Microelectronics Design Research for the Coming Decade:

Vision Statement for Research in Wireless Design

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Summary

This document sets out a vision for the key issues in design. The importance of large scale digital processing in acknowledged and supported. The authors' main focus is the key issues of wireless technology design. Proposals are made for the topics and themes that should be addressed as a basis for future economic exploitation.

Overall Landscape

Semiconductor manufacturing in the UK, as in most of Europe and the US is not growing as the larger investments flow to Asia, but nonetheless, there remain significant manufacturing businesses, particularly in niche markets. One the brighter side, there is still a large design sector in various manifestations. The traditional multinationals' design centres remain, while there has been a growth and maturing of fabless semiconductor companies as well as design houses.

To sustain and grow the large contribution of this key industry, there must be a supply of ideas and people who have new concepts to research and exploit, and this requires significant support for the academic research sector. Without these, the business goes elsewhere.

Digital Processing

In the computing and DSP areas there are notable successes in IP generation, licensing and fabless production. These areas, which depend on technology scaling and large "SoC" design technologies, are likely to remain key sectors of the industrial community. The future problems for are now becoming more generally discussed. On the one hand, one needs tools to manage the scale of complexity involved. More significantly, CMOS scaling runs into territory of more challenging physics – particularly leakage and timing. A Boolean view no longer suffices.
Economically, these issues crudely translate into **Cost** and **Power**.
It seems that these issues will need to be approached on a variety of fronts, and architectural ideas will evolve in different directions, possibly more with application areas, to exploit the huge potential processing power of technology in areas outside the premium computing market. In this area, the UK has some very significant strength, and research into processing architectures and the associated SoC design and software disciplines should be strongly supported.

Wireless

At the other end of the scale, wireless is the other really key enabling technology, and central pillar of such paradigms as connected home, mobile internet, intelligent cars and "Ambient Intelligence". The UK had an historic basis in this field, and there are also many successful manufacturing and fabless companies achieving international success in wireless IC technology. Here again we see that from an industrial point of view, there must be new ideas and people to research and exploit technologies and systems and generate new wealth. In practical terms, **cost** and **power** also determine the viability of a system for mass-market mobile applications. To meet these requirements, there must be an approach at both a technological and a system level; reworking old ideas in the latest technology is not enough. Several UK commercial groups have shown just such innovation in system and technology in the cellular and w-PAN space. However, the presence of UK participants in the major conferences is very small.

Research Vision for Wireless Technology Design

Wireless applications in the low-GHz are already ubiquitous – cellular radio, GPS, w-LAN, etc. These have come to market as a result of reducing **cost** and **power** in the implementation of high specification radios. The superhet radio is no longer the default for cellular and w-LAN applications. Now direct-conversion and low IF are the favoured systems, using $\Sigma\Delta$ synthesis, self-calibrating filters and quadrature data conversion paths. These system techniques have come from combinations of DSP as well as circuit architecture and improved semiconductor technology; one alone could not have delivered the results.

The new challenges are now to take this thinking and develop capabilities in much higher frequency ranges (mm-Wave), while maintaining acceptable **cost** and even reducing **power.** The motivation for higher frequencies is a manifestation of the continual needs for bandwidth – applications have continuously moved up in frequency as technology has made it economically possible. Power reduction is clearly essential for the Ambient Intelligence vision.

New system architectures imply a mix of the optimum techniques to transit or recover a signal from the RF domain. Technology plays a key part inasmuch as there must be the capability to integrate significant complexity, including digital functions, alongside linear circuits at 10s of GHz. Hence, GaAs is excellent for simpler functions, but the main systems must be SiGe BICMOS or even CMOS.
Design techniques are also changing. We can see a distinction between "Old RF design" with emphasis on S-parameters and distributed effects etc, and "New RF design", where lumped and time-domain techniques are more often used with very high precision. The boundary between these complementary disciplines is gradually moving upwards in frequency (as reflected in courses in analogue and RF design offered by the authors through the CEESI initiative) as technology and tools advance.

Research Theme Proposals

A collaborative programme is proposed centred on the theme:

Wireless Networking Capability Beyond 5GHz

with the aim of developing technology and capability in two related areas

Firstly, we suggest researching *Ultra Low Power Wireless Networks*. Here, the aim is to investigate providing the wireless capability for small low-bandwidth autonomous systems that underpin the Ambient Intelligence vision. One sensible strategy would be to avoid the present heavily populated ISM bands (2.4GHz, 5.5GHz) due to the plethora of devices of moderate power already installed. Going higher in frequency generally requires more power in circuits, and some more radical system circuit and technology choices are likely.

Secondly we extend the general trend for higher frequencies further to target
Wide Bandwidth Local Area Wireless Capability at 60GHz and Beyond
This is aimed at providing extremely channel high bandwidth capability for the consumer user in frequency bands where more than 5GHz of unlicensed spectrum is available. There are already some studies in this area started in other countries, but there is still a long way to go to get to the goals of acceptable system **cost** and **power** and many routes to explore. We propose to study this at technology, circuit and system level.

The basic tasks share a common flow:

System Concepts – UWB vs Narrow band; how much RF, how much DSP. Effect of protocols on overall system power.

Technology Choices - Depends on the *must-have* criterion – power or cost. For RF, different emphases are possible; focus on one reasonable cost technology and fit the system around it, eg, SiGeC BICMOS or CMOS, or go for a combination of technologies including GaAs and other III-V; substrate technology for RF transmission and matching elements; baseband technology; supply management.

Design of Critical Circuit Blocks – LNA, VCO, Mixer, Synth, TxPA, RF/IF Filters

At each level, critical dependencies are minimised, while ensuring that the aggregate of results has more value than the sum of parts.

The outputs from the project would be:

Capability in system and circuit design new mm-wave wireless applications
Research output in key international journals and conferences (Tr-MTT, JSSC, RFIC, ESSCIRC, ISSCC)
Research engineers with skills to start or develop new design or fabless RF business