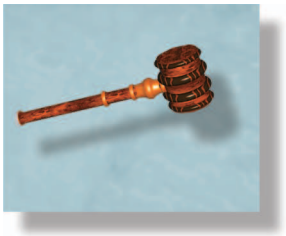

President's Column

Time for a 5G Technology Assessment and Road Map?

■ Dylan Williams

A few months ago, I wrote about the new "journal within a journal" section on microwave systems and applications that we introduced in the May 2017 issue of *IEEE Transactions on Microwave Theory and Techniques* (*T-MTT*), the flagship publication of the IEEE Microwave Theory and Techniques Society (MTT-S). This new section welcomes contributions concerning everything from conventional microwave systems to systems-on-a-chip and is dedicated to the systems side of our business. This change reflects the growing importance of the high levels of integration increasingly required in all that we do.

Considering the Systems Side of Microwave Engineering

This new section in *T-MTT* caters directly to the systems side of microwave engineering, which has always been an important aspect of our art. Just as important are the points of view cutting across systems, subsystems, circuits, components, and devices. Our goal is to better inform all members of our community as to the directions our field is taking—whether we are working on link budgets, designing RF integrated circuits, or focusing on component design with no particular application in mind. This mixed viewpoint emphasizing all aspects of our field has served the MTT-S well since its inception in the 1950s.

The development of next-generation (5G) wireless infrastructure has been no exception. Early on, many in our Society—recognizing the severity of the "spectrum crunch"—started thinking about what the next generation of wireless infrastructure would bring. We all began reading both system studies (e.g., [1]–[3]), economic studies (e.g., [4]), and technical papers (e.g. [5]–[8]) that explored this new space. These studies, and many others, presented a compelling view of the need to improve the infrastructure in current cellular bands by shrinking cell sizes and taking advantage of spatial diversity to the greatest extent possible—all as a way to better support today's need for broadband mobile data transfer.

I am most grateful to the authors of the numerous studies I have read for exposing me to these systems-level ideas. Being better informed about the directions of microwave engineering and what it will bring to communications systems allows me to better direct my work on microwave and millimeter-wave (mmW) measurements as we try to anticipate what will have the greatest impact in our field today, tomorrow, and a decade from now (see "The Promise of 5G").

Two Examples

Here are two small examples out of many. First, we now know that delivering reliable mmW wireless communication channels will require high-gain phased-array technologies with individually controlled elements capable of monitoring and quickly selecting alternative channels. This will dramatically impact the development of future test and measurement strategies.

Second, we now have a better grasp on the number of transmitters and receivers as well as the power levels required to accomplish these strategies. This helps greatly in understanding the challenges for power management and signal processing the next generation of mmW designers will face.

Open Questions

The required system-level specifications for 5G are becoming clearer. Road maps and white papers have been published and consortia formed. And the U.S Federal Communications Commission

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The Promise of 5G

Perhaps what many of us find most exciting are the outlines of next-generation (5G) application spaces that would be feasible if we could unlock the great open spaces in the millimeter-wave (mmW) bands for mobile communications, allowing real-time transfer of not only conventional data but also high-definition video and haptic (tactile and kinesthetic) information on millisecond time scales. Those spaces include applications in augmented reality, which relies on telecommunications to transfer high-definition video to a server where it is processed, augmented, and then sent back to the user in real time. The automotive industry is not just betting on systems that allow cars to negotiate the streets based on sensing the immediate surroundings; they envision globally aware autonomous automobiles that leverage immediate feedback from all the surrounding autonomous systems to maximize throughput and increase speeds, while driving more closely together and more safely than human drivers or their locally aware counterparts. And, of course, the public safety and other sectors are eagerly awaiting advances in communications that will allow robots to transfer not only real-time, high-definition video but haptic feedback as they fight fires, safely perform surgery, and carry out other functions to protect their human counterparts in the field. These applications are expected to create a US$3 trillion per year global market, and the companies and countries that can successfully unlock the mmW spectrum will immediately gain a critical advantage in deployment over their competitors.

has opened nearly 11 GHz of spectrum above 24 GHz for 5G development.

But what about the technology path we should follow to utilize the mmW part of the envisioned 5G spectrum? As I see it, this is the proverbial "elephant in the room." We have a good understanding of the applications that are driving us toward mmWs as well as an outline of the systems we must develop. However, there does not seem to be any consensus on what, if any, technology will get us there.

We know that we cannot copy-and-paste fourth-generation technologies into the 5G mmW space. Will arrays of low-power, high-frequency silicon RF integrated circuits (RFICs) enable the cost-effective mmW handsets everyone is looking for, despite their lower efficiencies? Or will it be gallium arsenide, gallium nitride, or other III–V technologies? Will heterogeneous integration strategies being explored at the U.S. Defense Advanced Research Projects Agency and elsewhere be cost-effective enough to be adopted in the commercial sector?

Will we be looking at the same technologies for both the base station and mobile handsets? Will we need to develop new ultracompact filters and other passives? Or will we continue to replace passive circuitry with more compact active solutions that take advantage of passives constructed in the low-loss and microwave-capable interconnect stacks supported in modern ICs? And what are the tradeoffs in terms of size, loss, linearity, and so forth?

Would you like to get more involved in the MTT-S? If so, send me an e-mail at dylan@ieee.org with a short description of your interests, and I will get back to you about possibilities!

To date, most studies are silent on these subjects. And what little can be found in the open literature lacks the detail necessary for a true technology assessment and road map.

Opportunities and Challenges

All this presents the MTT-S with both an opportunity and a challenge. The opportunity is to leverage the neutrality and resources of the IEEE and work with our sister Societies to pull together a cohesive effort that can go beyond existing system-level studies and produce a comprehensive and well-thought-out mmW technology assessment and road map. Such an assessment and road map at this juncture would be a real contribution to our field, helping companies better understand their place and role in this emerging mmW community.

The challenge, as I see it, will be convincing microwave and mmW technologists that sharing their expertise (as the digital industry has done with the *International Technology Roadmap for Semiconductors* [9]) will ultimately be more beneficial than guarding that expertise within their own company or institution. One could easily envision technology-savvy Societies (such as the MTT-S along with the IEEE Antennas and Propagation Society; IEEE Electromagnetic Compatibility Society; IEEE Electron Devices Society; IEEE Solid-State Circuits Society; IEEE Components, Packaging, and Manufacturing Technology Society; and others) joining together to seek collective answers, perhaps under the auspices of the *IEEE 5G Technology Roadmap* [10].

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