EP1: Is RF Doomed to Digitization? What Shall RF Circuit Designers Do?


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To support the ever-increasing levels of system-on-chip (SoC) integration required by the consumer insatiate appetite for sophisticated yet cheap mobile phones and internet devices, the RF circuit design has recently been moving to the finer CMOS process geometry nodes. There, it can harness the enormous potential of nearly free digital logic and memory. Enter the digital assistance of RF, which offers calibration, compensation, linearization and predistortion of linear devices, which can boost the RF system performance to the point that it is now better and more reliable than with the conventional approaches. The related field of RF built-in self-test (RF-BIST) allows for an RF-SoC to exploit the power of digital signal processing to autonomously test its own RF almost for free. Enter "digital RF", which transforms the continuous-time analog RF functionality into digitally-intensive or even all-digital implementations. With the transition frequency f_T of over 200MHz in 40nm CMOS, the RF circuits operating at 2GHz now feel just almost like the low-frequency mixed-signal circuits of the past.

This is all very exciting and intriguing but, at the same time, it could be quite scary for the traditionally-minded designers as well as students educated on the contemporary textbooks that are yet to be updated. What will happen to their 'investment' in the traditional RF knowledge? Will RF ultimately share the same digitization fate as, for example, the audio on cellular phones? Are there any alternatives or safe havens far from the digital encroachment? Will mm-wave and THz electronics with their frequency of operation somewhat comparable to the f_T of advanced CMOS technology be forever 'safe'? Seven leading experts from the industry and academia will debate this controversial topic.

Panelist's Statements

Borivoje Nikolic, *UC Berkeley, CA*
The need to design commercial radios with ever-increasing number of modes, while supporting an increasing number of bands and standards, inevitably leads to a higher degree of 'digitization' of the RF transceiver chain. However, the requirements for linearity, interference suppression, power consumption, dictate the need to continuing improvement in performance of LNA's, filters, synthesizers - components that can be improved by using digital aids, but cannot be replaced. As a result, RF designers will continue to be in high demand - although the number of opportunities may not grow as fast as in the past.

Oren Eliezer, *Xtendwave, Plano, TX*
The extent of digitization in RF transceivers is clearly on a rising trajectory, while the cost per function is declining. These opposite trends are related, with one driving the other. Since cost reduction is always desirable, the future of this trend may be predicted by simple extrapolation. Much like with Moore's law, which was believed to have reached a 'wall' several times since its inception, the engineering community will continue to come up with the technology to allow for this digitization trend to continue, with the ultimate goal being the placement of the data converters as close as possible to the antenna, both in the receiver and in the transmitter. The advantages of digital implementations are well recognized, ranging from automated design flows and scaling to design robustness and low-cost productization. It is therefore reasonable to state that digital implementations in RF transceivers are replicating the successful digitization of audio.

Ken Hansen, *Freescale, Austin, TX*
Of course, digital circuits are more repeatable, predictable and testable, so why not attach data converters to the antenna and process everything digitally? The issue is power consumption. The front-end of a receiver has to be as wide in bandwidth as the communication standard supports. Within this bandwidth there will not only be the desired signal, but many undesired signals that, if nonlinearly processed, will create many interference issues. Therefore, the A/D converter dynamic range must support signal levels from the sensitivity to full strength, must have a bandwidth commensurate with the communication system, and most likely the RF signal must be oversampled, which in many cases is in the GHz range. Unless a breakthrough in battery technology occurs, the power consumption for this approach is unacceptable. RF designers should continue to develop and hone their skills – they'll be needed for a long time into the future.

Rik Jos, *Nijmegen, The Netherlands*
If history has taught two lessons to the analog and mixed signal IC designers, they are: "If you can use silicon, use it" and "If you can digitize, do it". These lessons seem to hold also for the RF IC designer. However, there are still severe limitations to what can be achieved by replacing RF circuits by digital. One of the most challenging RF applications that cannot be easily replaced by digital circuits is the RF power amplifier. Nevertheless, several attempts are ongoing in the industry and academia for cellular applications at below 5 GHz, using a hybrid approach of combining RF and digital circuitry to achieve higher energy efficiency, better linearity and multiband capability. Therefore, the expectation is that RF power amplifiers will undergo a transition to more digital solutions. This will stimulate full digitalization of the RF transmit and receive paths in cellular systems in the long run.

Andreas Kaiser, *IEMN-ISEN, Lille, France*
Digital switching energy and die area per function continues to decrease with more advanced technology nodes. Implementing large parts of RF transmitters and receivers digitally becomes therefore more and more attractive. Only a few analog elements will remain in transceivers for GHz frequency radios. This trend is enforced by the need for flexible multi-band multi-standard radios. On the transmitter side, it has already been shown that frequency generation, modulation and up-conversion can be done in a fully digital way up to the PA input. On the receiver side, the most critical point is interferer rejection, which is up to now achieved through off-chip high-Q passive filters offering no flexibility. The goal is to simplify the analog frontend and to achieve interferer rejection through adaptive digital processing in appropriate architectures. Making expertise of RF designers available in trans-disciplinary design teams is crucial to enable progress in that direction.

Lawrence Loh, *Mediatek, Hsinchu, Taiwan*
With years of observations of IC design industry for storage, communication and consumer applications, the retrospect suggests that certain history always repeats itself! As Moore's Law continues to progress on mainstream bulk CMOS technologies, the needs of RF digitization for GHz wireless systems would never stop. On one end, nanometer-scaled CMOS RF/analog designs require digital assisted circuit structures to fix physical limitations and signal impairments. On the other end, higher degree of digitization helps to resolve size/scaling issue, which is essential to justify the continuing integration of RF and other analog frontend functions. All-digital PLLs, for example, have become realities to provide effective frequency synthesis for numerous RF subsystems to date. More challenging part remains at the RF frontend, which differs from many other analog systems in its stringent frequency selectivity, which requires further technology breakthroughs to handle blockers/sensitivities and spectral leakage/linearity for receive and transmit blocks, respectively.

Akira Matsuzawa, *Tokyo Institute of Technology, Tokyo, Japan*
We should recognize the discussed issue as the development stages of the wireless technology. In the early stage, pure RF device, circuit, and measurement technologies explorer a new field and realize basic circuits and characteristics. Next, RF chips will be developed by integrating these circuits. Some digitally-assisted techniques will be introduced mainly to adjust the mismatches. Finally full wireless SoCs will be developed by integrating not only RF, but also baseband analog and digital circuits. More sophisticated signal processing and control methods will be used to realize more complex systems; such as multi-standard and reconfigurable systems and to address the self-testing and compensation. More advanced CMOS technology can be used along with the development stages to realize higher integration and higher frequency of operation. Traditional RF designers are still needed to explorer the new field and the digital approach designers are also required to develop the total wireless systems.

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