Flexible Smart Antenna Architecture for WLAN Application Success

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Outline

- Smart Antennas
- WiFi Appliqué
- WiMax Appliqué
- Conclusions

Service Limitations - WiFi

- Quality of service for each user is not consistent:
  - Too far away from the access point
  - Behind a wall
  - In a “dead” spot
  - Working off a battery, as with a laptop
  - Suffering from low bandwidth due to range/interference
- Lack of range
  - One AP cannot cover some houses

Solutions

- Ad Hoc Networks
  - Interconnections of multiple clients (standardization in progress)
- Smart Antennas
  - Can be implemented today (further improvement with standards in future)

Smart Antennas

A smart antenna is a multi-element antenna where the signals received at each antenna element are intelligently combined to improve the performance of the wireless system. The reverse is performed on transmit.

Smart antennas can:

- Increase signal range
- Suppress interfering signals
- Combat signal fading
- Increase the capacity of wireless systems

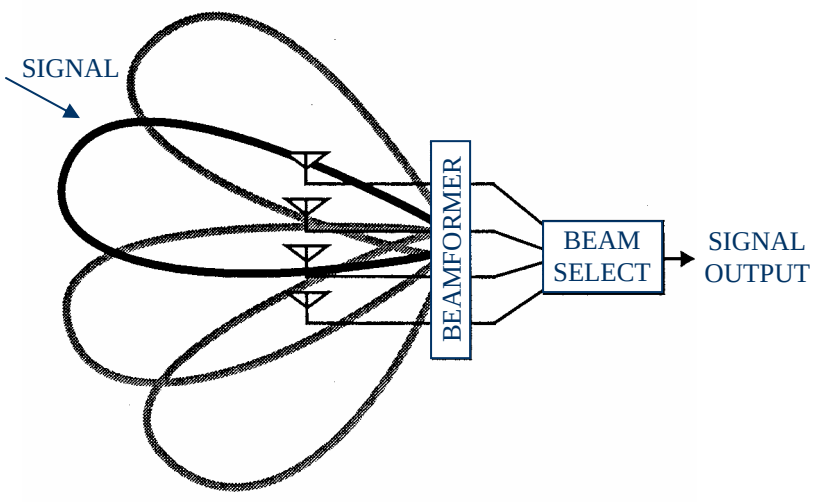
Smart Antennas

Smart antenna technologies can be used to improve most wireless applications, including:

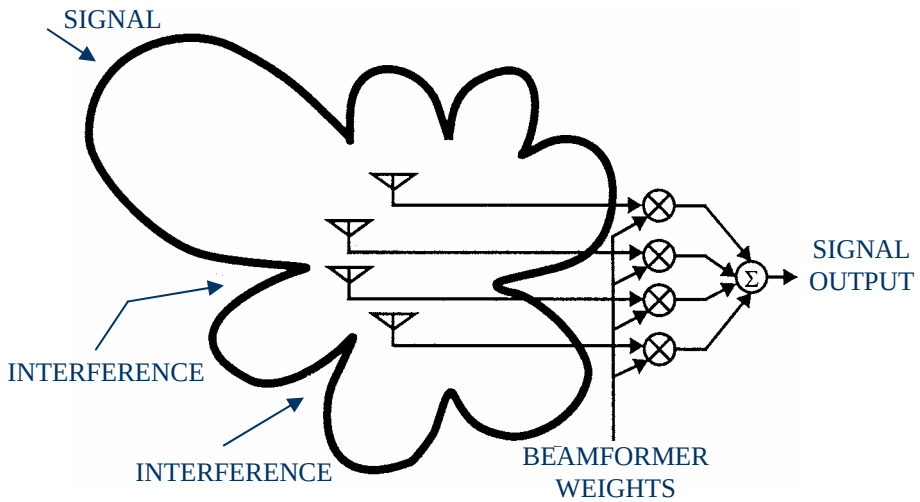
- Wi-Fi a/b/g access points and clients
- In-vehicle DBS entertainment systems, such as:
  - Mobile video
  - Mobile broadband/gaming
- Satellite/digital radio
- GPS
- 3G Wireless
- WiMax
- RFID

Smart Antennas

Switched Multibeam Antenna



Adaptive Antenna Array

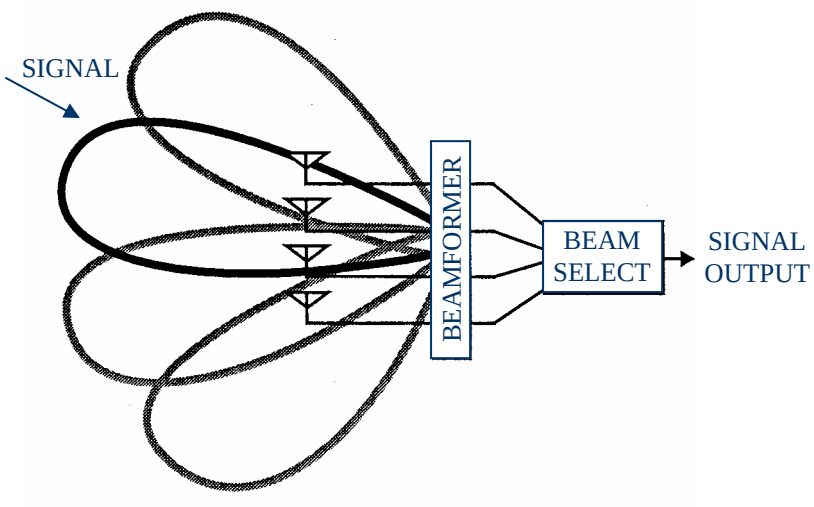


Smart antenna is a multibeam or adaptive antenna array that tracks the wireless environment to significantly improve the performance of wireless systems.

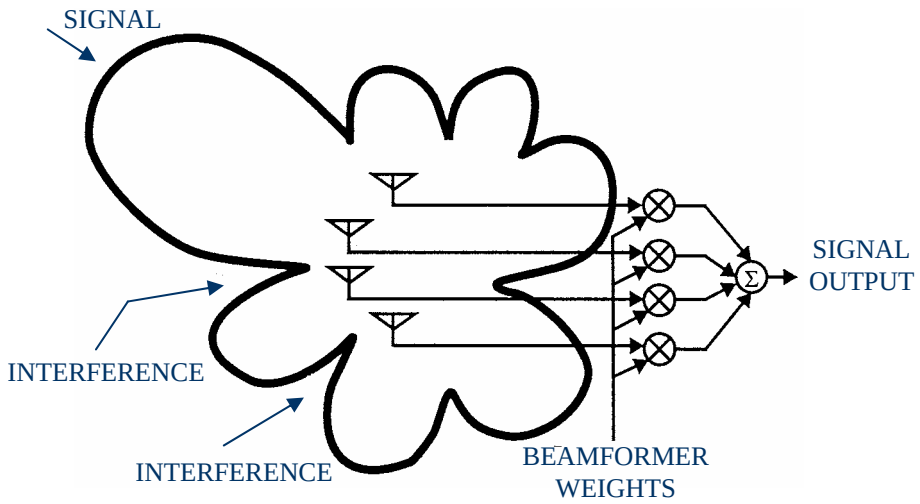
Switched Multibeam versus Adaptive Array Antenna: Simple beam tracking, but limited interference suppression and diversity gain, particularly in multipath environments

Smart Antennas

Switched Multibeam Antenna



Adaptive Antenna Array



Adaptive arrays in any environment provide:

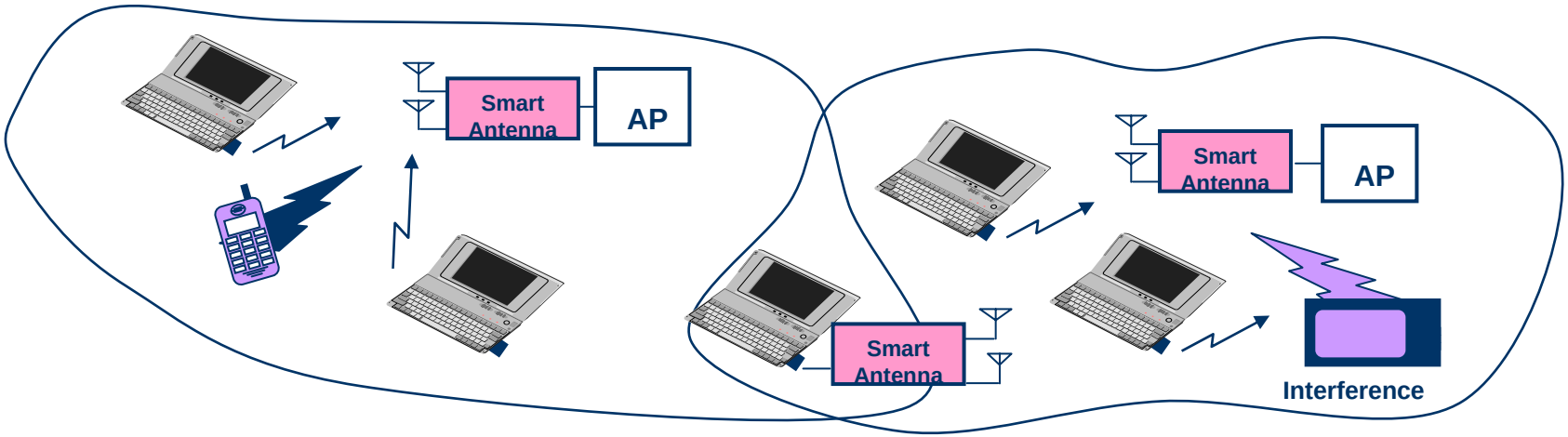
- Antenna gain of M
- Suppression of M-1 interferers

In a multipath environment, they also provide:

- M-fold multipath diversity gain
- With M TX antennas (MIMO), M-fold data rate increase in same channel with same total transmit power

WiFi

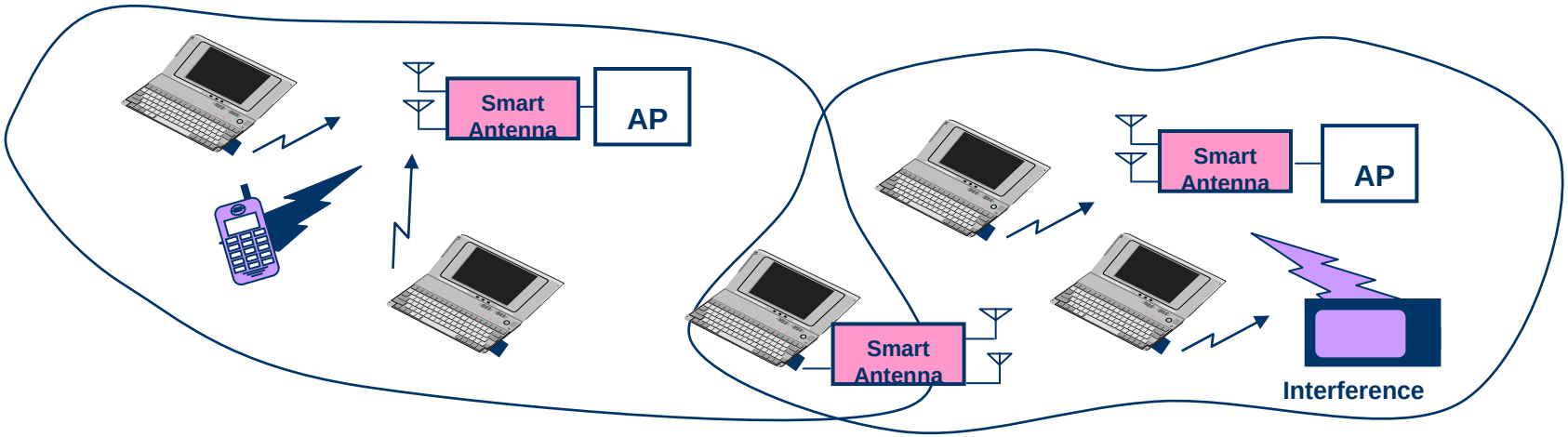
Smart Antennas for WLANs



Smart Antennas can significantly improve the performance of WLANs

- **TDD operation (only need smart antenna at access point or terminal for performance improvement in both directions)**
- **Higher antenna gain ⇒ Extend range/ Increase data rate/ Extend battery life**

Smart Antennas for WLANs



Smart Antennas can significantly improve the performance of WLANs

- **Multipath diversity gain ⇒ Improve reliability**
- **Interference suppression ⇒ Improve system capacity and throughput**
  - **Supports aggressive frequency re-use for higher spectrum efficiency, robustness in the ISM band (microwave ovens, outdoor lights)**
- **Data rate increase ⇒ M-fold increase in data rate with M TX and M Rx antennas (MIMO 802.11n)**

802.11b Beamforming Gains with 4 Antennas

Performance Gain over a Single Antenna in a Rayleigh Fading Channel

2 Antenna Selection	Adaptive One Side	Adaptive Both Sides	Theoretical Bound Both Sides
6.1 dB	12.8 dB	18.0 dB	22.2 dB

2X to 3X Range + Uniform Coverage

3X to 4X Range + Uniform Coverage

Smart Antenna Value Proposition

- **Extends Range by 200% - 300%**
- **Increases Data Throughput by 100% - 200% (802.11n in future with >600% increase)**
- **Facilitates Enhanced Radio Resource Management**
- **Improves Wireless Network Security**
- **Potentially Reduces Client Transmit Power by 90% for Increased Battery Life**

Can be implemented Analog (RF) or Digital

Analog Advantages:

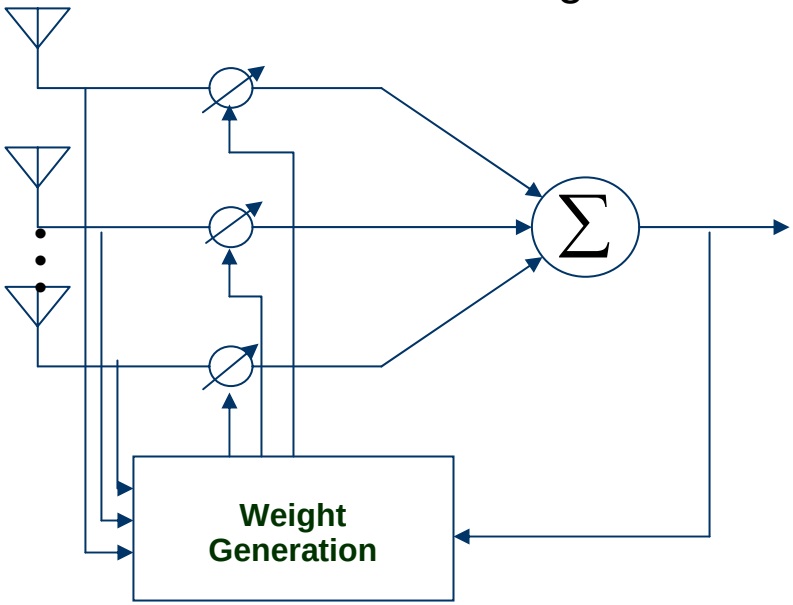
- Digital requires M complete RF chains, including M A/D and D/A's, versus 1 A/D and D/A for analog, plus substantial digital signal processing
- The cost is much lower than digital
- An appliqué approach is possible - digital requires a complete baseband

Digital Advantages:

- Slightly higher gain in Rayleigh fading (as more accurate weights can be generated)
- Temporal processing can be added to each antenna branch much easier than with analog, for higher gain with delay spread
- Modification for MIMO (802.11n) possible

WEIGHT GENERATION TECHNIQUES

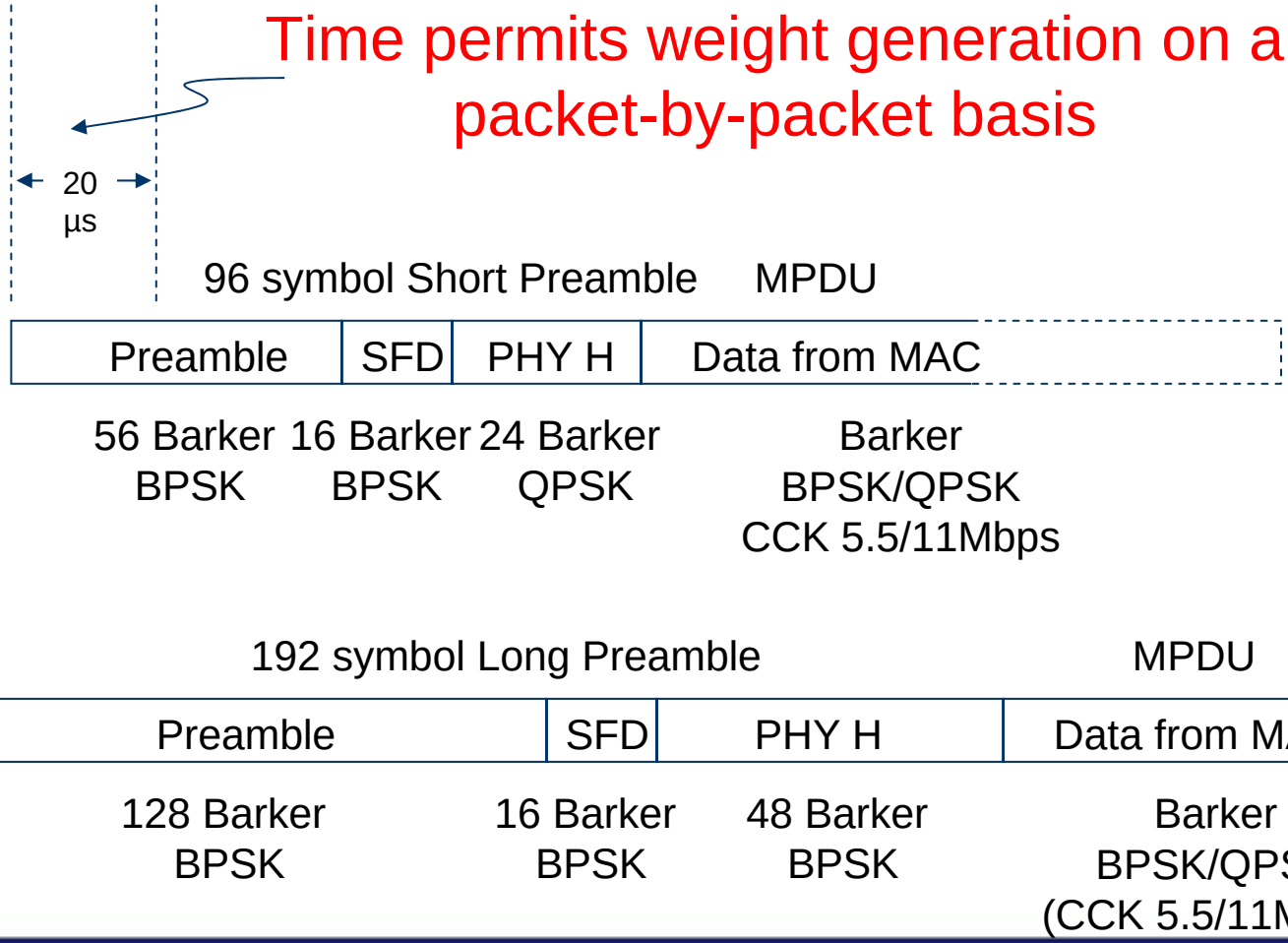
For Smart Antenna: Need to identify desired signal and distinguish it from interference



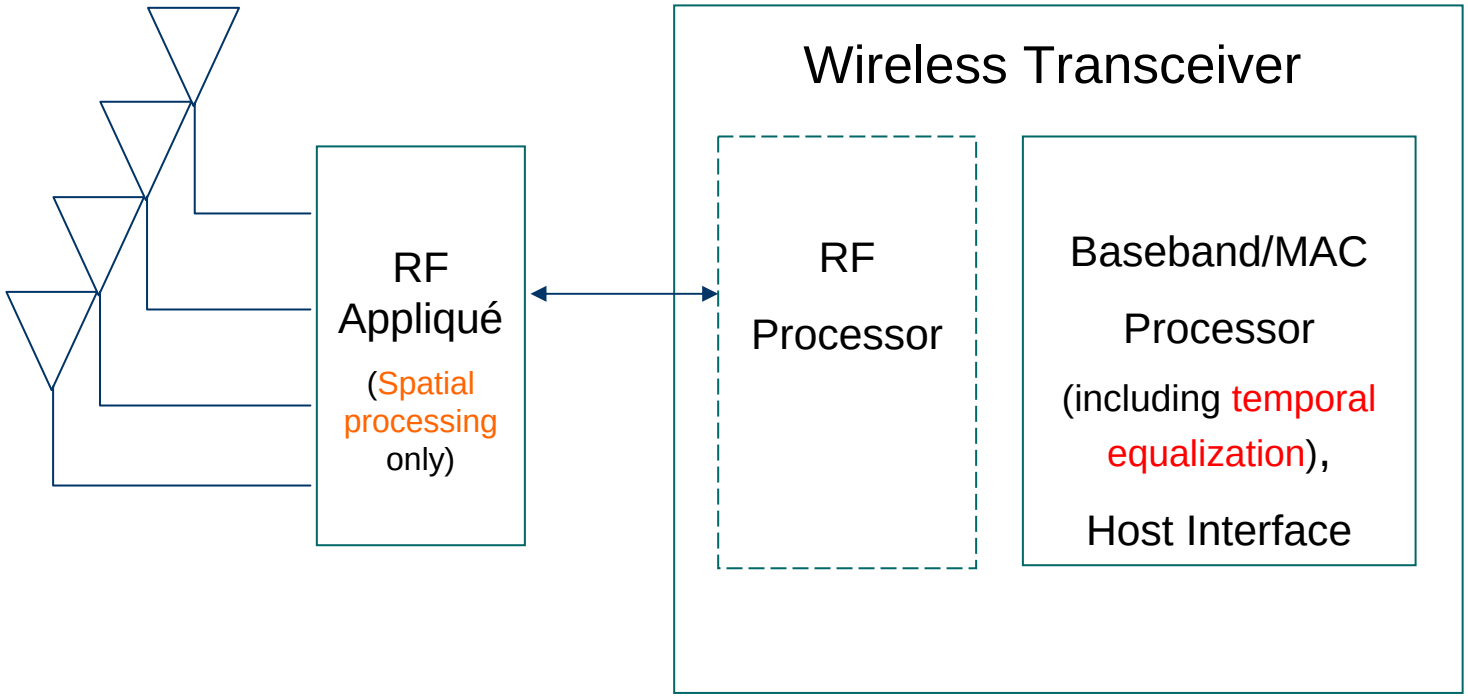
Blind (no demod): MRC – Maximize output power
Interference suppression – CMA, power inversion, power out-of-band

Non-Blind (demod): Training sequence/decision directed reference signal
MIMO needs non-blind, with additional sequences

802.11b Packet Structure



Appliqué

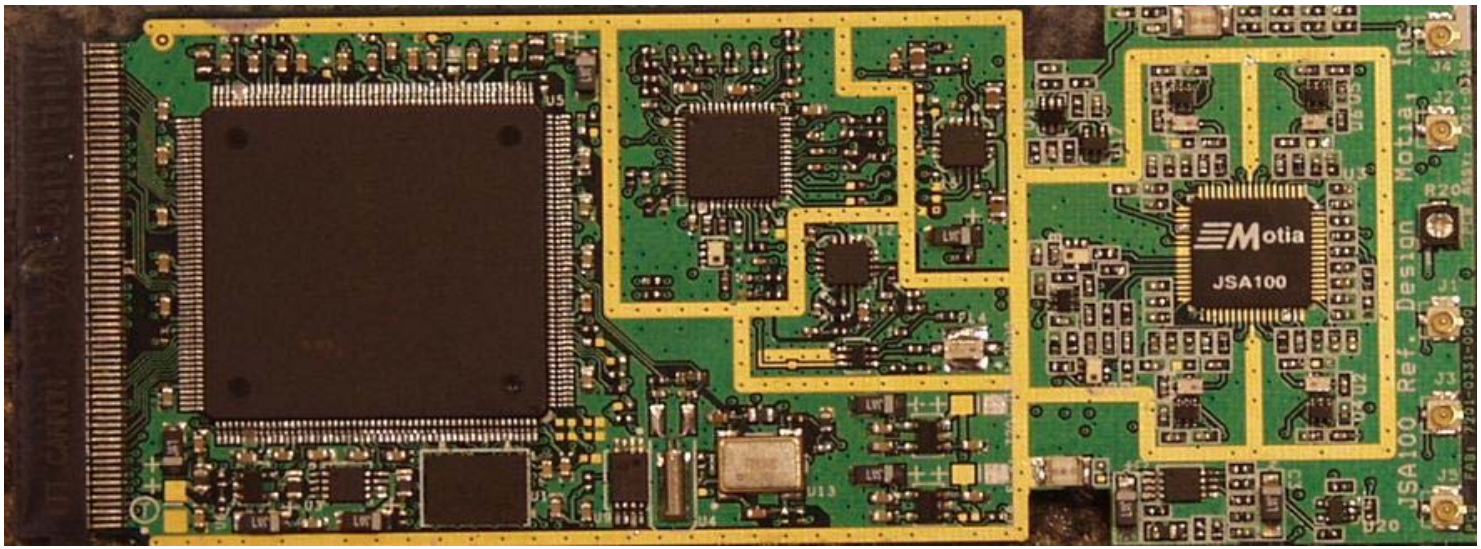


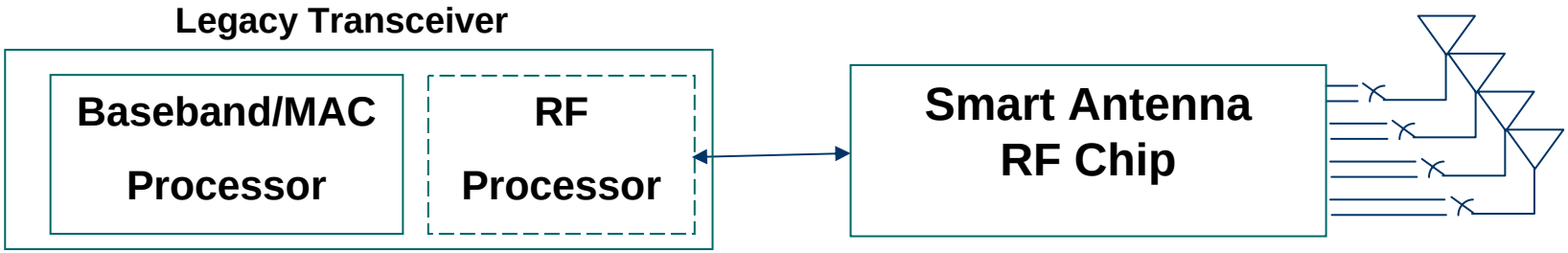
- **Conforms to 802.11 standard (blind beamforming with MRC)**
- **Appliqué configuration requires minimal modifications to legacy designs**

Smart Antenna WiFi
(PCMCIA Reference Design)

Appliqué Architecture Plug-and-Play to legacy designs

PCMCIA - CARDBUS Interface





Appliqué

Appliqué works with any existing baseband and RF solution chipset and easily integrates into existing products enabling smart antennas to:

- Create a uniform service quality for end-users, no matter the location or equipment used
- Increase Wi-Fi range
- Suppress interfering signals and limit signal fading
- Realize gains on both the uplink and downlink with implementation at either the client or access point alone

A Key Source of Degradation in the Appliqué is Delay Spread/Frequency-Selective Multipath Fading

Example: Channel Model D – 802.11n

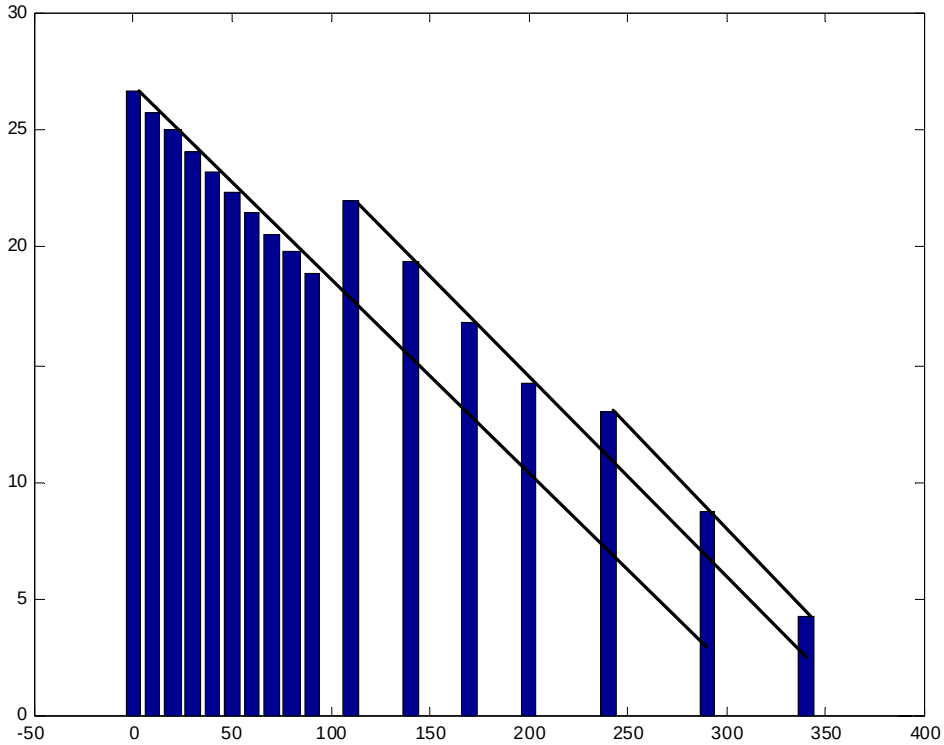
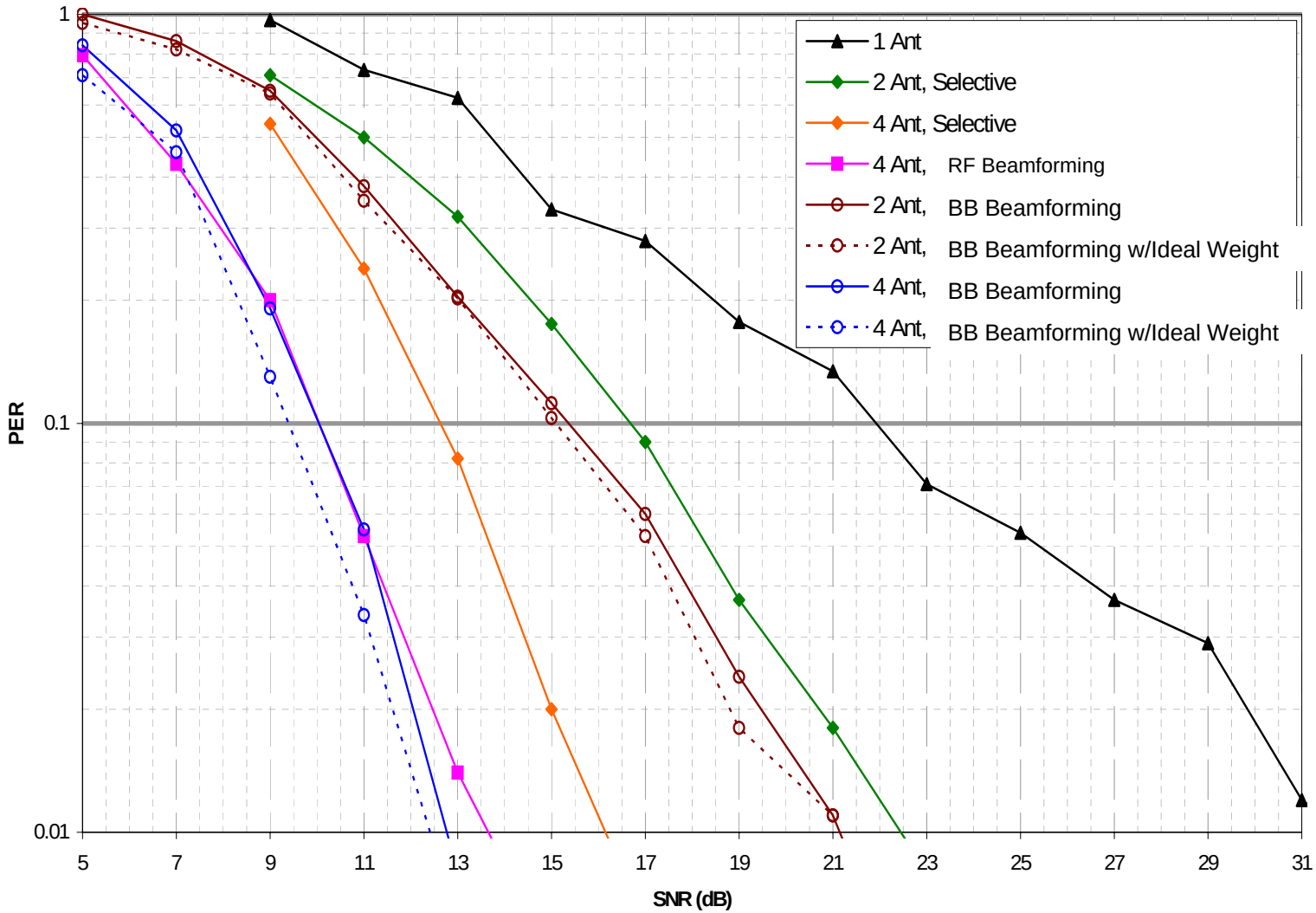


Figure 1. Model D delay profile with cluster extension (overlapping clusters).

802.11a/g - Flat Rayleigh Fading, 24Mbps, Short Packet

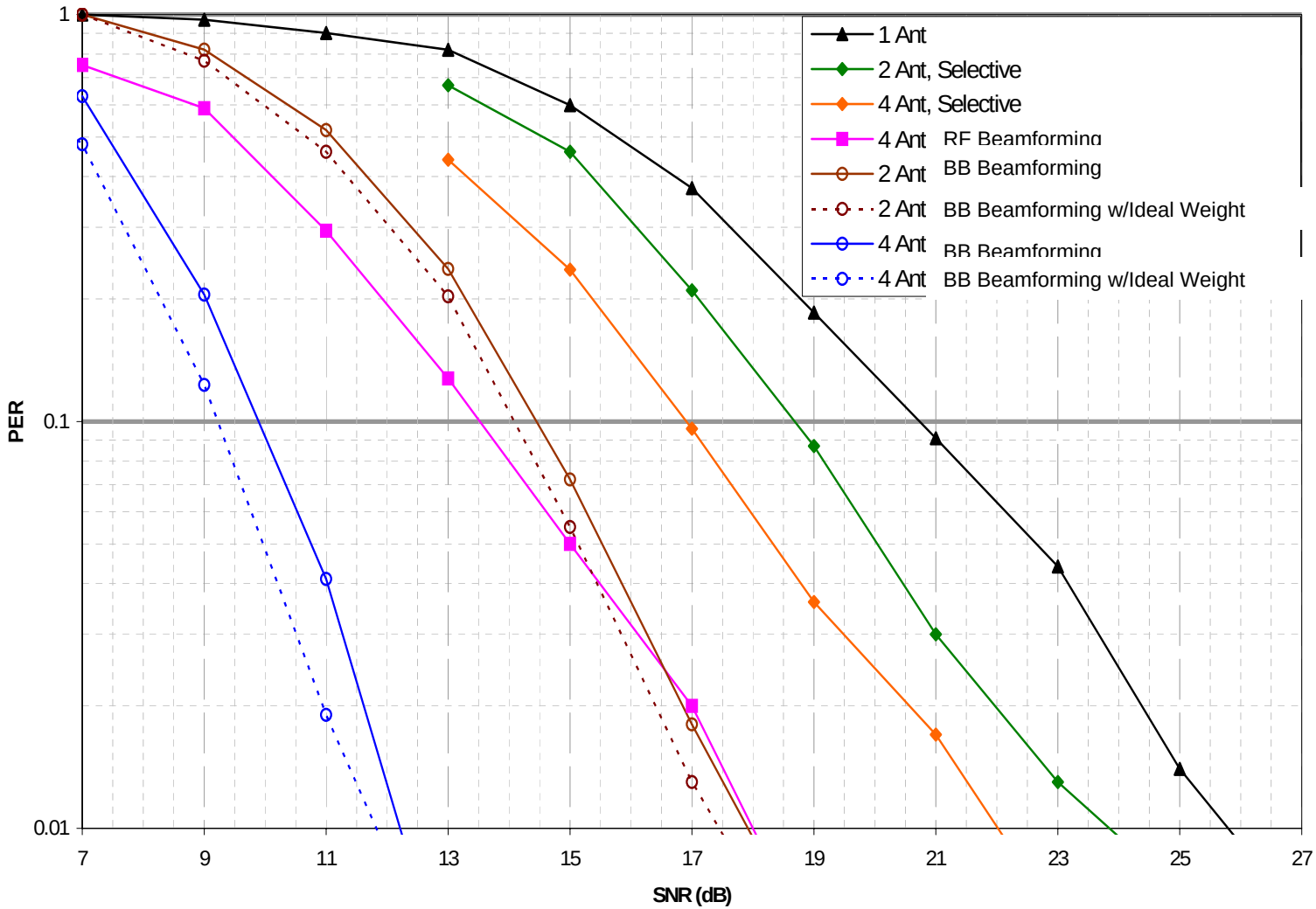
4-antenna appliqué has near ideal performance in flat fading



8 symbols/packet

802.11a/g - 50ns Exp Decay Rayleigh Fading, 24Mbps, Short Packet

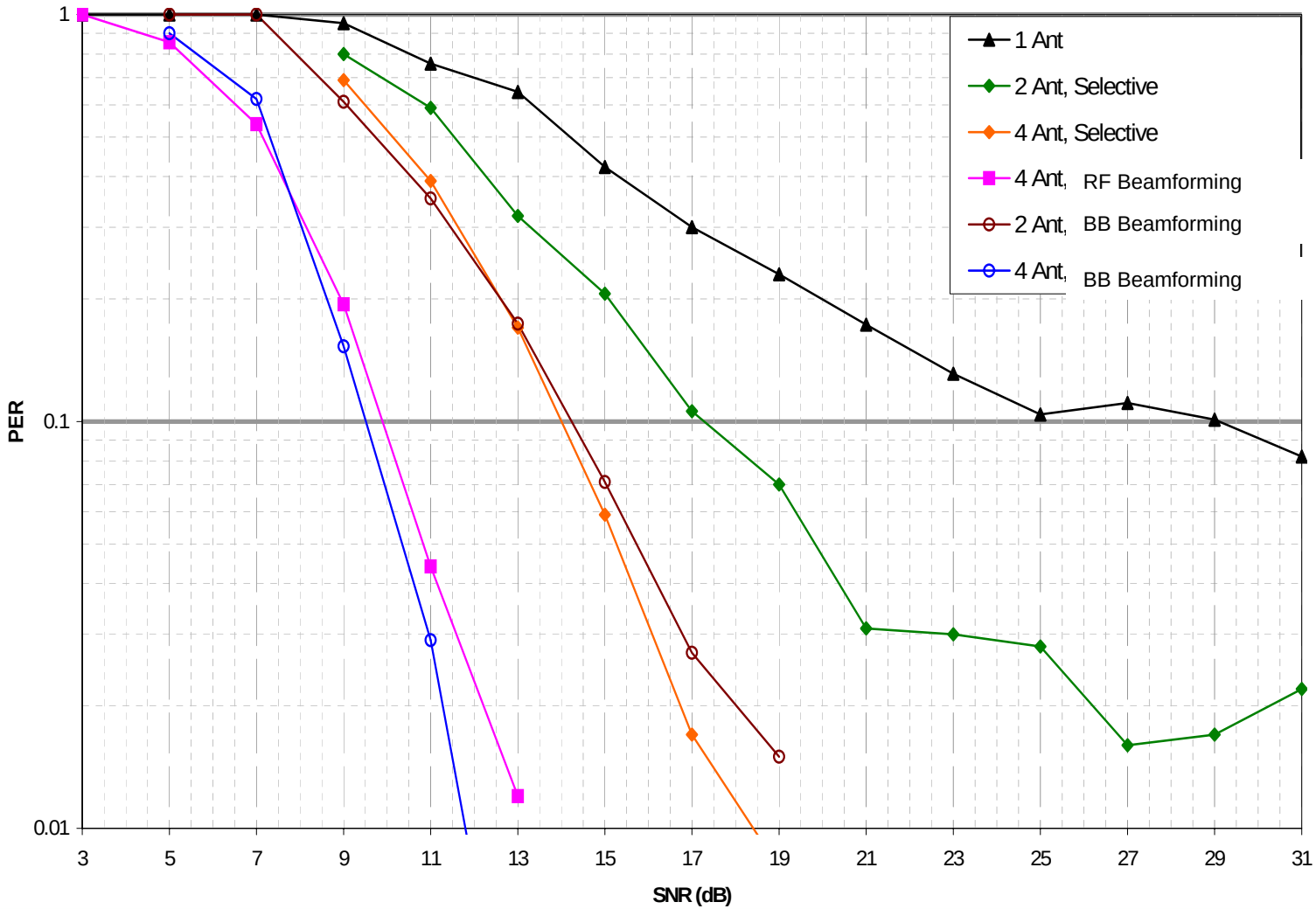
4-antenna appliqué performs better than 2-antennas with full processing in typical indoor delay spread



8 symbols/packet

802.11a/g - SUI-2 – WiMax Channel Model, 24Mbps, Short Packet

4-antenna appliqué has near ideal performance in typical outdoor WiMax environment

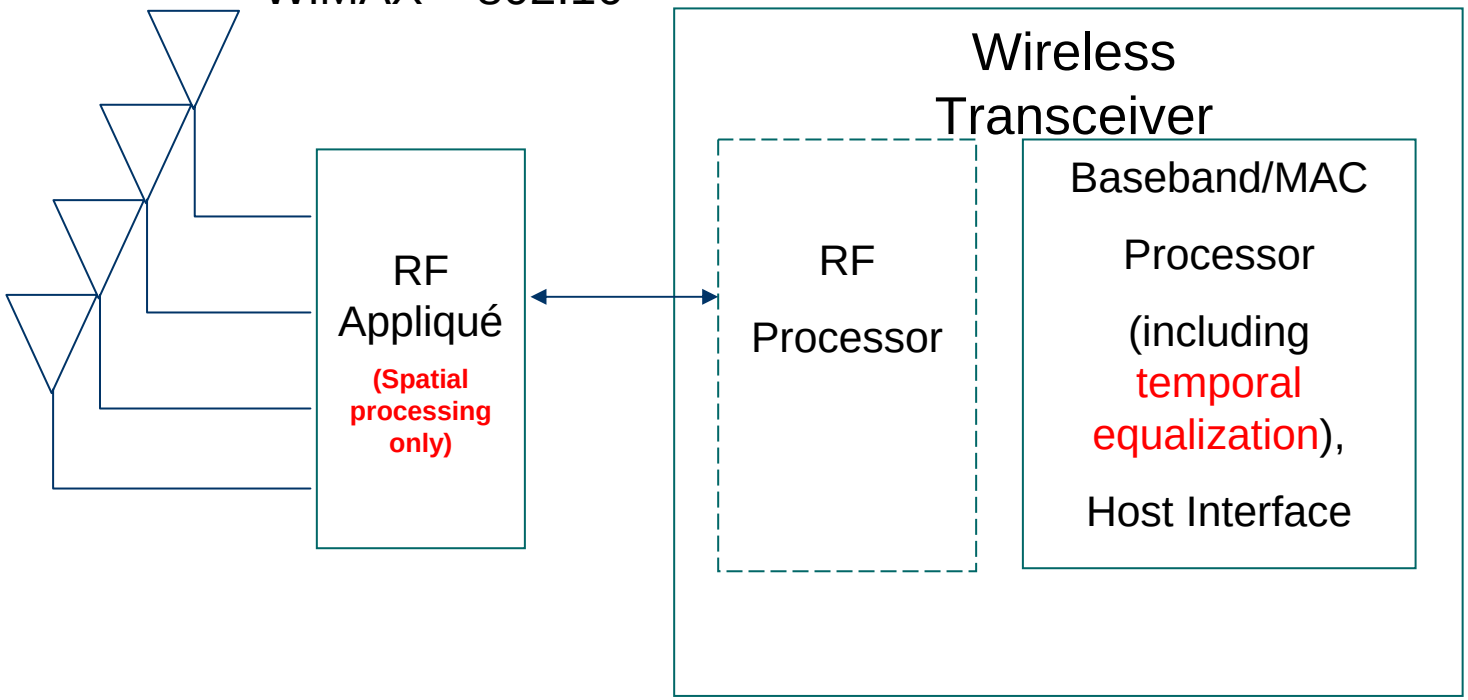


8 symbols/packet

WiMax

Same RF front-end with appliqué can be used for multiple systems:

- WLANs – 802.11a/b/g
- WiMAX – 802.16



WiMax Appliqué

Can use WiFi (802.11b/g) appliqué RFIC in WiMAX:

- Operates at 2.3 to 2.7 GHz
- Operates with 20 MHz bandwidth

Can modify to operate at other bands (3.5 GHz, 5 GHz – 802.11a), as well as with variable bandwidths (1.75/3.5/7/14 MHz)

Add to existing systems with little or no modification

Add at base station or client to provide improvements (in both directions with TDD):

- >10 dB increase in SNR
  - Compensates for building penetration loss
  - Permits use in buildings (on clients – no truck rolls)
- Increased interference robustness
- Improved QoS

Conclusions

The appliqué approach allows a WiMax/WiFi transceiver to employ smart antenna technology which results in:

- **Extended range (2-4 times for WiFi, use in buildings for WiMax)**
- **More uniform coverage (QoS)**
- **Increased interference robustness**

Designed to require minimal changes to the WiMax/WiFi Network Interface Card (NIC) or Access Point.:

- **Universal Application**
- **Low Cost**
- **Quickest Time to Market**