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The A to D in LTE

All digital radio systems at some point in the processing chain move from the analogue to digital domain. In user equipment the point at which the transform is performed is generally determined by the amount of power available in a small form factor device.

In this month's technology topic we review the receiver front end architectures, ADC and signal processing bandwidth options for LTE user equipment, the relative performance tradeoffs implicit in the available choices and the implications for future regulatory and competition policy.

Channel bandwidth and dynamic range

Wider channel bandwidths deliver higher per user data rates and multiplexing gain which translate at least theoretically into an improved user experience (user value) and more capacity (network value).This is the rational for moving from 5 to 10 to 20 MHz LTE channel bandwidths.

A 20 MHz channel means that an LTE radio has the same bandwidth as a WiFi radio.

The multiplexing gain is a function of the number of devices co sharing the channel. Dynamic scheduling means that devices are supported on a varying number of resource blocks at varying power levels. The combination of wider channels and more users per channel increases the amount of dynamic range required in the ADC. Because LTE is a wide area network the difference in received power level (the difference between wanted and unwanted signal energy) is significantly higher than a WiFi network. The result is that an ADC capable of handling a 20 MHz LTE channel needs at least 60 dB of dynamic range.

The dynamic range needed in the ADC determines the bit width of the ADC. The bit rate of the ADC is a function of the bit width and sampling frequency which must be at least twice the signal bandwidth. The bit rate of the ADC and associated signal processing together determine the amount of power consumed. The bit width has to allow for additional resolution to accommodate RFIC imperfections including direct conversion DC off sets and adjacent channel interference.

The majority of ADC's to date have what is called a successive approximation register and are known as Successive Approximation Register (SAR) ADC's. The input analogue voltage is tracked and held and then compared with prior samples using a binary search algorithm. The power dissipation scales with the sample rate which is useful for lower sampling rates but not so useful for higher rates.

For LTE the two alternative options are either the sigma delta ADC or pipeline ADC.

A sigma delta ADC produces a high resolution and low resolution signal and uses error feedback to compare the two signals. A pipeline ADC as the name implies produces a high resolution description of an analogue signal from a series of lower resolution stages with the first stage working on the most recent sample and the following stages working on analogue remainder voltages left over from previous examples.

All ADC's generate quantization noise and are sensitive to clock jitter. Noise and jitter become particularly important when demodulating 16 QAM or 64 QAM signals.

Power efficiency is therefore a composite of conversion efficiency and conversion effectiveness expressed as a signal to noise ratio which in turn determines error vector magnitude which in turn determines throughput efficiency.

The benefits of a well-designed well behaved front end can therefore be compromised by a poorly implemented ADC. Conversely a well-designed ADC can compensate for a poorly implemented front end though the additional resolution required may result in unnecessarily high power consumption.

Specifying an ADC to handle the dynamic range required in a 20 MHz channel will however mean that the ADC will have substantial headroom when processing narrower band channels. This might allow for a relaxation of analogue filtering which in turn would reduce component count, component cost and insertion loss. Alternatively an ability to dynamically reduce the bit width of the ADC for narrower band channels would reduce ADC power drain which would probably be more useful.

ADC performance and LTE band plan auctions

From a technical perspective it can be argued that wider channel bandwidths are more efficient. High per user dates improve the user experience (user value) and scheduling gain can be translated into capacity gain. Both increase operator EBITDA.

This however implies a disconnect with present regulatory and competition policy which remains based on the theory that any available spectrum should be auctioned to allow four or five operators to compete in any band in any market.

A two by 30 MHz duplex at 700 MHz is obviously not going to support five operators with five 20 MHz channels.

When CDMA was first proposed there was a suggestion that operators should bid for Walsh codes rather than RF channel bandwidth but at the time this was felt to be too radical.

The equivalent approach in LTE would involve bidding for resource blocks.

The sigma delta and or pipeline ADC make such an approach more feasible.

ADC performance is one of the many topics addressed in RTT's latest book '**Making Telecoms Work-from technical innovation to commercial success'** published In January 2012 and available from the **RTT book shop.**

A detailed analysis of ADC (and DAC) options in LTE can be found in Harri Holma and Antti Toskala's excellent book **'LTE for UMTS - evolution to LTE Advanced'** also available from John Wiley and the **RTT book shop.** .

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geoff@rttonline.com

00 44 208 744 3163