Super-Het Tuning

Say we wish to **recover** the information encoded on a radio signal operating at a frequency that we shall call f_0. Recall that (typically) we must **down-convert** to an IF frequency f_{IF}, by **tuning** the LO frequency f_{LO} to a frequency such that:

$$\left| f_0 - f_{LO} \right| = f_{IF}$$

Note for a given f_0 and f_{IF} , there are **two** possible **solutions** for value of LO frequency f_{LO}:

$$\begin{aligned} f_0 - f_{LO} &= \pm f_{IF} \\ -f_{LO} &= -f_0 \pm f_{IF} \\ f_{LO} &= f_0 \mp f_{IF} \end{aligned}$$

In other words, the LO frequency should be set such that it is a value f_{IF} **higher** than the desired signal frequency, **or** set such that it is a value f_{IF} **lower** than the desired signal frequency.

The first case, where $f_{LO} > f_0$, we call **high-side tuning.**

The second case, where $f_{LO} < f_0$, we call **low-side tuning**.

For **example**, consider again the FM band. Say a radio engineer is designing an **FM radio**, and has selected an **IF** frequency of **30 MHz**. Since the FM band extends from 88 MHz to 108 MHz, the radio engineer has two choices for LO bandwidth.

If she chooses **high-side** tuning, the LO bandwidth must be $f_{IF} = 30MHz$ **higher** than the RF bandwidth, i.e.,:

$$88\ MHz + f_{IF} < f_{LO} < 108\ MHz + f_{IF}$$
$$118\ MHz < f_{LO} < 138\ MHz$$

Alternatively, she can choose **low-side** tuning, with an LO bandwidth of:

$$88\ MHz - f_{IF} < f_{LO} < 108\ MHz - f_{IF}$$
$$58\ MHz < f_{LO} < 78\ MHz$$

Q: *Which of these two solutions* ***should*** *she choose?*

A: It **depends**! **Sometimes** high-side tuning is better, **other** times low-side is the best choice.

Let's be positive and look at the **advantages** of each solution:

Advantages of low-side tuning:

1. Lower oscillator frequency generally means **lower cost**.

2. Likewise, lower frequency generally means greater **output power.**

Advantages of high-side tuning:

1. Higher LO frequency means **harmonics** and other higher-order mixer terms are higher in frequency, and thus generally **easier** to filter out.

2. Higher LO frequency results in a smaller **percentage bandwidth**, which generally results in a more stable and better performing local oscillator.

Q: ***Percentage*** *bandwidth? Jut what does* ***that*** *mean?*

A: Percentage bandwidth is simply the LO bandwidth Δf_{LO}, **normalized** to its center (i.e., average) frequency:

$$\% \text{ bandwidth} \doteq \frac{f_{LO} \text{ bandwidth}}{f_{LO} \text{ center frequency}}$$

For our example, **each** local oscillator solution (low-side and high-side) has a bandwidth of **20 MHz** (the same width as the FM band!).

However, the **center** (average) frequency of each solution is of course very **different**.

For **low-side** tuning:

$$\frac{58+78}{2}=68 \text{ MHz}$$

And thus the **percentage bandwidth** is:

$$\% \text{ bandwidth} \doteq \frac{20}{68}=0.294=29.4\,\%$$

For **high-side** tuning:

$$\frac{118+138}{2}=128 \text{ MHz}$$

And thus the **percentage bandwidth** is a far **smaller** value of:

$$\% \text{ bandwidth} \doteq \frac{20}{128}=0.156=15.6\,\%$$

Stability concerns are generally **not** a substantial issue as long as % bandwidth is relatively small (i.e., > 50%). However, if the LO % bandwidth begins to **approach 100%,** then we begin to worry!

In fact, wide LO bandwidth is generally **not** specified in terms of its % bandwidth, but instead in terms of the ratio of its highest and lowest frequency. For our examples, either:

$$\frac{78}{58}=1.34 \qquad \text{or} \qquad \frac{138}{118}=1.17$$

Again, a **smaller** value is generally **better**.

If the LO bandwidth is **exceptionally** wide, this ratio can approach or exceed the value of 2.0. If the ratio is equal to 2.0, we say that the LO has an **octave** bandwidth → do **you** see why?

Generally speaking, it is **difficult** to build a **single** oscillator with a octave or greater bandwidth. If our receiver design requires an octave or greater LO bandwidth, then the LO typically must be implemented using **multiple oscillators**, along with a microwave **switch**.

For example, an LO oscillator with a bandwidth from 2 to 6 GHz might be implemented as: