AM Radio

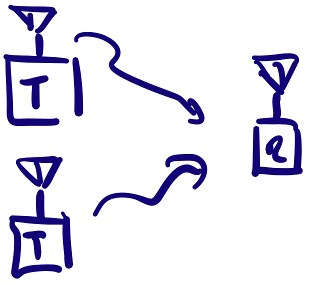
Consider an example application of the circuit techniques we have studied: wireless communications

Challenges in transmitting audio information (or data) via radio waves

① Equipment size: Antenna dimensions are inversely proportional to the frequency at which they work well. Directly trying to transmit audio frequencies would lead to huge antennas ($@ f = 100\,Hz,\ \lambda \sim c/f \sim 3000\,km$!)

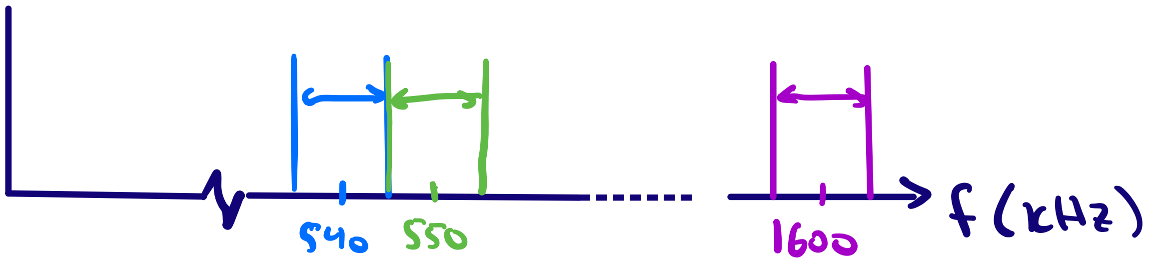
This topic is studied in 6.230 (EM waves)

② Interference: Early transmitters + receivers had no selectivity so would interfere with one another.
(e.g. "spark gap" transmission of morse code is "broadband")



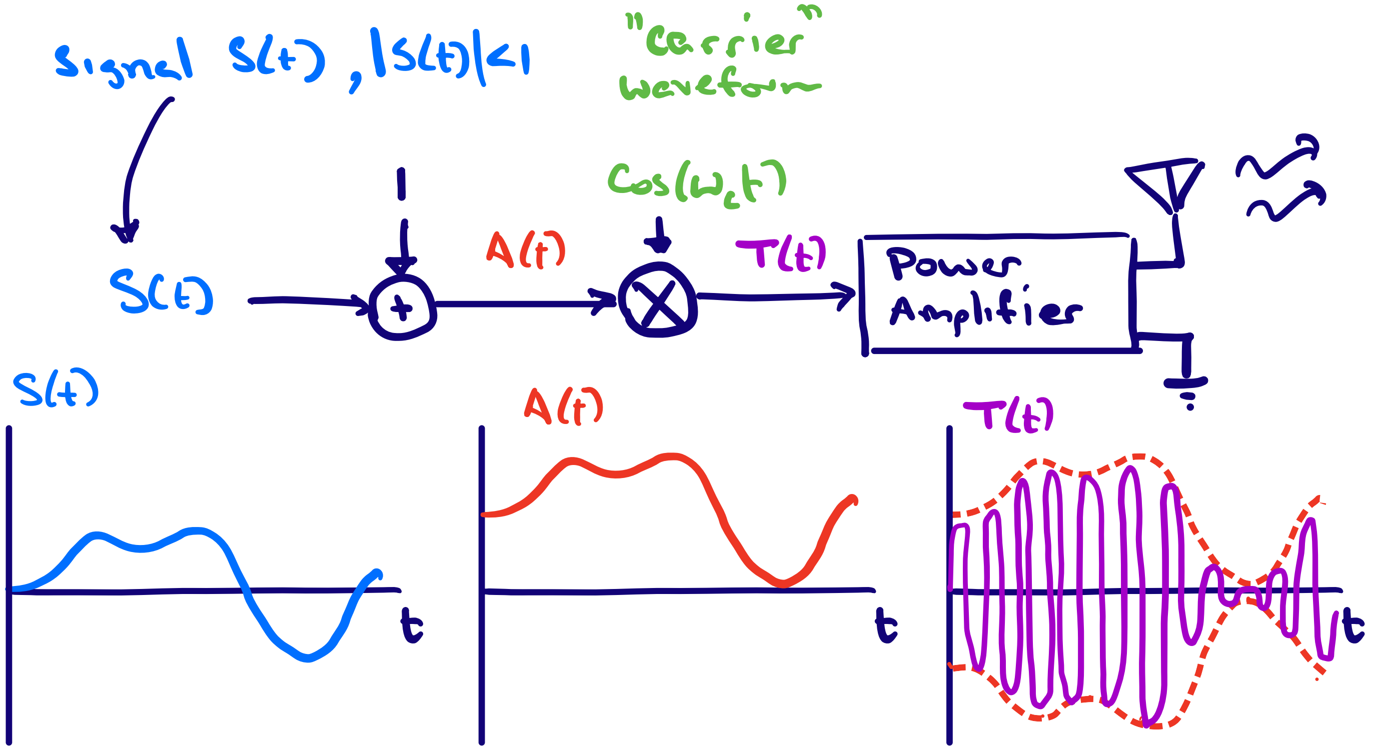
One way to encode information is with frequency selectivity.
(originally developed by Lodge, Tesla, ...)

Each transmitter is allocated a narrow range of allowed frequencies (e.g. in the AM band there are 10kHz slots centered @ 540 kHz – 1.6 MHz)
(AM stands for "Amplitude Modulation")

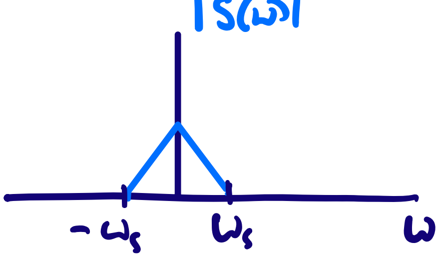


Each transmitter only transmits in the specified frequency band. To get information from that transmitter, tune the receiver to that frequency band!

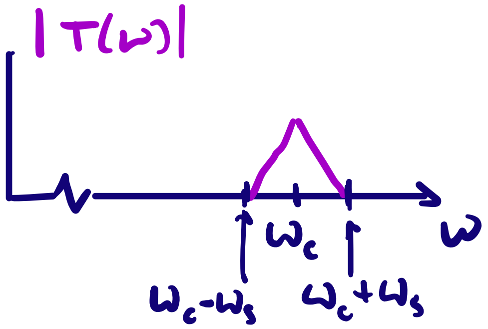
How do we encode our information to be in a given frequency band? One way is Amplitude Modulation, or AM. (we could also modulate frequency, phase, ...)



These signals have a certain content distribution across frequency (This topic covered in 6.300, 6.301)



"modulation" (multiplication) by carrier moves signal energy to near ω_c



Note that modulation (multiplication) is inherently a <u>nonlinear</u> operation. (If it were not, it would not act to change the frequency content of the signal!)

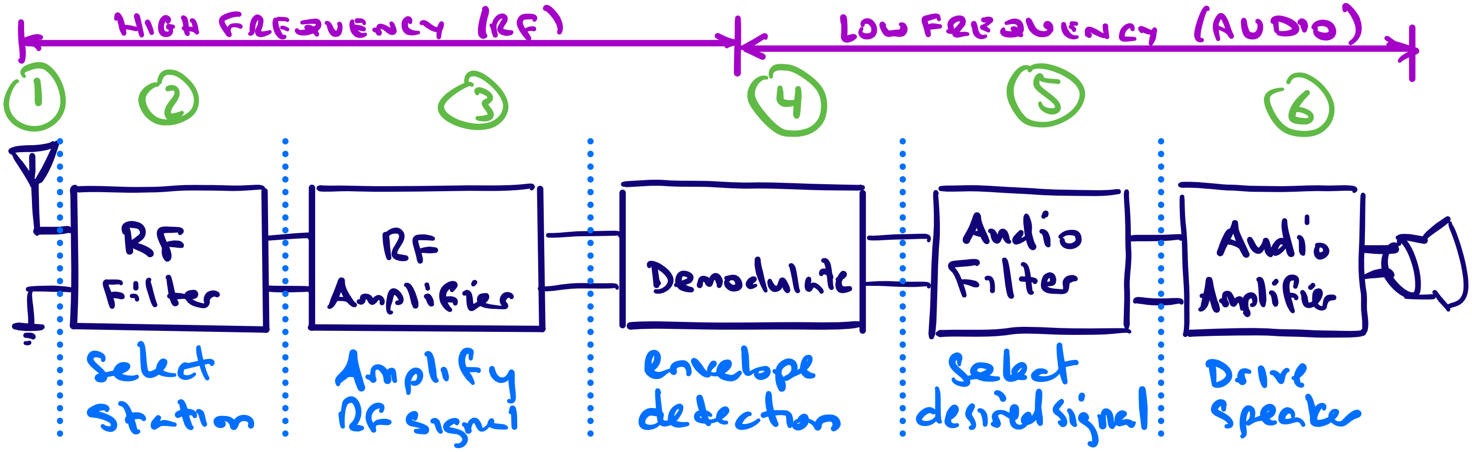
⇒ Nonlinear circuits are interesting and important!

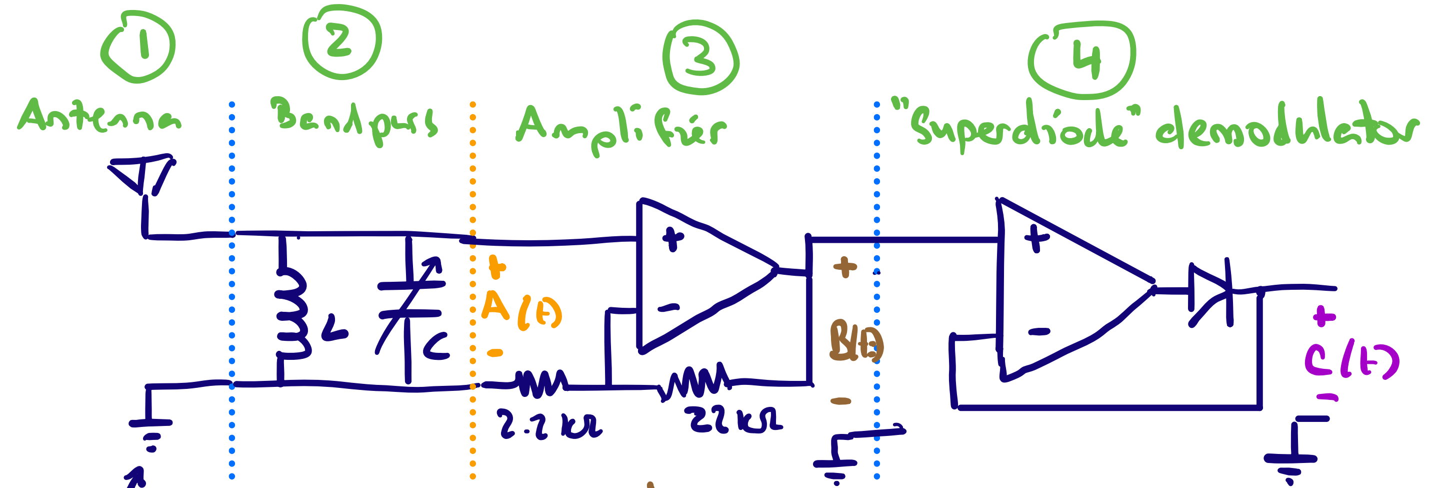
(nonlinear circuits and how to analyze them are introduced in 6.208) modulator (multiplier) could be realized with many circuit designs

Power Amplifier operates @ high frequency to drive antenna.

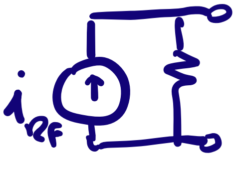
(See 6.204, 6.208, 6.209, 6.602, 6.622, ...)

Today, lets look at how to recover our desired signal from the received radio waveform:

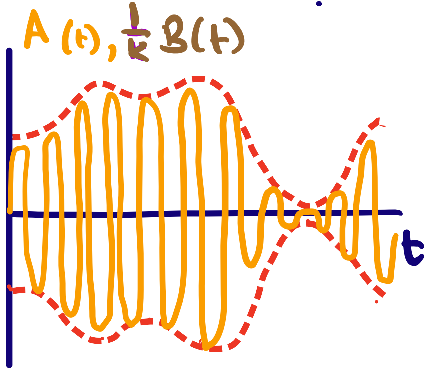


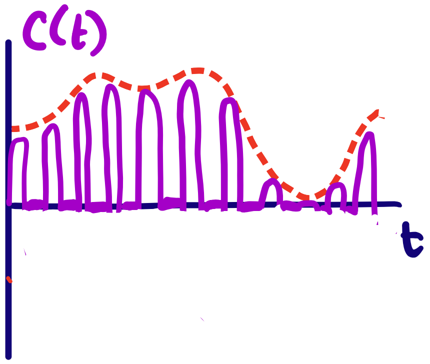


model as norton equivalent



Tuneable high-Q_0 bandpass filter



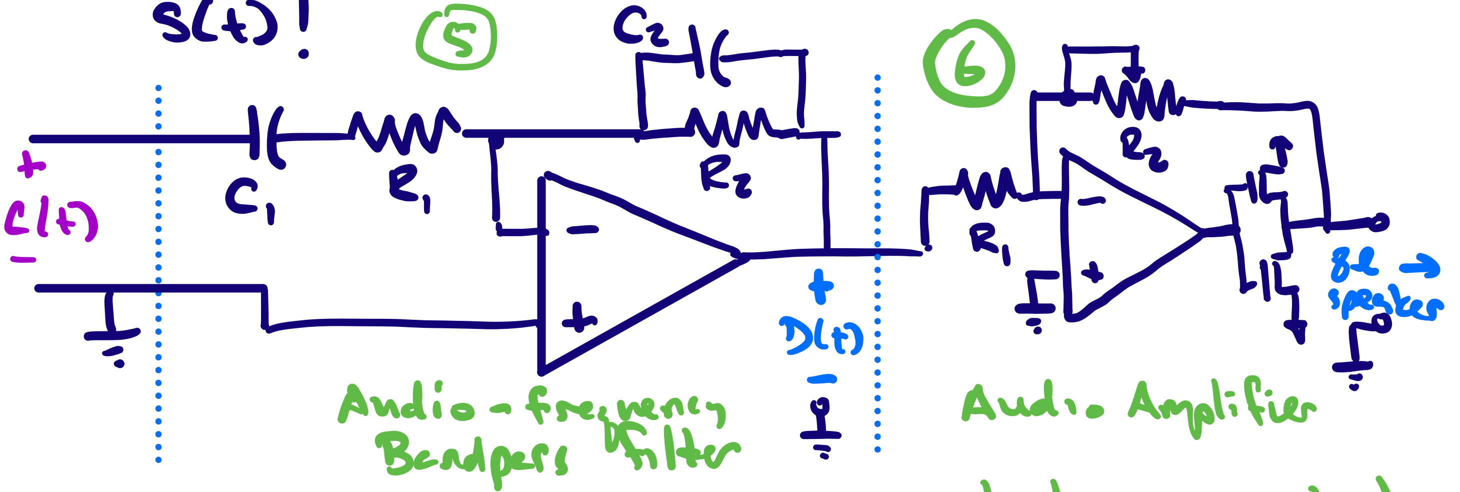


The superdiode clips off the negative portion of B(t) to generate C(t). This is a nonlinear operation that gives C(t) different frequency content than B(t). (Some low-frequency content near ω_c and below, some high-frequency content near ω_c.)

⇒ The "local average" of C(t) tracks the envelope of B(t)

C(t) is: low-frequency envelope content + high-frequency (carrier frequency ω_c) stuff

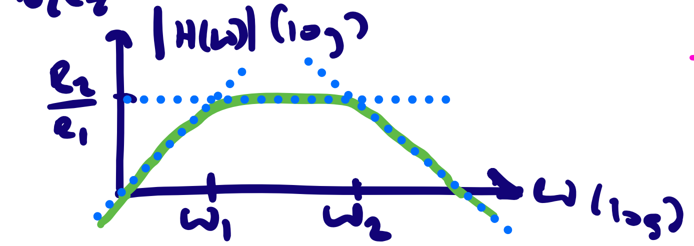
⇒ If we filter off the high-frequency content and the dc content, we can recover our audio signal S(t)!



@ $R_1 = 10k\Omega$, $C_1 = 1\mu F$
$R_2 = 100k\Omega$, $C_2 = 470pF$

$$\frac{1}{R_1C_1} = \omega_1 \sim 100 \text{ rad/sec}$$

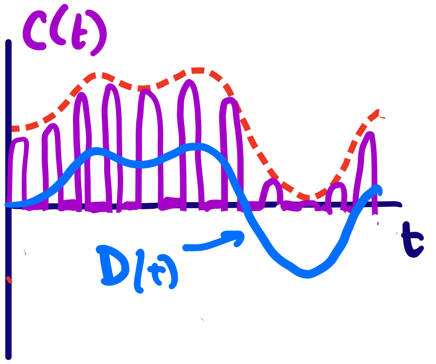
$$\frac{1}{R_2C_2} = \omega_2 \simeq 2100 \text{ rad/sec}$$



- high-power output stage with "feedback linearization" from op amp.

6.208, 6.209, ...

dynamics in 6.310



D(t) has the same content as our original signal S(t)! We have transmitted it via radio waves near frequency ω_c and recovered it!

AM radio is one way to encode information and send it over a channel at radio frequencies (near a "carrier" frequency ω_c.

We can also use encoding methods besides Amplitude modulation, and can also send digital data (like wifi or a cell phone).

Consider a "modulated" sinusoid

$$v(t) = M(t)\cdot\cos(\omega_c t + \phi(t))$$

- Varying $M(t)$ to carry information is AM
- If we instead varied phase $\phi(t)$, or made a variable frequency by $\phi(t) = \Delta\omega(t)\cdot t$, we could encode our signal in frequency variation $\Delta\omega(t)$.
  - → This is Frequency Modulation, or FM, radio

We can send digital signals by selecting different combinations of M, ϕ to represent different digital "symbols", and vary M, ϕ with time to send data.

⇒ Time-varying Phasors carry our information!

→ This is how cell phones + wifi work