Problem with using a single multiplier for LOFT

Neil Birkett Apr. 25, 2005

Background

LOFT calibration currently utilizes a filtered detector to determine the presence of LOFT and IQ imbalance. The detector output is subsequently digitally donconverted and filtered to obtain a 5MHz or 10MHz tone. In the original design, the frequency translation is done using a single mixer. This is shown in Figure 1.

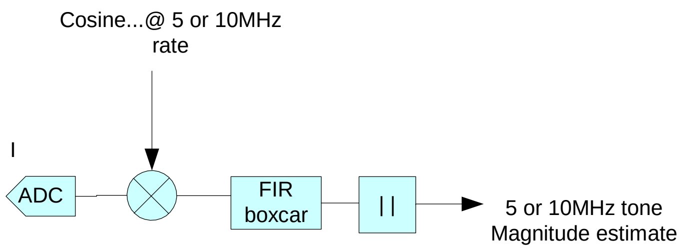

Figure 1 Digital down conversion and filtering to obtain an estimate of the magnitude of the detector 5 or 10MHz tone.

Math

Let the detector signal be represented by

$$S_d = A\cos(\omega_c t + \varphi_d) \qquad \textbf{Equation 1}$$

Where *A*, ω_d and φ_d are the magnitude and frequency of the detected filtered signal respectively and φ_d is the phase of the detected signal with respect to the mixer local oscillator.

The phase φ_d is comprised of two parts,

- a fixed phase φ_{gd} due to absolute group delay between the transmitted tones and the sampled baseband.
- A relative phase delay φ_r due to the magnitude of individual I and Q DC offsets.

$$\varphi_d = \varphi_{gd} + \varphi_r \qquad \textbf{Equation 2}$$

The relative phase delay φ_r is described by the following equation;

$$\varphi_r = \tan^{-1}(\frac{Q_{DC}}{I_{DC}})$$ **Equation 3**

Let the digital multiplying tone be represented by

$$S_m = \cos(\omega_d t)$$ **Equation 4**

The resultant signal after multiplication is;

$$S_r = A\cos(\omega_c t + \varphi_d)\cos(\omega_d t) = \frac{A}{2}[\cos(\varphi_d) + \cos(2\omega_d t + \varphi_d)]$$ **Equation 5**

After filtering, the double frequency components are removed so that the signal can be represented by;

$$S_{out} = \frac{A}{2}\cos(\varphi_d) = \frac{A}{2}\cos(\varphi_{gd} + \tan^{-1}(\frac{Q_{DC}}{I_{DC}}))$$ **Equation 6**

Problem with the single downconversion

Equation 4 illustrates the problem. Basically, the phase of the detected signal relative to the multiplying signal can result in a zero (or small magnitude) output from the filter if φ_d is close to 90 degrees. It is compounded by the fact that the phase of 5MHz signal out of the detector is also dependent on the individual magnitudes of the I-path DC and Q-path DC offsets. As well, the S_{out} value will have a polarity associated with it depending on the phase φ_d.

An I path DC offset will create a 5MHz detector tone which is 90 degrees out of phase with that generated by a Q path DC offset. This means that in real situations, the magnitude of the downconverted DC signal (i.e. the error signal) will wander according to how much I and Q path DC offset there is, and this changes the phase of the detector signals with respect. Unfortunately we have no control over this.

Solution to the problem

One solution to the problem is to implement a *quadrature* downconversion in digital, which would require multiplications using digital cosine and sine multiplying functions and a magnitude function. Instead of a magnitude function, a reasonable estimate can be obtained by using absolute values. Figure 2 illustrates this technique.

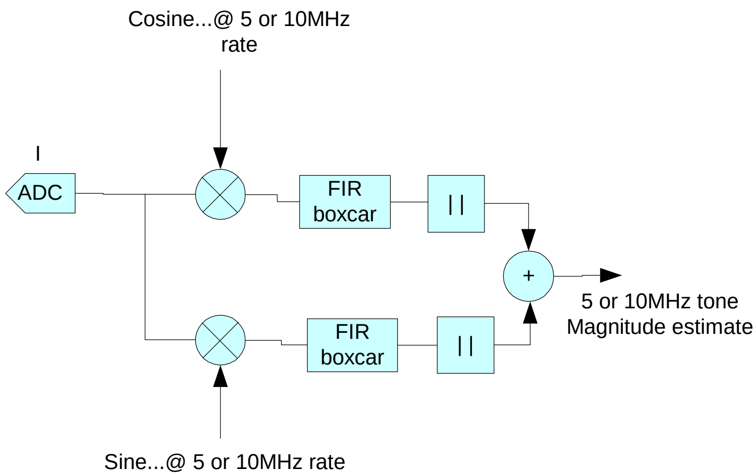

Figure 2. Quadrature conversion eliminates magnitude wandering due to phase variation.