# Testing Mobile Communications Products

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**Abstract:** The cost of testing mobile communications products and their infrastructure is under constant scrutiny due to the competitive nature of the markets. This paper provides an overview of the continuing technology advances of mobile chip-sets and the development of enabling technologies such as software-defined radio. These technologies while offering the user new facilities and services also offers potential manufacturing test cost savings and quality improvement opportunities despite the trends for increasingly complex modulation formats and ever-higher frequencies. This paper shows the importance of manufacturing test and the drive to avoid expensive functional testing by developing structural RF test strategies so that product verification can be measured at an economical cost.

## 1. Introduction

Suppliers of test and measurement equipment to the telecommunications industries need to provide their customers with appropriate solutions from both technical and business standpoints. The technology employed by mobile telecommunications is advancing rapidly with shorter product life cycles, shortening time to market expectations, increasing quality expectations, and a higher customer expectation of more capability for less cost. The cost of testing of products like handsets is under constant scrutiny due to the competitive nature of mobile telecommunications. Davis [1] states that test is ultimately a cost avoidance activity. The component of each of these test costs is described by Trott [2]. These are:

1) Test development costs. These would include any new capital for test equipment and test development labour.
2) Production costs. These costs will be dominated by test technician labour and test equipment maintenance costs.
3) Service and support costs. These are the costs of supporting the product during its warranty period and beyond.

The test process adopted by mobile handset manufacturers is designed to screen out manufacturing defects, load software, adjust for optimum performance and verify key functional criteria. The manufacturing operations are designed for huge volumes and are highly tuned for minimum overall cost. Fault yields are closely monitored and assembly processes continually optimized. Clearly, although mobile phones have evolved becoming ever more sophisticated with countless more features, their dimensions have shrunk to pocket size. As shown in figure 1, in 1983 mobile phones were large, heavy and had few of the features that we have come to expect and rely upon in modern phones.

*Figure 1: DynaTAC 8000X - the World's First Mobile Phone ('Dynamic Adaptive Total Area Coverage')*

These types of handsets had many hundreds of discrete components on multiple printed circuit boards. Manufacturers would need to ensure that the handsets conformed to the relevant network standard with a combination of design validation processes and manufacturing verification processes. For instance, more recently in the US, this would be the TIA/EIA/IS-95 Mobile Station-Base Station Compatibility Standard for Dual-mode Wideband Spread Spectrum Cellular System. In manufacturing, printed circuit boards would be structurally tested using manufacturing defect analysis (MDA) techniques or in-circuit test (ICT) techniques. Structural testing of printed circuit boards would be essentially inspecting for correct assembly placement and correct values of individual components. Functional RF testing and adjustment of performance would follow. Received signal strength and adjacent channel performance using interferers would be checked at this stage. After final assembly actual phone calls would be placed as the method for checking the overall phone. A technician listening to the phone call would check the audio quality.

Technology has of course moved on and will continue to progress as the demand for more services grows. It is essential that the test processes need to be aligned to these changes. It is therefore necessary to consider the major technology changes that challenge the test and measurement suppliers.

## 2. Chip-Set Technology

The designs of handsets are reducing to a small set of highly complex integrated devices with significant a reduction in board interconnects. In figure 2, the Motorola chip-set shows the building block approach to phone design. The chip-set devices, although small in geometry, contain virtually all of the hardware intellectual property. These chip-sets are manufactured by companies, which, in the main, have divested themselves of their mobile handset manufacturing. They now sell their chip-sets to global manufacturing corporations who can drive down the costs of the complete product. Qualcomm in the US, for instance, perform their manufacturing in collaboration with Kyocera a Japanese based company.

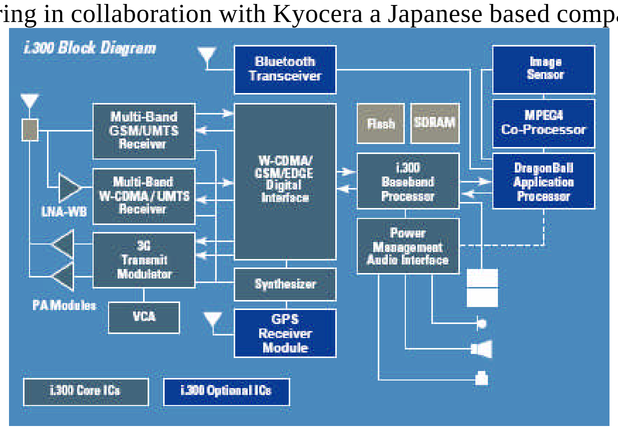

*Figure 2: An example of a chip set sold by Motorola*

Clearly fabrication of chip sets is extremely competitive with time to market, quality and cost being key drivers. In a similar way to printed board test, digital testing techniques are well developed. There has been a long hard drive to reduce or even eliminate functional testing due to the time and cost involved. The need for RF functional testing in manufacturing has been reduced as direct conversion from RF to baseband (Zero IF) technology has been implemented in the some chip-set designs. An example is shown in figure 3. Test costs, though, are still an issue. Mustapha Slamani [3] of IBM, Wireless Test Development Group, has stated at the International Test Conference (ITC) 2002 held in Baltimore,"The test cost becomes almost the main factor determining profit margin. To economically test high volumes of integrated RF ICs at a fraction of the cost of the IC we have to define a complete new test strategy". As complexity rises with frequencies increasing the drive to maintain or reduce the test cost remains. Indeed, Mayberry [4] from the Intel Corporation presented a paper called "Realizing the Benefits of Structural Test for Intel Microprocessors" where he said that they expected to be producing desktop microprocessors containing more than one billion transistors before the end of the decade. Structural testing methods determine that the chip-set has been fabricated correctly but does not exercise the product as it would be eventually used. Structural testing can, though, realize significant cost savings, as tools, techniques and metrics are available to measure the success. Mayberry [4] cited the lessons being learnt by Intel include the need for better 'design for test' techniques so that the test process can be synthesized, generated, evaluated, applied and observed as well as the need for better testers.

Mobile handset chip-set manufacturers not only have all of the problems discussed above with the test cost constraints of digital products but they also have the RF analogue issues that make structural tests much more difficult and potentially costly. In discussion with Dr.R G Bennetts a Design for Test (DFT) Consultant, it has been learnt that the major mobile chip-set manufacturers are keen to develop their DFT expertise and exploit techniques like boundary scan and its' derivatives. These are test techniques that enable structural testing developed and are standardized by the IEEE. As well as achieving the structural testing objective of verifying that the product is built correctly there are modes whereby 'Built In Self Test' (BIST) can enable analogue tests to validate conformance. The provision of the BIST does have significant advantages. It can provide 'at-speed testing', is re-useable throughout the product life and has intellectual property protection. It also can assist the diagnosis of faults in manufacturing and service environments.

Unfortunately, BIST has disadvantages. It can impact on silicon real estate, affects and potentially degrades the RF performance and adds time to the design cycle due to the lack of automatic test generation tools. Figure 3 shows the implementation of boundary scan, sometimes called JTAG, in a CDMA mobile handset chip-set.

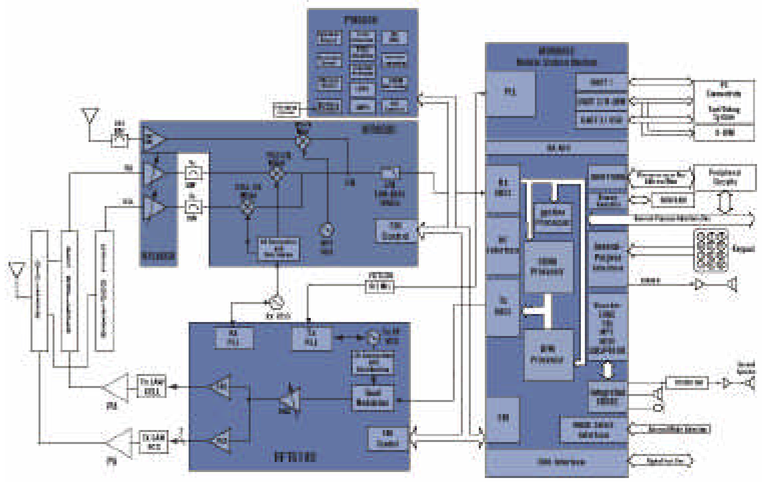

*Figure 3: Qualcomm Zero IF chip-set employing JTAG*

## 3. Software Defined Radio

Some of the disadvantages of BIST may be overcome by another enabling technology. Many of the chip-set manufacturers are embracing software-defined radio, (SDR). In a similar scenario to where CDMA was initially explored by the US military because of its' inherent covert properties, SDR is being deployed in the Joint Tactical Radio System [5], (JTRS). The aim is that the US military and its' allies will have a software programmable and hardware configurable digital radio networking system designed to increase interoperability, flexibility and adaptability. Traditionally the land, air and sea based armed services have bought different systems that cannot communicate with each other. Clearly this is a major disadvantage and the intention is for seamless communications for voice, data and video

Aside from military uses there is an international non-profit making organization dedicated to the development, deployment and use of SDR technologies for commercial purposes. This is called the SDR Forum. This organization has members that include NTT DoCoMo, Intel, NEC and Motorola. They are working on technology that allows handsets and base-stations to have modes changed or augmented, post manufacturing, via software. 'End of line' software configuration has been a technique used by manufacturers for many years to reduce inventory and lead times. Manufacturers test products to a common standard and then install the software at the time of customer order. SDR, though, uses adaptable software and flexible hardware platforms to address the problems that arise from the constant evolution and technical innovation in the wireless industry particularly as waveforms, modulation techniques, protocols, services, and standards change.

SDR has the potential for structural RF wireless test methods, analogous to the digital structural testing, whilst not creating a huge testing overhead. The real estate, the time of loading protocol and placing calls for functional tests is removed thereby saving time and cost.

## 4. Visions of the Road Ahead

It is vital that designers of test strategies understand the product road maps and the teamed technologies being developed to support them. There are forums that try to visualize the future directions in the wireless field that are supported by major companies. These include the Wireless World Research Forum with members fromAlcatel, Ericsson, Nokia and Siemens who contribute to the direction of research such as 4$^{th}$ Generation mobile (4G). There are many views about what 4G may be. The consensus view seems to be a convergence of technologies. This is supported by the view fromMobileinfo.com [6] in table 1. The accuracy of the view could be debated. For instance, data was not an add-on for 3G or that 100MHz bandwidth will be insufficient for 4G.

Table 1: Comparing Key Parameters of 4G with 3G

| | 3G (including 2.5G, sub3G) | 4G |
|---|---|---|
| Major Requirement Driving Architecture | Predominantly voice driven - data was always add on | Converged data and voice over IP |
| Network Architecture | Wide area cell-based | Hybrid - Integration of Wireless LAN (WiFi, Bluetooth) and wide area |
| Speeds | 384 Kbps to 2 Mbps | 20 to 100 Mbps in mobile mode |
| Frequency Band | Dependent on country or continent (1800-2400 MHz) | Higher frequency bands (2-8 GHz) |
| Bandwidth | 5-20 MHz | 100 MHz (or more) |
| Switching Design Basis | Circuit and Packet | All digital with packetized voice |
| Access Technologies | W-CDMA, 1xRTT, EDGE | OFDM and MC-CDMA (Multi Carrier CDMA) |
| Forward Error Correction | Convolutional rate 1/2, 1/3 | Concatenated coding scheme |
| Component Design | Optimized antenna design, multi-band adapters | Smarter Antennas, software multiband and wideband radios |
| IP | A number of air link protocols, including IP 5.0 | All IP (IP6.0) |

## 5. Conclusions

Clearly, as radio communication and computer technologies continue to converge, businesses are making huge on-going investments in technology. It has been shown, that in order to satisfy the manufacturing test cost imperatives, it is likely that test strategies, will need to driven to become more structural based. Advances in chip-set and software defined radio technologies, whilst offering countless new services to users, have potential for profound changes to enable new test strategies. DFT techniques could be applied to enable RF structural testing. To achieve this, test needs to remain a vital part of the product development programmes linking test and measurement companies more closely with the research and development teams within the chip-set manufacturers.

## 6. Further Research

This research is expected to lead to discussions with large chip-set manufacturing corporations as well as examining the test needs of the infrastructure. The intention is to innovate new RF structural test techniques using DFT facilities enabled by new technologies.


## 7. Acknowledgements

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## 8. References


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