Ph 623 – 28 April 2020 ("Day 36")

- No HW
- FPGA II + III (or combo) due at Final exam
- Final Exam: 7:45 AM CDT Monday May 4th
  - Closed book
  - calculator and one 3x5 card (both sides)
  - $2^{\frac{1}{2}} + \frac{1}{2}^{h}$

Today

- Communication

Balanced Modulator
AM
FM
SSB
Heterodyne
Homodyne
Bi-Phase
NRZ
Class A, B, AB, C, D amplifiers

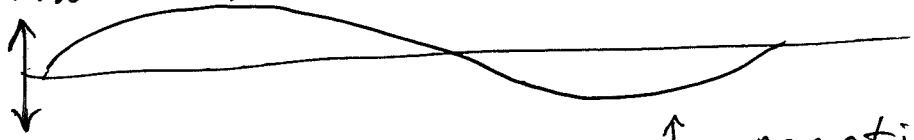
PWM
Error Correction
Modulation Factor

Modulation

AM

carrier (1 MHz)

V_{mod} ← positive side increases carrier amplitude



modulation (1 kHz)

↑ negative side decreases

Actually usually a mixture of frequencies and amplitudes (voice, music)

{ say, 50 Hz – 10 kHz
0 – A_{max} peak

positive

distortion – many frequency components not in original: "over-modulation"

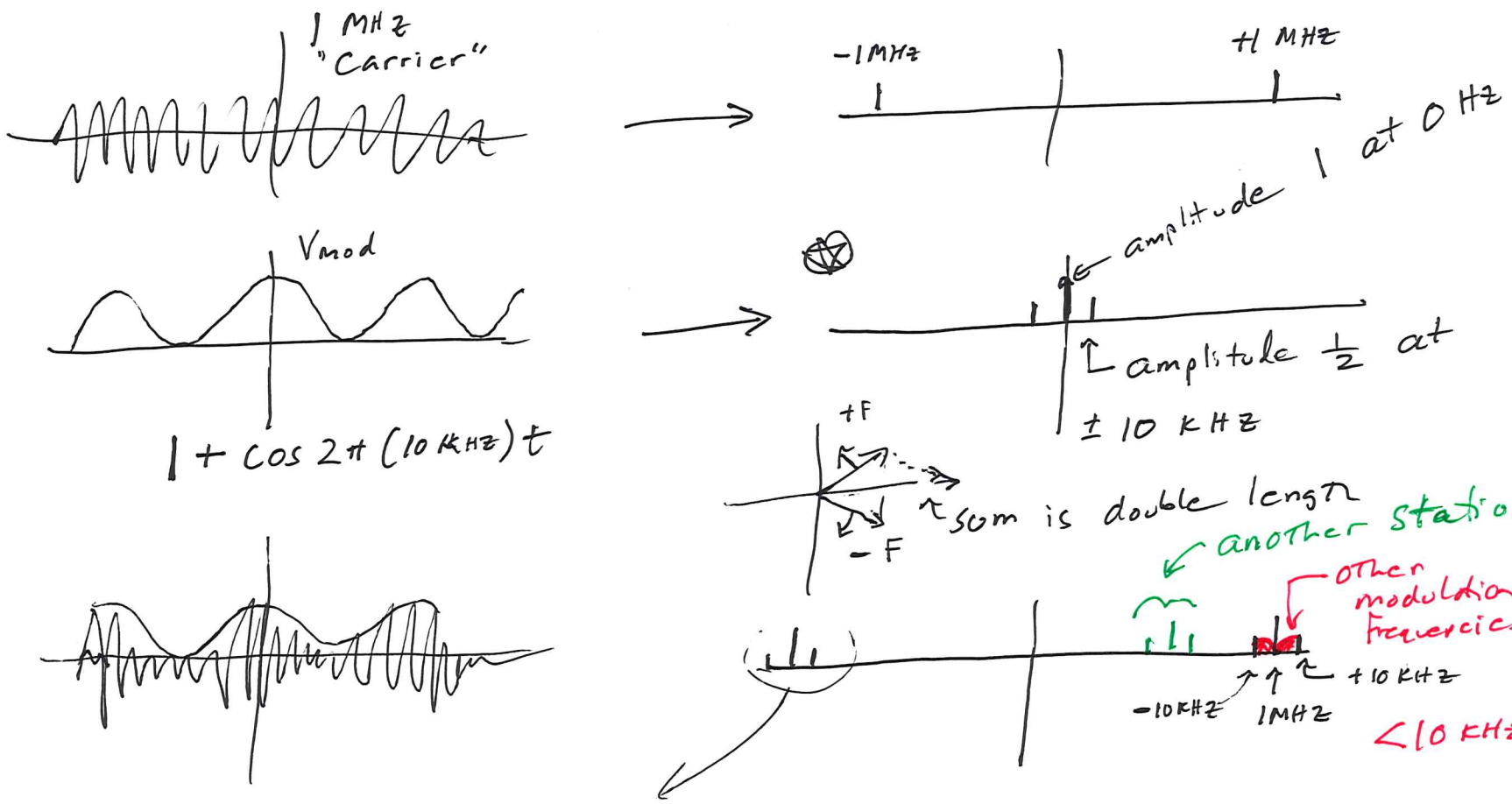
∴ need $(A_{max} + V_{mod}) \times$ carrier

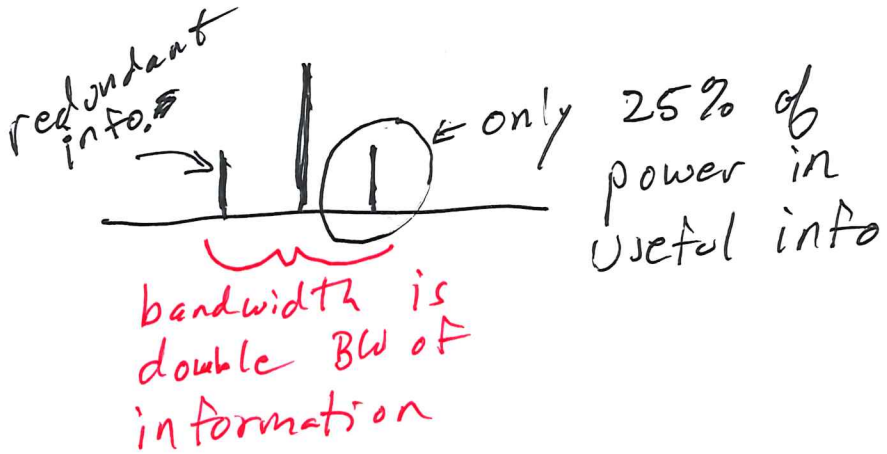
Suppose $A_{max} = 1$ Volt and we have $V_{mod} = 1$ v pk @ f_{max}

Say $f_{max} = 10$ kHz

What does transmitted signal look like?

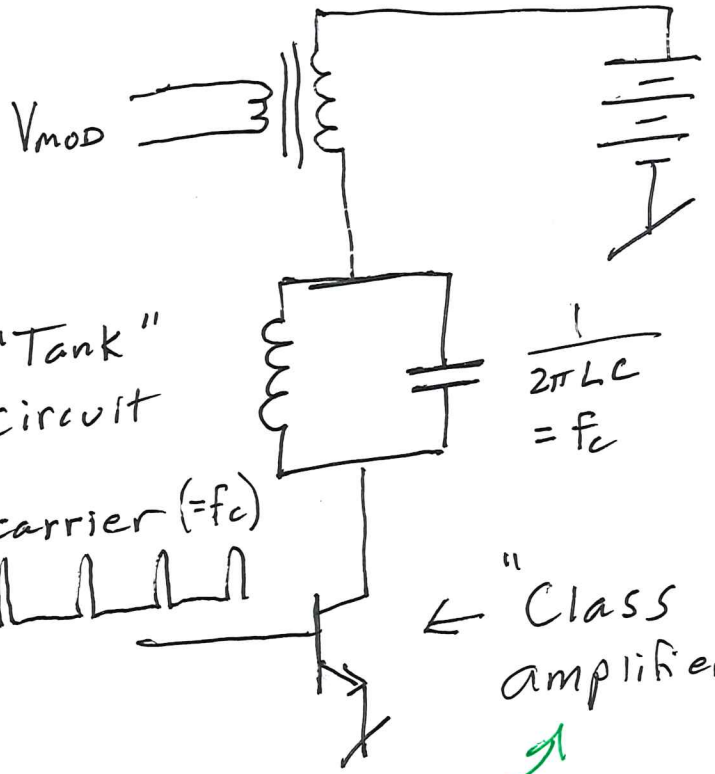
?

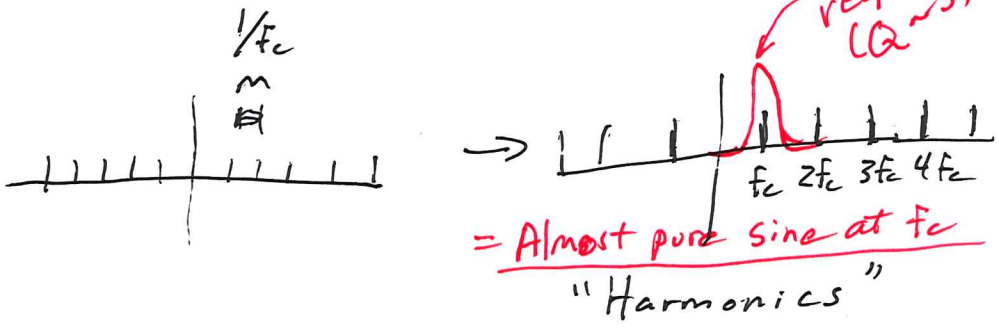




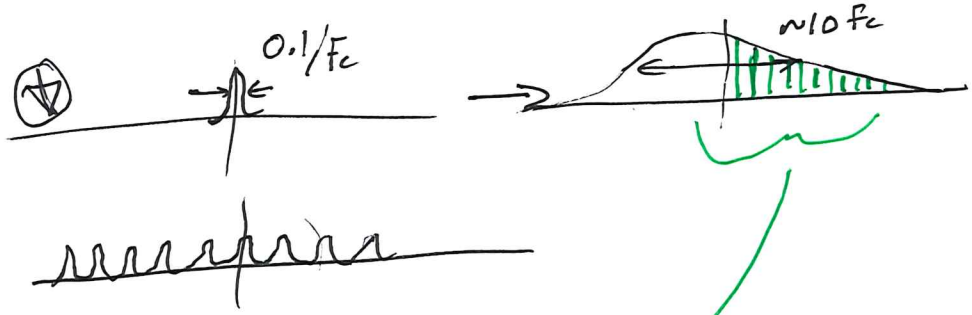
25% of power in useful info

Advantages: simple efficient*

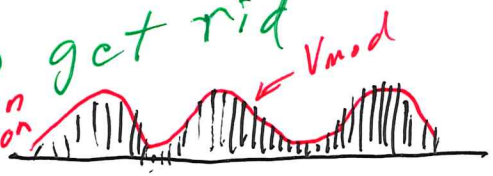


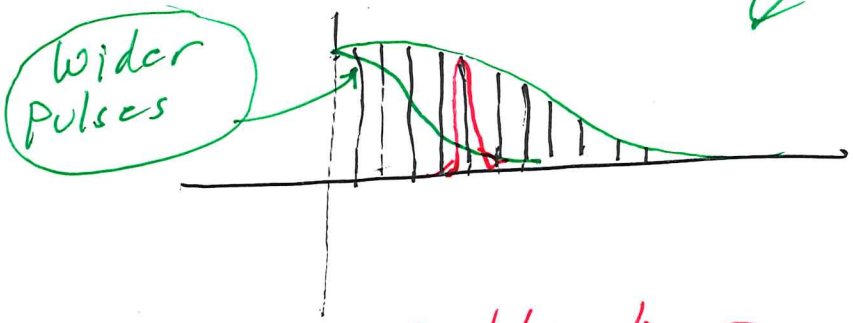


δ-Function was approximation



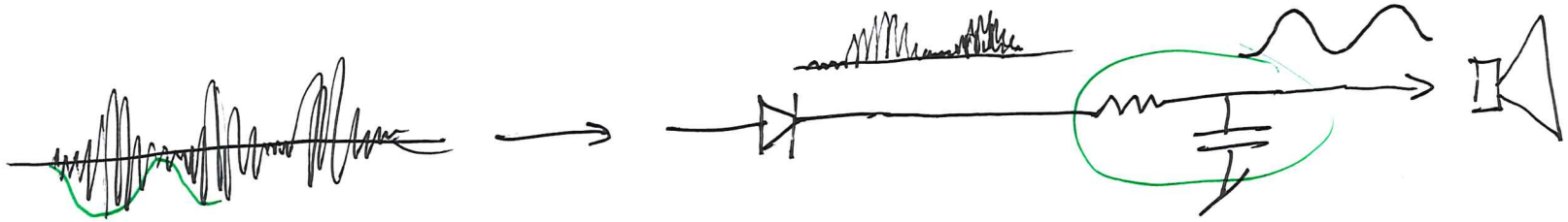
Very efficient use of output transistor - switch on or off - no power lost in switch - no heat to get rid of.





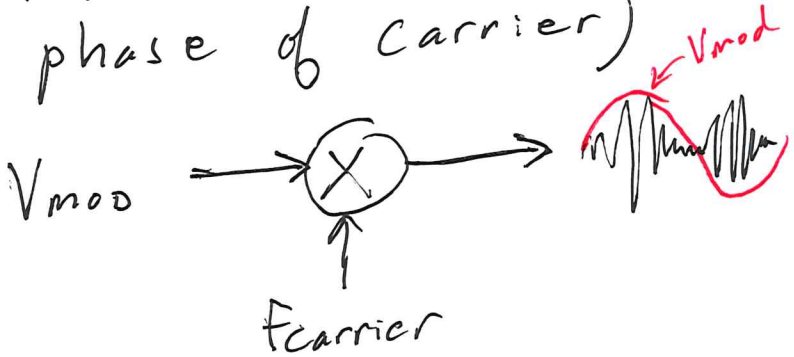
Frequency Multiplier - tune tank to 5 F_c (need higher Q to keep pure)

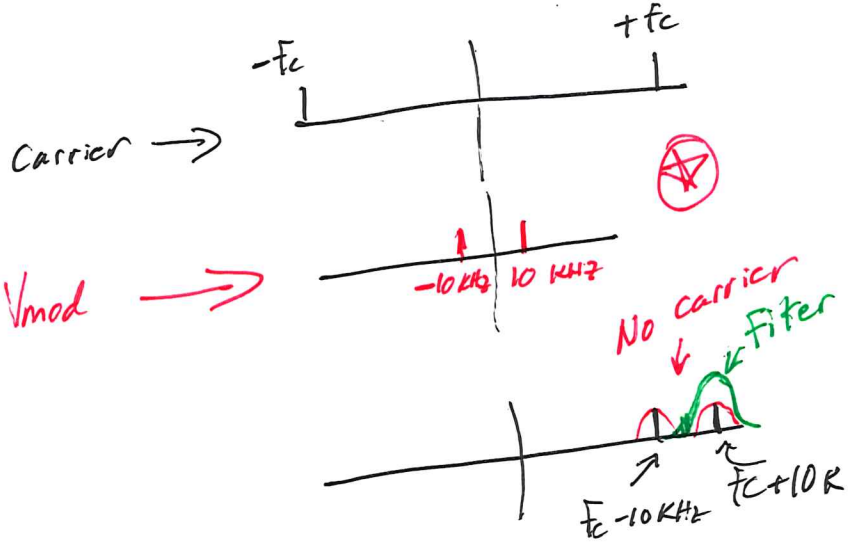
Demodulation also simple:



More Efficent: "Balanced Modulator"

≡ 4-quadrant multiplier: (negative V_{mod} reverses phase of carrier)





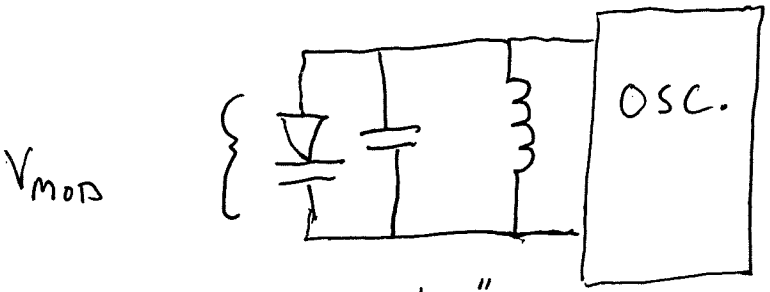
"Single Side Band"

- minimum use of spectrum → space
- All transmitted power is useful
- balanced modulator and filter at low level
  - need linear power amplifier after — inefficient
- Demodulation hard — need to supply carrier — Guess frequency?

FM

"Frequency Modulation

V_{MOD}



"Varactor Diode"

f_{max} = maximum frequency component of V_{MOD} (15 kHz for commercial FM)

Δf = maximum frequency deviation of carrier produced by $V_{MOD-MAX}$

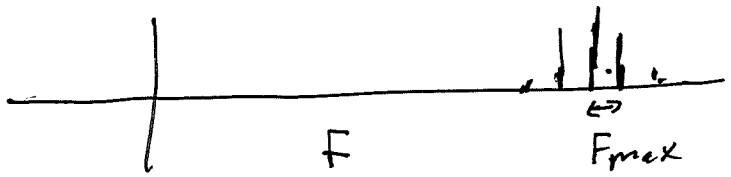
"modulation factor" $h \equiv \frac{\Delta f}{f_{max}}$

$h < 0.5$ "narrow-band FM"

$h >> 1$ "wide-band FM"

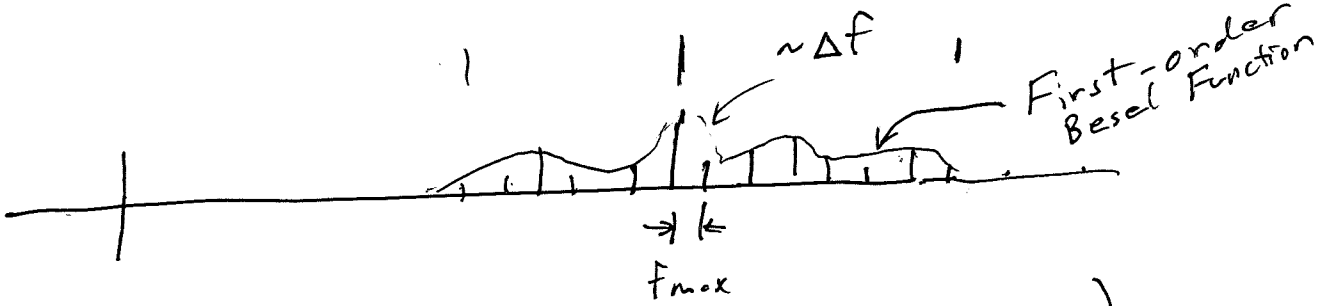
For Sine wave at F_{max}, V_{max}.

$h = .1$



~ Same as AM

$h = 10$

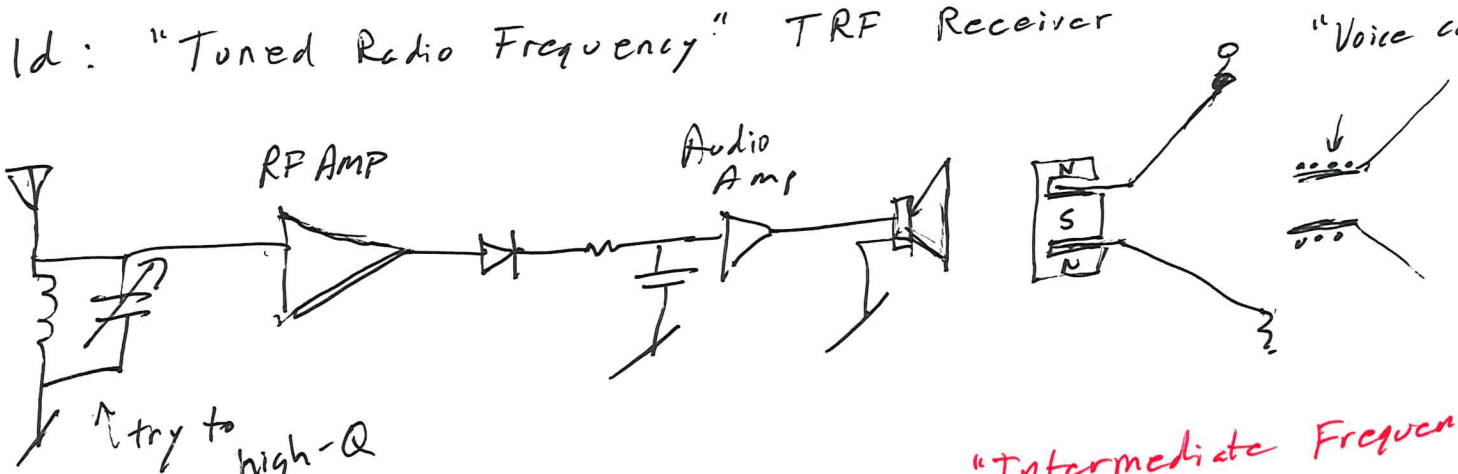


Total Bandwidth (ignoring sidebands < 1% of carrier)

$$\approx 2(F_{max} + \Delta f) = 2F_{max}(h+1)$$

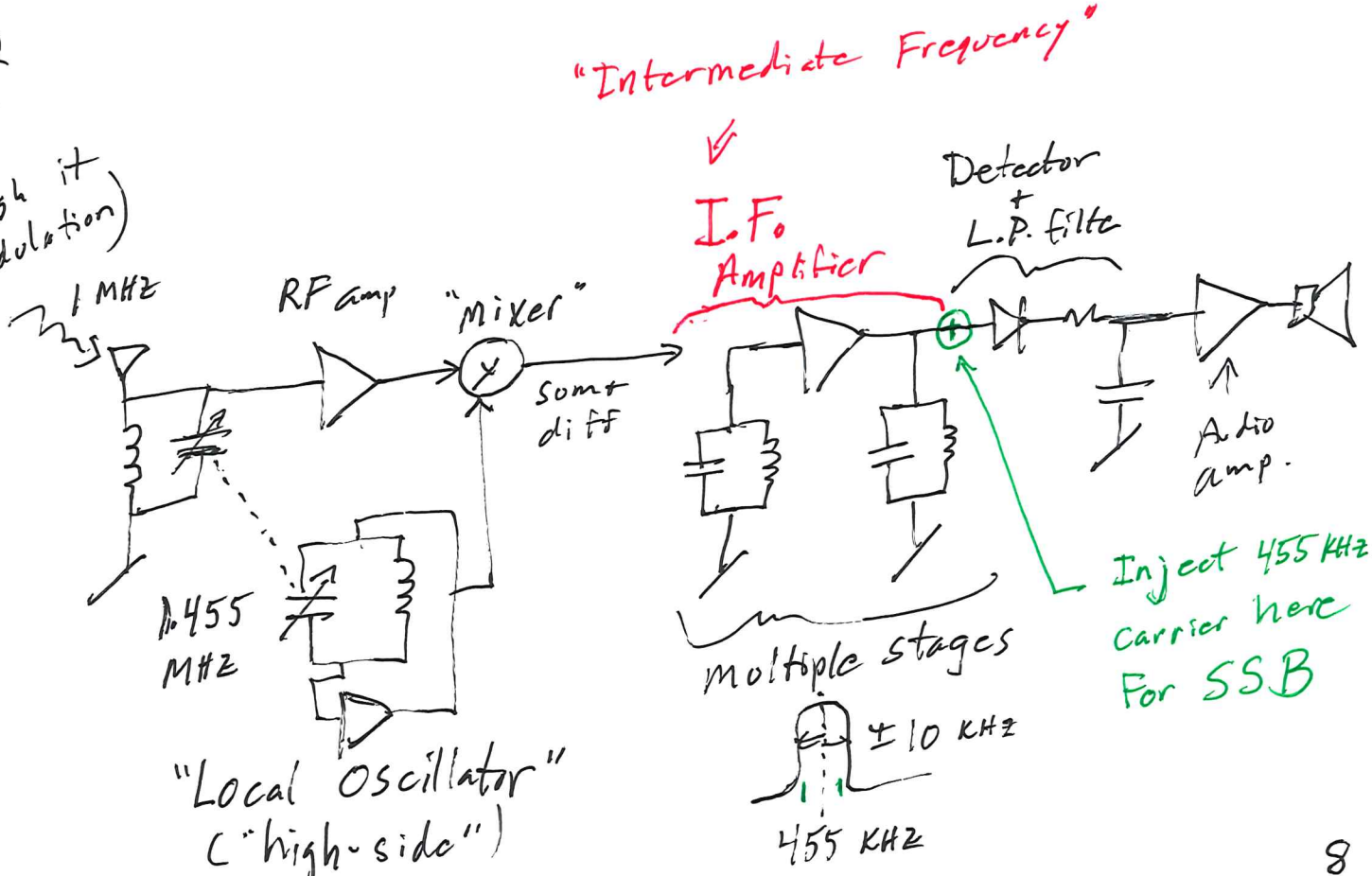
Heterodyne or "Superheterodyne" Receivers

Old: "Tuned Radio Frequency" TRF Receiver

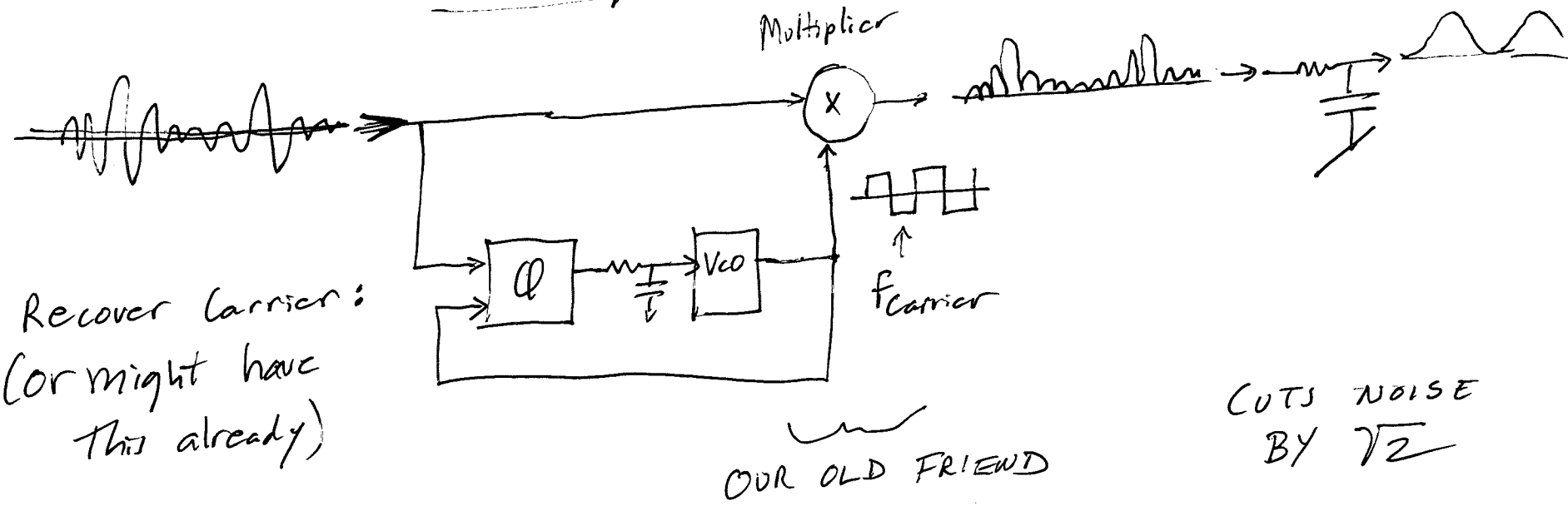


↑ try to make high-Q to separate stations (but not so high it cuts off modulation)

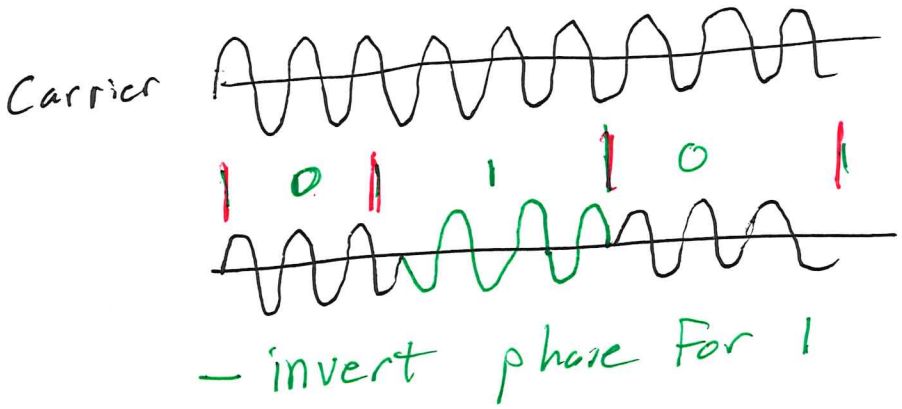
"Superhet"



Homodyne Detection



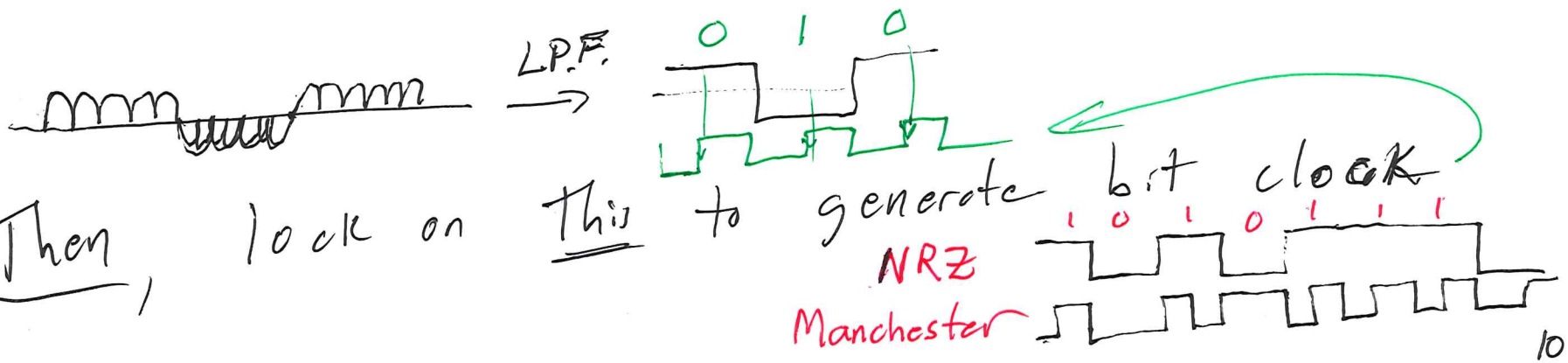
Bi-Phase Modulation

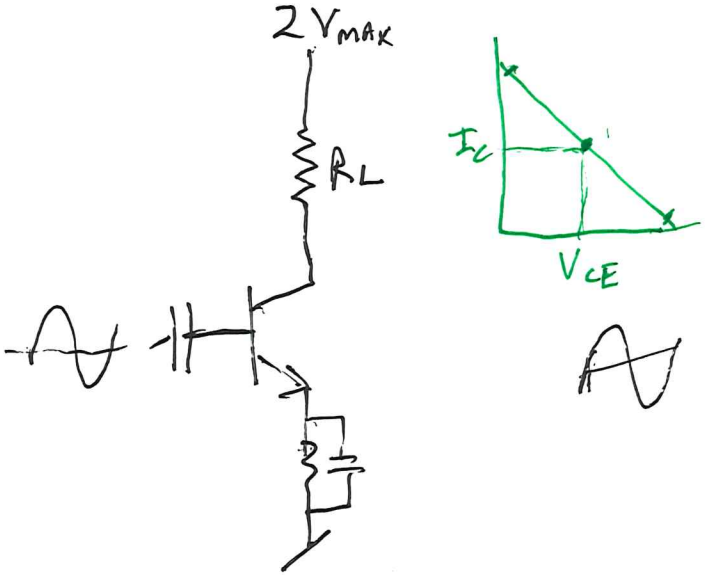


- invert phase For 1

How to demodulate? This is a "balanced modulator"
- so no carrier. Can't lock a PLL.

Trick: Square modulated signal: Get continuous sine at 2Fc. Use PLL to lock on This.
Divide output by 2.

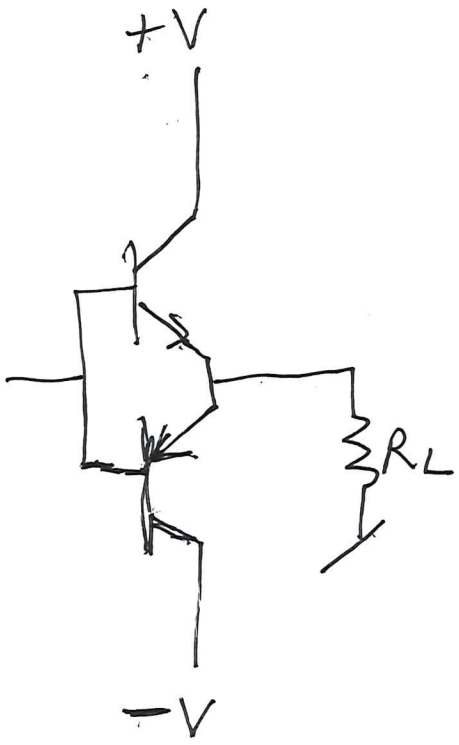




CLASS A

100% (360°)

$\mathcal{E} \leq 25\%$

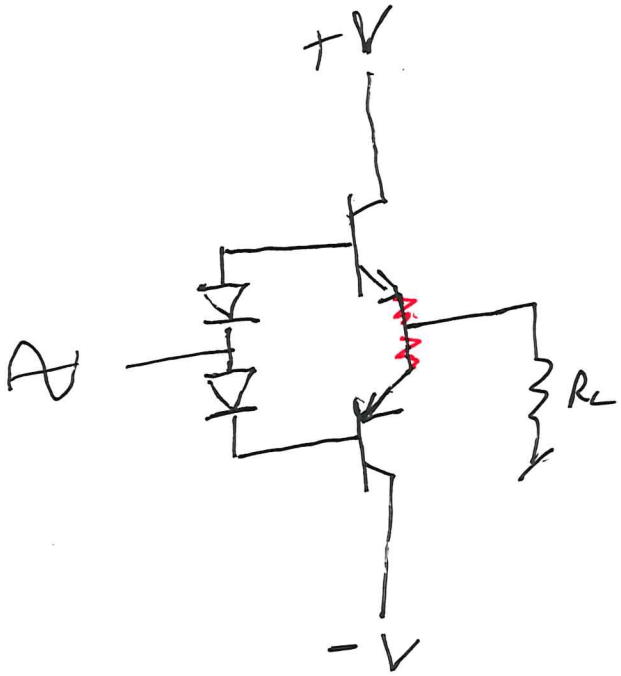


CLASS B

≈ 180° (each ½)

$\mathcal{E} \leq 50\%$

"crossover distortion"



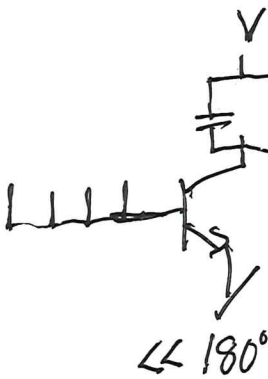
CLASS AB

> 180°

Stability ?

Vs

efficiency



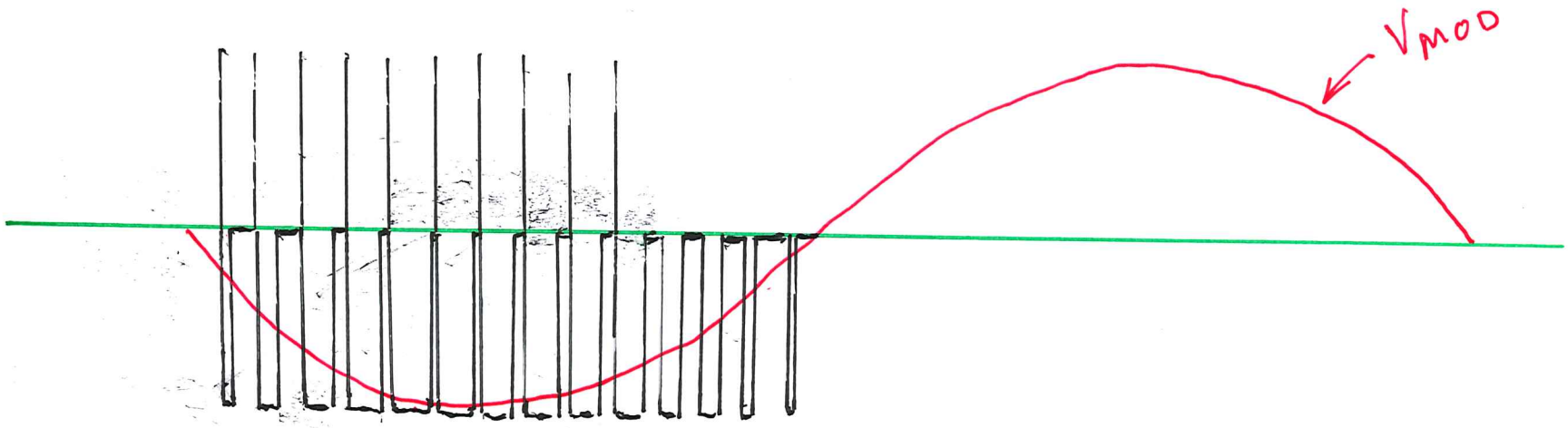
CLASS C

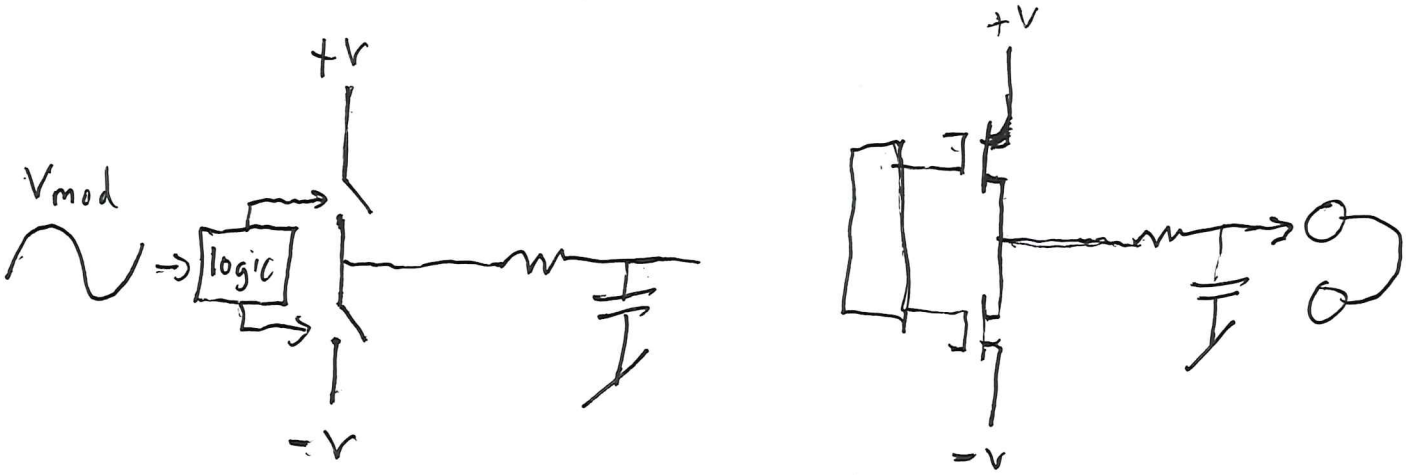
≪ 180°

$\mathcal{E} < 100\%$

CLASS D

"Pulse-width Modulation" (PWM)

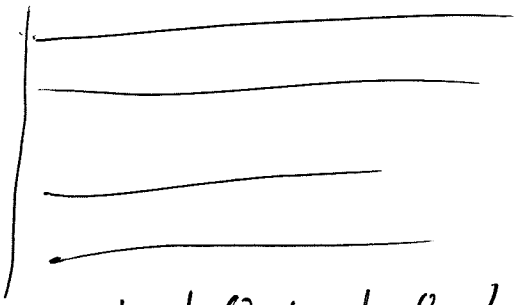




Digital Signals

Win by going to modest SNR (3 db is plenty). Noise will introduce some errors, but use error correcting codes embedded in bit stream, to detect and correct errors.

0 1 0 1 0 0 1 0 ← parity bit ensures odd # of 1's if correct



parity word 0 1 1 0 0 1 0 1 ← should have odd # in column