Zero IF receivers have had limited success in high performance systems, such as wireless basestations, due primarily to their limited dynamic range.

Until recently, most basestations needed to only deal with a 20MHz channel bandwidth, typically allocated to various carriers. Associated with this 20MHz channel is a companion 100MHz bandwidth digital predistortion (DPD) receiver to measure intermodulation distortion spurs up to the fifth order for effective distortion cancellation. These requirements can generally be met with high IF (heterodyne) receivers, but such designs become more challenging as the industry pushes for basestations that support operation over 60MHz bands.

To accommodate the threefold increase in bandwidth, DPD receiver bandwidth has to increase to 300MHz. In 75MHz bands, DPD bandwidth grows to 375MHz. Designing receivers that support this bandwidth is not trivial – noise increases due to the wider bandwidth, gain flatness becomes more difficult to achieve and the a/d converter sampling rate increases dramatically. Not only is bandwidth higher, so too is the cost of components.

The modest bandwidth of a traditional high IF receiver is no longer sufficient to support the 300MHz or higher DPD signal with a typical gain flatness of ±0.5dB. The 300MHz baseband requires an IF frequency of at least 150MHz and it is not a trivial task to find a reasonably priced a/d converter which is capable of more than 600Msamples/s, even at 12-bit resolution. This means designers may have to compromise and resort to a 10-bit device.

Linear Technology's LTC5585 I/Q demodulator is designed to support direct conversion, allowing a receiver to demodulate the 300MHz wide rf signal directly to baseband. The I and Q outputs are demodulated to a 150MHz wide signal; half the bandwidth of a high IF receiver. In order to attain a passband gain flatness of ±0.5dB, the device's -3dB corner must extend well above 500MHz.

The LTC5585 supports this bandwidth with a tuneable baseband output stage. The differential I and Q output ports have a 100Ω pull up to Vcc in parallel with a filter capacitance of about 6pF [see fig 1]. This simple RC network allows for the formation of off chip lowpass or bandpass filter networks to remove high level out of band blockers and equalisation of gain roll off in the baseband amplifier chain that follows the demodulator. With a 100Ω differential output loading resistance in addition to the external 100Ω pull up resistors, the -3dB bandwidth reaches 840MHz.

A single LC filter section can be used to extend the bandwidth of the baseband output and the chip's baseband equivalent circuit with baseband bandwidth extension is shown in fig 1.
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With 200Ω loading, the -0.5dB bandwidth can be extended from 250MHz to 630MHz using a series inductance of 18nH and a shunt capacitance of 4.7pF.

In a direct conversion receiver, the second order intermodulation distortion products (IM2) fall directly in band at the baseband frequencies. Take, for example, two equal power rf signals – f₁ and f₂ – at 2140MHz and 2141MHz, while the LO is 10MHz away at 2130MHz. The resultant IM2 spur would fall at f₂ – f₁, or 1MHz. The LTC5585 can adjust for minimum IM2 spurs independently on the I and Q channels by using external control voltages (see fig 2 for a typical setup). The differential baseband outputs are combined using a balun and the 1MHz IM2 difference frequency component is selected with a lowpass filter to prevent the strong main tones at 10MHz and 11MHz from compressing the spectrum analyser front end. Without the lowpass filter, 20 to 30dB of attenuation and long averaged measurement times are necessary for good measurement.

Two calibration strategies

With this optimisation capability, two calibration strategies may be considered. One is a ‘set and forget’ step at the factory, where a simple trim potentiometer for each adjustment pin suffices. Alternatively, an automatic closed loop calibration algorithm can be implemented in software, allowing the equipment to be calibrated periodically. For DPD receivers that already monitor their transmitters’ output, this is trivial; the transmitters can generate the two test tones. For main receivers, this calibration may involve additional hardware to loop back the two test tones to the receiver channel.

A similar adjustment capability is integrated into the chip to zero the I and Q’s dc output voltage. DC offset, a product arising from internal mismatch and self mixing of the LO and rf input leakages, can diminish the a/d converter’s dynamic range when the signal chain is dc coupled throughout. An output dc offset voltage of 10mV, when passed through a 20dB gain stage, would result in 100mV of dc offset at a/d converter’s input. With the 2Vp-p input range of a 12bit converter, this effectively reduces the converter’s dynamic range by 0.9dB.

Potential cost savings make a zero IF receiver particularly compelling, but because zero IF demodulation produces no image at the baseband, there is no need for a relatively expensive SAW filter. Perhaps most attractive of all, the a/d converter’s sampling rate can be reduced significantly.

In the example above, the 150MHz I and Q baseband bandwidth can be addressed with a 310Msamples/a/d converter – such as Linear’s LTC2258-14 – without having to resort to a more expensive device with a higher sampling rate.

But as the bandwidth and performance of wireless receivers increase, a wideband quadrature modulator offers a different approach that helps to address architectural shortcomings and which improves receiver performance whilst helping to reduce costs.

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