WHITE PAPER

Reimagining Antenna Design Solutions for Next-Generation Mobile Devices

Rapid innovation in next-generation mobile devices is creating significant engineering challenges in the form of antenna implementation. A key issue is that 5G handsets typically have more than twice as many RF paths as LTE phones due to new bands and requirements in the cellular, Wi-Fi, Ultra-Wideband (UWB), mmWave (mmW) and GPS standards. However, a lack of space limits the ability to add new antennas and/or sharing antennas among many bands creates complex problems. Innovations in industrial design, such as foldable or rollable screens and the replacement of physical buttons with virtual controls impose significant constraints on antenna design and placement. Additional challenges are created by conflicting targets of increases in carrier power requirements and OEM system efficiency targets and improvements – i.e., battery life. With an extensive track record of helping companies solve the toughest RF problems, Qorvo Antenna Solutions Reimagined (QASR) helps engineers navigate space, design and performance challenges to harness the true power of antennas in their RF architectures.

The Rapidly Evolving Mobile Industry

The mobile industry's rapid pace of innovation continues unabated as smartphone and wearable manufacturers along with mobile operators race to offer increased coverage, higher data rates, new wireless communications capabilities and revolutionary industrial designs.

Smartphone manufacturers are expanding 5G support across product lines to support ever-growing demand for data-intensive services such as video streaming, video conferencing, music and gaming. Accordingly, support for 5G high-bandwidth sub-6 GHz bands (n77/n78 and n79) and even wider mmW bands (n257-n261) is spreading from premium to mid-tier and mass market phones. Adding to the RF complexity, 5G requires not only the addition of new cellular bands but also 4x4 MIMO support on higher-frequency bands to deliver faster data speeds.

Manufacturers are also adding more non-cellular bands into handsets to provide faster networking and support new location-based services. For example, Wi-Fi 6E/7 expands Wi-Fi into the 6 GHz band and provides extra-wide 160-320 MHz channels to provide higher performance for applications such as high-definition streaming, virtual reality and peer-to-peer gaming while easing congestion of heavily used Wi-Fi spectrum.

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UWB technology, first implemented in premium phones, is also increasingly appearing in mid-tier and mass-market phones. UWB enables distance and location to be calculated indoors or outdoors with unprecedented accuracy – within a few centimeters – and it is enabling entire new categories of location-based applications and devices. As its name suggests, UWB uses channels that are at least 500 MHz wide, over a broad 3.1-10.6 GHz frequency range with a focus of 6-9 GHz in mobile applications to-date. Manufacturers are also adding the new GPS L5 and L2 bands, which offer advantages such as increased positioning accuracy for mission-critical applications.

Figure 1. RF challenges continue to increase.

Meanwhile, smartphones are adding an ever-growing number of complex combinations of multiple cellular bands as mobile operators seek to optimize the use of their existing spectrum to offer higher data rates. Many operators are using EN-DC (E-UTRAN New Radio – Dual Connectivity), which enables them to deploy 5G data speeds much more quickly in certain regions by using a 4G anchor band in combination with 5G data bands. Carrier Aggregation (CA), which combines multiple Component Carriers (CCs) to provide greater bandwidth and faster data rates, is becoming much more complex as more bands are being added to combination options. 5G defines hundreds of new combinations of up to 16 CCs, each with contiguous bandwidth up to 100 MHz, for a total aggregated bandwidth up to about 1 GHz. These include challenging new aggregations of two or more low-frequency bands, such as B20 + B28 combinations in Europe or Asia and B5 + B12, B13 or B14 in North America, which offer the advantage of extended range as well as greater throughput.

Manufacturers are also implementing higher transmit power to increase coverage with higher-frequency signals, which don't travel as far as those using lower frequencies. Already in widespread use is Power Class 2, which doubles transmit power at the antenna to 26 dB, and the industry is currently exploring Power Class 1.5 which specifies a further two-fold power increase to 29 dB.

Industrial Design Innovation

Smartphone industrial design is evolving rapidly as manufacturers seek new ways to differentiate their products and offer exciting new consumer experiences. Revolutionary designs include phones with expanding rollable screens and flip phones with foldable displays. Displays that wrap around the edges of phones offer a sleek, cutting-edge appearance while maximizing the screen area available to consumers. Physical buttons are being replaced with virtual controls, typically located on the lower or side edges of these handsets. And manufacturers continue to add other new features that users value, such as better displays, more cameras, multiple biometric authentication methods, and higher-quality speakers and larger batteries. While they are highly attractive to consumers, these features consume space, reducing the amount of space available for the RF front end (RFFE), and they also place new restrictions on where RFFE components and antennas can be located.

Accompanying these trends is the explosion of small Internet of Things (IoT) devices with cellular and/or non-cellular connectivity, including watches, other wearables, and small tracking devices. Space is at a premium in these devices, and the ability to squeeze RF content into a tiny amount of space is essential.

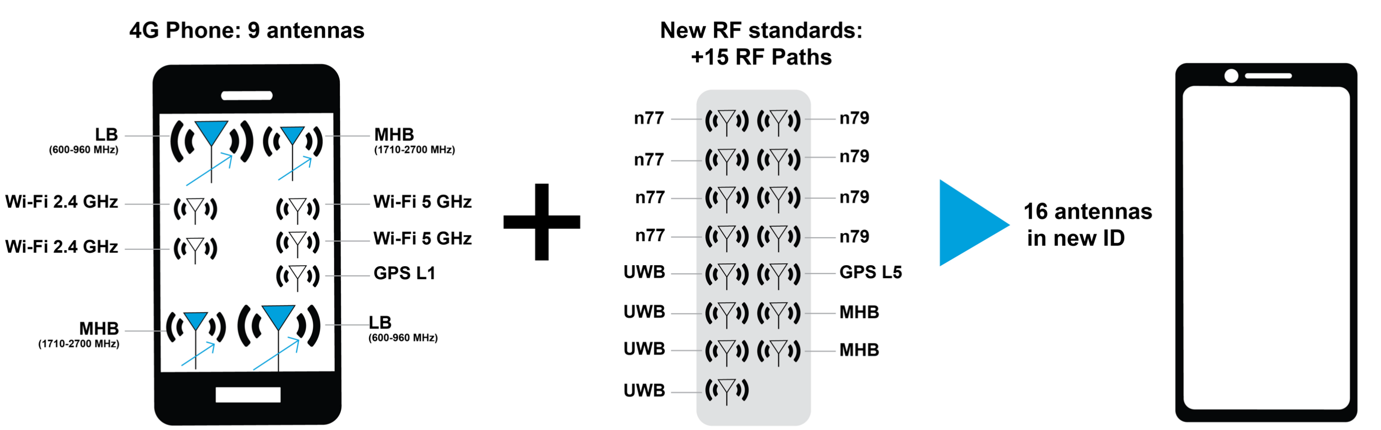
Antenna Challenges

These innovations in connectivity and industrial design create a broad variety of interrelated antenna challenges for engineers working on next-generation smartphones and other mobile devices.

RF Paths More Than Double

The addition of new cellular and non-cellular bands is massively increasing the total number of RF paths in mobile devices. A typical 5G phone with support for mmW bands and UWB has more than twice as many RF paths as a typical 4G phone. Each RF path needs to connect to an antenna, but it’s simply impossible to double the number of antennas. This is due to the limited space available in handsets: increasing the number of antennas means they must be closer to each other, which reduces the isolation between them. This causes coupling-related issues, increasing the potential for non-linear elements in the RFFE, which desenses the receiver.

Figure 2. 4G to 5G transition increases constraints on the RF.



Given the limitation on the total number of antennas that may be implemented in a fixed form-factor, the logical approach to handling the growing number of RF paths is to increase each antenna's bandwidth to support a larger number of bands. However, this approach brings its own challenges. Wider-bandwidth antennas tend to be more lossy. They may require more space, since the size of an antenna is determined by the lowest frequency it supports. Furthermore, using a single antenna to transmit and receive multiple bands simultaneously increases the risk of non-linear spurious emissions generated by mixing signals. Solving these problems is not easy: It requires careful analysis and specialized antenna design techniques, in combination with appropriate filtering and routing within the RFFE.

Ultra-Wideband

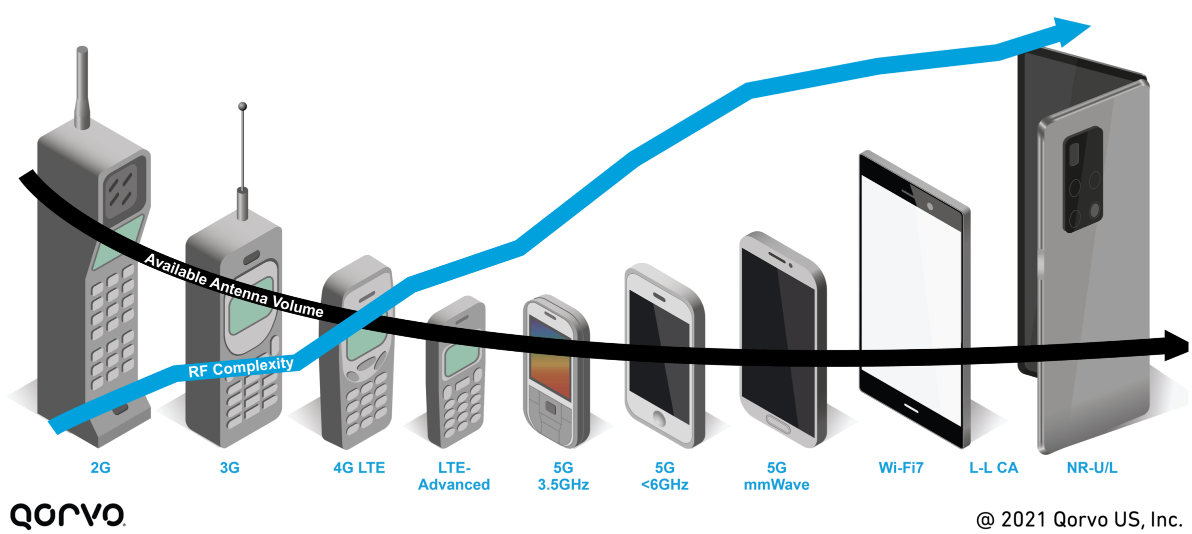
Supporting UWB requires three or four relatively large patch antennas, which consume a considerable amount of the already-crowded space within handsets. Accordingly, manufacturers are looking for ways to combine some of these antennas to reduce the overall area required. A further consideration is whether to position one antenna on the edge of the phone for optimal omnidirectional ranging.

Carrier Aggregation and EN-DC

The rapid increase in band combinations for CA and EN-DC exacerbates the antenna challenges. Potential aggregations now include hundreds of different permutations of high, mid and low-frequency bands. They include combinations of multiple bands within each frequency range (such as low-low or mid-mid aggregations) as well as combinations of bands in different regions of the spectrum (such as low-mid and low-mid-high). Furthermore, the maximum bandwidth of each CC has also increased. While 4G limited carrier bandwidth to 20 MHz, 5G increases the maximum contiguous bandwidth to 45 MHz for bands below 2300 MHz, and up to 100 MHz for bands above 2300 MHz.

Because the total number of antennas is limited, each antenna may need to provide high performance for wideband transmit and receive signals over a very wide frequency range, from 600 MHz to 5000 MHz.

Figure 3. RF complexity increases as standards mature, IDs change and add more complexity.



Low-low aggregations create some of the most difficult antenna design problems. Mobile phones typically support low-band frequencies using two primary antennas located at the top and bottom of the phone. These antenna locations minimize the likelihood that user interactions with the phone will impair performance, because consumers generally position their hands at the sides of phones, not at the top and bottom. A key problem is that low-low aggregations may need a third antenna capable of low-band transmissions. That means manufacturers need to find yet more space for this antenna within the handset and ensure that chosen antenna location provides adequate performance under all use conditions.

Higher Tx Power

The higher power output defined in the PC 2 and PC 1.5 specifications impacts smartphone battery life. It also means that all post-PA components within the RFFE, including antenna tuners, need to handle more power. This generally means that components will need to be larger, which is problematic given the significant space constraints. The increased output power also means higher levels of spurious signals will be generated by RFFE components, requiring additional attention to mitigating desense and RSE issues.

New Designs Reduce Space for Antennas

New handset designs with foldable and rollable screens create a whole array of antenna challenges. The phone must be able to operate in different physical states – rolled or unrolled, folded or open – which severely limits the potential locations for antennas, and may also require the use of different antenna materials. Adding to the challenge, the constraints imposed by the design may mean that antennas must be placed in sub-optimal locations that make their performance more susceptible to human interaction. Antenna grounding may be affected, impacting radiation efficiency. Careful antenna design and positioning will be needed to ensure efficient operation in all use conditions.

Figure 4. New innovative and complex industrial designs add to the complexity.

The replacement of mechanical buttons with software-defined virtual buttons creates additional antenna challenges. Locating these buttons along the bottom of phone maximizes convenience and the screen space available to users, but this also means that they may interfere with the primary antenna traditionally placed in this location.

Who Will Solve the Challenges First?

As this paper demonstrates, next-generation mobile devices present considerable antenna design and engineering issues. Who will be the first to solve the challenges? The team that wins the innovation race will create a significant competitive advantage in the battle for consumers' minds and wallets, in addition to the well-deserved sense of pride that comes from overcoming extremely difficult obstacles.

How QASR Can Help

Qorvo Antenna Solutions Reimagined (QASR) is uniquely placed to help smartphone engineers solve the antenna challenges in next-generation smartphones and other devices.

Qorvo is dedicated to investing in the technologies that enable innovation and support the mobile phone's continuing evolution. Though innovative technologies alone are not enough to solve tough RF problems. That's why Qorvo works closely with the mobile industry to help engineers overcome the unique design problems of each mobile device. Qorvo has an unparalleled track record of helping manufacturers incorporate innovative solutions into smartphones and other devices, including:

- The industry's first antenna tuners, helping to help to improve antenna efficiency over a wider range of bands.
- Understanding combinations of antenna-plexers, new paths and standards to address and simplify complex scenarios that are emerging.
- Driving new and custom technologies to address 5G requirements across antenna tuning, transmit capability and RF routing.

QASR helps you navigate space, design and performance challenges to harness the true power of antennas in your RF architectures.