Handset and consumer platform RF design and antennas

Brian Collins
Antenova Ltd, UK

Spectral Efficiency Innovation
Mobile World Congress 2011, Barcelona

Handset performance today

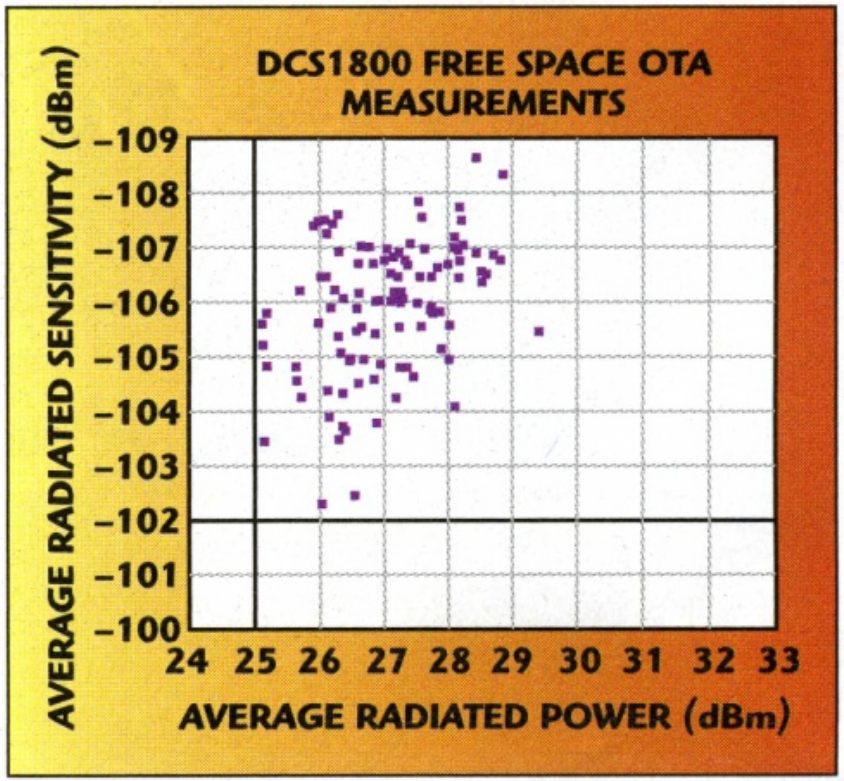


Fig. 1 TRP vs. TRS for GSM 1800 commercial devices.[1]

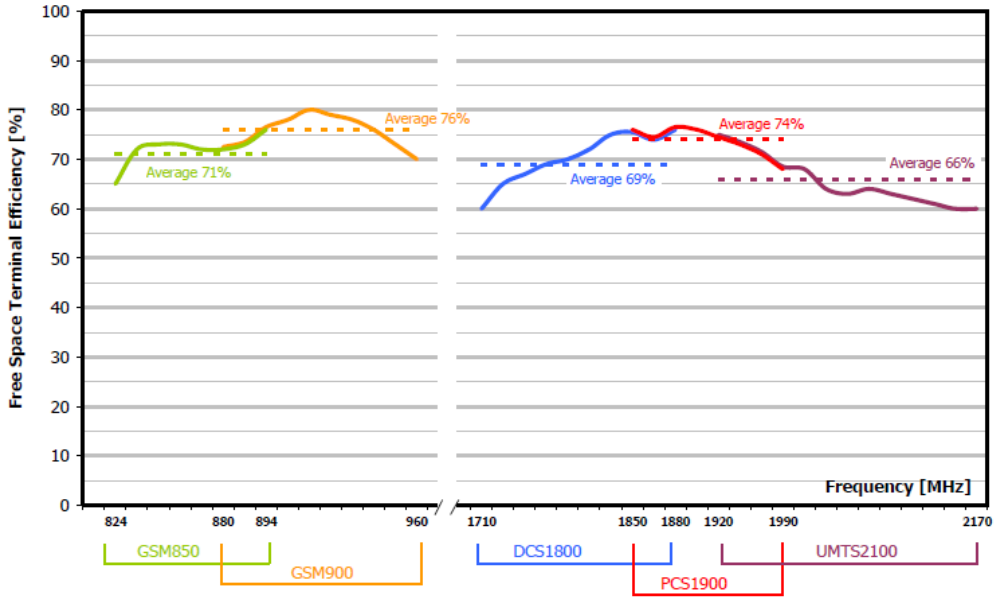
Source, Agilent [1]

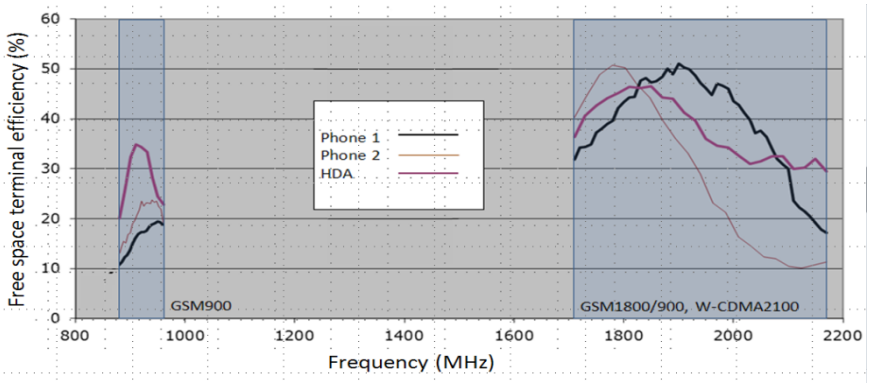
- 5.5dB spread in TX band and 6.5dB in RX band
- Low correlation between TX and RX performance (Duplex separation 60MHz)
- The GSM 850/900MHz performance is likely to be more scattered
- Is this inevitable?
- Why do the operators (or the users) put up with this situation?

Handset RF efficiency

- 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 will fall by around 10dB
- Handset platforms are very 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.

Could do better…





Well designed antenna on a bare handset-size PCB

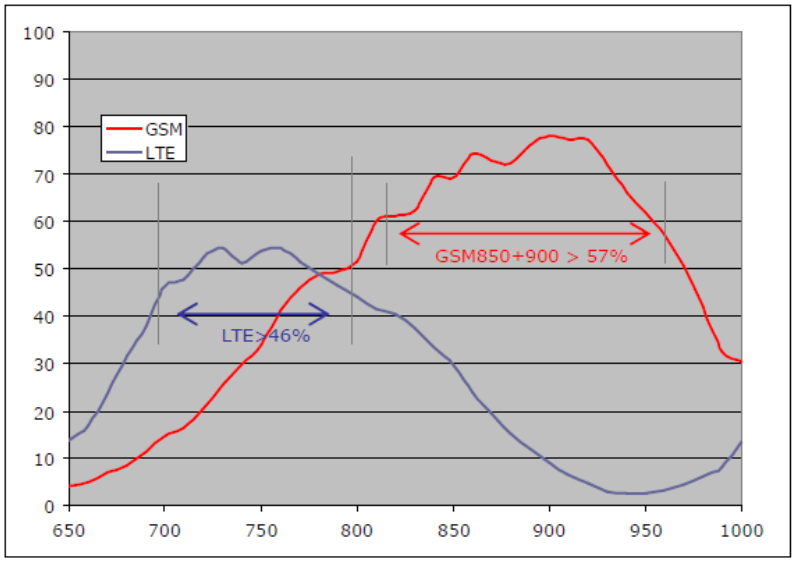
Real handset bought from network operator's shop in Aug 2010

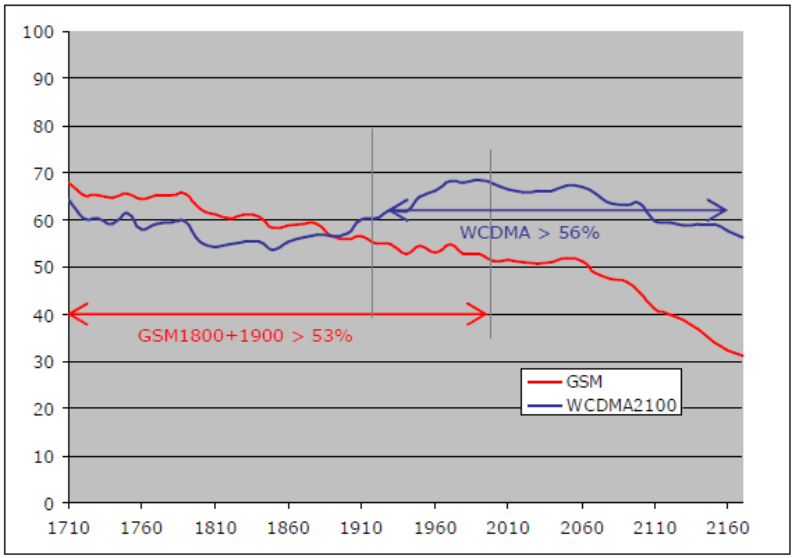
Results shown were both measured in Antenova's SATIMO Stargate-64

Switched antenna example

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





Antenova Agilis

Handset constraints

- RF efficiency depends on design of whole handset,
- **A good antenna is necessary but not sufficient**
- Large gap between best performance and achievement
- Increasing use of data and effect of adaptive transmission systems places a premium on performance for the network operators
- Low efficiency = low *user* data rate
  - » = loss of network capacity
  - » = loss of revenue

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

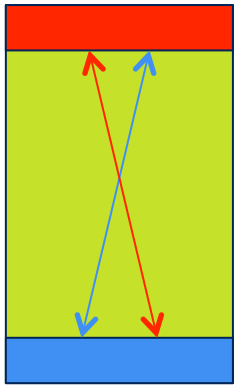
- The kings of handset design are the ID and software engineers
- Increasing HW functionality is packed in small, lightweight packages
- The display, battery, cameras, speakers and other flashy hardware occupy most of the available volume
- A modern smartphone typically contains
  - Main 5-band antenna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

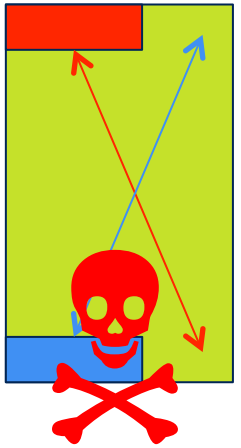
UE Performance standards

- The RF performance of UEs is invisible to purchasers who don't understand its significance
- Network Operators need to better understand the bad economics of under-performing UEs
- Stronger control of UE specifications and performance is likely to be needed if the hoped-for benefits of MIMO are to be realised
  - US networks currently impose CTIA specs [2], with testing regulated by PTCRB [3]
  - Standard OTA test methods are needed for MIMO.

MIMO in the lower bands

- Many studies have investigated the decorrelation available with closely spaced antennas – problem is greatest in low bands
- Antennas placed at each end of the handset groundplane excite the same current mode; the separation between their phase centres is smaller than the distance between the physical antennas
- There can be useful asymmetry in their radiation patterns, so some pattern diversity is achieved, but unless the user's hand is considered, incorrect and optimistic conclusions are reached.





Future handset outlook

- New frequency bands, 698MHz – 2.6GHz (450MHz)
- New air interfaces: LTE and LTE-A and WiMAX
- Traffic increasingly dominated by data
  - Adaptive coding schemes
  - Adaptive modulation schemes
  - MIMO
- More added functions
  - FM radio
  - TV
  - NFC/RFID for security and instant payments
  - HF & MF radio?

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 4]

Getting real

- We have all seen impressive demonstrations of LTE running at 150Mb/s
- 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?
- Traditional USB dongles do not seem to be a good bet for MIMO

Facilitating MIMO

- Realizing the possibilities of MIMO raises issues in
  - UE antenna and platform RF design
  - base station antenna system design
  - system protocols
  - spectrum planning and radio propagation
- They extend down the whole value chain, from component manufacturers, handset designers and network operators to users
- Even UE batteries are RF components!
- Real improvement requires unprecedented cooperation between workers in all the disciplines involved and between industry and network operators.

Conclusion

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

References & bibliography

[1] The MIMO Antenna, unseen, unloved, untested, *Microwave Journal*, Aug 2010

[2] *Test Plan for Mobile Station Over the Air Performance, Method of Measurement for Radiated RF Power and Receiver Performance,* CTIA, Washington DC, 2003

[3] See www.pctrb.com

[4] 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

[5] Zhi Ning Chen (Editor), *Antennas for Portable Devices*, New York and London, John Wiley, 2007

[6] *LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception,* 3GPP TS 36.101 version 9.4.0 Release 9, also available as ETSI TS 136 101,

[7] Technical Specification Group, Radio Access Network; Spatial channel model for Multiple Input Multiple Output (MIMO) simulations, TR 25.996 V9.0.03, 3GPP TSG-RAN

[8] J Bernhard, *Reconfigurable Antennas*, ser. Synthesis Lectures on Antennas, San Rafael, CA, USA: Morgan & Claypool, 2007, ISBN 978-1-598-29026-4.

[9] 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

[10] ETSI TR 125 996 V9.0.0: *Spatial channel model for Multiple Input Multiple Output (MIMO) simulations*

[11] 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

[12] C-X Wang, *Cooperative MIMO Channel models: A Survey,* IEEE Communications Magazine, Feb 2010 pp 80-87.

[13] B S Collins, *Handset antenna design: The next five years.* Video of paper presented at LAPC, Nov 2010 http://tv.theiet.org/technology/electronics/10018.cfm

Antenova Ltd
Far Field House, Albert Road
Quy, Cambridge, CB25 9AR, UK
Phone: +441 223 810 600

Brian Collins, Chief Engineer, Applications & Business Development
email: brian.collins@antenova.com