Radio Receivers

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Role of the Receiver

- The **Antenna** must **capture** the **radio wave.**
- The **desired frequency** must be **selected** from all the EM waves captured by the antenna.
- The **selected signal** is usually very weak and **must be amplified.**
- The **information** carried by the radio wave, usually an audio signal, **must be recovered – Demodulation.**
- The **audio signal** must be **amplified.**
- The amplified **audio signal** must then be **converted** into **sound waves** using a speaker or headphones.

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The 3 S's of Receivers

- Sensitivity
- Selectivity
- Stability

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Sensitivity

- Refers to the **minimum signal level** that the receiver can **detect.**
- Measured in **Microvolts** or **fractions of Microvolts** at 50 Ohm, or dbm - db below 1 mW at 50Ω, e.g. - 130 dbm.
- Sensitivity given as **"MDS" (minimum discernable signal)** or **10db S/N (signal to noise ratio)** or **S+N/N ratio.**
- The **greater the sensitivity** (ie: the smaller the number of microvolts) the **weaker a signal** it can **receive.**

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Sensitivity

- Very weak signals can be received – **sensitivity is generally not an issue** with modern receivers.
- *Between 1.7 and 24.5 MHz on SSB, the Kenwood TS-870 has a sensitivity of 0.2 microvolts or less.*

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Selectivity

- Refers to the **receiver's ability** to **separate** two **closely spaced signals.**
- The **more selective** a receiver, the **narrower** the **bandwidth and/or the steeper the filter skirt.**

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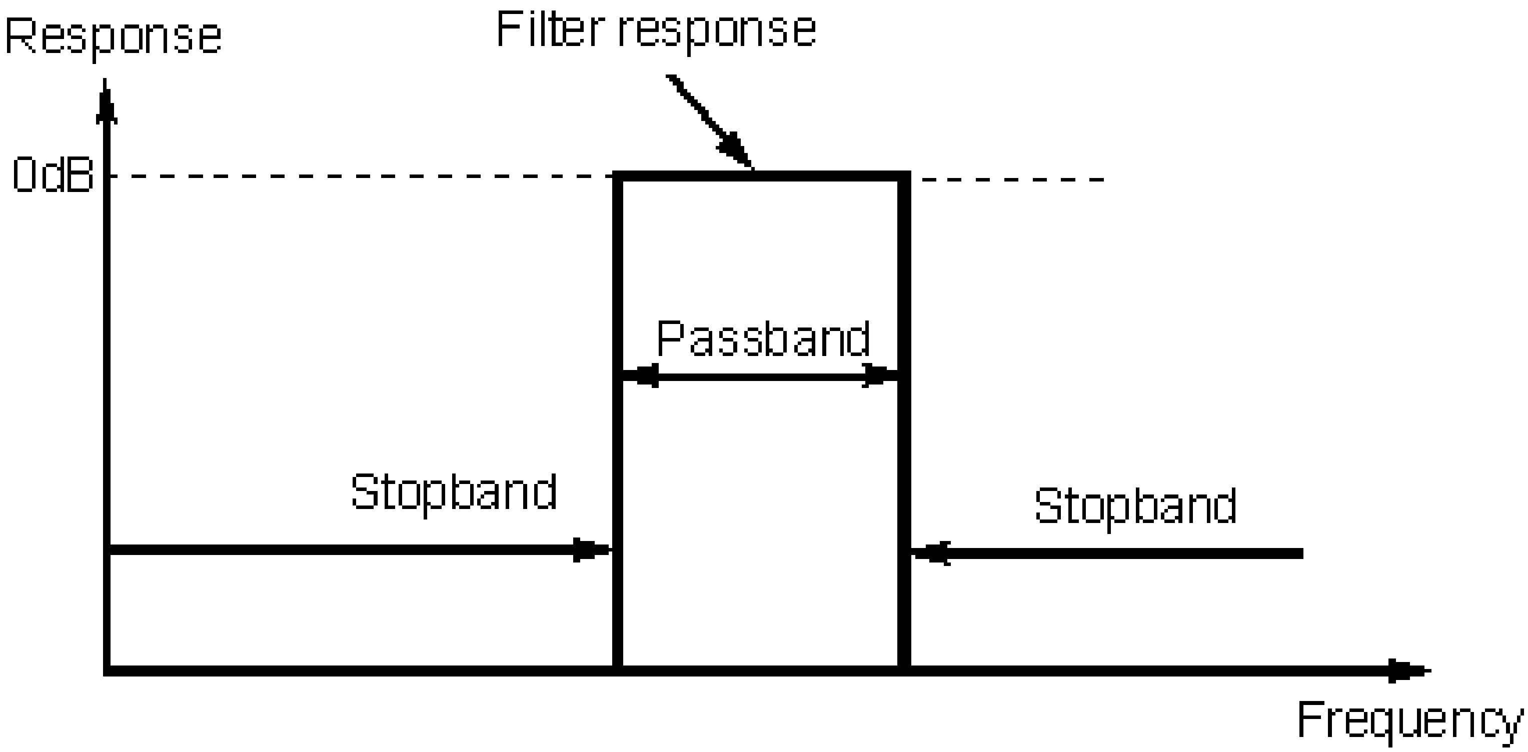
Selectivity

- **Specified** as the **bandwidth** at **6 dB** attenuation, and at **60 dB** attenuation (ie: the –6 dB and –60 db points).
- Filter Skirt steepness is perhaps **THE key characteristic** that separates the boys from the men in HF receiver design!
- *Example: On SSB the Kenwood TS-870 has a selectivity of 2.3 kHz at – 6 dB and 3.3 kHz at – 60 dB. This is a very selective receiver.*

Ideal Receiver Selectivity



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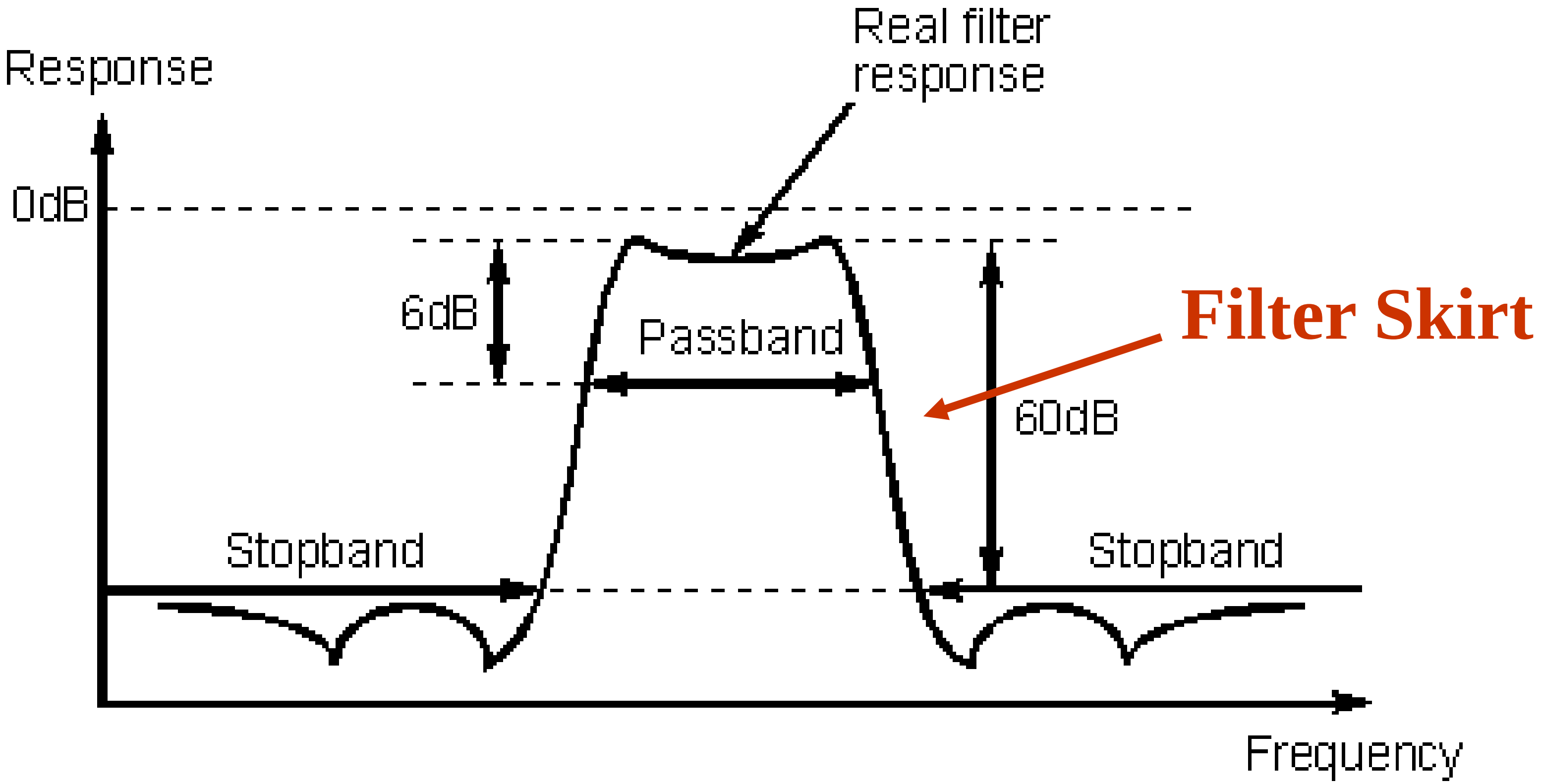
Actual Receiver Selectivity



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Stability

- The **receiver's ability** to **remain on a frequency** for a period of time.
- **Unintended change** in frequency is **called drift.**
- Specified as **number of Hz drift** over a **period of time** after warmup, or as **ppm (part per million)** for more modern radios.
- **Not an issue for modern receivers**, but is a consideration for older designs, especially those using vacuum tubes.

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Other Receiver Characteristics

- **Frequency precision:** ability to determine the frequency.
- **Resettability:** ability to return to a frequency.
- **Interference rejecting features:** filters, DSP, noise blanker, noise limiter, RF preselector, Notch Filters.
- **Dynamic range:** range of signal strength through which the receiver operates properly.

Cross Modulation

- **Cross Modulation** occurs when a **strong signal** is **too powerful for the receiver's front end** (first RF Amplifier) to pass through without **distortion.**
- It results in the **wanted signal being Amplitude Modulated by the strong unwanted signal** ie: the unwanted signal can be heard on top of the wanted signal.

Curing Cross Modulation

- To prevent cross modulation, many receivers have an **Attenuator** that inserts a resistive pad (circuit) between the antenna and the receiver.
- This **weakens the strong signal** enough that it **no longer causes problems.**
- If the **interfering signal** is **out of the band altogether,** then an appropriate **filter** between the antenna and the receiver may also help.
- **FM receivers** are **immune to Cross Modulation** as they are **unaffected** by **amplitude variations** on received signals.

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Attenuator – Kenwood TS-950SDX

Intermodulation

- **"Intermod"** is sometimes incorrectly called Cross Modulation, but is a different phenomena.
- It is the result of **two or more signals** of different frequencies **being mixed together**, forming **additional signals at frequencies** that are **not, in general, at harmonic frequencies** (integer multiples) of either.
- The **mixing** usually takes place **inside the receiver,** but can even take place at rusty fence joints!
- **Very prevalent problem** on **2M and 70cm** FM when driving through **downtown!**

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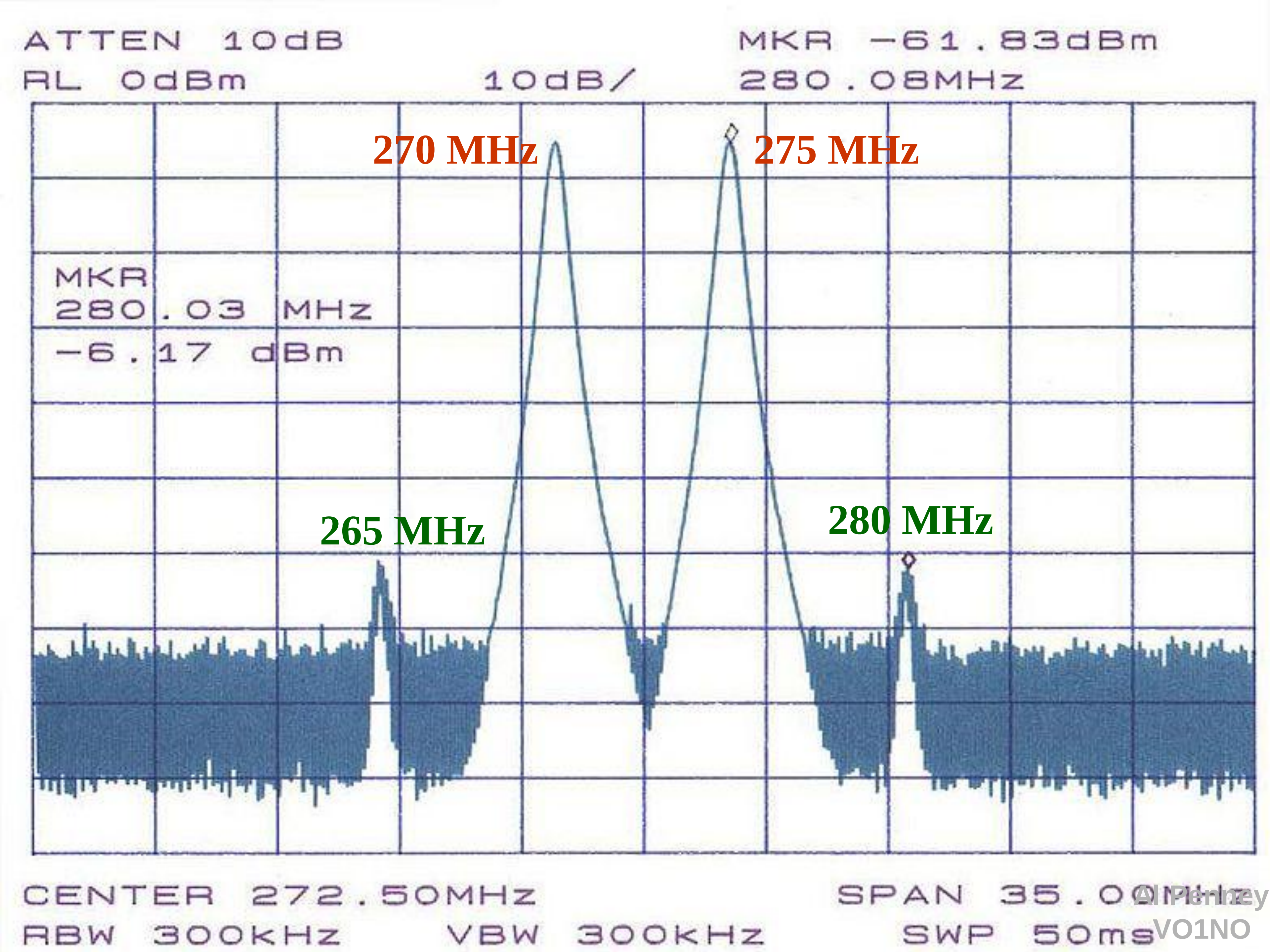

ATTEN 10dB
RL 0dBm
10dB/
MKR -61.83dBm
280.08MHz
MKR
280.03 MHz
-6.17 dBm
270 MHz
275 MHz
265 MHz
280 MHz
CENTER 272.50MHz
SPAN 35.00MHz
RBW 300kHz
VBW 300kHz
SWP 50ms
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Images

- **Signals** on a **different frequency** than the one tuned to, but which are **received anyway.**
- Occurs because of the **frequency conversions** that are conducted **within the receiver.**
- **Image rejection** is specified in **dB.**
- *The image rejection specifications for the Kenwood TS-870 are 80 dB or greater.*

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Natural Noise

- **Natural noise**, called **QRN**, is also called **Static.**
- It comes from **objects in the galaxy** that radiate RF energy, and from **natural phenomena** such as **lightning.**
- The presence of natural noise sets the **Noise Floor** for the band in question at that particular time, and appears as a steady hiss.
- **Lightning** appears as a **burst of static**, and can be dealt with to some degree by noise limiters.

Man-Made Noise

- Also called **QRM**, Man-Made Noise generally comes from **sparking equipment**, and also from **equipment that generates RF.**
- Some countries use **HF radars** that produce sharp pulses.
- The best solution to most man-made noise is to **eliminate it at the source**, as it is often close to home.
- Start at **home**, and then **search the neighborhood**, using a portable receiver to track down the noise.
- **Digital Signal Processing (DSP)** is of great assistance in reducing QRM.

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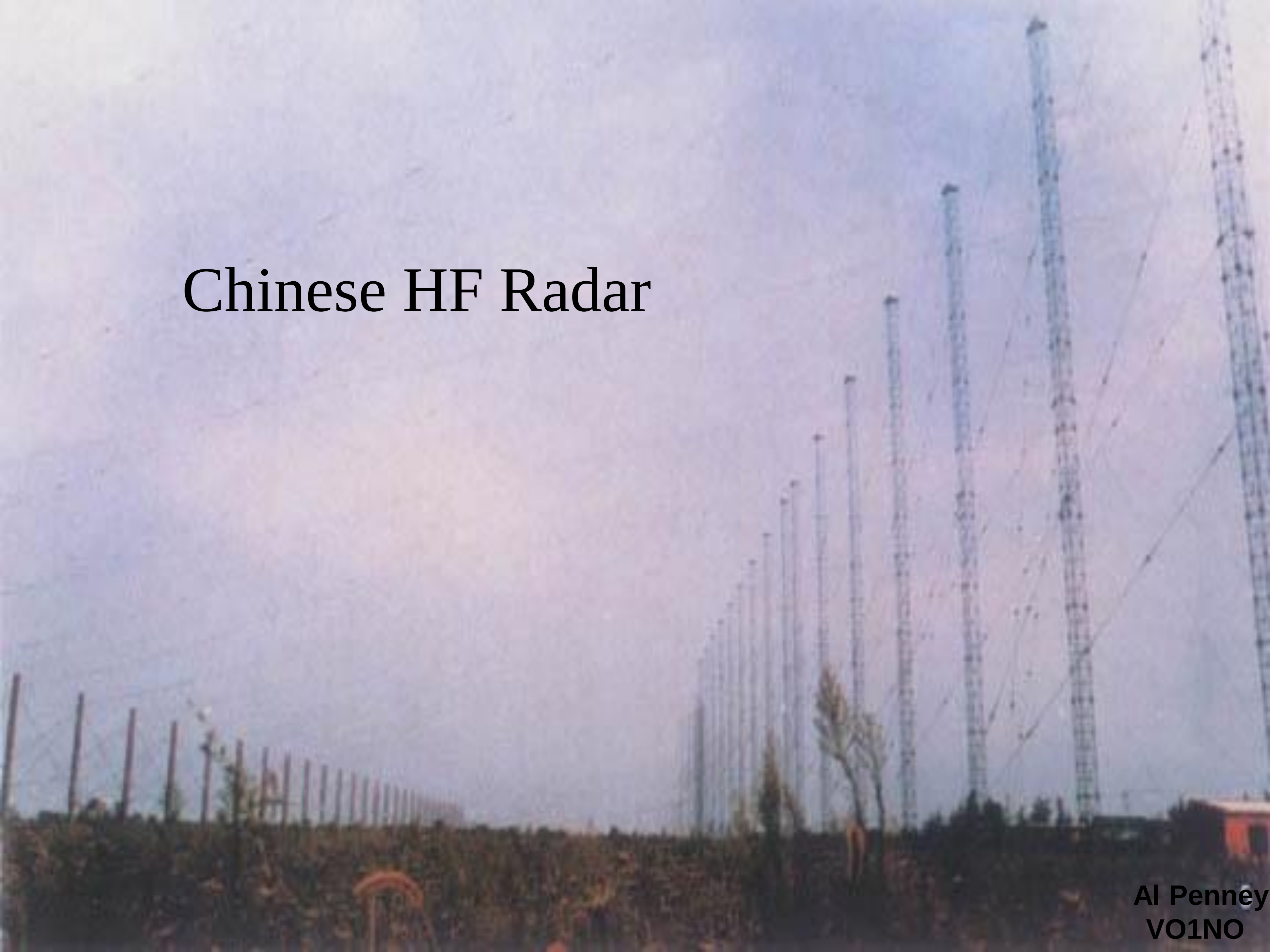
Chinese HF Radar



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Receiver Limitations

- It does **no good** to make HF receivers **any more sensitive** – they are already sensitive enough to **hear the natural noise floor,** and cannot hear anything below that level anyway.
- Any **component that generates gain** also **generates internal noise** – it is unavoidable!
- So, while the noise floor on VHF and UHF is much lower than HF, the **quality of the active device** (transistor) in the **front end of the receiver** determines the **sensitivity of the system.**

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Signals and Noise

- Another way to specify the **sensitivity** of a receiver is to express how many **microvolts of signal** are required to give a certain **Signal to Noise Ratio (SNR).**
- Some use the **Signal + Noise to Noise Ratio**, or **(S+N)/N.**
- These ratios are specified in dB.

Can we Increase Selectivity?

- While it is **possible to add filters** (either discrete or virtual using DSP techniques) to increase selectivity, remember that **every mode** has a **defined bandwidth.**
- If the **selectivity is too wide, excess noise** will be received. If **too narrow** however, the **complete signal will not be received.**
- **CW filters of 250 Hz** are common, but going too narrow will result in **"ringing".**
- **Human voice** requires a range of **300 – 2700 Hz.** Using too narrow a filter will make the voice unintelligible.

Frequency Calibration

- **YOU** are **responsible** for ensuring that you **operate within the Amateur bands!**
- **Radio dials** can be **analog** or **digital.**
- **DO NOT assume** that they are always **correct!**
- Older radios use **Crystal Calibrators** to enable you to check the accuracy of the dial.
- Newer, synthesized, radios use a **master time base** in the microprocessor to derive frequency information. If that time base is off, so will the calibration.
- Use **WWV / WWVH** to calibrate your radio.

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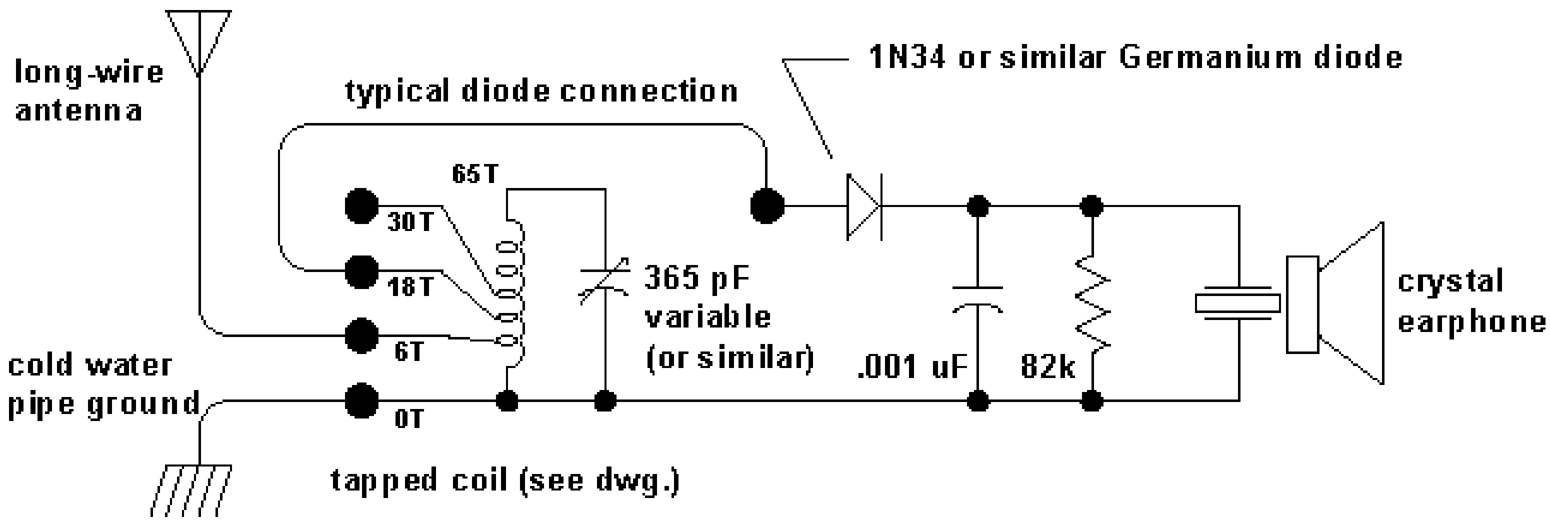
Simple Crystal Radio



Crystal radio with typical connections for a long wire antenna and good ground connections. The diode is connected for weak signals and moderate selectivity.

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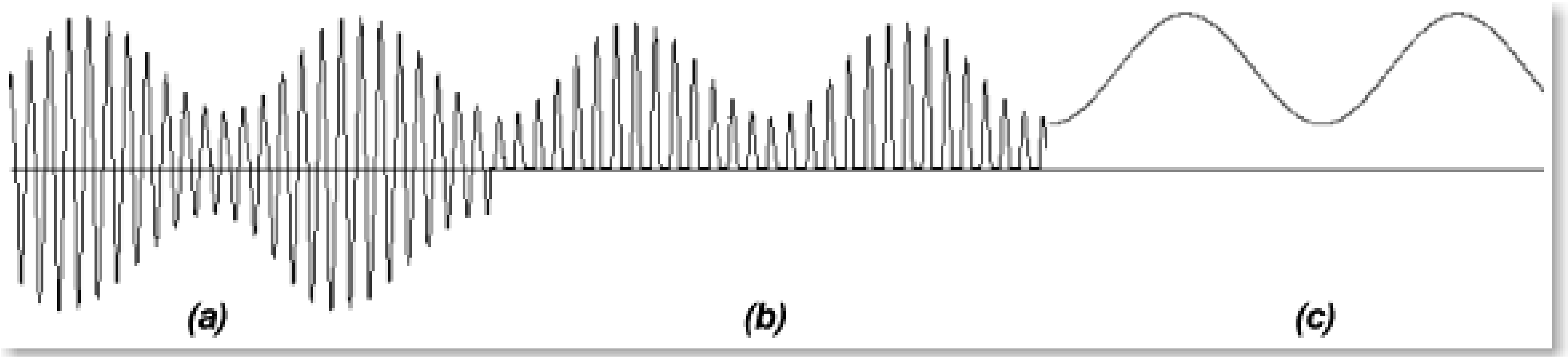
AM Demodulation



Signal Diode Action Low Pass Filter

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“Baby Grand” Crystal Receiver

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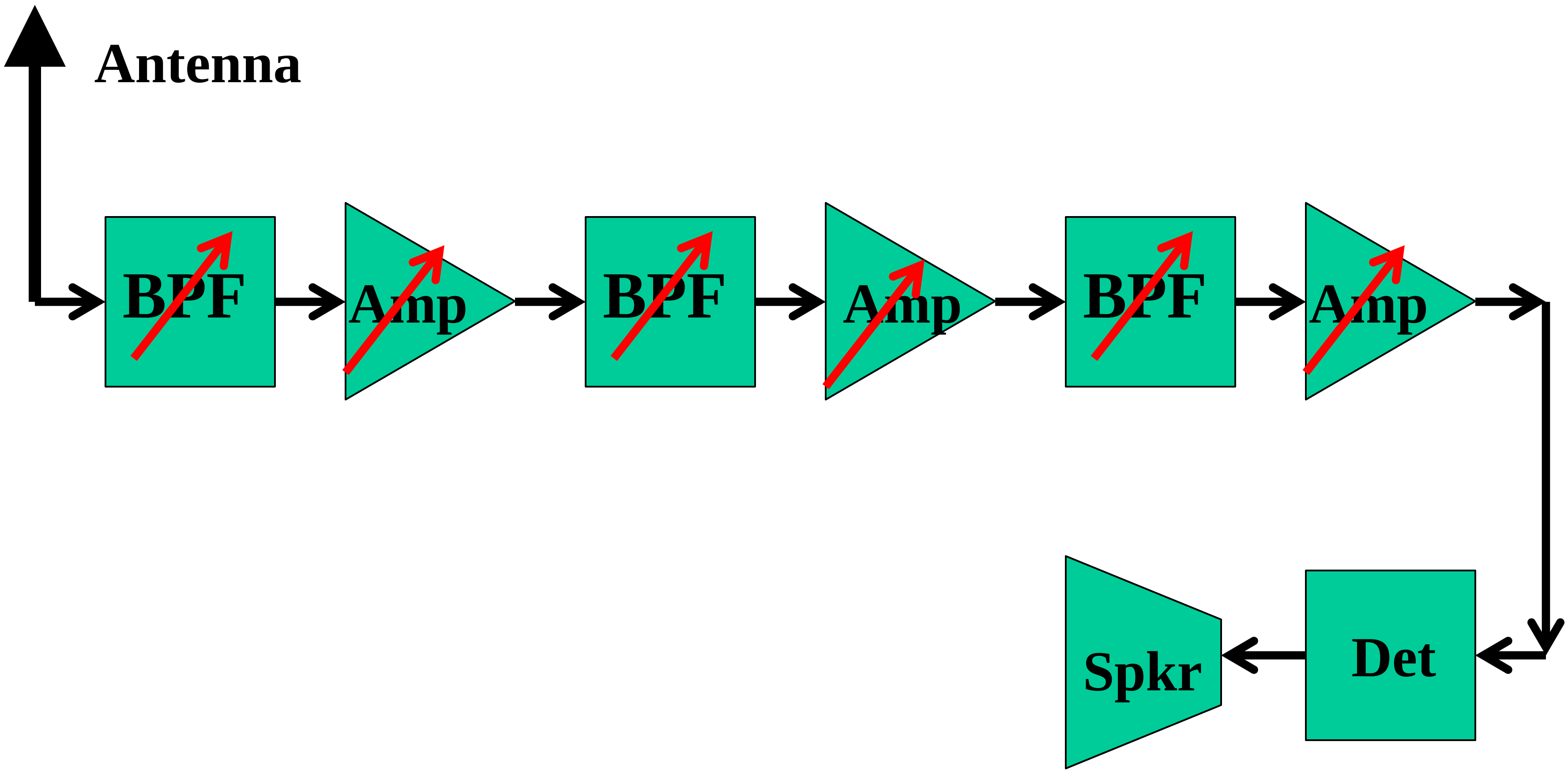
Tuned Radio Frequency Receiver

- A **Tuned Radio Frequency (TRF)** receiver has **several RF amplifier stages** followed by detector and audio amplifier stages.
- **Each RF amplifier** stage must be **tuned individually.**
- This is a very **cumbersome process!**
- For technical reasons, it is also **difficult** to achieve **sufficient selectivity** as the **frequency increases.**

Tuned Radio Frequency Receiver



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American Beauty TRF Receiver

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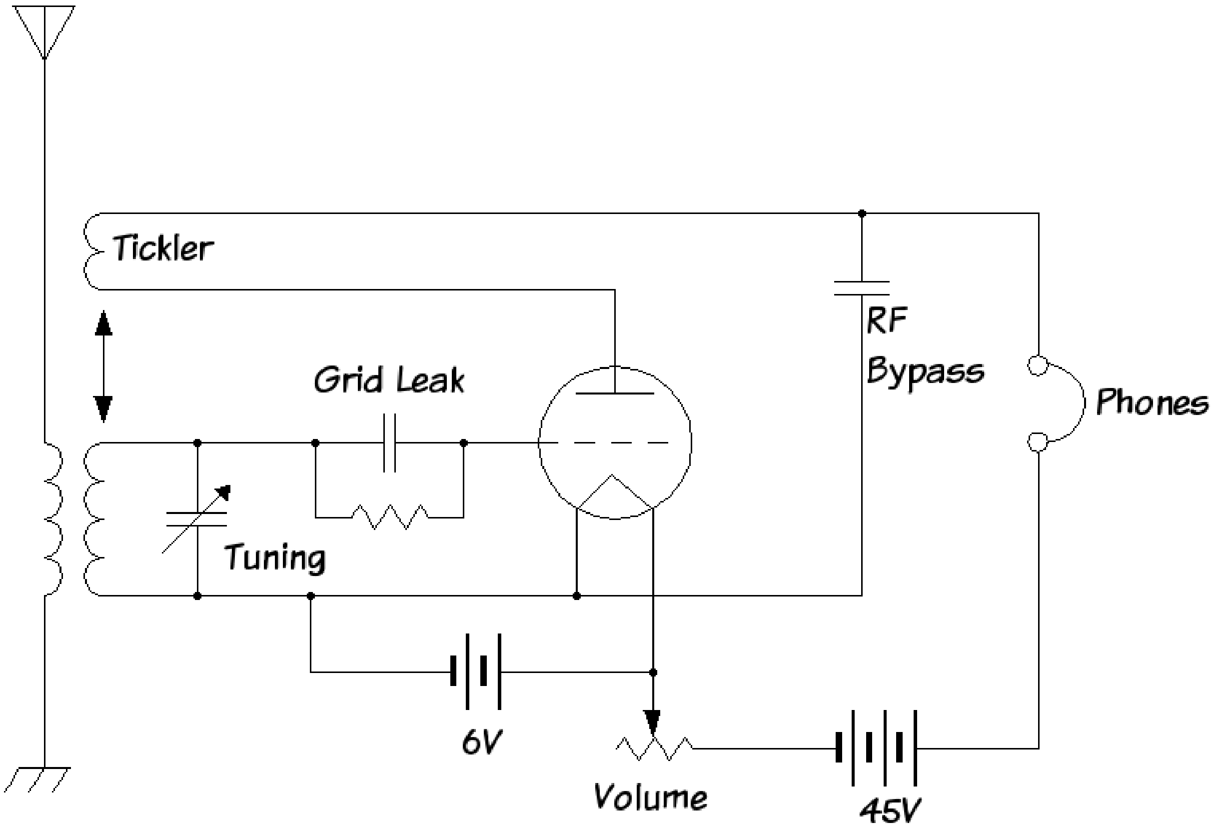
Regenerative Receiver

- High sensitivity
- High selectivity (for weaker signals)
- Poor stability
- Poor immunity to overload
- Mediocre resettability / logging
- Generates a signal that can cause interference to others.
- Cheap + easy to build!
- Best performance requires careful design

Regenerative Receiver



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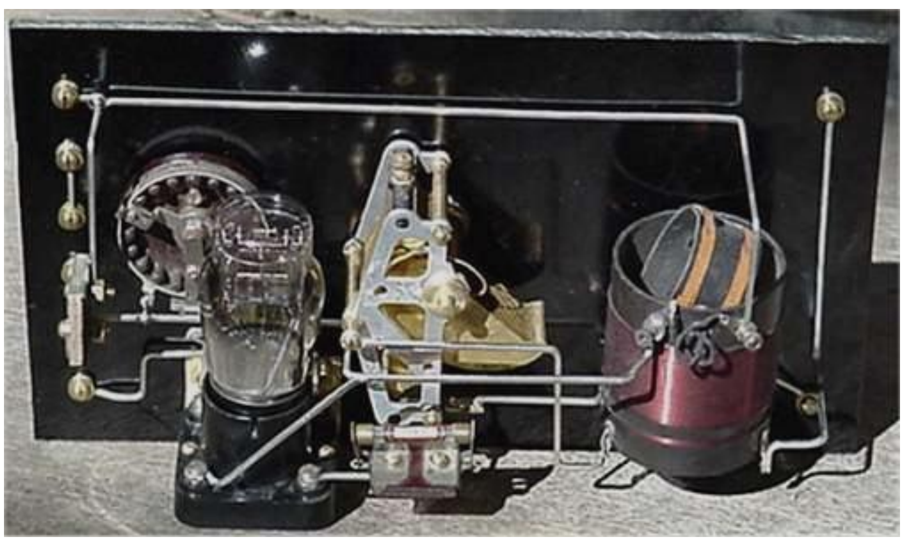

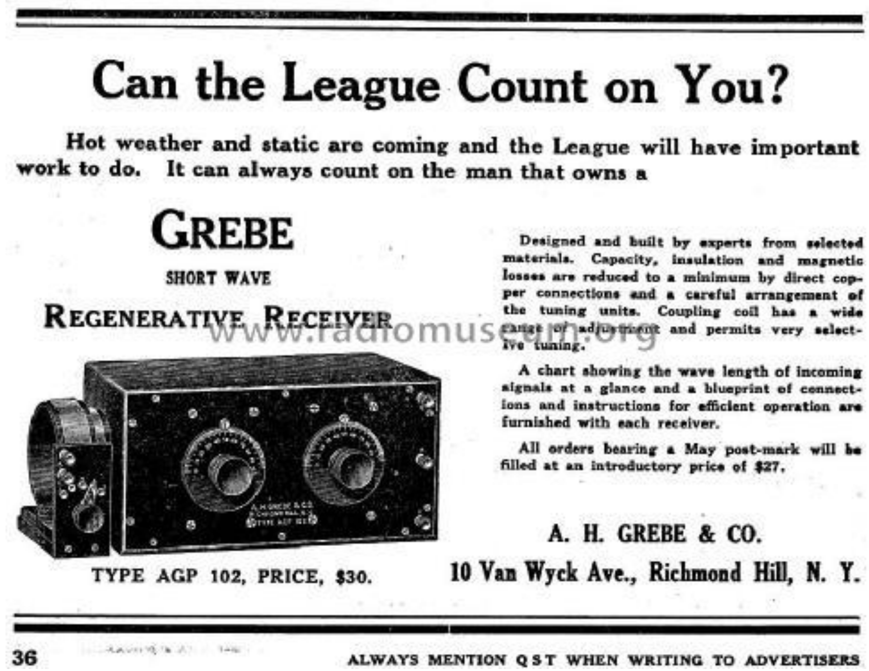

Can the League Count on You?

Hot weather and static are coming and the League will have important work to do. It can always count on the man that owns a

GREBE
SHORT WAVE
REGENERATIVE RECEIVER

TYPE AGP 102, PRICE, $30.

Designed and built by experts from selected materials. Capacity, insulation and magnetic losses are reduced to a minimum by direct copper connections and a careful arrangement of the tuning units. Coupling coil has a wide range of adjustment and permits very selective tuning.

A chart showing the wave length of incoming signals at a glance and a blueprint of connections and instructions for efficient operation are furnished with each receiver.

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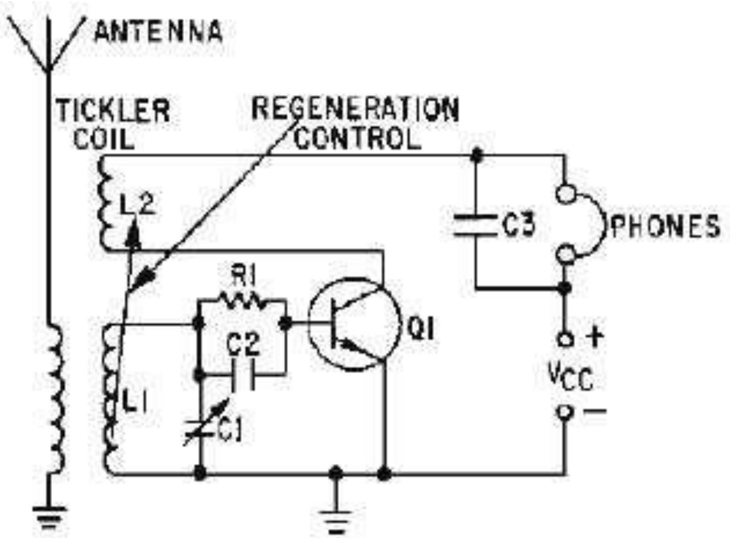

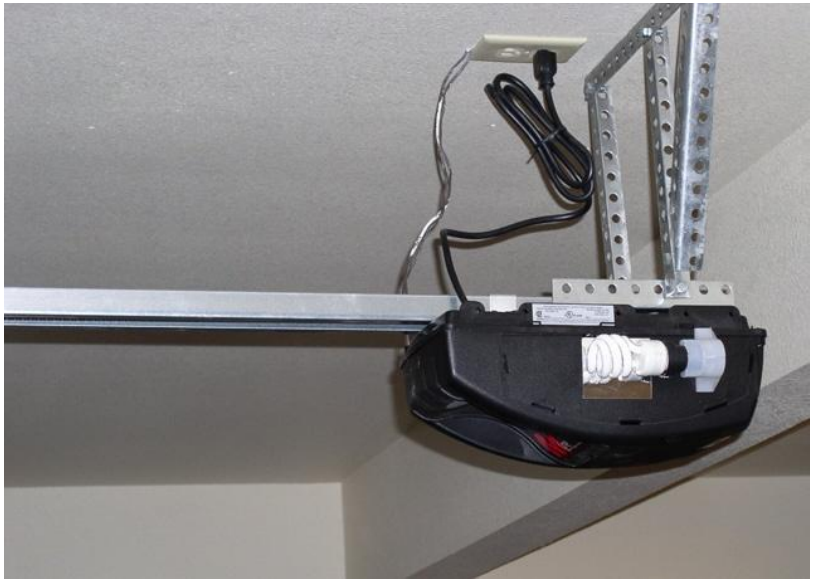

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The Superheterodyne Receiver

- In 1918 **Major Edwin Armstrong** developed the **Superheterodyne receiver** to correct the problems of the TRF radio.
- It **mixes an incoming signal** with a **locally generated RF signal** to produce an **Intermediate Frequency (IF).**
- That IF is then **amplified, detected** and turned into **sound.**
- The Superhet is still the **most popular form of receiver,** accounting for 99% or more!

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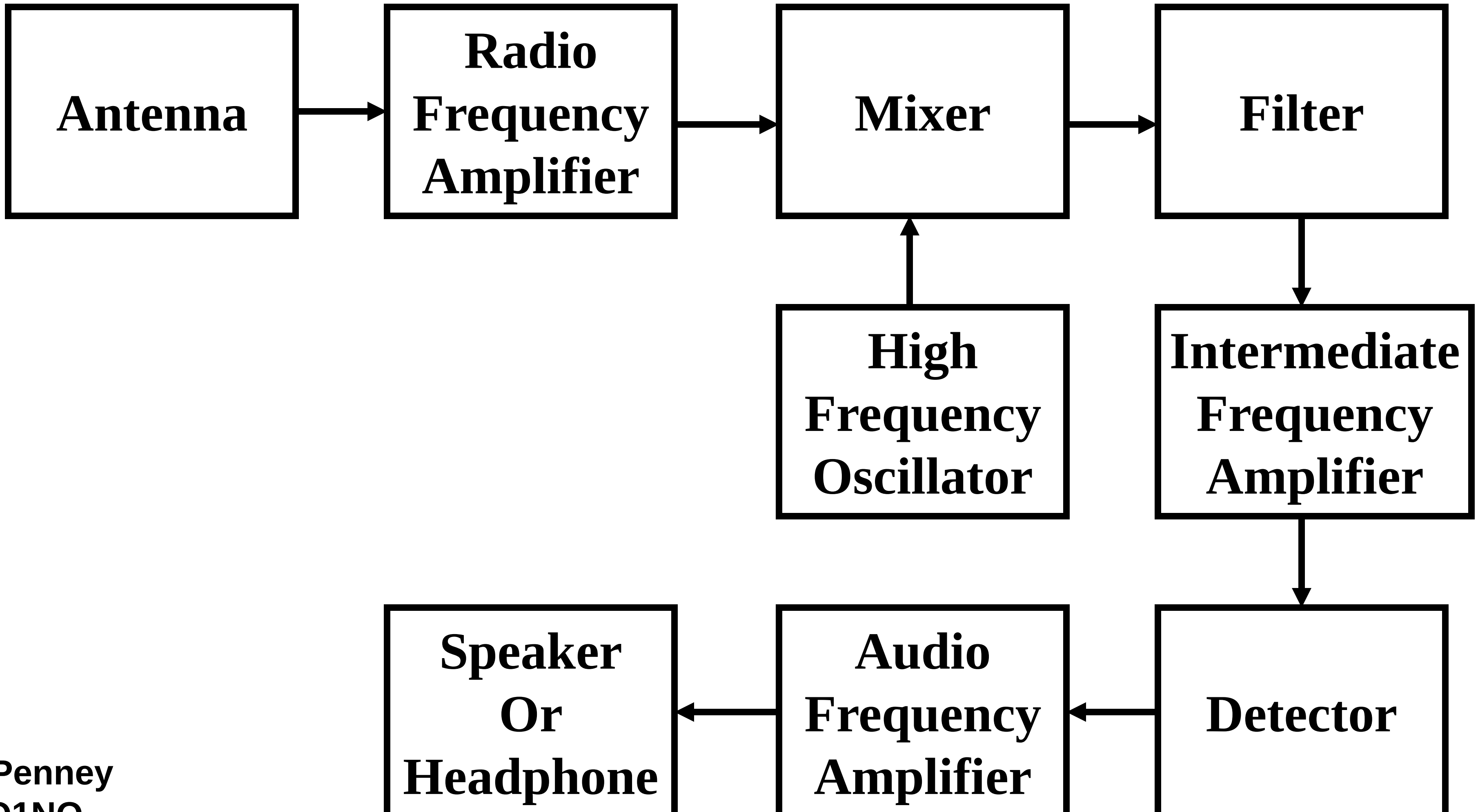
Superheterodyne Receiver



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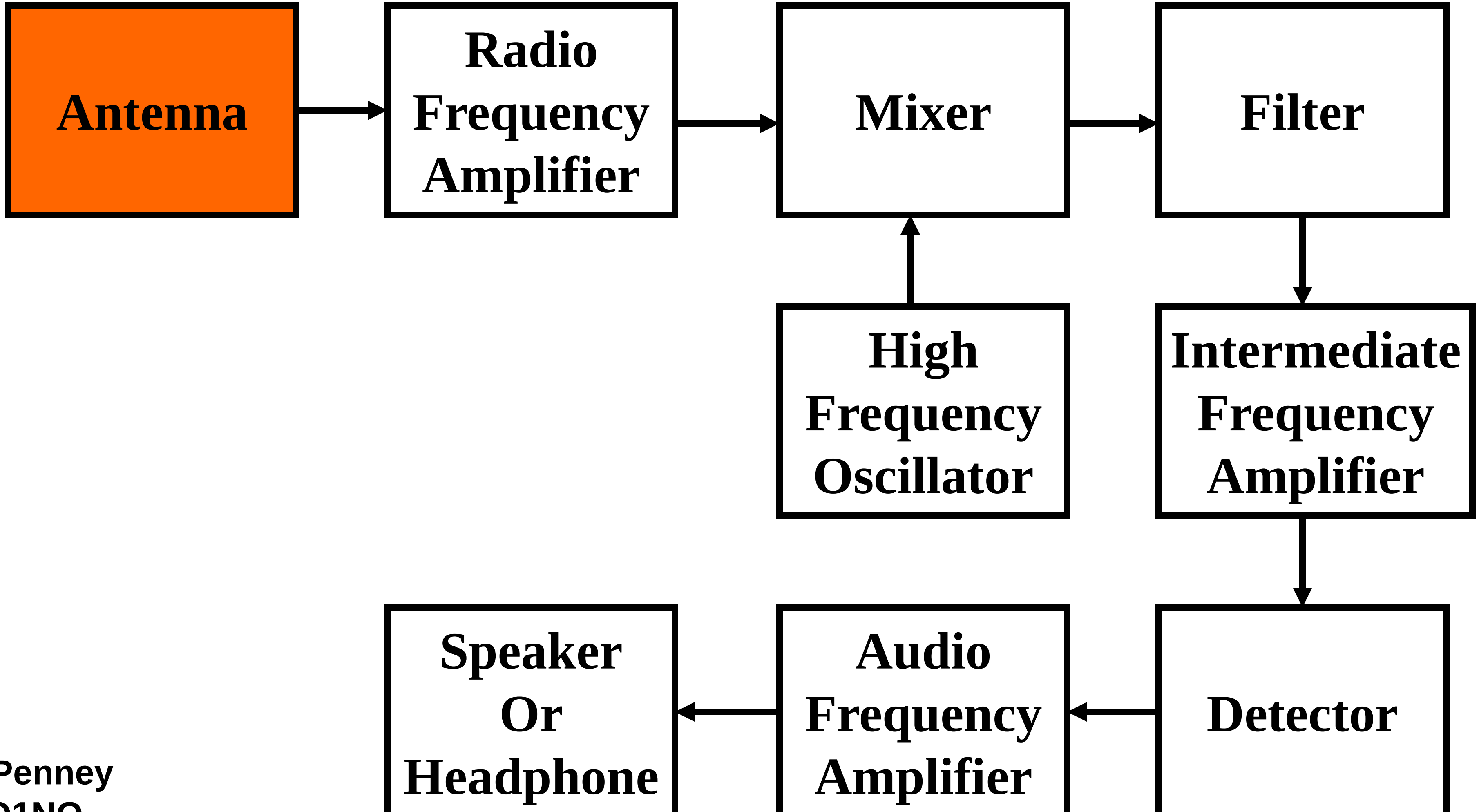
Superheterodyne Receiver



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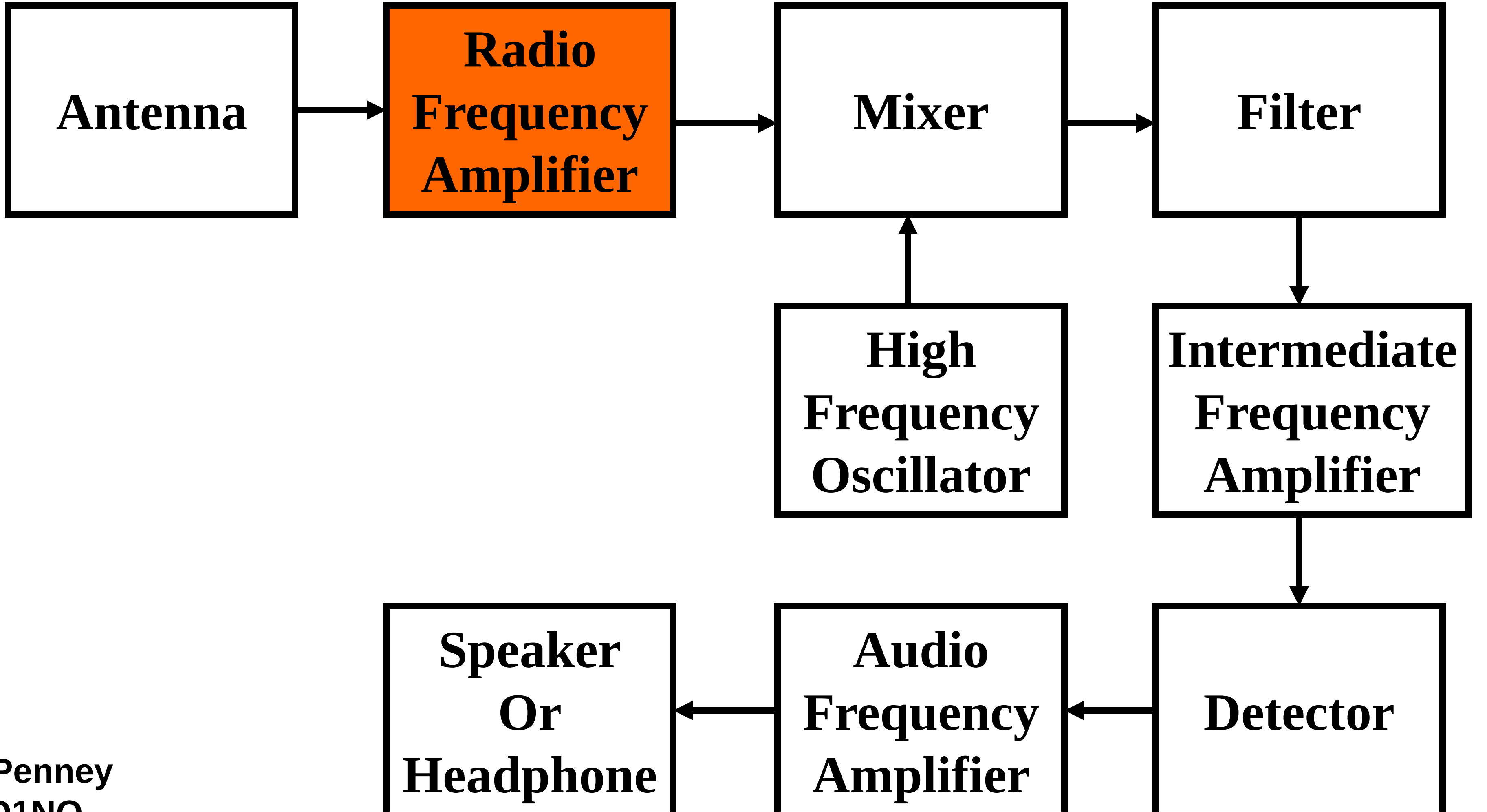
Antenna

- While technically the **antenna** picks up a **wide range of frequencies,** in practice some antennas are more **narrow-banded.**
- **Resonant antennas** eg: a half-wave dipole, are better able to pick up signals around their **design frequency.**
- **Non-resonant antennas** eg: Rhombics, can be used over a much **broader frequency range.**

Superheterodyne Receiver



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Radio Frequency Amplifier

- The **RF amplifier** takes the **weak signals** from the antenna and **amplifies them.**
- This is usually a **fairly broadband amp.** In better radios it consists of a **number of separate modules** that cover individual bands. These modules would be selected automatically as the radio is tuned.
- **Older radios** had a **manually tuned continuous preamplifier.**
- This stage does have **tuned circuits** to help **reject strong out-of-band signals** that could cause **Cross Modulation.**

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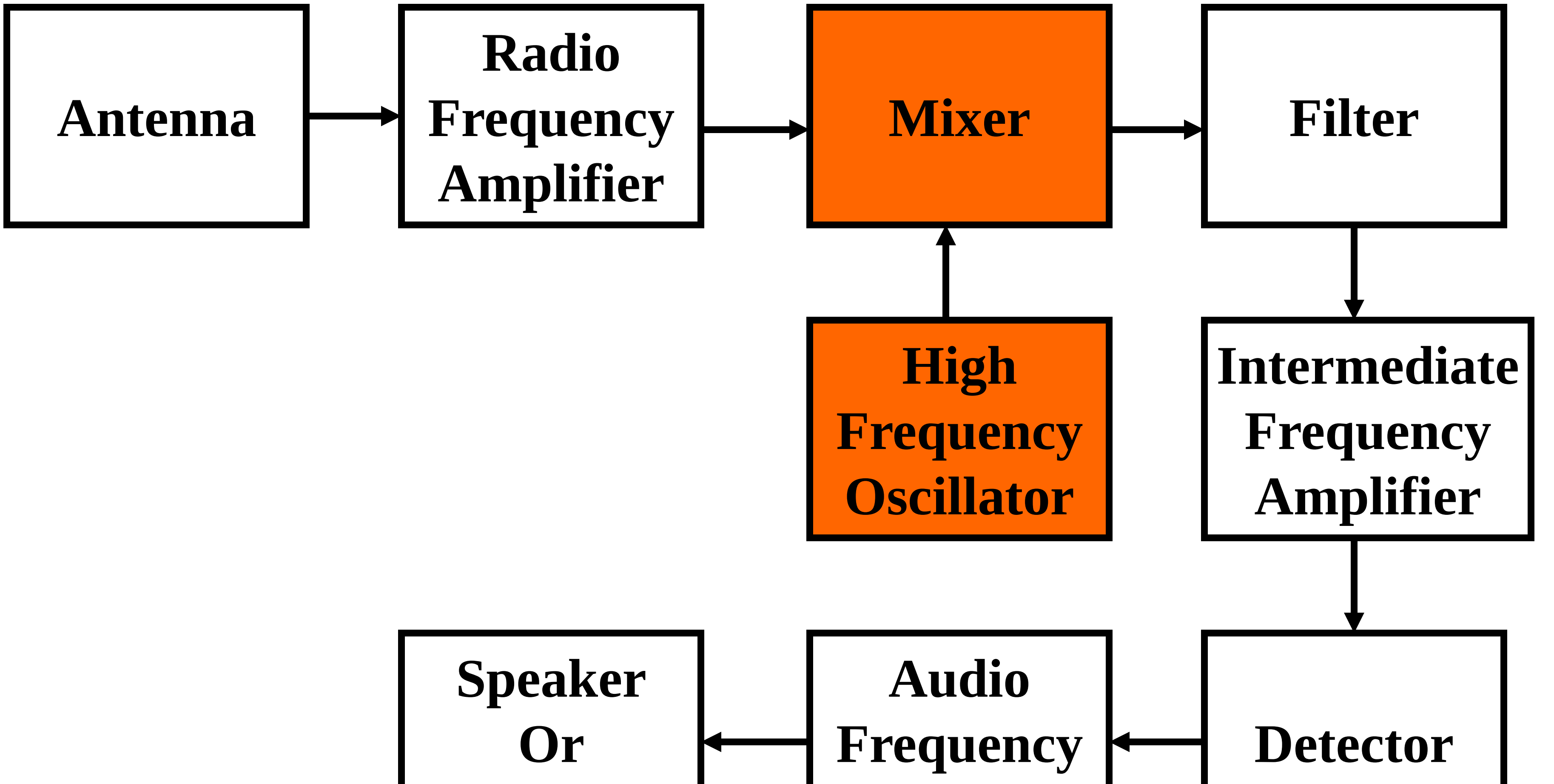
Superheterodyne Receiver



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HF Oscillator and Mixer

- The **HF Oscillator,** more usually called the **Local Oscillator,** generates an **RF signal** that is **higher or lower** than the desired receive frequency by an amount called the **Intermediate Frequency.**
- It **mixes** with the signal from the **RF Amp** inside the **Mixer.**
- **Output** from the mixer is **the sum and difference** of the two signals.
- One of those two signals is the **Intermediate Frequency.** The choice is an engineering decision.

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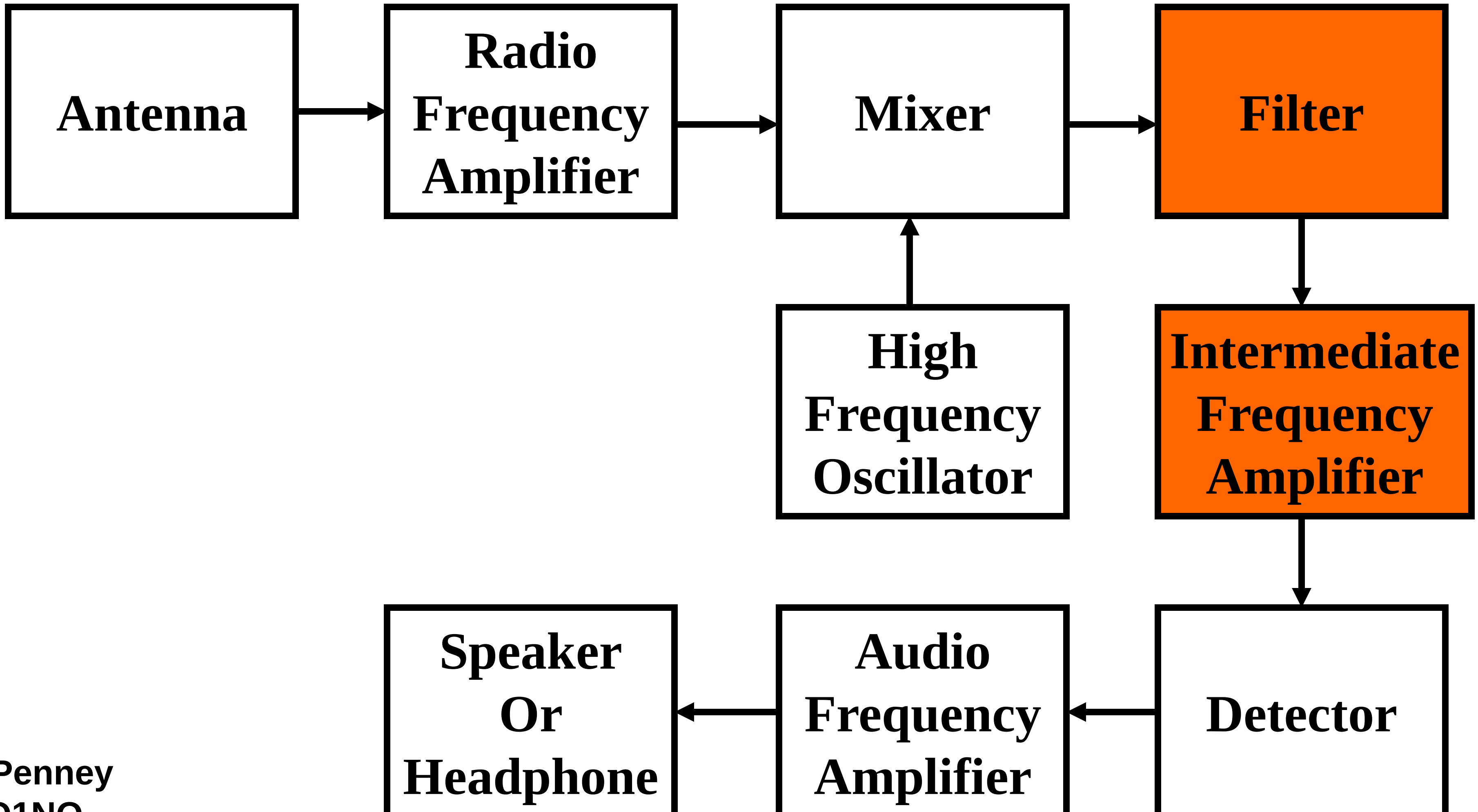
Superheterodyne Receiver



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Filter and IF Amplifier

- The **Filter** can be **mechanical, crystal or ceramic.** Newer radios employ a **synthetic filter** using **Digital Signal Processing (DSP)** techniques.
- It **filters out** not just the non-IF signal, but is also the **primary location** where **selectivity** is obtained.
- The IF Amp **can** consist of **several stages that amplifie the IF signal.** Because the IF has been pre-defined by the receiver's design, the **IF amp does not need to be tuned** after calibration by the manufacturer.
- A total of 40 – 80 dB gain.

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Receiver Filters

- **Receivers** often have **several filters** that can be switched in as **required by the mode.**
- Examples of the **filter widths** and the usual mode they would be used for are:
  - 250 Hz CW (for severe interference)
  - 500 Hz CW (for more relaxed conditions)
  - 2.4 kHz SSB
  - 6 kHz AM, possibly SSB if band is not busy

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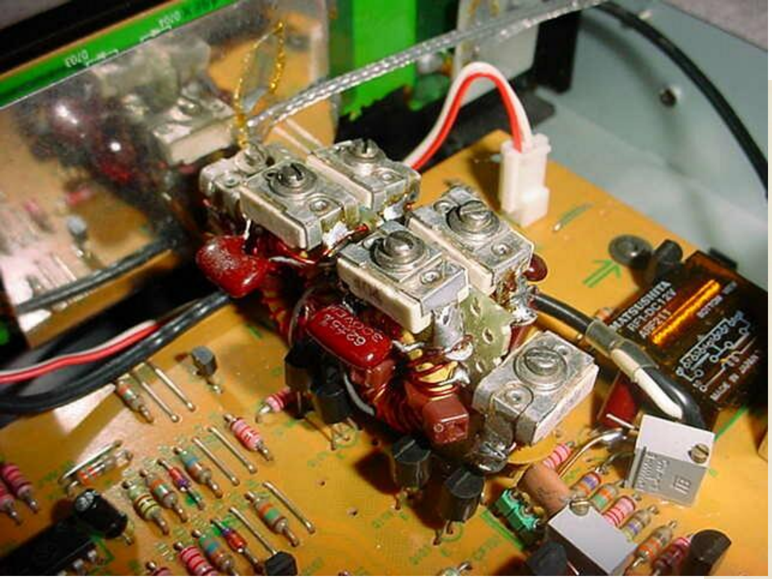

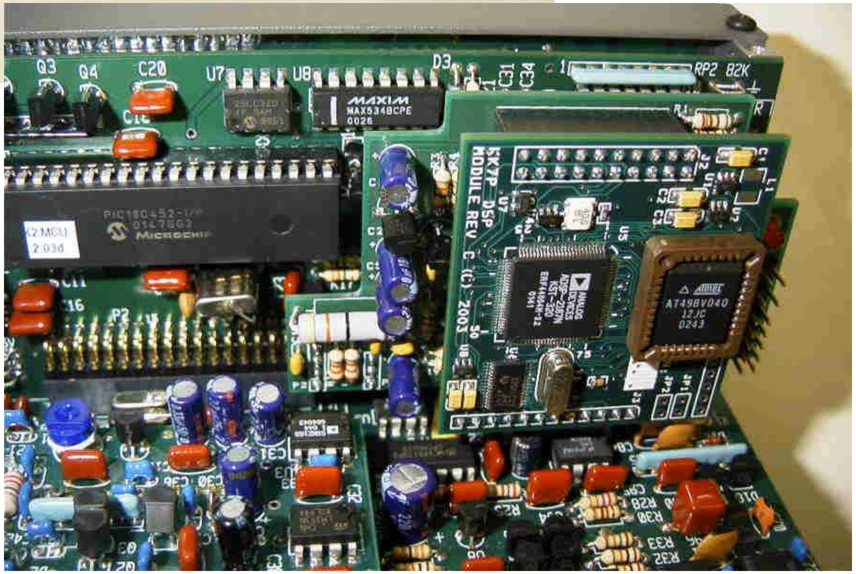

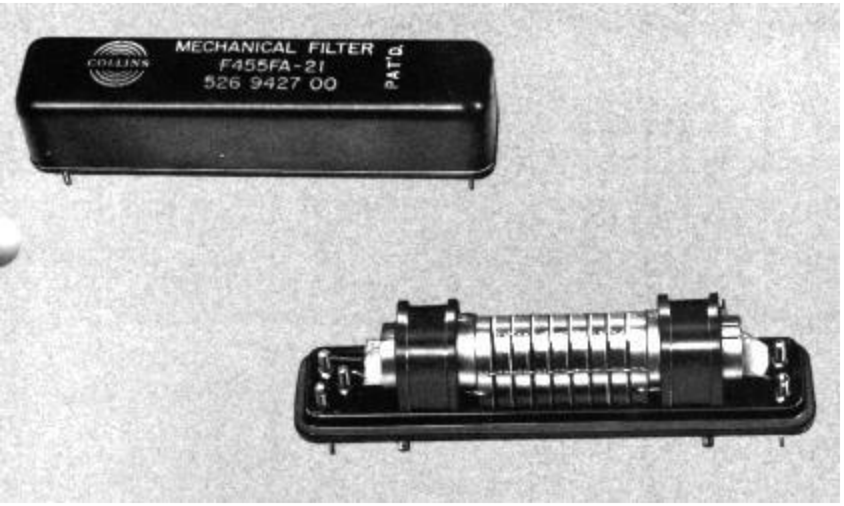

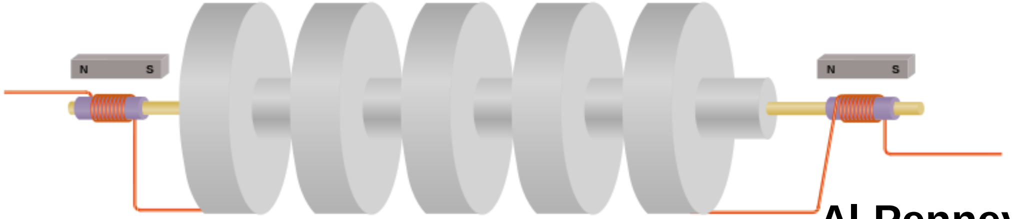

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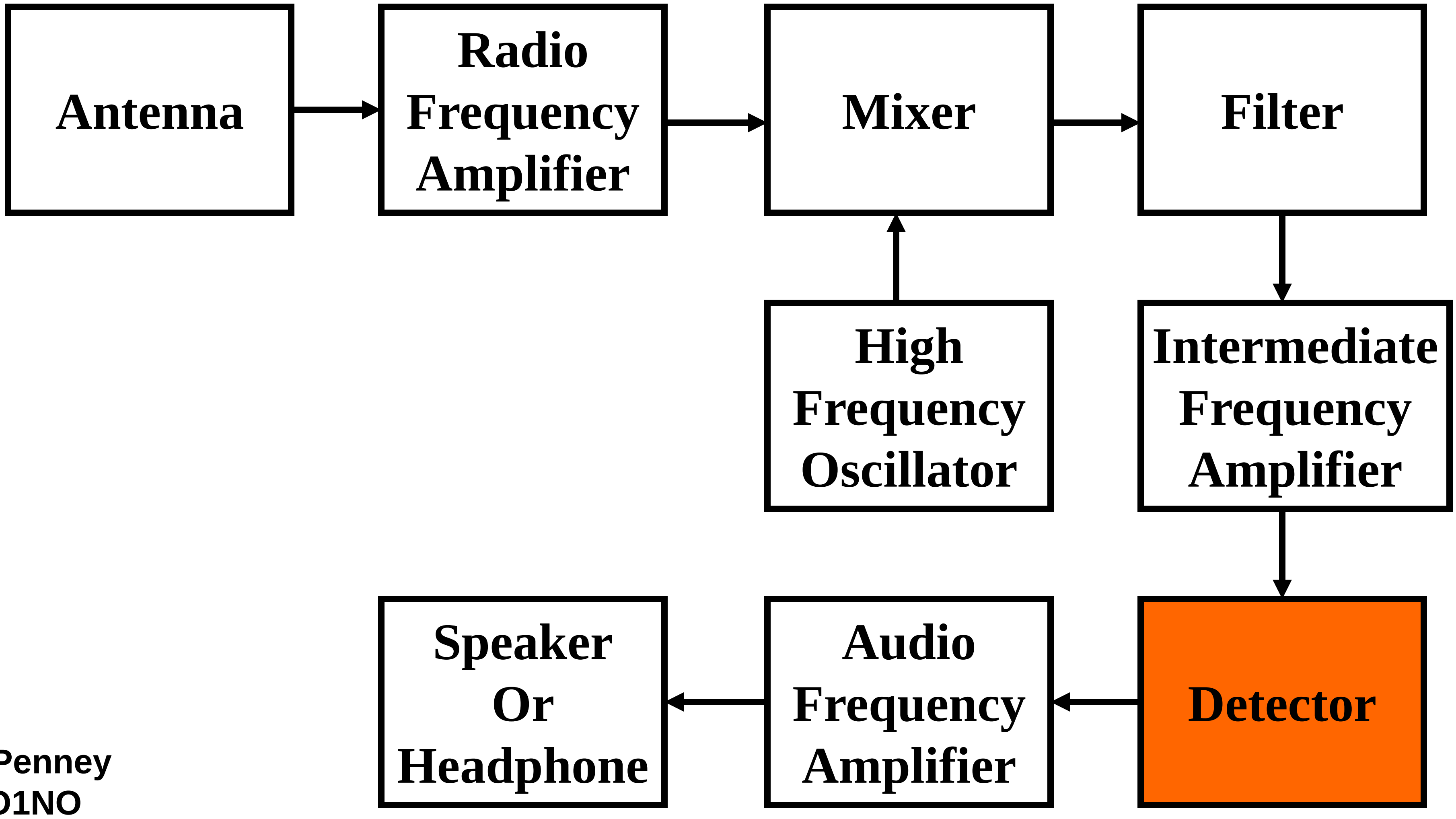
Superheterodyne Receiver



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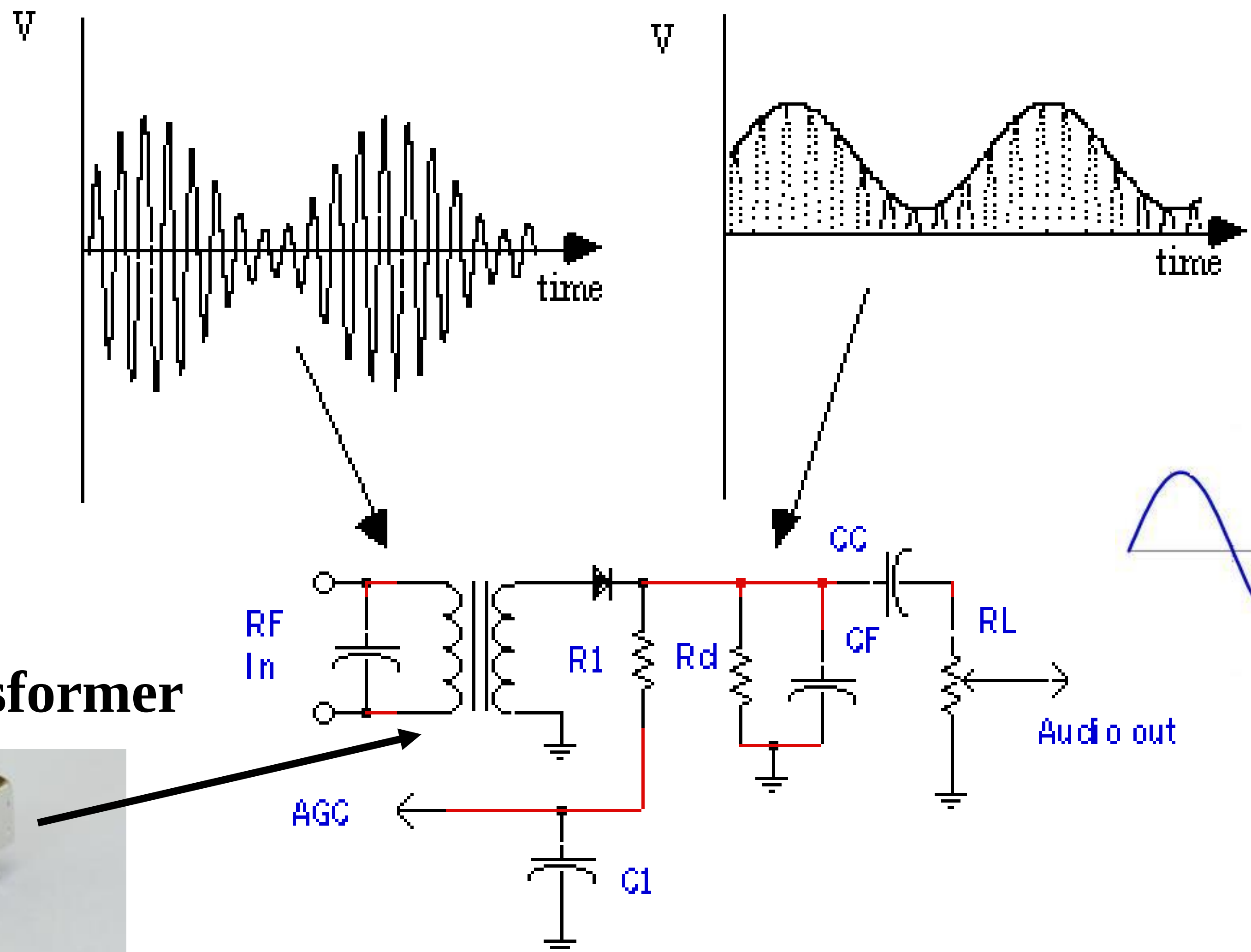
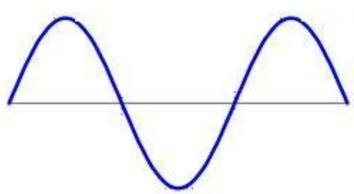
Detector Stage

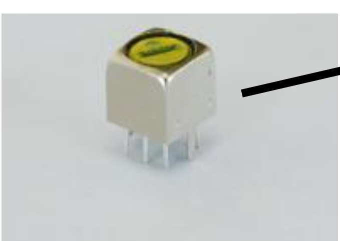
- The **amplified IF signal** is sent to the **Detector**, where it is **rectified** and the **RF filtered out.**
- This leaves only a **weak audio signal** which is sent to the **AF amplifier** before going to the **speaker or headphones.**

AM Demodulation





IF Transformer



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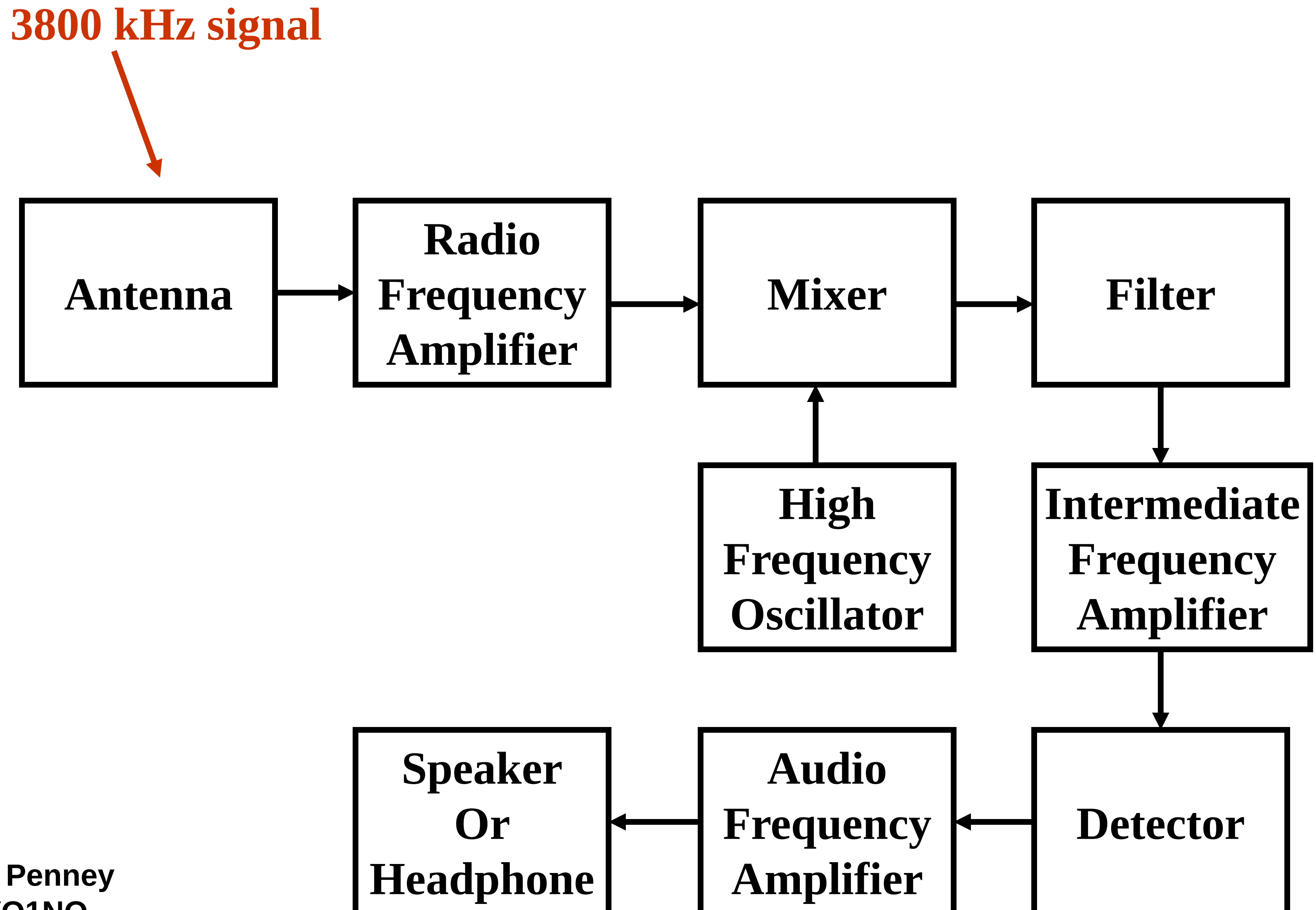
Superhet Example

- In order to better illustrate how a Superhet receiver works, let's look at an example of how the **frequency conversion process** operates.
- We want to receive a signal on **3.8 MHz (3800 kHz)**
- Assume our receiver has an **IF of 455 kHz.**



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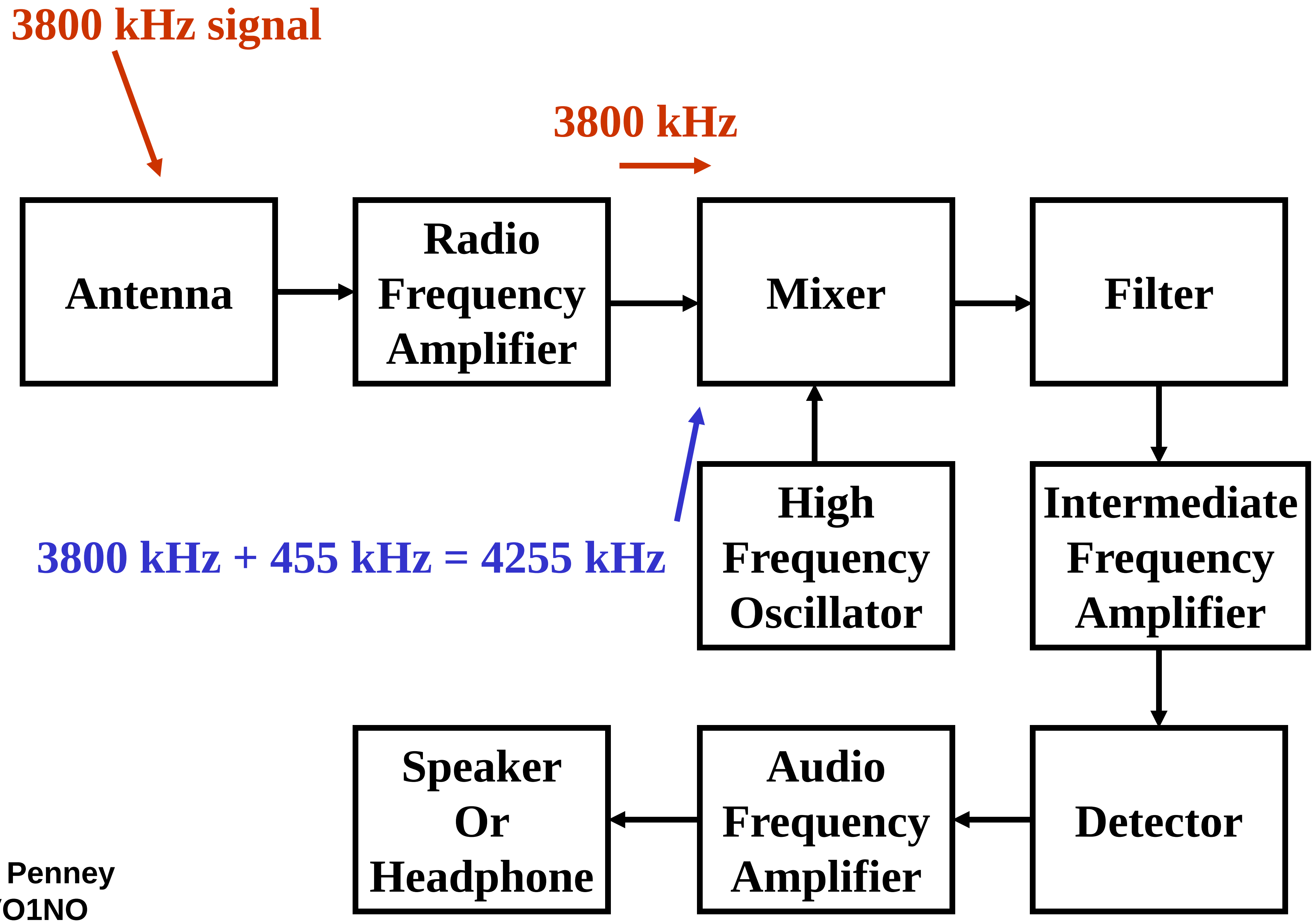

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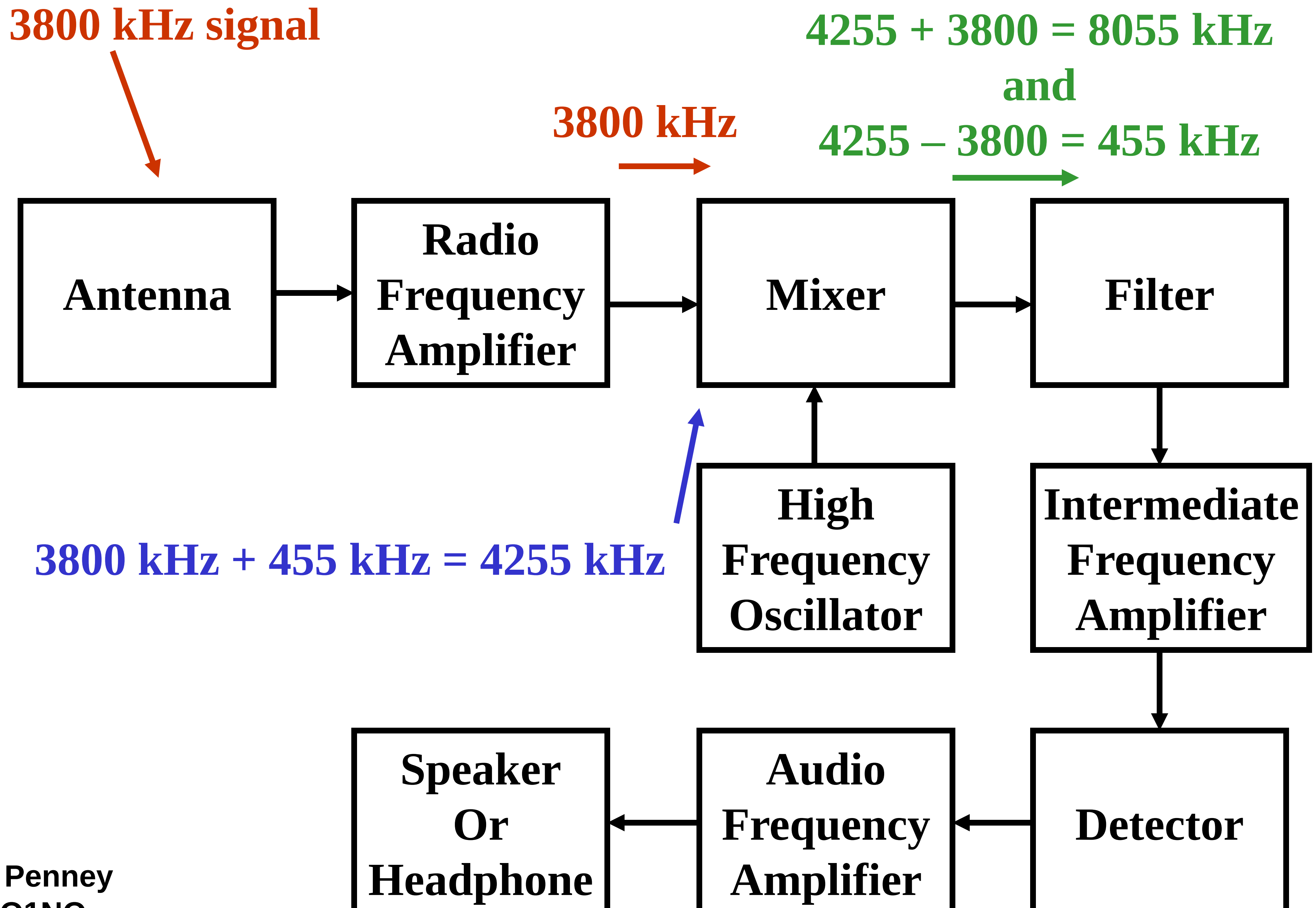

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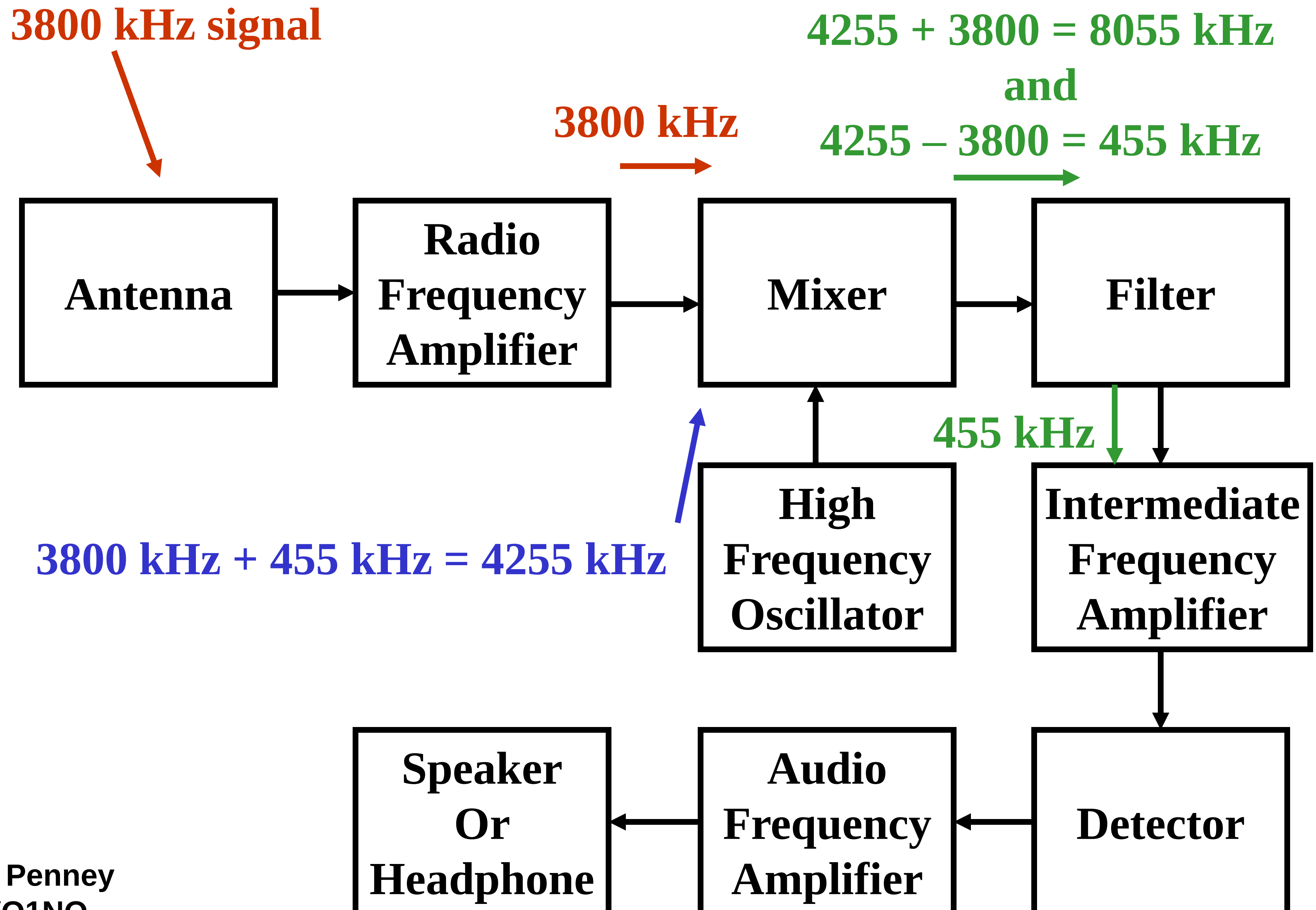

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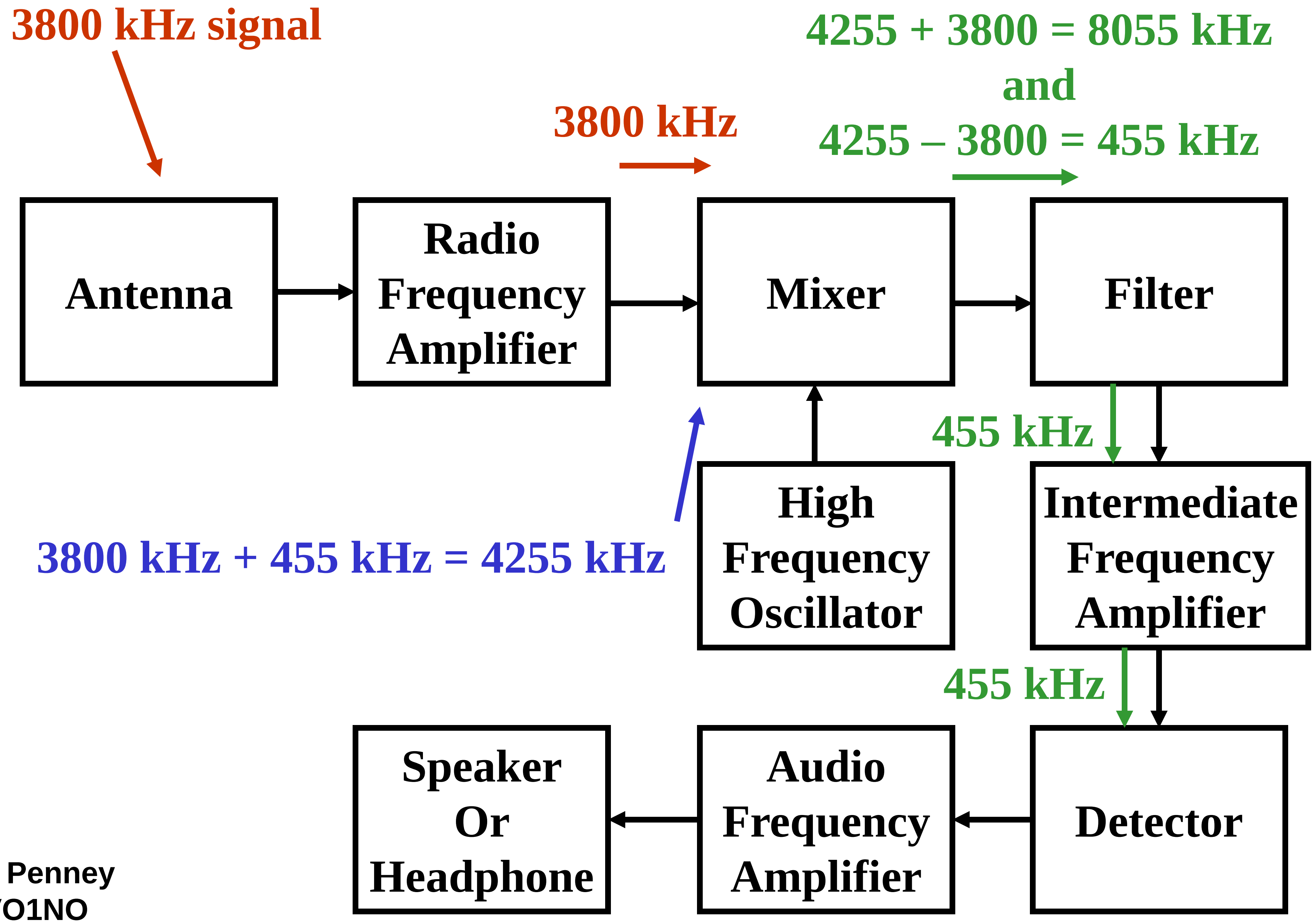

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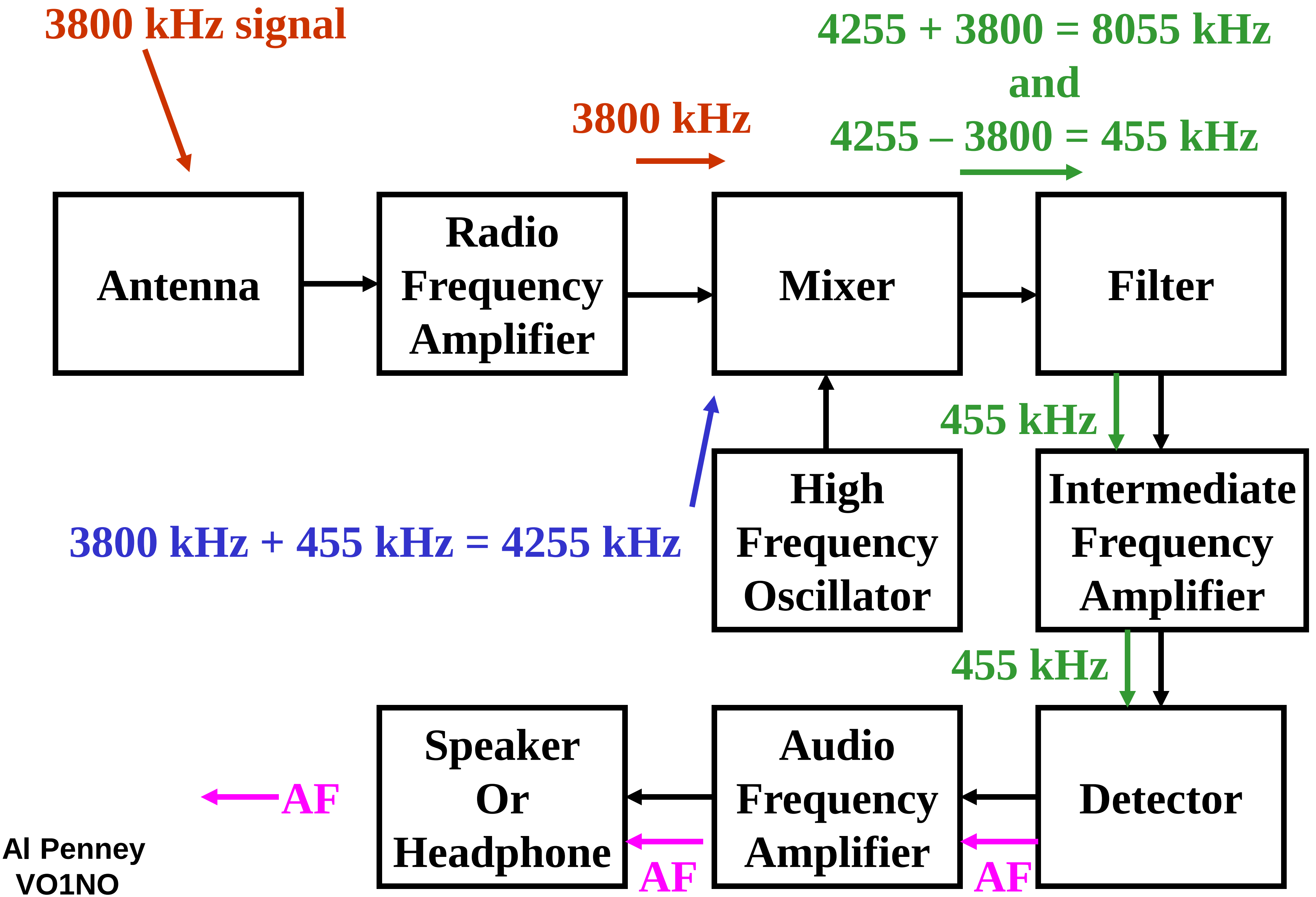
3800 kHz signal
4255 + 3800 = 8055 kHz
and
4255 – 3800 = 455 kHz
3800 kHz
Antenna
Radio Frequency Amplifier
Mixer
Filter
455 kHz
High Frequency Oscillator
Intermediate Frequency Amplifier
3800 kHz + 455 kHz = 4255 kHz
455 kHz
Speaker Or Headphone
Audio Frequency Amplifier
Detector
AF
AF
AF
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Advantages of the Superhet

- Much **more sensitive, selective** and **stable** than TRF radios.
- By **converting higher frequencies** to the **IF**, we are able to design much **more selective and sensitive filters and amplifiers** that use **more reliable components.**
- Much **easier** to use.

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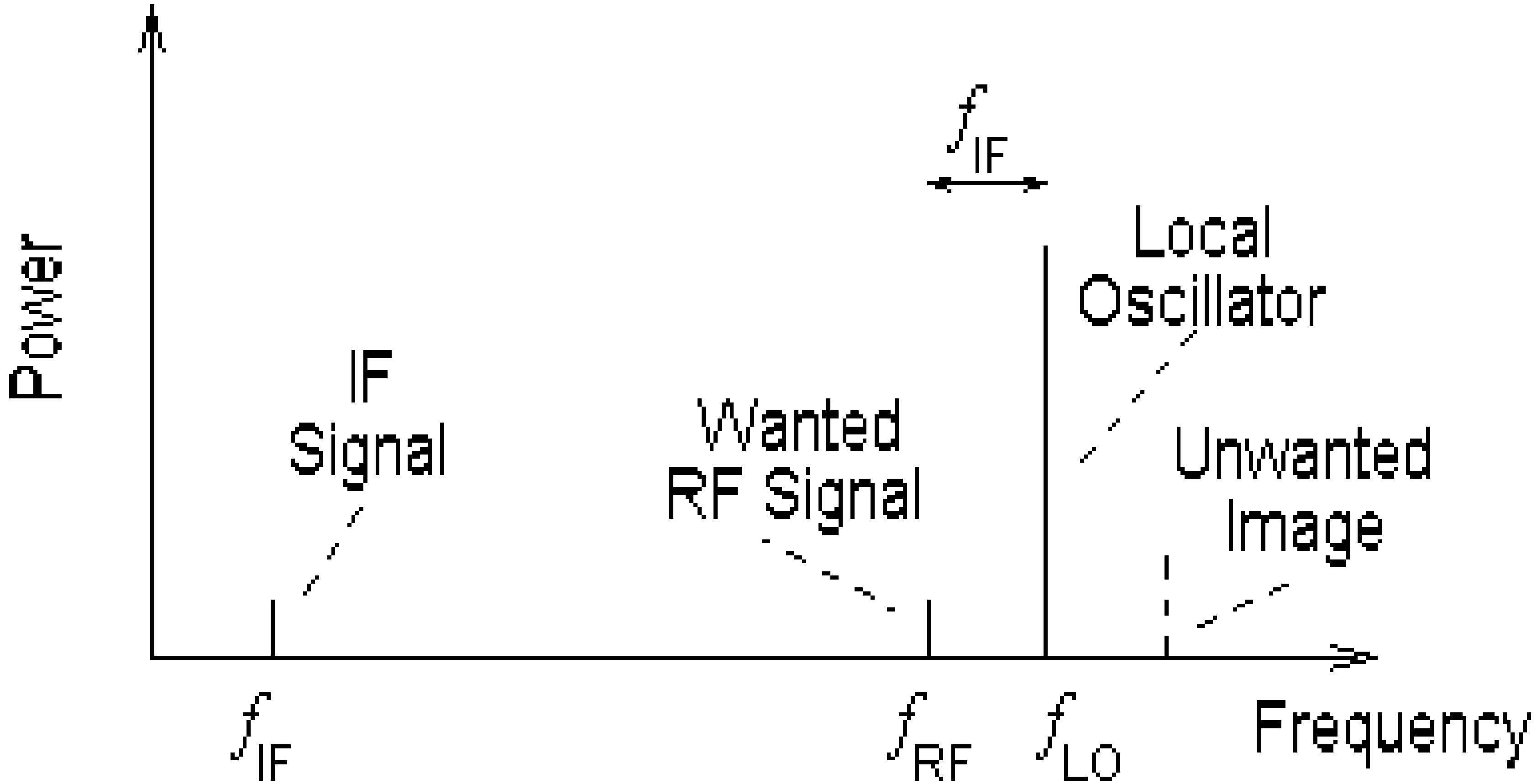
Primary Disadvantage

- Superhets have **one big problem** however – they are subject to receiving **images,** or stations that are **not actually on the frequency** we are listening to.
- This occurs when a **station is transmitting** on a frequency **twice the IF** away from the **desired frequency.**



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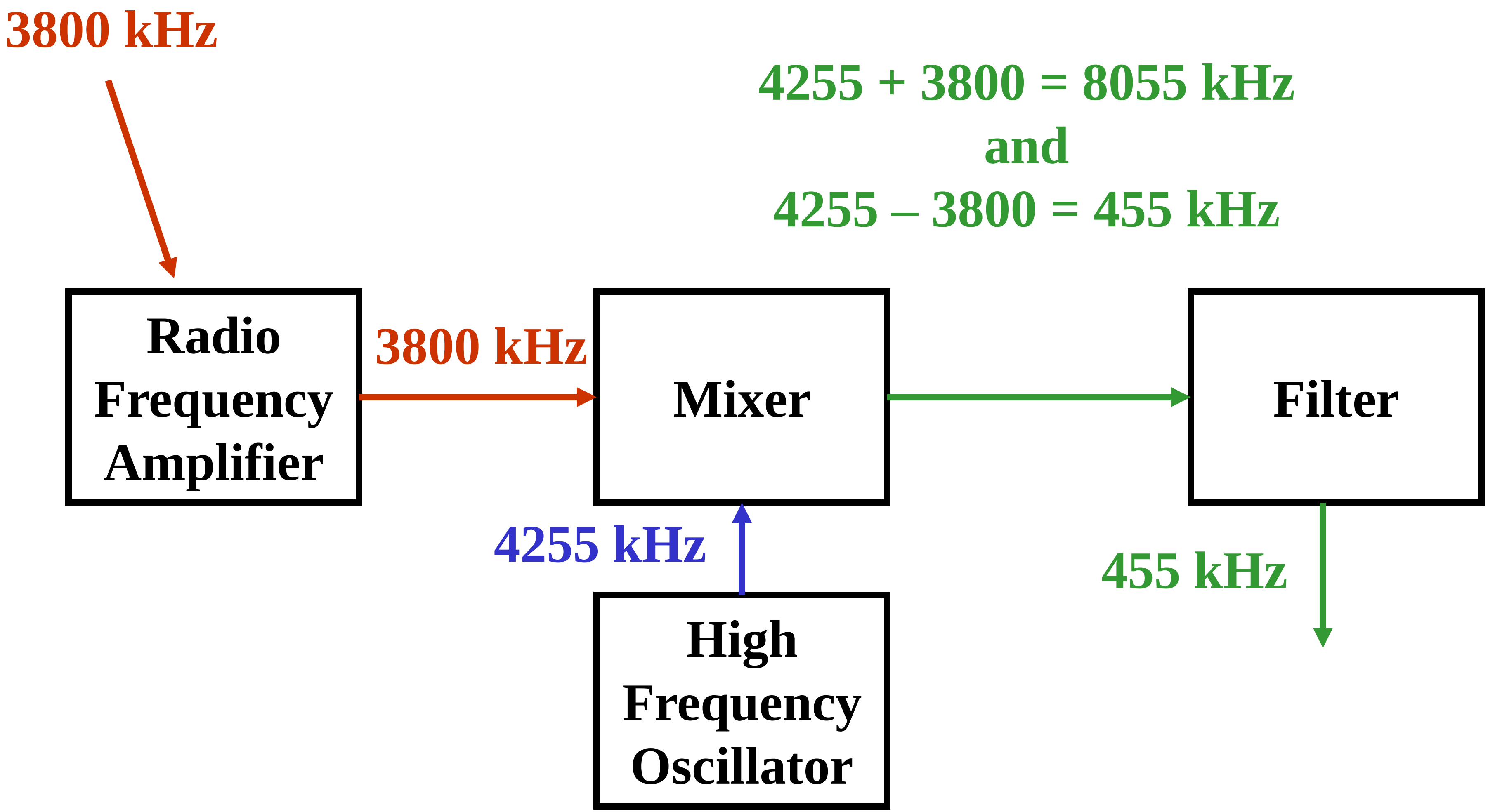
No Image



3800 kHz + 455 kHz = 4255 kHz

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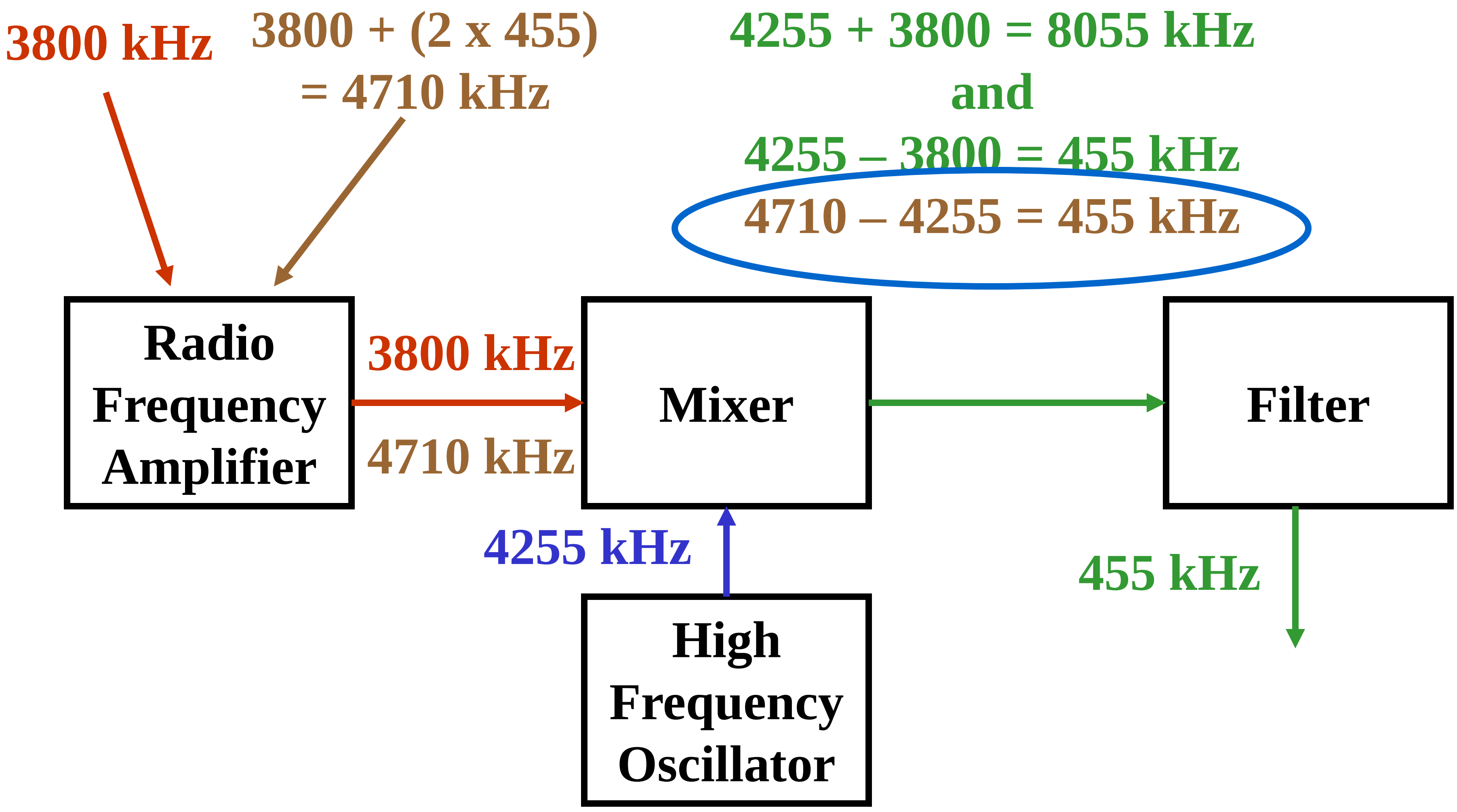
Image



3800 kHz + 455 kHz = 4255 kHz

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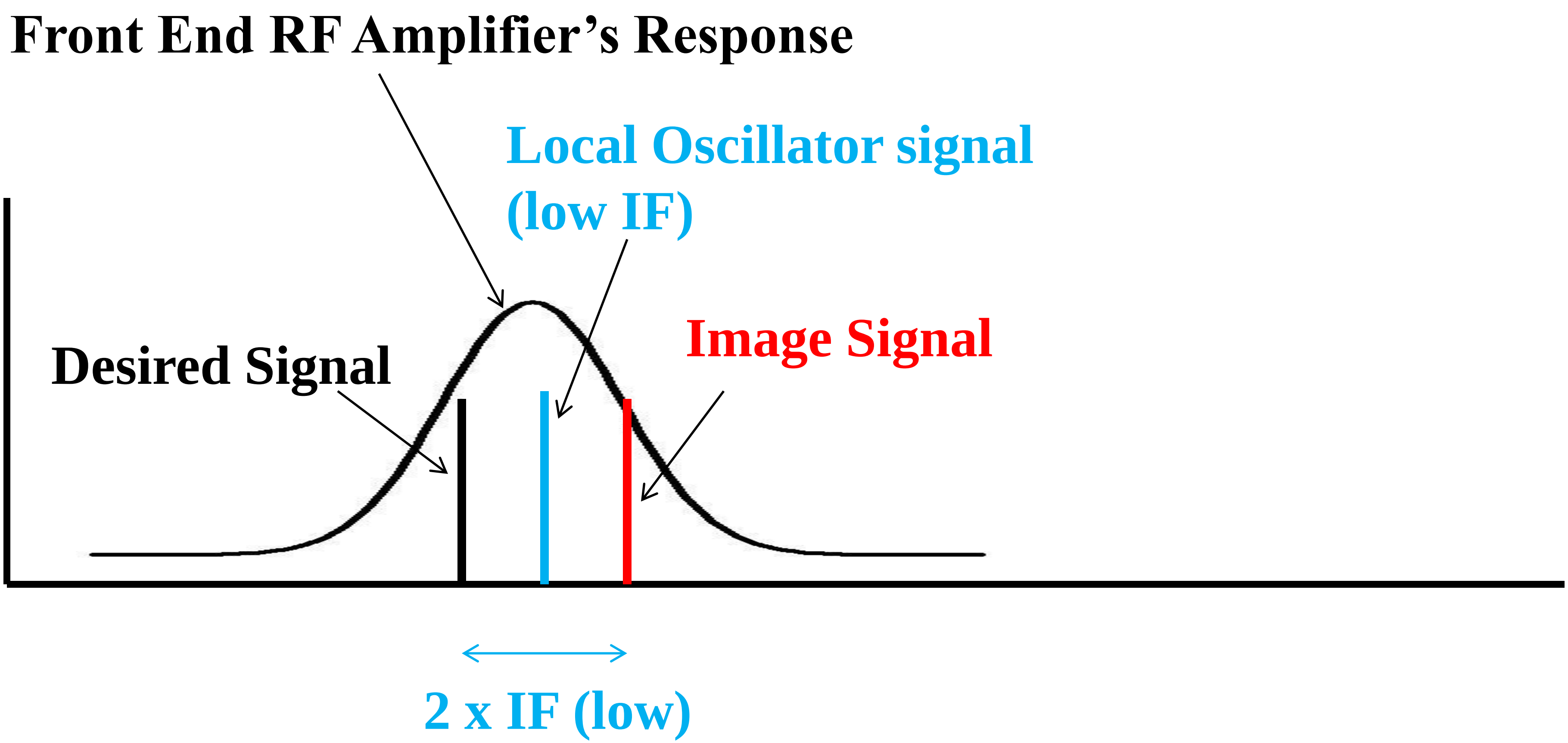
The Solution!

- More expensive superhets employ **double or triple conversion** to improve **image rejection.**
- The **first IF** is chosen so that it is **larger than the bandwidth** of the **bandpass filters** in the front end of the receiver, and so the image **not make it to mixer stage.**
- The **first IF** signal is then **amplified,** and **converted** again to a **lower IF** to take advantage of the **greater selectivity** available at lower Intermediate Frequencies.

Advantages of a High First IF



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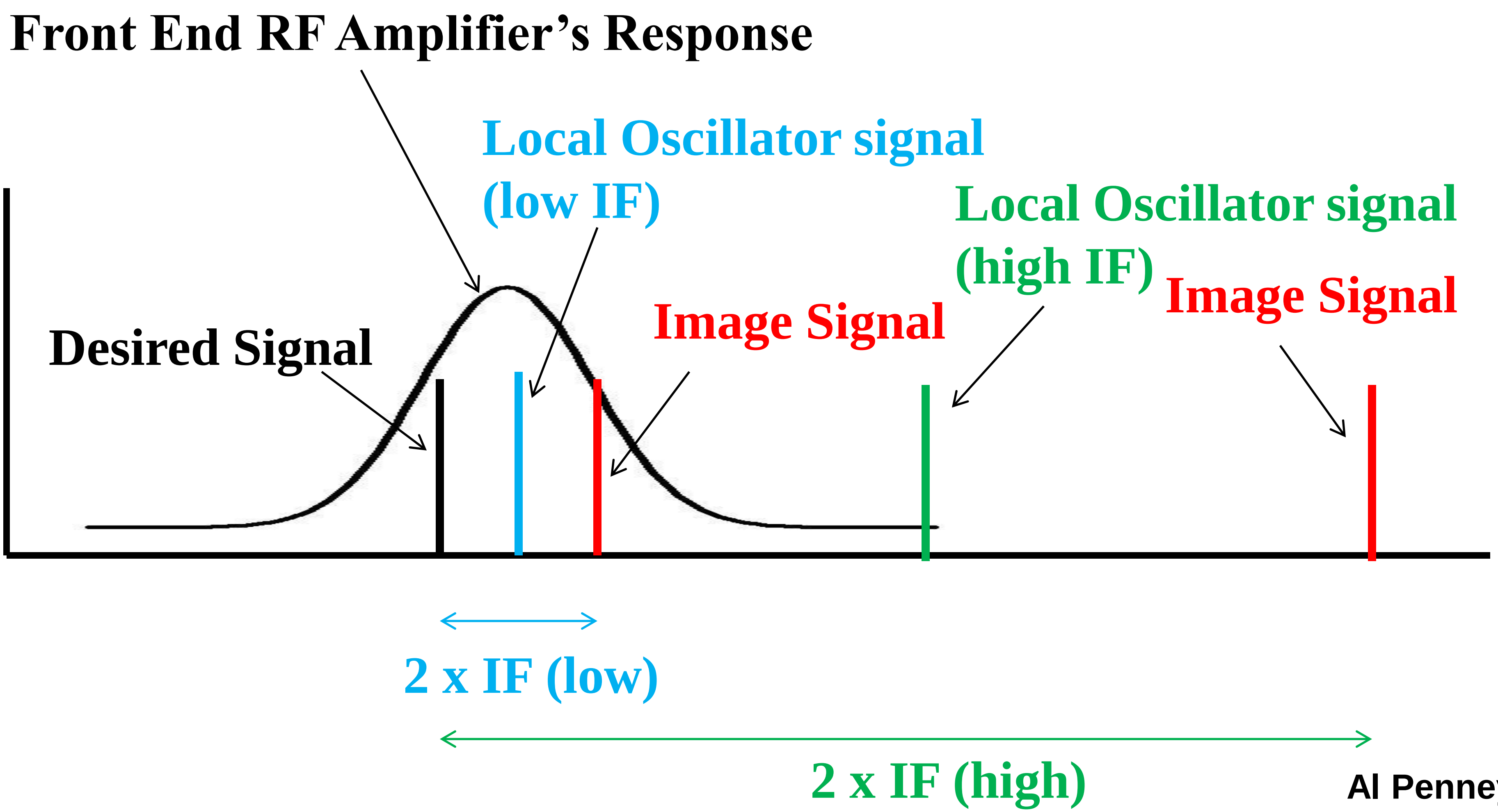
Advantages of a High First IF



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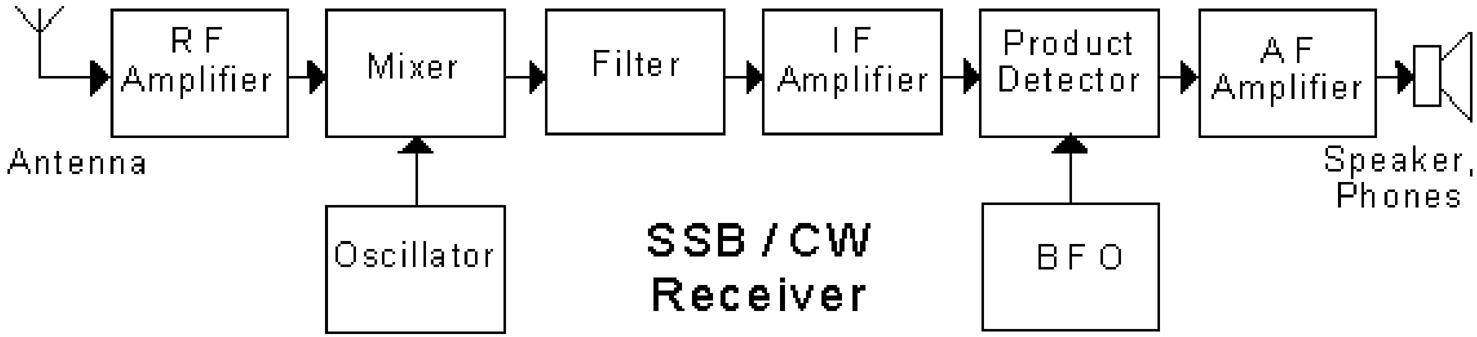
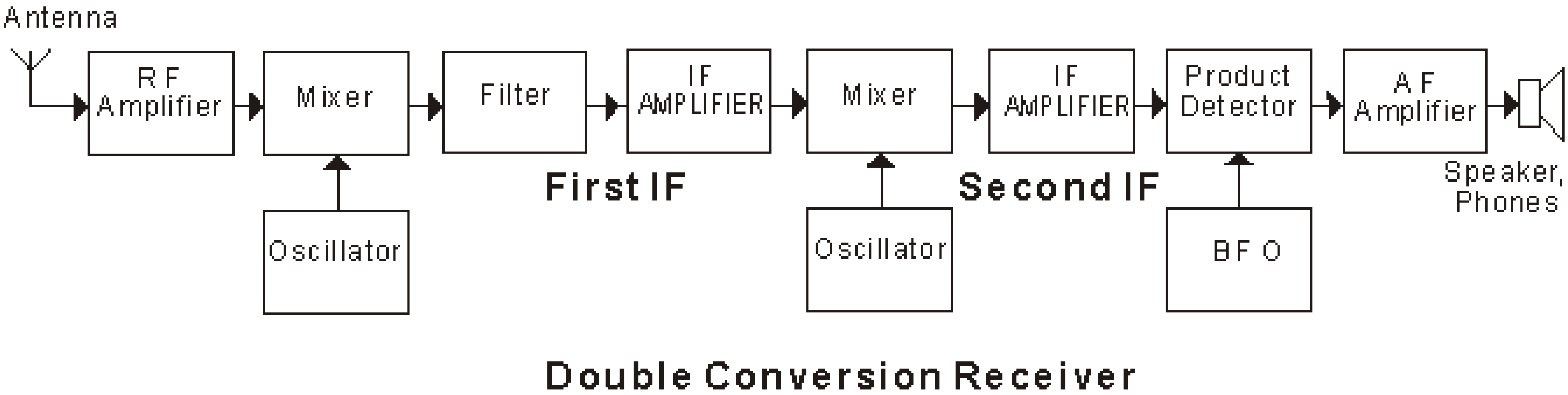
Single versus Dual Conversion Superhet Receiver





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FM Receiver

- The **FM receiver** is very similar to an AM receiver up to the IF Amplifier.
- Instead of a Detector however, the FM receiver uses two different stages:
  - **Limiter**
  - **Frequency Discriminator**

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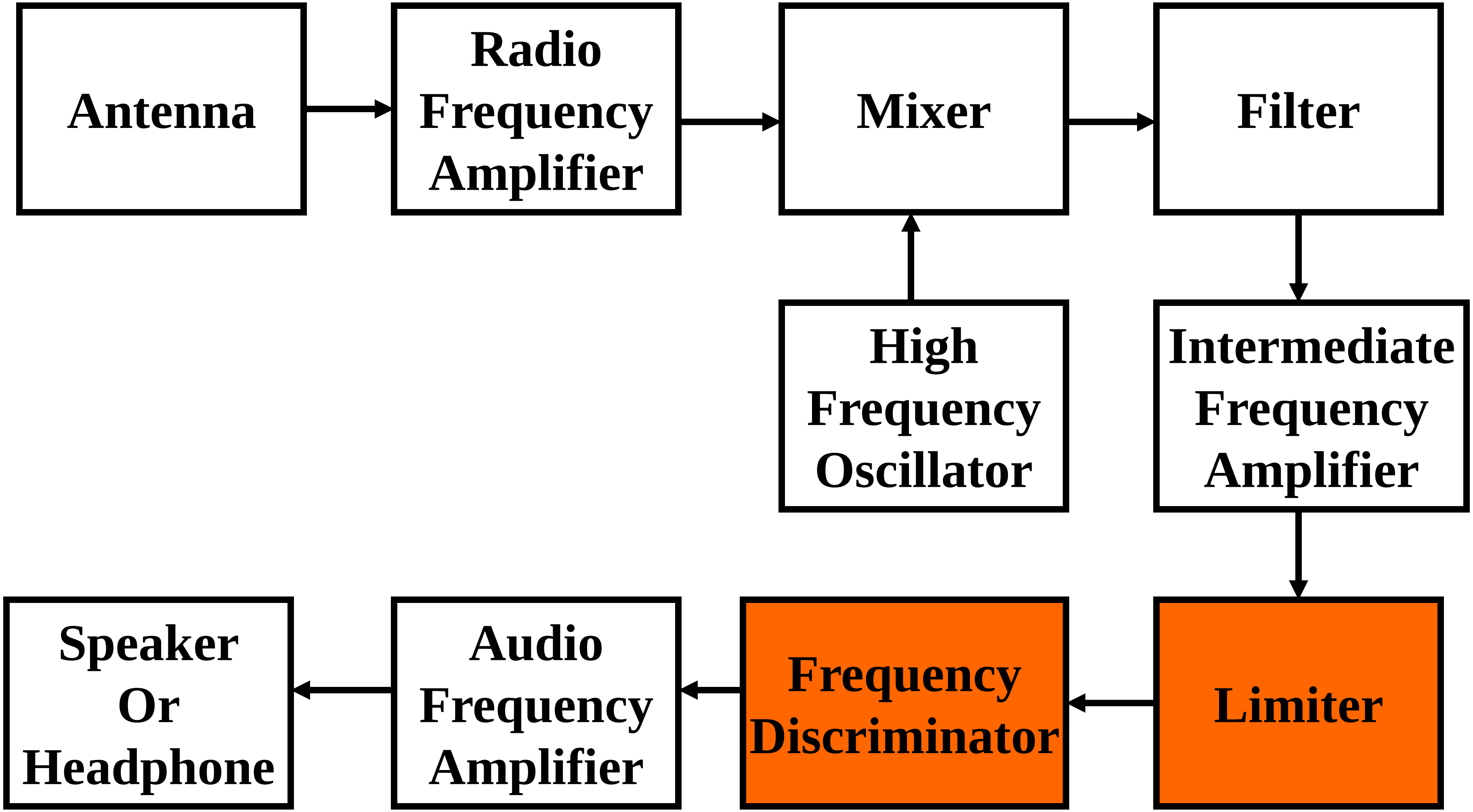
FM Receiver



Limiter

- The **Limiter Stages** are **high gain amplifiers** that **remove all traces of Amplitude Modulation** from the received signal.
- **Static crashes** are mostly **amplitude modulated,** and so are removed by the Limiter.
- This gives FM its greatest benefit – a very high **SNR – Signal to Noise Ratio.**

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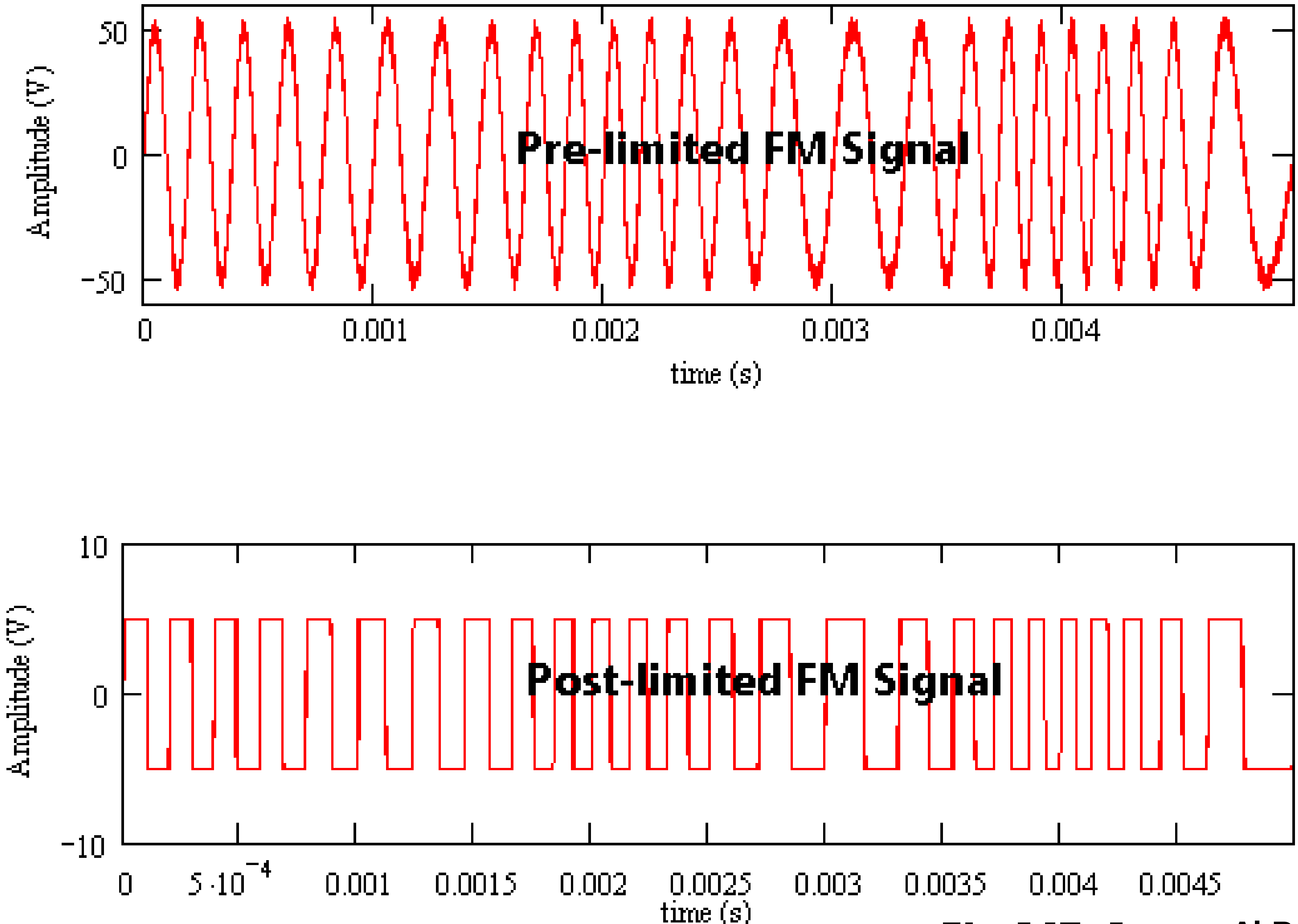

Fig M7-6

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Frequency Discriminator

- The **Frequency Discriminator** converts **frequency variations** into **voltage variations.**
- This is fed to the **Audio Frequency Amplifier** and then the **speaker or headphones.**

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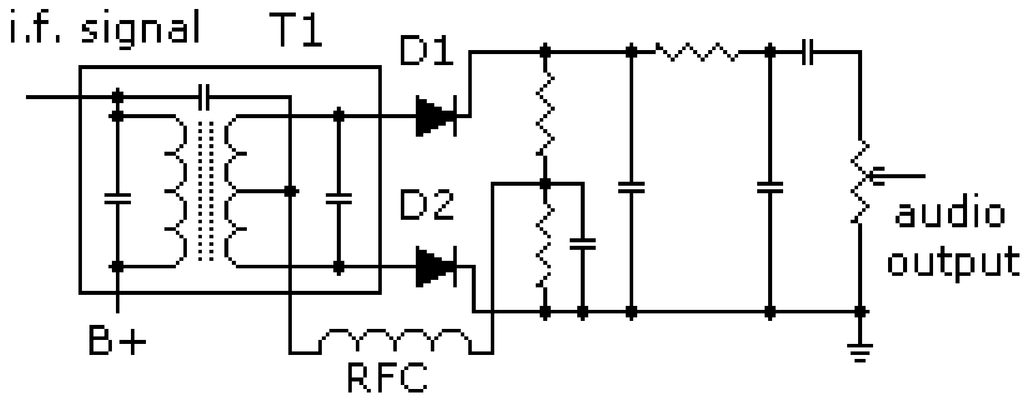
Frequency Discriminator

Common types include :

- Foster-Seeley Detector
- Ratio Detector
- Quadrature Detector
- Slope detector
- Phase-locked Loop



Foster-Seeley Detector

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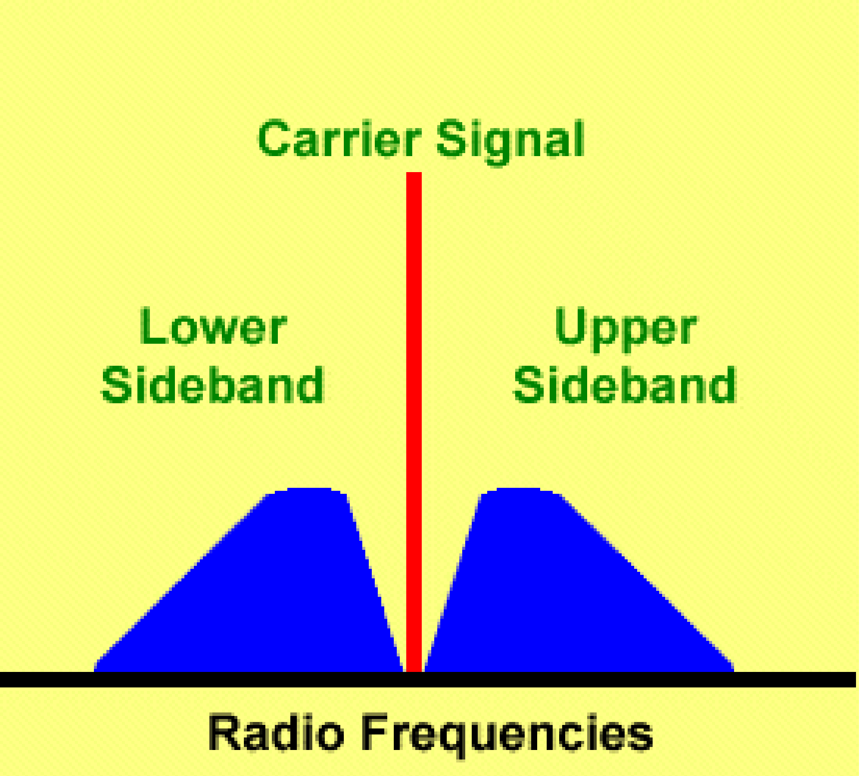
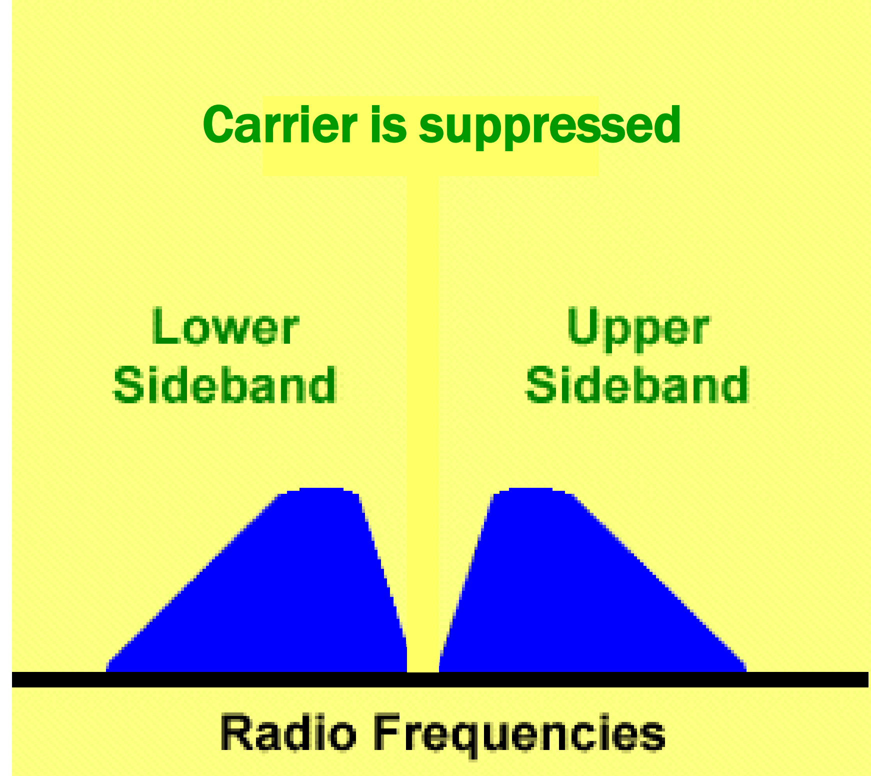
Receiving SSB and CW

- The **SSB/CW receiver** is very similar to an AM receiver up to the IF Amplifier.
- Instead of a Detector however, the SSB/CW receiver uses two different stages:
  - **Product Detector**
  - **Beat Frequency Oscillator (BFO).**





Amplitude Modulation → **Double Sideband Suppressed Carrier**

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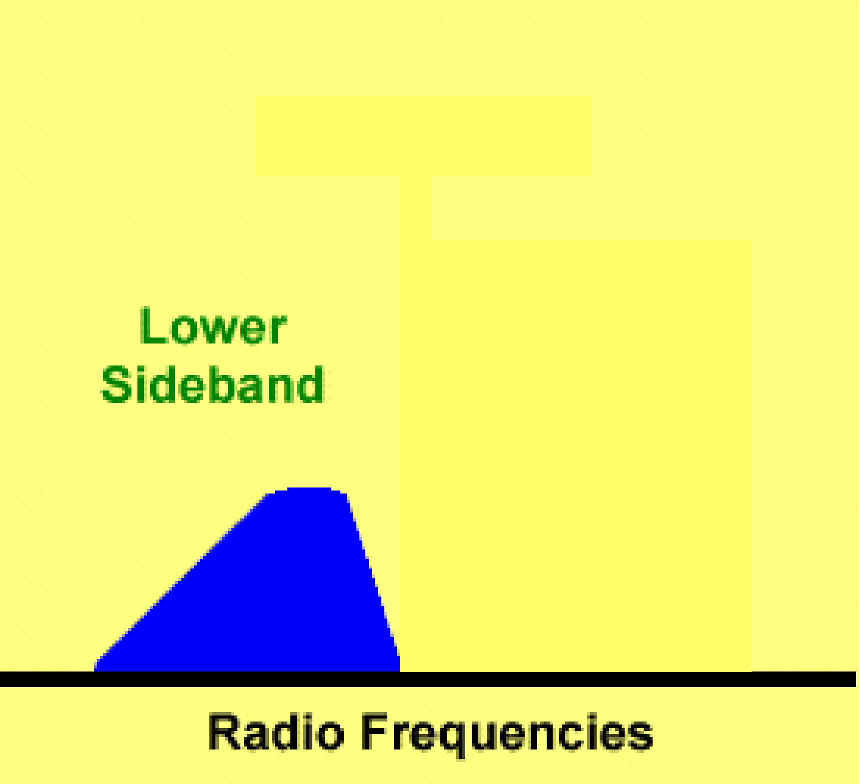

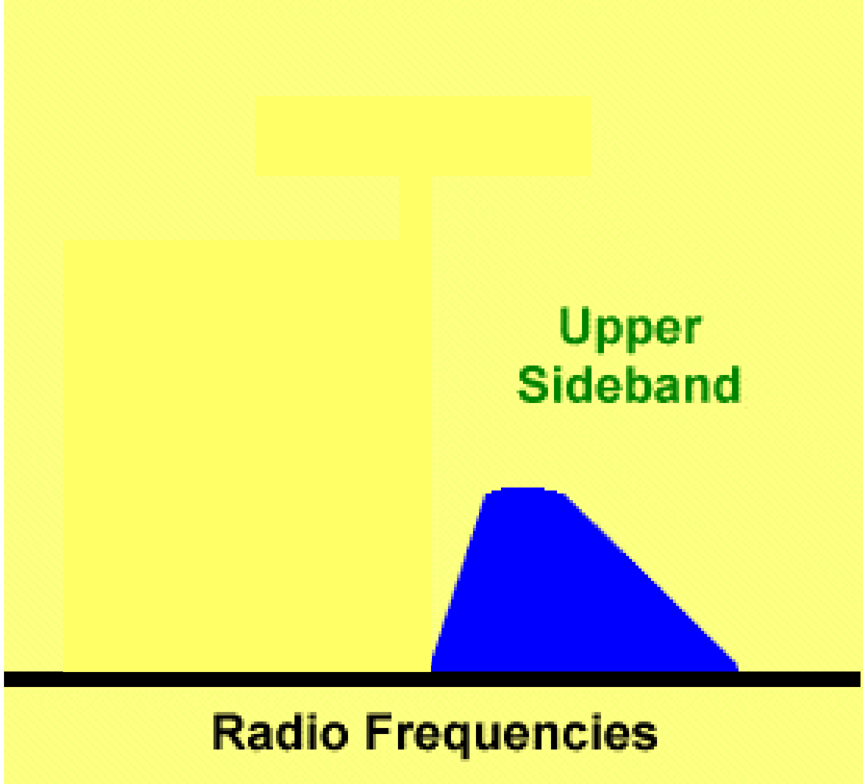

Lower Sideband **Upper Sideband**

Single Sideband Suppressed Carrier

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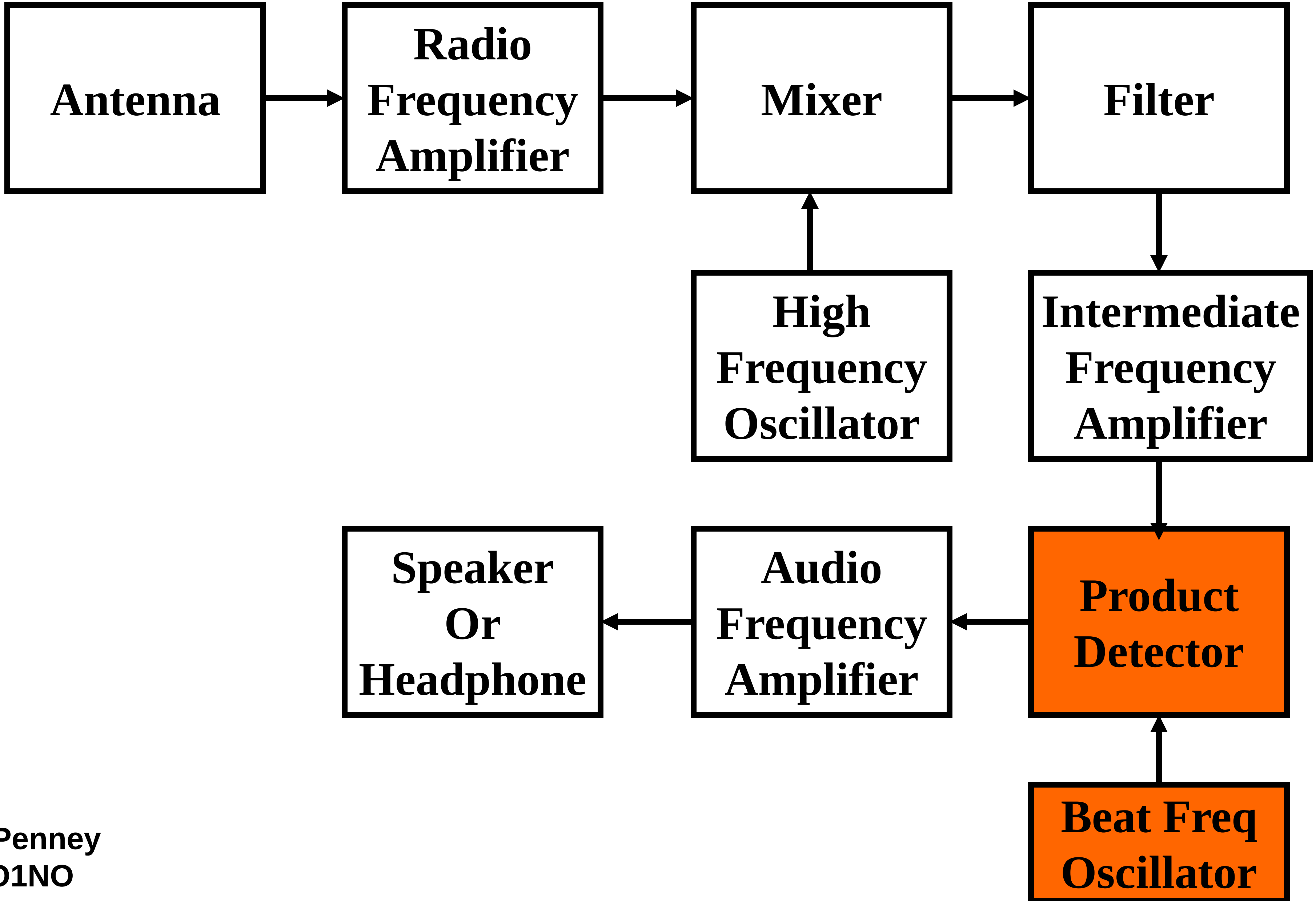
SSB / CW Superheterodyne Receiver



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Product Detector

- Because the **carrier** has been **removed** from an SSB transmission, it **must be re-inserted** so that the original audio can be recovered.
- This is accomplished using the **Product Detector.**
- The **source** of the **carrier** is the **Beat Frequency Oscillator (BFO).**

Beat Frequency Oscillator (BFO)

- The **BFO** is an **oscillator** that replaces the **carrier** in an **SSB transmission.**
- **CW transmissions** also require a carrier to **“beat” against (mix with)** to produce an **audio tone.**
- Older receivers use a BFO that could be **varied in frequency** as the **operating mode** is changed from **USB to LSB to CW.**
- Modern radios **automatically switch** the **operating frequency** of the BFO as the mode is changed.

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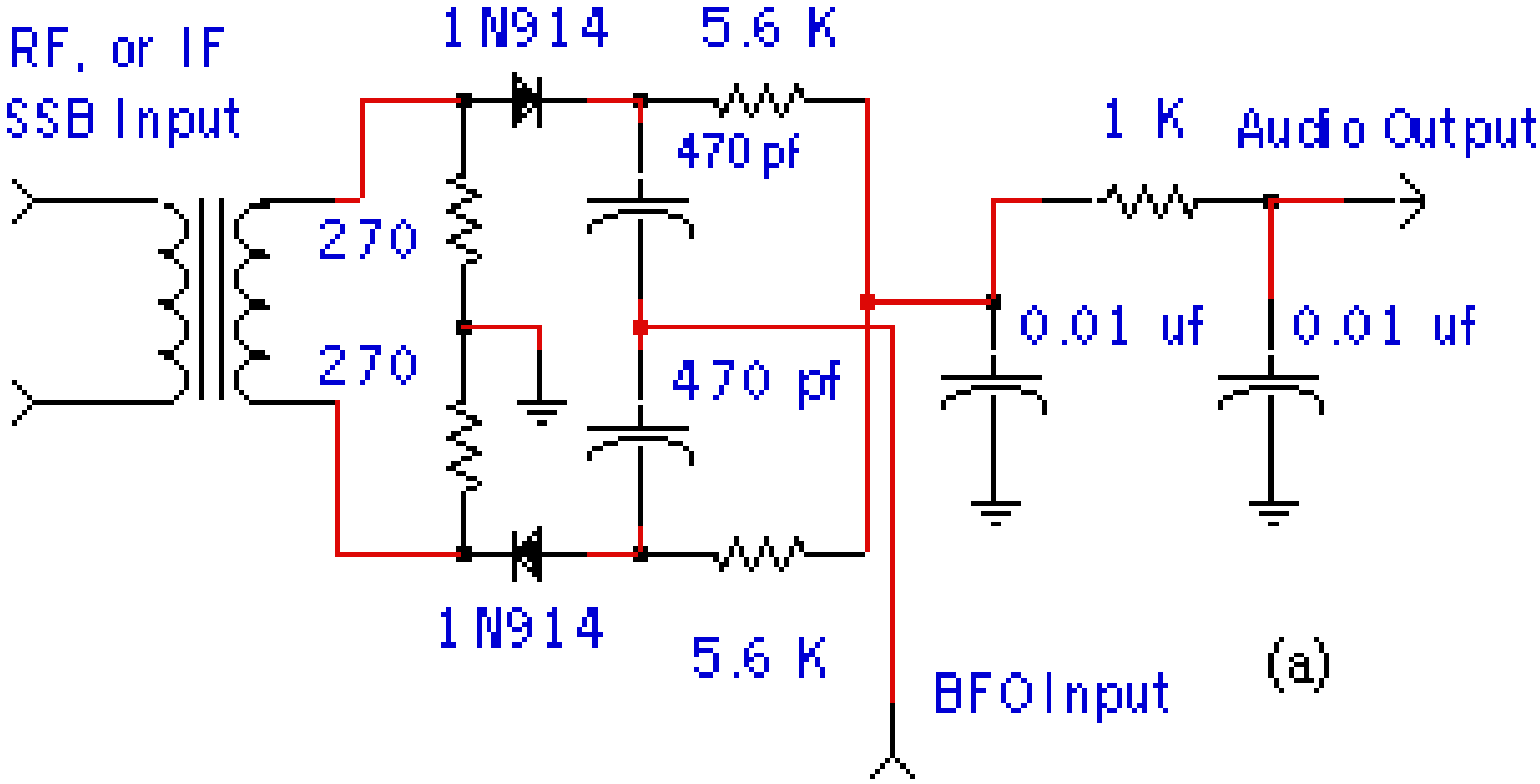
Product Detector



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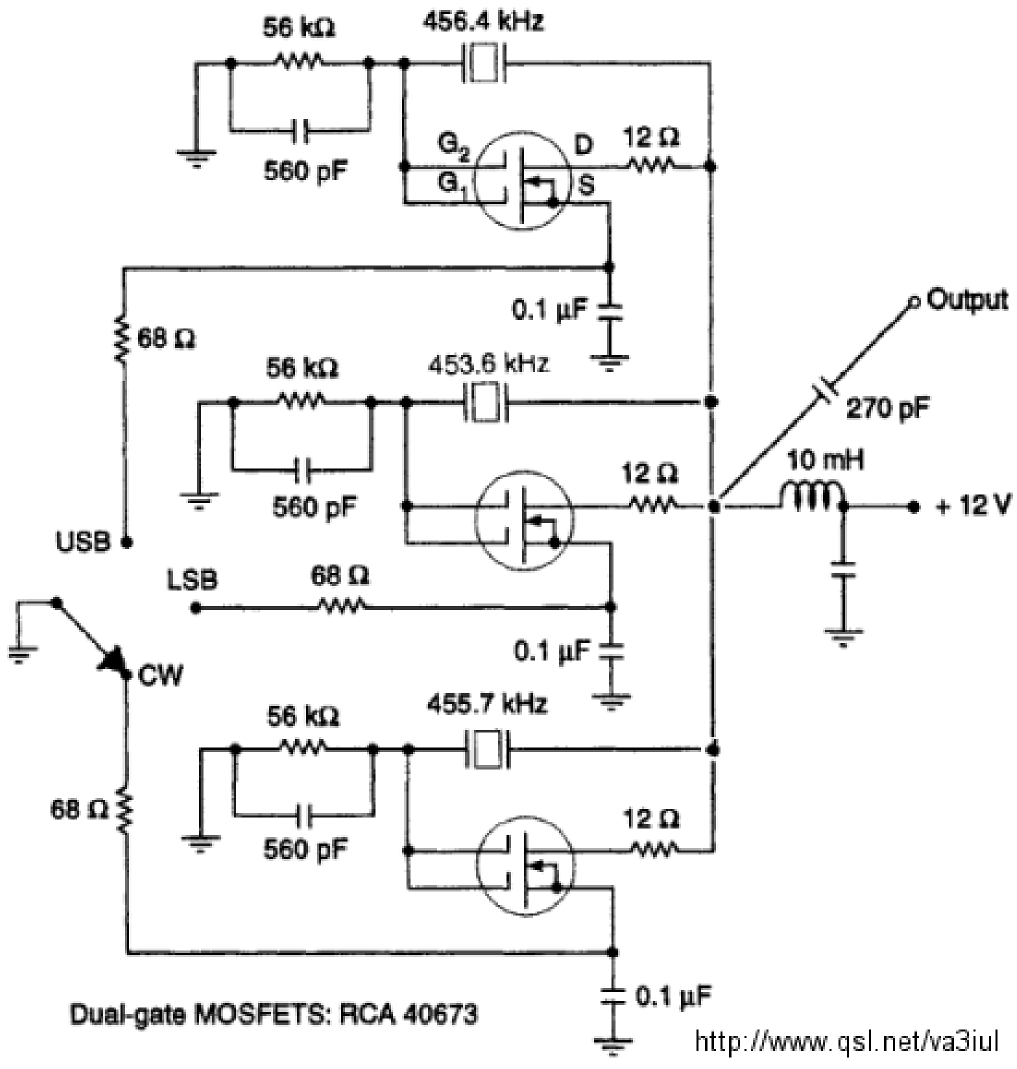
Beat Frequency Oscillator



http://www.qsl.net/va3iul

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Audio Filters

- Hams sometimes employed **active or passive external audio filters** with older receivers in an effort to **remove interference** and **improve selectivity.**
- A **Notch Filter** can be used to **remove an interfering carrier signal** (ie: CW signal).
- To **improve CW selectivity,** an audio **bandpass filter** for **750 – 850 Hz** would be appropriate.
- Modern radios incorporate **DSP techniques** even more effectively, at the **IF stages** rather than the audio stages.

MFJ- 784B DSP Filter

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Signal Strength Meters

- An **S-Meter** enables you to make comparisons between received signals.
- Unfortunately, even on identical receivers, most S-meters are **not properly calibrated** and will give **different readings** when using the same antenna.
- The scale is divided into **9 increments**, designated **S0 to S9,** up to the **center point of the meter.** The scale is then **graduated in dB,** usually in multiples of 10.
- A **signal strength report** would be **"S6"** or **"S9 plus 15 dB".**

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S-Meter Standards

- According to the standards adopted by the **International Amateur Radio Union (IARU)** in 1981, **S9 corresponds to a signal strength of 50 microvolts at the receiver's 50 ohm impedance antenna input.**
- Each **S unit** then reflects a **6dB change in signal strength.**
- This is **rarely achieved,** as S-meters are often **not linear in their response.**
- Still, they give a relative indication of signal strengths!

S-Meter

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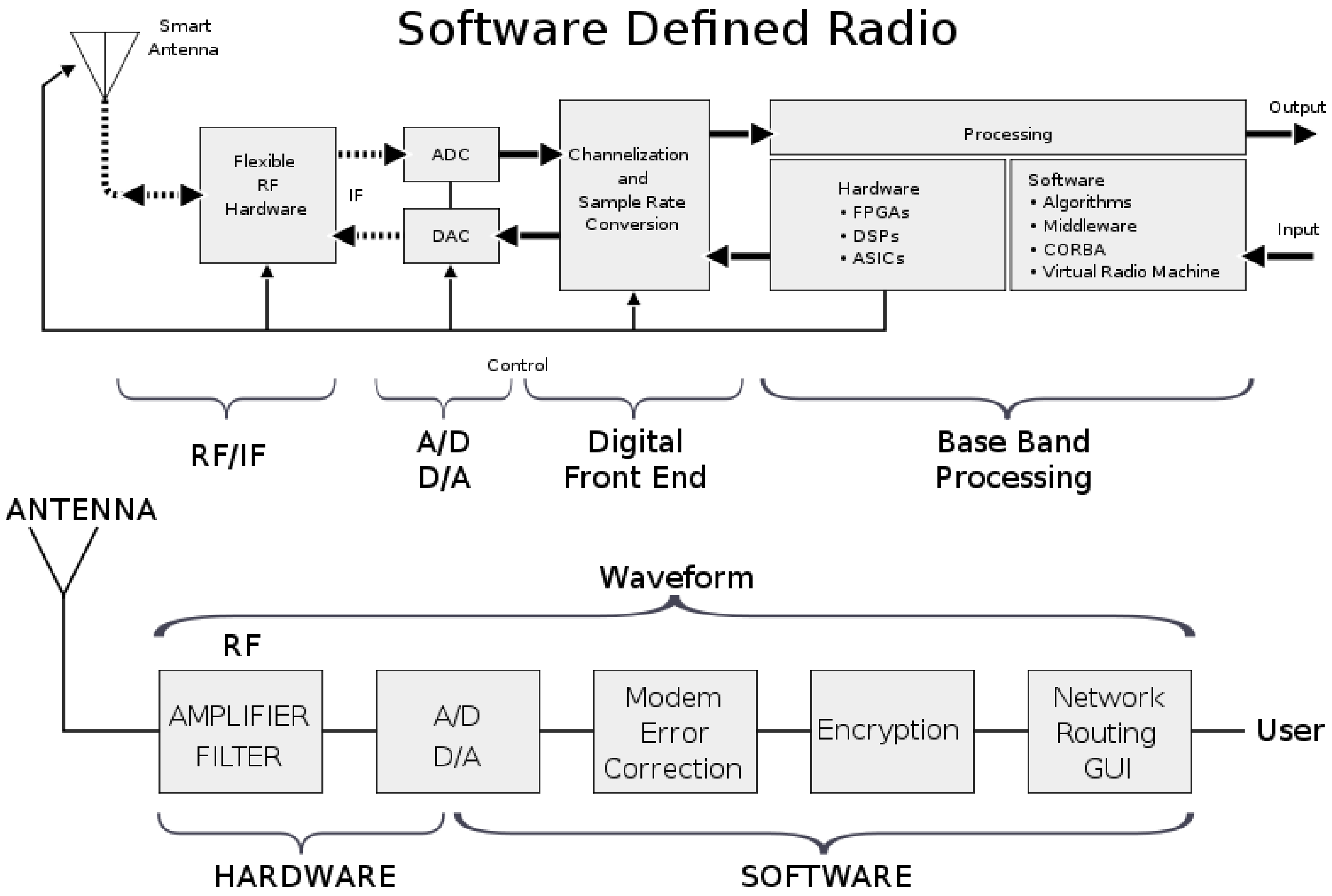
Software Defined Radios



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Questions?

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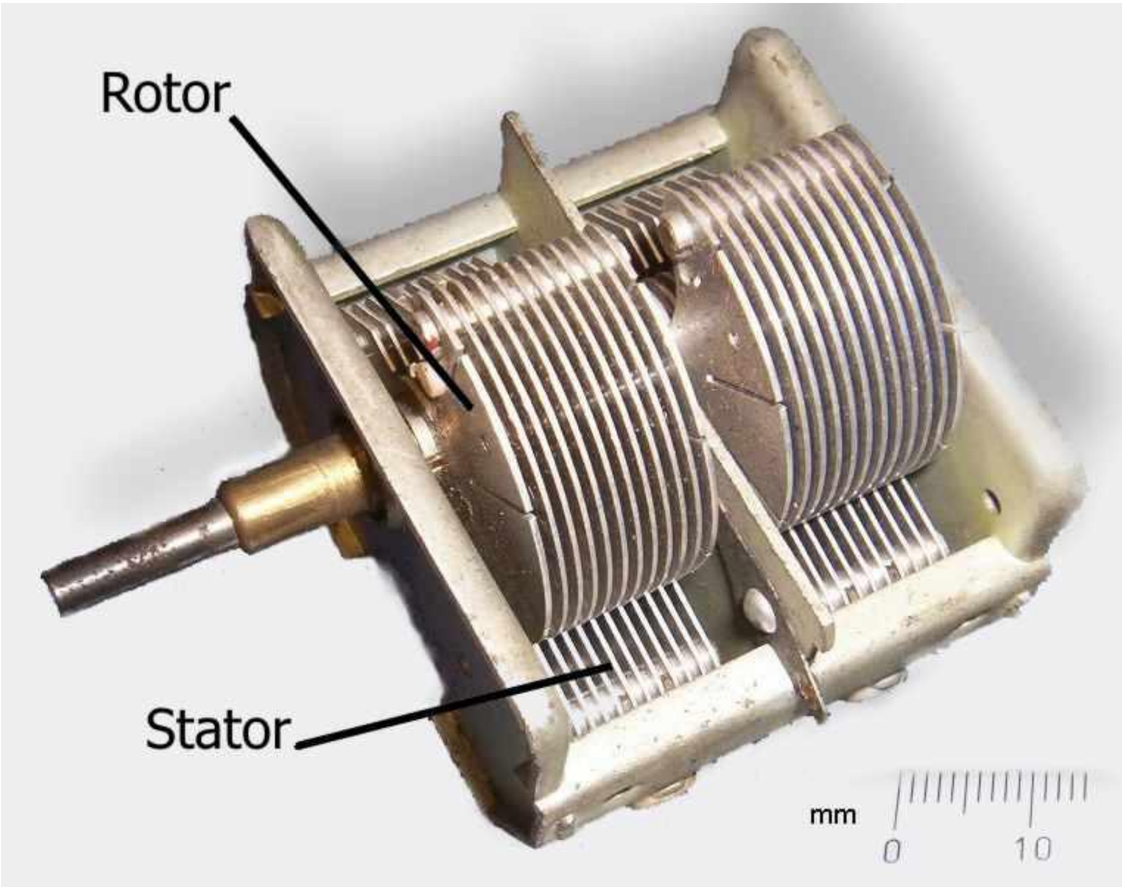
Two Section Tuning Capacitor



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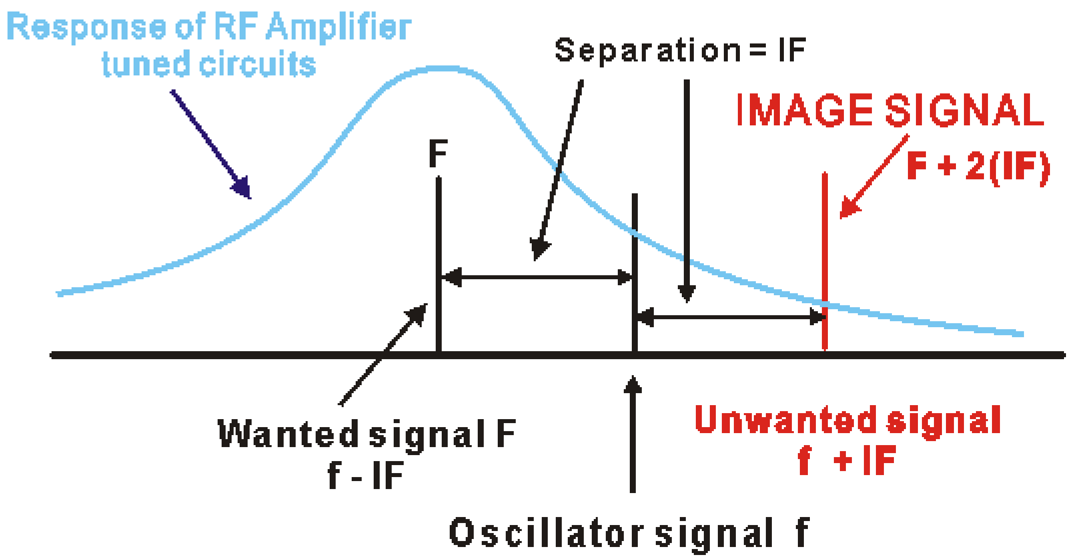

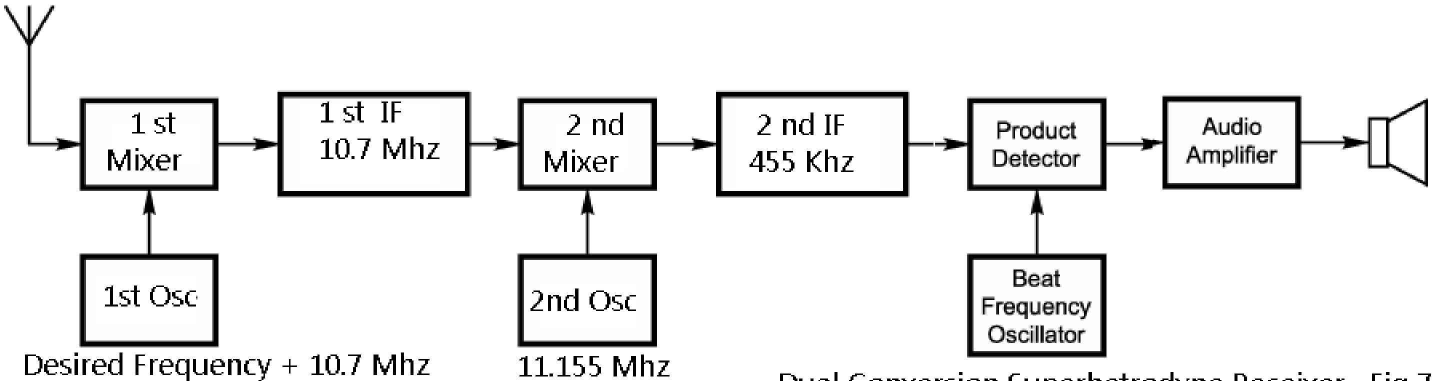

Dual Conversion Superhetrodyne Receiver Fig 7-3

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