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

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

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




Introduction

Dear Reader,

Both 5G and Wi-Fi provide the basis for an essential network to service the multitude of connections developing around the globe. Operating in both licensed and unlicensed blocks of spectrum, both these rapidly evolving standards have highly specific tests and test set-ups with stringent tolerances on test parameters in order to ensure ideal performance under various conditions as well as to verify that these devices are not operating at high enough power levels to interfere with other devices. This can be seen with the Wi-Fi 6E device power classes where standard power (SP) access points (AP) have to operate under a automated frequency coordination (AFC) system that assigns a lists of frequency to the AP based for safe operation without interfering/interference. Moreover, as IoT continues to encompass industries and applications, the need to reliably and repeatably test the low-latency, critical communications found in grid, industrial automation, public safety, and healthcare applications is increasingly important.

The 5G and Wi-Fi design and test challenges for commercial wireless manufacturers are as follows:

- **Successful conformance testing**
- **Ensuring network features perform as design**
- **Optimizing MIMO and beamforming performance**
- **Integrating IoT as a standard network add-on**
- **Guarantee device feature compatibility**
- **Certify against standards (3GPP, Wi-Fi Alliance, etc)**

While over-the-air (OTA) testing cannot be ignored for 5G in order to test specific radiative performance parameters and conformance of radio hardware/antenna array. Conductive RF testing is also necessary to accurately characterize chipset performance and for the development of software and system protocols by:

- **Simulating real-world conditions in a controlled fashion**
- **Providing control for phase (delay), attenuation, and multiplexed interconnect that can be used to simulate every type of network configuration (e.g., star, mesh)**

This ebook discusses the backdrop of connectivity between 5G and Wi-Fi networks and how specific advancements such as MU-MIMO call for cutting-edge testing solutions. APITech offers key components for test set ups such as RF Transceiver Test Systems and RF Network Simulators with programmable attenuator matrices, butler (phase shifter) matrices, power splitters/combiners, RF switches/relays, and control modules. These conductive test solutions allow for reliable and repeatable with accurate test simulators.

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.

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

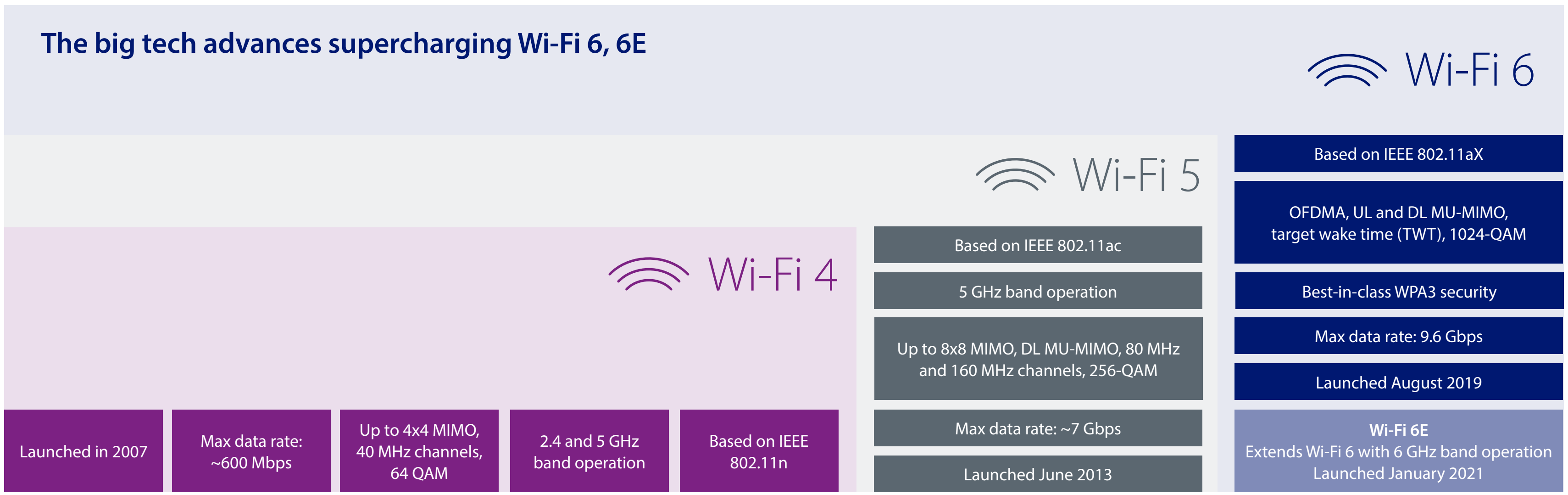
Don is a Product Line Manager with over 37 years of experience helping the top players in wireless telecom industry solve EMI and RFI problems to improve information transfer over their network interconnects for commercial RF systems. He has an engineering degree from Ryerson University in Toronto.

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

How 5G and Wi-Fi Provide Essential Connectivity

Billions of wirelessly connected devices are likely to be used in the next several years in virtually all applications from consumer to military and scientific research.

In order to connect all of these devices to the internet, extremely capable, flexible, and ubiquitous wireless networking technology is essential. This is where 5G and Wi-Fi step in. 5G cellular networking technology will be key in connecting diverse wireless devices over relatively long distances, at speeds automobiles travel on the interstate. The main purpose of 5G will be to connect devices over dedicated and licensed spectrum. Wi-Fi, on the other hand, operates in unlicensed spectrum and allows users, businesses, and even municipalities to provide wireless connectivity to a huge host of devices. Importantly, Wi-Fi provides some redundancy for 5G and the ability for 5G to offload traffic to Wi-Fi when congestion is high, so that wireless users can experience seamless connectivity.



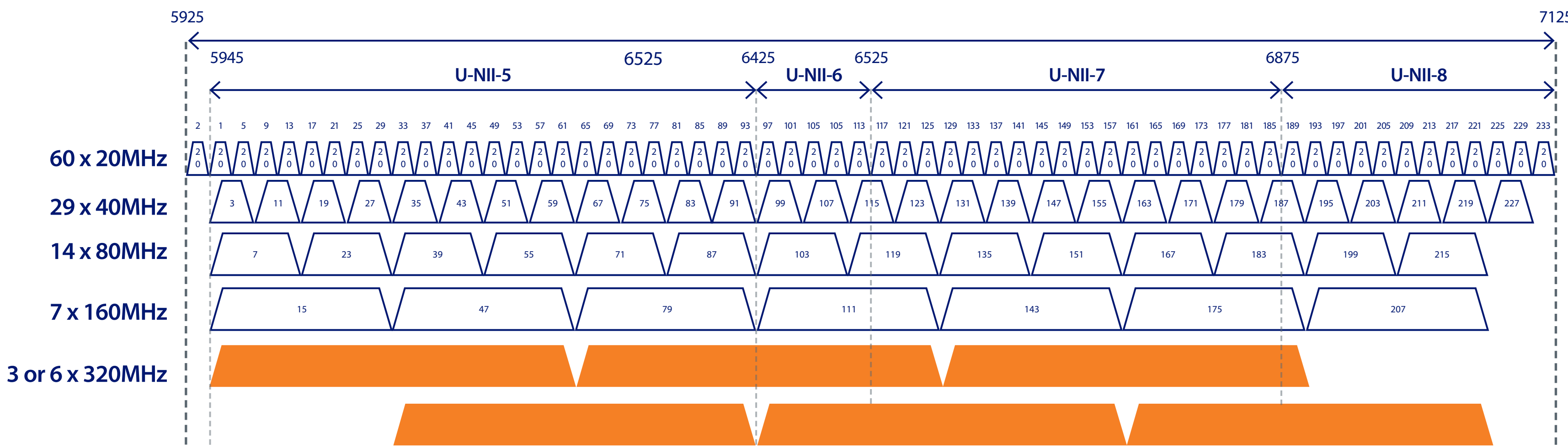
A Dive into Wi-Fi 6/6E

The latest version of Wi-Fi is Wi-Fi 6, which provides some substantial upgrades over previous generations of Wi-Fi, like channels as wide as 160 MHz, orthogonal frequency division multiple access (OFDMA), up to 1024 quadrature amplitude modulation (1024-QAM), and transmit beamforming.

Additionally, target wake time (TWT) functionality was added to Wi-Fi 6 to better support Wi-Fi devices operating on battery power. New WPA3 security is also a part of Wi-Fi 6, enabling more enhanced authentication and security protections and better network performance for wireless devices in commercial, industrial, and mass transit scenarios. Wi-Fi 6 also offers a host of other features, including Overlapping Basic Service Sets (OBSS) which enables a Wi-Fi client device to be better categorized and allows for internetwork communication that limits competition over Wi-Fi channels. This results in less latency and more stable communications than prior methods of handling congestion in crowded spaces.

In Q2 of 2020 the Federal Communications Commission (FCC) opened up new unlicensed spectrum in the 6 GHz band (1,200 MHz of new spectrum). Wi-Fi 6 extended (Wi-Fi 6E) is an upgrade of standard Wi-Fi 6 that includes the 6 GHz spectrum with either fourteen, 80 MHz wide channels or seven, 160 MHz wide channels. Since the 6 GHz spectrum has just been made unlicensed, this spectrum is relatively sparsely used, but the standards authors and device makers are preparing for that to only be a temporary reality. Unlike previous Wi-Fi generations, Wi-Fi 6E is also designed so that the 2.4 GHz, 5 GHz, and 6 GHz can be used in tandem to yield a maximum data rate of 9.6 gigabits per second (Gbps).

There are serious concerns of aggregate interference from Wi-Fi access points with the current microwave backhaul infrastructure and other devices that use this previously licensed 6 GHz spectrum. Standards around the Equivalent Isotropically Radiated Power (EIRP) of devices operating within this spectrum have been put in place as safeguards where there are different classes of access points (APs) for unlicensed operations. These classes include low-power indoor (LPI) APs, very low power (VLP) APs and standard-power (SP) APs that use an automated frequency coordination (AFC) system to automatically determine and provides a list of frequencies which are available for use in the 5.925 to 6.425 GHz and 6.525 and 6.875 GHz bands.



As the number of channels available to devices grows with the 6 GHz band, there will be opportunities to make trade-offs between higher speeds and higher device counts.

Unleashing MU-MIMO for Wi-Fi 6

One of the most significant upgrades of Wi-Fi 6 over Wi-Fi 5 is the unleashing of multi-user multi-input multi-output (MU-MIMO) technology with up to eight spatial streams (8x8 MIMO). This technology uses the multiple signal paths in an environment, as well as complex antenna arrays and MIMO processors, to operate multiple spatial streams as separate data paths. Effectively, MIMO increases the amount of data channels that can be used, adding additional throughput potential with each channel. Multi-user MIMO technology is able to offer enhanced throughput to a larger number of devices concurrently, without having to prioritize or swap throughput between devices.

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Due to the new Wi-Fi 6E features and capabilities, device manufacturers are aggressively moving forward with new Wi-Fi 6E devices; consumer routers, phones, and enterprise access points will soon be released that support the new Wi-Fi 6E spectrum and features. These new devices require a new breed of Wi-Fi test equipment to verify the operation and performance of these devices according to the latest compliance standards. Wi-Fi 6E chipsets require verification and performance testing under conditions that most accurately simulate the real-world, which is best done in conductive test environments to ensure reliability, repeatability, and accuracy.

4x Greater Scalability

OFDMA enables managed, reliable, efficient connectivity across more devices. This means plenty of headroom for future growth or fewer APs required to support existing devices.

Reduced Interference

OBSS enhancements help routers and devices identify local traffic and tune out noise from other networks.

Improved Security

Wi-Fi 6 uses new WPA3 security features, enabling next-generation authentication and best-in-class encryption.

3X Faster Performance

1024 QAM and support for optional 160 MHz channels enable clients and routers to deliver best-in-class Gigabit speeds for the office or home.

75% Lower Latency Responsiveness

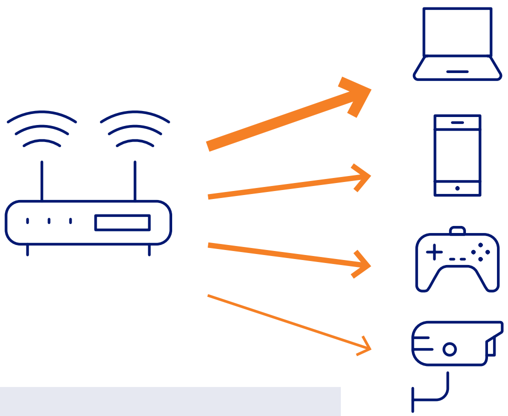
Wi-Fi 6 helps slash lag times to give you the edge you need to win with OFDMA data management and OBSS interference avoidance features.

Increasingly stringent usage (e.g., industrial IoT, AR/VR, robotics, cloud gaming) requirements demand continued evolution.

Unleashing MU-MIMO – The Requirements for RF Multipath Test Simulators

Wi-Fi device developers need Wi-Fi 6E testing and link simulation technology that is also able to perform MU-MIMO simulation test scenarios. Using different systems to test performance /link simulation and MU-MIMO separately will likely yield simulation results that are more difficult to compare and will generate less actionable data. Wi-Fi 6E routers, access points, and client devices will all need the most optimal test and simulation systems to handle the explosion of devices soon to hit public spaces and industrial complexes. All of this, while offering the best performance in the highly competitive Wi-Fi ecosystem.

Wi-Fi 6E test and link simulators are an answer to this requirement, but there are a few key factors to keep in mind when looking into this technology. Wi-Fi 6E systems require a wide frequency range of test and simulation, from about 2 GHz to 7.25 GHz to cover the 2.4 GHz, 5 GHz, and 6 GHz Wi-Fi spectrum.

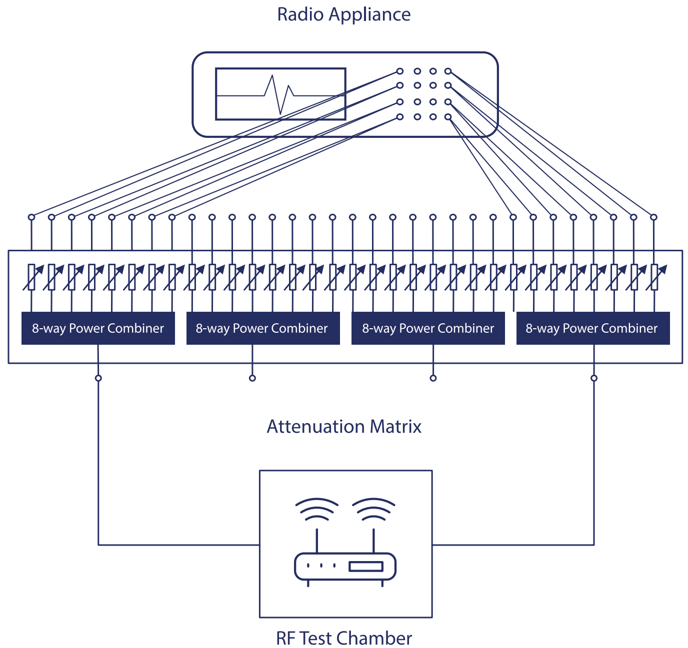


Challenge

Emulate up to 16 Wi-Fi (802.11ax) clients to connect conductively with a Wireless Access Point for MIMO throughput Testing

These devices also need to have several independent channels that can be designated in multiple clusters. Wi-Fi 6E simulators should also be able to simulate TGn-A/B Channel Models and also offer programmable phase shifting/delay line capability on each channel. Without the phase shifting/delay line capability, only channel attenuation is possible. This limits the "real-world" accuracy of a simulation and the resulting capability of the Wi-Fi 6E devices being developed.

Lastly, Wi-Fi 6E simulators need to be deployed rapidly as an out-of-the-box solution to meet present demand for these testers, but also allow for modification of the cluster spacing to best fit Wi-Fi device developer requirements.



Solution

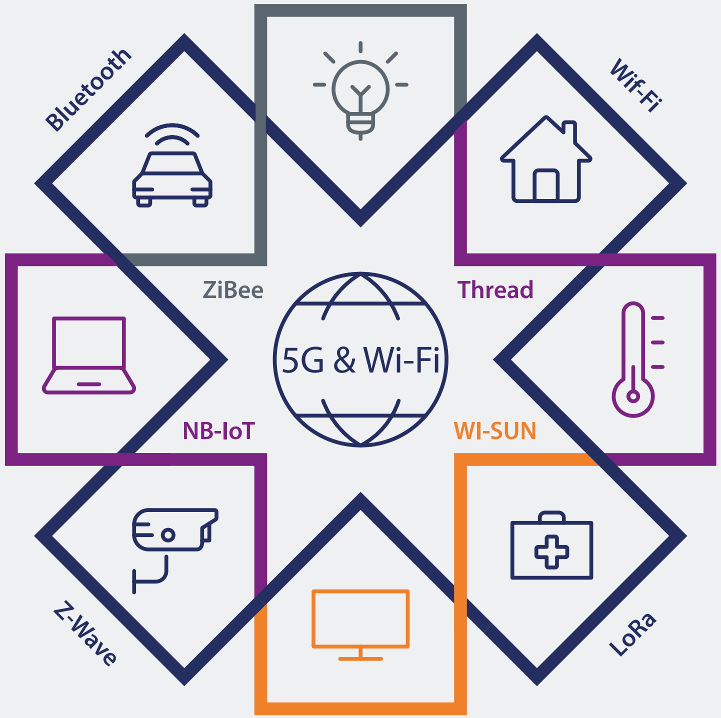
- Quad 1x8 Programmable Attn Matrix
- Wide-frequency range – 2 to 8 GHz
- Fine resolution for attenuation (63dB in 0.5 dB steps)

The IoT Sprint to Connecting Everything

The adoption of wirelessly connected devices and wireless networking is continuing to increase as wireless standards and technology is being developed for a greater range of applications and use cases.

The latest arena where the internet of things (IoT) is entering is in industrial applications, including medical facilities. Industrial automation and control applications, as well as electric grid implementations have always relied on a diverse range of sensors and communication protocols, but are now being augmented with wireless networking to realize higher regimes of connectivity, lower latencies, and the connection of a huge number of devices. This new use case, a key pillar of 5G, is massive machine type communications (mMTC), where multitudes of sensors, actuators, controllers, edge-compute nodes, and wireless communication devices are connected via gateways to the internet or intranets.

This burgeoning expansion of wireless devices is impacting land, air, and even sea industries, from agriculture to marine fleet management and logistics. 5G and Wi-Fi have been and likely will continue to be the main wireless networking technologies used for these new applications, especially considering the 5G standards development efforts in this direction and the ubiquity of Wi-Fi. Given the diverse requirements for these applications, these standards are being developed to be flexible and adaptable to a wide range of wireless and networking parameters.



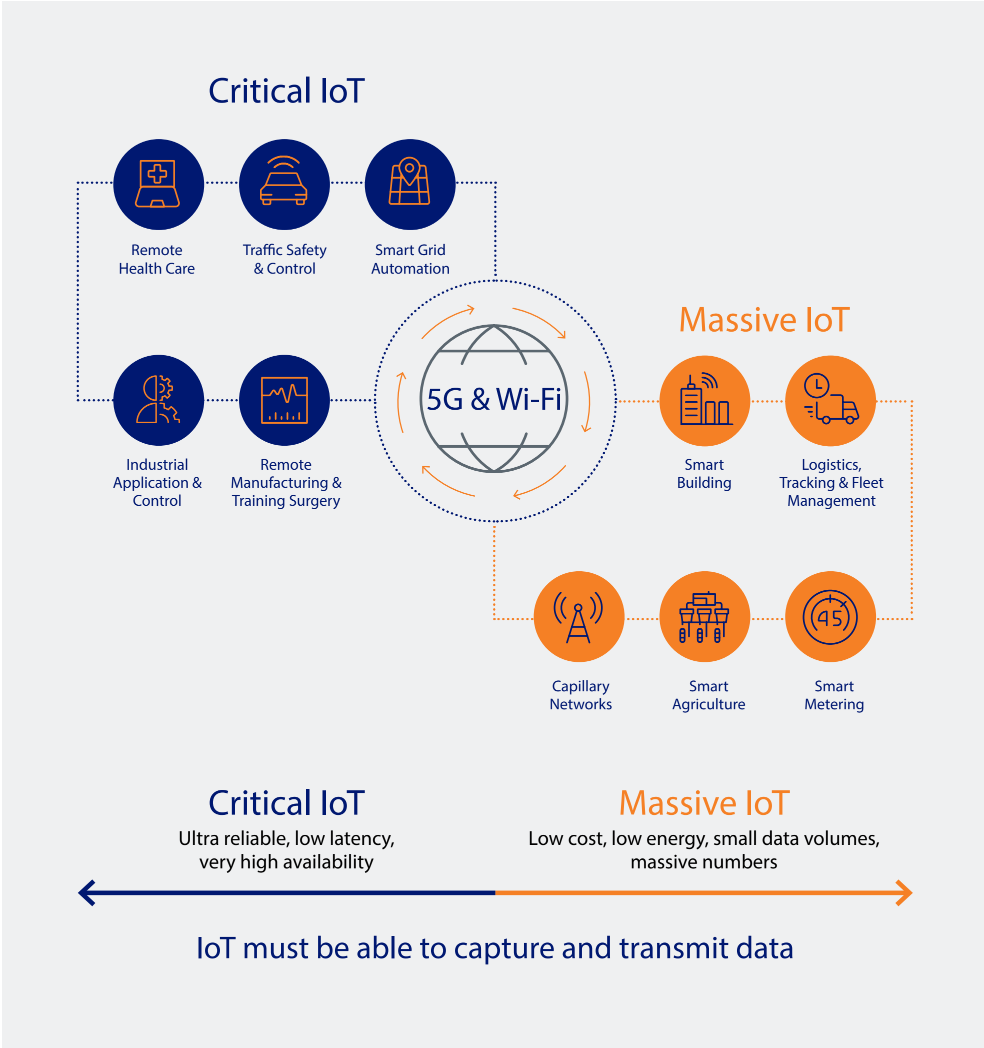
Test Considerations Around Massive IoT and Critical IoT

Two super-categories of these requirements are referred to as Massive IoT and Critical IoT. With Massive IoT, the main considerations are being able to efficiently and economically maintain low volume/transient data traffic amongst a massive number of devices in a point-to-multipoint, star or mesh topology.

Critical IoT on the other hand, relies on high availability communications that experience extremely low latency and high reliability connections. Critical IoT may communicate with a wide area network (WAN), a local area network (LAN), within/between cells via a specific IoT protocol, or via a direct connection between devices.

Both types of IoT use cases – which may even need to coexist on the same network – pose design and deployment challenges more complex and difficult than previous wireless networking technology. This is especially true considering these networks are becoming increasingly heterogeneous. Moreover, these networks are being deployed in harsh environments with innumerable obstacles and RF interference generators. Being able to perform high quality testing that is fast, consistent, and economical is of the utmost importance when designing, optimizing, and verifying hardware and software for these networks.

Designing these new wireless networks to be able to operate while facing interference is also a huge priority, but is also very challenging in over-the-air (OTA) testing environments. Traditionally, conductive testing using transmission lines and wireline interconnect has been the gold standards for quality and speed for optimizing and verifying wireless network hardware and software. Given the massive numbers and new requirements of IoT applications, many standards have turned to OTA testing for conformance, be it for wireless network standards or electromagnetic compliance (EMC).



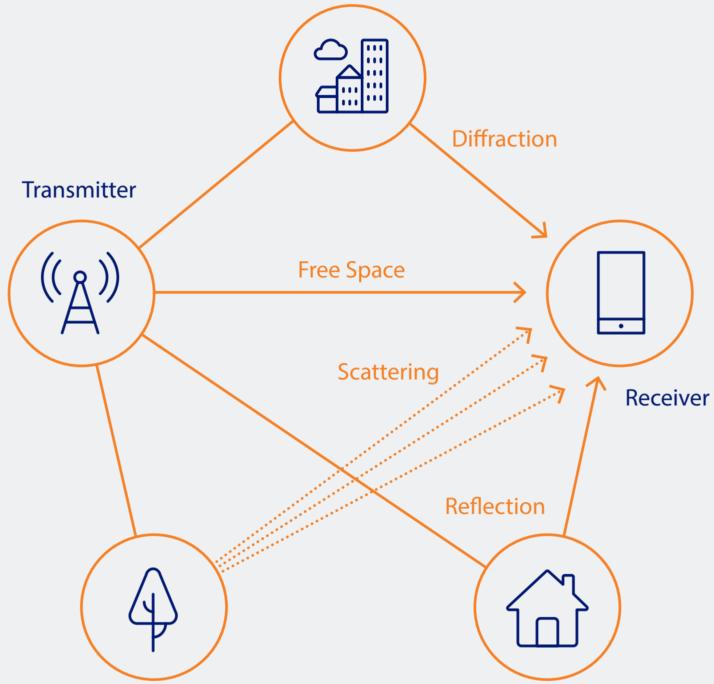
The Potential for Conductive RF Testing

RF conductive testing can now be more efficiently performed with a new breed of RF conductive testing hardware, software, and control technology.

With more economical solid-state attenuation matrix boxes designed for extremely high channel counts, IoT networks can be simulated without the need for large anechoic chambers, reverberation chambers, or quality-limited OTA testing environments.

High performance and high channel RF conductive test systems enable testing in laboratory conditions, as well as in the field – be it a manufacturing environment, quality control testing facility, or wherever an IoT network may be deployed. RF conductive test systems open the doors for testing of limited propagation environments deep indoors/underground, simulation of "one-to-many" connectivity scenarios, and the ability to simulate propagation interference accurately and consistently.

One way of doing this testing in a conducted lab environment is to monitor device and network behavior while the network is actively being subjected to intermittent losses in connectivity. Data would then be collected in real-time and compared to ideal propagation dynamics. RF conducted testing can also be used to create real-time scenarios essential in the development of robust wireless networking software and hardware protocols. This approach can also be used to consistently evaluate multiple technology platforms and software protocols by making apples-to-apples comparisons based on repeatable conditions, as opposed to OTA testing.



Challenge

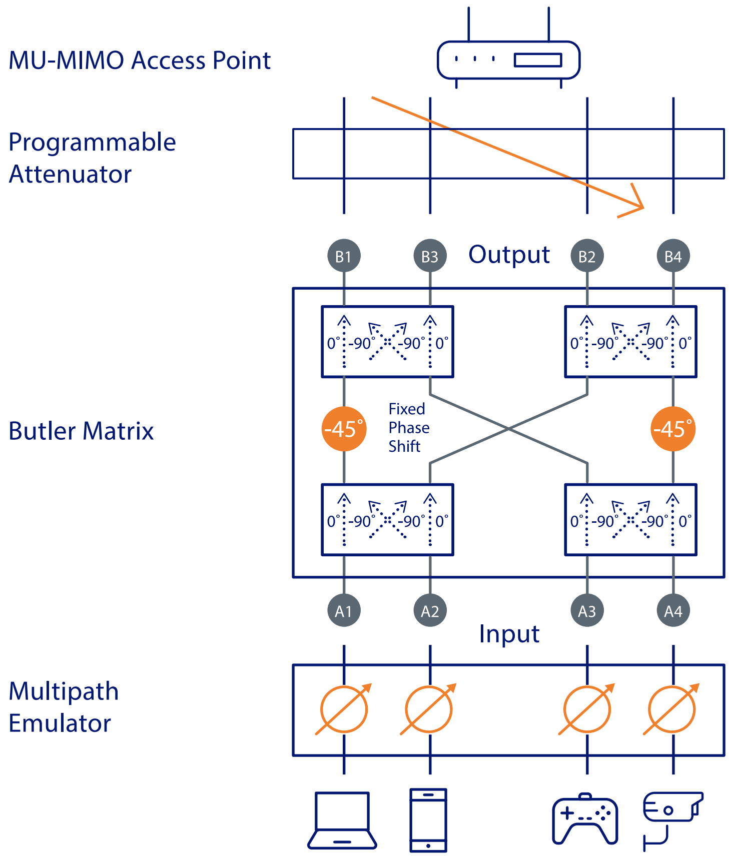
To verify chipset / AP is able to meet performance requirements under real-world conditions via conductive testing:

- **Wi-Fi 6E Testing and Link Simulation**
- **MU-MIMO simulation test scenarios**

What it Takes to Obtain the Full Value Out of a Conducted Test System

In order to realize the value of an RF conducted test system, several features are important to note. First, high quality solid-state attenuator matrices are key in providing repeatable and reliable propagation dynamics. These systems also need to cover low to mid 5G bands and Wi-Fi bands – this means a frequency range from the hundreds of megahertz to several gigahertz. These attenuation matrices also need to feature a high level of synchronization capability, customizability, and timing skews that can be programmed or triggered externally. As controlling a large number of attenuation channels is essential to implement a RF conducted test system for modern IoT applications, next-generation controller hardware and software is essential. This software also needs to be highly configurable and allow for web-hosted application implementation, as well as a high level of instrument virtualization to simplify the software and control of high instrument and channel count test systems.

> RF conductive test systems open the doors for the testing of limited propagation environments such as deep indoors/underground, the simulation of "one-to-many" connectivity scenarios, and the ability to simulate propagation interference accurately and consistently.



Solution

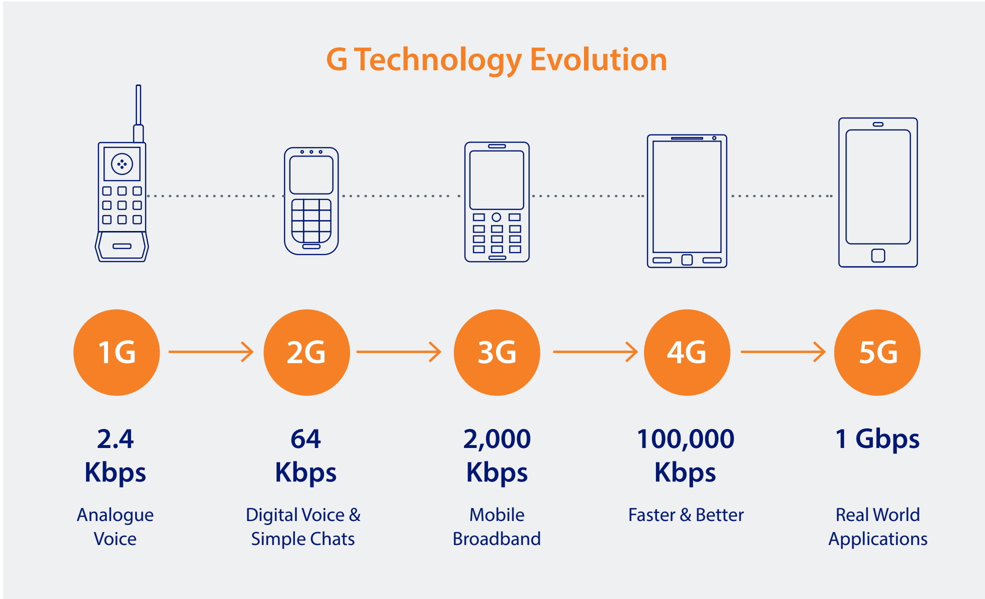
- Wide-frequency range (4.7 to 7.25 GHz)
- Simulates TGn-A/B Channel Models
- 4 independent channels with 2 clusters per channel
- Integrated programmable phase shifter / delay line
- Wi-Fi 6E Testing and Link Simulation
- MU-MIMO simulation test scenarios

The Potential for Conductive RF Testing

How Evolving 5G Standards Call for More Complex Test Requirements

Testing 5G systems and chipsets continues the trend of evolving cellular standards, leading to more complex testing requirements. The RF performance and physical layer specifications for 5G and Wi-Fi 6 are much more stringent than prior generations and as these standards continue to evolve, these specifications will continue to increase in complexity with tighter tolerances. Given the complexity of testing 5G new radio (NR) technology, over-the-air (OTA) testing methods have been introduced to tackle some of the challenging multi-input multi-output (MIMO) and beamforming tests necessary for the latest generation of multi-antenna standards. However, OTA testing methods present their own challenges and are not comparable to conductive testing in regards to:

- **Repeatability**
- **Accuracy**
- **And in some cases, speed**



The latest 5G standards outline methods of certifying and testing 5G devices using OTA techniques. These OTA test methods use radiative methods, sending and receiving RF signals through an atmospheric medium between the device under test (DUT) and OTA test antennas. In order for OTA to be most effective, the DUT needs to be pre-programmed with OTA test protocols in order to provide consistent test conditions and coordinate testing between the OTA test instruments and data capture systems. This is especially crucial as the more complex 5G MIMO and beamforming technologies with high-element antenna arrays which have an infeasible number of operating states to test in compliance, prototyping, or software development time scales.

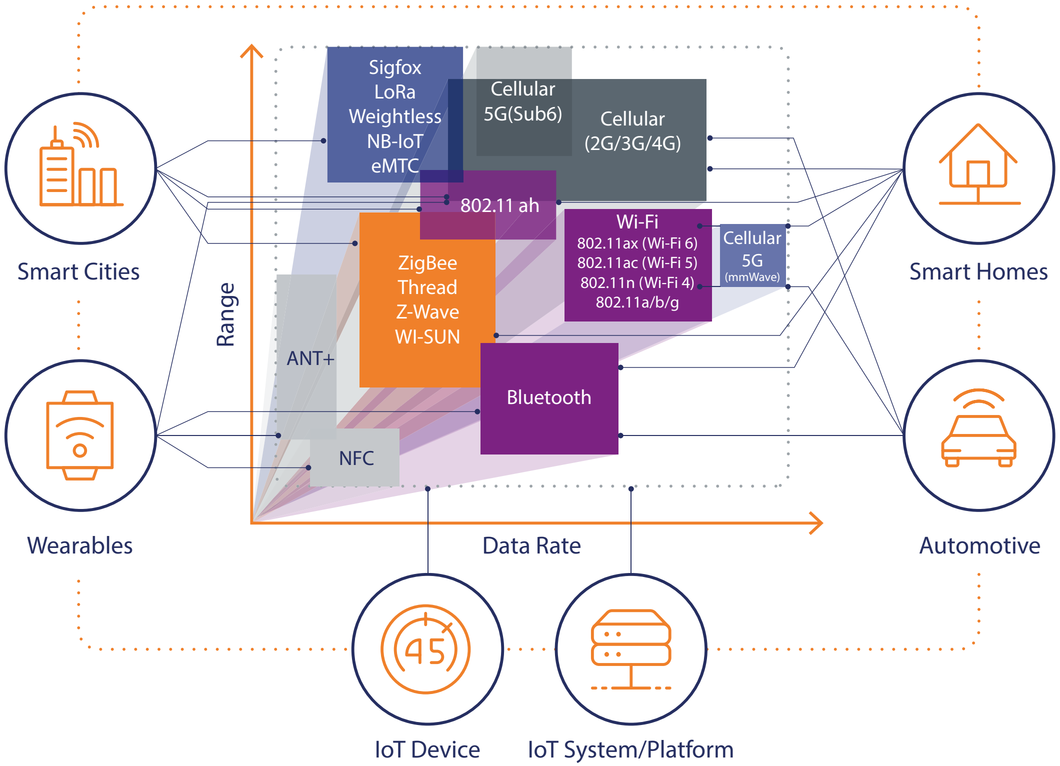
Testing Considerations with Coexistence of 5G and Wi-Fi

The Need for OTA Testing

As coexistence considerations between the two wireless networking standards are only deepening, there is a growing need for test systems that can accommodate both standards. Given that these networks are becoming integrated more into the daily life of users and part of infrastructure and critical systems, RF module testing and radio resource management in poor RF conditions such as high congestion and while experiencing interference, is also an expanding priority.

The challenge of testing RF device/module performance and wireless communication standard physical layer is not easily addressed with a single test approach. OTA test methods are useful for testing compliance and software development for wireless networking systems in some cases, but are not nearly repeatable or accurate enough for chipset or system development. However, the diversity of devices and level of integration of modern digital with RF technology in 5G and Wi-Fi systems means that OTA testing is likely the only viable way to test certain radiative performance parameters and to test conformance of radio hardware and antenna arrays.

> Best connection coexistence is about focusing on the idea of developing a way to ensure a device is always connected to the RF technology providing the best, most reliable connection.



Testing Considerations with Coexistence of 5G and Wi-Fi

The Need for Conductive Testing

However, conductive testing is needed in order to characterize chipset performance and for the development of software and system protocols. This is due to the fact that the accuracy and repeatability of conductive testing can reach thresholds that are acceptable for enterprise and industrial grade hardware and software development. Moreover, conductive testing methods and hardware that exist can accurately simulate real-world conditions in a controlled fashion. This simulation capability enables wireless networking hardware and software developers to test their devices, algorithms, and software features in controlled testing environments where external interference, noise, and effects are minimized. Additionally, RF simulation test systems are now able to provide control for phase (delay), attenuation, and multiplexed interconnect that can be used to simulate every type of network configuration, including cellular, star, and mesh configurations. Such capability allows for true network dynamics comparison between hardware and software revisions, even in especially challenging situations such as handover fading tests.

For instance, with OTA testing, shielded chambers are needed to isolate test hardware from the external environment to minimize errors and interference, as the OTA signal strengths received by the test antennas is usually very low and any external wireless signals could overwhelm the weak testing signals. This isolation also presents challenges with testing multiple devices at the same time, as control and monitoring OTA testing with multiple devices is a substantial challenge and chamber time is sometimes prohibitively expensive for performing iterative development approaches.

Hence, conducted multipath and fading environment testing is essential for testing enodeB (eNB)/NR/Wi-Fi modem chipsets for devices, as well as microwave transport links in 5G and Wi-Fi networks. In order to simulate massive IoT network conditions in a laboratory environment, RF Transceiver Test Systems and RF Network Simulators are ideal tools to enhance the development of 5G and IoT hardware and software in a cost effective and timely fashion.

Key components of RF Transceiver Test Systems and RF Network Simulators for conducted testing are programmable attenuator matrices, butler (phase shifter) matrices, power splitters/combiners, RF switches/relays, and control modules.

How Can We Help You Conquer Your Commercial Wireless Strategy?

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

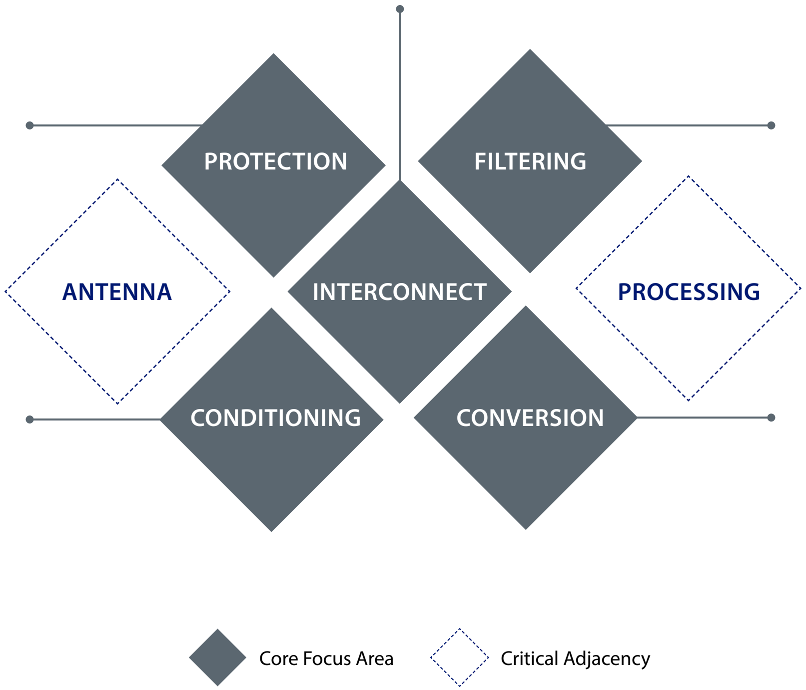
RF hardware and test systems are the keystone in bringing 5G to the masses and realizing new mobile wireless use cases. The competitive and fast pace landscape of mobile wireless is now expanding into new spectrum and technology developers are now facing previously unforeseen design, testing, and deployment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

High-reliability interfaces and **INTERCONNECTS** for distributed RF systems

PROTECTION against increasingly congested electromagnetic spectrum for military and commercial systems

FILTERING to ensure the optimal mix of products are passed on to stages of an RF system to maximise mission success



Size, weight and **CONDITIONING** optimized for distributed processing of RF signals

Multi-disciplined integration enables complex **CONVERSION** of RF signals

How Can We Help You Conquer Your Commercial Wireless Strategy?

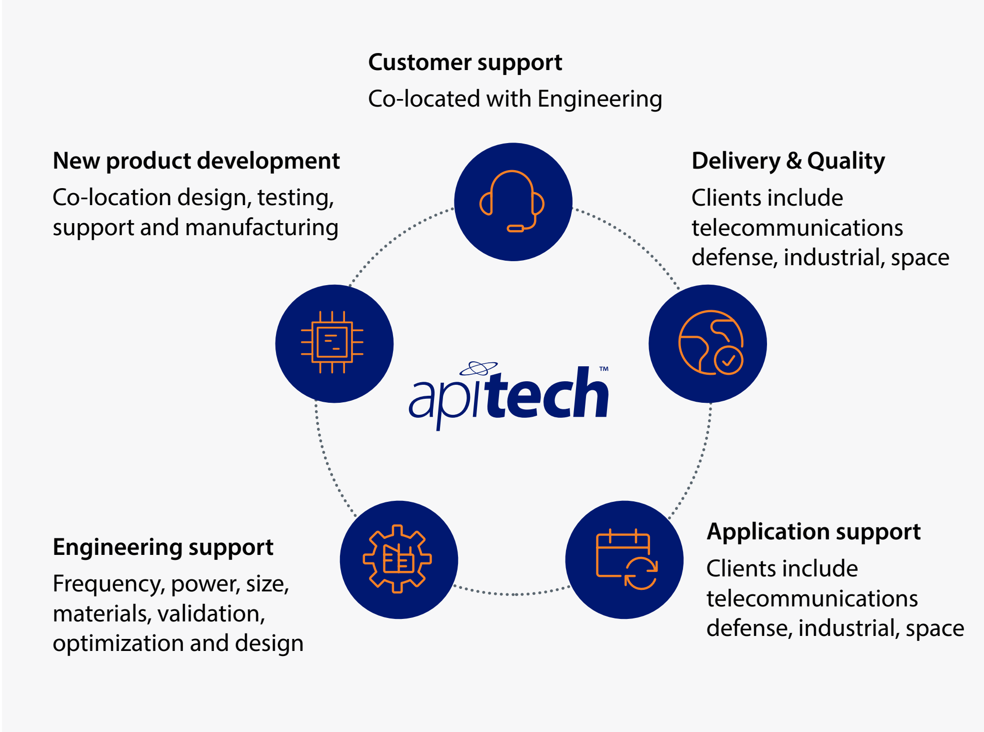
APITech can help 5G and Wi-Fi device manufactures and telecommunications operators overcome these challenges and unleash a new paradigm of connectivity with a unique three stage approach:

- **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.

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