
# Design and Developers Forum: Application and Design of In-Building RF Distribution Systems – Part 2

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# Agenda – Part 2

1. *DAS Applications*
    1. Small buildings
    2. Large buildings
    3. Campus environments
2. *Types of DAS*
    1. BDA – Coax
    2. Single band dedicated cable system
    3. Fiber based systems
    4. Neutral Host systems

## RF Propagation Fundamentals- Outdoors

Free Space Propagation Model

-In free space, RF path loss increases by $d^2$

-In free space, there are no multipath effects

-Path loss at the reference distance, $d_0$, is defined by the equation:

$$PL(d_0) = 20\log\left(\frac{4\pi d_o}{\lambda}\right)$$

… where λ is the wavelength of the RF transmission signal

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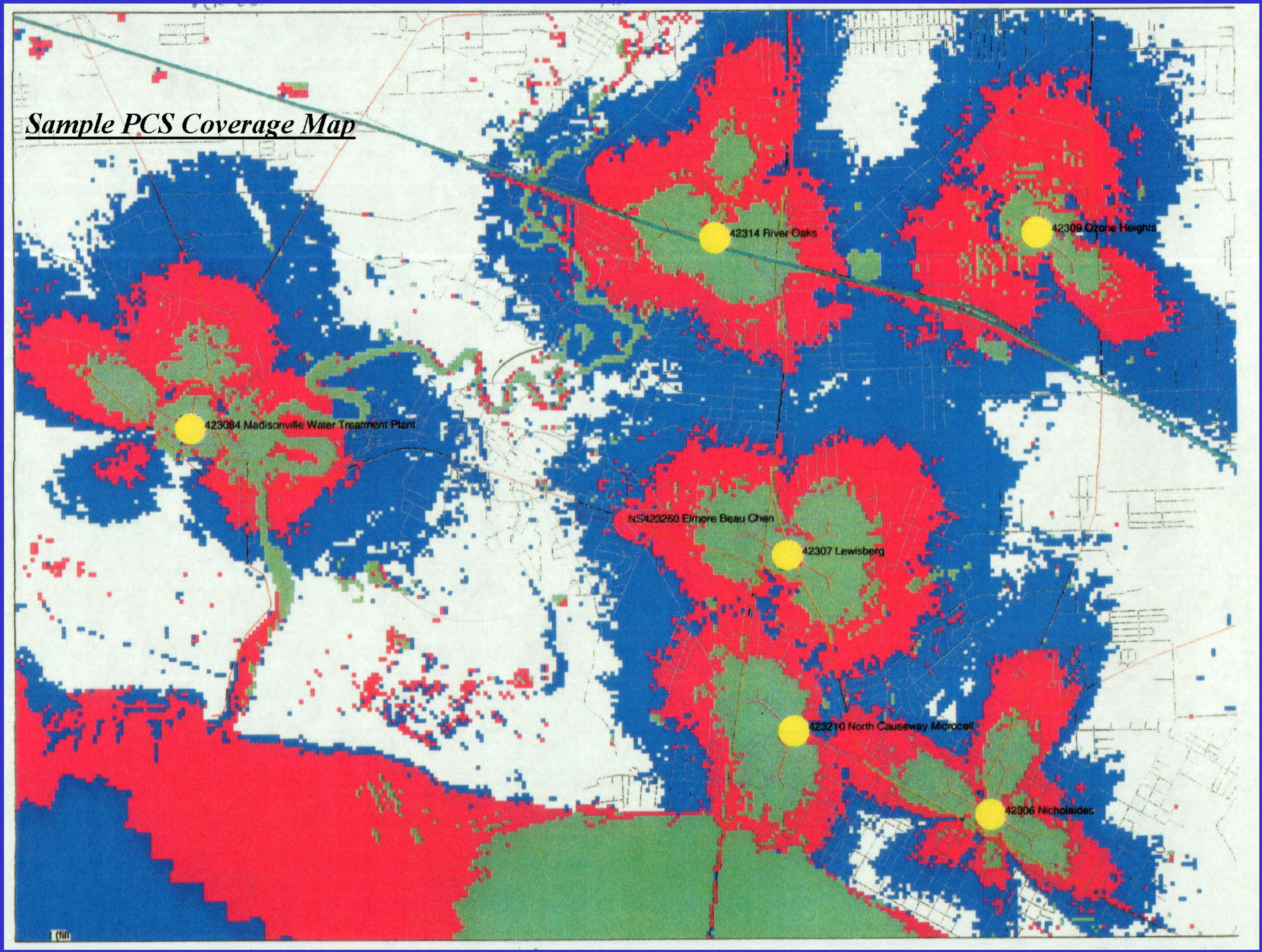
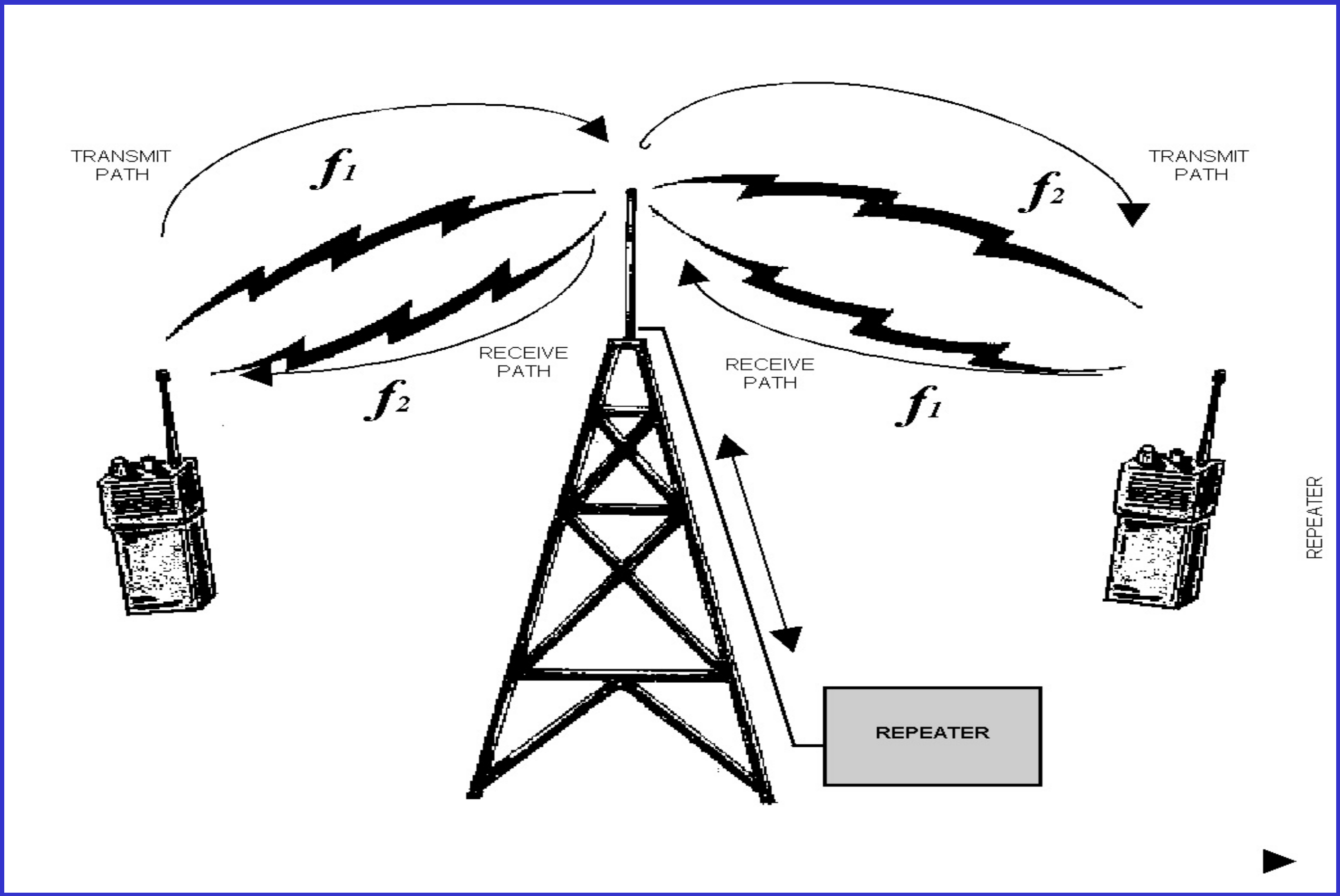
## RF Propagation Fundamentals- Outdoors

RF Coverage analysis uses a geographic database that provides terrain data to approximate the losses due to hills, mountains, foliage, buildings, and other RF obstacles and absorbers. .



## RF Propagation Fundamentals- Outdoors

Complete analysis includes **Forward path** (Station to Mobile) and **Reverse path** (Mobile to Station) calculations because transmit power and receive sensitivity are different for each type of equipment



## RF Propagation Fundamentals- In-Buildings

In-Building and Indoor Coverage is more difficult to analyze. RF Signal strength at the exterior of the building can be predicted by coverage models, or by testing. Propagation throughout the building will depend on construction type, building materials, interior interference sources, etc.

In-building Coverage Enhancement Systems can either provide supplementary signal to dead spots in a building, or can provide complete coverage throughout a building.

## RF Propagation Fundamentals- In-Building Technologies

Passive Systems - Overcome building path loss

Lossy, short distance

Coax cable, splitters

Active System Types:

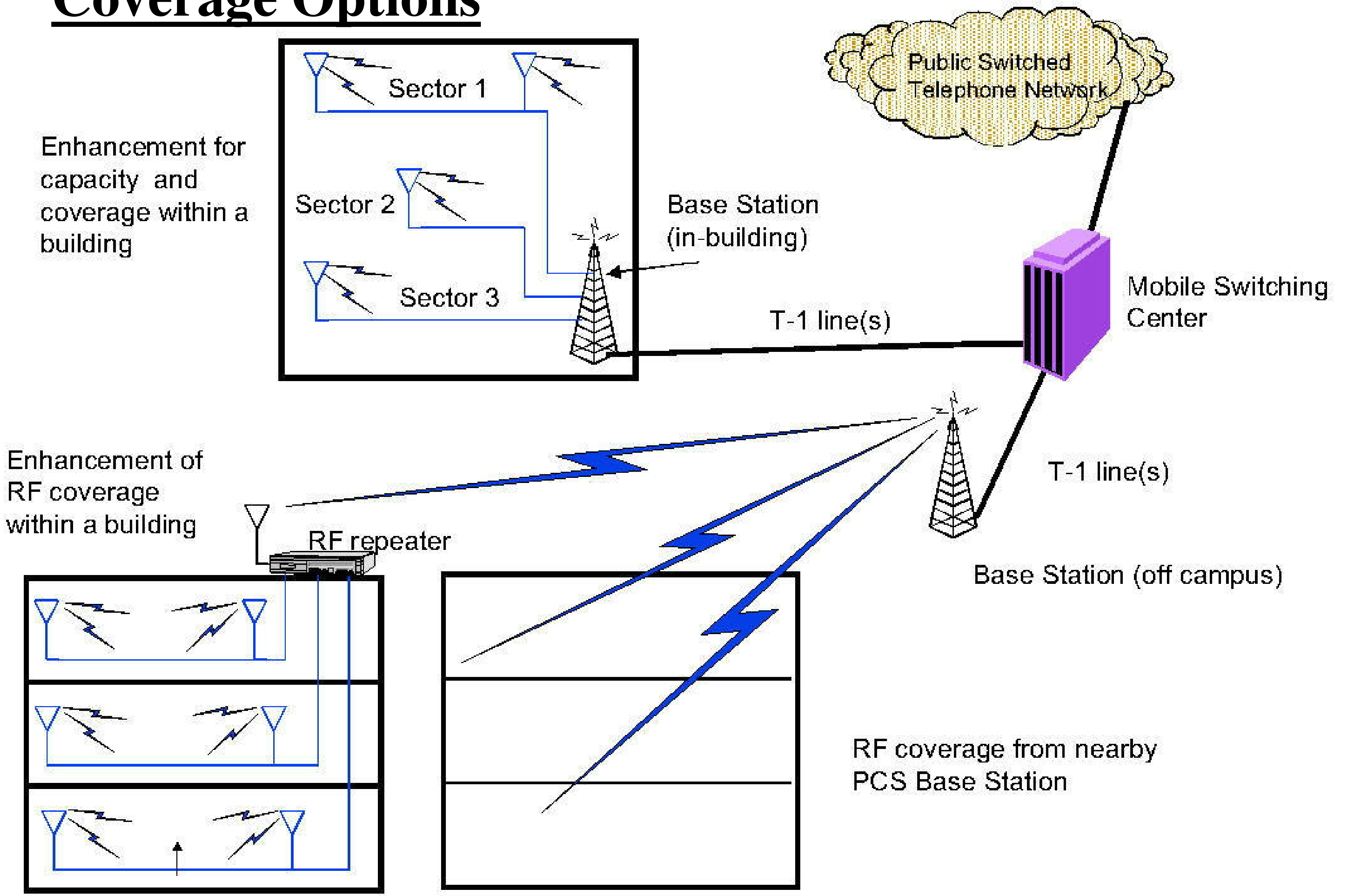
Simplex Repeater

Bi-directional Amplifier (BDA) - single, Multi-band or Band Specific BDA

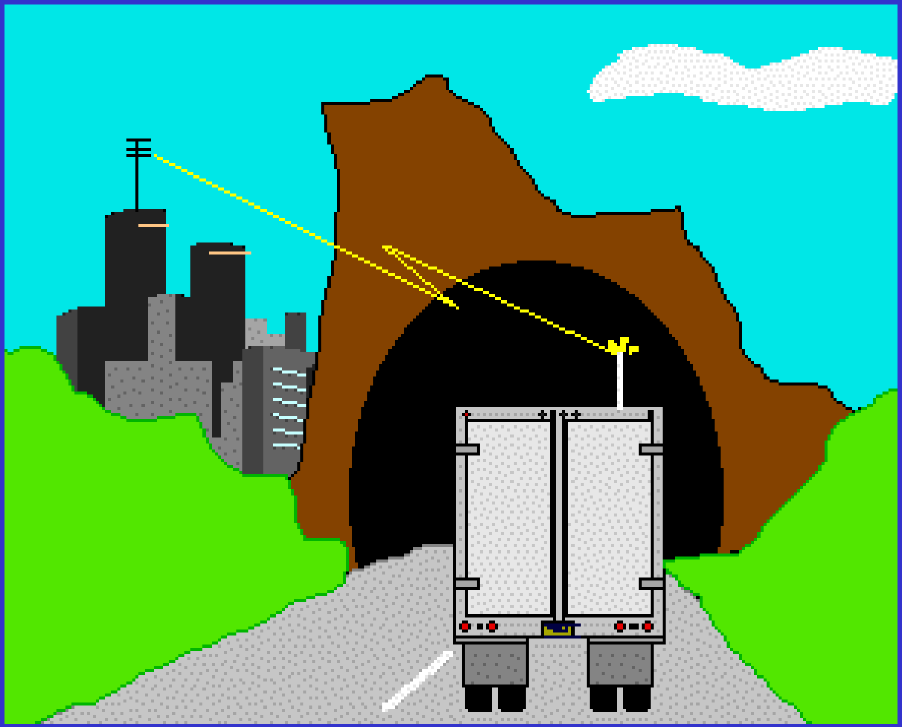
RF Amplifier - single stage or multi-stage; coax cable, splitters, amplifiers

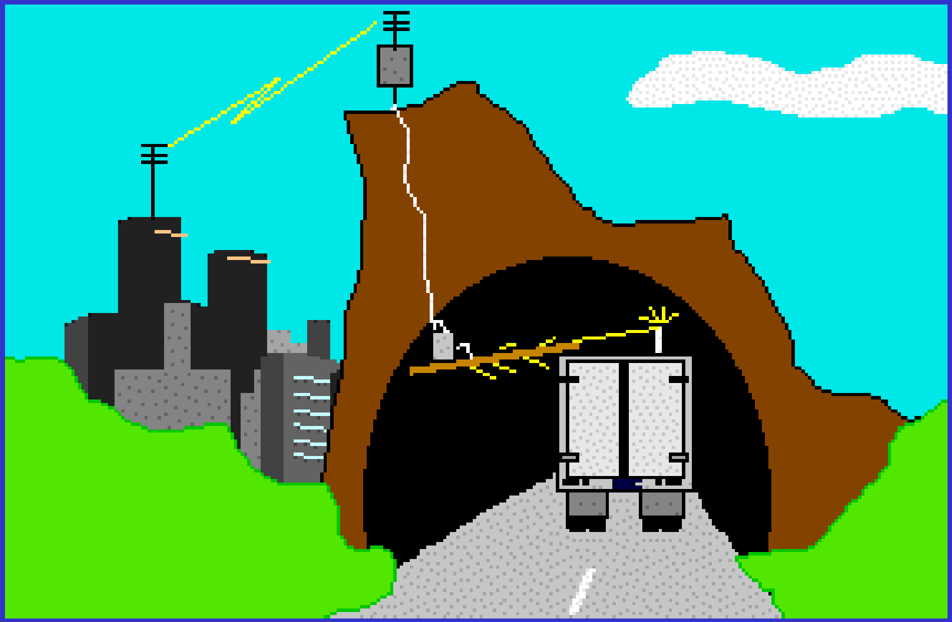
Active low power Distribution systems - Optical, analog or digital, CAT-5 UTP

# Coverage Options



## Supplementary Repeater System





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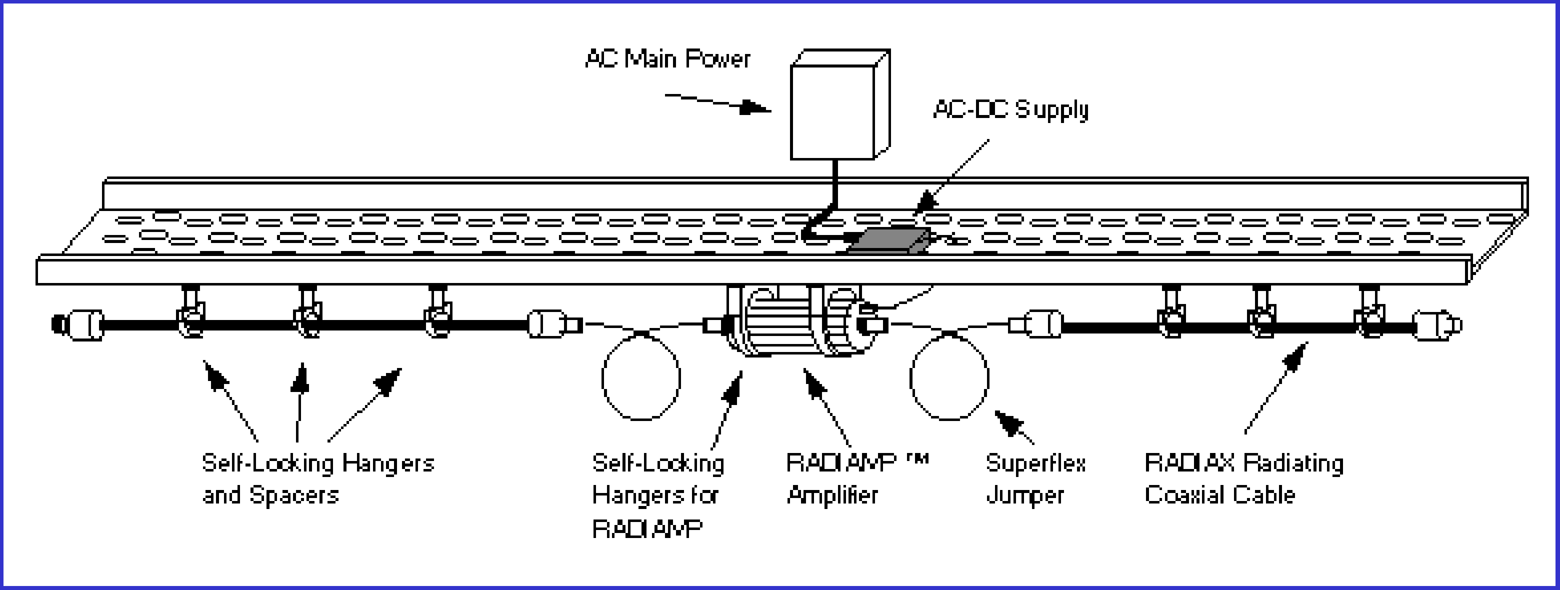
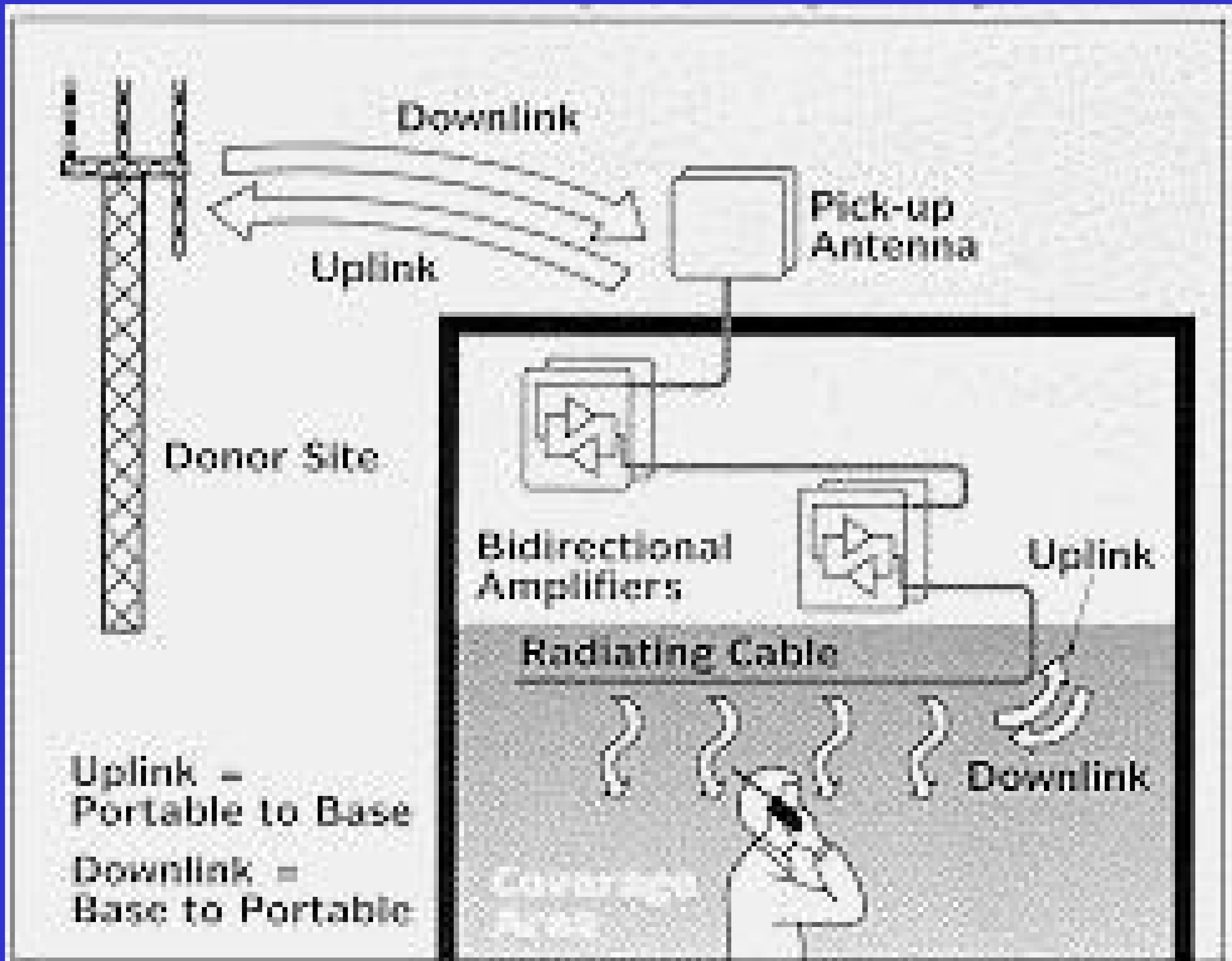
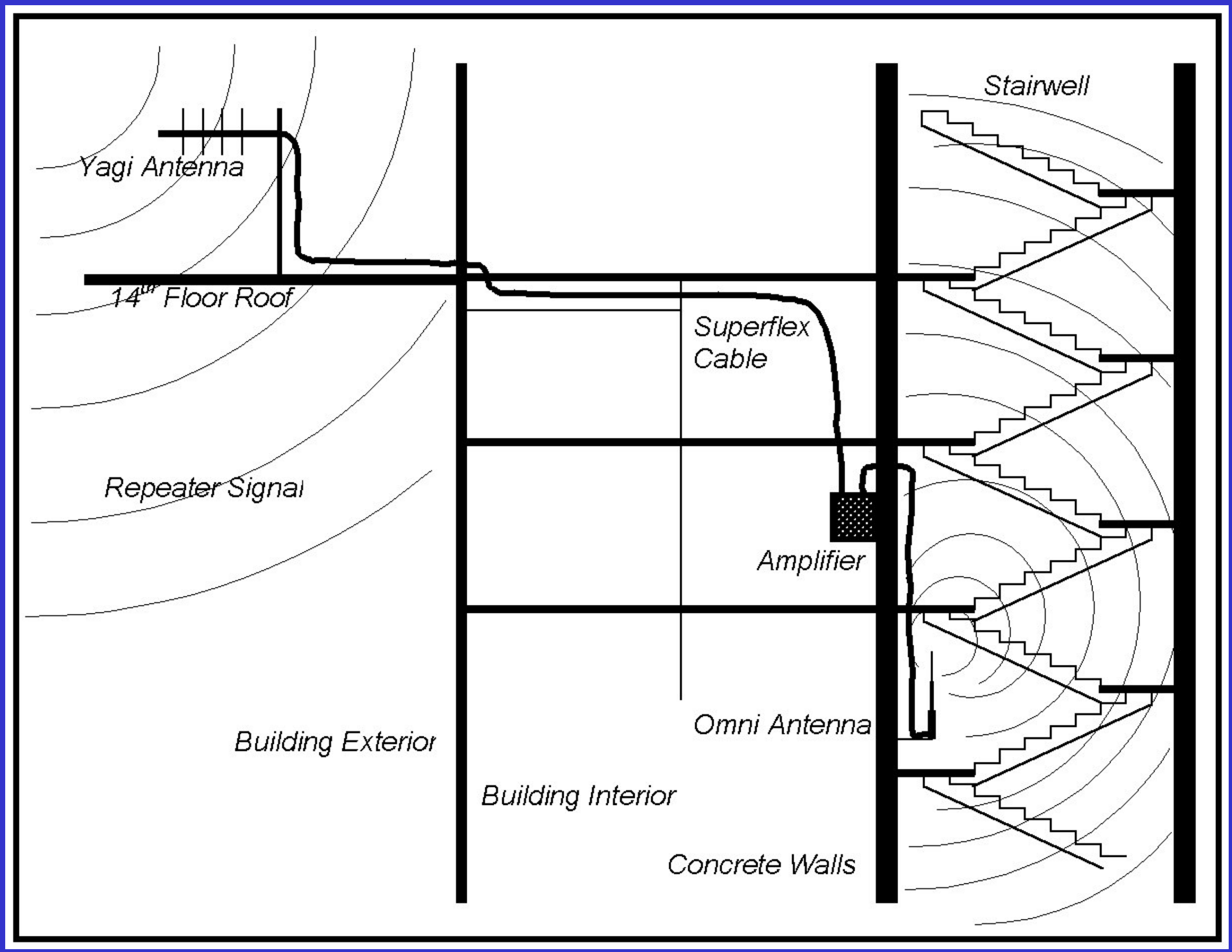


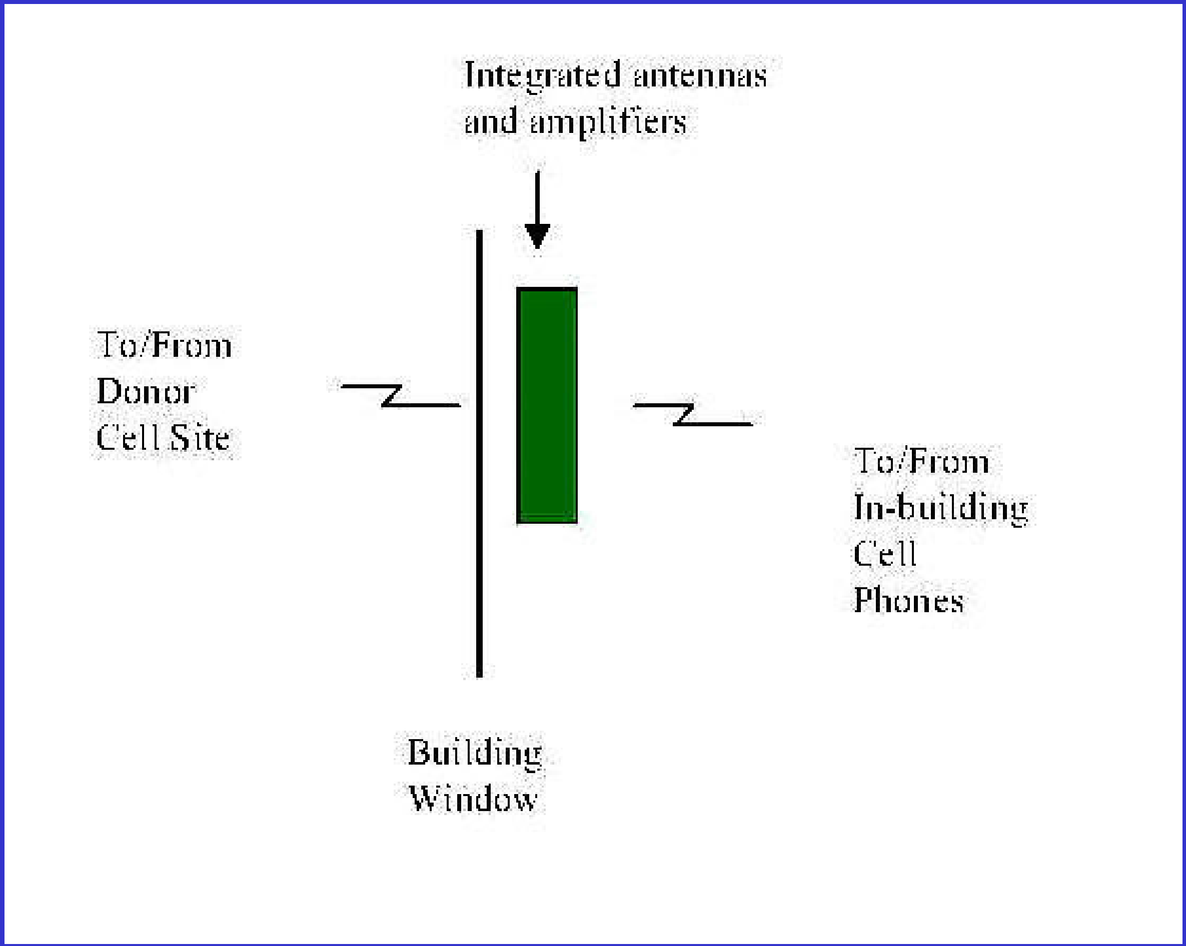
# Bi-Directional Amplifier System



# Bi-Directional Amplifier System



# Modular RF Enhancement System - Donor Antenna on window side, integral amplifier, and downlink antenna on office side



# Distributed Antenna Systems (DAS)

- A Distributed Antenna System consists of multiple low power antennas fed by a single (or many) cellular base station or cell
- Because there many antennas, the system can cover a larger indoor service area than a single cell
- Distributed Antenna Systems are designed to amplify two-way radio signals in buildings in a safe and efficient manner
- DAS's provide high quality signal, eliminating dropped calls, and also increase call capacity for wireless Telco carriers
- They can also increase E911 Capabilities

# Distributed Antenna Systems (DAS)

- Indoor DAS must be coordinated with the outdoor systems. The interface should allow a stable handoff
- Outdoor (macro) cell sites must be re-optimized to work with the indoor system
- Market for these systems is just being realized
- 4.7 Million Commercial buildings in the US - 2% are >100,000 square feet
- Benefits to Carriers
  - Higher Traffic Capacity
  - Better Quality of Service
  - Capture "Hot Spot" Markets
  - Satisfy Enterprise Business Customers

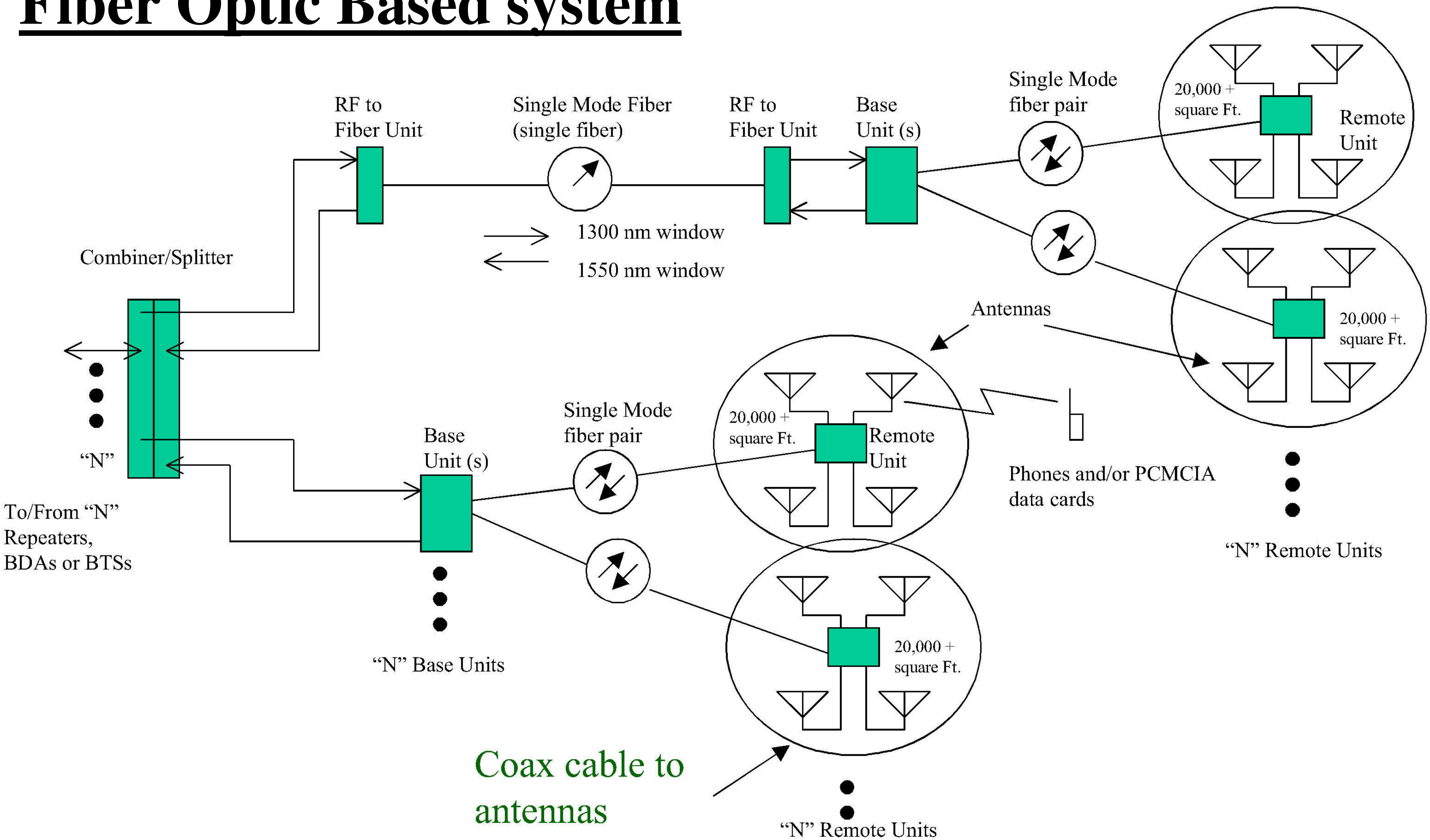
# Distributed Antenna Systems (DAS)

Architecture and Design Options

- Single Band / Multi-Band
- Coax / UTP Cat 5 / Fiber Optic Cabling
- Discrete Antennas / Radiax (leaky coax)
- Star / Run and Drop / Multi-level amplifier topologies
- Local / Central Power System
- Analog / Digital Modulation, encoding

# Distributed Antenna Systems (DAS)

## Fiber Optic Based system



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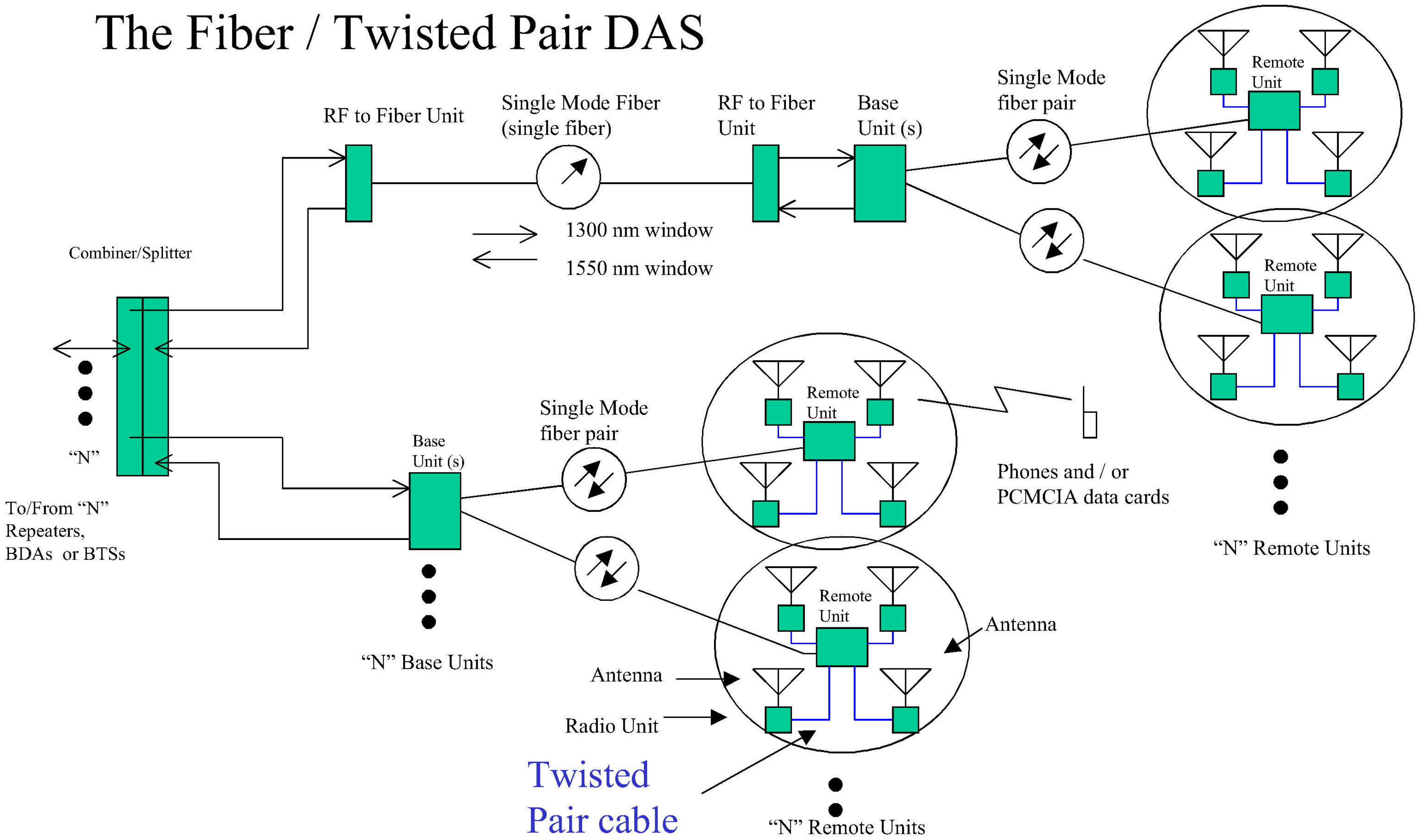
# Distributed Antenna Systems (DAS)

## The Fiber / Twisted Pair DAS



# Design of Indoor RF Distribution Systems

Design Issues

Indoor Radio Noise Sources: Computers, Rotating Machines, Power Distribution Equipment, RF Heating Equipment, Other Transmitters

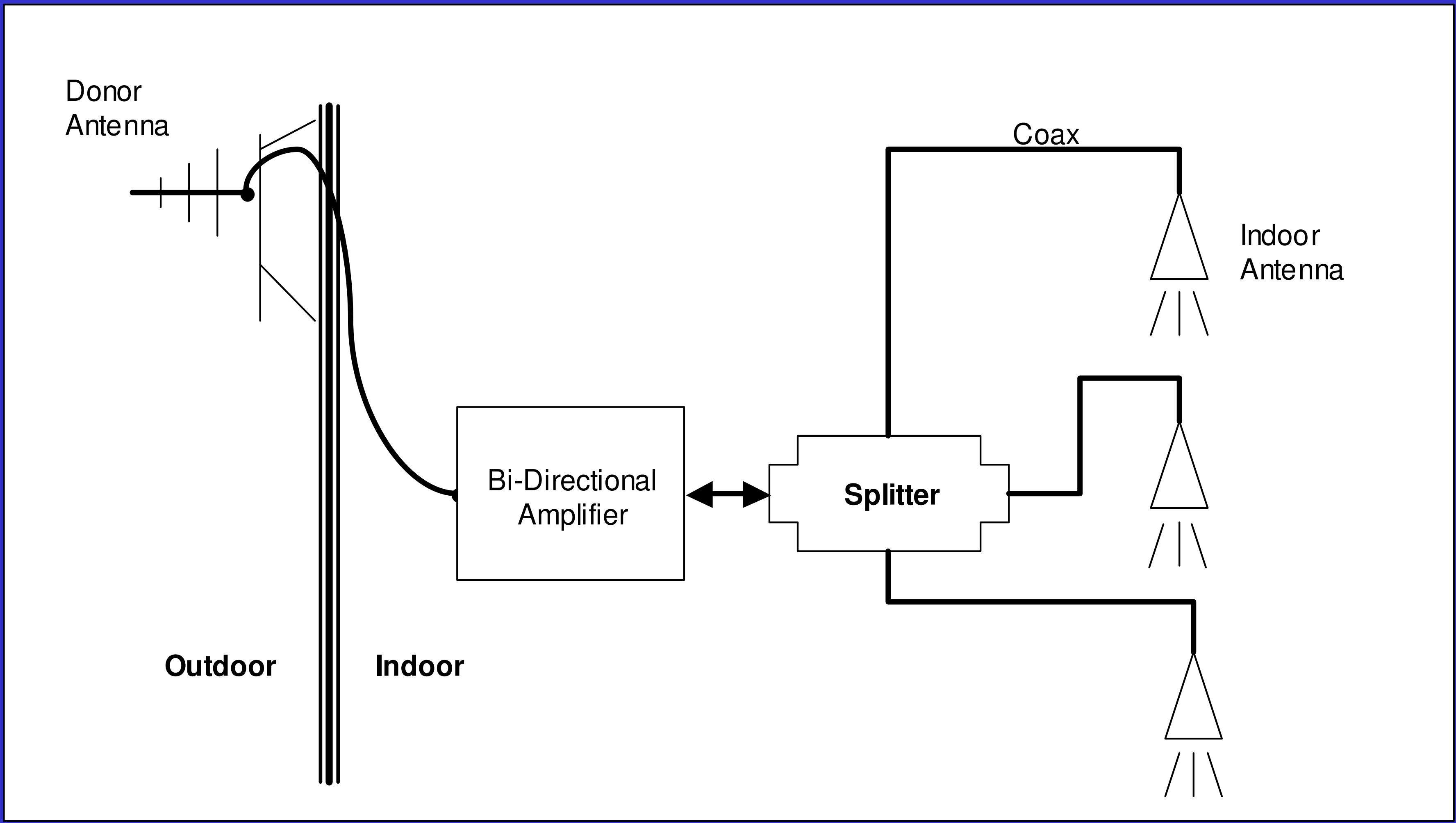
Need sufficient capacity in outdoor donor cell

Noise floor levels on both sides of BDA

Placement of BDA and antennas

# Design of Indoor RF Distribution Systems

## Design Method: Calculate Forward Link Budget (downlink)



# Design of Indoor RF Distribution Systems

## Design Method: Calculate Forward Link Budget (downlink)

| | | | | | | |
|---|---|---|---|---|---|---|
| **BASE TALK-OUT (DOWNLINK) ANALYSIS** | | | | | | |
| 1. Base Tx Frequency (F1) | | | 493.600 | MHz | | |
| 2. Base Tx Pow er | | | 100.00 | W | | |
| 3. Portable Squelch Threshold | | | -113.00 | dBm | | |
| **BASE TO DOWNLINK AMPLIFIER** | | | | | | |
| 4. Base Tx Pow er | | | **+50.00** | dBm | | |
| 5. Base Tx Combiner/Filter Loss | | | -10.70 | dB | | |
| 6. Base Tx Feedline Loss | | | -2.40 | dB | | |
| 7. Base Tx Antenna Gain | | | +6.00 | dBi | | |
| 8. Base->Site Free-Space Loss | | | -97.20 | dB @ | 3.50 | Km |
| 9. Shadow and Other Path Losses | | | -10.00 | dB | | |
| 10. Site Antenna Gain | | | +9.50 | dBi | | |
| 11. Site Feedline Loss | | | -1.20 | dB | | |
| 12. Other Loss | | | | dB | | |
| 13. Dow nlink Amp Input Pow er | | | **-56.00** | dBm | | |
| 14. Dow nlink Amp Gain | | | +65.00 | dB | | |
| 15. Dow nlink Amp Output Pow er | | | **+9.00** | dBm | | |
| 16. Dow nlink Amp OIP3 | +44.00 | dBm | | | | |
| 17. Number of RF Carriers | 8 | | | | | |
| 18. Max Pow er/Carrier | +15.50 | dBm | | | | |
| 19. Dow nlink Amp Margin | **+6.50** | dB | | | | |

Base Station Power -

Path Loss to Site +

Site Antenna Gain -

Feedline Cable loss +

BDA Amp Power Gain =

BDA Output Power (available for distribution throughout building)

# Design of Indoor RF Distribution Systems

## Design Method: Calculate Forward Link Budget (downlink)

| | | | | |
|---|---|---|---|---|
| 15. Downlink Amp Output Power | +9.00 | dBm | | |
| **DOWNLINK CABLE SPECIFICATIONS** | | | | |
| 20. Cable Type | RXL5-1 | | | |
| 21. Cable Length | 665.00 | m | | |
| 22. Coupling Factor @ 20 ft | 63.53 | dB | | |
| **DOWNLINK AMPLIFIER TO PORTABLE/MOBILE** | | | | |
| 23. 2-Way Splitter & Tunnel Feedline Loss | -4.10 | dB | | |
| 24. Downlink Cable Transmission Loss | -25.19 | dB | | |
| 25. Downlink Cable Coupling Loss | -63.53 | dB @ | 20.00 | ft |
| 26. Downlink Antenna Decoupler Loss | | dB | | |
| 27. Downlink Antenna Gain | | dBi | | |
| 28. Space Loss to Downlink Antenna @ F1 | | dB @ | | |
| 29. Design Margin | -15.00 | dB | | |
| 30. Portable Antenna Gain, Rx Mode | -10.00 | dBi | | |
| 31. Portable/Mobile Rx Input | **-108.83** | dBm | | |
| 32. Required Rx Input | -113.00 | dBm | | |
| **33. Rx Margin** | **+4.17** | dB | | |

**BDA Power output -**

**Path Loss to antenna +**

**Antenna Gain =**

**Power at Antenna**

**Use this power to find antenna range by comparing to receiver sensitivity**

# Design of Indoor RF Distribution Systems

## Design Method: Calculate Reverse Link Budget (uplink)

| PORTABLE/MOBILE TALK-BACK (UPLINK) ANALYSIS | | |
|---|---|---|
| 34. Portable/Mobile Tx Frequency (F2) | 503.600 | MHz |
| 35. Portable Tx Power | 2.50 | W |
| 36. Base Squelch Threshold | -113.00 | dBm |

| UPLINK CABLE SPECIFICATIONS | | |
|---|---|---|
| 37. Cable Type | RXL5-1 | |
| 38. Cable Length | 665.00 | m |
| 39. Coupling Factor @ 20 ft | 63.67 | dB |

| PORTABLE/MOBILE TO UPLINK AMPLIFIER | | | | |
|---|---|---|---|---|
| 40. Portable Tx Power | | | **+34.00** | dBm |
| 41. Portable Antenna Gain, Tx Mode | | | -6.00 | dBi |
| 42. Space Loss to Uplink Antenna @ F2 | | | | dB |
| 43. Uplink Antenna Gain | | | | dBi |
| 44. Uplink Antenna Decoupler Loss | | | | dB |
| 45. Uplink Cable Coupling Loss | | | -63.67 | dB |
| 46. Uplink Cable Transmission Loss | | | -25.48 | dB |
| 47. 2-Way Splitter & Tunnel Feedline Loss | | | -4.10 | dB |
| 29. Design Margin | | | -15.00 | dB |
| 48. Uplink Amp Input Power | | | **-80.25** | dBm |
| 49. Uplink Amp Gain | | | +57.00 | dB |
| 50. Uplink Amp Output Power | | | **-23.25** | dBm |
| 51. Uplink Amp OIP3 | +39.00 | dBm | | |
| 52. Number of RF Carriers | 8 | | | |
| 53. Max Power/Carrier | +12.20 | dBm | | |
| 54. Uplink Amp Margin | **+35.45** | dB | | |

Radio Power output +

Antenna Gain -

Path Loss to UL Ant -

Cable loss +

BDA Power Gain =

Power out of BDA

(This is power to reach base station)

# Design of Indoor RF Distribution Systems

## Design Method: Calculate Reverse Link Budget (uplink)

| UPLINK AMPLIFIER TO BASE | | |
|---|---|---|
| 55. Other Loss | | dB |
| 11. Site Feedline Loss | -1.20 | dB |
| 10. Site Antenna Gain | +9.50 | dBi |
| 56. Site->Base Free-Space Loss @ F2 | -97.40 | dB |
| 9. Shadow and Other Path Losses | -10.00 | dB |
| 57. Base Rx Antenna Gain | +9.00 | dBi |
| 58. Base Rx Feedline Loss | -2.80 | dB |
| 59. Base Rx Multicoupler Net Gain | +9.00 | dB |
| 60. Base Rx Input | **-107.15** | dBm |
| 61. Required Rx Input | -113.00 | dBm |
| **62. Rx Margin** | **+5.85** | dB |

**Power out of BDA** -

**Cable loss +**

**Donor Ant Gain -**

**Path Loss to Base Ant +**

**Antenna Gain -**

**Cable loss =**

**Power at Base Station (compare to base station sensitivity)**

# Design of Indoor RF Distribution Systems

## Design Method: Calculate Carrier to Noise Ratio or margin

**DOWNLINK AMPLIFIER ANALYSIS**

| | | | | |
|---|---|---|---|---|
| Portable Rx Frequency | 880.0150 | MHz | | |
| Portable Squelch Sensitivity | 0.50 | uV | -113.00 | dBm |
| Total Downlink Amp -> Portable/Mobile Loss | | | -117.83 | dB |
| Maximum Allowable IM3 Power @ Amplifier Output | | | **+4.83** | dBm |
| Downlink Amplifier Output Power (per Carrier) | | | +9.00 | dBm |
| Computed 2-Carrier IM3 Level @ Amplifier Output | | | **-61.00** | dBm |
| IM Level Correction for | 3 | Third-Order, 2-Carrier Products | +4.77 | dB |
| IM Level Correction for | 15 | Third-Order, 3-Carrier Products | +11.76 | dB |
| Third-Order, 2-Carrier IM Level | | | -56.23 | dBm |
| Third-Order, 3-Carrier IM Level | | | -50.23 | dBm |
| Total Third-Order IM Level | | | **-49.26** | dBm |
| **Downlink Carrier/IM3 Ratio** | | | **+58.26** | dB |
| **IM3 Level @ Receiver Input** | | | **-167.08** | dB |
| Downlink Amplifier Noise Figure | | | 13.00 | dB |
| **Downlink Amp Noise Output Power, BW=** | 30.00 | KHz | **-51.23** | dBm |
| **Downlink Carrier/Noise Ratio** | | | **+60.23** | dB |

**Carrier to Noise Ratio at Mobile**

# Design of Indoor RF Distribution Systems

## Design Method: Calculate Carrier to Noise Ratio or margin

**UPLINK AMPLIFIER ANALYSIS**

| | | | | |
|---|---|---|---|---|
| Base Rx Frequency | 835.0150 | MHz | | |
| Base Squelch Threshold | 0.50 | uV | **-113.00** | dBm |
| Uplink Amplifier Output Pow er (per Carrier) | | | -23.25 | dBm |
| Computed 2-Carrier IM3 Level @ Amplifier Output | | | **-147.75** | dBm |
| IM Level Correction for | 3 | Third-Order, 2-Carrier Products | +4.77 | dB |
| IM Level Correction for | 15 | Third-Order, 3-Carrier Products | +11.76 | dB |
| Third-Order, 2-Carrier IM Level | | | -142.98 | dBm |
| Third-Order, 3-Carrier IM Level | | | -129.99 | dBm |
| Total Third-Order IM Level @ Uplink Amplifier Output | | | **-129.78** | dBm |
| **Uplink Carrier/IM3 Ratio** | | | **+106.53** | dB |
| Uplink Amplifier Noise Figure | | | 13.00 | dB |
| **Uplink Amp Noise Output Power, BW=** | 30.00 | KHz | **-59.23** | dBm |
| **Uplink Carrier/Noise Ratio** | | | **+35.98** | dB |

**Carrier to Noise Ratio at Base Station**

# Design of Indoor RF Distribution Systems

Automated Design Tools do exist!

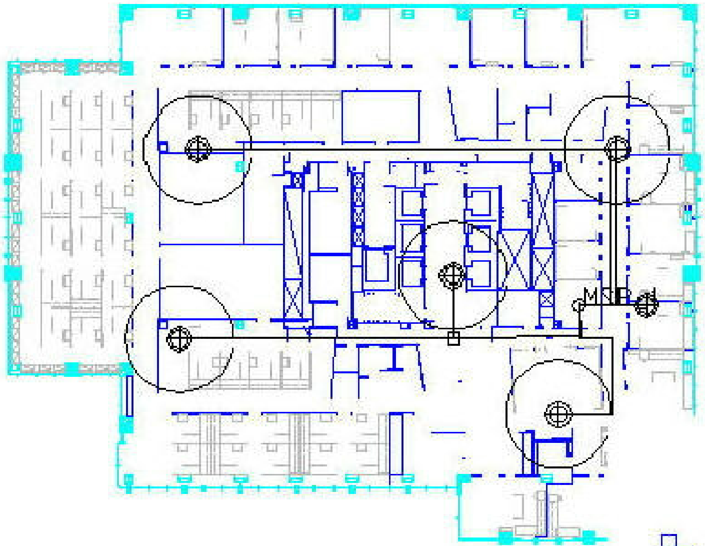
Field Test Measurement Automation tools: Allow automated data acquisition of field RF signal strength both indoors and outdoors. Include mapping and location tools.

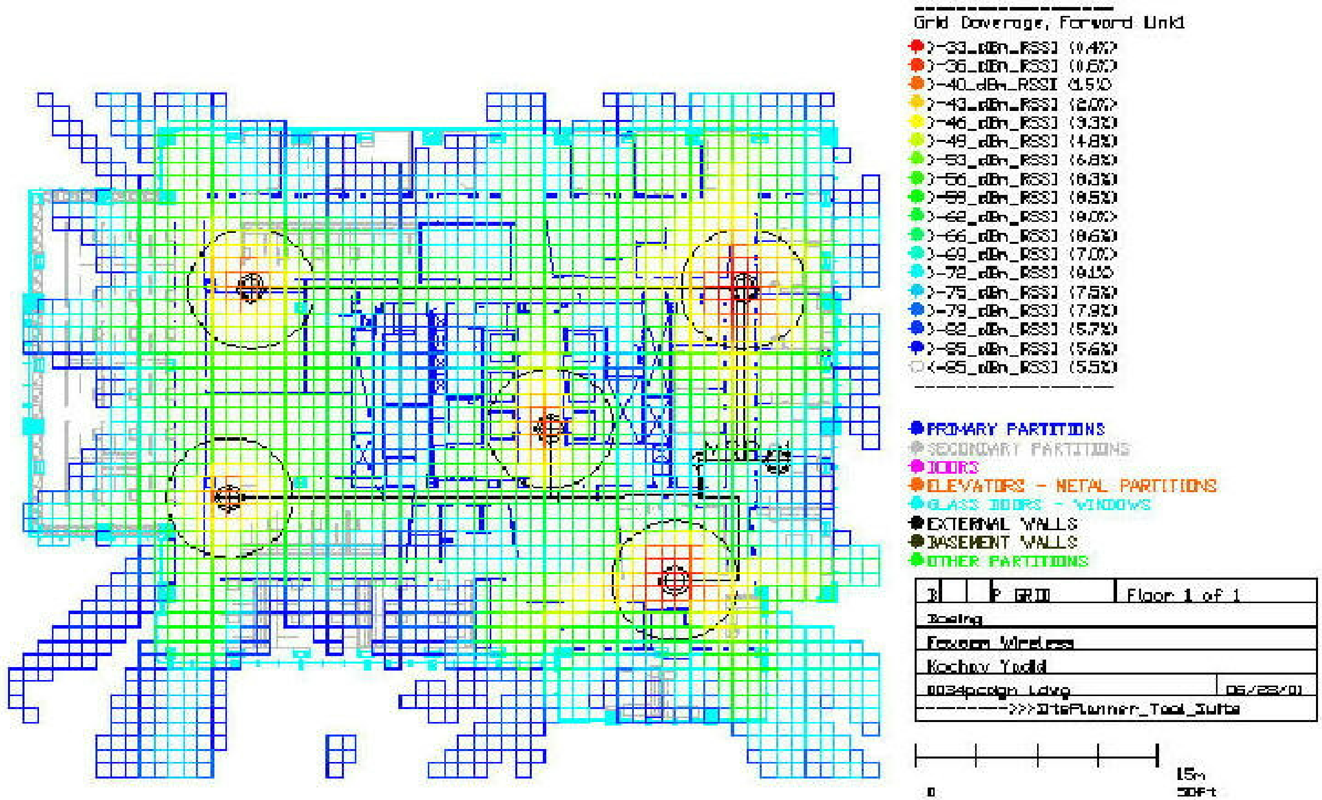
Indoor Signal Propagation Analysis - software tools have been developed that model signal propagation indoors. They allow you to place antennas and "see" the signal spread through the floor plan. They also document system design, material used, part numbers, etc.

Wireless LAN Designer - for the design and implementation of wireless computer networks

Example follows:

# Antenna Placement and RF Plot Examples





**Just a note on RF Safety –**
**The effects of RF radiation on humans has been documented and the limits of exposure well defined by the FCC OET STD 56 and ANSI. DAS are designed to be low power systems so that there is no risk to humans in the space.**

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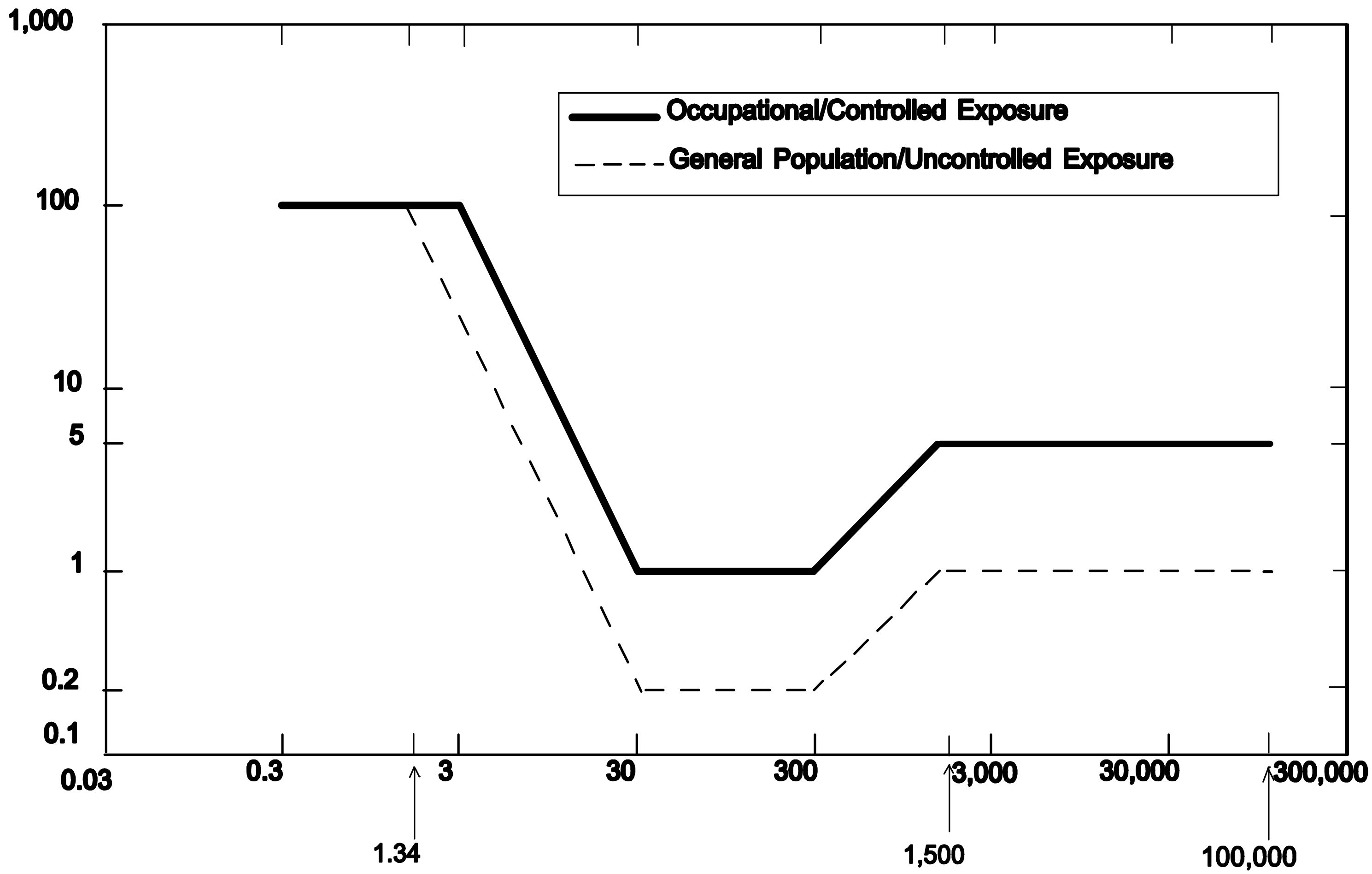
Figure 1. FCC Limits for Maximum Permissible Exposure (MPE)

*Plane-wave Equivalent Power Density*



# Please go on to Part 3 – thanks!