WM101m MIMO Adapter

Ralink is a leading developer of patented **Multiple Input Multiple Output (MIMO)** technologiesthat providenext-generation wireless communications products with the throughput, range and reliability to enable mobile wireless applications in the home, at the office and on the road.

MIMObility™ and 802.11n

Ralink patented MIMObility™ technology supports up to 300Mbps PHY and robust connections at extended range while mitigating dead spots. With MIMObility™, Wi-Fi applications can be extended from traditional PC networking to a wide range of digital multimedia and handheld devices including cell phones, PDAs, cameras, print servers, HDTV and video game players. On the path to draft 802.11n, Ralink chipsets will integrate multiple channels on a single die, with 2T3R mode for a very high level of RF integration on-chip. Customers can anticipate six times the coverage for the same throughput when compared to legacy 802.11a/b/g implementations.

MIMO XR™

MIMO XR™ (eXtended Range) employs multiple techniques – including frame aggregation, packet bursting and maximum ratio combining (MIMO-MRC) – to dramatically increase the throughput and range of wireless networking products. Our current maximum-ratio-combining (MRC) solutions deliver sustained high throughput to mitigate indoor multi-path, cost-effectively, while ensuring compatibility with legacy devices. Ralink partners are choosing MIMO XR™ for its field-proven range expansion, throughput performance, reliability and value for wireless networking applications. Ralink offers a draft 802.11n product utilizing MIMO technology, with plans for 802.11a and g enhancements.

Understanding MRC-OFDM

Understanding MRC-OFDM: a first step in MIMO technology

INTRODUCTION

The market for wireless LANs, particularly in the consumer and small business segments, has grown significantly in recent years. By all accounts, annual growth in wireless LAN device shipments has increased from threefold to fivefold since 2001. With huge opportunities for wireless LANs looming in home entertainment, Voice over IP (VoIP), and public access, the biggest market growth may yet lie ahead. Next generation wireless LANs will include new technology to enable these exciting applications.

Market adoption of wireless LANs has been spurred by the growing popularity of the broadband access in the home. Twenty-nine percent of North American households connected to the Internet using broadband connections in 2004, up from 19 percent in 2003. Networks can be found in 8.8 percent of US households, and these tend to be dominated by homes with multiple PCs and broadband access to the Internet. Access to music, video and online gaming becomes possible when the network can interface seamlessly with entertainment centers, laptops, and handheld devices. The wireless medium is ideal for these applications, but today's wireless LANs need improved performance to meet the challenge.

The typical user experiences three basic qualities of a wireless connection: speed, range and reliability. Prior to the development of MIMO-OFDM, the three parameters were interrelated according to strict rules. Speed could be increased only by sacrificing range and reliability; while range could be extended only at the expense of speed and reliability. And reliability could be improved by reducing speed and range. MIMO OFDM has redefined the tradeoffs, clearly demonstrating that it can boost all three parameters simultaneously. While MIMO will ultimately benefit every major wireless industry including mobile telephone, the wireless LAN industry is leading the way in exploiting MIMO innovations.

Multiple Input/Multiple Output (MIMO) is an area of intense development in the wireless industry because it delivers profound gains in range, throughput and reliability. As a result, manufacturers of wireless local area network (WLAN), wireless metropolitan area network (WMAN), and mobile phone equipment are embracing MIMO technology.

This White Paper describes how MIMO-OFDM (Multiple Input Multiple Output-
Orthogonal Frequency Division Multiplexing) technology delivers significant performance improvements for wireless LANs, enabling them to serve existing applications more cost-effectively as well as making new, more demanding applications possible. It also explains how manufacturers and end-users can benefit by deploying MIMO-OFDM products today without sacrificing compatibility with the popular 802.11a and 802.11g standards.

NEXT GENERATION WIRELESS CHALLENGES: Overcoming Multipath

Often, Wi-Fi transmission is limited by a phenomenon called multipath: In an obstacle-rich environment the signal bounces off the obstacles (for example, brick walls, office furniture, etc.), in the process generating reflected signals which degrades the reception of the signal. At the receiver, the signal loses quality because the obstacles cause the signal path lengths to be unequal, which results in several time-delayed copies of the information signal arriving at the receiver, as depicted in Figure 1. The total signal is the sum of all signals according to their phase relationships; and in general, the received signal is spread out in the time domain.

The receiver is designed to correct signal distortion, but can only do so to within certain limits. For example, if two signal paths are received out of phase, the total signal may cancel out entirely. Places where this happen in a typical user setting, such as a corner room away from the transmitter (AP), are called "dead spots". Wi-Fi users may also experience locations at home where the signal strength is weak, or where dropouts occur intermittently. Performance fluctuations like this are frustrating for the user, and, indeed, unacceptable for future applications that require stable, high throughput connections.

In a home environment, the user may find he can only use a laptop a limited range; while in the workplace several APs may be required to eliminate dead spots and allow wireless access to cover the entire floor. Of course there has been much research and development in recent years to overcome such factors limiting the stability and range of wireless broadband links. Presently, the IEEE standards committee is working on the next generation of the existing IEEE 802.11g standard that will include advanced technologies to enhance performance of broadband wireless LANs.

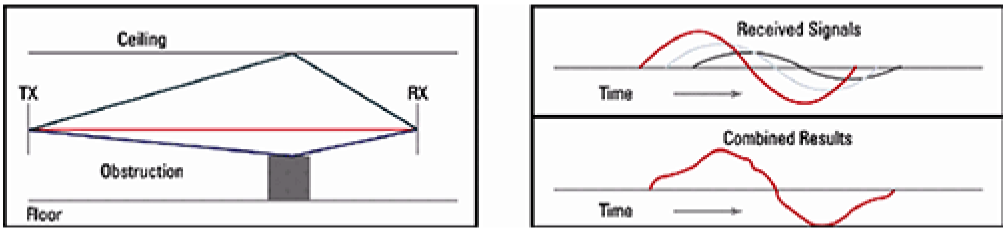

Figure 1: Multipath phenomena in wireless communication

WIRELESS TECHNOLOGIES FOR ENHANCED PERFORMANCE

The multipath problem is a longstanding issue in wireless communications. To reduce the multipath, the earliest Wi-Fi standard (802.11b) uses a technique called spread spectrum. Using this modulation, the data is spread signal out in the frequency domain to reduce the possibility of destructive interference totally wiping out a connection. This technique is effective, and is still used in current 802.11g modems, but it can provide limited throughput because it uses only a single channel for communication.

Other approaches to improving signal quality involve using multiple receiver antennae. Antenna diversity is method by which the receiver switches between two antennae to select the one with best signal strength, as shown in Figure 2. More advanced versions apply weights to the received signals and combine the two in order to further improve reception. Such methods, sometimes referred to as smart antenna design, are very effective means for combating multipath, particularly if the proper weighting for the received signals can be established. One such approach will be discussed below.

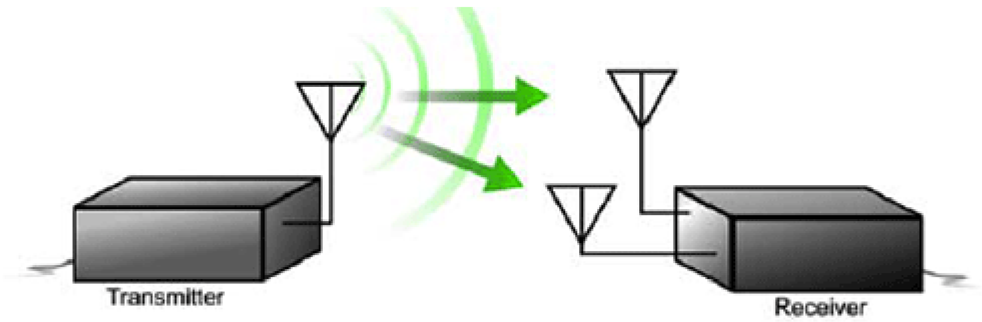

Figure 2: Diversity (receive combining) uses two or more receiver antennas two capture the best multipath signal.

Multiple antennas can be employed at the transmitter side of the link as well to boost link quality. By adjusting the relative phase and gain of the transmitter, the signal can directed toward the receiver to maximize the strength of the signal at the receiver antenna, as illustrated in Figure 3. Such a technique is referred to as beamforming. This requires advanced communication protocol between the two ends of the link that is presently not part of the current wireless LAN standard.

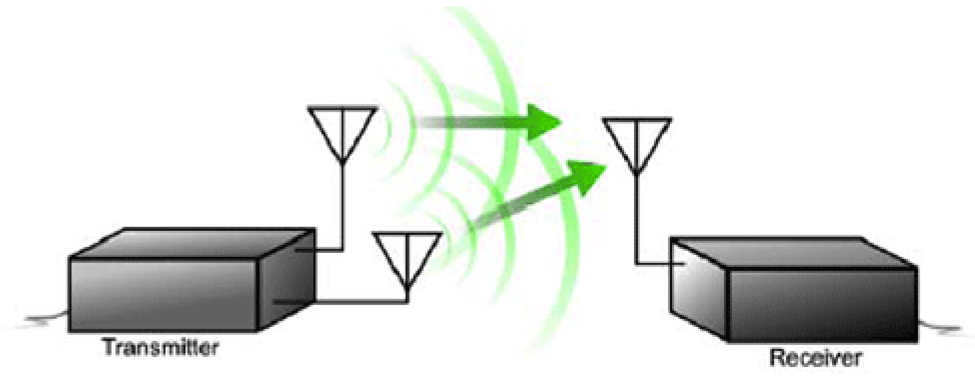

Figure 3: Beamforming (beam steering) directs the signal of two or more antennas toward the receiver.

The current Wi-Fi standard is based on a technology commonly known as OFDM: Orthogonal Frequency Division Multiplexing. The OFDM signal provides five times higher throughput than is achievable the spread spectrum signal. The increase in throughput is accomplished by making efficient use of the channel bandwidth.

OFDM is a multi-carrier transmission that divides the spectrum into 48 sub-channels equally spaced across the spectrum; the channels transmit data independently, each at a different frequency. In addition to boosting data rates, OFDM is resistant to multipath because it is unlikely that all the sub-channels will be affected at once. However, at longer ranges where multipath becomes more severe, OFDM modems can still be affected. In these cases it is not uncommon for entire groups of subcarriers to encounter destructive interference, or fading, and cause losses in throughput or connection entirely.

NEXT GENERATION WIRELESS: SMART ANTENNAS AND MIMO

Smart antenna technologies capable of automatically adapting to dynamic changes in the environment to maximize the availability of quality signal paths have become the focus of next generation Wi-Fi solutions. Indeed, the future wireless LAN standard (802.11n) is currently in development and scheduled for ratification in early 2007. It is intended to build on the current OFDM standard and allow higher throughputs, longer ranges and more stable connections by introducing multiple antenna technologies.

The technique of using more than one antenna to transmit and receive OFDM signals is referred to as the Multiple Input/Multiple Output OFDM, or MIMO-OFDM. The basic principle behind MIMO technology is to exploit multipath signals in order to improve signal quality and increase range and throughput. MIMO uses multipath signals to carry more information, which is recombined on the receiving side by the MIMO algorithms. When strong multipath is present, multiple antennas can be used to send more than one data stream on each subcarrier, and theoretically double the achievable data rate. This sophisticated method of exploiting multipath to transmit more than one data stream on a single OFDM subcarrier is referred to as spatial multiplexing.

Several vendors today are offering proprietary products employing spatial multiplexing in advance of the upcoming 802.11n standard that demonstrate promising performance improvements. Of course when multipath conditions are not present, or when these devices interoperate with non-proprietary devices, they must revert back to the standard single stream mode. When processing single stream data, MIMO-OFDM receivers use a smart antenna technique referred to as maximum ratio combining, or MRC-OFDM.

In essence, MRC-OFDM is the most basic form of MIMO technology that is fully compatible with the current 802.11g standard. Used with today's wireless LANs, the user will experience the smart antenna benefits of increased throughput, range and link robustness. The MRC-OFDM receiver works by first converting the signals from multiple antennas into the individual subchannels, and then combining them signals on a subcarrier basis to optimize the quality of the OFDM signal, as is shown in Figure 4. Because the signal combination is done in the frequency domain (FD), MRC-OFDM is able to utilize the multipath diversity to further enhance the OFDM signal. As a result, dead spots are eliminated, range is improved, and effective throughput is increased.

Conceptually, MRC-OFDM is the diversity combining smart antenna technology discussed above, and shown in Figure 2, but optimized for the OFDM signal. However, other techniques that combine the antenna signals in the time domain are ultimately less effective than MRC-OFDM. Even if eight or ten antennas are used, as with the BeamFlex system, the optimal combining for each data subcarrier cannot be achieved. As a result, fading will occur at certain frequencies, and performance will be lost. Lab testing was done to confirm these trends, and the findings are summarized below.

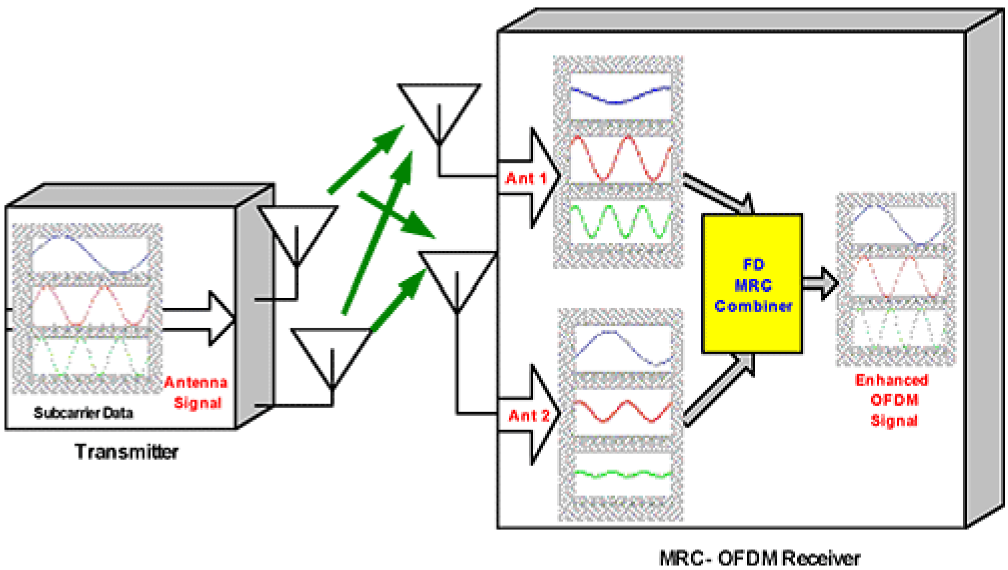

Figure 4: MRC-OFDM receivers combine the signals from two or more antenna in the frequency domain (FD) to enhance OFDM performance.

CONCLUSION

Smart antenna techniques such as MIMO-OFDM will greatly improve the performance of the next generation of wireless LAN systems. The IEEE is working toward the next standard for wireless products using multiple antennas to increase throughput fivefold, and greatly improve link range and reliability. The 802.11n standard will include other technologies as well, such as advanced coding, extended channel bandwidths (channel bonding), and efficient networking protocols, while at the same time providing backward compatibility with today's wireless LANs.
Fortunately a smart antenna technology is available now that optimizes the performance of today's standard wireless LANs. This is MRC-OFDM: it is completely compatible with all 802.11 devices and it is the first true step toward MIMO wireless.