Receivers’ Architectures

Τηλεπικοινωνιακά ηλεκτρονικά

Σπύρος Βλάσσης

General considerations

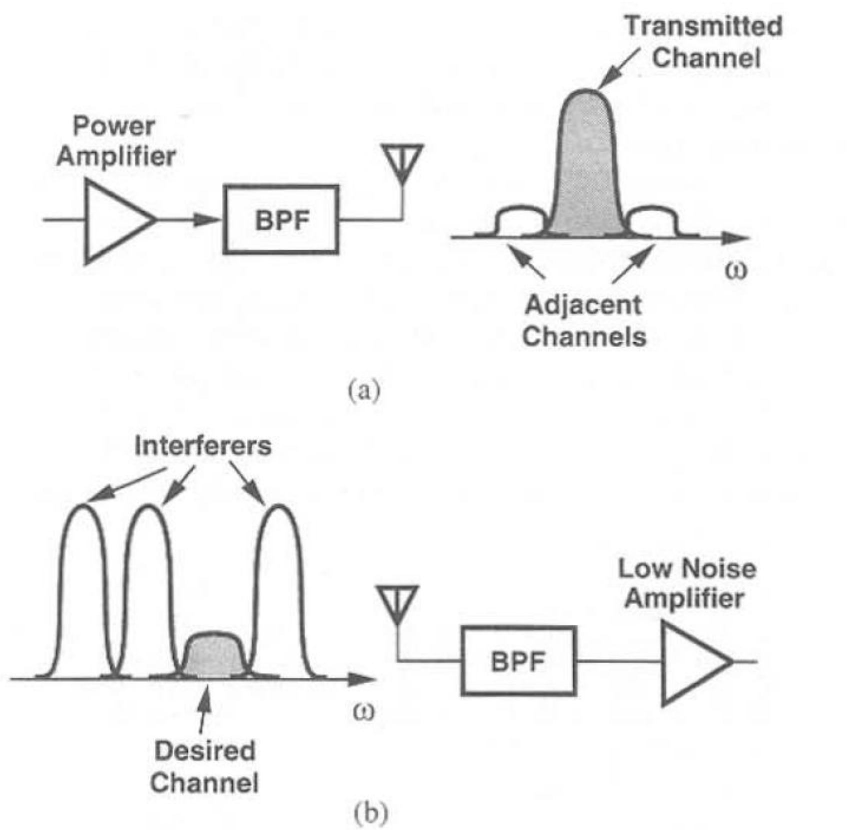


Figure 5.1 (a) Transmitter and (b) receiver front ends of a wireless transceiver.

- Limited spectrum allocated to each user. 30kHz in IS-54 and 200kHz in GSM, 10-20MHZ to 802.11
- Receiver
  - Process the desired signal
  - Reject the strong interferers
- Transmitter
  - Narrow band modulation
  - Amplification
  - Filtering to avoid leakage to adjacent channels

General considerations

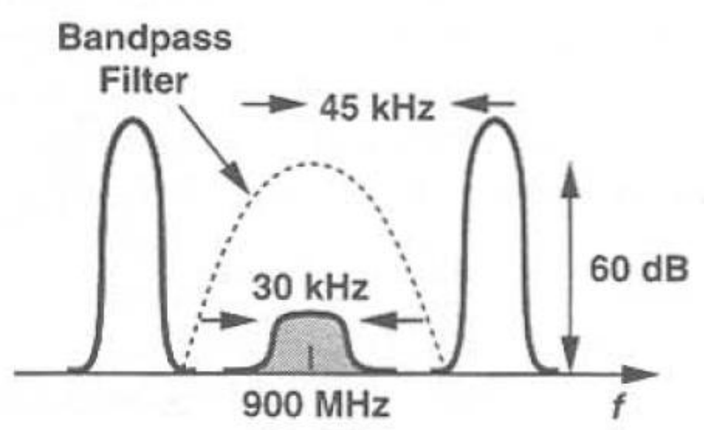


Figure 5.2 Rejection required of a hypothetical front-end bandpass filter.

- 900MHz receiver
- Channel 30kHz
- Interferer rejection at 60kHz (away)
- LC filter : 60dB attenuation 45kHz (away) needs $Q=10^7$
  - very difficult

General considerations

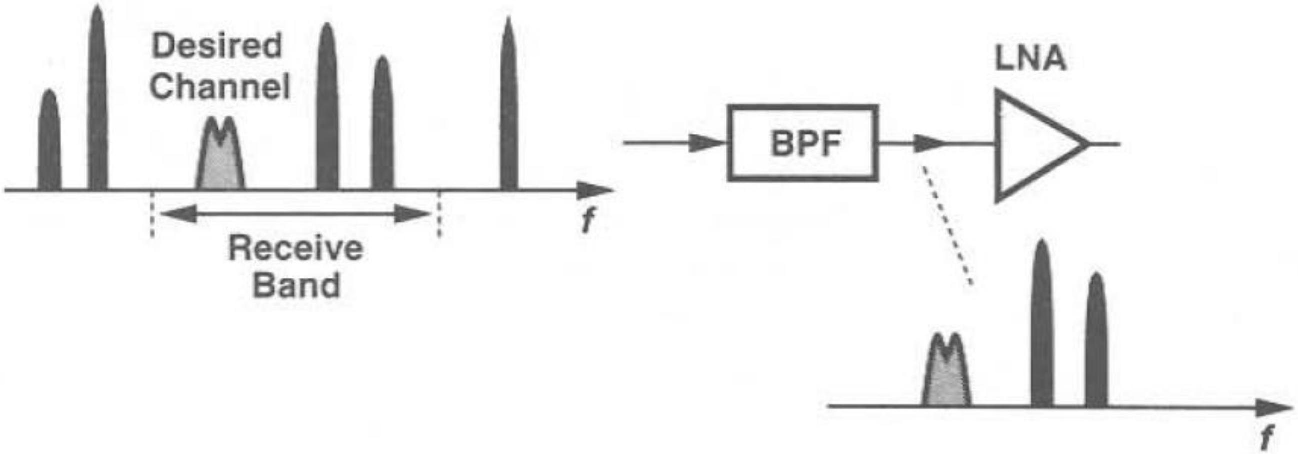


Figure 5.3 Band selection at the front end of a receiver.

- Band: the entire spectrum according to standard
  - GSM: 935MHz to 960MHz)
  - Band selection: out-of-band interferers rejection
- Channel: refers to the signal BW of only one user
  - GSM:200kHz
  - Channel selection: out-of-channel interferers rejection

General considerations

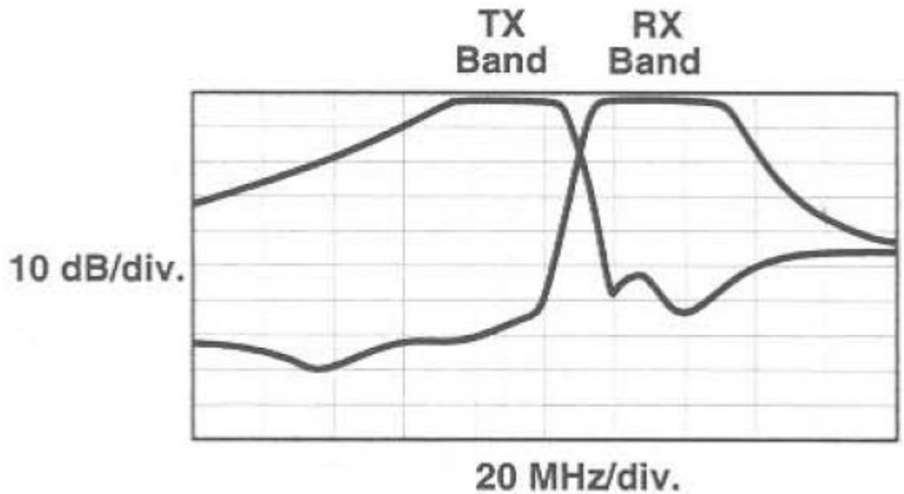


Figure 5.4 Typical duplexer characteristic.

- Frond-end filters
  - Finite BW
  - Finite out of band rejection
    - Eg. 30dB rejection@20MHz (away)

General considerations

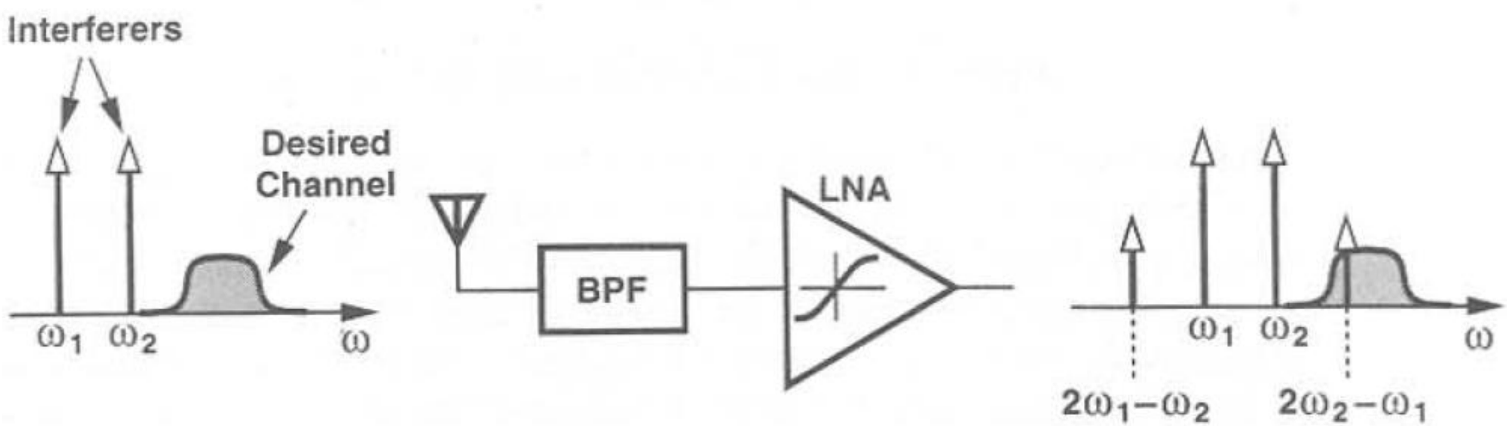


Figure 5.5 Effect of nonlinearity in the front end.

- Need for low lon-linearities of LNA+MIXER
  - Odd-order non-linearity yields intermodulation (IM) product in the channel
    - 3rd order distortion (IP3) sufficient high to avoid signal corruption with IM product
- Need for low loss of front-end BPF
  - 3dB loss (attenuation) gives 370mW loss of power

General considerations

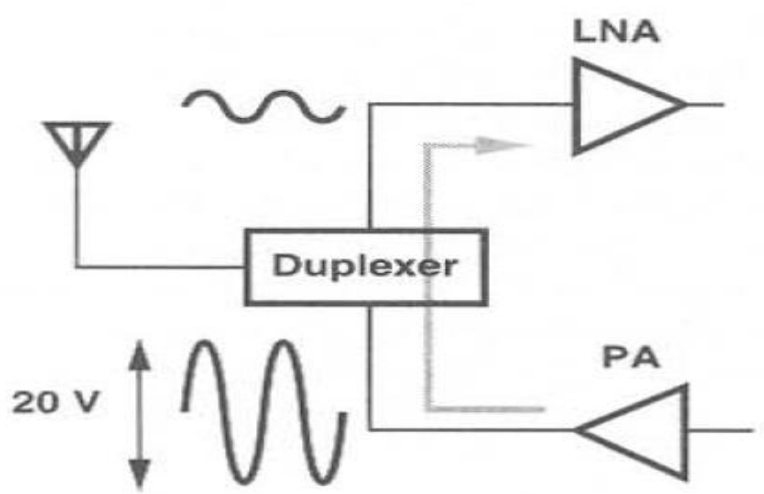


Figure 5.6 Desensitization of LNA by PA output leakage.

- Dynamic range (DR)of signals
  - Signal fading+path loss need DR>100dB
  - Minimum detectable signals <uV need low noise and cross talk
- Cross talk requires high isolation
  - TX power amp: 1W@50Ω =20Vpp with -26dBm leakage gives 30mVpp which is compared to LNA 1-dB compression point (-25dBm)

Heterodyne receiver

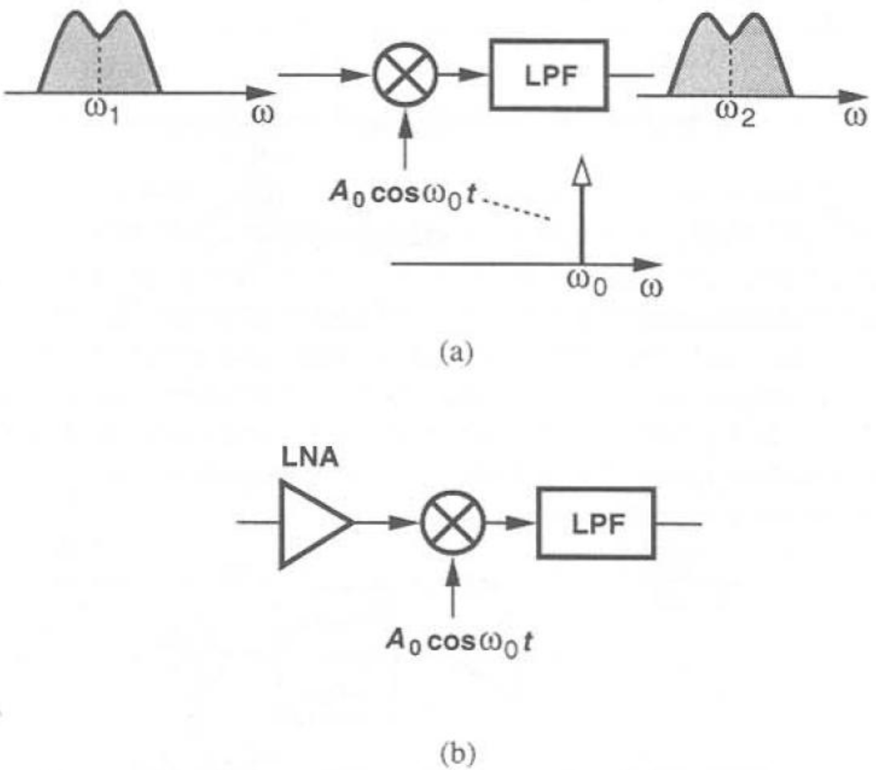


Figure 5.7 (a) Simple heterodyne downconversion, (b) inclusion of an LNA to lower the noise figure.

- Problems
  - Image frequency
  - Half IF frequency
- Dual IF Topology

Heterodyne receiver

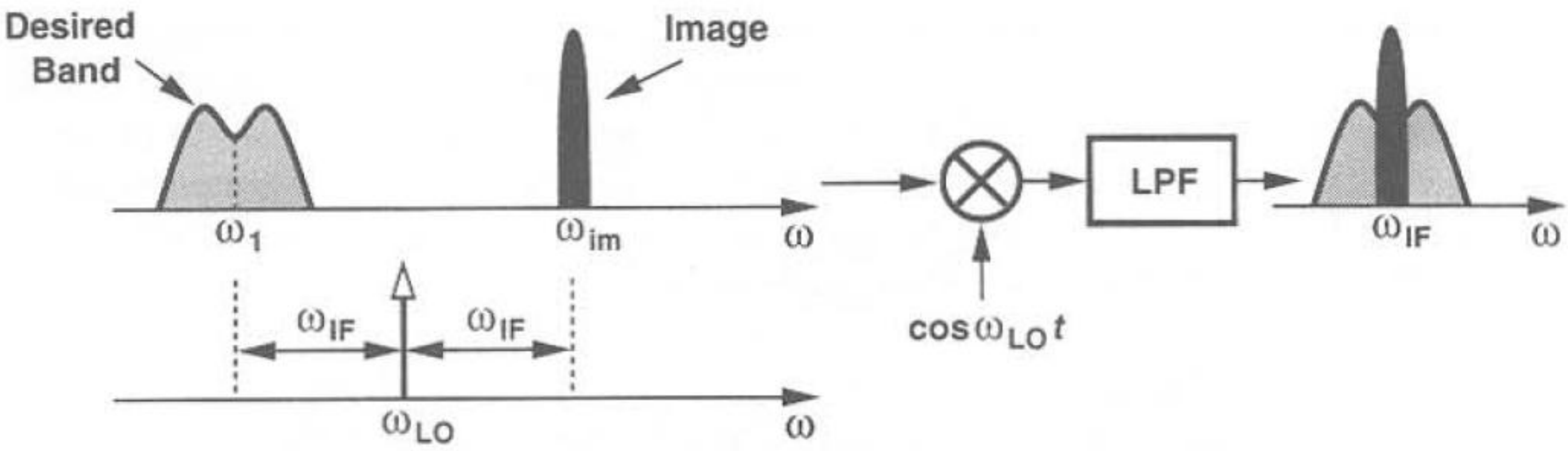


Figure 5.8 Problem of image in heterodyne reception.

- Problem of image
  - There are users (power) in the image freq.
  - High power than the desired signal
  - Need for ''image rejection''

Heterodyne receiver

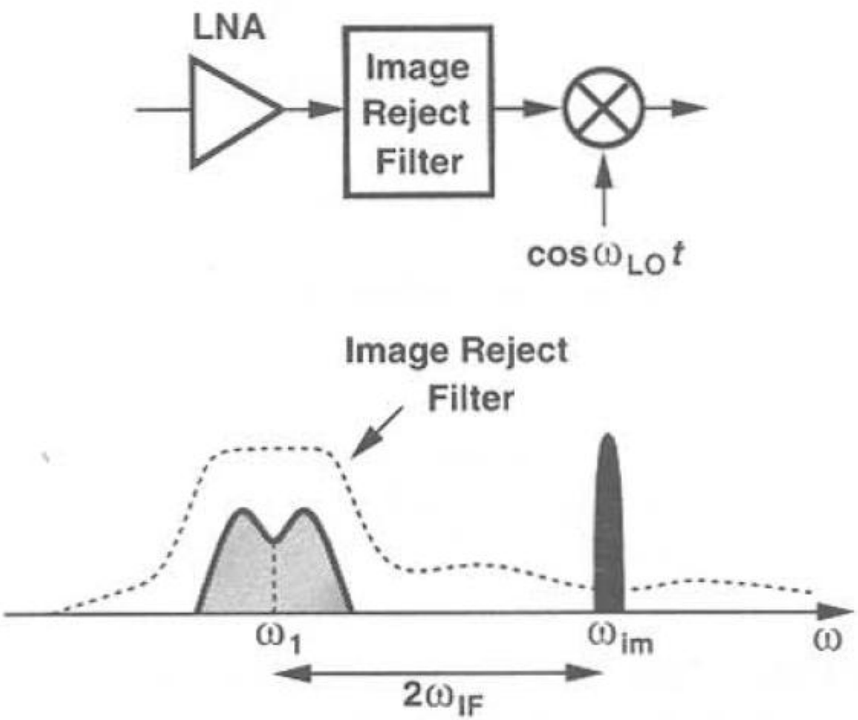


Figure 5.9 Image rejection by means of a filter.

- Image reject filter (before mixer)
  - Small loss in the desired band
  - Large attenuation in the image band
  - Depends on $2\omega_{IF}$
  - Image Filters: SAW or crystal devices. eg. 10.7MHz
    - 50Ω input impedance
    - High power to drive 50Ω

Heterodyne receiver

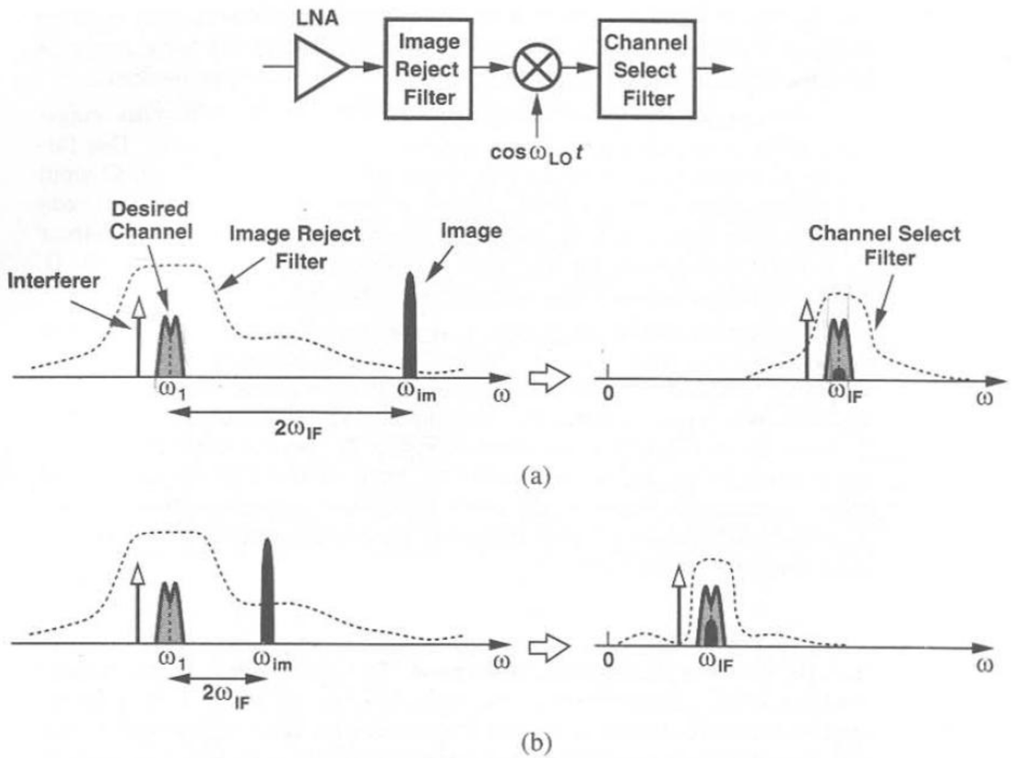


Figure 5.10 Rejection of image versus suppression of interferers for (a) high IF and (b) low IF.

- High IF
  - Substantial rejection of image
  - Lower Q($=1/\omega_{IF}$) of the channel select filter
- Low IF
  - Low efficient image rejection
  - Higher Q of the channel select filter
- Don't forget the image reject filter loss

Heterodyne receiver

Dual IF Architecture

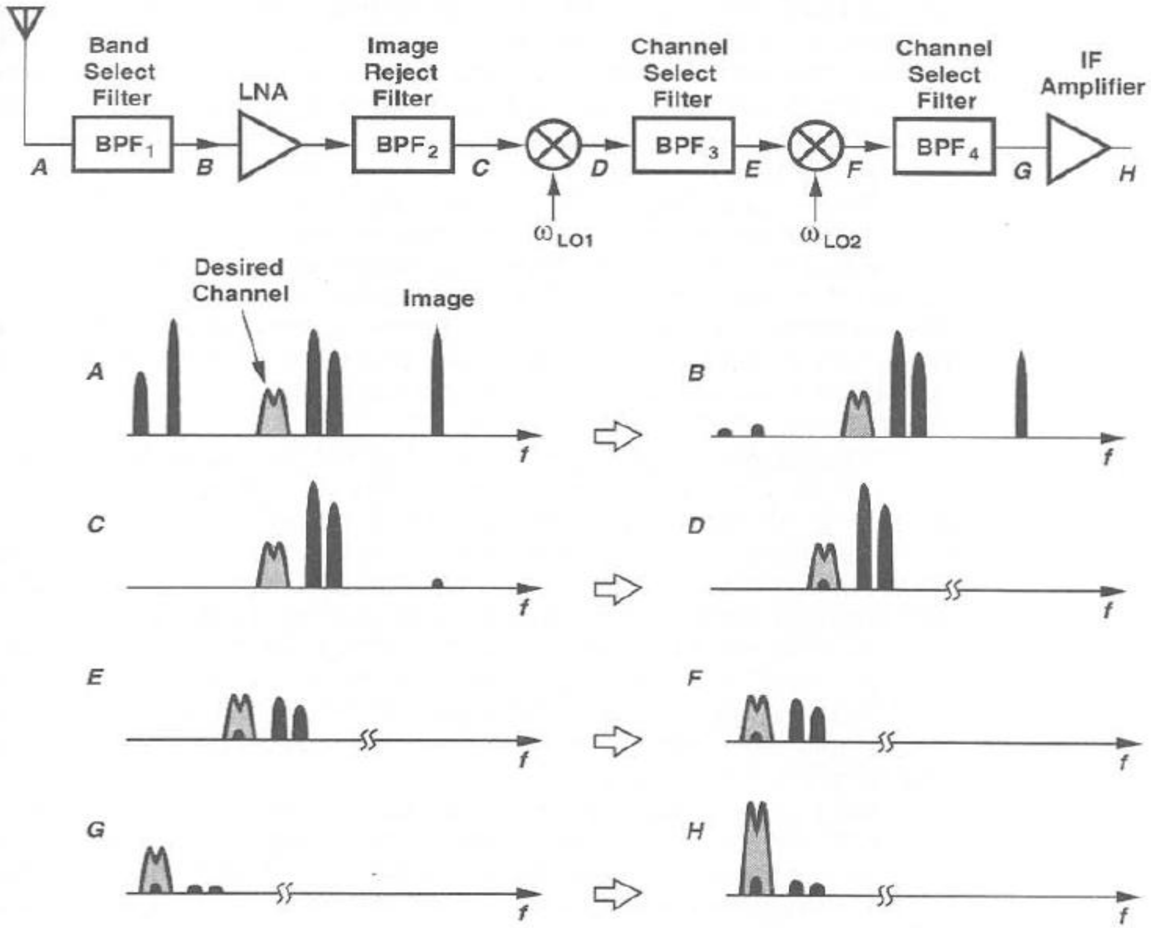
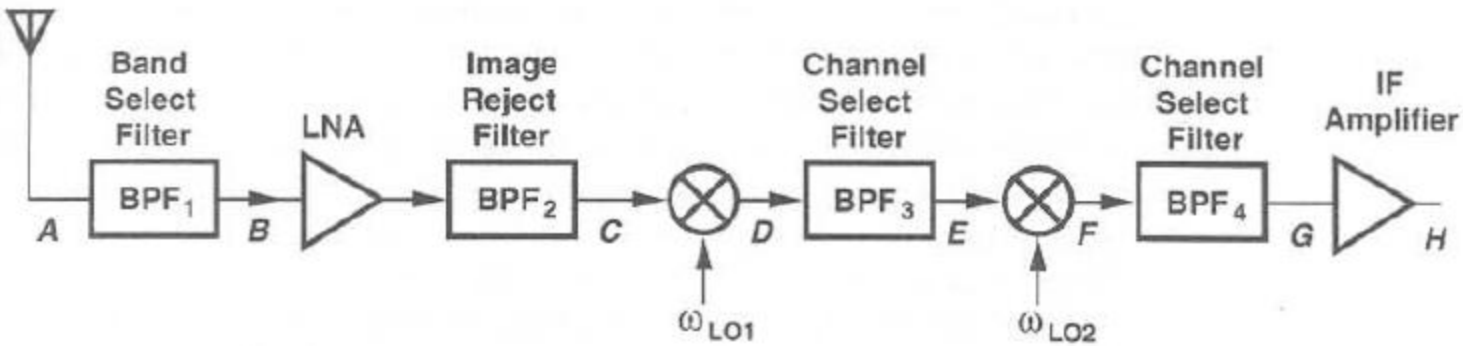


Figure 5.12 Dual-IF heterodyne receiver.

Heterodyne receiver



- Partial channel selection
- Progressively lower center frequencies
- Filter’s Q relaxation

Heterodyne receiver

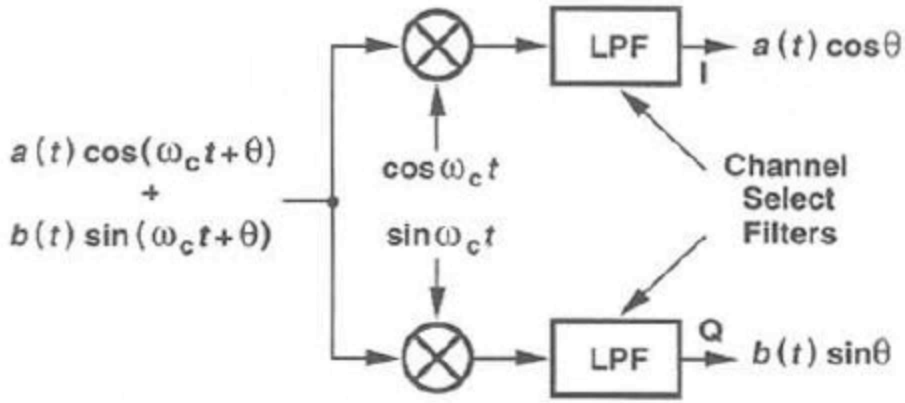
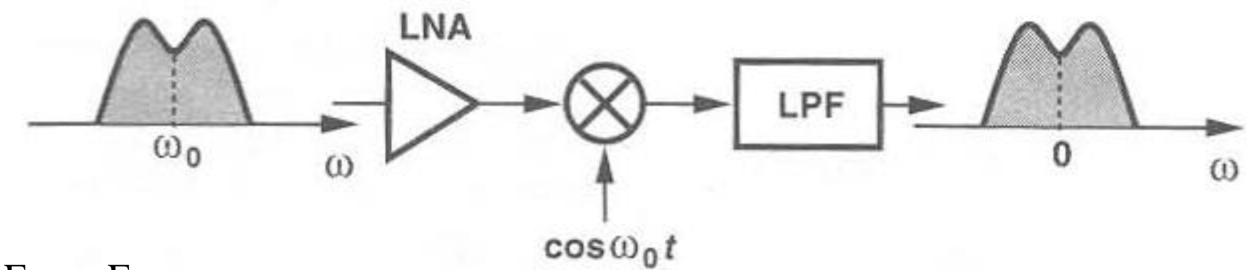


Figure 5.13 Quadrature downconversion.

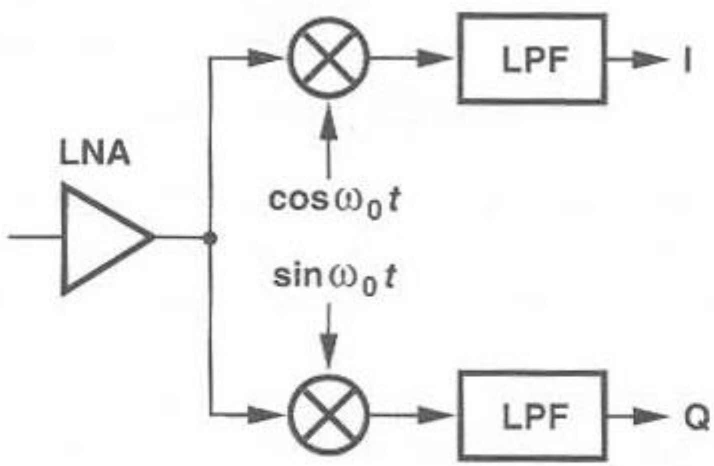
- The second downconversion offers both
  - In-phase (I) component
  - Quadrature in phase (Q) component
- The signal spectrum translated to zero frequency
- Next: Automatic control loop, A/D
- Each Mixer generates many spurious components related to RF, IF signal and LO
- Need for “frequency planning”

Homodyne Receivers



(a)

- $F_{LO}=F_{RF}$
- Need for a LP filter
- FM/PM need quadrature demodulation



(b)

- Advantages
  - Problem of image is circumvented
    - No RF SAW image filters
    - LNA need not drive 50Ω
  - IF SAW filter + IF mixer replaced with
    - low pass filters
    - Baseband amplifiers

Figure 5.14 (a) Simple homodyne receiver, (b) homodyne receiver with quadrature downconversion.

Homodyne Receivers: Channel Selection

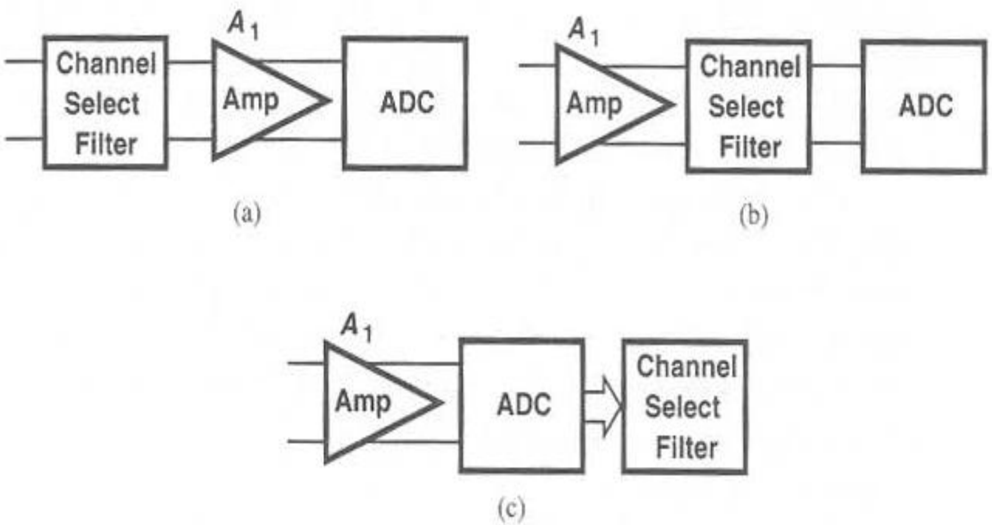


Figure 5.15 Three permutations of baseband functions.

- Active filters: noise-linearity-power trade offs compared with the passive counterparts

(a) LPF before Amp
- LPF: suppress out-of-channel interferers
- Amp1 linearity relaxed
- Amp1 with high gain
- ADC (4 8 bits)

(b) Amp before LPF
- LPF: noise specs relaxed
- Amp1: higher performance
- Need for extra Amp

(c) Digital filtering
- ADC high linearity
- ADC noise < 2mV

Homodyne Receivers: DC offsets

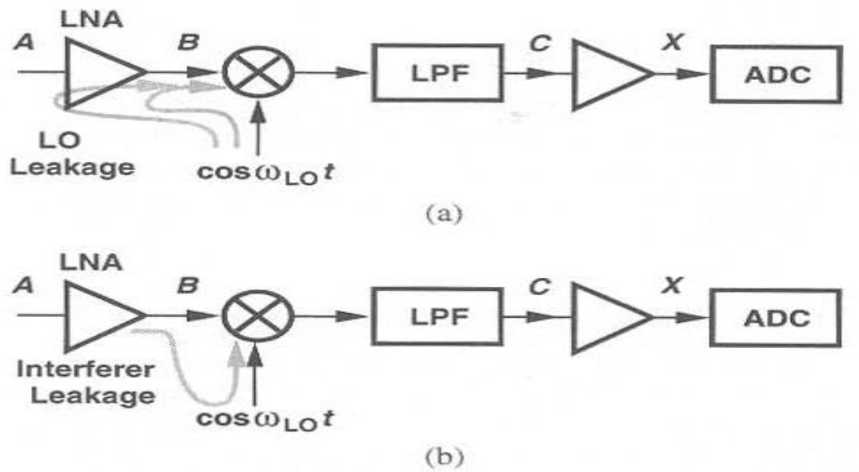


Figure 5.16 Self-mixing of (a) LO signal, (b) a strong interferer [5].

- Isolation between port is not infinite

  LO leakage – Self mixing – DC offset

- Time varying offset

1. $Gain_{(A \rightarrow X)}$ ~ 80dB-100dB
2. $Gain_{LNA+Mixer}$ ~ 30dB(40) and $Gain_{LPF+Amp}$ ~ 50dB(315)
3. VLOpp=0.63V(~0dBm@50Ω) appears with 60dB attenuation at port A
4. $V_{LOpp@portA}$=VLOpp/1000=0.63uV,
5. VLOpp@mixer_out=0.63mV*40=25mV (RF signal ~30uVrms)
6. VLOpp@mixer_out*$Gain_{LPF+Amp}$ =25mV *315~8V → RX chain saturated

Homodyne Receivers: offset cancellation

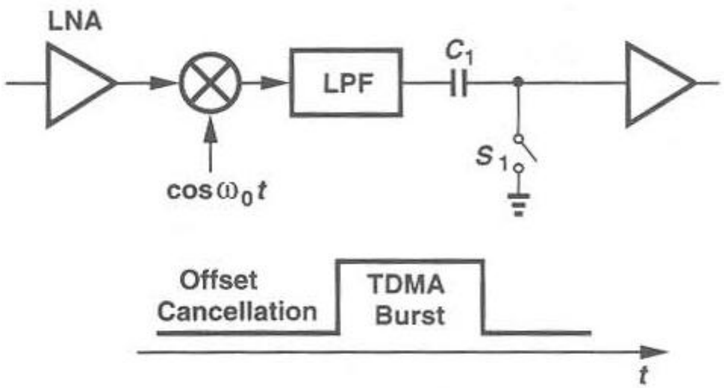


Figure 5.17 Simple offset cancellation in a TDMA system.

- HP filtering
  - Substantial energy near dc– very low corner frequency -- large capacitors
  - Fails to track fast offset variations

Offset cancellation Techniques

1. Baseband signal encoded
   - little energy near dc (dc free coding)
2. Idle time interval (depends on standard)

Homodyne Receivers: Quadrature generation

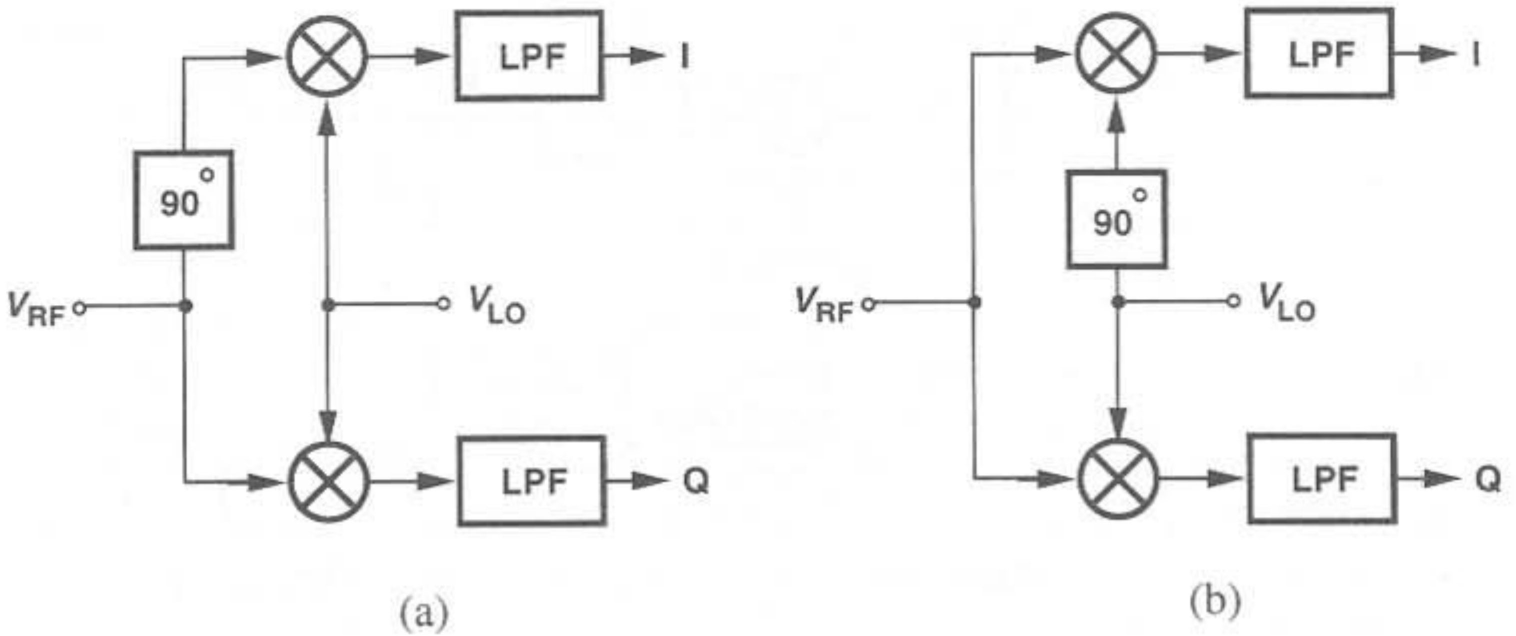


Figure 5.18 Quadrature generation in (a) RF path, (b) LO path.

Homodyne Receivers: IQ mismatch

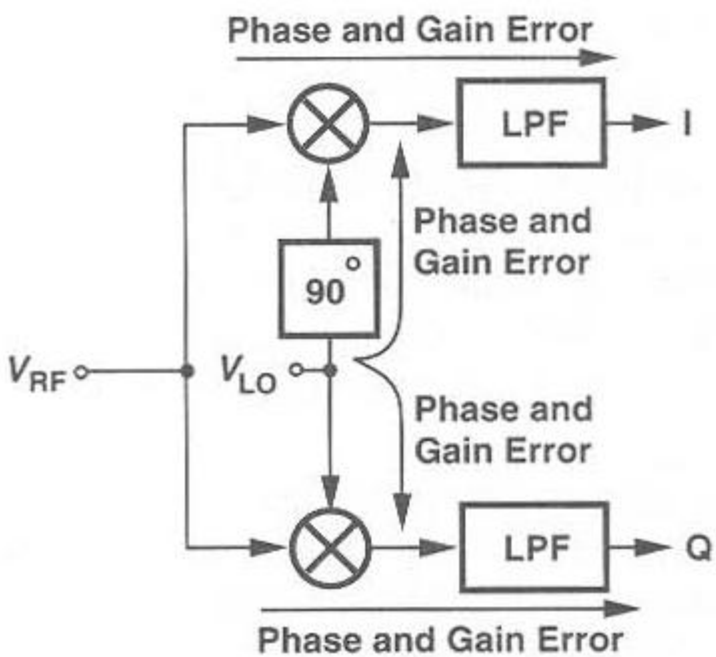


Figure 5.19 I/Q mismatch contributions by various stages.

$$x_{LO,I}(t) = 2\left(1 + \frac{\epsilon}{2}\right)\cos\left(\omega_c t + \frac{\theta}{2}\right)$$

$$x_{LO,Q}(t) = 2\left(1 - \frac{\epsilon}{2}\right)\sin\left(\omega_c t - \frac{\theta}{2}\right)$$

- Amplitude mismatch
- Phase mismatch

Homodyne Receivers: IQ mismatch

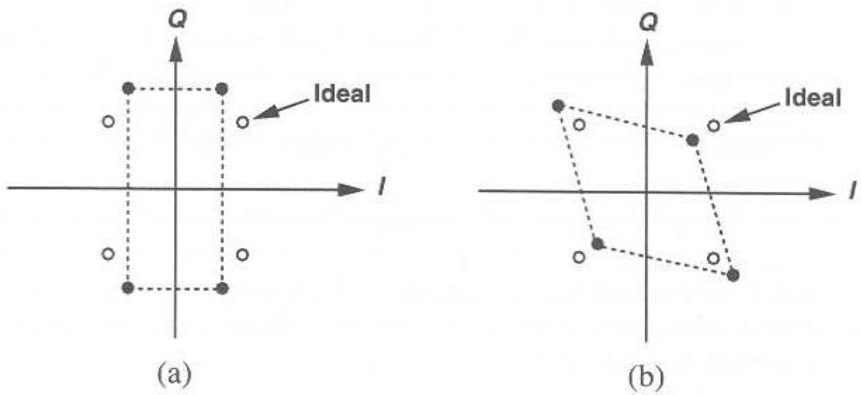


Figure 5.20 Effect of I/Q mismatch on QPSK signal constellation: (a) gain error, (b) phase error.

$$x_{BB,I}(t) = a\left(1+\frac{\epsilon}{2}\right)\cos\frac{\theta}{2} - b\left(1+\frac{\epsilon}{2}\right)\sin\frac{\theta}{2}$$

$$x_{BB,Q}(t) = -a\left(1-\frac{\epsilon}{2}\right)\sin\frac{\theta}{2} + b\left(1-\frac{\epsilon}{2}\right)\cos\frac{\theta}{2}.$$

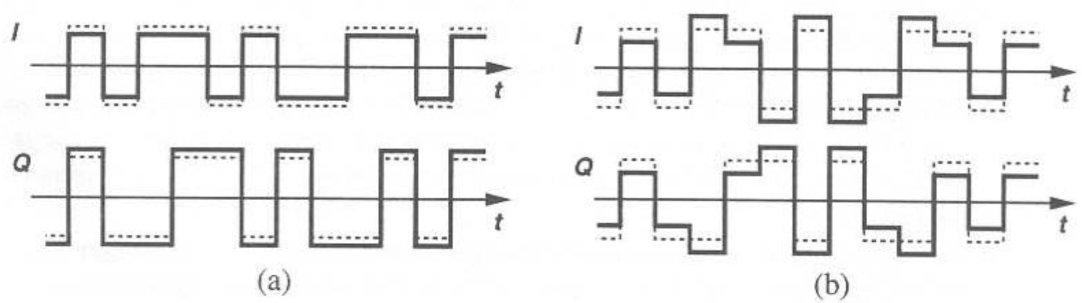


Figure 5.21 Effect of I/Q mismatch on a demodulated QPSK wavefom: (a) gain error, (b) phase error.

1. Amp mismatch <1dB
2. Phase mismatch <5^{o}

Homodyne vs Heterodyne Receivers: IQ mismatch

- Heterodyne RX:
  - Lower IF frequency – less sensitive to mismatches
  - Lower frequency – larger devices – less mismatches
  - The signal is enough amplified before IQ separation– less stages afterwards
- Homodyne RX:
  - Incorporates several stages (LPF+Amps) after IQ separation – more sensitive to mismatches

RF section of a cellphone