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

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

2 Spectrum Management
With Enhanced Filter Solutions

Introduction

Dear Reader,

Constant innovation within the wireless realm has opened up opportunities in utilizing new technologies in new blocks of allocated spectrum for all sorts of industry verticals. From highly-specific, critical, time-sensitive applications, to ubiquitous handsets for everyday use, there is an ever-increasing demand on meeting throughput, latency, coverage, and capacity requirements regardless of the traffic load or location of the wireless equipment. Both licensed and unlicensed spectrum is being allocated for use in 5G and Wi-Fi wireless services. This can readily be seen with the FCC's recent approval to expand unlicensed bandwidth into the 6 GHz (5.925 to 7.125 GHz) spectrum space traditionally used for microwave backhaul to support Wi-Fi 6E and 3GPP 5G NR-U standards for 5G unlicensed networks. The FCC has already begun auctioning off 280 MHz in the C-band (3.7 to 3.98 GHz) in order to propel low-band 5G roll outs that allow for comparable speeds that the millimeter-wave spectrum enables, without compromising as much on range.

This however, leads to serious interference considerations in the low- and mid-bands where systems leveraging new channels must be able to effectively manage inter-channel interference while old systems may need upgrades to prevent interference from new device congestion. This is where filter technology is key. APITech uniquely serves this need with filtering solutions that allow for both the addition of channels while mitigating interference. These can be used in a myriad of applications from static base stations (e.g., eNodeBs, gNBs) and distributed antenna systems (DAS) to mobile aircraft in order to better harness the established terrestrial network for in-flight connectivity.

APITech has written this short form ebook discussing these new challenges, and provides illumination on how device designers and wireless network systems developers can enhance their products with leading filtering, electromagnetic interference/electromagnetic compliance components, as well as wireless network testing systems.

To dive deeper and find out how APITech can help you address network and device RF challenges, 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.

5G Spectrum Management With Enhanced Filter Solutions

How the Momentum in Wireless Innovation is Opening Doors in Technology, Applications, and Spectrum

5G and the latest generations of Wi-Fi are creating excitement and innovation across the RF and microwave industry.

The possibilities presented when discussing future visions for wireless networking and connectivity are raising expectations for wireless and radio applications in even slightly unrelated areas. For instance, the user experience and ubiquitous connectivity potential of 5G and Wi-Fi 6E, as well as its new use cases, is leading to the demand for satellite services to provide higher bandwidth and lower latency connectivity for a global wireless networking experience. Similarly, aircraft and other transportations services are now feeling an increasing pressure to provide a more enhanced wireless experience for passengers, users, and internal systems.

In order to better facilitate this, wireless standards bodies and spectrum regulatory agencies, such as the FCC in the US and EC/ECC in Europe, are assigning licensed and unlicensed spectrum for use with these new wireless services. The C-band is of particular focus right now, with most of the world having auctioned, or beginning to auction, parts of the C-band spectrum. The International Telecommunication Union (ITU) segmented the C-band into three parts, n77, n78, and n79. The majority of European and Asian countries currently use n78 (3.3 GHz to 3.8 GHz). In the US and Japan, band n77 is in use from 3.3 GHz to 4.2 GHz.

The Importance of Mitigating the Impact of Interference with Increasing Device Congestion

This creates a two-fold issue:

- **The new blocks of spectrum are already being used by other applications**
- **Device density has gone up within a given block of frequency**

One side of the challenge with this is that the new spectrum being assigned is already being used by other applications, in some cases government/military applications and in others, scientific research, satellite, and space sensing applications. The other side of this is that even with the addition of huge swaths of new spectrum, there will also be many more devices operating in much closer proximity. The early visions of the Internet-of-Things (IoT) and it's pervasiveness are certainly coming to pass, with billions of wireless devices being deployed each year. Though most of these devices are still operating in spectrum bands that has been used for years, manufacturers and wireless service businesses are looking to differentiate their products by developing technology that work in the new, and as of yet, less congested spectrum bands.

The reality these two situations create is that there is a growing opportunity, and likelihood of interference. Even with these current issues, critical applications such as autonomous vehicles, industrial automation/robotics, public safety, and healthcare are moving toward wireless connectivity solutions. Minimizing the impact of interference is an essential priority. Hence, the latest wireless standards are also leading to more stringent physical (PHY) layer specifications which is in turn, presenting a greater design challenge to designers of new hardware and wireless system operators with legacy hardware. Designing wireless standards compliance with new hardware is always challenging, but the shifting landscape of the RF spectrum with new standards and new generations of standards is also making compliance difficult for pre-existing wireless systems.

Mastering 5G Spectrum Management With Enhanced Filter Solutions

The outcome for many wireless system operators is that they have to account for these new players in and around the spectrum they operate in and are experiencing pressure to enhance their wireless system performance to meet new user demand and to stay competitive.

As part of this outcome, wireless system designers are now increasingly faced with the need to enhance the RF filtering in their products. New filtering requirements may come from the following needs to:

- **Stop interference generated by their wireless systems**
- **Retrofit their current systems to be less susceptible to new interference**
- **Push their current hardware to new levels of performance with enhanced spectrum management**
- **Implement entirely new channel plans to enable new services and improved wireless system performance**

An indispensable component in any of these solutions is a multiplexer filter, which are also commonly known as diplexers. Diplexers are filters that are able to separate signals from a single input to multiple outputs based on frequency. As with any filter design, the complexity of the frequency response specified for a diplexer is directly related to the complexity of the diplexer design and hardware implementation.

Key Diplexer Parameters

- **Peak and average power handling**
- **Modulation signal types**
- **Number of channels**
- **Channel spacing**
- **Channel bandwidth**
- **Selectivity/Close in rejection requirements (suppression)**
- **Isolation**
- **Insertion loss**
- **Voltage Standing Wave Ratio (VSWR)**
- **RF connector/interconnect specifications**
- **Size and weight**
- **Environmental specifications**

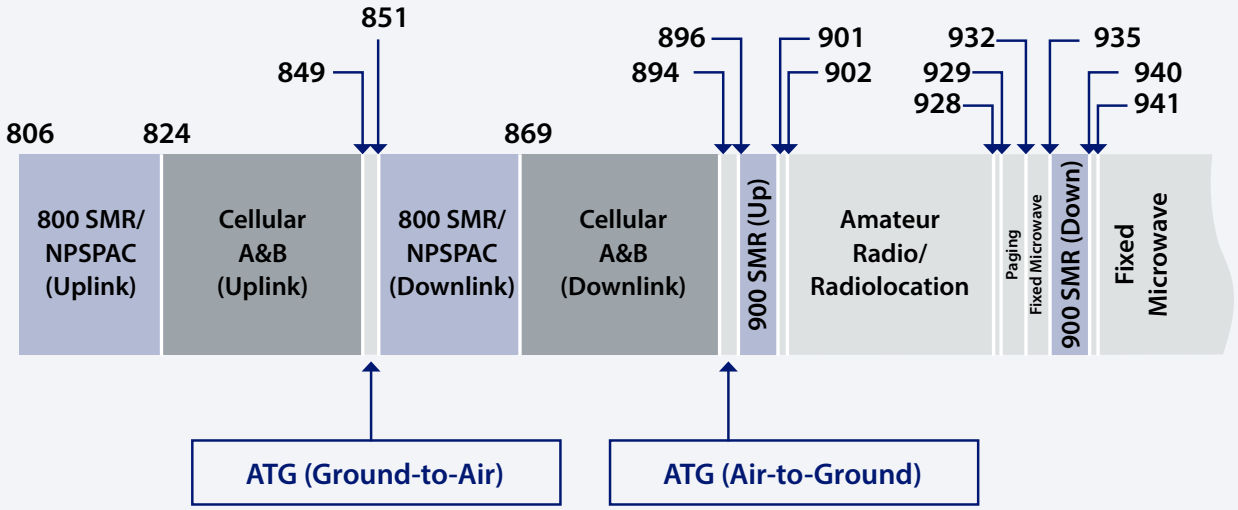
Mastering 5G Spectrum Management With Enhanced Filter Solutions

How Diplexers Can Accommodate Spectrum Management

In many cases, operators now require diplexers with an increased channel count, more stringent close in rejection requirements, and enhanced performance (isolation) to better accommodate much higher order modulation schemes.

An example case of this is an air-to-ground network operator that provides mobile service to aircraft passengers using a network of 200 towers across the US and Canada. This operator uses eNodeB technology to deliver their service and faced a need for greater channel count while further mitigating the interference at a key frequency (851 MHz). The diplexer designed to meet these requirements needed to meet the demand for very high selectivity and four additional FCC compliant channels. The resulting diplexer enabled the operator to retrofit their mobile service and deliver an enhanced user experience and network reliability.

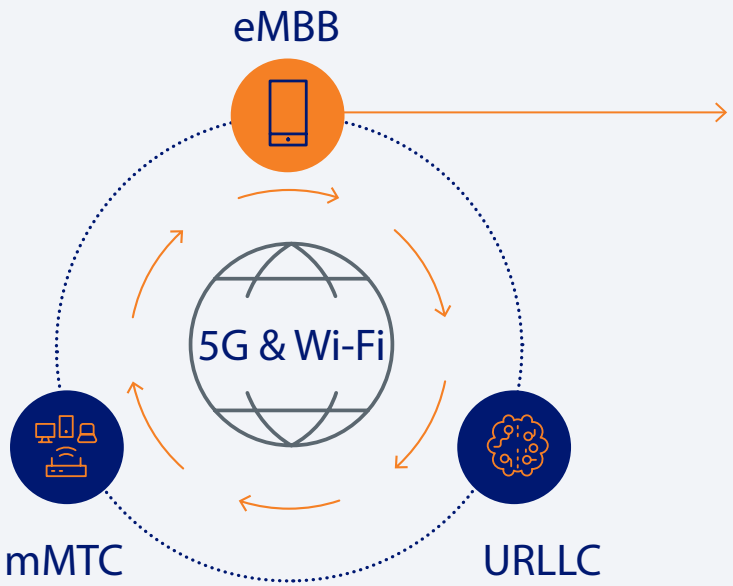
Table of Frequency Allocations



Mastering 5G Spectrum Management With Enhanced Filter Solutions

Diplexers – Spectrum Band Capacity Addition

- An air-to-ground network delivers mobile service to aircraft passengers from more than 200 towers across the US and Canada.
- Use eNodeB technology to deliver mobile service.
- Requirement is to expand bandwidth to accommodate 9 FCC compliant channels, while still mitigating interference at 851 MHz.
- A design was provided meeting the challenging selectivity, while providing the 4 additional channels required.
- What to keep in mind when specifying a diplexer to perform a specific application:
  - **Peak and average power handling**
  - **Number of carriers / type of modulation**
  - **Insertion loss and close in rejection requirement**



APITech's mini case study enhances an air-to-ground network's connection with over 200 4G base stations by engineering diplexers to increase channel count and mitigate interference. This allowed the passengers to access seamless in-flight Wi-Fi and 4G.

The Importance of Distributed Antenna Systems (DAS) for Connectivity

There are many industry consortiums / alliances and regulatory agencies that have been studying the convergence of 5G and Wi-Fi as a unified network for large venues, public spaces, and certain transportation scenarios.

The goal of this convergence would be to offer a seamless experience with a continuity of connectivity and services between 5G networks and Wi-Fi. This is accomplished with Wi-Fi integrated as part of the 5G core network as another radio in the cellular network aggregate strategy. Whether or not this convergence will occur is as of yet unknown, but a key value of a 5G and Wi-Fi convergence would be distributed antenna systems (DAS) that can support both licensed and unlicensed spectrum that can communicate with both Wi-Fi and mobile devices. Currently, there are DAS that allow for the coexistence of multiple cellular bands and some Wi-Fi bands. These are relatively common, but the deployment strategy for these is more complex than one under a 5G and Wi-Fi convergence.

In the meantime, DAS designers and installers need to design their systems with the premise that Wi-Fi and cellular networks are very different technologies that do experience – and may experience greater levels of – coexistence challenges. A new 1,200 MHz block of spectrum in the 6GHz band has been designated by the FCC for both licensed and unlicensed use. This means that cellular and Wi-Fi networks will operate at the same frequencies, including all other sub-6 GHz cellular bands, 2.4 GHz Wi-Fi, and 5 GHz Wi-Fi all coexisting in some venues and public spaces. This leaves DAS designers and installers having to account for thousands of channel combinations and the challenge of designing systems to account for interference is growing.

The Importance of Distributed Antenna Systems (DAS) for Connectivity

Designing and Installing a DAS

More so now than ever, carefully designing and installing DAS systems is crucial, especially as business opportunities exist to enhance user experience in public venues, arenas, and in transportation complexes and users are increasingly demanding seamless connectivity. Increasing urbanization, also means a greater number of people will be relying on enhanced connectivity experiences in ever more congested environments. Hence, heterogeneous cellular networks are becoming increasingly necessary with an emphasis on small cells and DAS installations in urban environments.

DAS installations are dependent on multiple RF feeds and service providers. This requires DAS installations to split/combine multiple RF signals amongst several cable paths to multiple antennas. Hence, precise control of the RF signals as well as reliable power splitting/combining is critical in achieving a DAS installation that minimizes interference between DAS radios, cellular base stations, and other coexisting wireless networks.

Both precise control of the RF signals and reliable power splitting/combining is critical in achieving a DAS installation that minimizes interference between DAS radios.

Optimizing a DAS for Ideal Performance

RF power splitters/combiners are RF devices that split the signal energy from a single RF feed to two or more feeds, combine multiple RF feeds into a single feed, or do both depending on the direction of the RF signal (with a symmetric RF splitter/combiner). Naturally, the RF energy in an RF feed that is split is divided amongst the outputs, sometimes evenly or asymmetrically, depending on the design. This means that the splitting of RF feeds decreases the signal strength in the split feed. Since DAS systems depend on highly controlled signal strengths and antenna radiated energy, it is important to ensure the RF feed strength is within a desirable range. In some cases an active DAS system may rely on amplification of the RF feeds to ensure that their signal strength is high enough that the RF energy that reaches the most distance (i.e., highest attenuation transmission path) DAS node. The lower transmission attenuation path DAS nodes may then have higher signal strengths then is acceptable, which then requires additional attenuation at the DAS node to ensure the signal strength at the antenna isn't excessive.

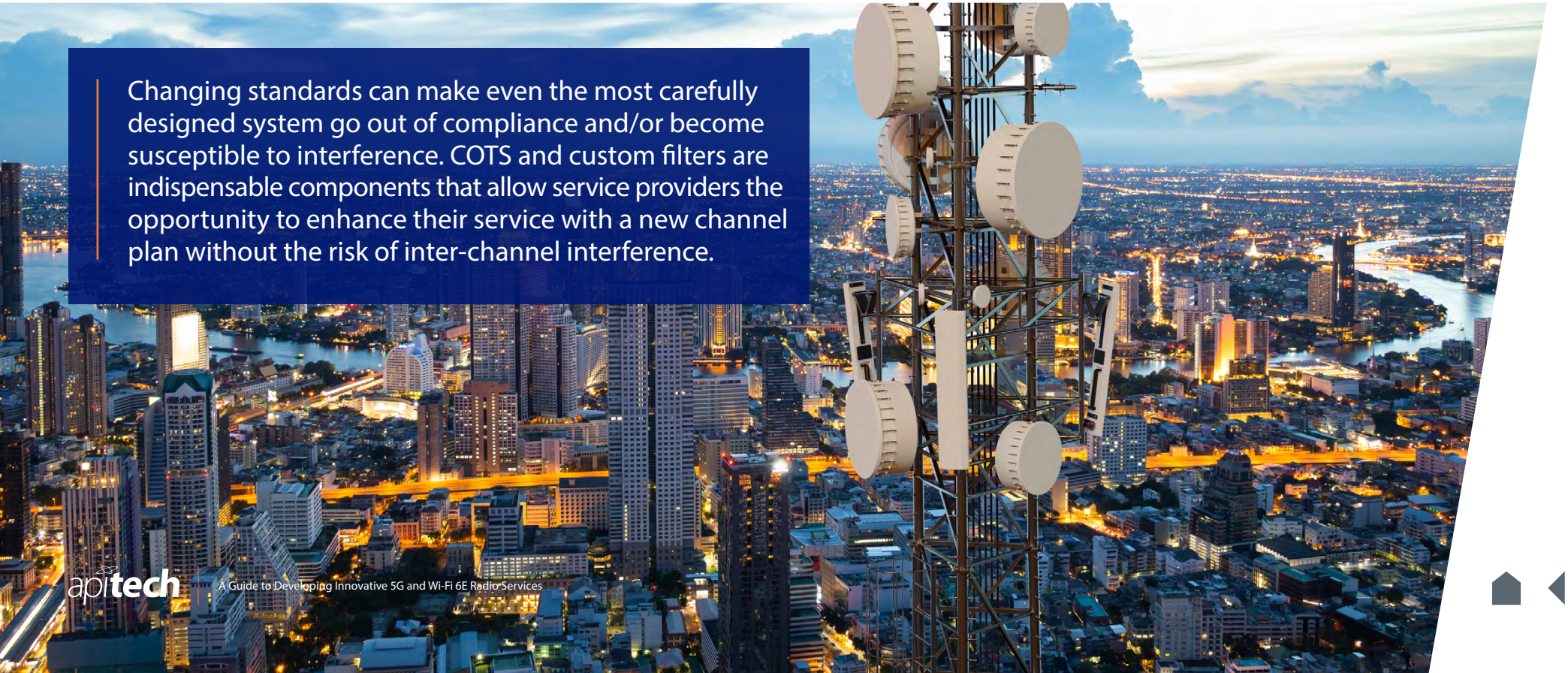
The Importance of Distributed Antenna Systems (DAS) for Connectivity

Interference Mitigation Considerations for DAS

Even with optimized DAS and cellular installation design, interference mitigation and spectrum management consideration are often unavoidable. Changing standards and regulations can make even the most carefully designed system go out of compliance or lead to new wireless networks in the vicinity that may cause interference. This is where off-the-shelf or custom filters and diplexers become indispensable. Moreover, a service provider may also have an opportunity to enhance their service with a new channel plan or adding channels, which would require new diplexers to ensure avoidance of inter-channel interference.

Filters and diplexers are already incorporated into the mobile base station infrastructure to combat known potential co-site interference and to address some coexistence issues. In some cases, additional filtering or diplexers are needed to address new interference or as a response to a complaint that a service provider's wireless network is generating interference conflicting with another service. Though site planning and thorough checks are supposed to curtail the possibility of this happening, with such a dynamic spectrum landscape and explosion of wireless services/devices, the chance of this occurring is escalating.

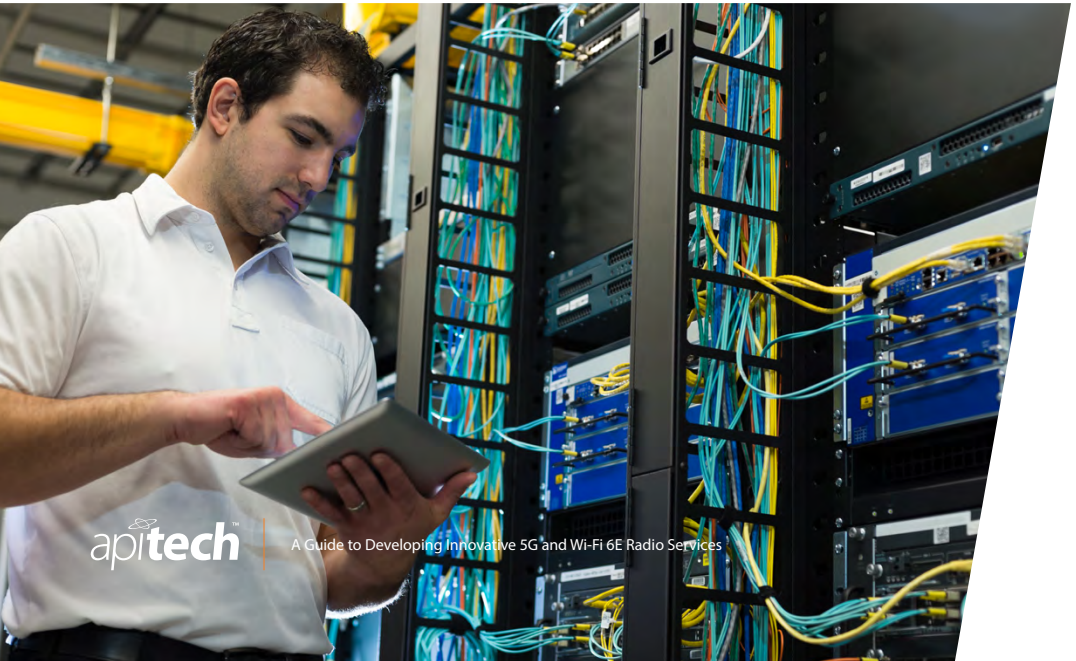
> Changing standards can make even the most carefully designed system go out of compliance and/or become susceptible to interference. COTS and custom filters are indispensable components that allow service providers the opportunity to enhance their service with a new channel plan without the risk of inter-channel interference.



The Future of Wireless Is More Interference & Stricter Compliance, Be Prepared With Filtering Solutions

Wireless connectivity has facilitated the rise of a growing horde of new use cases in the consumer, industrial, medical, scientific, and even defense industries.

In anticipation of the economic benefits and exciting new technology opportunities, spectrum regulatory agencies around the globe have reallocated spectrum for use with 5G cellular technology, unlicensed services, and made spectrum available for new applications. These spectrum assignments naturally threaten existing applications in the same and nearby spectrum with troublesome, and possibly even debilitating interference. On the flip side of the same coin, 5G and other wireless services in this newly available spectrum will have to contend with interference from the existing wireless systems while maintaining strict electromagnetic emissions requirements to prevent interference with legacy wireless systems.



Proper Spectrum Management

Emerging 5G and wireless services are hitting higher frequency areas of the spectrum, as well as lower frequencies, and these wireless services are poised to become essentially omnipresent in buildings, factories, public spaces, homes, metropolitan areas, public transportation venues/vehicles, and more. Hence, where there were previously only a few wireless services operating in only small slices of spectrum that could potentially interfere with each other, there will soon be countless wireless devices using a wide variety of wireless services and technologies

It is easy to see how without proper spectrum management technology – such as electromagnetic interference (EMI) filters, power-line filters, interconnect filters, and other device protection technologies – the new wireless revolution could just amount to more noise. This is especially true, when we consider how these new technologies are being powered at the increasingly digital heart of wireless devices.

> D-Sub interconnect filters are becoming increasingly common with 5G and Wi-Fi test enclosures to ensure a high level of EMI attenuation between the noisy outside world and the test chamber.

The Integration and Shrinking of the RF Device

In years past, wireless systems were predominantly composed of discrete RF hardware that required basic conversion to digital baseband signals. Now, wireless systems are increasingly digitized with the RF portions of the hardware being limited to the "front-end". This means that virtually all of the other communications functions are handled in the digital realm with advanced systems-on-chip (SoCs), systems-in-package (SiP), application specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), digital signal processors (DSPs), and various other forms of digital processors. Even the RF portions of wireless systems have become highly integrated, with some entire wireless systems now being delivered in a single package.

The Future of Wireless Is More Interference & Stricter Compliance, Be Prepared With Filtering Solutions

Sensitivity And Susceptibility within the Wireless Device

All of these digital circuits require a wide range of power supply voltages/currents that meet very stringent standards for the digital electronics to function as desired, not to mention, similar requirements for high performance RF circuits. To deliver the variety of power rails needed by high performance digital systems, switch-mode power supplies are now the norm. These power supply devices can emit undesirable interference at RF frequencies if not properly designed. Moreover, the functions of these digital circuits are now so fast, they themselves may emit undesirable RF interference, possibly even in the communication bands of their system. Hence, the interference between components within these new wireless systems, is as much of a concern as external interference impacting the performance of the digital or RF components.

The Need for EMI Filtering and Power-Line Filtering

This challenge is compounded as throughput of the wireless systems are being upgraded from megabits per second (Mbps) to tens of gigabits per second (Gbps). This is very much the case in 5G and Wi-Fi 6e, which requires higher clock rates, more complex modulation schemes, and more capable digital systems to process the RF signals being transmitted and received. Higher speed digital signals and more complex RF signals are both more susceptible to external and internal interference, which ultimately allows for more easily degraded signal integrity of the digital signals and signal quality of the RF signals.

With greater sensitivity and susceptibility, more capable spectrum management, EMI, and power-line filtering is required to ensure the new generation of wireless system electronics can meet the ambitions performance requirements set for them while also providing highly reliable operation needed for the emerging industrial applications anticipated for 5G and new Wi-Fi standards. Key components in this "war" against interference are:

- **Filtered interconnects, such as D-Sub connectors for 5G and Wi-Fi test enclosures and feed-through coaxial filters**
- **Single and multi-line power filters to protect boards and assemblies from powerline EMI, as well as electromagnetic pulse/high-altitude electromagnetic pulse (EMP/HEMP)**
- **High voltage ceramic capacitors (HVCC) for onboard protection and filtering**
- **Filter Arrays and Plates, which protect electronic system modules from EMI passed along the signal lines between the modules**

Layers of Protection to Meet Compliance

It is important to note that with EMI and filtering solutions, there is often a need for several layers of protection to reach stringent compliance standards for emissions and susceptibility. Beyond shielding, filtered interconnects are key for mitigating the EMI entering and leaving shielded board sections or enclosures. Placing filtering capacitors near devices on a board is a way to provide targeted protection to highly susceptible circuits. An optimal mix of EMI and filter solutions used from the powerline to the circuit level help to ensure mission success and avoid costly regulatory issues.

How Can We Help You Conquer Your Commercial Wireless Strategy?

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

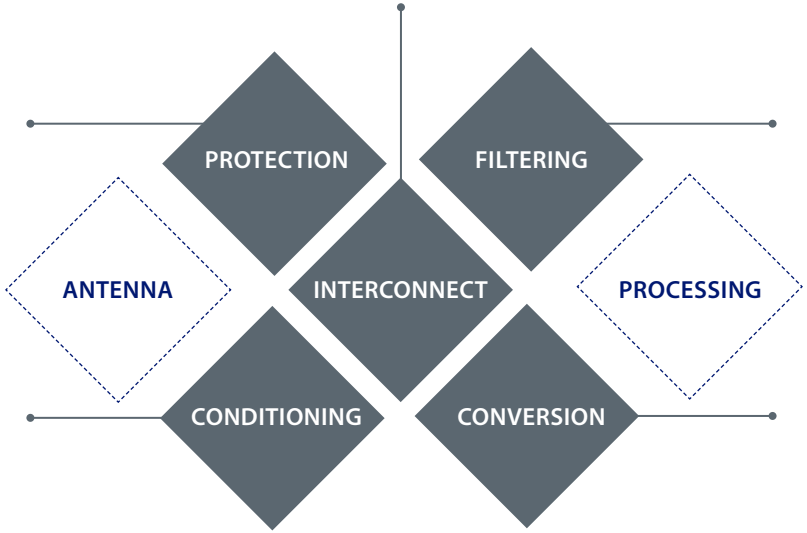
RF hardware and test systems are the keystone in bringing 5G to the masses and realizing new mobile wireless use cases. The competitive and fast pace landscape of mobile wireless is now expanding into new spectrum and technology developers are now facing previously unforeseen design, testing, and deployment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

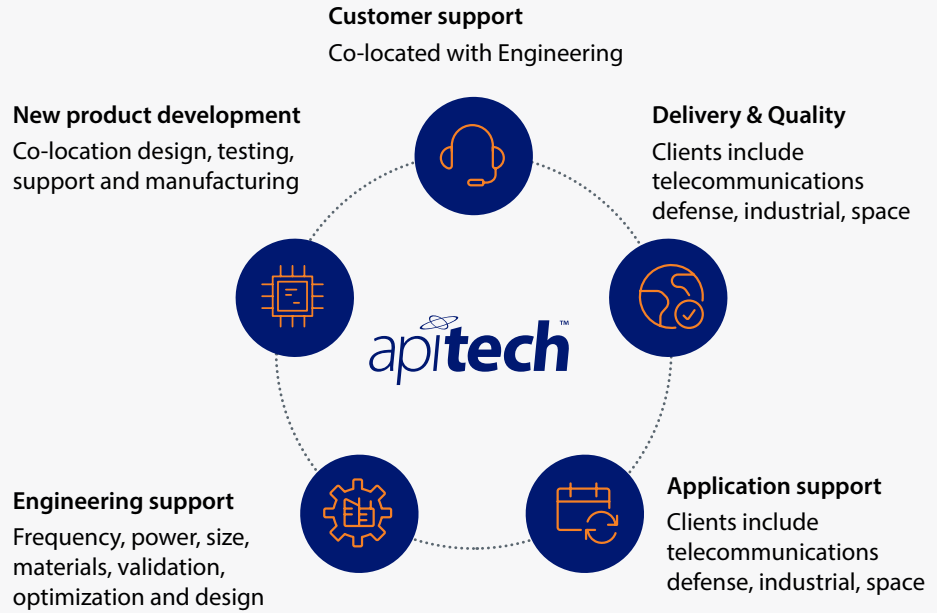
APITech can help 5G and Wi-Fi device manufactures and telecommunications operators overcome these challenges and unleash a new paradigm of connectivity with a unique three stage approach:

- **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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