AIRHEADS 2013

Large Public Venues and High Density Environments

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Agenda

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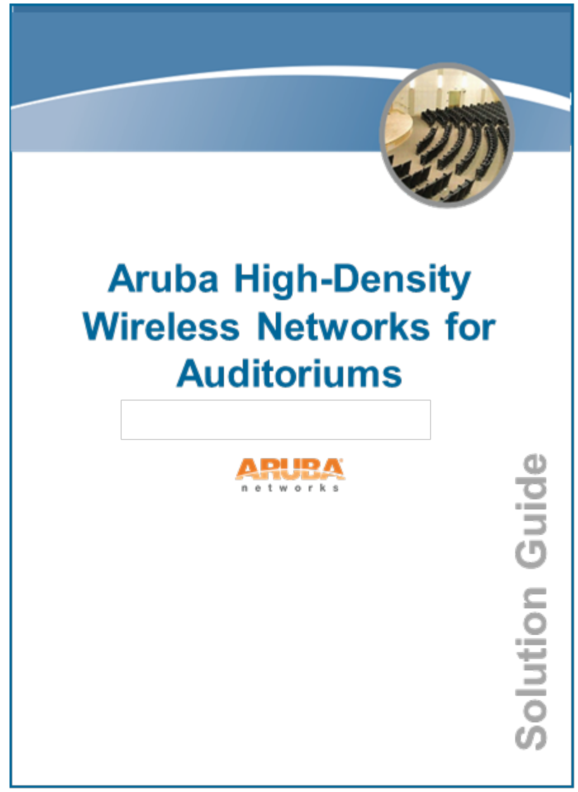
HD/LPV WLAN Update 2013

- Terminology
- Planning and Capacity
- Key Design Goals
- RF and Antennas
- Configuration Notes
- Coming Soon…
  - ARM 3.0 benefits
  - Multicast?

Background

- Aruba Networks produces a library of Validated Reference Designs
- The High Density (HD) WLANs VRD covers ultra high capacity spaces such as auditoriums, arenas, stadiums and convention centers
- The recommendations have been field proven at dozens of customers
- VRDs are free to download from Aruba Design Guides web page:

  http://www.arubanetworks.com/VRD



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HD/LPV WLAN UPDATE 2013

- **This presentation should be considered an update to the HD WLAN VRD (1st published 2010)**
- **Information is supplemental**

Key Differences

- The VRD focused primarily on concurrent usage by clients of similar type, all within range of each other, in a clean/ controlled environment
- This update supplements the VRD with recommendations based on deployed venues having a much broader mix of client types, some clients within range (coordinating), some clients interfering (hidden node), and all in "unclean" environments.

HD and LPV Terminology

HD/LPV Terminology Update

- Experience in HD/LPV environments has forced a rethink of some terminology related to users and devices
- Some users have multiple devices
- Some devices are associated but not active
- For LPVs in particular, tighter definitions of devices/users/active/inactive/associated are helpful for planning and capacity analysis

Terminology Update

- **Terminology for HD/LPV WLAN environments**
  - ***Facility Capacity***
    - The maximum stated capacity of the venue or space where WLAN coverage is desired. Stated in units of "people", or "seats"
  - ***Maximum Device Count***
    - The expected maximum device count. Usually a percentage of facility capacity with adjustments for expected client behavior
      - Example 1: A large stadium maximum device count is expected to be 60% of the facility capacity based on the unique mac addresses measured in the air, e.g.12,000 unique MAC addresses in a 20,000 seat arena.
      - Example 2: A university stadium or smaller venue is expected to approach 120% of facility capacity based on multiple devices per user.

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Terminology Update

- **Terminology for HD/LPV (cont)**
  - ***Associated Device Count***
    - Count of devices associated to the infrastructure within any 5 min window
      - 5 mins is the recommended Hotspot 2.0 timeout, and semi-industry agreed method to count associated devices for LPVs,
      - If no traffic (not a single packet) passes in 5 mins, then user is timed out and no longer counted as "associated"
      - Because clients in this category have done something in the past 5 mins, they can be considered "concurrent" users, i.e. concurrent within a 5 mins period

Terminology Update

- **Terminology for HD/LPV (cont)**
  - ***Active Devices***
    - Devices actively sending/receiving data at any instant in time, usually at maximum available throughput/bandwidth that their device and the environment will support.
    - Active Devices area a subset of associated devices

- This is the type of device used to generate all the scaling results in the HD VRD !

Terminology Examples

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- **A 22,000 seat arena typically has 12,000 devices that can be seen over the air**
  - Maximum Device count = 12,000
- **Within any 5 minute window, "show user role all" shows approximately 1,000 – 1,500 devices are associated to the infrastucture**
  - Associated Devices count = 1,000 to 1,500
- **At any moment in time "show ap association ap name ap-name" shows approximately 30-50 users are on each AP**
  - Per AP associated device count is 30-50
  - But, how many of these are "active" users?

Terminology Example

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- **Active Devices / Active Users**
  - Active devices/active users is the most difficult metric to define
  - The bandwidth required to support them will depend heavily on the applications offered (video vs. general internet use)
  - Based on analysis of deployed stadiums, we know that active devices are a subset of associated devices, i.e. not every device associated in a 5 min window is trying to send/receive data at exactly the same time using their maximum available connection speed.
  - Devices with faster connection speed will need less time to transact a fixed payload (i.e. not streaming),
  - Streaming applications need different budget/analysis/activity model than general internet use

Planning and Capacity

Planning and Capacity

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- Suggested models for planning are based on analysis of data in deployed venues ranging in size from 7,000 to 70,000 capacity.
- Indoor and Outdoor venues inclusive
- Data is roughly consistent for several metrics across these facility sizes and in published reports for other large venues (non-Aruba deployments)

Planning and Capacity

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Planning and Capacity Analysis Process

1. Ensure enough APs are available for the expected Maximum Associated Device Count
2. Estimate per client bandwidth required for active devices based on anticipated applications

Planning Metrics – Large Stadiums

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Client Session Summary	
Number of unique clients:	
Average session duration:	
Total traffic (MB):	
Average traffic per client (MB):	
Average bandwidth per client (Kbps):	

Typical Values

- Number of unique clients: This is the total number of devices that connect during a game or event, ~15-20% of facility capacity
- Average session duration: 5-10 mins (due to timers set to 5 min)
- Total traffic (MB): Multiply unique clients x traffic per client
- Average traffic per client (MB): 5 Mbytes – 15 Mbytes
- Average bandwidth per client (Kbps): “Average” not “Peak”. These numbers are typically very low over 5 min period, 6-20 kbps

Above is representative of general internet use on smartphone type devices – what about video?

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Video Planning – Two Cases

- **Case 1: Live Streaming (e.g. Yinzcam)**
  - The required per user bandwidth is calculated from the stated application bandwidth, example 300 kbps.
  - Usage counts must be realistically estimated- not everyone is going to sit there and watch the video feed
  - Large scale deployments with these types of applications REQUIRE 5 GHz in the support model, simply not enough bandwidth in 2.4 GHz to support significant numbers of clients on live video (a few maybe in the mix, OK, but not thousands)

Video Planning – Two Cases

- **Case 2: Video Replay**
  - Video Replay is a concurrent usage driver, as multiple users try to download the same clip simultaneously
  - Can also drive concurrency for authentication, captive portal, etc. as users try to get devices online to access the replay.
  - Peak loading considerations for replay
    - 15 second H.264 replay video, 320x240 size, ~1 Mbyte
    - Assume 1000 fans want to view at the same time, ~1 Gbyte of data to download
    - Can the infrastructure support this? How quickly?

Max Associations

- A per radio limit of 250 associations is possible, i.e. 500 associations per dual radio AP with 50/50 balancing of 2.4 GHz and 5 GHz bands
- Max concurrent associations is typically ~100 in 2.4 GHz and 20-30 associations on 5 GHz
- For planning purposes, a designed coverage area allowing for 100-250 max associations per 2.4 GHz radio should be considered an “HD” deployment.
- Consideration for 5 GHz can be given to this number, typically 20-30% in 2012. This can be used to increase the expected coverage area based on max associations to 120-325 max associations per dual radio access point.

Planning and Capacity Analysis

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- Since there are many, many variables a "Heuristic" approach to planning and capacity analysis may be the best strategy
- At each stage in the analysis, parameters can be "tweaked" based on expectations such as user counts, device counts, etc.
- At the end of the process we have to check the results against known limitations, such as AP max associations or throughput/bandwidth constraints.
- In other words – We have to start somewhere!...

….But when we are finished lets double check if things still make sense

Planning and Capacity Example

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LPV: General Internet Use Smartphones

			Expected Associations			Active Devices			Per AP Associations			Per AP Active Devices			Per AP Estimated Uplink
Area	Seats	APs	2.4 GHz	5 GHz	Total	2.4 GHz	5 GHz	Total	2.4 GHz	5 GHz	Total	2.4 GHz	5 GHz	Total	Average (Mbps)
Section 118	734	5	138	46	184	69	23	92	28	10	38	14	5	18	0.490666667
Section 117	1366	9	257	86	343	129	43	172	29	10	39	14	5	19	0.508148148
Section 116	1066	7	200	67	267	100	34	134	29	10	39	14	5	19	0.508571429
Section 314	811	5	153	51	204	77	26	102	31	11	42	15	5	20	0.544
Section 321	1002	7	188	63	251	94	32	126	27	9	36	13	5	18	0.478095238
Section 110	378	3	71	24	95	36	12	48	24	8	32	12	4	16	0.422222222

Step 1: Start by listing sections, capacity and rough number of APs in a spreadsheet. This is like reading a book by the last chapter first. We start where we want to end up, so initial AP counts may be based on such considerations as budget or rough notional density goal. Above example uses 1 AP per 150 seats as the starting point, could be 1 per 250 or 500. Just plug in a number!   We ARE going to double check everything...

Planning and Capacity Example

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LPV: General Internet Use Smartphones (cont.)

			Expected Associations			Active Devices			Per AP Associations			Per AP Active Devices			Per AP Estimated Uplink
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Section 110	378	3	71	24	95	36	12	48	24	8	32	12	4	16	0.422222222

Step 2: Next, estimate the expected associations.

This example used 25% of seats as total expected associations, with 25% of associations on 5 GHz and 75% on 2.4 GHz.

Planning and Capacity Example

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LPV: General Internet Use Smartphones (cont.)

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Step 3: Estimate the Active Devices

In this example, Active Devices are estimated at 50% of associations, i.e. only half the total devices that will connect over the course of the event are connected at the same time and “doing something”.

Planning and Capacity Example

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LPV: General Internet Use Smartphones (cont.)

			Expected Associations			Active Devices			Per AP Associations			Per AP Active Devices			Per AP Estimated Uplink
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Section 110	378	3	71	24	95	36	12	48	24	8	32	12	4	16	0.422222222

Step 4: Check the per AP associations

This is the first of several checks. Do we have enough APs in each section to handle the expected associations? We want these numbers to be below 250 for both radios

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Planning and Capacity Example

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LPV: General Internet Use Smartphones (cont.)

Area	Seats	APs	Expected Associations 2.4 GHz	5 GHz	Total	Active Devices 2.4 GHz	5 GHz	Total	Per AP Associations 2.4 GHz	5 GHz	Total	Per AP Active Devices 2.4 GHz	5 GHz	Total	Per AP Estimated Uplink Average (Mbps)
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Section 110	378	3	71	24	95	36	12	48	24	8	32	12	4	16	0.422222222

Step 5: Check the Active User Counts

The second check. Do we expect the AP can handle the active device counts shown given the available applications in the venue? The HD-VRD is an excellent source for this information, it is based on "active" devices (next slide).

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Planning and Capacity Example

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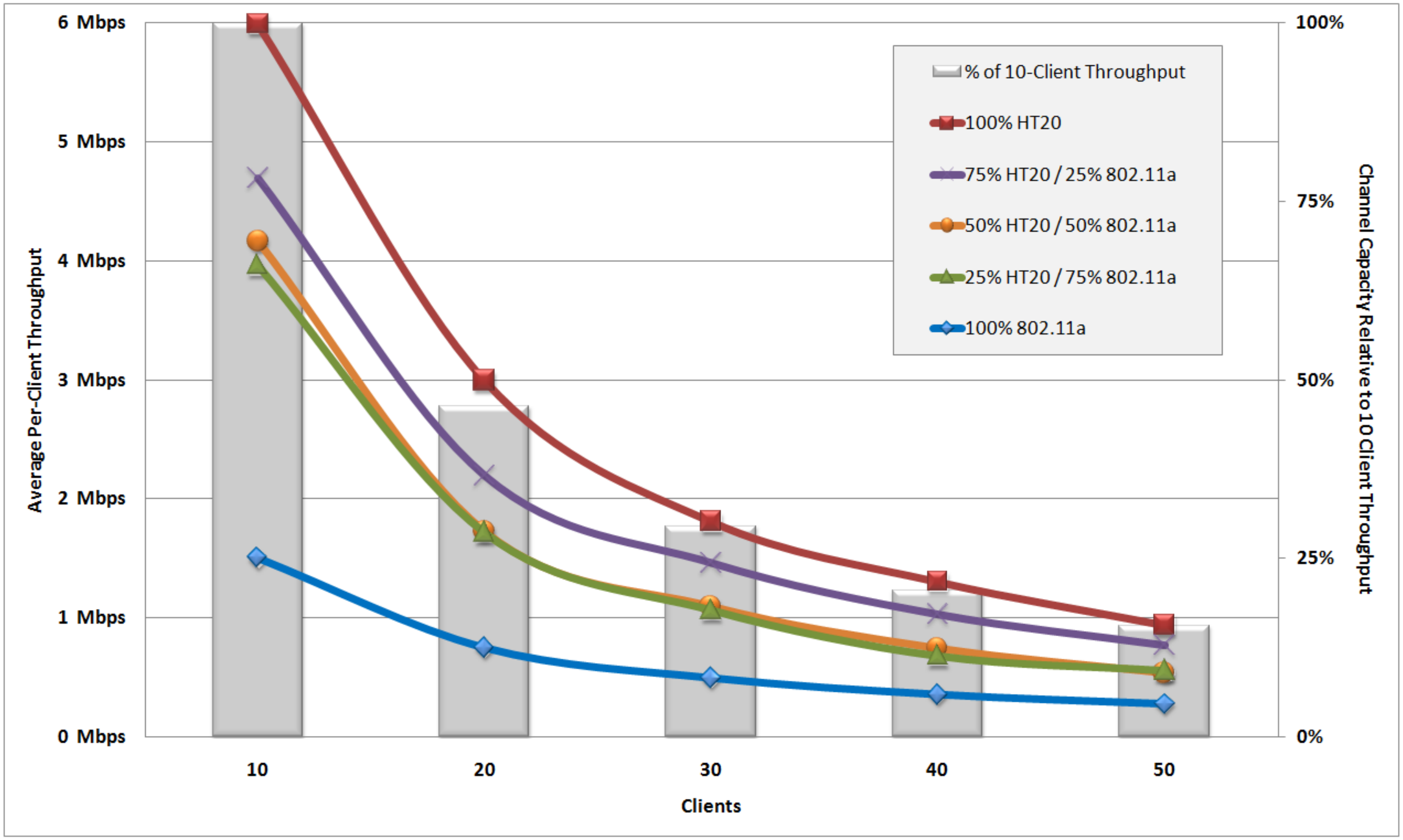
Active Device Testing Results (AP12x)



Planning and Capacity Example

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LPV: General Internet Use Smartphones (cont.)

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Section 110	378	3	71	24	95	36	12	48	24	8	32	12	4	16	0.422222222

Step 6: Uplink Estimate

For general internet use, 20 kbps is a good estimate for uplink budget per user
For video or other applications scale accordingly or breakout another column under active devices for different application budget bandwidths to roll up to the link estimate

Planning and Capacity Example

- By performing work in a spreadsheet, totals by section, by IDF, and eventually for the WLAN system venue wide can be estimated
- In the above example, the initial target of 1 AP per 150 seats may be overly conservative (over dense) if the intended application is truly internet use only. Likely this analysis would be re-run with 1 AP per 300 seats with same assumptions would double all the totals and still look pretty good (next slide)

Planning and Capacity Example

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LPV: General Internet Use Smartphones (cont.)

			Expected Associations			Active Devices			Per AP Associations			Per AP Active Devices			Per AP Estimated Uplink
Area	Seats	APs	2.4 GHz	5 GHz	Total	2.4 GHz	5 GHz	Total	2.4 GHz	5 GHz	Total	2.4 GHz	5 GHz	Total	Average (Mbps)
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Section 117	1366	4	257	86	343	129	43	172	65	22	87	32	11	43	1.143333333
Section 116	1066	3	200	67	267	100	34	134	67	23	90	33	11	45	1.186666667
Section 314	811	2	153	51	204	77	26	102	77	26	103	38	13	51	1.36
Section 321	1002	3	188	63	251	94	32	126	63	21	84	31	11	42	1.115555556
Section 110	378	1	71	24	95	36	12	48	71	24	95	36	12	48	1.266666667

Revised with target density 1 AP per 300 seats (rounded down to save cost). How do our per AP checks and uplink budget look now?

Planning and Capacity: Summary

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- **We need to adhere to the HD-VRD guidance for active devices. The number of active devices that can be supported depends on**
  - AP Type
  - Client Type
  - Applications to be supported
- **For general internet use in a large venue, max associations is also an important consideration.**
- **Proposed AP count per section must be expected to satisfy both max associations and active device requirements, but assumptions about usage and "uptake" are required to estimate the breakdown**
- **Example provided is pretty representative of deployed large venues today, i.e. 25% associations (uptake), 50% active, 25% on 5 GHz, 75% on 2.4 GHz. This may change by next year!**

RF Design for HD and LPVs

RF and Antenna Considerations

- Goals of the RF Design
  - Uniform, high signal strengths everywhere to support high association data rates in the venue
    - The higher the rates, the less time each client takes to download a transaction (such as load a webpage, or video replay file), the more time is then left available for other clients to do the same.
  - Minimize Interference between clients and APs on the same channels
  - IF possible, create opportunities to reuse channels, i.e. pico-cell design

Coverage Strategies for Auditoriums

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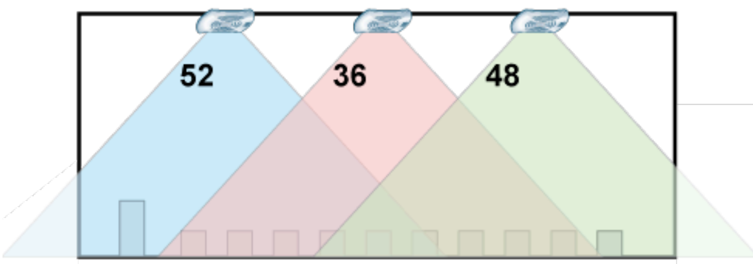
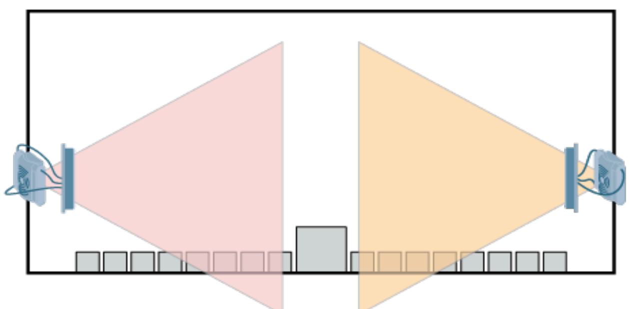
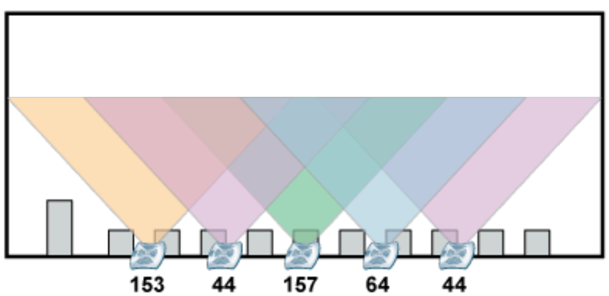


Overhead coverage is a good choice when uniform signal is desired everywhere in the auditorium



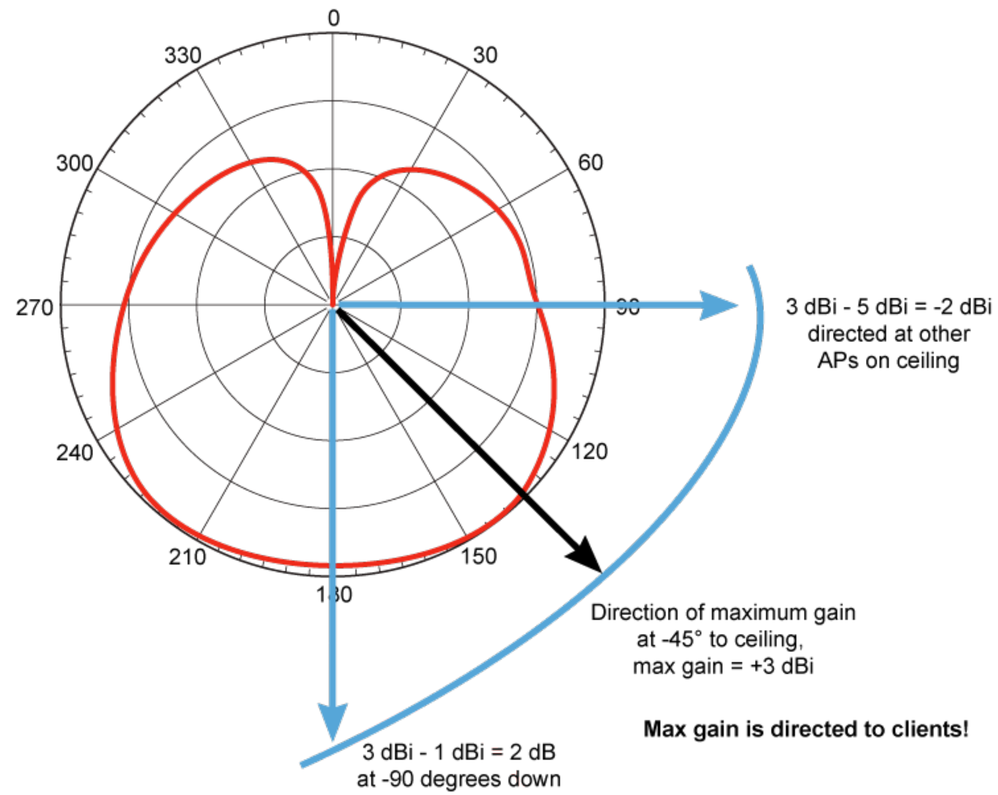
Wall installations are most often seen where ceiling or under-floor access is not possible or too expensive.

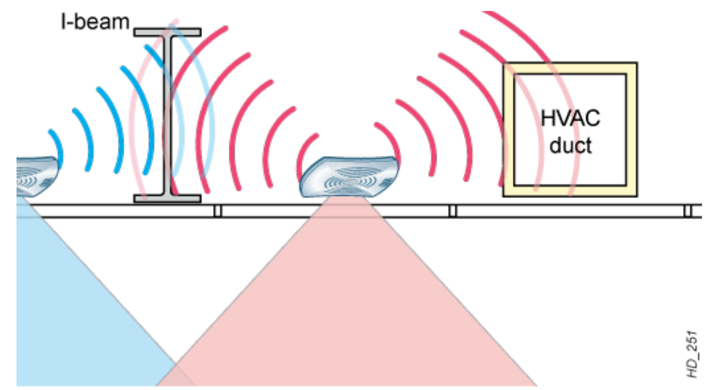


By far the best coverage strategy for auditoriums is mounting under, in, or just above the floor.

Overhead Coverage — RF Radio Patterns

E-Plane Antenna Pattern of AP135 produces a coverage pattern shaped like a "cone" underneath the antenna.





Use Attenuating Building Materials to Reduce AP-AP Coupling

Picocell Coverage - Link Budget Analysis

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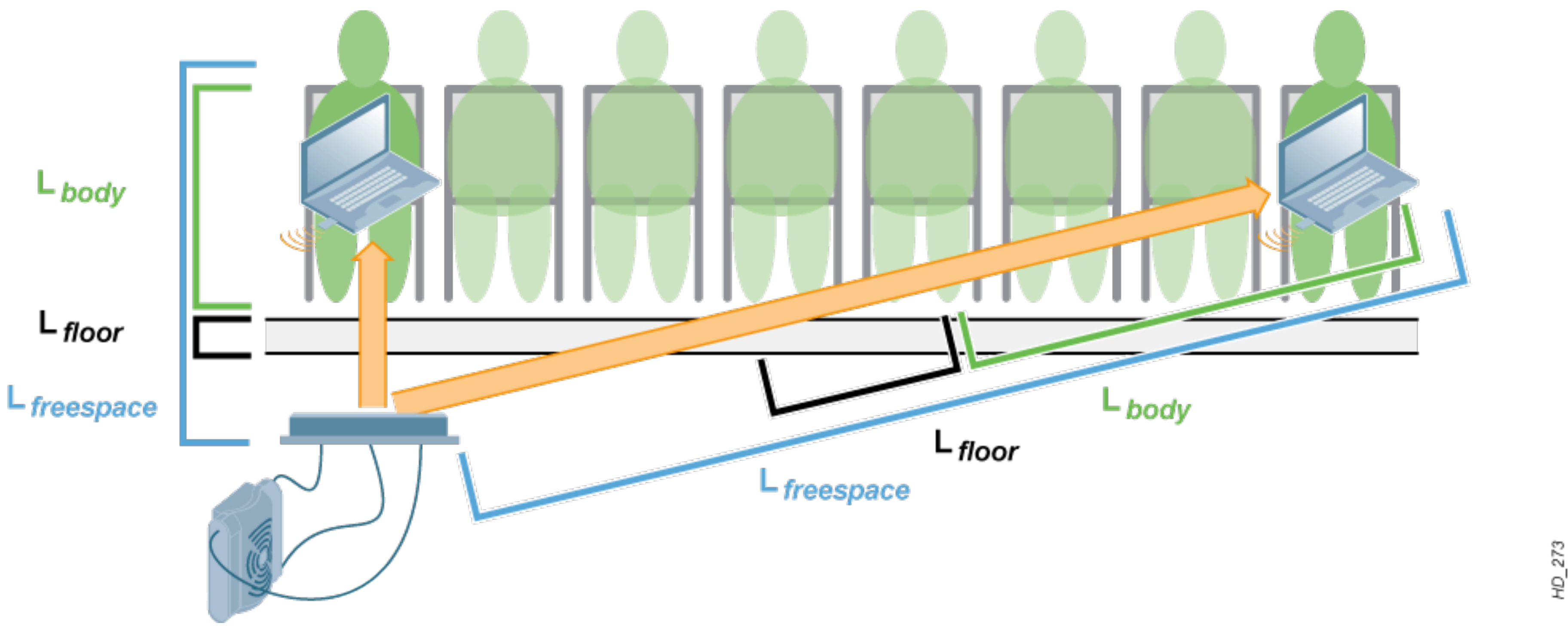

Picocell link budget formula

PRX = PTX – Lfreespace – Lfloor – Lbody + GTX + GRX

AP Coverage Strategies – Pros and Cons

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Strategy	PROs	CONs
Overhead Coverage	• Can be concealed inside ceiling. • Mounted above eye level. • Uniform signal, APs evenly spaced. • Clear line-of-sight to devices. • Minimal human-body attenuation. • Better CCI/ACI control.	• Channel reuse not possible. • Difficult to pull cable.
Side Coverage	• Easy to install and pulling cable. • Columns can be used to deliberately create RF shadows.	• Channel reuse not possible. • Inconsistent signal levels. • Increased body attenuation. • Harder to control CCI/ACI. • Signal bleed outside area.
Floor Coverage	• Channel reuse possible. • Higher AP densities can be achieved. • APs can be easily concealed. • More uniform signal in the room. • Clear line-of-sight to devices. • Minimal human-body attenuation. • Better CCI/ACI control.	• Access underneath the auditorium. • Availability of cable pathways beneath the floor.

Adjacent HD WLANs

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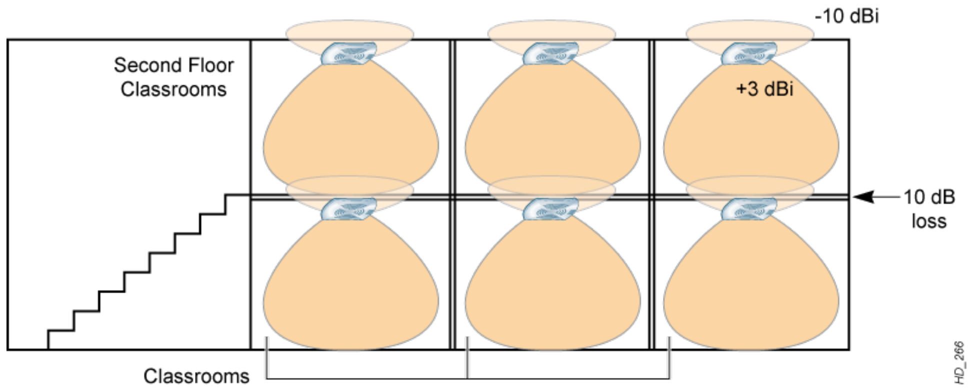
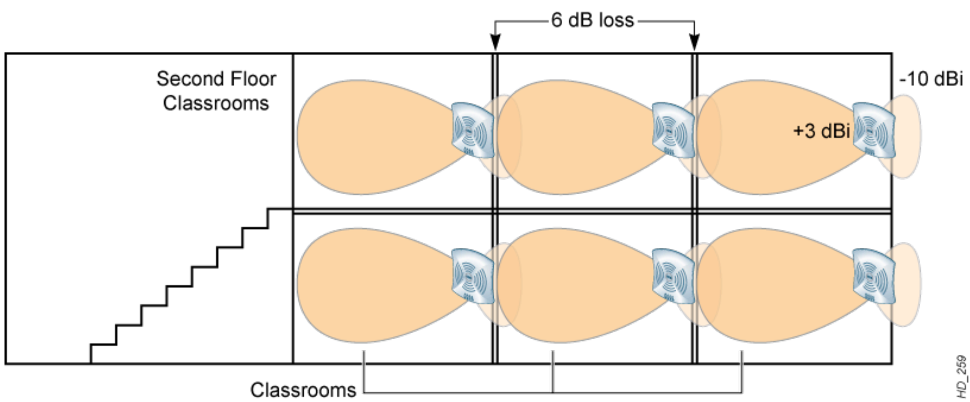
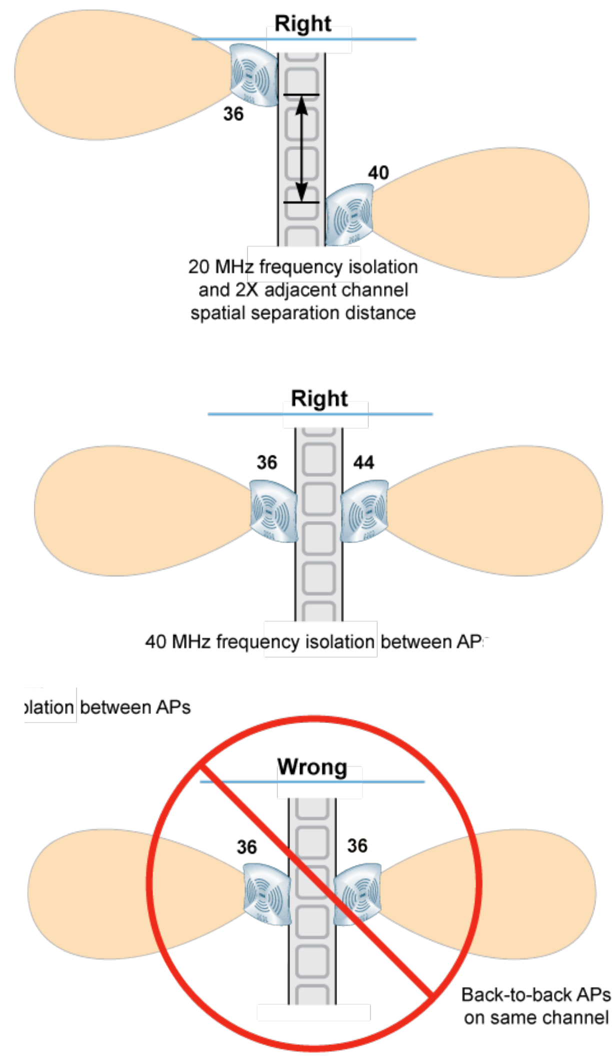


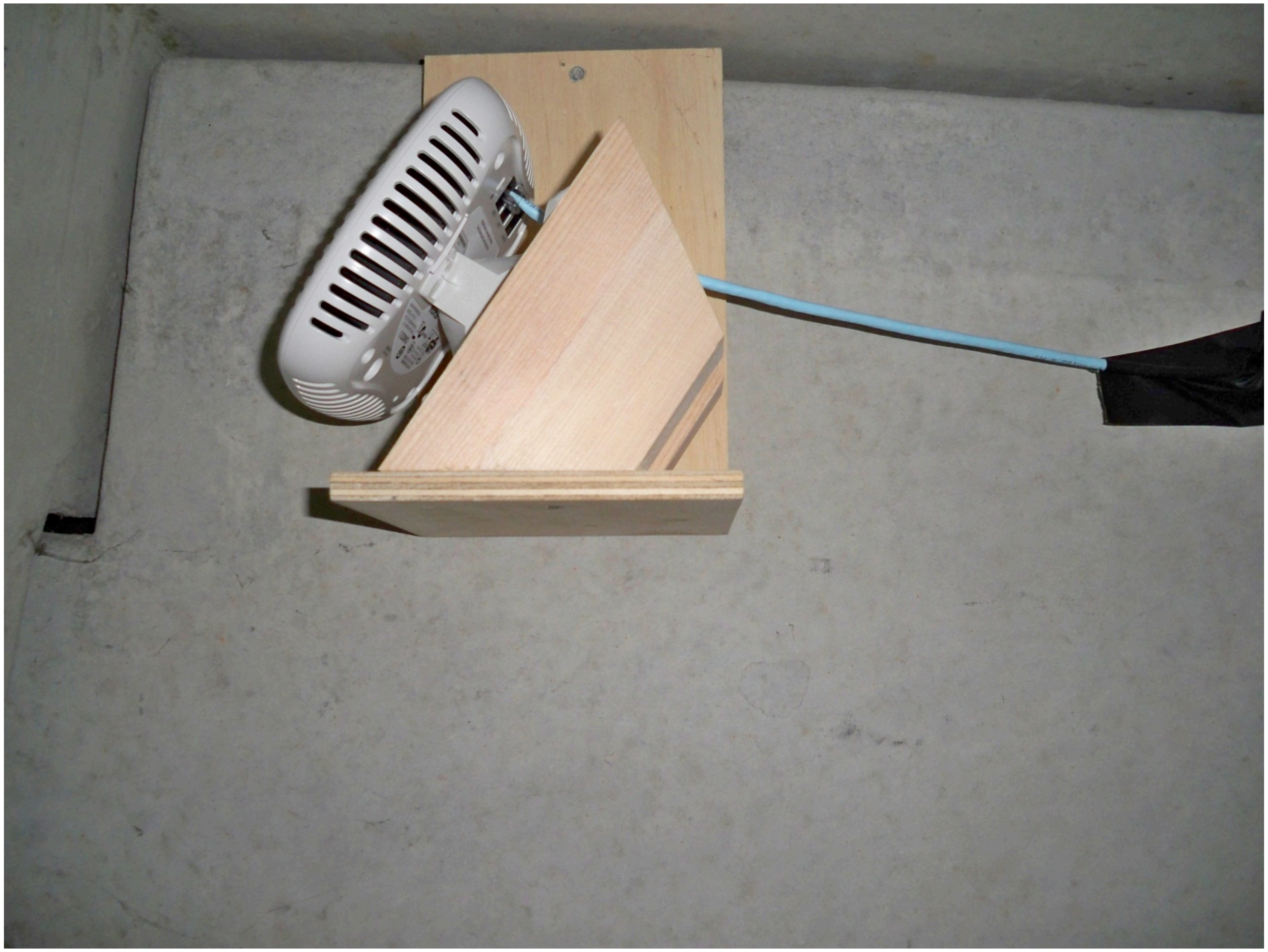
AP-105 Integrated Directional Antenna to Isolate Adjacent HD WLANs



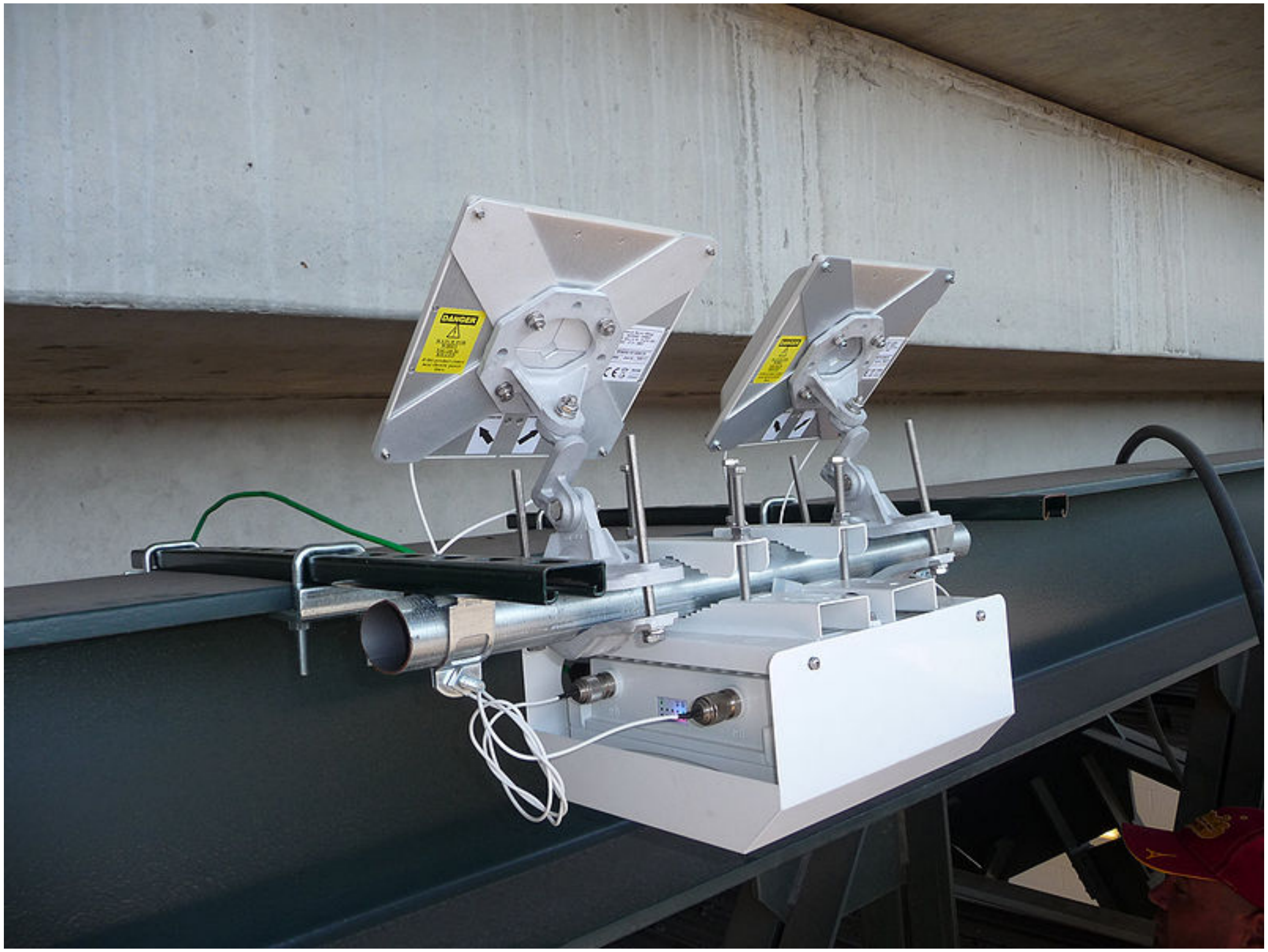


“Under-Seat” Installation

“Under Concrete” Installation

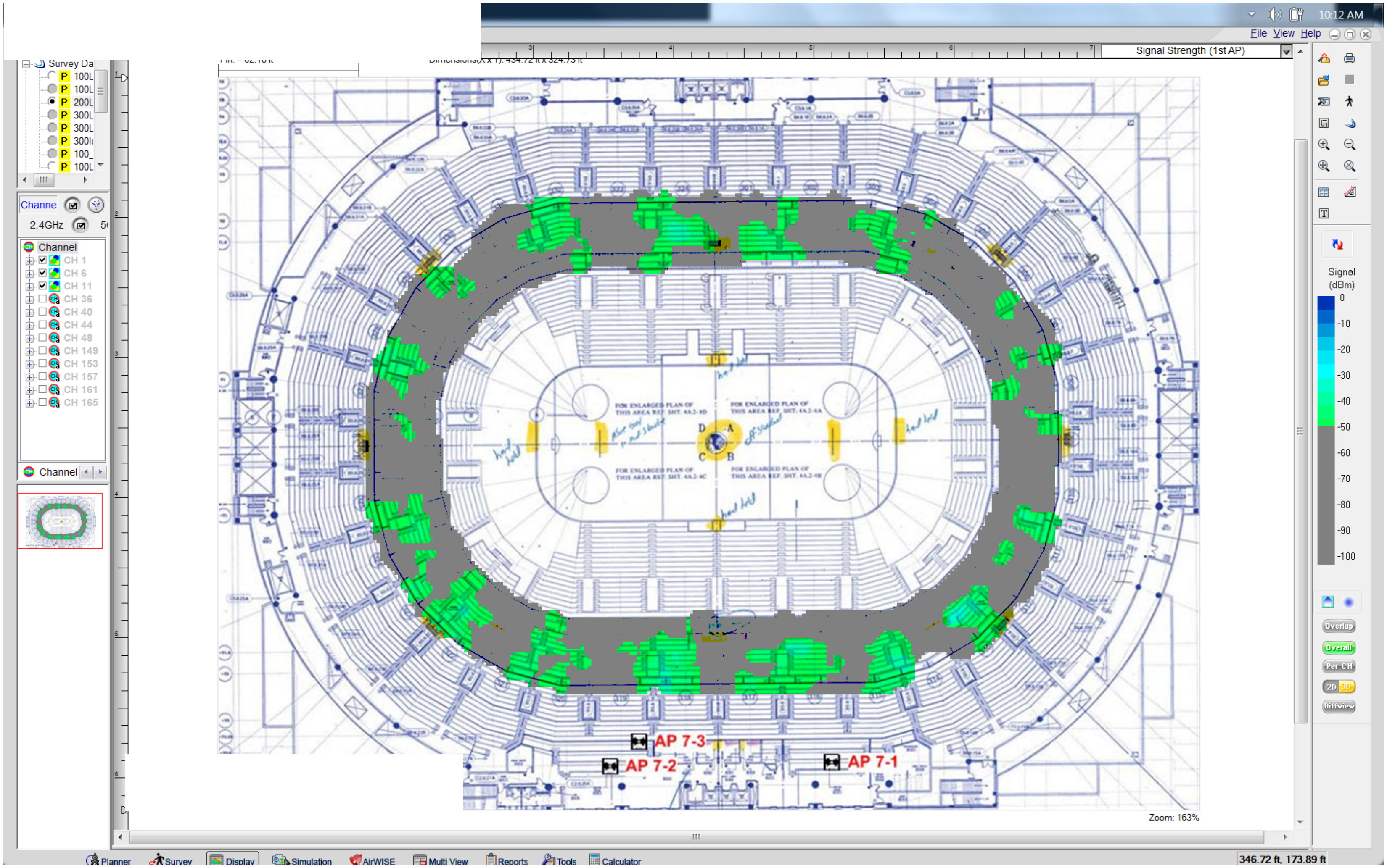


Under Concrete Example



Overhead Installation Example

Under Concrete: -50 dBm



Under Concrete: -55 dBm

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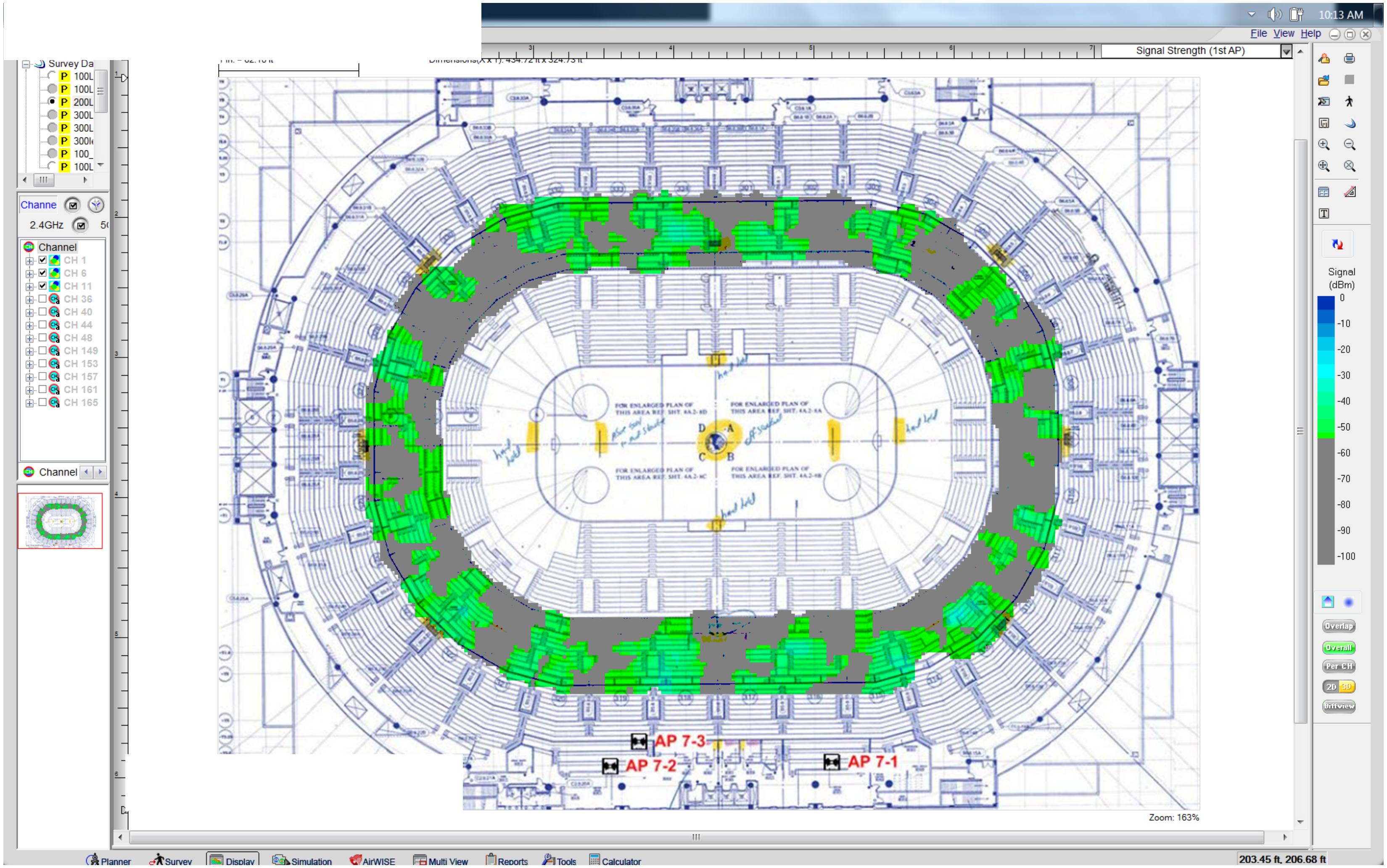

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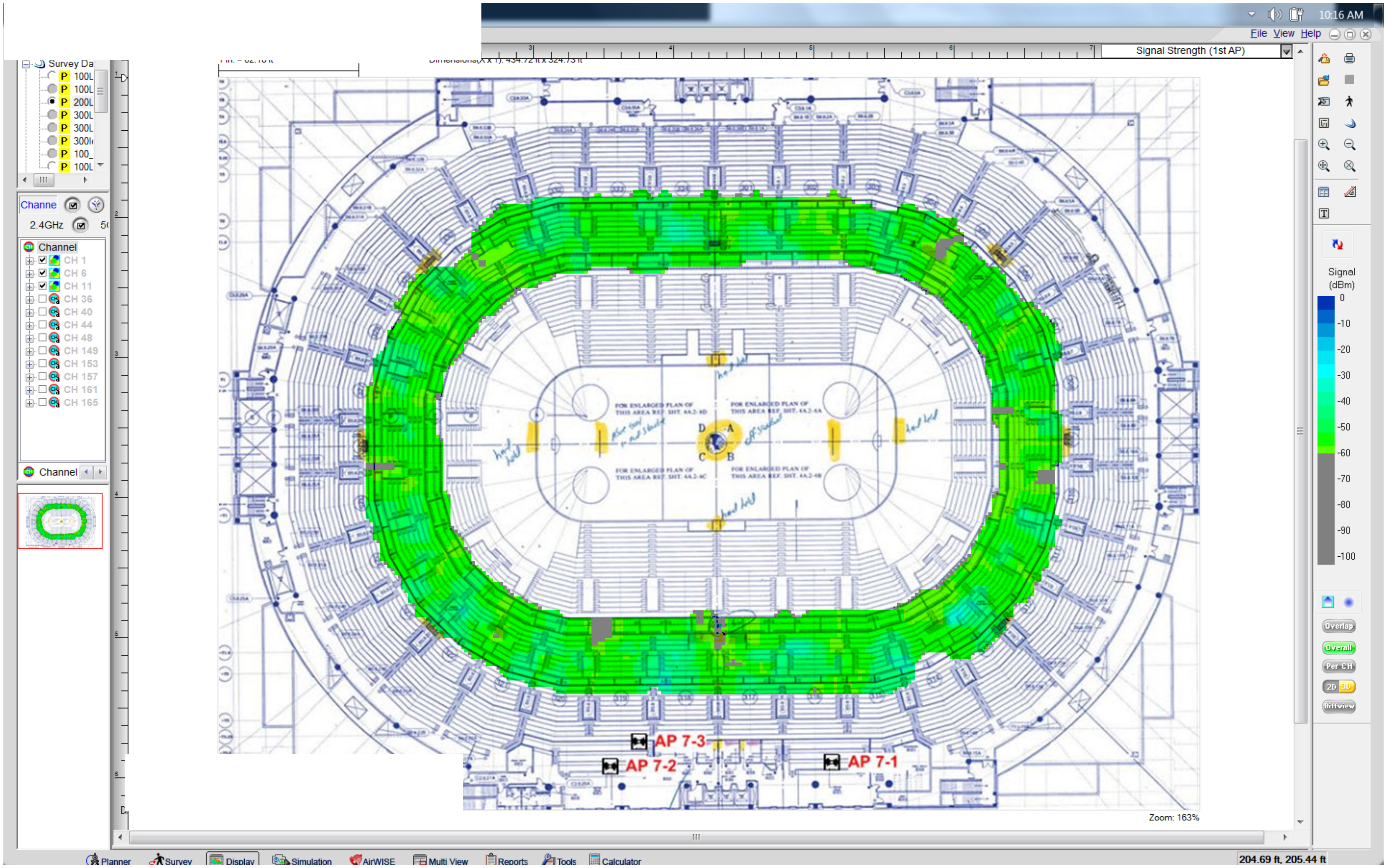
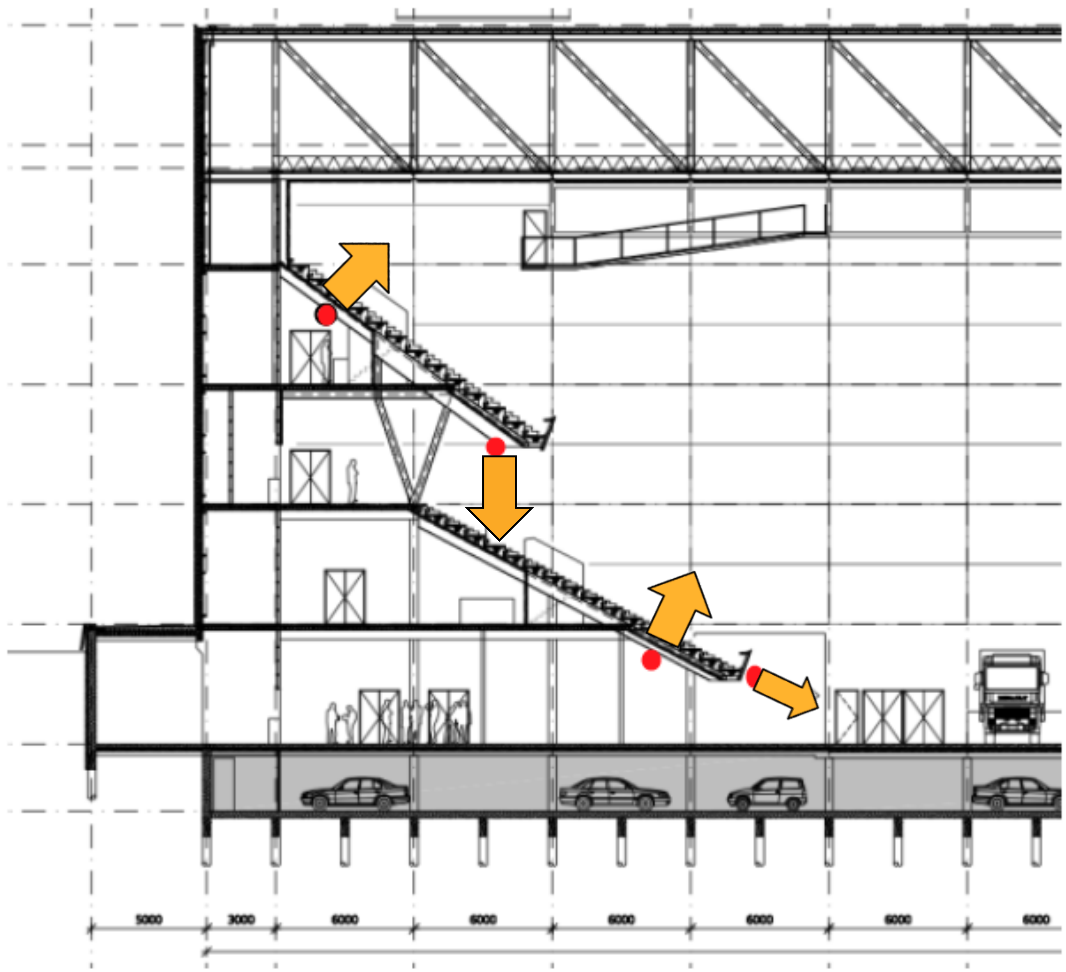
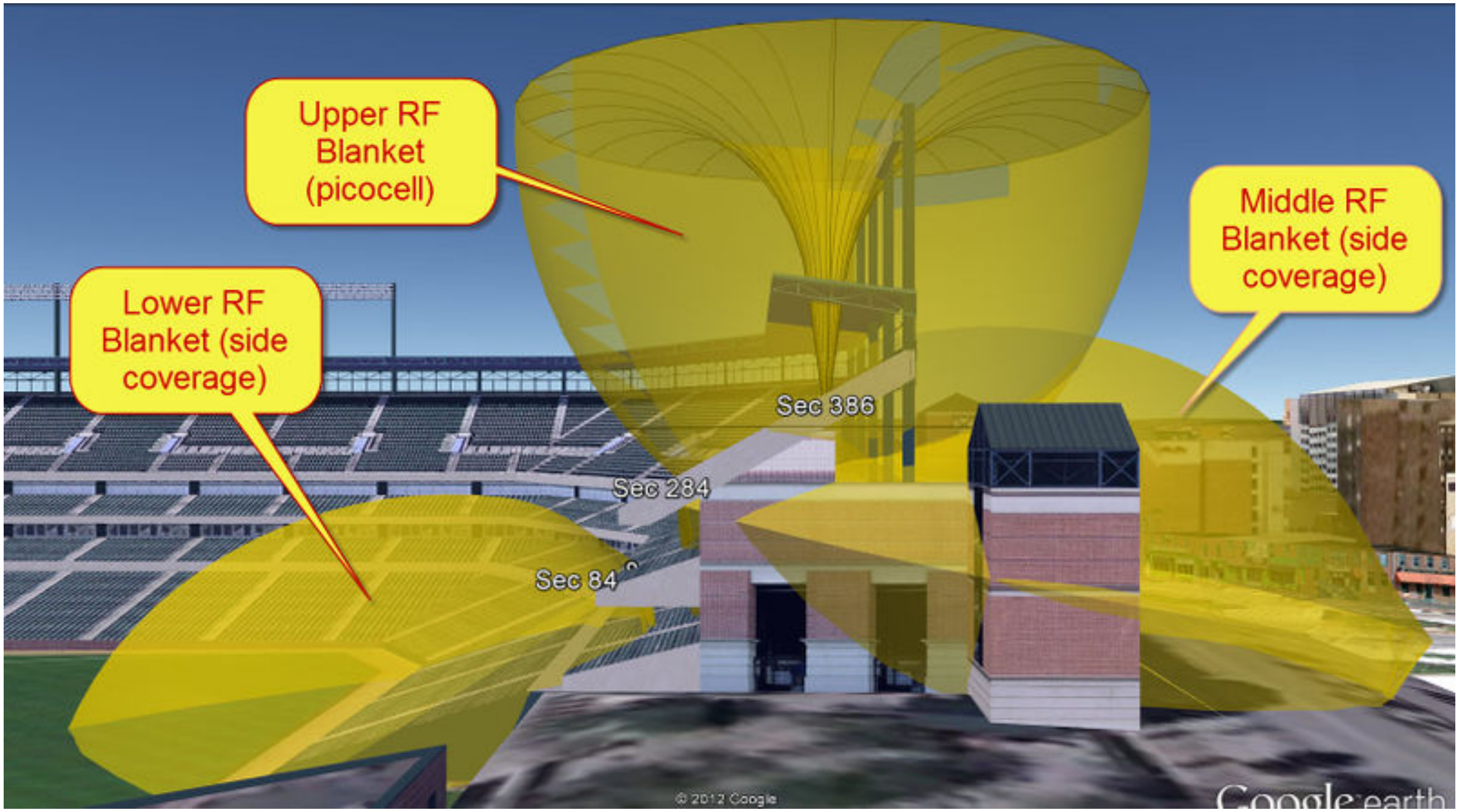
Under Concrete : -60 dBm



"Hybrid" Installation



“Hybrid” Installation



Multiple Installation Strategies can be used in a single deployment

Comparison of Install Methods

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Installation	Advantages	Disadvantages
Overhead	• Clear LOS to clients • High Gain/ Narrow Beam antennas useful • Easy to design/ sometimes easier to install	• Clear LOS between APs • Distance to Clients • Can be difficult to control coverage areas • May not lend to highest density (number of APs) due to limited mounting locations
Under Seat	• Easiest to Design, no survey required	• APs are in boxes under seats • Core drilling cost
Under Concrete	• APs can be hidden completely	• Detailed Design / RF Survey required • Not all structures can support this approach due to RF performance

Installation Considerations

From wikipedia on a recent stadium project research

"Controversy arose when entire rows of seating collapsed during the game. Each row of seats is fixed to an aluminium rail which in turn is mounted to the concrete floor. Some of the mounts proved too weak to withstand the weight of the crowds, breaking off as people began to *take their seats*."

Comment: RF not always the only consideration, local variables may have to be considered!

LPV Antennas

Stadium/LPV "30 Degree Sector" Antenna Comparison

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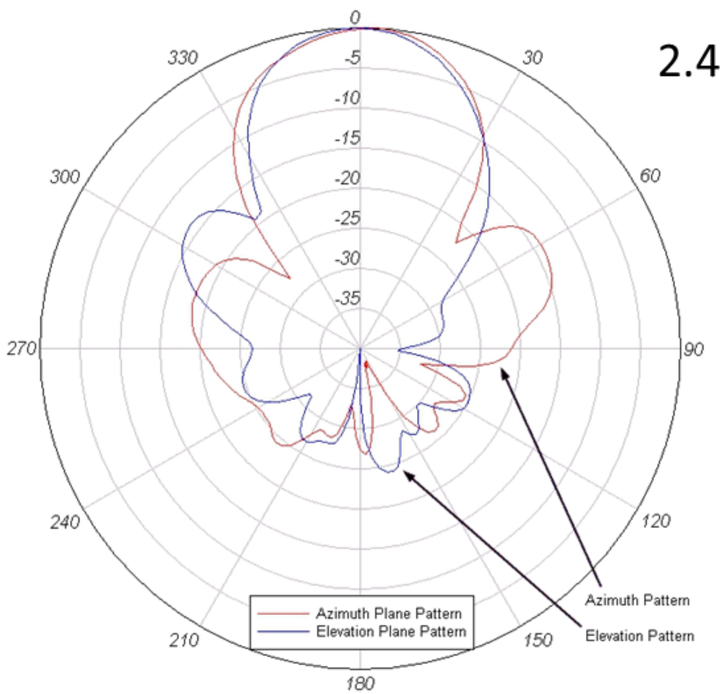
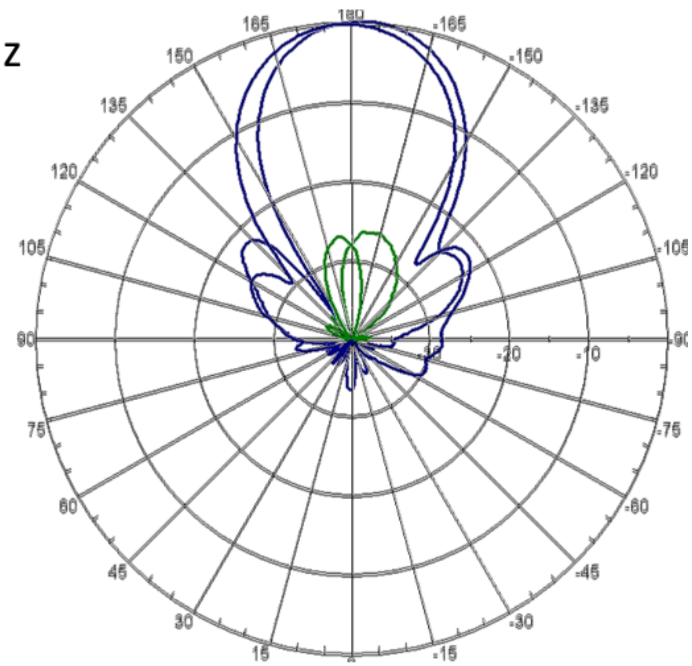


2.4 GHz



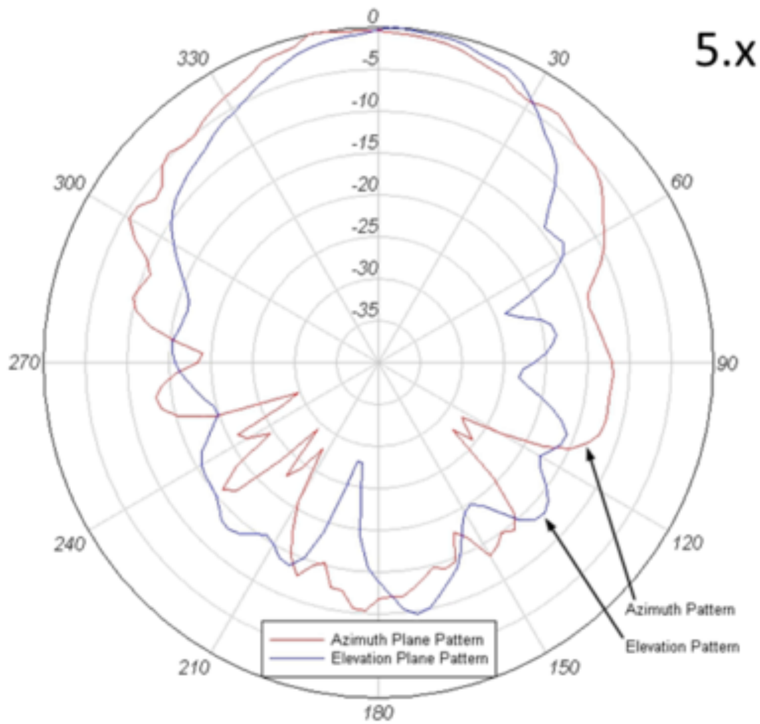
Cisco

Aruba

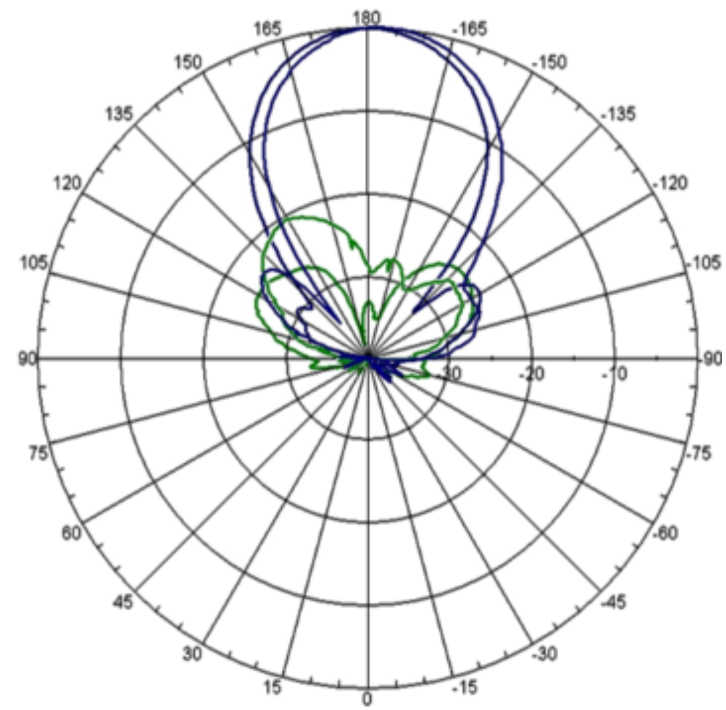
THESE ARE PLOTTED ON EXACTLY THE SAME SCALE

Stadium/LPV "30 degree Sector" Antenna Comparison

5.x GHz



Cisco



Aruba

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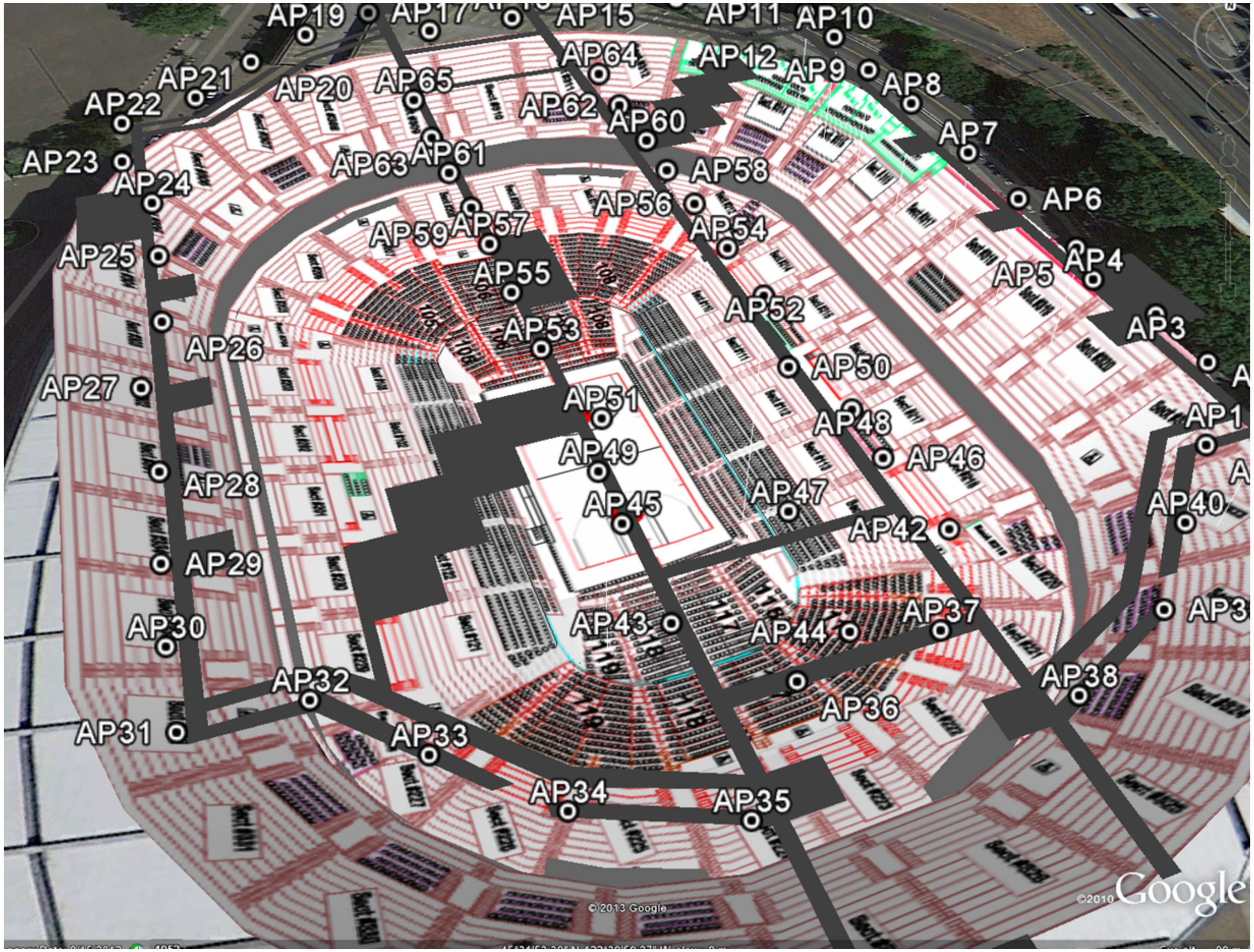
LPV Antennas

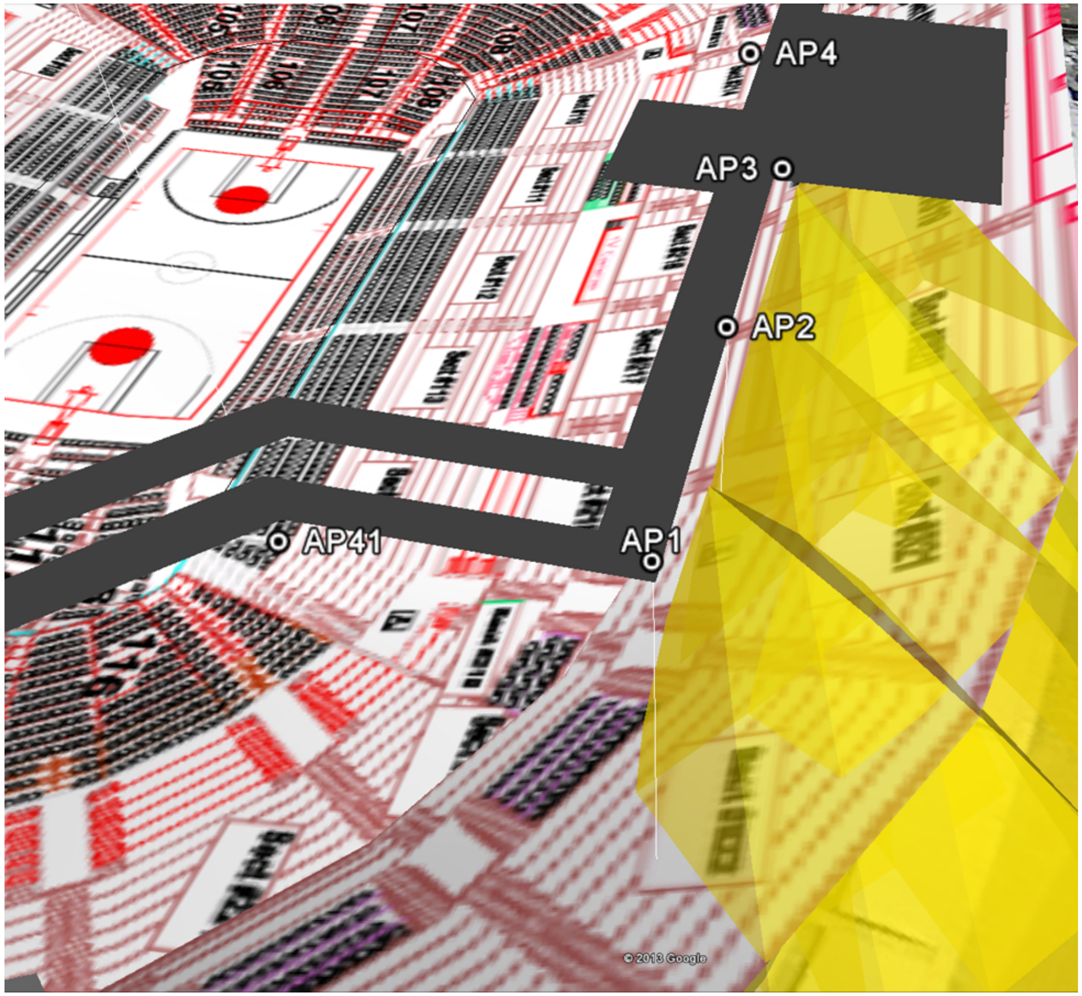
- **Narrow Beam antennas are useful for creating cells to areas that are otherwise hard to reach**
  - Example: front rows at a baseball stadium

- **Potential exists to use these types of antennas for overhead/catwalk deployment, although at lower density (~50%) of typical of under seat or under concrete deployment due to “2D” AP placement as opposed to “3D”.**

Catwalk Installation?

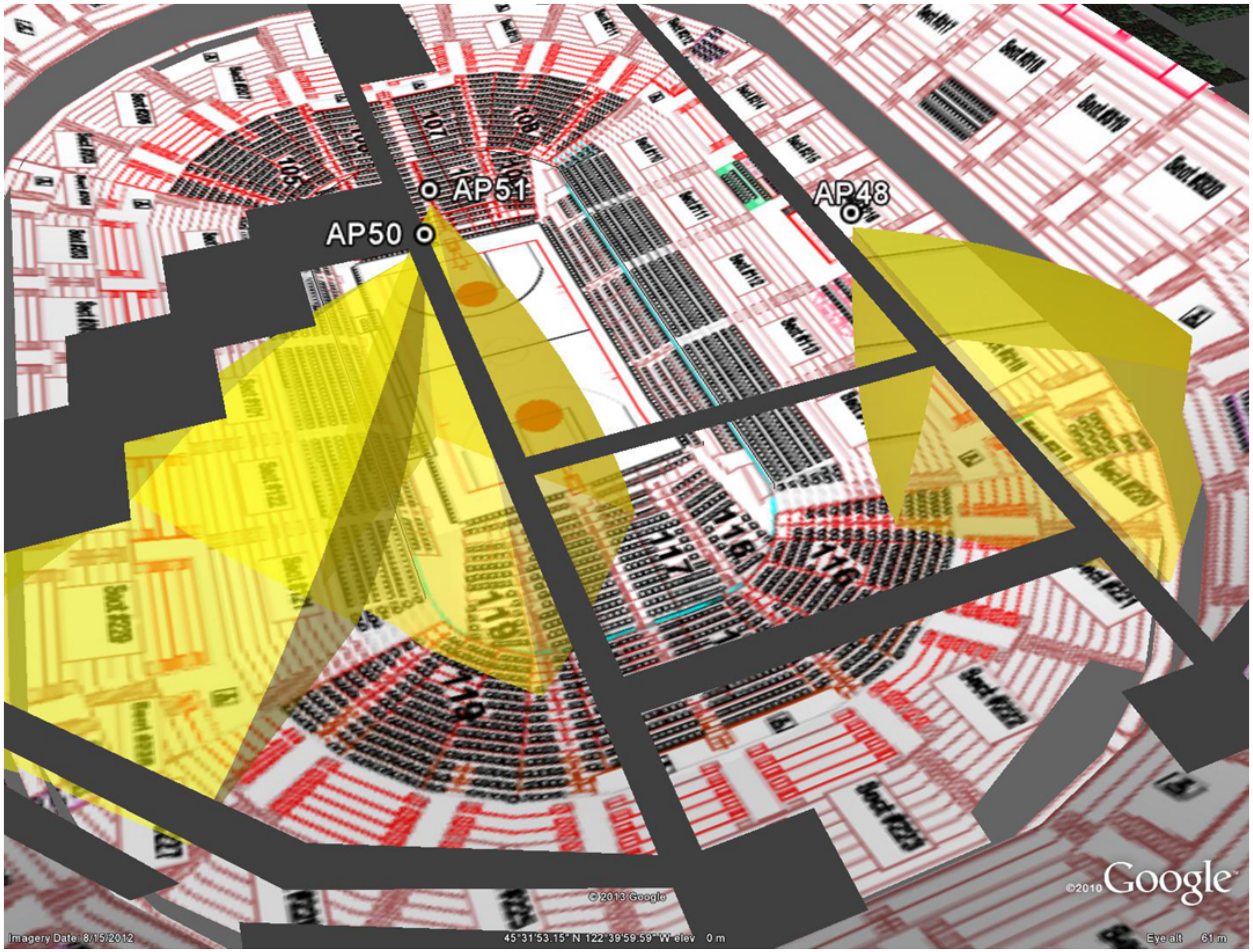


Outer Catwalks, Picocells?



-65 dBm coverage with Catwalk APs and ANT-2314/5314

Inner Catwalks, Different Angles



-65 dBm coverage with Catwalk APs and ANT-2314/5314

Configuration

Configuration Notes

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- Auto vs Fixed Channels
  - Generally, fixed in present deployments “in the bowl”
  - Auto channel is possible in suites, concourse, areas, etc.

- Power
  - Uniform high signal strength is needed for smartphone clients.
  - Typically design now for -55 dBm to -60 dBm criteria (empty bowl)
  - This means often driving APs at “higher” power than typical of non-smartphone deployments

Configuration Notes

- Band Steering
  - Recently some popular smartphone clients “Balk” at band steering
  - When it can be enabled, it works very well at getting clients on 5 GHz, especially high bandwidth hungry laptops (press, etc)
  - When disabled, total numbers of clients on 5 GHz drops about ~5% but overall numbers now still look relatively good compared to 1 year ago with ~15-20% of smartphone clients connecting on 5 GHz even without band steering enabled.

Configuration Notes

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- Temporal Diversity and Retries
  - Increase Max Retries from default of 12 to a larger value (24 or 48)
  - Enable temporal diversity: ~20% reduction in peak airtime utilized by spreading of retries through a more efficient algorithm

Coming Soon

Coming Soon

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- ARM 3.0
  - The “sticky client” is believed to be a major issue in LPVs
  - Clients move (example concourse to bowl) but don’t also roam
  - Slow clients bring everybody down
  - In trials now,
    - We want to see average SNRs go up and average connection rates go up
    - Faster clients need less airtime, leaving more airtime to support more clients or higher bandwidth applications

Coming Soon

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- Multicast?
  - Inherently a difficult proposition in a noisy environment
  - In a single application flow environment, clear advantages
  - In a mixed environments (i.e. some multicast, a lot of general internet use) advantages less clear
  - Aruba does have ability to prioritize multicast based on application level criteria, i.e. some multicast, not others
  - Present deployed in-seat video delivery systems do not rely on multicast (Yinzcam)

Major Deployed Venues

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- United Center – Chicago
- American Airlines Center – Dallas
- Turner Field – Atlanta
- Ziggo Dome – Amsterdam
- Bryce Jordan Arena – Penn State
- Galen Center – USC
- Jordan-Hare Stadium – Auburn
- Allen ISD – Allen, TX
- ? (very actively adding more)
-
- Any data presented in this session is a hybrid and should be viewed as representative of all of the above and also consistent with published releases / reports from other vendor deployments

The Airheads Challenge

Use Unlock Code "LPV"

To get the quiz for this session

Login to play at

community.arubanetworks.com

Thank You

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