CDMA Capacity Evolution – Mobile Receive Diversity

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Agenda

- Terminal cost business case
- Receive Diversity
  - Implementation
  - Antennas
  - Other issues
- Adaptive Antennas
- Advanced Receiver, Single Antenna
- Multiple BS antennas
- Conclusion
Acceptable Terminal Cost Addition

- Voice 50 mErl
- Data 0.5 MB/hr
- Data 5 MB/hr

Max terminal cost

~$2 max

subscribers/km²
Rx Diversity - Terminal Implementation

- Extra Hardware
  - 2\textsuperscript{nd} antenna, Rx only
  - 2\textsuperscript{nd} Receive chain
  - 2\textsuperscript{nd} A/D converter
  - 2D Rake

- New Algorithms
  - 2\textsuperscript{nd} AGC
  - New multi-antenna searcher
  - New finger assignment. More fingers?
  - New multi-antenna combiner

- Added cost
  - Additional ~10% material cost
  - ~3-4x greater than acceptable terminal cost adder

- Other
  - Added PCB area: ~10%
  - RF Rx on current increase: 70-80%
Rx Diversity Antenna Issues

- Rx Diversity Antenna should have low correlation to main antenna
  - **Polarization Diversity** – 2 antennas have different polarization
  - **Pattern Diversity** – 2 antennas have different radiation patterns
  - **Separation Diversity** – significant (> ½ λ) separation between antennas

- Low coupling needed to have low correlation
- Rx Diversity Antenna performance must be comparable to main antenna
- Must prevent interference/coupling with GPS and/or BT antenna
- SAR not an issue for RX Diversity Antenna – not used for transmit
  - Best position is location of main antenna -> May create coupling
Rx Diversity - PCS vs. Cell Band Antennas

- Wavelength of PCS (~15 cm) smaller than Cell band (~30 cm)
  - Easier to obtain polarization, separation or pattern diversity in PCS only

- Cell band antenna polarization aligned along long dimension of phone
  - Rx Diversity Antenna would have same polarization

- PCS only antenna could be internal and quite small
  - Single band only, only 60 MHz
  - Size possibly 10mm x 20mm x 4 mm, about half area and quarter volume of main antenna
  - Placement still an issue, since optimal position is in same location as main antenna

- For Dual Band (Cell/PCS) operation, RX Diversity Antenna would need to be same size as main antenna.
  - Causes problems with mechanical concept flexibility
Rx Diversity – Other Issues

• Many antennas already – Cell/PCS, Bluetooth, GPS
  • Additional antennas limit mechanical concept possibilities

• Placement of Rx Diversity Antenna more challenging for voice
  • Place away from hand -> near main antenna
  • Data products have different usage models than voice, antennas may be placed differently

• Disconnect between CDMA and GSM
  • Any global company will have harder time re-using global mechanical concepts -> more limited terminal choice in CDMA
  • More cost disadvantage to CDMA terminals compared to GSM
Adaptive Antennas

• Multi-antenna techniques for a single receiver phone
  • Switching, steering, beamforming, Phased combining, etc.

• Technology maturity needs to improve
  • Physical / Form Factor – antennas are very large
  • Implementation issues
    • Algorithms still in development phase
    • May cause intermodulation problems
  • Cellular system issues to be resolved as well
    • Soft handoff, mobility, power control..

• Potentially 1 – 3 dB gain

• Cost Range: < $2
Advanced receiver with single antenna

• Advanced receiver techniques for improving performance

⇒ Key Drivers: low cost, improved performance and reliability key
⇒ Up to 4 dB gain: an incremental, fast, and evolutionary step
  ⇒ improved RF performance
  ⇒ Bigger/better whip antenna
  ⇒ Interference cancellation (e.g. Pilot)
  ⇒ Chip equalizer
  ⇒ As much gain potential as Rx Diversity
⇒ Cost range: < $1
Multiple Antennas at the BS

- Multiple Antennas deployed at the BS
  - Multiple Transmitters at the BS; two, four, etc.
  - Extra PA cost for 2x2, new technologies enabling 4x2 and larger arrays, and eventually lowering the BS upgrade cost
  - New baseband algorithms for MS needed; space-time coding, etc
  - Similar MS hardware as Rx Diversity
  - Requires 3GPP2 standardization
  - Gain: double the data throughput around 2007/8
Cost Comparisons

- Advanced Receiver antennas
- Adaptive antennas
- Dual-receiver antennas
- BS multiple antennas

[Chart showing cost comparisons]
Key Messages

• Any dual-receiver solution is a significant cost for handset and therefore discontinuity in business model and needs to be studied carefully

• Initial study shows that dual-receiver cost is justified only for very high speed data segment but not for voice capacity improvement

• Multi-antenna approaches severely limit mechanical concept design

• Adaptive antennas are not mature enough for deployment