THE IMPORTANCE OF LEADING-EDGE MODEM TECHNOLOGY

EXECUTIVE SUMMARY

As power consumption of smartphone processors and displays continues to decrease, modems become a focal point of the power consumption discussion. The modem is, without a doubt, one of the most crucial parts of the smartphone in today's connected society. With 4G LTE, users consume orders-of-magnitude more data than with 3G. Increased consumption, paired with the advent of cloud technologies, requires that smartphones always be connected to the network—always sending data back and forth. As a result, **the modem and RF frontend have become pivotal components of the smartphone** in enabling connectivity and doing so without impacting battery life.

Modem vendors have undertaken efforts to improve not only the performance of their modems but also power consumption as well. The combination delivers the best experience for the end user, and it also brings benefits to the wireless carrier. In the US, wireless carriers themselves are the predominant smartphone purchase channel, and carriers prefer their smartphone vendors to adopt the most efficient and highest throughput modems available. This preference improves the overall experience that their customers have on their network, and it maximizes carriers' network efficiency.

This paper describes test results of LTE modems from Qualcomm and Samsung on throughput and power consumption as well as Qualcomm's antenna tuner capability.

TEST RESULTS

CATEGORY 4 LTE THROUGHPUT COMPARISON

Using band 3 LTE (1800 MHz) and a Qualcomm Snapdragon 810 test smartphone versus a Samsung Galaxy Alpha (SM-G850K) with a Samsung Exynos 303 modem, there were interesting performance differences between the two at a network simulated signal strength of -65 dBm on Category 4 LTE. Category 4 LTE was tested because both modems were tested in a 20 MHz configuration although both devices are capable of faster than Category 4 speeds.

Using an Anritsu MD8430A signaling tester with an MF6900A fading simulator, the Qualcomm test smartphone (with Snapdragon 810 SoC) managed a maximum Category 4 LTE downlink throughput of 87.5 Mbps. The Samsung Galaxy Alpha managed a throughput of 72.5 Mbps under the same signaling conditions and test configuration—a difference of 20% between Qualcomm's and Samsung's S300 modem at Category 4 LTE speeds. Tests in Korea on live LTE-A networks, like Signals Research had done with the LG G Flex 2, found that the Snapdragon 810 reached average downlink speeds of 158 Mbps and a maximum of 296.5 Mbps with speeds exceeding 200 Mbps for over 30% of the time.[1]

Having 20% faster speeds means that downloads in many cases will be finished much faster, so the device will need to connect to the network for a shorter time. Shorter connection time benefits both the carrier and the user. Carriers have fewer concurrent connections to their towers pulling down data, and users get better smartphone battery life while the modem is on for shorter periods of time. The inherently bursty nature of today's high-speed modems means that **the faster the bursts, the less time the modem needs to be powered on**. The real world benefit to end users is less time spent downloading image and video files. As image and video files become more high-resolution, carriers need to push these files more quickly to users' devices. A 20% faster network connection means that users will get their files faster and use less power.

Category 9 LTE Throughput

In tests, the Snapdragon 810 test smartphone obtained Category 9 LTE performance. This was achieved with two Anritsu 8430A signaling testers to simulate three different signals, each at 20 MHz combined via Carrier Aggregation for speeds up to 450 Mbps. The antennas in the device were directly connected to the Anritsu signaling testers which are designed to simulate a cellular tower. Then, the device was directly connected via USB 3.0 to a PC which measured overall UDP throughput.

The test was done on the Snapdragon 810 MTP with bands 3, 7, and 7 and is capable of all 3GPP 3-band CA configurations. The tested bands correspond to frequencies of 1800 MHz, 2600 MHz, and 2670 MHz. Using these bands and this test setup obtained application layer speeds between 440 Mbps and 450 Mbps. The average speed due to

[1] Signals Research Group: Signals Flash, February 19, 2015

the primary cell's fluctuation from control channel overhead resulted in real speeds closer to 442 Mbps.

Qualcomm's Snapdragon 810 chipset's modem is well ahead of its competition and represents speeds unmatched by any competitor at this point. Qualcomm is the only company delivering Category 9 (450 Mbps) speeds and 3 CA aggregation. Competitive products support only Category 6 LTE, which has downlink speeds of only 300 Mbps and uplink speeds of 50 Mbps due to only having 2 CA aggregation. This means that Qualcomm's modem is capable of an extra carrier on their modems compared to their competitors, which could include some unlicensed bands in future chipsets and may actually be a possibility relatively soon. Most carriers are only now capable of multiple bands, but have yet to implement more than 2-band Carrier Aggregation, enabling speeds of up to 300 Mbps.

Wireless 100 Mbps real world speeds are still unattainable in most of the US. Part of that may be because carriers simply don't have enough 20 MHz blocks of spectrum. Another part may be because the devices haven't really supported it—yet.

Category 4 Modem Power Consumption

In this scenario the testing was done once again via LTE, but by fully saturating LTE Category 4 with 150 Mbps downlink and 50 Mbps uplink. This scenario used band 1 (2140 MHz) and 20 MHz width with 64-QAM modulation for downlink and 16-QAM for uplink. This was done on three identical Rohde & Schwarz CMW 500 wideband radio communication testers with the identical settings.

Each device was tested directly at the battery if possible. Current was measured by three identical GW Instek PSM-2010 power supplies which fed readings into a Xerxes hardware power monitor which was connected to the PC via USB to feed back the power measurements. The measurements fed into the Xerxes software which continuously tested the device's power consumption while pushing full Category 4 LTE uplink and downlink. The Xerxes software then took a 20-second interval of the testing and found the maximum, minimum, and average power consumption over this interval.

- The Samsung Galaxy Alpha had an average power consumption of 259 mA in a range between 202 mA and 356 mA.
- The LG G Flex 2 had an average power consumption of 248 mA in a range between 199 mA and 372 mA.

- The Qualcomm Snapdragon 810 test smartphone had an average power consumption of 232 mA in a range between 175 mA and 318 mA.

Although the LG G Flex 2 (which is also a Snapdragon 810-based device) will ship in the US shortly, the model that was tested was a pre-production version, and it likely doesn't fully represent the final power consumption of the G Flex 2. On average, the pre-production LG G Flex 2 performs better than the Samsung Galaxy Alpha, and it will likely improve upon release. Nonetheless, the numbers we have now show the Snapdragon 810 reference device is still more power efficient under full Category 4 LTE load.

Figure 1: Power Consumption: 4G LTE Category 4 Fully Saturated

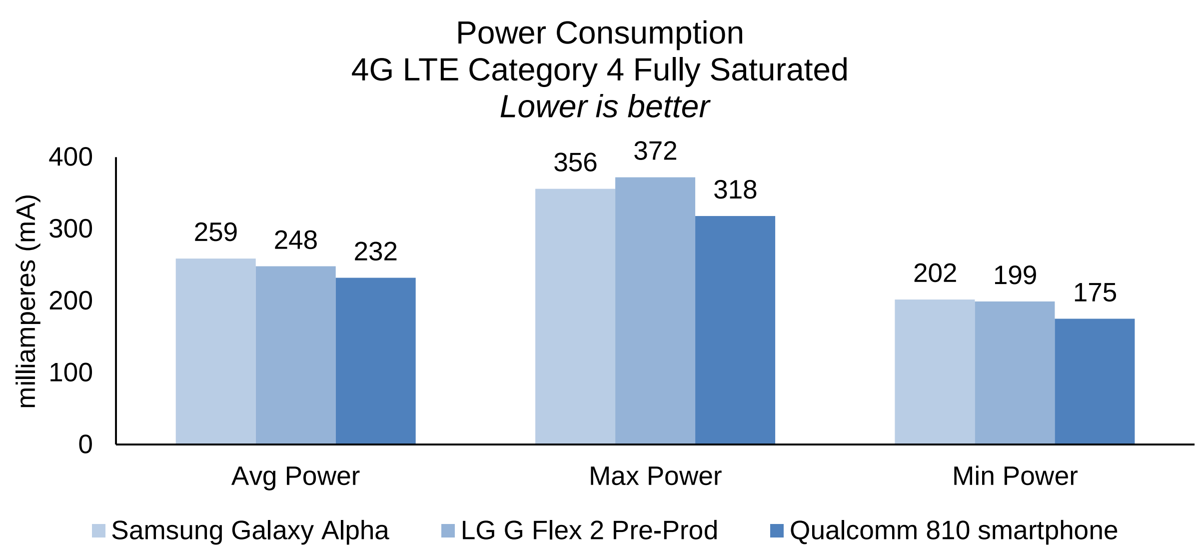

Table 1: Power Consumption Comparison: Baseline = Qualcomm 810 Test Smartphone

Device	Average Power	Maximum Power	Minimum Power
Qualcomm 810 test smartphone	100%	100%	100%
LG G Flex 2 pre-production	107%	117%	114%
Samsung Galaxy Alpha	112%	112%	115%

Between the LG G Flex 2 and the Samsung Galaxy Alpha, there was a 5% difference in average power consumption. The difference between the Snapdragon 810 test smartphone and the Samsung Galaxy Alpha was 12% which represents the best case scenario for Qualcomm's modem. A 5% to 12% improvement is fairly large in phones with 10+ hour battery life. In some cases, users could see an hour more battery life. However, the display would likely consume more power than the modem in such scenarios (all of the tests were run with displays turned off). Even so, a more power-hungry modem ultimately results in less time that the phone is on, so even a few critical minutes difference could be gained easily from 10% lower power consumption.

At the time of testing, these were the latest modems available. Tests compare common LTE modes across the most recently available Samsung modem, the CMC303.

Antenna Matching Tuner

Antenna tuners are becoming more important in smartphones to avoid scenarios like Apple's well known antenna problem due to certain types of users' grip. Antenna issues have existed for some time on many devices, and some smartphone manufacturers recognize the importance of **tuning** antennas to prevent such issues. An impedance mismatch between the antennas and the RF frontend is generally what causes these issues. When the mismatch is too great, the signal weakens and drops by a few dBm.

However, simply having an antenna tuner isn't enough. The tuner should communicate constantly with the modem to prevent connection loss at the cell edge or when antennas are blocked by a human hand or head. Some of the leading edge RF frontend manufacturers, like Qualcomm, have implemented closed loops that use smart algorithms to compensate for antenna blocking and cell edge scenarios. This dynamic tuning ability is inherently enabled through these closed loops which are powered by the intelligence and compute within the modem itself. The end result is that when the loop is closed and the algorithm is working correctly, devices are able to stay connected to the network even in poor coverage when they otherwise would be unable to. Qualcomm's antenna tuner, combined with their modem, allows them to reduce this impedance mismatch and overall improve the signal strength and transmit power.

In LTE band 17 (700 MHz) testing at 10 MHz bandwidth, path loss was increased by 30 dBm to simulate a cell edge scenario. The modem—in concert with the rest of the RF frontend including the antenna tuner—was able to maintain a connection. By having a closed loop, the antenna tuner was able to communicate constantly with the modem to adjust the match between the antennas and the RF frontend to acceptable levels. Once the loop was opened, the modem no longer regularly communicated with the antenna tuner, and the transmit signal power dropped to -28 dBm. At -31 dBm the connection was dropped. When the loop was closed and enabled, the power went up to -26 dBm, and a connection was re-established eventually. This -5 dBm difference is essentially what means the difference between having signal on the cell edge or not. When the loop was closed, the return loss was reduced to only -13 dBm rather than -5 dBm when the loop was open, which is a significant improvement and explains the measured transmit power difference.

Table 2: Antenna Matching Tuner: Open vs. Closed Loop

Cellular Scenario	**Loop Open**	**Loop Closed**
Cell center	1 dBm	3 dBm
Cell edge	-28 dBm	-26 dBm
Impedance mismatch, return loss	-5 dBm	-13 dBm

Higher is better, except in return loss

Additionally, even in scenarios where signal strength is fairly good (near the cell center), the amount of power consumed can be reduced thanks to improved signal strength. Also using LTE Band 17 for testing, there was an improvement of about 2 dBm for the received signal strength (using the same Anritsu MT8820C by setting up the device about a foot away from the antenna connected to the Anritsu radio communication analyzer). The improvement from 1 dBm to 3 dBm by closing the loop translates to **reduced modem system power consumption of 67%** and an overall better experience by the user.

All LTE Modems are Not the Same

There is quite a bit of value in having a cutting edge modem for both performance and power purposes. Both inevitably affect the users' experience on their handsets or tablets with 4G LTE connectivity—which is nearing ubiquitous coverage in most countries. As cloud technologies continue to become more prevalent around the world, the need for more power efficient and intelligent modems will only increase. The burden is on the device manufacturers to make the right decisions on the modems they choose to put in their devices.

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