Signals and Communication II.

Dr. Ciira Maina
ciira.maina@dkut.ac.ke

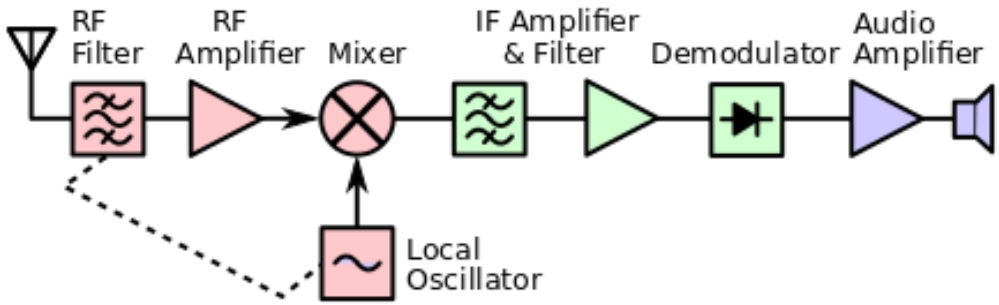
12th January, 2021

Functions of a communication receiver

- Carrier frequency tuning
- Filtering
- Amplification

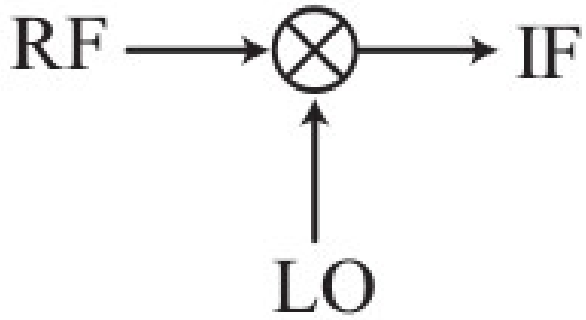
The superheteredyne receiver (superhet)

- Achieves all three functions
- Overcomes difficulty of designing high-Q variable filters



Superheterodyne receiver - Source Wikipedia

Mixing



- An ideal mixer is represented by a multiplier symbol
- Let

$$\begin{aligned} v_{RF}(t) &= A(t)\cos(2\pi f_{RF}t + \phi(t)) \\ v_{LO} &= A_{LO}\cos(2\pi f_{LO}t) \end{aligned}$$

- The output of the mixer is given by

$$\begin{aligned} v_{out} &= v_{RF}(t)v_{LO}(t) \\ &= \end{aligned}$$

Mixing

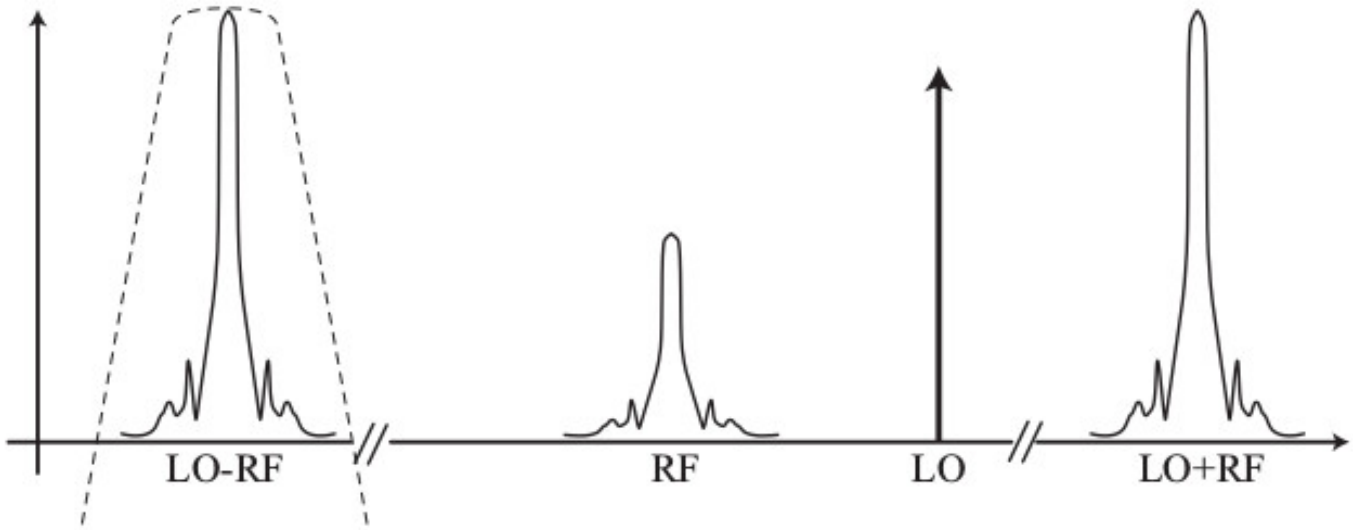
- The output of the mixer is given by

$$\begin{aligned} v_{out} &= v_{RF}(t)v_{LO}(t) \\ &= \frac{A(t)A_{LO}}{2}\Big[\cos\left(2\pi(f_{RF}+f_{LO})t+\phi(t)\right) \\ &+ \cos\left(2\pi(f_{RF}-f_{LO})t+\phi(t)\right)\Big] \end{aligned}$$

- The incoming RF has been translated into two frequencies $f_{RF} \pm f_{LO}$
- Here we assume $f_{LO} < f_{RF}$ which is known as lower side injection
- When $f_{LO} > f_{RF}$ it is known as upper side injection

Mixing

- Upper side injection.



Intermediate Frequency

- The frequency $f_{RF} - f_{LO}$ or $f_{LO} - f_{RF}$ is known as the intermediate frequency.
- The IF section of the supehet consists of a series of tuned amplifiers.

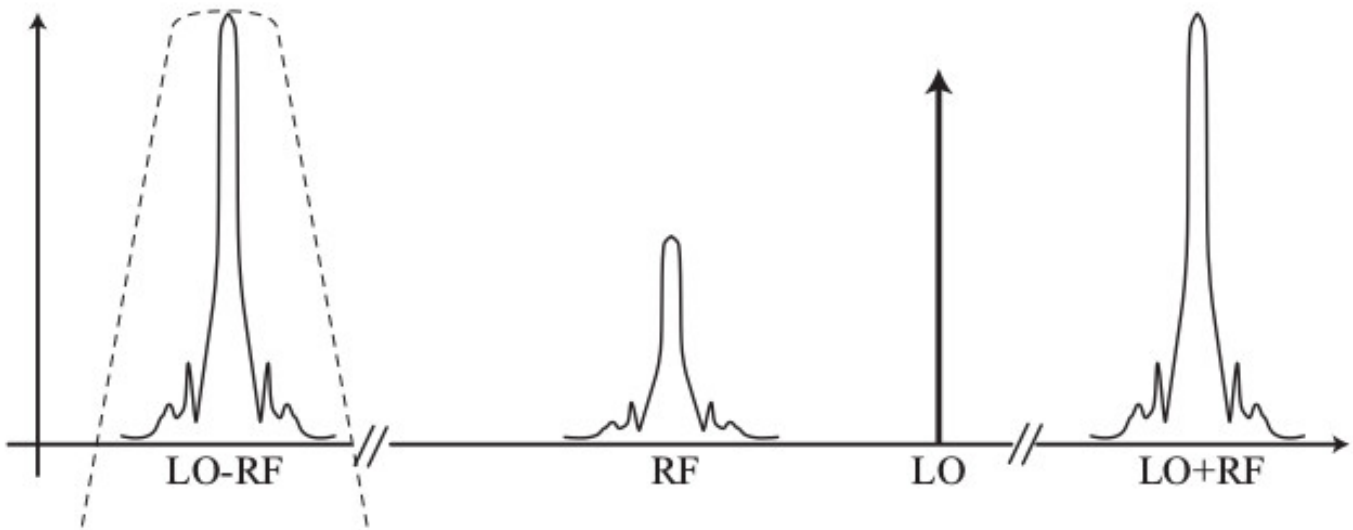


Image Frequency

- Radio frequencies given by $|f_{LO} \pm f_{IF}|$ result in signals at f_{IF} at the mixer output
- This is known as the image interference problem
- The RF section include an image rejection filter
- The bandwidth of this filter is approximately IF

Example

- Consider an FM signal at 101.1 MHz
- $f_{IF} = 10.7 MHz$
- Assuming upper side injection, $f_{LO} = 111.8 MHz$
- The image frequency is 122.5MHz

Example

- Consider an FM signal at 101.1 MHz
- $f_{IF} = 10.7 MHz$
- Assuming lower side injection, $f_{LO} =$?
- The image frequency is ?

Image Frequency Rejection

- To reject the image frequency a filter whose bandwith is approximately IF is used in the RF section
- The Q of the filter is given by

$$Q = \frac{f_c}{BW}$$

- For FM systems, channel bandwidth is $200kHz$, if we eliminate the IF section, we would need tunable filters with

$$Q \approx \frac{100 \times 10^6}{200 \times 10^3} = 500$$

- With an IF of 10MHz, the RF section filter Q is approxiamtely 10
- High Q filters are expensive and difficult to design