# Receivers and Receiver Specifications

## Communications Academy 2019

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# Goals for the Session

- What do receiver specifications mean?
- What do they mean to me?
- What receiver tradeoffs should I make when selecting radio?
- Does more expensive mean better?
- Help make a better decision on how to spend your hard earned dollar or the money your spouse gives you as an allowance.

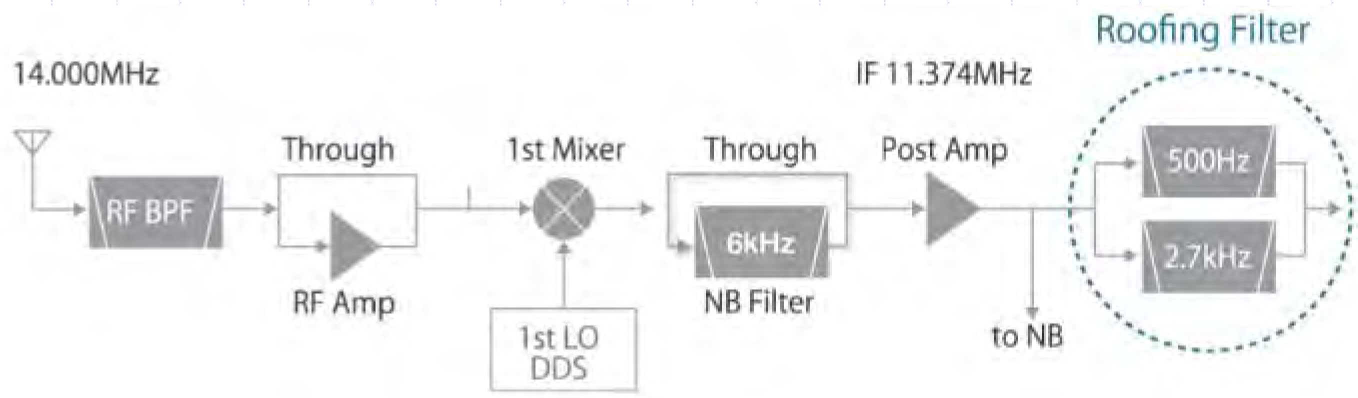
# What are we going to cover?

- Not features – Features are things like dual receivers, 100 watts versus 10 watts, LCD display, number of knobs, RTTY or FT8 capability, number of bands, etc.
- Not transmitters – Transmitters are relatively simple. Power output and the modulation type, in some cases spurious emission but for the most part transmitters are the same.
- Receivers are the complicated area due to the number of factors affecting performance.

# Receiver specifications

- Tradeoffs
  - Broad versus narrow frequency coverage
  - Noise floor
  - Receiver IF bandwidth (or equivalent thereof)
  - Audio distortion
  - Ability to operate in a high RF level environment
  - Spurious responses
  - Artifacts
  - Size
  - Cost

# Typical Receiver Block Diagram




- Receivers may have more IF stages and the IF frequencies can vary
- They may use "real" filters or they may use Digital Signal Processing (DSP) filters or both.
- There may or may not be an RF amplifier.

# Receiver Noise Floor

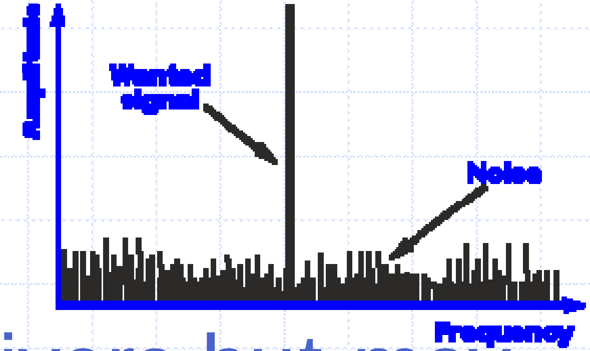
- The bandwidth determines the minimum noise floor, both theoretical and actual
- Bandwidth and noise floor are proportional
  - 2X bandwidth increases noise 3 dB
  - 10x bandwidth increases noise 10 dB

| Bandwidth | Thermal noie power | Notes |
|---|---|---|
| 1 Hz | −174 dBm | |
| 10 Hz | −164 dBm | |
| 100 Hz | −154 dBm | |
| 1 kHz | −144 dBm | |
| 10 kHz | −134 dBm | FM channel of 2-way radio |
| 15 kHz | −132.24 dBm | One LTE subcarrier |
| 100 kHz | −124 dBm | |
| 180 kHz | −121.45 dBm | One LTE resource block |
| 200 kHz | −121 dBm | GSM channel |
| 1 MHz | −114 dBm | Bluetooth channel |
| 2 MHz | −111 dBm | Commercial GPS channel |
| 3.84 MHz | −108 dBm | UMTS channel |
| 6 MHz | −106 dBm | Analog television channel |
| 20 MHz | −101 dBm | WLAN 802.11 channel |
| 40 MHz | −98 dBm | WLAN 802.11n 40 MHz channel |
| 80 MHz | −95 dBm | WLAN 802.11ac 80 MHz channel |
| 160 MHz | −92 dBm | WLAN 802.11ac 160 MHz channel |
| 1 GHz | −84 dBm | UWB channel |

# Minimum Detectable Signal

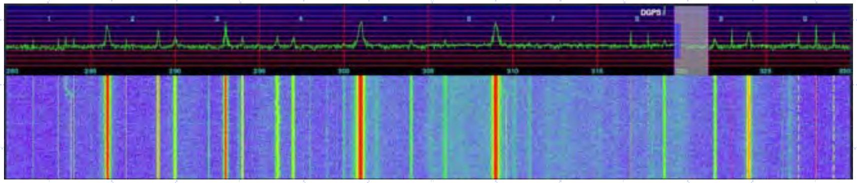
- Indirect measurement of the receiver noise floor
- Must be measured at a reference bandwidth. ARRL uses 500 Hz for HF receivers and 3 dB above the noise with an unmodulated carrier
- Different modulations may have different results

# Noise Figure




- Often not specified for receivers but may be specified for amplifiers
- Amount of noise the receiver adds above the thermal noise
- Receiver noise figure is basically determined by the noise figure of the first amplifier so noise figure will change with a pre-amp in or out.

# Noise Figure

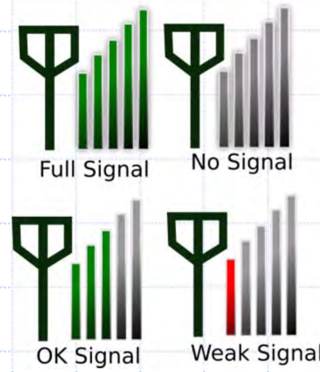


- ARRL uses the minimum detectable signal to determine the noise figure
- Examples
  - Thermal Noise @ 500 Hz = -147 dBm
  - HF Receivers @ 14 MHz
    - #1 = Preamp off 28 dB, Preamp on 19 dB
    - #2 = Preamp off 16 dB, Preamp on 8 dB
  - Which one has the lowest noise floor?

# Things to Remember

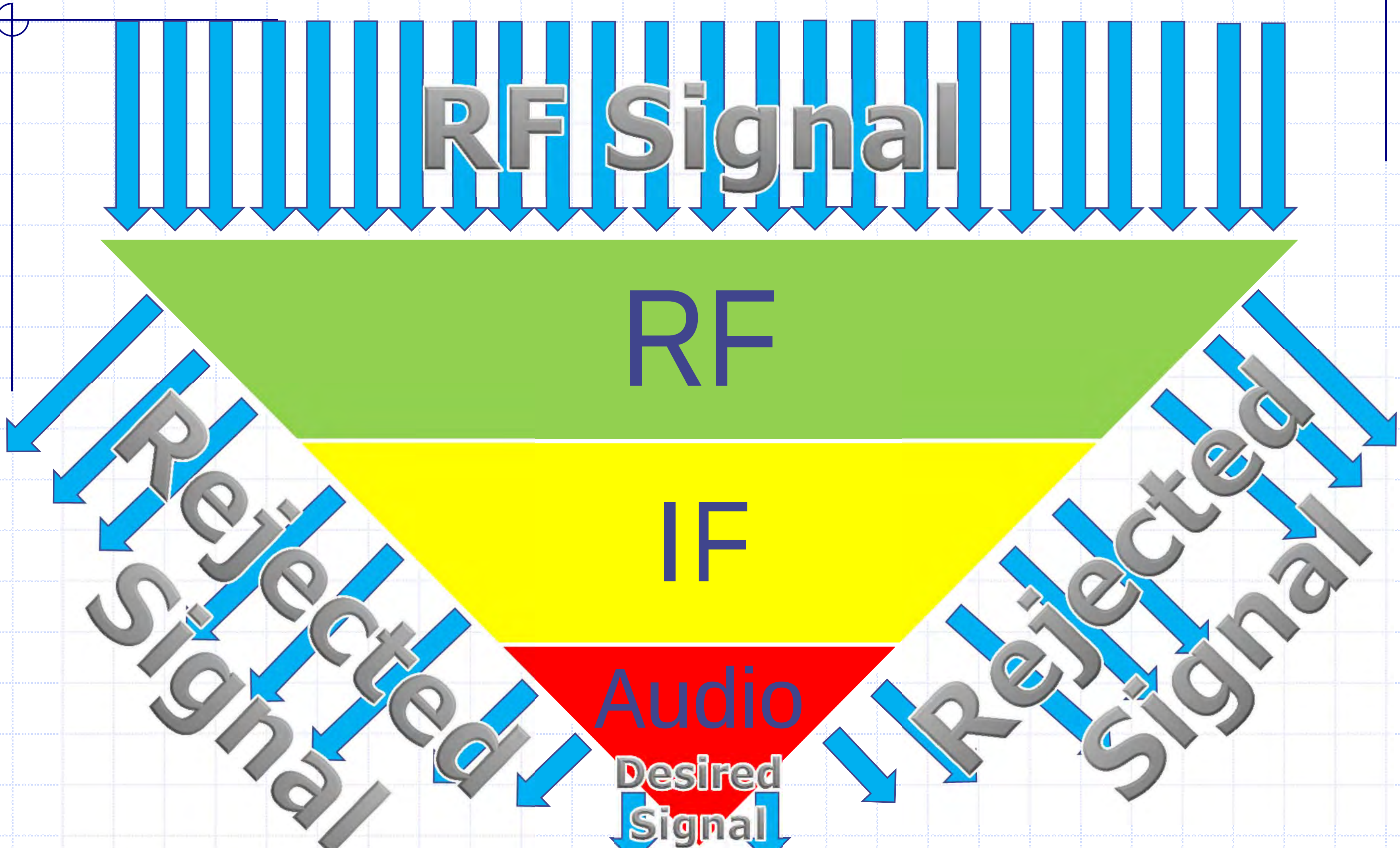
- The best a receiver can be is the thermal noise plus the noise figure at the desired bandwidth
- Why is there a preamp on and off switch? Low noise amplifiers generally do not handle high level signals resulting in receiver intermodulation.
- Higher cost may not mean a lower noise figure
- Unless you have a very quiet location, lower noise figure may not be required

# Sensitivity

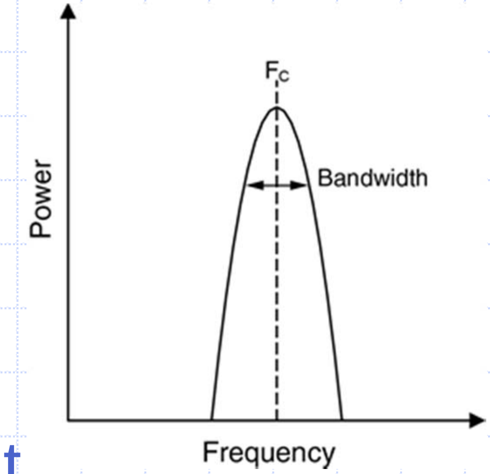



- Sensitivity is relative to noise floor but is measured for some modulation type at a reference distortion and bandwidth
  - CW usually considered at the MDS
  - AM @ 10 dB (S+N)/N (30% modulation)
  - FM @ 12 dB S+N+AD (Signal+Noise+Audio Distortion)(SINAD)
  - Digital @ specified BER typically 5% maximum 3% typical
- HF Receivers AM sensitivity @ 29 MHz
  - #1 Preamp off 9 uV  Preamp on 1 uV
  - #2 Preamp off 1.3 uV Preamp on 0.4 uV
- VHF Receiver @ 12 dB SINAD
  - #1 0.16 uV
  - #2 0.21 uV

# Selectivity



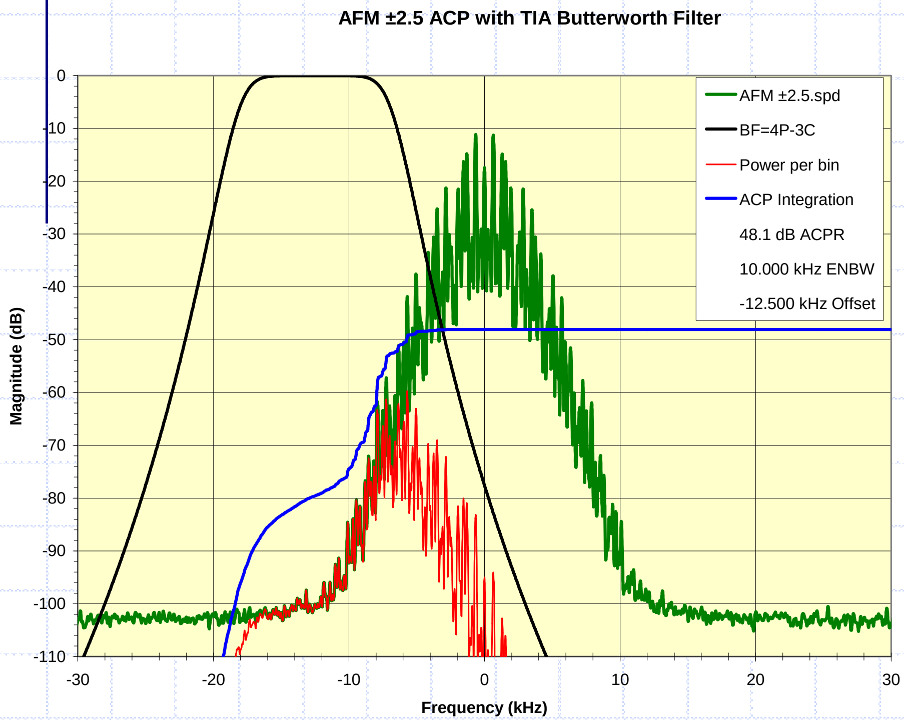
# Selectivity

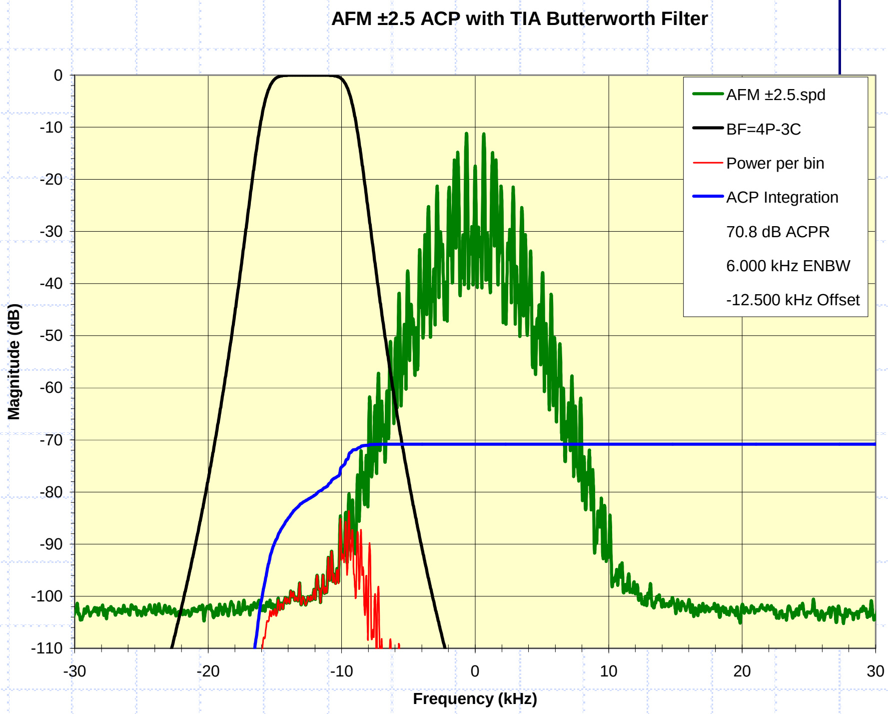



- Selectivity generally refers to close in signals. However, overall receiver front end selectivity does affect receiver performance.
- Selectivity affects the MDS, narrower = less noise
- Filter bandwidth is usually measured at the 3 dB down point. However, ARRL uses 6 dB
- FM receiver specifications are often in “adjacent” channel bandwidth. What is adjacent channel?
  - It depends, one has to read the fine print. Possibilities are: 12.5 kHz, 15 kHz, 20 kHz, 25 kHz, and 30 kHz

# Selectivity

- IF filters do make a difference



# Selectivity

- IF Rejection – Signals on the IF frequencies
  - First IF frequency is most likely to be a problem
- Image Rejection – Signals on the "other" output of the mixer
  - Can be a problem in a high signal environment
- Out of Band (OOB) selectivity not measured but can have an effect. Use Intermod test results to get an indication of OOB performance

# Selectivity

- Selectivity must match the modulation type for best performance. Too little selectivity allows more noise and interference, too much blocks some of the signal
  - CW selectivity can be narrow around 500 Hz but too narrow and filters may exhibit some artifacts (ringing)
  - SSB should match the communications quality voice frequency energy around 2.2 kHz
  - AM needs both side bands so around 5 kHz
  - FM depends on modulation 5 kHz modulation needs around 10 kHz

# Selectivity

- IF Rejection is the ability to reject signals coming in at the IF frequencies. Normally, 1st IF is the most likely to have a problem
- Not normally a problem for VHF and higher receivers due to front end filters
- HF IF frequencies can be 11.374 MHz, 73.095 MHz, 69.0115 MHz, or others
- Newer DSP receivers can directly sample the RF spectrum, IF stages are all in software

# Selectivity

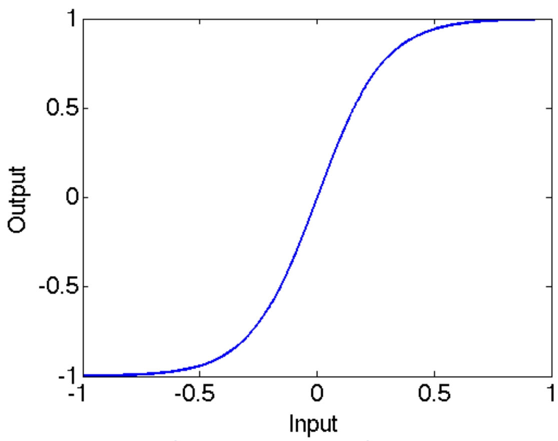
- Image rejection can be a problem in some receivers
- What is the image frequency?
  - Example: VHF Receiver, IF = 10.7 MHz
    - Desired frequency is 146.52 MHz
    - Local Oscillator is 146.52 + 10.7 = 157.22
    - Image frequency is 157.22 + 10.7 = 167.92
    - 167.92 MHz is in the Federal Government LMR band

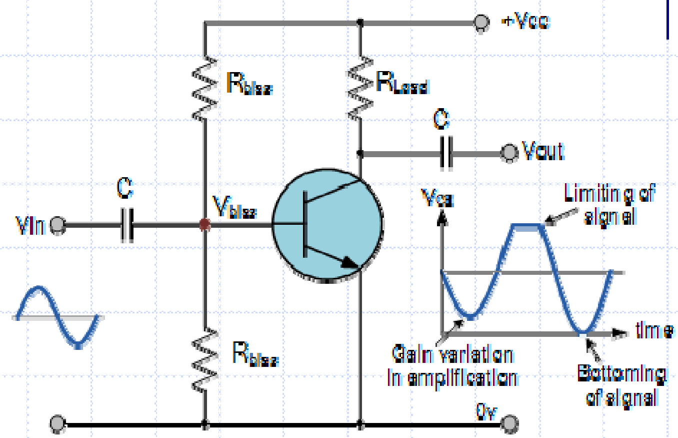
# Things to Remember

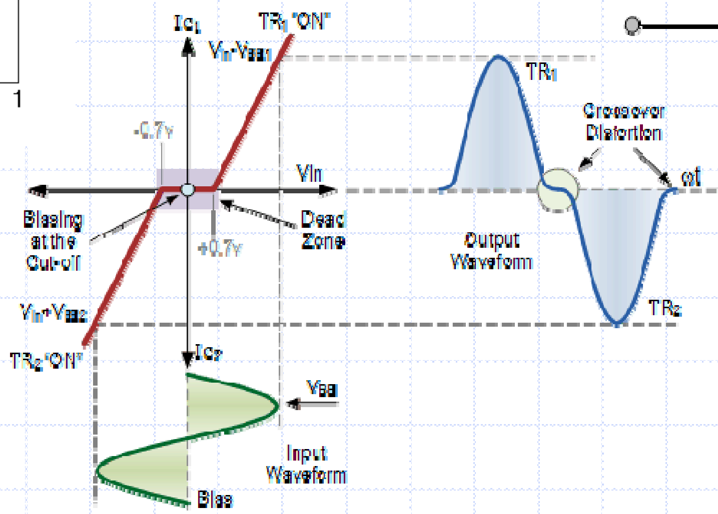
- More selectivity is generally good but must match the modulation type. Too narrow a filter will result in distorted modulation
- Cost does not define selectivity as with many specifications
- IF signal interference is not usually a problem but can be
- Intermodulation response can make a receiver seem less selective

# Intermodulation and Blocking

- Amplifiers are not 100% linear and have an upper signal limit

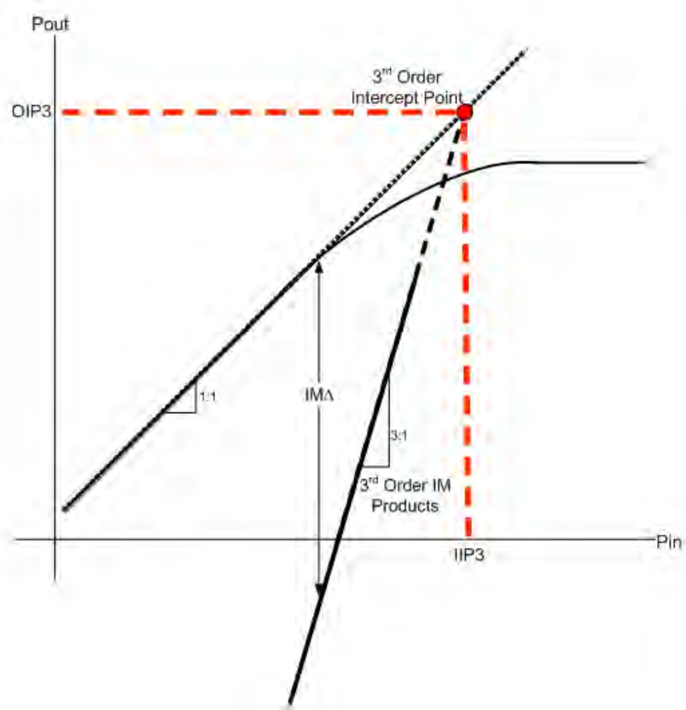


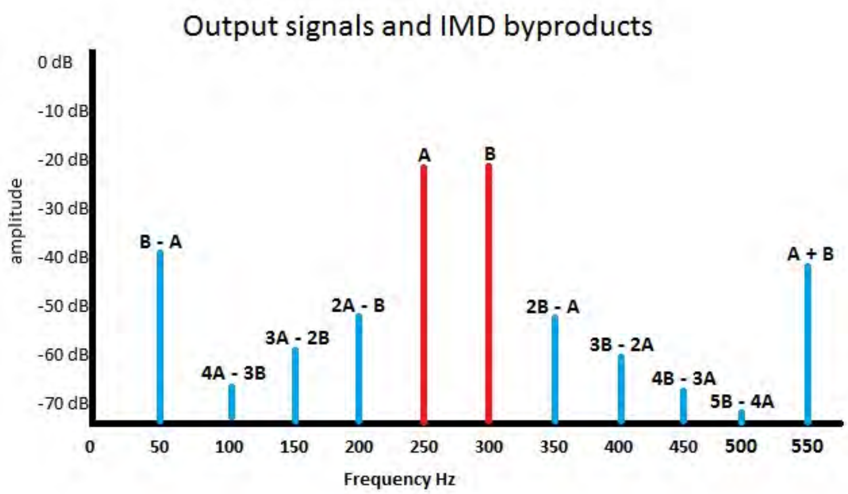



# Intermodulation and Blocking

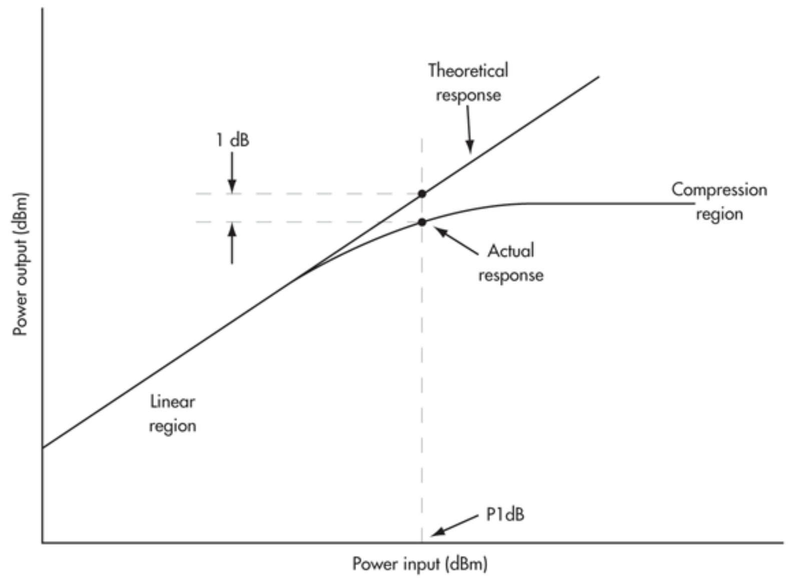
- Non-linear operation in amplifiers causes additional signals to be created



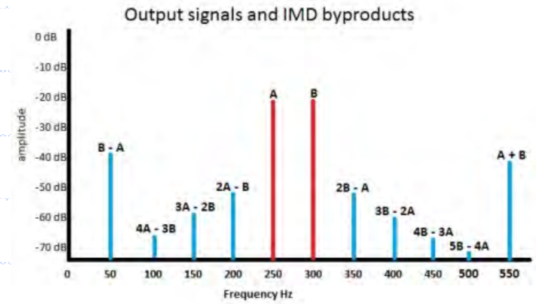



# Intermodulation and Blocking

- Non-linear operation also defines the maximum signal that can be amplified. The amplifiers will eventually go into compression. The standard is the 1 dB compression point.
- Strong signal other than desired signal may cause amplifier to go into compression resulting in loss of linearity and gain.
- This also causes distortion and intermodulation



# Intermodulation




- IP3 (3rd Order Intermodulation Point) is a measure of the ability to handle strong signals without generating intermodulation
- Higher is generally better but higher IP3 amplifiers are generally noisier
- HF is usually measured with two signals 20 kHz apart.
- VHF/UHF are measured with two signals 20 kHz and 10 MHz.

# Intermodulation and Blocking

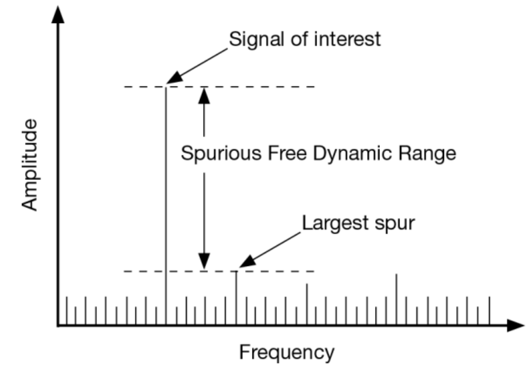


Illustration of SFDR

- Test results typically are:
- HF
  - Rcvr #1: Blocking 128 dB, IMD 100 dB, IP3 +36 dBm
  - Rcvr #2: Blocking 111 dB, IMD 94 dB, IP3 +17.3 dBm
- VHF
  - Rcvr #1: IMD 20 kHz 68 dB, 10 MHz 86 dB, Adj 74 dB
  - Rcvr #2: IMD 20 kHz 69 dB, 10 MHz 103 dB, Adj 78 dB
- In both of these cases the more expensive receiver performed better

# Almost Final Thoughts


- Receiver specifications are a balance of needs. A more sensitive receiver may not handle large signals very well.
- Determine what you really want or need for receiver performance. If you live in an urban area with a high noise floor and strong signals, having the most sensitive receiver may be counter productive. IMD performance may be more important.
- 10 MHz intermodulation performance is critical in VHF/UHF radios operating in urban areas. In general, low cost radios do not have adequate IMD performance. Since the IMD response is non-linear even a few dB better performance will make a difference.

# Next to Final Thoughts


- In reality, a more balanced system may be less frustrating.
- For example, an Elecraft KX3 portable HF radio has a receiver sensitivity of 0.9 uV without the pre-amp. There are other receivers with better sensitivity but if you have a very sensitive QRP rig receiver, you can hear things you most likely cannot work.
- Sometimes the most expensive rigs may have lots of features but lower performance specifications in some areas
- DSP based receivers often respond differently than do more traditional receivers when experiencing high signal levels. Not a bad thing but may be different than one is expecting.

# Final Thoughts


- Be realistic in what you want. Better noise blanking performance may be a good tradeoff for sensitivity.
- Don't buy a rig because someone else says it works great for them without comparing specifications for yourself. They may be in a different operating environment.
- Don't spend more money then your spouse has allocated to get marginal performance improvements. The local QRN probably isn't work it!

# Questions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