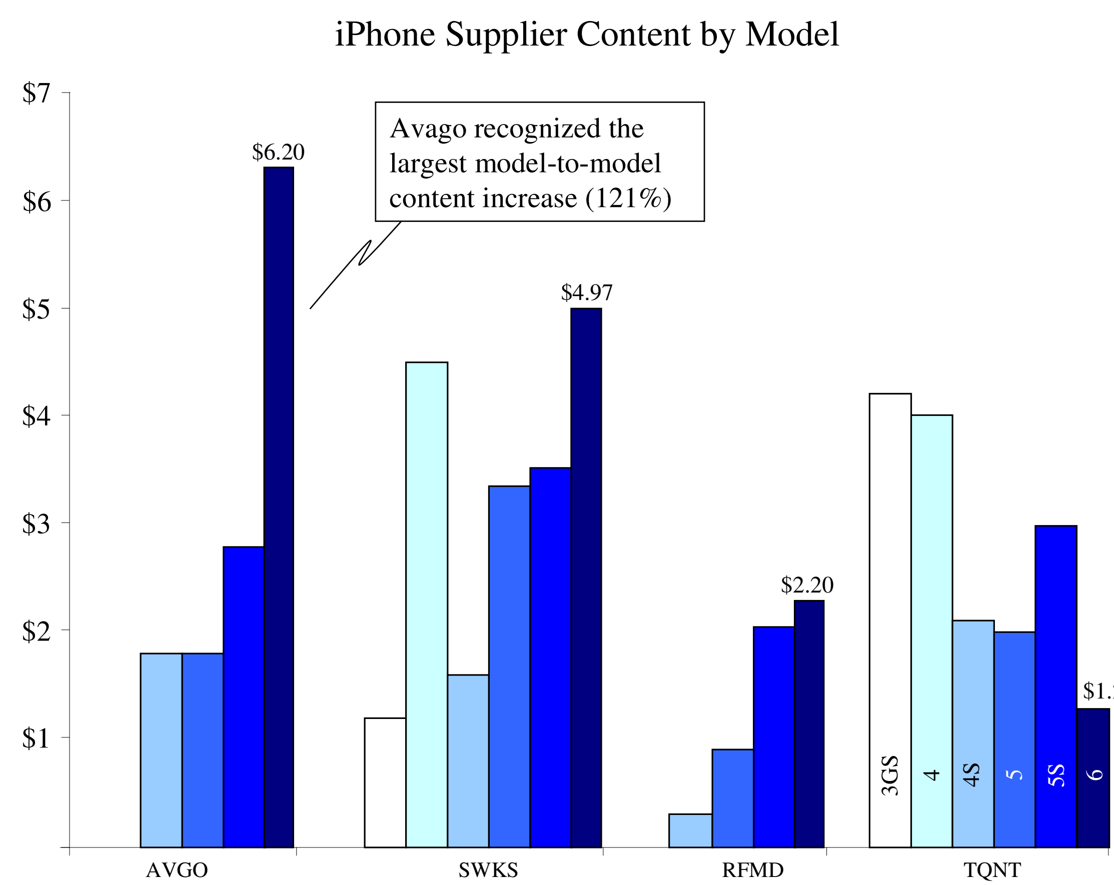
Edward Snyder
Managing Director
Ph: 415.931.9955
esnyder@charterequityresearch.com

iPhone 6: A detailed teardown analysis

Higher content, fewer SKUs; expect more of the same in 2015.

Apple's philosophy of minimum SKUs pushes total RF content up again. Contrary to what we thought two years ago, rather than segment its phones by region to reduce BOM costs, Apple has taken the opposite path, and decreased the number of RF SKUs to two with iPhone 6. This has increased the number of bands, as well as the complexity and cost per phone. Even if the unthinkable occurs and unit volumes are flat y/y, total dollars spent on RF by Apple will increase about 30% on higher content alone. As we expected, Avago has the highest content in the new phone with an estimated $6.20, and also the largest model-to-model increase (~120%). As we predicted on Monday's conference call[1], the company won the mid and high band PADs, the two most expensive components in the RF section, as well as the WiFi coexist filter. Skyworks secured a good portion of the analog content, landing the 2.5G/5G WiFi amplifiers for most phones[2] and the GPS LNA module in all SKUs. We believe the company also supplies the QBE PAM and ultra low band PADs for all models, as well as the low band PADs for the iPhone 6 (not iPhone 6 Plus), yielding about $4.97 in content, up 46% from iPhone 5S/C. RF Micro Devices has once again demonstrated its strength in switching by winning the antenna switch, antenna tuners, and the diversity switch in all models. We estimate these sockets total about $2.20, which is up 8% from total content in iPhone 5S/C. We also believe the company will supply the ultra-low band PAD in the next iPad, which should be announced in October, but relatively low volumes[3] for tablets will limit the revenue impact of the win. With ~$1.30 in content, Triquint is the only RF semi manufacturer to experience a model-over-model decrease (down about 57%), which we believe is the result of distractions brought on by the merger. The company was selected to supply the low band PADs for iPhone 6 Plus and the WiFi amplifiers for one model. The 28% increase in RF content across what we expect will be higher unit sales will once again make Apple the most valuable customer for RF semiconductors. We don't expect this to change anytime soon.



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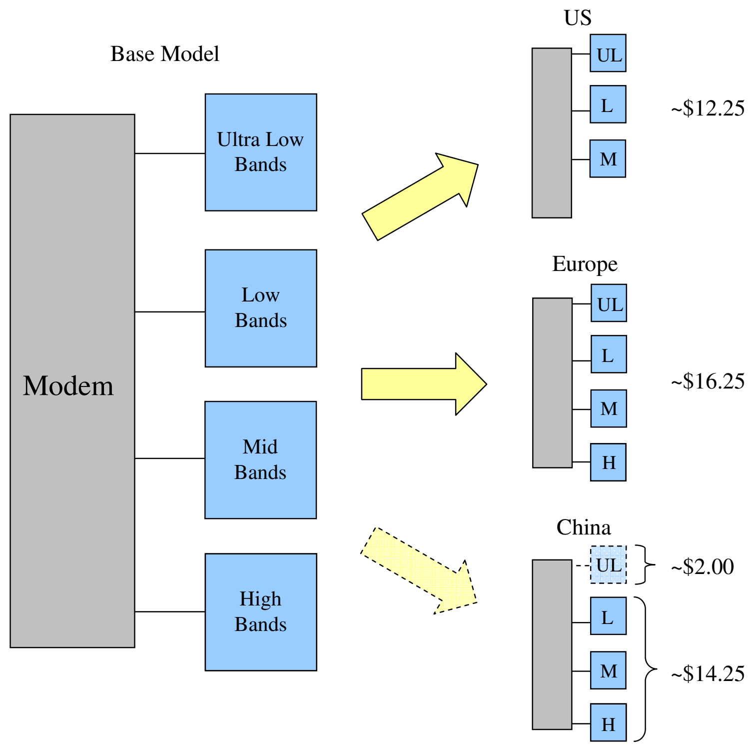
iPhone Content History

($)

	iPhone 6	iPhone 5S/C	iPhone 5	iPhone 4S
AVGO	6.20	2.80	3.00	1.80
SWKS	4.97	3.40	4.25	1.60
TQNT	1.29	2.98	1.60	2.10
RFMD	2.20	2.03	-	0.30

U.S. and Europe models available at launch; Chinese phone delayed. Just as Intel's fascination with Moore's law has guided the company's product map, Apple has become notorious for packing increasingly more bands into every new phone. iPhone 6 is the latest, and most expensive, example of this. We believe the average RF content of this phone is about 30% higher than iPhone 5S/C. The European/Asian SKU supports 20 LTE bands and has the highest RF content, totaling about $16.25. By dropping support for TD-LTE bands (China), Apple was able to reduce its RF costs to approximately $12.25 in the U.S. model. We believe the absence of China in the list of countries to first receive iPhone 6 is the result of political issues, and it remains unclear whether Apple will use a different architecture for the SKU. If it drops the ultra-low band PAD that supports U.S. LTE bands in the Chinese model, it could reduce BOM costs by about $2.00[4], but that would make roaming between North America and China difficult. Apple's pursuit of the fewest SKUs suggests it's likely that the OEM will include support for all bands in its Chinese model, making it identical to the European phone. This would push blended content to $14.65, representing a 28% increase over iPhone 5S/C.

iPhone 6 RF SKUs



iPhone 6 RF Supplier Content by Model Breakdown

Model A1549 (iPhone 6 US)

Function	Part	AVGO	RFMD	SWKS	TQNT	Total
		Content ($)				
	Total Content ($)	**3.80**	**2.20**	**6.25**	**0.00**	
PADs	Ultra Low - B12/13/17/28			2.00		
	Low - B8/18/19/20/5/26			2.30		
	Mid - B1/3/4/2/25/39	3.30				7.60
PAM	QBE			0.65		0.65
Switches	Antenna Tuners		1.00			
	Antenna Switch Module		0.85			
	Diversity Switch		0.35			2.20
WiFi / GPS	5 GHz			0.45		
	2.4 GHz			0.45		
	GPS			0.40		1.30
Filters	2.5G WiFi	0.50				0.50
	Total	**3.80**	**2.20**	**6.25**	**0.00**	**12.25**

Model A1522 (iPhone 6 Plus US)

Function	Part	AVGO	RFMD	SWKS	TQNT	Total
		Content ($)				
	Total Content ($)	**3.80**	**2.20**	**3.05**	**3.20**	
PADs	Ultra Low - B12/13/17/28			2.00		
	Low - B8/18/19/20/5/26				2.30	
	Mid - B1/3/4/2/25/39	3.30				7.60
PAM	QBE			0.65		0.65
Switches	Antenna Tuners		1.00			
	Antenna Switch Module		0.85			
	Diversity Switch		0.35			2.20
WiFi / GPS	5 GHz				0.45	
	2.4 GHz				0.45	
	GPS			0.40		1.30
Filters	2.5G WiFi	0.50				0.50
	Total	**3.80**	**2.20**	**3.05**	**3.20**	**12.25**

Model A1586 (iPhone 6 Europe, Asia)

Function	Part	Content ($) AVGO	RFMD	SWKS	TQNT	Total
	Total Content ($)	**7.80**	**2.20**	**6.25**	**0.00**	
PADs	Ultra Low - B13/17/28			2.00		
	Low - B8/18/19/20/5/26			2.30		
	Mid - B1/3/4/2/25/39	3.30				
	High - B7/38/40/41	4.00				11.60
PAM	QBE			0.65		0.65
Switches	Antenna Tuner		1.00			
	Antenna Switch Module		0.85			
	Diversity Switch		0.35			2.20
WiFi / GPS	5 GHz			0.45		
	2.4 GHz			0.45		
	GPS			0.40		1.30
Filters	2.5G WiFi	0.50				0.50
	Total	**7.80**	**2.20**	**6.25**	**0.00**	**16.25**

Model A1524 (iPhone 6 Plus Europe, Asia)

Function	Part	Content ($) AVGO	RFMD	SWKS	TQNT	Total
	Total Content ($)	**7.80**	**2.20**	**3.95**	**2.30**	
PADs	Ultra Low - B13/17/28			2.00		
	Low - B8/18/19/20/5/26				2.30	
	Mid - B1/3/4/2/25/39	3.30				
	High - B7/38/40/41	4.00				11.60
PAM	QBE			0.65		0.65
Switches	Antenna Tuner		1.00			
	Antenna Switch Module		0.85			
	Diversity Switch		0.35			2.20
WiFi / GPS	5 GHz			0.45		
	2.4 GHz			0.45		
	GPS			0.40		1.30
Filters	2.5G WiFi	0.50				0.50
	Total	**7.80**	**2.20**	**3.95**	**2.30**	**16.25**

iPhone 6 RF Content

($)

	iPhone 6 U.S. (25%)	iPhone 6 Europe & Asia (25%)	iPhone 6 Plus U.S. (15%)	iPhone 6 Plus Europe & Asia (35%)	Total (Weighted Average)
AVGO	3.80	7.80	3.80	7.80	6.20
SWKS	6.25	6.25	3.05	3.95	4.97
TQNT	-	-	3.20	2.30	1.29
RFMD	2.20	2.20	2.20	2.20	2.20
Total	**12.25**	**16.25**	**12.25**	**16.25**	**14.65**

September revenue guidance provides a reality check on our content estimates.

All the RF semiconductor companies supplying Apple provided September guidance that included significant q/q increases in revenue from the ramp of iPhone 6. The most prominent was Avago, which guided for a 60% q/q increase, almost all of which was due to this new product ramp. Similar, albeit more modest increases were evident in guidance from Skyworks, RF Micro Devices and, to a lesser extent, Triquint. This data combined with our forecast of component wins by vendor provides a reality check on our ASP and total content estimates. The correlation between company guidance and our content estimates for each company is good suggests that our assumptions are generally in-line with what is actually occurring at Apple.

Guidance v. Bottoms-Up Model

	AVGO*	SWKS**	TQNT**	RFMD
Total Revenue Guidance, Next Quarter ($M)	934	680	262	345
Wireless Segment, Next Quarter (CER Estimates, $M)	576	531	182	345
Wireless Segment, Previous Quarter ($M)	360	452	144	316
Wireless Sequential Increase (Company guidance, CER Estimates)	60%	17%	26%	9%
Due to Apple	more than 80%	less than 50%	40% - 60%	more than 80%
Next Quarter's iPhone 6 Revenues:				
Implied from Guidance ($M)	151 - 194	32 - 43	15 - 23	23 - 29
Derived from Bottoms-up Model ($M)	183	41	23	24
Within 10% of guidance?	**Yes**	**Yes**	**Yes**	**Yes**

* AVGO's figures are ex-LSI.
** Incremental revenues for Skyworks and Triquint only reflect sales from PADs, which are shipped directly.

iPhone 6: Changes from iPhone 5S/C

AT&T's requirement that all high-end smartphones support carrier aggregation made it inevitable that Apple would either have to find a new way to jam more bands into less space, or give up its devotion to the "one-size-fits-all" approach to phones. There wasn't enough room to squeeze all the bands that iPhone 6 needed to support all of the LTE networks, and also add the redundant received channels required for carrier aggregation. The solution was to combine multiple PADs[5] in a single package by using a switch to connect a wide-band amplifier to an array of duplex filters, creating what is essentially a wideband PAD. This significantly reduces overall footprint by putting more content in fewer packages. But like a game of musical chairs, it creates a situation in which the same number of suppliers are vying for fewer slots, increasing the chance that someone will lose. Some of this risk is offset by higher total content (more LTE bands + CA), but the concentration of that content into fewer parts makes it more of a winner-take-all game.

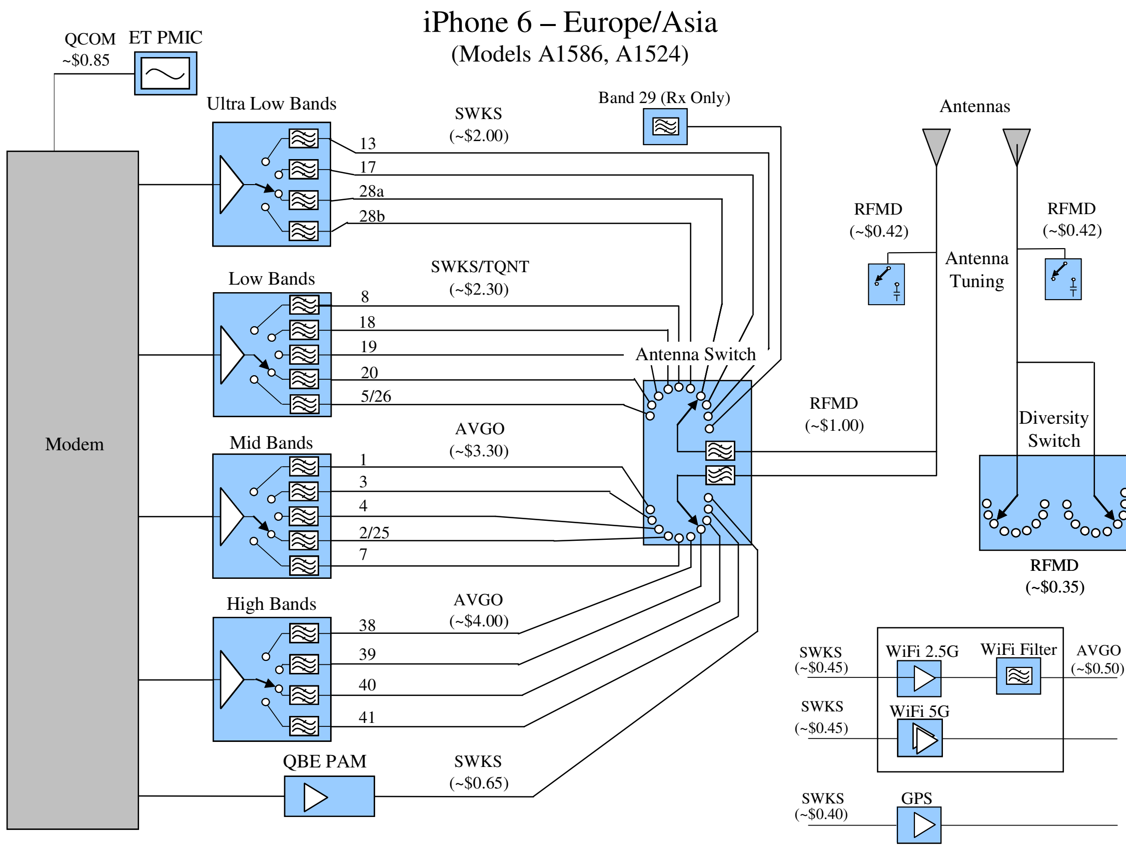
The multiband PADs in this phone use the wideband amplifiers Samsung developed for MMPAs[6] with an array of filters. This consolidates two or three of the dual-band PADS used in iPhone 5S into a single package, greatly reducing the area consumed by the RF section. It also allows Apple to get around the biggest problems with CA receivers, namely interference between the two received signals. Grouping bands by frequency physically isolates the two channels AT&T is aggregating, greatly reducing interaction and interference. The fall-out from all of this is an RF front end that uses four packaged amplifiers versus the six used in the last phone. Each package contains an amplifier, a switch and four to six duplex filters. Because they are segregated by frequency, each device tends to use filters of the same technology[7], so where the ultra-low PAD employs SAW filters, the high band device uses BAW, and the low-band, TC-SAW. The only exception is the mid-band PAD, which uses a few of each technology, because the bands it contains fall in the transition range between SAW and BAW. This is important, because understanding which filter technologies are being used in which parts provides a good indication of which vendor is supplying the device, or at least which vendor is not.

Filter Technology
(2013)

	SAW	TC-SAW	BAW
AVGO			✓
RFMD	✓[1]	✓[2]	
SWKS	✓[1]	✓[2]	
TQNT	✓	✓	✓

1. Widely available on the merchant market.
2. Available through Panasonic.

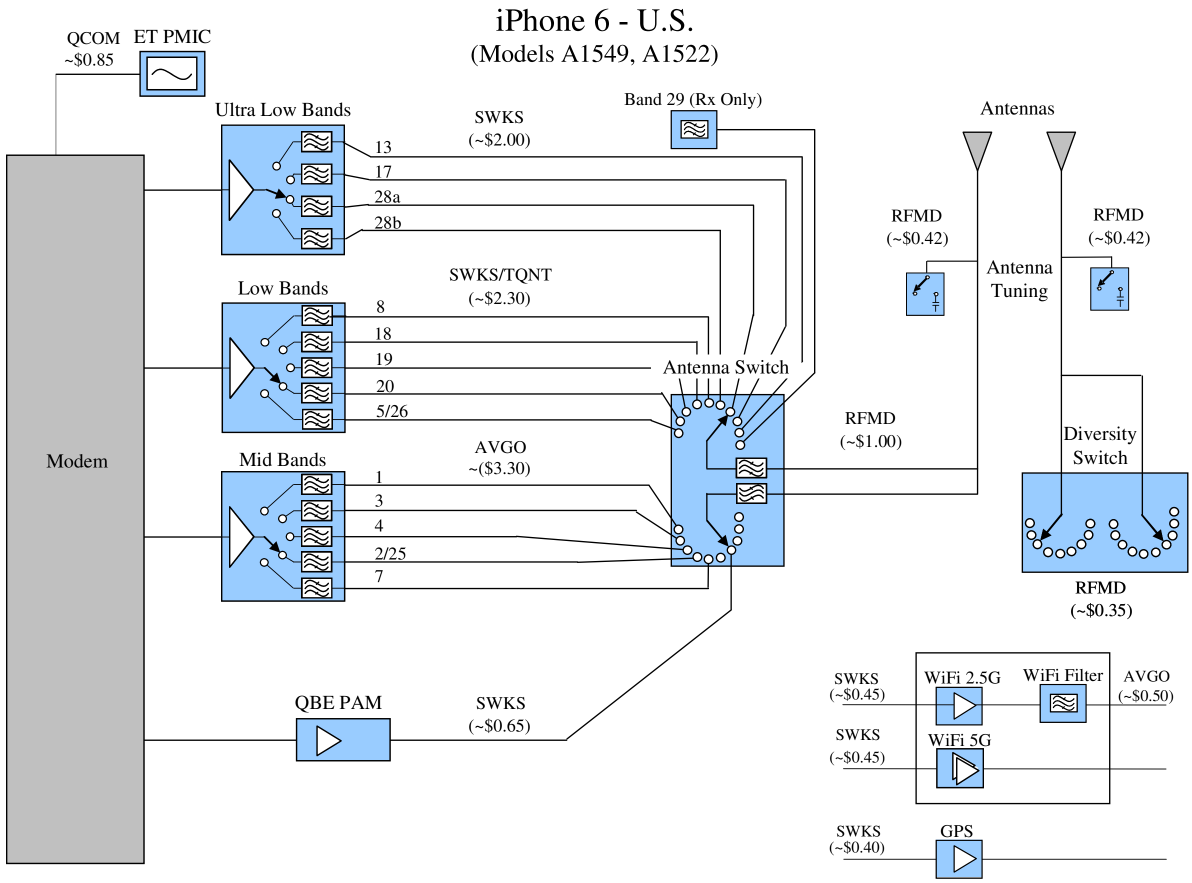
Apple is on a two year development cycle (Samsung is more like nine months), which is essentially a year of design followed by a year to ramp to production. That means the development of iPhone 6 occurred in 2013, when neither Skyworks nor RF Micro Devices had an internal source for filters, limiting which parts they could compete for. SAW filters were cheap and plentiful in 2013 but TC-SAW could only be had from Panasonic[8], and there was no merchant market source for high performance BAW[9]. This meant that if Skyworks and RF Micro Devices were going to bid on any of big amplifier components, it would have to be the ultra low band PAD and, if they could secure a supply of TC-SAW from Panasonic, the low-band PAD. The mid and high band devices were out of reach, and could only be supplied by Avago or Triquint, both of which fab their own high-performance BAW filters. And that's how it went, with Skyworks winning the ultra-low and low-band PADs, and Avago taking the mid and high bands devices.



Dual Sourcing

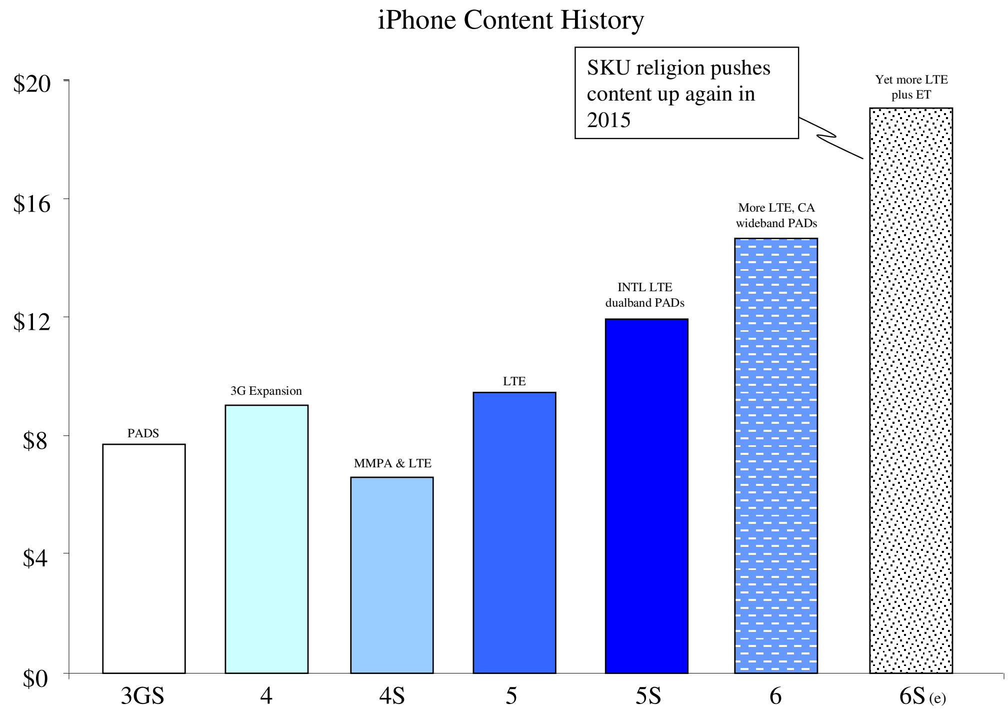
Unlike with past handsets, Apple moved to a dual source strategy for major RF components on the iPhone 6. It was a change in philosophy for the company, but really just a regression to the mean in the industry, which has always used dual-sources. Because Apple only used custom parts and had relatively small volumes initially, it used sole sources for most of the complex RF components, relying on a draconian supplier agreement to ensure it always got what it needed. As volumes rose, sole sourcing became increasingly problematic. Suppliers were spending small fortunes developing custom components, supplying production-like volumes for qualification tests, and expanding production capacity to meet Apple's aggressive forecasts in the run up to the launch. Most of this spending occurred before the company even knew if it had landed a design win. The stress on the supply chain had many manufacturers questioning the wisdom of chasing Apple, especially once Tim Cook took over and started squeezing suppliers on price. Vendors would spend millions striving for a win, be kept in the dark on progress and then walk away with nothing when the award went to a competitor. In many ways it was worse than dealing with Samsung, a notoriously parsimonious customer.

Dual-sourcing mitigated many of these problems by reducing supply chain risk for Apple and development risk for suppliers by spreading volumes across multiple vendors. Without the supply chain prowess of a manufacturing powerhouse like Nokia, Apple wouldn't be able to split the volume anywhere close to evenly between vendors. Instead, it would have to allocate wins by product, with the lead vendor supplying the phones and the back-up vendor the tablets. The only exception would be the low band PAD, which uses TC-SAW. With so little industry capacity for TC-SAW, we believe Apple has split suppliers by phone SKUs.



Outlook for the 2015 iPhone 6S

Industry trends and the product roadmaps of the RF semiconductor manufacturers provide a wealth of clues as to the likely configuration and RF content of Apple's next phone, iPhone 6S. Apple's reliance on incremental improvements (thinner, lighter, faster) in the iPhone 6, and the shift in its go-to-market strategy from features to experiences suggest the days of big innovation are over. Growth will now rely almost exclusively on expanding its channel into new regions and carriers. This will require the new phone to support even more LTE bands, which means space constraints are going to become more acute. So just as with the iPhone 6, we expect most of the innovation in the RF section will revolve around size reduction.

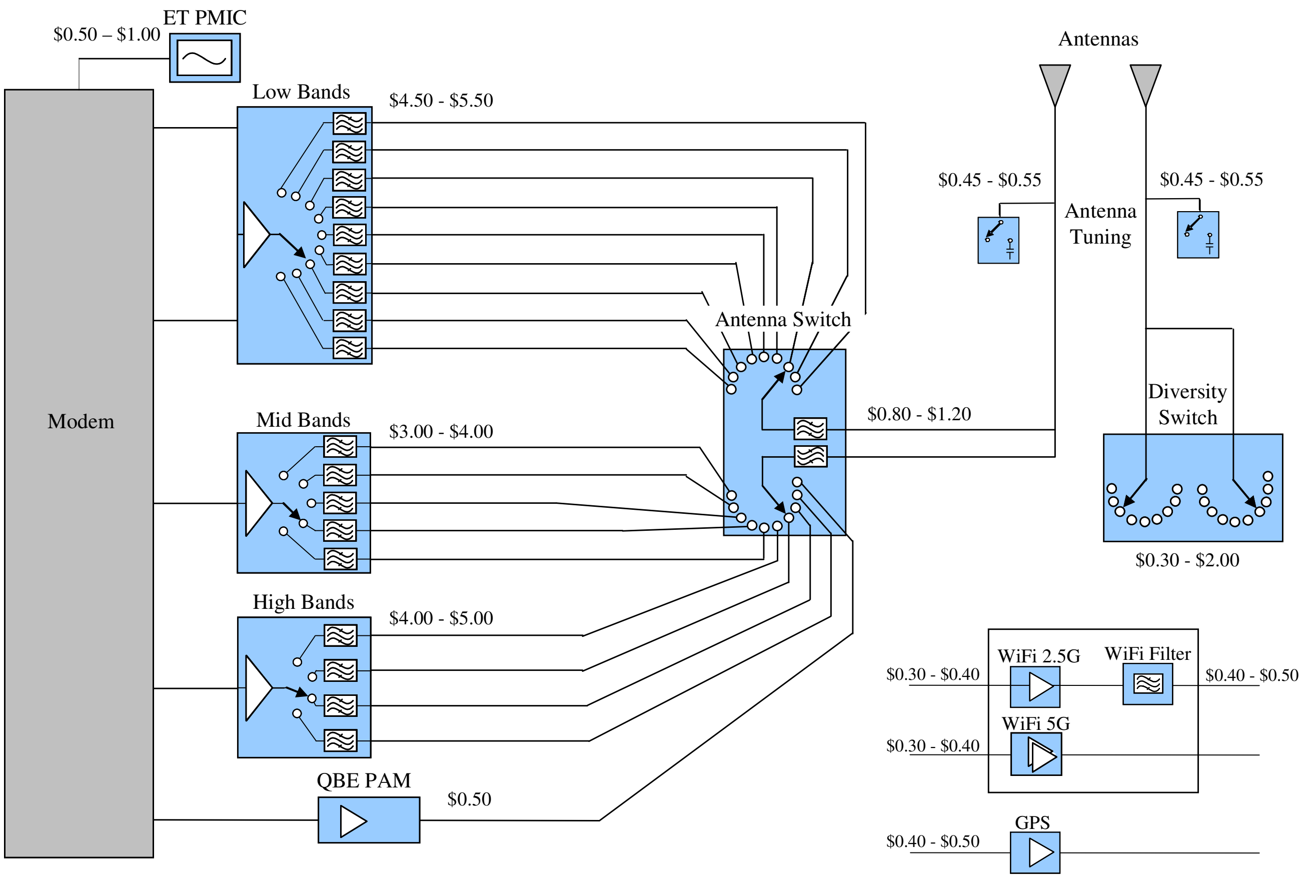


Apple can reduce the footprint of the RF section in the same way it did on the last phone, by jamming more parts into fewer packages. The opportunity for gains is limited, however, because the more that is stuffed into one package, the fewer suppliers can deliver the part. No one vendor has all the required amplifier, switch, filter and tuner technologies in-house today, and although the RF Micro Devices/Triquint merger will create such a firm (NewCo), it wouldn't be in Apple's best interest to design a part that can only be obtained from one vendor. For this reason, we believe Apple will refrain from combining all its amplifiers and filters into one massive PAD, and will instead combine the ultra-low and the low band PADs into a single package.

This approach will avoid mixing BAW, SAW and TC-SAW bands in the same package which would raise the hurdles to Avago and Skyworks while lowering them for NewCo. Combining the ultra-low and low band PADs leaves the two BAW-centric PADs for Avago and NewCo, while creating a high-content device that both Skyworks and NewCo could supply. This reduces the footprint of the RF section without increasing supply chain risk by eliminating vendors.

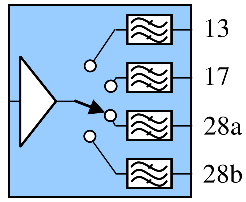
The antenna and diversity switches could also become more complex if AT&T moves to three-band receiver carrier aggregation (CA), but we're not convinced this will occur given the difficulty it has experienced getting dual-band CA deployed. If we are wrong and the world does move to three-band CA, the ASM and diversity switches will become even more complex and expensive.

iPhone 6S Schematics
(CER Estimates)



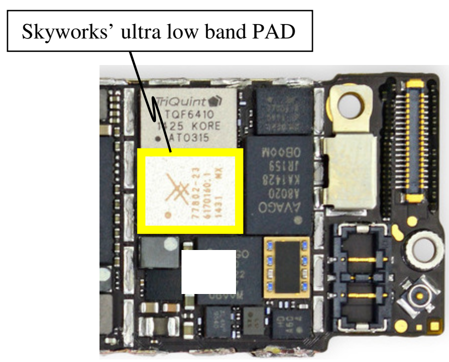
WiFi could also see higher content next year if Apple expands the MIMO[10] capabilities of its WiFi section. This would add additional amplifiers, antennas and filters, and would also require more complex switching. We've no indication whether Apple is considering this, but given the sizable lead Samsung enjoys in features and performance, if the Note 4 or the Galaxy 6 builds on these features, it will be forced to include them sooner or later. Although much remains to be determined, we believe RF content in the iPhone 6S will be $15 - $22, which is flat to up substantially over iPhone 6.

Ultra Low Band PAD



Ultra-low band PAD – $2.00
Rev/yr: SWKS $331M, RFMD $20M

The ultra low-band PAD covers all the 4G bands between 700 MHz - 790 MHz[11]. SAW filters perform well in this range and are vastly cheaper than BAW, which makes them ideal for every band in this device. The only exception to that would be Verizon's requirement to avoid interference with public safety radio in Band 13. That requirement (called NS-07) can only be met by using a more expensive filter, usually a TC-SAW device from Triquint, although Avago has a BAW part that could also meet the specification[12]. However, to avoid driving up costs and limiting the supplier base, Verizon extended the waiver for NS-07 compliance for another year, allowing SAW to be used for band 13 just as it had with the iPhone 5S/C. This probably won't occur again in 2015 which could give Triquint/RF Micro Devices the edge in competition for the wideband PAD that includes this band.

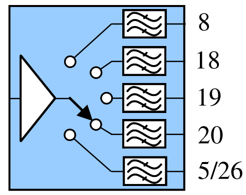


Source: iFixit

Because they are inexpensive and widely available, even manufacturers without filter assets can vie for PADs that use SAW filters, which should make the ultra-low band PAD the most competitive part in the phone. That didn't turn out to be the case however, because the margin profile of SAW falls below Avago's minimum requirement, and the lack of capacity in its Florida SAW fab and more lucrative opportunities in BAW precluded Triquint from participating. That left Skyworks and RF Micro Devices, both of which supplied SAW based PADs to Apple in these bands for the iPhone 5S/C.

We believe RF Micro Devices' dominance of the switch and signal section of the phone, combined with Skyworks advantages in cost and Apple's desire to spread content across vendors, led to Skyworks landing this part in all the phones and RF Micro Devices supplying it for all tablets. With an ASP[13] of about $2.00, we estimate the ultra-low band PAD will generate about $331M for Skyworks in the first twelve months of production (Aug '14 – Aug '15) and about $20M for RF Micro Devices.

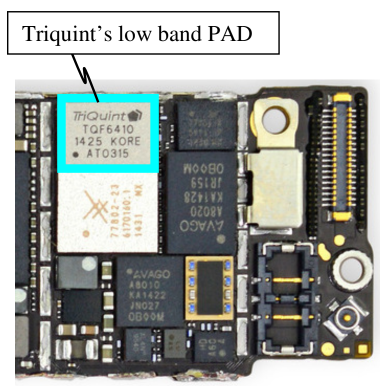
Low Band PAD



Low-band PAD - $2.30
Rev/yr: SWKS $190M, TQNT $190M

The low-band PAD covers the 3G and 4G bands in the 790 MHz - 960 MHz[14] range, which is generally considered too low for BAW to be economically viable. But because they have to support LTE, these bands can't be filtered with SAW either, which means they will use TC-SAW filters. This narrows the field of suppliers considerably, as only Panasonic and Triquint have TC-SAW devices of the performance required for these bands. Avago could use BAW filters but they'd be large, expensive and be competing against lower cost TC-devices, which would make it unappealing from a margin perspective.

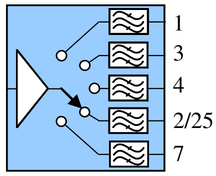
Neither Skyworks nor RF Micro Devices has an internal source for TC-SAW, but both have worked closely with, and sourced filters from Panasonic for devices in the iPhone 5S/C. We believe Skyworks has the advantage though, because the PADs it supplied to Apple last year used TC-SAW filters, while all of RF Micro Devices' parts were SAW based. The experience Skyworks gained from that win[15], and the fact that it has an equity stake in and a joint venture with Panasonic all but guaranteed it would lead the field for this slot. Triquint is also a leading contender given it has its own source of TC-SAW and has fielded some of the highest-performance filters available.



Source: iFixit

We believe a major consideration in awarding this slot was the lack of industry capacity in TC-SAW. As we detailed in our filter report[16], the TAM for TC-SAW last year was only about $50M versus about $800M for BAW and $1.5B for SAW. The flood of bands that will require TC-SAW in the move to LTE this year is expected to stretch industry capacity to its limit, so we believe that to minimize supply chain risk and ensure it has enough products for the initial ramp, Apple split this slot by model between Skyworks and Triquint. We believe Skyworks supplies the component for all the iPhone 6 Plus models, Triquint takes the smaller iPhone 6. At about $2.30, the low-band PAD should generate about $190M in revenue for Skyworks and $190M for Triquint in the first 12 months of production.

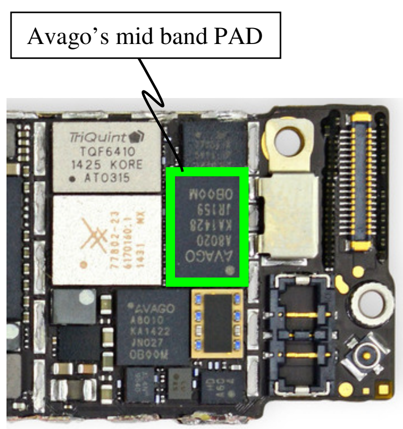
Mid Band PAD



Mid-band PAD - $3.30
Rev/yr: AVGO $546M, TQNT $35M

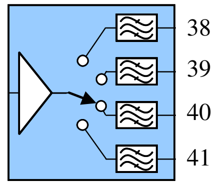
The mid-band PAD covers the 3G and 4G bands in the 1,700 MHz - 2,200 MHz[17] range, which is the transition region between SAW and BAW. It also includes band 7 (2,500 MHz – 2,700 MHz) which is a support band in nearly every region. Like several of the other bands, band 7 can only be filtered with BAW, while others will use SAW. With no merchant market source for high-performance BAW, it would be impractical for Skyworks or RF Micro Devices to compete for this slot[18], so we don't believe either tried. Avago has the highest performing BAW filters available, but it doesn't have an internal source for SAW, so it buys those filters from TDK. Avago could develop BAW filters for the SAW slots, as long as the cost of the device is lower than the ASP of TDK's parts. Either approach is dilutive to margins, but given the steep price premium of BAW over SAW, and the large number bands requiring these high-performance parts, the dilution is probably modest.

Triquint fabricates filters in all of these technologies (BAW, SAW, TC-SAW), which would make it the leading contender for the mid-band PAD. It is the second largest supplier of BAW filters, but with a few exceptions, trails Avago in performance. This, combined with the distraction of the proxy fight and merger negotiations, probably led to execution problems that prevented it from winning the lead slot on this part. The tear-down analysis and financial guidance from both firms lead us to believe Avago will supply the mid-band PAD to all phone models while Triquint won the tablets. With so much BAW content, the mid-band PAD is expensive, and has ASP of about $3.30. In the first 12 months of production, we expect this part to generate about $546M for Avago and $35M for Triquint.



Source: iFixit

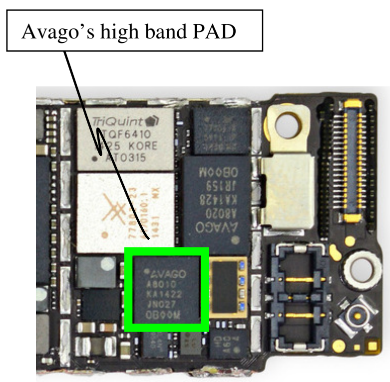
High Band PAD



High-band PAD - $4.00
Rev/yr: AVGO $397M

The high-band PAD covers the 4G bands in the 2,300 MHz to 2,600 MHz[19], as well as band 39 (1,880 MHz – 1,920M MHz), which is included to support the Chinese TD-LTE networks[20]. Bands 38, 40 and 41 are well beyond the reach of SAW, and while band 39 could be done in that technology, it was probably implemented in BAW for this phone. The Chinese TD bands are so difficult that only the highest performance BAW will do. That being the case, Triquint and Avago are the only two suppliers who could even hope to supply this part.

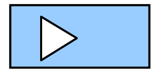
Without a source for or experience in SOI switches, Avago was at disadvantage until it purchased Javelin Semiconductor (RF CMOS) in April of 2013. Once it had that design team, the company could leverage its edge in performance and production capacity to become the leading contender. Triquint's proxy and M&A distractions, combined with rapid growth in its discrete BAW filter business, probably undercut its motivation to chase this slot. In the end, we believe this was an easy win for Avago, which we expect to be the exclusive supplier to all phone and tablet products.



Source: iFixit

By combining all the Chinese TD bands into this one part, Apple could eliminate it in the U.S. model to reduce BOM costs. We believe this is the primary motivation for pulling band 39 into what is essentially a high-band part. Band 39 is a Chinese TD-LTE band, while band 7 (a high frequency band not included in this part) is a world roaming band for LTE. Dividing bands between parts in this manner makes it easy for Apple to cut out TD-LTE bands and still support band 7 in the U.S. model. Lots of BAW and little competition make this the single most expensive RF part with an ASP of about $4.00. We expect that to generate about $397M in revenue for Avago in the first 12 months of production.

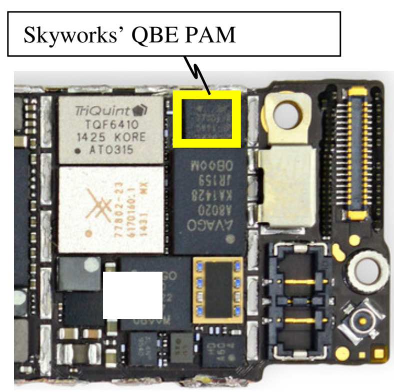
QBE PAM



2G Quad Band Edge PAM[21] - $0.65
Rev/yr: SWKS $107M

With 4.5B subscribers still on 2G, carriers must continue to support GSM, and all high-end smart phones must be capable of roaming into 2G coverage. So like all of its predecessors, the iPhone 6 includes support for quad-band EDGE (QBE). Because it's a half-duplex system, GSM does not require a filter, but does need a switch to toggle between transmit and receive. Normally, the switch, amplifier and power detector are combined on the same substrate in what is commonly called a Transmit Module[22]. That's not the case this year, because the requirement to support carrier aggregation has made it more economical to offload the switch and detection functions to the antenna switch module (ASM). As we will see, changes to the ASM to handle carrier aggregation make it significantly more complex with more switch and signal routing. Because it is a custom silicon part, it could easily accommodate the silicon based 2G switch and detection functions normally found in the TXM. This doesn't add much cost or complexity to the ASM but does simplify the 2G transmit path which can now be implemented with a PAM (simple) instead of a TXM (complex).

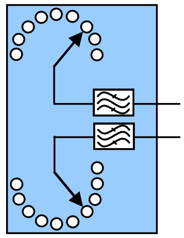
The only drawback to this configuration is higher loss between the amplifier and the antenna, but that was already in the cards when carrier aggregation and antenna tuners[23] were added. To overcome this additional loss, the 2G amplifier has to achieve a higher output power so some of what was saved by off-loading the switch and detection functions is spent on higher 2G output power. That will be reflected in the ASP of the 2G PAM which we believe will be about $0.65.



Source: iFixit

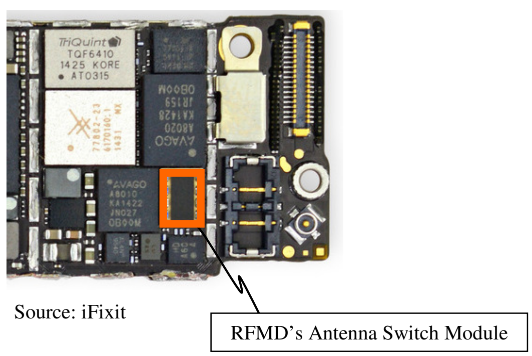
All of the RF semi manufacturers can build this part, but Avago has avoided 2G products to hold the line on margins and RF Micro Devices has never won this slot at Apple. With Triquint deemphasizing its 2G business, we believe Apple chose Skyworks to continue supplying the component, since it already had the slot in iPhone 5S/C. We expect this part to be worth about $107M in revenue in the first year of production.

Antenna Switch



Antenna Switch Module - $1.00
Rev/yr: RFMD $165M

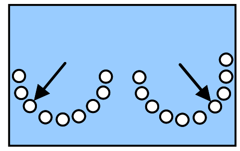
Perhaps the biggest change in the iPhone 6, next to the move to wideband PADs, is in the ASM. In order to support carrier aggregation, the antenna switch has to receive two signals simultaneously, which means it must provide two separate signal routes into the phone. This adds significant complexity and requires higher performance to minimize interaction between, or interference from the two received signals. The addition of three more LTE bands also increases complexity by adding additional connections and routing. The switch supports well over 20 connections even in regional variants that don't use all bands or every wide-band PAD. This is a consequence of Apple's aversion to SKUs, and its willingness to suffer higher COGS to simplify inventory stocking and supply management.



Source: iFixit

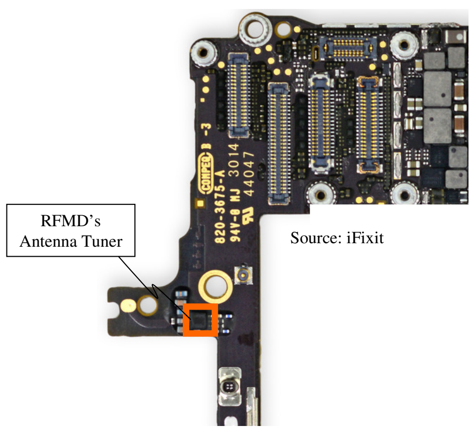
The proximity of the ASM to the antenna and its interaction with it and the antenna tuners force close collaboration between the antenna, ASM and board designs, making it a "stickier" win. It comes as little surprise then that the vendor that won this slot on iPhone 5S/C, RF Micro Devices, has also landed it on this phone. The company's strength in switch and signal products is making it the vendor of choice for LTE ASMs and, as we outline below, antenna tuners. It has become Apple's vendor of choice for SOI products in the RF front-end. We believe the added complexity of carrier aggregation is reflected in the ASP for this part which we estimate to be about $1.00. That equates to $165M for RF Micro Devices in the first year of production.

Diversity Switch



Diversity Switch - $0.35
Rev/yr: RFMD $58M

The diversity antenna switch is used to ensure uninterrupted reception of high-data rate signals[24]. It provides a redundant receive path that the phone can select if the signal on the main antenna is lost. Diversity reception is particularly important for maintaining connection to high-data signals, and as such, is a requirement for all LTE bands. In addition to providing a redundant path to the receiver, the diversity switch in the iPhone 6 must also be able to route two signals through two different paths simultaneously to satisfy AT&T's requirement for carrier aggregation. Unlike the ASM, however, it only has to receive signals and not transmit them, which eases the performance requirements and lowers the cost. We believe RF Micro Devices' work on the ASM and antenna tuners made it the natural choice for the diversity switch, which we estimate to be a $0.35 device. Given our unit volume assumptions, we believe the first year of production will generate about $58M in revenue for RF Micro Devices.

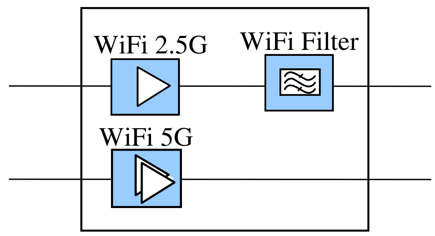


Source: iFixit

Antenna Tuners - $0.85
Rev/yr: RFMD $141M

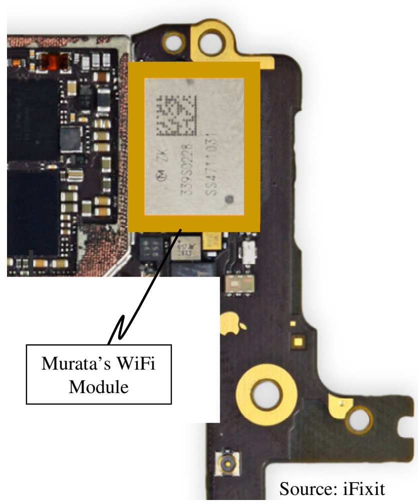
The wide range of frequencies over which the iPhone 6 must operate make it nearly impossible to build an antenna that works well across all bands. If it is optimized for the low bands, reception and transmission at the high frequencies wills suffer and vice versa. This can be corrected by using a different antenna for each group of frequencies, but that would add cost and complexity, as well as increase the size significantly. A better way to solve the problem is to use tuners, which optimizes the antennas' performance in whatever frequency range it is operating. Apple took this approach with its first LTE handset (iPhone 5), employing SOI tuners from RF Micro Devices, which had an early lead in SOI switch and signal products. Unlike amplifiers and filters, the design of tuners and switches that attach to the antenna is highly iterative and requires close collaboration between antenna, tuner and switch engineers. This injects an element of inertia to antenna switch module and antenna tuner wins, especially at Apple, which uses custom designed parts for each phone. It's little wonder then that RF Micro Devices has been the exclusive supplier of tuners to Apple, landing the ASM on the iPhone 5S/C and again in iPhone 6. As is typical for high-end phones, both the main and diversity antennas employ tuners, giving RF Micro Devices three slots at about $0.28 each. This win should generate about $158M for the company in the first year of sales.

WiFi Module

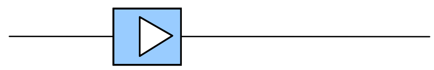


WiFi - $1.40
Rev/yr: SWKS $126M, TQNT $22M, AVGO $83M

The WiFi connectivity problems that plagued the iPhone 4 convinced Apple that the only way to achieve reliable, high-data rate connections is by using an external RF amplifier. That configuration has been employed in all subsequent phones including the iPhone 6, which offers dual-band operation (2.4GHz & 5GHz) and 802.11ac. WiFi on 2.4GHz is problematic because the channel lies perilously close to LTE bands in Europe (7) and China (40, 41). To reduce interference, Apple uses a relatively expensive BAW filter. Last year, that part was supplied by Avago, and we believe the same has happened this year. The 2.5GHz WiFi amplifier will almost certainly be supplied by Skyworks on most models given it got the slot when it acquired SiGe Semiconductor in 2012. The 5GHz amplifier on the iPhone 5S/C was a GaAs PAM supplied by both Skyworks and Triquint. We believe both firms will supply those parts into the new phone with Skyworks taking the lion's share of content and Triquint supplying two amps in one SKU. This dovetails with Triquint’s February 2014 announcement that it was exiting discrete amplifiers products of this type. The parts are not visible in the teardown because they are included in the WiFi module that also contains Avago's 2.4GHz WiFi coexist filter. We expect that the ASP for the module is about $1.50, with Skyworks’ portion at about $0.80 and Triquint’s at $0.35 in the models each has landed. Avago's WiFi coexist filter will sell for about $0.50 and will be in every SKU.



Source: iFixit



GPS - $0.40
Rev/yr: SWKS $66M

Technology and cost advantages have landed Skyworks the GPS module in the past several phones, and based on its guidance and that of its peers, we believe it has captured the slot on iPhone 6 as well. At about $0.40, we estimate the GPS module is worth about $66M to Skyworks in the first 12 months of sales.

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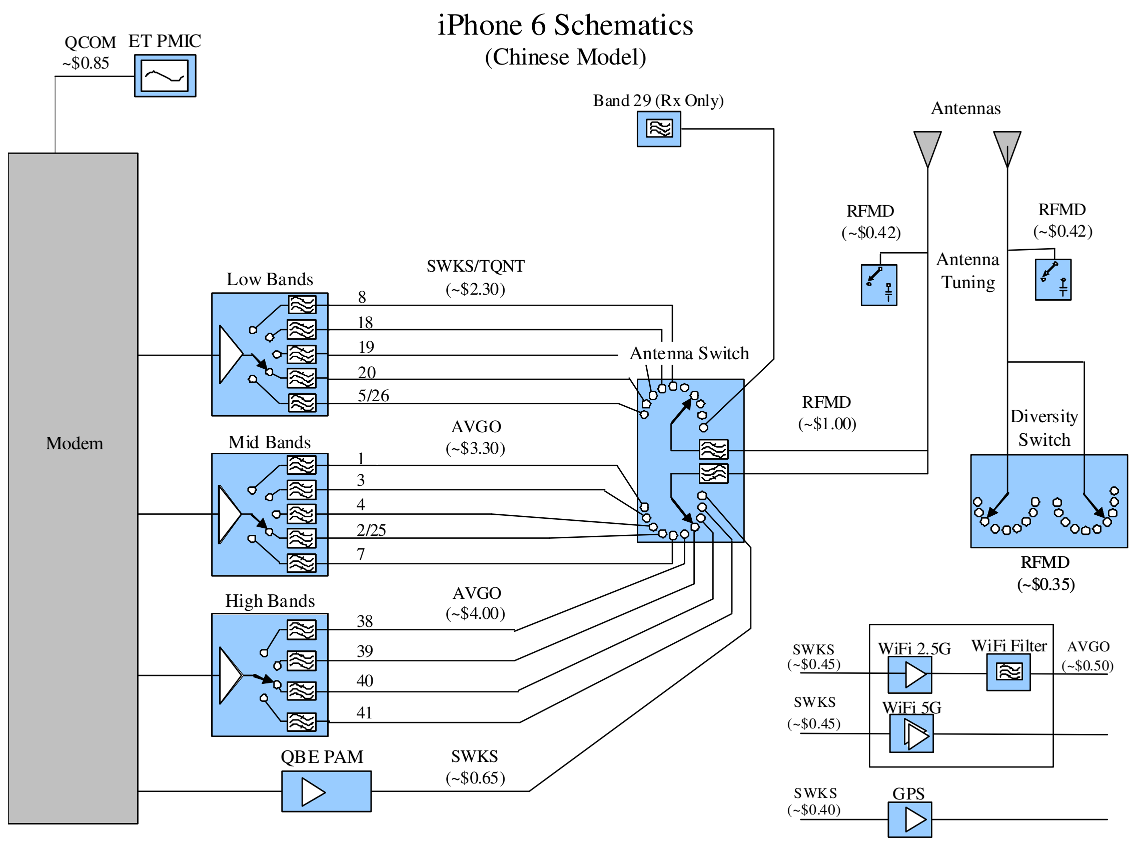
Endnotes

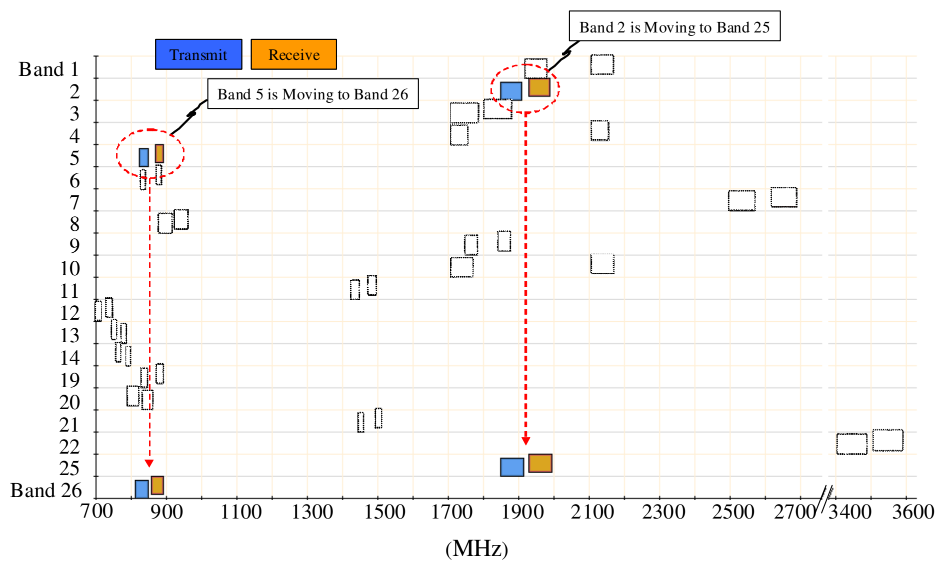
1 “Content Predictions for iPhone 6 and iPhone 6S”, Charter Equity Research, September 15, 2014.
2 We believe Apple is using three manufacturers for the WiFi module, and that Skyworks is supplying its WiFi amps into two of them.
3 Not all iPads sold are cellular-enabled. In fact, we believe less than 20% of all tablets sold by Apple have the feature. This, combined with the fact that worldwide tablet sales have flattened in the past quarter, limit the upside potential of design wins into the device.
4 The schematic for the China SKU if Apple decides to not include support for the U.S. bands would be as follows:



5 PAD: Power Amplifier Duplexer. A power amplifier die and a duplex filter die mounted on the same substrate with matching components. The entire device is called a module because the amplifier is matched to the filter and the inputs and outputs are matched to 50 ohms. The module is encapsulated in plastic and sold as a packaged part.
6 MMPA: Multiple amplifiers in a single package are commonly called either an MMPA (Multimode, Multiband Power Amplifier) or MMMB (Multimode, Multi-Band) with the terms used interchangeably. The original MMPAs were simply a packaging exercise where manufacturers would take the GaAs die from individually packaged amplifiers and combine them in a larger package. That approach has largely been abandoned in favor of wideband amplifiers so that MMPAs consist of fewer die covering more bands.
7 The three types of filters used in PADs are SAW, TC-SAW and BAW. For an understanding of the differences between the products, manufacturers and applications see “A Field Guide to Filters”, Charter Equity Research, September 9, 2013.
8 Panasonic and Triquint were the leading manufacturers of TC-SAW, but only Panasonic was offering merchant market parts. Triquint used all of its TC-SAW production for its own parts. Murata also fabricates TC-SAW, but it is smaller, and like Triquint, uses those filters in modules it sells directly to handset OEMs.
9 High performance BAW of the type required by Apple is only produced by Avago and Triquint. TDK/EPCOS and Taiyo Yuden offer BAW filters on the open market, but selection, quality and quantity are much more limited and unsuitable for use in any of the leading smartphones. This is why of all the components supplied by Skyworks and RF Micro Devices to all the iPhones ever built, none have included a BAW filter.
10 MIMO: multiple-input and multiple-output is the use of multiple channels to increase the throughput of a WiFi signal. Like Carrier Aggregation in cellular, MIMO requires the simultaneous transmission of two or more carriers, increasing the number of transmit and receive circuits in the WiFi module.

[11] We believe the ultra-low band PAD covers and includes filters for bands 13, 17, 28a and 28b. Bands 13 and 17 are the low LTE bands for Verizon and AT&T respectively. Band 28 is a new band used for global roaming, primarily in Asia. It is too wide and contains too many interferes for one filter, so it's split into bands 28a and 28b and uses two separate SAW filters.
[12] A BAW filter in band 13 would be vastly larger, and therefore more expensive than a TC-SAW device. This would limit the margin Avago could expect from the part. Moreover, because its business model requires strict adherence to a relatively high margin profile, Avago tends to avoid highly competitive slots or products with a lot of externally sourced content, such as the SAW filters in the ultra-low band PAD. It has also, so far, declined to sell its band 13 BAW filter in discrete form to avoid being pulled into a design project with another vendors' GaAs amplifier. For these reasons, we don't believe Avago participated in design competition for the ultra-low band PAD on iPhone 6.
[13] ASP: Average Selling Price
[14] We believe there are five bands (8, 18, 19, 20, 26) in the low band PAD, the majority of which require TC-SAW filters. Band 8 was a relatively benign 3G band that, once converted to LTE, could no longer be filtered with SAW. Bands 18 and 19 are Japanese LTE bands, but the filtering requirements are modest enough for SAW. Band 20 is a global roaming band that has used SAW in the past, but would almost certainly use TC-SAW for high-end device like iPhone 6. Band 26 is an extension of band 5 for Sprint's LTE service, so by using a band 26 filter, Apple can address both bands with one filter. The filtering requirements for band 26 are the most difficult of any in this part and therefore require TC-SAW.
[15] We believe Skyworks' experience on the TC-SAW-based 8/26 dual-band PAD in the iPhone 5S/C was not always a pleasant one. Early problems with production yields on the TC-SAW part from Panasonic apparently caused considerable consternation at Apple. The situation was rectified and we believe the knowledge acquired in the process gave Skyworks an advantage in competing for the TC-SAW based PAD in iPhone 6.
[16] "A Field Guide to Filters", Charter Equity Research, September 09, 2013.
[17]

LTE Frequency Bands (MHz)



[18] Panasonic has worked closely with Skyworks and RF Micro Devices in SAW and TC-SAW, but it does not offer BAW filters. We do not believe a merchant market source for high-performance BAW filters exits, and none of the components Skyworks and RF Micro Devices has supplied to Apple for past phones have included BAW devices.
[19] We believe the high-band PAD is included in the European and Asian models to support operation on, or roaming into China Mobile's TD-LTE network. As such, it includes bands 38, 39, 40 and 41, all of which are LTE and three of which (39, 40, 41) are particularly difficult to filter. The interference issues between these bands and the 2.4GHz WiFi band are well established and can only be ameliorated with high-performance BAW filters. We believe the high-band PAD is eliminated in the U.S. model to lower costs.
[20] At the time of this publication, Apple has only listed two models, one for the U.S. and Japan and the other for Europe.
[21] PAM: Power Amplifier Module. A GaAs amplifier die mounted on a small substrate with discrete matching components.
[22] For a detailed description of the various power amplifier configurations see our "A Brief Tutuorial on PADs", Charter Equity Research, April 26, 2013.

[23] Every device has some insertion loss, and the more devices that are placed between the amplifier and the antenna, the greater the total loss.

[24] The nuances of cellular signals are such that reflections off of objects like walls can cause the radio signal to cancel itself out in certain areas. Like a wave in the water, at some point, where it reflects into itself, the wave will be completely eliminated, leaving the surface undisturbed. The same effect occurs with radio waves and is called a "fade". A fade can reduce the signals strength to a point where it is too low to detect. When this happens the transmission is lost. Fades occur in any environment where there are objects to reflect the radio wave, and are particularly prevalent inside buildings. Fortunately the physical distance between a fade and a normal radio signal is relative small, on the order of inches for cellular signals. If a second antenna is placed a few inches from the primary antenna, the system can switch between the two if it detects a fade on either. In practice, the second antenna is called the diversity antenna and its sole purpose is to provide a duplicate signal that the transceiver switches to if the signal strength on the primary antenna falls below a minimum threshold. Diversity antennas only receive signals, so the circuits connected to them are vastly simpler and less expensive than on the primary antenna.