Università degli Studi di Firenze
Dipartimento di Elettronica e telecomunicazioni

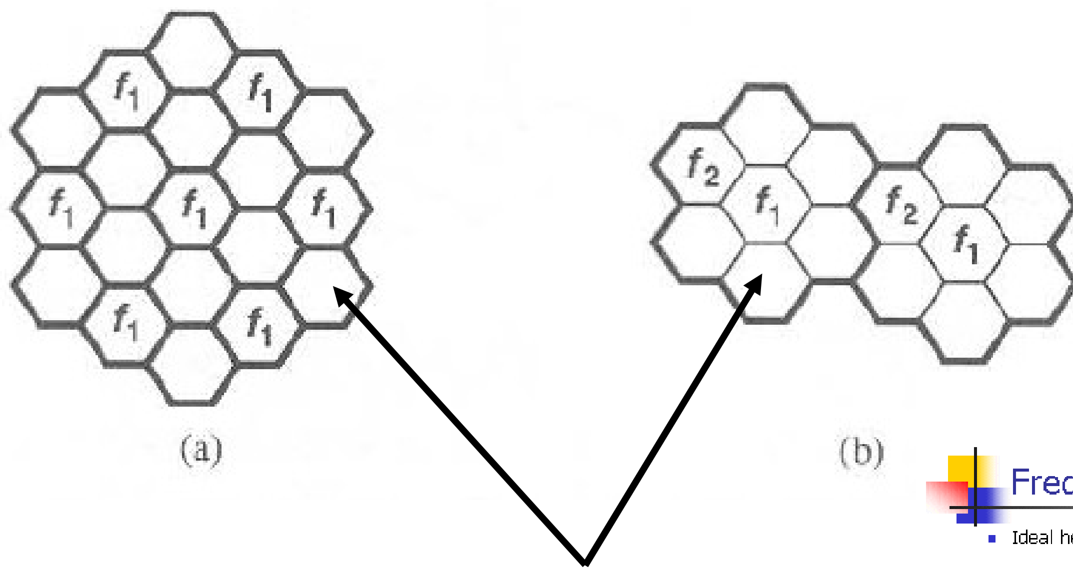
Iacopo Magrini, iacopo.magrini@unifi.it

Appunti del corso "Lab in alta frequenza"

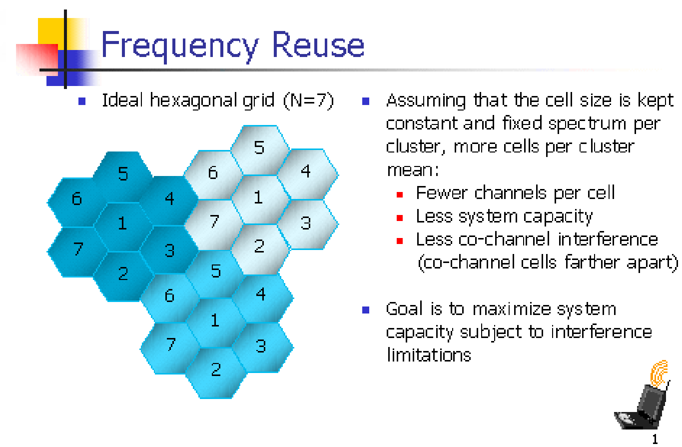
Tecniche di accesso ed architetture dei ricetrasmettitori per applicazioni wireless

Frequency reuse

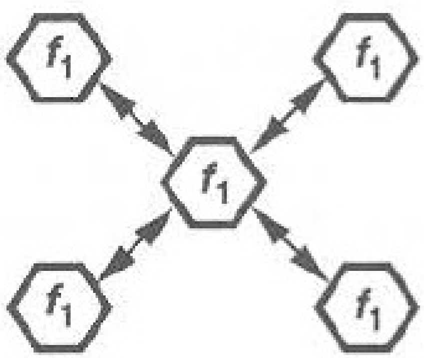
(a) Symple cellular system **(b) cellular system with "reuse"**



Single GSM cell



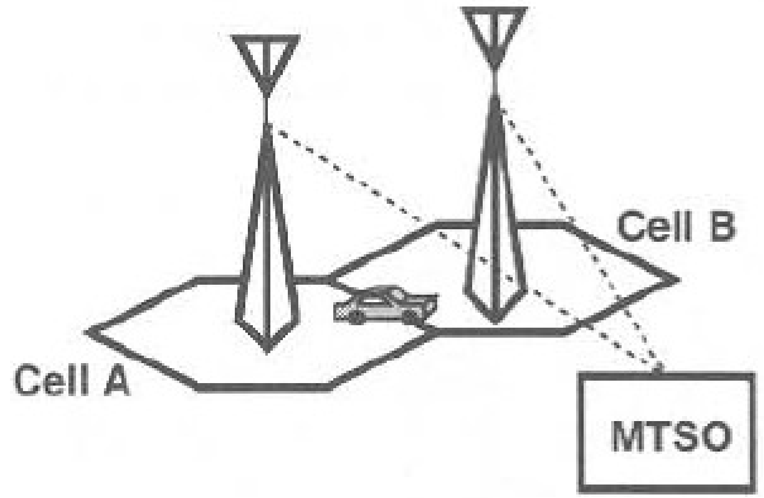
Co-Channel interference (CCI)



$$CCI = \frac{\text{Distance between two cells with the same f}}{\text{Cell radius}}$$

Dependent by the frequency reuse

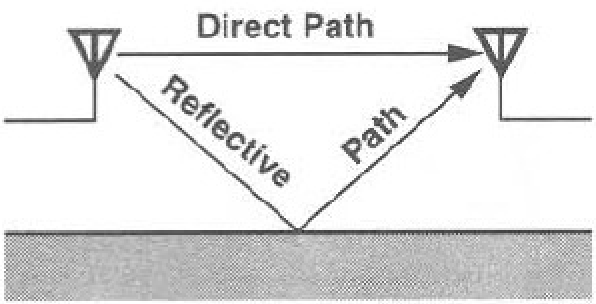
Handoff

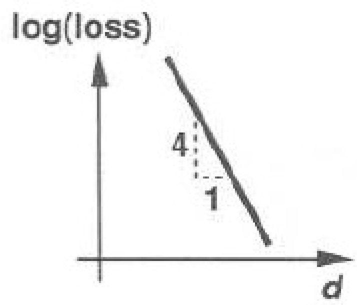


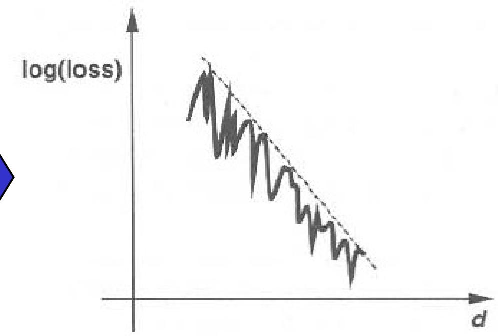
"Handoff"= When S/N ratio drops below a thresold the MTSO switch the link to another cell

Multipath fading

Fading due to phase shift



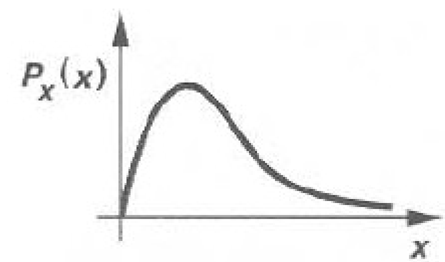




$$
\begin{aligned}
x_R(t) &= a_1(t)\cos(\omega_c t + \theta_1) + a_2(t)\cos(\omega_c t + \theta_2) \\
&\quad + \cdots + a_n \cos(\omega_c t + \theta_n) \\
&= \left[\sum_{j=1}^{n} a_j(t)\cos\theta_j\right]\cos\omega_c t - \left[\sum_{j=1}^{n} a_j(t)\sin\theta_j\right]\sin\omega_c t .
\end{aligned}
$$

$$
x_R(t) = \boxed{\sqrt{A^2 + B^2}}\cos(\omega_c t + \phi),
$$

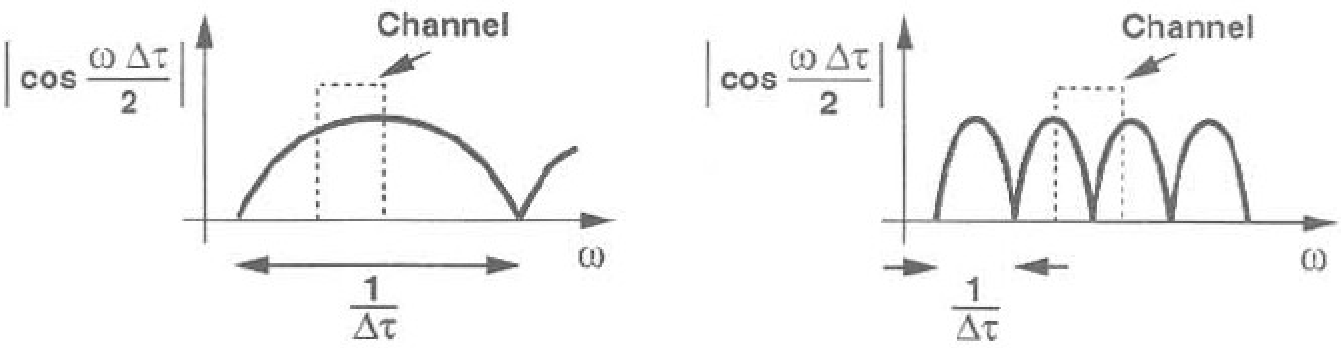
Rayleigh distribution



Delay Spread

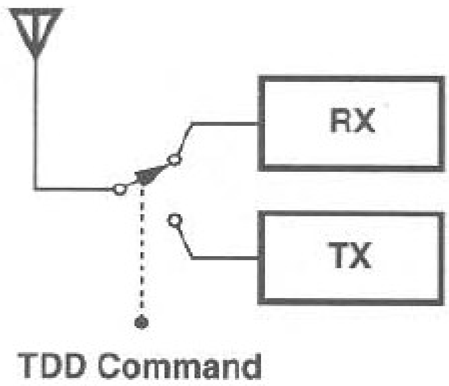
Fading due to the delay signal

$$x(t) = A\cos\omega(t-\tau_1) + A\cos\omega(t-\tau_2) = 2A\cos[(2\omega t - \omega\tau_1 - \omega\tau_2)/2]\boxed{\cos[\omega(\tau_1-\tau_2)/2]}$$

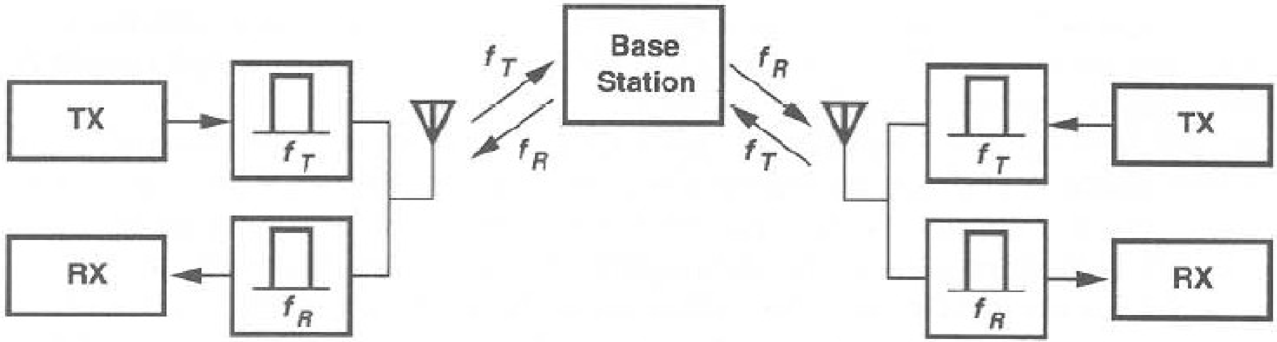


TDD & FDD

Time Division Duplexing

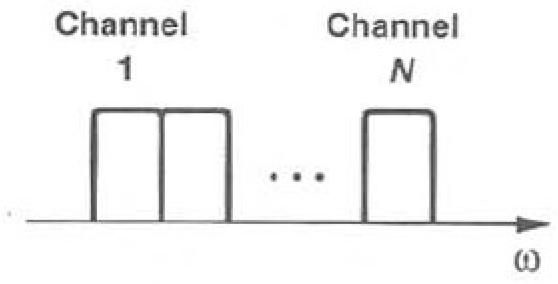


Frequency Division Duplexing

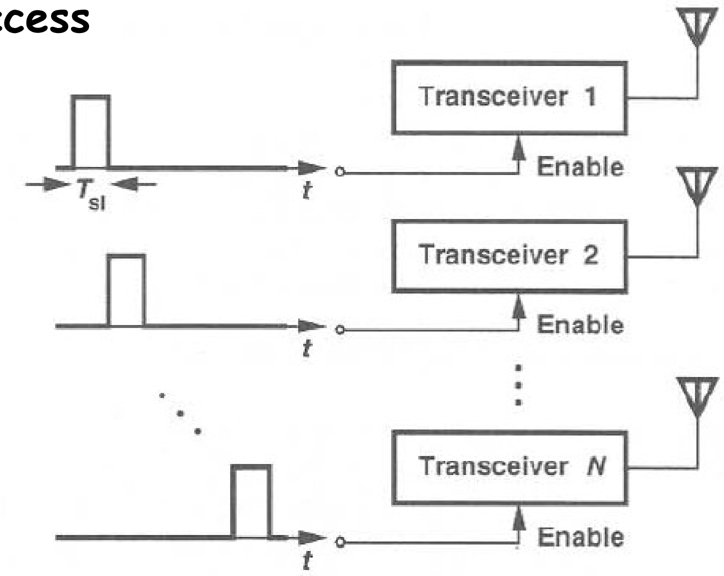


TDMA & FDMA

Frequency Division Multiple Access



Time Division Multiple Access



MODULATED RF SIGNAL

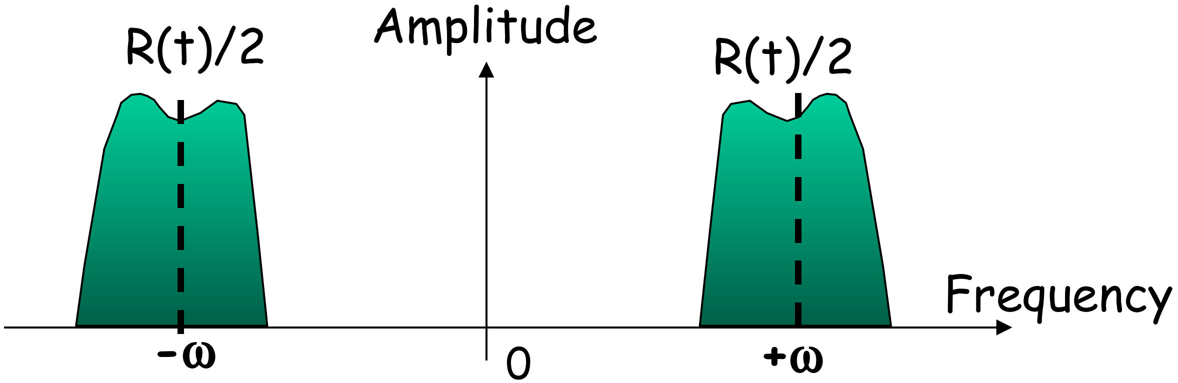
$$S(t)=\mathrm{Real}[A(t)e^{j\omega t}]$$

With $A(t)=R(t)e^{j\theta(t)}$

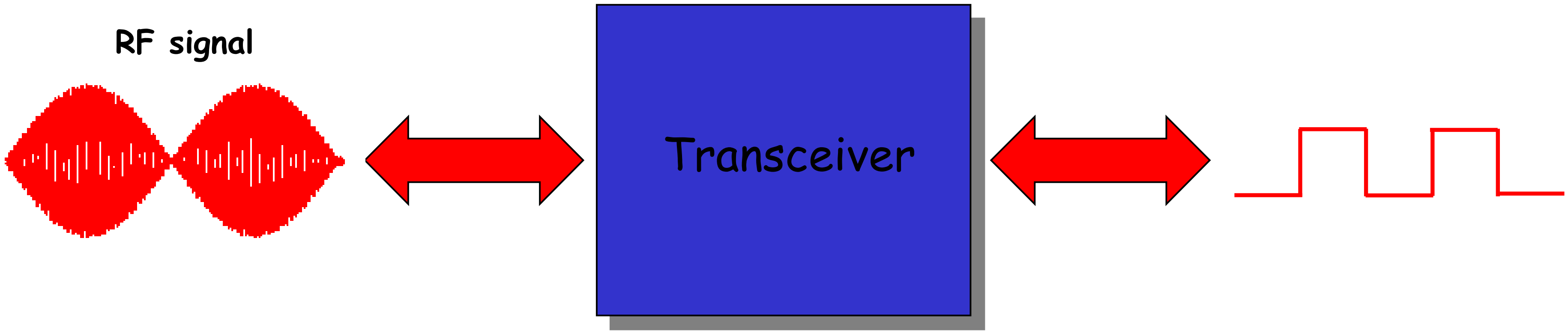
$$S(t)=\mathrm{Real}[R(t)e^{j\theta(t)}e^{j\omega t}]=\mathrm{Real}[R(t)e^{j(\omega t+\theta(t))}]$$

$$S(t)=\mathrm{Real}[R(t)\mathrm{Cos}(\omega t+\theta(t))+jR(t)\mathrm{Sin}(\omega t+\theta(t))]=R(t)\mathrm{Cos}(\omega t+\theta(t))$$

And finally :
$$\boxed{S(t)=\frac{R(t)}{2}e^{j(\omega t+\theta(t))}+\frac{R(t)}{2}e^{-j(\omega t+\theta(t))}}$$



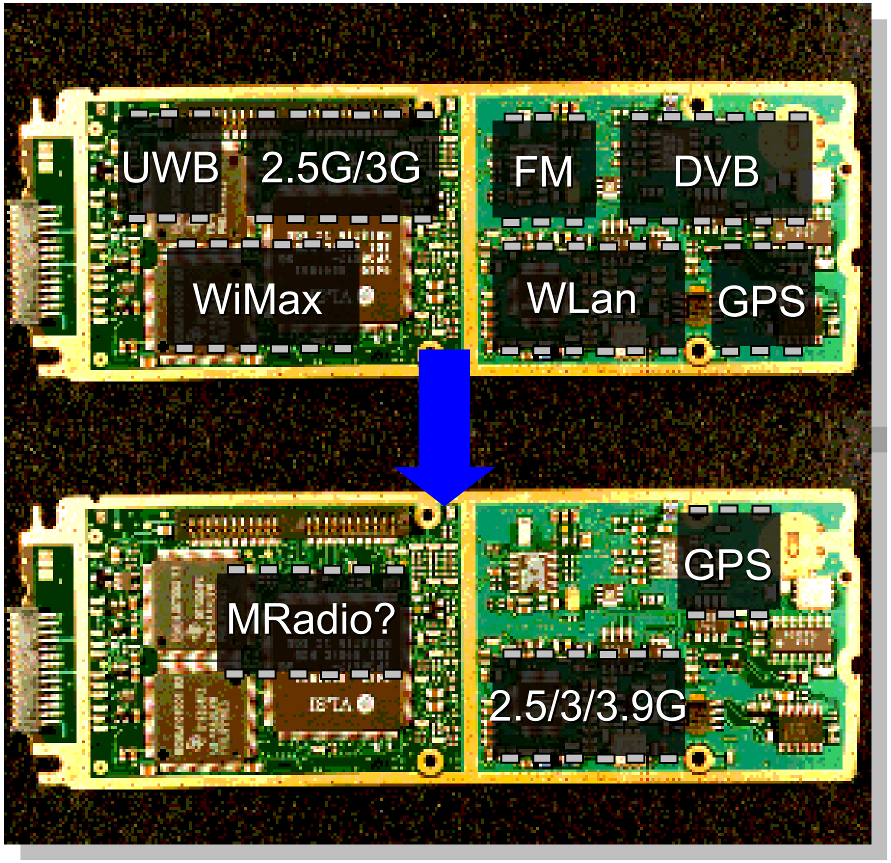
TRANSCEIVER FUNCTIONALITY



Transceivers trend

The trend for handset devices is to provide a global interconnectivity, the next generation of such systems will include:

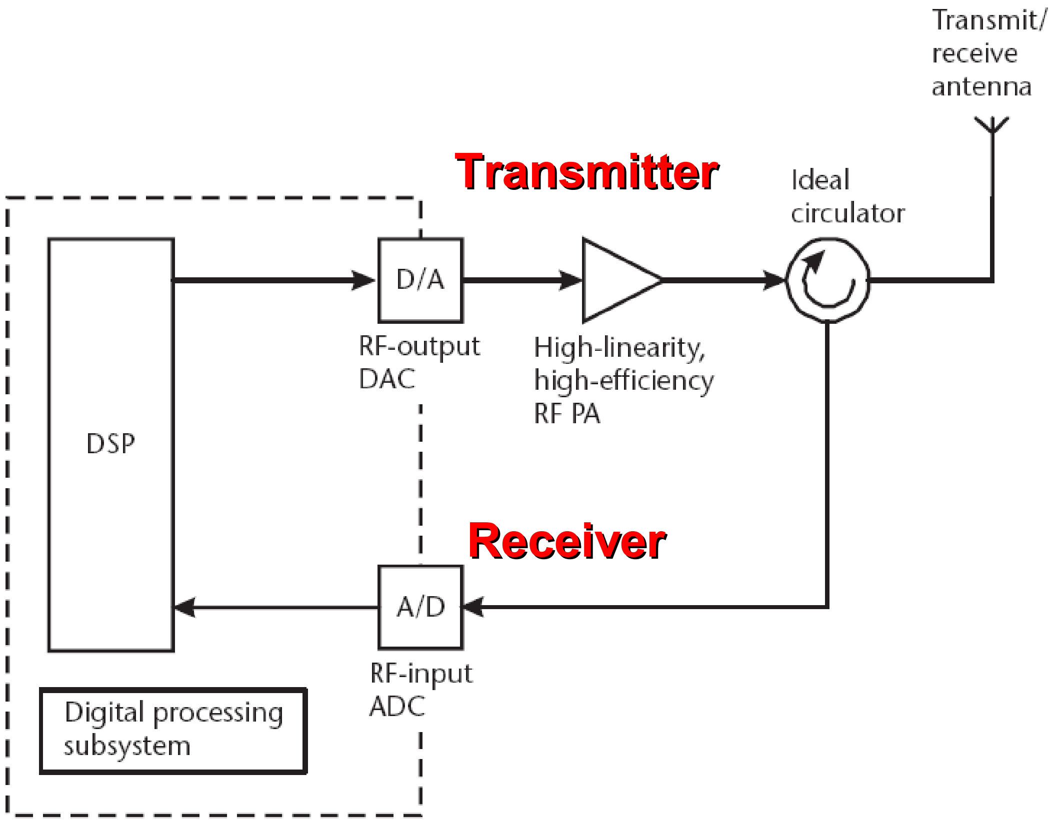
- **GSM/EDGE WCDMA**
- **802.11 a/b/g standards**
- **GPS**
- **UWB**
- **DVB**
- **WiMax**
- **........................**



Obviously the multiradio functionality involves the antenna design as well

Ultimate solution

Cognitive radio concept based on SDR architecture, analog blocks confined to PA only



ADC/DAC compliant probably available within the next 15/20 years!

RX/TX Topologies

RX

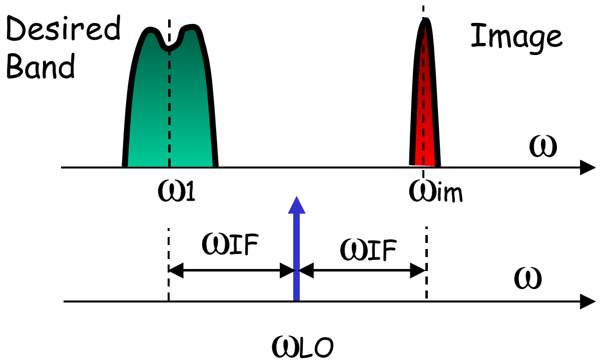
- Heterodyne receivers
- Homodyne receivers (Zero-IF)
- Quasi Homodyne receivers (Low-IF)

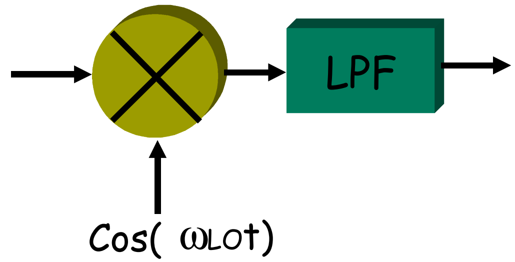
TX

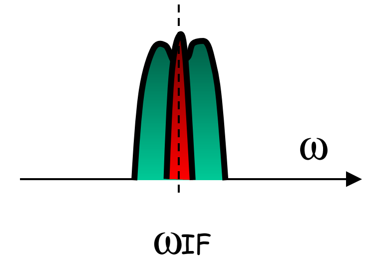
- Direct modulation
- Indirect modulation
- Polar

RECEIVER ARCHITECTURE(1)

Heterodyne reception







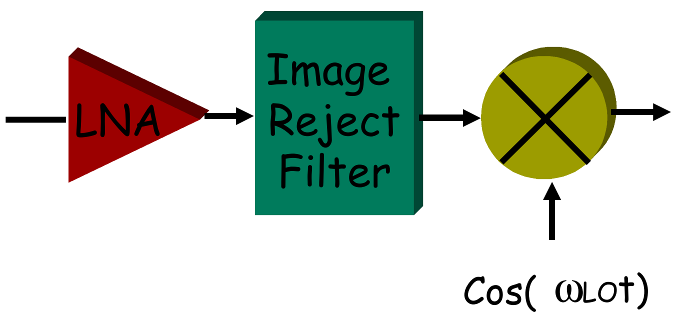
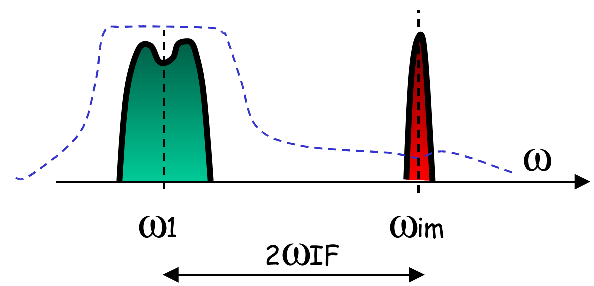
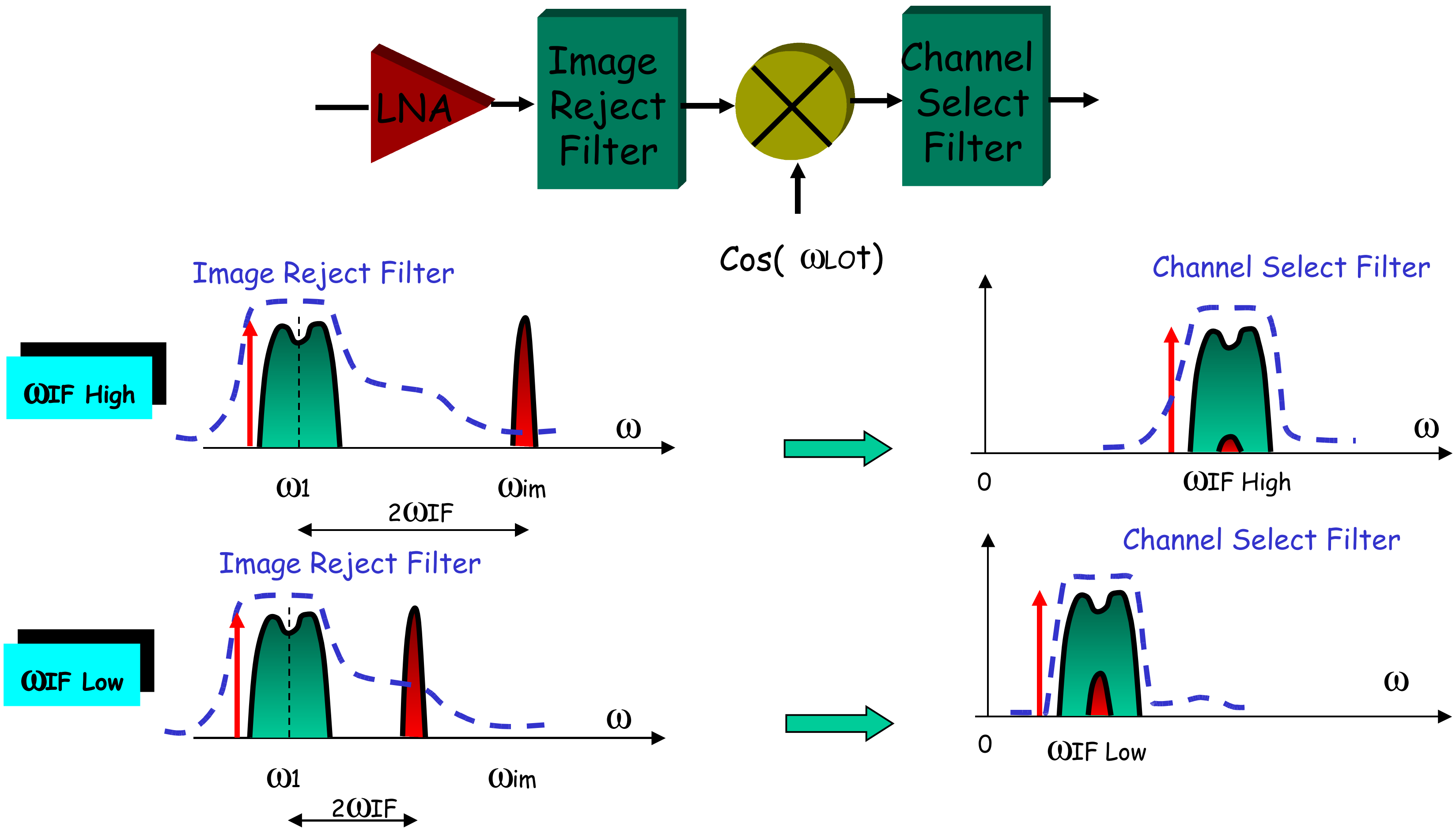


Image Reject Filter



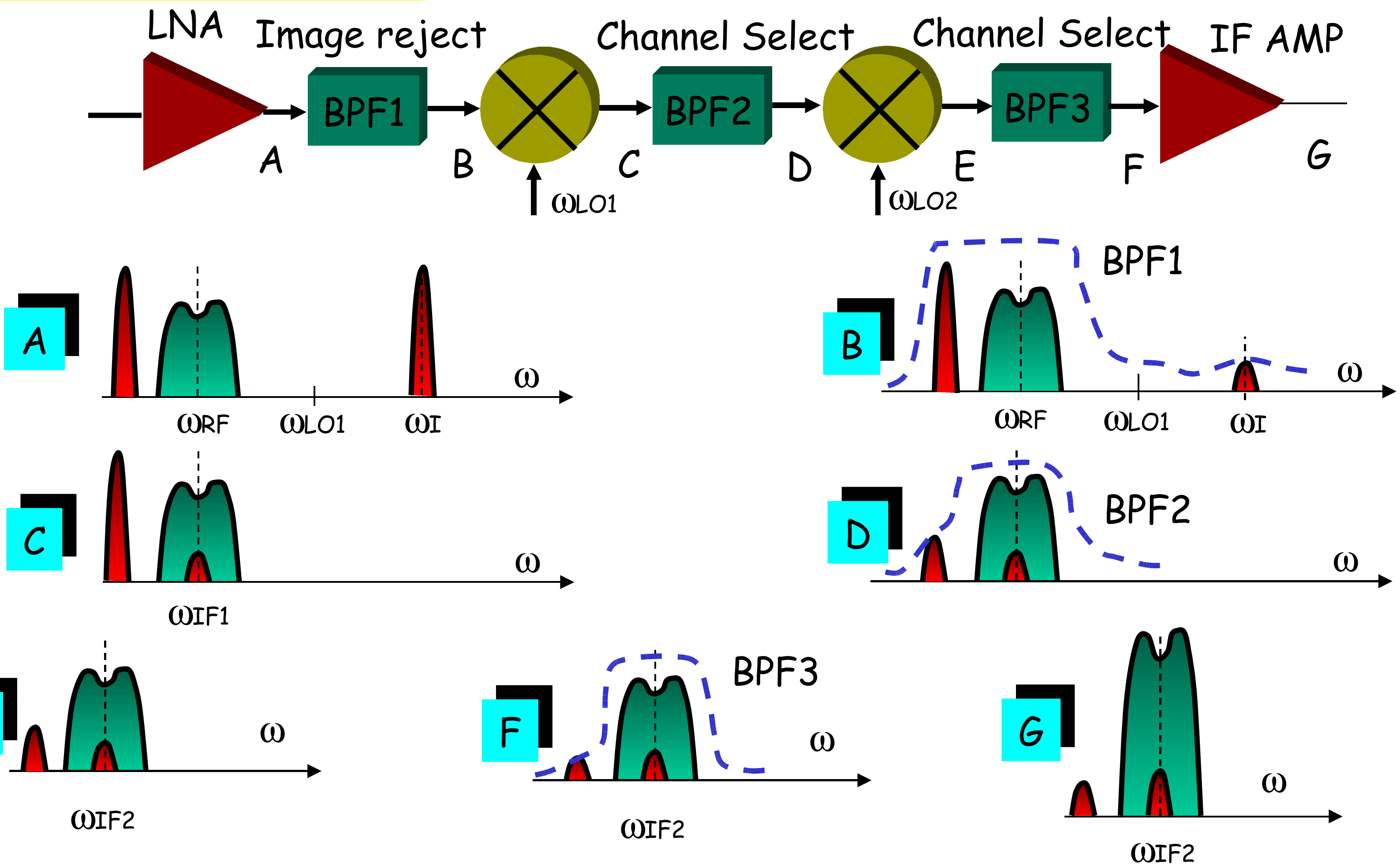
RECEIVER ARCHITECTURE(2)

Heterodyne reception



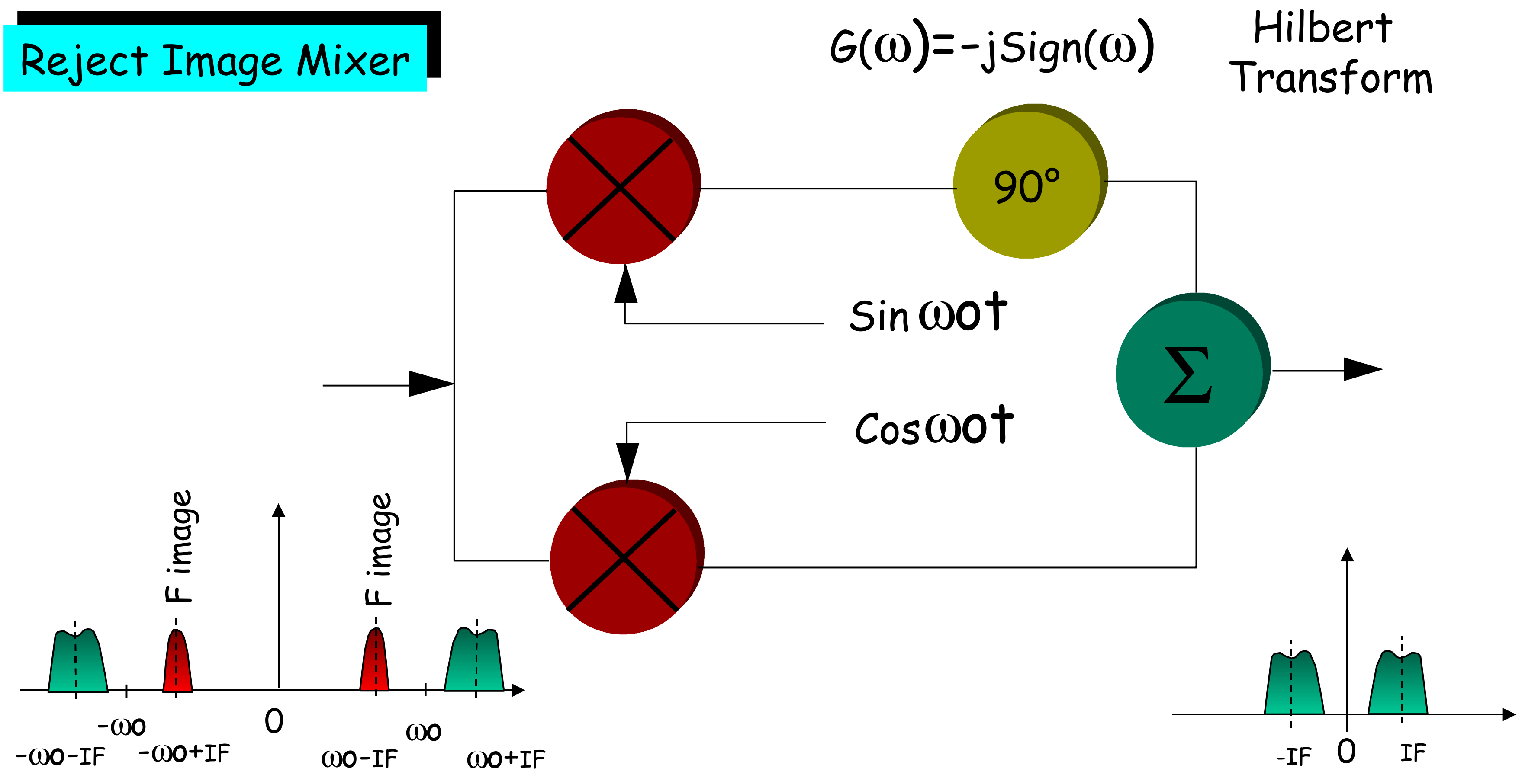
RECEIVER ARCHITECTURE(3)

Superheterodyne reception

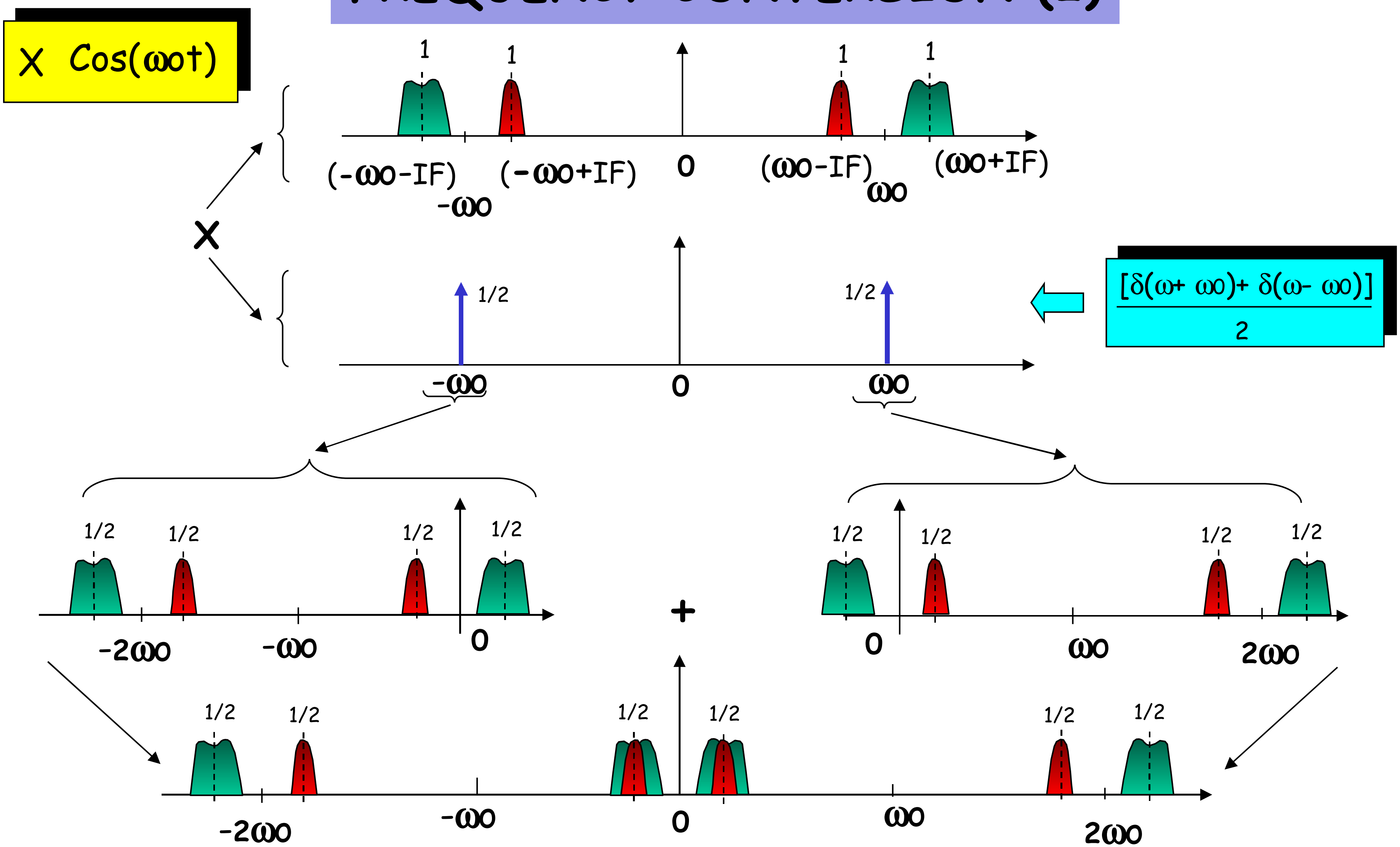


FREQUENCY CONVERSION (1)

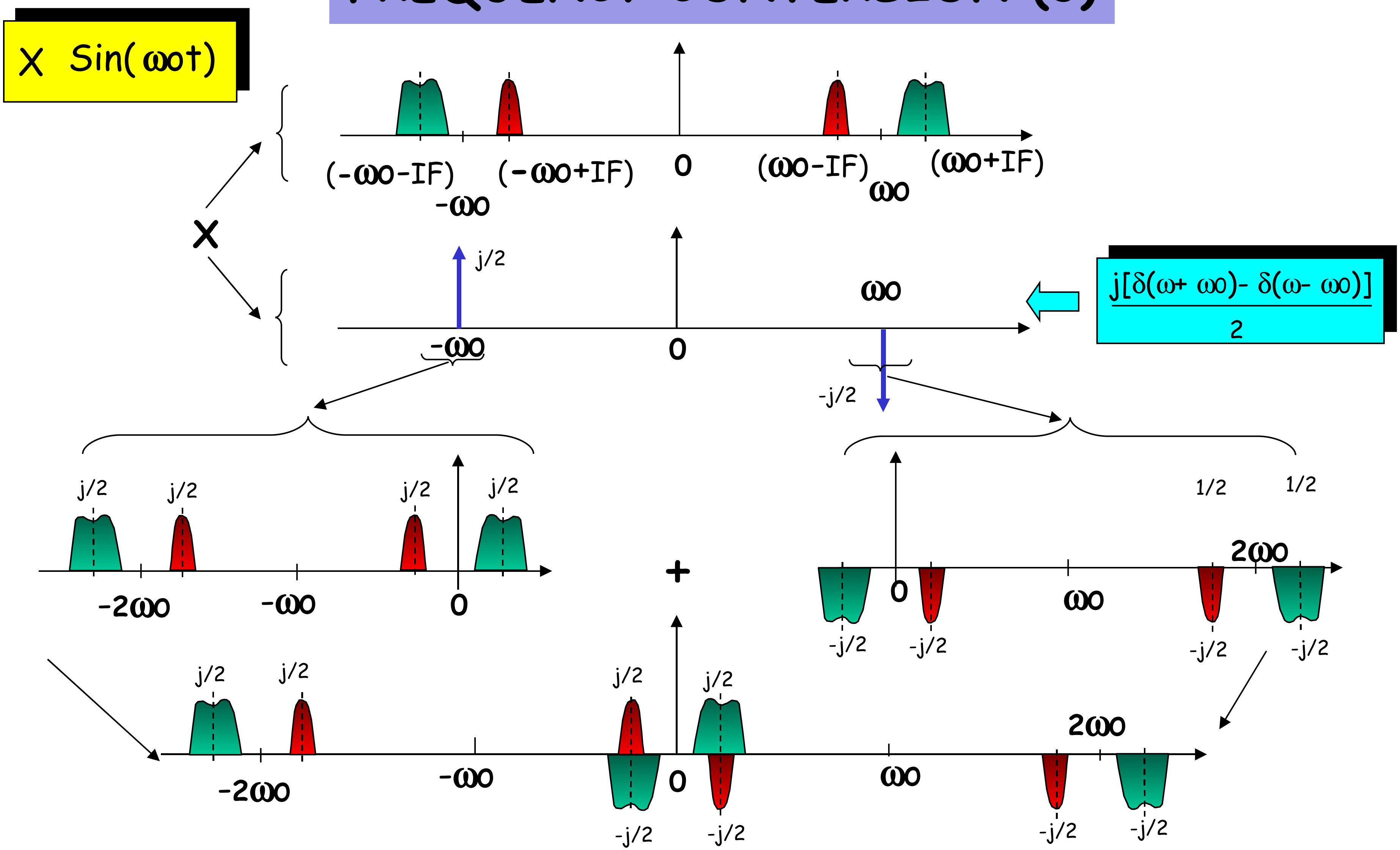
Reject Image Mixer



FREQUENCY CONVERSION (2)

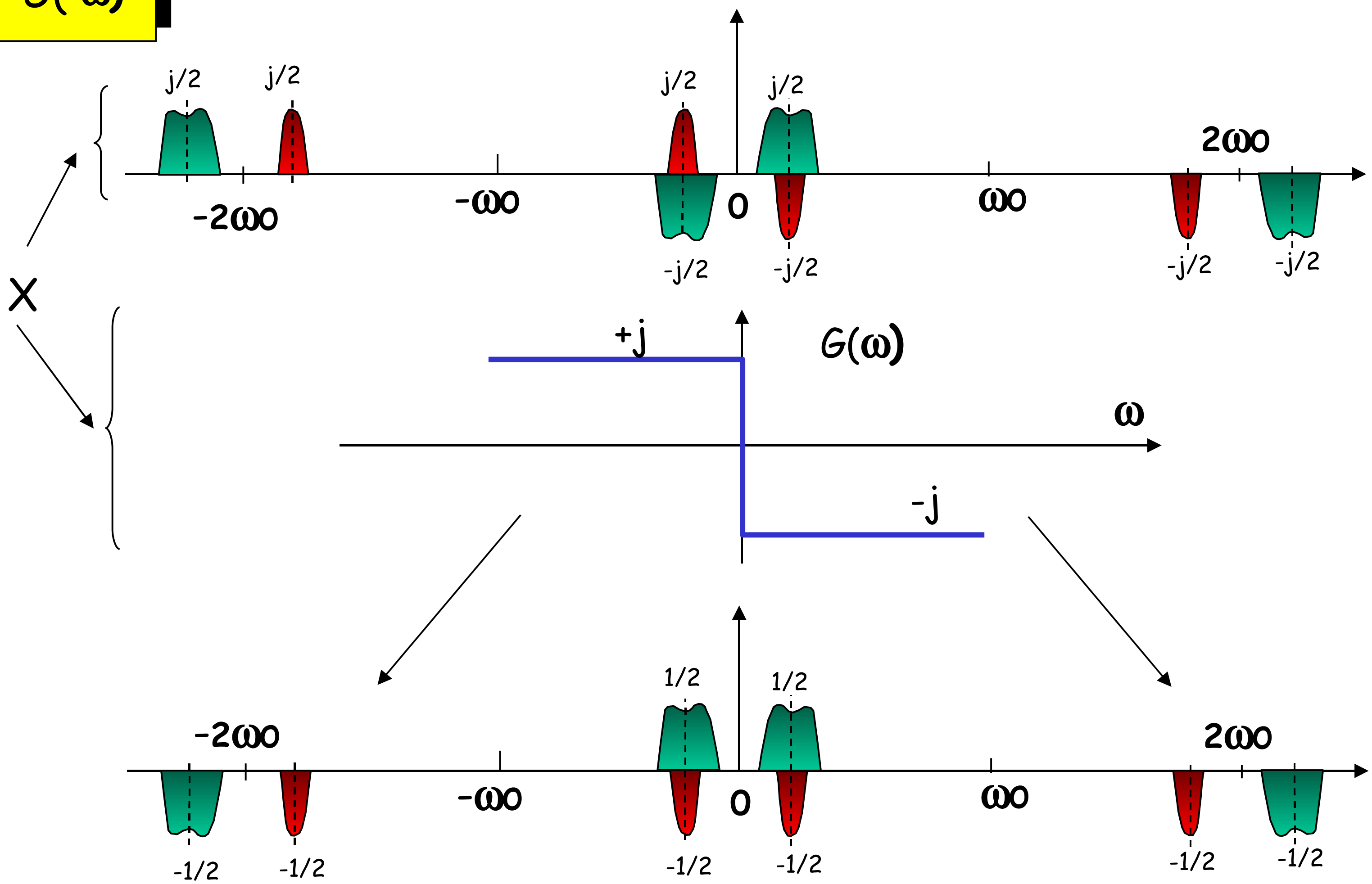


FREQUENCY CONVERSION (3)

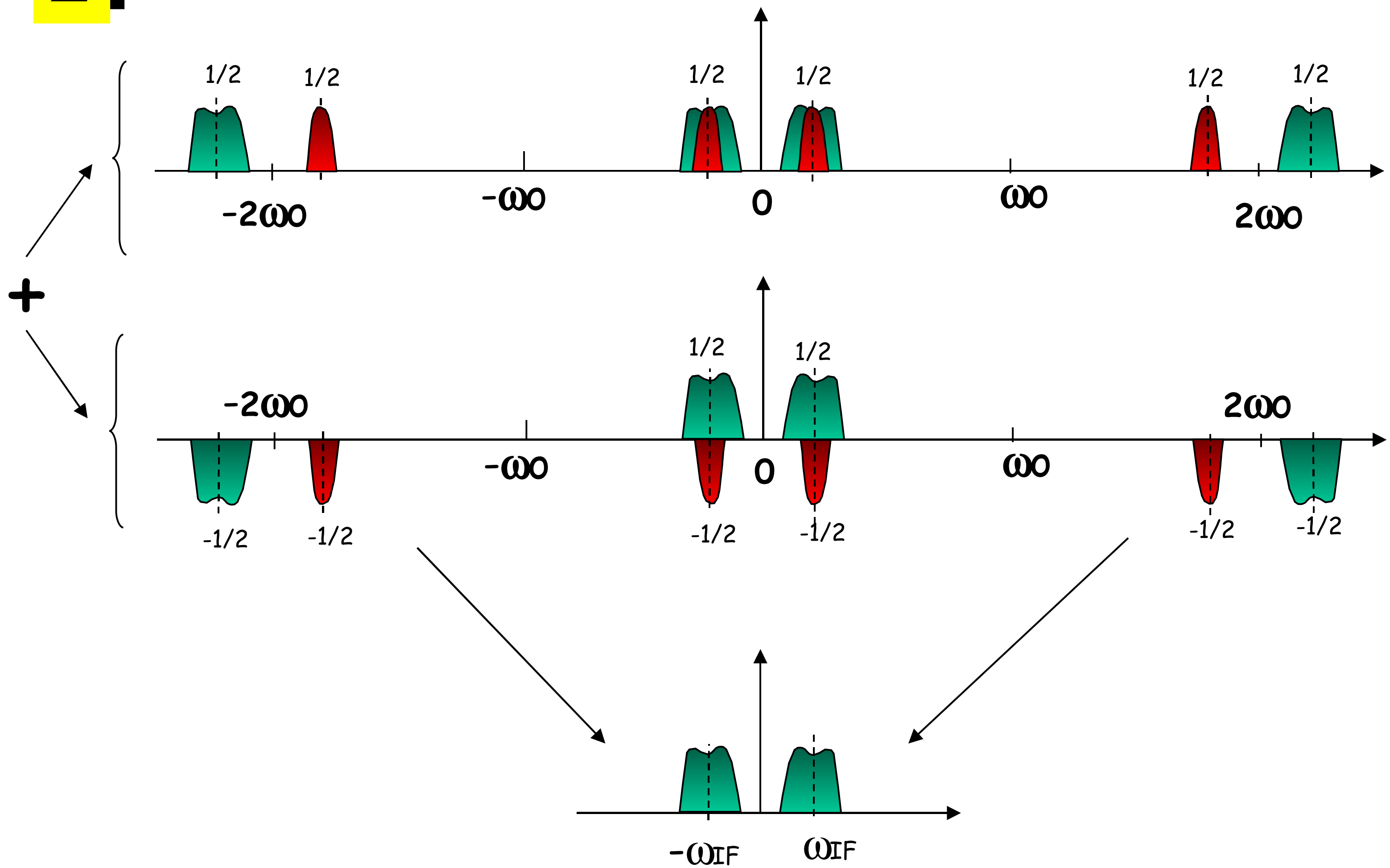


FREQUENCY CONVERSION (4)

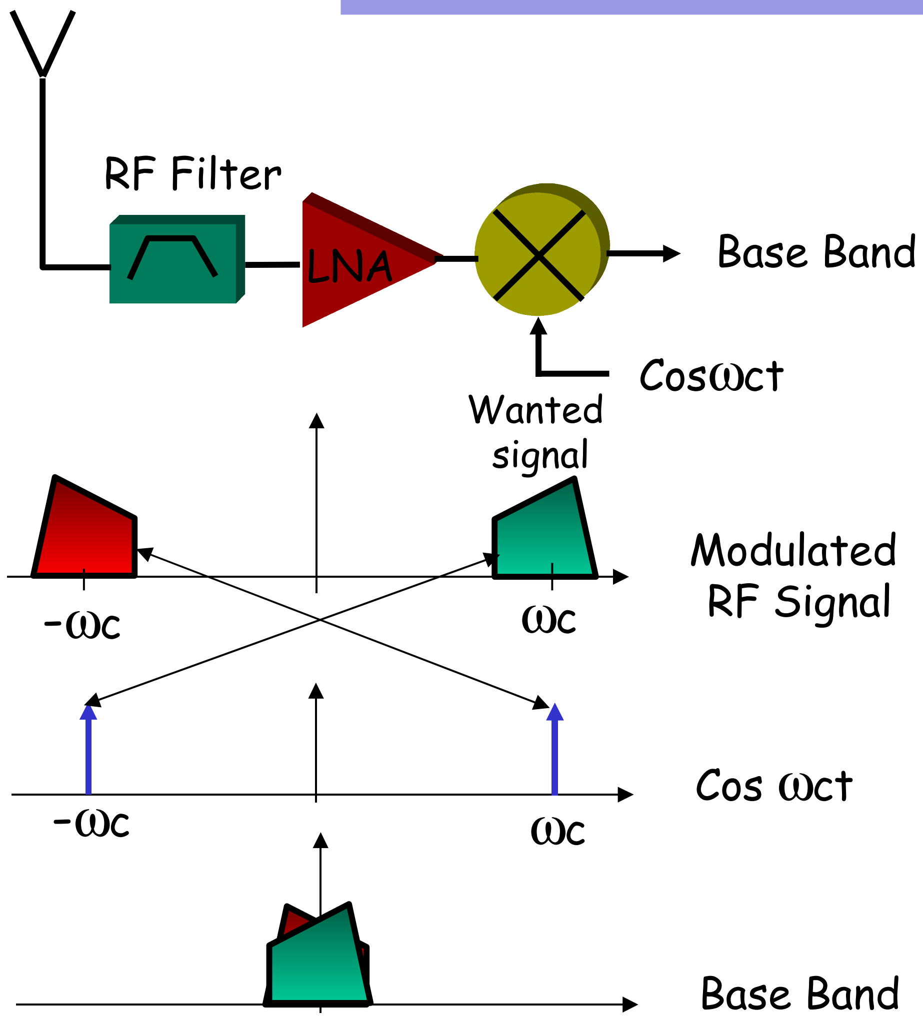
X G(ω)



FREQUENCY CONVERSION (5)

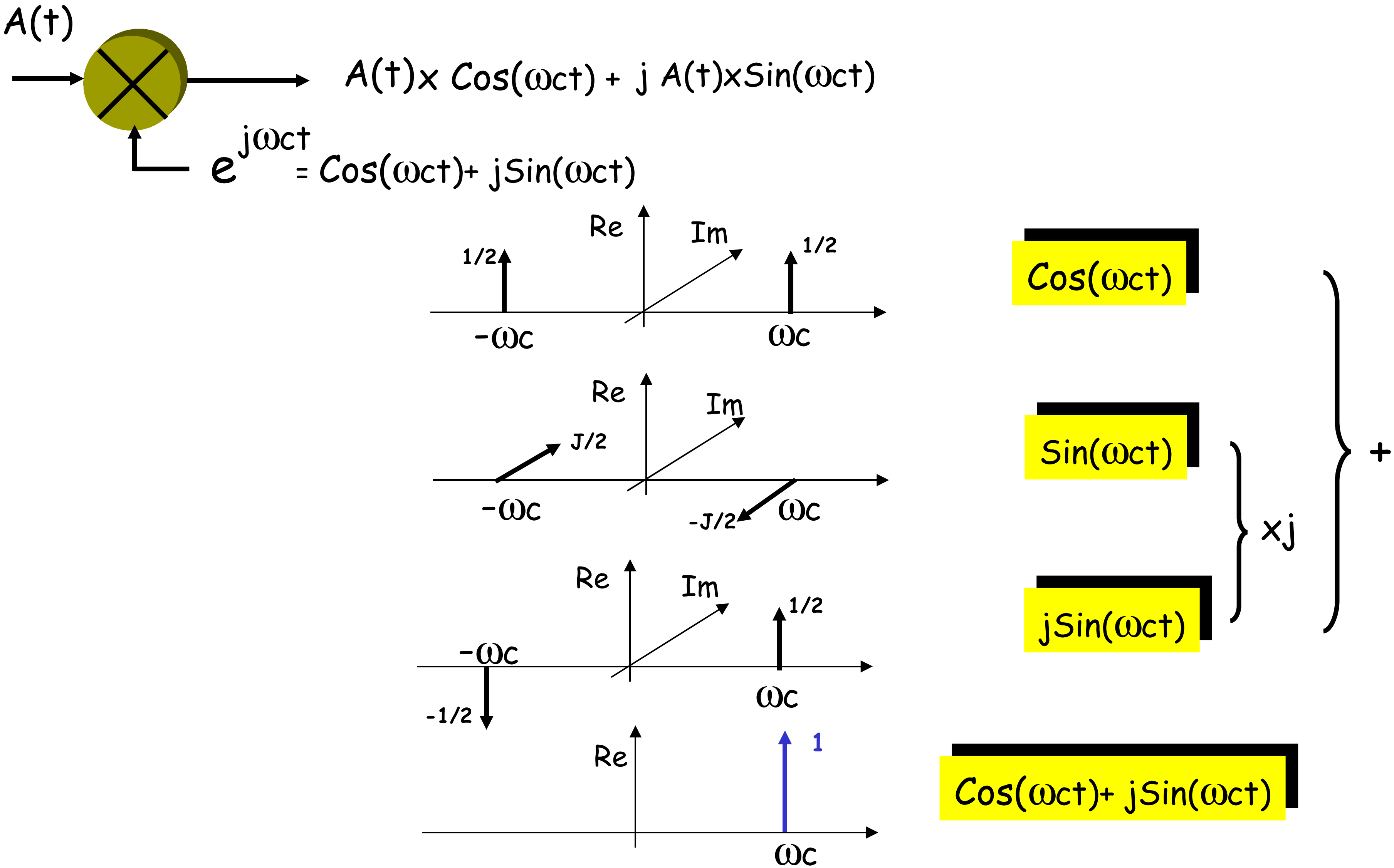


ZERO IF RECEIVERS(1)

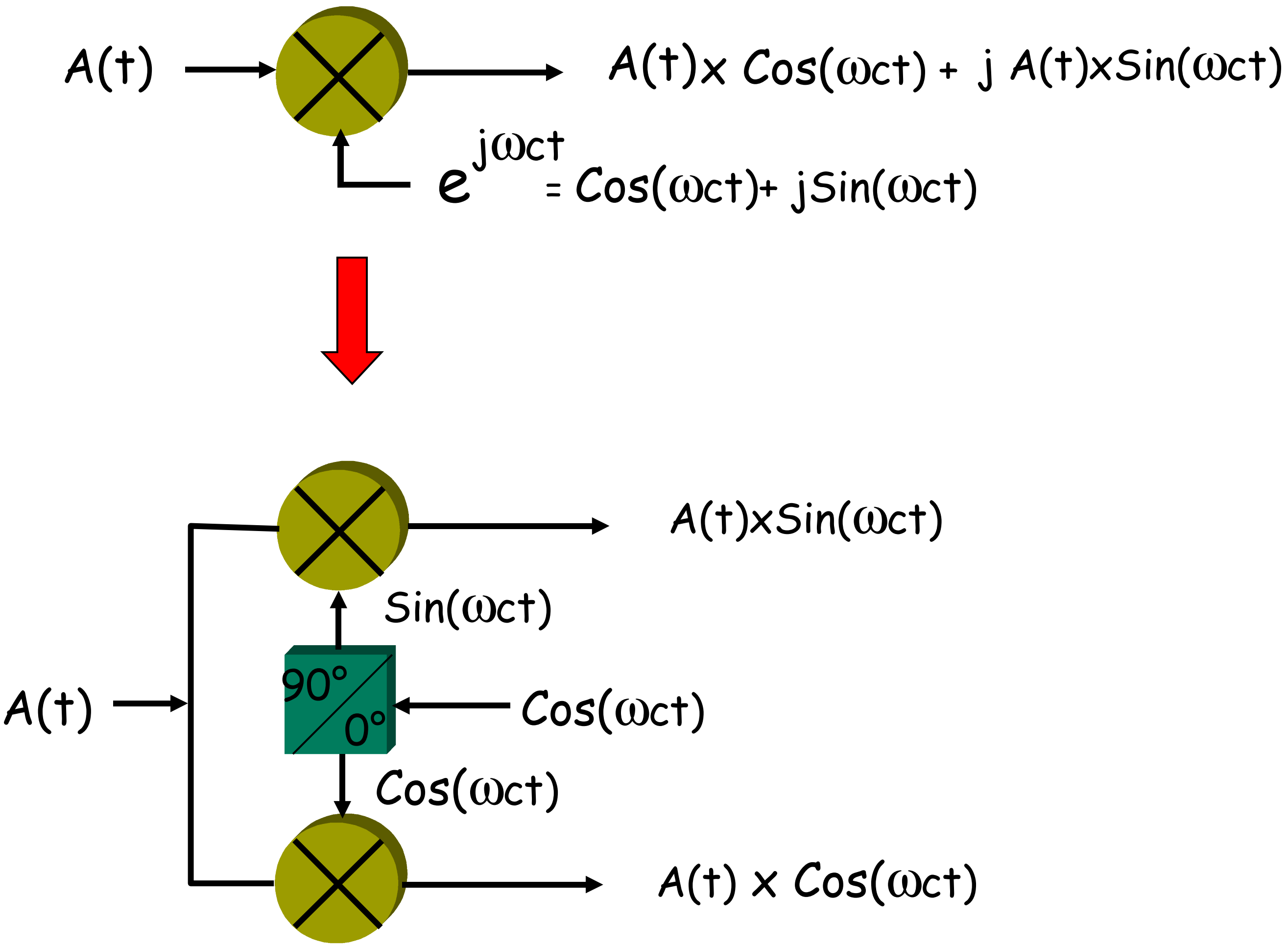


- The IF is then zero & the mirror signal is equal to the wanted signal
- A sine brings both the wanted signal from the positive & negative frequencies to the base band.
- These signals are each other mirror
image & are superimposed
- This problem is solved by doing the down conversion twice.

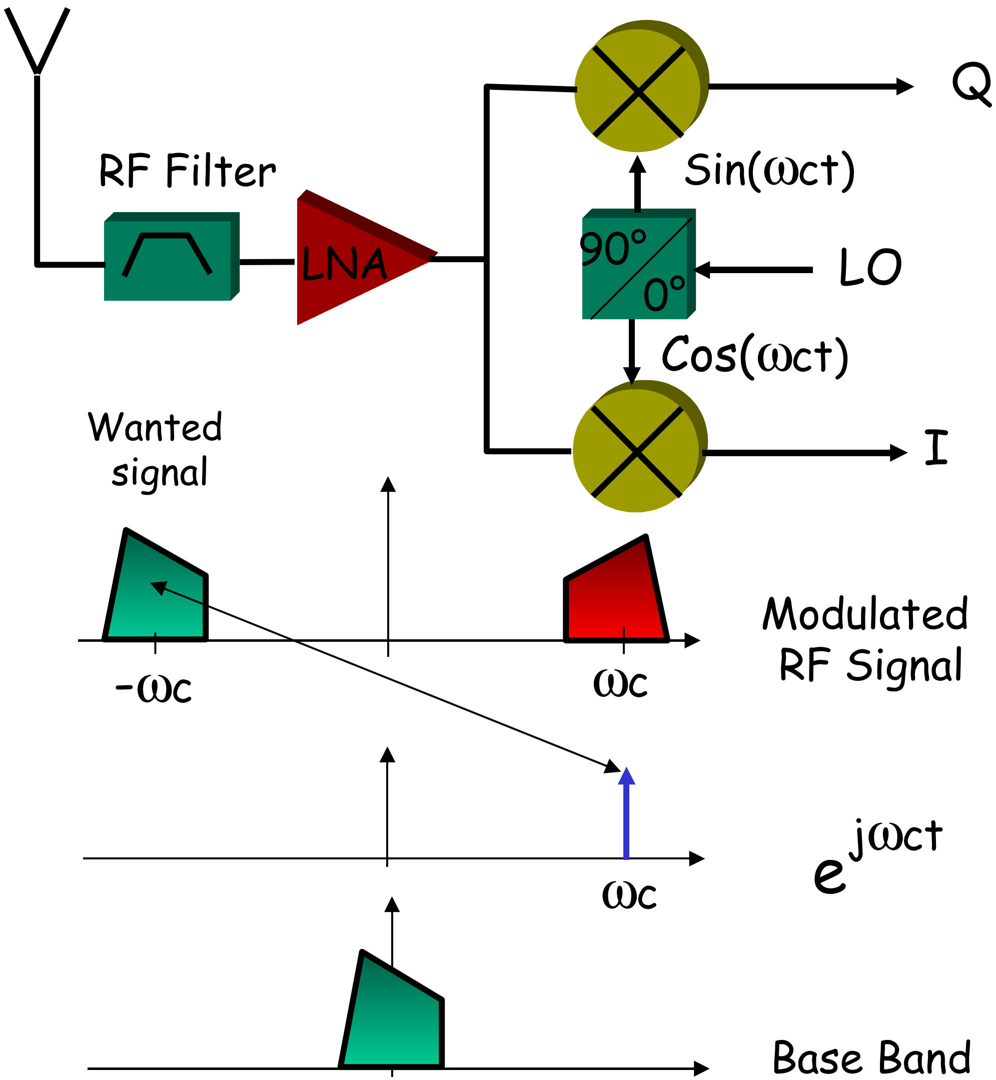
ZERO IF RECEIVERS(2)



ZERO IF RECEIVERS(3)



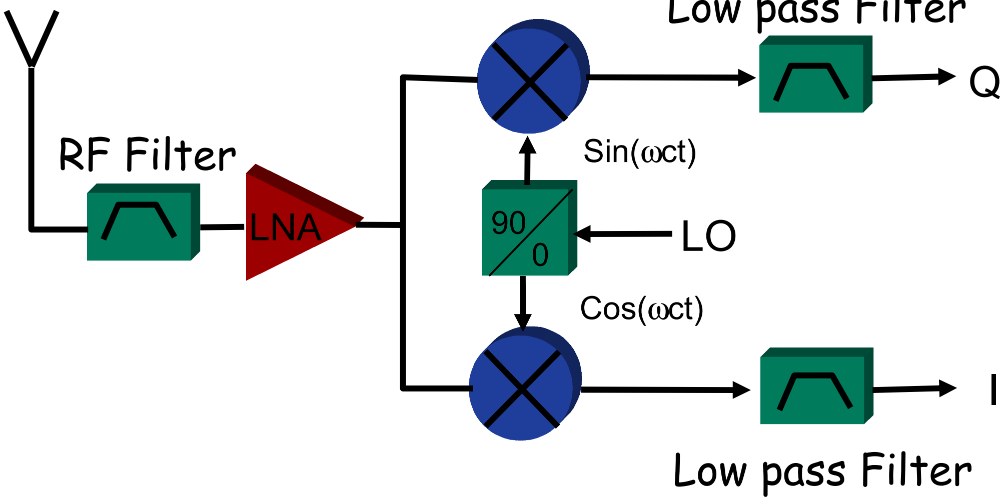
ZERO IF RECEIVERS(4)

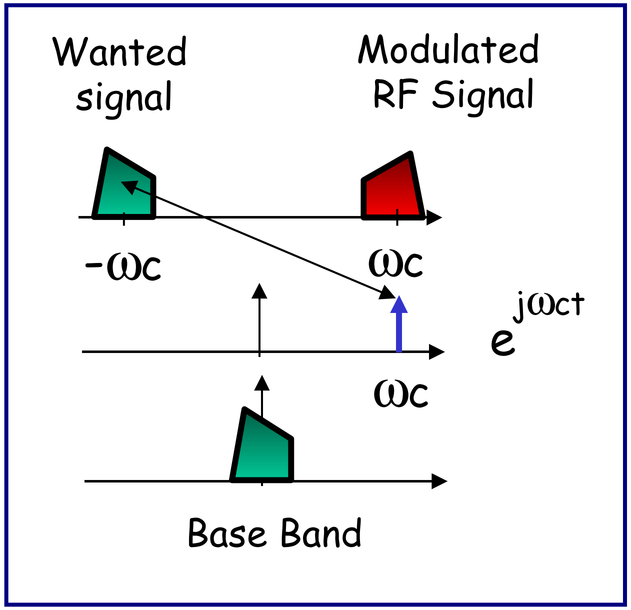


- The advantage of the zero IF receiver is :no need for high Q tunable band pass filters.
- A drawback of the zero IF is the DC offset which is created during the down conversion (result of the crosstalk between the RF & LO inputs of the mixers.

Zero_IF pro & cont

Zero-IF

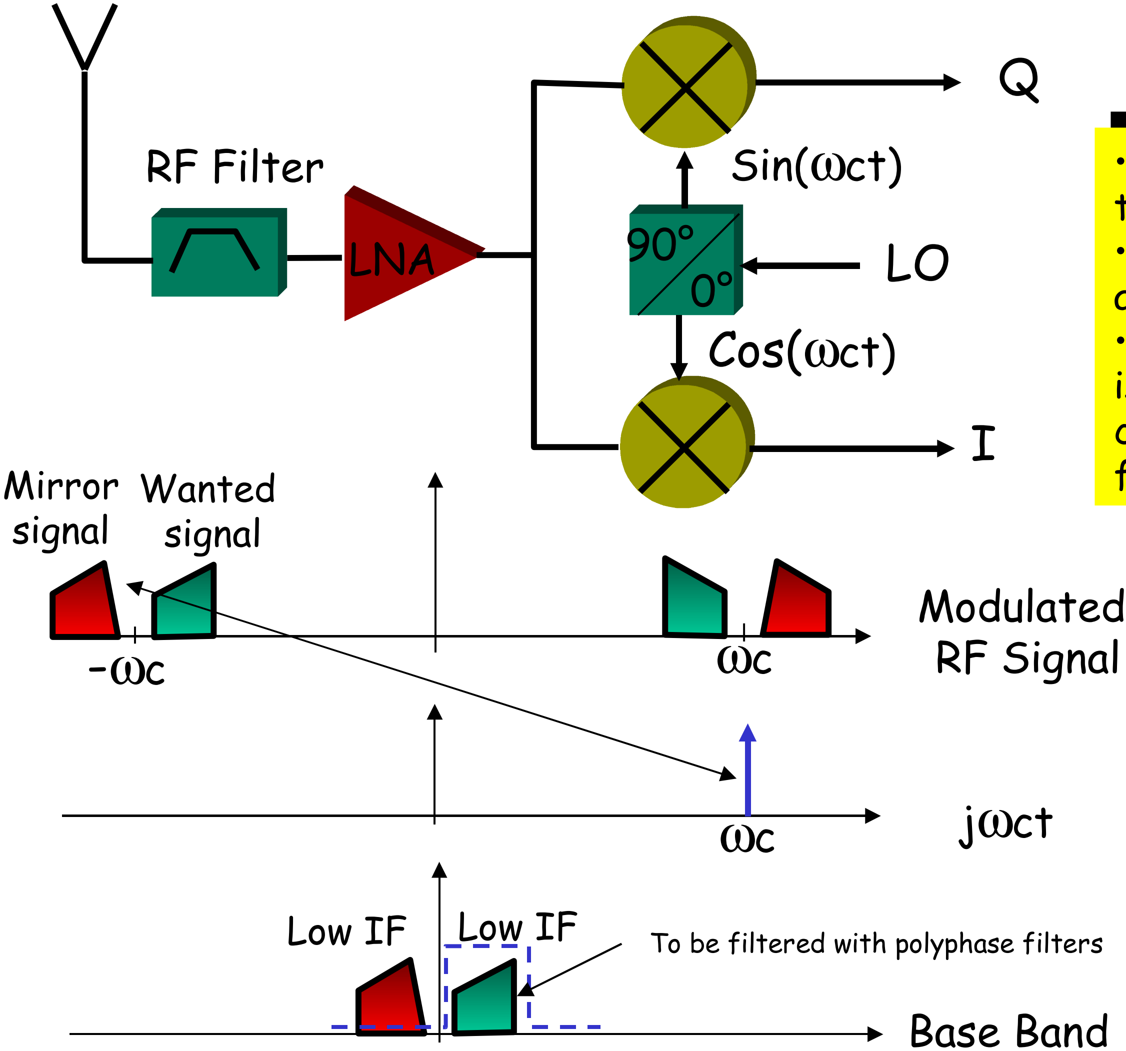




- ✓ Simple structure
- ✓ No image frequency
- ✓ Low pass filtering
- ✓ No 50 Ohm load to drive

- ➢ Dc-offset
- ➢ IM2 sensibility
- ➢ Flicker Noise sensibility
- ➢ Low isolation between RF ed LO ports

NEAR ZERO IF RECEIVERS



- The near zero IF is totally insensitive to any DC-signal whatever its origin .
- The low IF filters will be LF filters that allow analog integration easy .
- The main problem of the near zero IF is the reqired mirror suppression that can be performed only by polyphase filters .

POLYPHASE FILTERS(1)

•A Polyphase filter is a normal filter plus an image rejection.

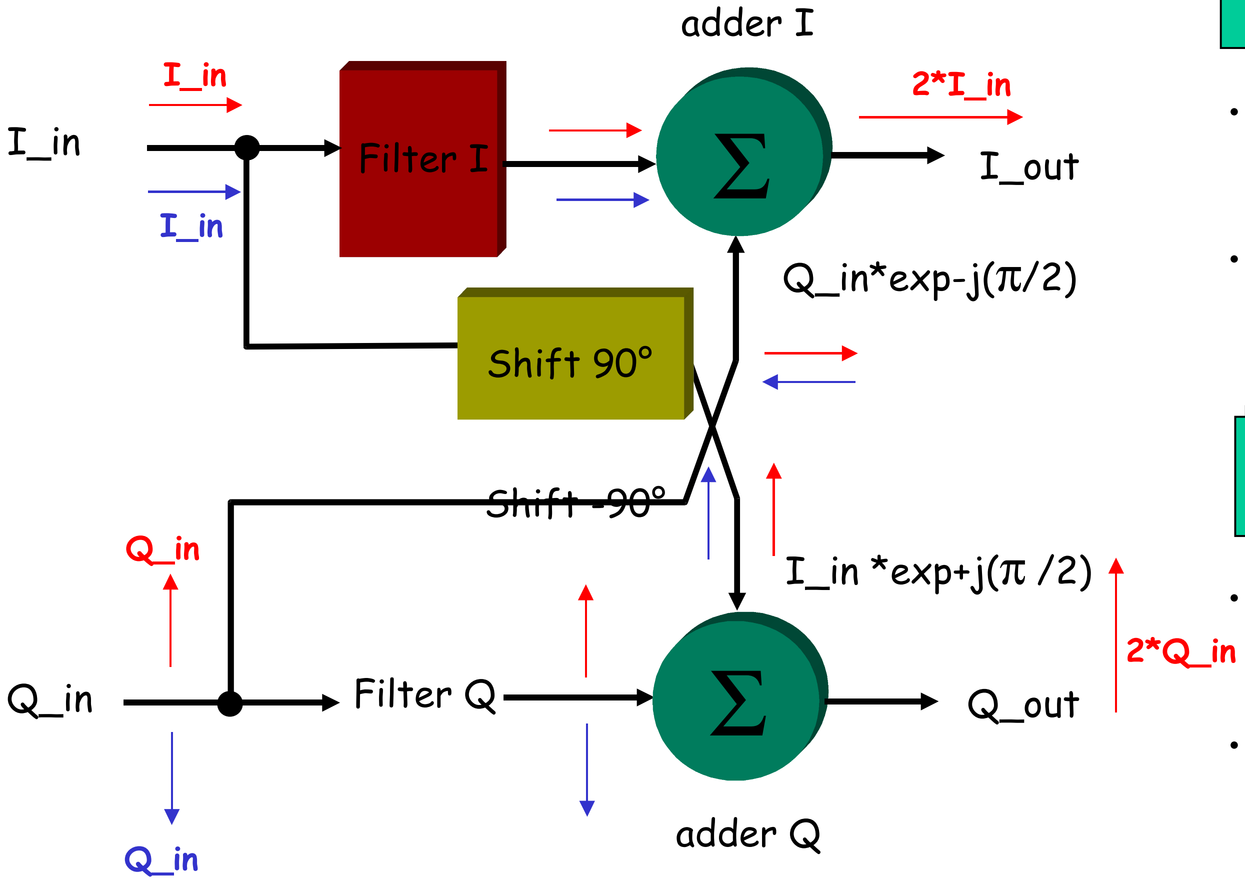
•A Polyphase filter is similar in function and implementation to a real filter exept for the fact that it is able to diffentiate between positive & negative frequencies.

•A real filter has a transfer function that is symetric about DC (i.e it has two identical pass bands corresponding to positive & negative frequencies).

•A polyphase filter can have its passband either positive or negative ,or both .

POLYPHASE FILTERS(2)

Polyphase filter with negative frequency rejection



Positive frequency input
Q_in = I_in*exp+j(π /2)

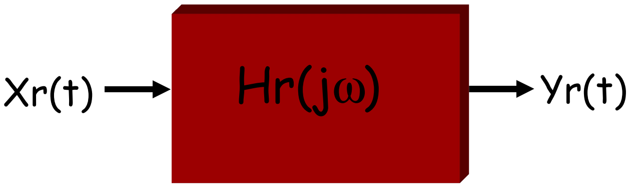
- I_out = I_in + Q_in*exp-j(π /2)
  = I_in + I_in
  = 2*I_in
- Q_out = Q_in + I_in*exp+j(π /2)
  = Q_in + Q_in
  = 2*Q_in

Negative frequency input
Q_in = I_in*exp-j(π /2)

- I_out = I_in + Q_in*exp-j(π /2)
  = I_in - I_in
  = 0
- Q_out = Q_in + I_in*exp+j(π /2)
  = Q_in - Q_in
  = 0

POLYPHASE FILTERS(3)

Real Filter



The impulse response (time domain) is a real

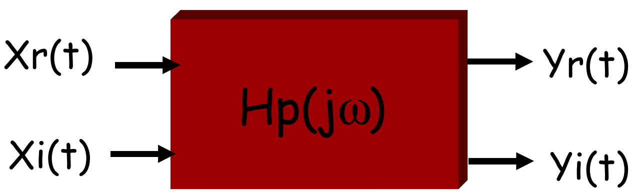
Hr(t)=Real

The response for positive freqencies is the same than for negative frequencies

$Hr(j\omega)=Hr^*(-j\omega)$

$|Hr(j\omega)|=|Hr(-j\omega)|$
$\arg(Hr(j\omega))=-\arg(Hr(-j\omega))$

Polyphase Filter (two phases)



The impulse response (time domain) is a complex

$Hp(t)=Hr(t)+jHi(t)$

The response for positive or negative frequencies is different

$Hp(j\omega)=Hr(j\omega)+jHi(j\omega)$

$|Hp(j\omega)|\neq|Hp(-j\omega)|$
$\arg(Hp(j\omega))\neq-\arg(Hp(-j\omega))$

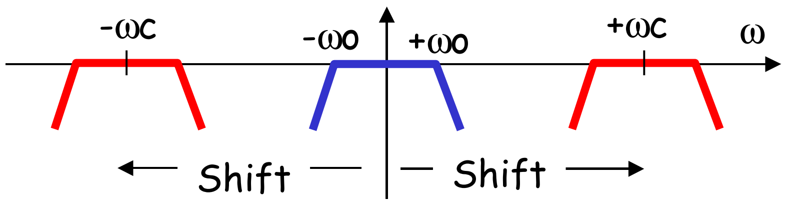
POLYPHASE FILTERS(4)

The most important application for a polyphase filter is the suppression of positive or negative frequency component of a complex signal .

This can be done with a band pass filter resulting of the linear tranformation of a low pass filter .The classic lowpass to bandpass transformation does not change the real properties of the lowpass filter .

In that case the band pass filter has the lowpass filter characteristic around +/-ωc .

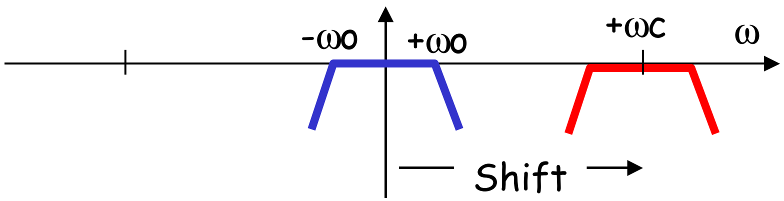
$$j\,\omega \longrightarrow j\,\omega c\left[\frac{\omega}{\omega c} - \frac{\omega c}{\omega}\right]$$



$$\frac{1}{1+j\,\dfrac{\omega}{\omega_0}} \quad \text{LP} \qquad \Longrightarrow \qquad \frac{1}{1+j\left(\dfrac{\omega^2-\omega c^2}{\omega_0\;\omega c}\right)} \quad \text{BP}$$

With a polyphase filter the linear transformation in use (lowpass to band pass) makes the bandpass characteristic similar to the lowpass only around + ωc .

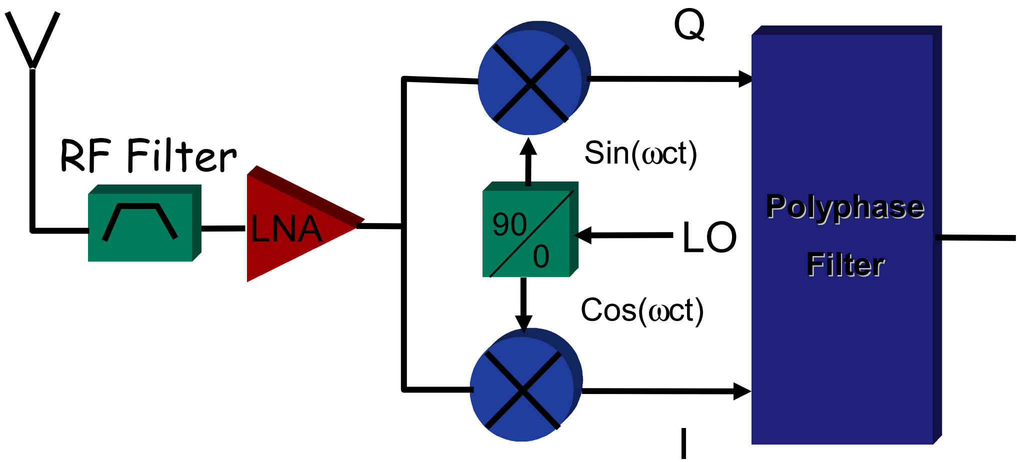
$$j\,\omega \longrightarrow j\,\omega - j\,\omega c$$

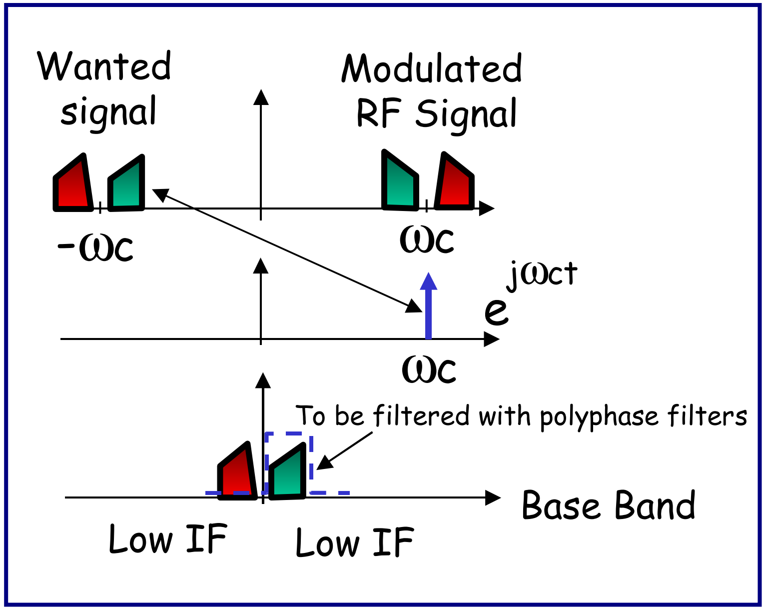


$$\frac{1}{1+j\,\dfrac{\omega}{\omega_0}} \quad \text{LP} \qquad \Longrightarrow \qquad \frac{1}{1+j\left(\dfrac{\omega-\omega c}{\omega_0}\right)} \quad \text{BP}$$

Receivers Structures (III)

Low-IF



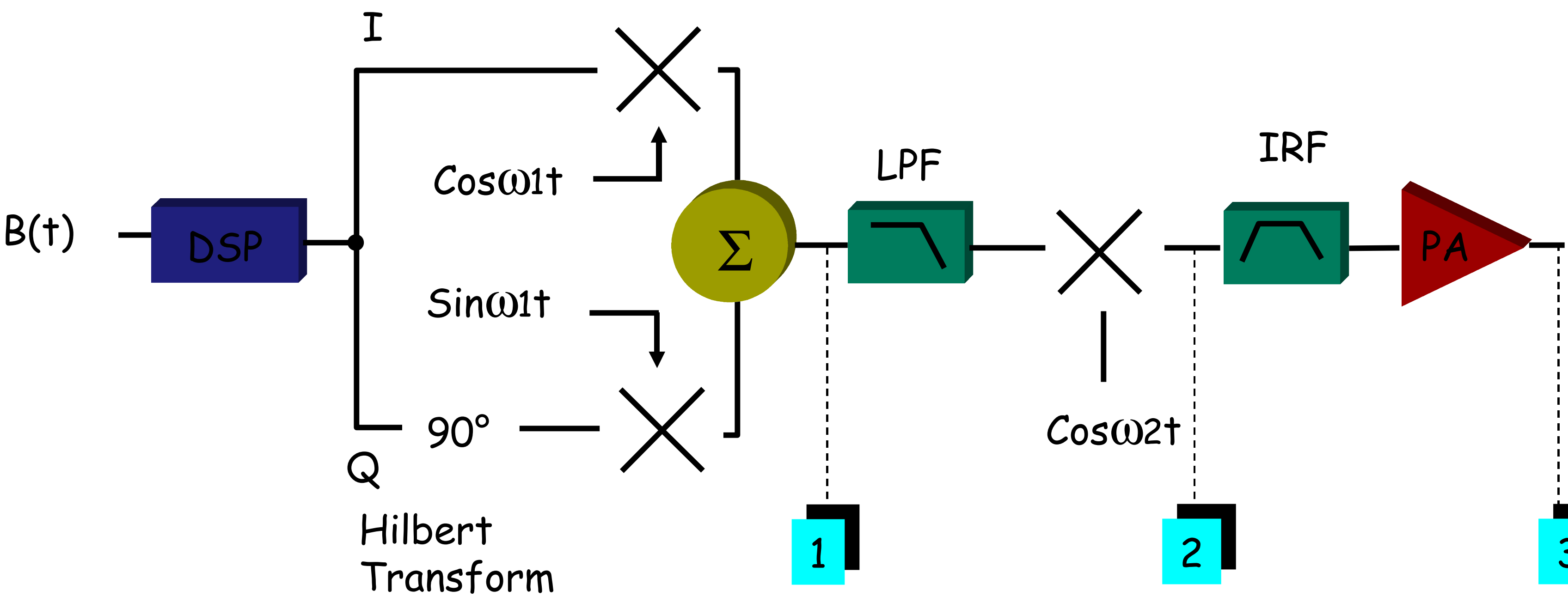


- ✓ Simple structure
- ✓ Low pass filtering
- ✓ No 50 Ohm load to drive

- ➢ IM2 sensibility
- ➢ Low isolation between RF ed LO ports
- ➢ Structure balancing

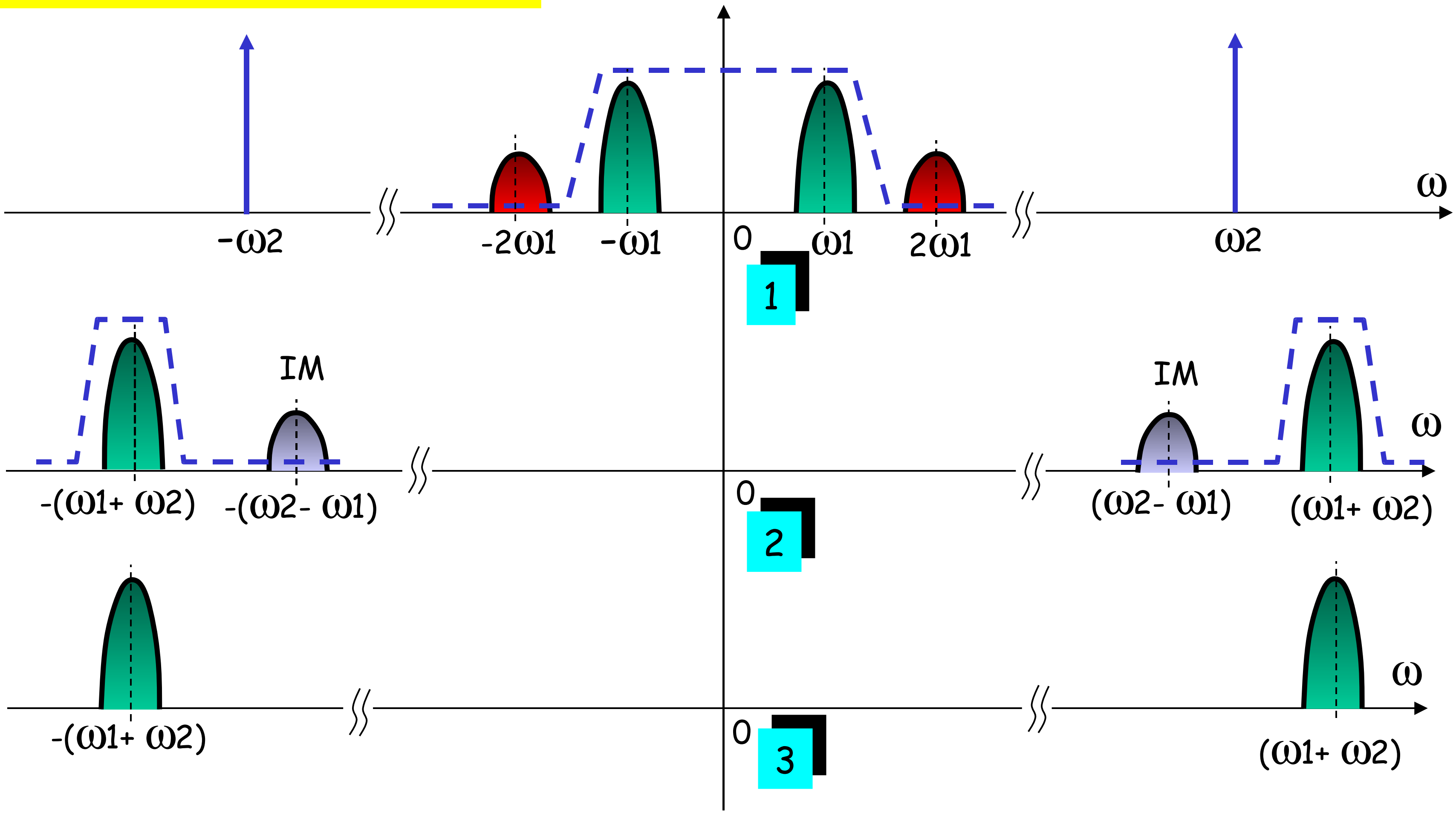
TRANSMITTER ARCHITECTURE(1)

Indirect Modulation Transmitter



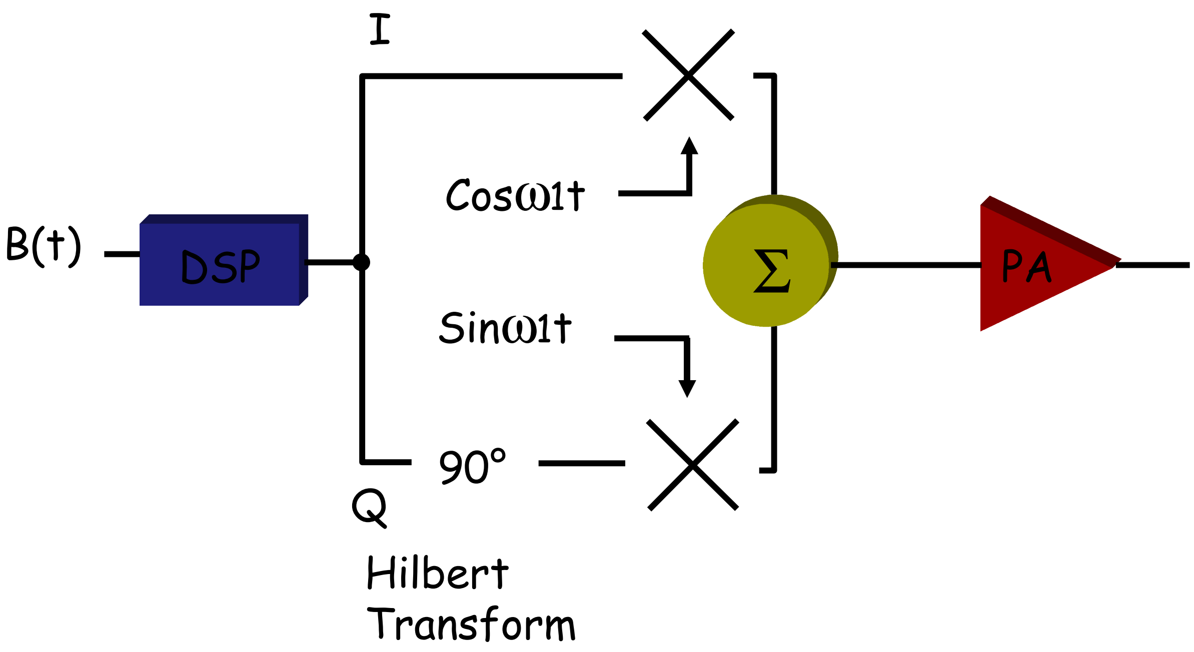
TRANSMITTER ARCHITECTURE(2)

Indirect Modulation Transmitter

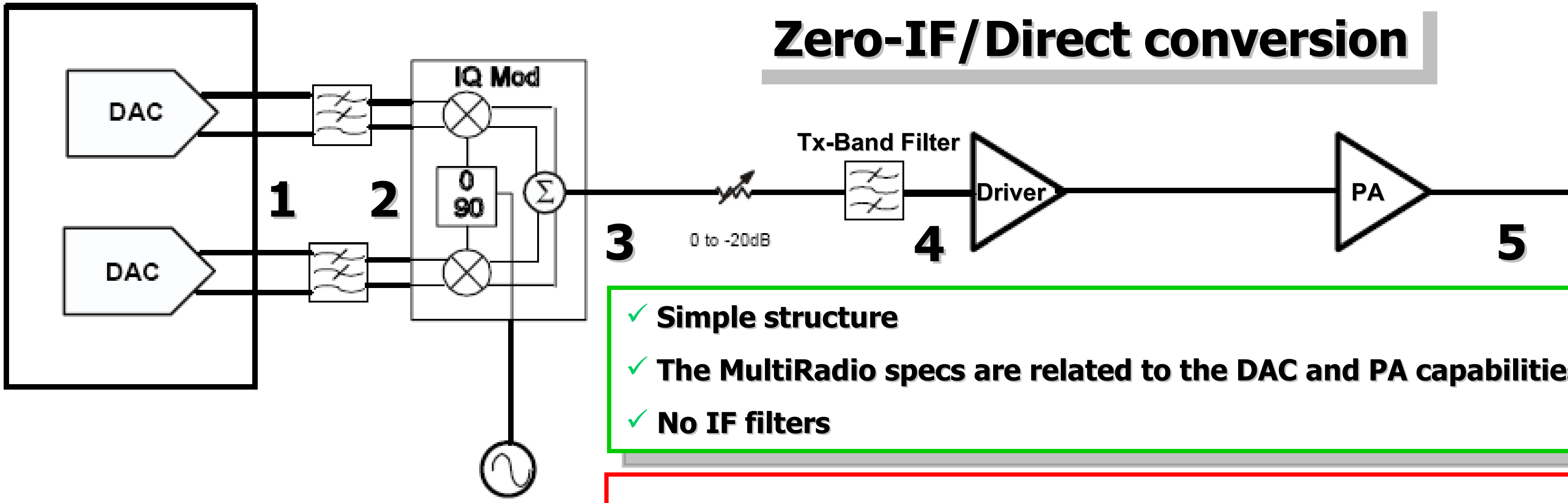


TRANSMITTER ARCHITECTURE(3)

Direct Modulation Transmitter

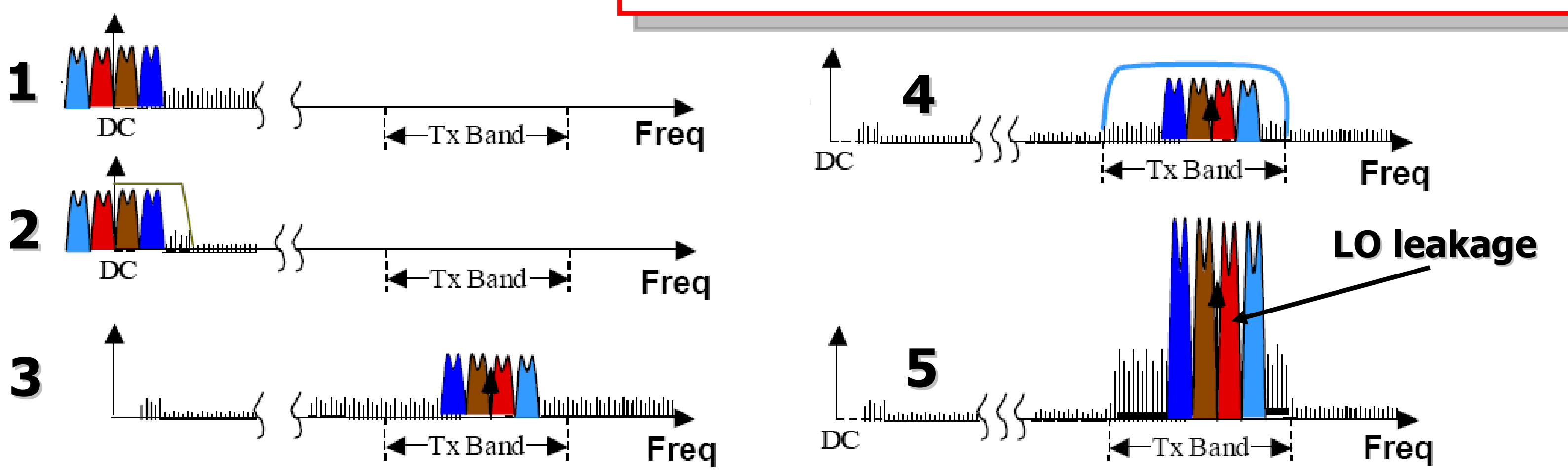


Zero-IF/Direct conversion

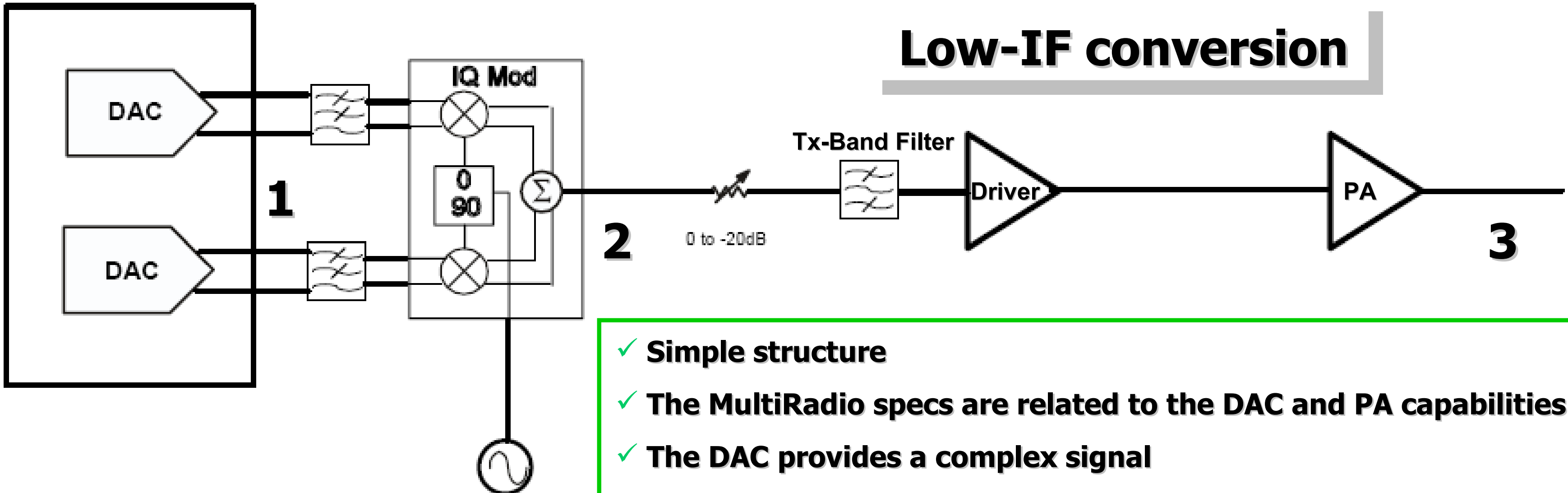


- ✓ Simple structure
- ✓ The MultiRadio specs are related to the DAC and PA capabilities
- ✓ No IF filters

- ➢ LO residual affects the EVM (good LO suppression is needed)
- ➢ PA to LO leakage can modulate or pull the VCO

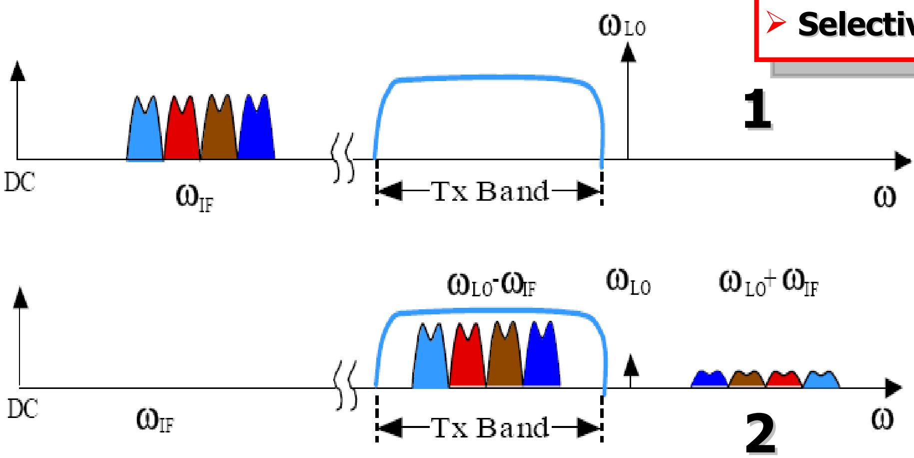


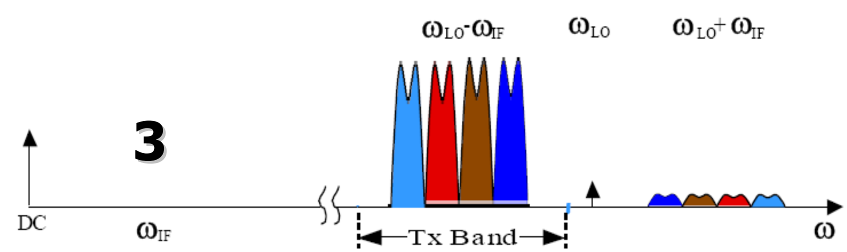
Low-IF conversion



- ✓ **Simple structure**
- ✓ **The MultiRadio specs are related to the DAC and PA capabilities**
- ✓ **The DAC provides a complex signal**
- ✓ **Lo signals can be theoretically filtered out**

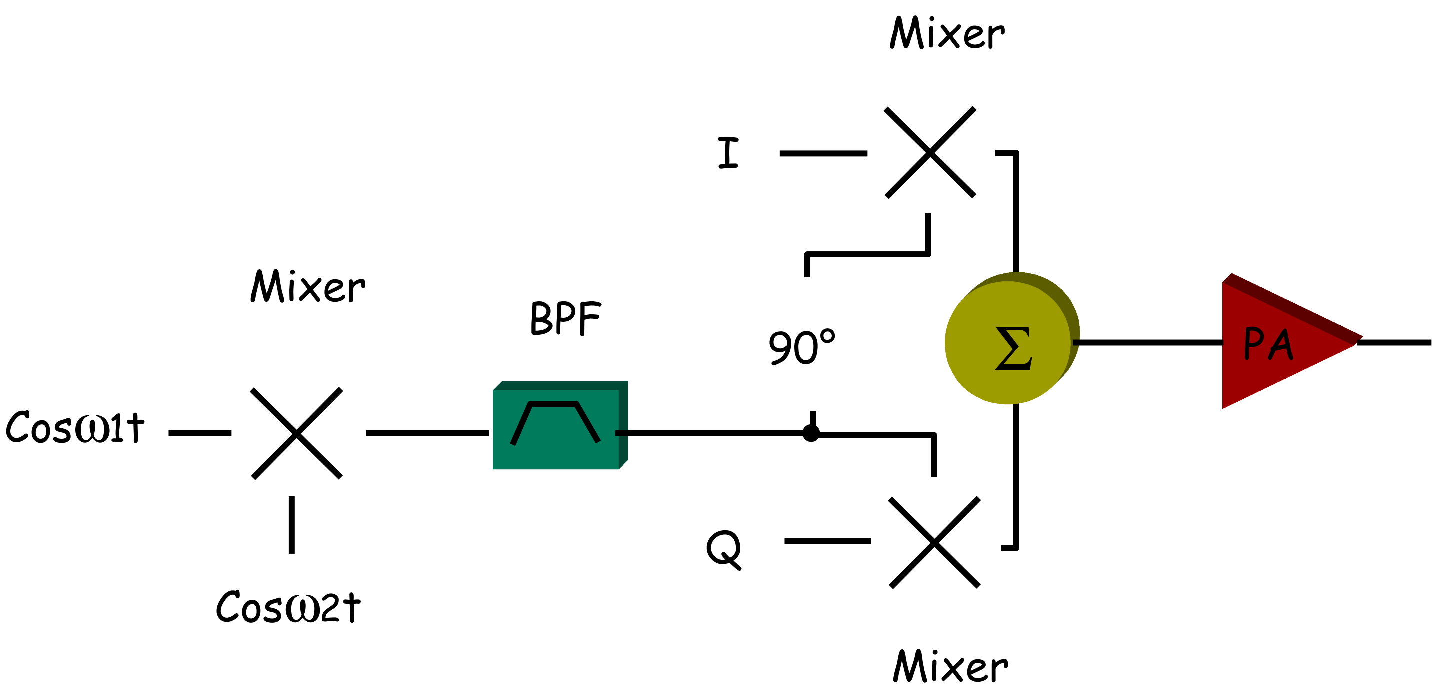
- ➢ **To cut LO residual the IF has to be quite high (tough DAC specs)**
- ➢ **Selective RF filters**





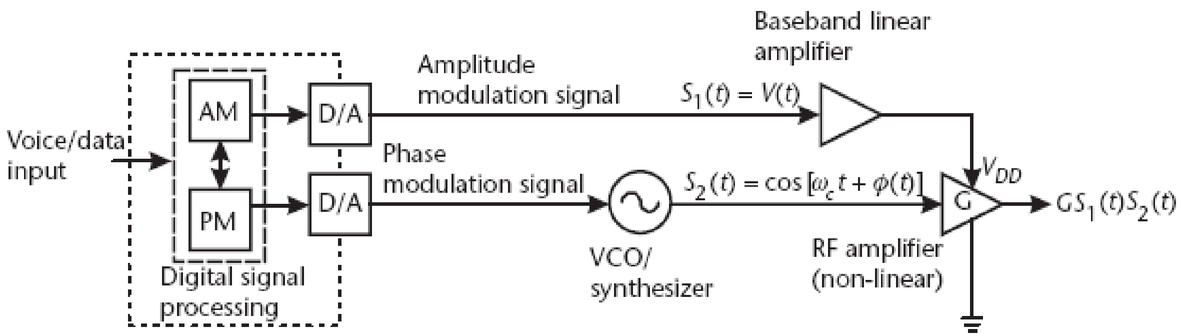
TRANSMITTER ARCHITECTURE(3)

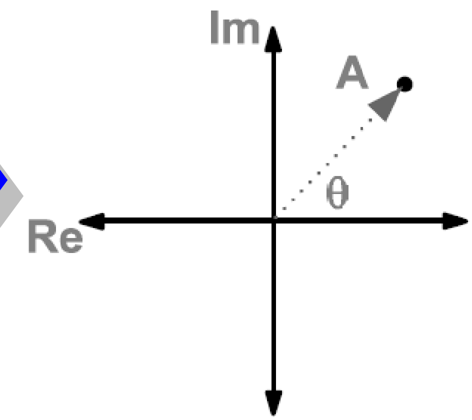
Direct Modulation Transmitter With Offset VCO



TRANSMITTER ARCHITECTURE(4)

Polar transmitter

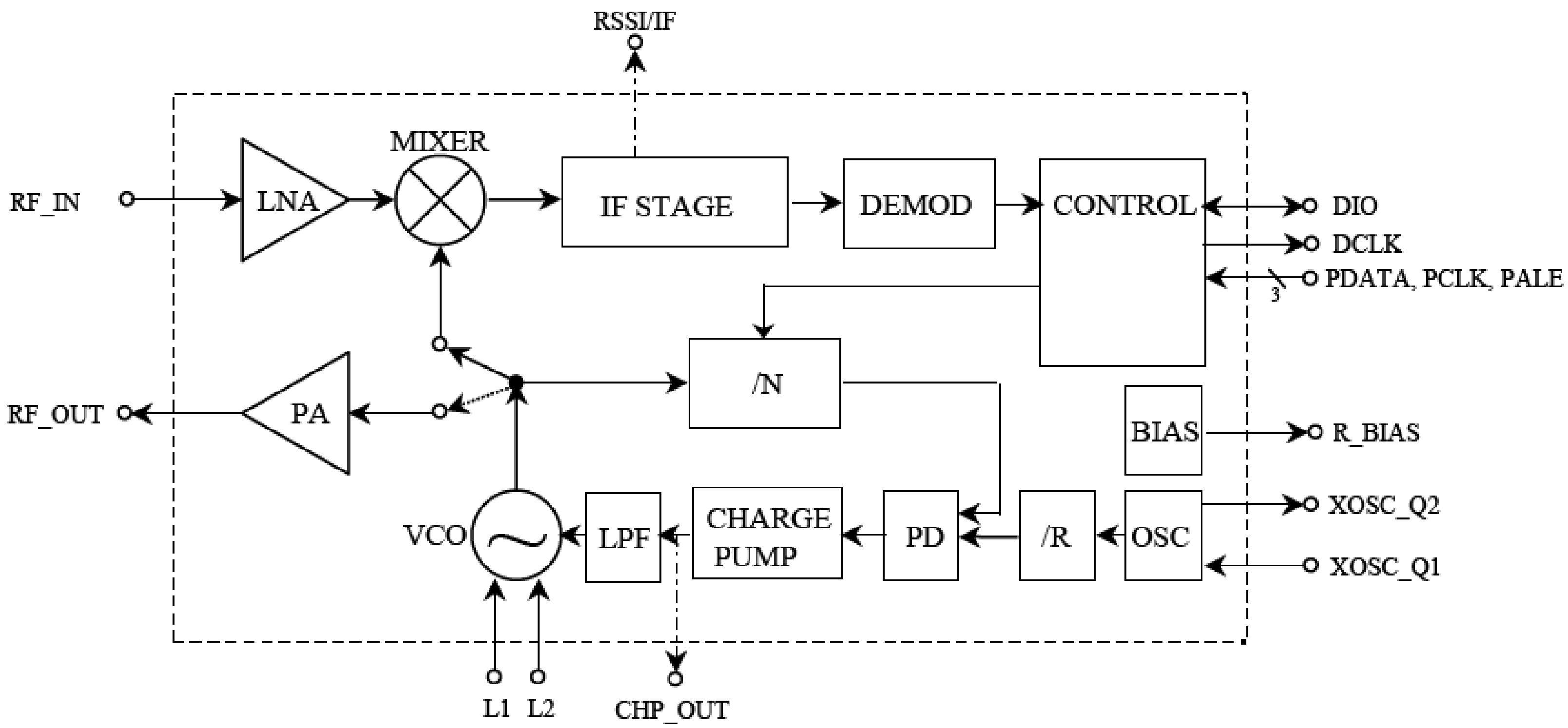




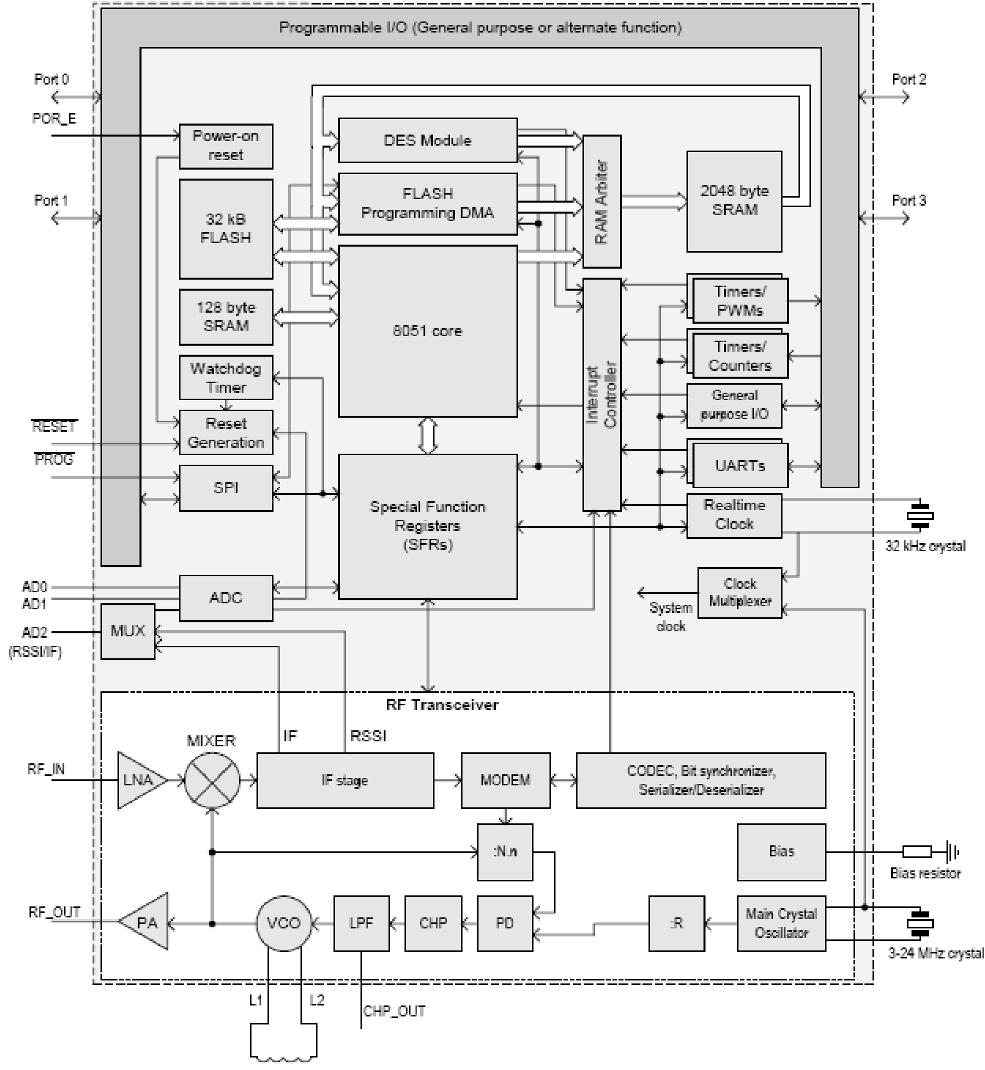
$$S(t) = G \cdot S_1(t) \cdot S_2(t) = G \cdot V(t) \sin\left[2\pi f_C t + \phi(t)\right]$$

- No up-conversion, RF signal operated by synthesizer and PA amplitude
- Theoretically open to whatever modulation
- Theoretically no filtering is needed
- Symbol mapping is nonlinear function → narrowband application

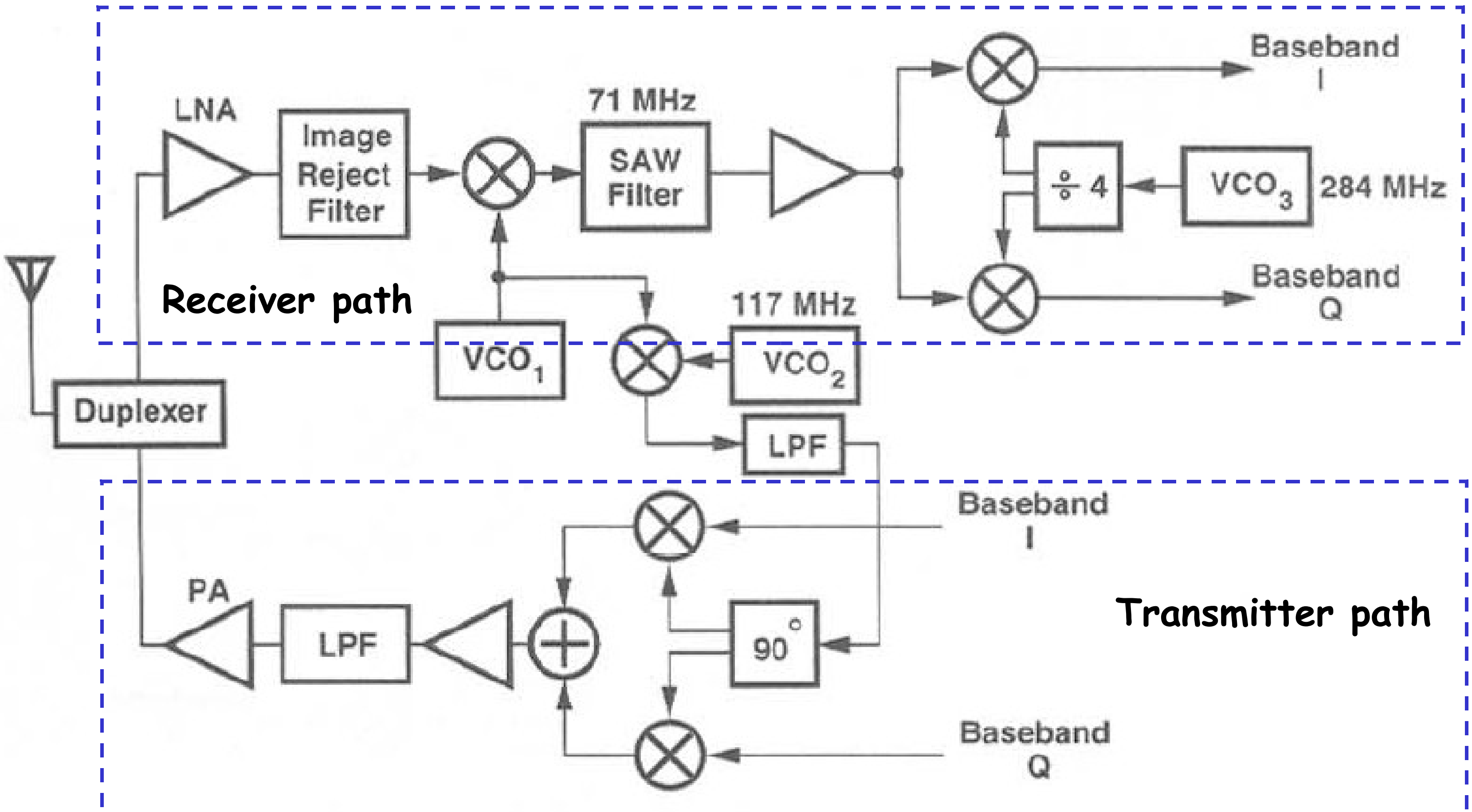
TRANSCEIVER EXAMPLE (I)



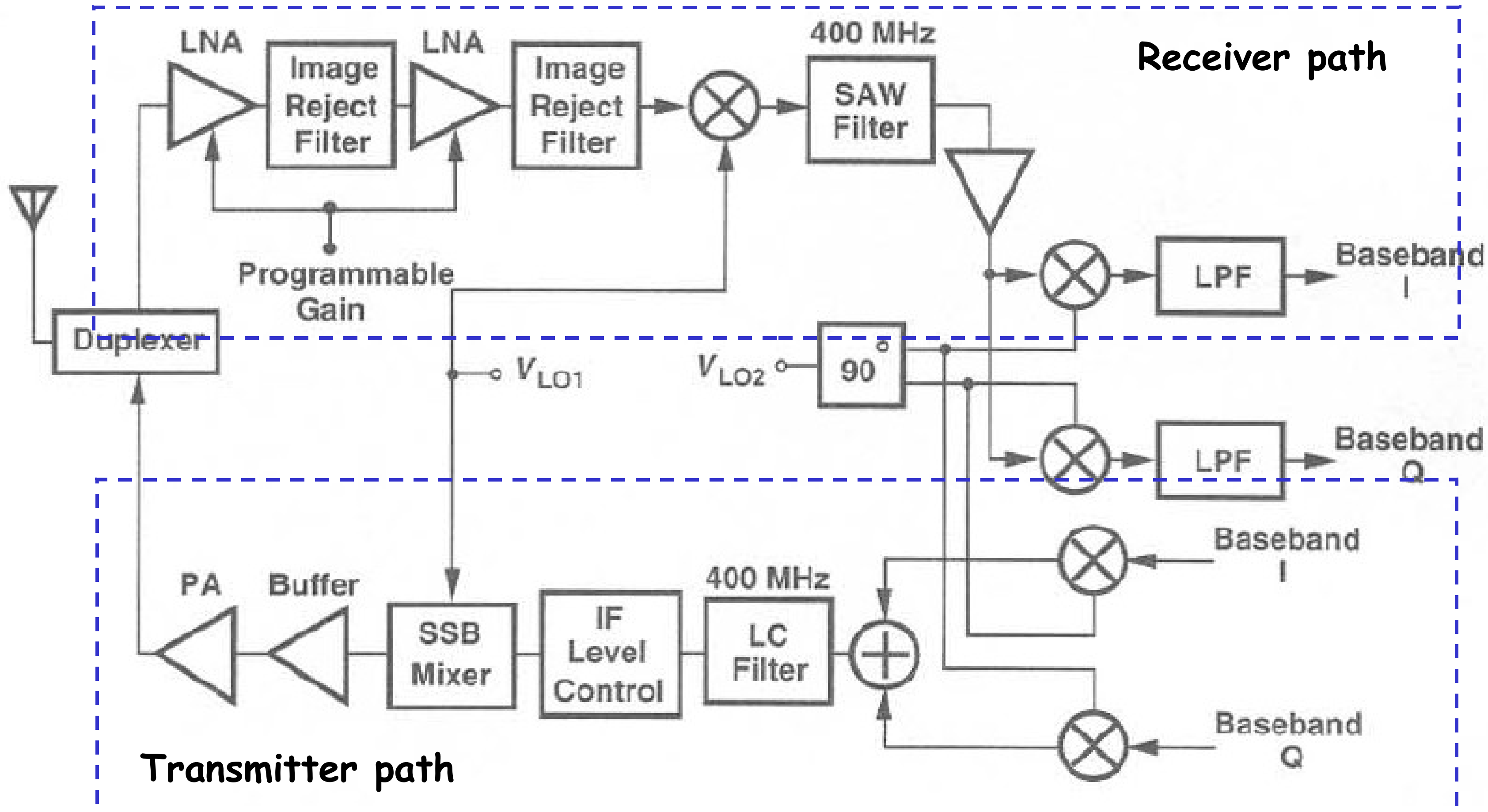
TRANSCEIVER EXAMPLE (II)



TRANSCEIVER EXAMPLE (III)



TRANSCEIVER EXAMPLE (VI)



TRANSCEIVER EXAMPLE (V)