WiMAX Summit 2007

Testing Requirements for Successful WiMAX Deployments

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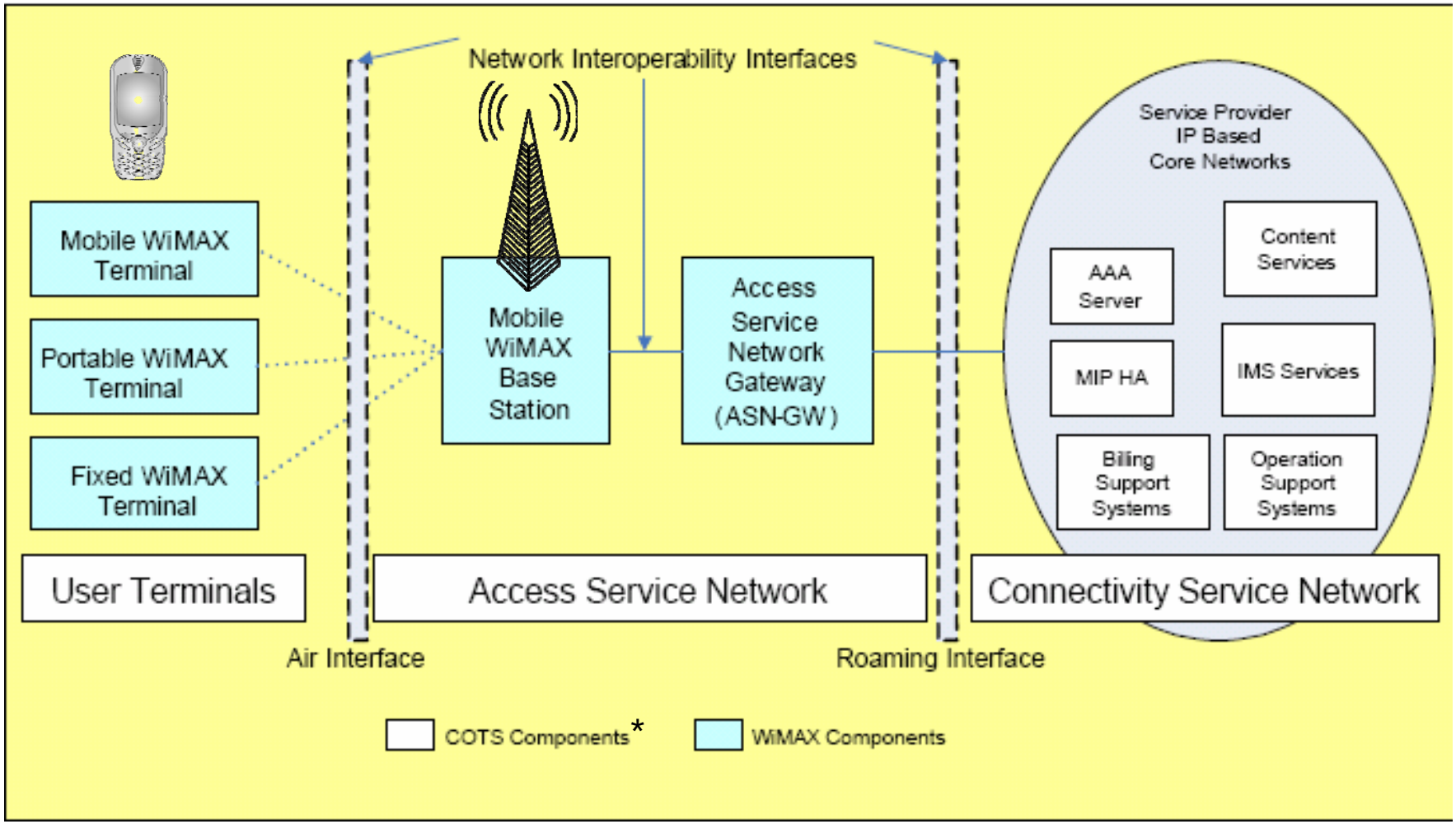
Municipal Multipath Environment

WiMAX IP-Based Architecture



*** Commercial off-the-shelf** software or hardware products

WiMAX IP-OFDMA

- The IEEE 802.16e-2005 Wireless MAN standard is based on the concept of scalable OFDMA* (S-OFDMA).
  - A range of bandwidths to accommodate available spectrum
- WiMAX Forum Release-1
  - Based on 802.16e-2005
  - 1.25, 5, 7, 8.75, 10 and 20 MHz channel bandwidths
  - Initial profiles are 5 and 10 MHz
  - Licensed worldwide spectrum allocations include 2.3, 2.5, 3.3 and 3.5 GHz bands

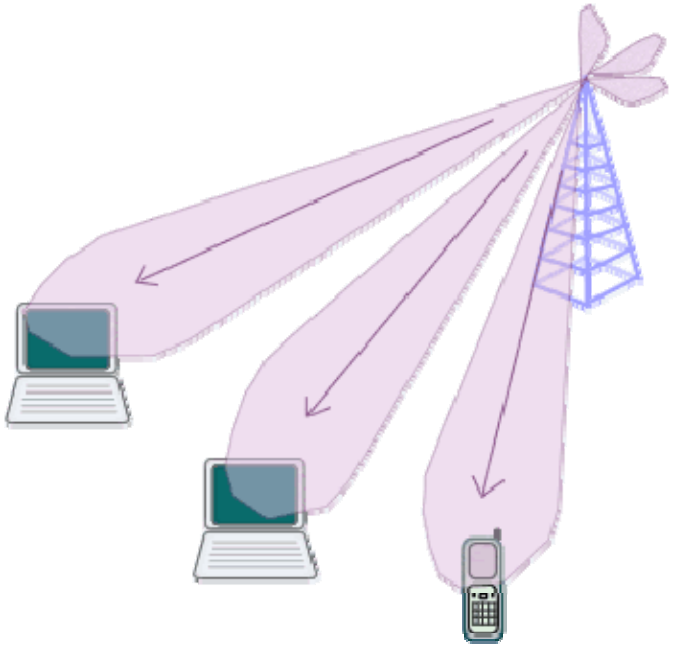
* Orthogonal Frequency Division Multiple Access

ITU IMT-2000 and IEEE 802.16

- Next generation network framework developed by ITU-R M.1457, “Detailed specifications of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)”
- IEEE 802.16 is working with ITU-R to make the terrestrial air interface of M.1457 be based on the WiMAX IP-OFDMA
- IEEE 802 official response to ITU-R is due in May 2007

WiMAX Smart Antenna Technologies

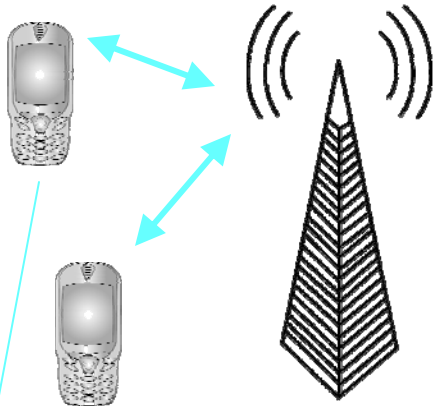
- **Beamforming**
  - Use multiple-antennas to spatially shape the beam to improve coverage and capacity
- **Spatial Multiplexing (SM)**
  - Multiple streams are transmitted over multiple antennas
  - Multi-antenna receivers separate the streams to achieve higher throughput
  - In uplink single-antenna stations can transmit simultaneously
- **Space-Time Code (STC)**
  - Transmit diversity such as Alamouti code [1,2] is supported to reduce fading

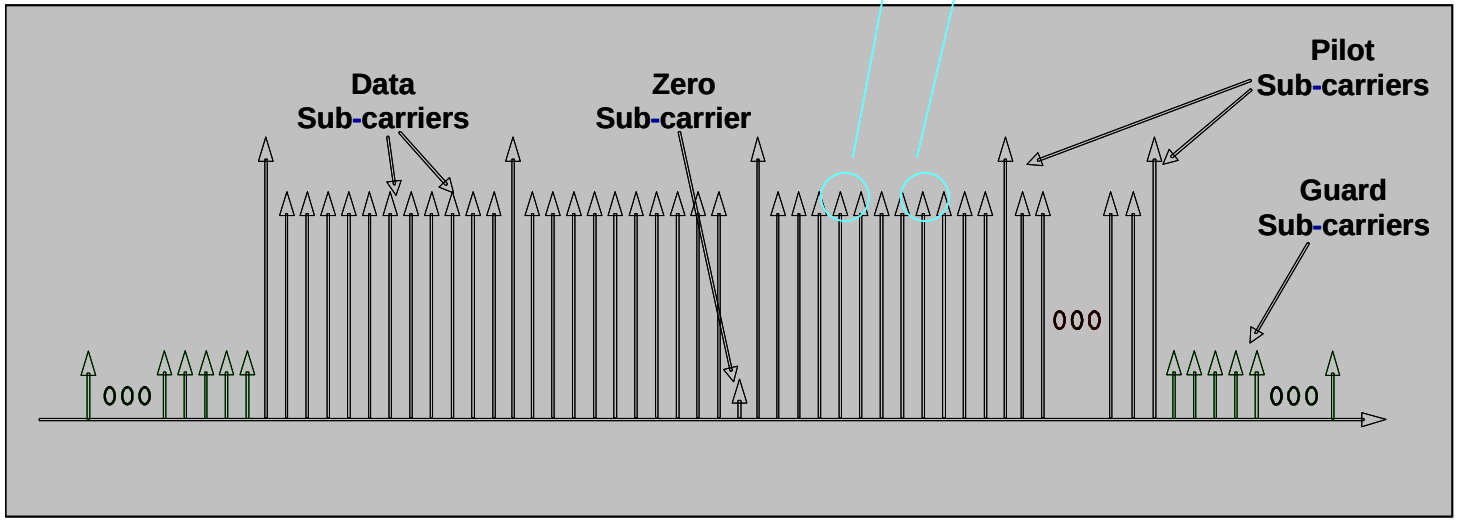


2x2 MIMO SM increases the peak data rate two-fold by transmitting two data streams.

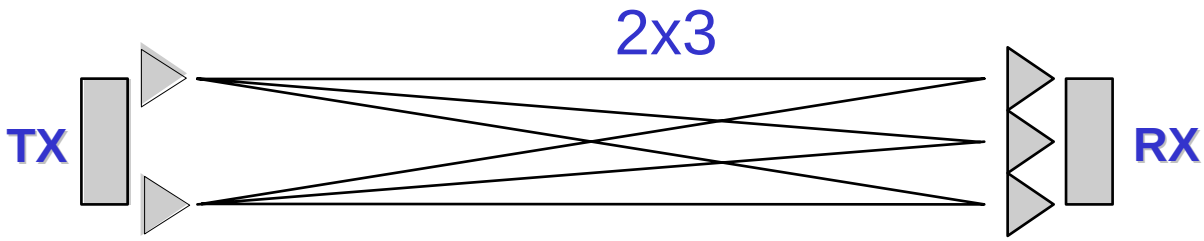
Collaborative Uplink Transmission

- Upstream/Downstream carrier allocation
  - Stations transmitting on their own carriers to share OFDM bandwidth
- Phase lock important for this use case to avoid interference





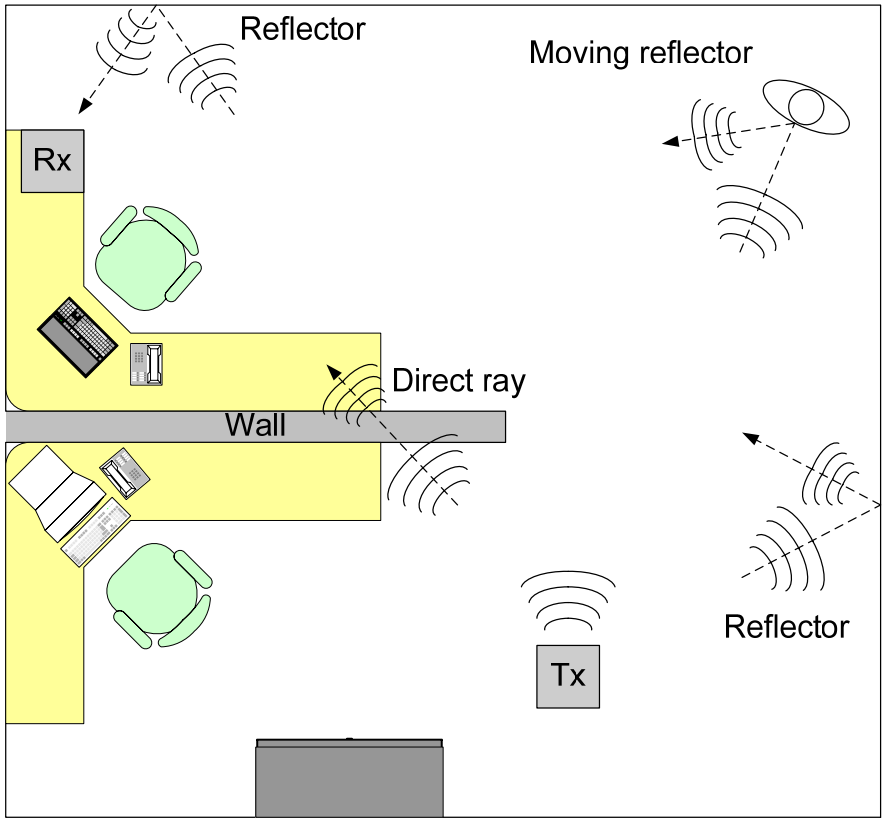
MIMO Radio Systems



- Data is organized into spatial streams that are transmitted simultaneously
- **SISO**: Single-Input/Single-Output; **MIMO**: Multi-Input/Multi-Output; **SIMO**: Single-Input/Multi-Output; **MISO**
  - Refers to the streams between a set of transmit and receive antennas
- There's a propagation path between each transmit and receive antenna (a "MIMO path")
  - *N* transmit antennas
  - *M* receive antennas
  - Total of *N* x *M* paths
- Hence MIMO system characterization: "4x4", "2x2", "2x3", etc.

Indoor MIMO Multipath Channel

- Multipath reflections come in “clusters”
- Reflections in a cluster arrive at a receiver all from the same general direction
- Statistics of clusters are key to MIMO system operation and a critical part of channel emulation for MIMO
- 802.11n developed 6 models: A through F

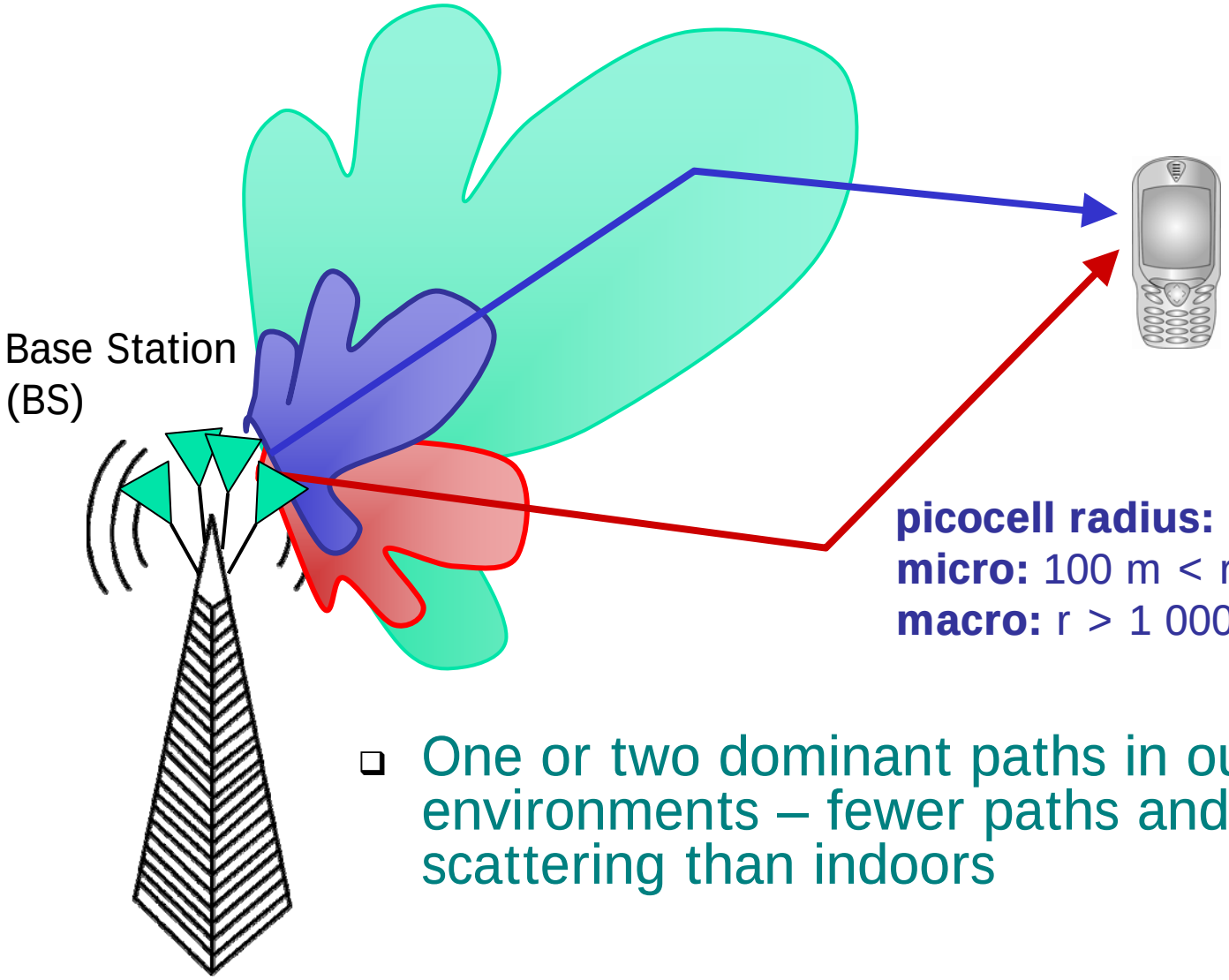


802.11n Channel Models

Parameters	Models					
	A	B	C	D	E	F
Avg 1st Wall Distance (m)	5	5	5	10	20	30
RMS Delay Spread (ns)	0	15	30	50	100	150
Maximum Delay (ns)	0	80	200	390	730	1050
Number of Taps	1	9	14	18	18	18
Number of Clusters	N/A	2	2	3	4	6

- Delay spread is a function of the size of the modeled environment
- Number of clusters represents number of independent propagation paths modeled
- Doppler spectrum assumes reflectors moving in environment at 1.2 km/h, which corresponds to about 6 Hz in 5 GHz band, 3 Hz in 2.4 GHz band

Outdoor Multipath Environment



picocell radius: r < 100 m
micro: 100 m < r < 1 000 m
macro: r > 1 000 m

- One or two dominant paths in outdoor environments – fewer paths and less scattering than indoors

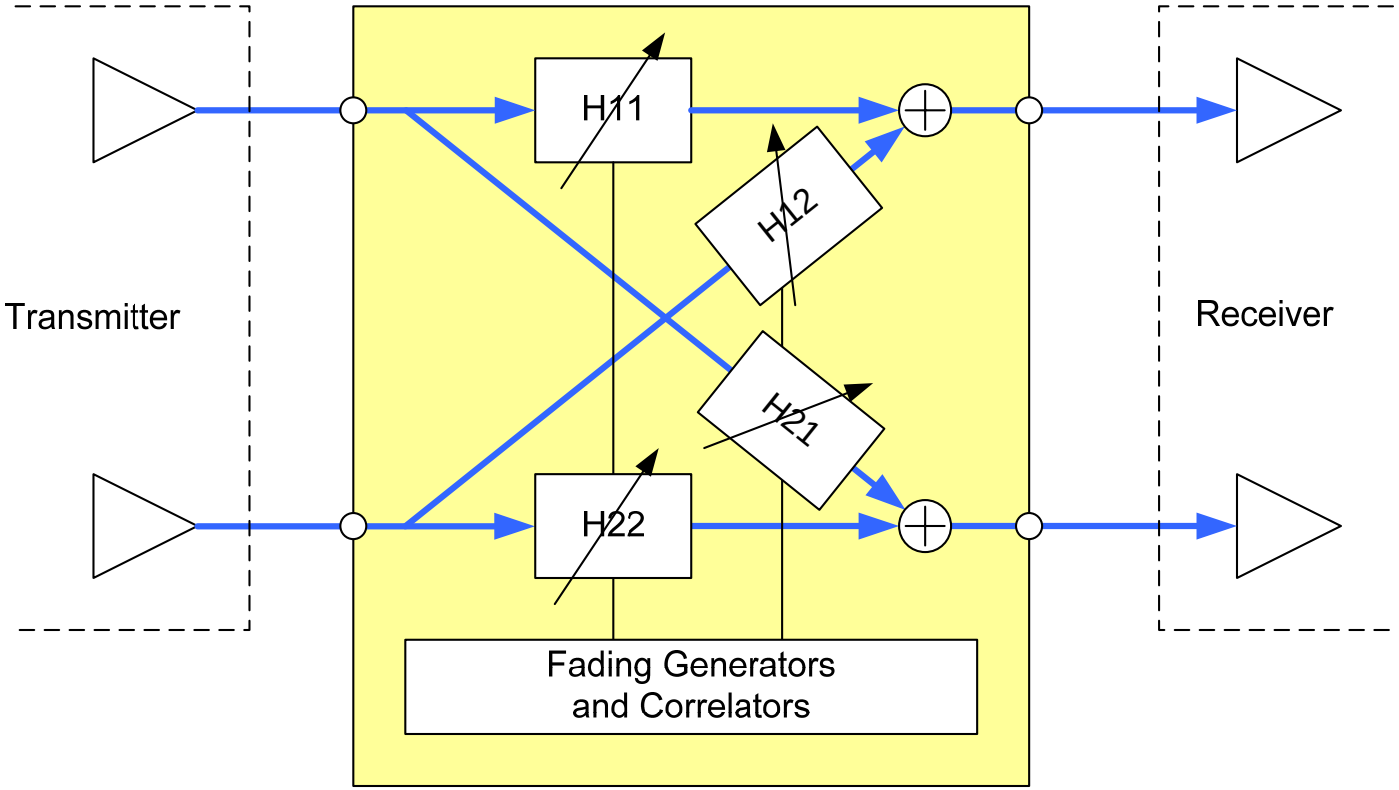
IP-OFDMA MIMO Channel Models

WiMAX system performance simulations [3,4,5] are based on ITU models

Channel Model	Path 1	Path 2	Path 3	Path 4	Path 5	Path 6
ITU Pedestrian B (relative figures)	0 dB 0 ns	-0.9 dB 200 ns	-4.9 dB 800 ns	-8.0 dB 1200 ns	-7.8 dB 2300 ns	-23.9 dB 3700 ns
ITU Vehicular A (relative figures)	0 dB 0 ns	-1.0 dB 310 ns	-9.0 dB 710 ns	-10.0 dB 1090 ns	-15.0 dB 1730 ns	-20.0 dB 2510 ns

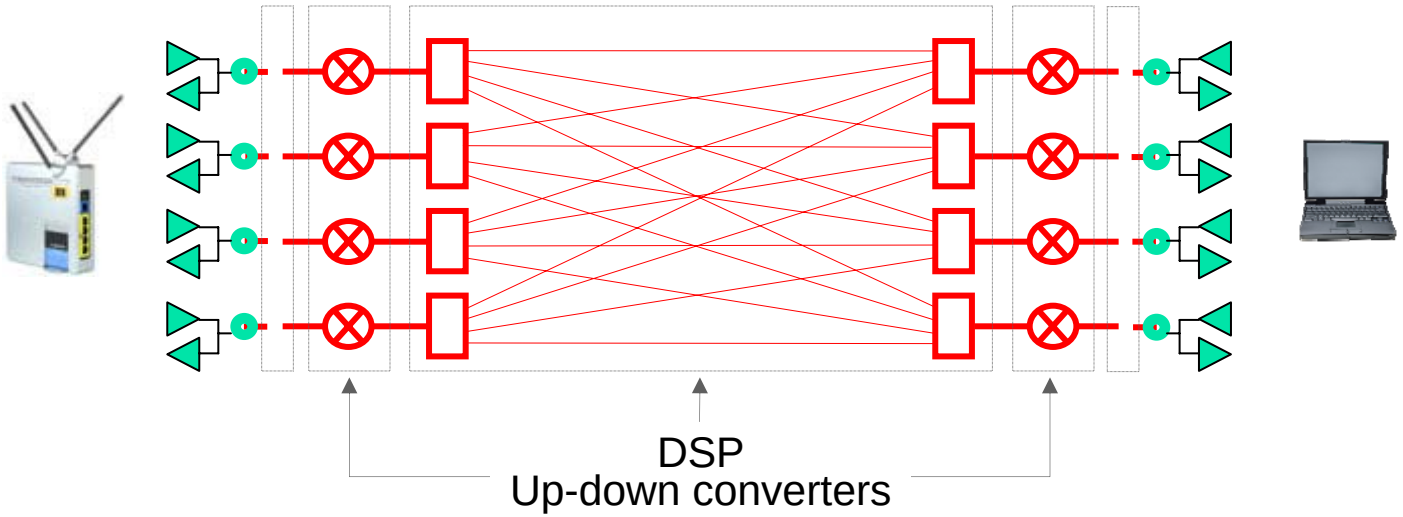
Channel Model	Speed	Probability
ITU Pedestrian B	3 km/hr	60%
ITU Vehicular A	30 km/hr	30%
	120 km/hr	10%

Example 2x2 MIMO Channel Model



- Time-varying FIR filter weights
  - Spatially correlated: H_{11} correlated with H_{12}, etc., according to antenna spacing and cluster statistics
  - Time correlated according to the Doppler model

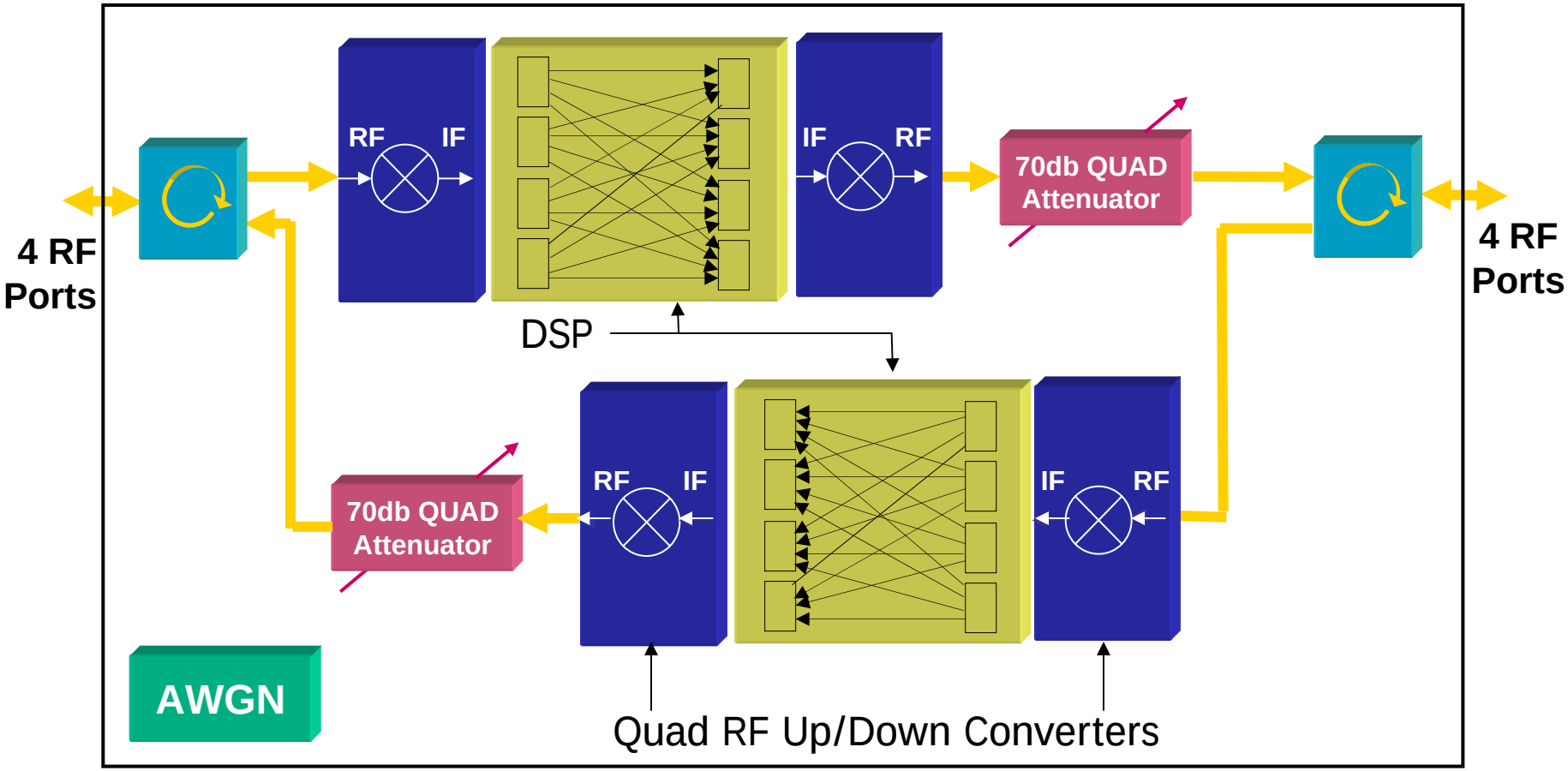
MIMO Channel Emulation



- 4 x 4 MIMO paths to support 802.11n; WiMAX requires 2 x 2, which is a subset of 4 x 4
- 802.11n [6] and ITU M.1225 [7] channel models
- Bidirectionality to support beamforming
- Independent fading of paths for range testing
- AGWN* emulation for testing in the presence of noise per *WiMAX Forum™ Mobile Radio Conformance Tests (MRCT)* document

* additive white Gaussian noise

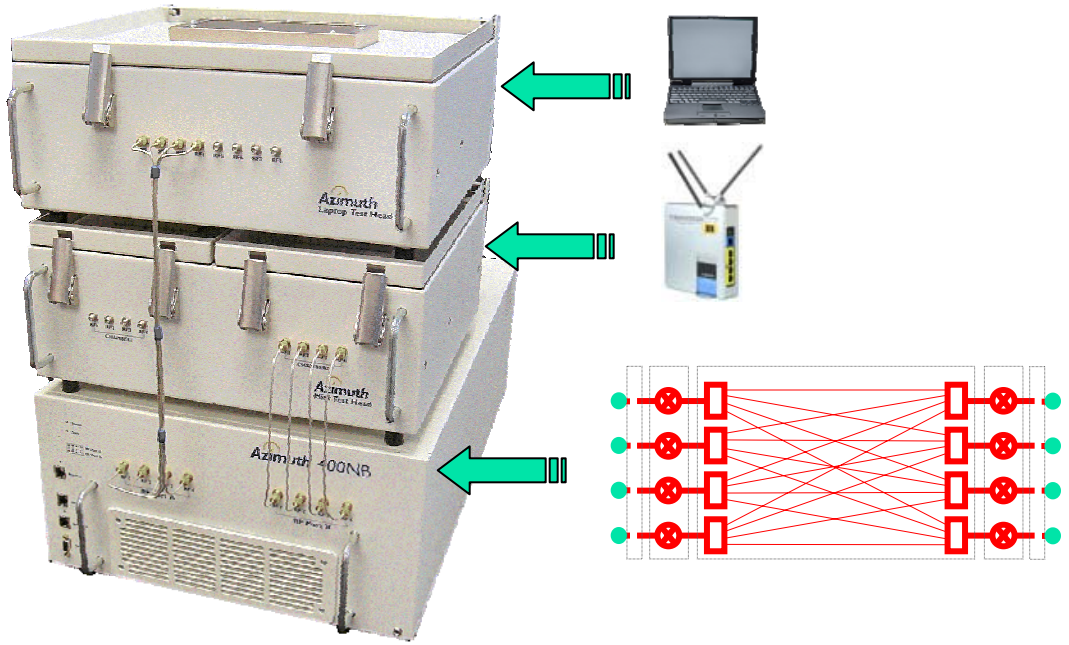
4X4 MIMO Multipath Bi-directional Channel Emulator Block Diagram



Bold path = 4 RF Lines

Controlled Test Environment

ACE (Azimuth Channel Emulator) [8]



- RF Isolation is required to prevent crosstalk among nodes under test

References

- [1] S.M. Alamouti, “A Simple Transmit Diversity Technique for Wireless Communications,” IEEE Journal on Selected Areas in Communications, vol. 16, pp 1451-1458, October 1998.
- [2] V. Tarokh, H. Jafarkhani and A. R. Calderbank, “Space-time Block Codes from Orthogonal Designs,” IEEE Transactions on Information Theory, vol. 45, pp. 1456-1467, July 1999.
- [3] 3GPP2 C.R1002-0, CDMA2000 Evaluation Methodology, December 2004
- [4] 3GPP TSG-RAN-1, “System-Level evaluation of OFDM - further Considerations”, R1-031303, November 17-21, 2003
- [5] WiMAX Forum, “Mobile WiMAX- Part 1-Overview and Performance”, August 2006
- [6] “TGn Channel Models,” V. Erceg et al, IEEE 802.11 document 11-03/0940r4
- [7] Recommendation ITU-R M.1225, “Guidelines for Evaluation of Radio Transmission Technologies for IMT-2000”
- [8] Azimuth Systems ACE ™, www.azimuthsystems.com