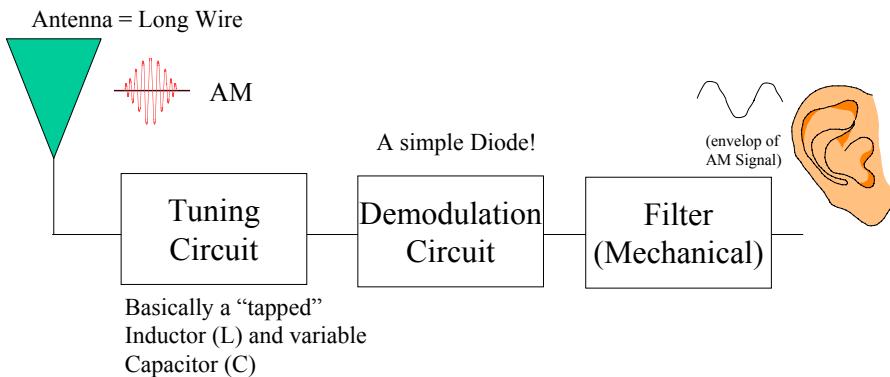


AM Demodulation (peak detect.)

Demodulation is about recovering the original signal--Crystal Radio Example



We'll not spend a lot of time on the AM "crystal radio", although I love it dearly as a COOL, ultra-minimal piece of electronics--Imagine, you get radio FREE with no batteries required.

But...

The things we will look at and actually do a bit in lab is to consider the "peak detector" (I.e. the means for demodulating the AM signal)

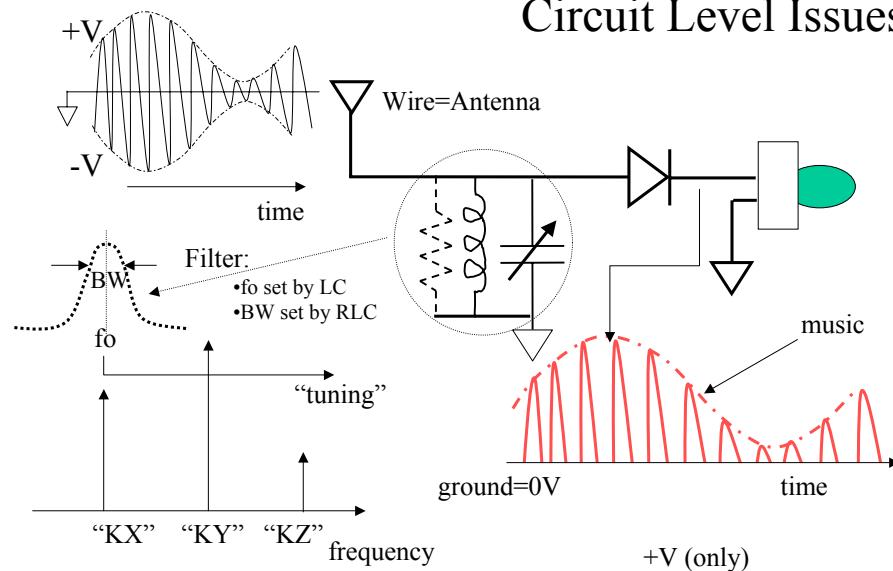
From a block diagram point of view, the circuit has a tuning component (frequency selective filter) attached to the antenna (basically a wire for the basic X-tal radio).

The demodulation consists of a diode (called the "crystal" from the good old days of "Empire of the Air"...movie we'll watch) and an R-C filter to get rid of the carrier frequency.

In the Radio Shack version there is no "C" needed; your ear bones can't respond to the carrier so they act as "the filter".

The following slide gives a more electronics-oriented view of the circuit...

Signal Flow in Crystal Radio-- Circuit Level Issues



So, here's the incoming (modulated) signal and the parallel L-C (so-called "tank" circuit) that is hopefully selective enough (having a high enough "Q"--a term that you'll soon come to know and love) that "tunes" the radio to the desired frequency.

Selective enough means that you receive "KX" and don't also get KY and KZ (for AM you definitely won't get KZSU:)

The diode rectified signal looks as shown; basically we keep the positive side of the signals (referenced to GROUND)

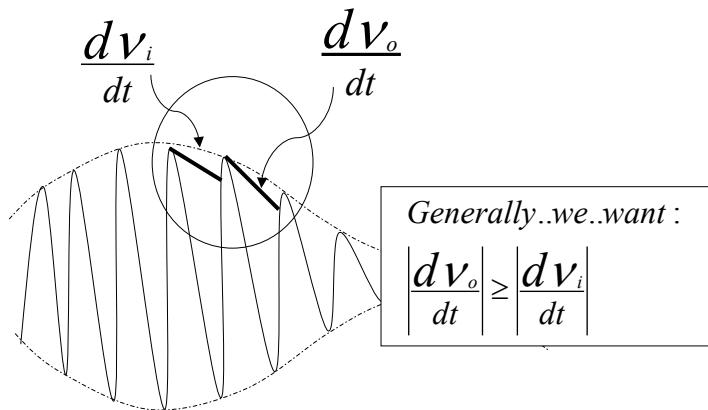
[Comment about X-tal Radios; To get a good signal, you do indeed need a solid ground...an interesting challenge unto itself]

Back to the detection...

Now, our challenge is to keep the envelop and "get rid of" the carrier...basically to filter it out.

Per the NEW EE101A diodes are used to create "power supplies" (a lab experience now in progress:). Here we are using the incoming AM signal to create a power supply (I.e. no battery needed) where the "ripple" is the information (music etc.) that we want to hear.

About “Peak Detection” and Waveforms



So, let's look at a cycle of the “music” that rides on top of the much higher frequency carrier.

By analogy to the power supply example we will use an R-C filter to decay at a rate that hopefully follows the modulated signal but doesn't decay too fast and therefore follow the carrier.

This plot shows us that the modulated signal has a slope and the result of the R-C filter will also have a slope.

Generally speaking, we want the slope of the filtering to be steeper than the envelope.

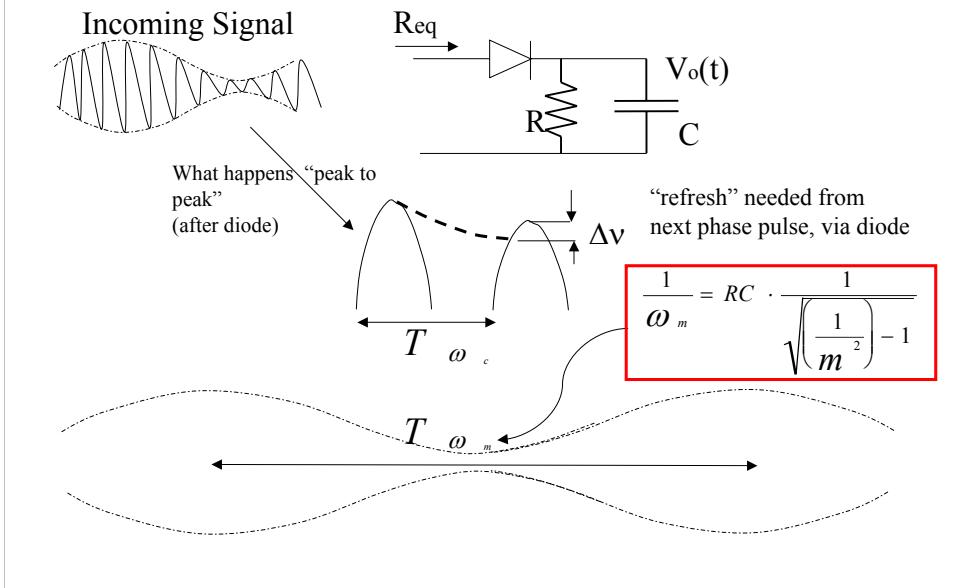
If it is NOT steeper, we're not following the modulating signal (the very last slide in this set corresponds to “Diagonal Clipping”-- the consequence of going too slowly).

If it's TOO STEEP, we're not filtering out the carrier.

OK...

Let's try and put that in a more formal (mathematical) form

Condition for Optimum RC



Here we define the circuit to be considered (and used in lab!) a bit more formally.

We have the diode that gets us half-wave rectification.

Going from one carrier peak to the next, we have an RC fall-off as shown.

At the end of the following few pages we will determine an “optimum” C value (in terms of R , m and ω_m)

This figure simply is showing graphically both the circuit RC in relationship to the carrier period and also how that compares to the period of the modulating signal.

The BOXED equation tells us the final result in terms of how the RC and modulation index should ultimately relate to the modulating frequency...

Now let's take a very quick stroll through the derivation of the real inequality that is involved.

About the Equation for “optimum”...

$$v_i = V_i(1 + m \cos \omega_m t)$$

$$v_o = V e^{-\frac{t}{T_{RC}}}$$

$$\frac{V}{T_{RC}} e^{-\frac{t}{T_{RC}}} \geq V_i m \omega_m \sin \omega_m t$$

equating $v_i = v_o$ (at some t)

$$\frac{1 + m \cos \omega_m t}{T_{RC}} \geq m \omega_m \sin \omega_m t$$

Given that we want...

$$\left| \frac{d v_o}{dt} \right| \geq \left| \frac{d v_i}{dt} \right|$$

This is **THE** constraint equation...now let's make it useful.

Assume that the incoming (envelop) waveform looks as shown above (first equation)

The R-C circuit will have a response that looks like that shown in the second equation.

Taking the derivative of both equations with respect to time and applying the desired inequality (per the previous slide), the third equation is obtained.

Also, at some point in time the top two equations can be equated and that result, combined with the third equation, gives the fourth equation--an inequality that relates:

- RC time constant T_{RC}
- Modulation index “m”
- Modulation frequency ω_m

Unfortunately, how to work with this equation is NOT so easy and another page of “equation hacking” is needed.

[We won’t spend much time on the “hacking”...but we need to get to the final result!]

And the answer is...

after some "trig" manipulations...

$$\frac{(1-m^2)^{\frac{1}{2}}}{m} \geq \omega_m T_{RC}$$

where $T_{RC} = RC$ then :

$$C \leq \frac{(1-m^2)^{\frac{1}{2}}}{m} \frac{1}{\omega_m R} = \frac{\sqrt{\frac{1}{m^2} - 1}}{\omega_m R}$$

The KEY equation for C (in terms of m, ω_m & R)

There are some trigonometric identities that allow us to simplify the inequality from the previous page to the one shown here.

The RC time constant is defined as shown.

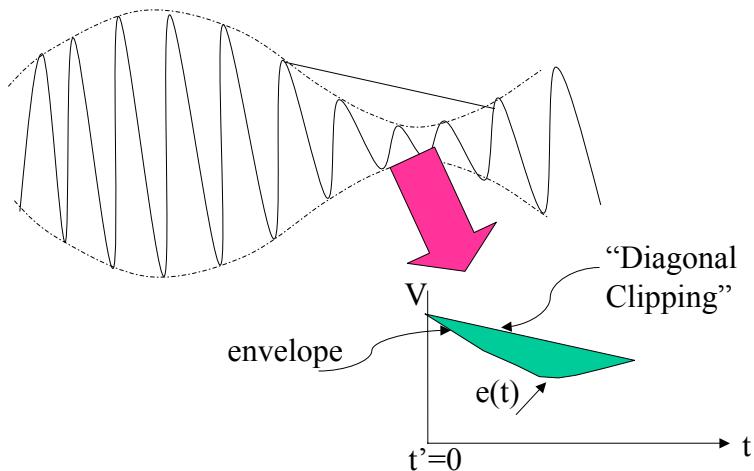
The [bracketed/boxed] equation tells us how small to make C (in the RC) in terms of ω_m , m and R.

If C is larger, then we start to "loose" information in the envelop due to diagonal clipping.

If C is too small (I.e. why not make it ZERO?) then we certainly follow the envelop but we are NOT getting rid of the carrier...

Basically, if C is too small we've kept too much and we haven't really "demodulated" the signal.

What we DON'T want--Clipping



Considering “the dark side”... what we DON’T want...

If the slopes in the above inequality are reversed, here’s what it looks like.

Basically, if the RC time constant is too long then as the modulated signal decreases the sampled point shown simply falls off and “ignores” the stuff below it.

This is called “Diagonal Clipping” and means that the envelop ($e(t)$) is not followed by the circuit.