Technology Initiatives for 5G Radio Front-End Elements

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INTRODUCTION

It is difficult to overstate the importance of wireless technology in a modern society today. Rapid and globally standardized developments that permit ubiquitous access to information is transforming how we do business, work, and interact socially. Moreover, access to information has equalized opportunity, giving us the advantage of finding and working with talented individuals from almost any demographic or educational circumstance.

Two of the most important and successful radio standards -- LTE (4G) and Wireless LAN (Wi-Fi) have been the backbone of these societal changes. With strong business success and the insatiable demand for improved performance, our technical community is again defining and specifying the next generation of mobile radio technology and networks – 5G [2].

An objective of this presentation will be to examine component technology platforms and how those platforms might be used in emerging 5G concepts. Methodically, this paper first reviews the RF communications market context, focusing specifically on the user equipment (UE) devices. The architecture of the RF front-end systems (RFFE) follows a contextual framework, and we can conclude that there are many technology options that might come into play for 5G enhancements to RFFE components.

MARKET CONTEXT

As a standard, 4G LTE 4G has been evolving to fill market demand in a manner that is a testament to the ingenuity of technologists and engineers. For example, peak download speeds have progress from approximately 150Mbps circa 2012 to over 450Mbps in 2015 using, as a leading example, the Qualcomm® Snapdragon™ LTE modems followed the path of LTE Advanced (3GPP Release 12). Not to be surpassed, Intel recently announced a 5G modem [1] and we can surmise that a guiding objective is that 5G will enable billions of "things" to become empowered through seamless connectivity, access to computing power that leverages rich data and analytics stored at the edge of the cloud.

The targets for 5G can be visualized in Figure 1 and comprise three fundamental capabilities: Enhanced mobile broadband, ultra reliable low latency communications, and massive machine type communications. Deploying those capabilities requires a combination of macro and small-cell base station installations that will leverage current cellular spectrum and, for the first time, millimeter wave (mm-wave) spectrum as seen in Figure 2.

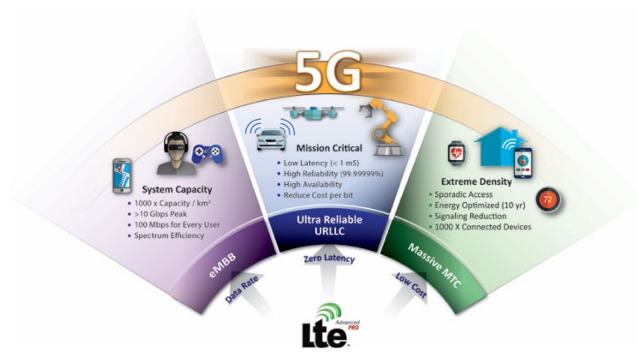

Fig. 1. 5G Vision and Targets: eMBB –enhanced mobile broadband – will deal with growing system capacity, with the goal of 1000 x capacity, greater than 10 Gb per second peak, and a minimum of 100 Mb per second for every user. This will have aspects of sub 6 GHz 4G and 5G, and above 6 GHz 5G NR communications. – Ultra reliable low latency communications (uRLLC) will deal with new applications that require mission-critical communications with almost no latency. The goals for these new market verticals are to ensure high reliability and availability with extremely low latency below two milliseconds. Massive machine-type communications (mMTC) will be associated with extremely low cost and low data rate emerging market segment. This is most closely correlated with the Internet of Things and is embodied by several orders of magnitude new connections to the LTE network.

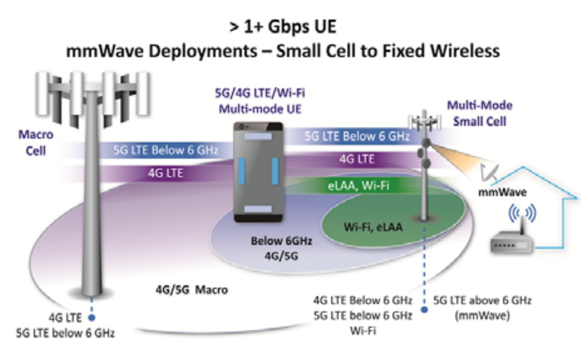

Fig. 2. RFFE components will find application in a variety of macro and small cell installations both in the cellular and mm-wave frequency bands interacting with the UE device.

In the context of 5G utilizing millimeter wave spectrum, a clear observation we can make is that more of the radio (TRx) content needs to be placed in a system-in-a-package (SIP) solution as seen in Figure 3. In fact, a clear progression in terms of circuit integration and module form factor can be seen as one moves from using microwave spectrum to mm-wave spectrum. 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.

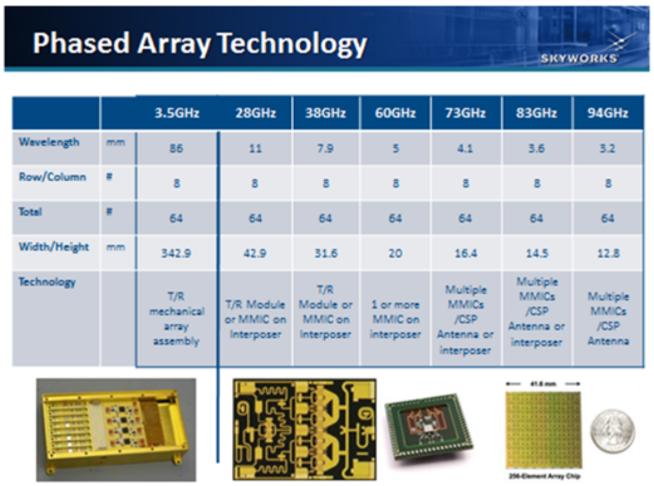

Fig. 3. From highly mechanical implementations at 3.5GHz to single chip phased-array systems at 94GHz, the impact on technology selection and form factor is profound.

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 in Figure 4.

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 [3-10]. Furthermore, in respect of the power amplifier (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 65nm, 45nm and 28nm CMOS and SOI are certainly contenders even with two or four levels of transistor stacking and f_o at 60GHz.

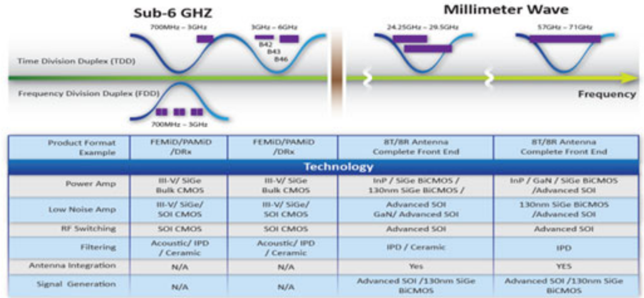

Fig. 4. The choices for active and passive elements include nm-SOI and CMOS, PHEMT, HBTs, GaN HEMT, and potentially MEMS technology platforms. One observation is that acoustic filtering (SAW, BAW or FBAR) are less suitable in the 5G mm-wave bands and, perhaps, less stringent filtering will be required for 5G TDD bands below 6 GHz as compared to FDD bands.

CONCLUSIONS

Many issues arise when considering the integration of a wider bandwidth signals and mm-wave radio in a UE form-factor. The technology choices available now will direct future UE integration of mm-wave radios and/or sub-6GHz, wide-bandwidth radio access solutions. SiGe BiCMOS, 45nm 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 mixes the best technology choices, will provide advantages in time to market and flexibility.

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