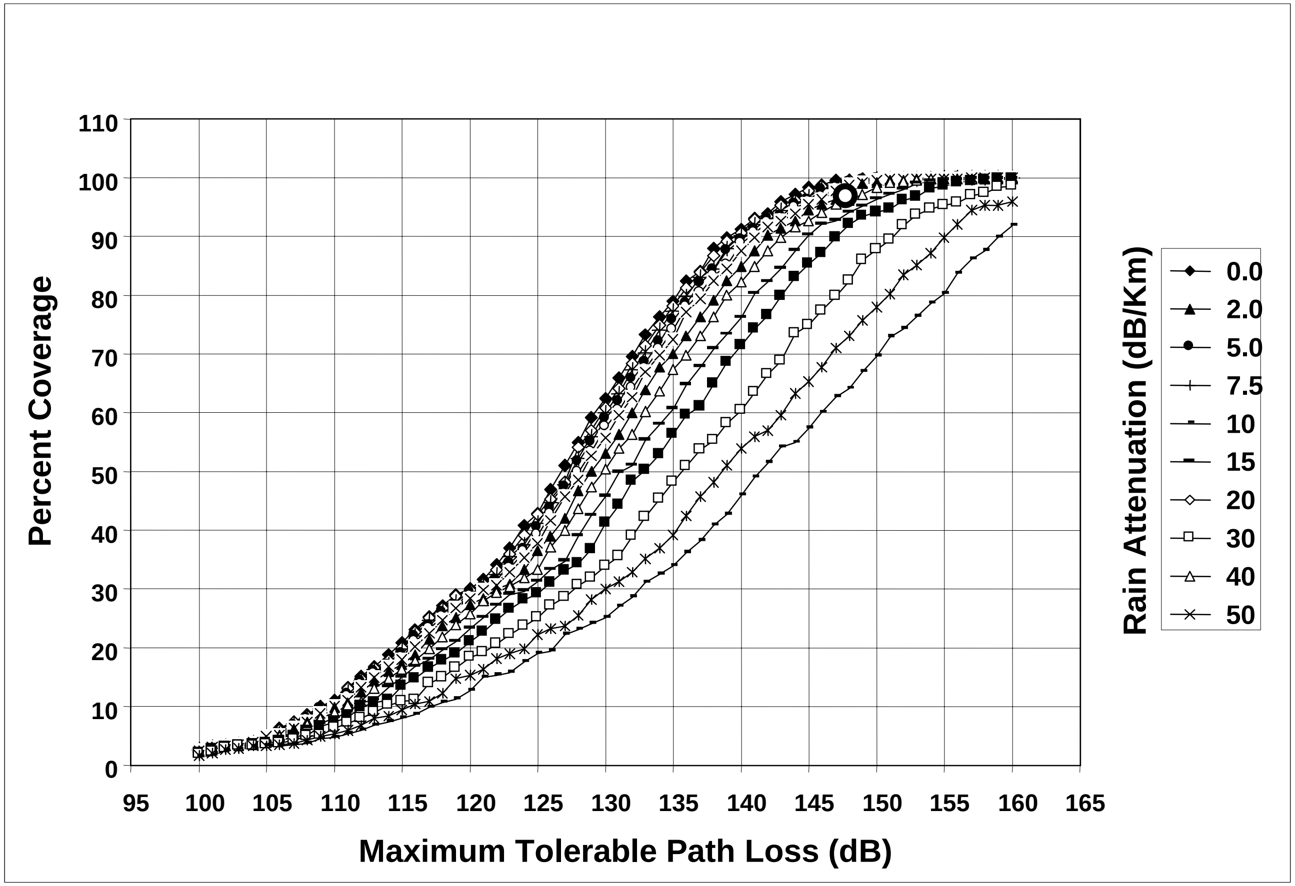
10m height

100m grid

additional high gain antenna

55% $\rightarrow$ 92%

microcell coverage

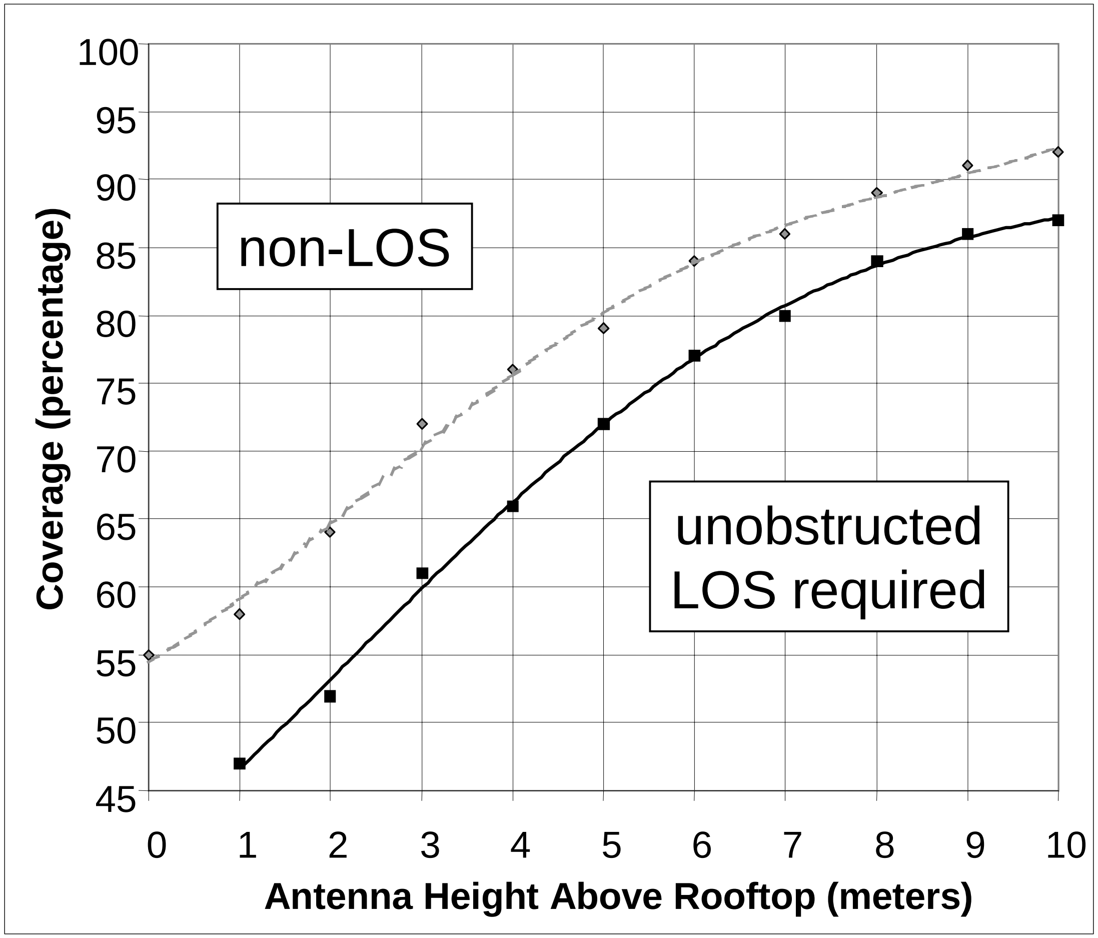


300 meter cell radius

10m height

less sensitive to rain

subscriber mast height



mast heights can be increased selectively

to reach 90% coverage

given non-LOS operation:

- increase MTPL by 17 dB
- selectively increase subscriber mast height up to 9 meters
- decrease cell radius to ≈1 km
- add ≈1 repeater per km^2
- use microcells, cell radius ≈ 400 meters

given clear LOS operation:

- selectively increase subscriber mast height up to 13 meters
- decrease cell radius to ≈0.5 km
- use microcells, cell radius ≈ 200 meters

additional results

coverage gains from inexpensive methods:

• reflections, optimally combined:	2%
• macrodiversity:	4%
• rooftop site selection:	12%
total gain:	18%

- macrodiversity and reflection gains limited by rain
- reflection gains are surprisingly low but confirmed by measurements
- rooftop site selection gain subject to experimental verification (measurements not well suited here)

conclusions

• propagation model developed to predict coverage for fixed mm-wave BWA systems in suburban areas; results are subject to further experimental verification

• the use of obstructed paths for link establishment can increase coverage significantly if additional channel impairments can be mitigated; 90%+ coverage appears feasible

• naturally occurring reflections provide negligible increase in coverage, but may be useful to combat fading

• careful selection of the subscriber antenna rooftop site is a significant factor

• repeaters are an economical way to reach high coverage targets

• it is extremely difficult (expensive) to reach high coverage given a strict requirement for unobstructed LOS

recommendations

- more measurements are needed to determine the generality of the model
- coverage predictions could be improved by a study of rain statistics on short links (≈ 1 km)
- better modelling of channel impairments, especially fading due to motion of trees, would be helpful
- an expanded analysis could involve interference, system capacity and the use of diversity to combat channel impairments