Benefits of Smart Antennas in 802.11 Networks

Presented to:

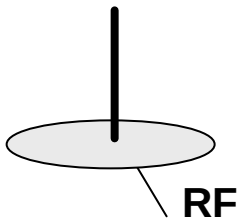
IEEE802.11 Wireless Next Generation Standing Committee

14 January 2003

Presentation Goals

1. Show the test results that illustrate the benefits of applying Smart Antennas to 802.11 equipment.
2. Highlight/introduce the opportunity within the Standards to further optimize the control & operation of Smart Antennas.

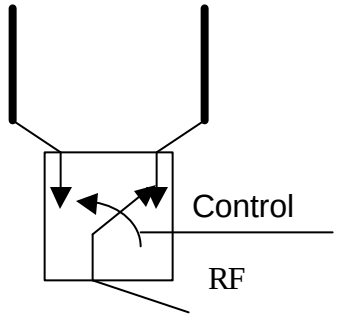
Today's Antenna Topologies



Omni-directional

Monopole over ground plane

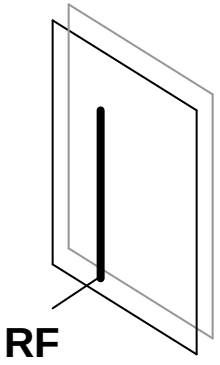
- Low Cost
- Baseline performance
- No interference protection
- Subject to multi-path fades



Switched Diversity

Two dipoles

- Higher cost
- No interference protection
- Select antenna with stronger signal to mitigate fades



Directive

Dipole with back reflector

- Low Cost
- Fixed pattern of coverage
- Directional interference suppression
- Directional suppression of multi-path components

Benefits of a Smart Antenna for 802.11 Applications

- Improved Signal-to-Noise Ratio
  - Increased coverage / range
  - Increased data rate reach
- Interference Reduction
  - Confine Tx RF energy to desired areas
  - Rx signal controlled by antenna pattern
- Multi-path Reduction
  - Signal paths reduced or eliminated by coverage pattern
  - Signal strength variance reduced
- Increased network capacity
  - Clients / Stations operate at higher data rates
  - Reduced probability of collisions
- Increased Battery Life
  - Clients / Stations reduce Tx power
  - Increased data rate reduces Tx time

Smart Antenna Definition

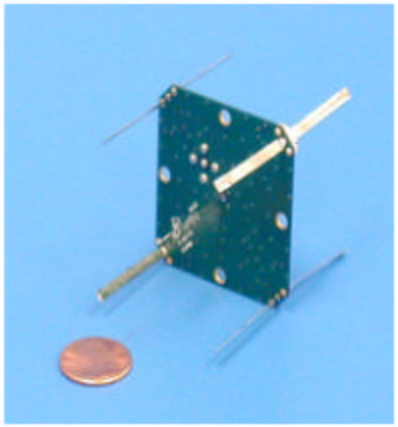
- Multiple mode antenna: Omni & Directional
- Switching: < 100 nsec between modes / directions
- Interfaces: Single RF I/O, digital control lines
- Designed for Consumer applications
- Antenna control:
  - Automatic steering via HW or SW implementation
  - Integrated with communications protocol
  - Integrated within device for simplicity & cost

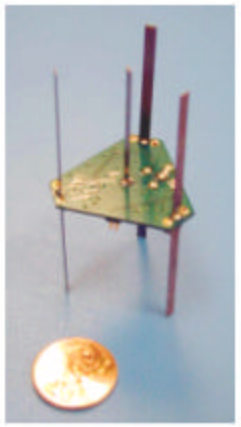
Smart Antenna Implementation

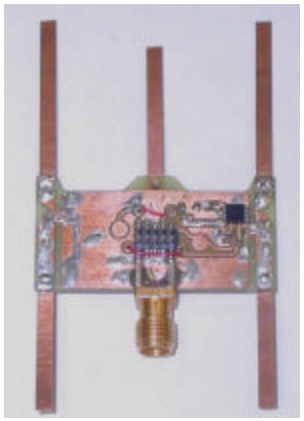
- Omni & directional modes
- Single transceiver design input / output
- Simple digital control from PHY / MAC
- Directional beam-forming at RF
  - Noise suppression provided by pattern
  - Multi-path components suppressed by pattern
- Printed circuit board implementation
  - Standard commercial materials and components
  - Simple fabrication, assembly, and test

Multiple Antenna Configurations

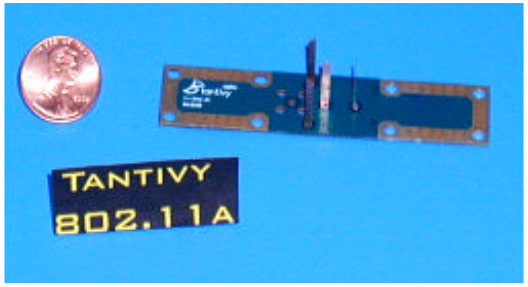
2.4 GHz

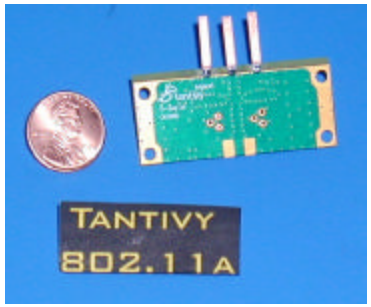




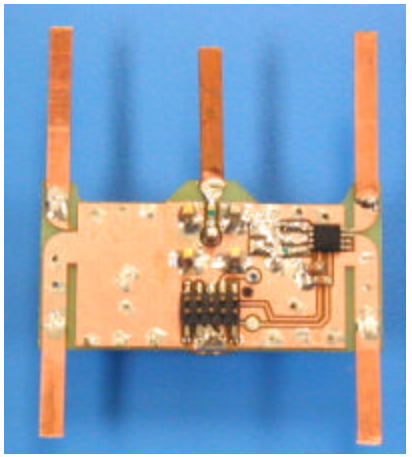


5 GHz





Dual Band

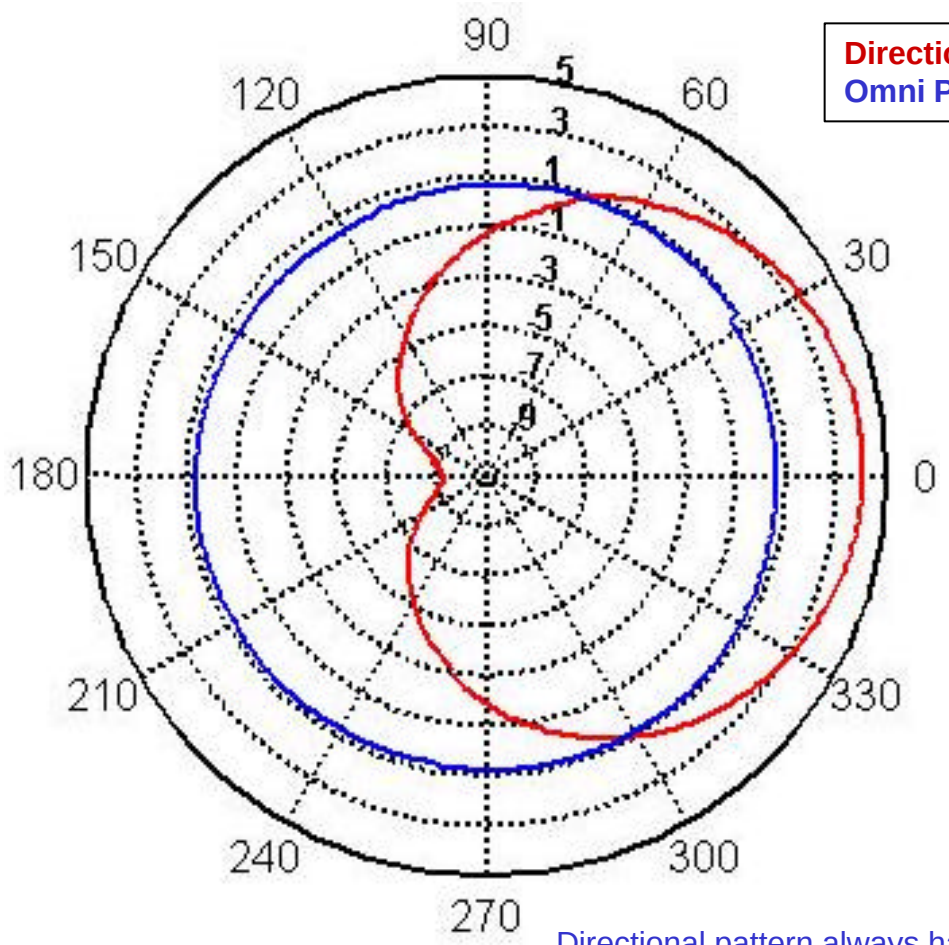


Smart Antenna Description

- Gain
  - Omni mode: 0 dBi
  - Directional mode: 3.5 to 5 dBi
- Beam-width
  - 1 dB: 60°
  - 3 dB: 110°
- Front-to-back ratio: 13 dB
- Interfaces
  - RF: 50Ω
  - Control: 2 to 4 Digital signals
  - Power: 3 VDC, 200µA

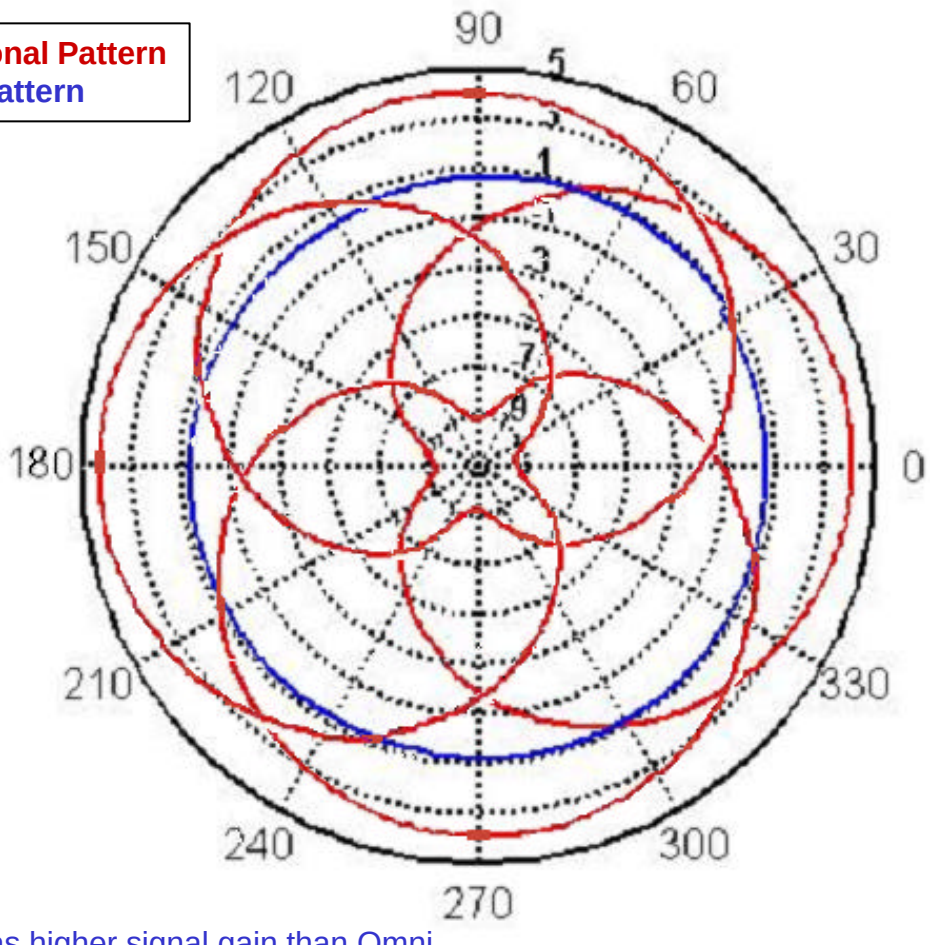
Representative Coverage Patterns

Omni & Directional



Directional Pattern
Omni Pattern

Omni + 4 Directions



Directional pattern always has higher signal gain than Omni

Smart Antenna Test Objectives

- Collect range-rate data with a 802.11b WLAN to investigate performance advantages with the use of Smart Antenna
- Investigate the impact of Smart Antennas for both downlink and uplink file transfers
- The goal of this testing is to demonstrate a data rate improvement with the Smart Antenna as compared to a switch diversity antenna

Smart Antenna Test Equipment

- Hardware
  - Commercially available Access Point and Client / Station
- Software
  - WarFTPd 1.70.b01.04 (Aug 18 1998) application on the laptop connected to the AP
  - DOS ftp command imbedded in batch files on the laptop connected to the Client
- Antennas
  - AP: Internal diversity or External Smart Antenna
  - Client/Station: Internal diversity antenna

Test Setup

Client/Station

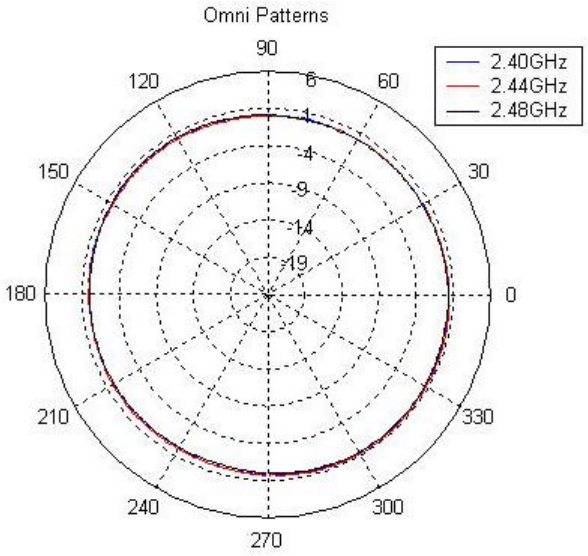
- Laptop - IBM ThinkPad
- DOS FTP commands
- Internal Switched Diversity Antenna

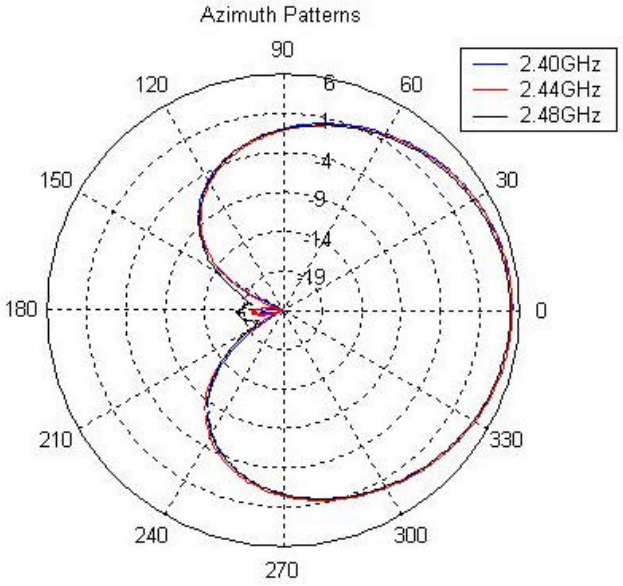
Access Point

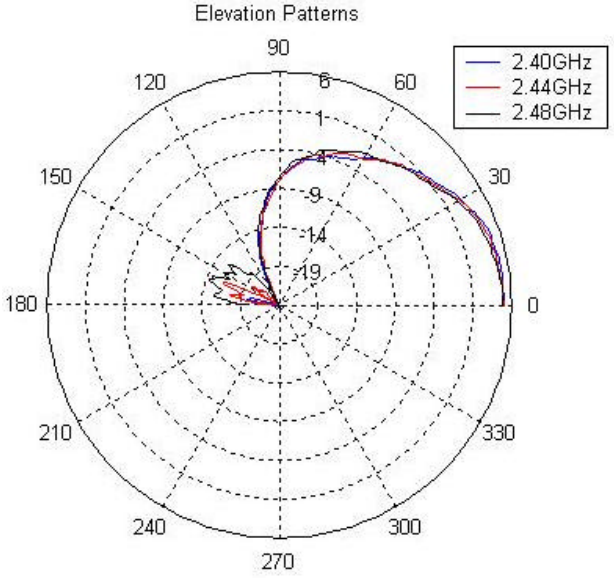
- Server - IBM ThinkPad
- War FTPd software
- Internal Switched Diversity Antenna
- External Smart Antenna

Test Antenna

- Photo and coverage patterns of test antenna
- Antenna provides eight directional beams in 45º increments



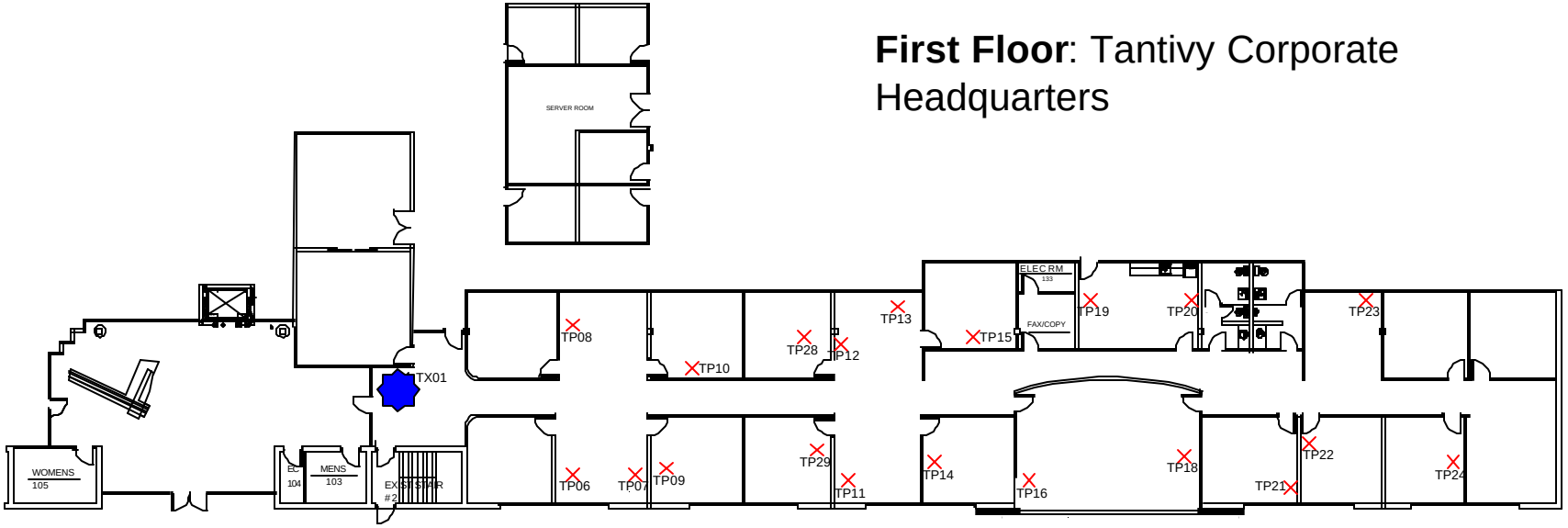




Smart Antenna Test Procedure

- File transfer size: 3 MB
- Antenna Configurations
  - Internal Switched Diversity
  - Smart Antenna in Omni mode
  - Smart Antenna at each of 4 angles (90° steps)
- Locate Client/Station at the desired test location
- For each antenna configuration, transfer 5 files in the desired direction using a DOS ftp command from Client/Station

Smart Antenna Test Locations



First Floor: Tantivy Corporate Headquarters

LEGEND

Access Point Location

Test Location

Test Point TP#	6	7	8	9	10	28	29	11	12	13	14	15	16	18	19	20	21	22	23	24
Dist Tot (ft)	37	47	35	52	54	74	75	83	80	92	97	103	114	141	124	142	160	162	172	188

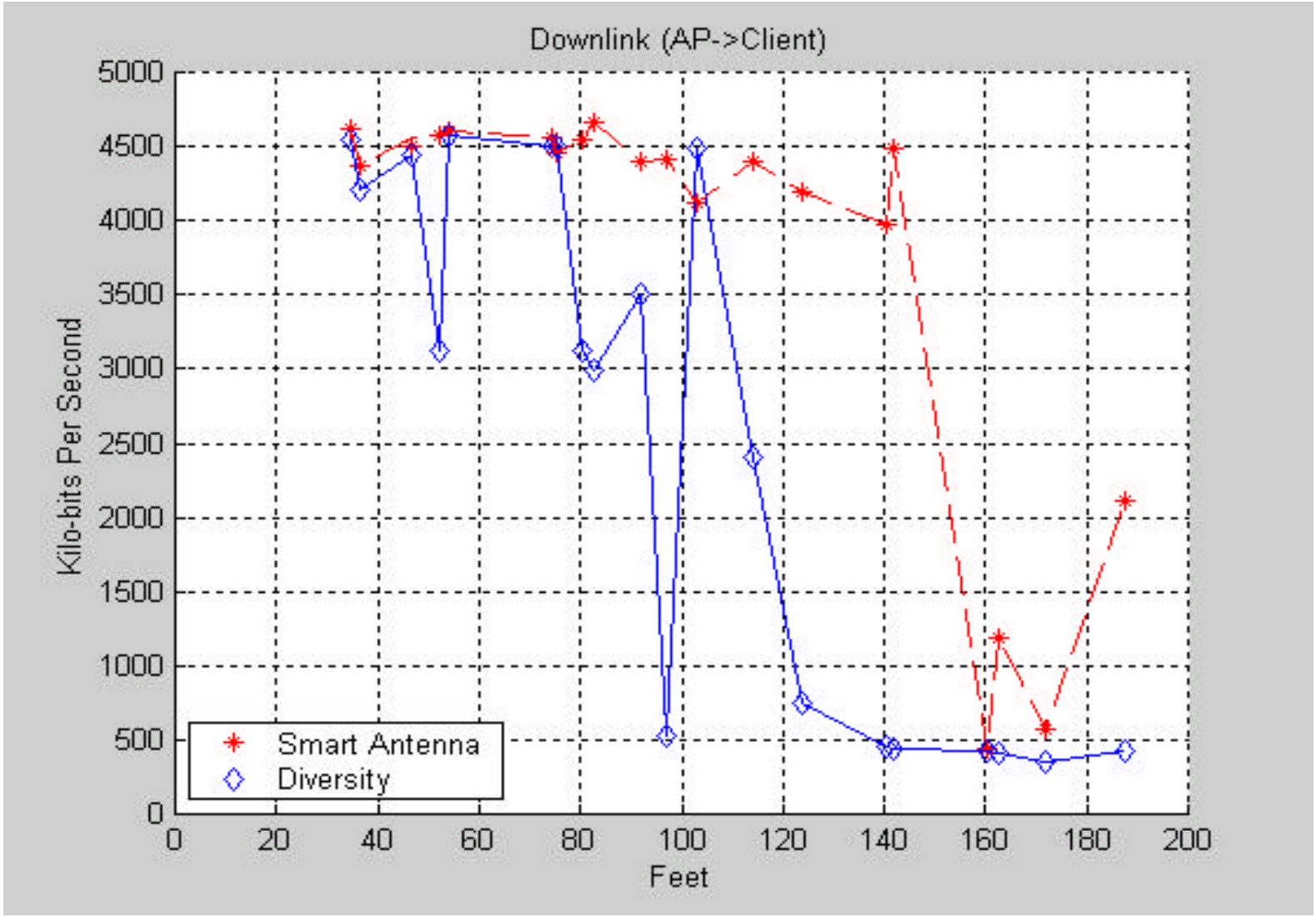
Smart Antenna Test Environment

- Commercial Office Space
- Exterior walls: Concrete block
- Interior walls: Steel Studs with sheet rock
- Ceiling height: 9 feet
- Ceiling type: Suspended acoustic tiles
- Data Collection: Daytime work hours

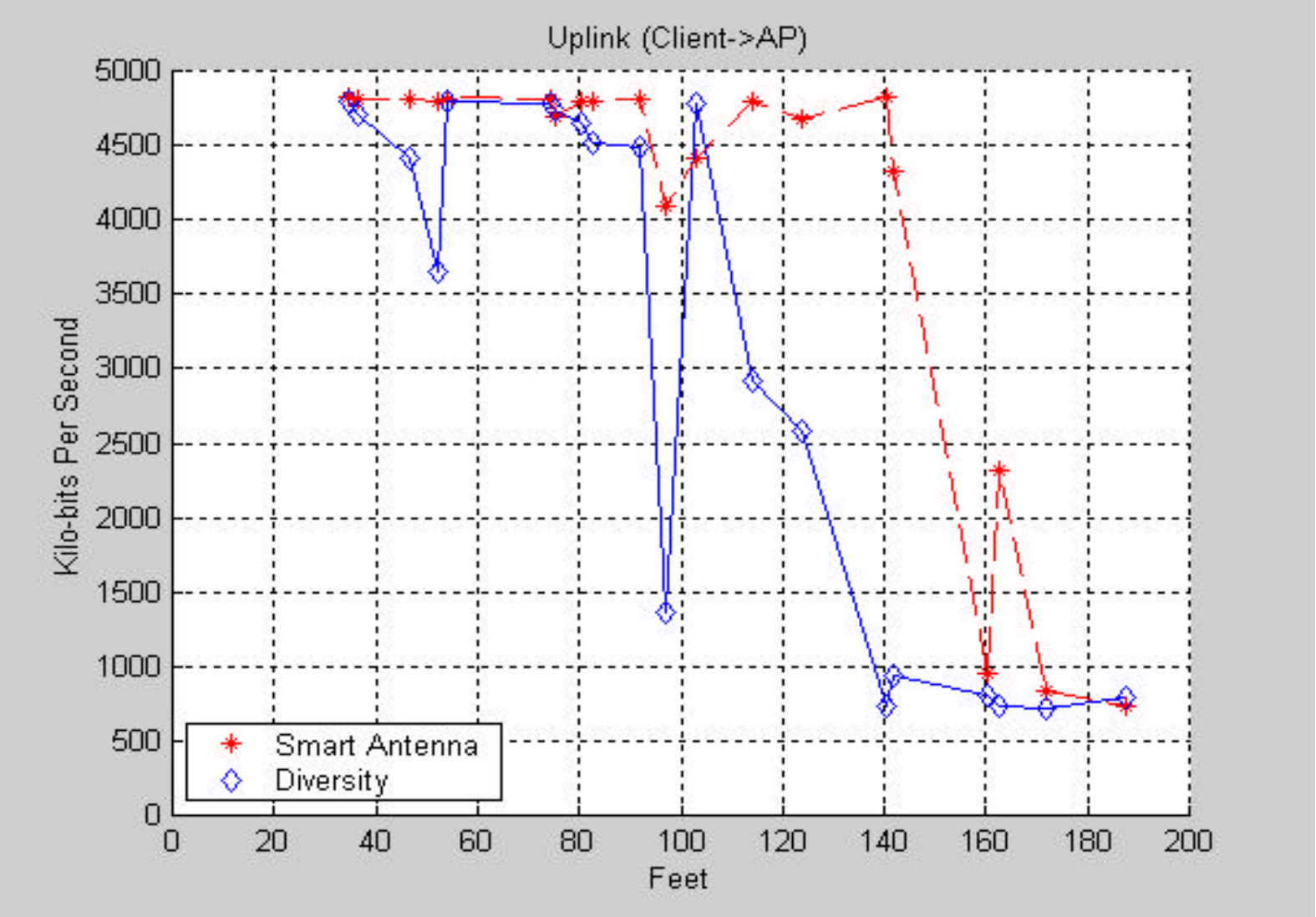
Smart Antenna Test: Data Analysis

- Average the 5 file transfers
  - Uplink and Downlink
  - Internal Switched Diversity Antenna
  - External Smart Antenna: Omni mode
  - External Smart Antenna: 4 directional positions
- Plots
  - Average Data for Uplink and Downlink
    - Switched Diversity Antenna
    - Smart Antenna
  - Min/Max/Avg Plot for Uplink and Downlink
    - Switched Diversity Antenna
    - Smart Antenna

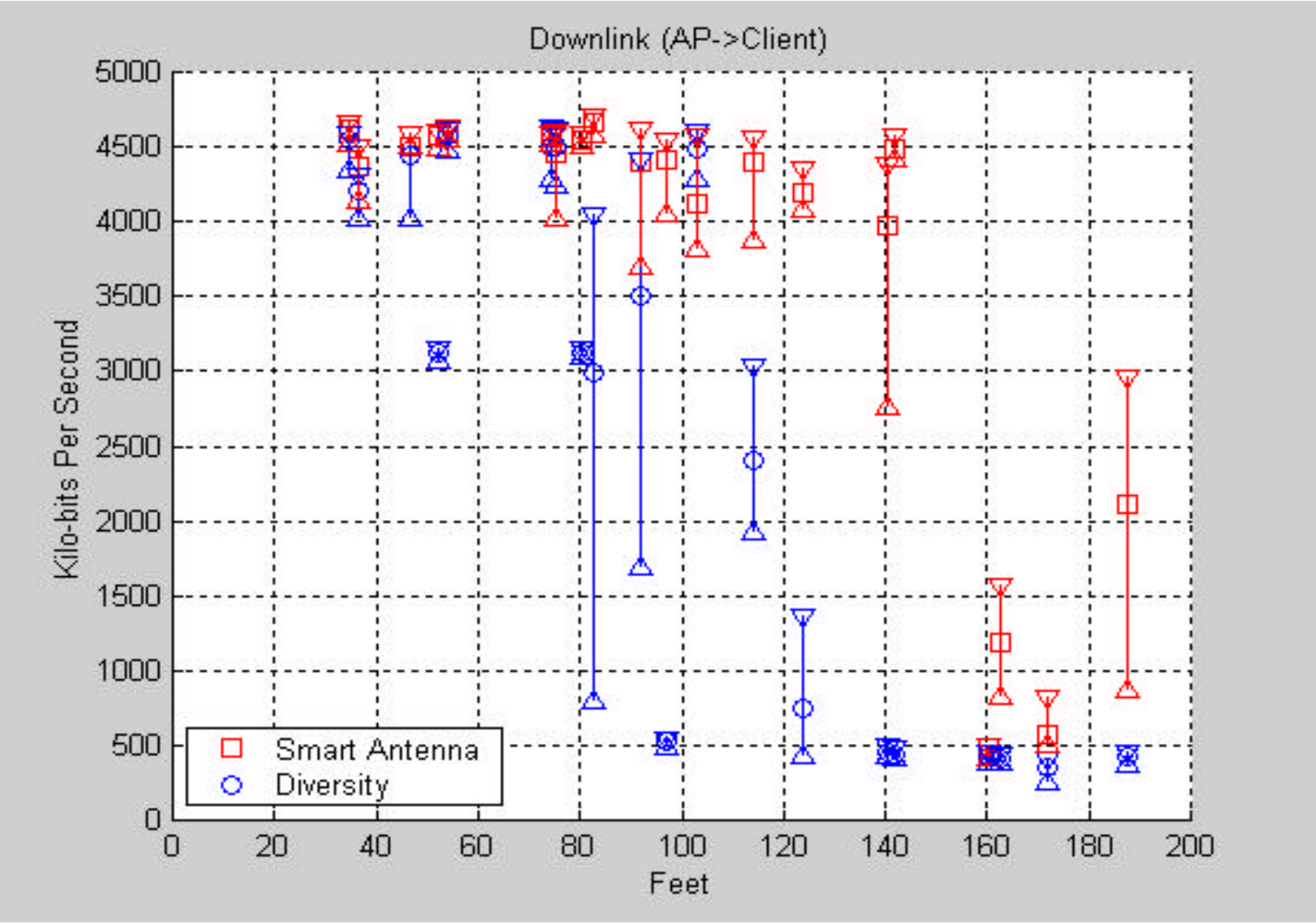
Smart Antenna Test Results - Downlink



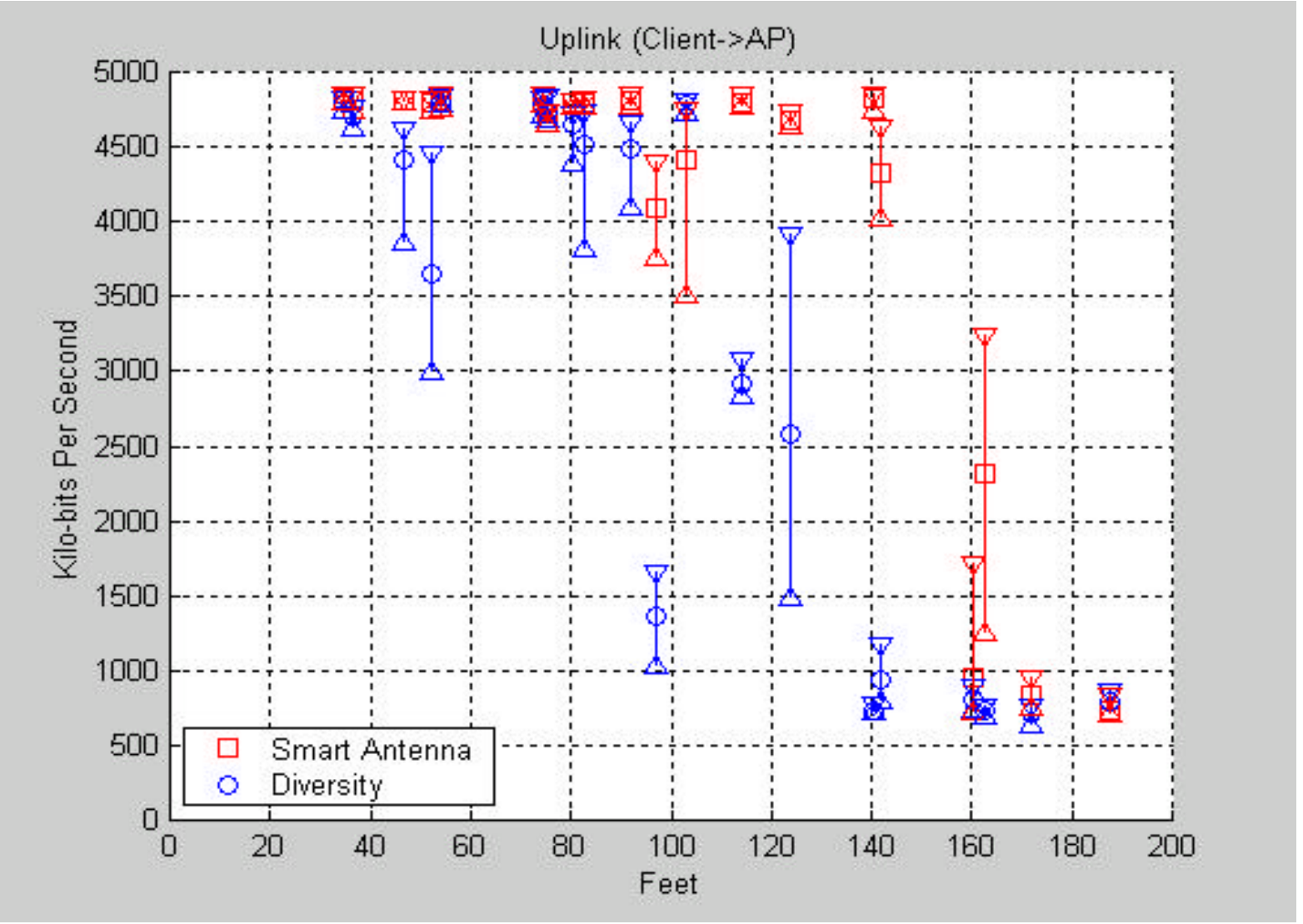
Smart Antenna Test Results - Uplink



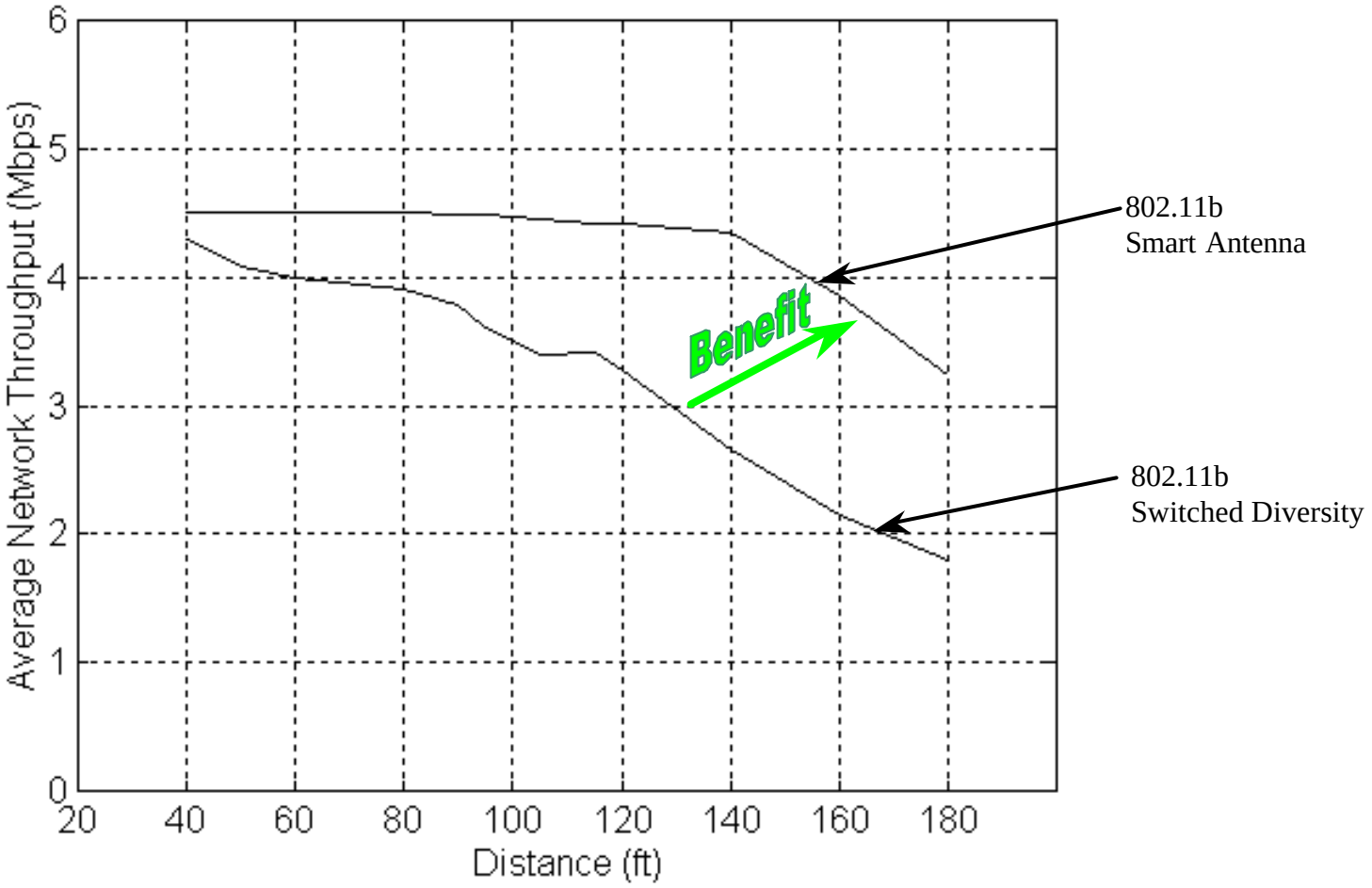
Smart Antenna: Downlink Min/Max/Avg



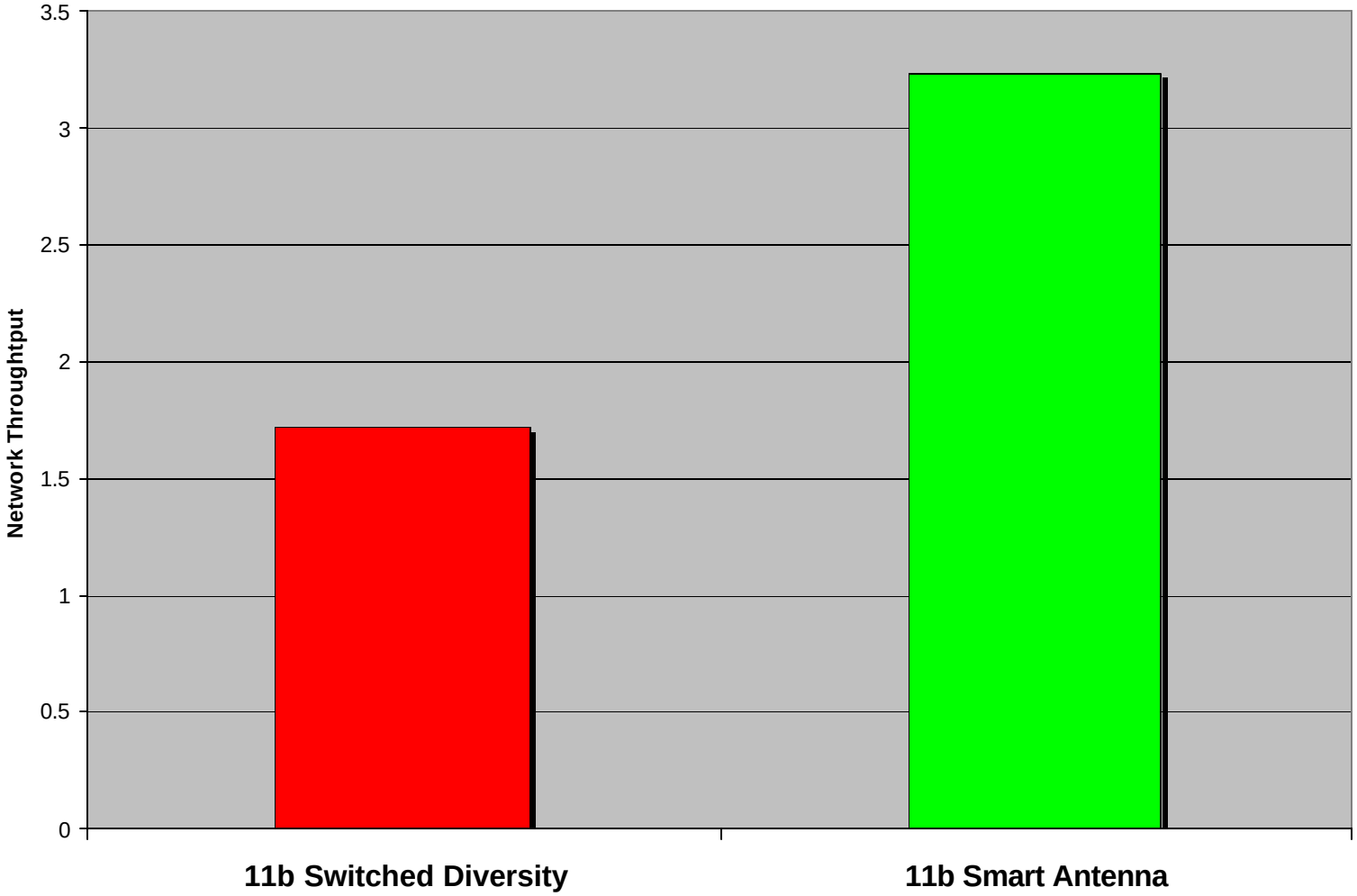
Smart Antenna: Uplink Min/Max/Avg



Smart Antenna Benefits Network Capacity



Average Network Throughput



Summary

The Smart Antenna improved WLAN performance

- 82% increase in coverage (3.8dB to 5dB)
- Benefits similar for Uplink and Downlink directions
- Significant reduction in Min/Max difference results in reduced variance
- Performance improvements expected from interference reduction
- Test results were collected using existing technology, not simulations