Enhancements for
High Speed Downlink Packet Access
(HSDPA) using multiple antennas

Outline

- **Impact of multiple antennas on Shannon capacity**

- **Space-time transmission and processing techniques**

  - **space-time transmit diversity**

  - **spreading code re-use**

- **Implementing these techniques for the downlink shared channel (DSCH)**
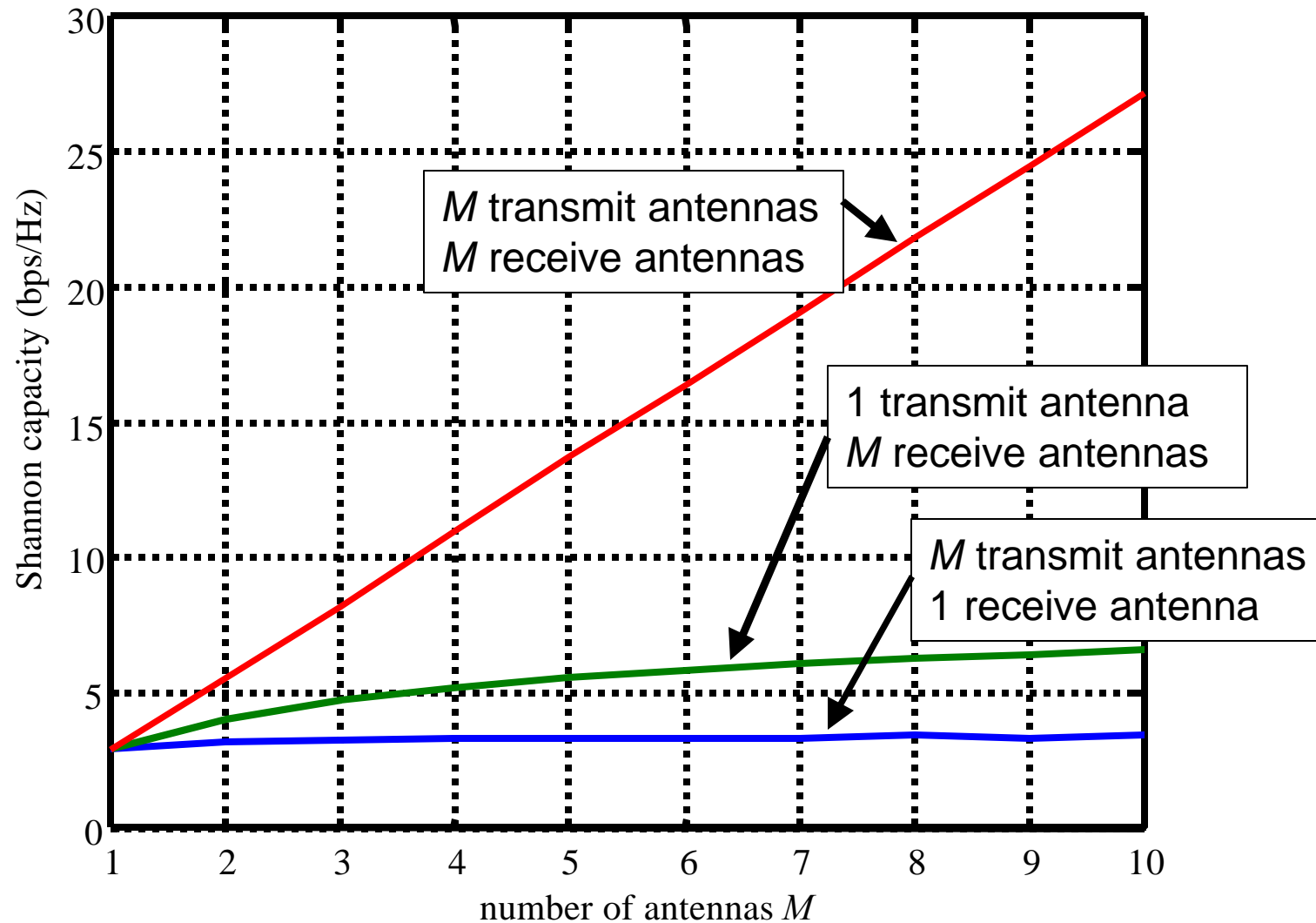
Multiple antenna advantage

◆ **Consider a multi-input multi-output channel with independent Rayleigh fading channel, $\mathbf{H}_{M \times N}$**

◆ **The Shannon capacity as measured in bits per second per Hertz is:**

$$C = \log_2 \det\left(\mathbf{I}_M + SNR * \mathbf{H}^H \mathbf{H} / M\right)$$

$$\approx \log_2 \det\left(\mathbf{I}_M + SNR * \mathbf{I}_M\right) \quad \longleftarrow \quad \text{As } M, N \text{ increase,}$$
$$\text{with } M = N$$

$$= M \log_2(1 + SNR)$$

◆ **If multiple antennas are used at both the transmitter and receiver, capacity grows *linearly* with number of antennas.**

Multiple antenna advantage

How do we realize the capacity?

- **Space-time (ST) transmission and processing:**
  - **Transmit data with redundancy across antennas (space) and time dimension.**
  - **Process received signal in space and time.**
  - **Multiple receive antennas allow combining advantage to increase SNR.**
- **Examples:**
  - **Alamouti space-time block code**
  - **AT & T space-time trellis code**
  - **BLAST (Bell Labs Layered Space-Time)**

Alamouti space-time block coding

◆ **Achieves full two-branch transmit diversity without using additional bandwidth or power resources compared to a single transmit antenna system.**

◆ **Implemented as space-time transmit diversity (STTD) in UMTS standard.**
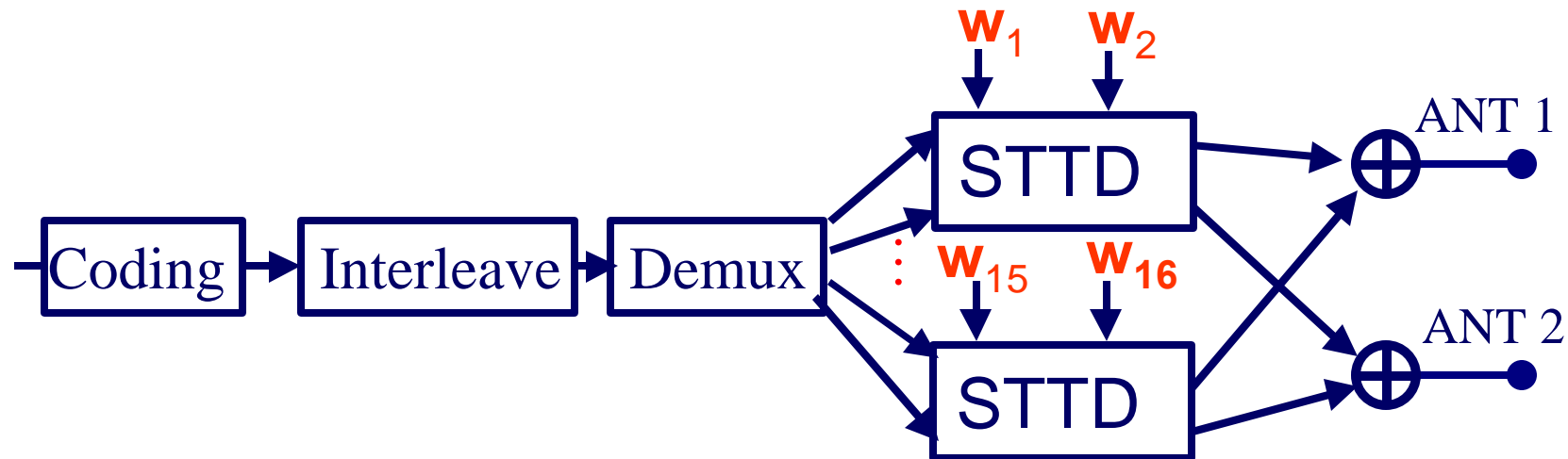
Space-time trellis coding

◆ **Systematic approach to achieve maximum transmit diversity and coding gain**

– **very useful when there is only one receive antenna and no other form of diversity**

◆ **With constellation size of M maximum throughput is limited to $\log_2 M$ bits per symbol when designed for maximum diversity.**

– **Example : max of 2 bits/sym with QPSK**

BLAST

- ◆ **When multiple receive antennas are also available need for transmit diversity is not as critical**
- ◆ **Trade off higher diversity in favor of higher spectral efficiency.**
  - – **Increase throughput by sending independent information from different transmit antennas and separate the streams at the receiver**
  - – **Much higher peak throughputs with small constellations. Example: With QPSK and 4 Tx and 4 Rx antennas can achieve 8 bits per symbol period.**
- ◆ **In general, the number of receive antennas must be greater or equal to the number of transmit antennas.**
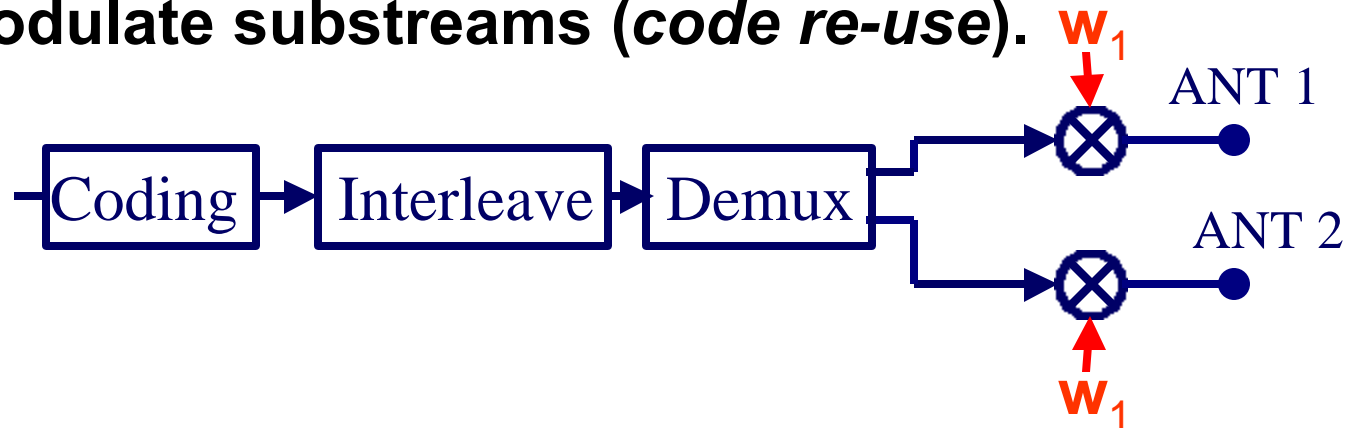
BLAST

◆ **Demultiplex coded data stream among antennas**

ANT 1

| Coding | → | Interleave | → | Demux |

ANT 2
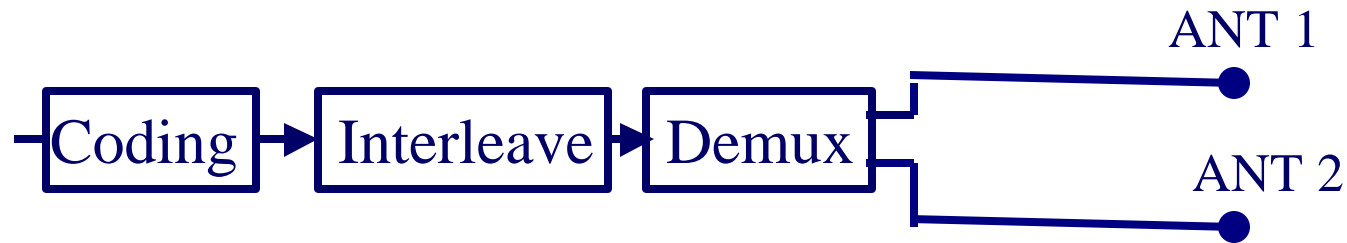
◆ **Because conventional codes are used, decoding complexity is much less than for space-time codes.**

◆ **In a CDMA system, use same spreading code to modulate substreams (*code re-use*).** w_1

ANT 1

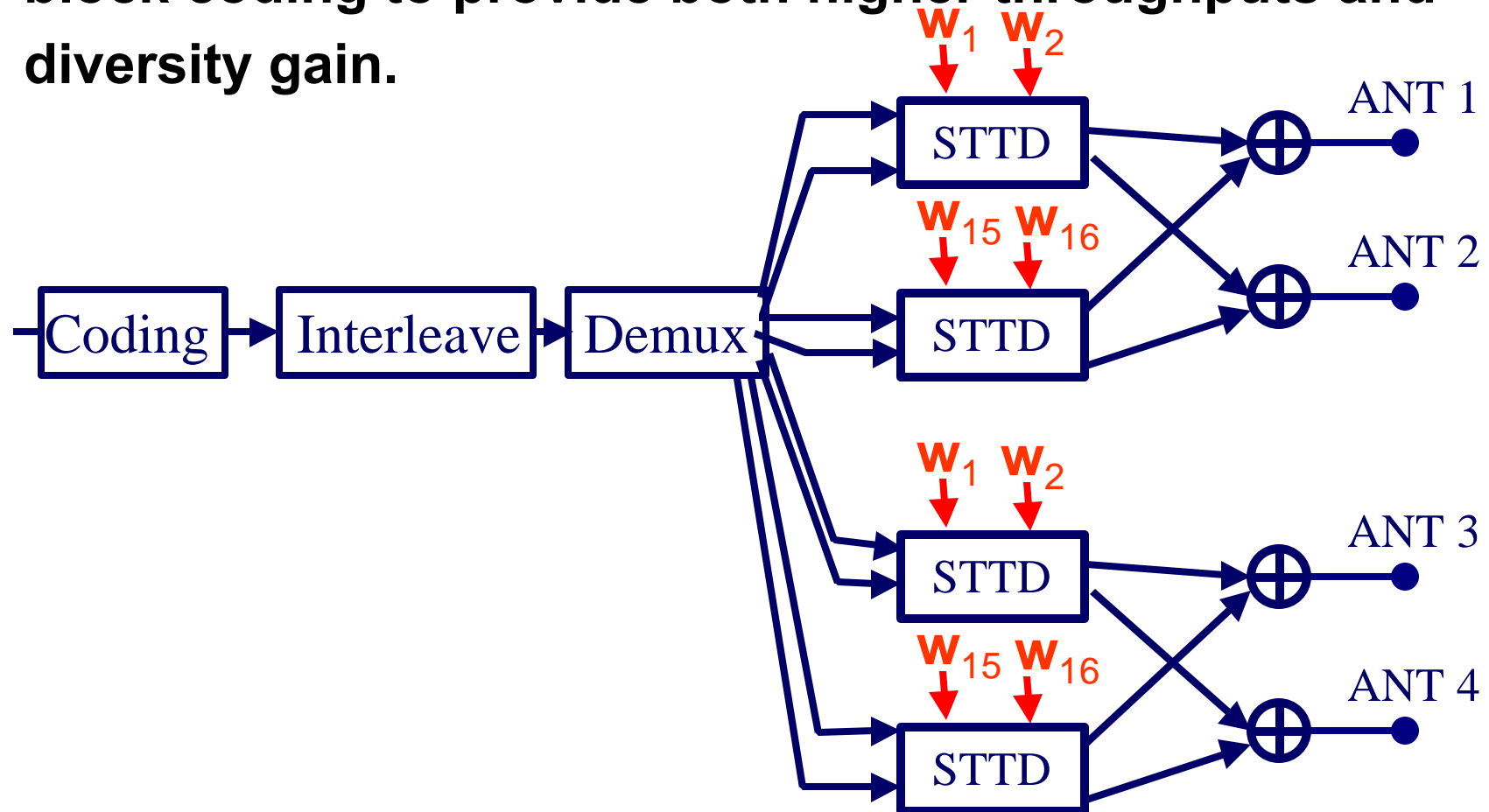| Coding | → | Interleave | → | Demux |

ANT 2

w_1

Code re-use in DSCH

◆ **Combine multicode transmission and code re-use for transmission on downlink shared channel (DSCH).**

◆ **Example: 2 antennas, 16 codes**
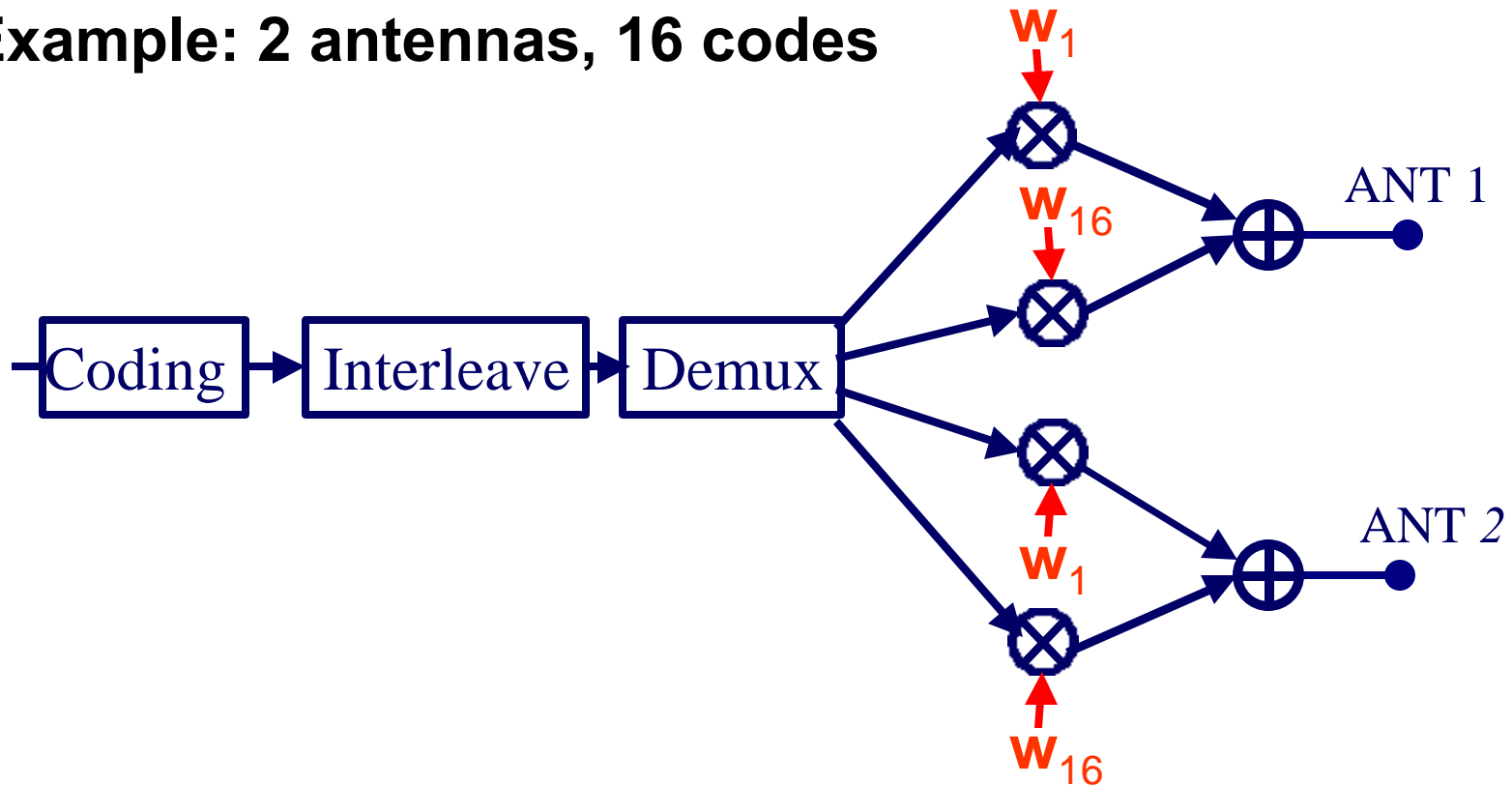
Combined code re-use and ST block coding

◆ **It is possible to combine code re-use and space-time block coding to provide both higher throughputs and diversity gain.**

How do multiple antennas help HSDPA?

◆ **Additional receive antennas improve C/I allowing the use of higher rate schemes more often.**

◆ **New schemes with higher peak throughput can be introduced**

– **example: 16 QAM with 2 Tx antennas and rate 3/4 coding yields 6 bits/symbol (doubling of peak throughput with 16QAM)**

◆ **Improvement in performance of current rates:**

– **example for 3 bits/symbol:**
rate 1/2 coded 8 PSK with 2 streams may be superior to rate 3/4 coded 16 QAM with Tx diversity

Transmit Options

◆ **Original**

- **Variable constellation size (QPSK, 8 PSK, 16 QAM, 64QAM)**
- **Variable channel code rate (rates 1/2, 3/4)**

◆ **With multiple antennas**

- **Transmit diversity via STTD**
- **Code re-use: independent data streams on the same CDMA code transmitted on different antennas**

Adaptive Coded Modulation Order

◆ **Based on preliminary simulation results without coding we have the following schemes with increasing Ec/Nt requirement for 4 transmit and 4 receive antennas**

  – **STTD QPSK   (2 bits/sym)**
  – **STTD-BLAST (2 streams) QPSK   (4 bits/sym)**
  – **STTD-BLAST (2 streams) 8 PSK   (6 bits/sym)**
  – **BLAST (4 streams) QPSK   (8 bits/sym)**

◆ **With coding we will have additional schemes with finer granularity.**

Summary

Lucent Technologies
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◆ **Additional receive antennas improve C/I allowing the use of higher rate schemes more often.**

◆ **Technique for increasing the throughput using multiple antennas can give up to 4 times peak throughput and improvements in average throughput when there are 4 Tx and 4 Rx antennas.**

◆ **Simulations with Turbo coding and system simulations are necessary.**