Image frequency in RF and wireless circuits

The image frequency in radio receivers is an issue that has to be understood and tackled for good design. Here is a description of the problem.

Lets assume that we have RF signals at the input of a receiver which uses heterodyning, i.e. generation of an intermediate frequency or IF frequency. Two conditions can exist. In low side tuning the local oscillator is set at a frequency lower than the expected RF input signal and in high side tuning the local oscillator frequency is set higher than the expected RF input signal.

A good way to get an intuitive understanding is to use some numbers. Lets say the IF is selected (for various reasons) to be 30 Mhz. Then for a RF input signal of 130 Mhz a local oscillator running at 100 Mhz will produce: (in an idealized case)

\[ \text{FIF} = \text{FRF} - \text{FLO} \]
\[ \text{FIF} = 130 - 100 = 30. \]
(All frequencies in Mhz).

Here the RF signal frequency is, \[ \text{FRF} = \text{FIF} + \text{FLO} \]

Simple?

Now assume that an input RF signal of 70 Mhz also is present. Then because of the heterodyning* action we can have:

\[ \text{FIF} = \text{FLO} - \text{FRF} \]
\[ \text{FIF} = 100 - 70 = 30. \]
(All frequencies in Mhz).

The 70 Mhz signal is termed an image signal because it will also produce the same IF as a 130 Mhz signal.

\[ \text{In the above case,} \]
\[ \text{FRF(image)} = \text{FLO} - \text{FIF} \]

These results hold true for low-side tuning.

*Please see the effects of heterodyning on signals in the appendix.
If the system is set up for high side tuning then we have:

\[
\text{FIF} = \text{FLO} - \text{FRF}
\]
\[
\text{FIF} = 160 - 130 = 30
\]
\[(\text{All frequencies in Mhz})\]
\[
\text{FRF} = \text{FLO} - \text{FIF}
\]

Similar to the effects for low side tuning we can also generate 30 Mhz by:

\[
\text{FIF} = \text{FRF} - \text{FLO}
\]
\[
\text{FIF} = 190 - 160 = 30
\]
\[
\text{FRF(\ image)} = \text{FIF} + \text{FLO}
\]

In both cases of low side and high tuning, the difference between the input rf signal and its image is :

\[
|\text{FRF} - \text{FRF(\ image)}| = 2\text{FIF}.
\]

(An interesting result here is that we can space the desired and image input frequencies as far apart as required by choosing an appropriate IF frequency. This helps in pre-filtering the inputs).

**Appendix I**

Heterodyning is a process whereby two signals at frequencies of f1 and f2 are mixed together in a non-linear element so as to produce two new frequencies. A *sum frequency* component, f1 + f2 and a *difference frequency* component f1 − f2. Note that the two components will always be created together in this technique. Filtering can be used to suppress either of these components as desired.

**Appendix II**

*A brief note on solutions*. Two widely used approaches to the image frequency problem are the pre-selector filter which is situated before the input RF enters the mixer and suppresses the frequency component of the input signal that creates the image. The other is the image suppression mixer. More on these approaches in other posts on this blog.