

Avago Technologies' FBAR Filter Technology Designed Into Latest Generation of 4G & LTE Smartphones



White Paper

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The worldwide mobile handset quarterly growth rate remains in the single digits, but shipments of smartphones continue to explode; and with each successive generation, smartphones continue to offer more user features and capabilities without significantly growing the size and weight of the phone. The driver behind these new devices is the rollout of new cellular networks known as 4G and LTE (Long Term Evolution), with most people equating the latest service with faster download speeds and a better mobile internet experience. As expected, most if not all of the industry news revolves around the features of these latest phones (i.e. battery life, brilliance and resolution of the display, etc.), but what about the semiconductor building blocks that make such wondrous gadgets work?

One very important component in modern day smartphones is the RF (radio frequency) filter. At its most basic, the filter serves to pass wanted frequencies and reject unwanted frequencies, and is instrumental in allowing the many receivers found in phones to only process the intended signal. In the past, phones primarily operated over a small number of frequency ranges in any given region of the world. Today, there are often multiple radios operating at the same time in a phone (cell band, Bluetooth, WiFi, and GPS) and manufacturers want to build a phone that can be used in different regions of the world and by different carriers. The more frequency bands and regions a phone needs to support increase the demands on RF filtering in that phone.

In previous generations of wireless technology, filtering requirements were not very difficult to achieve, and could adequately be handled using SAW (surface acoustic wave) filters. With the evolution of carrier networks to CDMA and 3G, Avago Technologies found that its Film Bulk Acoustic Resonator or FBAR technology was well suited to meet the challenging filter requirements for US PCS and a few other bands. To take advantage of today's 4G/LTE services, the smartphones themselves have necessarily become more complex. As a result, phone manufacturers have expanded their usage of Avago FBAR technology to address the issues unique to 4G/LTE described below.

RF Filter Challenge #1: 4G/LTE Smartphones Operate Over Multiple Frequency Bands

The latest smartphones are designed to operate across multiple frequencies around the world. The overall size of a multi-band smartphone is no larger than its predecessor, so to accommodate more filters in the same space reserved for the RF front end circuitry, the filters must obviously be small. With Avago Microcap encapsulation technology, FBAR filters can be offered in a chip scale package for the most size-constrained applications. Furthermore, because FBAR is a bulk material, it offers exceptional power handling capability for its size without having to use parallel structures typical of SAW filters. In addition, the size of the FBAR device also shrinks with increasing frequency, making FBAR well positioned to address many of the new 4G/LTE bands operating between 2300 MHz to 2700 MHz, and 3.5 GHz in the future.

Perhaps the most important aspects of FBAR technology are the steep filter skirts and superior out-of-band rejection that support challenging frequency band plans (see Figure 1). This is the case with the aforementioned US PCS, where the gap between the upper transmit frequency and lower receive frequency is narrow. These features become even more important for 4G/LTE as (i) the gap between transmit and receive frequencies are more narrow, and (ii) today's smartphones must function in congested spectrum adjacent to existing 2G/3G radio services while avoiding interactions that would otherwise decrease or interrupt data throughput. Often times, the transition frequency between bands is on the order of a few megahertz; sometimes there is no guard band at all.

FBAR Filter Advantages

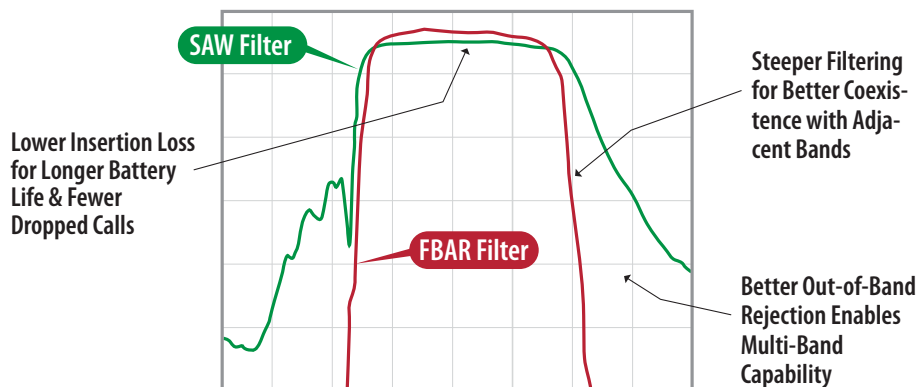


Figure 1. FBAR Filter Response Characteristics

An example of the value FBAR filters offer is provided by the circumstances around the use of Band-13 in the US. This spectrum, used by Verizon for LTE service, is only 2 MHz away from a new Public Safety Radio (PSR) band that will be used by police, fire and other emergency response agencies. To avoid interfering with PSR operation, the LTE standard can require handsets operating on Band-13 to drastically reduce transmitted power. Such a power reduction has a major impact on network efficiency, reducing the number of customers that can be served, as well as on the quality of service, greatly decreasing data throughput or even resulting in dropped calls. By combining a temperature compensated, extremely fast roll-off FBAR duplexer with a highly linear power amplifier in the well controlled environment of an integrated Front End Module (FEM), Avago has created a product capable of allowing Band-13 handsets to operate at full power without interfering with PSR operation. The performance of the FBAR duplexer is a critical enabler for this product.

RF Filter Challenge #2: 4G/LTE Smartphones Operate at Higher Data Rates

Compared with 3G, the download speed of 4G/LTE can be up to ten times faster for the same amount of data, or alternatively, 10x the data can be downloaded in the same amount of time. Higher data rates are accomplished in several ways. 4G/LTE uses different modulation waveforms depending on the detected signal strength. Simply put, the stronger the signal to noise ratio (SNR), the higher the data rate (moving from QPSK to QAM16/64). In multi-band 4G/LTE phones that combine the various duplexers through a lossy single pole multi throw switch, the detected signal could be low enough to reduce the data rate. FBAR's low insertion loss helps maximize the incoming signal strength, resulting in higher data throughput. The end result is a better user experience and higher data capacity per cell site.

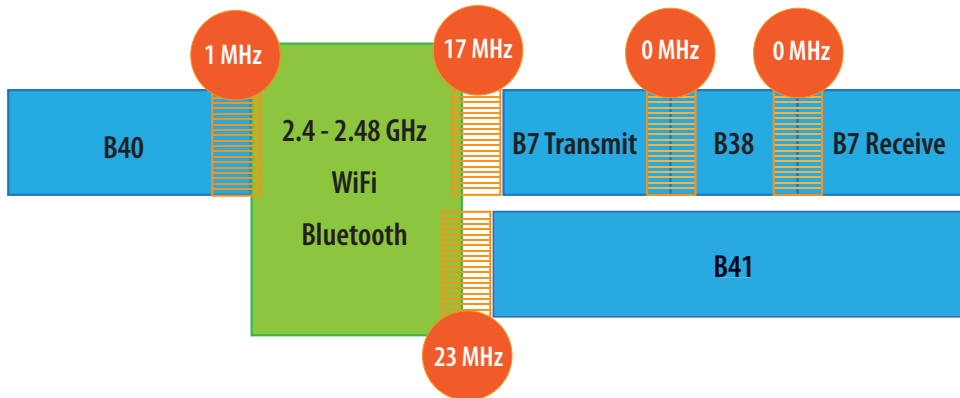
Phones that employ frequency division duplex (FDD) modulation use duplexers that allow for simultaneous transmit (Tx) and receive (Rx) of cellular signals. Because both the Tx and Rx filters are connected to the same antenna port, and therefore each other, the isolation between the two filters is very important. Higher isolation minimizes Rx band noise, and as we learned earlier, this amounts to increasing the SNR and data rates. The ACMD-6107 LTE Band-7 duplexer offers a typical isolation of -60dB in the Rx band.

Another way of increasing data rates is through carrier aggregation (CA). CA increases download data rates by operating in more than one frequency band simultaneously. Some of the new LTE bands occupy relatively small slivers of spectrum, as is the case for Band-25 (5 MHz), so this is a way for network operators to effectively increase their capacity. Since both the Tx and Rx of each frequency band is active at the same time, switches cannot be used. Instead, multiplexers are used to combine the various Tx and Rx filters to the same antenna port. Avago's FBAR filters provide a low signal loss path when combined in the multiplexer configuration, which as indicated above, helps to maximize data rates.

RF Filter Challenge #3: Smartphones Use Multiple Radios Simultaneously

It would be difficult to find a smartphone today that doesn't contain WiFi capabilities. Depending on the operating band of the phone, the phone's transmitted signal can interfere with the normal operation of WiFi without the proper filtering. As an example, the transmit frequency of European LTE Band-7 (2500 - 2570 MHz) is located just above the frequencies used for WiFi in Europe (2401 MHz to 2488 MHz). See Figure 2 below.

2.3-2.7 GHz Ecosystem Coexistence Requirements



Minimal guard bands require FBAR Filter performance to solve difficult coexistence problems

Figure 2. Guard Bands Between 4G/LTE Services in the 2.3 to 2.7GHz Frequency Range

WiFi operates simultaneously with a 4G/LTE radio when using a smartphone as a WiFi hotspot. Without superior filtering, the WiFi transceiver can potentially be "blocked" or overwhelmed by the LTE transmission on Band-7. The Avago ACMD-6107 duplexer provides sufficient protection to allow operation on even the highest frequency (closest) WiFi channels without interference. Competing filters do not provide the required out-of-band attenuation as effectively, possibly rendering the upper WiFi channels unusable. Used in conjunction with an Avago ACPF-7124 WiFi coexistence filter, the combination provides unparalleled performance that meets or exceeds system requirements.

The vast majority of phones today also support GPS, and more recently, GLONASS services. Because GPS/GLONASS signals are typically very low in power (between -125dBm and -150dBm), any transmitted signal in close proximity to the GPS frequency will desensitize the GPS/GLONASS receiver. The steep filter skirt and wideband attenuation of the AGPS-F001 pre-filter/LNA module provides excellent out-of-band blocking of cellular, PCS and WiFi signals; and linearity performance.

FBAR Technology Maximizes Battery Life and Improves Receiver Sensitivity

Battery life is a phone feature that is often benchmarked and compared against other phones. On the receive side, we discussed how FBAR's lower insertion loss supports the higher data rate capability of 4G/LTE phones by compensating for the higher losses associated with combining multiple bands in a radio front end. Another benefit is that cell coverage is improved by enabling the phone to detect weaker signals that might otherwise result in poor reception or dropped calls. On the transmit side, lower Tx filter insertion loss means less output power is needed from the power amplifier for the same radiated power at the antenna. Compared to other filter technologies, the insertion loss benefit provided by an Avago Band-4 duplexer is typically between 0.2 to 0.5dB. This equates to a reduction in current consumption of up to 50mA, and that results in increased battery life and extended phone use.

Avago Technologies' FBAR Technology Ideally Suited to Support 4G/LTE

When most applications were 3G based, only a few frequency bands benefitted from FBAR technology. As 4G/LTE multi-band smartphones become more popular, the highlighted advantages of FBAR technology – low insertion loss, steep filter skirts, high isolation, and miniature size - are leading to the rapid adoption by all of the leading smartphone manufacturers. Today, filters, duplexers and multiplexers based on FBAR technology have been designed into smartphones operating in 15 different frequency bands across the US, Europe and Asia. As new filtering challenges emerge, FBAR is increasingly being selected to provide the answer. FBAR technology has gone mainstream.

Further information on Avago FBAR products is available online at www.avagotech.com/fbar

For product information and a complete list of distributors, please go to our web site: www.avagotech.com

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