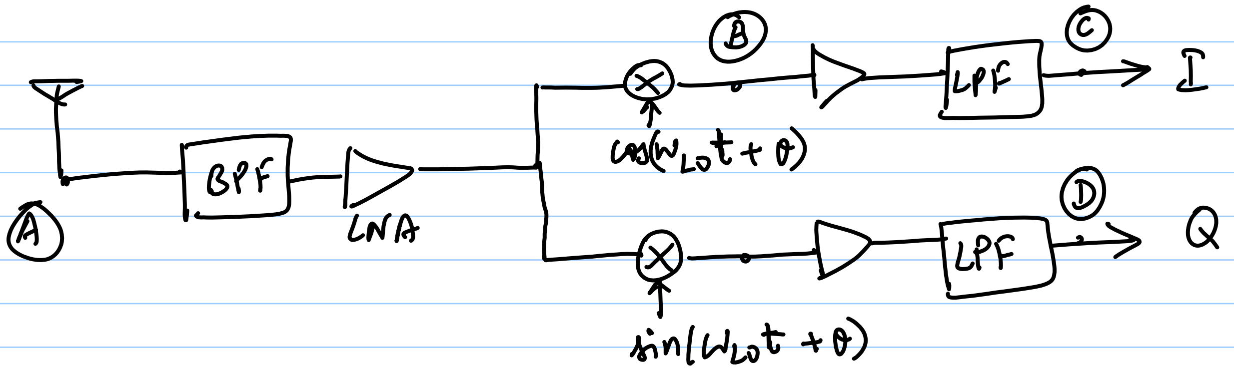
Lecture 25: Rx Architectures – I

I Direct-conversion / Homodyne / Zero-IF Rx



@ (A) : $x(t) = a(t)\cos(\omega_{LO}t + \varphi(t))$

@ (B) : $x(t)\cos(\omega_{LO}t + \theta) = \frac{1}{2}a(t)\left\{\cos(\varphi(t) + \theta) + \cos(2\omega_{LO}t + \varphi(t) + \theta)\right\}$

assume $\theta = 0$ (for now)

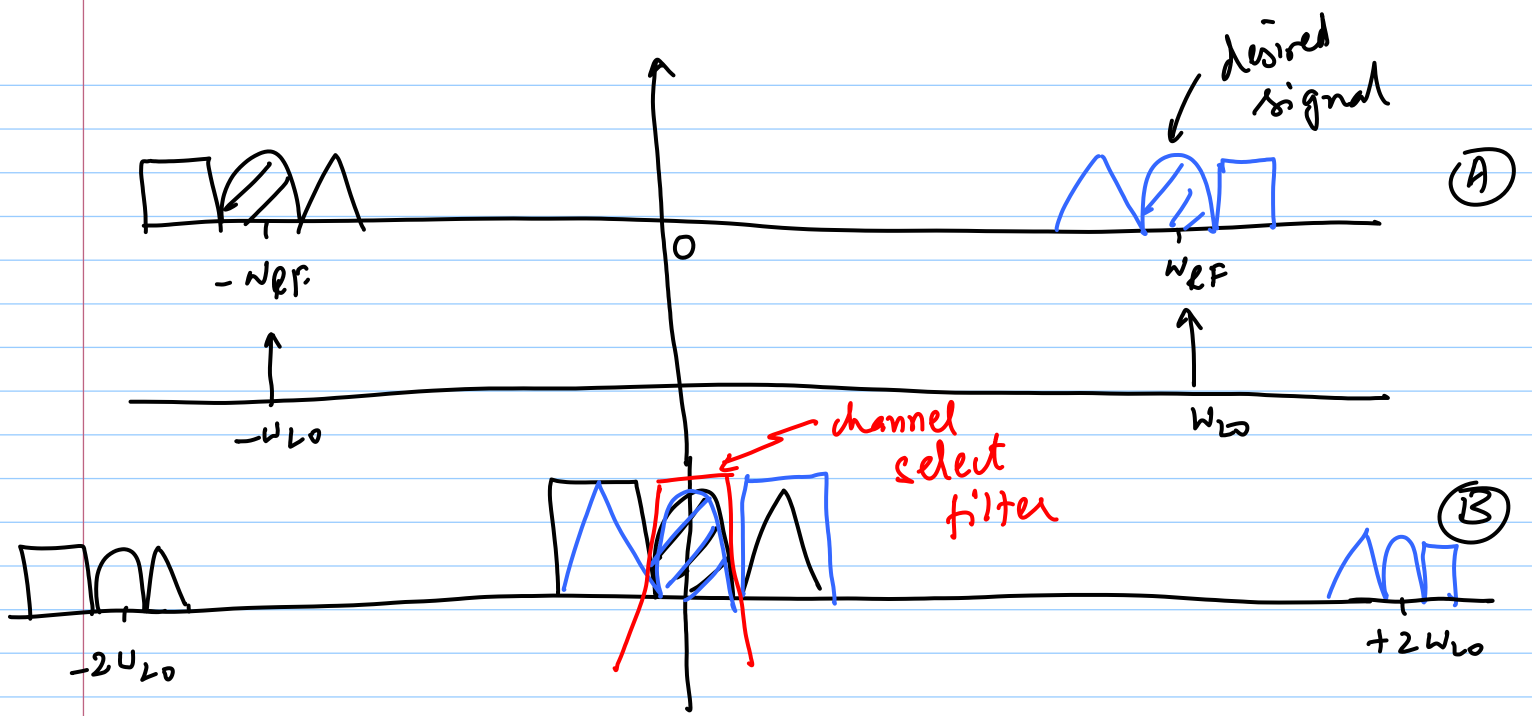
@ (C) : $\frac{1}{2}a(t)\cos(\varphi(t))$

@ (D) : $-\frac{1}{2}a(t)\sin(\varphi(t))$

Demodulation algorithm : $\sqrt{C^2 + D^2} = \frac{1}{2}a(t)$ ← AM component

four quadrant $\tan^{-1}$ } $-\text{atan2}\left(\frac{D}{C}\right) = \varphi(t)$ ← PM component

* channel selection applied @ C & D
* can digitise @ (C), (D) and use a digital C.S.F.



* Why do we need both I & Q?

(i) $x_I(t)$ & $x_Q(t)$ can be independently modulated

(ii) LO is usually not synchronized to RF (phase)

i.e. $\theta \neq 0$

e.g. consider AM {i.e. $Q(t)=0$}

$x(t) = a(t)\cos\omega_{LO}t$

Ⓒ : $\frac{1}{2}a(t)\cos\theta$ ← $=0$ for $\theta=90^\circ$

Ⓓ : $\frac{1}{2}a(t)\sin\theta$ ← $=0$ for $\theta=90^\circ$

→ if we had only I/Q channel, Rx output could be 0

→ with I & Q channels, we always have non-zero outputs @ Ⓒ and/or Ⓓ

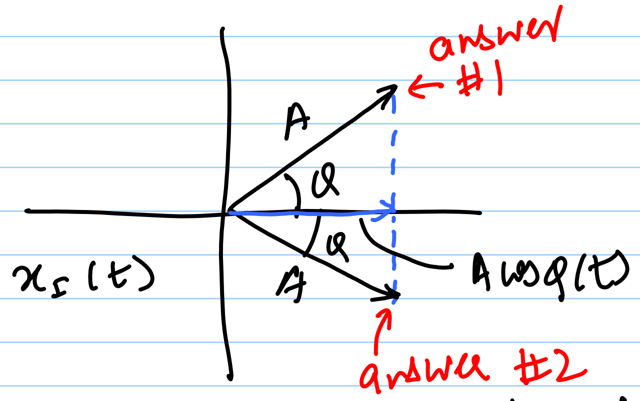
(iii) consider PM or FM

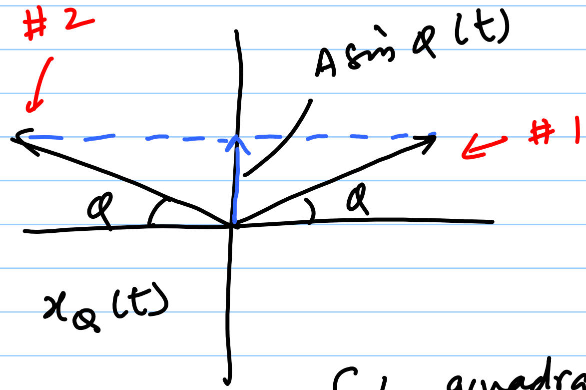
$$x(t) = A\cos(\omega_{LO}t + \varphi(t))$$

$$\Rightarrow x_I(t) = A\cos\varphi(t)$$

$$x_Q(t) = A\sin\varphi(t)$$

$\Rightarrow$ can't recover $\varphi(t)$ from $x_I(t)$ alone or $x_Q(t)$ alone





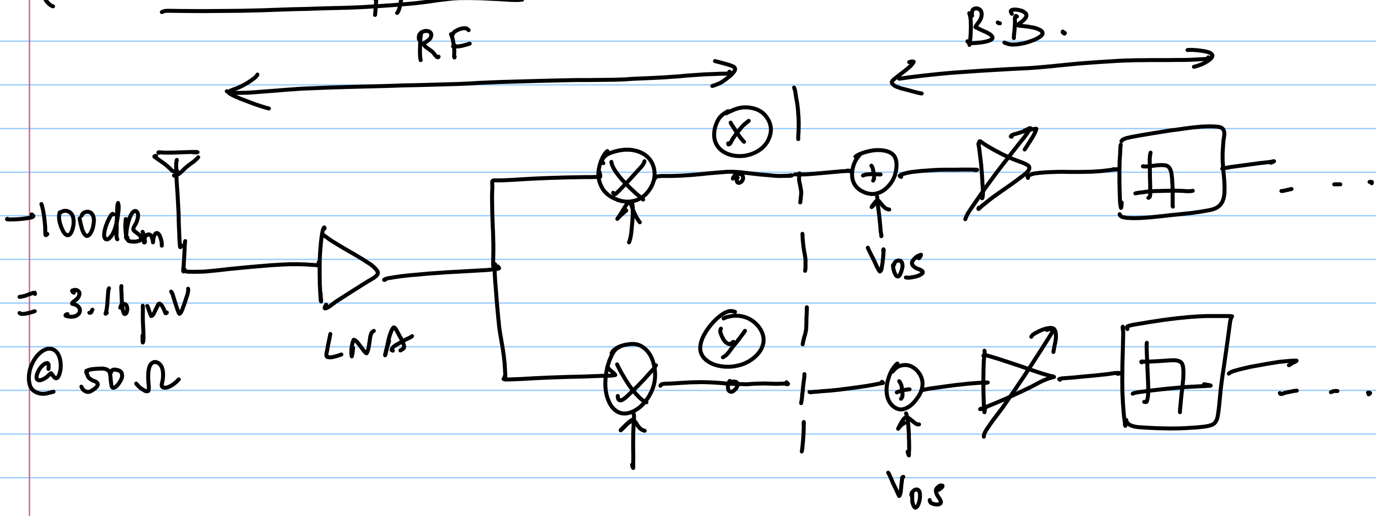
x_I & x_Q $\Rightarrow$ can determine unique $\varphi(t)$ [4-quadrant $\tan^{-1}$]

<u>Advantages</u>

* Simple architecture
* No image problem ($\omega_{IF} = 0$)
* Highly integrable - no off-chip filters except for Band-select filter
* No IR filter $\Rightarrow$ LNA need not drive $50\,\Omega$
* Easy prefiltering $\rightarrow$ only @ DC & $2\omega_{LO}$
* only 1 PLL required for frequency synthesis

Disadvantages

(i) D.C. offsets



Typically: RF Gain ~ 30dB

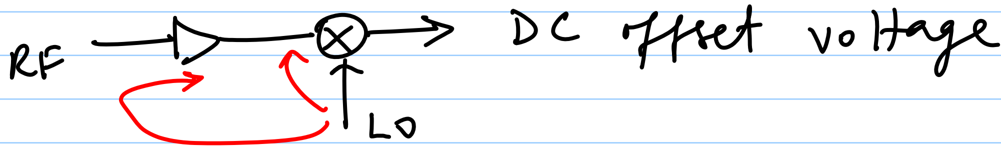
BB gain ~ 70dB

signal @ X, Y ~ 100μV

Vos (input referred offset of BB) ~ 10mV !

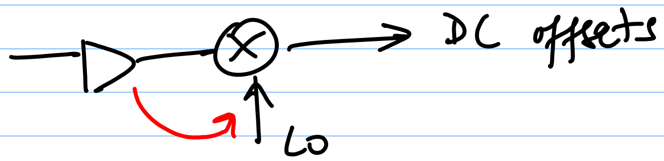
→ DC offset can saturate succeeding stages (i.e. desensitisation)

(ii) LO self-mixing (LO leakage)



→ can be time varying due to path variations (e.g. LO Leakage radiated from antenna & then reflected back to Rx)

(iii) Interferer leakage



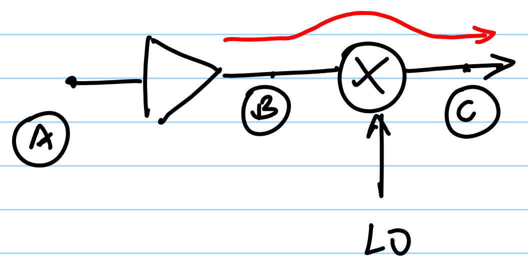
(iv) <u>1/f noise</u> of mixer & BB ckts

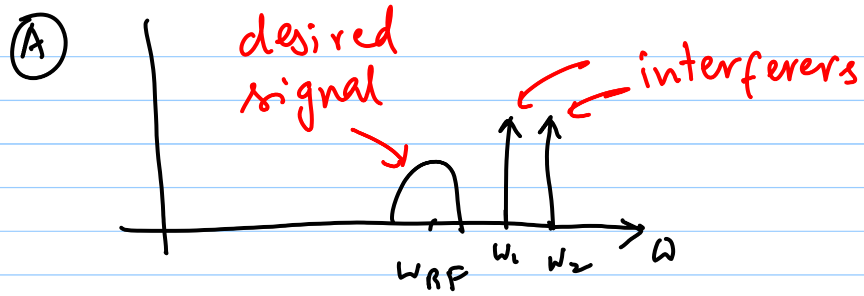
→ same effect as time-varying DC offsets

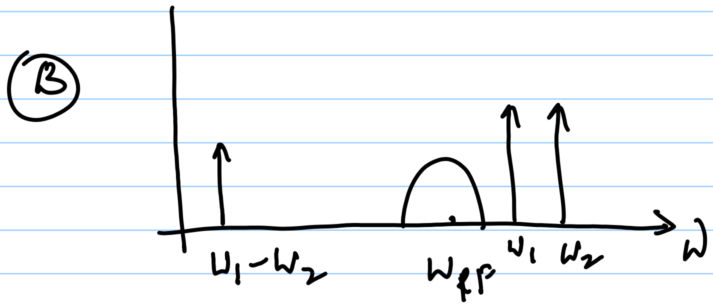
(v) <u>LO pulling</u>

If RF signal is large, RF-to-LO leakage can cause "LO pulling" {e.g. RF modulation transferred to LO}

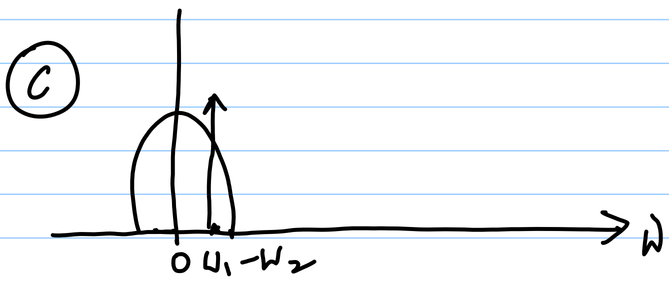
(vi) <u>Even order distortion</u>







* LNA produces even order distortion components (IM_2)

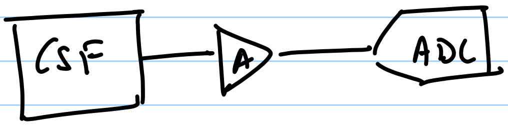


* RF-to-IF feedthrough corrupts down-converted signal

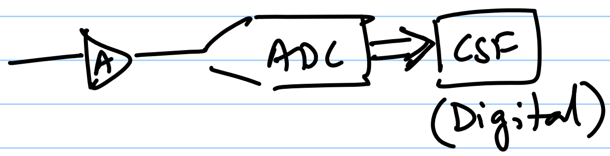
* even-order distortion in mixer RF port has same effect
* Linearity performance is specified by IIP_2 (similar to IIP_3)
* Differential ckts improve IIP_2
  → mismatch usually limits IIP_2
  → higher power dissipation

(vii) I-Q mismatch can degrade performance (less severe for heterodyne systems – freq. is much lower; lower # of stages after I/Q separation)

(viii) <u>Channel Selection</u>

(a) 

(b) 

(c) 

(a) ⇒ CSF has strict noise-linearity tradeoffs
A = non-linear, high gain; ADC = moderate DR

(b) ⇒ CSF noise relaxed; A = low noise, high linearity

(c) ⇒ ADC = high linearity + high DR
{digitises signal + blockers}

Solutions to issues

1) **D.C. offsets**

* High-pass filtering – ac coupling
  → corner freq. depends on signal spectrum
  {many signals have peak energy at and around DC}
  → Slow settling time (large caps)
  → fast variations in V_{os} are not tracked
* Encode Tx signal such that it contains little energy near DC – "DC-free coding"
* DC offset correction (calibration)

  → suitable for wideband signals {loss of a few kHz BW doesn't affect data rate}

2) **Flicker noise**

  1/f noise from devices:
  → worse in CMOS (compared to bipolar)
  → large mixer devices = more loading on VCO
* DC-free coding + HPF

3) **Linearity**

* Design LNA & mixer to have high IIP_2
* Differential structures (symmetry reduces IM_2 power)

4) <u>Gain</u>

* Most of gain occurs @ 1 freq.
  - → Avoiding parasitic feedback is critical (i.e. avoid stability issues)
  - → Good isolation is important