MIMO for Consumer Platforms and Handsets

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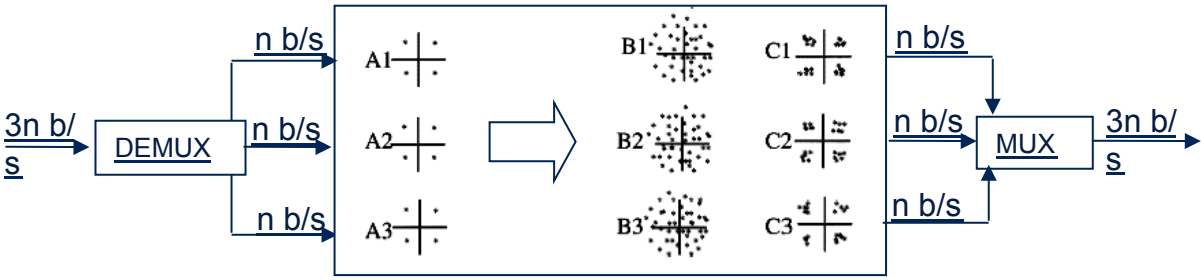
DCKTN: Spectral Efficiency – a broader view of broadband?

MIMO



Symbol constellations from a 3 x 3 example

A1,2,3 as transmitted by three TX antennas

B1,2,3 as received by three RX antennas

C1,2,3 after processing, at the inputs to three demodulators.

The three parallel symbol streams were derived from a single stream at 3 times the symbol rate, and are subsequently reassembled in the original time sequence

… **Magic!**

From [1]

Effective MIMO

- Multiple antennas, transmitters and receivers at both ends of the link
  - Cost, size and power demand issues
- Complex DSP at the base station and the mobile phone
  - Cost and power issues
- Rich multipath propagation
  - Dependent on the environment
  - Most effective in urban areas
- MIMO works!

Why MIMO?

- Combined with efficient modulation and coding schemes, MIMO is a way of passing more user data through a fixed RF bandwidth
  - Network operators see an opportunity for more user revenue from their spectrum resource
  - User software developers hope to be able to run applications that need higher bit rates
  - Users hope for ‘more’, but are they willing to pay for it?

The real world (1)

- Modern mobile systems employ adaptive coding and modulation systems which respond to the HARQ process on each user channel
- As the C/N ratio falls, the code rate is reduced (0.92 – ~0.1) and the order of the modulation scheme is backed off
  - The user experiences a lower data rate
  - The network suffers a loss of capacity, and a loss of actual or potential revenue

The real world (2)

- The MIMO process should make the best use of the available channel
- Maximum throughput depends on
  - Sufficient independent multipath channels
  - Sufficient C/N ratio on these channels
- In the absence of these, the performance of MIMO gracefully falls back

Getting real

- In the last months I have seen impressive demonstrations of LTE running at 150Mb/s
  - but there were no antennas – the channel was simulated
- Much 3GPP work has been based on the assumption of a dual-polar antenna pair in the UE
  - but dual polar antennas in the lower bands are not practicable in handset-size platforms
- There are good field results for MIMO tests
  - but many are on laptop-size platforms
  - can effective MIMO be squeezed onto handsets in the lower frequency bands?

User handset choice criteria

- Appearance : Format, size, weight, colour…
- Ease of use: Touch screen or keyboard, software interface…
- Functionality: FM radio, LAN connectivity, GPS, MP3 player, audio & camera quality…
- Cost: Availability of PAYG, deals on contracts
- Network: Brand loyalty, experience, advertising, deals
- RF Performance: SAR, TRP, TIS,… ??

Compromise, compromise

- The kings of handset design are the ID and software engineers
- Increasing HW functionality is packed into small, lightweight packages
- The display, cameras, speakers and other flashy hardware occupy most of the available volume
- A modern smartphone typically contains
  - Main 5-band antenna
  - WLAN/BT antenna
  - GPS antenna
  - Diversity RX antenna (for 3G on a very few smartphones)
- …and now we want more?

Handset RF efficiency

antenova®

- Definition: Radiated power / Offered power from PA
- Falls as the handset shrinks and as the antenna shrinks
- Best possible on handset sized platform: c70%
- Well-designed handset: >50%
- Worst case for handset on market today: <10%
- These are free space figures
  - with hand losses they fall by typically 10dB
- Handset platforms are small for effective MIMO in the low bands (700-850-900MHz)
- If efficiencies are allowed to fall to squeeze more antennas in, then the advantages of MIMO will be severely compromised.

Future system development?

- Quote:
  - LTE-Advanced requirement, targets downlink peak spectrum efficiency of 30bps/Hz and uplink peak spectrum efficiency of 15bps/Hz
  - To achieve this, spatial multiplexing with antenna configuration of 8×8 for downlink transmission and 4×4 for uplink transmission is being investigated.

[Ref 3]

Handset antennas

- The design of handset antennas has improved over the last 10 years, creating the potential for high-performing multi-band handsets on small platforms
- The RF performance of many handsets falls well below what is possible using current best practice
- Antenova has shown that performance can be improved
  - Using state-of-the-art antennas *AND*
  - Ensuring constructive interaction between RF and ID engineers from the outset of design

UE Performance standards

- The RF performance of UEs is invisible to purchasers who don't understand its significance
- Do Network Operators need to better understand the bad economics of under-performing UEs?
- Stronger control of UE specifications and performance may be needed if the hoped-for benefits of MIMO are to be realised
  - US networks currently impose CTIA specs [5], with testing regulated by PTCRB [6].
  - Additional standardised test methods are needed for MIMO

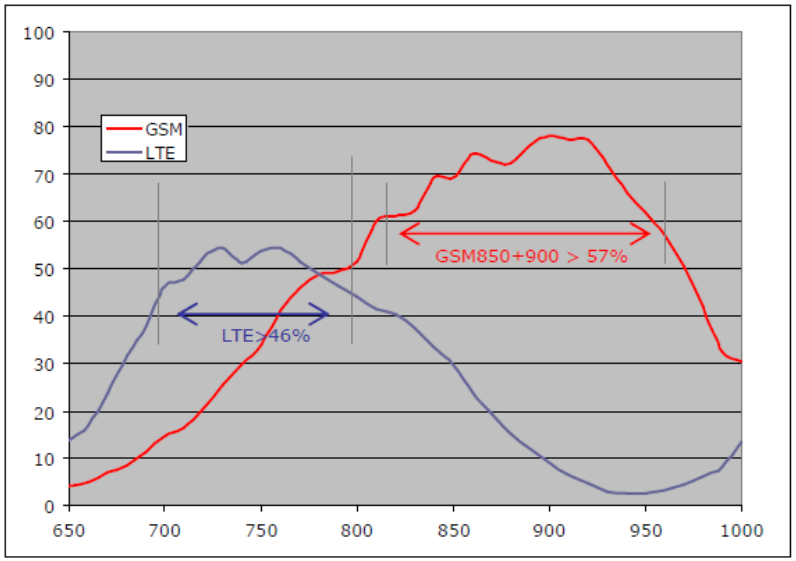
New techniques

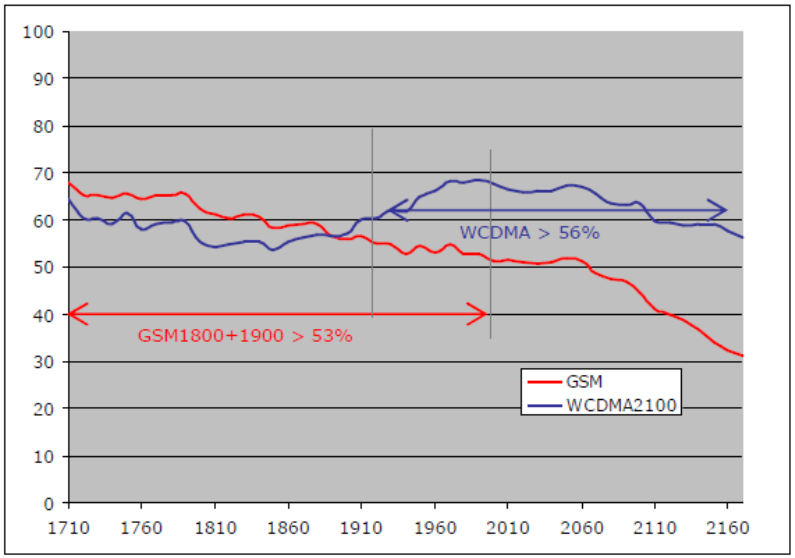
- The addition of more frequency bands for LTE has attracted attention to adaptively tuned and reconfigurable antennas
  - Example – Antenova's *Agilis*

Switched antenna example

Antenova's Agilis: A single antenna 40mm x 12mm x 3.2mm with switch-selectable LTE-700/W-CDMA2100 and 4-band GSM operation

Efficiency on 100mm x 40mm evaluation board





New techniques

- The addition of more frequency bands for LTE has attracted attention to adaptively tuned and reconfigurable antennas
  - example: Antenova's *Agilis*
  - many applications are currently restricted by cost, loss, high operating voltage and RF power limitations of available devices
- Channel correlation can be reduced by using optimised matching and coupling compensation between antennas
  - but if extended too far the result is loss of bandwidth and efficiency

Conclusion

- It is becoming increasingly complex and expensive to increase the spectral efficiency and capacity of mobile radio systems
- Handset performance limitations are likely to reduce the potential gains of MIMO
- Higher data rates and spectral efficiency will be increased most easily for large UE platforms
- The RF performance of handsets is still capable of significant improvement
- Is it time for cooperative UEs?

References

- [1] D Gesbert *et al: From theory to practice: an overview of MIMO space-time coded wireless systems*, IEEE Journal On Selected Areas In Communications, Vol. 21, No. 3, Apr 2003
- [2] ETSI TR 125 996 V9.0.0: *Spatial channel model for Multiple Input Multiple Output (MIMO) simulations* (Release 9, Jan 2010)
- [3] J Lee, JK Han and J Zhang*: MIMO Technologies in 3GPP LTE and LTE-Advanced*, EURASIP Journal on Wireless Communications and Networking, Vol. 2009, Article ID: 302092. Downloaded from http://www.hindawi.com/journals/wcn/2009/302092.html on 18.08.2010
- [4] L Thiele *et al: On the Value of Synchronous Downlink MIMO-OFDMA Systems with Linear Equalizers*, IEEE International Symposium on Wireless Communication Systems 2008 (ISWCS08), Reykjavik, Iceland
- [5] *Test Plan for Mobile Station Over the Air Performance, Method of Measurement for Radiated RF Power and Receiver Performance,* CTIA, Washington DC, 2003
- [6] See www.pctrb.com
- [7] C-X Wang, *Cooperative MIMO Channel models: A Survey,* IEEE Communications Magazine, Feb 2010 pp 80-87.

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