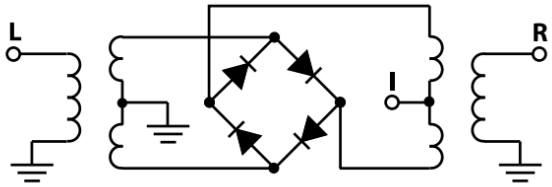
# Today's Agenda (Nov. 15)

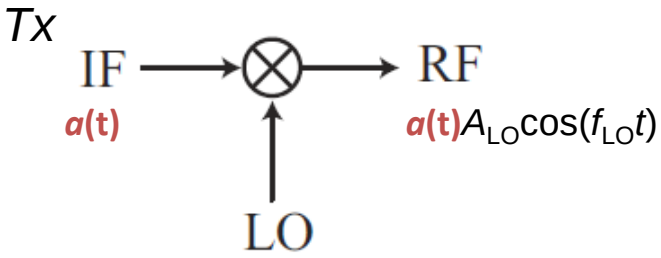
- Mixer Basics
- Mixer Performance Matrices
- IQ Mixer for Image Rejection
- IQ Mixer for SSB Tx


Electrical Schematic

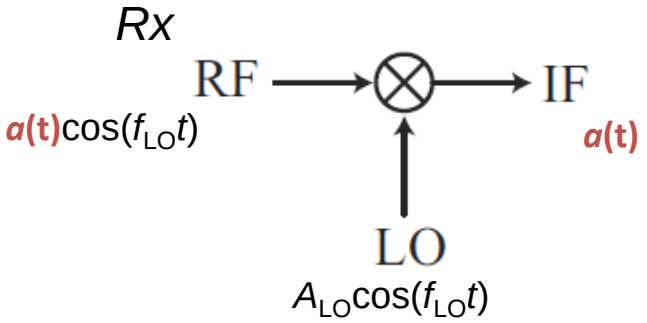


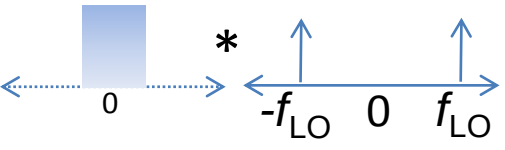

*No Discussion Session Next Week (Nov. 22)

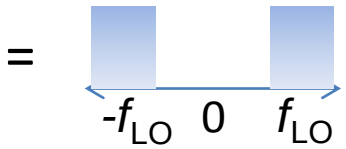
# Mixer/Rx Basics



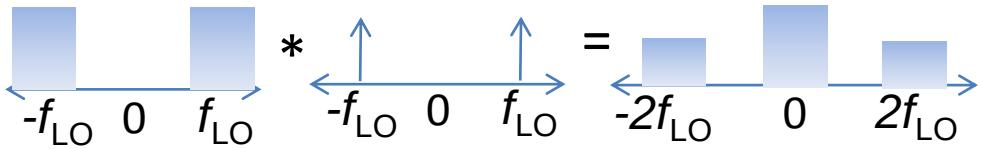

$A_{LO}\cos(f_{LO}t)$: LO magnitude usually fixed



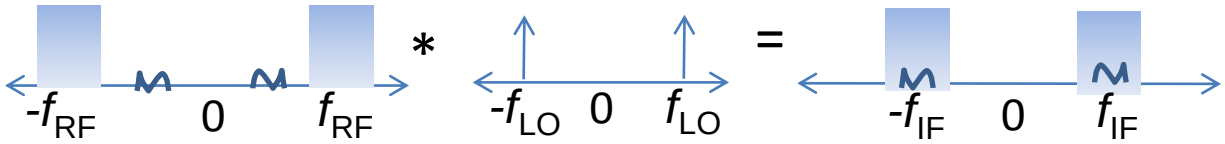




**Zero IF Rx**




**IF (super-heterodyne) Rx**




- Why not *a*(*t*) to *a*(*t*) directly?
- Why not using a high frequency ADC at Rx directly (e.g. 10 GS/s)?
- Why using super-heterodyne Rx?
- What are the disadvantages of super-heterodyne Rx?
- Is the double-side-band up-converter spectrum-efficient?
- What will happen if the LO and RF phases are not the same for a zero-IF Rx?

# Mixer Performance Matrices (1/2)

*Coaxial*

## Frequency Mixer

### ZX05-1MHW+

Level 13 (LO Power +13 dBm) 0.5 to 600 MHz

**Maximum Ratings**

| | |
|---|---|
| Operating Temperature | -40°C to 85°C |
| Storage Temperature | -55°C to 100°C |
| RF Power | 200mW |
| IF Current | 40mA |

Permanent damage may occur if any of these limits are exceeded.

**Coaxial Connections**

| | |
|---|---|
| LO | 1 |
| RF | 2 |
| IF | 3 |

**Features**

- rugged construction
- small size
- low conversion loss
- high L-R isolation
- protected by US Patents 6,133,525 & 6,790,049

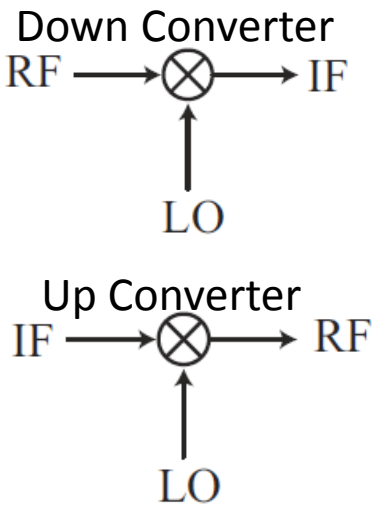
**Applications**

- cellular
- PCS
- instrumentation
- satellite communication

CASE STYLE: FL905

| Connectors | Model |
|---|---|
| SMA | ZX05-1MHW-S+ |

| Quantity | Unit Price |
|---|---|
| 1 - 4 | $39.95 |

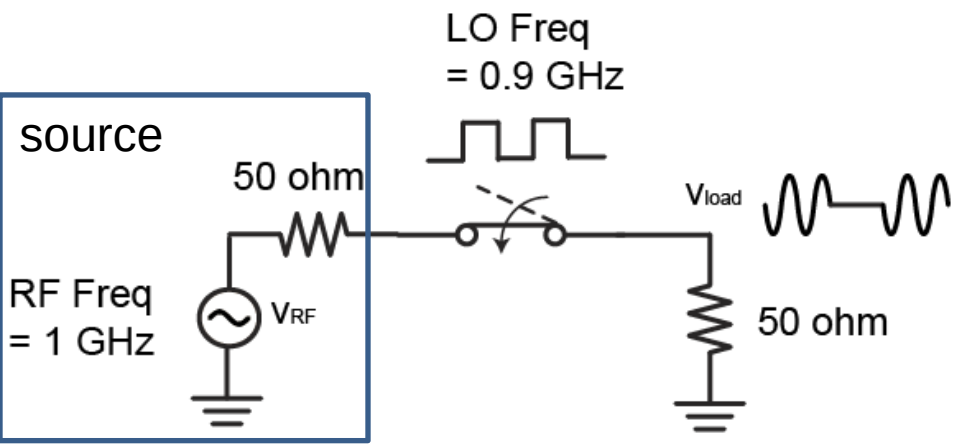



**Typical Performance Data**

| Frequency (MHz) | | Conversion Loss (dB) | Isolation L-R (dB) | Isolation L-I (dB) | VSWR RF Port (:1) | VSWR LO Port (:1) |
|---|---|---|---|---|---|---|
| RF | LO | LO +13dBm | LO +13dBm | LO +13dBm | LO +13dBm | LO +13dBm |
| 500.79 | 470.79 | 5.58 | 36.54 | 33.15 | 1.45 | 2.59 |
| 533.89 | 503.89 | 5.69 | 35.79 | 32.80 | 1.43 | 2.46 |
| 550.45 | 520.45 | 5.74 | 35.31 | 32.18 | 1.41 | 2.49 |
| 583.55 | 553.55 | 5.74 | 35.05 | 30.26 | 1.38 | 2.66 |
| 600.10 | 570.10 | 5.72 | 35.01 | 29.30 | 1.38 | 2.64 |

Why the above performance metrics are important ones?
RF-to-LO/IF leakage not important?

# Simple Mixer Analysis Example




0-1-0-1-0-1

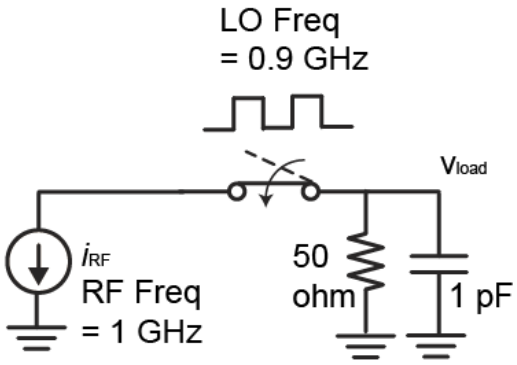
$$V_{load} = v_{RF}\cos(\omega_{RF}t)/2 \times LO(t)$$

$$LO(t) = 0.5 + (2/\pi)\cos(\omega_{LO}t) + (2/3\pi)\cos(3\omega_{LO}t)+\ldots$$

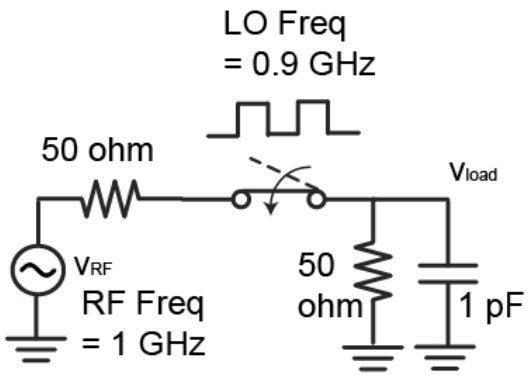
$$V_{load,IF} = v_{RF}\cos(\omega_{RF}t)/2 \times (2/\pi)\cos(\omega_{LO}t)$$

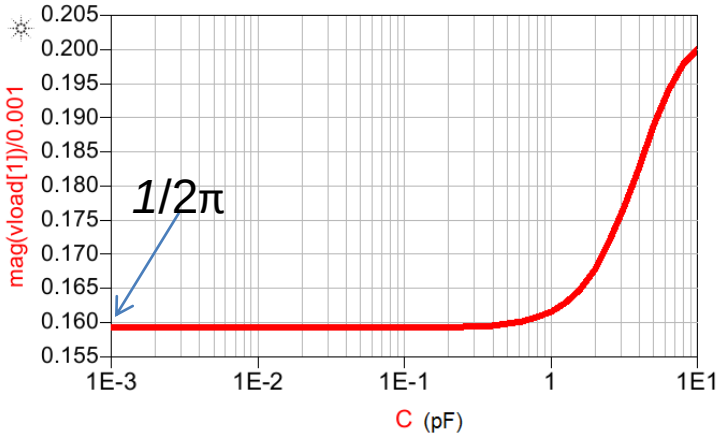
$$= (v_{RF}/2\pi) \times \cos(\omega_{IF}t)$$

## Easy Example



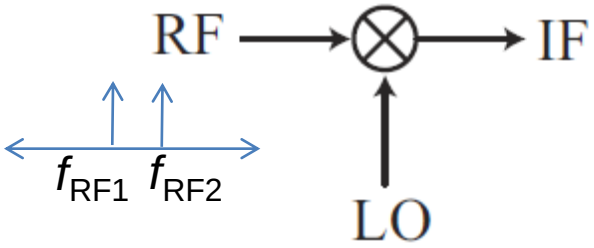

## Difficult Example

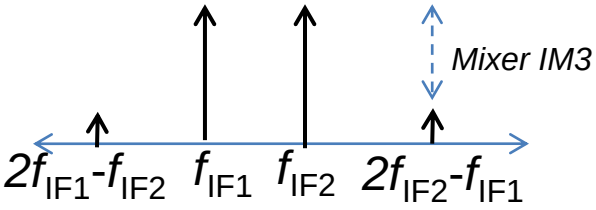


# Mixer Distortion Matrices (2/2)

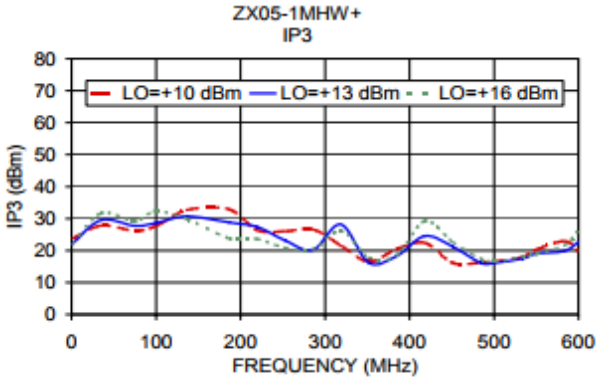
- **Mixer $IP_{1dB}$, IM3, and IIP3**



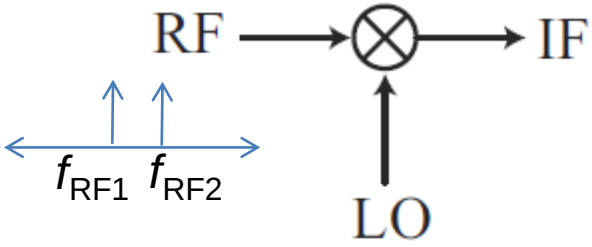



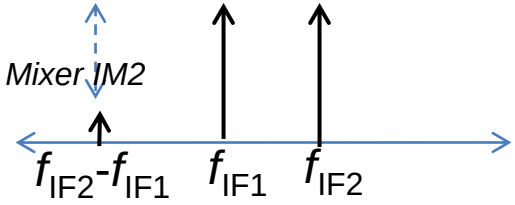

$f_{IF1} = f_{RF1} - f_{LO}$

$f_{IF2} = f_{RF2} - f_{LO}$




- **Mixer IM2 and IIP2**




super-heterodyne mixers can afford to have worse IM2/IIP2

# IQ Mixer for Image Rejection (1/3)

- Super-heterodyne mixers convert noise/blockers in image band to the IF
- Eg., Desired RF band at 1 GHz, LO at 0.99 GHz => Image band at 0.98 GHz
  Desired RF band at 0.99 GHz, LO at 1.0 GHz => Image band at 1.01 GHz

**IF (super-heterodyne) Rx**

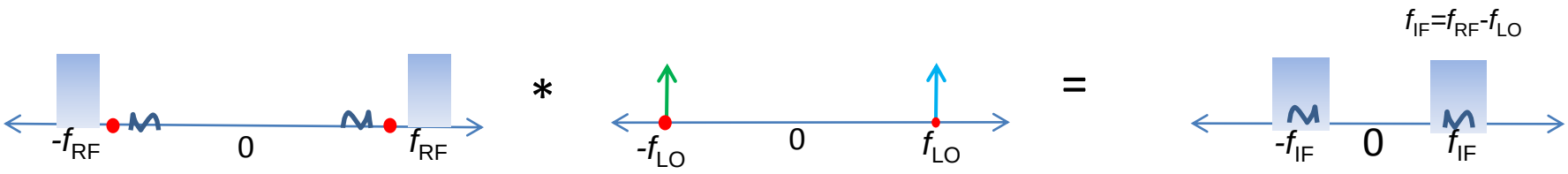
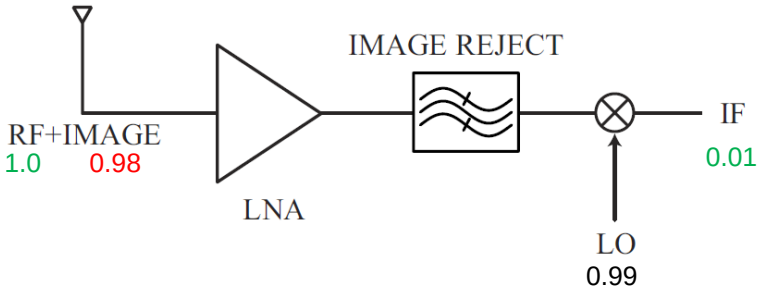
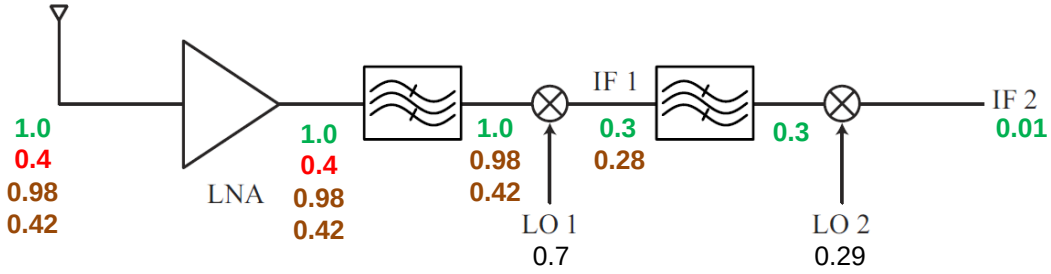


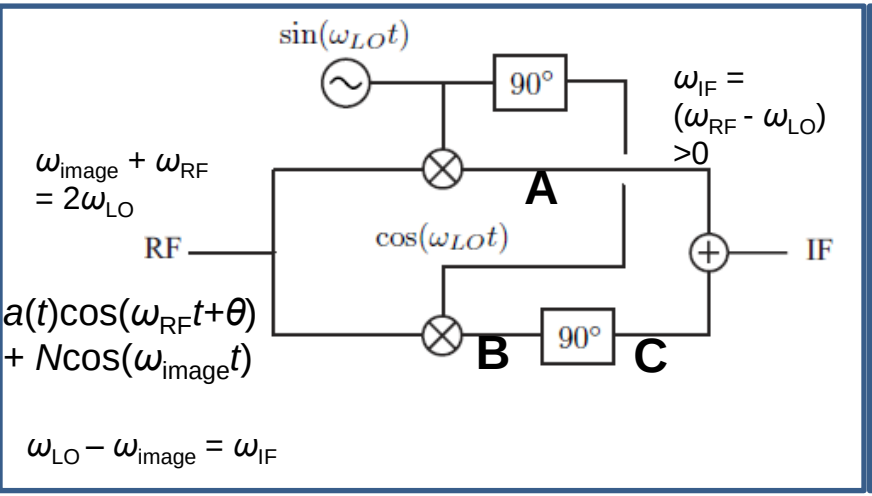

Image rejection with filter is not easy




What are the image frequencies for this 2-stage conversion?



# IQ Mixer for Image Rejection (2/3)




@A = $a(t)\cos(\omega_{RF}t)\sin(\omega_{LO}t)$ + $N\cos(\omega_{image}t)\sin(\omega_{LO}t)$

LPF=> $a(t)\sin(-\omega_{IF}t) + N\sin(\omega_{LO}t-\omega_{image}t)$

$= -a(t)\sin(\omega_{IF}t) + N\sin(\omega_{IF}t)$

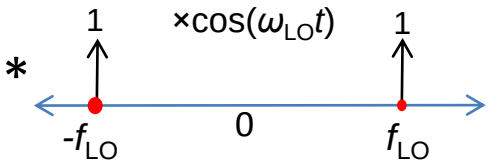
@B = $a(t)\cos(\omega_{RF}t)\cos(\omega_{LO}t)$ + $N\cos(\omega_{image}t)\cos(\omega_{LO}t)$

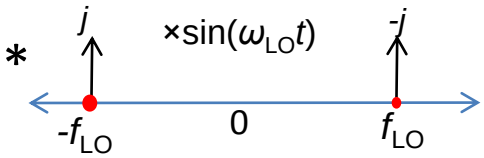
LPF=> $a(t)\cos(\omega_{IF}t) + N\cos(\omega_{IF}t)$

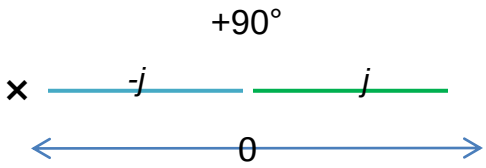
@C = $-a(t)\sin(\omega_{IF}t) - N\sin(\omega_{IF}t)$

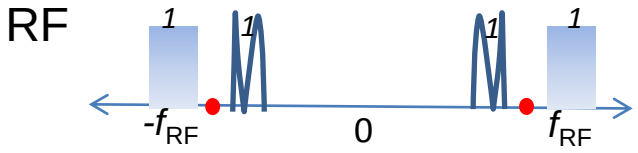
A + C = $-2a(t)\sin(\omega_{IF}t)$

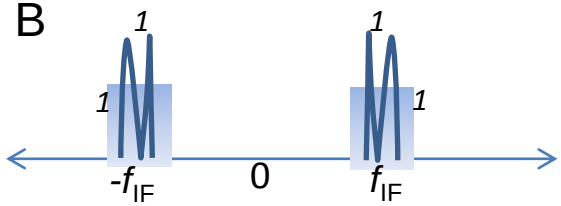
## Spectral representation

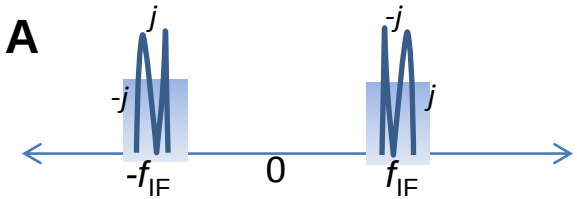


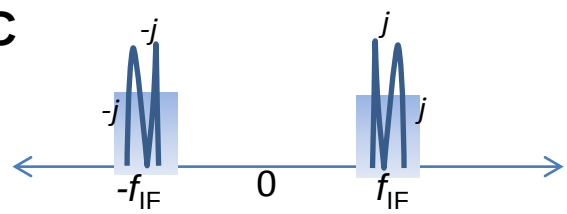



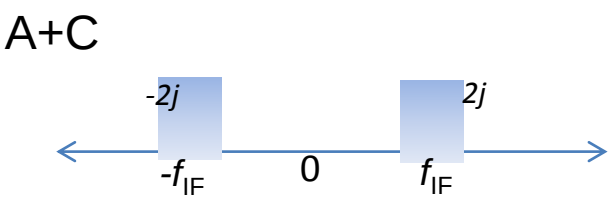



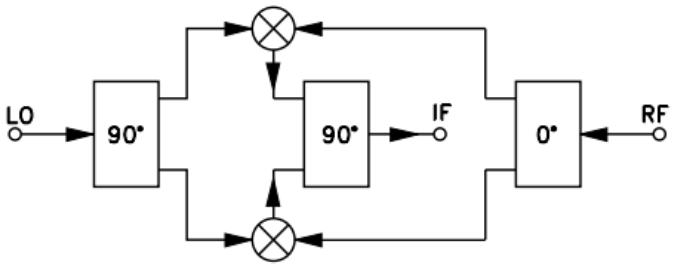
# IQ Mixer for Image Rejection (3/3)

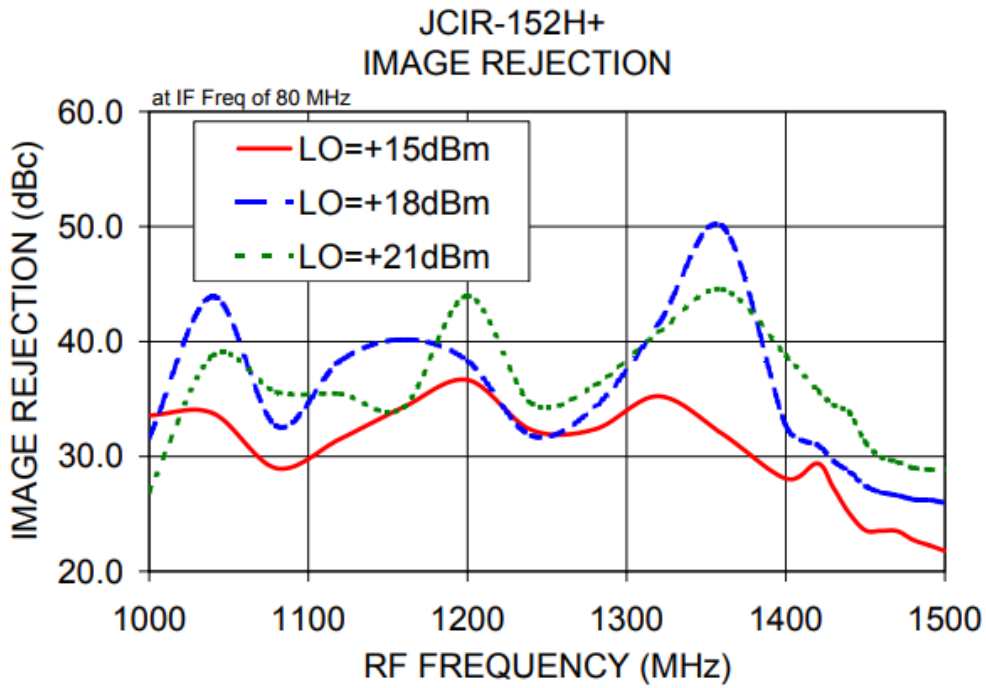
*Surface Mount*

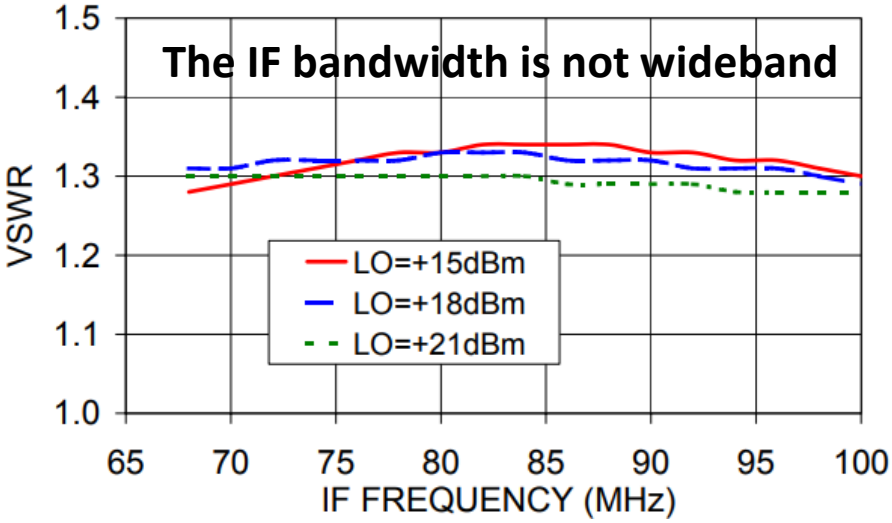
## Image Reject Mixer

Level 18 (LO Power +18dBm) 1000 to 1500 MHz

**Electrical Schematic**

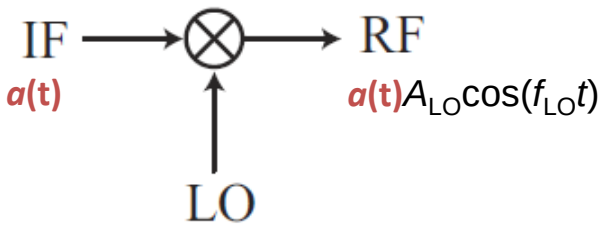


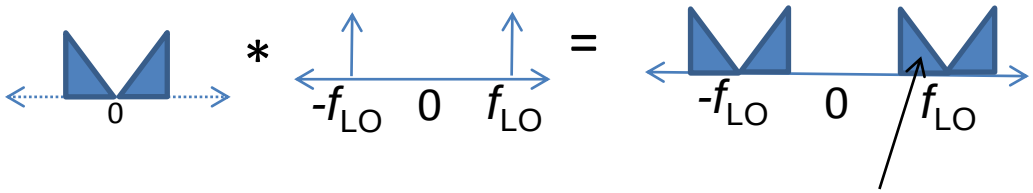



# IQ Mixer for SSB Tx

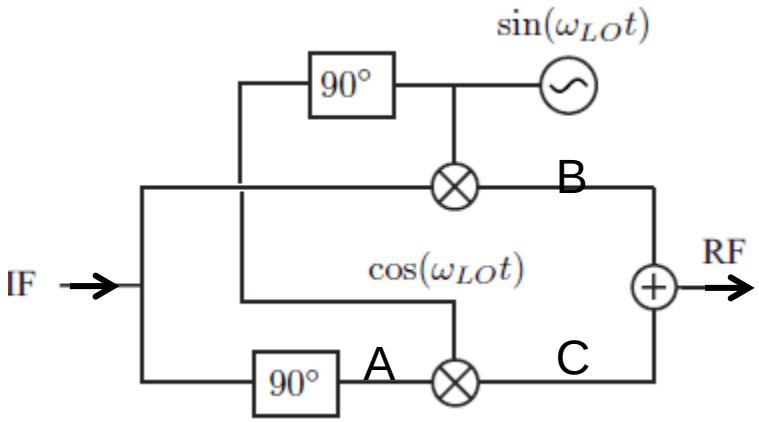
*Tx*




$A_{LO}\cos(f_{LO}t)$: LO magnitude usually fixed




Precious bandwidth used to transmit redundant signal




- Swap IF and RF port in an IR mixer
- 90° phase shift for the IF or baseband signal usually achieved by DSP