In-building Wireless Tutorial

The Last 100 Meters of the Wireless Revolution

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Today's Topics

- Motivation
- Emerging Trends
- Technical Details
- Equipment Choices
- Demo of Tools
- Design Examples

Tutorial Overview

- Motivation for In-building Wireless
- Service Types
- Design Objectives
- The Indoor RF Environment
- In-building Distribution Technologies
- Equipment Options & Design Issues
- Link Budget & Propagation Modeling
- Traffic Engineering
- Practical Deployment Issues
- Design Tools

Motivation for In-building Wireless

Why Cover Indoor Anyway?

- Last Great Coverage Frontier
- Offloads Macro System
- No Indoor Data Alternative

Why Campus/Indoor Wireless Coverage?

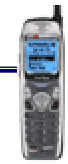
- Public areas, offices, classrooms need coverage
- Huge need to move in-building users onto in-building networks where interference is confined within building walls -- avoids saturation of outdoor network
- Consumers are adopting wireless appliances for ubiquitous coverage - capacity needed in buildings where people live, work, recreate
- Carriers and building/tower owners can offer savings through integrated services and billing

Wireless Access Issues in Buildings

- Buildings and Campus enterprises need planned wireless internet and cellular/PCS strategy
- Campus environments require design tools that support ongoing facilities management and maintenance for expansion and upgrades
- In-building wireless deployment in its infancy but will explode with Wireless Office, Wireless LANs, Wireless Video, VoIP, Bluetooth, and Wireless PDAs.

Service Types

In-building Service Types




- Cellular, PCS, WAP
- Wireless Office Service
- Wireless LAN (IEEE 802.11)
- Wireless PDAs (Compaq IPAQ, Handspring)
- Wireless VoIP
- Wireless Video
- Bluetooth



Service Types

- Indoor Public Voice & Data Service
- Wireless Office Service
- Wireless LAN

Indoor Public Service

- Base Station is Microcell or Picocell Radio Equipment
- Carrier Pays

Wireless Office Service (Private Service)

- Wireless PBX or Cellular Base Station
- PSID for User Re Registration
- Dialing and Billing Features
- Customer Pays

Public WLAN (PubLAN)

- Public Access to 802.11b WLAN
- Internet Service Provider (ISP) offers access
- In-building service provider (IBSP) installs and owns equipment

Design Objectives

Design Objectives

- RF Performance
- Cost
- Specific Customer requests
- Ease of Installation
- Ease of Maintenance

RF Planning Objectives

- Satisfaction of Specific Customer Needs
- RF and Network Performance (Coverage and Capacity)
- Minimal Cost (Equipment and Installation)
- Cooperation with macrocell systems and interference minimization
- Ease of installation and integration with building environment, all properly documented
- Ongoing infrastructure maintenance

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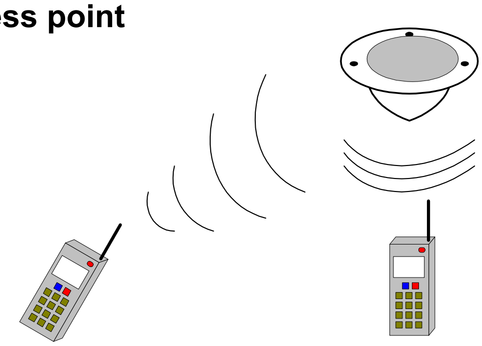
Design Objective: RF Performance

- **Sufficient Downlink Power for:**
  - **Phones to camp on to your indoor or microcell system**
  - **Good downlink voice quality anywhere customer can make a call**
  - **Internet access inside buildings**

Design Objective: RF Performance

- **Limit downlink power to prevent phone overload at closest access point**



Design Objective: RF Performance

- Transmit as little downlink power out of the building as possible
- Keep antennas away from exterior glass
- Minimize macrocell interference

Design Objective: RF Performance

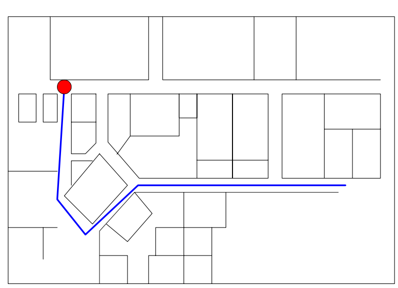
- Sufficiently Low-Loss Reverse Link Path for:
  - Good reverse link voice quality
  - Good reverse link with minimum power drain
  - Minimize uplink interference to macrocell
  - High speed Internet link

Design Objective: RF Performance

- Reliable handoffs with the macrocell System
- Walking into the building
- In an elevator on all floors
- Driving out of basement parking garage
- Exiting via elevated walkway

Best Placement Objectives

- Cover sensitive or secure areas without requiring installation of antennas or cable (i.e. hospitals)



Best Placement Objectives

- Hide or disguise the antenna system for minimum visual impact

Best Placement Objectives

- Achieve design objectives at minimum cost
- Equipment Cost: maximizing efficiency
- Installation Cost: best technology choice
- Leasing Cost: distribution system
    - RBS
    - Dark Fiber
    - CAT 3 or CAT 5

The Indoor RF Environment

The RF Propagation Environment

- Losses
- Fading
- Noise
- RF Exposure
- RF Overload
- Multipath

Indoor RF Fading Statistics

Outdoor	Indoor
Rayleigh	Rician

Bottom Line:

- **Indoor Environment is More Forgiving**
- **Use 17 dB C/(I+N) for IS-136 or PDC**
- **Use 13 dB C/(I+N) for GSM or GPRS**
- **Use 7 dB C/(I+N) for IS-95 or CDMA 2000**
- **Lack of substantial multipath inside buildings renders RAKE useless**

Indoor Radio Noise Sources

- **Computers**
- **Rotating Machines**
- **Power Distribution Equipment**
- **RF Heating Equipment**
- **Transmitters**

Indoor Maximum Power Exposure (MPE)

- Radiax Produces Low Power Density
- Be Careful of Directional Antennas Aimed Toward Floor
- Preventing Phone Overload Will Keep Power Density Well Below MPE
- FCC Requires Measuring Power Density for Indoor Sites in US (OET65)

In-building Distribution Technologies

In-Building Distribution Technologies

- Repeaters (coverage,but no capacity)
  - Bi-directional amplifier (BDA)
- Passive Distribution (lossy, short distance)
  - Coaxial cable, splitters
- RF Amplifier Distribution (expensive)
  - Coaxial cable, splitters, amplifiers
- Active Distribution (requires new wiring)
  - Optical, analog or digital; CAT-5

Repeater Design Issues

- Sufficient capacity in outdoor serving cell
- Noise floor levels on both sides of BDA
- Adjusting BDA gains for desired coverage
- Placement of BDA and antennas
- Overall cost vs. performance

Passive Distribution Design Issues

- Noise floor increases due to loss
- Signal loss through distribution network
- Additional loss due to splitters or taps
- Using radiating cable vs. run-and-drop
- Designing multi-antenna “star” topology
- Single or multi-band distribution
- Overall cost vs. performance

RF Amplifier Distribution Design Issues

- Correct allocation of gain in system
- Avoidance of intermod or spurious signals
- Limitation: dynamic range headroom
- Bi-directional gain and noise figure design
- Overall cost vs. performance

Active Distribution Design Issues

- Accurate provisioning: power per RF user
- Existing vs. installed distribution wiring
- Single mode fiber vs. multi mode fiber
- Upgradeable architecture
- Overall cost vs. performance

Example of Active Distribution

- LGCell™ by LGC Wireless
  - Supports multiple standards and bands
  - Main Hub connects to BTS/repeater
  - Fiber connects Main Hub to Expansion Hubs
  - CAT-5 connects Expansion Hubs to Remote RF units
  - Uses inexpensive fiber and copper wiring

Example of Active Distribution

- Litenna™ & Rfiber™ by Foxcom Wireless
  - Supports multiple standards and bands
  - RFiber transceiver connects to BTS/repeater
  - Fiber and optical BDA connect RFiber to Litenna base units
  - Litenna base units connect via fiber to many remote hub units
  - Uses inexpensive fiber and simple connectors

Example of Active Distribution

- Digivance™ by ADC
  - Supports multiple standards and bands
  - Digital Host Unit connects to BTS/repeater
  - Multi-mode fiber connects Digital Host Unit to Digital Expansion units
  - Digital Expansion Units connect via fiber to many Digital Remote Units
  - Uses all-digital RF-to-optical transport

Equipment Options & Design Issues

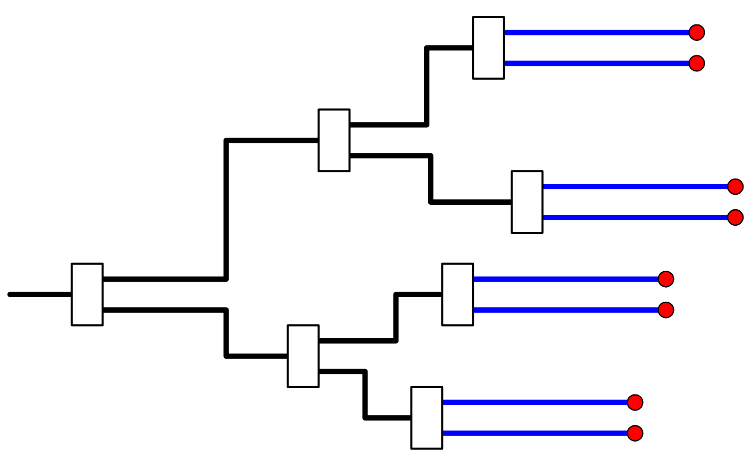
Equipment Options

- Branching Cable Network
- Signal Conversion for Distribution via:
  - Fiber Optic Cable
  - Cheap, Flexible Coax
  - Twisted Pair
  - Pre-Installed LAN Wiring

Branching Cable Network

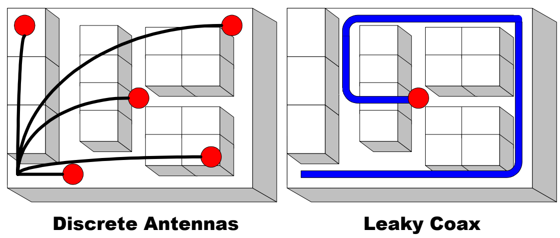
- Microcell Drives Backbone Directly
- LPA and LNA Boost Power Through Backbone Coax Cable
- Installation Cheap in Many Cases
- No Remote Power Required
- Cable Runs Limited to 500 Feet

Branching Cable Network Architecture



Discrete Antennas vs. Leaky Coax

- Uniformity of RF Power
- Installation Cost
- Power Leakage to the Outside
- Visual Impact



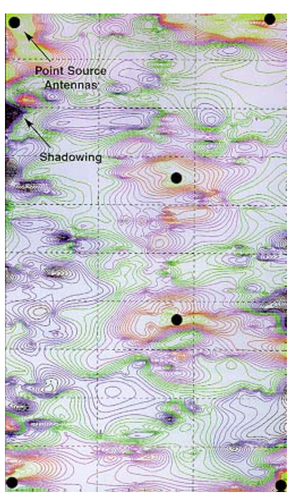
Discrete Antennas

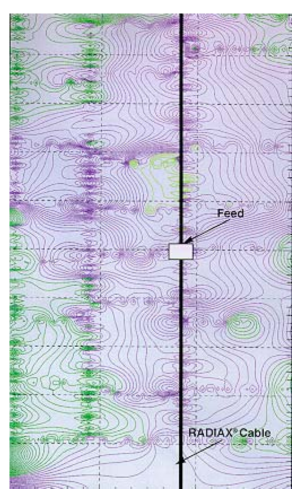
- Each Cable Run Ends in One Antenna
- Creates Hot Spots
- Troublesome Near Windows
- Phones Operate in Far Field
- Advantage: Directivity and Deployment

Leaky Coax

- Cable Run Is the Antenna
- No Hot Spots
- Phones Operate in Near Field
- Building Structure Spoils Far Field Pattern
- Simpler, Costly Installation
- Installs Out of Sight

RF Power Uniformity & Uplink Path Loss Uniformity

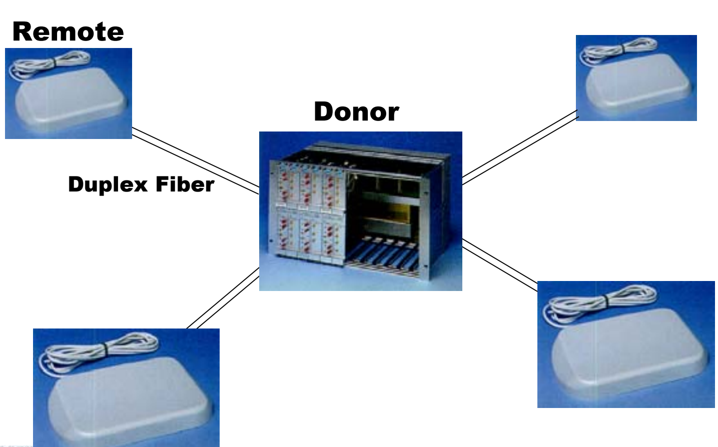




BriteCell (Allen Telecom)

- RF Modulates Laser Signal
- Light Travels Over Single Mode Fiber
- Fiber Runs to 9800 Feet + Coax
- Downlink Power: +18 dBm Composite
- Costly Materials, Equipment, Installation

BriteCell Architecture



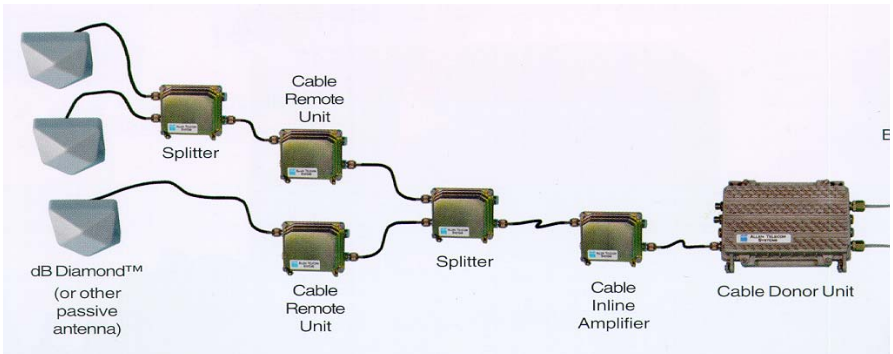
Fiber Design Issues

- Single vs. Multi-Mode
- Connector Types
- Best Approach: Get Vendor to Approve Fiber

Allen Telecom CableStar

- RF Downconverted to 400 MHz
- Travels on RG6 or RG11
- Runs to 3200 Feet + Coax
- Downlink Power: +20 dBm Composite
- No Remote Power Required
- Somewhat Weatherproof

CableStar Architecture

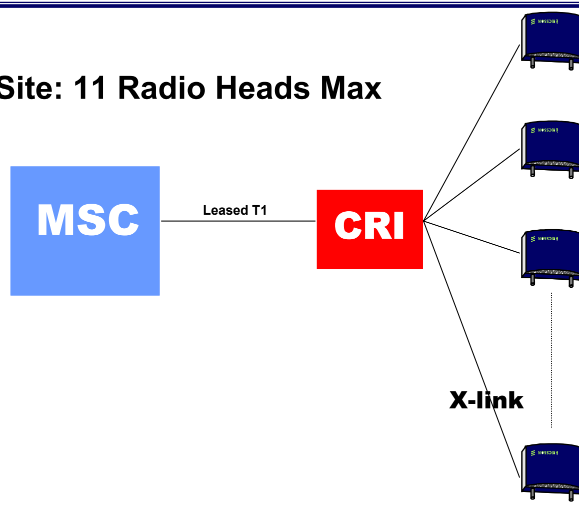


Ericsson Picocell

- All RF Stages Placed Near Antenna
- Coded Voice Signal Distributed Over 4 Wire LAN Cable
- Runs to 3300 Feet + Coax
- Downlink Power: +20 dBm per Channel
- Cheaper Equipment, Cheap Installation

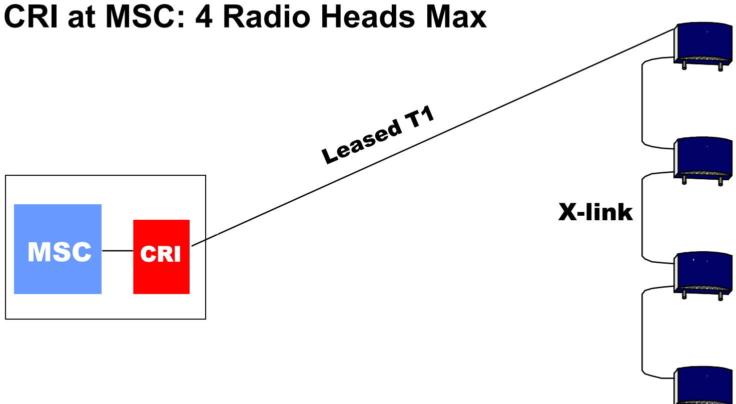
Picocell Architecture

- CRI at Site: 11 Radio Heads Max



Picocell Architecture

- CRI at MSC: 4 Radio Heads Max



Other Remoting Systems

- ADC Telecommucation (Duplex Fiber)
- LGC Wireless (Twisted Pair or Fiber)
- Foxcom Wireless (Duplex Fiber)
- CI Wireless (Duplex Fiber)
- Andrew Illuminator (Duplex Fiber)
- Many types of deployed equipment complicates:
  - Field technician training
  - Spares inventory

Link Budget & Propagation Modeling

Link Budget (Forward Link)

- PA Output + LPA Gain
  - \- Network Losses + Network Gains
  - \+ Antenna Gains
  - \- Prop., Environment & Body Losses
- Compare to Noise Floor + Receiver NF
- Consider most likely radio count
- Consider various RF distribution methods

Link Budget (Reverse Link)

- Desired Phone Power
  - \- Body, Prop. & Environment Losses
  - \+ Antenna Gains
  - \- Network Losses + Network Gain
  - \+ LNA Gain + Multicoupler Gain
- Compare to Noise Floor + Receiver NF
- Include NF of distribution system

Propagation Modeling

- Keenan-Motley (Seidel-Rappaport)
- Carter Model for Leaky Coax
- Measurement-Based Models
- Ray-tracing

Keenan-Motley

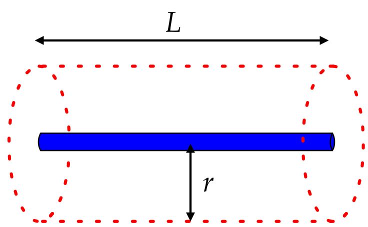
- Extended by Seidel-Rappaport
- Path Loss Exponent, Wavenumber, Distance, Site specific information
- Wall & Floor attenuation factors
- Used in *SitePlanner*®

$$\alpha \cdot \log(k \cdot r) + n \cdot W + m \cdot F$$

Source: Seidel and Rappaport, "914 MHz Path Loss Prediction Models for Indoor Wireless Communications in Multifloored Buildings," IEEE Trans. Ant. Prop., Vol. 40, No. 2, Feb. 1992, pp. 207-217

Carter Model for Radiax

- Radiax is like a uniform line source antenna
- Power is spread over a cylindrical surface



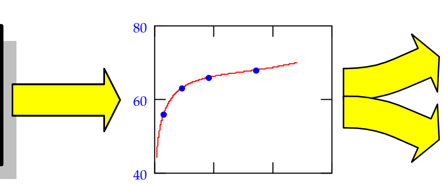
$$S_{av} = \frac{D_T \cdot P_T}{2 \cdot \pi \cdot r \cdot L}$$

Source: K. Carter, "Predicting Propagation Loss from Leaky Coaxial Cable Terminated with an Indoor Antena," pp. 71-82, 8th Virginia Tech/MPRG Symposium Wireless Communications Proceedings, June 10-12, 1998.

Carter Model for Radiax

- Empirical constants match uniform line source with real world leaky feeder

Frequency	Loss
150	**52**
450	**57**
900	**63**
1700	**69**



C_E

L_{int}

Source: K. Carter, "Predicting Propagation Loss from Leaky Coaxial Cable Terminated with an Indoor Antena," pp. 71-82, 8th Virginia Tech/MPRG Symposium Wireless Communications Proceedings, June 10-12, 1998.

Carter Model for Radiax

- Near Field Loss for a long horizontal run:

$$L_{nf}\left[L_h, f, r_h(H,V_h), C_E, L_{\text{int}}, x\right] =$$
$$10\cdot\log(L_h) + 20\cdot\log(f)$$
$$+10\cdot\log(r_h) - 43.037 + C_E + L_{\text{int}}\cdot x$$

Source: K. Carter, "Predicting Propagation Loss from Leaky Coaxial Cable Terminated with an Indoor Antena," pp. 71-82, 8th Virginia Tech/MPRG Symposium Wireless Communications Proceedings, June 10-12, 1998.

Indoor RF Losses

- Walls
- Floors
- People
- Furniture
- Large Metal Objects

Environment Testing

- Take measurements of test transmitter signals
- Calculate best-fit losses and path loss exponents
- Best results obtained with multiple transmitters
- Desire spatial decorrelation from transmitters
- Transmitter vendors include BVS, Andrew
- Receiver vendors include Anritsu, BVS, ZK Celltest, DTI, and Ericsson
- Measurement software and optimization software for all vendors are produced by Wireless Valley

Traffic Engineering

Traffic Engineering

- 50 – 75 mEr/User in offices
- Varies by business type
- Use Erlang B, then over-provision
- Trunking efficiency declines with Picocell
- Indoor handoffs complicate matters
- Traffic is very site-specific and event-specific
- Requires site-specific capacity modeling

Practical Deployment Issues

Preparing for Design

- Building Survey
- Locate Base Station Equipment
- Prepare Building Model

Design Steps

- Choose Antenna System Equipment
- Take a Best Guess at Initial Design
- Run Propagation Calculations
- Improve Design Coverage
- Look for a Cheaper Way
- Produce Documentation

Survey

- Obtain Letter Size Floorplan NTS
  - Fire Exit Map
  - Brochure From Info Booth
- Obtain E Size Scaled Floorplan or CAD File
- Scout Equipment Location
- Take Digital Photos

Survey

- Identify Wall Construction
- Locate Sensitive Areas
- Note Desired or Undesired Coverage Areas
- Locate Fire Walls
- Locate Stacked Rooms
- Determine Ceiling Heights and Types

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Survey Photos

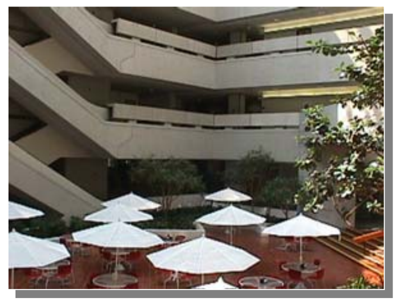
- Note Photo Number on Floorplan
- Include the Ceiling
- Shoot Wide for Many Details
- Shoot Close & Wide of Possible Antenna Locations
- Security May Follow You
- Smile at Them

Take Pictures of:

- All Candidate Antenna Locations
- Skylight Structures & Skylight Boxes
- Unusual Structures, Large Metal Objects

Take Pictures of:

- Windows, Entrances, Back Hallways
- Corridors, Equipment Rooms
- Areas Where Crowds Gather



Building Structure Types

- Brick or Poured Concrete Supporting Walls
- Prisons, Historic Buildings, COs

Building Structure Types

- Concrete Block Walls, Steel Skeleton
  - Schools, Malls
  - Supermarkets
  - Dept. Stores
  - Home Depot

Building Structure Types

- Poured Concrete Cells
  - Condos
  - Small Hotels
  - Apartments

Building Structure Types

- Curtain Wall, Reinforced Concrete Core
- Glass Office Buildings

Building Structure Types

- Wood Frame
  - Small Apartment Buildings
  - Single Family Homes

Airport Terminal

- Vast Areas to Cover
- Tremendous Cable Run Lengths
- Huge Capacity Needs
- Sensitive Area: Customs

Consider Fiber Distribution
Large Metal Objects: Escalators, Baggage Carousels

Arena, Convention Center

- One Huge Open Space
- Offices and Corridors
- Consider Distributed Antenna System passive or active
- Traffic Engineering Nightmare

Shopping Mall

- Minimum Visual Impact
- Glass Store Fronts Pass RF
- Covering Anchor Stores Difficult
- Need Skylight Plan
- Capacity Demands are High

Office Tower

- Glass Curtain Wall Construction
- Elevators & Bathrooms in Core
- Low transmit Power on Upper Floors
- Radiax Above Hung Ceiling
- Hot RF from Roof Antennas?

Factory

- Open Space Plus Offices
- Many Noise Sources
- Sensitive Areas: Clean Rooms, R&D Labs
- Cover the Break Rooms & Smoking Areas

Airplane Hangar, Kmart

- Open Space with Large Metal Objects
- Repeater with One Antenna
- Possibly Picocell with Built-in Antenna
- May Require Testing After Installation

Guidelines

- Cable Fire Ratings
- Puncturing Fire Walls
- Leaky Coax Types
- Leaky Coax Installation
- Indoor Antennas
- Mounting Antennas
- Documentation

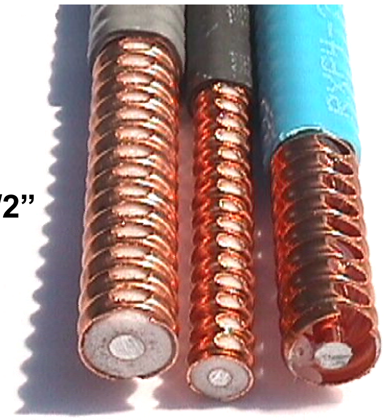
Cable Fire Ratings

- Refers to the jacketing & dielectric materials
- Plenum- CATVP
- Riser – CATVR

Suitable Coax: Andrew RXP

Leaky Feeder Types

- dB TransFill
- Andrew Radiax
- Air vs. Foam Core
- Practical Size for Indoor: 1/2”



Installing Leaky Feeder

- Mount With Standoff >= 2”
- Avoid Mounting Along Continuous Metal
- Avoid Installing Directly Above Light Fixtures or Ducts
- Track Inventory and Installation Cost in *SitePlanner*

Indoor Antennas

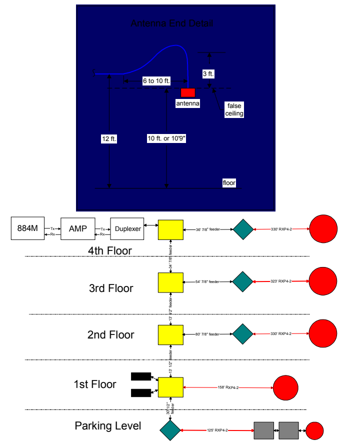
- Indoor Antennas vs. Outdoor Antennas
- EMS Omni
- Allgon
- DB Diamond
- Many Others

Antenna Mounting

- Below Hung Ceiling
- On Wall
- Hide the Port
- No Metal/Concrete in Near Field
- Directionals in the Skylight Structure

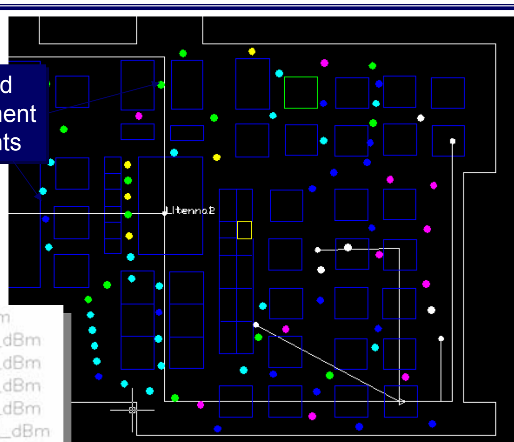
Documenting Your Design

- Plans
- Legend
- Detail Drawings
- Backbone Diagram
- Bill of Materials
- Photo Sims
- Files Stored Safely

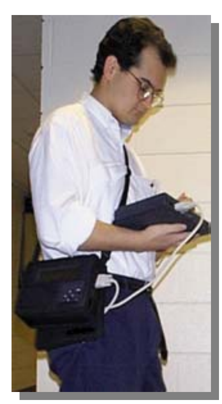


Quick and Easy Data Collection

Collected measurement data points



- >= -50 _dBm
- -50 to -62_dBm
- -62 to -73_dBm
- -73 to -85_dBm
- -85 to -97_dBm
- -97 to -108_dBm
- -108 to -120_dBm
- < -120 _dBm



Now with a Palm IIIc using *InFielder*® *PDA*

Design Methods

- Cut and Try – old method
- Educated Guess – old method
- Keenan Motley w/spreadsheet – current
- Better Models- *SitePlanner®*
- Better Calculators- *SitePlanner®*
- Graphical Environment – *SitePlanner®*
- Automatic archiving - *SitePlanner®*
- Asset Management – *SitePlanner®*

Design Tools

How can we talk the same language?

Millions of Buildings ... So Little Time

- How can we quickly design systems?
- How can we compare technologies?
- How can we save and communicate designs?
- How will integrators become designers?
- How will vendors verify design guidelines?
- How will building owners track hardware?
- How will we manage and maintain the in building infrastructure?

Spreadsheet Tools

- Difficult to Use
- No Design Graphics
- Few Antenna Patterns
- Questionable Support
- No Design Storage
- Difficult to Interpret, except for Engineers

Design/Planning History: Macrocell Design

- Original use of planning tools was for outdoor cellular networks - RF design and planning
- Planning decisions and tower placements could be simulated and analyzed prior to deployment
- Design strategies and techniques improved
- Cell tower placement became more efficient
- Lacked asset management or document support
- Difficult to track installed tower infrastructure

VA Tech MPRG Research

- Early in bilding propagation work
- Decade of measurement experience
- Decade of modeling and optimization experience
- Decade of Industry suggestions and practical advice
- *SitePlanner* is the result of over 30 years of student research

VA Tech MPRG Research (cont.)

- MPRG students and staff researchers have contributed to the body of knowledge used in the *SitePlanner* concept:
  - Scott Seidel, Joe Liberti, Dwayne Hawbaker, Ken Blackard, Alan Fox, Roger Skidmore, Idine Ghoreishain, Greg Durgin, Neal Patwari, Ray Lovestead, Ben Henty, Brian Gold, Charles Lepple, Bob Boyle, Kirk Carter, Juin Siew, Wesley Rios, Manish Panjwani

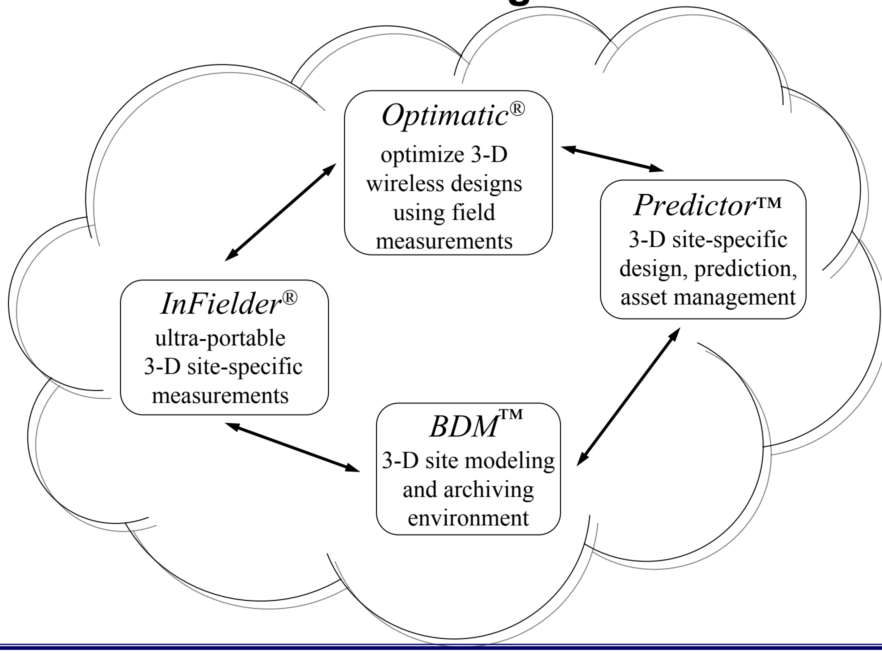
SitePlanner® Features and Benefits

- Facilitates rapid cost and performance tradeoff analysis of all technologies at low overall cost
- Simultaneously supports site designs, surveys, verification, and documentation with 3D graphical representation and complete database record
- Automatic archiving of installed infrastructure
- Automatic bill of materials created during design
- Asset management facilities built in
- Cellular, PCS, 3G, WLAN, MMDS, and beyond
- Accurate and practical modeling of any campus wireless system

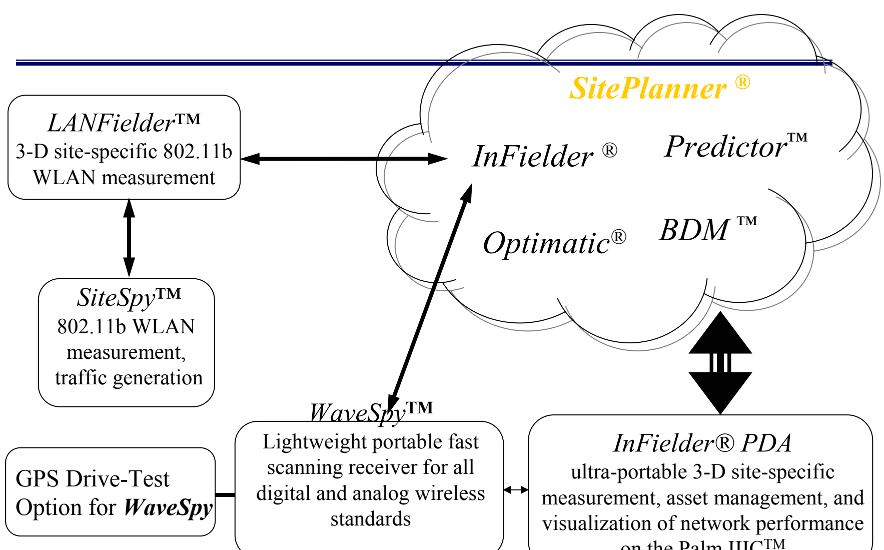
SitePlanner: Planning, Design, and Management for In-Building Telecom

- Provides rapid system design of complex technologies while minimizing costs and meeting coverage and capacity needs
- Indoor wireless coverage is non-intuitive and complex, but SitePlanner provides huge cost/time savings and rapidly trains the user
- SitePlanner allows flexibility and rapid "what if" designs to meet specific needs of customers
- Easy visualization of proposed systems
- *SitePlanner* provides *simultaneous* performance analysis, wireless equipment tracking, project documentation, and asset management!

The *SitePlanner*® Design Environment



SitePlanner 2000 and Add On Modules Work Together



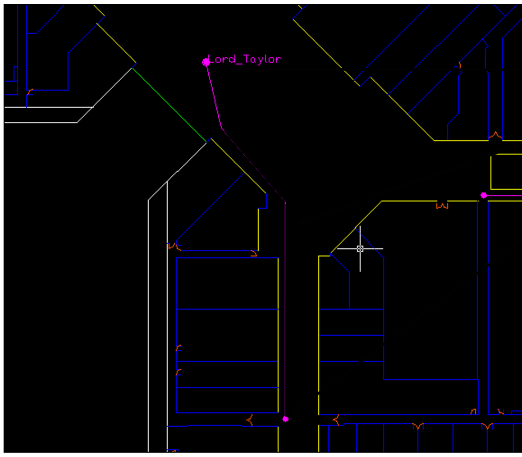
Typical Design Steps

- Use *SitePlanner* to simulate RF performance of several straw-man designs in facility of interest
- In-situ site survey and measurements with *SitePlanner*, including interference, throughput or signal strength with transmitter locations from most promising straw-man designs
- Use *SitePlanner* field measurements to optimize network performance and select final layout
- System Installation and Site survey/performance verification in SitePlanner
- SitePlanner provides Maintenance and Design Archiving for on-going support of infrastructure

Common Uses of *SitePlanner*

- Common software platform provides sharing of designs and "as-builts" throughout an organization or across users on a project
- Allows vendors, consultants, integrators, and manufacturers to share and archive designs
- Provides an objective "level playing field" for all in-building design, deployment, and optimization work
- Allows new hires or inexperienced personnel to become rapidly proficient in the field of in-building wireless design, specification, or integration
- Provides retrievable records of all aspects of an in-building project, for quality audits and maintenance
- SitePlanner can be shared by engineers, facilities managers, and accounting staff from cradle-to-grave

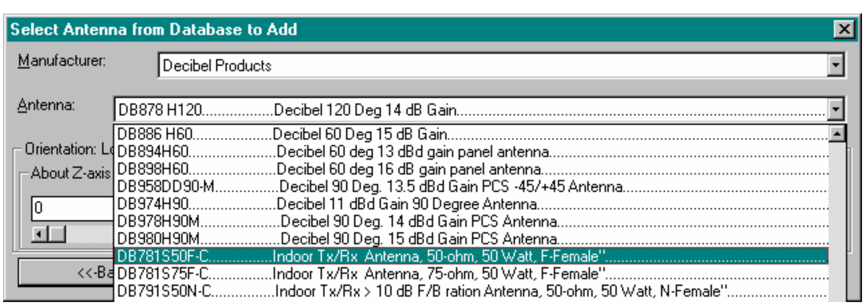
SitePlanner® Graphical System Design



Components are picked from a customizable Parts List Library consisting of more than 3,000 components from over three dozen manufacturers

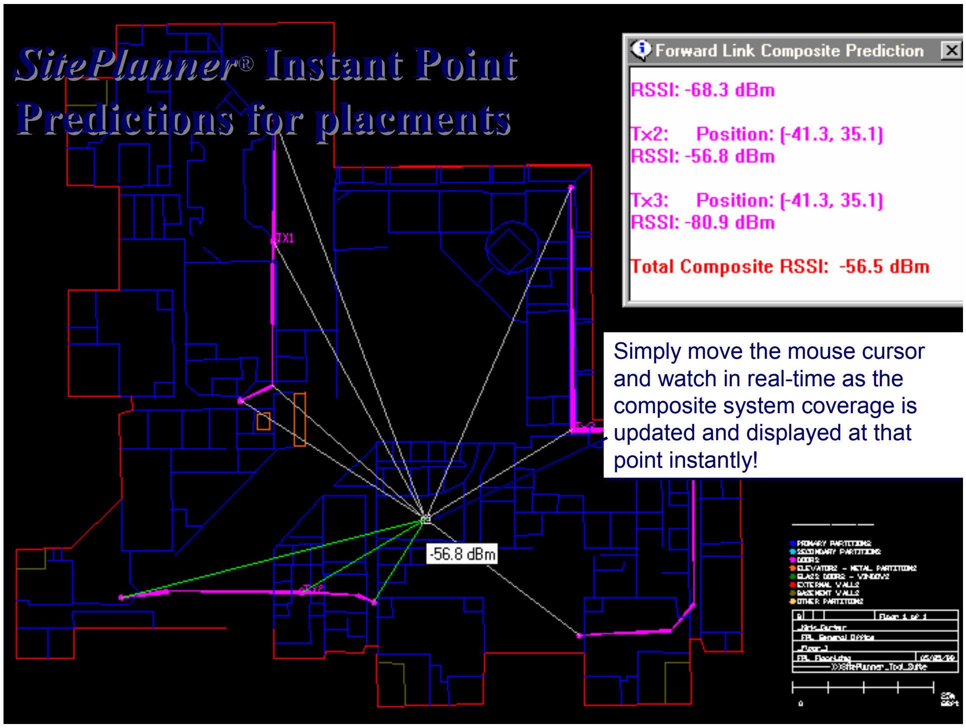
Point and click with the mouse to visually position wireless system components such as cables, antennas, amplifiers, splitters, in the building!

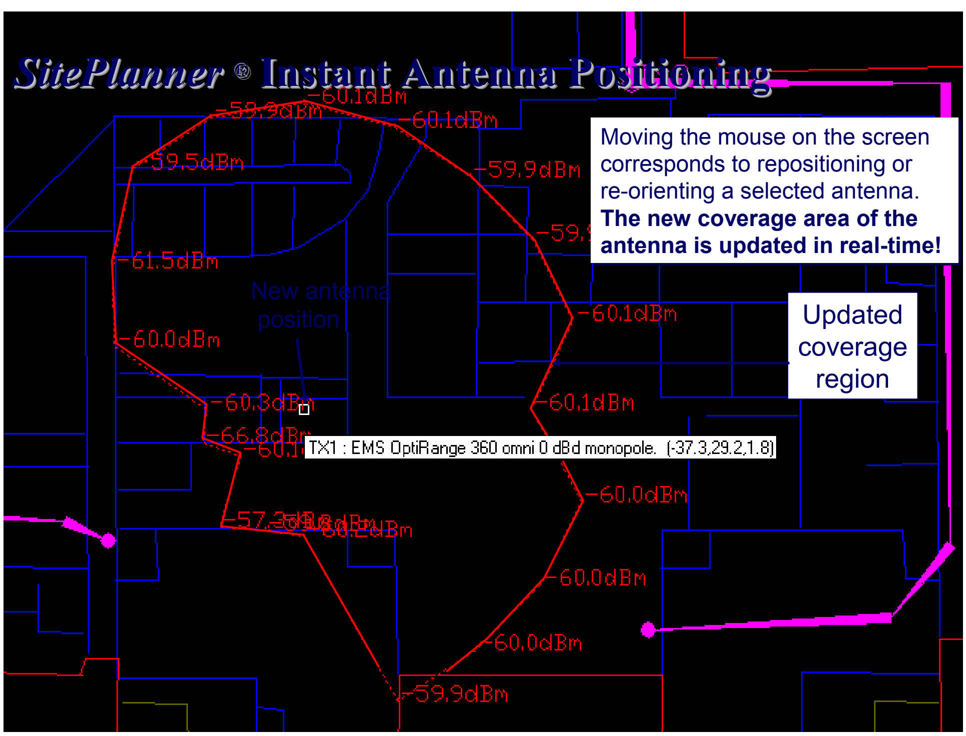
SitePlanner® Built-in Components Database



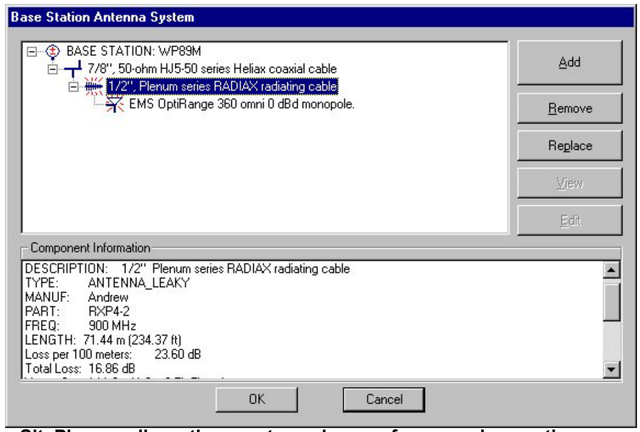
Parts List Library contains thousands of antennas, amplifiers, cables, splitters, and leaky feeder antennas

Quickly and easily analyze design tradeoffs in terms of cost and performance with the click of the mouse, while creating a complete bill-of-materials and cost analysis


SitePlanner® Instant Point Predictions for placments
Forward Link Composite Prediction
RSSI: -68.3 dBm
Tx2: Position: (-41.3, 35.1)
RSSI: -56.8 dBm
Tx3: Position: (-41.3, 35.1)
RSSI: -80.9 dBm
Total Composite RSSI: -56.5 dBm
Simply move the mouse cursor and watch in real-time as the composite system coverage is updated and displayed at that point instantly!
TX1
-56.8 dBm


SitePlanner ® Instant Antenna Positioning
Moving the mouse on the screen corresponds to repositioning or re-orienting a selected antenna.
The new coverage area of the antenna is updated in real-time!
Updated coverage region
New antenna position
TX1 : EMS OptiRange 360 omni 0 dBd monopole. (-37.3,29.2,1.8)
-60.1dBm
-59.9dBm
-60.1dBm
-59.5dBm
-59.9dBm
-61.5dBm
-60.1dBm
-60.0dBm
-60.3dBm
-60.1dBm
-66.8dBm
-60.0dBm
-60.0dBm
-60.0dBm
-59.9dBm

SitePlanner® Wireless System Layout



In real time, SitePlanner allows the user to analyze performance by creating a graphical wireless system component interconnection diagram, while simultaneously creating bill of materials and complete cost analysis

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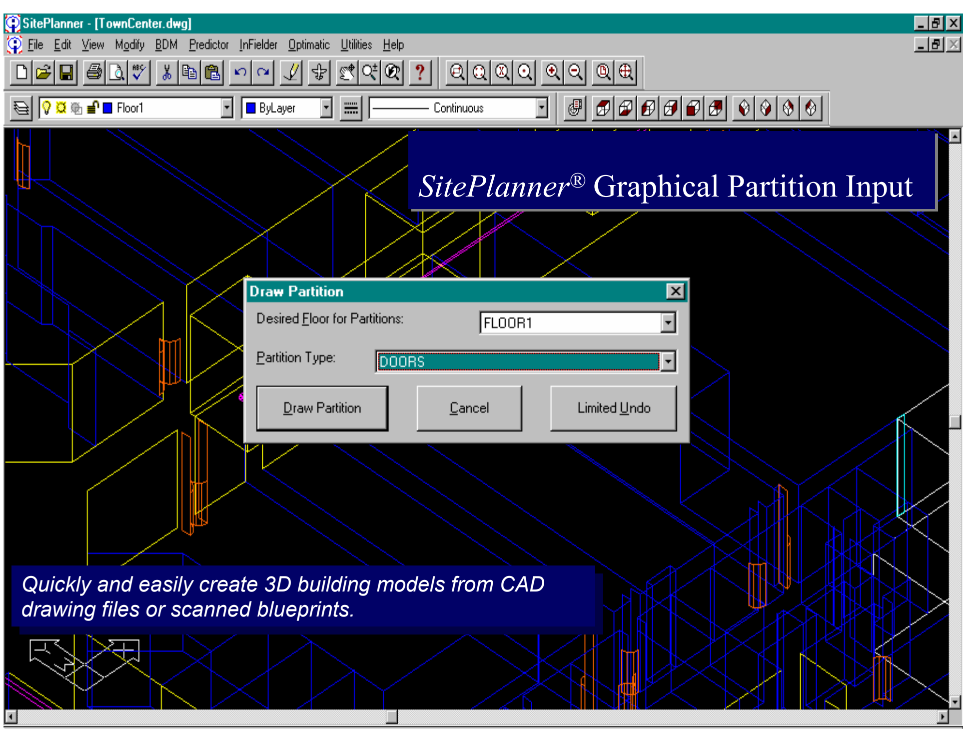
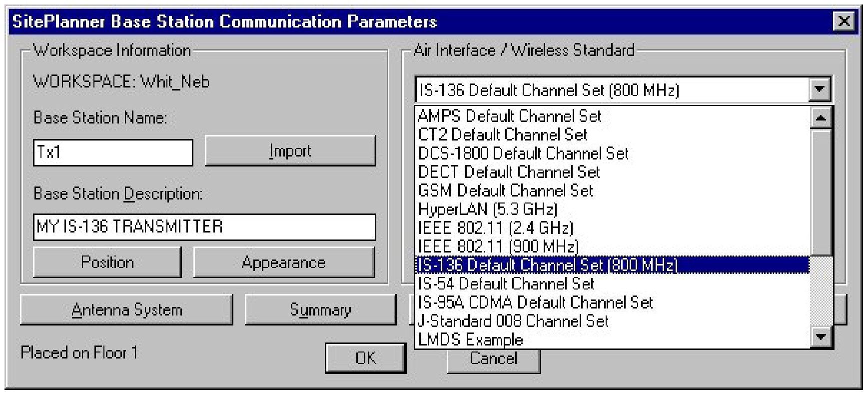
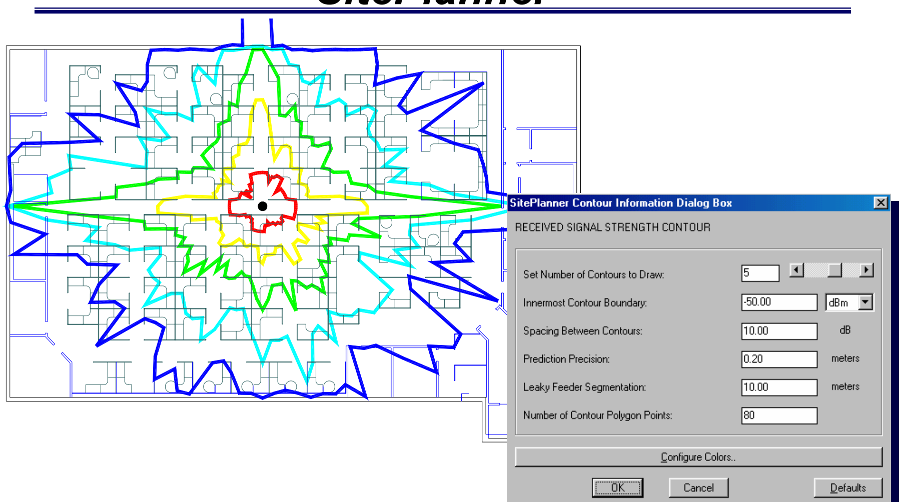
Virginia Tech VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

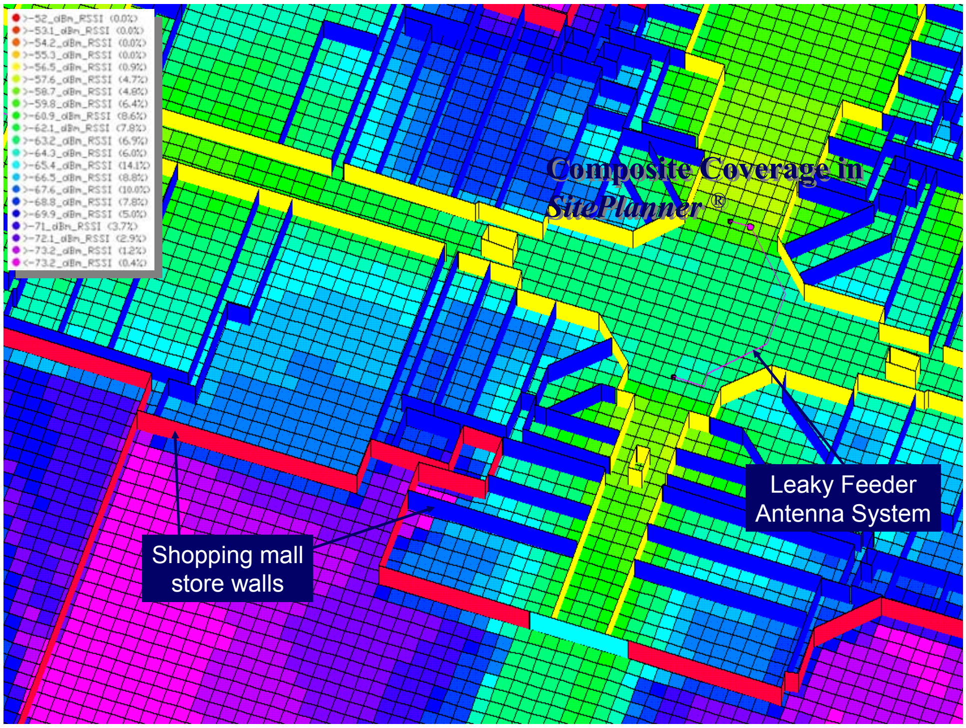


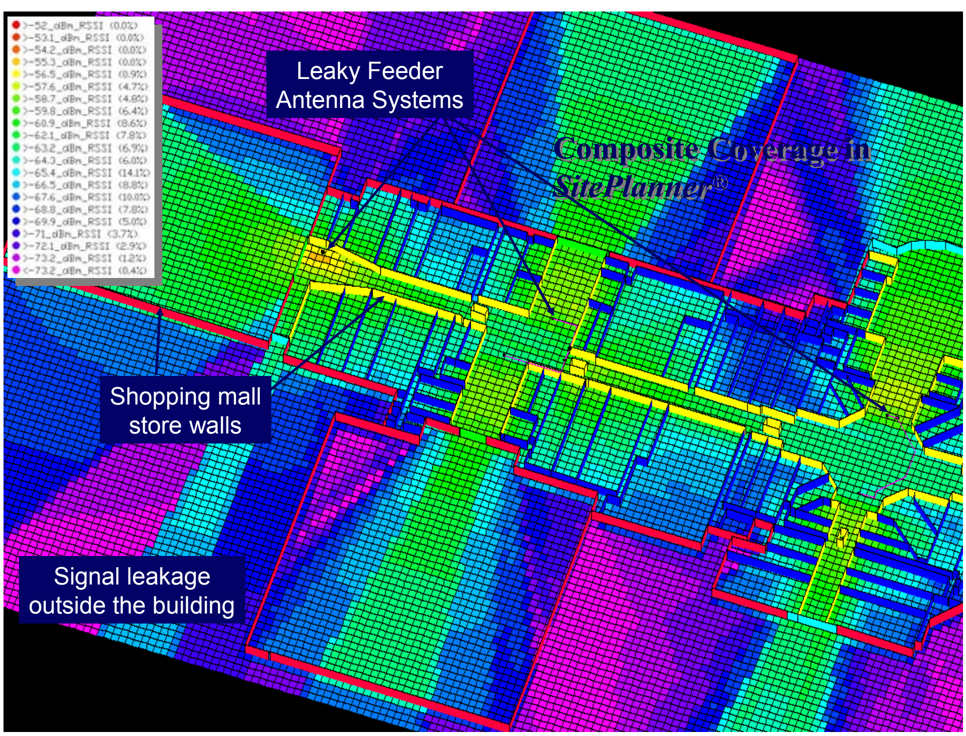
All Wireless Standards/Air Interfaces Directly Supported in *SitePlanner*®



Coverage Area Predictions in *SitePlanner*®




>-52_dBm_RSSI (0.0%)
>-53.1_dBm_RSSI (0.0%)
>-54.2_dBm_RSSI (0.0%)
>-55.3_dBm_RSSI (0.0%)
>-56.5_dBm_RSSI (0.9%)
>-57.6_dBm_RSSI (4.7%)
>-58.7_dBm_RSSI (4.8%)
>-59.8_dBm_RSSI (6.4%)
>-60.9_dBm_RSSI (8.6%)
>-62.1_dBm_RSSI (7.8%)
>-63.2_dBm_RSSI (6.9%)
>-64.3_dBm_RSSI (6.0%)
>-65.4_dBm_RSSI (14.1%)
>-66.5_dBm_RSSI (8.8%)
>-67.6_dBm_RSSI (10.0%)
>-68.8_dBm_RSSI (7.8%)
>-69.9_dBm_RSSI (5.0%)
>-71_dBm_RSSI (3.7%)
>-72.1_dBm_RSSI (2.9%)
>-73.2_dBm_RSSI (1.2%)
<-73.2_dBm_RSSI (0.4%)
Composite Coverage in SitePlanner®
Leaky Feeder Antenna System
Shopping mall store walls


>-52_dBm_RSSI (0.0%)
>-53.1_dBm_RSSI (0.0%)
>-54.2_dBm_RSSI (0.0%)
>-55.3_dBm_RSSI (0.0%)
>-56.5_dBm_RSSI (0.9%)
>-57.6_dBm_RSSI (4.7%)
>-58.7_dBm_RSSI (4.8%)
>-59.8_dBm_RSSI (6.4%)
>-60.9_dBm_RSSI (8.6%)
>-62.1_dBm_RSSI (7.8%)
>-63.2_dBm_RSSI (6.9%)
>-64.3_dBm_RSSI (6.0%)
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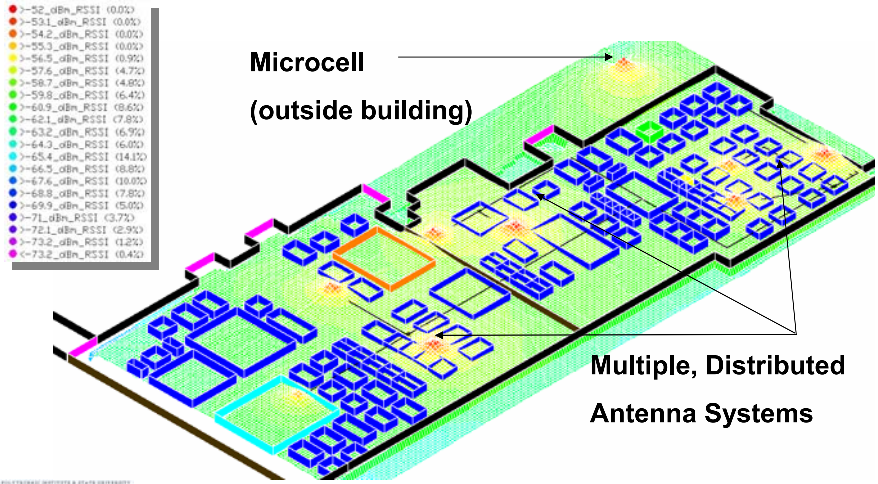
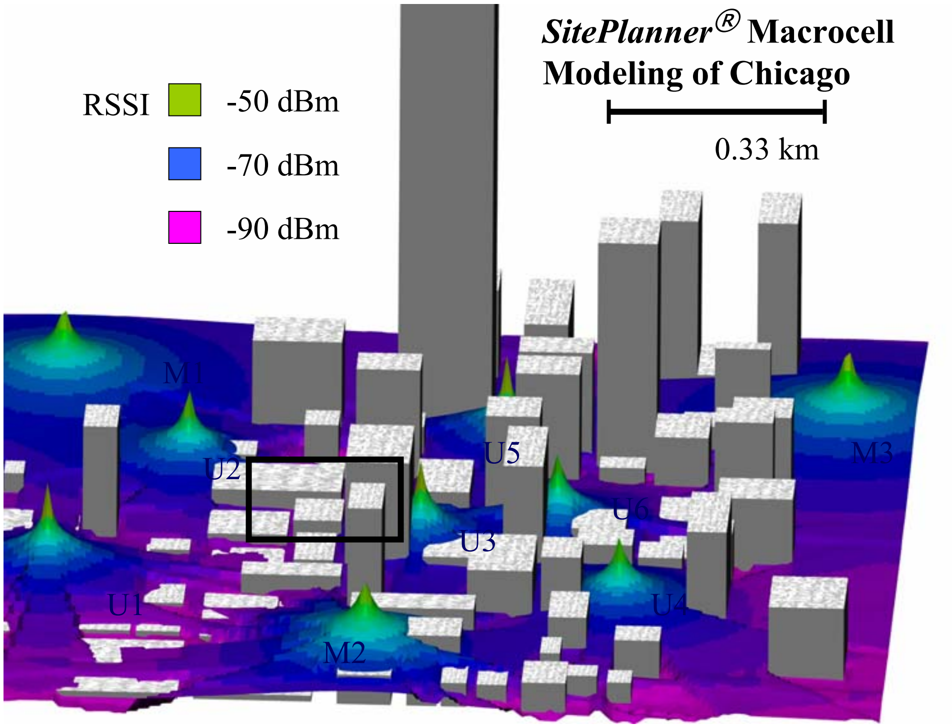
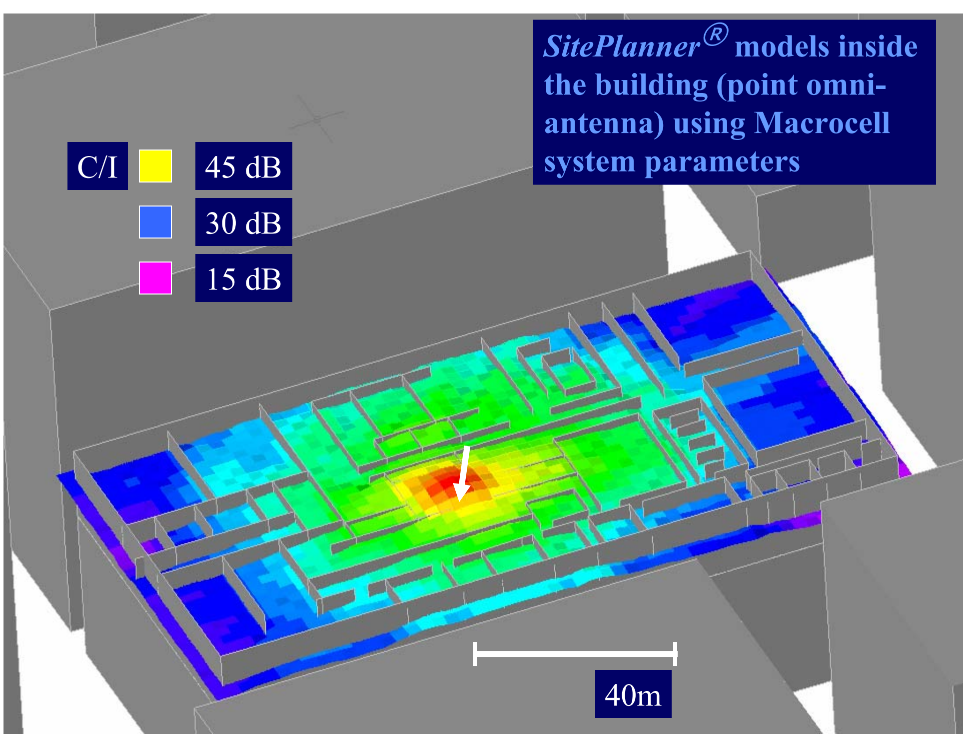
>-67.6_dBm_RSSI (10.0%)
>-68.8_dBm_RSSI (7.8%)
>-69.9_dBm_RSSI (5.0%)
>-71_dBm_RSSI (3.7%)
>-72.1_dBm_RSSI (2.9%)
>-73.2_dBm_RSSI (1.2%)
<-73.2_dBm_RSSI (0.4%)
Leaky Feeder Antenna Systems
Composite Coverage in SitePlanner®
Shopping mall store walls
Signal leakage outside the building

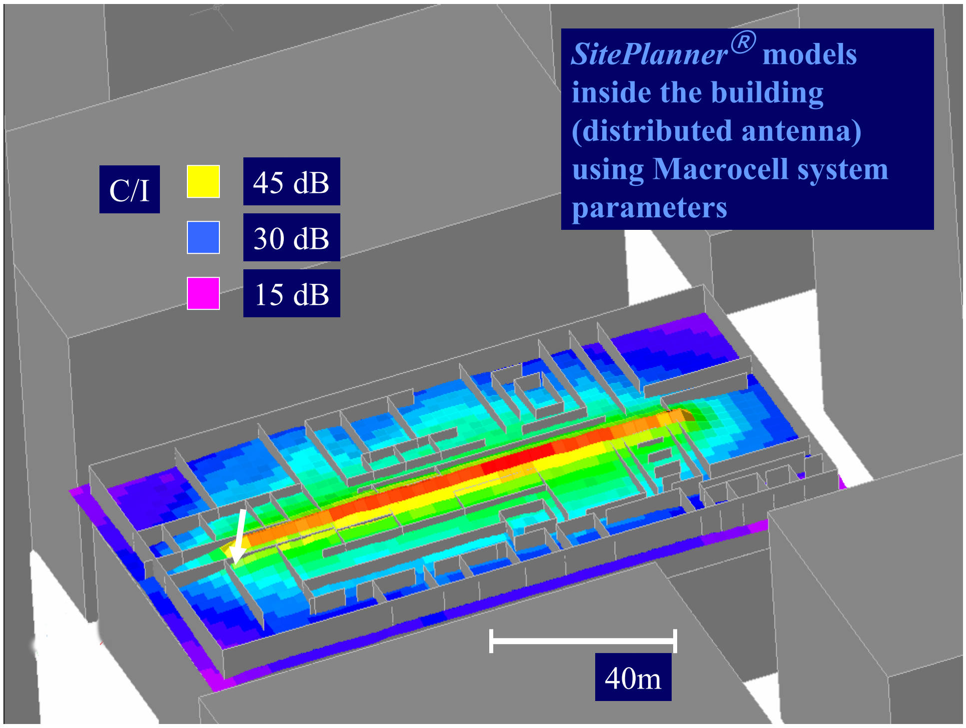
Composite Coverage in *SitePlanner*®



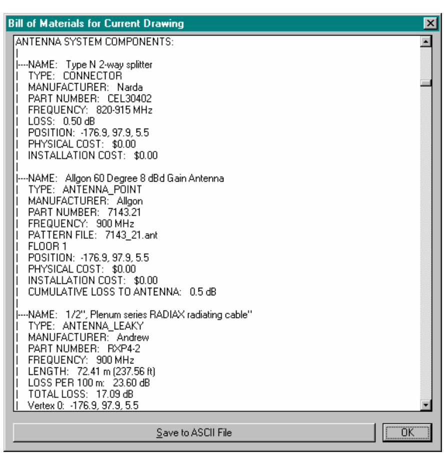
SitePlanner™ also models Macrocells!


SitePlanner® Macrocell Modeling of Chicago
RSSI
-50 dBm
-70 dBm
-90 dBm
0.33 km
M1
M2
M3
U1
U2
U3
U4
U5
U6


SitePlanner® models inside the building (point omni-antenna) using Macrocell system parameters
C/I
45 dB
30 dB
15 dB
40m



Automatic Bill of Materials

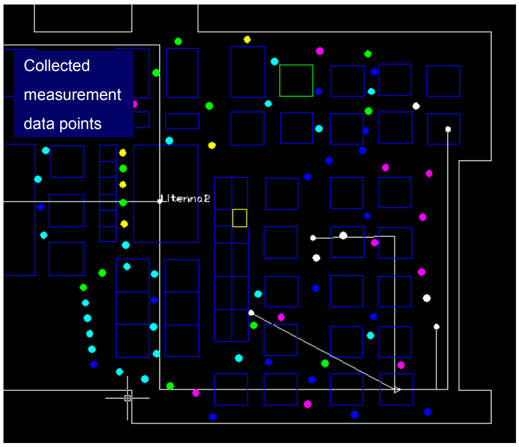


SitePlanner® Automatically tracks full bill of materials for your design

Automatically tracks both physical and installation cost for all components

Enables least cost design

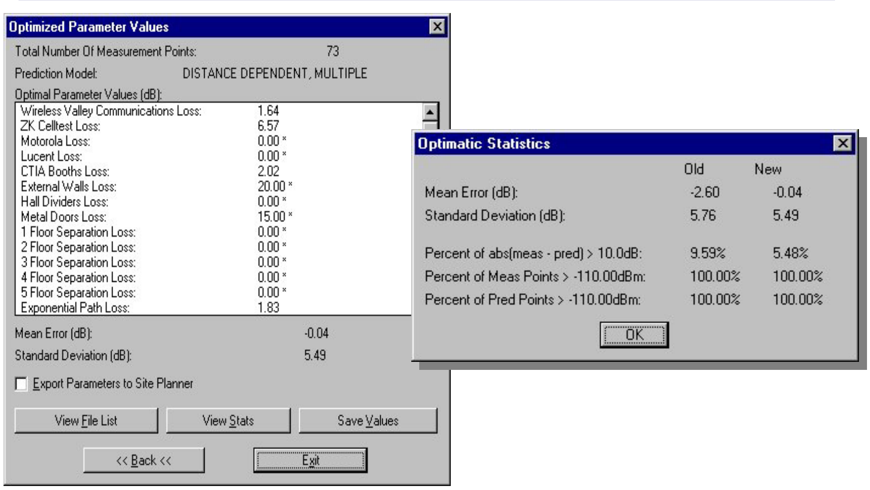
Measurement Data Collection *InFielder*® and ***InFielder*®** *PDA*



Plug-and-Play operation with:

Our *WaveSpy*	**Agilent**
ZK Celltest	**IEEE 802.11**
BVS	**Tektronix**
Protek	**Grayson**
Anritsu	**Safco**
TEMS Light	**DTI**

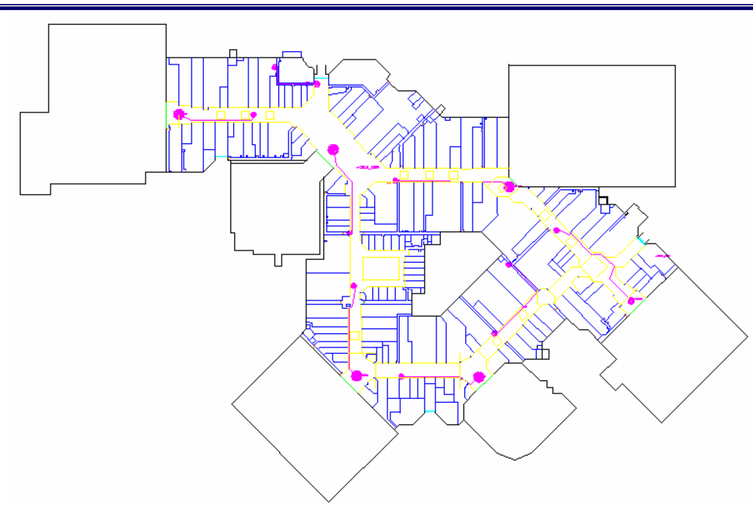
Optimization using *Optimatic*®



Case Study: Cellular/PCS Design in Shopping Mall

- ~2 million sq. ft. shopping center
- Design phase took less than a day by a single system engineer, compared to usual time of 2 – 3 weeks without SitePlanner
- Technology:
    - IS-136 picocell
    - Popular Fiber-based active distribution system
    - Mixture of directional and omnidirectional antennas, and radiating cable
    - Use of radiating cable intensifies need for accurate, upfront design

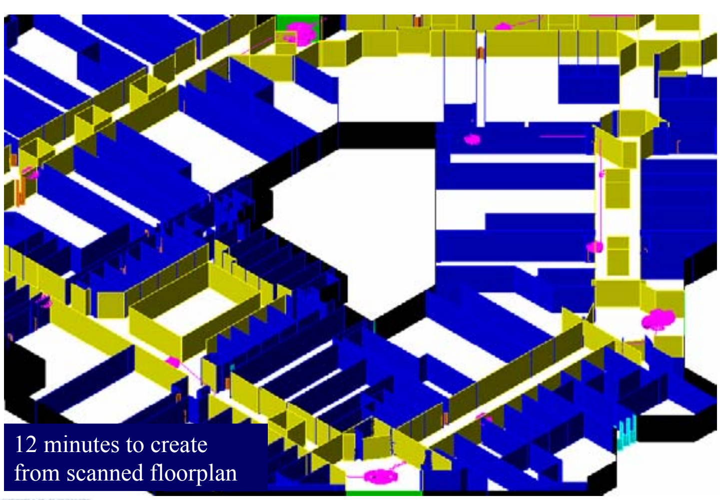
Case Study: Floor Plan of Mall

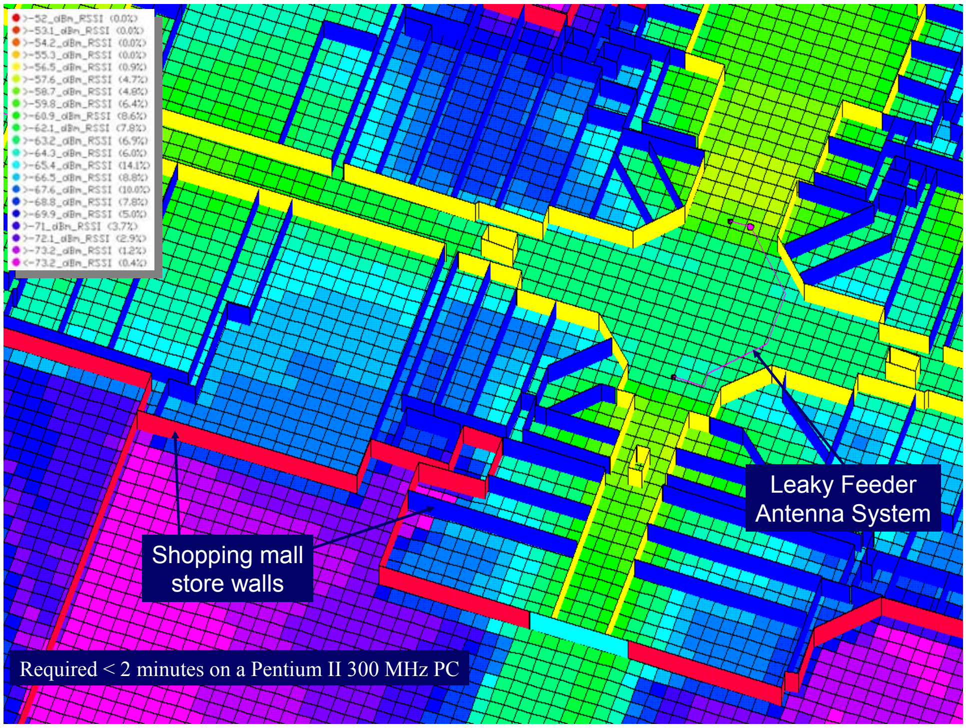


Cellular/PCS Design

- SitePlanner allowed instant selection of pre approved distribution components, both passive and active
- SitePlanner simultaneously computed coverage, capacity, installation cost, equipment cost, and created a complete bill of materials and graphical documents of proposed design
- The completed design was stored, transported, displayed, and used throughout the enterprise to provide a complete record of the installed project

Case Study: 3D Shopping Mall Model



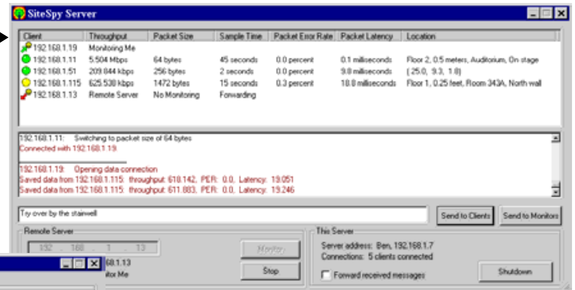


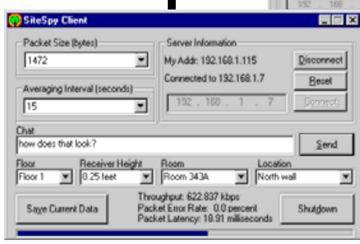
Shopping Mall Case Study: Conclusions

- Customer saved several weeks of time on overall design and deployment
  - Verification confirmed an accuracy within 5 dB standard deviation (predicted vs. measured)
  - Rapid predictions enabled numerous design tradeoffs to be analyzed within hours
- Greater RF designer satisfaction
  - Designer can "see" performance
- Greater building owner satisfaction
  - Building owner can "see" performance
- Automatic archival of design critical

Wireless LAN Planning: *LANFielder™* and *SiteSpy™*

Measurement results that you can understand without being an RF Engineer



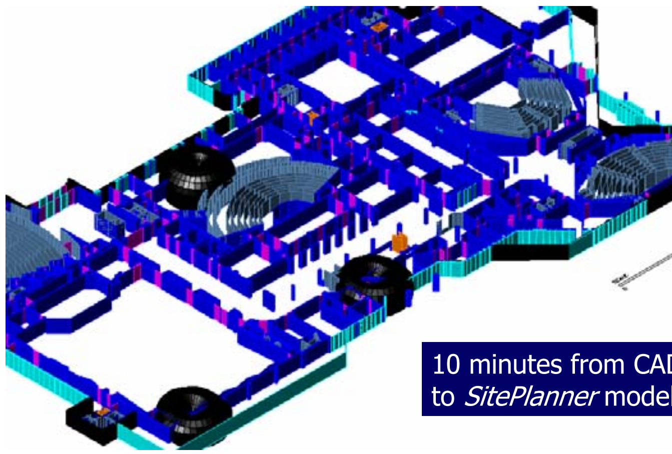


Provides wireless data network measurement using client/server technique

Case Study: WLAN Design

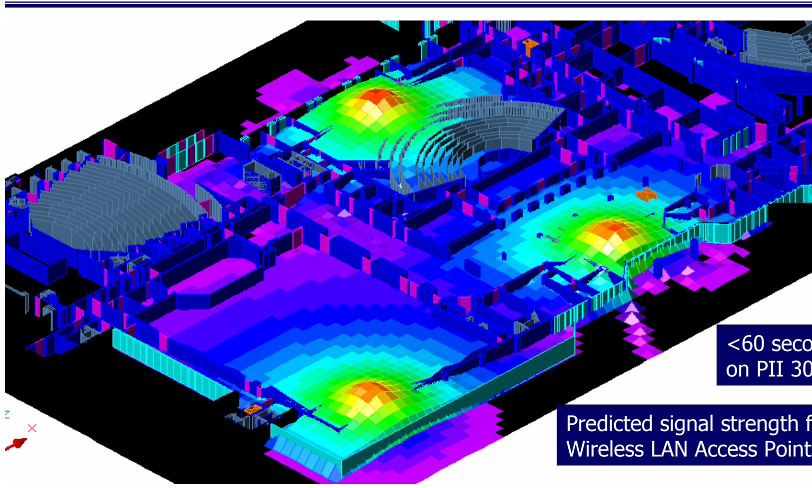
- 100,000 sq. ft., multi-story academic building on the University of Virginia Tech campus
- Technology:
  - IEEE 802.11b, 2.4 GHz DS-SS Wireless LAN
  - 11 Mbps Cabletron RoamAbout access points and modems (Lucent/ORiNOCO OEM)

WLAN Design: 3D Model



10 minutes from CAD file to *SitePlanner* model

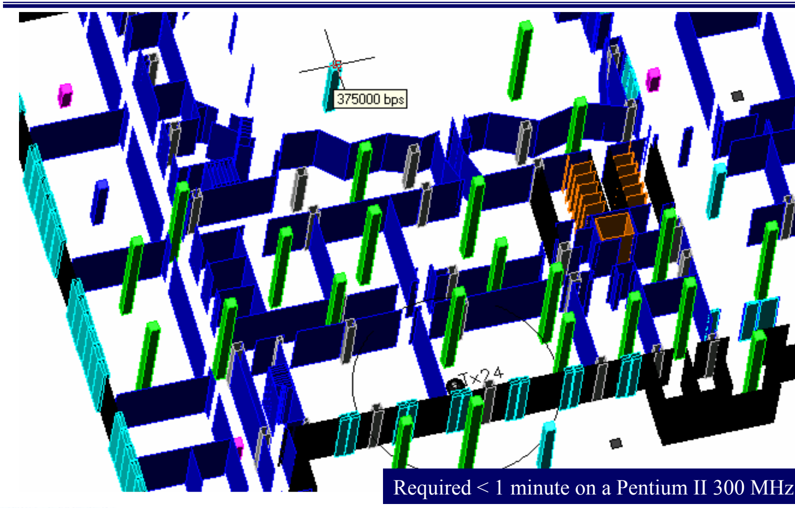
WLAN Design: Predicted Performance



<60 seconds on PII 300

Predicted signal strength for 3 Wireless LAN Access Points

Visualizing WLAN Measurements



Required < 1 minute on a Pentium II 300 MHz PC

Conclusions: WLAN Design

- Rapid predictions enabled analysis of 3 completely different system configurations
- 3D modeling enabled designer to leverage cross floor coverage of signal
- Enabled accurate outdoor coverage estimates
- Verification measurements validated predictions to within 3 feet
- Complete design (12 access points) required only an hour and was performed interactively

Conclusions: WLAN Design

- Significant time savings on overall design and deployment
  - Verification confirmed an accuracy within 5 dB standard deviation (predicted vs. measured)
  - Rapid predictions enabled numerous design tradeoffs to be analyzed
- Greater RF designer satisfaction
  - Designer can "see" performance
- Greater building owner satisfaction
  - Building owner can "see" performance
- Automatic design archiving and asset management is a key benefit of SitePlanner!

Conclusion

- In building/campus systems proliferating rapidly
- Engineering work load increasing rapidly
- Technology cost comparisons vital for deployment efficiencies
- Visual and textual records required for common procedures and shared strategies, archiving
- *SitePlanner*® facilitates cost and time savings for rapid deployment and ongoing maintenance for any in building or campus system

Final Remarks

- In-building wireless is next growth phase
- Many distribution methods to choose from
- Many design issues to confront
- RF Planning tools ease wireless system design
  - intelligent design tradeoffs
  - competitive system analysis and comparisons
- *SitePlanner* is based on over a decade of Virginia Tech research, and offers a revolutionary design environment that supports in-building wireless
- *SitePlanner* provides real cost and time savings for rapid deployment and ongoing maintenance
- Indoor design demonstrations

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