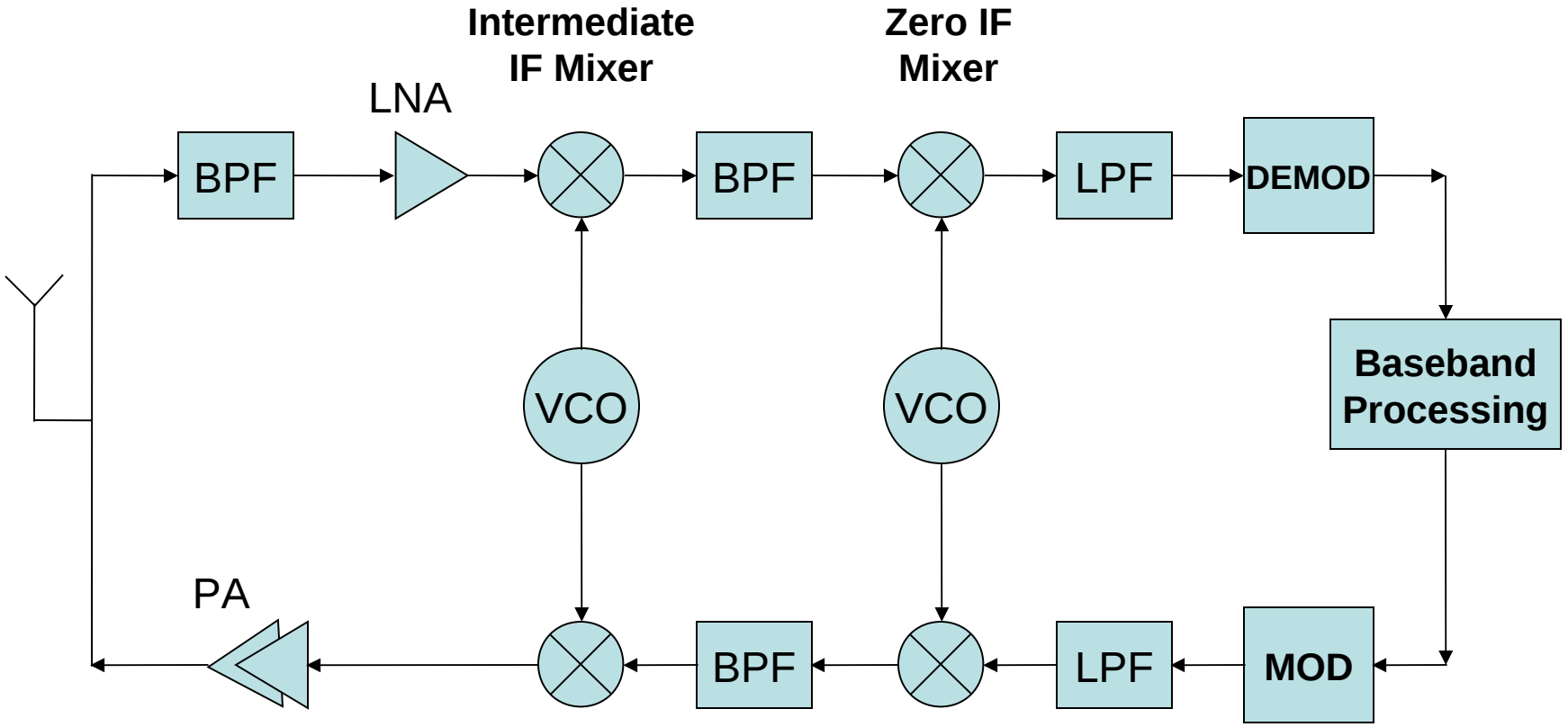
Mixers
EC434

Dr. Amr Bayoumi

Wireless Transceiver Architecture



Mixers

- **A mixer is mainly a multiplier (usually analog):**

  $A\cos(\omega_1 t) * B\cos(\omega_2 t) = (1/2)\,AB\,[\cos(\omega_1-\omega_2)t + \cos(\omega_1+\omega_2)t]$

- **Down-conversion (Receiver): use $(\omega_1-\omega_2)$**
- **Up-conversion (Transmitter): use $(\omega_1+\omega_2)$**
- **Could be either:**
  - **Intermediate Frequency (IF) : Heterodyne, or**
  - **Direct Conversion (Zero IF): Homodyne**
- **Needs careful filter design to remove image, out-of-band, and unwanted product terms:**
  - **Both input and output need these filters (Bandpass or Low pass)**

Building Blocks: Phase Locked Loop (PLL)

- **Local Oscillator (LO) needs to have:**
  - **Same Frequency as incoming signal**
  - **Predetermined phase (0, 90 deg, …) as incoming signal**
- **Multiplication Equation:**

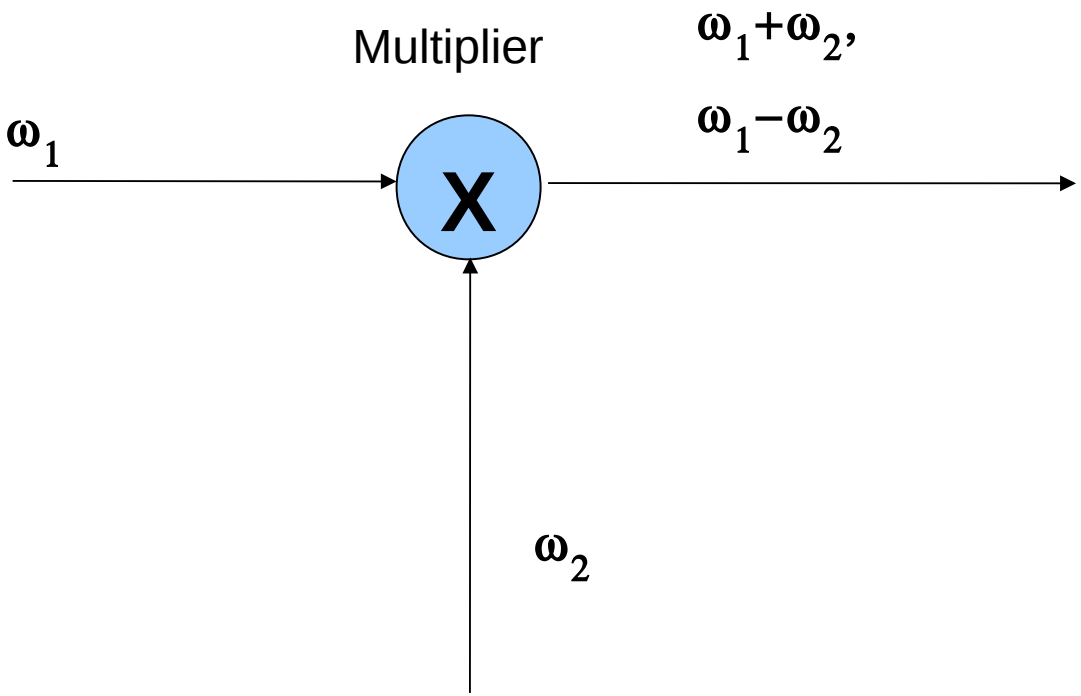
$$A\cos(\omega_1 t) * B\cos(\omega_2 t) = (1/2)\,AB\,[\cos(\omega_1-\omega_2)t + \cos(\omega_1+\omega_2)t]$$

- **Any added phase $(\omega t + \phi)$ or frequency drift $(\omega+\Delta)t$ will alter this equation**
- **PLL acts on error with incoming signal to "lock" frequency & phase**

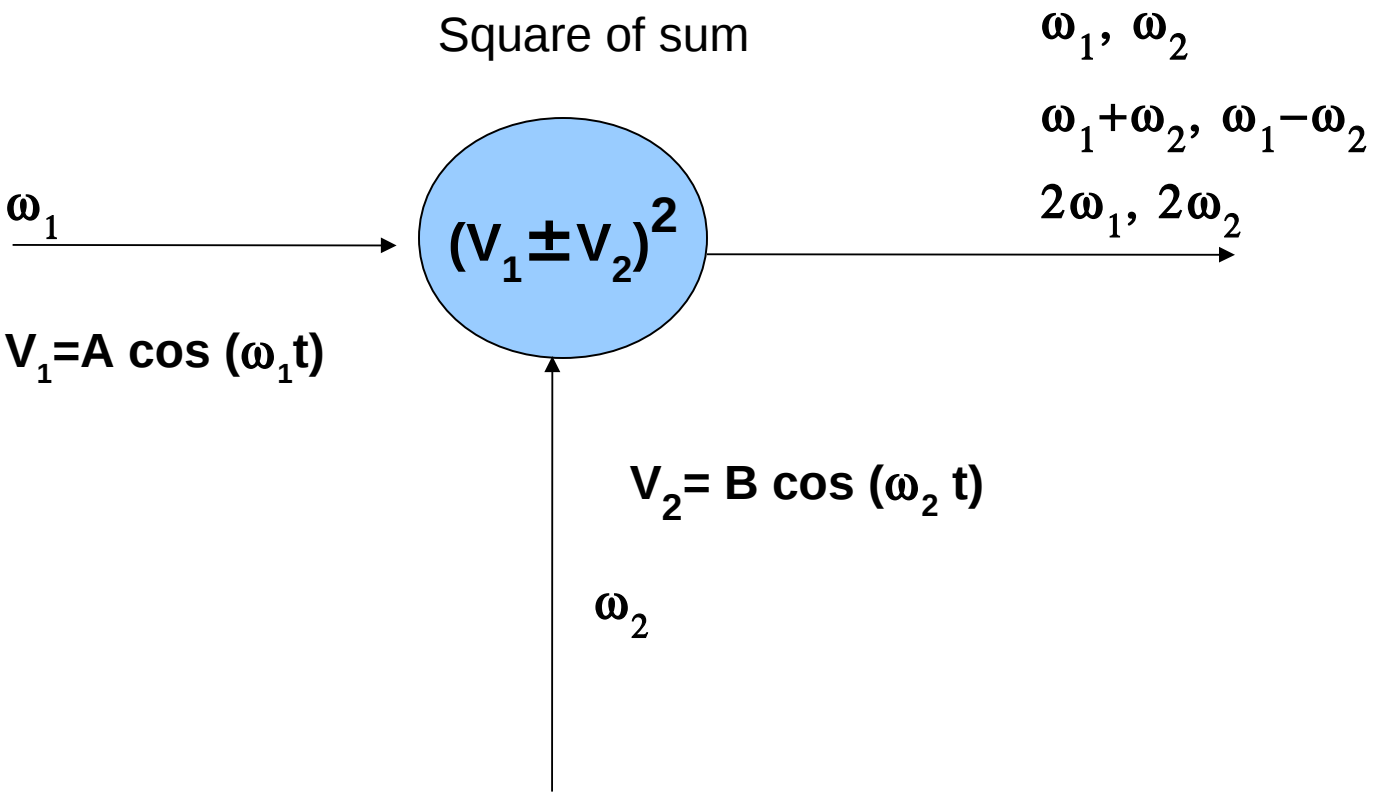
Building Blocks: Voltage Controller Oscillators (VCO)

- **Local Oscillator (LO) needs to track original signal:**
  - **Same Frequency as incoming signal**
  - **Predetermined phase as incoming signal**

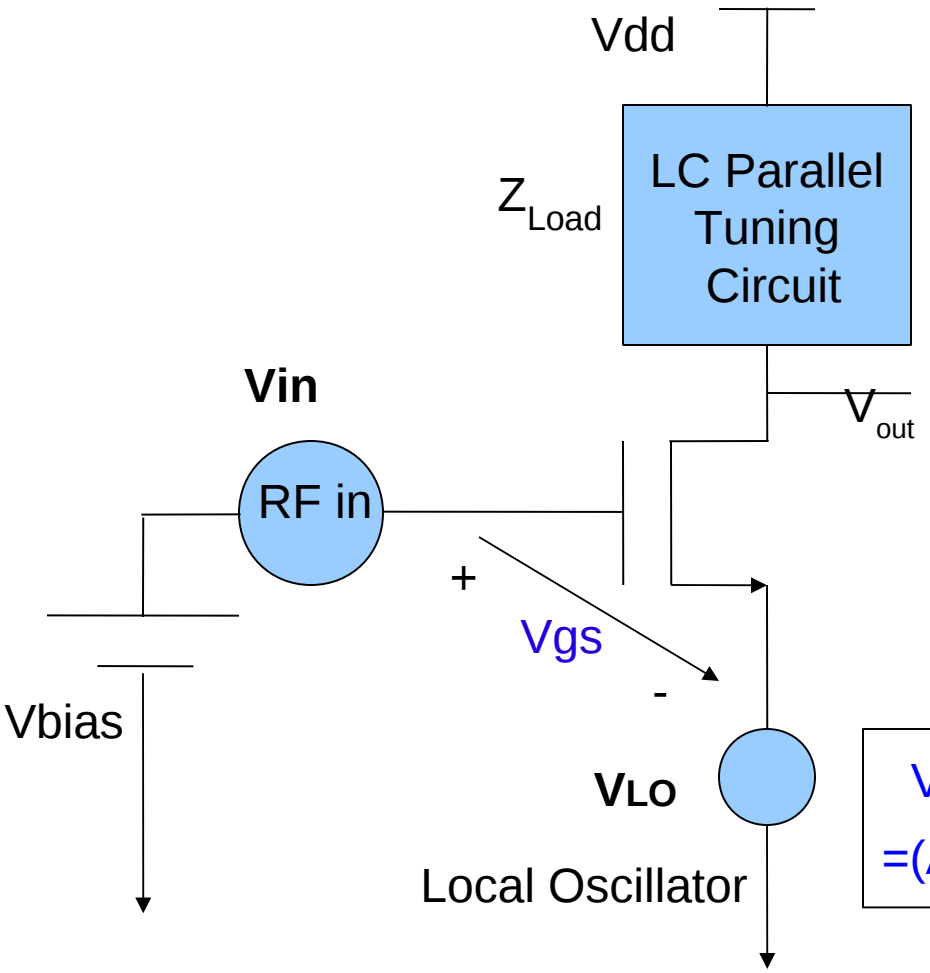
Ideal Case: Multiplier



Practical Case: Square Law Mixers



Transistor Implementation



In Saturation:

$$I_d = K1 (V_{gs} - V_t)^2$$

$$= K1 (V_{gs}^2 + V_t^2 - 2V_{gs} V_t)$$

$$V_{gs} = V_{in} - V_{LO} = A \cos \omega_1 t - B \cos \omega_2 t$$

ω_1, ω_2

$$V_{gs}^2 = V_{in}^2 + V_{LO}^2 - 2V_{in} V_{LO}$$

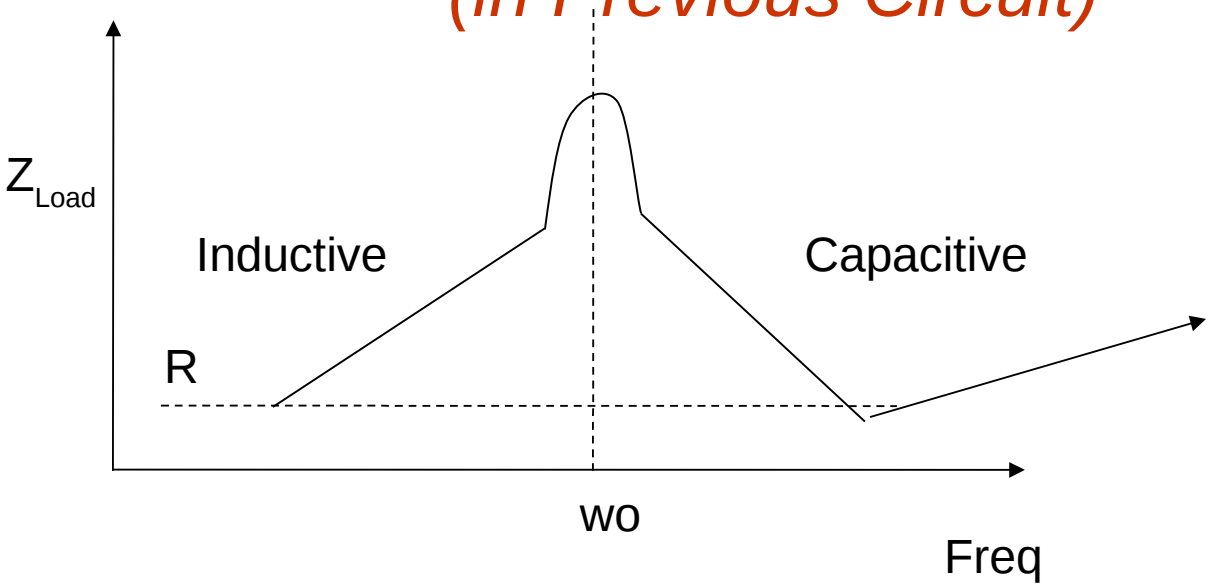
$V_{in}^2 = (A\cos\omega_1 t)^2$
$=(A2/2)(1+\cos 2\omega_1 t)$

$\omega_1 \pm \omega_2$

$V_{LO}^2 = (A\cos\omega_2 t)^2$
$=(B2/2)(1+\cos 2\omega_2 t)$

Using Parallel LC as Load (Z_{load})

(in Previous Circuit)



Usually there is a parallel R
Which comes from R_{Load}
and transistor r_{out}

Gain = $-g_m Z_{Load}$

$V_{out} = -i_d Z_{Load}$

Using a parallel LC tank as Z_{Load}:

Z_{Load} (ω) = maximum at: $\omega_o = \frac{1}{\sqrt{LC}}$

Use $\omega_o = \omega_1 \pm \omega_2$