Antenna Considerations in the Deployment of Wireless Broadband Networks

Antenna selection for wireless broadband networks is critical, due to the technology's inherent LOS limitations.

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In 1985 and in 1997, the Federal Communications Commission (FCC) allocated three Industrial, Scientific and Medical (ISM) bands for unlicensed commercial use. The unlicensing of the 902 - 928 MHz, 2.4 GHz and 5.8 GHz frequencies, referred to as Spread Spectrum bands drove the development of wireless data radios and other communications products that currently operate in these frequencies.

An array of sector panel antennas provides a robust installation that can be used to focus the signal towards specific geographic territories. At the CPE point, a narrow beamwidth panel can be focused toward the POP antenna.

With the monumental increase in the use of the world wide web, the development of corporate intranets, and the convergence of the computing and communications industries, Internet Service Providers (ISPs) all over the world are turning their eyes towards wireless broadband technologies. Current estimates indicate that wireless is expected to capture between 10% and 20% of worldwide broadband subscribers market, reaching 9 million by 2005. This could translate in revenues as high as $37.5 billion for wireless Internet applications alone including full user mobility, portable wireless data and fixed wireless data.
Aware of the promising market potential, new Wireless Internet Service Providers (WISPs) are emerging all over the world. A significant number of these WISP's

networks utilize equipment operating in the ISM unlicensed spectrum because it can be deployed without the time and cost involved in applying for a license from the FCC.

These organizations have discovered that when properly executed, wireless broadband networks have a potential for faster data speeds, and yet are simpler and cheaper to install, relatively easy to upgrade and cost-effective to operate. Most importantly, their independence from the network installations and services of local telephone companies make the overall network planning and execution faster and more efficient than those of copper or fiber networks.

However, wireless broadband technology has its limitations. The technology is susceptible to line-of-sight (LOS) obstacles. This means that the microwave antenna located at the customer's site (usually referred to as Customer Premises Equipment or CPE) should be in direct view of the WISP's central broadcast facility, commonly referred to as Point of Presence (POP). This location too, utilizes one or more microwave antennas to transmit data.

Wireless broadband can also be affected by other sources, including interference from neighboring wireless networks or environmental conditions. Moreover, FCC regulations limit the power output networks can produce thus making &quotlink budgeting&quot an important element of the network design.

Despite these shortcomings, wireless broadband network installations are on the rise. As the number of deployed networks increases, wireless interference problems could affect even already successfully deployed networks. It is, therefore, critical to prepare a thorough network plan based on the specific characteristics of the covered region.

Network Planning

Prior to purchasing the communications equipment, WISPs should study the environment around the future network installation. It is important for the planner to determine the targeted area of coverage, including those areas he or she does not wish to cover, and the distance of the POP to the farthest CPE, which will help depict a border for the covered territory. The planner should also become familiar with the work habits of his average customer base and apply this knowledge to the network plan. The average customer's usage rate including peak and non-peak hours of use, the volume of data typically transmitted and the location of his or her work area can be significant considerations in the selection of the various components of the wireless system.

After this initial step, a survey covering the topography, vegetation and climatic characteristics of the geographical sector should be conducted and a site map prepared. The survey should also plot the desired customer installations and account for future channel expansions, as the WISP's customer base grows. A link budget must then be prepared to calculate the power requirements at each access point and the type of equipment that can be utilized to meet these requirements, without exceeding legal limitations.

Various software simulation program tools are available to assist in the theoretical survey stage. However, these planning tools must be used with caution, for only properly conducted hands-on site surveys can account for specific environmental variables that may ultimately affect the network's performance.

The results of the survey will help network planners determine the optimal network equipment to avoid LOS obstacles, avert potential wireless interference and compensate for local climate conditions. Although wireless broadband networks require various components, antenna selection is most critical, due to the technology's inherent LOS limitations. The antenna's success (or failure) to meet the unique requirements of the survey will affect the ultimate outcome of the project.

Antenna Basics

Antennas transmit and receive radio waves. The focused strength of this radiated energy is measured in terms of gain in decibels (dB). Gain in microwave antennas is typically specified in dBi, which refers to the resulting decibel measurement in relation to a theoretic isotropic radiator, which is equal in all directions. The gain in the antenna focuses the transmitted signal towards the targeted area of coverage. It also focuses incoming energy on the receive side.

It is important to take gain into consideration when selecting network antennas. Enough gain on both the broadcasting and receiving side will be necessary to establish stable links, but not so much as to exceed the legal radiated power limitations of 4 watts (+36 dBm) maximum effective radiated power (ERP). The ERP is the total amount of power actually transmitted through the system's antenna and it is the product of the transmitter's power output, the cable's power loss and the antenna's gain capability. Antenna manufacturers typically include various gain models in their product offering in order to accommodate differing access point gain requirements.

Also important is the efficiency with which antennas emit and do not reflect energy across their structure. This is measured in terms of Voltage Standing Wave Radio (VSWR). The best ISM networking antennas typically have a VSWR of 1.5:1 or less. The VSWR is a direct result of the antenna design and will be affected by the quality of the components and construction materials used.

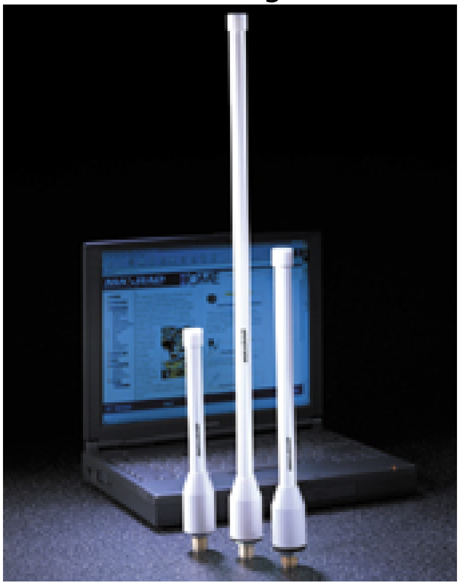
A third and most important aspect of antenna selection is the antenna's radiation pattern, which indicates how the transmitted radio wave energy is distributed in space. Since a pair of antennas must be within each other's radiation patterns in order to communicate, uniform radiation patterns across the frequency band are crucial to the network's performance and reliability. These too are a function of the antenna design.

The vertical cut of a radiation pattern, also known as elevation cut, is measured across the antenna's elevation plane. The horizontal cut of a radiation pattern, known as azimuth, is measured across the horizontal plane. Narrowing either pattern will increase the antenna's gain. Radiation patterns can also be altered according to the antenna polarization. This refers to the orientation of the antenna's radiated signal. Wireless broadband providers typically prefer vertically and horizontally polarized antennas for point to point and point to multi-point links.

The gain, VSWR and radiation pattern characteristics of an antenna design are closely related; altering one will have a direct effect on the other two and will impact the antenna's performance. This will, in turn, directly affect the network's efficiency. As a seasoned WISP put it in his discussion of wireless Internet networks and antenna selection: &quotYour choice of antennas will make or break your system, just like the choice of speaker will make or break a stereo system. Use the good stuff and even an inexpensive system will astound your customers&quot.

Signal Interference

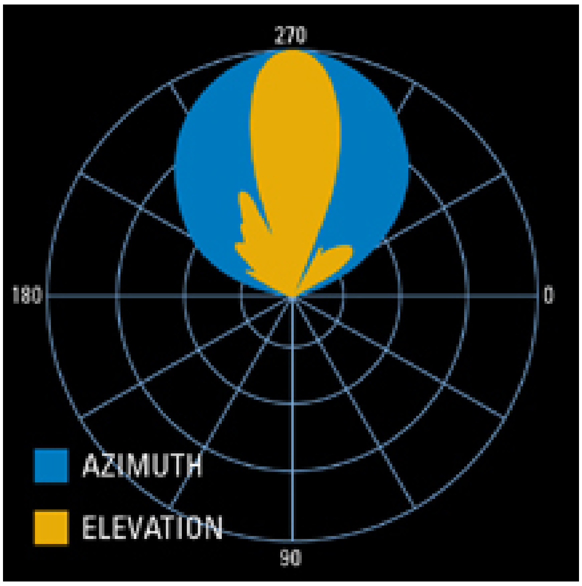
According to industry sources, 2.4 GHz frequencies need to have clear line of sight, and the Fresnel zone (the visual line of sight that the radio wave signals spread out into after they leave the antenna) must be at least 80% free of obstacles. Producing a strong, reliable signal in every link is, therefore, the broadband network designer's ultimate challenge.



Maxrad's omnidirectional antennas offer reliable performance and various gain options.

A radiated signal is composed of waves that oscillate simultaneously along a line of propagation from the transmit site towards a target. If they move within the same oscillation frequency, they reinforce each other and are said to be in phase. When waves are in phase and they encounter no obstructions, the received signal is strong and clear. However, if the waves encounter an object of different density, they will get reflected, bent or absorbed causing the waves to reach the target with different path lengths and at different times. Known as multipathing, this phenomenon results in the fading or nullification of the signal at the receiving end. The longer the path of the transmitted waves, the more likely they will get absorbed, reflected or suffer multipath interference. The effect of these obstructions over signal integrity becomes more significant at higher frequencies.

In order to establish stable links at 2.4 frequencies, the antenna(s) at the POP and the antenna at the CPE location must be within each other's path. In other words, the signal from the POP to the CPE must encounter no significant obstructions. The most significant signal blocker at these frequencies is foliage due to the high water content in most trees and shrubs. Water absorbs microwave signals causing partial fading or a complete signal outage. Some commonly used building materials such as wood, bricks, and mortar can also absorb microwave signals. On the other hand, metal structures such as cell towers, water tanks and some buildings can reflect energy and consequently contribute to signal deterioration. Moreover, microwave signals from other wireless networks can be detected by the antennas thus contributing to the interference.



Maxrad's MSP sector panels provide field-adjustable horizontal beamwidth options and industry-leading front-to-back ratio performance.

Other sources for potential interference include extreme atmospheric conditions such as sudden changes in temperature, drastic changes in atmospheric pressure, heavy rain or dense fog which could cause the radiated beam to bend upward or downward. However, at 2.4 GHz frequencies the effect of these influences is usually minimal.

Antenna Selection and Installation

The installation site should be robust enough to minimize oscillation due to heavy wind loads that could potentially affect the steadiness of the transmitted signal. This is particularly important if other antennas are installed in proximity, posing a risk for unwanted reflection and co-channel interference. Strong tower structures and high quality antenna mounts that offer robustness and mechanical downtilt flexibility can help alleviate some of these issues. In addition, antennas made of solid materials, such as high gain panels and aluminum parabolic reflectors can significantly reduce oscillation, as opposed to less expensive grid antennas that are typically weaker and prone to sway.

In addition, available space at the POP must be determined and taken into account at the antenna specification stage. The desired electrical specifications may not be practical given the space available in the tower, making mechanical specifications equally crucial to the success of the installation. Some antenna manufacturers offer models especially designed to provide maximum performance in compact spaces.

Maxrad's line of indoor antennas combine high performance with attractive, low profile designs.

The location of the POP antenna(s) should enable the provider to cover his or her entire customer base. It is advisable to select antenna locations that are well above tree tops or other natural and artificial structures that could potentially absorb or reflect the radiated signals.

If the path of the radiated signal is relatively clear of obstructions, short low density links can be established by using a single omnidirectional antenna with enough gain to reach the CPE antennas located around the POP. In this case, care must be taken not to use an antenna with too much gain for as gain increases the vertical beamwidth becomes narrower. This could cause the signal to propagate over its target. Some high gain omnidirectional antennas offer electrical downtilt features that can help redirect the beam. As with any outdoor antenna, omnidirectional antennas should be designed to withstand the environmental conditions of the covered territory.

For longer links, an array of sector panel antennas provides a robust installation that can be used to focus the transmitted signal towards the desired areas of coverage. This option is especially effective if the selected antennas feature efficient front-to-back ratio performance that minimizes the back reflections that contribute to co-channel interference and decreased signal strength.

One of the main advantages of sector antennas is that they allow WISPs to sectorize the coverage area by transmitting the radiated signal to those areas needing coverage, and not to areas lacking subscribers. Some sector panel antennas can be adjusted according to the horizontal beamwidth needed without the need to replace or remove the antenna from the tower. As the customer base grows, additional sectors and data radios can be added to customize the radiated patterns according to the geographical region covered and the density of the population within that region. This feature allows WISPs to re-use the same frequency at another location or in another direction.

Many CPE sites are located in residential or commercial areas that are surrounded by trees and shrubbery. Establishing a link to these locations is more difficult, especially if the removal of trees or other obstructions is not an option. In these cases, great care is needed to determine the antenna solution that offers the best combination of electrical and mechanical features to address the problem. In these instances, a high gain directional panel antenna at the CPE point can be very helpful. A panel antenna will allow the network designer to precisely focus the signal directly to the POP antenna with a very narrow beamwidth measured to avoid the obstacle.

To minimize co-channel interference, highly directional antennas with maximum energy in the front lobes, minimum side lobes and high front-to-back ratios should also be utilized. These features increase the likelihood that both ends of the link are communicating maximum signal strength from the front lobe of the transmitted signal, and not reflected energy from other sources detected through the side lobes of the receive signal. At the CPE site, narrow beam directional panels aimed at the POP, will help to reduce co-channel interference from other antenna installations.

Directional panels also offer a more attractive antenna solution for CPE locations where aesthetic considerations are important. Even if local city ordinances do not restrict the size and appearance of antennas used in residential or commercial areas, many homeowners will object to the installation of obtrusive or unattractive antennas in their properties.

Likewise, as coverage is extended indoors, aesthetic considerations become critical. The selection of indoor directional and omnidirectional antennas for in-building applications must not only blend with the building's décor, but must also take LOS restrictions and multipath issues into consideration. Potential sources of in-building interference include, but are not restricted to, co-channel interference from cordless phones, microwave ovens and reflected signals off walls or other surfaces along the path.

Conclusion

As the number of wireless network installations increases, the potential for signal interference is becoming a serious threat to the reliability of new and existing wireless broadband networks. Wireless Internet service providers that take into consideration current and potential sources of interference in their network plans and select the right combination of high quality network antennas and other components accordingly, will be better prepared to provide seamless service and superior customer support. This will provide the competitive advantage needed to survive as the market matures.

Editor's Note: For a list of references that accompanies this article, please email kstokes@cahners.com.

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