RF Technology Initiatives for 5G

Peter Gammel, Stephen J. Kovacic

Skyworks Solutions, Inc., 20 Sylvan Rd, Woburn, MA 01801, Phone: (781) 376-3000
e-mail: peter.gammel@skyworksinc.com, steve.kovacic@skyworksinc.com

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Abstract

Semiconductor and package technology choices for 5G communication systems are considered. The market context and existing RF Front-End UE architectures are reviewed with emphasis on SIP technology. SOI, InP HBTs, and other technology candidates are discussed within this context. Rapid customization at the module level is needed in order to serve different manifestations of 5G systems in the early phases of market deployment and demonstrators.

INTRODUCTION

Wireless communications are now part of the fabric of society for developed economies and is fundamentally changing how we communicate and do business. Those changes are visible across national boundaries, socio-economic categories, and age. Within this context, one can argue that access to information is being transformed from a privilege to a human right. Especially in Europe and North America, we are starting to think of access to the data network in the same way we think about water coming out of a faucet. Moreover, access to information has become a great equalizer giving us the advantage of finding and working with talented individuals from almost any demographic or educational circumstance.

LTE (4G) and Wireless LAN (WiFi) – two of the most successful radio standards in the short history of RF communications, have been the backbone of these societal changes. For those planning 5G systems, the daunting task is simply to find a way to be as successful. We must think through 1) what sort of enhancements over 4G and WiFi are needed, 2) when those enhancements are needed, and 3) how they can be successful in a business sense.

An objective of this presentation will be to examine different component technology platforms and how those platforms might be used in emerging 5G concepts. To achieve that objective, a review of the RF communications market context will be provided focusing specifically on the user equipment (UE) devices. After establishing that context, the architecture of the front-end RF system (RFFE) will be examined followed by a description of the technology options that might come into play for 5G enhancements to RFFE components.

Perhaps the most difficult challenges presented by the uses cases for 5G are data rate – upwards 1 to 10 Gpbs in a dense urban context, and latency (< 1 ms) [1]. Reduced end-to-end latency has as much to do with the network architecture as any other factor and future 5G networks are expected to be able to support heterogeneous networks (HetNet) using different access technologies and cell sizes. In addition, 5G must support peer to peer (P2P) networks of nodes such as device-to-device and machine-to-machine communication within the context of the HetNet.

MARKET CONTEXT

When is 4G capability not enough for the market? As a standard, LTE continues to evolve to fill market need in a manner that is a testament to the ingenuity of technologist and engineers. For example, peak download speeds have increased from approximately 150 Mbps circa 2012 to over 450 Mbps in 2015 using, as leading example, the Qualcomm® Snapdragon™ LTE modems following the path of LTE Advanced (3GPP Release 12). Concurrently, IEEE 802.11 has become an 'alphabet soup' of variants building upon the success of standardization and relative freedom of unlicensed ISM bands (2.4 GHz, 5–6 GHz, 60 GHz, etc.) as seen in Figure 2. Interestingly but perhaps not surprisingly, many of the uses cases envisioned in 5G overlap with the IEEE 802.11 evolution so, in some sense, the race is on!

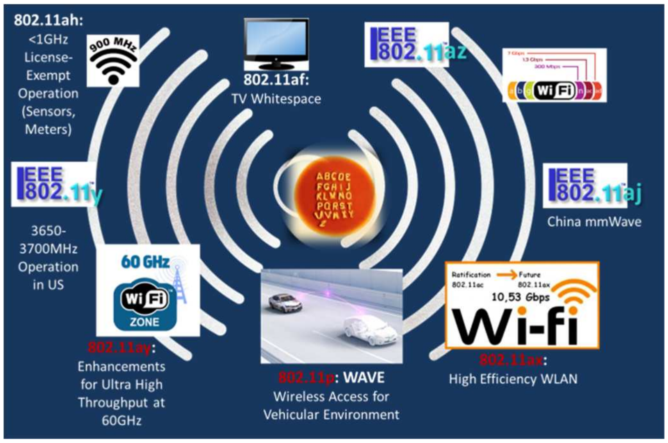

Figure 1. New flavours of IEEE 802.11 have emerged to satisfy different use cases. The standard comprises a set of media access control (MAC) and physical layer (PHY) specifications for implementing wireless local area network (WLAN) communication.

The UE RFFE component market is heavily influenced by some strong global themes. Some of these include expanding markets like LTE deployments into emerging economies with very specialized SKUs, new connected devices serving new vertical markets, and a fast-evolving set of IEEE 802.11 applications. Another theme is increasing complexity in the RFFE that is driving technology initiatives. Some examples of this include the proliferation of bands, MIMO, carrier aggregation, and new spectrum at higher frequencies. A final theme is disaggregation of embedded analog content, which is pushing more and more functional blocks into the RFFE with each generation of bulk CMOS.

In the context of 5G utilizing millimetre wave spectrum, a clear observation we can make is that more of the radio (TRx) content needs to be placed in a SIP solution as seen in Figure 2. Effectively, phase shifters, up-down converters, and the usual RFFE components, like filters, power amplifiers and low-noise blocks can, and should be placed close to the radiating element in order to avoid signal loss.

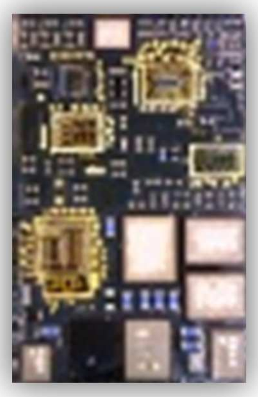

Figure 2. An example of a highly integrated and customized SIP solution where PAs, filters, LNAs, and controllers are deployed. It does not take much imagination to integrate antenna and other RFFE components like phase shifters into this mix.

Customization of the SIP solutions is an important market advantage as customers are faced with very rapid product introduction cycles, and reuse of proven signal conditioning circuit blocks reduces risk.

TECHNOLOGY OPTIONS

Within the context of a SIP solution, technology selection is made much easier for 5G systems. We choose the technology platforms (semiconductor, packaging, test, etc.) that deliver the performance that is required at a cost structure that is consistent with the module's value proposition. Anticipating wider bandwidth signals and higher frequency carriers, the choice of active device technology platforms can be summarized as shown in Figure 3.

CMOS or SOI at nanometer gate lengths has emerged as a very credible technology platform especially if we consider the integration of additional radio blocks into the traditional RFFE components [2-9]. Furthermore, in respect to the PA, if we accept a conventional rule of thumb requiring 5x the operating frequency (f_o) as a minimum requirement for the Fmax of the transistor amplifier, then 65 nm, 45 nm and 28 nm CMOS and SOI are certainly contenders even with two or four levels of transistor stacking and f_o at 60 GHz.

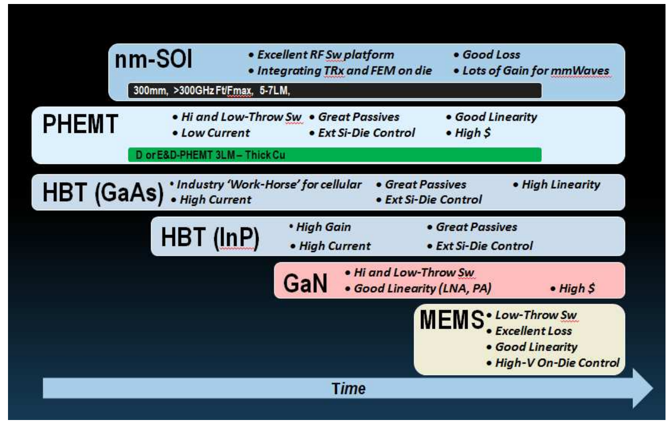

Figure 3. The choices for active elements include nm-SOI and CMOS, PHEMT, HBTs, GaN HEMT, and MEMS technology platforms. In each case, we are trying to leverage high gain, low loss, and/or linearity performance at mmwave signal frequencies.

Packaging options are an important technology choice because of the integration of the antenna elements. Cavity-based solutions as seen in Figure 4 can provide more bandwidth and better isolation between antenna elements but will require better alignment in a multi-layer organic context. LTCC solutions are common but perhaps might not provide the cost structure needed for all UEs.

Regardless of the packaging approach chosen, co-design of the IC, package routing and antenna is a crucial requirement for RFFE module success. Signal attenuation due to absorption by the chosen laminate is not as significant a factor, as poor impedance transitions cause reflections. For example, restrictions in the PCB technology design rules may limit wide bandwidth matching to the signal ports on the IC in a flip-chip to PCB coplanar waveguide transition.

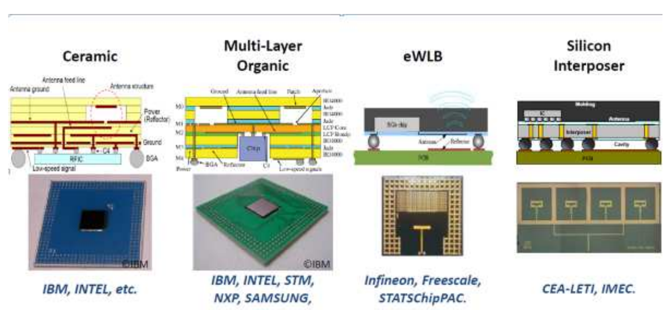

Figure 4. Packaging and antenna integration approaches have been pioneered by IBM, Intel, and others. Commercial vendors are now offering low-loss, multi-layer organic solutions such as Rogers 3003™ with rolled copper foil (0.5 – 2 oz) cladding.

CONCLUSIONS

Many issues arise when considering the integration of wider bandwidth signals and/or mm-wave RF front-end components in a UE form factor. The technology choices available now will direct future UE integration of mm-wave radios and/or sub-6 GHz, wide-bandwidth radio access solutions. In our survey, SiGe BiCMOS, 45 nm SOI and InP HBTs stand as credible candidate technologies for different functional blocks within the RFFE and much depends upon final requirements such as linear power output, bandwidth, and receive sensitivity. Consequently, the SIP approach ― which can mix the best technology choices ― will provide advantages in time to market and flexibility.

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