SDR ARCHITECTURE IDEALLY SUITED FOR EVOLVING 802.16 WIMAX STANDARDS

Michael Komara (Chief Scientist; AirNet Communications Corp., Melbourne, FL, USA,
mkomara@airnetcom.com)

ABSTRACT

Broadband, multi-carrier, software-defined radio (SDR) mobile wireless network infrastructure is directly applicable to the emerging WiMAX® 802.16 technology, particularly the 802.16e mobile high-speed data requirements. Orthogonal Frequency Division Multiplexing (OFDM) waveforms, as used in the 802.16 technology, can be very efficiently implemented using Fast Fourier Transform (FFT) techniques to provide significant architecture advantages.

AirNet Communications deployed the first commercial SDR cellular base station in 1997 and the first fully adaptive, smart antenna GSM base station in the middle of 2004. The AdaptaCell® broadband, software-defined base station provides the foundation for the software-centric realization of this adaptive array antenna system, enabling unprecedented spectral efficiency for network operators.

Knowledge gained from cost-effectively integrating smart antenna technology into a broadband, multi-carrier SDR base station and from commercially deploying digital cellular mobility using smart antennas provides an excellent foundation for the challenging high-speed mobile data requirements of WiMAX 802.16e. This paper provides insight into a base station employing the SDR, OFDM, FFT architecture – enabling broadband, multi-carrier, adaptive array technology in live commercial mobile environments.

1. SOFTWARE-DEFINED RADIO BASE STATION

In 1997, AirNet Communications Corporation introduced the first commercially available broadband, multi-carrier Software-Defined Radio (SDR) base station to the wireless industry. Capable of transmitting and receiving several different types of wireless standards, AirNet SDR base stations are currently deployed and operating using the worldwide GSM standard, processing both GSM voice and General Packet Radio Service (GPRS) data signals with adaptive smart antennas.

Software development and integration will be completed by the end of 2004 to upgrade the AirNet SDR base stations to support EDGE (Enhanced Data for GSM Evolution) high-speed data waveforms – triple the rate of GPRS. Following EDGE, which uses an 8PSK (Phase Shift Keyed) waveform, the fully adaptive SDR base station may be configured to support the emerging 802.16e mobile WiMAX (Worldwide Interoperability for Microwave Access) standard, using waveforms of SCa (Single Carrier), OFDM (Orthogonal Frequency Division Multiplexing), and OFDMA (Orthogonal Frequency Division Multiple Access).

Using a broadband SDR architecture, the hardware covers up to 20 MHz and almost all of the signal processing is performed in the digital domain, so the radio personality can be easily changed through software upgrade to support different air interfaces. It provides significant advantages over traditional narrow band approaches in terms of cost, performance and flexibility. This is especially true for an evolving standard, like 802.16.

2. THE CHALLENGES TO THE OPERATOR

Cellular operators need to increase their network capacity and coverage, increase performance, and improve spectrum utilization, while reducing the cost of infrastructure and operations. Many have started to roll out high-speed data services, while others are cautious about data expansions due to network capacity/coverage limitations and expense.

Enhanced GPRS (EGPRS), combining EDGE and GPRS, is the 3GPP standard for the next evolution toward 3G for packet data. Several North American GSM operators have already adopted and deployed EGPRS; however, existing cell sites using traditional radio equipment cannot provide the same coverage for high-speed data due to the high carrier-to-interference (C/I) requirements – demanding up to 5 times as many sites for the same coverage.

Adaptive beamforming can provide high capacity for high-speed data while maintaining the same coverage without adding more sites. Improved traffic handling capacity is achieved through focusing a signal beam on a specific user and to “null out” multiple co-channel interferers. Narrowband systems cannot economically provide these needed capabilities because most of the signal processing and filtering are done in the hardware; it is achievable only with broadband SDR technology. As expected, adaptive antenna technology will greatly improve coverage for the 4G emerging 802.16e WiMAX standard for mobile high-speed data, especially at the edge of a cell.

3. SUPERCAPACITY ADAPTIVE BASE STATION

A cellular base station product using broadband software-defined radio technology can easily evolve from 2G to 2.5G, 3G, and 4G WiMAX. SDR hardware provides the same platform while it is software that defines radio personality. Combining the benefits of both SDR and Adaptive Array (AA) technologies, the AdaptaCell SuperCapacity™ base stations utilizing adaptive array enhancements to eliminate the need for new sites when supporting the higher C/I requirements of 2.5G, 3G, and 4G high-speed data equipment. The field proven, commercially deployed AdaptaCell base station has integrated digital beamforming adaptive array algorithms developed by ArrayComm. For the first time, this technology is cost effective and practical for commercial use. It is a virtual necessity for high-speed data delivery.

3.1 Adaptive Array SDR Base Station Architecture

The multi-carrier adaptive array base station, based on the only commercial broadband SDR architecture, utilizes patented technologies in the areas of DSP (digital signal processing), A/D (analog-digital conversion), FFT (Fast Fourier Transform) and multiprocessing. Figure 1 shows the architecture of a WiMAX capable adaptive array base station using the SDR-based AdaptaCell BTS product.

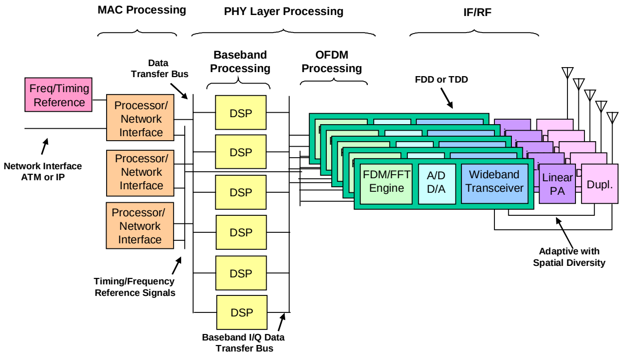


Figure 1 – AdaptaCell WiMAX BTS Architecture

Traditional base station technology employs narrow-band hard-wired logic that has changed little over the past 20 years, resulting in feature and performance compromises in these legacy systems. Operators are forced to constantly tweak their networks to support very high voice traffic at the major urban centers like Hong Kong, Beijing, and London. Most technology experts realize the limit of narrowband technology has been reached and the move to a wideband radio platform is necessary to support new data services and higher capacity.

The industry's approach is to "fork lift" their present equipment and replace entire Base station Transceiver System (BTS) with wideband Code Division Multiple Access (CDMA) technology or OFDM technology. With an SDR-based BTS product, software upgrades to the DSP are used instead of fork lifts.

3.2 Digital Beamforming Adaptive Array

Cellular systems are prone to interference and poor voice quality due to wasteful wide area RF transmission of signals. In traditional systems, this method is necessary because the user's location is unknown. Considerable radiated power is sent in every direction – making radio planning difficult and costly. In contrast, adaptive array systems determine the location of the user and the interferers to focus transmission and receive energy only on the intended user. Until recently, cost barriers have prevented adaptive array use in commercial mobile networks. The advent of low-cost DSPs and innovative algorithms has made smart antennas practical on a broadband, multi-carrier platform.

By adjusting to the RF environment as it changes, adaptive array technology can dynamically alter the signal patterns to optimize the performance of the wireless system, delivering dramatic increases in both capacity and coverage. The adaptive approach utilizes sophisticated signal processing algorithms to continuously distinguish between desired signals, multipath, and interfering signals – calculating the directions of arrival for each user.

3.3 Adaptive Array C/I Gains

The adaptive approach continuously updates its beam pattern based on changes in both the desired and interfering signal locations – smoothly tracking the users with main lobes and the interferers with deep nulls while constantly optimizing the link budget C/I ratio without micro-sectors or pre-defined patterns.

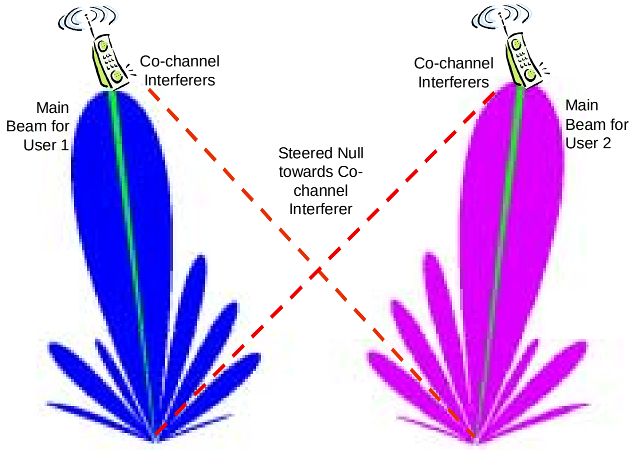


Figure 2 – Adaptive Array Principles

Figure 2 illustrates an example where one beam pattern is used to communicate with the user on the left and aim a null at the co-channel user on the right, while a second pattern is used to communicate with the user on the right and null the user on the left.

The adaptive array C/I gain is a combination of the main loop focusing gain and the reduction of interference. Since downlink spatial and amplitude information is derived from analysis of uplink information, the relative C/I gains for the uplink typically exceed those for the downlink.

In multiple field trials and commercial deployments using GSM cells operating at the same frequency and time slot, dynamic C/I gains of up to 30 dB were achieved, with 22 dB in the uplink and 16 dB in the downlink continuously demonstrated. Most of the C/I improvement was from interference rejection nulls, while focusing gain from the 4 antennas provided 5 dB. While other systems have primarily relied on just focusing gains, the adaptive array technology adds the benefits of active interference rejection. Co-channel interference is the primary performance limiter in high capacity networks and high-speed data networks.

4. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

Orthogonal Frequency Division Multiplexing (OFDM) has an inherent advantage over a single carrier system in a frequency-selective fading channel and its ability to handle the distortions of both wired and wireless channels without needing complex receiver algorithms has made it a popular choice for many applications and standards.

Many standardized wireline and wireless applications benefit from OFDM's spectral efficiency, ability to fight multipath distortion and delay spread, and resilience to inter-symbol interference (ISI). It is becoming the de facto standard for many broadband systems including:

- Wired Asymmetric and High-bit-rate Digital Subscriber Line (ADSL/HDSL) using Discrete Multi-Tone (DMT),
- ETSI Digital Audio Broadcasting (DAB),
- ETSI Digital Video Broadcasting (DVB),
- ETSI HiperLAN2 and HiperMAN,
- Wireless LAN such as IEEE 802.11a/g "WiFi",
- 4G such as IEEE 802.16-2004(d) "WiMAX",
- Mobile 4G such as IEEE 802.16e "Mobile WiMAX",
- Mobile 4G such as IEEE 802.20 "Mobile BWA",
- IEEE 802.15.3a Wireless Personal Area Network, and
- Other proprietary Broadband Wireless Access (BWA).

OFDM is a type of multi-carrier modulation where a single high-rate bit stream is converted to many low-rate N parallel bit streams and each parallel bit stream is modulated on one of N subcarriers. Each subcarrier can be modulated differently, typically using bi-phase shift keying (BPSK), quadrature phase shift keying (QPSK), or quadrature amplitude modulation (16QAM or 64QAM). To achieve high bandwidth efficiency, the spectrum of the sub-carriers are closely spaced and overlapped, where the nulls of each subcarrier's spectrum fall exactly on the centers of all other subcarriers. This makes them "orthogonal".

4.1 OFDM Waveform Advantages

Some of the advantages of OFDM waveforms include robustness in a multipath propagation environment and good tolerance of delay spread. Resulting from the use of many subcarriers, the symbol duration of the subcarriers is increased relative to the delay spread. Also, inter-symbol interference is avoided through the use of a guard interval.

OFDM inherently helps reduce ISI since, for a given overall data rate, the data rate that each individual carrier must support is reduced, and the symbol period increased, as the number of subcarriers increases. The longer symbol period for each subcarrier reduces ISI as the symbol duration becomes greater than the channel impulse response.

The transmission of multiple simultaneous carriers can also create inter-channel interference (ICI). To avoid ICI, the subcarrier frequencies are precisely spaced by the inverse of the active symbol period. By making the contents of the guard interval a "cyclic prefix" (CP) of data repeated from the end of the active symbol period, then a time window of length equal to the active symbol period can vary its position by as much as the guard interval and still recover the complete symbol without intersymbol interference.

In addition, the guard interval duration is such that an integer number of cycles occur over the total symbol period, so the subcarriers are then mutually "orthogonal" in that their correlation and integration over the active symbol period result in zero contribution.

With OFDM, there is simplified equalization compared to single carrier modulation and the waveform is more resistant to fading. Forward Error Correction (FEC) is used to correct for subcarriers that suffer from deep fades.

OFDM offers high spectrum efficiency (asymptotically optimum spectrum efficiency of Q bits/sec/Hz for a Q^2 modulation scheme), good cancellation of ISI (by inserting cyclic prefix), and efficient implementation by IFFT/FFT.

4.2 OFDM Design Considerations

One of the design considerations for OFDM includes sensitivity to frequency offset, where frequency offset correction must be performed in the receiver. OFDM is also sensitive to oscillator phase noise, so a clean and stable oscillator is required. The waveform also has a large peak to average ratio, so the amplifier must be backed off from saturation which reduces the transmit power efficiency. Another design consideration is FFT and inverse FFT implementation to optimize latency with performance.

OFDM waveforms experience inter-symbol interference (ISI) and inter-channel interference (ICI) due to multipath in the RF channel through which the signal is propagated. They can use a guard interval created by a cyclic prefix to mitigate the problem. The cyclic prefix is made by replicating part of the OFDM time-domain waveform from the back to the front. The duration of the guard period is longer than the worst-case delay spread of the multipath environment, so multipath delays up to the guard time will not cause ISI and the subcarriers will remain orthogonal for multipath delays up to the guard time, which eliminates ICI.

To reduce spectrum splatter, the OFDM symbol is multiplied by a raised-cosine window before transmission to more quickly reduce the power of out-of-band sub-carriers; however, the roll-off factor reduces delay spread tolerance.

The parallel transmission of data over many carriers helps protect against frequency-selective fading, where some subcarriers may be degraded and others are unaffected. Forward error correction coding is also used to provide redundancy so that the correctly received bits can be used to correct errors in poorly received channels.

Bursts of errors in a given time interval or over a given frequency band are reduced in the time domain by time staggering the coded bits and reduced in the frequency domain by interleaving the coded bits to specific subcarriers.

4.3 OFDM Waveform Transmission

OFDM waveforms consist of multiple modulated orthogonal sub-channel RF carriers multiplexed into a single composite wideband radio signal. Figure 3 shows an FFT (Fast Fourier Transform) based implementation of an OFDM system, where an Inverse FFT (IFFT) is used to generate the waveform and a forward FFT is used to receive it. Using the IFFT and FFT is very practical and eliminates the need to separately modulate and demodulate the many different OFDM subcarriers.

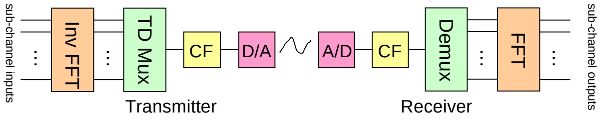


Figure 3 – FFT-Based OFDM System

By implementing an IFFT at the transmitter and an FFT at the receiver, OFDM converts an ISI-inducing channel with Additive White Gaussian Noise (AWGN) into many parallel ISI-free subchannels with gains equal to the channel's FFT frequency response. Each subchannel can be easily equalized by a single-tap equalizer using scalar division. To avoid inter-block interference (IBI) between successive blocks, a cyclic prefix is inserted ahead of each block at the transmitter and removed at the receiver.

Transmit functions characteristically include data scrambling, convolutional coding, interleaving, subcarrier modulation mapping, generation of pilot subcarriers, and OFDM modulation using an inverse FFT.

Figure 4 shows an OFDM transmitter algorithm and architecture using FFT-based processing. At the transmitter, the data is coded and interleaved. If there are to be M subcarriers, then baseband processing allows M parallel subcarrier modulation streams to be generated in the frequency domain as complex vectors, each reflecting the amplitude and phase of a subcarrier. Next, an inverse FFT of size N ≥ M converts the complex data from the frequency domain into the time domain – effectively modulating the parallel data streams onto M subcarriers. The cyclic prefix is then appended to each symbol prior to digital-to-analog conversion and transmission.

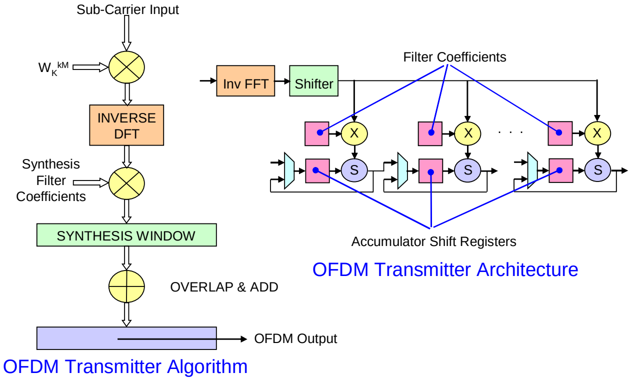


Figure 4 – OFDM Transmitter Architecture

Figure 5 shows an actual 256-channel OFDM waveform generated by AirNet's transceiver covering 5 MHz.

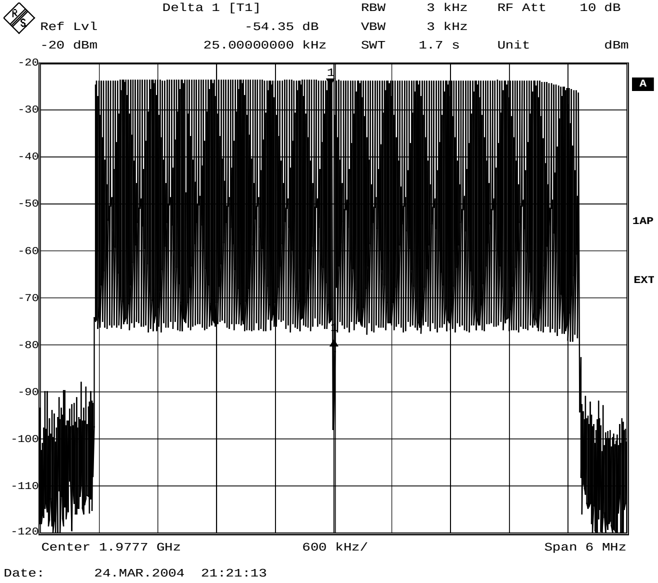


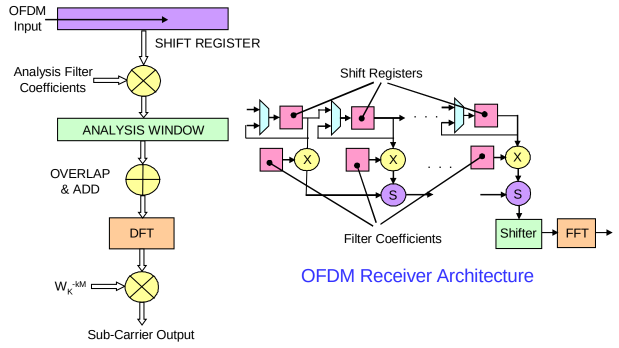
Figure 5 – 256-channel OFDM from AirNet Transceiver

4.4 OFDM Waveform Reception

Figure 6 shows an OFDM receiver algorithm and architecture using FFT-based processing. The FFT-based process is extremely efficient for processing a large number of frequency channels as found in an OFDM waveform. WiMAX 802.16 can have up to 2048 OFDM sub-channels.

Receive functions typically include automatic gain control (with control interface to the RF section), carrier and clock recovery, OFDM demodulation (using an FFT), equalization, demapping, deinterleaving, Viterbi decoding, descrambling, and channel assessment and indication to the Medium Access Controller (MAC) layer.

At the receiver, after down-conversion, analog-to-digital conversion, and removal of the cyclic prefix, then a size N FFT acts as a bank of matched filters to translate the received signal into a parallel stream of M ≤ N complex data representations of the received modulation constellation values for each of the M subcarriers. Equalization for channel distortions, deinterleaving, and decoding results in the receiver's estimate of the transmitted data stream.



OFDM Receiver Algorithm

OFDM Receiver Architecture

Figure 6 – OFDM Receiver Architecture

Advances in technology have allowed the FFT-based FDM engine at AirNet to dramatically evolve over the past ten years from 3 boards per sector to just a few components on one transceiver board per sector:

1994 – 2 Board Design
- Inverse FFT FDM Engine for Transmit
- FFT FDM Engine for Receive
- 3 Boards per BTS Cell (1 TX and 2 RX Boards)

1996 – 1 Board Design with ASICS
- FFT ASIC and Filter ASIC
- 2 FDM RX and 1 FDM TX Engine on 1 Board
- 1 Board per BTS Cell (TX and RX on Same Board)

2000 – 1 Board Design with FPGA
- Developed FPGA version of FFT
- 1 Board per BTS Cell (TX and RX on Same Board)

2003 – Wideband Transceiver & FDM Engine on 1 Board
- One Module of RF, IF, A/D, D/A, & Digital Filter.
- No Separate FDM Board. 1 Transceiver per Cell.

5. SDR BASE STATION FOR WIMAX

Since 1997, commercial base station products with scaleable multi-carrier RF power for multiple simultaneous users employing wideband software-defined radio (SDR) architecture have been shipped by AirNet. Experience using wideband radio FFT-based FDM technology with broadband multi-carrier base station equipment, wideband ultra-linear transceivers, and multi-carrier amplifiers is invaluable for developing the WiMAX equipment.

The AdaptaCell SuperCapacity SDR BTS will offer service providers a software reconfigurable solution for the WiMAX 802.16-2004 (d) emerging wireless networks with software upgrade capability for the future 802.16e mobility standard. It incorporates patented broadband transceiver technology that eliminates the need for multiple costly components typically found in other base station equipment. These enhancements dramatically reduce the need for new sites by providing higher base station capacity and eliminating the cell shrinkage that high-speed data causes when implemented with conventional products.

Experience integrating Spatial Adaptive Antenna Processing to improve carrier-to-interference (C/I) in interference-limited markets and to improve RF link budget in coverage-limited markets will also prove invaluable in WiMAX development. The AdaptaCell SuperCapacity BTS was the first to offer 2.5G Adaptive Array (AA) technologies, which focus the bulk of the transmitted power in the direction of a moving handset and provide a signal that is dramatically stronger and cleaner than previously possible.

Adaptive antenna array technology optimizes signals, lowers overall interference, increases capacity, and significantly improves the quality of both voice and data communications across the entire coverage area. Uplink C/I improvements by as much as 30 dB have been obtained with GSM waveforms along with 5 dB of RF link budget improvement by using an antenna array comprised of off-the-shelf antenna elements.

The service capabilities of the BTS are defined through software like a true SDR. This ensures that service changes and upgrades can be made easily and that emerging super-capacity mobile data services, such as 802.16e WiMAX, can be introduced faster and far more cost-effectively than with hardware-based solutions that require new base stations and towers.

Intellectual property forms the basis for WiMAX solutions. AirNet's patented, software-defined radio technology, and its associated intellectual property, forms a solid foundation for AdaptaCell 802.16 WiMAX base station products. For over 10 years, AirNet has led as the recognized pioneer in broadband SDR and digital FDM technology. A significant number of AirNet's approximately 70 patents cover key intellectual property related to wideband OFDM/FFT-based systems. These awarded patents will be critical in the development of such broadband wireless systems.

AirNet is a member of the Software Defined Radio Forum and has recently joined the WiMAX Forum as a principal member and will participate with the industry in promoting the WiMAX 802.16 standards.

The AdaptaCell SuperCapacity software-defined BTS benefits include:

- Support for 802.16d/e WiMAX protocol,
- High capacity, high speed data solution,
- Wideband, software-defined architecture,
- Patented Fast Fourier Transform (FFT) technology,
- Processing bandwidths from 1.25 MHz to 20 MHz,
- Access Modes: SCa, OFDM, OFDMA,
- Modulation Types: BPSK, QPSK, 16QAM, 64QAM,
- Coding: RS-CC, BTC, CTC,
- Supports Adaptive Array Technology,
- Reduces the number of required cell sites, and
- Adaptively reduces co-channel interference.

6. WIMAX CHARACTERISTICS

The IEEE 802.16 WiMAX standard is being based on global interoperability including ETSI HIPERMAN, IEEE 802.16-2004(d) for fixed, and 802.16e for mobile high-speed data. Both the fixed and mobile standards will include licensed (e.g. 2.5, 3.5, & 10.5 GHz) and unlicensed (e.g. 2.4 & 5.8 GHz) frequency spectrum; however, the frequency range for the fixed standard covers 2-11 GHz while the mobile standard covers below 6 GHz. Depending on the frequency band, it can be Frequency Division Duplex (FDD) or Time Division Duplex (TDD) configuration.

WiMAX will support line-of-sight (LOS) at a range up to 50 km (30 miles) and non line-of-sight (NLOS) typically up to 6-10 km (4-6 miles) for fixed customer premises equipment (CPE).

The data rates for the fixed standard will support up to 75 Mbps per subscriber, peak, in 20 MHz of spectrum, but typical data rates will be more like 20-30 Mbps. The mobile applications will likely support 30 Mbps per subscriber, peak, in 10 MHz of spectrum, with 3-5 Mbps, typical. The base station will support up to 280 Mbps to meet the needs of many simultaneous users.

Applications for fixed WiMAX (802.16-2004) include wireless T1/E1 enterprise backhaul and residential “last mile” broadband access, while applications for mobile WiMAX (802.16e) include nomadic & mobile consumer wireless DSL service.

6.1 IEEE 802.16 vs. HIPERMAN PHY & MAC

The IEEE 802.16-2004(d) fixed and ETSI HIPERMAN standards share common Physical (PHY) and Medium Access Control (MAC) characteristics:

- 75 Mbps (max.), 20-30 Mbps (typ.), 3-5 km (outdoor),
- Orthogonal Frequency Division Multiplex (OFDM),
- Single Carrier/TDMA, OFDM/TDMA, and OFDMA Access Modes,
- Channel Bandwidth Scalable from 1.25 to 20 MHz,
- 256 (OFDM) or 2048 (OFDMA) Sub-Carriers,
- Modulation (QPSK, 16QAM, and 64QAM) Adaptable to RF Link Conditions, and
- TDD and FDD.

6.2 IEEE 802.16e Supports Mobility

The IEEE 802.16e standard has modifications designed to support subscriber mobility, including the following:

- 15 Mbps (max.), 3-5 Mbps (typ.), 3-6 km (indoor), 6-10 km (outdoor),
- Channel Bandwidth Scalable from 1.25 to 10 MHz,
- 128, 256, 512, 1024, or 2048 (OFDMA) Sub-Carriers,
- Scalable OFDMA Modulation vs. SNR (BPSK = 6 dB, QPSK = 9 dB, 16QAM = 16 dB, and 64QAM = 22 dB),
- Mobile Data and Real-Time Voice Services fully working at 60 km/hr,
- HTTP, FTP, Telnet, SSH, POP3, SMTTP, P2P, TFTP, and 1-way Streaming Audio & Video must survive 120 km/hr,
- Streaming Audio, Video, and VoIP transport (IP QoS),
- Seamless Handoff – Low Latency (<50 ms) with <1% Packet Loss,
- Authorization, Authentication, & Accounting (AAA) Server in Network, and
- Base Station Access Switch provides Transport.

7. SUMMARY – AIRNET ADAPTACELL SUPERCAPACITY BASE STATION

AirNet has the only proven broadband software-defined radio platform that will support a seamless integration of adaptive array technology. The implementation is a key enabler for high capacity voice and packet data services, which is fundamental to success for WiMAX operators.

The AdaptaCell SuperCapacity base station, featuring adaptive array software, offers the following benefits:

- Improvement of dynamic C/I on a per subscriber basis,
- Improved quality throughout the network,
- Improved frequency spectrum utilization,
- Higher data throughput and Quality of Service,
- Overall cost reductions in both capital and operations,
- Software upgradeability for evolving standards.

AirNet's flexible SDR architecture will accommodate any of various WiMAX design considerations including:

- Processing Bandwidths: 1.25 to 20 MHz
- Access Modes: SCa, OFDM, OFDMA
- Modulation Types: BPSK, QPSK, 16QAM, 64QAM
- Coding: RS-CC, BTC, CTC (Turbo Co-processors Integrated with DSPs).

AirNet has commercialized products for 10 years with scaleable multi-carrier RF power for multiple simultaneous users using wideband radios, presently comprised of a 120 Watt integrated module. The radio equipment also incorporates 10 years of unique experience with the design of low noise figure (1.5 dB), high dynamic range, wideband 5 MHz RF receiver equipment, which also supports an integrated tower-mounted amplifier (TMA).

The waveform channel processing capability leverages 10 years of design experience using FFT-Based FDM technology and 7 years of actual operational experience with fielded wideband software defined radio technology.

AirNet has recently benefited from 4 years of unique experience integrating spatial adaptive antenna processing to improve C/I in interference-limited markets and to improve RF link budget in both directions – achieving up to 30 dB of C/I improvement for GSM and GPRS processing. GSM uplink C/I gains of 22 dB and downlink gains of 16 dB were repeatedly achieved, including 5 dB of uplink & downlink RF link budget gains using a 4-antenna array.

8. AIRNET OVERVIEW

AirNet Communications Corporation first deployed the AdaptaCell Base Station for commercial GSM applications in 1997, achieving major market successes both in North America and internationally. During the GSM Association conference in Cannes, France in February 1998, AirNet was honored to become the only GSM infrastructure manufacturer to be chosen to receive the coveted "Best Technical Innovation" Award based on the innovative broadband software-defined AdaptaCell and the Backhaul-free AirSite Base Station products.

During the PCS'99 exhibition in September 1999, AirNet further announced that the AdaptaCell base station would support the smooth migration from 2G GSM voice & data applications to GPRS, 2.5G (EDGE), 3G, and now to 4G (WiMAX) services on the same platform. This migration requires only minimal hardware modifications – not the "forklift upgrade" required by most other operators. Powerful digital beamforming processing for adaptive array antennas can be added simply by upgrading the software.

AIRNET™ ®