To lower the center frequency, the signal is multiplied by a sinusoid , which is generated by a local oscillator (LO). Since multiplication in the time domain corresponds to convolution in the frequency domain, we observe from Fig. 4.7(b) that the impulses at ± shift the desired channel to ±( ± ). The components at ±( ± ) are not of interest and are removed by the low-pass filter (LPF) in Fig. 4.7(a), leaving the signal at a center frequency of  - . This operation is called “downconversion mixing” or simply “downconversion.” Due to its high noise, the downconversion mixer is preceded by a low-noise amplifier [Fig. 4.7(c)].

Diagram

Description automatically generated

Called the intermediate frequency (IF), the center of the downconverted channel, - , plays a critical role in the performance. “Heterodyne” receivers employ an LO frequency unequal to and hence a nonzero IF.

How does a heterodyne receiver cover a given frequency band? For an N-channel band, we can envision two possibilities. The LO frequency is constant and each RF channel is downconverted to a different IF channel [Fig. 4.8(a)], i.e., . The LO frequency is variable so that all RF channels within the band of interest are translated to a single value of IF [Fig. 4.8(b)], i.e., . The latter case is more common as it simplifies the design of the IF path; e.g., it does not require a filter with a variable center frequency to select the IF channel of interest and reject the others. However, this approach demands a feedback loop that precisely defines the LO frequency steps, i.e., a “frequency synthesizer”.

Diagram, schematic

Description automatically generated

Problem of Image Heterodyne receivers suffer from an effect called the “image.” To understand this phenomenon, let us assume a sinusoidal input and express the IF component as

That is, whether is positive or negative, it yields the same intermediate frequency. Thus, whether lies above or below , it is translated to the same IF. Figure 4.9 depicts a more general case, revealing that two spectra located symmetrically around are downconverted to the IF. Due to this symmetry, the component at is called the image of the desired signal. Note that .

A picture containing text, clock

Description automatically generated

What creates the image? The numerous users in all standards (from police to WLAN bands) that transmit signals produce many interferers. If one interferer happens to fall at , then it corrupts the desired signal after downconversion.

While each wireless standard imposes constraints upon the emissions by its own users, it may have no control over the signals in other bands. The image power can therefore be much higher than that of the desired signal, requiring proper “image rejection.”