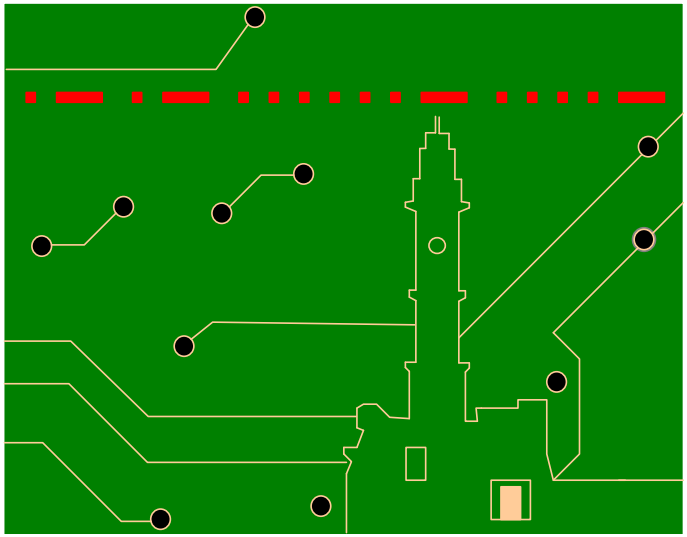
ΤΗΛ412 Ανάλυση & Σχεδίαση (Σύνθεση) Τηλεπικοινωνιακών Διατάξεων

Διάλεξη 4



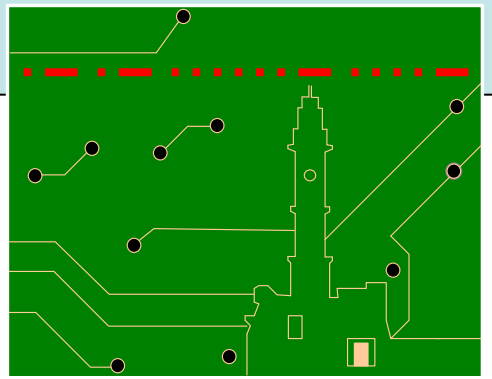
Άγγελος Μπλέτσας

Σχολή ΗΜΜΥ Πολυτεχνείου Κρήτης, Φθινόπωρο 2014

Lecture 4: Receiver Architectures (Part A)

Today,

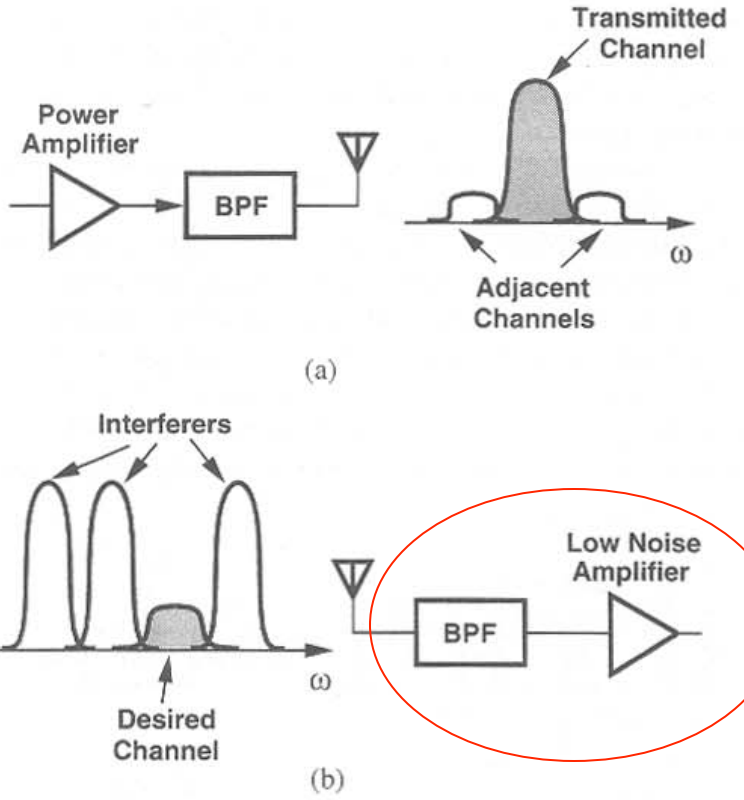
- Filter Quality Factor Q.
- Heterodyne Receiver.
- Image Reject Receiver.

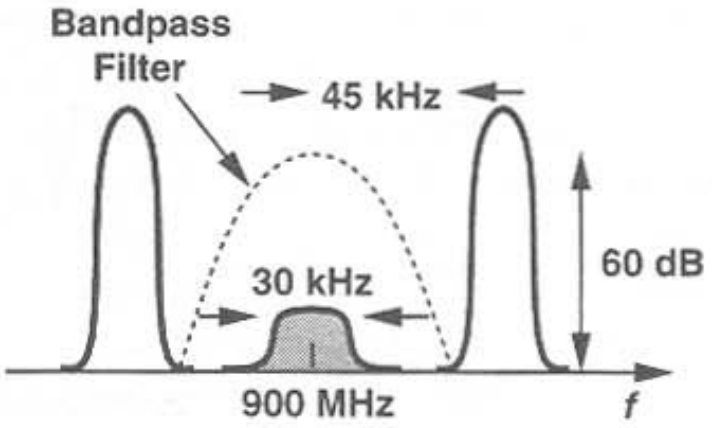


Διάλεξη 4

Most Figures for today's lecture come from:
B. Razavi, RF Microelectronics, Prentice Hall 1998.

Quality Factor of a Filter

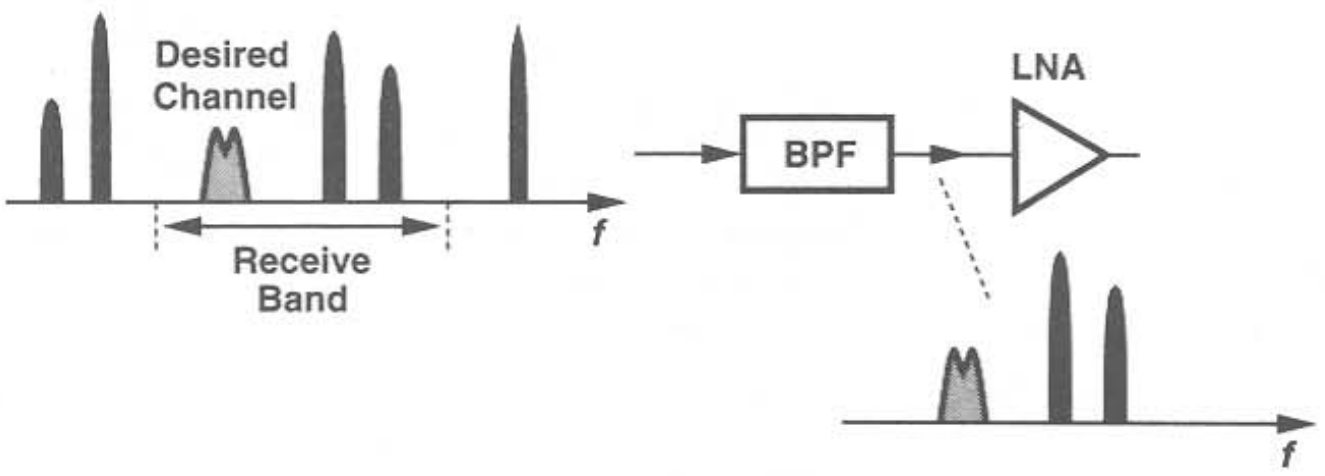




What is the NF of the marked chain?

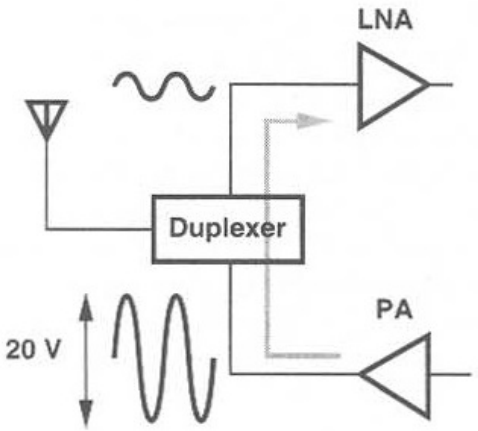
- Filter is needed at both transmit and receive RF-front end.
- Q = f_c/BW (ratio of center frequency with filter bandwidth).
- Q: indication of the complexity **(and cost)** to implement such filter!

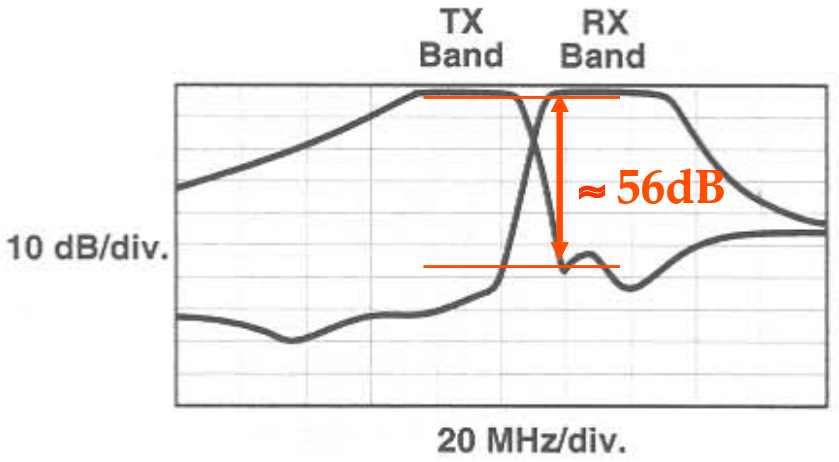
Two-step filtering due to Q requirements!



- First filter to grasp the band of interest (several channels)…
- Then filter to focus on the channel of interest…
- Receiver filter Q requirements are relaxed…

Things are not as simple as they look!





- Filters exhibit Q-loss tradeoff (the higher the Q, the higher the loss)!

Example: filter with 2dB loss amounts to a loss of 369mW for PA output of 1 Watt!

⇒loss at receiver affects transmitter path.

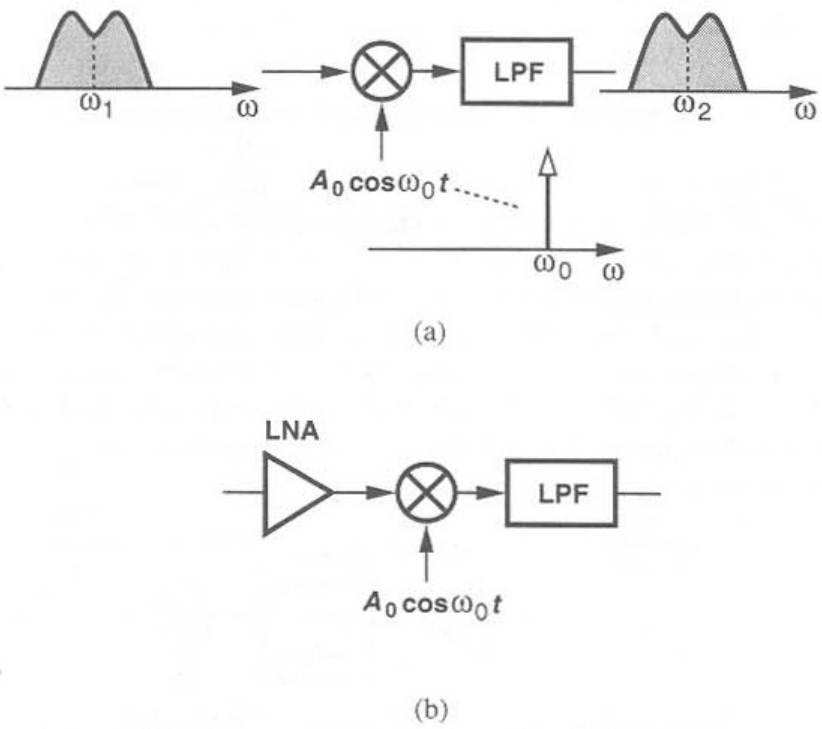
- Dynamic range on the order of 100dB or more is needed

(received signal at the μV range).

Example: tx 1 W at 50 Ωhm antenna => 20Vpp =>

rx leakage = -26dBm = 32mVpp at the rf chain!

Heterodyne Receiver: translation to lower band

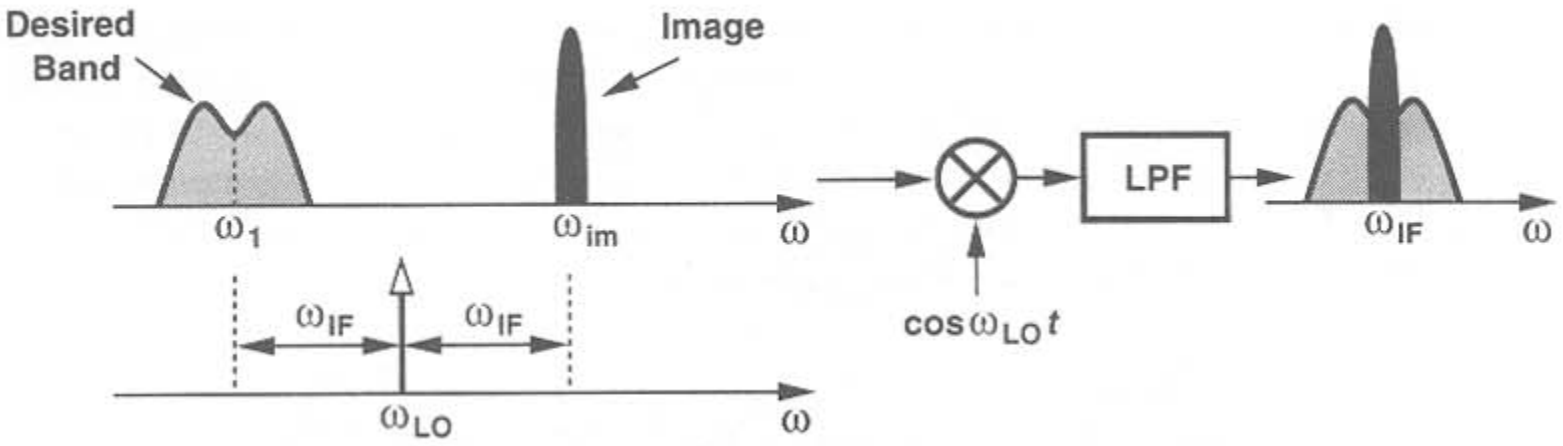


$\omega_0 \equiv \omega_{LO} = \omega_1 - \omega_2$

$\omega_2 = \omega_{IF}$

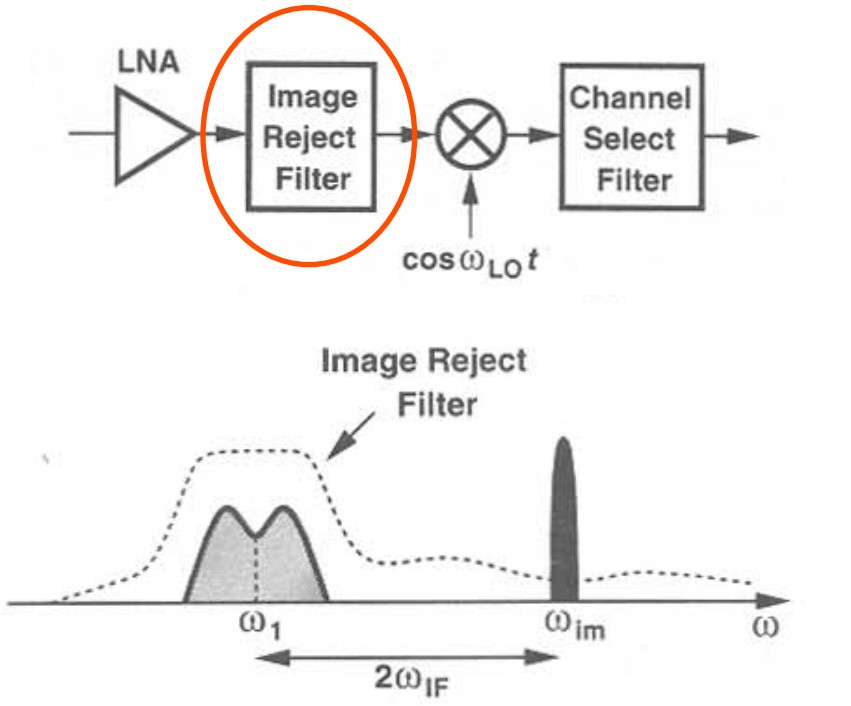
- Translation to lower band (not at DC) eases Q requirements as well as implementation.
- Notice that the component at $|\omega_1 - \omega_{LO}| = \omega_2$ is due to negative freq. of LO.

Heterodyne Receiver: Problem of Image!



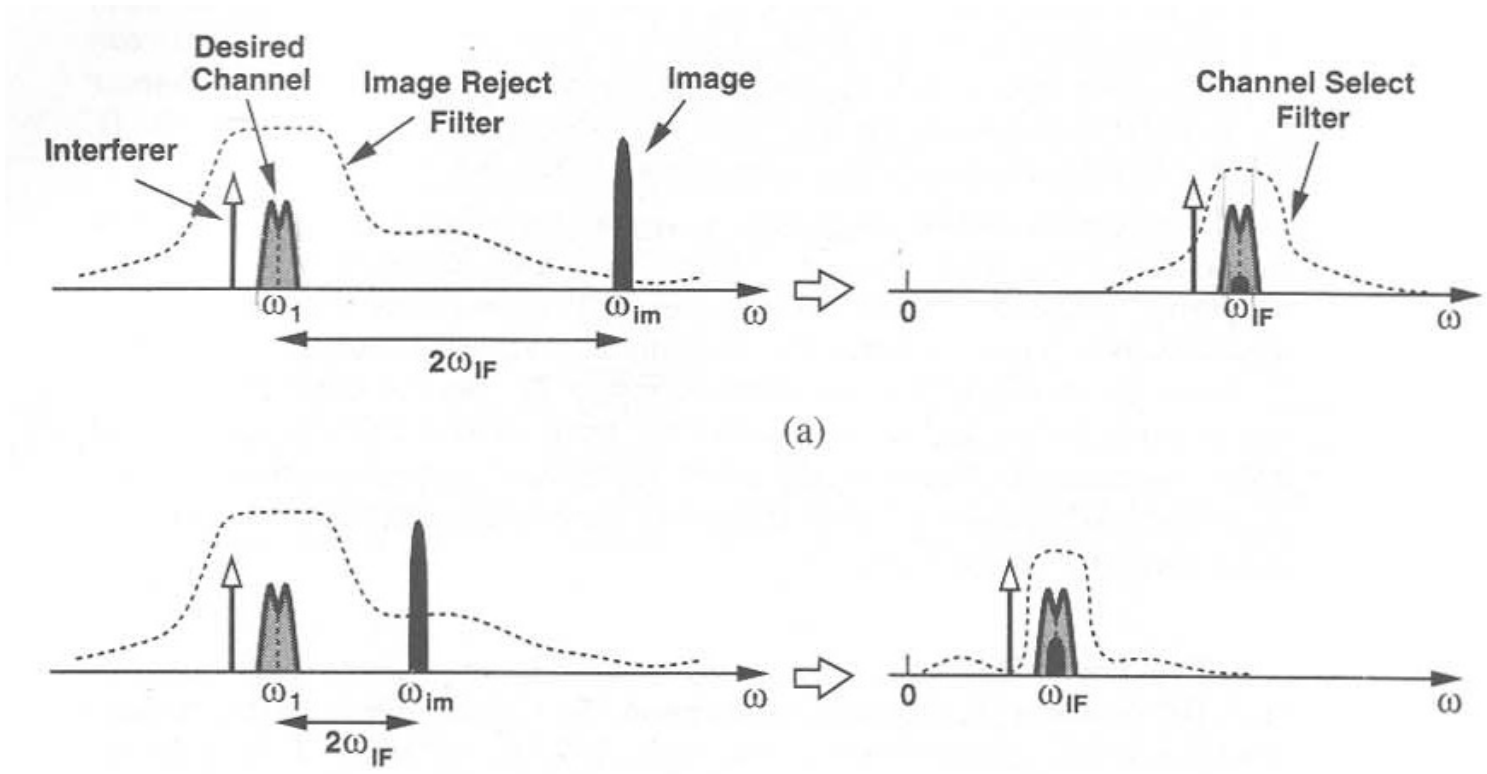
- Not only desired freqs are translated…
- Unwanted freqs (images), ω_{IF} away from ω_{LO}, are also translated!
- Serious problem.

One Solution to the Image Problem: Pre-filtering



- Using pre-filtering BEFORE mixing, to remove the unwanted image!
- Image Reject filter!

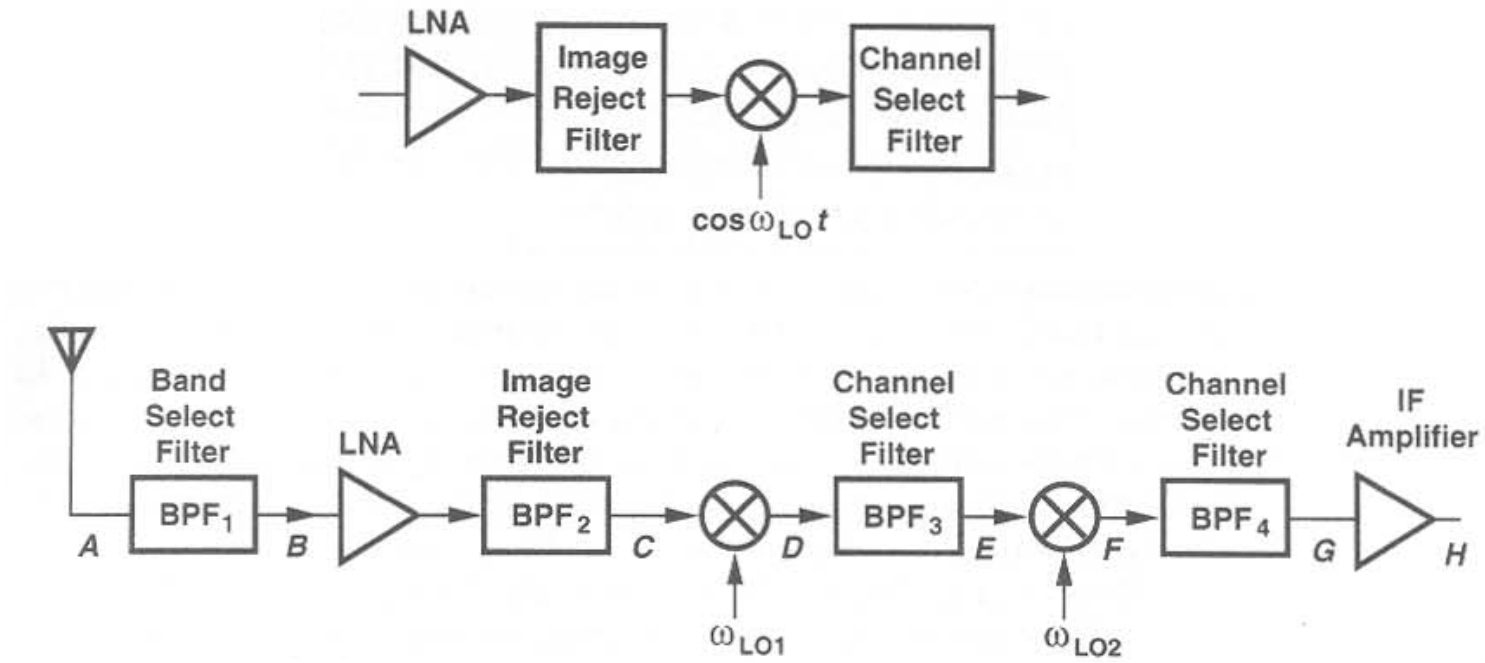
Heterodyne Receiver
Selectivity vs Sensitivity Tradeoff



Not so simple, as it looks:

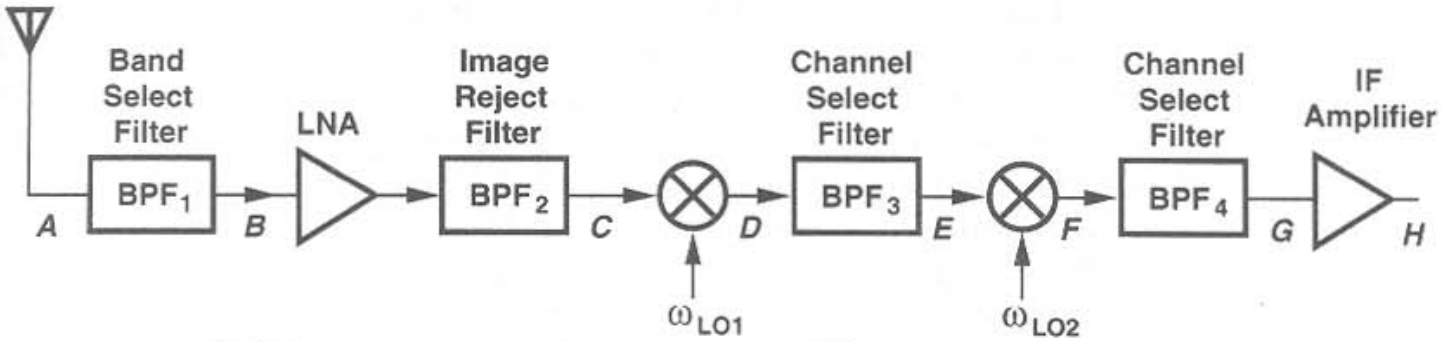
- higher ω_{IF} results to better image rejection (better sensitivity)…
- however, higher ω_{IF} requires higher Q for channel select => practically infeasible => worse channel selection (worse selectivity)!

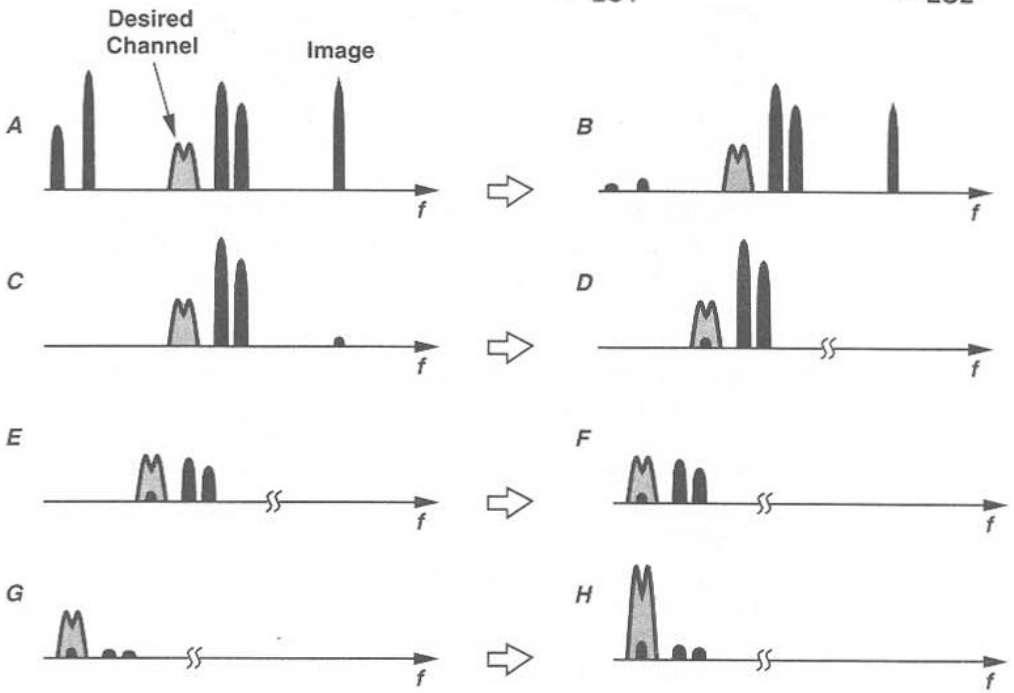
Addressing the tradeoff: dual-IF topology



- Two-step conversion (rather than just one)!

Addressing the tradeoff: dual-IF topology

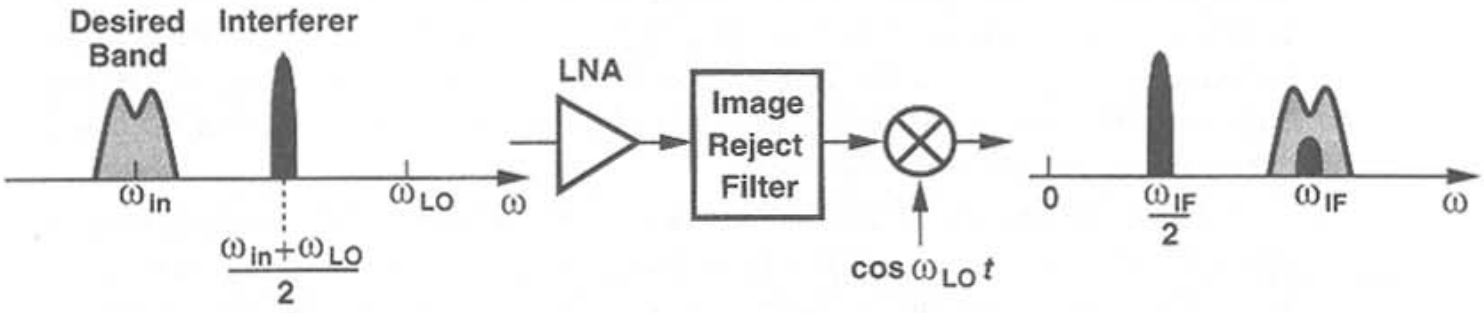




First stage: optimizes for image rejection (sensitivity)

Second stage: optimizes for channel selection (selectivity)

Another Heterodyne Receiver problem: half-IF



- Second order distortion at the RF chain (LNA or mixer):

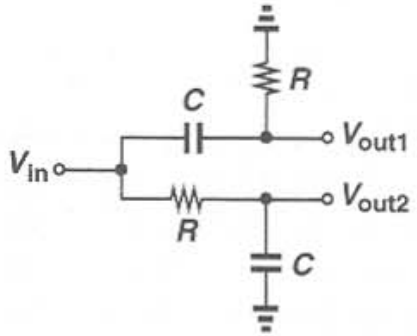
$$\frac{\omega_{in} + \omega_{LO}}{2} \Rightarrow \omega_{in} + \omega_{LO} \qquad \Rightarrow 2\omega_{LO} - (\omega_{in} + \omega_{LO}) = \omega_{LO} - \omega_{in} = \omega_{IF}$$

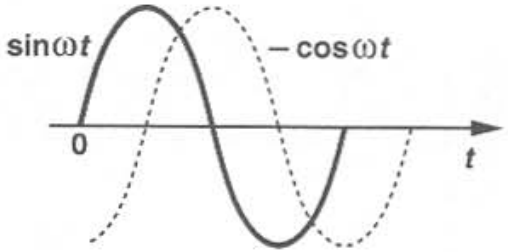
$$\omega_{LO} \Rightarrow 2\omega_{LO}$$

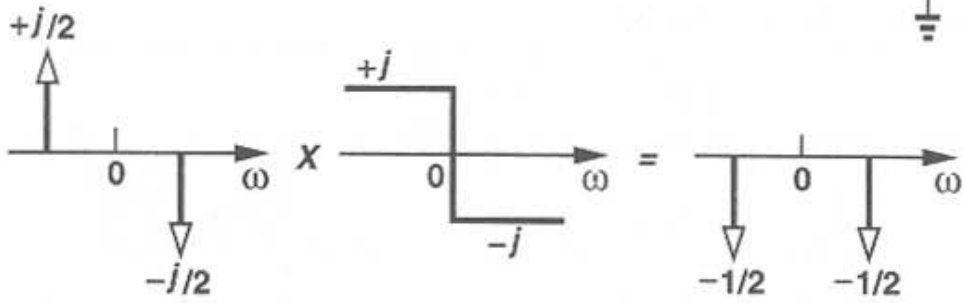
- …or interferer at $\omega_{IF}/2$ and second order distortion at the RF chain.

- Solution: minimize second order distortion and/or filtering.

Another solution to the Image Problem:
Image Reject Receiver







- Basic idea: process signal and image DIFFERENTLY

(and eventually cancel out the image).

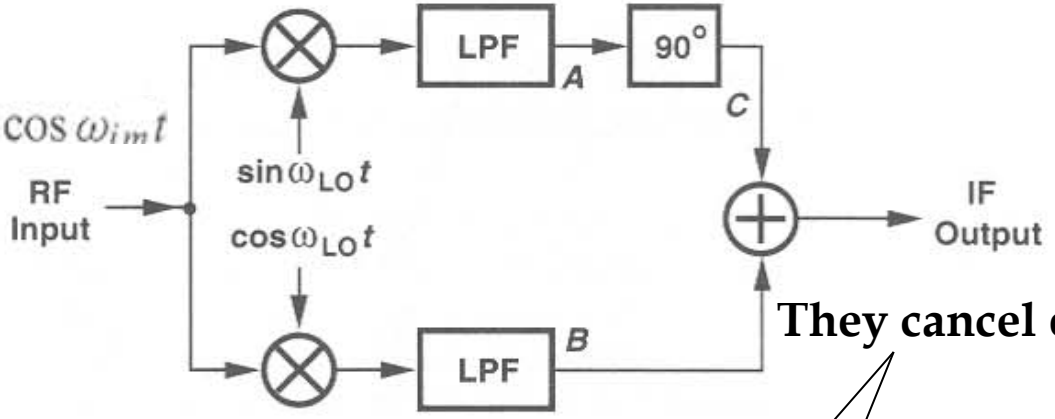
- Mechanism: Hilbert Transform or "shift by 90^0"!

$$H(\omega) = -j\,\mathrm{sgn}(\omega)$$

- In practice, cos(ωt) is converted to sin(ωt) and sin(ωt) to –cos(ωt) (shift by (t-T/4))

Image Reject Receiver: Hartley Architecture

$$x(t) = A_{RF}\cos\omega_{RF}t + A_{im}\cos\omega_{im}t$$



They cancel out…

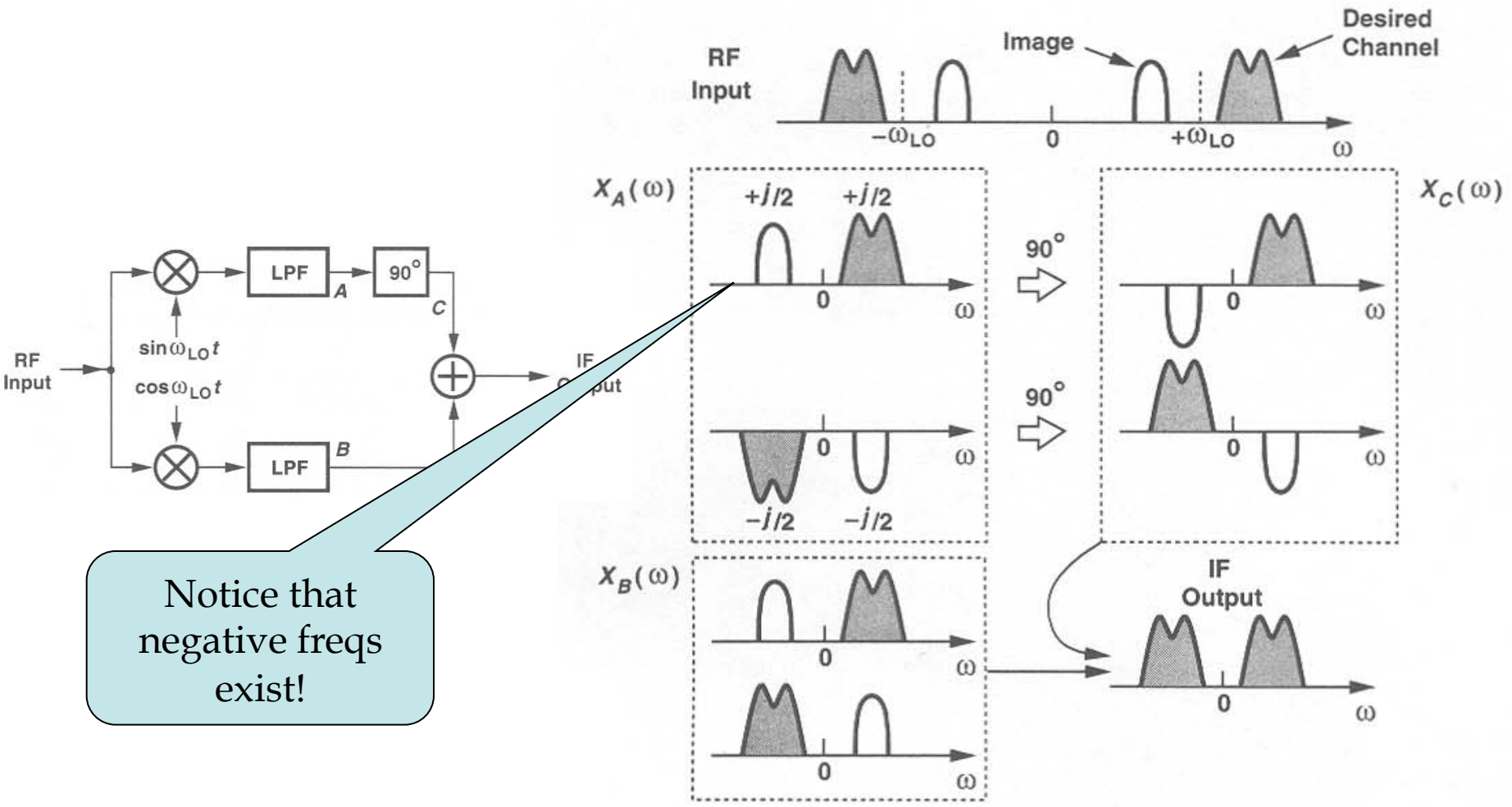
$$x_A(t) = \frac{A_{RF}}{2}\sin(\omega_{LO} - \omega_{RF})t + \frac{A_{im}}{2}\sin(\omega_{LO} - \omega_{im})t$$

$$x_B(t) = \frac{A_{RF}}{2}\cos(\omega_{LO} - \omega_{RF})t + \frac{A_{im}}{2}\cos(\omega_{LO} - \omega_{im})t$$

$$x_A(t) = -\frac{A_{RF}}{2}\sin(\omega_{RF} - \omega_{LO})t + \frac{A_{im}}{2}\sin(\omega_{LO} - \omega_{im})t$$

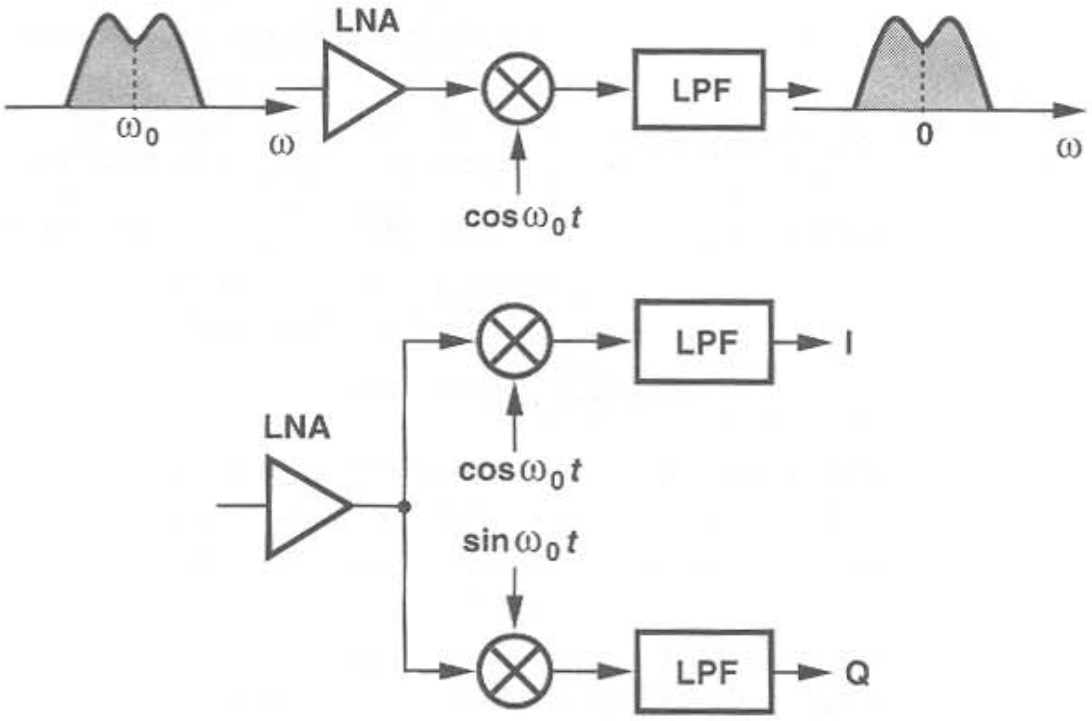
$$x_C(t) = +\frac{A_{RF}}{2}\cos(\omega_{RF} - \omega_{LO})t - \frac{A_{im}}{2}\cos(\omega_{LO} - \omega_{im})t$$

Image Reject Receiver: Hartley Architecture (graphical representation)



- Hartley architecture is sensitive to LO phases mismatch.

Homodyne (zero-IF) Receiver



- Directly convert to DC ($\omega_{LO}=\omega_{in}=\omega_1$, $\omega_{IF}=0$).
- Why don't we use zero-IF instead of heterodyne rec?

(answer at next lecture)

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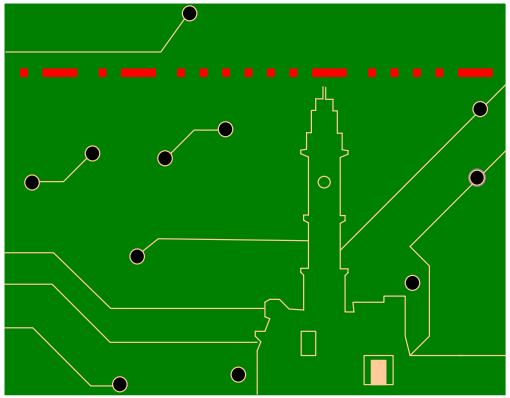

Next lecture: homodyne receivers and transceiver architectures (cont'd)