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5G Handsets Spark mmWave Debate

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Smartphone race faces fractured frequencies

SAN JOSE, Calif. — Engineers are racing to deliver the first smartphones supporting 5G networks, mainly targeting frequencies below 6 GHz. RF experts are sharply divided over whether any of the first batch of devices will support the standard's millimeter-wave bands.

All sides agree that the handsets face a fractured market, with carriers supporting frequencies spanning 600 MHz to 28 GHz, some guarding details of their spectrum plans. As a result, an optimized 5G world phone could be years away.

First-generation handsets will probably target specific regions with devices that may be slightly larger or have shorter battery lives than last year's LTE models. Price tags may inch up to stay in line with bills of materials estimated to increase 10% to 30% just for RF front-end components.

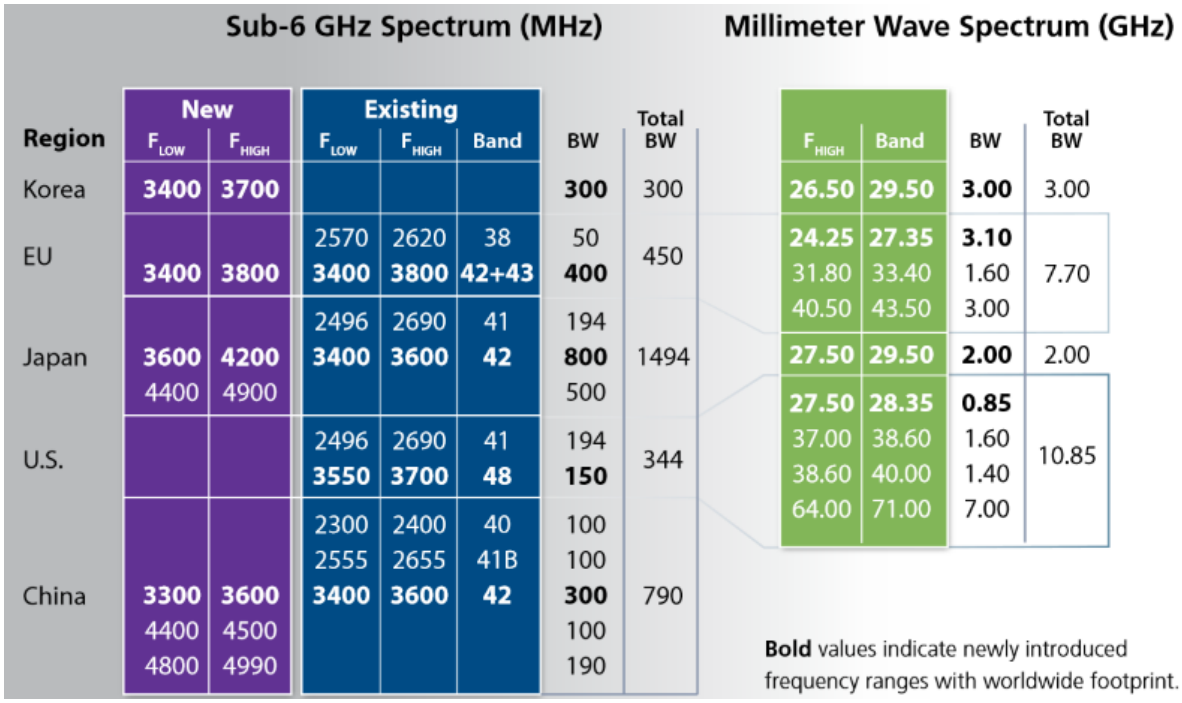
The transition to LTE faced similar problems but not at the scale of 5G, the first cellular standard to support bands at 28 GHz and up. In addition, while many countries will support 5G in 100-MHz swaths in the 3.5-GHz band, that band won't be available in the U.S. until sometime next year. Even then, the U.S. spectrum is expected to be at much smaller bandwidths, less than ideal for 5G.

With a lack of new spectrum for 5G in the U.S., T-Mobile is launching a network in a 600-MHz band that it has available while Sprint will use 2.5 GHz. A Verizon representative confirmed that it will use mmWave bands for smartphones next year.

The speed and breadth of the changes are taking the art of designing a smartphone to new heights.

"Everyone wants to claim a first in 5G, so people are designing hardware before the numbers are nailed down, and that creates headaches … overall, 2019 may be a year of the first rush of less integrated [handsets] with Band-Aids and teething problems," said William Mueller, a principal technology strategist in Broadcom's cellular group.

Blame carriers in a hurry to recoup spectrum efficiencies from the 5G standard, said Ben Thomas, director of technical marketing at Qorvo. “OEMs are under a tremendous amount more pressure than with LTE,” he said, recalling how Samsung shipped an extra battery with its first LTE phones.



Sub-6 GHz Spectrum (MHz)

Region	New F_{LOW}	New F_{HIGH}	Existing F_{LOW}	Existing F_{HIGH}	Existing Band	BW	Total BW
Korea	**3400**	**3700**				**300**	300
EU			2570	2620	38	50	450
	3400	**3800**	**3400**	**3800**	**42+43**	**400**	
Japan			2496	2690	41	194	1494
	3600	**4200**	**3400**	**3600**	**42**	**800**	
	4400	4900				500	
U.S.			2496	2690	41	194	344
			3550	**3700**	**48**	**150**	
China			2300	2400	40	100	790
			2555	2655	41B	100	
	3300	**3600**	**3400**	**3600**	**42**	**300**	
	4400	4500				100	
	4800	4990				190	

Millimeter Wave Spectrum (GHz)

F_{HIGH}	Band	BW	Total BW
26.50	**29.50**	**3.00**	3.00
24.25	**27.35**	**3.10**	
31.80	33.40	1.60	7.70
40.50	43.50	3.00	
27.50	**29.50**	**2.00**	2.00
27.50	**28.35**	**0.85**	
37.00	38.60	1.60	10.85
38.60	40.00	1.40	
64.00	71.00	7.00	

Bold values indicate newly introduced frequency ranges with worldwide footprint.

The need to support more frequency bands grows significantly with 5G *Click to enlarge. (Source: Skyworks)*

Bulls and bears on mmWave devices

Ted Rappaport, a New York University professor and veteran wireless researcher, is the most bullish on millimeter-wave handsets. “I expect to see handsets from multiple vendors by Christmas,” he said, noting that Intel and Qualcomm reported progress with the technology at an event he hosted in April.

Rappaport points to years of research that he and colleagues conducted at the NYU Wireless center he founded. The use of more antennas in a confined space provides greater gain, compensating for path loss. The higher data rates that result can make up for higher power consumption, he added.

Perhaps the biggest skeptic is Ali Sadri, a mmWave specialist at Intel who drove the 60-GHz WiGig standard for Wi-Fi. “I don’t think anyone will put out a [millimeter-wave] handset anytime soon,” said Sadri, who founded the WiGig Alliance, folded into the Wi-Fi Alliance in 2013.

Millimeter-wave technology “has a lot of challenges and takes a lot of expertise,” he said. “It’s catching up, but it’s still going to take a few years to come along … we’ve had WiGig for 10 years and few people are using it.”

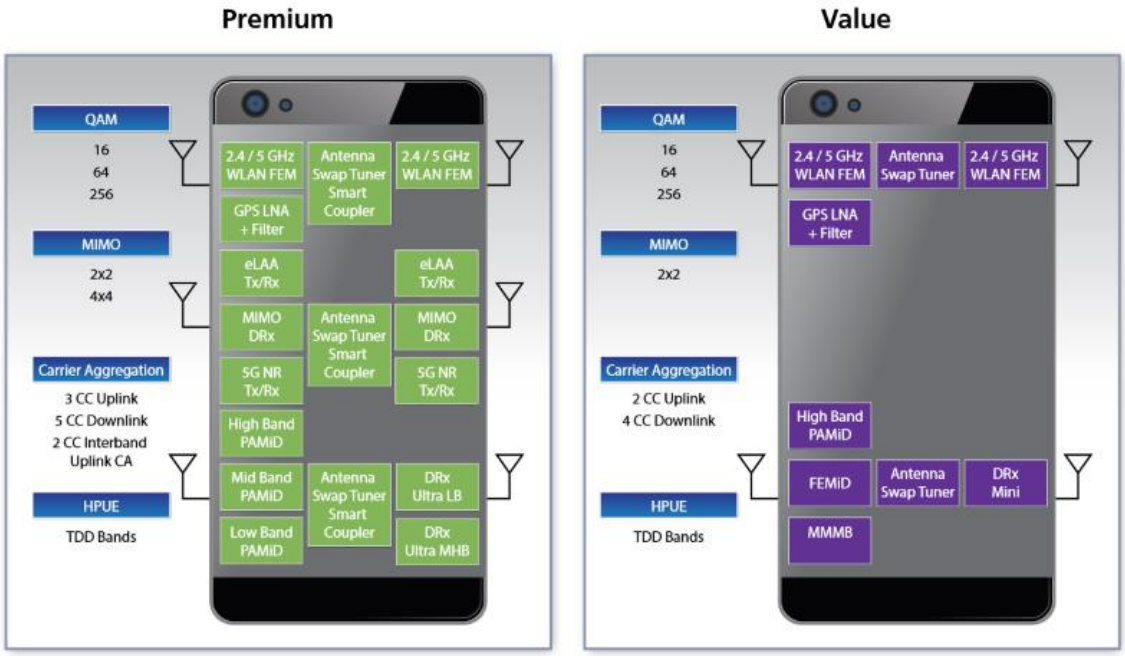
Challenges include creating novel filters, power amplifiers, and phase shifters suitable for mmWaves as well as combining signals from multiple antennas to form and point directional beams. In addition, handsets need to place antennas away from metal circuit boards and deal with hands obstructing signals, said Chris Barratt, CTO of Insight SiP, a wireless module designer.

Compared to familiar cellphone bands below 6 GHz, "high frequencies are a different ballgame … I think it will eventually come to fruition but not for a couple of years," said Barratt, who worked on multiple 60-GHz designs.

Qualcomm announced in July that it solved the problems in handset modules that it is sampling for 20- to 40-GHz networks. One analyst predicted that the modules could help China's rising handset makers get a jump on Apple, Samsung, and Huawei, which prefer to specify their own components.

RF rivals Broadcom, Qorvo, and Skyworks expressed skepticism. All three vendors of sub-6-GHz RF silicon have no immediate product plans for mmWave components. Meanwhile, startup Movandi said that it is trying to evolve its mmWave technology for base stations into the handset space.

Chris Pearson, president of 5G Americas, a trade group for carriers and their suppliers, took a middle ground. "New frequencies always have challenges, but these are innovative companies and they have added new frequencies in the past," he said.



RF front end chip content will expand with 5G. *Click to enlarge. (Source: Skyworks)*

A long and winding roadmap

Given the technical, business, and time-to-market challenges, "we won't see real optimized 5G handsets until 2021 in the flagship space, and mid-tier 5G phones will come after that … the RF designs have multiple years of complexity to work through," said Thomas of Qorvo.

Designs tailored for regionally fragmented bands "means less utilization of components across handsets," raising questions about "when designers make fundamental shifts to accommodate increased chip content," he said.

Ultimately, "we will see a fairly radical shift in what an RF front end looks like," he added, predicting more antenna tuning across a nearly doubled frequency range.

The Qorvo exec also foresees more levels of higher-quality filters. In addition, multiplexers will replace simpler switches to support more complex carrier aggregation schemes. "We're already seeing as many as six bands combined and used simultaneously," he said.

When the dust begins to settle in 2021, new standard RF modules may emerge in areas such as the 3.5-GHz band. Qorvo is already discussing ideas for modules with partners and rivals, including Skyworks.

5G designs could evolve into two modules, said Mueller of Broadcom. The separation would serve antenna diversity and mitigate interference from simultaneous LTE and 5G transmissions under the non-standalone architecture, he said.

"The toughest thing is the power efficiency," said Rappaport of NYU. "It will take a couple of generations of designs to find the tricks needed to get what we want at mmWave frequencies."

In the end, there's no doubt that 5G handsets will start emerging over the next several months. Sprint already announced that LG Electronics will provide it a 5G smartphone before June. But whether the handsets ride mmWave frequencies and how they evolve their RF designs remains to be seen.

— Rick Merritt, Silicon Valley Bureau Chief, EE Times

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