# Antenna Technology for WLAN and WLL Systems

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For this update on antenna technology, we will focus on two specific applications: Wireless Local Area Network (WLAN) and wireless network access—Wireless Local Loop (WLL), Wireless Internet Applications and other point-to-multipoint applications. Each of these represents applications that are active now, and will continue to grow in the foreseeable future.

Beyond these focus areas, there are many other interesting developments in antenna technology. A few that we will try to cover in the future include vehicular applications, satellite communications (particularly VSAT), embedded antennas and conformal antennas. Adaptive arrays ("smart antennas") are another major application area that we are following carefully for future articles.

**Aesthetics is an issue in an office WLAN environment, which is effectively addressed by these antennas from Cushcraft Corporation.**

## Antennas for WLAN

The primary challenges for WLAN antennas are related to signal propagation. These mainly involve the indoor environment where most of these antennas must operate. Some of the characteristics of this transmission medium include:

- Multipath due to reflections from walls, partitions and furnishings.
- Attenuation as signals pass through floors, walls and windows.
- Non-uniform signal strength, which can cause "dead spots" with unreliable connections.
- Aesthetic requirements for minimizing the visual impact of "yet another electronic gadget."

*Dealing with multipath*—Although WLAN terminal equipment includes digital time-domain filtering for reducing the effects of multipath, antenna engineers also have options that help this situation. The first is directive antennas. At 2.4 GHz, a two- or four-element patch array is not very large; even a single patch with a reflector has useful directivity. With a narrow beam of radiation, less area is illuminated and off-axis reflections are reduced.

*Attenuation solutions*—This is a system engineering problem, involving decisions on how many "cells" are required to provide uniform coverage. Antennas must be placed so they do waste energy by radiating toward lossy areas. Attenuation can also be considered as part of the next item.

*Providing reliable coverage*—The ideal WLAN system has the fewest number of nodes (and antennas) to serve the coverage area with reliable transmitted signal strength and receive sensitivity. The number of nodes should be minimized to avoid interference between adjacent nodes. The antenna pattern shape must be matched to the desired coverage of each node. For example, a corner-mounted antenna only needs a 90 degree horizontal beamwidth, while an antenna located in the center of a room should be omnidirectional. To combat multipath and the many possible user locations, some installations will require spatial diversity and polarization diversity.

*Aesthetics*—A good industrial designer can make a utilitarian product look good without affecting its performance. All indoor antenna manufacturers try to accomplish this task. The photo above shows some of the WLAN antennas from Cushcraft Corporation, which have neutral off-white radomes designed to blend in with typical office walls and ceilings.

Several design technologies are for WLAN antennas. Single polarization antennas may use classic dipoles, slots or patches, often implemented with innovative new manufacturing techniques. Several patch configurations can provide circular or elliptical polarization, and all of the above types can be combined in arrays or used with reflectors to achieve directivity.

WLAN antennas are generally low gain, since their application rarely requires the narrow beamwidths associated with high gains. The exception is inter-building links when WLAN is used to cover a larger, campus-wide area.

## WLL, Point-to-Point and U-NII

New applications at 3 to 6 GHz include various point-to-multipoint systems. These are often referred to as “last mile” systems that extend a fiber optic or microwave-linked network to individual subscribers.

The principal is similar to both the cellular/PCS phone system and CATV systems. The differences are that the data rate (bandwidth) is much greater than cellular and the drop from the trunk to each home is not a cable, but a wireless link. Also, these systems operate at much higher frequencies that either cellular or CATV.

Like WLAN, there are unique issues that must be accommodated in a microwave point-to-multipoint distribution system:

- A line-of-sight path is required between the hub and each subscriber premises.
- Multipath effects are magnified by the high data rate and the higher frequencies (shorter wavelengths.)
- Mechanical/environmental reliability is a major design issue, since most equipment is outdoors.
- Weather and seasonal variations affect propagation (rain, fog, snow, vegetation).
- Cost is paramount for subscriber equipment.

*Line-of-sight path*—Microwave frequencies exhibit little refraction, or “bending.” In addition, the short wavelengths are strongly attenuated by vegetation (leaves and pine needles) and other objects such as walls and roofs. The most significant impact is that *each path* from the hub to a subscriber must be analyzed to determine where the customer unit must be mounted. This has two parts: First, to design a system with optimal number and location of hubs, a large number of potential subscriber locations must be analyzed. Then, as individual subscribers are added, the installer must be able to determine where the equipment must be located to “see” the hub.

*Multipath effects*—The good news is that the hub and subscribers are in fixed locations, which does not require highly adaptive signal processing to eliminate multipath. However, when multipath exists, it may have an amplitude as high as the direct signal if the reflection surface is efficient (flat and metallic). Antenna directivity can help, either with sectorized coverage, or with steered or switched beams that can focus on one subscriber with a narrow beam, then quickly switch to handle another subscriber. This requires a significant additional level of complexity in the antenna design (highly directive with low sidelobes) and its control circuitry.

*Environmental issues*—Some designers of point-to-multipoint systems consider this to be the most difficult issue. The problem is obvious when combined with the low cost anticipated by subscribers. The design of low cost microwave equipment that must withstand high vibration (wind), humidity and direct contact with moisture, plus temperature extremes, is a challenge approaching that of cost-is-no-object military systems. The variability of propagation due to environmental effects must be quantified and incorporated into system coverage and reliability calculations.

*Cost*—Innovative circuit design must be combined with equally innovative antenna design. Low cost assemblies have been used for consumer satellite systems (DBS), which primarily use formed aluminum reflectors with offset feeds. Similar technology may be appropriate, although panel antennas appear to be the preferred choice, using easily-fabricated printed antennas under a low cost plastic radome. The photos above show a subscriber antenna unit from REMEC Broadband Wireless. REMEC is one of a few companies that have made a significant investment in WLL and U-NII (wireless Internet access) development, including antennas, transceivers, up/downconverters, fully configured hubs and customer premises equipment.

There are more issues in the design of systems for point-to-multipoint systems. One interesting scheme reduces the number of hubs by incorporating repeater capabilities in subscriber equipment, creating a ad-hoc network. My opinion is that this technique may be useful for early adopters, but will limit the capacity of a large system. It is more likely that nearby “repeaters” will only be used to reach subscribers who are blocked from line-of-sight access to the nearest hub.

In all these applications, antennas are a key element. The combination of radiated performance with low cost and environmental reliability require a range of design skills beyond simple electromagnetics. Like many of today’s applications, the design team represents a combination of many skills.