In-building Wireless Coverage and the Case for Pre-wiring

Introduction

Wireless cell phone coverage in general and indoor Distributed Antenna Systems (DAS) specifically have consistently grown over the past 20 years. What was once available only for high value executives is now indispensable for all. Technological changes have provided the platform for an unlimited number of services available anytime, anywhere… as long as there is coverage. The wide-spread use of cell phones throughout every strata of society has made the mantra "indoor coverage everywhere" a universal goal, from the high-rise office building and bustling manufacturing center to the local mall and big box store, from the apartment complex and hospital to the single family home. As subscriber penetration moves beyond 100%, expectation and real economics demand coverage everywhere. This need is juxtaposed with traditional ROI constraints as well as access and ownership issues, but perhaps the most difficult impediment of all is the mystique in planning such a system.

DAS Design Considerations

In the macro world, over the past 20 years, the design of cellular systems has evolved from planning a purely coverage model (high power, high elevation sites) to a capacity model, lower power, lower elevation sites. Indoors, a similar phenomenon is also taking place. Where once the only goal was for coverage, today's requirement are ones of uniformity with future proof upgradeability. The key driver of this is the consistent addition of new services and subsequently new frequency bands, utilizing of more and more capacity and thus requiring higher and higher signal-to-noise levels. The need to future proof a building for wireless coverage is critical as the cost and inconvenience of disturbing the building continues to rise.

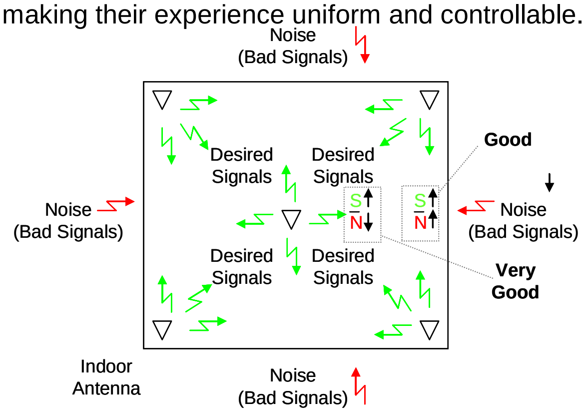
Minimum Signal Level Thresholds

For mobile devices to be perform optimally they require a minimum signal-to-noise ratio. However, signal-to-noise ratios require an understanding of the particular environments noise, which changes over time, both by time of day and by year and by location and are generally out of control of the designer of the indoor system. It is therefore critical to design the system in such a way that it will be fairly immune to the outside affects. This requires both a receive signal strength of -80dBm or better and an informed positioning of the antennas.

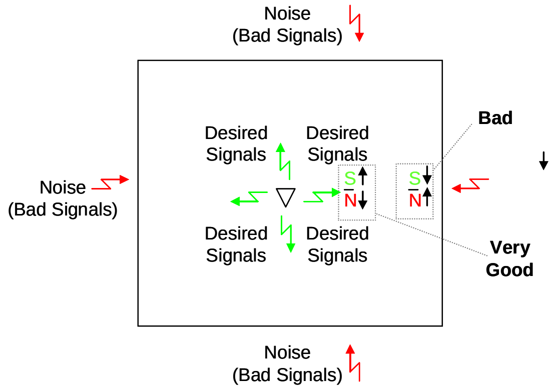
Antenna Locations

Placing antennas in the appropriate locations is one of the most critical factors in maximizing the effectiveness of the wireless system and simultaneously making it future proof. In many environments that have partial coverage around the outer walls of the building, one might think of placing the DAS antennas purely in the middle to provide coverage where there is none. This is often viewed as the least expensive solution, which may initially be true true; however it provides the worst possible system performance and the least likely future proof solution, thus the total cost of ownership is very high.

Antennas should be evenly spaced throughout the building, but *no outside antenna should be further than 20ft (6m) from an outer wall*. The outer ring of antennas can be directional (although omni antennas will also work), pointing back into the building, almost as if the building is being shielded by a blanked of invisible signals. In this way, the signal from the antenna will swamp out the signal from the outside environment, forcing all devices in the building to gain network access through the buildings system, thus making their experience uniform and controllable.

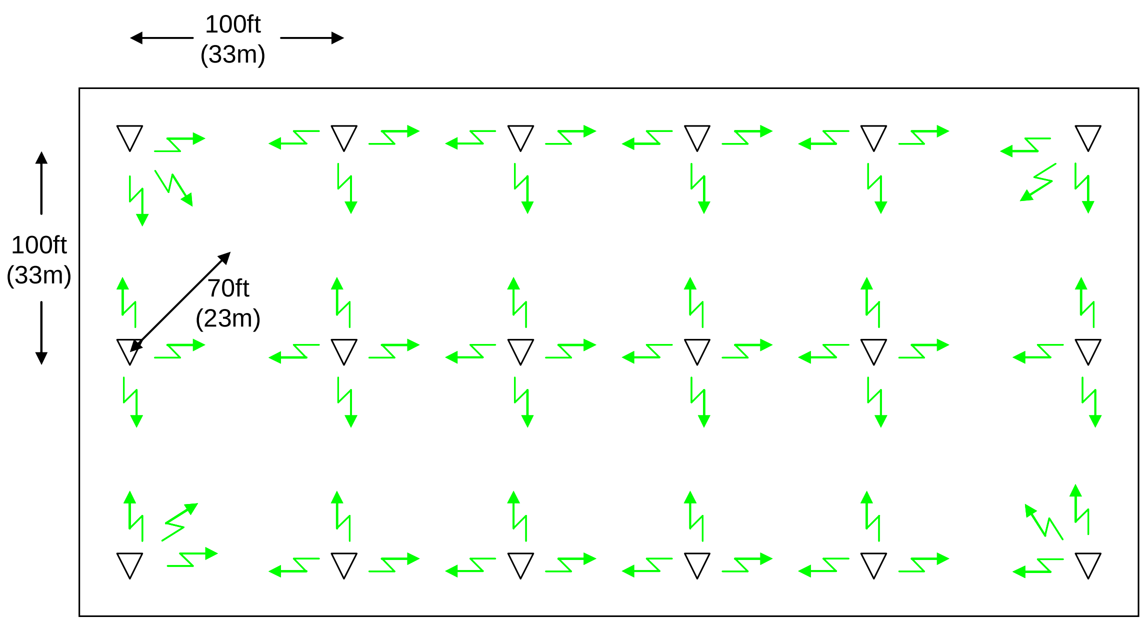


Desirable Antenna locations



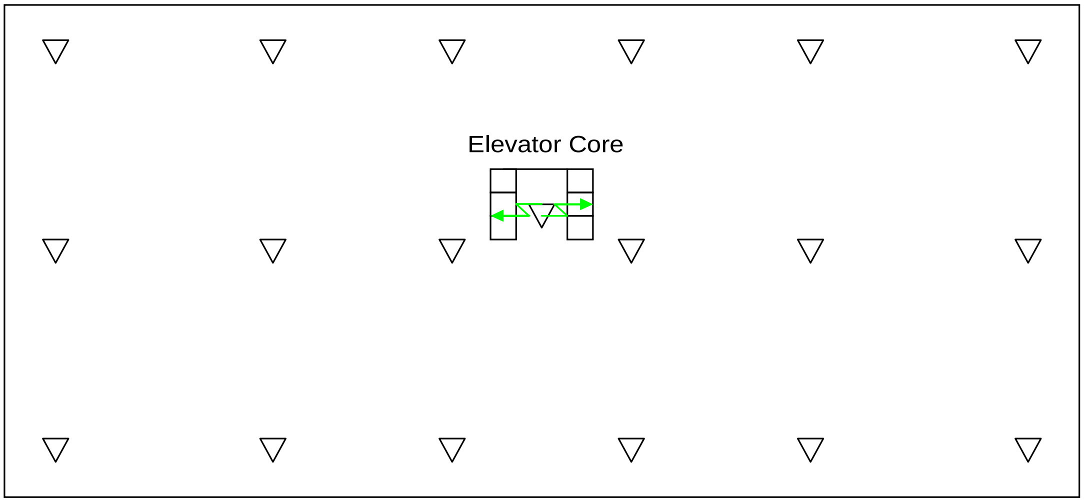
Undesirable Antenna Locations

In addition to maintaining antennas at the edge of the building, it is ideal to spread them evenly throughout the building. The grid used for DAS is much the same as used for Wi-Fi (802.11) systems in the 2.4GHz band. *Antennas should be placed throughout the building at 100ft (30m) intervals*. This will provide an access point within 70ft (23m) of any user, which provides homogeneous RF coverage and thus service through the structure.



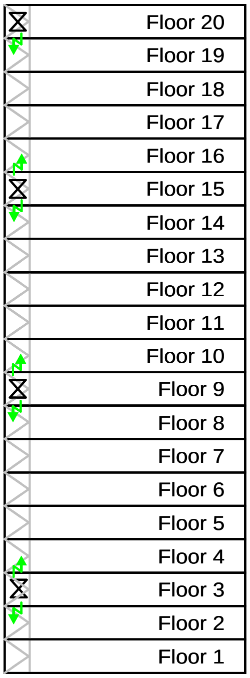
On Grid Antenna Locations

There are two other restrictions that limit where antennas should be placed. In the event there is an elevator core, an antenna must be placed on each floor *within 20 feet (6m) of the elevator*. In this case the requirement is to penetrate what is mostly a metal box, which is highly resistant to RF penetration.



Coverage of the Elevator

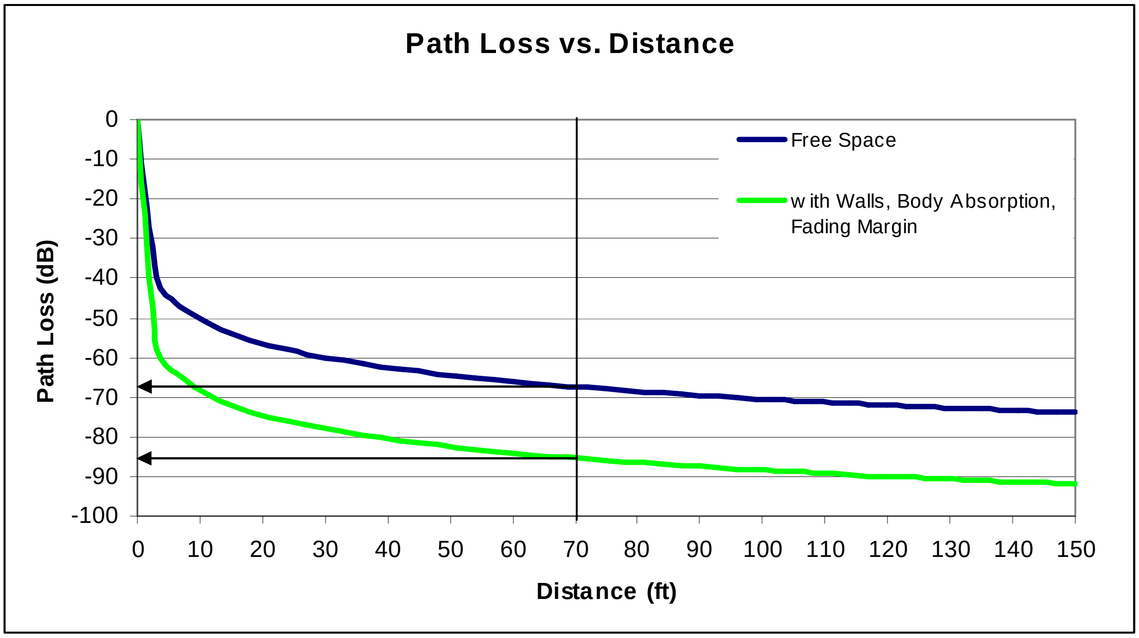
The final coverage requirement (mostly for public safety applications) is to cover stairwells. Typically stairwells are shielded by massive amounts of concrete and steel rebar and very little RF can penetrate such a structure. An antenna must be *placed on every 6th floor (starting with floor 3)* within the stairwell itself. This requirement moves to an antenna every floor if the stairwell has no central opening (if you cannot see floor to floor in the stairwell). In this case the antenna should be bi-directional or a simple splitter should be used to feed two antennas, one pointing up, the other down, so each antenna is covering 3 floors up and 3 floors down. Since this is an area which does not have a great deal of traffic for commercial purposes, the deployed frequencies may only be public safety, however, the media (cable) and antennas will, in all cases, work for both systems.



Coverage of the Stairs

In the final analysis the objective above is to blanket the entire building with signals that are received by the mobile devices at -80dBm/carrier or better. Although this article will not go through the math required in this link budget analysis it is valuable to see how RF signals attenuate with propagation and to understand that other materials such as walls or people also absorb RF energy and therefore attenuate signals as well. In a custom designed building, test transmitters are temporarily setup and RF losses are measured, in addition a signal scan is performed to measure the outside environment. Due to the above design principles, this costly and time consuming design step is eliminated and a slightly more conservative design approach is taken with respect to antenna placement.

By reducing the spacing between antennas it is safe to conclude that from any point in the building to the nearest antenna is no more than 2 walls away and thus attenuation factors can be managed. With these design rules the attenuation from walls can safely be approximated by 10dB of path loss. Furthermore the reduction in distance allows a fading margin to be established at a scant 5dB. Finally, free space loss can be determined explicitly for the maximum distance of 70ft (23m).



Path Loss in a Building with a 100 ft Antenna Grid

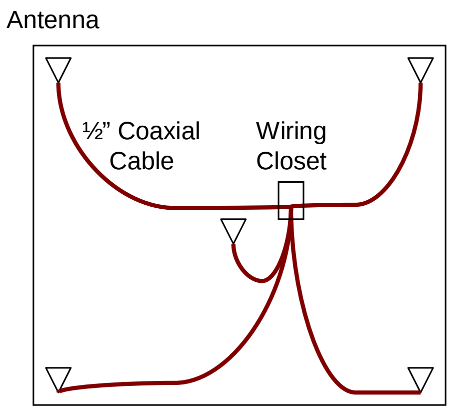
At 70ft (23m) one can see there this is 85dB of attenuation. Since the antennas used in an installation have approximately 3dB of gain, then to attain the -80dBm RSSI, the signal into those antennas should be +2dB. How one would get this output power to the antennas is the subject of the next section.

The Antenna Location Design Rules

- Outside antennas within 20ft of the edge of the building
- Antennas spaced at 100 ft apart
- 1 antenna per floor within 20 ft of the elevator core
- 1 back-to-back antenna every 6 floors in the elevator shaft starting on floor 3 (unless the stairwell is solid in which case antennas are required on ever other floor).

Laying the Media

Once the prior design rules are understood, it becomes easy to establish where the antennas should be located. The antennas must be connected to a signal source somewhere. The first leg of this connection is typically a ½" coaxial cable. The reason for this choice is one of bandwidth. Just as the antenna is capable of passing multiple signals and multiple services, so is coaxial cable. To ensure future proof design it is recommended that the antennas are each connected to their own coaxial cable and this is in turn routed directly back above the drop ceiling to a wiring closet. Both sides of the coax should be terminated in an N-type male connector. *No cable run should be more than 300ft (91m)*. This stipulation on distance is to limit the loss within the coaxial cable to 10dB. When installing the cable it is wise to note the distances of each cable and the location of the antenna with which the cable is mated so as to make the rest of the system design easy.



Routing the coaxial Cable

The Coaxial Cable Routing Rules

- Each antenna shall be connected by ½" plenum rated coaxial cable
- The coaxial cable shall run directly from the antenna to a wiring closet with 300ft (91m)
- Each end of the coax shall be terminated with an male N-type connector
- Notes shall be made on the length of the cable and the location of the antenna mated to the coax

The Rest of the DAS

At this point Distributed Antenna Systems architectures tend to vary. Some will connect to passive equipment such as other pieces of coaxial cable, while others will connect with certain pieces of active equipment (Remote Units) which will backhaul the signals over fiber. This paper is targeted at design and installation of the final leg of the DAS and thus will not discuss the merits and faults of each system. Instead it wishes to stress that regardless of the rest of the DAS and the frequencies, and the services that are desired today or tomorrow, this passive infrastructure investment will be viable.

Why Design and Install the Horizontal Runs of a DAS During Initial Building Construction?

There are two fundamental reasons installing media during construction is desirable and intelligent: Cost and Convenience.

Cost

Placing cable in cable trays or putting cable above a drop ceiling before it is completed is quick and easy. Much as installing electrical wiring, communication wires or for that matter plumbing, when a building is initial built is efficient, while adding post construction infrastructure is costly. It is not uncommon for the cost of a major retrofit to a building to be so high that it is demolish and rebuilt rather than retrofitted. It is estimated that the installation cost post-construction for the horizontal runs of a DAS is more than *4 times* that of pre-construction work. Furthermore the installation of a piece of coaxial cable post-construction can run *2 to 4 times greater* than the cost of the coaxial cable itself.

When designing the cabling in a building today, one often puts in more material than is needed. An office might have 2-4 times as many electrical outlets than are used at any one time, or have 2-4 Ethernet jacks, even though only one is currently in use. This is good, future proof planning, and a similar strategy should be taken with horizontal portion of a DAS. Assuming conservatively that *a single antenna and cable feed* will cover approximately 5000 ft^2, and that an office is approximately 10ft x 12ft, a cubical 8ft x 8ft and 20% of building is common space (hallways, bathrooms, etc), then each antenna will cover between 15 and 20 people. This same group of people will require more than 60 outlets and 30 Ethernet jacks and a bathroom. The cost of the vital wireless DAS horizontal feed communication channel pales in comparison to every other service.

Convenience

Just as the cost increases steeply in adding new infrastructure after a building is completed, so does the disruption to the building occupants. Adding additional wiring to a warehouse is relatively easy, as there are no ceilings to contend with and few people are disrupted. In a typical office this becomes more intrusive as a drop ceiling must be removed, and people are displaced during installation. In certain structures, like airports, infrastructure must be renovated during the night so as to minimize this disturbance (which increases costs). Perhaps the most difficult structure of all to retrofit is a hospital. Not only can it have public spaces which can be accessed only during restricted times, but it has requirements for air quality and thus special care and equipment must be used to eliminate particulates. This takes time and slows down the installation process and thus creates an even bigger inconvenience and cost.

Summary

Most companies and individuals consider their wireless services (both commercial and public safety) to be indispensable. The future holds more services that will become even more critical to everyone's day-to-day life. Installing broad band coaxial cable and antennas throughout a building during construction is a cost effective, non-disruptive, intelligent way to plan for today and tomorrow.

Suggested Equipment

Coaxial Cable: HL4RP-50A

Plenum Rated ½" Coaxial Cable

Connector: L4TNM-PS

N Straight Male Connector

Antenna: CELLMAX-O-25

Omnidirectional In-building Antenna