

A Guide to Developing Innovative 5G and Wi-Fi 6E Radio Services

Steaming Ahead to Bring 5G and Wi-Fi 6E Deployments to Life

5 Mobile RF
Traffic Simulation



Introduction

Dear Reader,

The ubiquity of handsets, mobile devices, and massive machine-type communications (mMTC) with IoT, 5G, and Wi-Fi has naturally led to an array of network configurations, traffic load challenges, and complex propagation environments. Each of these need to be addressed through appropriate testing in order to maintain a high user experience. RF Network Simulators are poised to address this specific challenge through conductive testing and the use of programmable attenuators with switched matrices and/or power splitters/combiners, to connect a multitude of channel inputs to an RF patch panel. Whether the use case involves a static device in relatively constant conditions or, a mobile device in dynamic conditions, RF network simulators can accommodate these varying environments through its inherent reconfigurability.

These qualities are also particularly valuable for handover testing where previous generations of handover test systems will likely not be able to serve the diversity of use cases that come with 5G. Newer generations of handover test systems will be required to support the bandwidth, ranges in signal strength, and responsiveness of all mobile 5G use cases with quality components/subsystems. Moreover, with the inclusion of mMIMO-based gNBs, these test systems must also consider cost and space constraints.

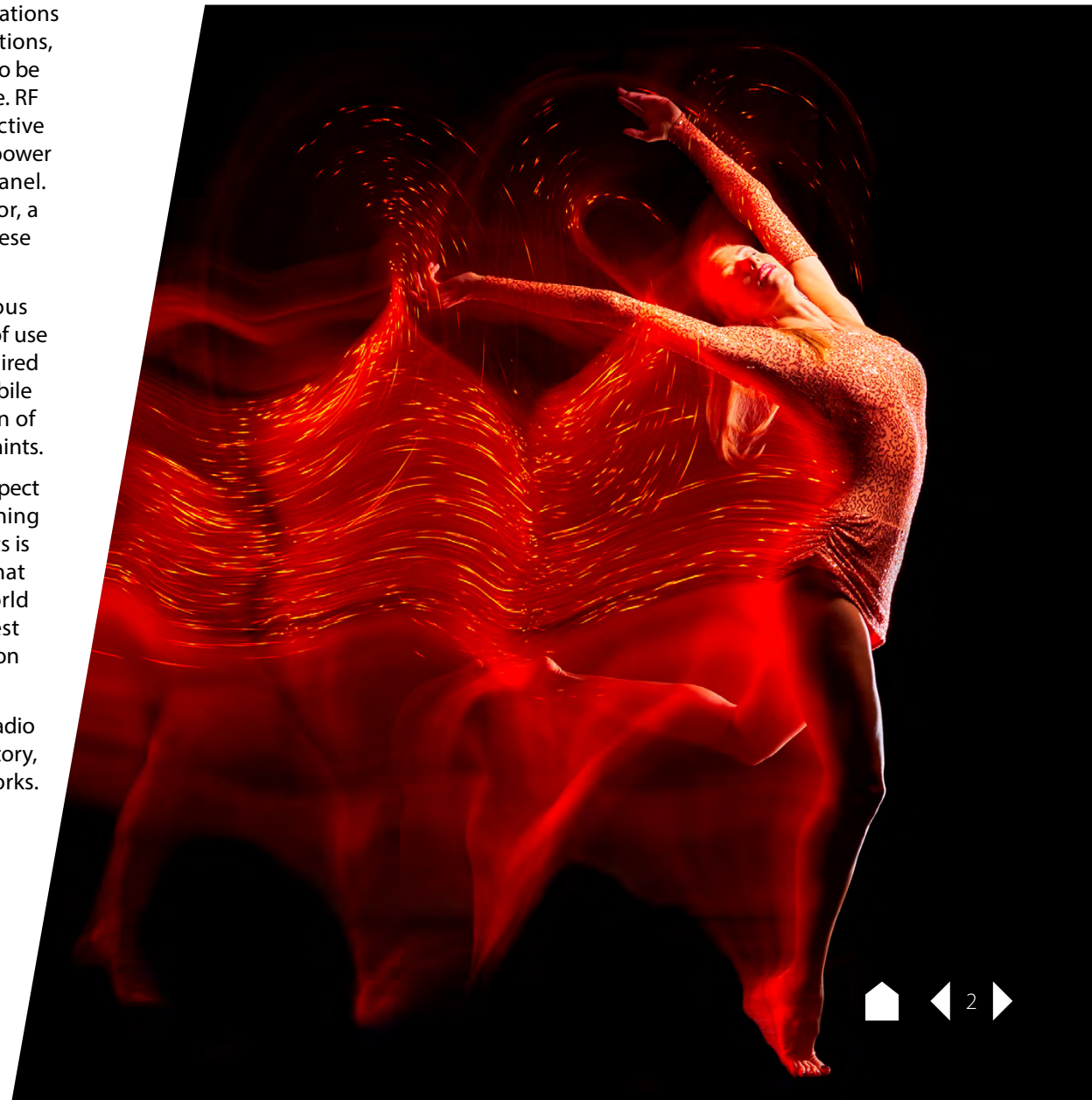
In addition to all this, mesh networking already is, and will continue to be, a critical aspect of communications. This is especially true for up-and-coming vehicle-to-everything (V2X) and critical IoT communications. Reliably simulating real-world environments is cornerstone in V2X testing in order to meet strict compliance and regulation that ensures safety. In order to accomplish reliable and repeatable testing of real-world environments, APITech offers modular and customizable test systems that can test multiple radios simultaneously and perform link simulation analysis with EMI injection and signal strength manipulation.

This final chapter finishes off the “Guide to Developing Innovative 5G and Wi-Fi 6E Radio Services” by discussing advanced testing solutions that meet the changing regulatory, standard-specification, and technology demands of cutting-edge wireless networks.

To dive deeper into RF testing for 5G or Wi-Fi networks, please reach out to me.

David J Swift

Global Director of Telecom Sales, APITech



Where do APITech and 5G / Wi-Fi Meet?

APITech has over 60 years of wireless device and system heritage developed through several business units, which are now joined as one to offer the most comprehensive wireless systems development organization.

APITech has expertise in developing essential wireless communications components, accessories, assemblies/modules, and even entire systems. With the expanding use of wireless communications technology in various applications, operators and wireless systems manufacturers need knowledgeable and skilled engineers able to meet the challenges of the latest wireless communications generations. Wi-Fi 6E and 5G in particular, are presenting a new realm of testing and system design challenges, and APITech is uniquely positioned to help.

Learn more about the evolving landscape of wireless communications in this book, and how APITech can augment your business with design services, wireless hardware, and innovative wireless network testing technology.

1

The global perspective on 5G and Wi-Fi 6E as well as the need for conformance testing.

2

A spectrum innovator's view on how filter technology is critical in mitigating interference for a world with an increasing device density.

3

Mastering the implementation of surface mount resistives in cutting edge wireless networks.

4

Insights on advancements in 5G and Wi-Fi call for cutting-edge test systems and how APITech uniquely serves this niche with conductive testing solutions.

5

Learning how RF network simulators are fundamental to reliably prototyping and validating the varying wireless propagation environments found globally.

The APITech team

APITech Insights – Commercial Wireless

We know the 5G and Wi-Fi 6E spectrum. By leveraging the power of our expertise in component design and manufacture, we can help you prepare for tomorrow's world.



David Swift

A hands-on wireless technology specialist who believes in innovative and disruptive technologies which challenge the status quo, and make a real difference. With over 24 years' experience involved working closely with customers and partners to successfully realise their visions.



John Yania

John has over three decades of experience in filter design for the harsh space environment. Co-founder and VP of FSY Microwave. Educated MSEE, Johns Hopkins University. Product Line Manager expert, responsible for design of Filter Products, RF/Microwave & Microelectronics technologies.



Norm Hansen

Norm is currently the Product Line Director for Passive Coaxial Products with over 30 years of experience in the RF/Microwave Industry including executive leadership roles in business development, sales, and marketing. He supports the wireless connectivity and optical markets.



Egor Alekseev

Egor Alekseev manages Powerfilm products for APITech Inmet, and holds PhD EE from UofM.



Aaron Singer

With over 15 years of experience with a Tier I automotive supplier, Aaron has experience with all levels of product development from concept and design to validation and production.



Nicholas Garneski

Nicholas specialisation is RF/Microwave design, computational electromagnetics modelling, test software and hardware development.



Prakash Hari

Prakash has been awarded 2 technology patents in telecommunications, with over 14 years expertise in the development of RF products, test platforms and managed services for commercial wireless, satellite and defence markets.



Jennifer Harkless

Jennifer is the Product Line Manager for Electro-Magnetic Devices at APITech, Electromagnetic Integrated Solutions Business Unit. She attended the University of Pittsburgh for Engineering and has been a Lean Six Sigma Black Belt for 18 years.



Donald Dilworth

Don is a Product Line Manager with over 37 years of experience helping the top players in wireless telecom industry solve EMI and RFI problems to improve information transfer over their network interconnects for commercial RF systems. He has an engineering degree from Ryerson University in Toronto.

The Role of APITech in 5G and Wi-Fi 6E Testing

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A Brief Introduction to the Types of 5G Testing that can be Accomplished Through APITech

The taxonomy of 5G testing involves many types of user equipment (UE), test parameters, testing attributes, and testing environments in order to properly gauge the radiative performance of these devices. APITech offers testing solutions for a wide array of commercial wireless applications including 5G, Wi-Fi, and IoT device solutions. This section offers a brief introduction to the myriad of test equipment options.

5G Massive MIMO Radio Testing

Massive MIMO enables a large increase in spectral efficiency and more concurrent transmissions within smaller bandwidths by deploying huge amounts of antennas, each with its own transmit and receive chain. The radio testing required of mMIMO involves the use of physically compact and highly customizable assemblies with integrated interconnect to reduce the size and cost of the system due to the high channel count. These testbeds must process data in real-time from hundreds of antenna elements with precise timing synchronization and phase alignment. The ability to custom design 5G waveforms is critical in order to validate real-world propagation environments. APITech offers testing solutions that can do the above for this use case.

Handover Test Solutions

The implementation of both homogenous and heterogenous networks in 5G calls for the use of complex handover test solutions that can properly test according to the wide range of propagation environments and be agile enough to perform emulate a mobile test environment for vehicle-to-everything (V2X) communications. APITech offers handover test platforms that can:

- Accommodate low- and mid-band 5G and Wi-Fi for a true wideband solution
- Offer fine attenuation steps and a broad attenuation range to effectively simulate handoff scenarios
- Include a quick responsiveness and attenuation resolution for a more realistic handoff scenario
- High power handling capability to better emulate the signal strength during experimentation
- Easily controlled with modern interfaces (e.g., Ethernet and USB)
- Full fan-out and bidirectional equipment



A Brief Introduction to the Types of 5G Testing that can be Accomplished Through APITech

Mesh Connectivity Testing

Another aspect of simulating static or dynamic real-world conditions for mesh networks is a conductive interconnect-based multi-user transceiver test unit (MUTTU). These components leverage multiple transceiver units connected via RF power dividers/combiners, switches, and attenuator matrices in order to properly mimic real environments.

APITech's MUTTU can:

- Accomplish multiple radio testing and link simulation analysis
- Inject artificial interfering signals to simulate EMI
- Do simultaneous, multi-channel signal transmission/reception on all RF ports
- Be modular and customizable to meet changing regulatory requirements

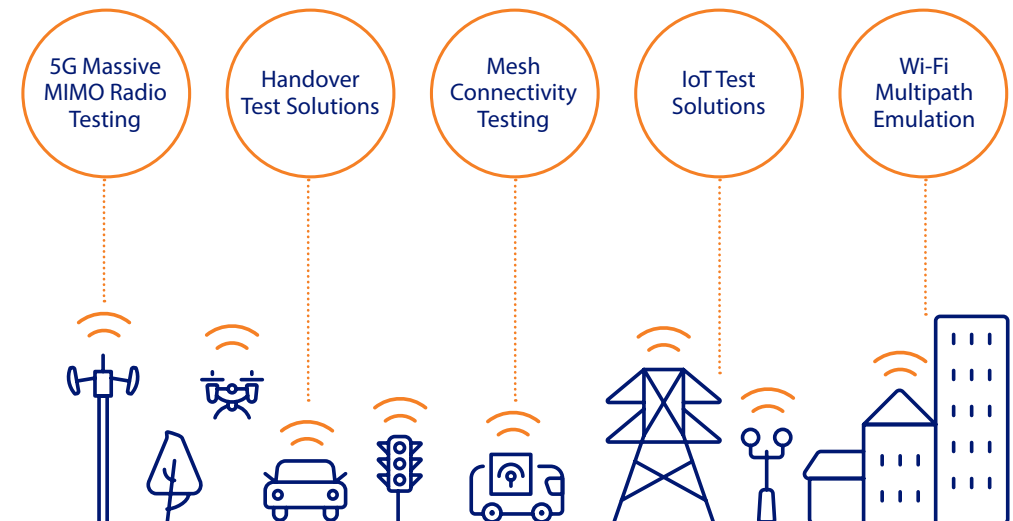
IoT Test Solutions

From basic IoT nodes for home automation and smart city, to hyper-specific sensor nodes for time-sensitive medical wearable and industrial automation, of any wireless device, IoT nodes account for the most device deployments and respective propagation environments. This includes environments in some of the harshest areas where countless signal obstacles exist. While it is becoming more commonplace to verify radiated power and EMC conformance to standards via OTA testing, in critical IoT applications conductive test equipment offer reliability, quality, and speed when it comes to optimizing and ensuring the performance of these systems. APITech offers a number of test platforms that serve this niche.

Wi-Fi Multipath Emulation

Wi-Fi device development will need testing and link simulation platforms that can perform multi-user MIMO simulation for next generation Wi-Fi 6/6E. APITech offers a unified test performance/link simulation solution with several independent channels that can be designated in multiple clusters, can simulate TGN-A/B channel models, and include programmable phase shifting/delay line capability on each channel. This diverges from other platforms that often only have channel attenuation capability, limiting the ability of the equipment to estimate a real-world transmission environment.

APITech's Test Solutions for Commercial Wireless



Simulating Network Traffic Scenarios for 5G Test

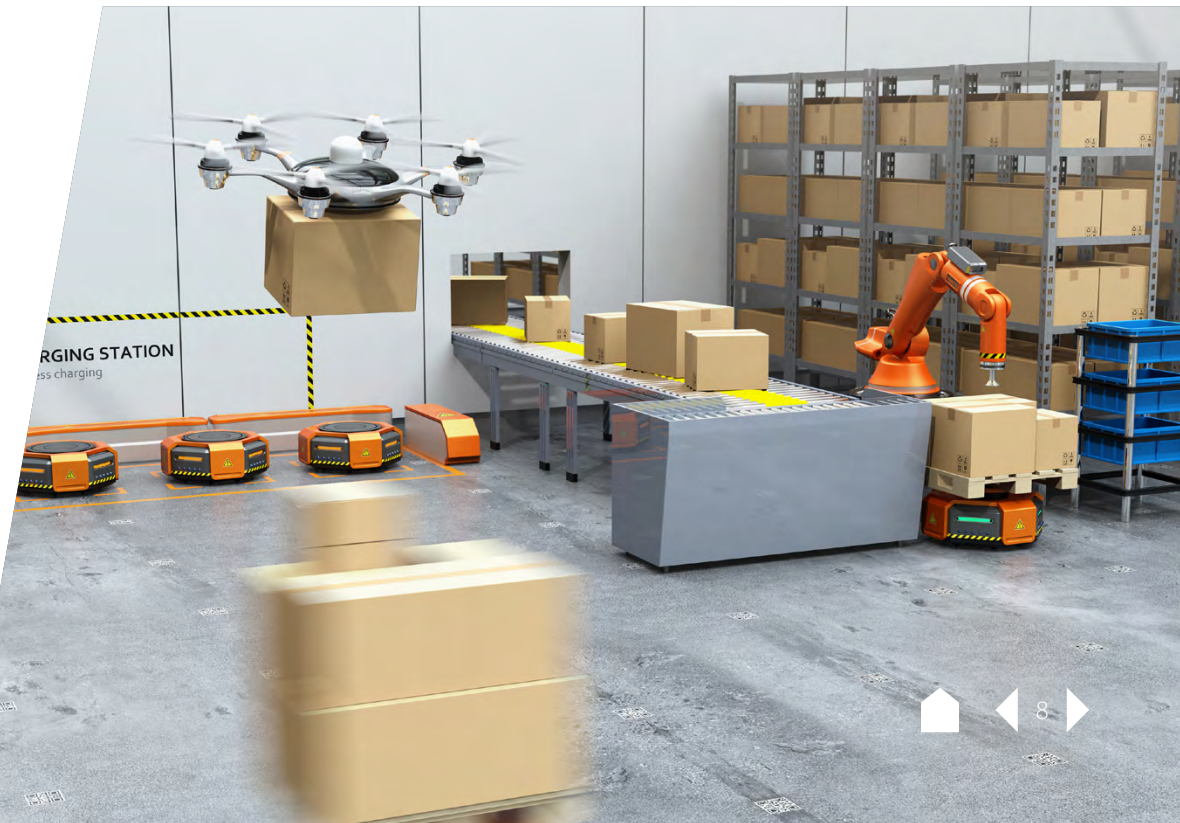
5G networks are becoming increasingly heterogeneous with the inclusion of licensed and unlicensed spectrum, new spectrum regimes (millimeter-wave), as well as integration with other wireless networking technology (Wi-Fi).

The diversity of user equipment (UEs) and complexity of traffic through these new networks places even greater challenges on operators trying to maintain high quality user experience. Additionally, there are now many novel use cases for mobile connectivity and many experts in these new markets are new to developing technology for cellular networks. Mobile traffic simulation is a key tool in hardware verification and conformance testing, be it base station (BTS) hardware or UE hardware.

Typically, inserted between the device under test (DUT) and the RF front-end of the wireless/cellular network radio transceiver, RF Network Simulators offer a solution for mobile traffic simulation. The network simulator individually attenuates the input and output of each DUT. Ethernet and USB control interfaces allow each channel to be attenuated via a software program. Since the system is bidirectional, the use of circulators is avoided.

This system is able to simulate network traffic scenarios as the strength of radio signals naturally attenuates through the atmosphere as a function of distance. Hence, a network simulator can be used to manipulate the external signals to a wireless system to make them appear at a programmed distance away from the simulator without the need for large anechoic chambers or large outdoor test ranges. RF Network Simulators are much like RF handover test systems, with the additional capability to be reconfigured to emulate network dynamics.

Moreover, an RF Network Simulator capable of mobile traffic simulation is also equipped with inputs and outputs that match with required wireless network interfaces. For cellular network simulation, such interfaces include azimuth inputs, remote radio head (RRH) outputs to azimuth, RRH outputs to telecom test interfaces, and telecom test interface inputs.



Realizing Complex Network Configurations

Being able to generate virtual mobile traffic scenarios with modular and reconfigurable hardware enables hardware designers and operators to test and refine 5G and other wireless network hardware in a controlled and consistent environment.

The heart of a RF Network Simulator is an arrangement of programmable attenuators with switch matrices and/or power splitters/combiners to connect the multitude of channels input to the RF patch panel. With a sophisticated enough RF Network Simulator, a more complex mobile traffic simulation can be performed that includes multiple Evolved Node Bs (eNBs), or other wireless network nodes, which allows for a more advanced network scenarios to be simulated.

Network simulators can be made of fixed components with predefined interconnect and structure, or made of modular components with a reconfigurable interconnect and structure. Modular RF Network Simulators uniquely enable users to reconfigure the rack assembly of the simulator for a variety of traffic scenarios. This type of simulators may have external access to the interconnect between the matrix attenuator components, as well as the switches and/or combiners/splitters. Therefore, user reconfiguration of these systems may only require reconnecting the interface patch panel at the front of the unit. In order to realize more complex network configurations, some modular RF Network Simulators may require further reconfiguration of the internal interconnect of the rack unit.

RF Network Simulators can either consist of fixed components with a predefined interconnect/structure or, are modular with reconfigurable interconnect/structure through a set of switches and combiners/splitters.

Accommodating a Specific Use Case with Custom RF Network Simulation Hardware

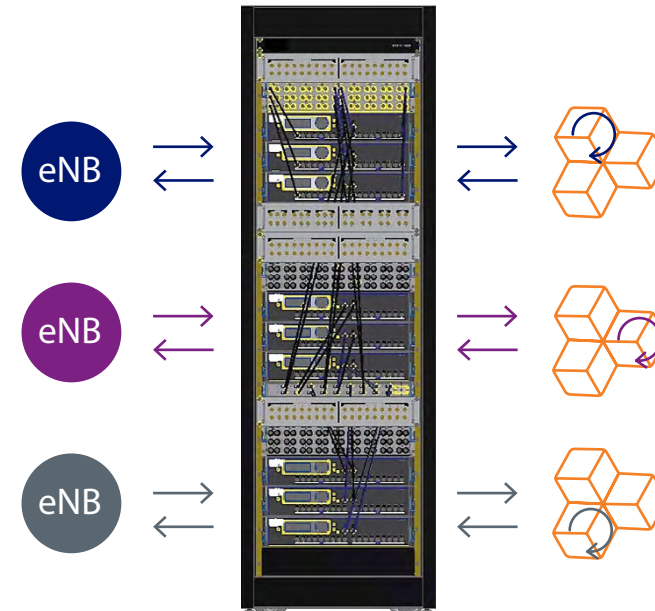
Though reconfigurable or even modular, there are many cases where a network operator or test system developer may need custom RF Network Simulation hardware to best meet the requirements of their application. In such a case, API experts were able to develop a Mobile Traffic Simulator based on a standard programmable attenuator matrix product with select modifications.

These modifications allowed for the programmable attenuator matrices to be configured as nine dual channel programmable attenuator handover units with a unique configuration capable of simulators specific traffic patterns and handover scenarios in a single unit. This unit was further expanded to feature three sectors that could be operated at the same time or separate to emulate three standalone networks.

During the development of this network simulator, the client didn't have all of their requirements firm and the client needed to update their requirements as the situation progressed. Initially, the client only requested modified attenuator matrices. Then the client wanted to combine nine dual channel programmable attenuators units into a single unit. Lastly, the client wanted to extend the system to accommodate three networks, and an entire custom rack system with 18 of the nine dual channel programmable attenuators was developed for this purpose. In this scenario, APITech experts were able to assist the client with spacing the requirements and working with their changing needs, which resulted in a cutting edge Mobile Traffic Simulation System that can readily be reconfigured to meet future traffic and handover test requirements.

APITech was able to design a Mobile Traffic Simulation System for a client based on a standard programmable attenuator matrix product with select modifications to readily simulate specific traffic patterns as well as meet future handover test requirements through reconfigurability.

RF Network Simulator



Seamless Handover is Critical for 5G Effectiveness

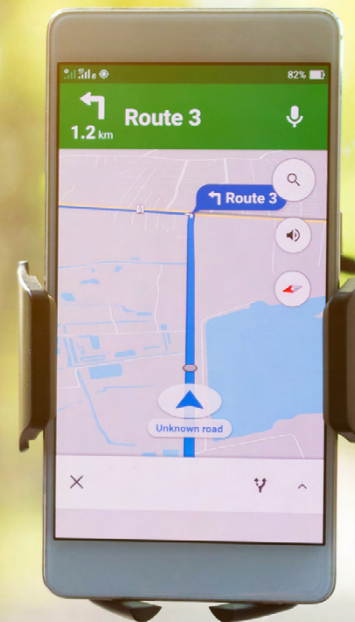
Handover, or handoff, occurs in cellular wireless networks when a data or voice connection is transferred from one cell to another as a mobile user travels through the region between the network coverage areas.

Without robust handover capability in the hardware and base station software, the quality of a mobile user's handover experience is likely to be low. In many cases failed handovers can cause dropped calls or connections, missed data, and possibly more severe failure modes with emerging 5G use cases.

As 5G technology becomes more accessible, mobile users in automobiles, on foot, in low-speed vehicles, and in public transit are assuredly going to use more bandwidth per connection. When autonomous vehicle communication supported by upcoming 5G standards becomes available, these data connections won't only be for mobile handsets, but also for critical autonomous infrastructure for high-speed vehicles. It is also likely that many urban areas will have 5G networks throughout the cities that also support first responders, other critical infrastructure, and technology features to stay competitive with other cities.



It is increasingly likely that Wi-Fi 6E, and possibly other wireless networks, will be integrated as part of the handoff strategy for 5G urban networks.



Handoffs in Homogeneous Networks Versus Heterogeneous Networks

In order to realize these applications, 5G networks will need to be heterogeneous, with a mix of macrocells, microcells, picocells, nanocells, and even femtocells to support the diversity of mobile connection requirements.

Handoffs between homogenous macrocells can be relatively straightforward and relatively simple compared to handoffs with diverse heterogeneous networks with a complex mix of mobile device connection requirements. With homogeneous macrocell handoffs it is likely that the user equipment has time to communicate the mobile network parameters of the device to its base station before the handoff occurs, so that the subsequent base station has time to coordinate and pick up the connection. Heterogeneous networks on the other hand, involve a wide variety of demands and high-speed connection scenarios where the challenge of facilitating a handoff – especially in critical applications with only milliseconds of round trip lag time allowable – is a far greater challenge.

Ultra-low latency 5G starts to enable greater use of robotics, they will be used across a wide range of industries. For example in agriculture using robotic arms for planting, growing and harvesting crops – all controlled from a remote location.

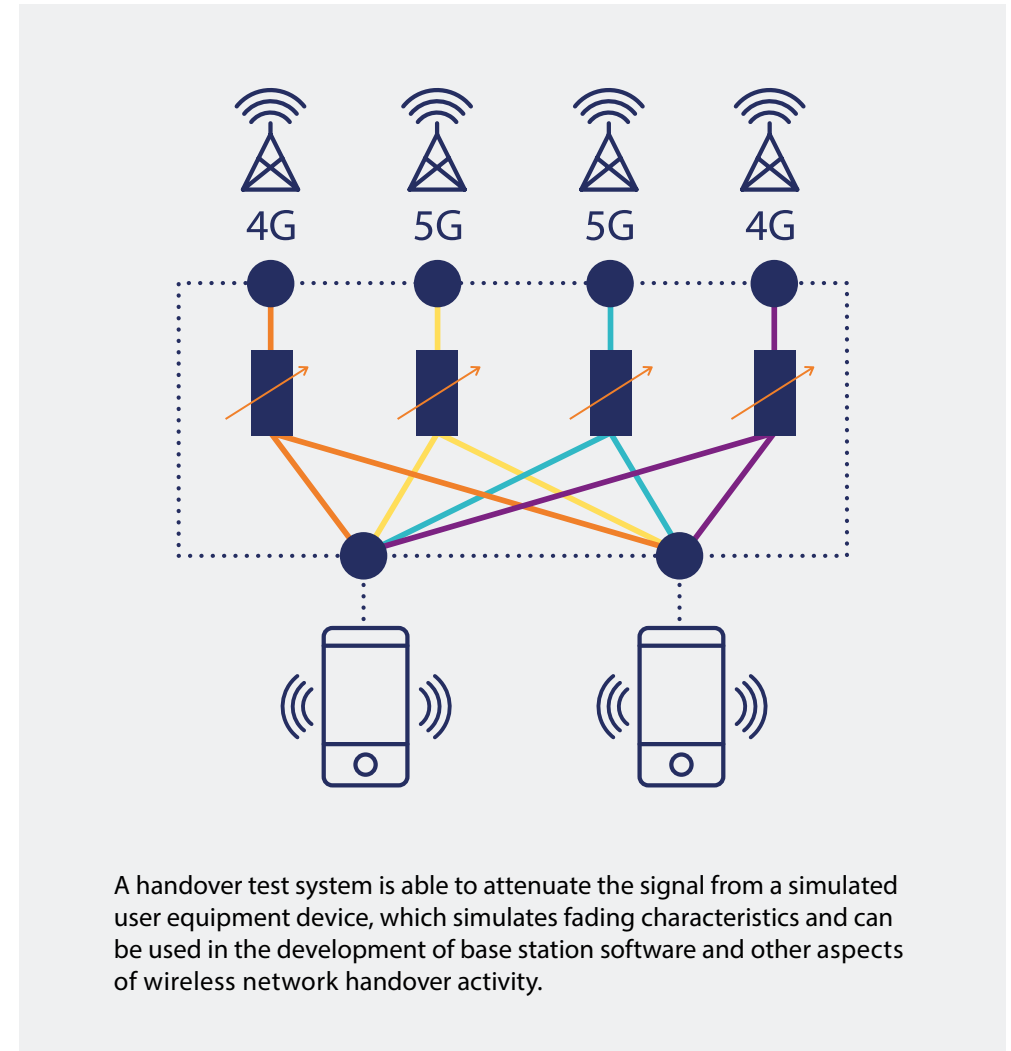


Addressing 5G Network Challenges with Handover Test Systems

Handover test systems are a key element in optimizing base station software and developing mobile technology to best handle the expansive range of scenarios faced by mobile operators.

Optimizing Base Station Software with Handover Test Systems

Handover test systems made for prior generations of mobile wireless will not be able to accommodate the diverse use cases that come with 5G, and also generally don't accommodate the frequencies of the latest standards. Given that wireless carriers are already offloading 5G network traffic to WiFi networks to save bandwidth, it is increasingly likely that Wi-Fi, and possibly other wireless networks, will be integrated as part of the handoff strategy for 5G urban networks. This means that handover test systems for 5G networks will also need to be able to operate with frequencies from the latest Wi-Fi standards, and possibly others.



Addressing 5G Network Challenges with Handover Test Systems

Evolving Handover Test Systems: Key Parameters

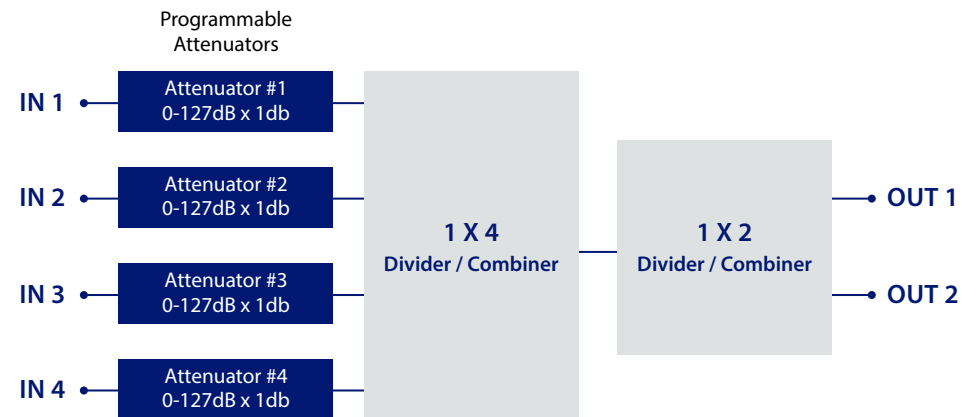
To address these 5G network challenges, handover test systems with greater capability and more convenient features are needed. For instance, just to accommodate the latest 5G low-band and mid-band spectrum, as well as Wi-Fi, a handover test system will need to operate with frequencies in the hundreds of megahertz to over 7125 MHz. True wideband solutions are needed, as banded solutions will introduce complexity and error in a handover test system. The latest multi-input multi-output (MIMO) and beamforming antenna arrays can also be extremely large, with as many as 128 elements. Hence, having a handover test system featuring a mechanically compact assembly with integrated interconnect can result in substantially reduced size and cost of a high channel handover test system.

Moreover, 5G handover test systems will also need to offer very fine attenuation steps and broad attenuation ranges to effectively simulate handoff scenarios likely with heterogeneous networks. 5G handover test systems also need to exhibit extremely fast switching, magnitudes faster than effects of high-speed mobile user equipment moving between cells. The speed and attenuation resolution of a handover test system directly impacts the capabilities of the base station software developed from using the handover test system. A higher performance handover test system enables the development of base station software that has been tested against much more realistic virtual mobility handoff scenarios, which performs better in actual deployments.

Teaching 5G & WiFi 6E testing new tricks. Conductive testing is as much about testing radios as the devices or network elements themselves.

Evolving Handover Test Systems: More Key Parameters

Another key parameter of 5G handover test systems is high power handling. The power handling capability of a handover test system dictates the maximum “range” and strength of signal that can be experimented with, which could directly lead to a limitation in the base station software if the base station hardware is more capable than the handover test system. It is also useful for handover test systems to be easily controlled with modern interfaces, such as Ethernet and USB. The most capable handover test systems are also full fan-out and bi-directional, which means that each RF path between the input and output is non-blocking and signals can travel in both directions. Handover test systems that have limited fanout and are unidirectional can still be useful, but are less capable to simulate the full range of scenarios that full fan-out and bidirectional handover test systems can.



Full fan-out, bidirectional handover test system is capable of presenting each input to each output simultaneously in both the forward and reverse directions, while a limited fan-out, unidirectional handover test system can only present an input at each specific output one-at-a-time and only in the forward direction.

Converging Automotive Connectivity with Information Technology

The convergence of automotive connectivity and information technology (IT) is now upon us.

Beyond safety beacons and cellular-based Wi-Fi hotspots, automotive communications are emerging as a variety of compelling use cases enabled by 5G. Vehicle-to-everything (V2X) communications is a super category of new vehicle communication technologies. V2X is just one subset of the three main and immediate 5G use cases, ultra-reliable low latency communications (URLLC), but also one of the most compelling.

V2X represents the latest in vehicle-to-network (V2N), vehicle-to-infrastructure (V2I), vehicle-to-vehicle (V2V), vehicle-to-cloud (V2C), vehicle-to-pedestrian (V2P), vehicle-to-device (V2D), and vehicle-to-grid (V2G) systems. These V2X technologies are being developed to provide the backbone to autonomous vehicle systems, enhanced user communications experience on-the-go, and to provide safer and more efficient automotive operation.

Bringing Intelligence to the Edge with V2X Communications

Current self-driving technology relies on a suite of advanced positioning and sensing systems that use machine learning/artificial intelligence (ML/AI) algorithms to interpret the complex flood of data coming from the sensors. With V2X technology augmenting internal self-driving algorithms, a vehicle's ML/AI can make use of sensory input and determinations of other vehicles on the road, nearby pedestrians, and nearby vehicle infrastructure. In this way, autonomous driving can be made safer and more efficient. For instance, vehicle support infrastructure, such as parking or charging station availability, can be updated in real-time and with high accuracy. Moreover, the drudgery of commuting and finding parking/charging stations can be curtailed by new entertainment options while enhancing pedestrian safety and reducing traffic congestion with V2X technology in development.



In the connected mobility system of the future, vehicles communicate with the world around them.

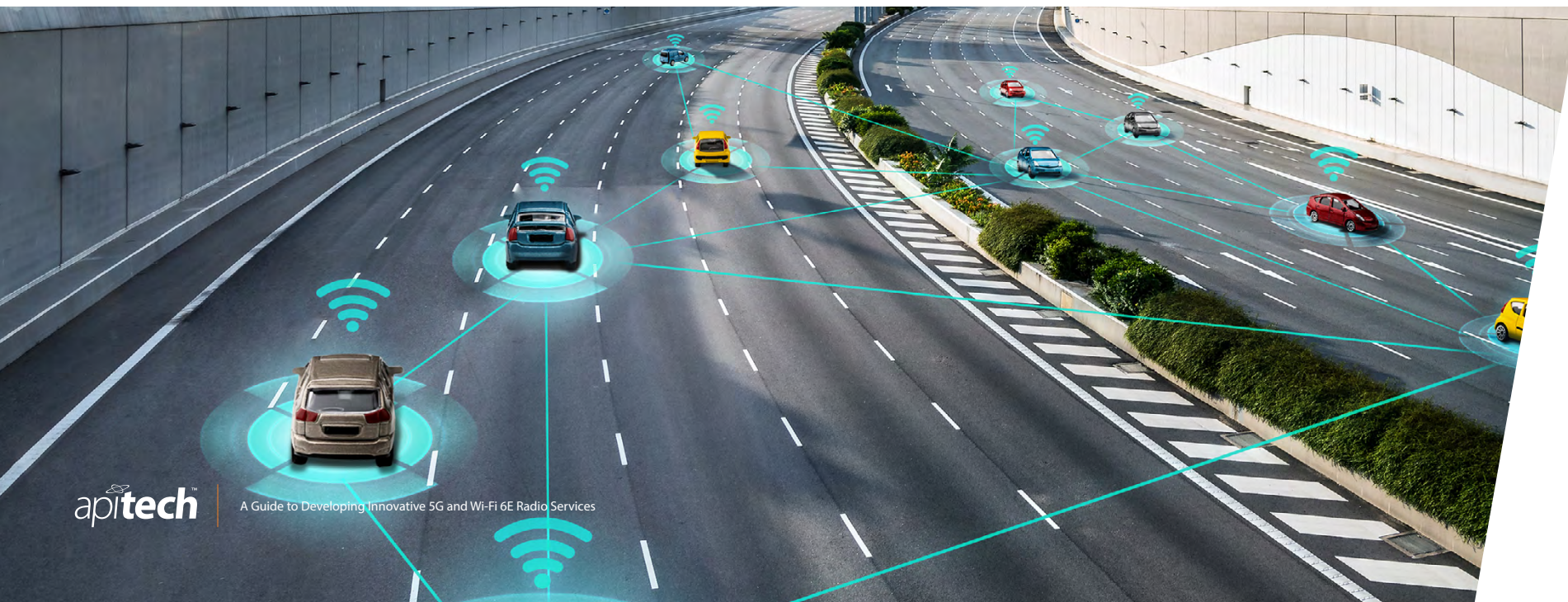
The Web of Support Technologies for V2X Communications

V2X technologies are not a static solution composed of a single communications technology, but a web of supporting technologies both inside an automobile and outside. Given the high rate of mobility of automotive vehicles, typical cellular or star node networking typologies are unlikely to be viable for all V2X applications. Hence, V2X communications technologies are also being developed that support true mesh networking, where every node in a network is able to intercommunicate and send/receive data from other nodes that are outside of their immediate communications range. A Mesh networking capable V2X backbone with the latest mesh networking features will be able to self-heal and assemble as needed and on-the-fly. This allows for V2X networks that expand as needed and can adapt to varying environments and network conditions without substantial computational overhead of a centralized network base station or gateway.

Realizing V2X Communications with Reliable Testing Solutions

In order to realize such a complex and infinitely variable heterogenous V2X communications network, vehicle communications device designers and vehicle infrastructure/network operators need to use testing strategies that can simulate static or dynamic real-world conditions. A major challenge in performing these simulation test scenarios is maintaining a high level of accuracy and repeatability. It is possible that a design team or operator may need to go through many iterations of various simulations to optimize the hardware, software, and network design to ensure reliability and safety while minimizing latency.

The drudgery of commuting and finding parking/charging stations can be curtailed by new entertainment options while enhancing pedestrian safety and reducing traffic congestion with V2X technology in development.



Testing Mesh Networks with a Multi-User Transceiver Test Unit (MUTTU)

A key component to implementing simulated test scenarios for mesh networks, and other wireless network technologies, is a conductive interconnect-based multi-user transceiver test unit (MUTTU).

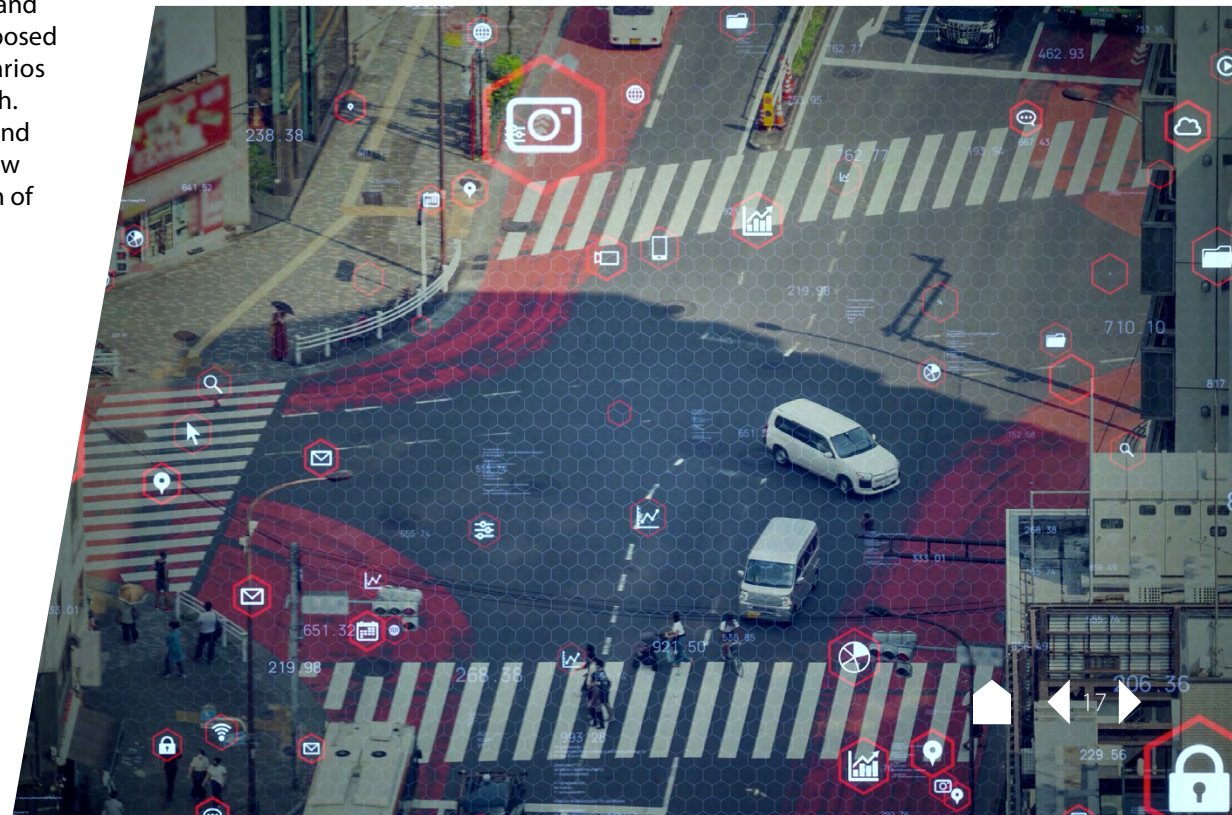
For V2X applications, these units should be able to provide multiple radio testing and link simulation analysis in a compact and high performance unit. An additional advantage for a MUTTU for V2X is the ability to inject interfering signals to mimic real-world scenarios where electromagnetic interference (EMI) from natural, man-made, or intentional sources is all too real a likelihood.

Such a MUTTU should also be able to feature simultaneous, multi-channel signal transmission and reception on all RF ports to provide the highest level of flexibility and simulation of the most complex network configurations. V2X networks will be composed of many users, so a high user count MUTTU will be useful in simulating test scenarios with users beyond what a device, software, or network is likely to have to deal with. Modularity and customizability are also essential aspects to MUTTUs, as standards and other supporting technologies may be changed or modified to accommodate new legislation, compliance with evolving standards, or to facilitate the latest generation of V2X technology features in order to stay competitive.

General Motors plans to launch vehicles capable of 5G connectivity for Chinese Consumers. This upgrade will provide faster connection for remote, or over-the-air, updates as well as communications with other connected vehicles and infrastructure*.

*Source: Julian Blissett, GM Executive 'Tech Day for China' on August 19, 2020.

MUTTUs are typically composed of multiple transceiver units connected via RF power divider/combiner, switch, and attenuator matrix modules. More integrated and higher performance RF modules enable greater levels of accuracy in the simulations and better prepare V2X mesh networking technology to operate in real-world conditions. A part of that is using RF attenuator modules with high dynamic range that also minimize degradation factors, such as signal "sneak path" effects caused by unwanted leakage characteristics. Interfacing with MUTTUs should also be straightforward and capable with a variety of industry standard and customizable interfaces, such as Ethernet, USB, and serial control interfaces. Being able to design and control the test units with common software, such as with a LabView-based graphics user interface (GUI) or custom control software, is also a benefit in making MUTTUs with the greatest utility.

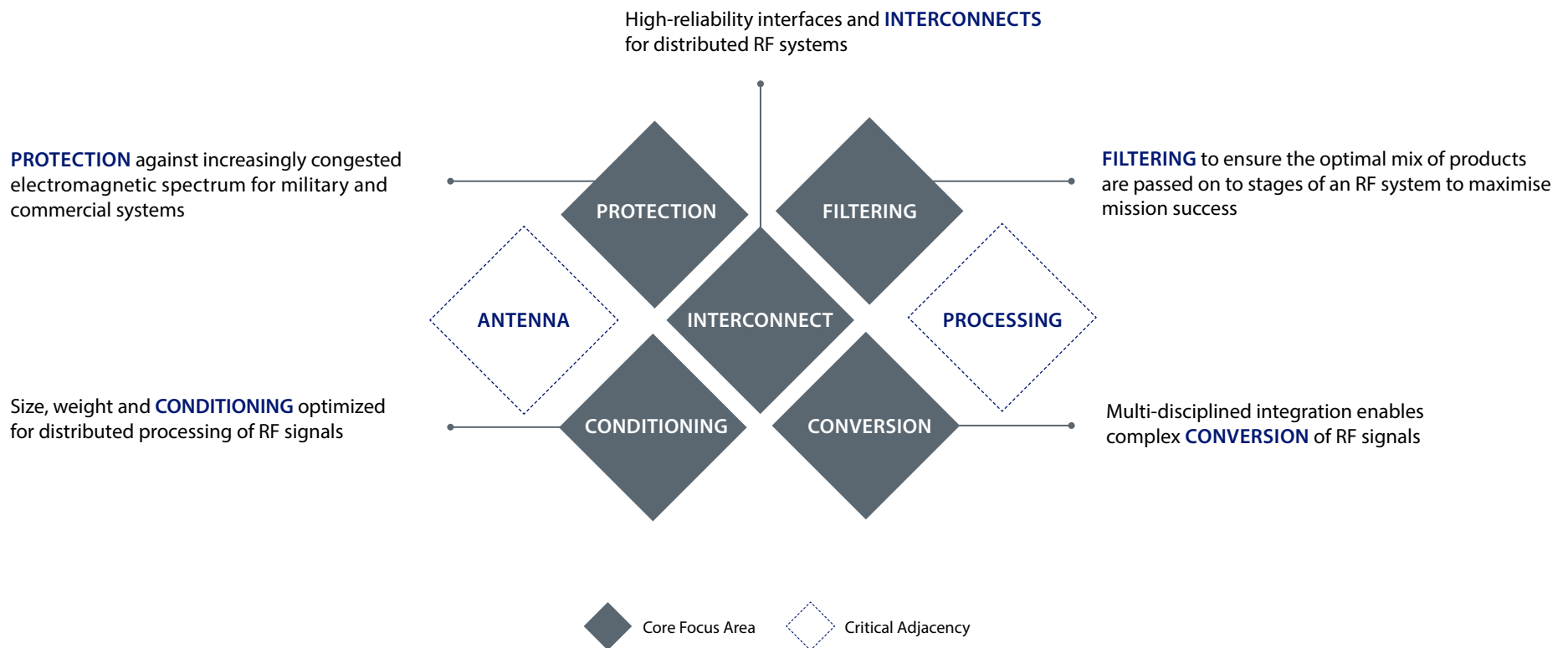


How Can We Help You Conquer Your Commercial Wireless Strategy?

Making the most of RF technology is at the heart of this telecommunications revolution.

RF hardware and test systems are the keystone in bringing 5G to the masses and realizing new mobile wireless use cases. The competitive and fast pace landscape of mobile wireless is now expanding into new spectrum and technology developers are now facing previously unforeseen design, testing, and deployment challenges.

As shown in the defense block diagram below, APITech provides solutions in five core focus areas. From basic passive and active RF components, to integrated microwave and multifunction assemblies. APITech brings its unique legacy and multi-disciplinary expertise to modern wireless systems – allowing for support at every stage of product development and telecommunications deployment.



How Can We Help You Conquer Your Commercial Wireless Strategy?

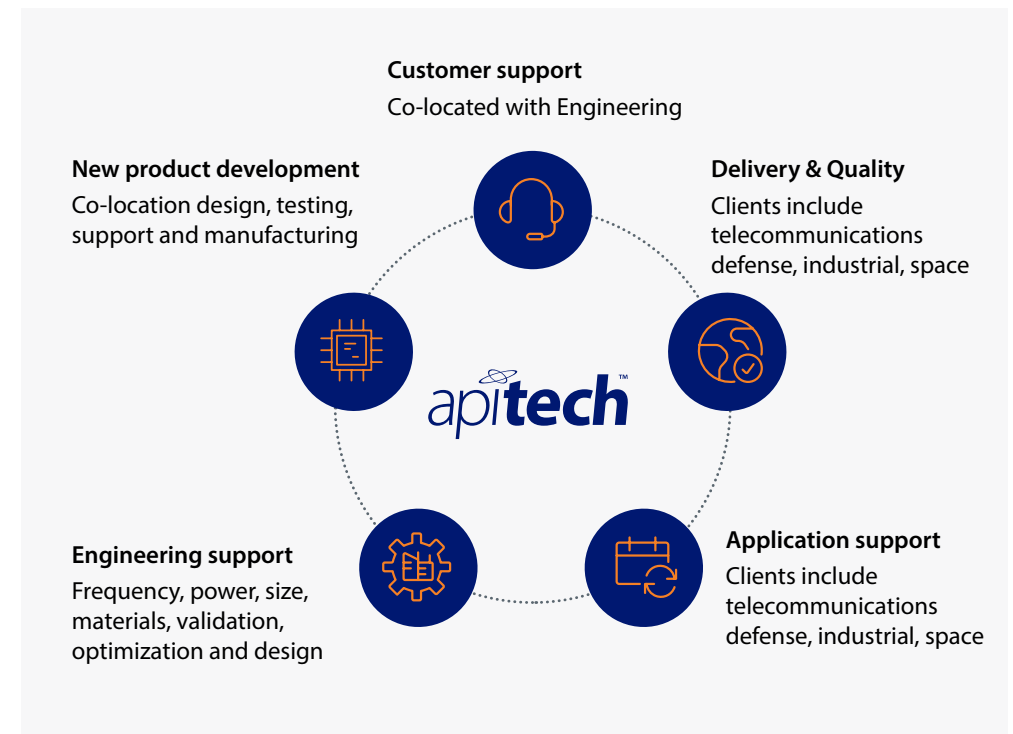
APITech can help 5G and Wi-Fi device manufacturers and telecommunications operators overcome these challenges and unleash a new paradigm of connectivity with a unique three stage approach:

- **Design Thinking Workshop**
- **Hackathon Prototype Strategy**
- **Product Fabrication Services For Full Commercial Rollout**

This approach leverages APITech's proprietary design thinking frameworks to discover insights and implications of a client's challenges. This strategy also benefits from APITech's design scenario driven style that takes into account the changing dynamics across industries and delivers new opportunities for key industries. APITech facilitates this process by engaging in dialogue and generating strategic options to bring 5G and Wi-Fi solutions to life.

APITech is here for you at every stage of product development and telecommunications deployment.

Contact APITech to learn more about our offerings for 5G and Wi-Fi technology. From passive components to EMI filtering and RF conductive test solutions, we cover the increasing RF power, frequency, and bandwidth constraints in next generation wireless protocols.



Contact us

Please get in touch if you would like to talk to us about anything related to 5G & Wi-Fi spectrum innovation.

David Swift
Global Director of Telecom Sales

Commercialwireless@APITech.com



www.apitech.com

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