Advanced Antenna Technology

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School on
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Advanced Antenna Technology

Agenda:

Multisectorial Antennas

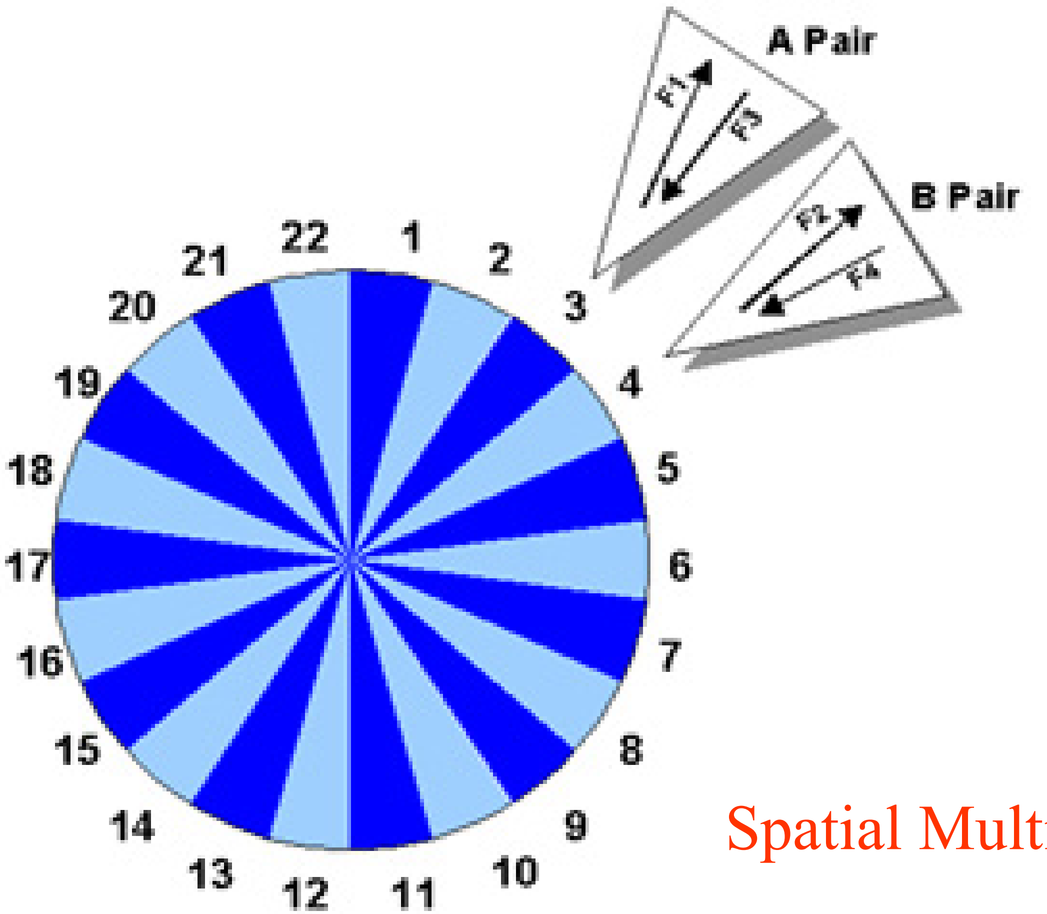
Smart Antennas

MIMO

Space – Time Coding

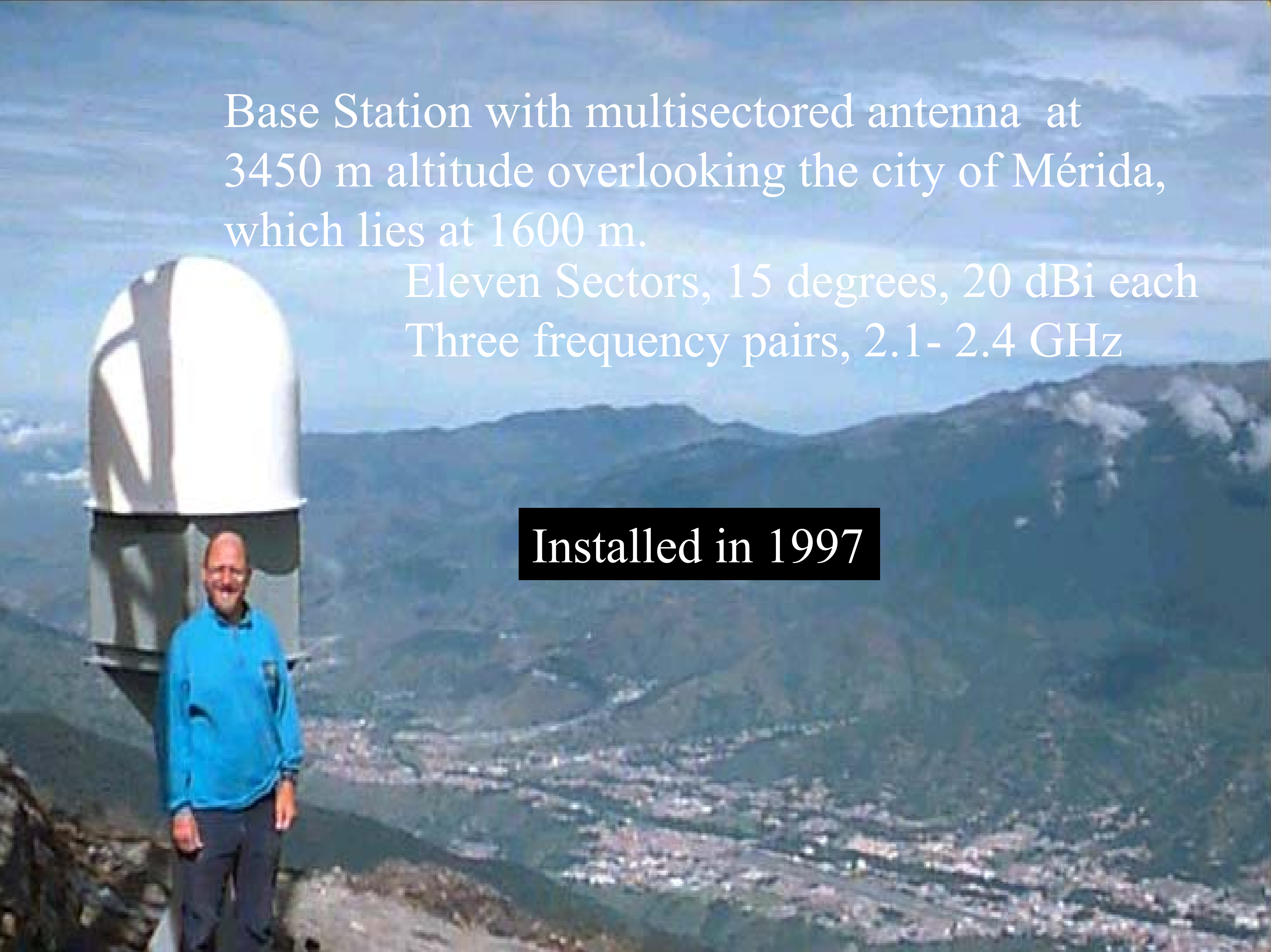
High density multisectored antenna

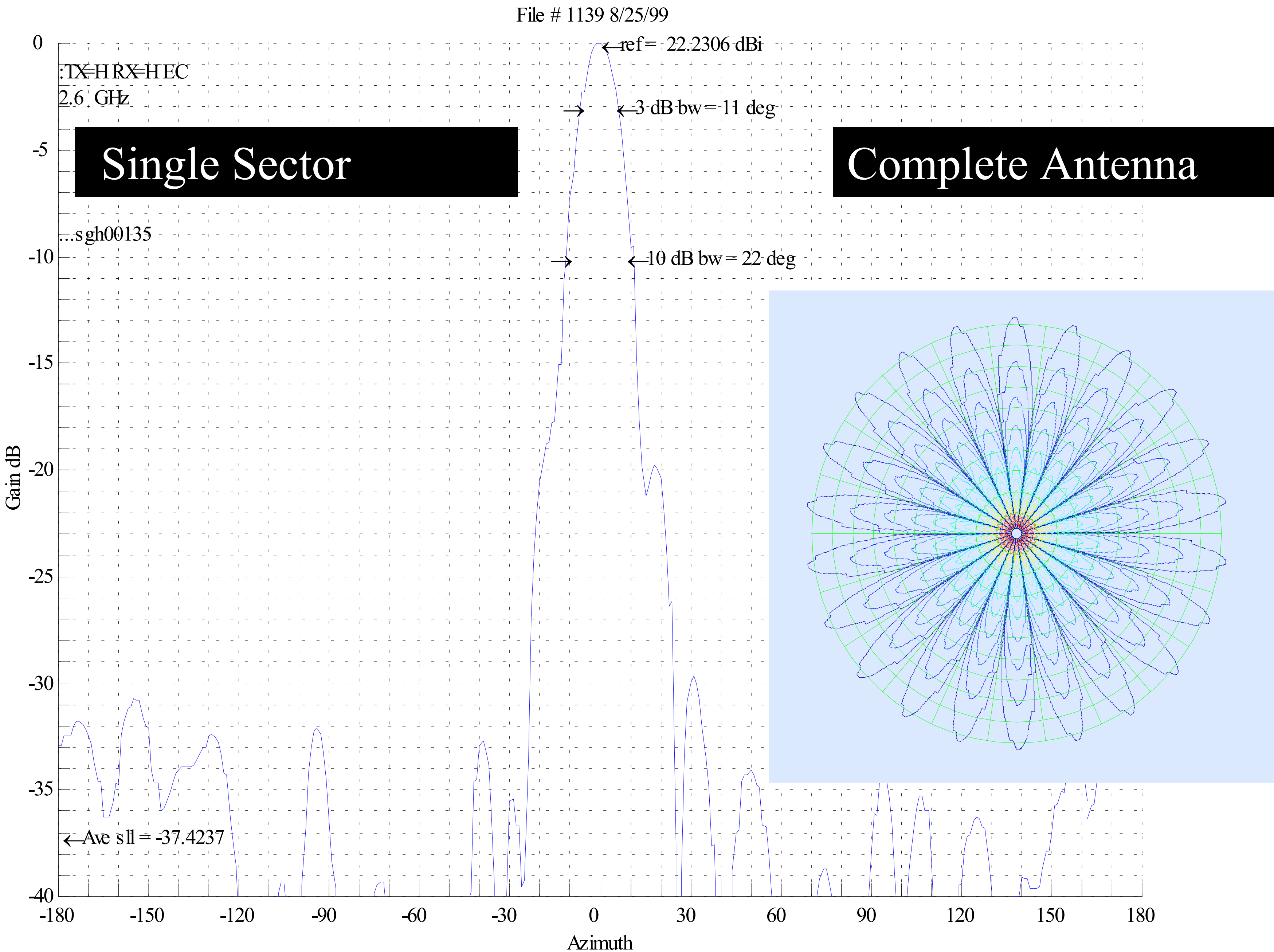
THE SECTORED APPROACH



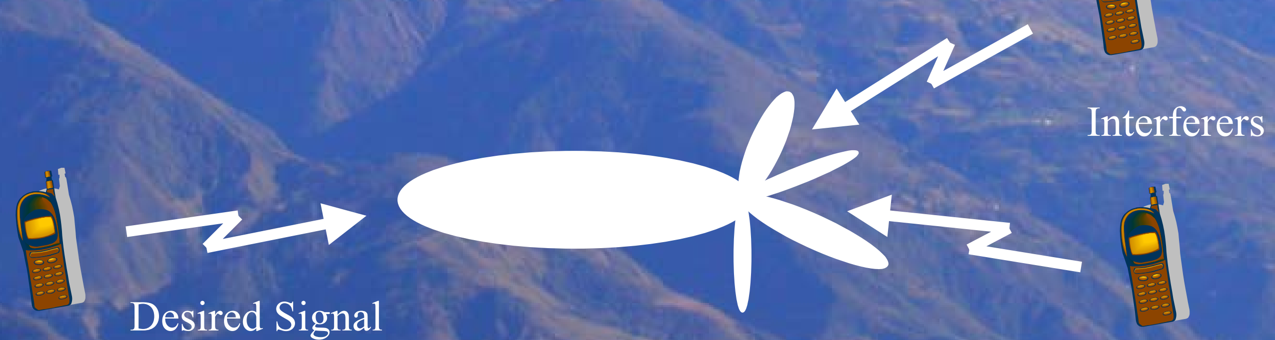
- PRIZM BDS utilizes a patented, sectored single aperture that allows spectral reuse of two channel pairs
- Spectral efficiency of this model results in a ratio of 11:1

Spatial Multiplexing


Base Station with multisectored antenna at 3450 m altitude overlooking the city of Mérida, which lies at 1600 m.
Eleven Sectors, 15 degrees, 20 dBi each
Three frequency pairs, 2.1- 2.4 GHz
Installed in 1997


File # 1139 8/25/99
Single Sector
Complete Antenna
:TX=H RX=H EC
2.6 GHz
...sgh00135
ref = 22.2306 dBi
3 dB bw = 11 deg
10 dB bw = 22 deg
Ave sll = -37.4237
Gain dB
Azimuth
0
-5
-10
-15
-20
-25
-30
-35
-40
-180
-150
-120
-90
-60
-30
0
30
60
90
120
150
180

A smart antenna system combines multiple antenna elements with a signal-processing capability to optimize its radiation and/or reception pattern automatically in response to the signal environment. It can automatically adjust the antenna beam pattern, frequency response and other parameters such that the performance of the system is enhanced in some defined manner



Smart antenna systems offer the following benefits:

- Higher capacity (traffic/area)

  Spectrum is expensive therefore of great interest to operators
- Better transmission quality and/or coverage

  Energy better focussed on user (greater C/I) or greater coverage

  Co-channel interference suppression

  Dynamic cell coverage
- Reduction of transmitter power
- Reduction of delay spread

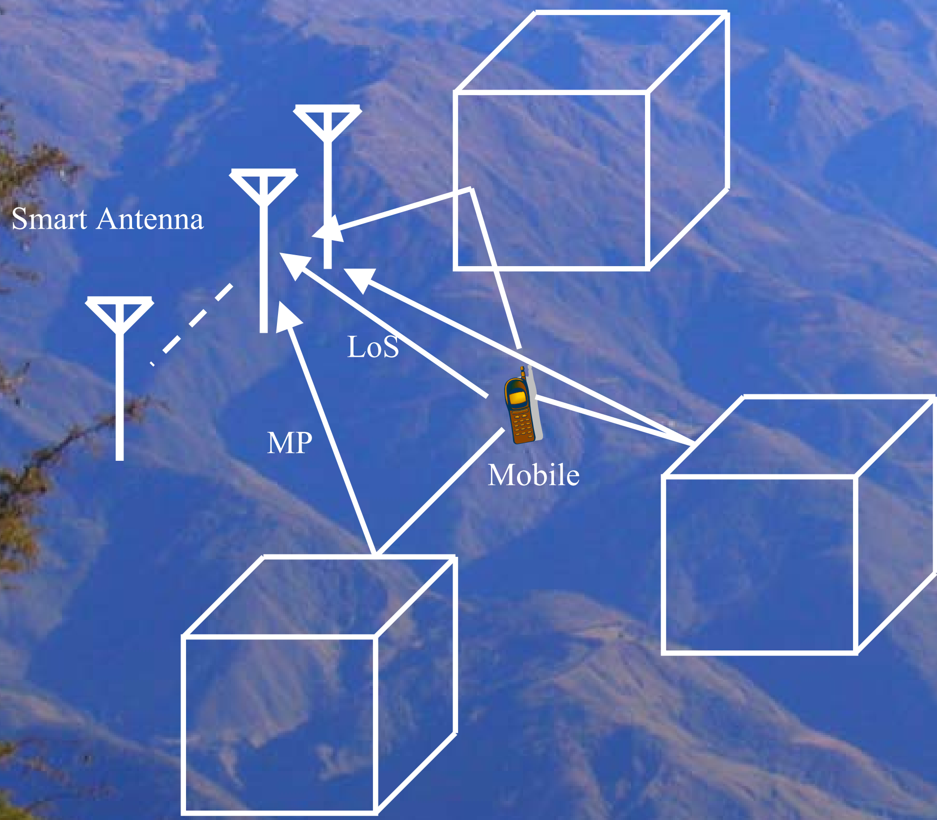
  Tuning of the channel for desired delay profile characteristics
- Accurate user position estimation

  Requirement for new standards

Limiting effects of the wireless channel:

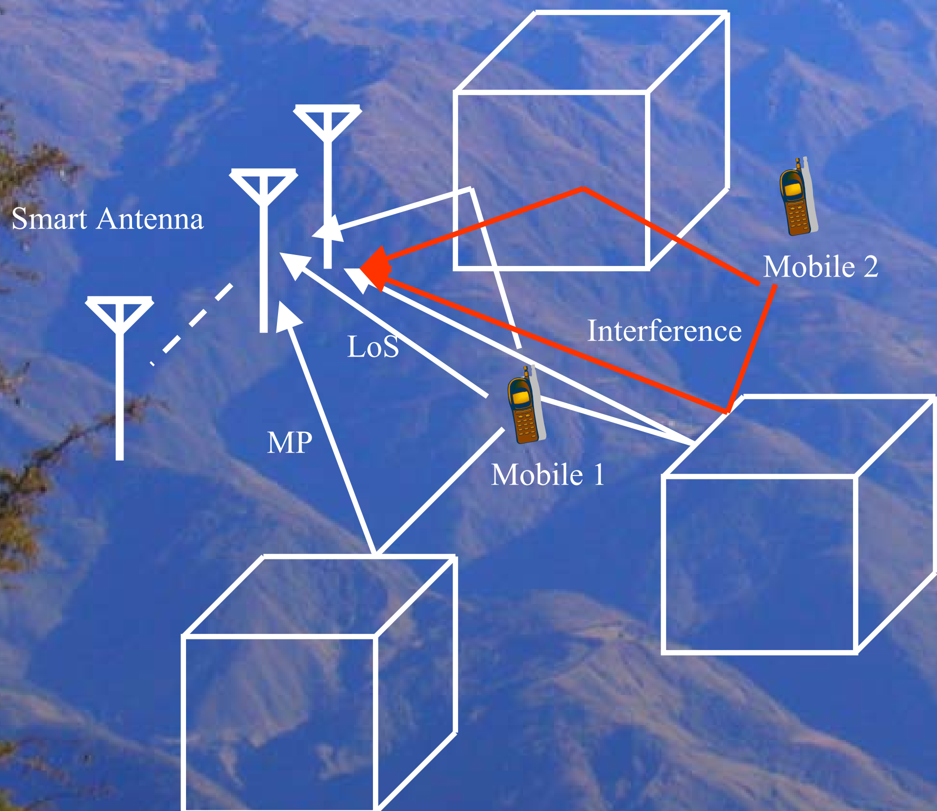
- Multipath propagation gives rise to
  - fading
  - intersymbol interference
  - time variation of signals
- Co-channel interference gives rise to
  - increased noise level and hence greater errors

Multipath Propagation



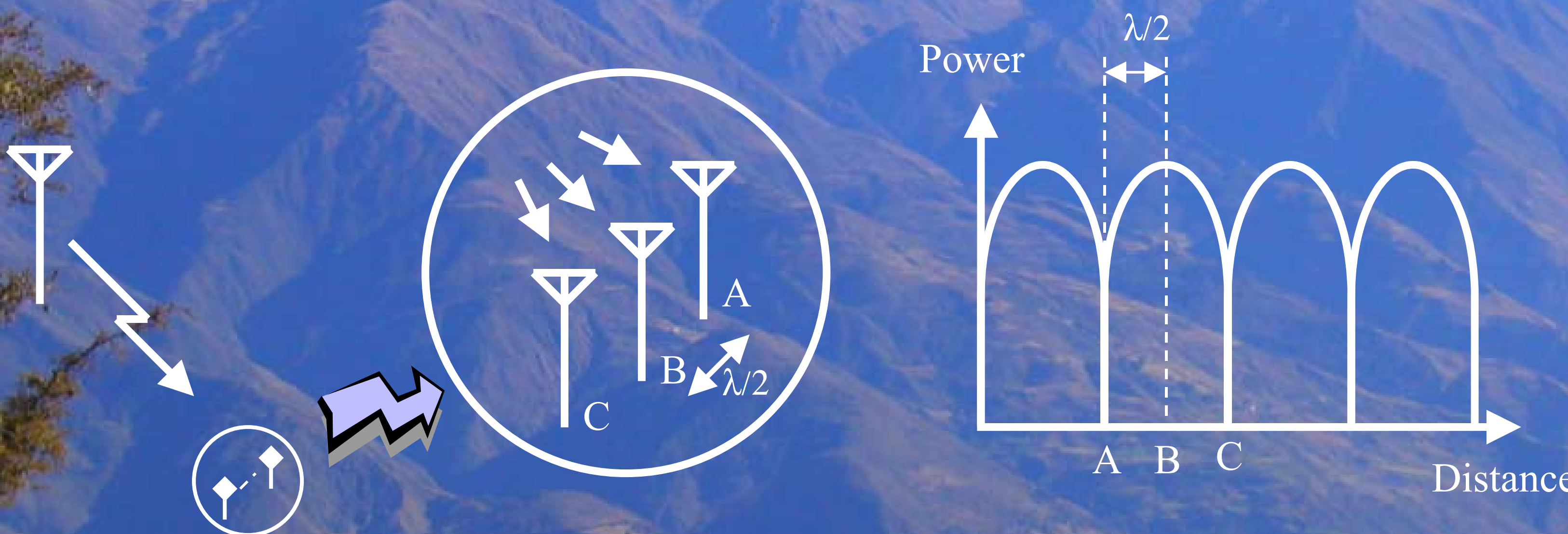
- Multipath components suffer different delays, which result in ISI
- Smart antennas can dynamically reject or stimulate multipath components by changing their radiation patterns

Co-channel Interference



- Co-channel interference from other users
- Other user interference comes from different directions than wanted user
- Smart antenna can suppress unwanted user by changing its beam pattern to place nulls in directions of unwanted signals

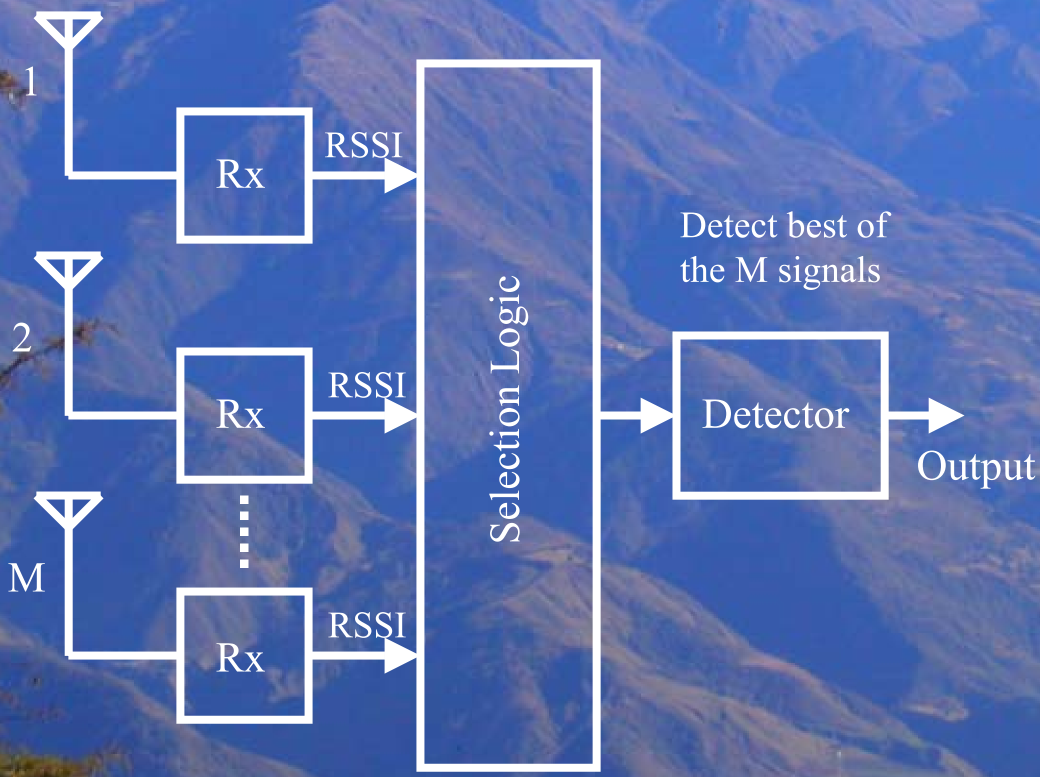
Spatial Diversity



(a) Spatial Diversity

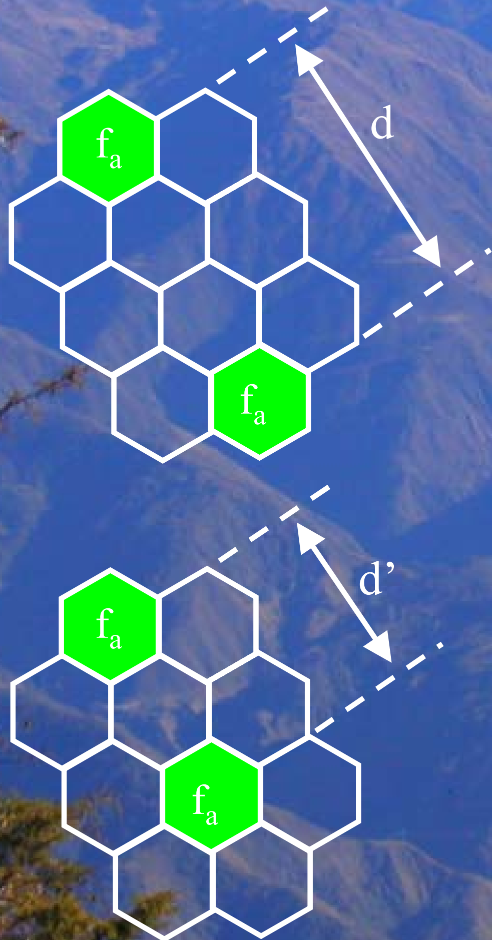
(b) Power Variation with Distance

Diversity Combining: Selection Combining



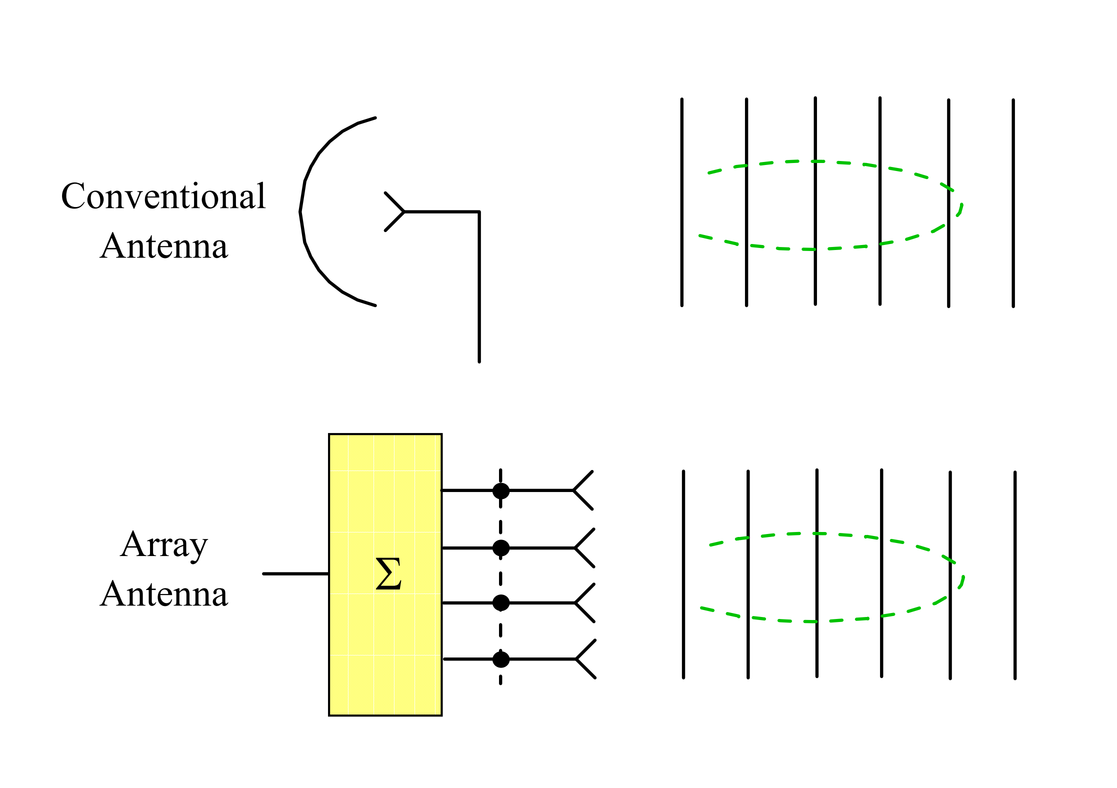
- The most appropriate branch is always selected. Slight performance advantage over switch diversity.
- Using RSSI as an indication of quality is non-ideal since it's unduly affected by interference.

SFIR - Spatial Filtering for Interference Rejection:

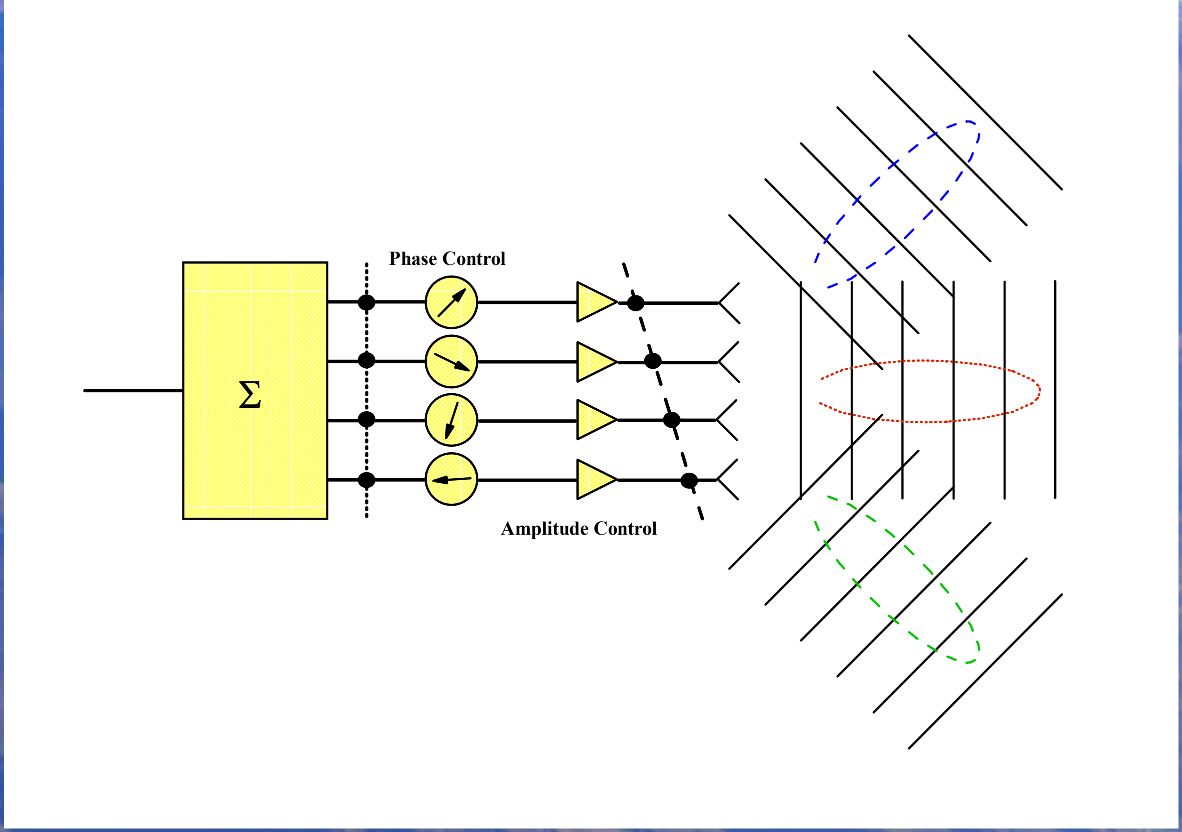


- Main beam of each smart antenna within each cell is directed towards a desired user
- Nulls of the smart antenna radiation pattern are directed towards undesired users
- Reduces the re-use factor in TDMS/FDMA systems
- A re-use factor of 1 becomes a possibility

Conventional and Array Antennas

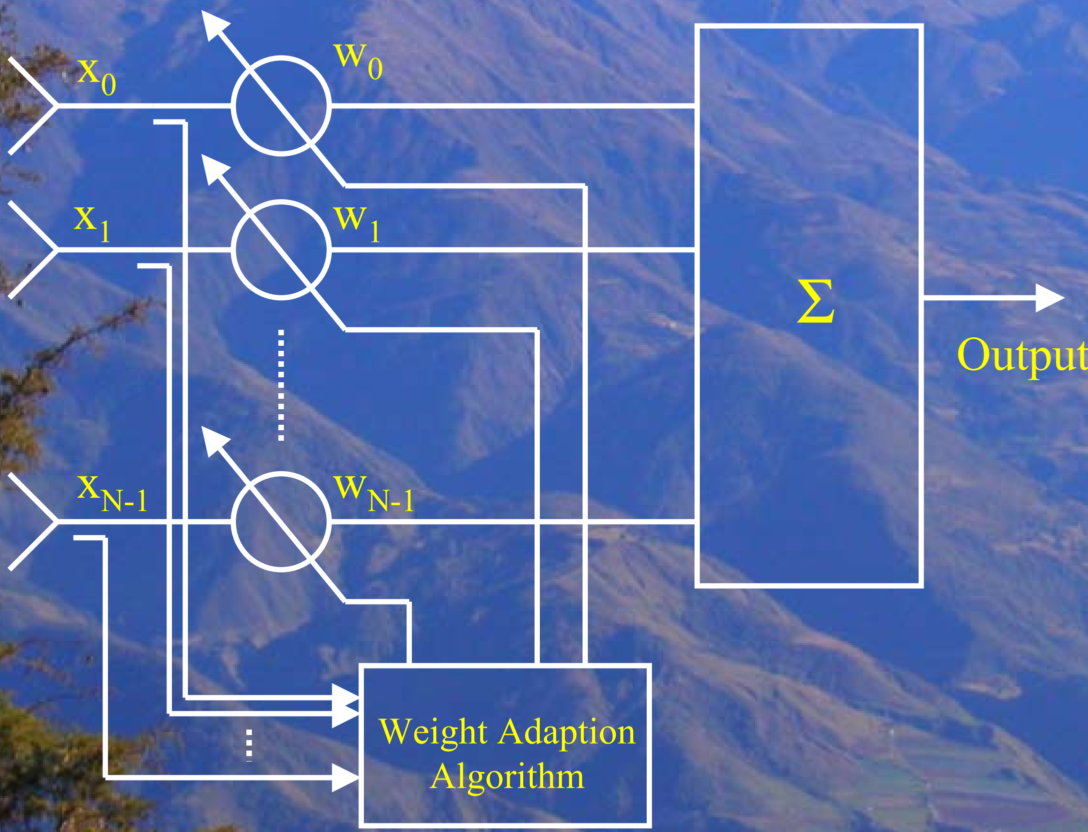


Phased Array Antenna



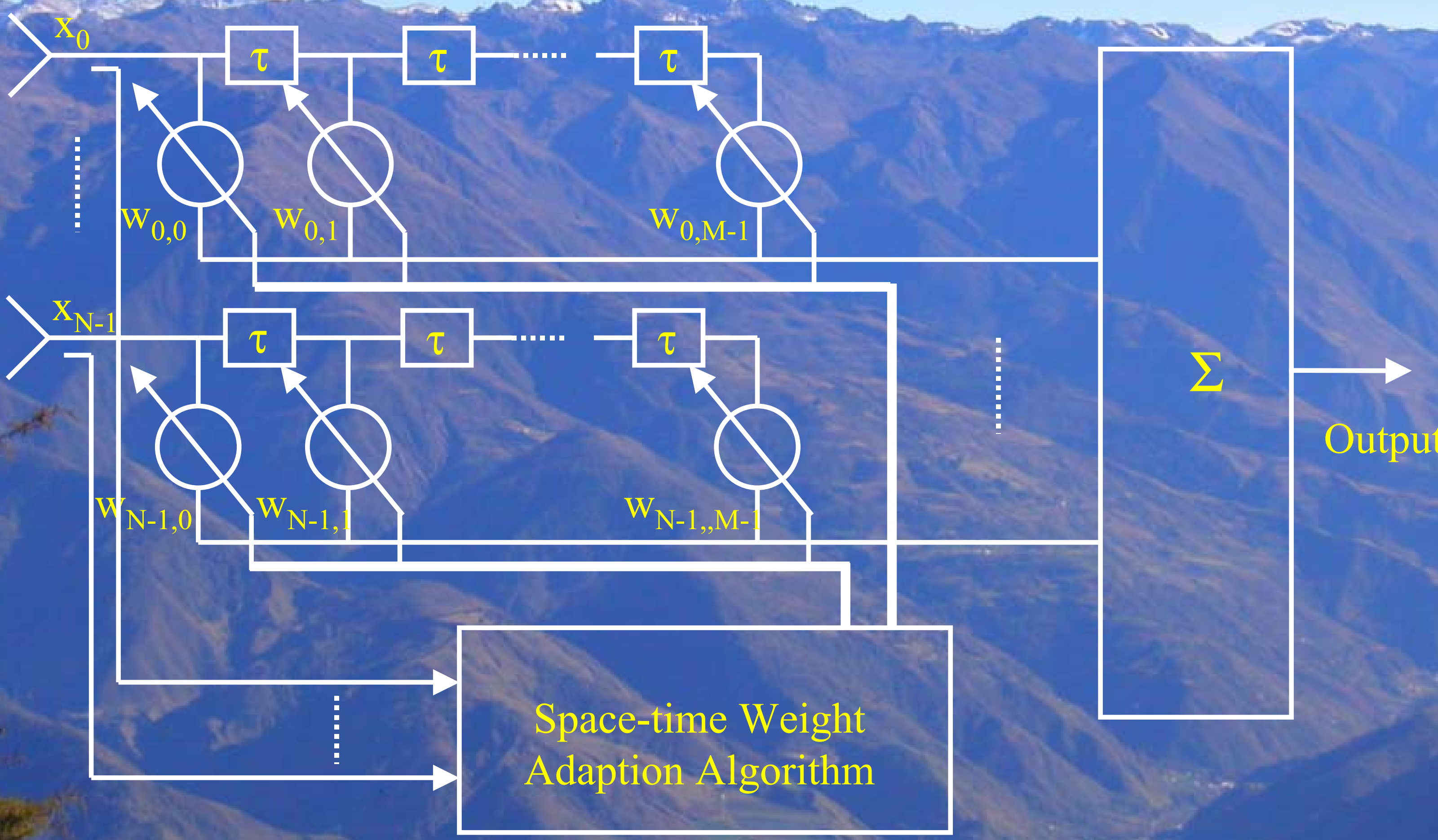
- Fast, Agile, Independent Beams
- Control of beam radiation patterns

Smart Antenna: Spatial Processing Architecture



- Spatial filtering
- Suitable for flat fading channels (or equalisation in beamspace)

Smart Antenna: Space-time Processing Architecture



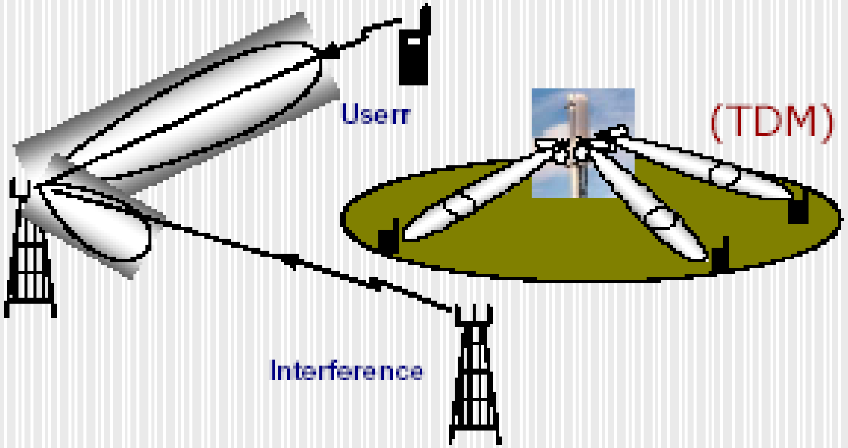
- Space-time equaliser array
- Wideband array architecture

Terminology

Terms commonly heard today that embrace various aspects of a smart antenna system technology include intelligent antennas, phased array, SDMA, spatial processing, digital beamforming, adaptive antenna systems, and others. Smart antenna systems are customarily categorized, however, as either switched beam or adaptive array systems.

Adaptive Antennas

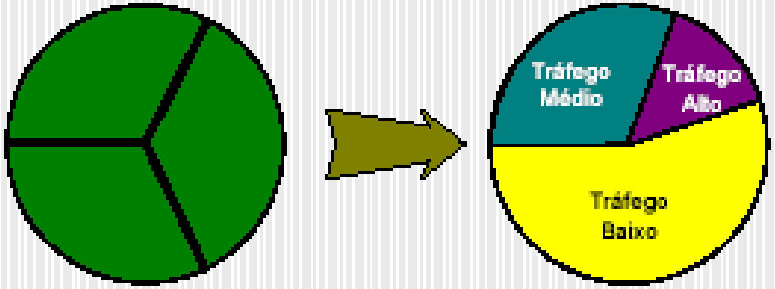
- Interference Reduction



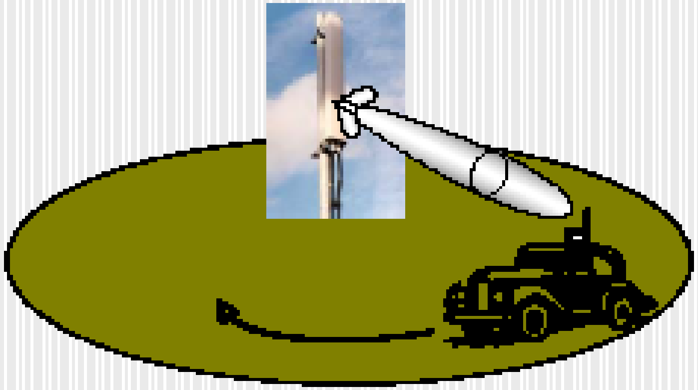
- *Tilts*

- Traffic Balancing

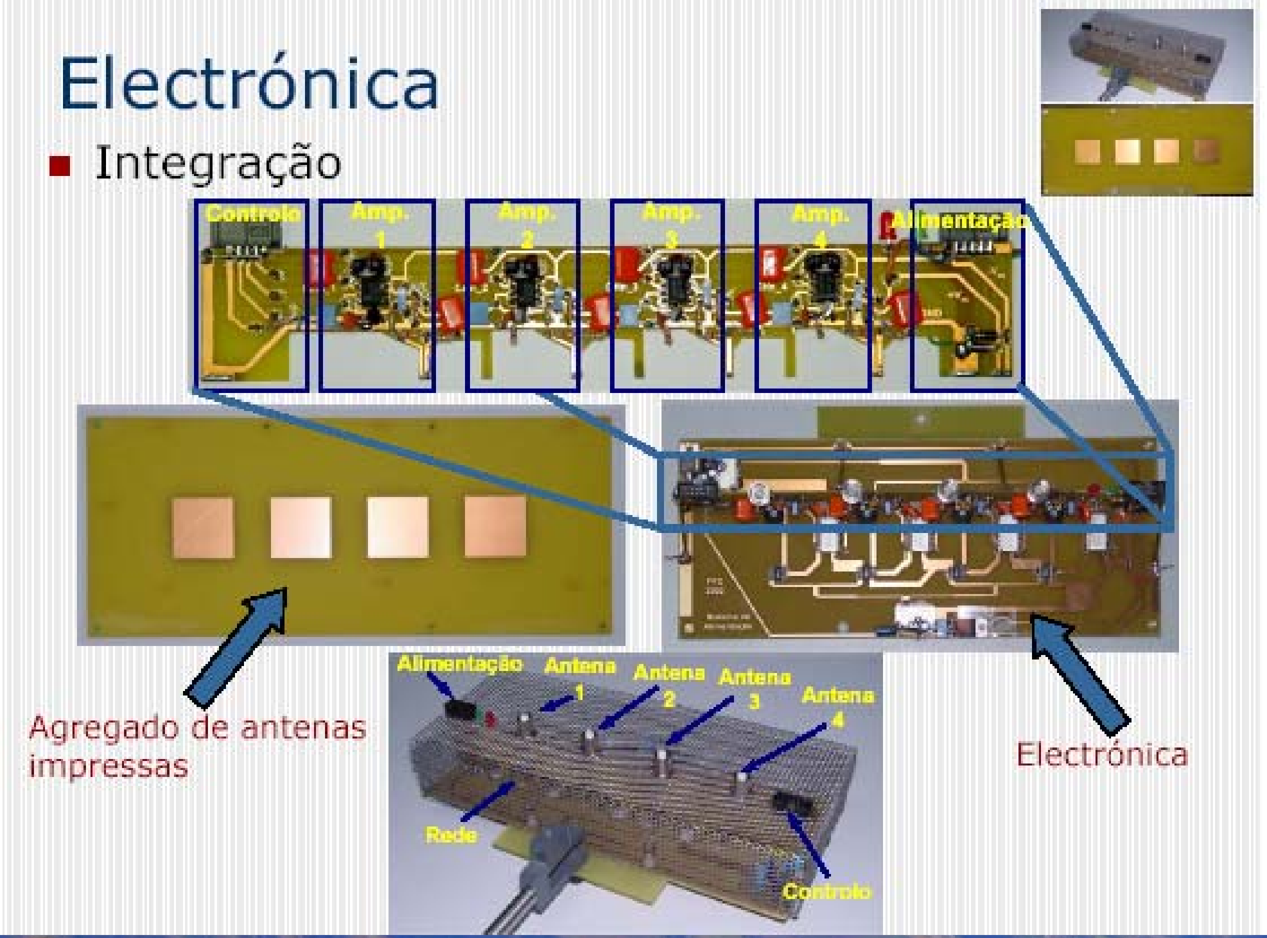
Uniform traffic **Balnced traffic**



- *Tracking*



Example of steer able antenna



Feature	Benefit
signal gain—Inputs from multiple antennas are combined to optimize available power required to establish given level of coverage.	better range/coverage—Focusing the energy sent out into the cell increases base station range and coverage. Lower power requirements also enable a greater battery life and smaller/lighter handset size.
interference rejection—Antenna pattern can be generated toward cochannel interference sources, improving the signal-to-interference ratio of the received signals.	increased capacity—Precise control of signal nulls quality and mitigation of interference combine to frequency reuse reduce distance (or cluster size), improving capacity. Certain adaptive technologies (such as space division multiple access) support the reuse of frequencies within the same cell.
spatial diversity—Composite information from the array is used to minimize fading and other undesirable effects of multipath propagation.	multipath rejection—can reduce the effective delay spread of the channel, allowing higher bit rates to be supported without the use of an equalizer
power efficiency—combines the inputs to multiple elements to optimize available downlink processing gain.	reduced expense—Lower amplifier costs, power consumption, and higher reliability will result.

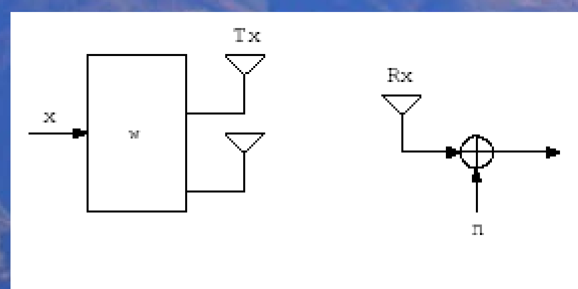
MIMO: Multiple Input/Output

MIMO systems can be defined simply. Given an arbitrary wireless communication system, consider a link for which the transmitting end as well as the receiving end is equipped with multiple antenna elements.

Signals on the transmit (TX) antennas at one end and the receive (RX) antennas at the other end are “combined” in such a way that the quality (bit-error rate or BER) or the data rate (bits/sec) of the communication for each user will be improved.

MISO: Multiple Output, Single Input

Another powerful effect of smart antennas lies in the concept of *spatial diversity*. In the presence of random fading caused by multipath propagation, the probability of losing the signal vanishes exponentially with the number of decorrelated antenna elements being used. A key concept here is that of *diversity*.

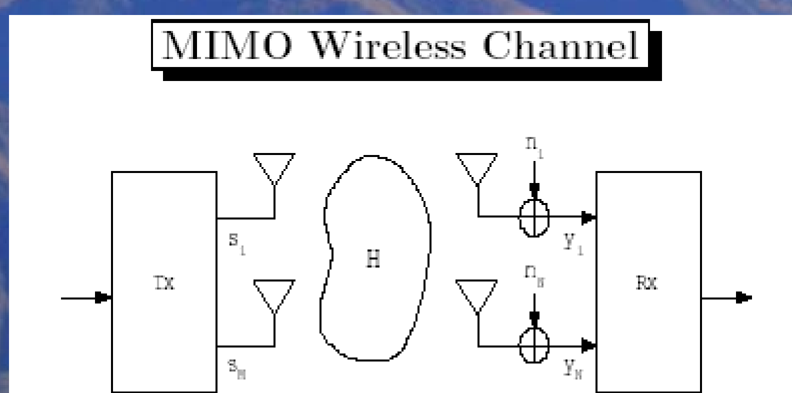


$$C = \log_2 \left(1 + \rho \sum_{i=1}^{M} |h_i|^2 \right) \quad \text{b/s/Hz}$$

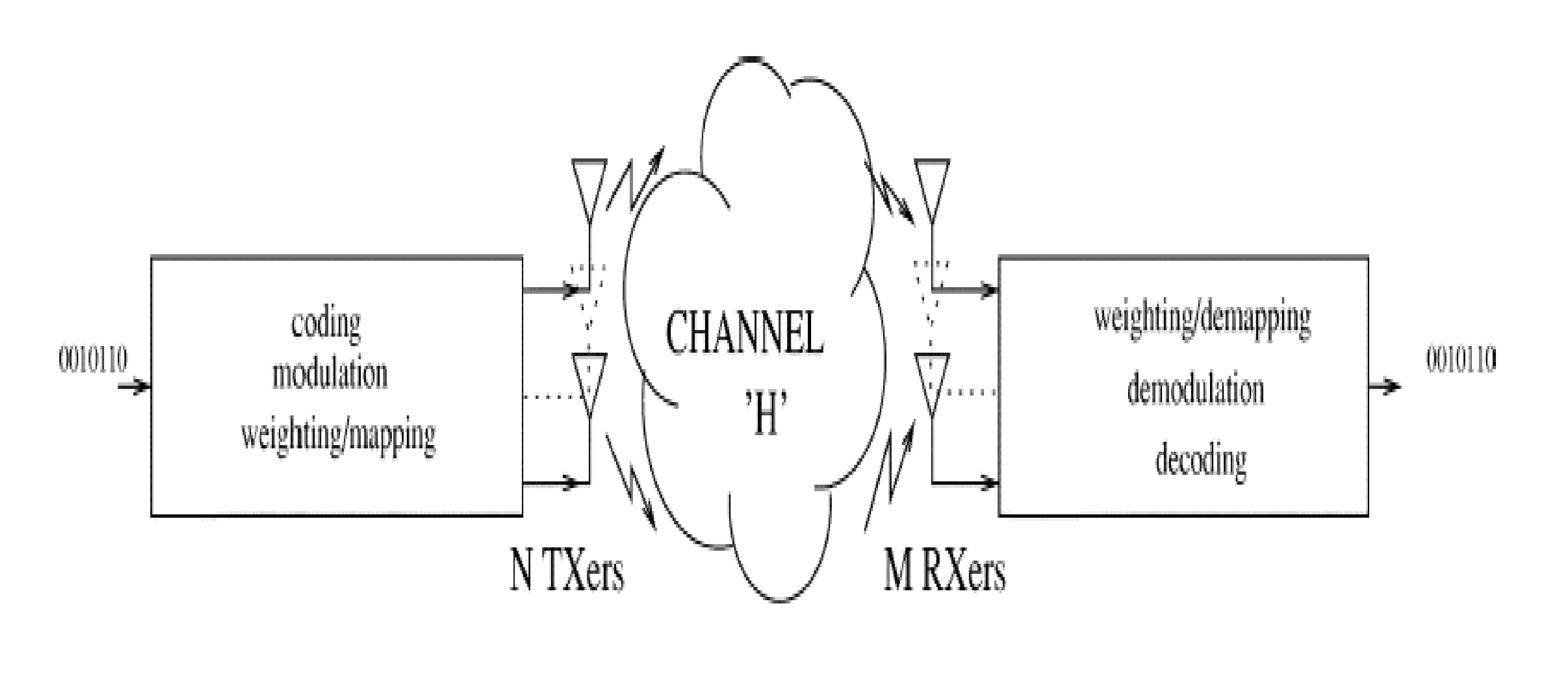
Space-Time Processing

A core idea in MIMO systems is *space–time* signal processing in which time (the natural dimension of digital communication data) is complemented with the spatial dimension inherent in the use of multiple spatially distributed antennas.

MIMO systems can be viewed as an extension of the *smart antennas*, a popular technology using antenna arrays for improving wireless transmission dating back several decades and used by some cellular systems operators

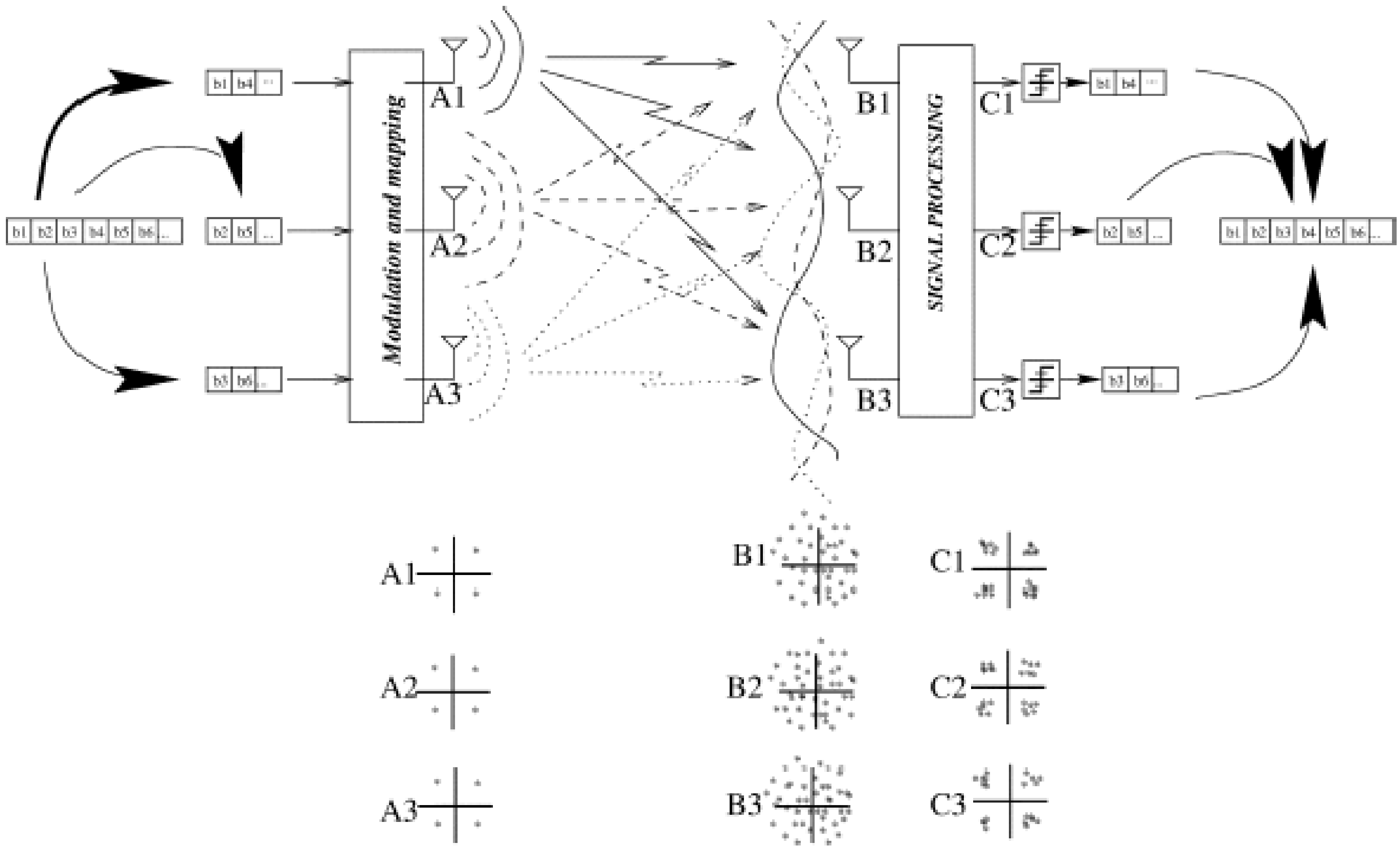


MIMO, SMART Antenna, ST Coding



The key concept in smart antennas is that of beamforming by which one increases the average signal-to-noise ratio (SNR) through focusing energy into desired directions, in either transmitter or receiver.

Basic Spatial Multiplexing Scheme yielding a three-fold improvement in spectral efficiency



Comparison of different architectures

PEAK DATA RATES OF VARIOUS MIMO ARCHITECTURES

(M,N)	Tx technique	Code rate	Modulation	Rate/sub-stream	# sub- streams	Data rate
(1,1)	Conven-tional	3/4	64QAM	540 kbps	20	10.8 Mbs
(2,2)	MIMO	3/4	16QAM	360 kbps	40	14.4 Mbs
(2,2)	MIMO	3/4	QPSK	180 kbps	80	14.4 Mbs
(4,4)	MIMO	1/2	8PSK	540 kbps	80	21.6 Mbs

Questions?

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