19/03/2021

Image Frequency (f_{im})

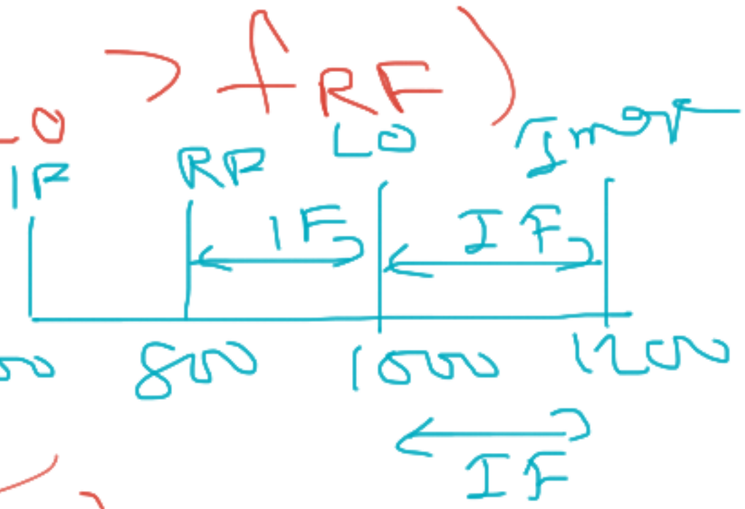
→ It is any frequency, other than desired RF carrier, if it enters into system (RX) & mix with LO frequency, will create an intermediate frequency (which is equal to desired IF) ↳ but it is not desired IF

High Side injection ($f_{LO} > f_{RF}$)

$\Rightarrow f_{LO} = f_{RF} + f_{IF}$

(in mixer) X

f_{RF} → LPF → f_{IF}



1000 = 800 + 200

X

800

$(f_{RF} + f_{LO})$

$= 1000 - 800$

$f_{IF} = 200 \; (= f_{LO} - f_{RF})$

desired

If a freq (1200) is

$f = f_{LO} + f_{IF}$

$f = 1000 + 200 = 1200$

i.e., $f = (f_{RF} + f_{IF}) + f_{IF}$

$= (800 + 200) + 200 = 1200$

Image freq

i.e., $f = f_{RF} + 2f_{IF}$

$= 800 + 2(200) = 1200$

manages to enter into system

then

$f \times f_{LO}$

↓ LPF

f_{IF} (not desired IF)

1200 × 1000

↓ LPF (2200)

200 = IF

→ not desired IF because it can come from adjacent RF (1200)

Low side Injection ($f_{LO} < f_{RF}$)

ie, $f_{LO} = f_{RF} - f_{IF}$

$600 = 800 - 200$

f_{RF} → LPF → f_{IF} → 200 (because it is from desired RF) — desired IF

Image freq

$f = f_{LO} - f_{IF}$ $\quad f = 600 - 200 = 400$

ie, $f = (f_{RF} - f_{IF}) - f_{IF} = (800 - 200) - 200 = 400$

ie, $f = f_{RF} - 2f_{IF}$ $\quad 400 = 800 - 2(200)$

mixer to enter the signal then

$f \times f_{LO}$

↓ LPF

f_{IF} (not desired IF)

400 × 600

↓ LPF

~~1000~~

200 → not desired IF

Summary

1) High side injection ($f_{LO} > f_{RF}$)
ie, $f_{LO} = f_{RF} - f_{IF}$

Image $f = f_{LO} + f_{IF}$

or $f = f_{RF} + 2f_{IF}$

2) Low side injection ($f_{LO} < f_{RF}$)
ie, $f_{LO} = f_{RF} - f_{IF}$

Image $f = f_{LO} - f_{IF}$

or $f = f_{RF} - 2f_{IF}$

Image is separated from RF by 2IF

Example: AM broadcast system

RF = 600 kHz (AM channel)

LO = 1055 kHz

Image freq ?

Solution: Here, LO > RF

(High side injection)

$f_{IF} = f_{LO} - f_{RF} = 1055 - 600 = 455$ kHz

$f_{image} = f_{RF} + 2f_{IF} = 600 + 2(455)$

$= f_{LO} + f_{IF} = 1055 + 455$

$= 1510$ kHz

AM: 535 — 1605 kHz

Image is there in AM band

IFRR (Image Frequency Rejection Ratio)

↳ numerical measure of ability of pre-selector (filter) to reject image freq.

Mathematically,

$$IFRR = \sqrt{1 + Q^2 \rho^2}$$

where $\rho = \frac{f_{im}}{f_{RF}} - \frac{f_{RF}}{f_{im}}$

Q = Quality factor of filter

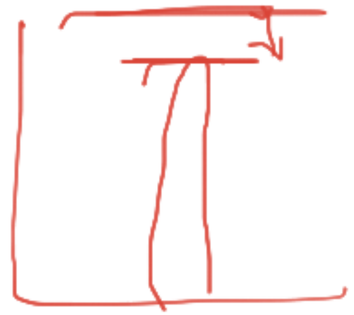
$$IFRR_{(dB)} = 10\log(IFRR)$$

Previous example of AM Radio

Let filter Q = 100

$Q = \frac{f_0}{\Delta f}$

bandwidth



$$\rho = \frac{f_{im}}{f_{RF}} - \frac{f_{RF}}{f_{im}}$$

$$= \frac{1510}{485} - \frac{455}{1510} = 2.51 - 0.397$$

$$= 2.113$$

$$IFRR = \sqrt{1 - Q^2\rho^2} = \sqrt{1 - (100)^2 (2.113)^2}$$

$$= 212$$

$$\Rightarrow IFRR_{(dB)} = 10\log(212) = 25\ dB$$

FM Radio (88 — 108 MHz) → RF

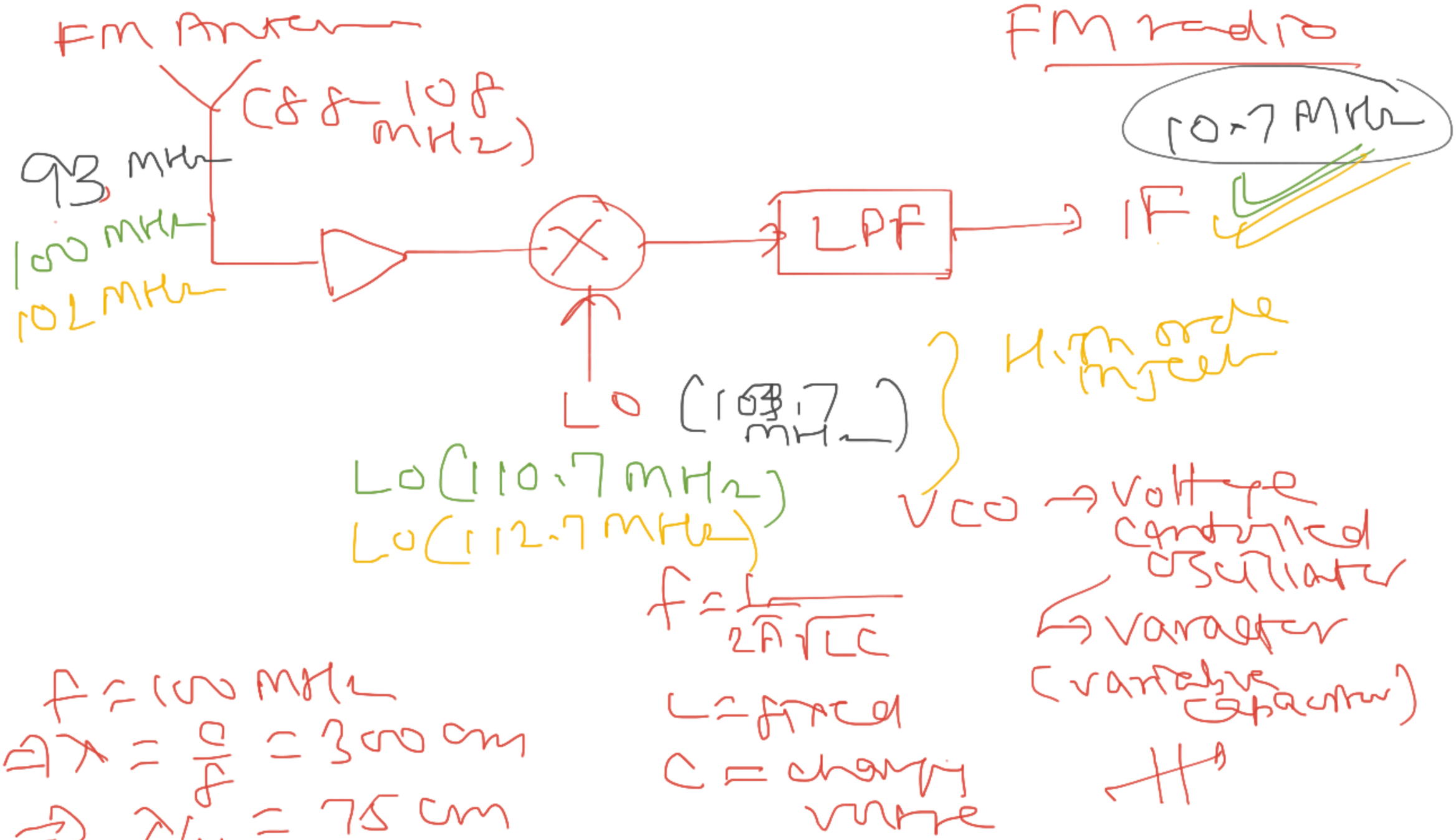
$$f_{IF} > \frac{BRF}{2}$$

BRF = 108 − 88 = 20 MHz

ie, $f_{IF} > \frac{20}{2}$, ie, $f_{IF} > 10$ MHz

Then IF = 10.7 MHz

- Hartley architecture
- Weaver architecture


FM Antenna
FM radio
(88-108 MHz)
93 MHz
100 MHz
102 MHz
10.7 MHz
LPF
IF
LO (10.7 MHz)
LO(110.7 MHz)
LO(112.7 MHz)
Hi-Side Injection
VCO → Voltage controlled Oscillator
→ Varactor (variable capacitor)
f = 100 MHz
⇒ λ = c/f = 300 cm
⇒ λ/4 = 75 cm
f = 1 / 2π√LC
L = fixed
C = changing value

Standard IFs (off-shelf components)

AM → 455 kHz

FM → 10.7 MHz

TV RXs = 46 MHz

Radar / communication / satellite / Defence = 70 MHz

Ex-1 2.4 GHz ISM band

↳ bluetooth

or

RF 2.4 GHz ⟶ IF = 70 MHz

= 2400 MHz

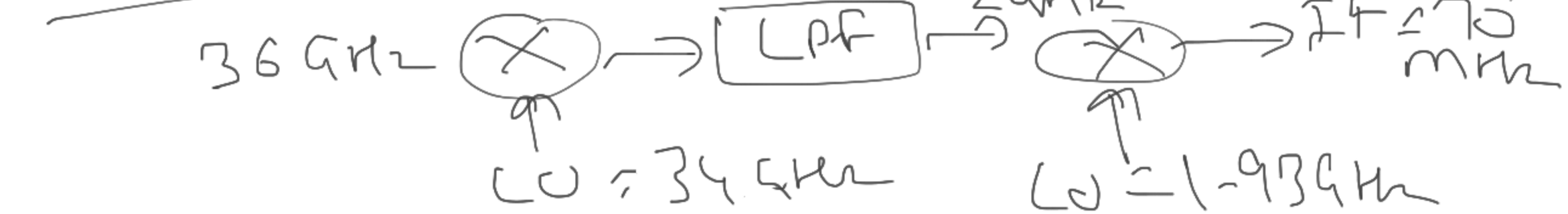
choose LO = 2930 MHz

or

2470 MHz

LPF ⟶ 70 MHz

Ex-2 RF = 36 GHz ⟶



Conclusion

Image is separated from RF by 2IF (twice of IF)