WHITE PAPER

Overcoming the RF Challenges of Full-Screen Smartphones

Executive Summary

Smartphone manufacturers are introducing new full-screen handsets with edge-to-edge displays and an 18:9 screen aspect ratio. The form factor impacts antenna performance by reducing the space available for antennas, potentially causing problems including shorter battery life, connectivity problems, and lower data rates. Increased performance is required throughout the Tx and Rx pathways in the RF front end to compensate for antenna impacts and maintain total radiated power and Rx sensitivity.

Introduction

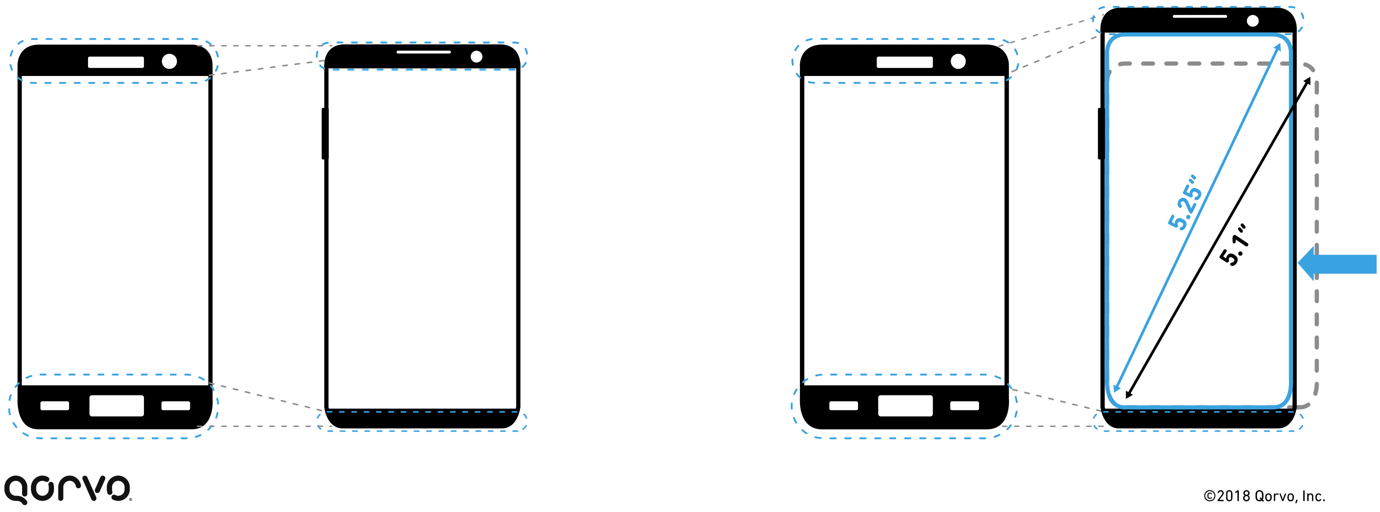
Smartphone makers continuously aim to design and build next-generation handsets that deliver a compelling user experience. This means creating devices that not only have an attractive form factor, but also provide high-performance connectivity. However, sometimes these two goals conflict: next-generation form factors make it harder to achieve the required RF signal quality, potentially compromising smartphone connectivity and data rates. The challenge for RF engineers is to enable the next-generation handset design without sacrificing RF performance.

The Antenna Space Problem

Manufacturers are moving to “full-screen” designs with edge-to-edge displays occupying nearly the entire face of the smartphone. At the same time, media format requirements are driving a shift in screen aspect ratio, from 16:9 to 18:9.

These changes reduce the space available for antennas, which must be located outside the area occupied by the screen. The antenna area is shrinking by up to 50 percent, with the bezel at the top and bottom of the screen reduced from 7-8 mm in height to 3-4 mm (Figure 1a). Phones are also becoming narrower due to the aspect ratio change (Figure 1b), so antennas must be shorter.

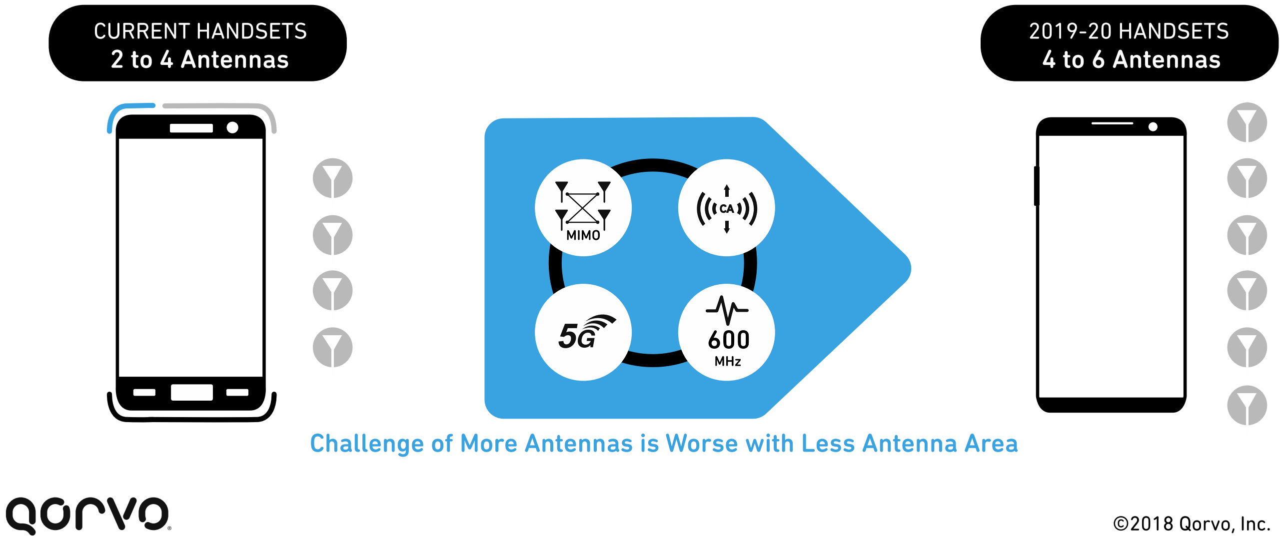
Figure 1a,b. Full-screen designs shrink the bezel area available for antennas. Phones are also becoming narrower due to the shift to an 18:9 aspect ratio.



More Antennas in Less Space

Exacerbating the problem, the typical number of antennas in the smartphone is increasing from 2-4 to 4-6, or even more, while the space available for antennas shrinks (Figure 2). More antennas are needed to deliver higher data rates using a variety of approaches, including multi-band carrier aggregation (CA), 4x4 LTE MIMO, Wi-Fi MIMO, and the addition of new 5G frequency bands. The spectrum range is growing both at the low end, with the addition of the 600 MHz band, and at the high end, with frequencies above 3 GHz coming into use.

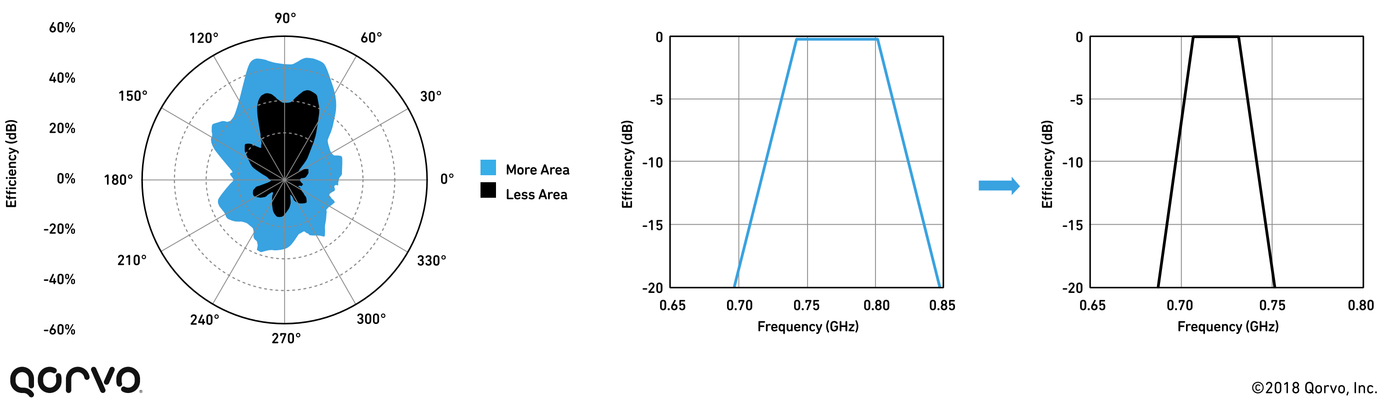
Figure 2. Full screen is part of a bigger problem: phones need to accommodate more antennas in less space.



Antenna Performance Impacts

The reductions in antenna area and length both impact antenna performance. Reduced antenna area substantially reduces antenna efficiency (Figure 3a). Bandwidth is also reduced, making it more difficult to optimize efficiency at specific bands (Figure 3b). The antenna impacts can significantly reduce Tx and Rx performance, causing problems such as shorter battery life, poor connections, reduced operating range, and lower data rates.

Figure 3a, b. Reducing antenna area impacts antenna efficiency and bandwidth.



Overcoming the Challenges

The lower antenna efficiency and bandwidth due to the full-screen design directly impact key transmit and receive RF performance metrics: total radiated power (TRP) and receive (Rx) sensitivity. Compensating for these impacts requires increased performance throughout the Tx and Rx pathways within the RF front end (RFFE).

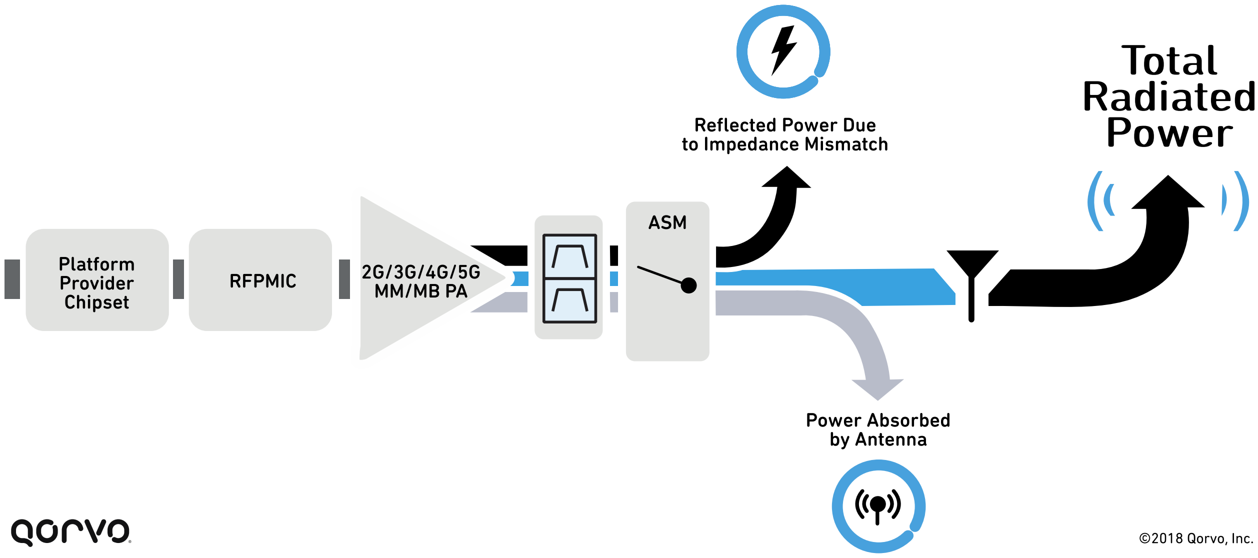
Integrated modules are key to achieving these performance improvements, while also making it possible to keep adding RF functionality within the limited space allocated to the RFFE. Integration of individual components into modules reduces signal loss caused by on-board matching. Integration also helps manufacturers simplify and accelerate handset design and development. The simplified design and improved performance reduce the risk of missing target dates for product release and carrier non-compliance.

Below we review key design approaches that engineers can use to address the full-screen challenges.

Increasing Total Radiated Power (TRP)

To increase TRP, it is necessary to maximize the performance of key components in the Tx pathway (Figure 4). These include the power amplifier (PA), filters and antenna tuners.

Figure 4. Stages in the RF pathway that affect TRP.



Advanced PAs Increase Linear Power Output and Efficiency

Increasing PA output power is a key first step in delivering higher TRP. The challenge is to increase PA output power while maintaining linearity, minimizing current consumption and avoiding thermal issues.

Increasing power output is becoming even more important with the industry adoption of the new Power Class 2 (High Performance User Equipment) standard. The Power Class 2 specification doubles output power at the antenna to 26 dBm to overcome the greater propagation losses at high frequencies. Mobile operators are beginning to use Power Class 2 to increase coverage for Band 41.

Advanced manufacturing processes and packaging technology are required to achieve the goals of higher PA power output, linearity, efficiency, and thermal performance. Qorvo utilizes the proprietary HBT5 GaAs process, which delivers industry-leading linear power output and power added efficiency (PAE). HBT5 also provides a significantly higher median lifetime improvement compared with earlier processes, which allows operation at higher current density for increased gain and power efficiency. Thermal performance is enhanced by advanced packaging, using copper pillars to efficiently dissipate the heat produced at higher power levels.

Qorvo's Gen-5 portfolio of RF Flex™ RF front end modules integrate PAs, low-loss switches and other core components, helping to deliver increased LTE power output in full-screen designs. The RF Flex Gen-5 QM56022 multi-band PA module, which includes high-, mid-, and low-band PAs together with post-PA switches, increases LTE power output by > 1dB, helping to meet operator requirements for Power Class 2. The RF Flex Gen-5 QM57508 transmit module features a 2G PA, low-loss switch and an antenna coupler to deliver 0.5 to 1dB more 2G power.

Improved Power Management

Power management components can be used in conjunction with compatible PAs to maximize power output while minimizing current consumption. Qorvo PAs including the QM56022 are compatible with envelope tracking (ET) solutions, which optimize efficiency by continuously adjusting the PA supply voltage to track the RF envelope. For average power tracking (APT) applications, an alternative approach is to use a voltage boost component such as the Qorvo QM81050. This increases the supply voltage to the PA when higher output power is required, such as when the user is farther from the mobile network base station.

Filters

Each year, engineers depend more and more on RF filters to manage interference, with today's phones supporting up to 40 bands as well as other wireless technologies such as Wi-Fi and Bluetooth. Low-loss filters, including duplexers and multiplexers, are essential to minimize post-PA losses in order to help achieve the goal of higher TRP. In addition to offering low insertion loss, filters must be able to handle the higher power produced by the PA in full-screen designs. Qorvo BAW solidly mounted resonator (SMR) filters are designed and validated for high-power applications, including Power Class 2. BAW SMR filters efficiently dissipate heat through a solid reflector stack, providing lower thermal resistance and a shorter thermal time constant.

BAW filters deliver the greatest benefits at frequencies above 1.5 GHz, and are used for many higher-frequency LTE bands. This makes them a good fit for new and refarmed high-band and ultra-high-band spectrum that will be used for 5G.

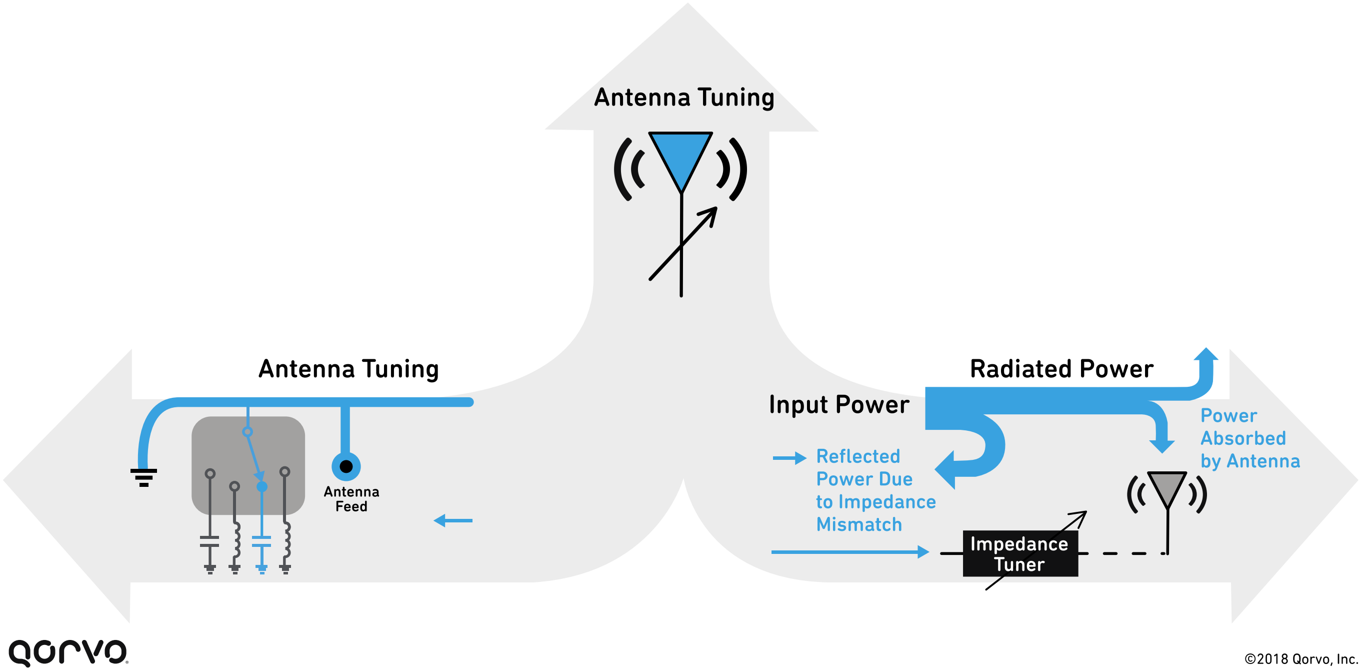
Antenna Tuners

Antenna tuning makes a huge difference in full screen designs, helping to improve battery life and data rates. Antenna tuning commonly increases TRP by as much as 3 dB. This can substantially improve handset battery life, because less current is needed to produce the required power at the antenna.

Antenna tuning is becoming even more important as the number of antennas continues to increase and the available space decreases. Smartphones may use antenna-tuning solutions for multiple antennas. Antenna tuners deliver the biggest benefit in the low band, where the need is greatest because low-band transmissions are the most heavily impacted by the reduced antenna area in full-screen designs.

Smartphones can utilize two approaches to antenna tuning. Aperture tuning (Figure 5) is particularly important for optimizing antenna efficiency across multiple bands, as well as compensating for environmental effects such as the user's hand position. Impedance tuning increases TRP by reducing the power reflected at antenna due to impedance mismatch. Qorvo is the industry leader in mobile antenna tuning solutions, with a broad portfolio of aperture and impedance tuning products based on low-loss switches offering superior on-resistance (Ron) and off-capacitance (Coff).

Figure 5. Impedance and aperture tuning.



Increasing Rx Sensitivity

High-performance RFFE components such as antenna tuning solutions, low-loss filters and duplexers, and low noise amplifiers (LNAs) are equally important for increasing Rx sensitivity in full-screen designs. Together, these can increase Rx sensitivity by several dB, compensating for the reduced antenna size and improving the user experience by increasing operating range and data rates.

Antenna Sharing

Looking ahead, antenna sharing is becoming an increasingly important approach for accommodating the increasing number of antennas in full-screen handsets. Antenna sharing enables a single antenna to be used for multiple purposes, reducing the need to add antennas and helping to avoid performance degradation. Innovative RFFE solutions will be required to enable antenna sharing and keep the number of antennas within manageable limits as RFFE complexity continues to increase.

Summary

High-performance RFFE solutions are essential to compensate for the antenna impacts caused by the transition to full-screen handsets and the 18:9 screen aspect ratio. Increased performance is required throughout the Tx and Rx pathways to maintain TRP and Rx sensitivity while minimizing power consumption. Qorvo provides the industry's broadest portfolio of solutions to help overcome the challenges, including high-power PAs, low-loss filters and antenna tuners.

About Qorvo

Qorvo (NASDAQ:QRVO) makes a better world possible by providing innovative RF solutions at the center of connectivity. We combine product and technology leadership, systems-level expertise and global manufacturing scale to quickly solve our customers' most complex technical challenges. Qorvo serves diverse high-growth segments of large global markets, including advanced wireless devices, wired and wireless networks and defense radar and communications. We also leverage our unique competitive strengths to advance 5G networks, cloud computing, the Internet of Things, and other emerging applications that expand the global framework interconnecting people, places and things. Visit **www.qorvo.com** to learn how we connect the world.