The latest standard specification for 5G brings with it some big challenges for the designers of 5G systems, as Ken Karnofsky explains.

In June 2018, the wireless networks community had an enormous box ticked with the completion of 5G NR (new radio) standard. For many, the announcement was a long time coming, but it’s important to remember that, compared to 4G, 5G will use different kinds of antennas, operate on different radio spectrum frequencies, connect many more devices to the internet, minimise delays, and deliver ultra-fast speeds. Therefore, the latest standard specification presents some significant challenges for the designers of 5G systems.

The necessity to increase the data rate and capacity of mobile broadband networks is an overarching factor.

To accomplish this goal, 5G will use higher frequencies, which introduces new complexity that will require different baseband algorithms and radio architectures to contain cost and achieve performance goals.

5G NR introduces significant changes to the physical layer of mobile communication systems requiring different algorithms in baseband modems to implement the flexibility needed to achieve the high-speed, high-capacity, and low-latency goals of 5G. These changes affect the design of the receivers in base stations and mobile devices, and they have a large impact on the testing strategy for all components in a 5G NR system.

Operation at higher millimetre wave (mmWave) frequencies is driving dramatic changes to the architecture of the radio front end, including massive MIMO (multiple input, multiple output) antenna arrays and beamforming techniques to overcome high frequency propagation losses.

The proficiency required to design the highly integrated 5G radio technology includes RF, antenna, DSP (Digital Signal Processing), control logic, hardware, and software – as well as a working knowledge of the new standard specifications. 5G system and design engineers need the latest methods to verify that components will work together and eliminate the problems that lead to expensive hardware failures and delays to project run-times.

The engineering organisations that have separate workflows for doing baseband, RF front end, and antenna design will likely struggle to keep pace with their peers. Having an approach that is too siloed with different methodologies and different teams will cause issues further down the line.

For example, achieving power efficiency and linear performance across wide bandwidths in the RF front-end, including power amplifiers is another obstacle that needs to be overcome. This requires adaptive DSP techniques such as DPD (Digital predistortion), which often must be designed and verified in simulation.
before the RF hardware is even available.

With the increased complexity of 5G new radio (NR), development teams are looking to FPGA (field-programmable gate array) prototypes and testbeds to validate their designs. This is a significant hurdle for many teams that lack experience with FPGA development workflows and RTL (register-transfer level) implementation of signal processing and communications algorithms. For a typical R&D group that consists of engineers with strong signal processing and algorithm development backgrounds but relatively little experience with hardware implementation, it is often difficult to implement these radio prototypes and testbeds without outside assistance.

Lastly, the use of mmWave frequencies now make it essential for designers to characterise RF signal propagation channels in various outdoor and indoor scenarios early in the R&D process. While higher frequencies are essential to transmitting information at ultra-fast rates, unfortunately there is an unwanted side-effect that they don’t travel as far and are easily absorbed by the atmosphere, terrain, and other objects. Therefore, 5G radio and network designs need to account for these effects.

All of these technologies that enable 5G to function can drive up the cost of development and create a strong incentive to get the implementation right the first time. To successfully transition from 4G to 5G and create a totally new mobile network that works, it is crucial for designers to utilise tools that enable modelling and simulation of the critical 5GNR technologies and ensure conformance to the standard specification.

Fortunately, there are new tools for 5G engineers that efficiently explore algorithms and architectures, optimise system performance, identify critical problems in simulation, and automate hardware implementation and testing on COTS (Commercial Off-The-Shelf) or custom hardware.

Engineers on all aspects of 5G development will need a means to ensure that their design conforms to the 5G standard. Software that provides 5G-compliant waveforms, algorithms, and end-to-end reference models can simplify the process of design space exploration, design verification, and conformance testing.

**Modelling software**

For engineers designing these new massive MIMO antenna arrays and RF front end architectures, new modelling software can provide multi-domain simulation that permits full-system verification of digital, RF, and antenna design. Previously, these different domains have been designed separately, using different specialist tools for each component, but now they can be planned and simulated in unison, resulting in more precise results and quicker design cycles. This approach is being used successfully by engineers designing various 5G technologies, such as:

- Digital predistortion & CFR (crest factor reduction) algorithms, which require fast simulation of accurate RF models together with compensating DSP algorithms.
- Hybrid beamforming architectures for massive MIMO systems, where the number of digital receiver paths can be limited by partitioning beamforming across analog and digital parts of the system.
- Future antenna architectures where the tightly coupled nature of the system requires antenna, RF and digital ICs to be considered as an integrated system.

What about engineers with limited hardware experience to create and deploy hardware testbeds? Happily, the latest model-based design techniques mean those engineers can take algorithms all the way from concept to 5G testbeds, and then on to production-quality IP implementations for future 5G ASICs (application-specific integrated circuits).

This is particularly suited for prototyping and proof-of-concept projects with tight design schedules. Engineers are no longer dependent on specialised hardware experts or scarce implementation teams. Compared to a traditional process, this approach has several advantages:

- Using a single model for simulation and code generation greatly simplifies the process and eliminates handoffs between system design and implementation teams.
- Models can be interfaced to a range of commercially available RF test and SDR equipment from different vendors. This enables flexible, cost-effective design verification with live RF signals.
- Once the model has been verified, it is ready for FPGA implementation. Iteration cycles for design changes are much shorter, enabling the engineering team to respond quickly to changes in specifications or standards. The generated HDL (hardware description language) code is hardware-independent and can be deployed to COTS and custom testbed hardware.

The fundamental benefit of modelling and simulation is that as the specifications and engineering changes are coming in to the design teams, they are able to iterate on their designs quickly. They’re able to ensure that their designs can support the new changes. And then to validate it, they are able to quickly take the new version of what they are working on and deploy it in a radio test bed.

Overall, modelling tools allow designers to verify their projects using simulation, rather than waiting for expensive and time-consuming lab and field tests. The models can be used as a golden reference for implementation and can help to automate testing in order to verify that designs function correctly throughout the development process.