Department of Communications Engineering

Communication Systems

Third Year Class

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Lecture 11

Receivers

Introduction to Receivers

The receiver translates RF signals to baseband.

– In the receiver ∴
1. Shift frequency,
2. Amplify,
3. filter, and
4. Demodulate

} In fact, it is not easy to recover the message because of the interference and noise.

Hence ∴ → The receiver must be capable of handling a very wide range of signal powers.

→ Handling signal powers must be done in the presence of noise and interference, which occasionally can be much stronger than the desired signal.

Noise: sets the threshold for minimum detectable signal power.

Distortion: sets the maximum signal power level.

Power	-174 dBm	-130 dBm	-80 dBm	$+10$ dBm
	4×10^{-12} W	10^{-16} W	10^{-11} W	10^{-2} W
Volts (rms) in 50 Ω	0.6 nV	0.1 μV	32 μV	1 V
	thermal noise of resistor in 1 Hz bandwidth	Minimum Detectable signal for good comm receiver in 3 KHz BW	Minimum Detectible signal for Cell Phone	Strong Local signal at input of receiver

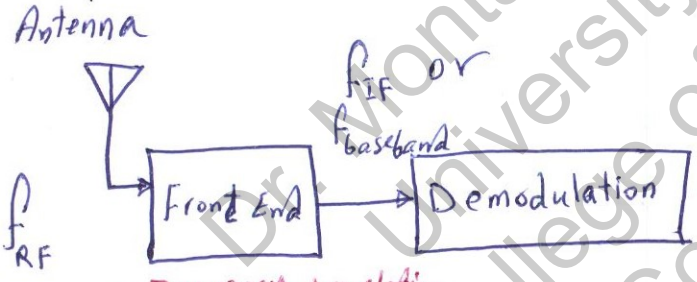
To achieve RF-to-Baseband conversion :-

* there are two methods

Both use frequency translation - i.e., mixer for up-conversion or down conversion.

① Superheterodyne
- by E. H. Armstrong in 1917,
- uses intermediate frequency (IF), and
- Around 99% of the receivers uses it.

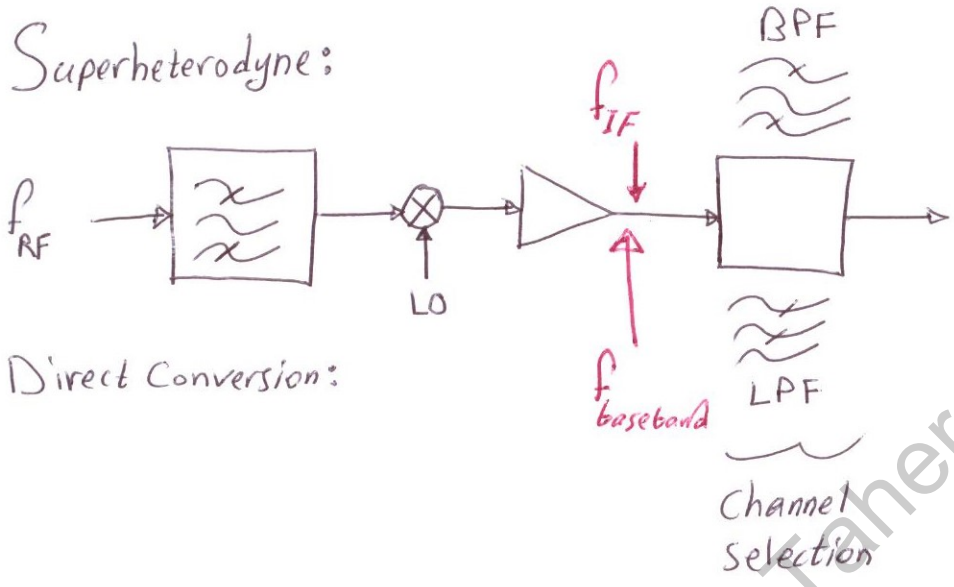
② Direct conversion
- used in single-chip radios
- Less hardware, but troublesome.



- Frequency translation
- Amplification
- Selectivity

Thus, the Front End of the receiver performs the frequency translation, channel Selection and amplification of the signal.

Superheterodyne:

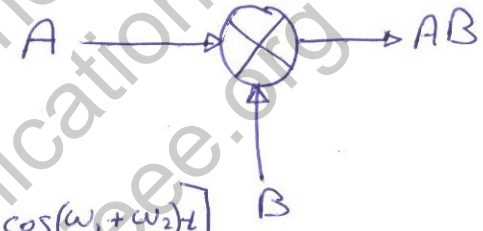


Direct Conversion:

Mixer (Revisited)

It is a frequency translation device.

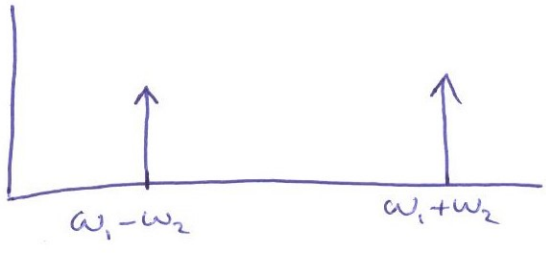
ideal mixer is a multiplier.



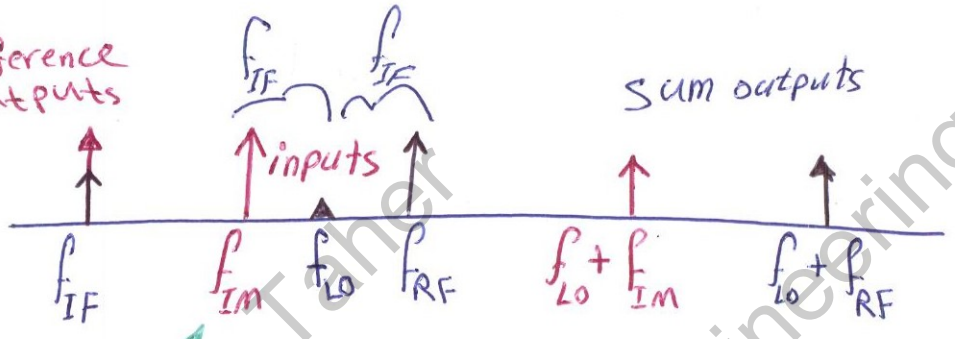
$$(A\sin\omega_1 t)(B\sin\omega_2 t) = \frac{AB}{2}\left[\cos(\omega_1-\omega_2)t - \cos(\omega_1+\omega_2)t\right]$$

Downconvert — Upconvert

* In downconversion, $\omega_1+\omega_2$ will be filtered out.
* In upconversion, $\omega_1-\omega_2$ will be filtered out.



Generally speaking, two inputs (RF & Image) will mix to the same output (IF) frequency



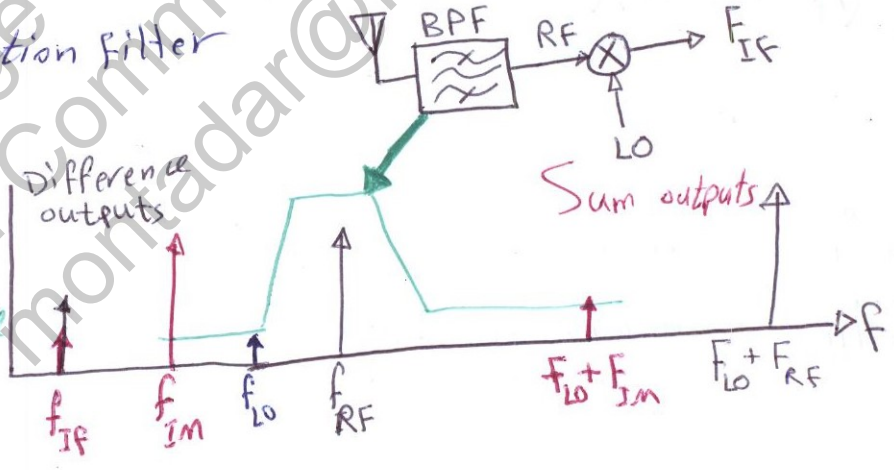
* $F_{LO} - F_{IM} = F_{IF} = F_{RF} - F_{LO}$

i/p mix o/p

Lower input is an image which is undesired

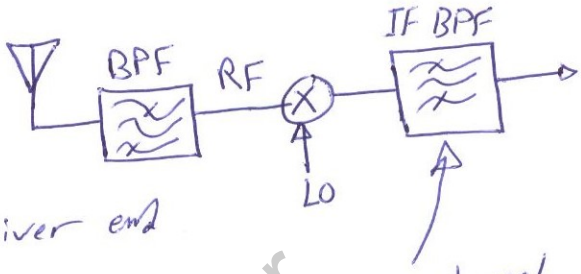
Thus a BRF should be used prior the mixer :-

this BPF is called BPF preselection filter



The received signal with image frequency could cause interference when it mixed with the IF frequency

Channel Selection: is done after the mixer by using a narrowband fixed frequency BPF.



Hence: The LO tunes the receiver end to select the channel

$$f_{IF} = F_{RF} - F_{LO}$$

*So, the superhetrodyne will downconvert to the Lower IF.

* The superhetrodyne was invented by Armstrong.

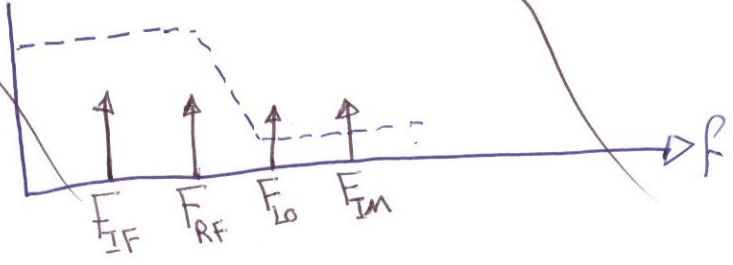
Another choice is by downconvert directly to the baseband (zero IF), then it will be demodulated using DSP processing. This is not superhetrodyne.

* Image, Downconversion

- Two cases: For downconversion when $F_{IF} < F_{RF}$

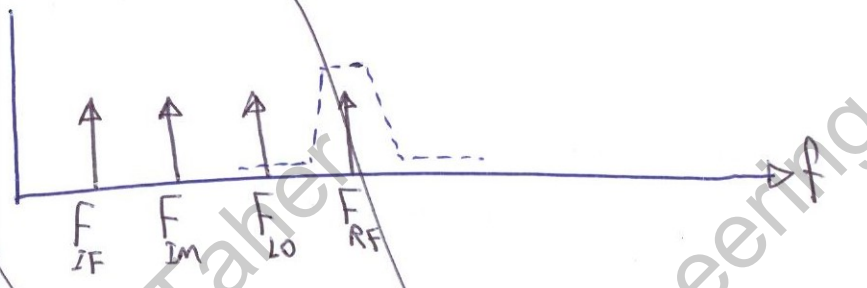
First case: $LO > RF \Rightarrow F_{IM} = 2 f_{IF}$ above the RF. Hence sharp LPF or BPF can be used to attenuate the Image.

$$f_{IF} = f_{RF} - f_{LO}$$



second case: RF > LO, hence, $F_{IM} = 2f_{IF}$ below RF, in this case, F_{IM} is inside the LPF, therefore, a BPF (sharp) must be used to attenuate the image frequency.

$$F_{IF} = F_{LO} - F_{RF}$$



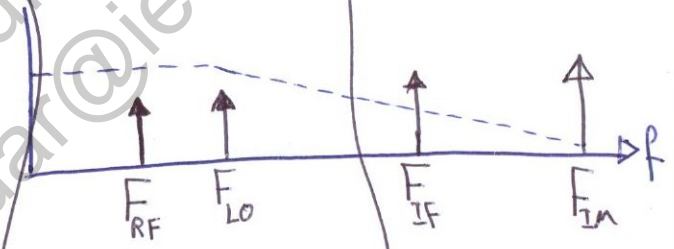
* **Image UpConversion:** A LPF can be used! Because the image frequency becomes higher and higher. Four cases are conducted for the upconversion :- (Last two case are almost ≡ 1 & 2)

Case ①: In this first case LO > RF, two i/p produces the same IF

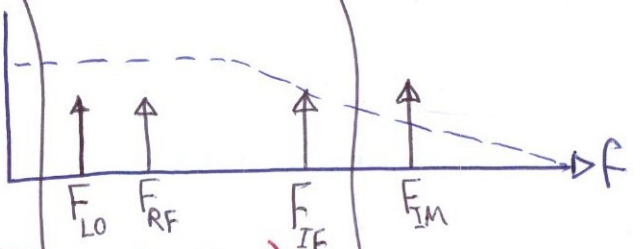
$$F_{RF} + F_{LO} = F_{IF} \quad \text{---(1)}$$

$$F_{IM} - F_{LO} = F_{IF} \quad \text{---(2)}$$

$F_{IM} \gg F_{RF}$, So it's easy to use a simple LPF.



Case ②: Equations (1) & (2) still valid but in this second case $F_{LO} < F_{RF}$, hence, F_{IM} & F_{IF} become near to the RF-frequency, therefore, the LPF must be better (to provide a significant image rejection).

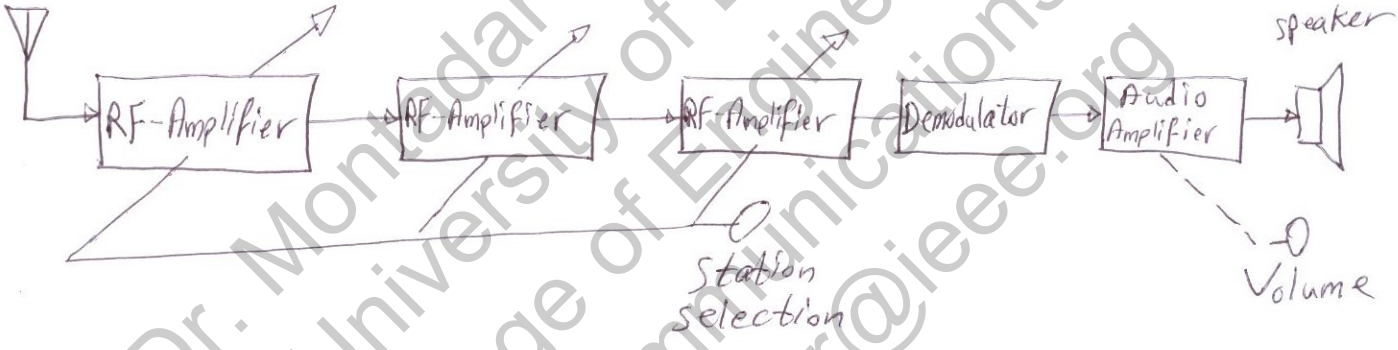


Superheterodyne Receiver

In General, there are two receiver structures :-

① Tuned Radio-Frequency (TRF) receiver, and

② superheterodyne receiver.



Tuned Radio-Frequency (TRF)

Because of changing RF-Amplifiers altogether is not accurate, the sensitivity and selectivity are degraded.