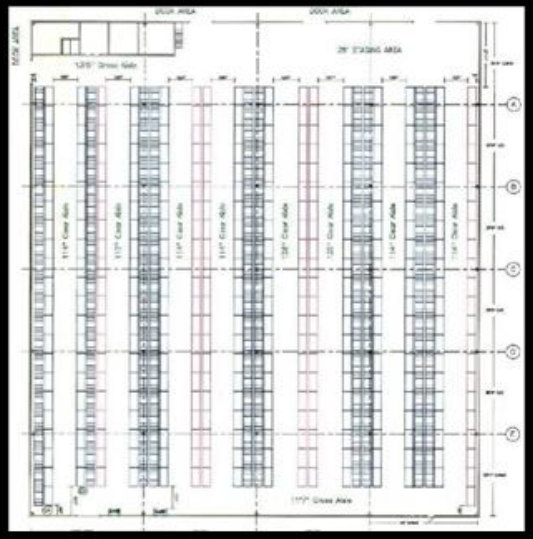
Wireless Expressways® inc.

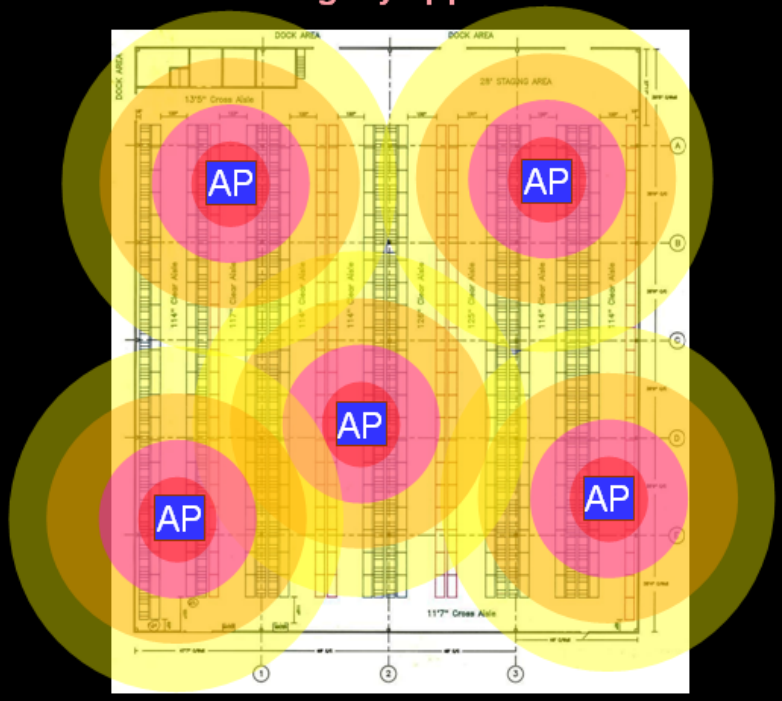
How to Cover a 40,000 square-foot Warehouse with High-Level Wi-Fi Signals Using Waveguide Technology



+ WE Waveguide + AP =

First, a review of how warehouse (802.11b) Wi-Fi networks have been designed in the past. Here's an example of a typical 5 AP system, each AP using standard omni antennas.

The legacy approach



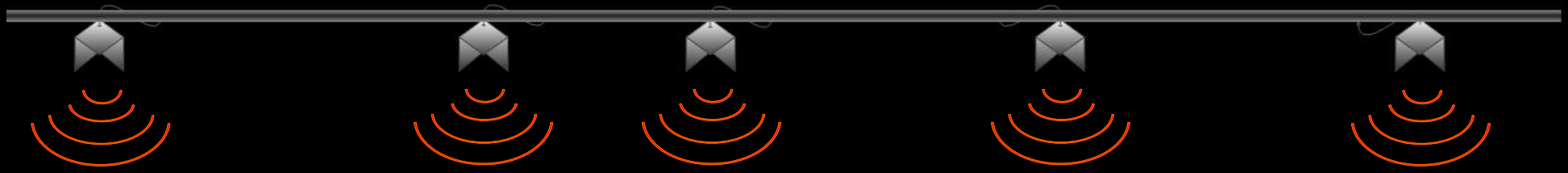
- **Signals to clients are variable from day to day due to changing products on rack shelves that can cause slow data and dead spots**
- **More than three access points cause transmission holdoffs and slower responses due to co-channel interference**
- **Excessive roaming events can occur due to highly variable signals from multiple, scattered access points**
- **Reliability is lower – a failure of an AP can take out a zone**
- **Omni antennas transmit signals indiscriminately, including to locations outside buildings, causing a significant waste of AP transmitted power and a potential data security problem**
- **APs are typically mounted in the hot, dusty overhead structural iron --- not an optimal location for either the APs or those who will need to service or replace them**
- **Installation of multiple, scattered APs throughout a warehouse requires running a data cable to each AP. Distant APs often require fiber data feeds, long runs of conduit to supply backup power, or a local switch and UPS, all of which are unnecessary expenses.**

WEI waveguide-based systems solve these problems while lowering capital equipment costs. Site surveys are simplified, the entire system runs faster, is more reliable, and ongoing system maintenance costs are significantly reduced. And any enterprise-grade access point with external antenna connectors will work with the system.

HOW OUR SYSTEM WORKS

We use an easy to configure distributed antenna technology based on WE's inexpensive, very low-loss, passive (no electronics) microwave waveguide.

The waveguide is used as a backbone to very efficiently transport one or more wireless signals, such as 802.11a,b,g,n,ac, to all user areas for radiation by antennas that are local to clients.



Our new method of signal distribution allows predictable, high-quality, high speed, wireless coverage in all areas of cluttered offices, malls, hotels, schools, warehouses, manufacturing facilities, and hospitals.

Reliable, high-speed wireless coverage can now be provided to all users.

Wireless security is enhanced by reducing signal leakage to outside areas.

The system has been in development for the last six years and is an outgrowth of a decade of implementing precursor large-scale indoor wireless networks.

It's covered by fifteen US and international patents, with more US and international patents pending.

WE Waveguide System in a Typical Warehouse

We installed an 802.11b (2.4GHz) waveguide system in a typical commercial warehouse and measured the resulting coverage and signal strengths throughout the facility

The characteristics of this warehouse at the time of the installation were:

- 40,600 square feet under roof
- Eight product aisles, nine product racks, all 175ft in length
- Height to structural iron of 24ft (~23ft to antennas)
- Racks were typically > 98% full of a wide variety of products
- Gap between products in top of racks to red iron ~4ft, typical
- 12 ft cross aisle in back of warehouse, (behind racks 2-8), was blocked with boxed metallic products stacked ~ 8ft high

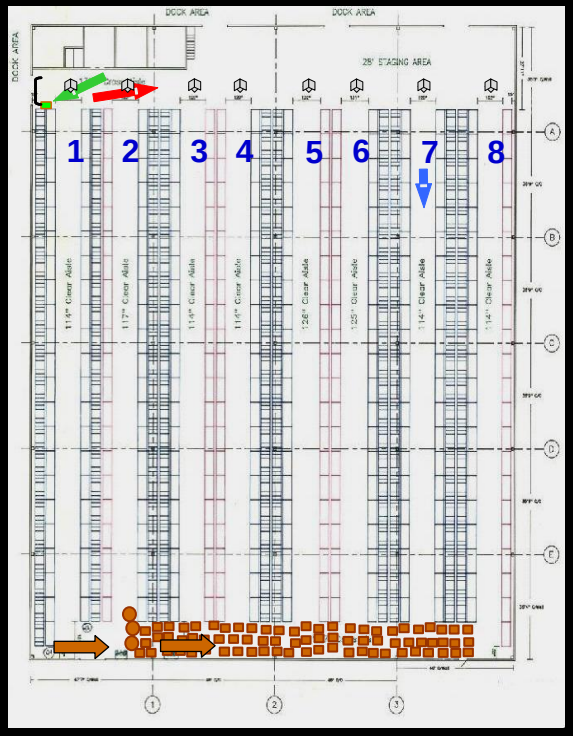
Only ONE AP was needed to fully illuminate the entire warehouse. Variable couplers on the single 183 ft. waveguide backbone provided +8.5 dBm signals to seven high-efficiency antennas. The termination port at the end of the waveguide also provided +8.5dBm and fed the antenna in aisle #8, (total of eight antennas, one per aisle).

Signal strengths were recorded with AirMagnet software on a notebook computer using a Cisco CB21AG-A-K9 client card operating on 802.11b channel 6.

Views of Sections in the Test Warehouse

WE Waveguide Along Dock Cross Aisle

Single Access Point Mounted on Rack



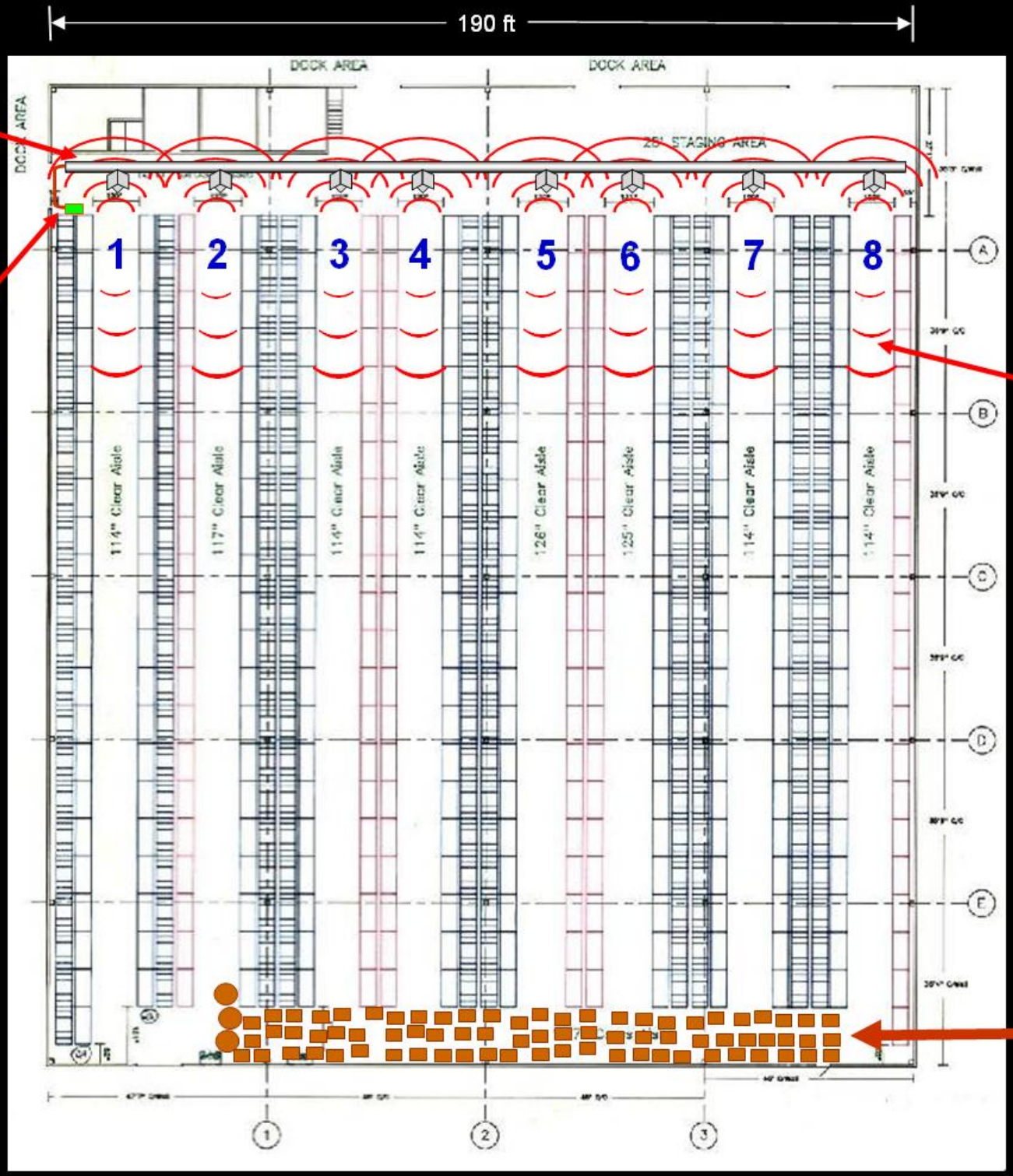
Typical 175ft Aisle

Rear Cross Aisle

The color of each arrow on the floor plan above shows the direction viewed in each picture .

Product “Canyon” in rear cross aisle

Each Aisle is Fed Separately and Equally



Waveguide and Antennas mounted below red iron fed all aisles

ONE Access Point at floor level with feed cable to Waveguide

Aisles and racks are 175ft long

Aisles

Equal signals down each aisle

8ft high stacks of metallic products stored in cross aisle

WE Waveguide System in a Warehouse

- One run of waveguide backbone is suspended from the "red iron" structure along the front cross aisle.
- Clearance is provided for other pipes, conduits, etc. under the red iron.
- Each standard waveguide section is 10ft long.
- Mechanical couplers that join waveguide sections install easily with minimal tools.
- An enclosure for AP(s) is mounted at floor level.
- A coax line connects the AP to the feed point of the waveguide, which can be at either end, or in the middle of the waveguide if more convenient.

- Low-loss, low-cost microwave waveguide transports signals to each aisle location.
- Variable signal couplers connect into pre-placed waveguide apertures near aisle centers.
- Directional antennas matched to warehouse aisles provide full and consistent aisle illumination.
- A Short coaxial cable connects the output of each coupler to an aisle antenna.
- "Spot beams" or other geometries of coverage can be accommodated anywhere with other antennas.
- All RF connectors are standard type "N".

WE Waveguide-based System Is Highly Efficient

The only practical way to cover a warehouse is to direct a high-level signal down each aisle. This approach, unlike that in the legacy example shown previously, *eliminates* the need to propagate signals through products on rack shelves. An access point and antenna could be used at the end of each aisle, but that's expensive and would cause excessive co-channel interference and poor results.

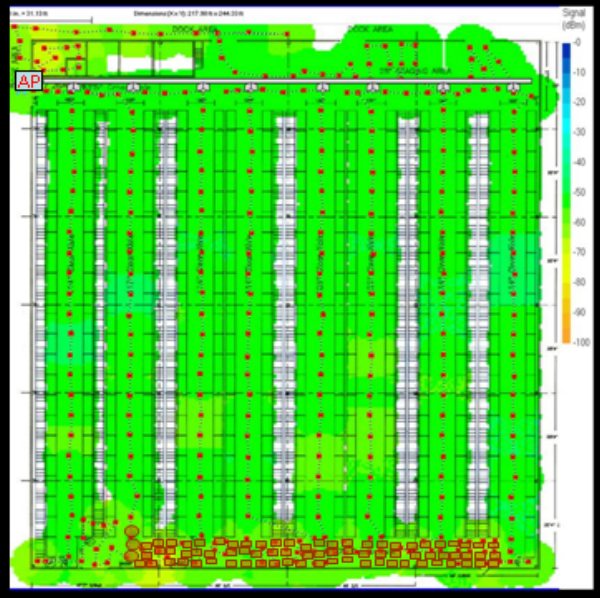
We use extremely low-loss, low-cost, microwave waveguide to deliver equal, optimum, signals from one or more access points to every aisle. Adjustable output ports in the waveguide apportion signals to aisle-optimized antennas positioned at the end of each aisle. (see heat map below)

Results of Warehouse Tests and System Features

- ONE AP easily covered the 40ksqft warehouse with high-level signals.
- Signal strengths along all aisles and front of the facility were high level and highly consistent (~ +/- 4dB throughout). (The rear cross aisle contained stacked metal products, but was still amply covered.)
- Signal patterns were optimized for minimum radiation outside the facility.

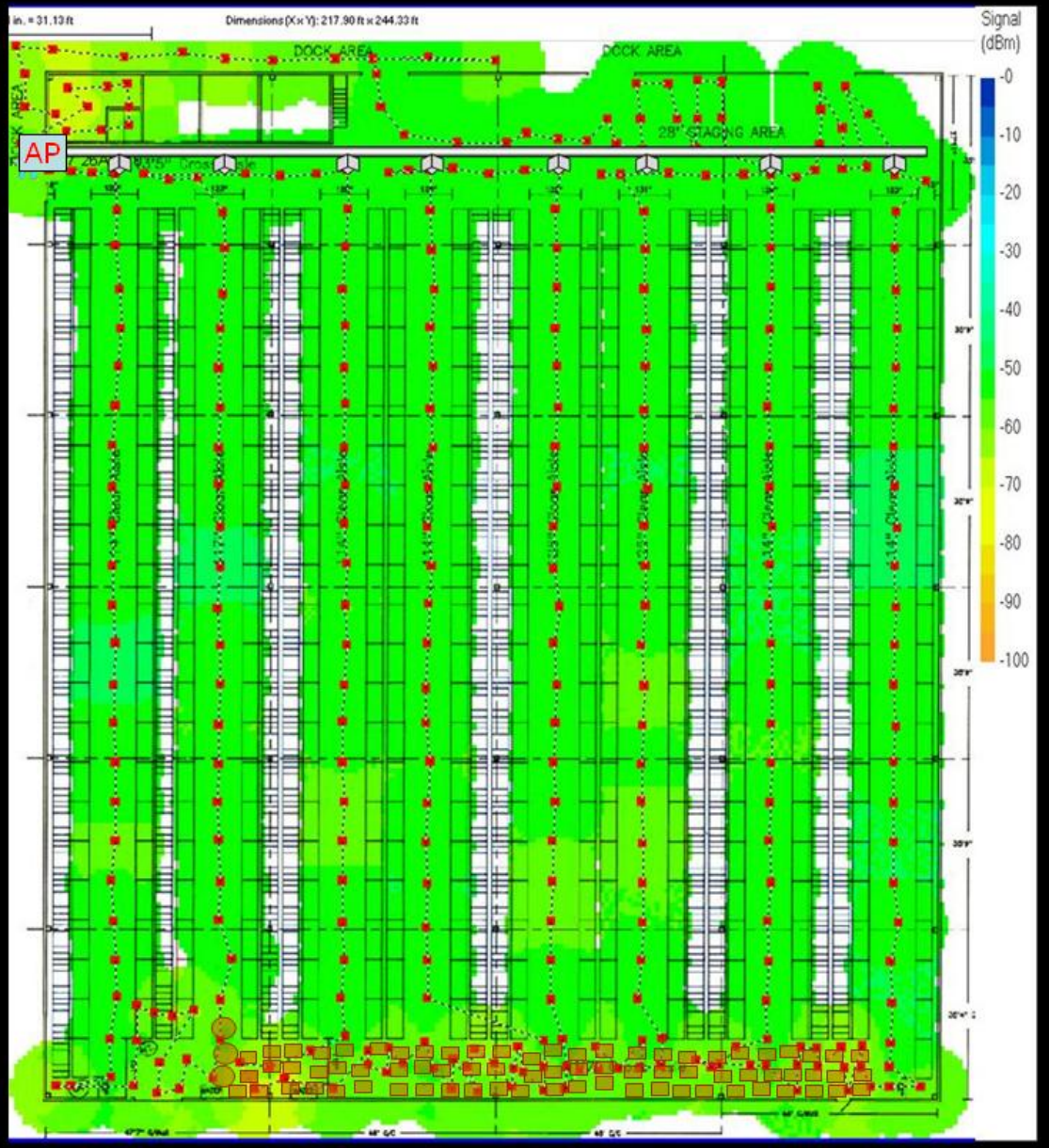
- The system is totally passive, needs ~ zero maintenance (not including access points) and can be easily modified or moved to other applications.
- Up to 3 multiplexed AP channels can occupy the same waveguide.
- APs can be mounted in an enclosure at floor level for easy access and longer equipment life
- The system is straightforward to install by communications technicians.

40.6ksqft, 8- 175ft Aisles, 9 Racks



Extensive Sampling of Signals Showed Complete High-Strength Coverage

- Over 320 signal samples were taken throughout the warehouse using Fluke AirMagnet Survey software
- The parameter measured was AP signal strength in dBm.
- All readings were taken with a notebook PC using a Cisco CB21AG-A-K9 Wi-Fi card whose antenna was at ~ 42 inches from the floor during all readings.
- Signals on the external dock were recorded to show dock signal coverage
- Some areas were left blank without samples due to inaccessibility caused by products stacked in those areas
- The radius of equal levels in each of these signal recordings is ~4 feet
- Rack spaces that appear to have no signals are artifacts of the way each measurement is displayed; although signal levels inside racks are high, they are of little or no concern
- Stacked metallic objects in boxes in the rear of the warehouse partially blocked signals, but signals survived with sufficient threshold for full speed.



Detailed Signal Levels at ~ 8 foot Intervals Throughout the Facility

The signal levels provided by a WEI waveguide-based system driven by a single Cisco 1240 access point *mounted at ground level* are shown in the figure at right. The AP was connected to our waveguide system through a coaxial feed line. Transmit power input to the waveguide was +17.3dBm (due to coax line loss.) A data rate of 11Mbps, 802.11b, was used.

We measured the signal levels at all accessible client areas in the warehouse.

NOTE THE CONSISTENT SIGNAL LEVELS

RESULTS

The tests clearly show that our system provides complete, high-level coverage in all locations, even in the "canyon" of products at the rear of the warehouse. The receive level at any location was at least 20-35dB above threshold, an exceedingly high signal margin.

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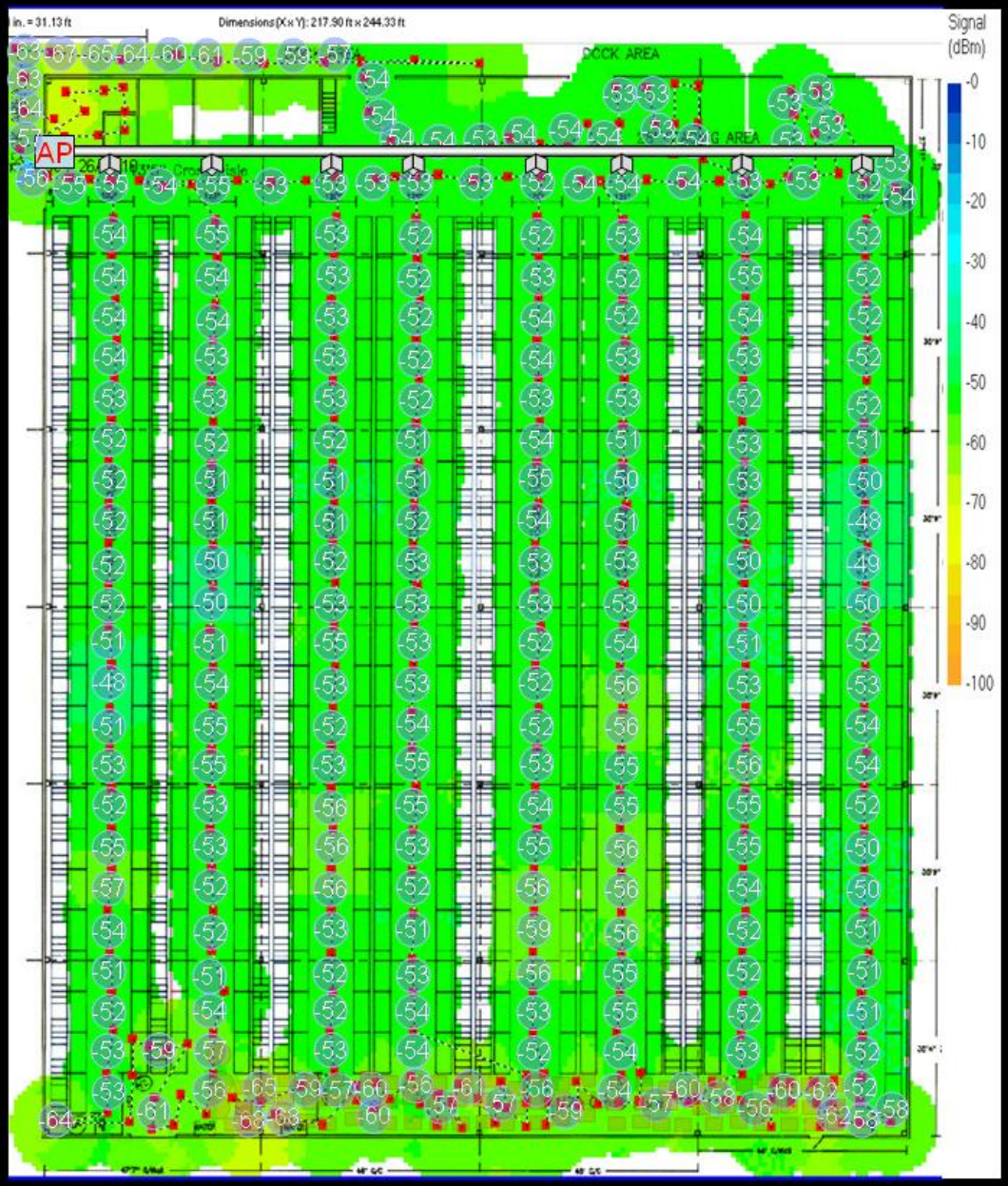
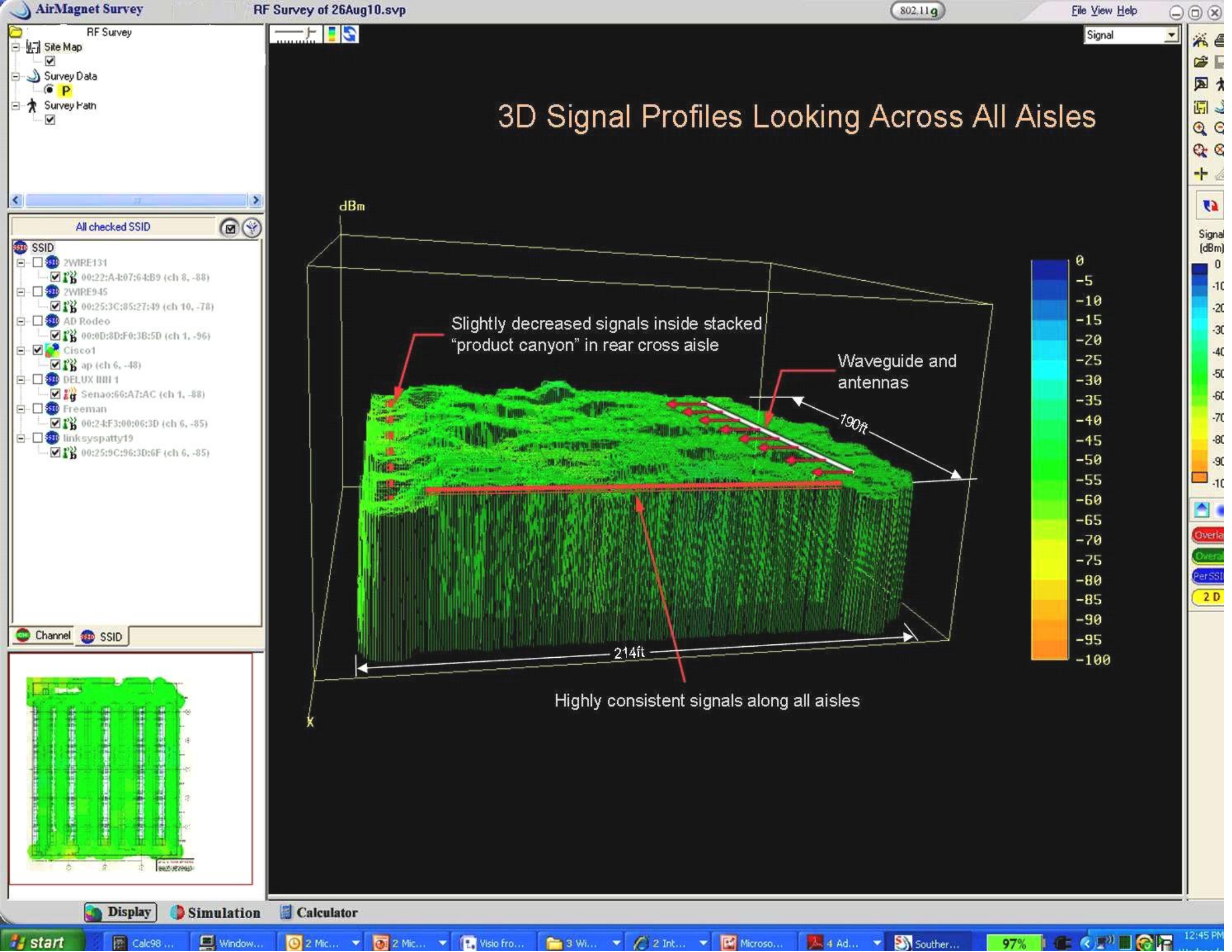
The system efficiency (power into antennas vs. power into the waveguide) was ~80%.

The test also confirms that many variations in highly efficient system topologies can be easily configured using our waveguide approach.

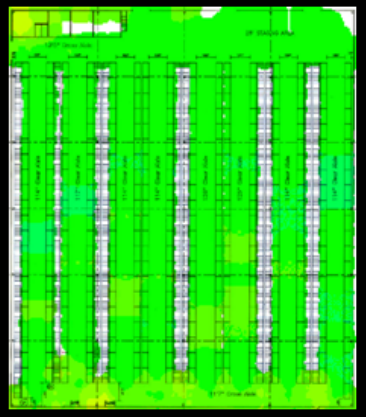



AirMagnet Survey
RF Survey of 26Aug10.svp
802.11g
File View Help
RF Survey
Site Map
Survey Data
P
Survey Path
All checked SSID
SSID
2WIRE131
00:22:A4:07:64:B9 (ch 8, -88)
2WIRE945
00:25:3C:85:27:49 (ch 10, -78)
AD Rodeo
00:0D:8D:F0:3B:5D (ch 1, -96)
Cisco1
ap (ch 6, -48)
DELUX IIII 1
Senao:66:A7:AC (ch 1, -88)
Freeman
00:24:F3:00:06:3D (ch 6, -85)
linksyspatty19
00:25:9C:96:3D:6F (ch 6, -85)
Channel
SSID
Signal
3D Signal Profiles Looking Across All Aisles
dBm
Slightly decreased signals inside stacked "product canyon" in rear cross aisle
Waveguide and antennas
190ft
214ft
Highly consistent signals along all aisles
X
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100
Signal (dBm)
2 D
Display
Simulation
Calculator
start
97%
12:45 PM

Projected Configurations Based on Field Test Data

Client loading is normally not a factor in a warehouse Wi-Fi system since devices, such as handheld bar code scanners, burst short messages from clients using 11Mbps 802.11b. Additional applications, e.g. VOIP phones and devices that require higher signal availability or speed can be added to the same waveguide backbone on 1 or 2 *separate* channels at minimal cost. Channels 1, 6, and 11 may be combined on a waveguide and will be equally propagated to ALL client areas. The additional channel(s) can also be used for backup. Other configurations can be extrapolated from the test data.

Using the documented 40.6ksqft warehouse as a basis for iteration:

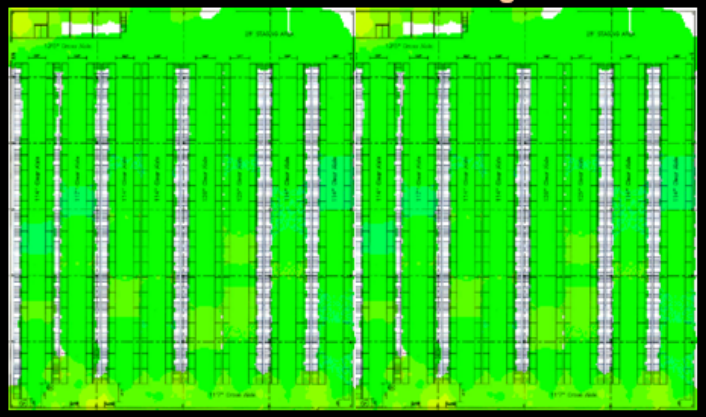


Add a **Second AP** to the waveguide on a second channel for redundancy or a separate application, e.g. VOIP phones

Reduces receive margin by: 2dB
Remaining margin: 18-33dB

Both channels appear equally everywhere. This option can be easily added to a basic one-channel WEI system.

Cover **2 warehouses** using **1 AP**



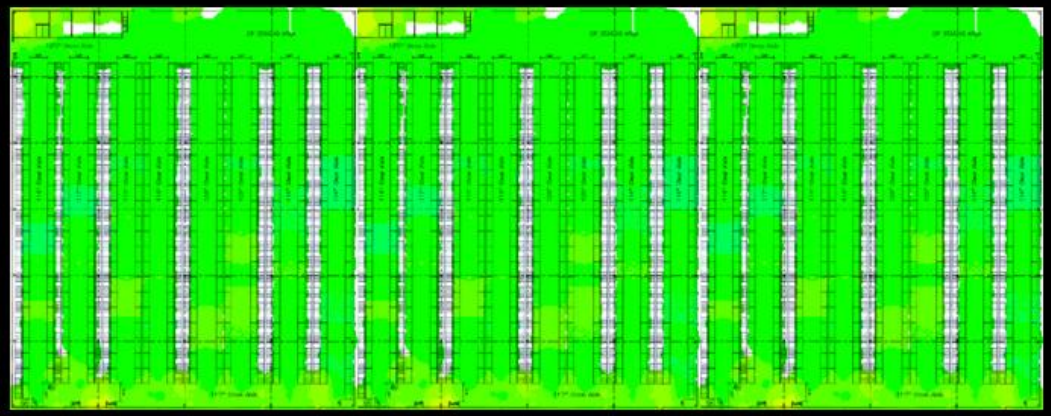
Total coverage area: **81ksqft**

Reduces receive margin by: 5dB to each warehouse

Remaining margin: 15-30dB

Projected Configurations Based on Field Test Data …cont.

Cover **3 warehouses** using **2 APs,** both of which appear in all **122ksqft**

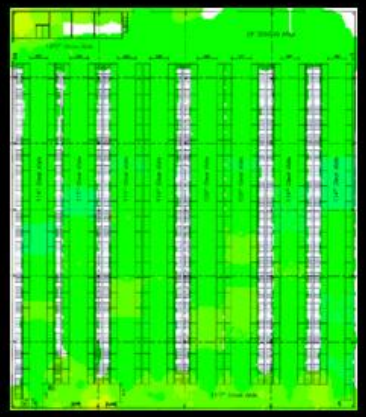


Total coverage area: **122ksqft**

Both APs appear everywhere.

Reduces receive margin by: 9dB
Remaining margin: 11-26dB

Cover **1 warehouse with low client transmit power**



If the rear cross aisle was clear of obstructions, this entire warehouse could be covered with **all client devices running 5mW transmit** level, enabling an increase in client battery lifetime before recharge. Signal receive margin would be ~ 10dB at the AP.

Notes: tandem waveguides may be connected through intervening walls with a signal loss of ~ 1dB per interconnect between them.

Special areas, such as dock offices, coolers, etc., may be covered with narrow beamwidth antennas placed at the waveguide or carried over coaxial extension cables to the area to be covered.

The main waveguide may be fed from either end or the middle. One or more waveguide branches may be attached to the main waveguide to service special areas.

Summary

- The guesswork is taken out of wireless network design and deployment -- the system can be accurately preconfigured to fit each user environment
- Signals are “taken to the user” over a very high efficiency, low-loss (0.4dB/100ft) waveguide backbone that, in effect, “short circuits” free-space and clutter loss
- Signal levels to each antenna are adjustable over a 40dB range by variable signal couplers on waveguide ports for precise, prescribed user area illumination
- Antenna pattern and gain are matched to the requirement in each client area
- Far fewer access points, port switches, AP controllers, wiring, etc., are needed to implement high-quality large-area indoor systems
- Roaming among access points by clients attempting to establish a suitable link is virtually eliminated since high-quality signals are available in all areas
- Signal levels outside the facility are reduced in the design of each system to improve data security by limiting radiation into external areas and reducing incoming interference to APs in the warehouse from external sources
- Co-channel interference among access points inside a facility is virtually eliminated, allowing maximum client access and data throughput
- Highest data rates and minimum transmission delays are provided everywhere
- The system described here is also very applicable to manufacturing sites

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