RF Spectrum Use in WiMAX

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This article discusses implementation of IEEE 802.16a/d/e WirelessMAN (broadband wireless access), also referred to as WiMAX (worldwide interoperability for microwave access), in terms of frequency spectrum. Regulating bodies around the world have earmarked frequency bands, both licensed and unlicensed, for broadband deployment. Semiconductor suppliers offer flexible chipsets and reference designs for WiMAX-certifiable systems to equipment vendors. These reference designs allow for a selection of RF front-ends to be combined with a highly-integrated baseband processor and MAC processor system on a chip (SoC), to address a wide range of markets using different parts of the spectrum. The RF front-end interface to baseband (SoC) is also discussed along with power considerations and future spectrum allocation.

Standardization with Spectrum Diversification

Just as the Wi-Fi WLAN boom took off on the wings of the IEEE 802.11 standards, an emerging Metropolitan Area Network (MAN) rocket is preparing to launch based on the IEEE 802.16 WirelessMAN standards which lays out specifications for standardization and interoperability. The WiMAX Forum, the global Broadband Wireless Access (BWA) industry association, provides the quality control and certification to ensure successfully standardized deployment. The primary task of the WiMAX Forum is to rally a host of worldwide stakeholders – composed of chipmakers, software developers, equipment manufacturers and service providers – in support of the IEEE WirelessMAN/ETSI HyperMAN standards, and to ensure worldwide compatibility and interoperability of equipment to accelerate deployment of broadband metropolitan area networks. WiMAX-certified equipment not only ensures compatibility but also creates a broad competitive field that leads to lower cost for service providers and subscribers. IEEE 802.16 and WiMAX will propel BWA forward to accelerate affordable worldwide deployment.

However, standardization does not mean worldwide “sameness” and automatic interoperability for all deployed WiMAX-certified equipment. Standards define and suggest key profiles for the Media Access Control (MAC) layer, which packs/unpacks raw data based on standard protocols to accommodate data, voice and video, and for the Physical Layer (PHY), which handles the air interface and modulation schemes based on subscriber needs and RF link quality. The IEEE 802.16 standard generates profiles but also allows for vendor customization to meet specific or localized market needs, or to allow the vendor to differentiate itself with value-added features.

What is more, on a global scale, the actual RF interface varies by region. That is where spectrum-governing authorities, such as the US's FCC, play a key role in determining useable spectrum for various, sometimes competing, services. Through those authorities, governments make available spectrum to given segments that may, or may not, be in harmony with the rest of the world. Such is the case with the global deployment of WiMAX. Though some fairly common RF ground does exist, there is also a great deal of diversity in spectrum allocation and regulation.

But it is not just regulation that creates RF band diversity in the global deployment of WiMAX-certified wireless MANs. Service carriers and Wireless Internet Service Providers (WISPs) within a region have band choices. Available and allocated spectrum includes various licensed and unlicensed (license-exempt) bands. A carrier may choose to use its licensed spectrum to provide service and/or opt to use unlicensed spectrum. Most WISPs opt to use unlicensed spectrum because it is free for the using, and greatly reduces cost to the customer subscribers.

This diversity of spectrum for the deployment of WiMAX-certified MANs results in the demand for RF-diverse base stations (BS) and subscriber stations (SS). A Generic WiMAX SS system (Fig. 1) includes a control processor, MAC unit, baseband processor (BBP) and an analog RF front-end that serves as the means to place 802.16x into a specific licensed or unlicensed band. Equipment vendors look to chip makers like Fujitsu Microelectronics America to provide complete reference designs, bills of material, components, software/firmware and technical support so that they can rapidly manufacture WiMAX-certifiable equipment to meet the needs of the RF-diverse markets. The interface for serving a particular band segment is the RF front-end.

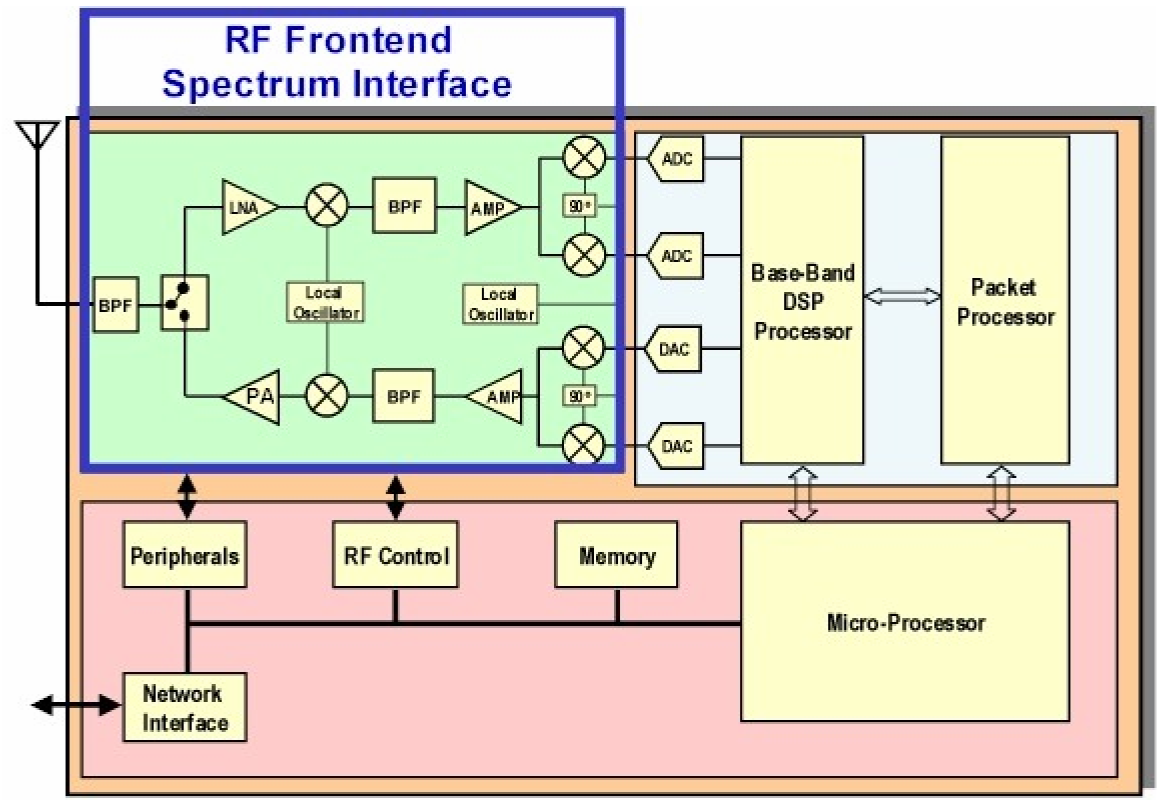

Fig. 1: Block Diagram Of WiMAX Subscriber Station:
Band Flexibility Comes From Different RF Front-Ends

Focus on 802.16REVd: Non-Line-of-Site Point-to-Multipoint Spectrum

WiMAX-certified BWA applications include backhauling for cellular networks, wide-bandwidth backhauling for wired and wireless LANs and for wireless MANs to bring BWA to homes and businesses as an alternative to DSL or cable access. However, the greatest market explosion will take place in the future 802.16x versions addressing portability and mobility, bringing BWA directly to the end-user. This “last-mile” market is by nature a Point-to-Multipoint (PMP) architecture using non-line-of-sight (NLOS) RF propagation. WiMAX-certified networks will be emerging worldwide in both licensed and unlicensed bands within this spectrum, in many cases replacing existing proprietary pre-802.16 services.

Currently, focus has been given to frequency bands that exist in the 2-GHz to 6-GHz portion of the spectrum, where allocated bandwidths are relatively narrow compared to those that are available in the 10-GHz to 66-GHz range. Frequencies below 10 GHz are referred to as centimeter bands and those above 10 GHz are millimeter bands which, with their much wider channel bandwidths accommodate large data capacities. So, millimeter bands are generally most suitable for very high data-rate line-of-sight backhauling applications (major pipelines), while centimeter bands are well suited for multipoint, NLOS, tributary and last-mile distribution.

The centimeter spectrum contains a significant tributary – and last-mile market worldwide. IEEE 802.16d supporting fixed NLOS BWA to supplant, or supplement, DSL and cable access for last-mile service is the foundation for the first wave of WiMAX deployment. Moving forward, IEEE 802.16e, to be ratified in 2005, will add mobility and portability to applications such as notebooks and PDAs for spectrums below 6GHz range. Both licensed and unlicensed spectrums will be used in these deployments.

Spectrum Options: Band Characteristics of Licensed and Unlicensed Spectrum

Fig. 2 shows the various bands available for BWA in the 2-GHz to 6-GHz range. Note that these bands are identified as either licensed or unlicensed (license exempt). Licensed bands are those that are currently "owned" by carriers that have paid for the use of these bands. Unlicensed bands are freely available for any experimental, or enterprise application. IEEE 802.11a/b/g-based Wi-Fi resides in unlicensed bands and has proven to be very robust in spite of competing technologies within these bands. Within each band, channel spacing is relatively narrow, thus limiting data rates as compared to the higher frequency millimeter band channels.

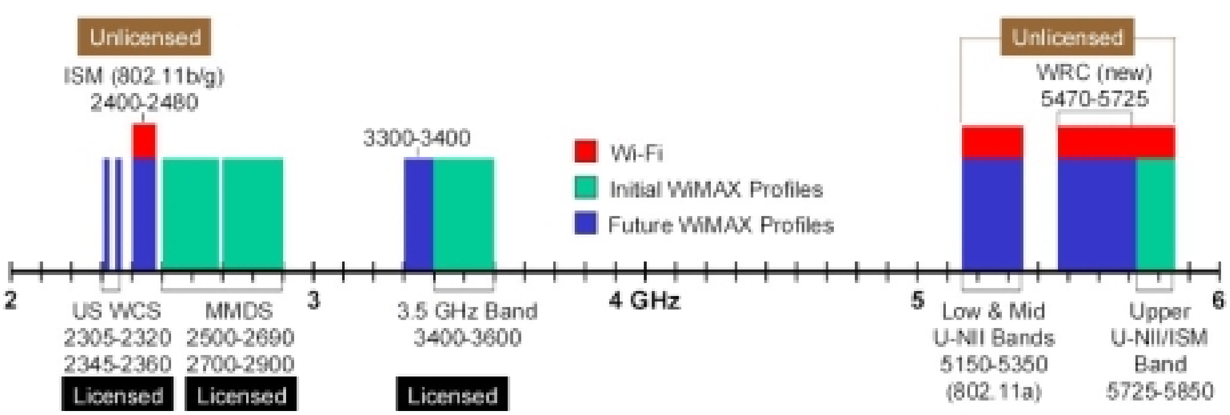

Fig. 2: 2-GHz To 6-GHz Centimeter Bands Available For BWA

Wireless ISPs and Major Carriers

Many WISPs seek to use unlicensed bands because they are free, saving both money and time for network deployment. This also reduces costs for the subscriber and provides a competitive alternative to DSL and cable modem services; it is also attractive in the US because there isn't much licensed spectrum available in the 2-GHz to 6-GHz range. On the other hand, major carriers that have licensed spectrum can market it at a premium for "business-class" service as it is perceived to be more robust and reliable, riding on the reputation of a major brand name.

Band Distinctions

3.5-GHz Band: The 3.5GHz band is licensed spectrum available for BWA use in many European and Asian countries, but not in the US. It is the most heavily-allocated band representing the largest global BWA market. Covering 300 MHz of bandwidth, from 3.3 GHz to 3.6 GHz, this band offers great flexibility for large-pipeline backhauling to WAN services. With this licensed spectrum, major carriers will be able to offer competitive subscriber fees through the economy of scale and the lower equipment costs that WiMAX certification brings.

Broad Global Utilization of 3.5GHz Bands

EMEA

Czech Republic, France, Germany, Hungary, Greece, Ireland, Norway, Poland, Romania, Russia, Spain, Switzerland, UK
Israel, Turkey, Nigeria, Mali

Americas

Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, Ecuador, Mexico, Peru, Uruguay, Venezuela

Asia Pacific

Australia, NZ, China, Indonesia, India (3.3-3.4 GHz), Japan, Malaysia, Taiwan
China 3400-3430 and 3500-3530 to start
Hong Kong & Singapore – band allocated to fixed satellite only

5-GHz U-NII & WRC Bands: The Unlicensed National Information Infrastructure (U-NII) bands are in three major frequency groups: low and middle U-NII bands (5150 MHz – 5350 MHz) (802.11a), World Radio Conference (WRC) (new) (5470 MHz – 5725 MHz), and upper U-NII/ISM band (5725 MHz – 5850 MHz). Wi-Fi exists in the lower and middle U-NII bands, which has demonstrated viability for BWA. Many overlapping 5-GHz frequency bands earmarked for BWA growth exist around the world. The newly-allocated WRC band adds significant license-exempt bandwidth. Most WiMAX activities are in the upper U-NII band because there are fewer competing services and less interferences there, i.e. Wi-Fi and the outdoor power allowance are in the higher 2 W to 4 W range as compared to only 1 W in the lower and middle U-NII bands. Analysts and marketers expect strong WiMAX growth in this unlicensed space.

WCS: The two Wireless Communications Service (WCS) bands are twin 15-MHz slots, 2305 MHz to 2320 MHz and 2345 to 2360MHz. The 25-MHz gap between these bands is assigned to the Digital Audio Radio Service (DARS), which poses a potential interference problem caused by DARS terrestrial repeaters. Primary license holders for the WCS bands include Verizon, BellSouth, AT&T and Metricom along with some smaller entities. Successful deployment in these bands will require exceptional spectral efficiency such as offered by Orthogonal Frequency Division Multiplexing (OFDM), an RF modulation technique used by both Wi-Fi and WiMAX.

2.4-GHz ISM: The 2.4GHz Industrial, Scientific and Medical (ISM) band is unlicensed and offers roughly 80 MHz of bandwidth for BWA deployment. Wi-Fi now exists in this band and has demonstrated robust service for WLANs. Future WiMAX profiles that specify interoperable MAC and BBP requirements will bring the two services together for complementary operation that delivers wide-area mobility to the user.

MMDS: The Multichannel Multipoint Distribution Service (MMDS) spectrum includes 31 channels of 6 MHz spacing in the 2500 MHz to 2690 MHz range and includes the Instructional Television Fixed Service (ITFS). This spectrum has been significantly under-utilized for its original instructional TV purpose and has been allocated for BWA service in the US by the FCC. BWA providers have gained access to this spectrum through FCC auctions and/or by leasing channels from ITFS channel holders. Sprint and Nextel are key spectrum holders here. Analysts expect significant BWA market growth in this band over the next few years.

WiMAX Forum Spectrum Initiative

Because of the potential for very high growth and utilization, the WiMAX Forum is focusing its initial profiling and certification efforts on the MMDS, the 3.5-GHz licensed bands and the unlicensed upper U-NII 5-GHz band, where there is less interference, reasonable power levels and adequate bandwidth. This will help ensure a high growth rate for WiMAX-certified BWA service worldwide because these bands represent the largest potential markets and allow for lower costs through economies of scale.

Transmitting and Receiving Signal Strengths

Power levels and power control for both transmit and receive are extremely important for system efficiency in any WiMAX network. Levels must be actively managed to ensure solid communications and to mitigate potential interference. In addition, power levels are dynamically adjusted on a per-subscriber basis, depending on the subscriber’s profile and distance from the BS. Overall data throughput starts with adequate power levels.

Receive Requirements

As specified by the WiMAX standard, receive level specifications are the same across the centimeter bands, 2 GHz to 11 GHz. The receiver must be able to accurately decode an on-channel signal of -30 dBm (1 µW) maximum and must be able to tolerate a signal as strong as 0 dBm (1 mW) at the receiver input without damage to the front-end. In addition, the receiver should be able to provide a minimum image rejection of 60 dB. The WiMAX standard specifies that "the image rejection requirement be inclusive of all image terms originating at the receiver RF and subsequent intermediate frequencies." Adherence to these requirements will ensure reliable near and far operation.

Transmit Requirements

Subscriber stations (SSs) that do not use subchannels (single carrier) must exhibit a minimum of 30-dB range of monotonic power control. For SSs that do use subchannels (OFDM), a category that will include all WiMAX-certified SSs in the 2-GHz to 11-GHz range, the transmitter must have a dynamic power control range of at least 50 dB in no less than 1-dB steps with accuracy within ±1.5 dB over a 30 dB range, or ±3 dB over any range greater than 30 dB.

For the BS transmitter, output-power-level control must have at least a 10-dB range. Actual transmitted power will depend on the subscriber distance, propagation characteristics, channel bandwidth, and modulation scheme (BPSK, QPSK, 16-QAM, 64-QAM). BPSK is the least data-efficient method and is employed where the SS is farthest from the BS, thus requiring additional transmit power. 64-QAM, on the other hand, offers very high data efficiency (bits per symbol) and is used when the SS is relatively close to the BS, thus requiring less transmit power.

SoC to RF Interface

Referring again to Fig. 1, the interface between the RF front-end and the SoC involves control signals to handle operation and housekeeping functions for the transmitter and receiver along with I/Q signals interfacing with the ADCs and DACs.

Receive data delivered by the demodulator circuit to the SoC should be differential "I" and "Q" signals. Attenuators can be employed on the receive side to handle calibration and gain control to ensure maximum bit usage and conversion efficiency of the ADCs.

Future Spectrum for WiMAX: More Room and Service Options

Additional bands are being considered today by different regions around the world for the deployment of WiMAX and other similar broadband wireless access services. In Japan the 4.9-GHz to 5.0-GHz band will be used after 2007, while the 5.47-GHz to 5.725-GHz band is also being considered for future use. The first one will require a license for BS deployment and will support 5-MHz, 10-MHz and 20-MHz bandwidths, while the second one will possibly not require a license and would support 20-MHz bandwidths.

The North American market is indicating some interest in deploying WiMAX in the 4.9-GHz broad-spectrum public safety band.

There is even some interest in using lower-frequency bands such as the licensed 800-MHz and the unlicensed 915-MHz ISM bands for WiMAX and similar types of services and deployments.

The WiMAX standard is set to bring the long-awaited spectral efficiency and throughput to meet users' needs for combined mobility, voice services and high data rates. It will enable access for more users due to its non-line-of-sight capability, lower deployment costs, wide range capability and penetration into the mass consumer market with lower CPE costs as a result of standardization and interoperability.

Needless to say, it is the clear path to broadband mobility and it will form the basis of "4G" offering a true freedom of mobility.

For more information

More information on the IEEE802.16 standard for BWA and the WiMAX Forum is available at http://www.wimaxforum.org and http://www.ieee802.org/16. For more information on Fujitsu's broadband wireless SoC, please address e-mail to inquiry.bwa@fma.fujitsu.com or visit http://www.fujitsu.com/us/services/edevices/microelectronics/wpbwaRF.html

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