WHITE PAPER

Through the 5G Antenna Design Maze with Antenna-plexers

Abstract

Antenna-plexers solve a key problem facing manufacturers of 5G handsets and other devices: how to accommodate the dramatic increase in RF complexity, even as the space allocated to antennas continues to shrink. Antenna-plexers enable manufacturers to accommodate new 5G bands, 4x4 MIMO, and other new requirements with fewer antennas, and with no impact on existing form factors or features. They combine multiple acoustic filters to allow several different radios [cellular, Wi-Fi, GPS, ultra-wideband (UWB)] and a greater number of bands to share a single antenna. By using antenna-plexers, manufacturers can deliver the full benefits of 5G without impacting their ability to add innovative features that attract consumers.

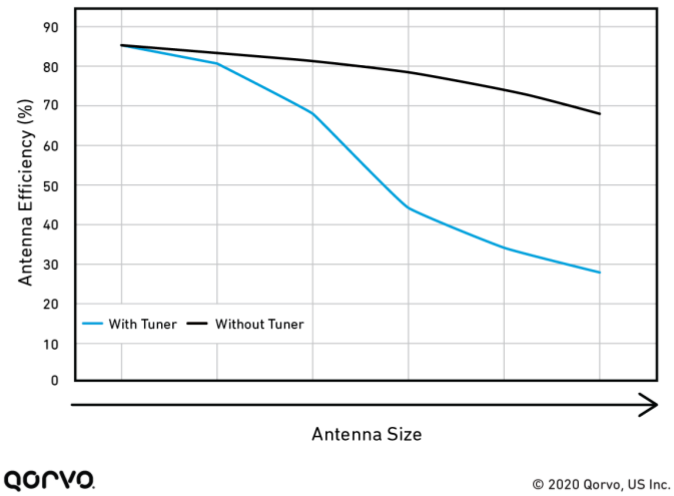
Introduction

Handset manufacturers face the continuously recurring challenge of finding ways to support new RF standards and bands-plus expanding requirements for multi-band coexistence-even as handset design trends make it more difficult to add antennas to meet those needs.

A typical 4G phone already includes 4 to 8 antennas, and 5G phones will need even more antennas. That is because they need to add support for 5G and other emerging standards like UWB, while continuing to support all the frequencies and standards implemented in 4G phones. Meanwhile, the space available for antennas is actually shrinking in 5G phones as manufacturers cram other new features into handsets, such as additional cameras, facial recognition and motion sensing.

This creates antenna efficiency problems since an antenna's efficiency (its ability to minimize losses) is proportional to the antenna size as well as the transmission frequency. As the number of antennas increases and the area available for them shrinks, it becomes much harder to maintain the antenna efficiency and isolation needed to meet handset performance requirements.

Figure 1. Proportional relationship between loss, frequency use and antenna area.



Growing RF Complexity Creates Antenna Design Problems

RF complexity increases dramatically in 5G phones, due to the addition of new 5G bands and requirements like 4x4 multiple input, multiple output (MIMO), EUTRA dual connectivity (EN DC)/dual UL, mmWave, as well as emerging standards like UWB. At the same time, 5G phones must also continue to support all the existing and refarmed low-, mid- and high-band frequencies and other requirements of 4G phones, such as GPS Level 5 (L5), GPS/GNSS, 2.4 GHz and 5 to 7 GHz Wi-Fi (Wi-Fi 6E).

New 5G Bands

To deliver dramatically higher data rates, 5G uses new higher-frequency, wideband cellular spectrum. This is allocated in two main regions of the spectrum, both of which are above the frequency range traditionally used for cellular communications:

- Frequency Range 1 (FR1): These new ultra-high bands (UHB) (n77, n78, n79) use spectrum between 3.3 GHz and 5 GHz.
- Frequency Range 2 (FR2): This represents the first use of mmWave spectrum for commercial cellular communication. FR2 includes several bands above 24 GHz (n257, n258, n260, n261). Because signal propagation is challenging at FR2 frequencies, 5G phones use relatively large arrays of 3 to 4 small antennas to increase signal strength and beamforming.

4x4 MIMO

To increase data rates, 4x4 MIMO is required for most 5G bands. It is also being used for existing LTE bands where possible. This requires four cellular capable antennas, two more than in traditional 4G handset architectures, which use two independent cellular RF paths, one as a primary and the other for diversity.

Wi-Fi 6E and NR-U

With Wi-Fi 6E, the unlicensed spectrum available for Wi-Fi use is expanding not only into more complex modulation but also to an upper limit above 7 GHz, far higher than the previous upper limit of 5850 MHz. This spectrum is also proposed for use by 5G in the unlicensed spectrum (NR-U). The additional 1.2 GHz of spectrum increases the bandwidth available and number of use cases that require high data rates. However, filtering and more efficient high-frequency antenna designs are still required to ensure this spectrum can be used while handsets are simultaneously operating on other bands.

UWB

UWB is a relatively new technology that is uniquely capable of extremely precise location and distance sensing – offering accuracy within a few centimeters. It's being applied to different applications in many different industries, including proximity awareness applications and automotive applications such as keyless car entry and start.

As its name suggests, UWB transmits over a very wide bandwidth (500 MHz or greater). Initial mobile designs use frequencies between about 6.2 GHz and 8.3 GHz. UWB requires its own array of 3 to 4 antennas, which consumes a large amount of the critical space available within a handset.

Figure 2. Reduction in RF PCB and antenna year after year.

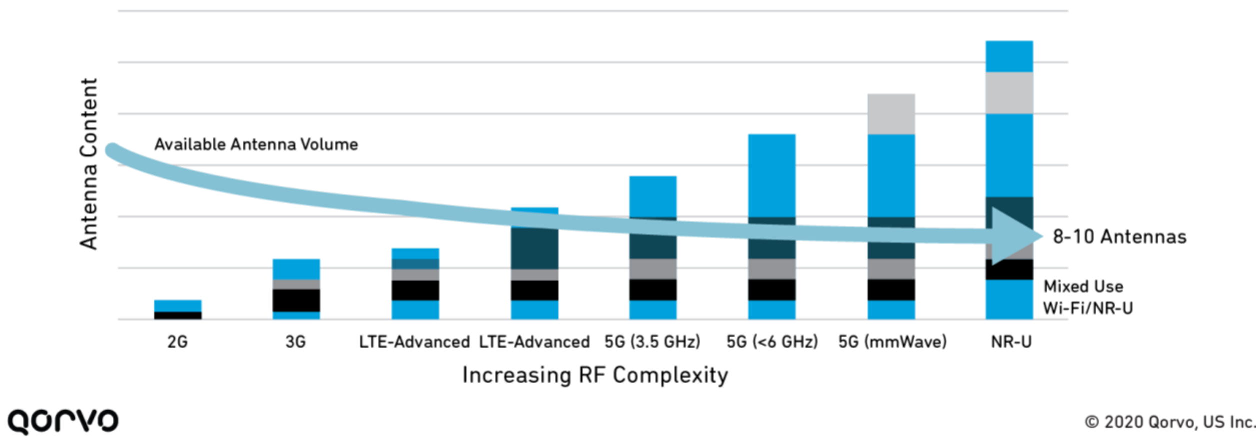
The Difficulty of Adding More Antennas to Handsets

Even as new RF requirements and standards emerge, trends in smartphone and device design are making it more difficult to add antennas while maintaining adequate antenna performance. High antenna performance requires adequate antenna volume and spacing, but evolving smartphone designs actually reduce the space available for antennas, as shown in Figure 2.

Among those trends:

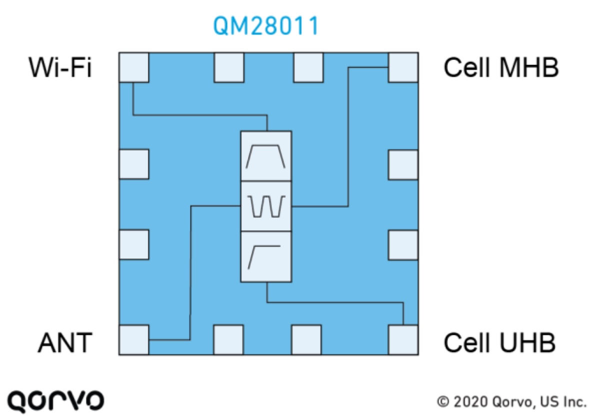
- Metal frames and smaller bezels, glass backs and edge-to-edge or wrap-around screens limit the area available for antennas.
- Addition of features that are attractive to consumers reduces the space that can be allocated to the RFFE and antennas. These features include bigger batteries for longer battery life, more cameras, motion sensing, fingerprint and facial recognition.
- Emerging designs for folding smartphones reduce the space available for antennas, since antennas cannot be placed in the hinge area.
- Wearables represent a rapidly expanding market. These extra-small form factors offer very limited space for antennas.

Figure 3. Antenna challenge in 5G handsets: 5G drastically increases RF complexity while the available antenna volume decreases.



Solving Antenna Design Problems with Antenna-plexers

Manufacturers face a tough architectural decision. They can attempt to add more antennas in an ever-shrinking area, with potential reductions in antenna performance and the resulting impact on overall handset performance. Or they can use a new alternative: Antenna-plexers, which reduce the need to add antennas – and address coexistence filtering and insertion loss requirements.



Antenna-plexers combine multiple RF filters to allow several different radios (cellular, Wi-Fi, GPS, UWB) increasing the number of bands capable of sharing a single antenna. They enable handsets to use the existing antenna area more efficiently, adding support for new bands with no impact on existing form factors or features.

Figure 4. Antenna-plexer enabling a single antenna to be shared between Wi-Fi and cellular mid-and ultra-high band frequencies.

Antenna-plexers can be used in combination with other RFFE technologies to further optimize antenna performance and compensate for reduced antenna area.

Antenna tuning. Antenna performance can be considerably improved using aperture and impedance tuning, which compensate for the reductions in size and allow a single antenna to cover more bands.

Multiplexers. These multi-filter modules enable carrier aggregation (CA) by aggregating multiple bands into a single path to the antenna.

Advantages of Qorvo Antenna-plexers

Antenna-plexers provide a broad set of advantages, including greater design flexibility for handset manufacturers, more efficient use of space, and reduced cost.

Design Flexibility

By using antenna-plexers, smartphone manufacturers have more flexibility to create innovative smartphone designs. Reducing the number of antennas means that manufacturers have fewer design restrictions, so it's easier to add other features and explore innovative form factors such as folding phones. Fewer antennas also mean fewer antenna notches in the handset case, which leads to a more appealing handset appearance and means the case has fewer weak points.

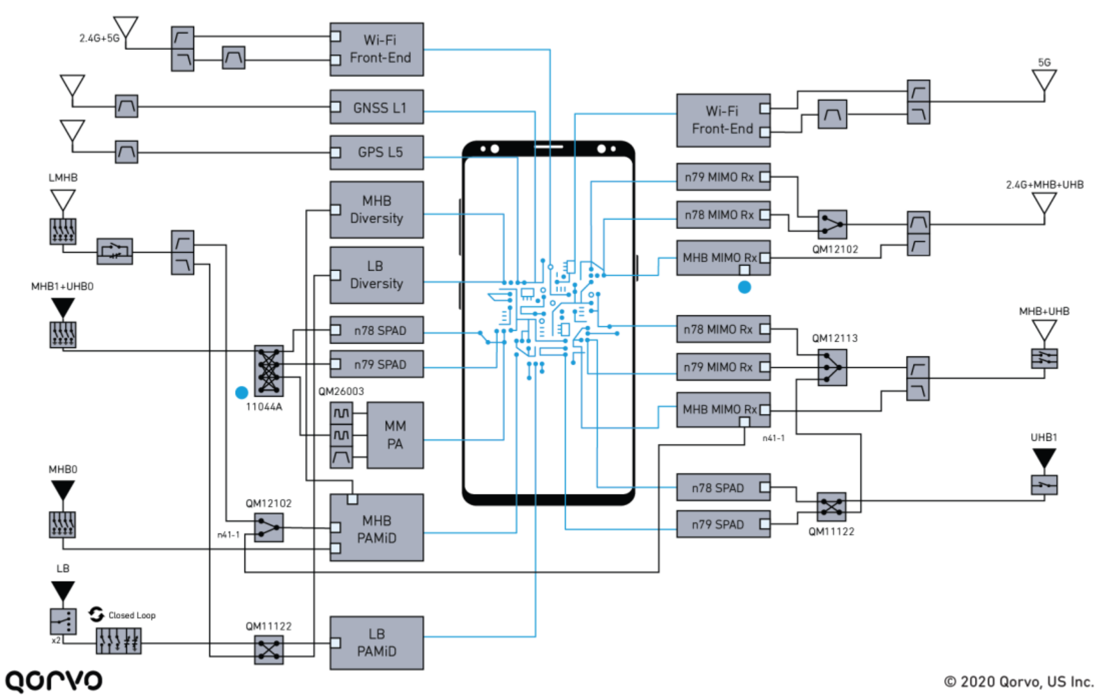
Better Use of The Available Antenna Area

Antenna-plexers allow handsets to make the best possible use of the space available: handsets can do more with fewer antennas. Antenna performance and spacing can be optimized.

Less On-Board RF Routing Reduces Cost

Fewer antennas mean there is less need for internal cabling, connectors and springs. Instead of routing separate lines to multiple antennas, you can route one combined line to a single antenna. This saves a substantial amount of space and reduces cost.

Figure 5. Demonstrating architecture without acoustic antenna-plexers.



Fewer SKUs

Antenna-plexers allow greater potential reuse of antenna architectures across different regions, which means manufacturers need fewer handset models (SKUs) to obtain broad geographic coverage. A single antenna architecture can be used across multiple regions, instead of requiring a different antenna arrangement depending on the bands used in each region. Reducing the number of SKUs can result in considerable savings in manufacturing and inventory costs.

Applying Acoustic Antenna-plexers in 5G Smartphones

Acoustic antenna-plexers can be applied to many different scenarios, depending on the specific requirements and challenges of each device.

Each antenna operates most efficiently at several resonant frequencies, which are harmonically related: the higher frequencies are multiples of the lowest frequency. The most effective way to use an antenna-plexer is to combine RF standards and bands that use these resonant frequencies and therefore can efficiently share a single antenna.

Antenna-plexers based on acoustic filters generally offer the best performance, because they provide a combination of low insertion loss, address OOB rejection for multi-band coexistence and high isolation between the RF frequencies sharing the antenna. They can also support the ultra-high frequencies used for 5G, Wi-Fi and UWB.

Figure 5 (continued). Demonstrating with antenna-plexers.

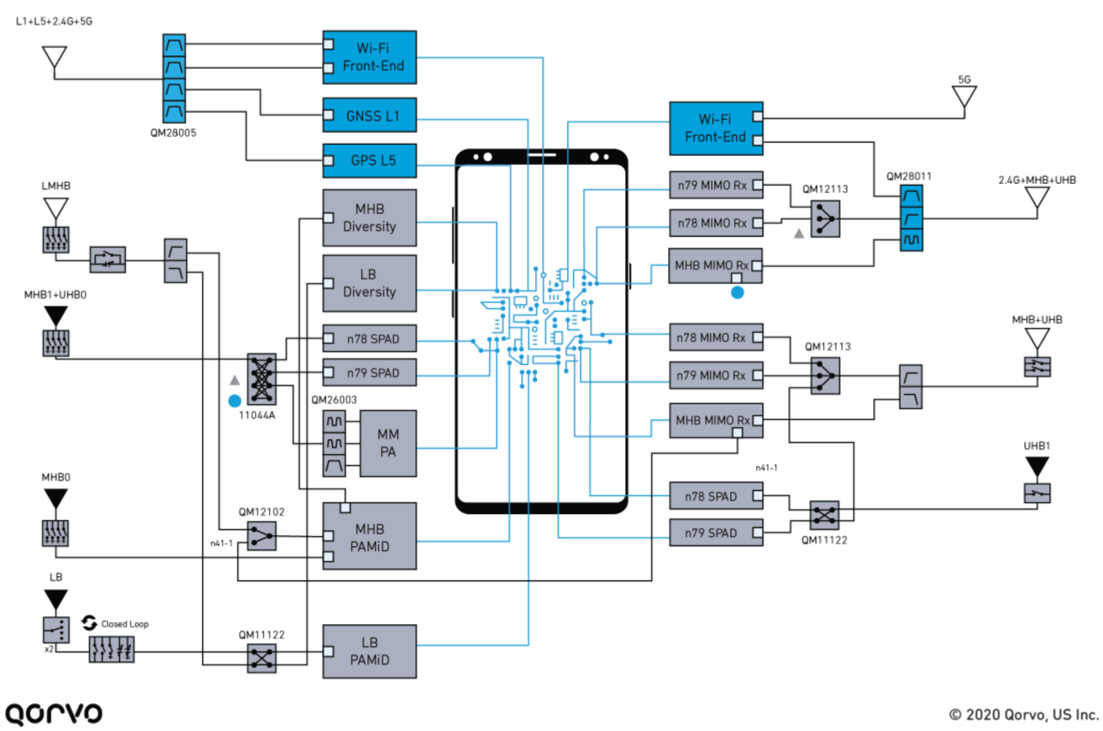
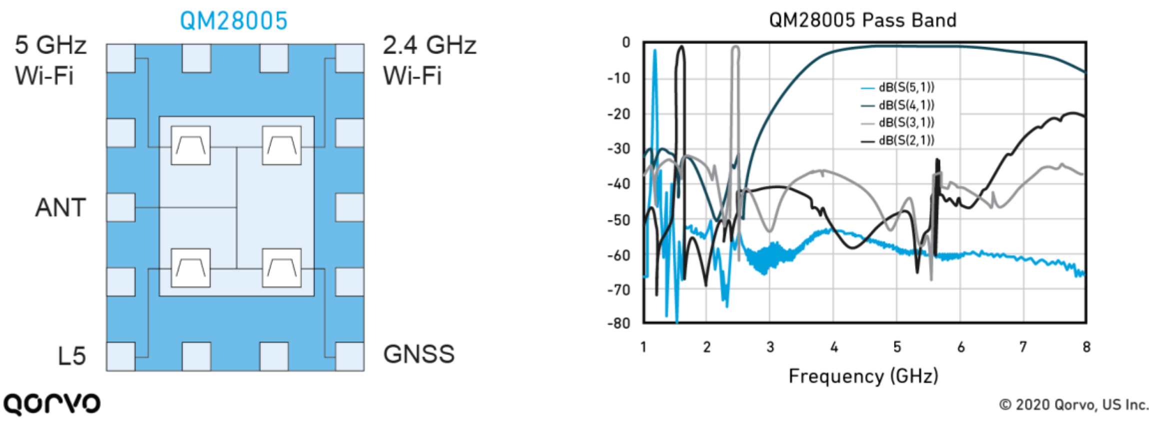


Figure 5 (continued) shows an example of an antenna-plexer that combines four acoustic filters to enable a single antenna to be shared by 2.4 GHz and 5 GHz Wi-Fi, L5 GPS and GNSS. As the performance chart shows, the antenna-plexer provides low insertion loss within the pass band for each of these signals, as well as a high degree of isolation between the signals.

Figure 6. Block diagram and performance chart for antenna-plexer that enables a single antenna to be shared by 2.4 GHz and 5 GHz Wi-Fi, L5 GPS and GNSS.



Summary

Antenna-plexers provide an elegant solution to a major problem facing all manufacturers of 5G handsets and other devices: how to accommodate ever-expanding RF complexity as the available antenna area continues to shrink. Using antenna-plexers enables manufacturers to continue adding innovative features that attract consumers, such as bigger batteries and more cameras, while delivering the full benefits of 5G.