E190Ak S18 — Lec 22 - Intro to Linearity

spec. an. & mixer review

Intro to Linearity

spectrum analyzer review - what's up w/ mixer?

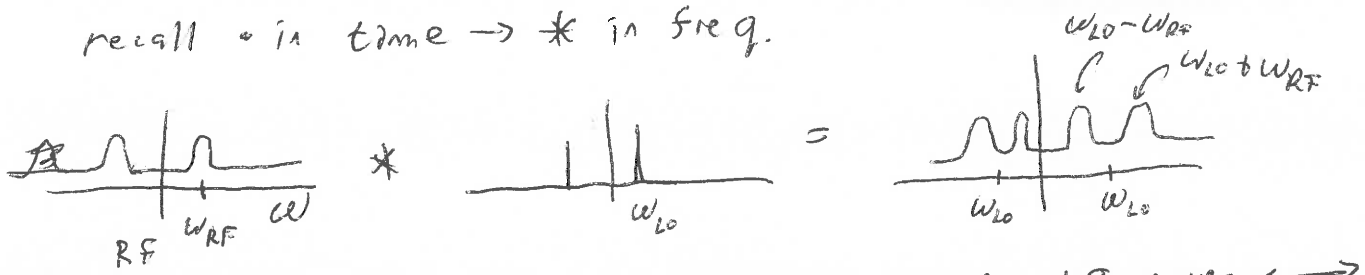
↳ last time $A_1 \cos(\omega_{RF} t) \cdot A_2 \cos(\omega_{LO} t) = \frac{1}{2} A_1 A_2 \left(\cos(\underbrace{(\omega_{RF} + \omega_{LO})}_{\text{image}} t) + \cos(\underbrace{(\omega_{RF} - \omega_{LO})}_{IF} t) \right)$

controlled by VCO

↳ Easy math & time, but signals often tricky / variable (eg: ω_{LO})

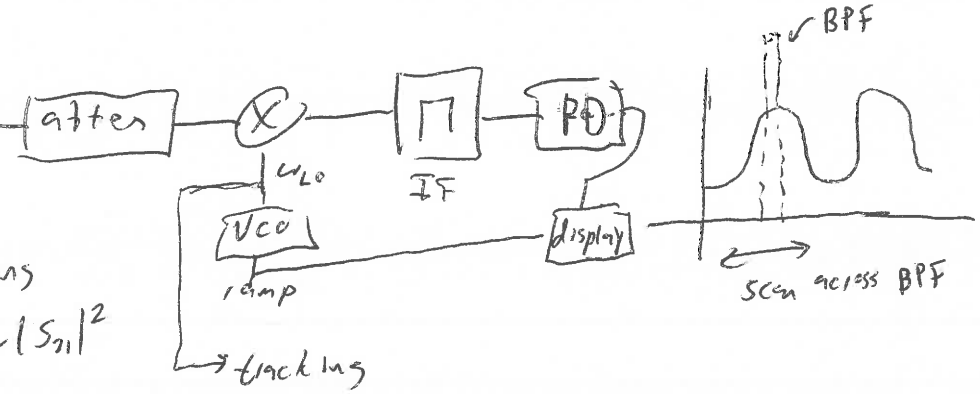
↳ want visual intuition

recall · in time → * in freq.



varying LO moves ↔

- In spec an: in → atten → X → IF → PD
  - move signal across IF



- Tracking is handy for making Bode plots... generates $\sim |S_{21}|^2$

Talking about noise & getting good models of noise voltage

- why? (other than I like it)
- minimum receivable signal → max range & data rate
  → Detection threshold ...etc.
- max receivable signal → min range → power handling
  → interference resistance

what components fail as amplitude gets big?

↳ attenuators No ~ resistors are linear

↳ antennas No ~ fields are really linear

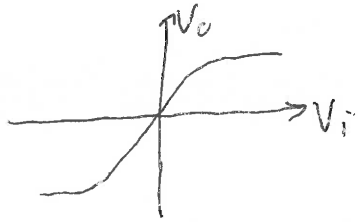
↳ mixers maybe ~ depends how they're built, but non-linear typically

↳ filters probably not ~ LC is linear

↳ power detectors yes - hit rails & saturate

↳ amplifiers yes - see power detectors ← use as our model non-linear element

Full amplifier model
- pretend it's linear, but really has saturating nonlinearity



$$V_o = f(V_i(t))$$

$$\approx a_0 + a_1 V_i(t) + a_2 V_i^2(t) + \cdots$$

Taylor expand
- Note even coeffs fall out for odd fn.

- If input signal is sinusoid $V_i(t) = V_I \cos(\omega t)$

$$\approx a_0 + a_1 (V_I \cos(\omega t)) + a_2 V_i^2 \cos^2(\omega t) + V_I^3 \cos^3(\omega t)$$

$$\cancel{\approx a_0 + a_1 (1 + \cos(2\omega t))}$$

2nd harmonic

$$\approx a_0 + a_1 V_I \cos(\omega t) + \frac{a_2 V_I^2}{2}(1 + \cos 2\omega t) + \cdots$$

DC op gain 2nd order non-linearity creates DC offset

$$\cdots \frac{a_3 V_I^3}{4}(\cos 3\omega t + 3\cos \omega t)$$

3rd harmonic

- In-band!
- affects gain
- "gain compression" if $a_3 < 0$

- measure quality of amplifier based on effect of these components

eg. P_{-1dB} is input power @ which 3rd order compression shrinks output by 1dB (IIP3, HD2, HD3, IM2, IM3 ...) THD