Handset antennas: The next five years

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The present scene

Over the last five years, what has driven the design of handset antennas for the major international mobile frequency bands?

- Frequency bands to be covered
- Cost
- Dimensions available in the handset
- Coexistence with other handset hardware
- RF Performance

Handset constraints

- RF efficiency depends on design of whole handset, not just the antenna
- 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

Handset performance today

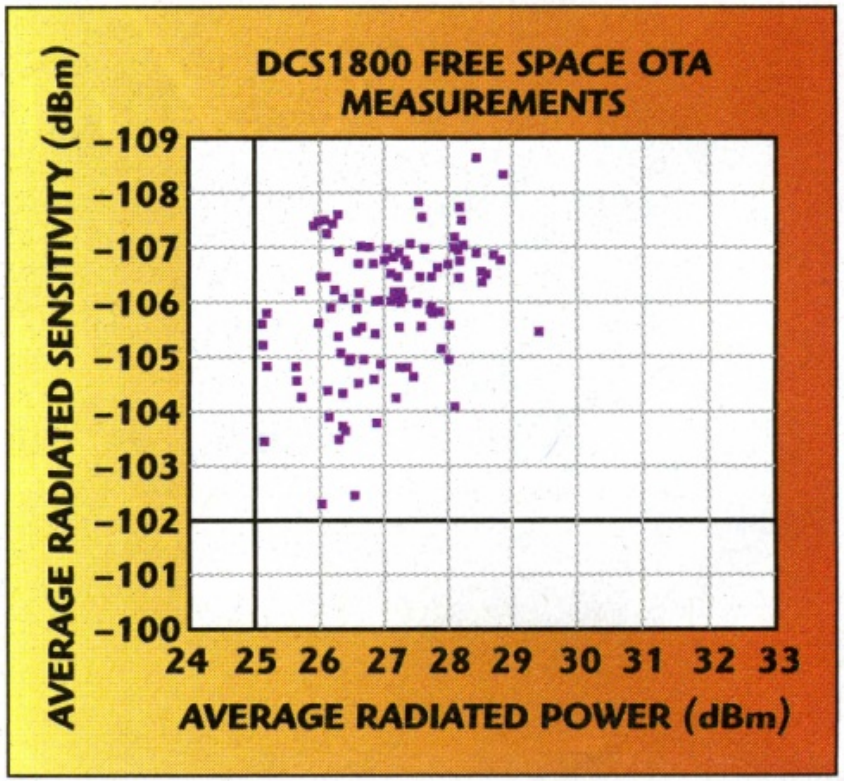


Fig. 1 TRP vs. TRS for GSM 1800 commercial devices.[1]

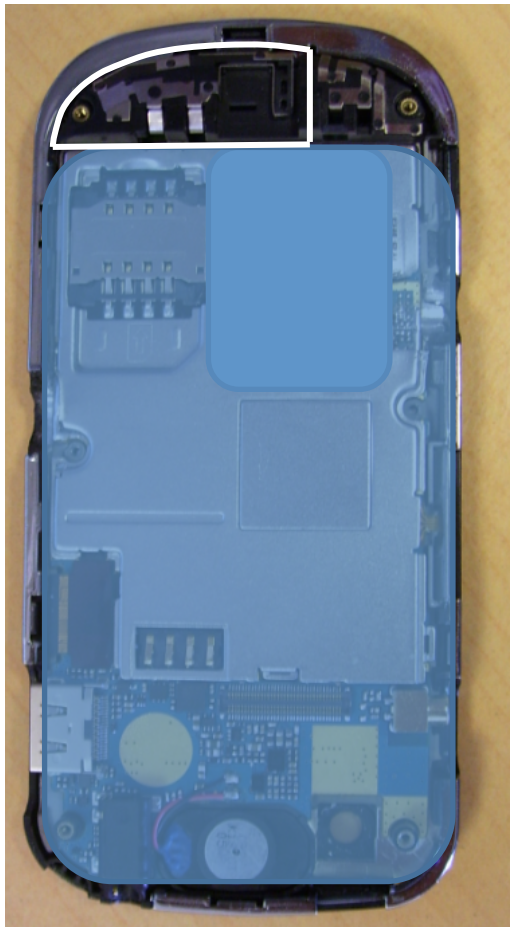
(Source, Agilent in MWJ)

- 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?

Today's handset antennas

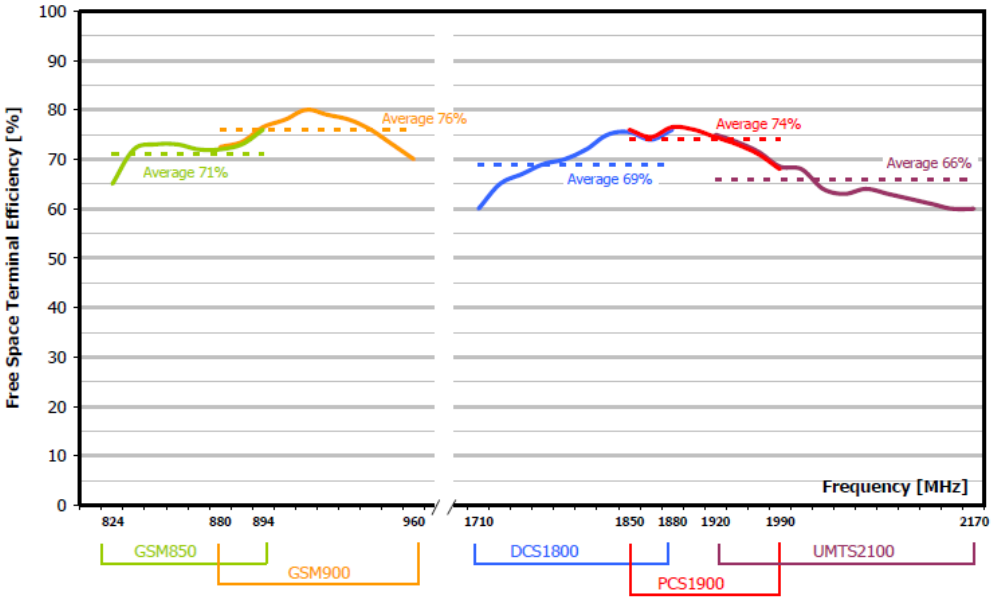
- Usually 4 or 5 frequency bands
- Typical designs
  - on-groundplane branched PIFA or higher-performing variant such as HDA
  - Off-groundplane branched monopoles and PIFAs
  - Volume around 2cc
- handset often contains additional antennas for GPS, WiFi, BT

Hardware example

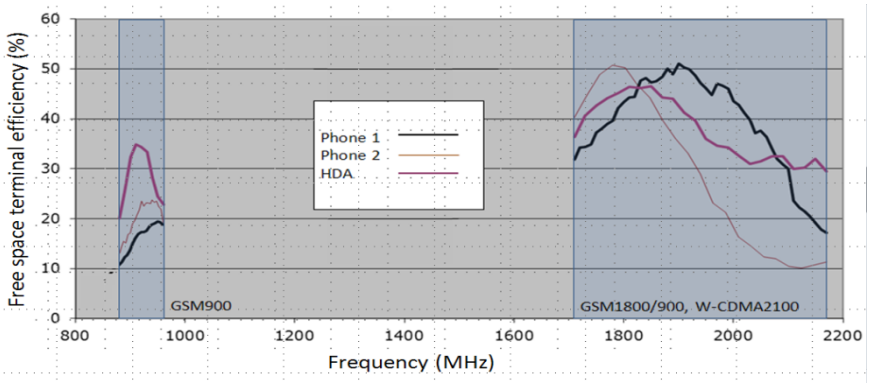


- Typical current-generation smartphone
- Tiny antenna space
  - Main antenna share space with GPS antenna
- Very little clearance around the antenna
- Poor ground continuity over whole area of handset
- Antenna represents c $0.20 out of whole BoM cost of $100

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

Future handset outlook

- New frequency bands, 698MHz – 2.6GHz (450MHz?)
- New air interfaces: LTE and LTE-A (and/or 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?

Rising to the challenge

- Better handset integration
  - requires a **major** culture change in the industry
    - can only be driven by network operators
    - and better-informed users
- An efficient handset requires a good antenna
  - but a good antenna does not guarantee an efficient handset
  - necessary, but certainly not sufficient!

Tuneable and reconfigurable

- There is no way that very small antennas can provide the needed bandwidth in the low band (698-960MHz)
- Tuneable and reconfigurable antennas offer new solutions
  - good academic work has been done in this area
  - more attention needs to be paid to the effects of lossy components in the antenna and control circuits, and ways of minimizing it.

Switching and tuning devices

- Switching and tuning devices must have low loss, low control voltages, low power consumption, low intermodulation products, small dimensions and low cost
- They must have high peak power ratings, high reliability and high repeat-ability in production
- Varactor diodes are a mature technology, but new components are needed with low operating voltages, low minimum capacitance and low ESRs
- MEMs devices are promising, but there is still much work to be done if they are to find application in high-performance handset antennas.

Multiple antenna techniques

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

Lower frequencies

- Almost everything you read suggests that lower frequencies are “better” for mobile use
- Propagation losses are lower, but
  - Handset antenna performance is *inevitably* lower
  - Multi-antenna correlation is likely to increase
  - Net benefit may be small

Compensation techniques

- Good work has been done on optimum termination impedances, matching and cross-coupling between antennas to improve decorrelation
- These need to be extended to include realistic component and antenna losses
- Studies usually assume identical antennas, but need to include the problems of heterogeneous antennas and hand effects

Dual-polar antennas

- Handset antennas have trad-itionally been limited to single-polar operation, the plane of propagation being strongly aligned with the axis of the handset PCB
- Handset dimensions make it possible to create a pair of orthogonally polarised antennas in the high bands, but the limited width of a handset makes it difficult to design an orthogonal antenna pair with wide bandwidth in the low bands
- A tuned solution might be possible.

New antenna structures

- New, smaller, efficient broad-band antennas will always find ready application
- While it may be possible to create new antenna structures with wider bandwidths, we are close to fundamental size/bandwidth/efficiency limits related to the whole dimensions of the handset
- It is not clear exactly how small the device that excites the radiating modes in the handset (the physical component we call the antenna) can be. This is a subject that needs further work.

Electrically very small antennas

- Some future applic-ations use frequencies at which the handset is only 0.002λ long or less
- At these frequencies the environment is very noisy; if we add a low noise amplifier between the antenna and the receiver the penalty for poor antenna efficiency can be less than we may expect
- Non-linear effects should be controllable
- Work is needed here to investigate the best way to make use of the very small available dimensions, the presence of the handset groundplane ,and available low-noise semiconductor devices.

Cooperative platforms

- System-level tech-nique that could enhance user experience while allowing more realistic performance objectives
- A second terminal – for example in a vehicle – which provides one or more of the MIMO signal streams could work cooperatively with a small user device to provide it with a much higher data rate than the device operating by itself
- A laptop and a handset could co-operate in the same way
- Cooperative techniques are planned for base stations.

Multi-function user platforms

- Multiple radio functions, concurrently transmitting on a small platform create major potential problems of mutual interference
- These create further constraints on antenna placement and dimensions
- New solutions are needed in antenna hardware, platform design and system software
- In M2M devices, the environment may create more problems!

Agenda for education & research

- Many current devices have inadequateperformance
- New transmission systems require more and better antennas in small devices if they are to deliver the spectrum efficiency, economic benefits and user experience which are the reasons for their introduction
- RF engineers – now in short supply – have unique know-ledge and skills necessary to improve the performance of mobile devices. They cannot do this alone, but must engage everyone involved in the process of handset design, specifi-cation and testing.

Credibility gap

- There is a large gap between the theoretical modelling of networks and protocols, and the nuts-and-bolts work of developing and characterising antennas and RF platforms
- Too much acad-emic resource is spent *following* what has already been done in industry – we must avoid this
- Many research proposals claim applicability to small mobile devices, even when such an application seems entirely unrealistic.

Timescales

- Timescale for the introduction of LTE/WiMAX networks is very short
- There is still very important and challenging work to be done if we are to realise the potential of these systems
- Some of the problems are of great practical importance, bearing on issues such as the spectrum most suitable for their deployment
- Others relate to fundamental limits that we must understand and work around.

Conclusions

- A substantial deficit exists between the theoretically possible RF performance of a handset and the performance typically achieved
- This deficit is currently only occasionally seen by users, but with the introduction of LTE/WiMAX it will impact both user experience and network costs.

Cross-disciplinary issues

- The issues embrace
  - antenna and platform RF design
  - radio propagation
  - system protocols
  - spectrum planning
- They extend down the whole value chain, from component manufacturers, handset designers and network operators to users
- Their solution – or mitigation – requires cooperation between workers in all the disciplines involved and also between academia, industry and network operators.

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Thank you!

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