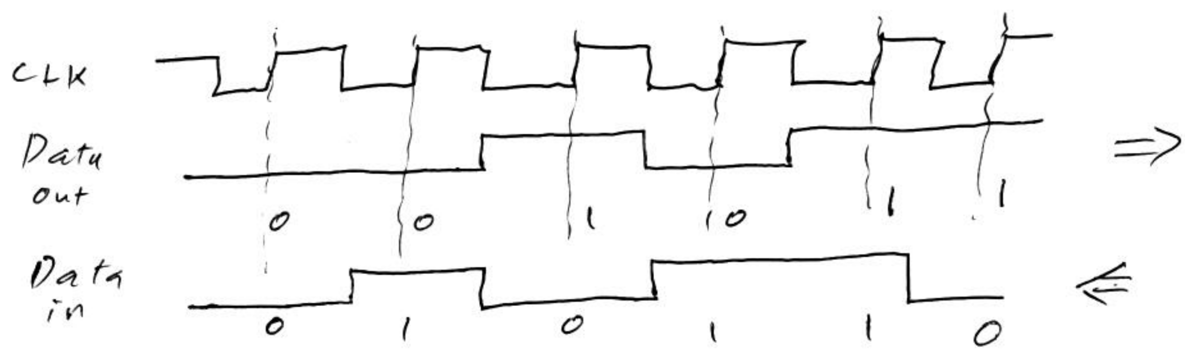
Data Transmission

Goals are:

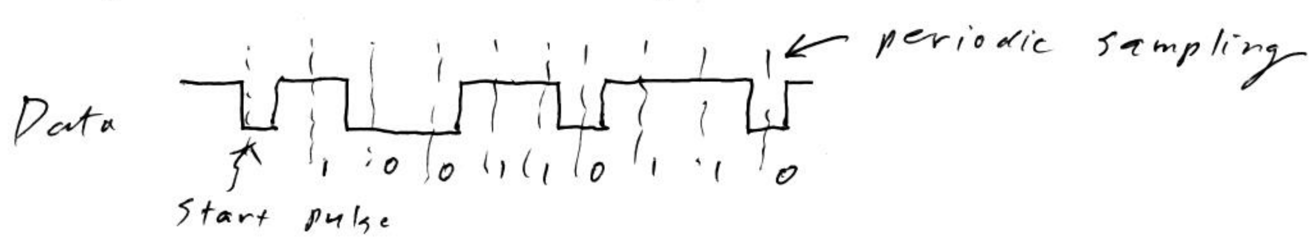
1) overcome losses
2) " noise (more on this soon!)
3) " dispersion in time

Many interface schemes exist; most for long distances use a <u>serial</u> (i.e., sequential) digital data stream. (Notable exception: radio)

Some versions, like the short-distance SPI interface, are clocked:



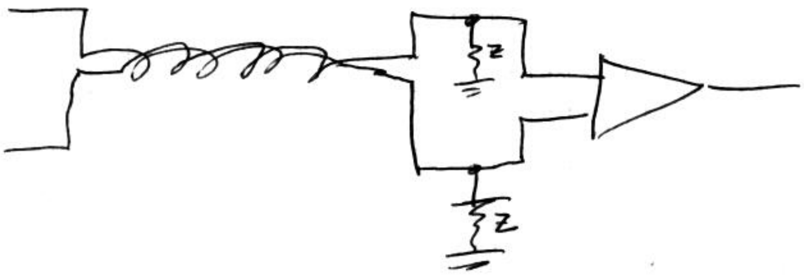
Many others, like RS-232 and USB, depend on synchronizing to a known data rate



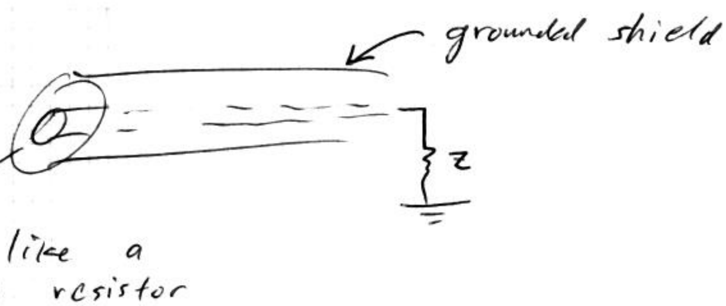
Once-Common but not best are RS-232 (serial) & RS 422/423
balanced

Allows ~ 500 k bits/s for ~ 1000 ft of cable.
Twisted pair cables preferred. (USB 2.0: 480 Mb/s !)

Idea is differential receiver, ± 2V min --

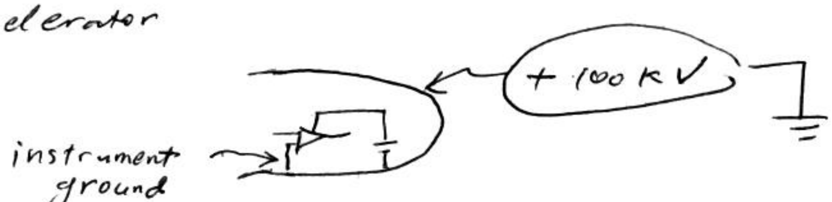


This is <u>not</u> done in RS232, which uses +5 to +15 V L,
-5 to -5 V H.
<u>USB does</u> work this way: twisted pair + 5V pwr, gnd. Note the clever "ground-first" connector design. Max current ~~pair~~ = 0.5 A, normally.
Alternative approach -- even faster -- coaxial cable

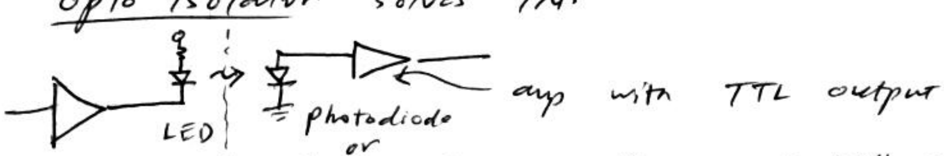


Familiar from cable TV, internet. Low loss, low noise, low dispersion (no reflections or mismatch.) Drive with transistors or "line driver" chips, receive with Schmitt trigger.
What to do if 'ground' is not preserved?

<u>Ex</u>: accelerator



The <u>opto-isolator</u> solves this --



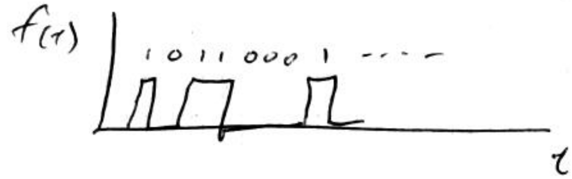
<u>Many</u> variations -- p. 597.
Make nice motion detectors, too!

Transmitting information -- Modulation

We may want to communicate either

analog information,

or digital,



(Or a coded analog data stream, now very common)

In either case, for long-distance use we need to encode the information on a radio or optical carrier wave,

$$E_{(t)} = A \cos(\omega t + \phi_0)$$

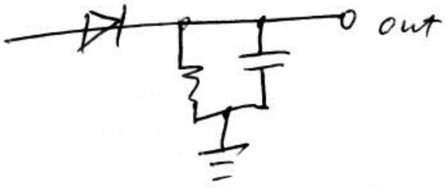
two constants; can adjust either.

I. Amplitude modulation:

$$A = A_0 + f(t), \text{ so} \qquad (\text{or } A_0 f(t))$$

$$V_{(t)} = \left(A_0 + f_{(t)}\right) \cos(\omega t + \phi_0)$$

To demodulate just take $|V_{(t)}|$ and use a low-pass filter. Most simply,



(what happens if R omitted?)

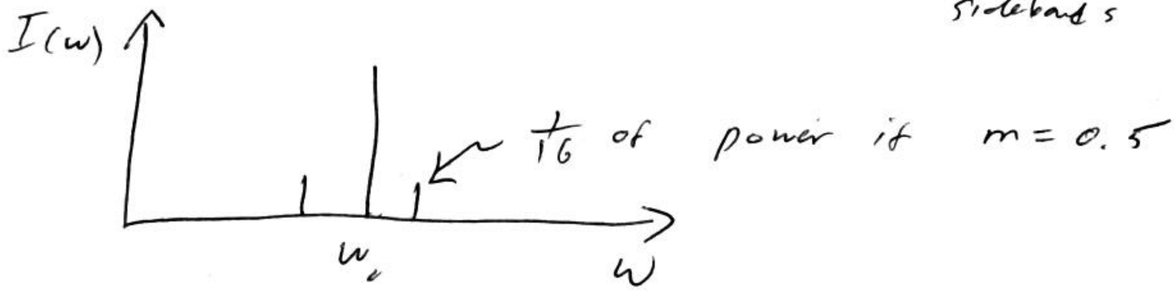
If the signal is just a sine wave,

$f(t) = A_0 m \cos \omega_m t$, we get

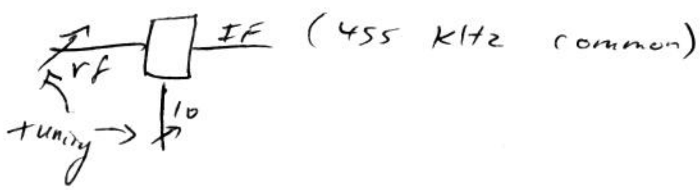
$$V = A_0 (1 + \underbrace{m}_{\text{mod. index}} \cos \omega_m t) \cos \omega_c t$$

$$= A_0 \Big(\underbrace{\cos \omega_c t}_{\text{carrier}} + \tfrac{1}{2} m \big[\cos (\omega_c + \omega_m) t + \cos(\omega_c - \omega_m) t \big] \Big)$$

sidebands



At high freq's just add a mixer to do <u>IF</u> amplification --



Problem: Most of power in carrier, does no good! (For voice communications, "SSB" partially resolves this.) Also, many noise sources affect primarily the amplitude.

II. FM

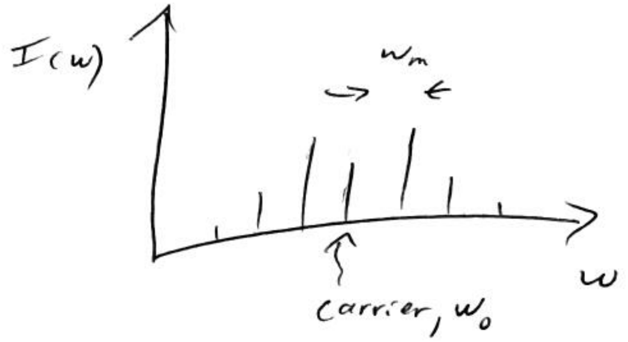
Can do better by adjusting Φ.

$$\text{Let } V(t) = A \cos (\omega_0 + \underbrace{k f(t)}_{\substack{\text{frequency modulation;} \\ \text{vary slowly wrt } \omega_0}}) t$$

(Variation: phase modulation)

(or cos)

If $f(t) = \cancel{\cos}\ \sin(\omega_m t)$, we get a regular pattern of sidebands, which can exceed the carrier in intensity,



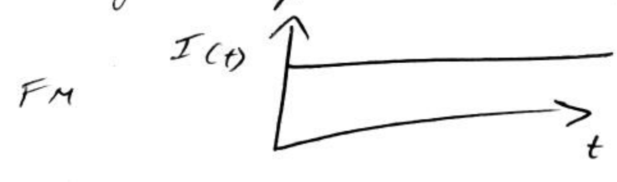
If $f(t) = \sin \omega_m t$, we have explicitly,

$$V(t) = A\Big[J_0(K)\cos\omega_0 t + J_1(K)\cos(\omega_0+\omega_m)t$$
$$- J_1(K)\cos(\omega_0-\omega_m)t$$
$$+ J_2(K)\cos(\omega_0+2\omega_m)t + J_2(K)\cos(\omega_0-2\omega_m)t$$
$$+ \cdots \Big]$$

J's $\equiv$ Bessel functions.

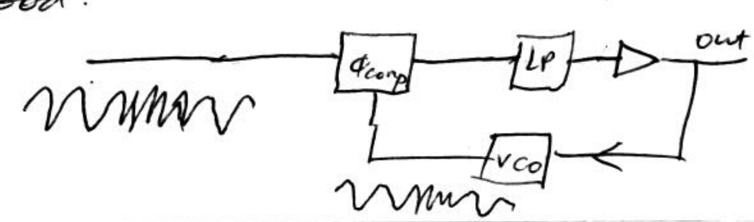
For small K, $J_1 \cong \frac{K}{2}$

Advantage: full power all the time, much in sidebands:



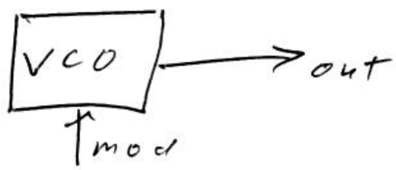
Much higher S/N. Also less pickup from random rf sources (usually AM only).

Detection: PLL is good:



Can also suppress sideband(s) on one side and look for the resulting beat note on a detector. This is used by most older designs.

Production:



(often done with varactor)

Note: if harmonics are generated, some sidebands are enhanced, others eliminated due to signs of (+) vs (−) sideband phases.

For <u>digital</u> data, several FM schemes are possible. The simplest is binary frequency shifting or FSK modulation,