Using Audio Equalizers to Improve SSB Communications

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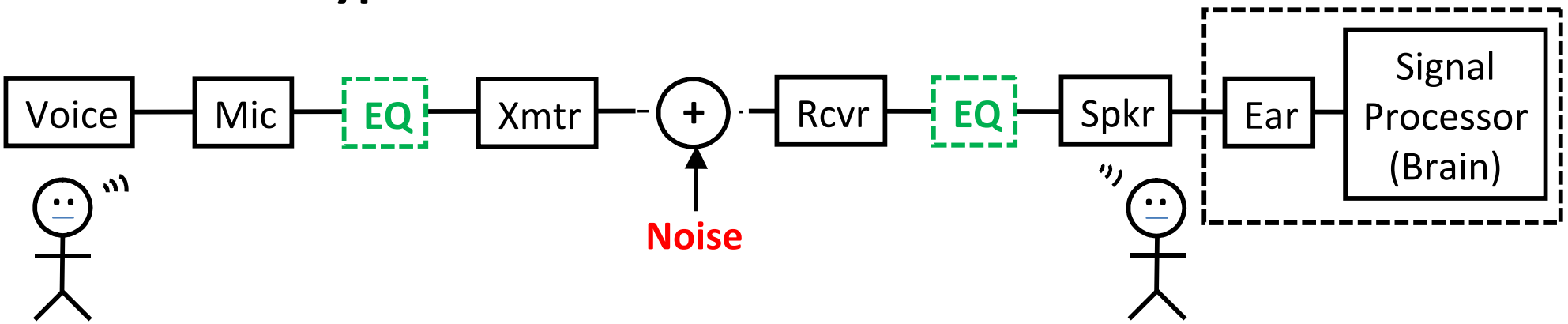
Topics:

- **Commonly Used Methods for Improving HF SSB Comms**
- **Key points about speech and hearing**
- **Equalization:**
  - What is it
  - When to use it
  - Where to use it
    - Transmit applications
    - Receive applications
      - Three cases
  - How to use it
  - What it can do
  - What it cannot do
  - Some Equalizer Examples:
    - W2IHY Eight Band Equalizer
    - MFJ-616/618 Speech Intelligibility Enhancers
    - A Custom Homebrew Two Band Equalizer

How to Improve SSB Communications?

1. Improve Received Signal-to-Noise Ratio (SNR)
2. Improve Received Signal-to-Interference Ratio (SIR)
3. Use/Improve Signal Processing
   - Digital
   - Analog
     - **Equalization**

Typical SSB Communication Path



To Improve Received SNR:

- Use higher gain ***antennas***
- Raise ***peak*** transmit power
- Raise ***average*** transmit power
  - Common method: ***compression*** *(RF not audio)*
    - 5-10 dB of compression is typical
  - There is a limit:
    - Must trade-off between distortion and SNR improvement
- "Matched ***filter***" detection
  - Most modern radios have adequate filtering
- Reduce receiver ***noise figure***:
  - Will not help when atmospheric noise is dominant
    - Frequently the case on the low HF bands

Signal Processing:

- Used to improve the extraction of signal information from noise and interference
- **Digital Signal Processing (DSP):**
  - *"Although God made an analog world, Humans keep trying to digitize it!"*
  - **"Brick Wall" filters**
    - **Noise reduction**
    - **Interference cancelling**

    } **Improve SNR/SIR**
- **Analog Signal Processing**
  - Speech compressors:
    - **RF**
      - Better than audio compressors by 8+ dB
    - **Audio**

    } **Increase average transmit power**
  - The Human **Brain = A very effective signal processor for speech**
    - **Speech intelligibility**
      - *Can be improved by "tailoring" the frequency content of the voice signal to better match the Brain's speech processing algorithm*
      - ***"Tailoring"* <=> Equalization**
        - Hams don't normally use equalizers to equalize

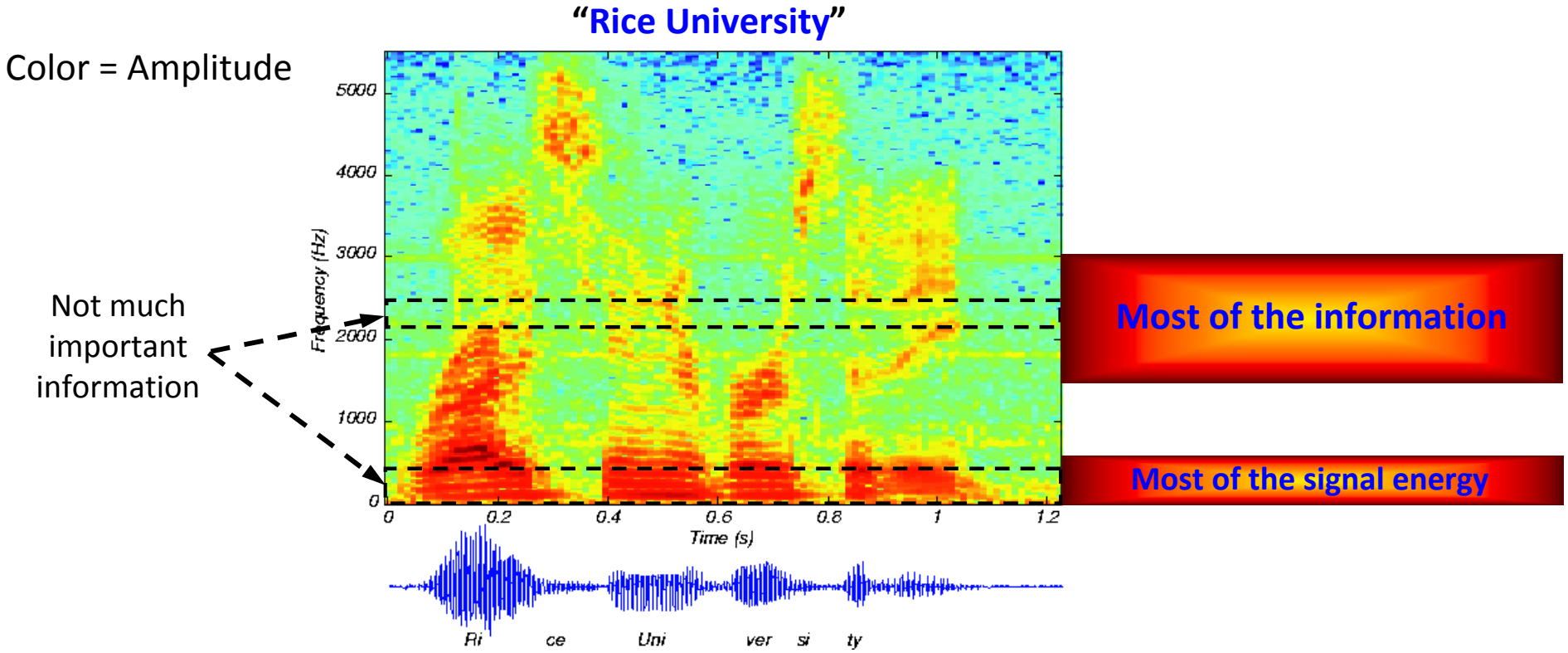
What is Equalization:

- In Music applications:
  - "Equalize" the response of two or more signal paths
  - Compensate for deficiencies in the electronics
  - Emphasize or de-emphasize one or more instruments
- In Ham applications:
  - **"Equalization" => Tailoring (ie, intentionally distorting) the frequency response to improve the intelligibility of voice signals**
    - **Most commonly used at the transmit end**
      - **Emphasize important frequency ranges and de-emphasize others**
    - **Can also be very beneficial at the receive end**
  - Equalized response goals for SSB ***transmit*** applications:
    1) For **rag-chew** applications:
       - Improve "**fidelity**" of the transmit audio for a more natural sounding voice
    2) For **DX & Contest** applications:
       - Increase the "**punch**" of the transmit audio
       - Can be fatiguing to listen to for long periods of time
  - Equalized response goals for ***receive*** applications vary widely

What is Important in Speech Recognition:

- Frequency content of speech varies with time
  - Some frequency ranges are more important than others
- "Good" vs.. "Bad" audio response is ***very*** subjective

Spectrogram: Amplitude vs. Frequency vs. Time



What is Important in Speech Recognition (continued):

- Speech is made-up of **vowels** and **consonants**
- **Vowels**:
  - Longer duration sounds (***Lows***: 30-300 ms)
  - Examples: "**ah**" & "**oh**" sounds
  - Significant in determining "***Who***" is speaking
  - Contain ***most of the sound energy*** in human speech
    - Energy in consonants can be >20-30 dB below energy in vowels
- **Consonants**:
  - Shorter duration sounds (***Highs***: 10-100 ms)
  - Examples: "**f**" vs. "**s**" & "**d**" vs. "**t**" sounds
  - Significant in determining "***What*** *is being said*"
  - Contain ***most of the information***
    - Importance of Bandwidth:
      - Accuracy for single syllables:

15.0 KHz Bandwidth => 100%
7.0 KHz Bandwidth => 95%
3.3 KHz Bandwidth => 75%
1.0 KHz Bandwidth => <50%

Where to Equalize?

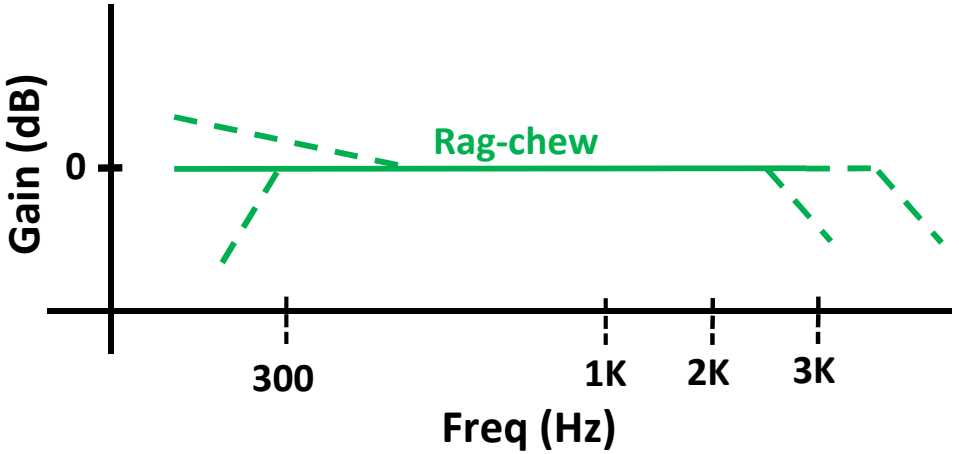
- At **Transmitter:**
  - Best place to put an audio equalizer
    - Point of ***highest SNR***, ***and***
    - Location for ***most benefit to the station using equalization***
    - Settings depend on intended use:
      - **Case 1:** Rag-chew
      - **Case 2:** DX or contesting
    - ***RF & 60 Hz hum getting into transmit audio can be a problem***

- At **Receiver:**
  - Placed between the receiver and the speaker/headphones
  - Can improve the intelligibility of voice signals when:
    - **Case 1:** They are missing critical frequencies ***and*** there is adequate received SNR
    - **Case 2:** They need more "Punch"
    - **Case 3:** There is a hearing deficiency on the receive end

How to Equalize?

- At the **TRANSMIT** end
  - **Case 1:** Improve "**fidelity**" for **rag-chew** applications
    - **Flat overall response:** 100 Hz to 3.0+ KHz
    - Sometimes lows are emphasized

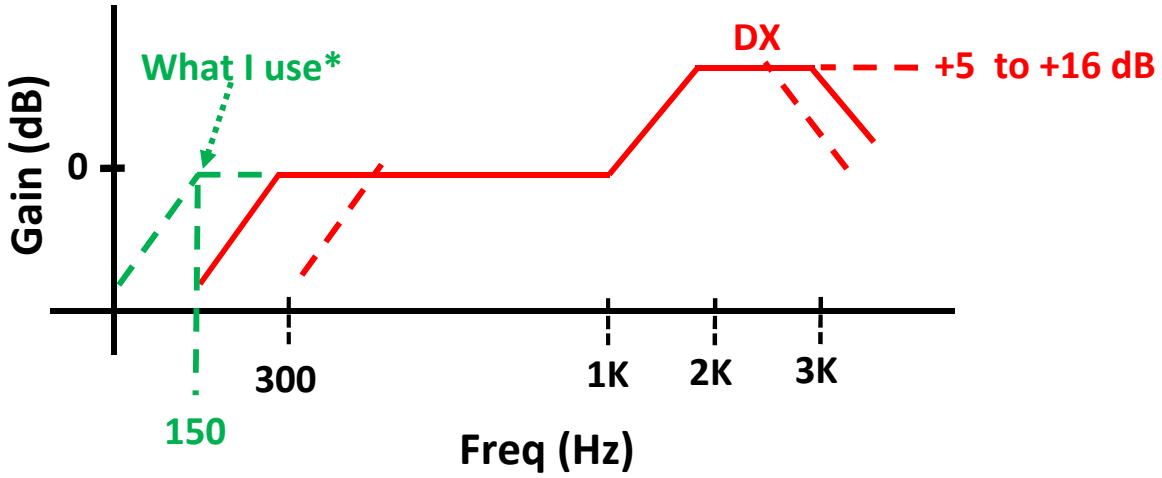
Net Overall Transmit Frequency Response:



How to Equalize?

- At the **TRANSMIT** end (continued)
  - **Case 2:** Increase the **"punch"** for **DX & Contest** applications
    - **Cutoff "lows":** ~300 HZ (typical)
    - **Flat "mids"**
    - **Emphasize "highs"**
      - Starting ~1 KHz
      - Maximum emphasis from 2 KHz up
      - Upper cutoff anywhere from 2.4-3 KHz

Net Overall Transmit Frequency Response:



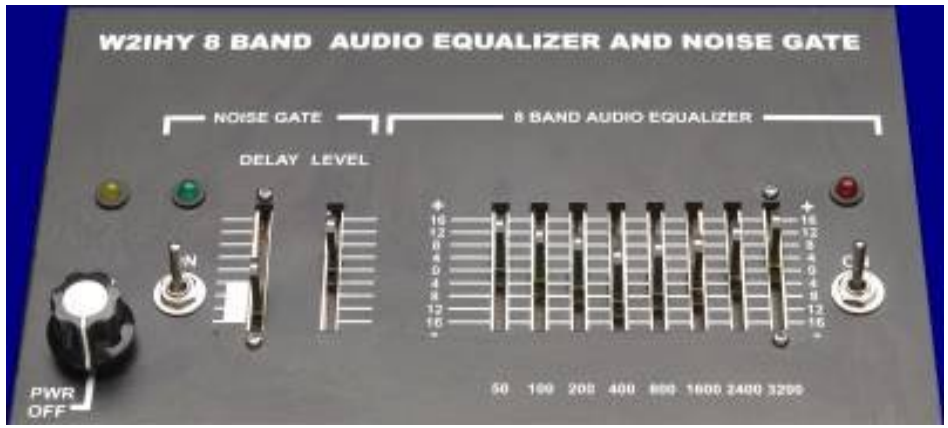
*Increases "punch" and maintains fidelity

Transmit Equalizer Settings:

- **Initial** settings are based on microphone and rig
  - Available from W2IHY for his equalizers
- **Final** settings:
  - Usually arrived at after on-the-air testing
  - Depend on numerous variables:
    - Frequency content of the transmitter operator
    - Frequency response of the microphone
    - Frequency response through the hardware (transmitter + receiver)
    - Use of compression
    - ***Hearing response at the receiving end?***
      - Try to find a station that can use a spectral display to evaluate the audio of received signals
        - Flex 5000, Perseus,etc
  - The equalizer gain settings usually do ***not*** represent the final end-to-end response

Equalizers for Transmit Applications

- **Built-in** equalizers
  - Most only have 2-3 sub-bands
  - Some newer high end SDR's have very sophisticated DSP based equalizers
- **Heil microphones**
  - HC-4 (DX), HC-5 (rag-chew), HC-6 (all purpose) elements
- **MFJ-655B 8 Band Equalizer + ...**
  - Designed for use at transmit end
  - ~$220 new
  - eHam: **1.8/5 from 6 reviewers**
- **W2IHY 8 Band Equalizer + Noise Gate**
  - Designed for use at transmit end
  - ~$300 new ($150-200 used)
  - eHam: **5.0/5 from 174 reviewers**



The W2IHY 8 Band Equalizer + Noise Gate:

- **8 Band Equalizer:**
  - Splits the input signal into 8 sub-bands with center frequencies of:

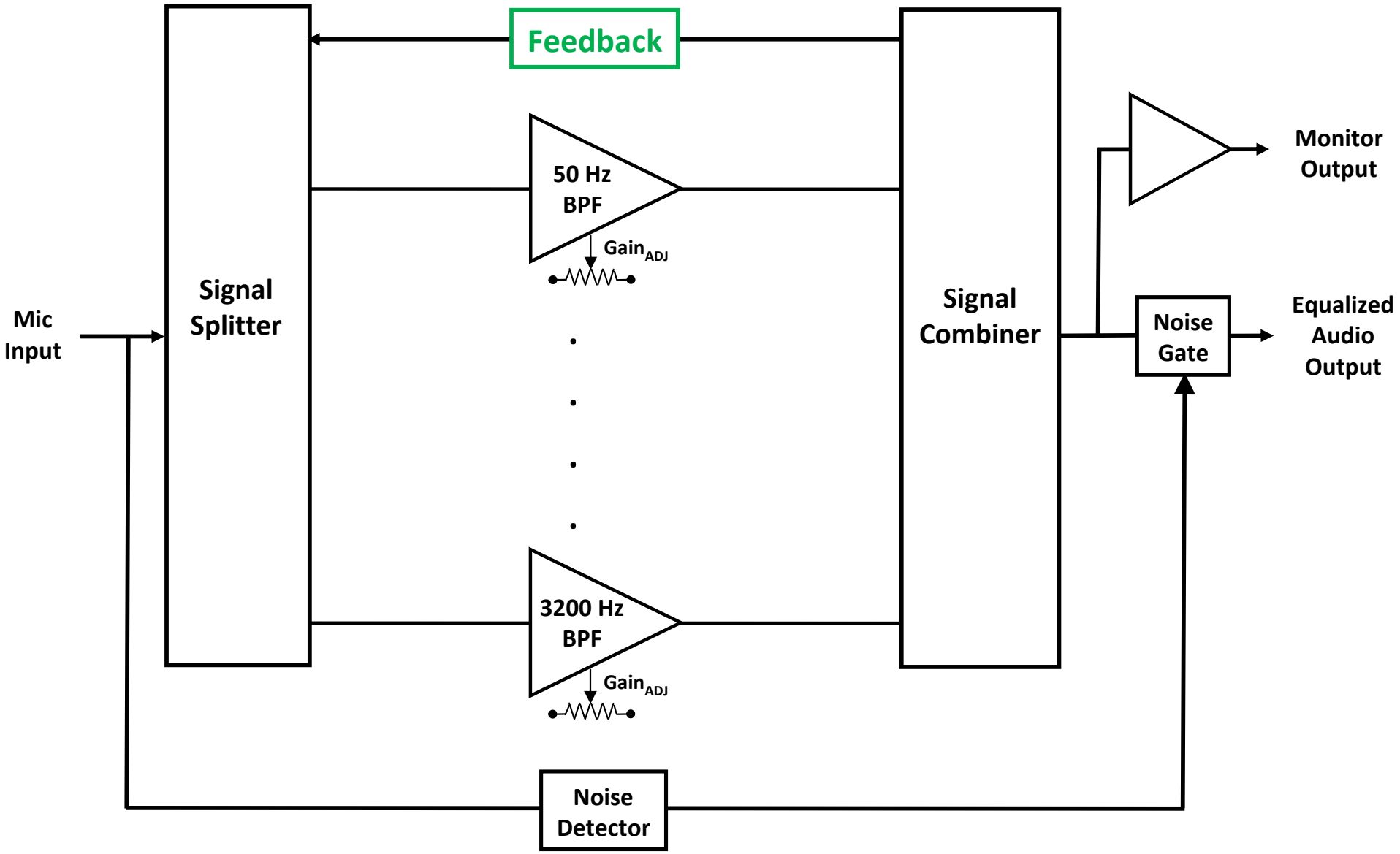
50 Hz
100 Hz
200 Hz
400 Hz
800 Hz
1600 Hz
2400 Hz
3200 Hz

} Mid-band gain adjustable: -16 to +16 dB

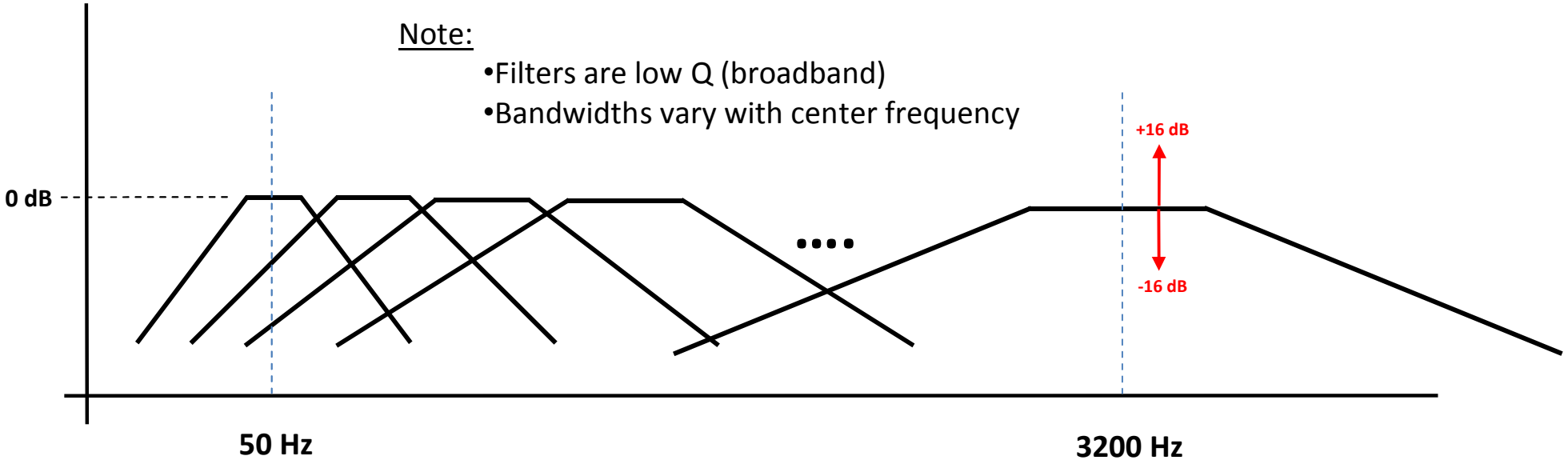
- **Noise Gate:**
  - Shuts off the audio during periods when there is no speech:
    - Effectively eliminates the background noise from capturing the transmitter during pauses and between sentences
    - Does ***not*** improve communication capability
- **Monitor:**
  - Somewhat helpful in setting up the equalizer
    - Doesn't account for frequency response of transmitter
  - Also allows for use of equalizer on receive

The W2IHY 8 Band Equalizer (continued):

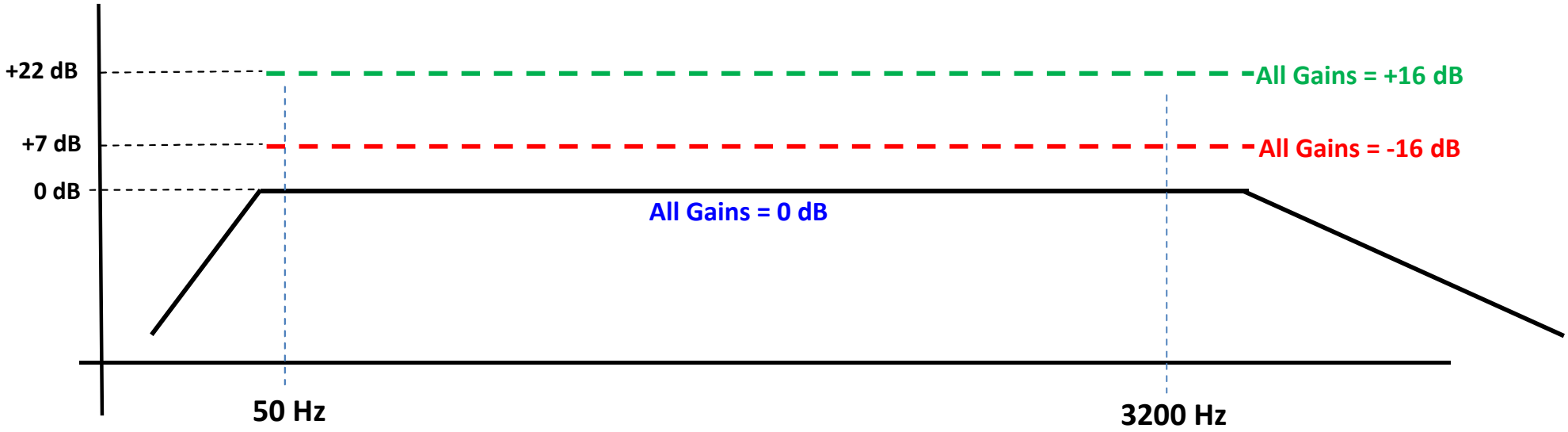
- Uses eight, one-pole bandpass filters (BPF) in parallel



The W2IHY 8 Band Equalizer (continued):

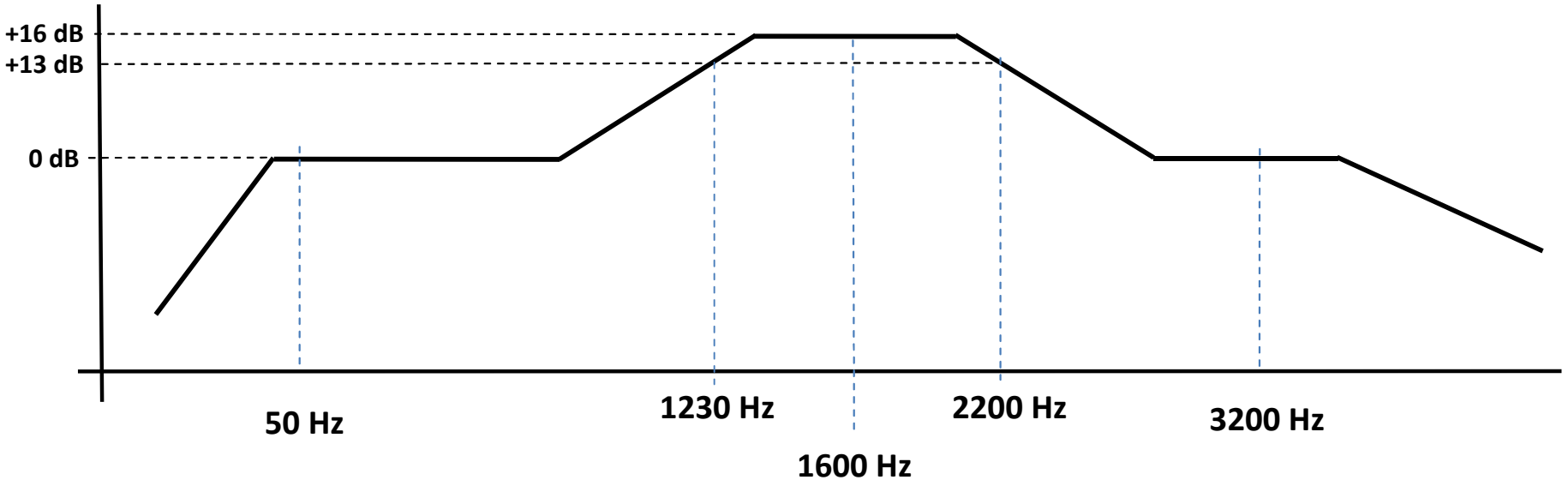


Note: Feedback modifies overall behavior of equalizer



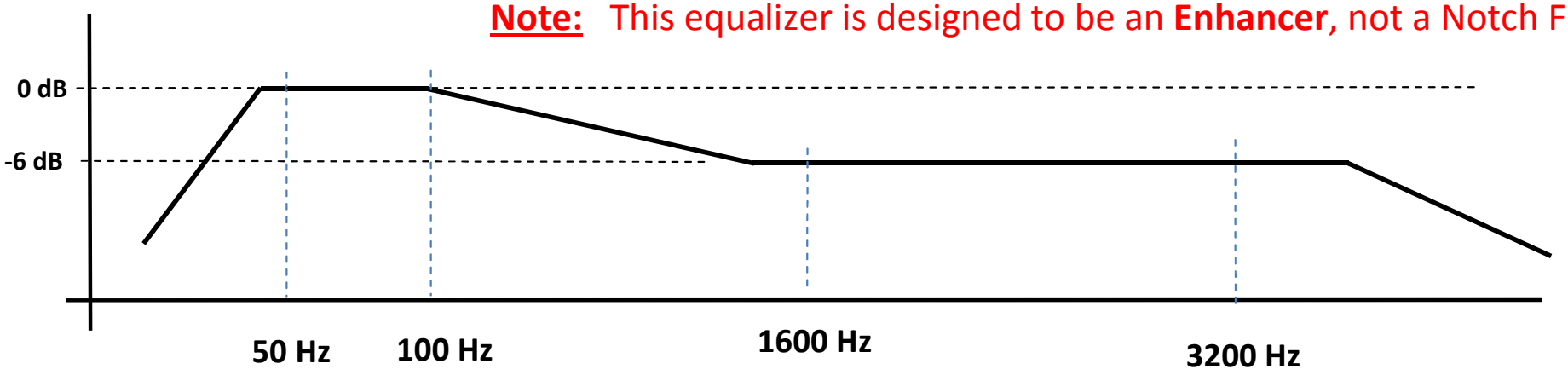
The W2IHY 8 Band Equalizer (continued):

1600 Hz Band Gain Set to +16 dB



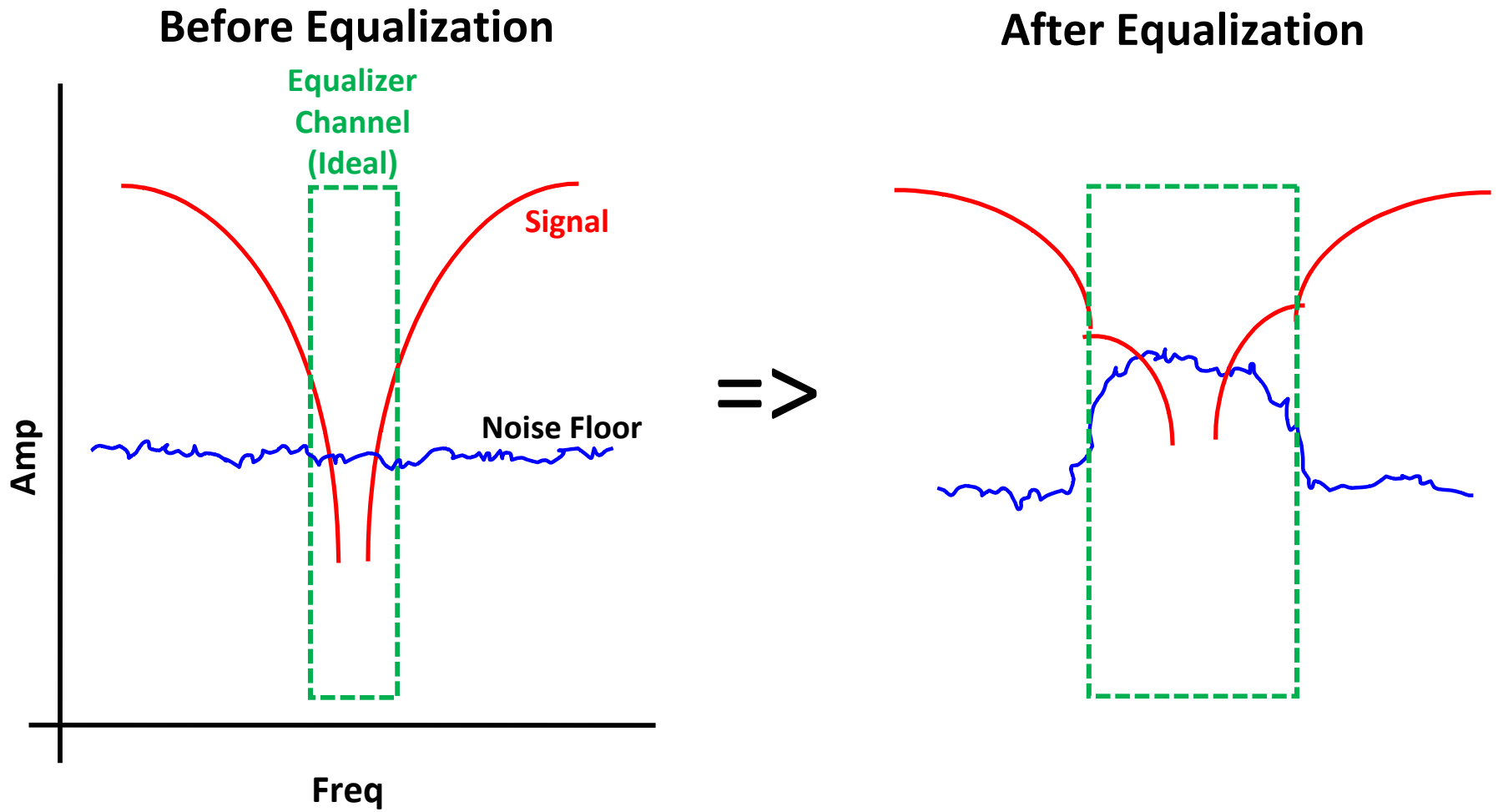
1600 Hz Band Gain Set to -16 dB

Note: This equalizer is designed to be an **Enhancer**, not a Notch Filter



Signals Below the Noise Floor:

- Can ***not*** be recovered by an equalizer!
- **Negative SNR + Gain = Negative SNR**



Some Equalization Examples:

Example 1: Two hams:

- Two hams both want flat audio response (ie, for rag-chewing)
- One buys used cheap mic and a used 8 band equalizer
- The other buys a new expensive mic and a new 8 band equalizer

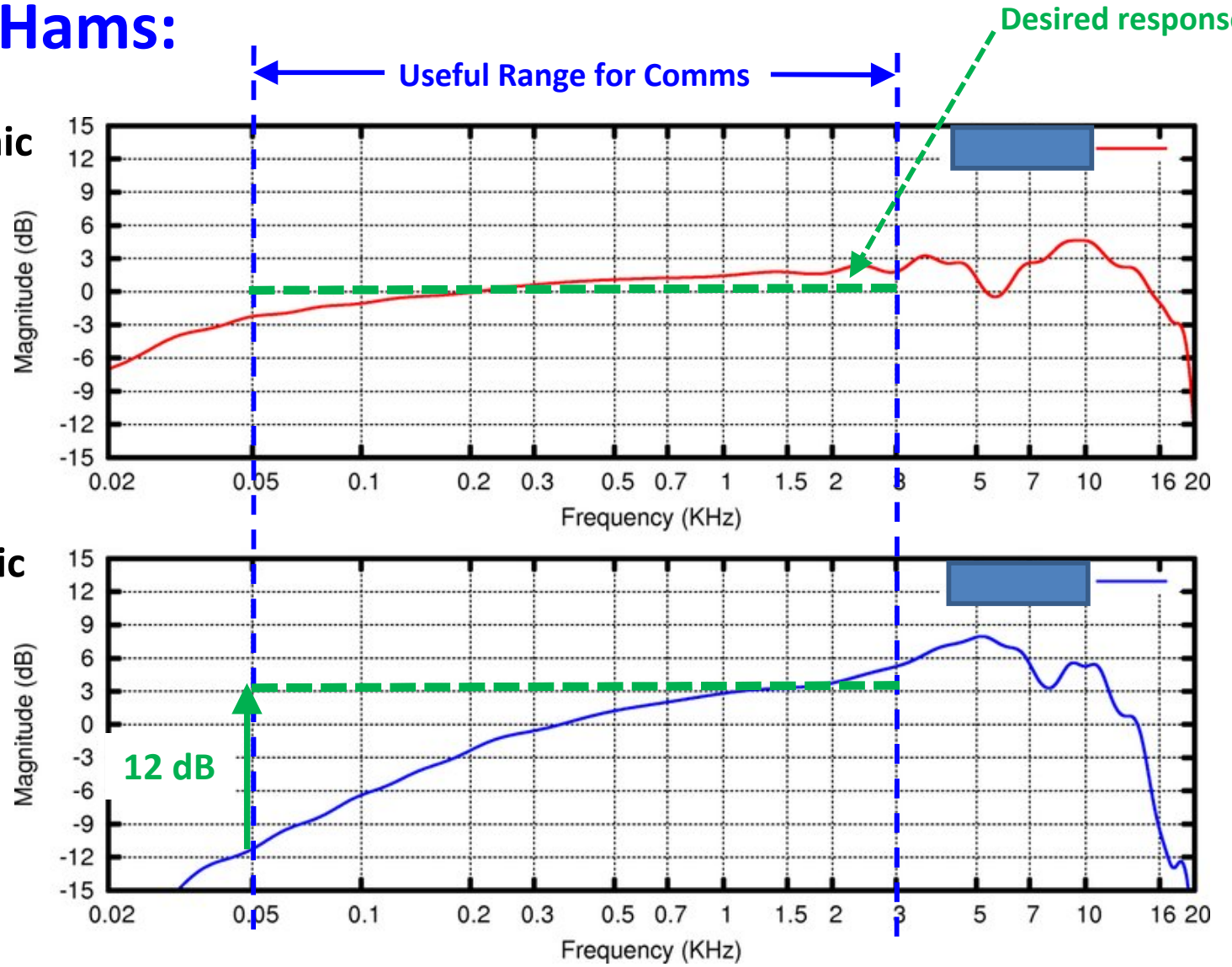
Example 2: My Station

- Icom 7600
  - 10 dB of compression
  - Bass and treble set at 0 dB
- W2IHY 8 Band Equalizer
- Heil Proset IC

Two Hams:

Studio mic

Cheap mic



Net cost

>$600

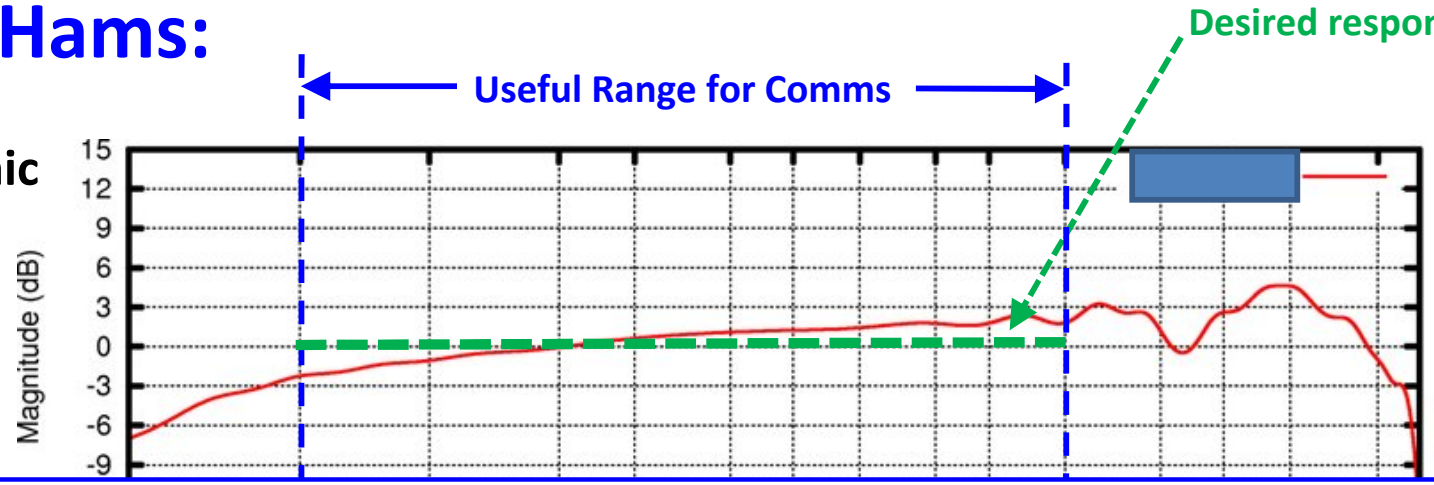
<$160

Two Hams:

Studio mic

Net cost

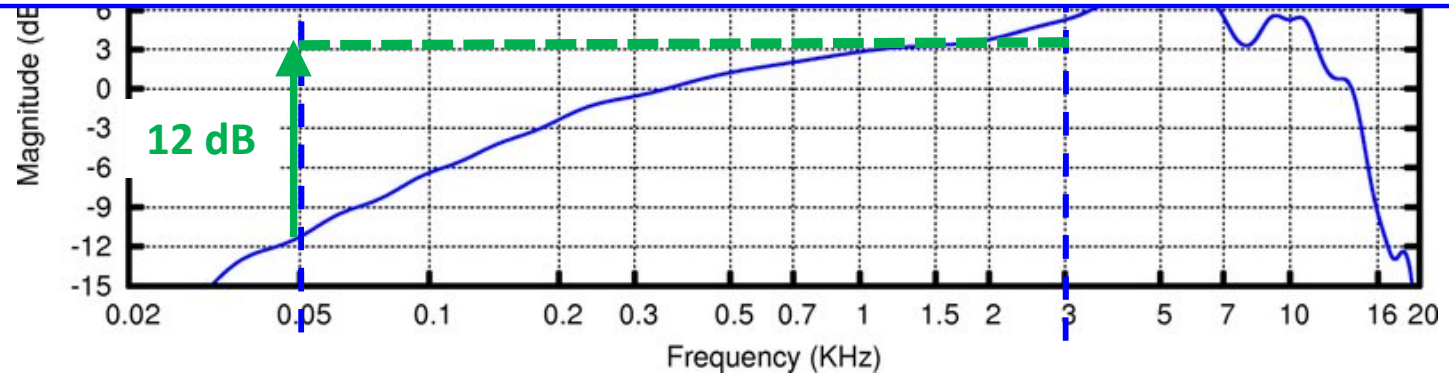
>$600



An good equalizer can:

- **Make a cheap mic sound like an expensive mic**
- **Make an expensive mic sound like an expensive mic**

Ch



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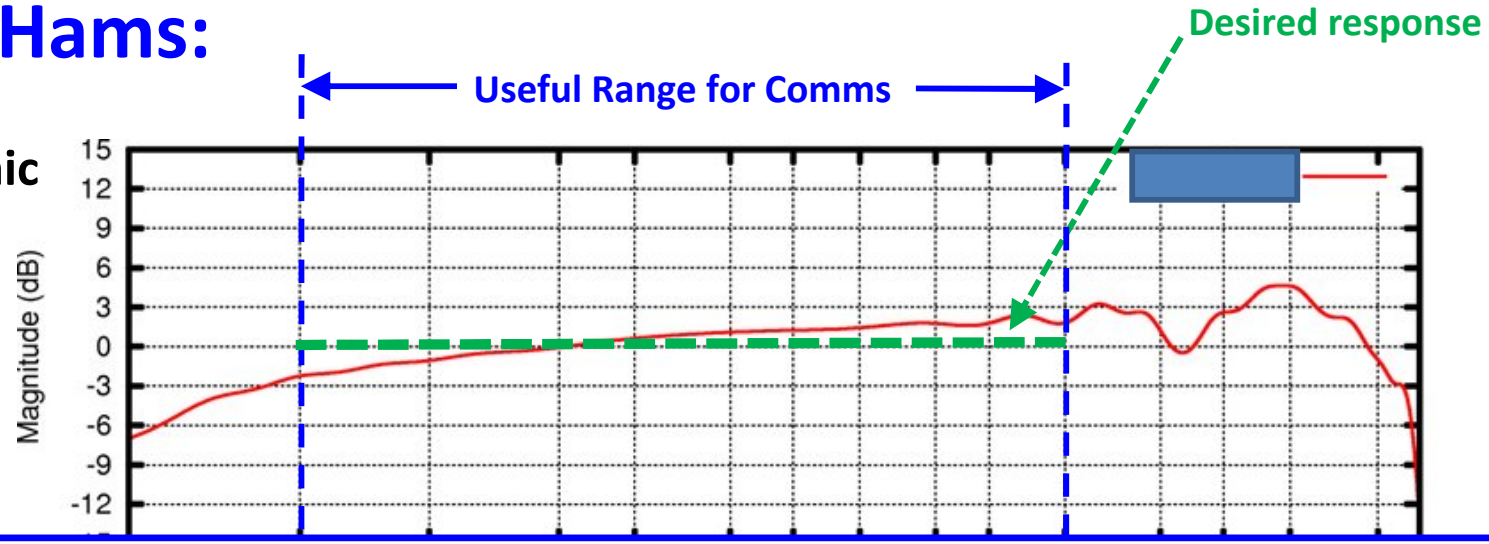
Two Hams:

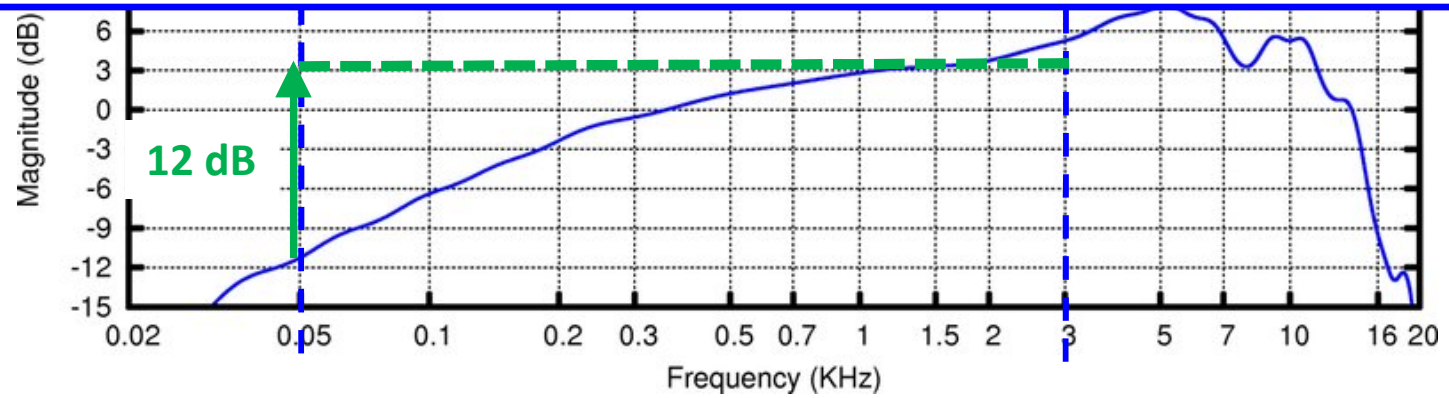
Studio mic



Net cost

>$600

Both Hams would have done better to just buy a good quality communications style microphone for ~$100!

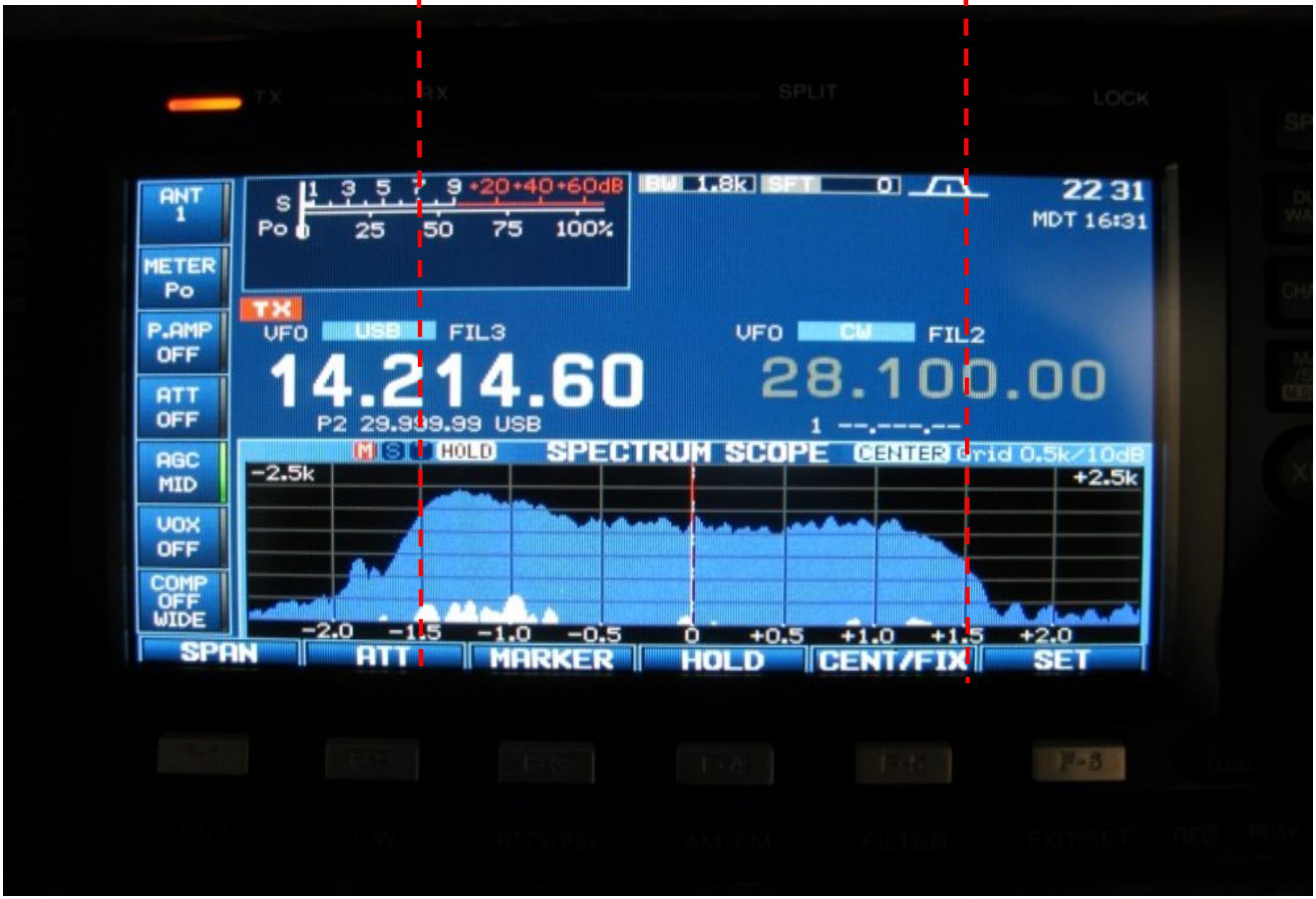


<$160

My Station:

Transmit Spectrum

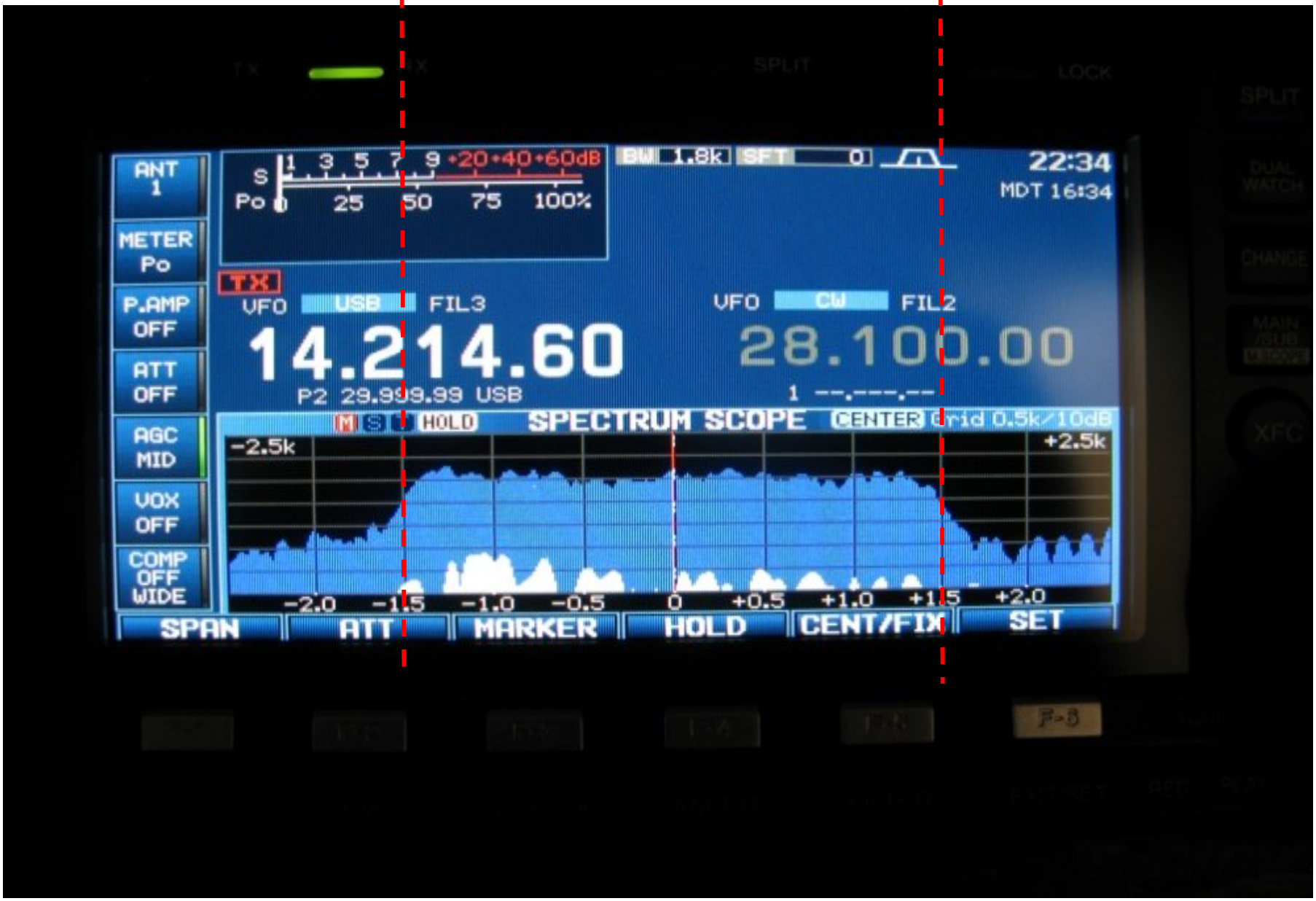
No Equalization



My Station:

Transmit Spectrum

"Rag chew" setting



My Station:

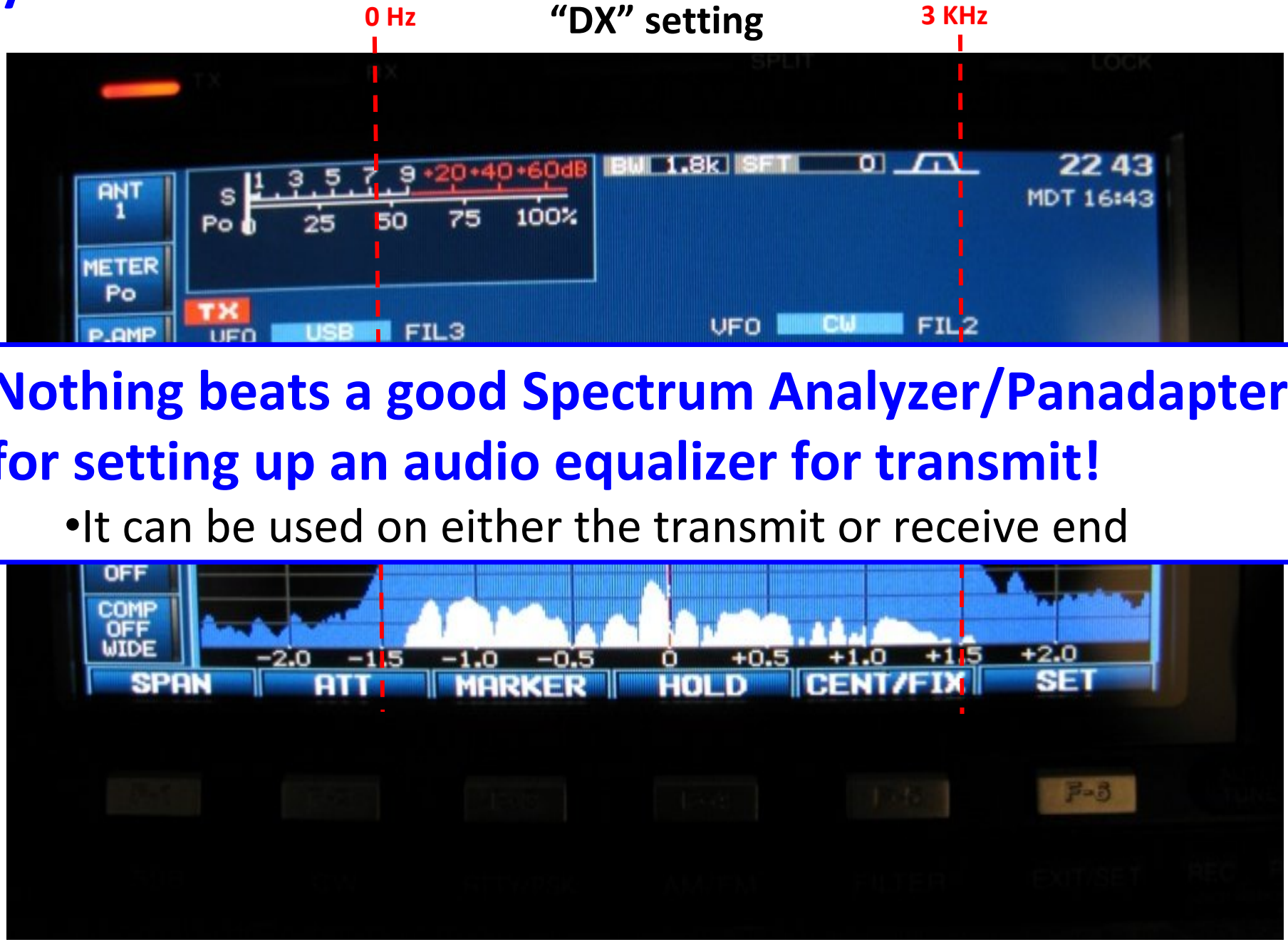
Transmit Spectrum

"DX" setting

My Station:

Transmit Spectrum

"DX" setting



Nothing beats a good Spectrum Analyzer/Panadapter for setting up an audio equalizer for transmit!

- It can be used on either the transmit or receive end

Equalizers at the Receive end:

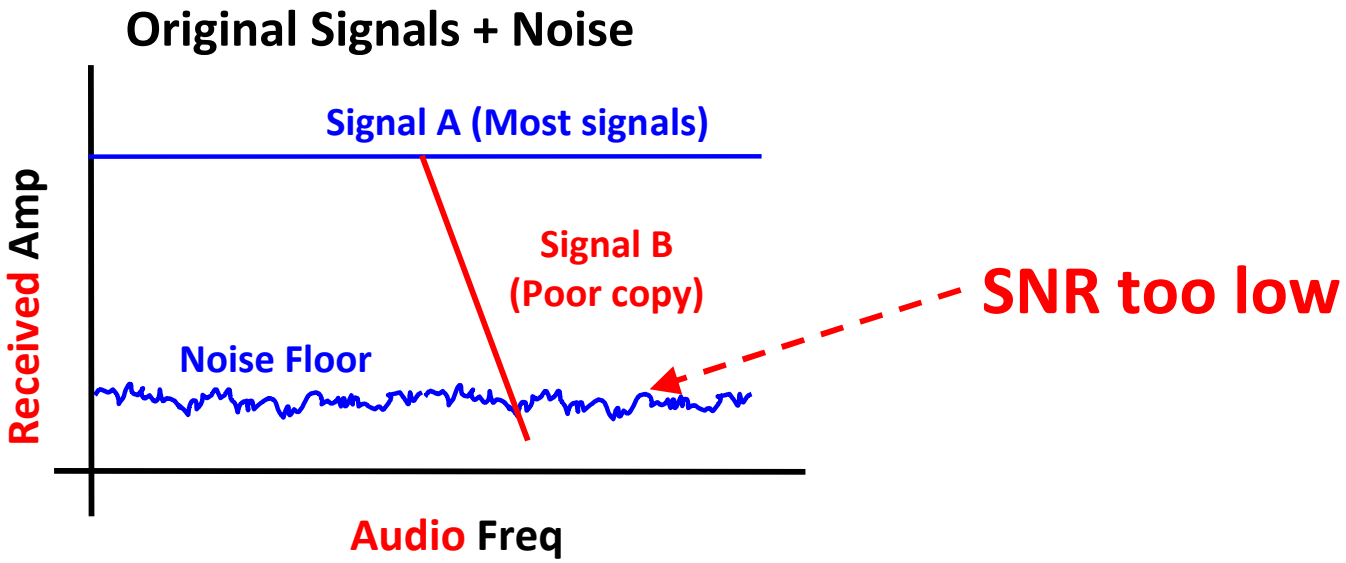
"Possibly the best kept secret in Ham Radio"

- How to equalize at the receive end:
  - Some transceivers offer "Bass" & "Treble" adjustments for the receiver
    - Limited capability
      - Only "Highs" and "Lows" can be adjusted
        - Corner frequencies usually not adjustable
      - May only have +/- 5 dB of gain adjustment range
    - Adequate for many applications
  - After market units:
    - **MFJ-616 Speech Intelligibility Enhancer**
      - 4 Band **single** channel equalizer designed for Rx applications
    - **MFJ-618 Speech Intelligibility Enhancer**
      - 4 Band **dual** channel equalizer designed for Rx applications
    - The **W2IHY 8 Band Equalizer**
      - Designed for transmit applications, but fully functional during receive
  - **Custom homebrew design**

Equalizers at the Receive end (continued):

Case 1: The transmit signal is missing critical frequencies ***and*** the *missing frequencies have adequate received SNR*:

- **Symptoms: *some*** signals are "muffled" or "tinny" and hard to understand, others are not



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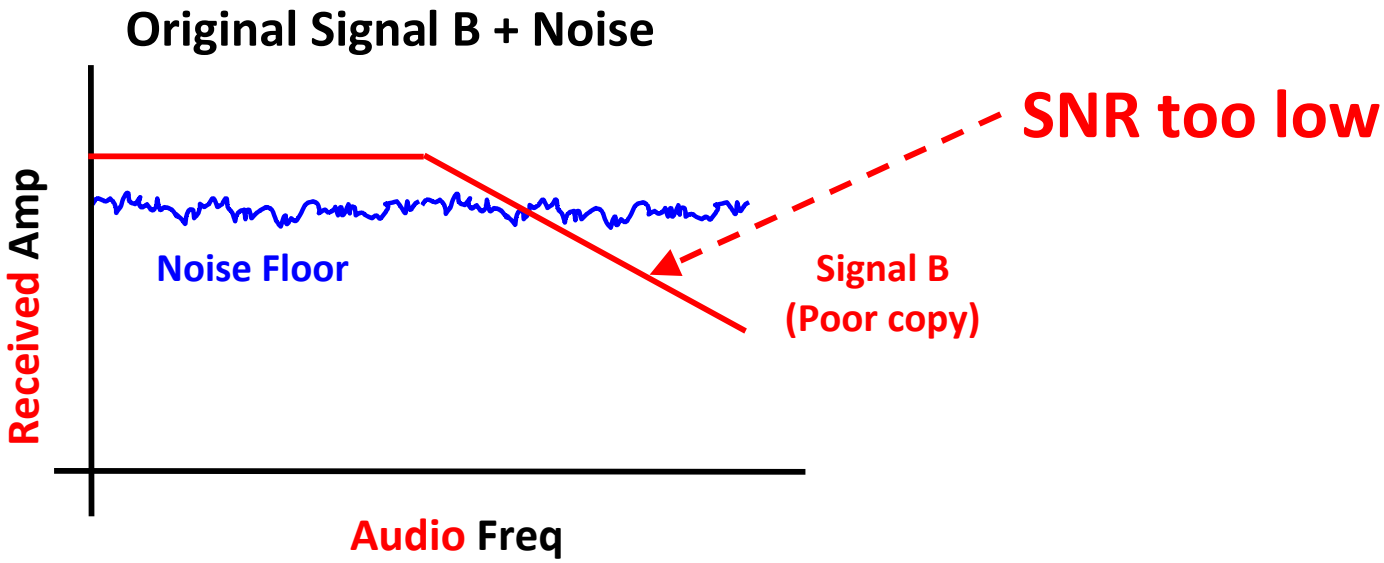

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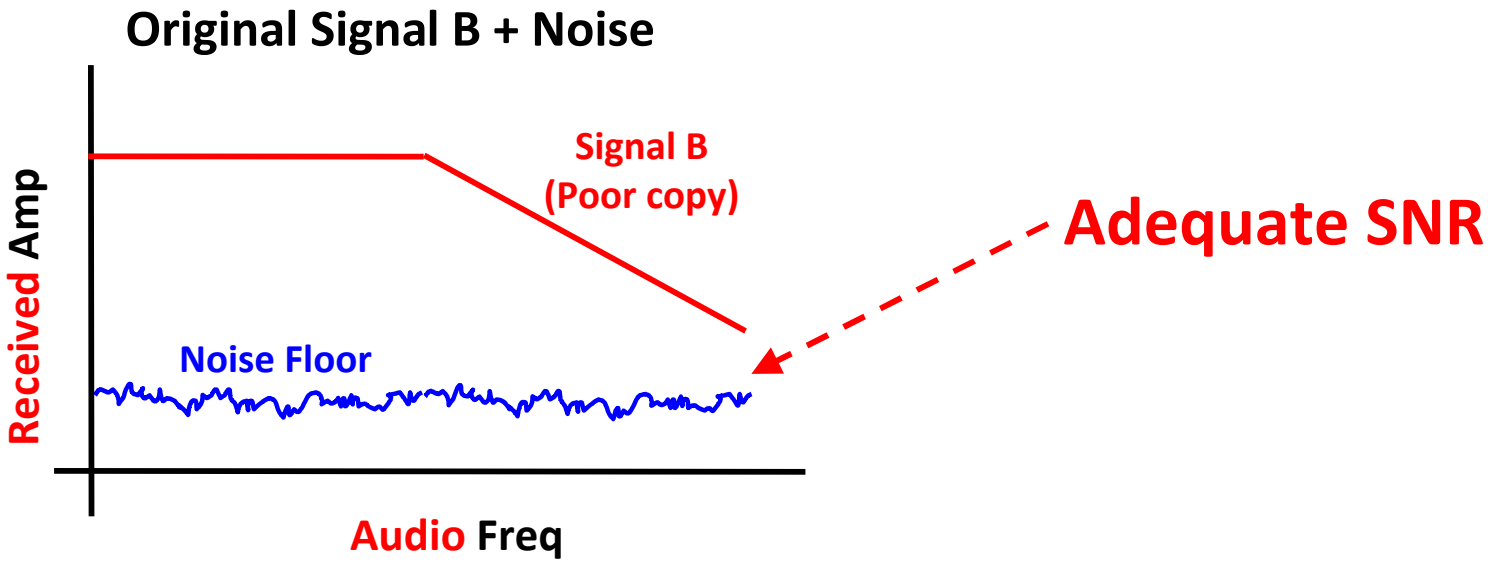

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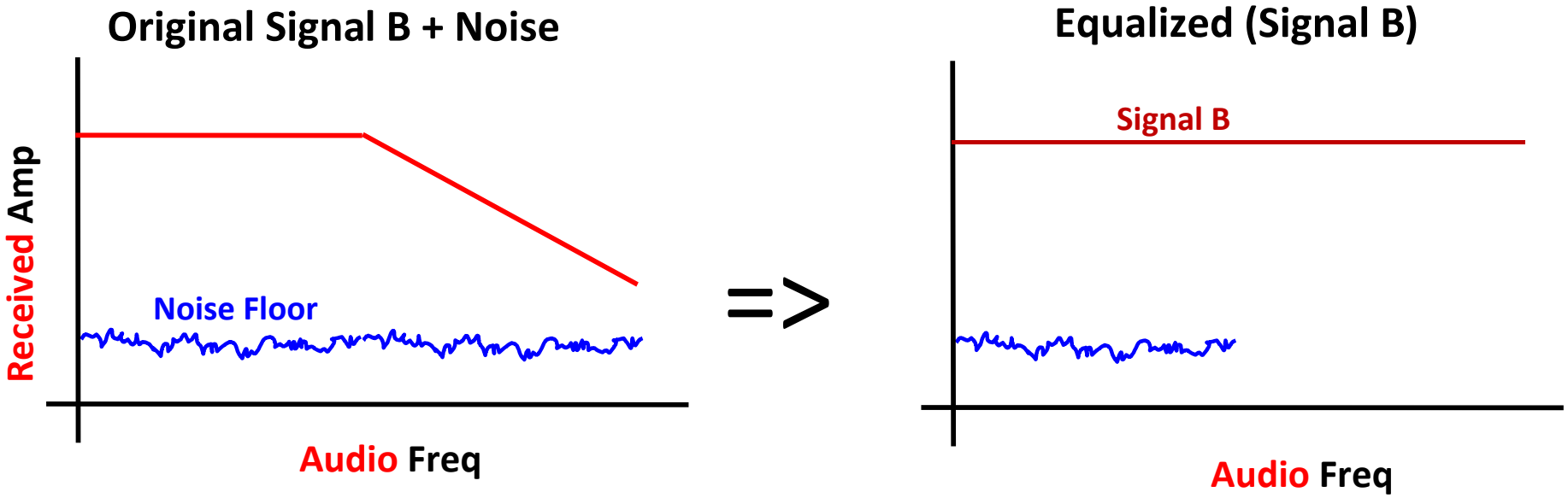

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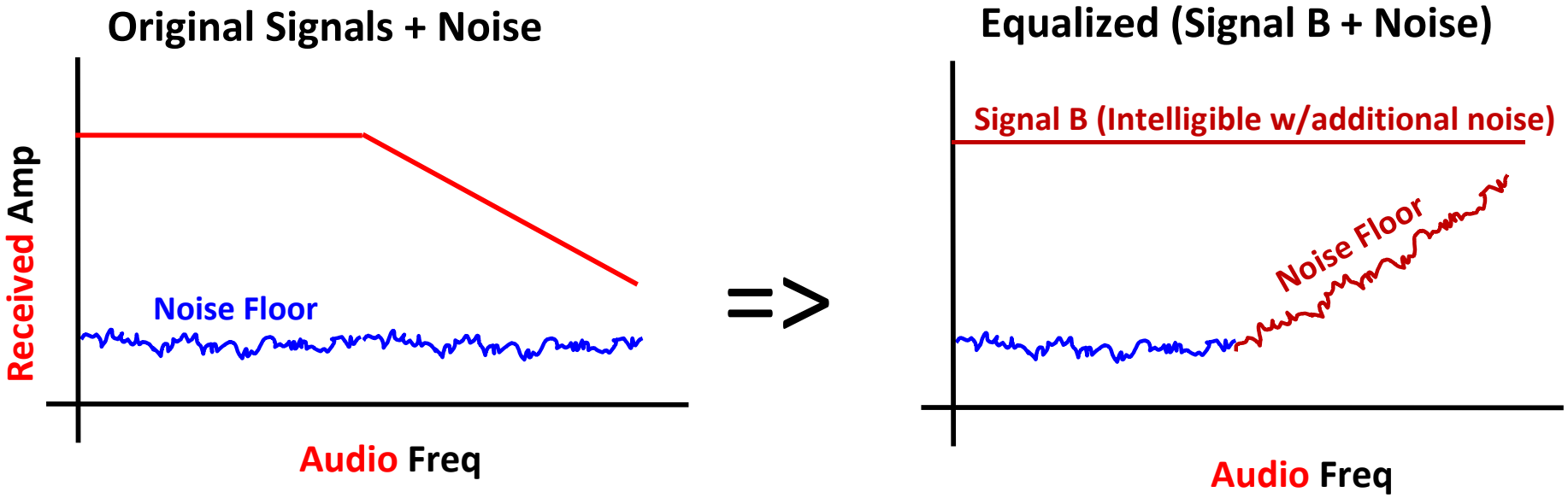

Equalizers at the Receive end (continued):

Case 1: The transmit signal is missing critical frequencies ***and*** the *missing frequencies have adequate received SNR*:

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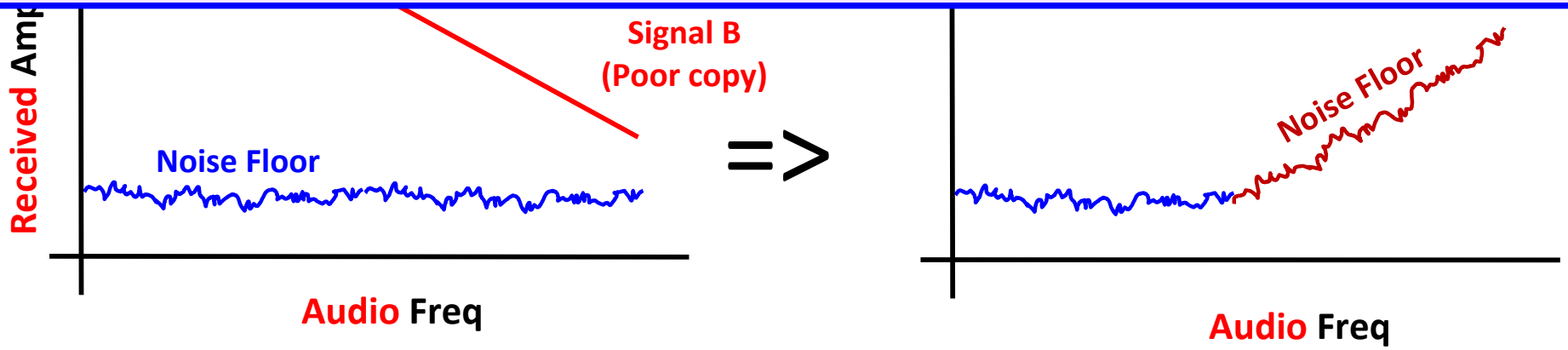
How can you get really messed-up audio settings?



A well intentioned backup OP!

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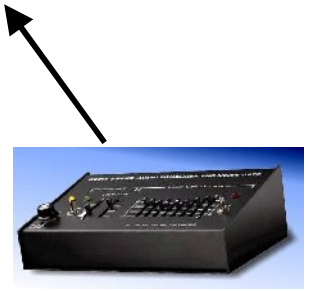


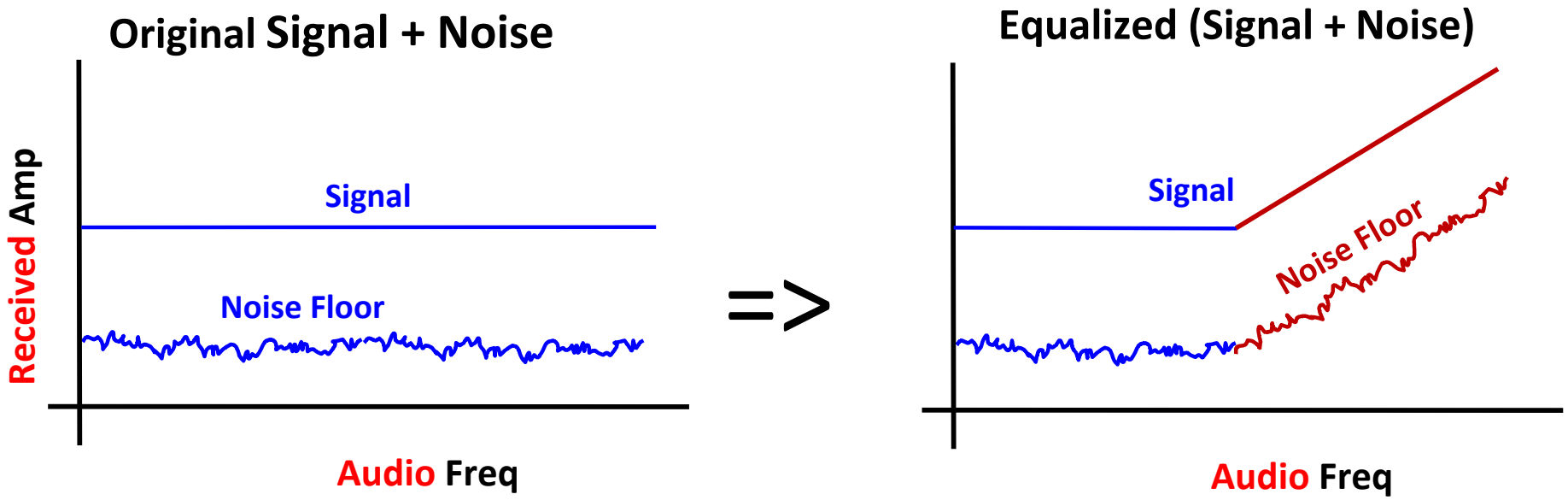
“Keep the damn box covered!”

“Keep the damn box covered!”

Keeping it covered is a good idea even if you don’t have any backup ops

Equalizers at the Receive end (continued):

Case 2: The received signal needs more "Punch" ***and*** there is adequate SNR at the receiver output:

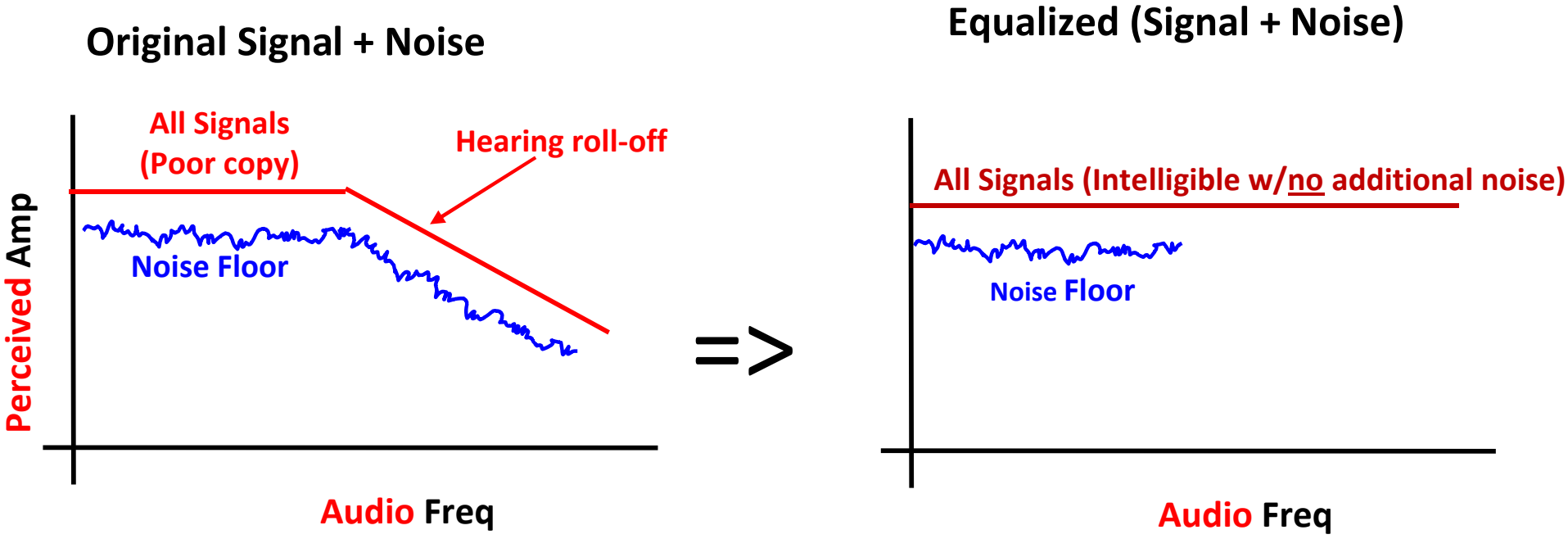


May be SNR dependent?

Equalizers at the Receive end (continued):

Case 3: The receive operator has a **hearing deficiency**:

- **Symptoms: *all*** signals are "muffled" or "tinny" and hard to understand



- **Perceived Amp** = what the Brain actually hears
- Signal and Noise are equally affected

***Not* SNR dependent**

Equalizers at the Receive end (continued):

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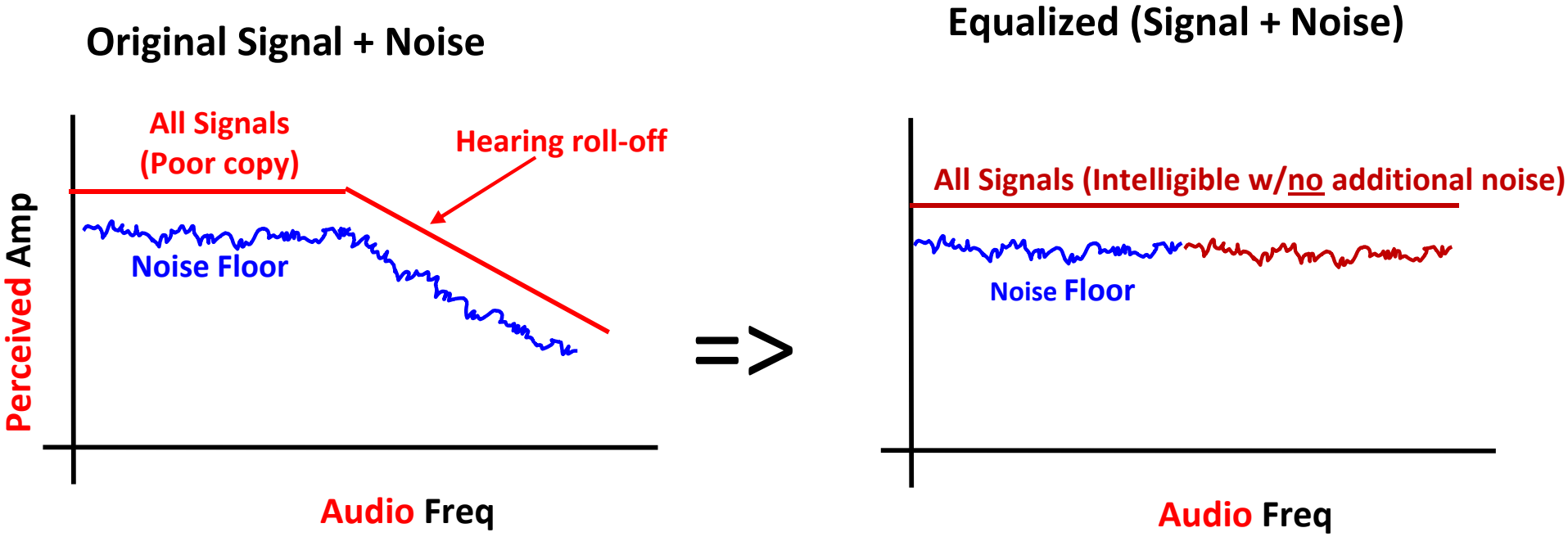


- **Perceived Amp** = what the Brain actually hears
- Signal and Noise are equally affected

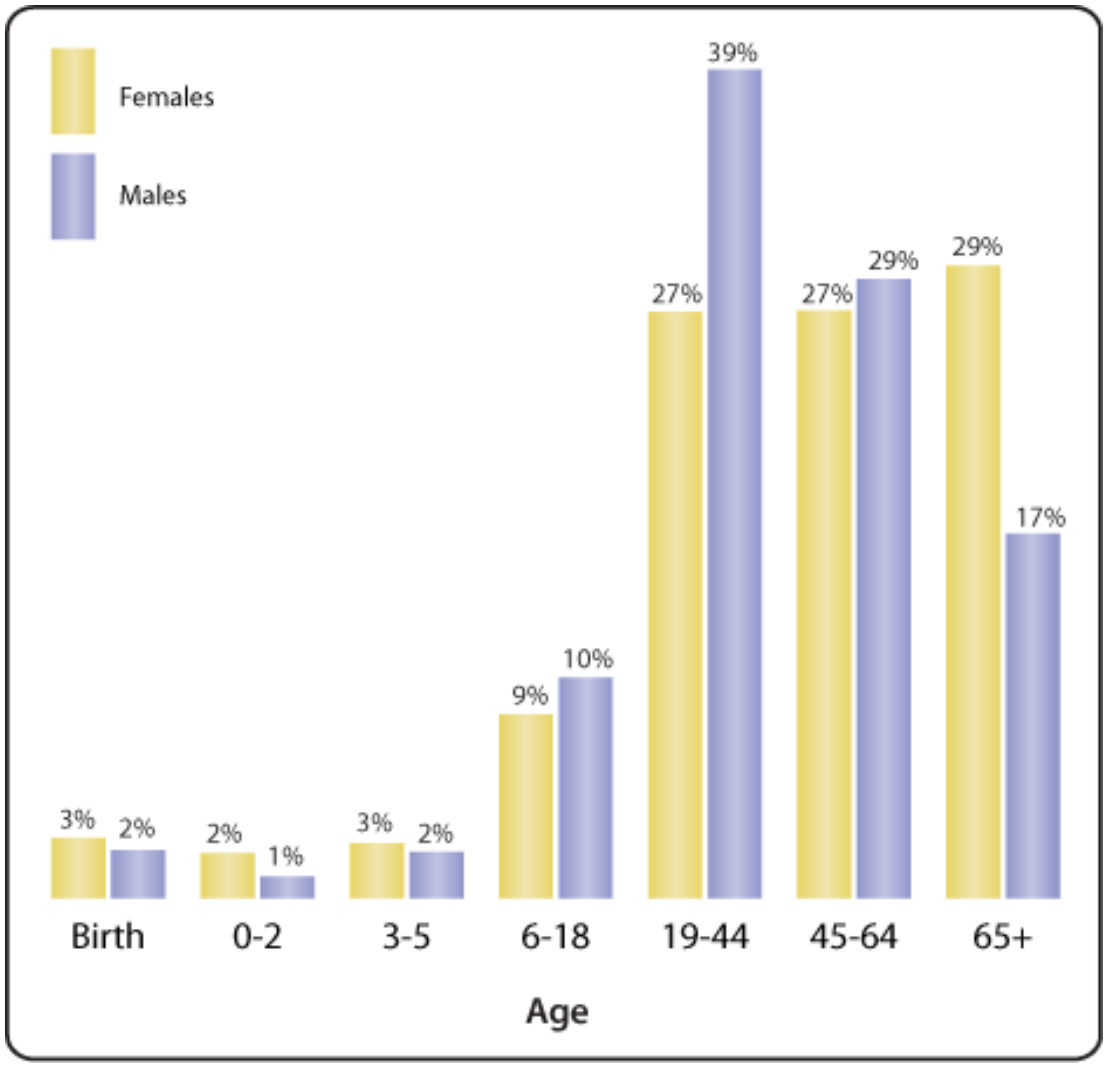
***Not* SNR dependent**

Equalizers at the Receive end (continued)**:**

- **A hearing deficiency can result from**:
  - **Presbycusis**: a gradual, age-related reduction in the ability to hear the higher frequency sounds
  - Noise induced hearing loss (NIHL)
  - Illness induced

- **Age at which hearing loss begins?**

Onset of hearing loss versus age:



A Hearing Deficiency Example

- **How is your hearing?**
  - Free On-line hearing test:

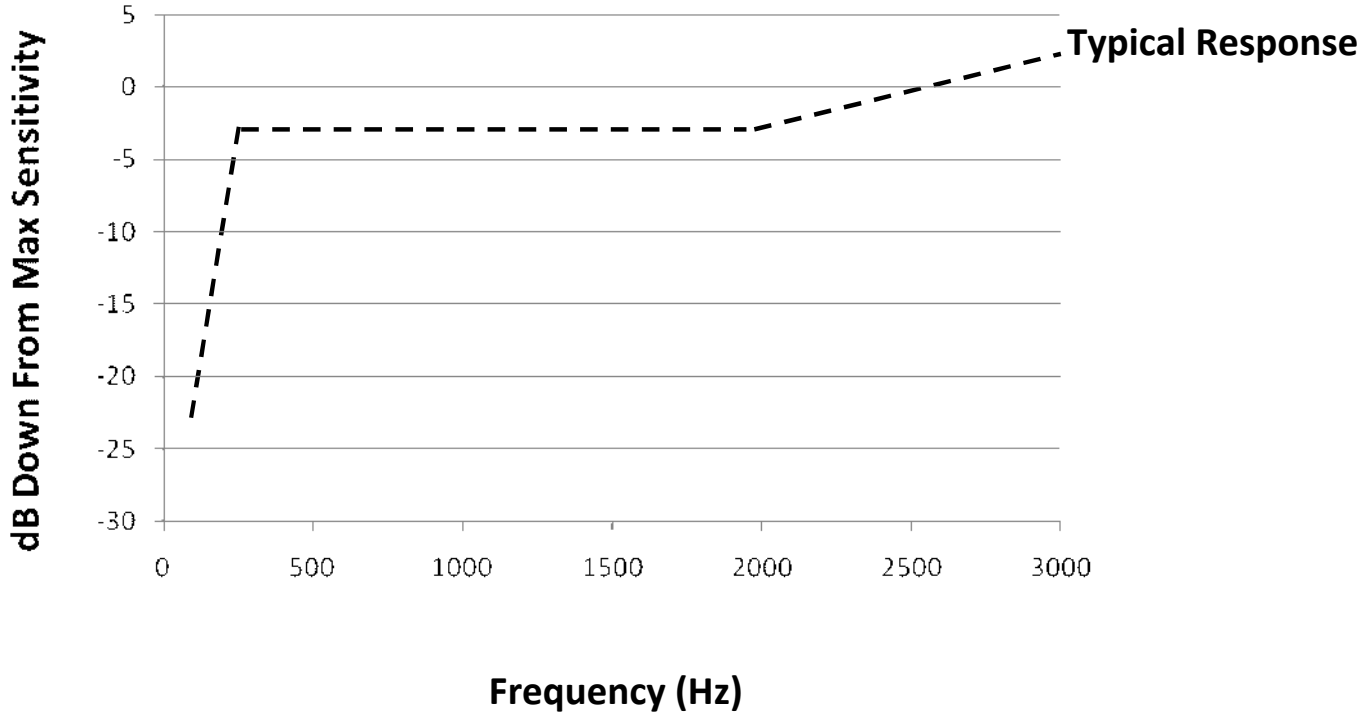
http://www.phys.unsw.edu.au/jw/hearing.html

Note:

- Results are *relative* sensitivities, not absolute
  - The shape of the response curve can be very accurate
- Assumes that your sound card & speakers have a flat frequency response
  - Can use the computer speakers with an ear plug
  - Good earphones recommended over computer speakers

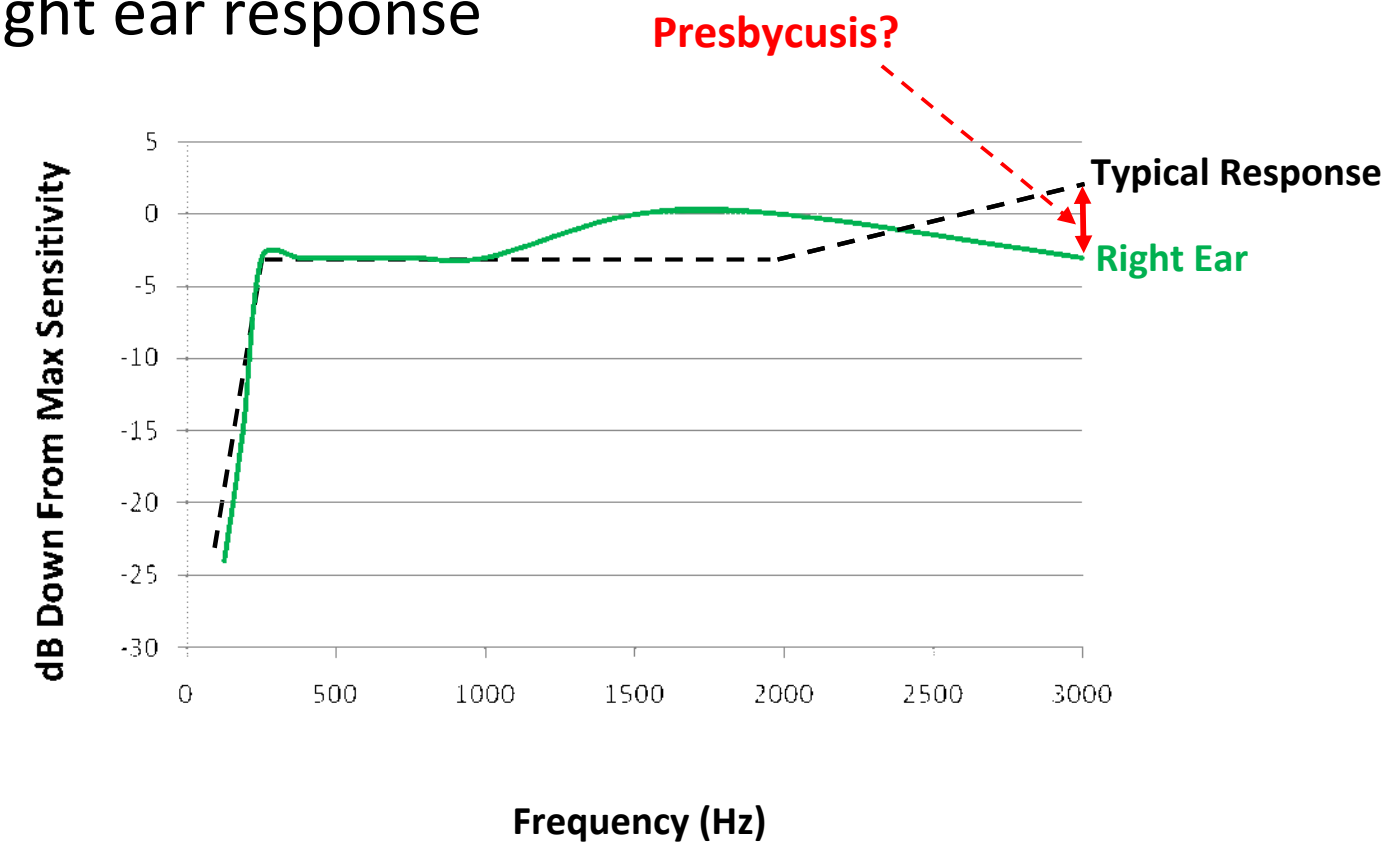
A Hearing Deficiency Example (continued)

Typical response



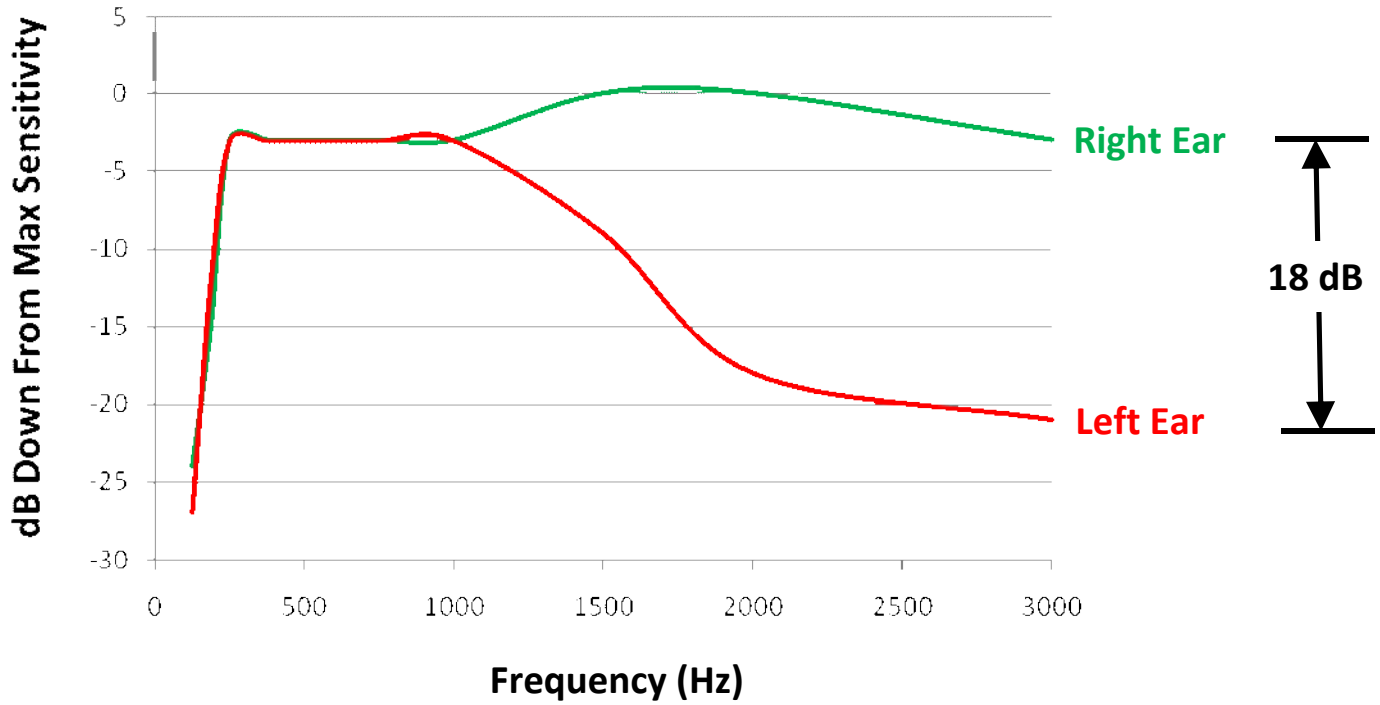
A Hearing Deficiency Example (continued)

- My right ear response



A Hearing Deficiency Example (continued)

- My left ear has a significant deficiency above 1 KHz



Options:

1. Go **monaural** (ie, use only right ear)
   - The Brain is programmed for "stereo" reception
   - I copy signals better when both ears are used
2. Use an **Equalizer** to "**Equalize**" the response of my left & right ears

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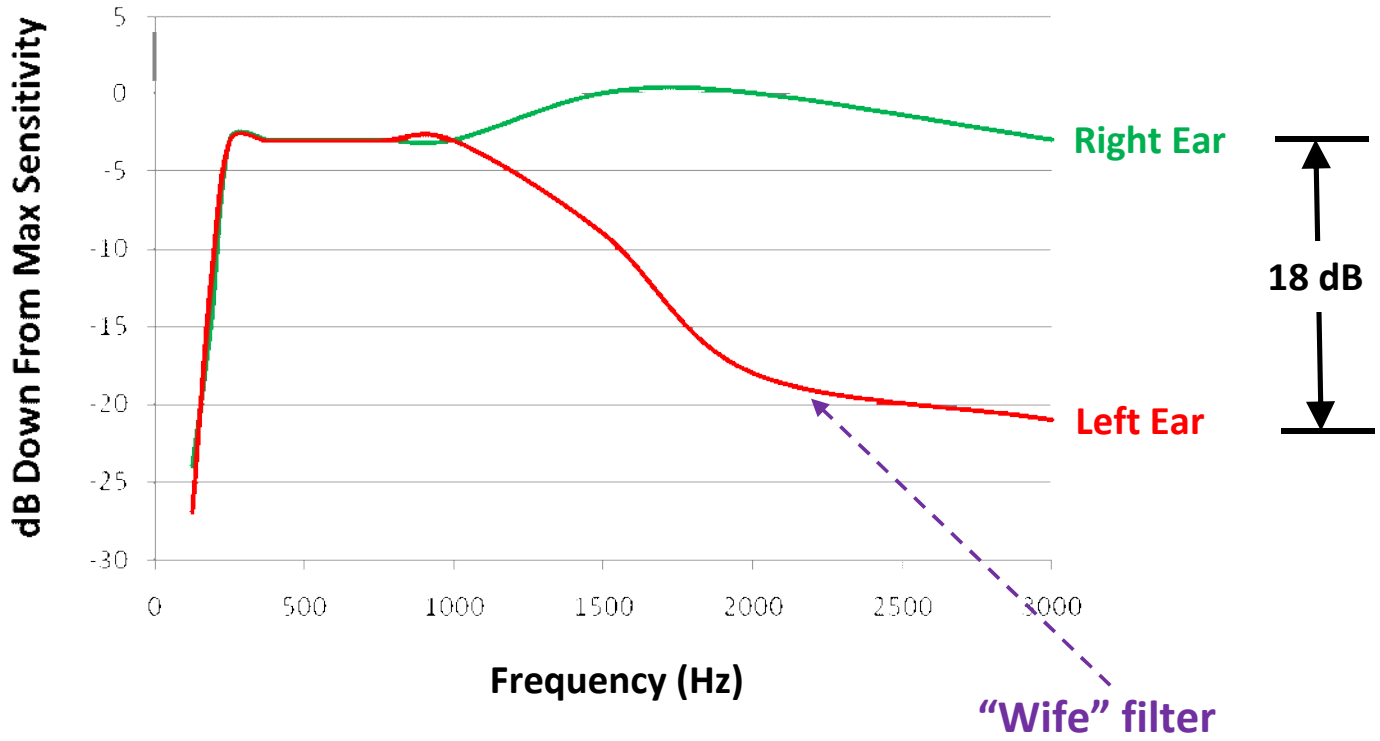

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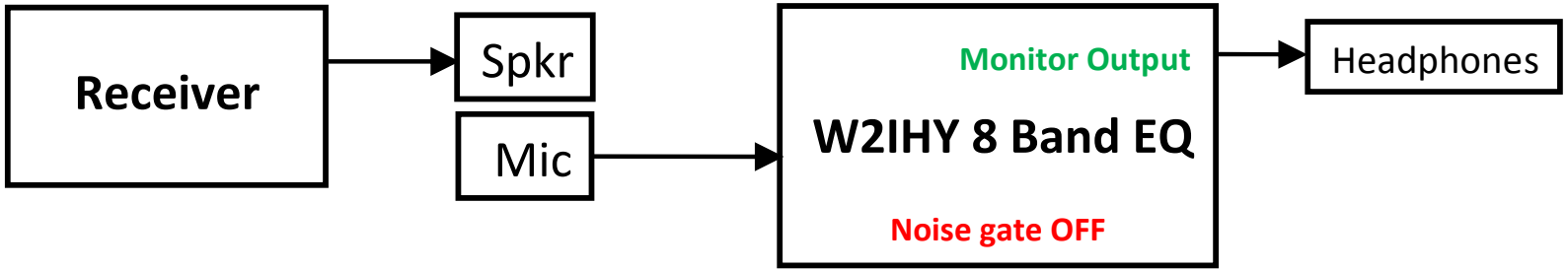
The W2IHY 8 Band Equalizer for Receive:

- Designed for transmit applications, however it is fully functional during receive

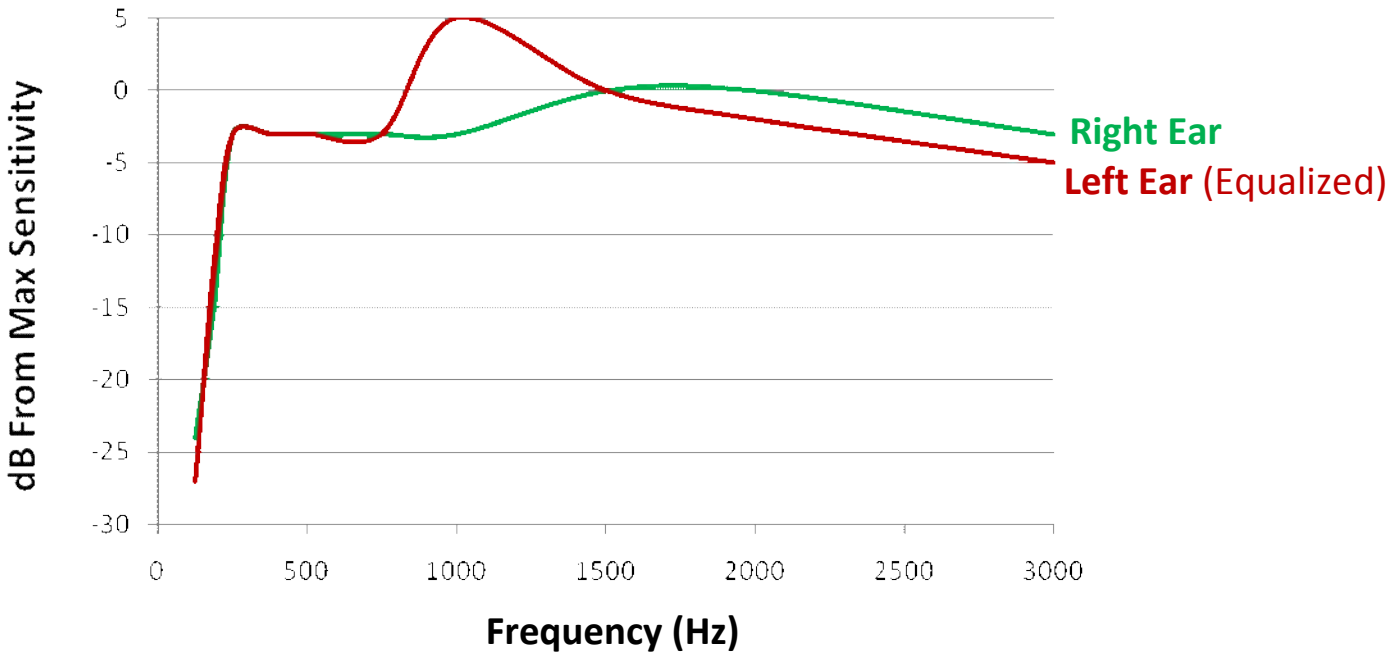


- Settings used to equalize my left ear and right ear responses:

BAND (Hz)	50	100	200	400	800	1600	2400	3200
GAIN (dB)	0	0	0	0	-16	-16	16	16

W2IHY 8 Band Equalizer:

Results:



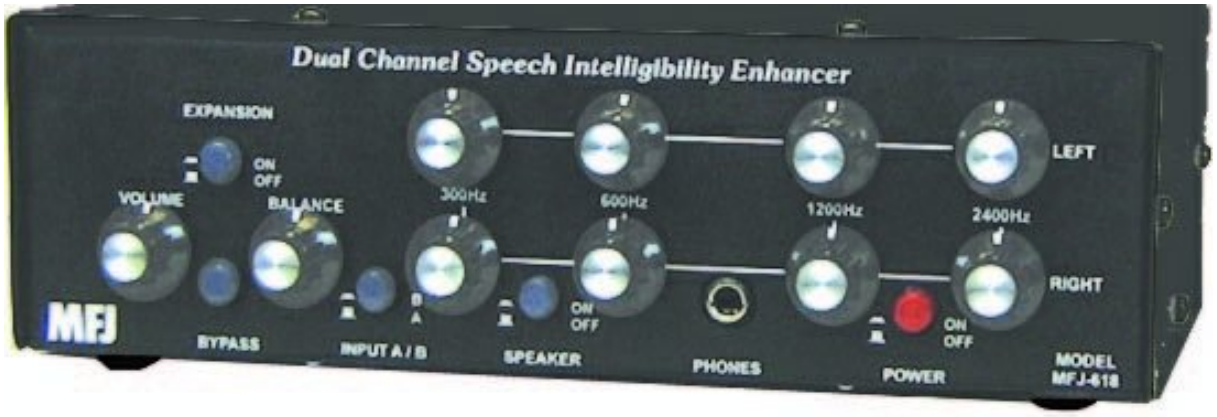
This correction resulted is a <u>significant</u> improvement in my ability to copy SSB signals with the left ear!

MFJ-616:

- "Single Channel Speech Intelligibility Enhancer"
  - 4 band audio equalizer ***intended for use at the receiver***
    - Sub-band center frequencies:
      - 300 Hz
      - 600 Hz
      - 1200 Hz
      - 2400 Hz
    - Each sub-band gain adjustable +/-12 dB
- Designed to compensate for a wide range of hearing deficiencies
- $190 new
- eHam: **5.0/5** from **6 reviewers**

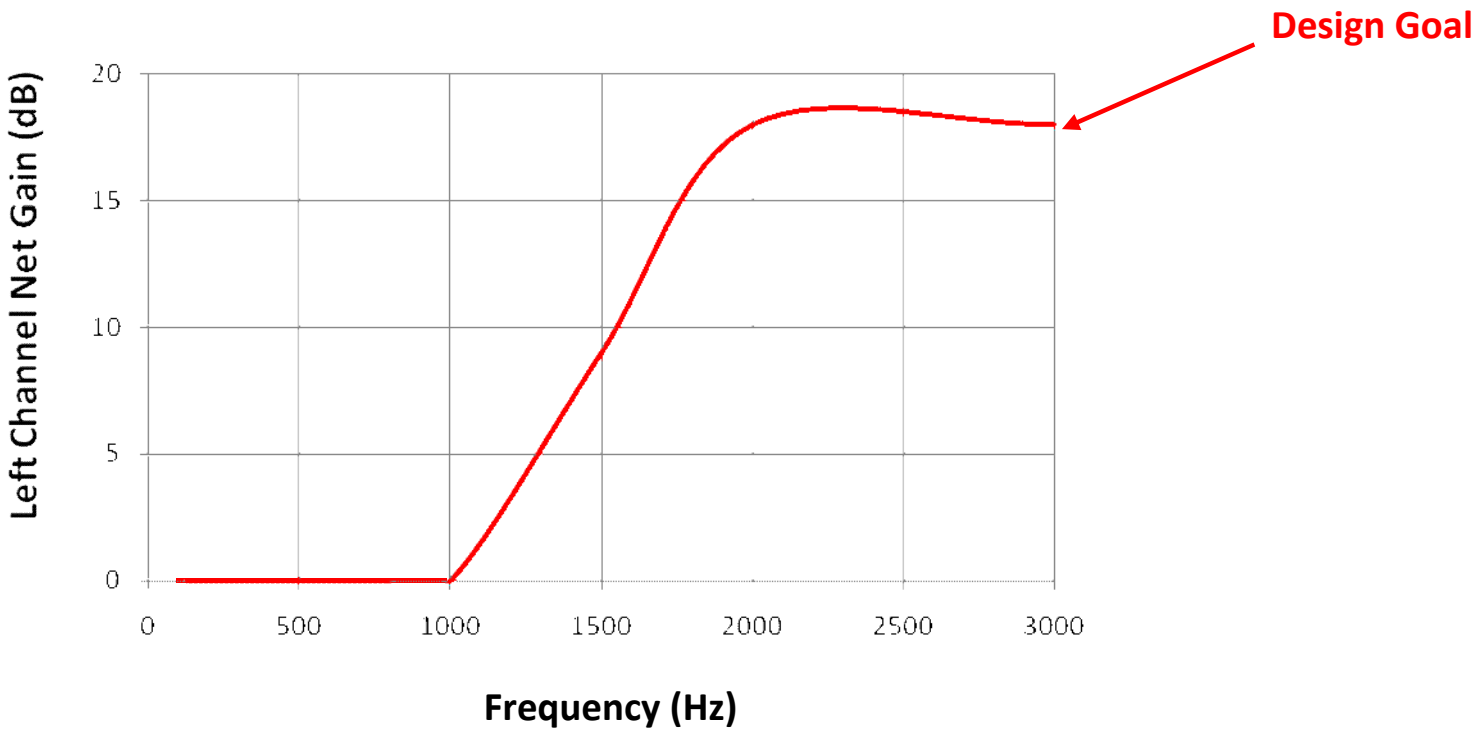
MFJ-618:

- "Dual Channel Speech Intelligibility Enhancer"
- Dual channel version of MFJ-616
- $220 new
- eHam: no reviews

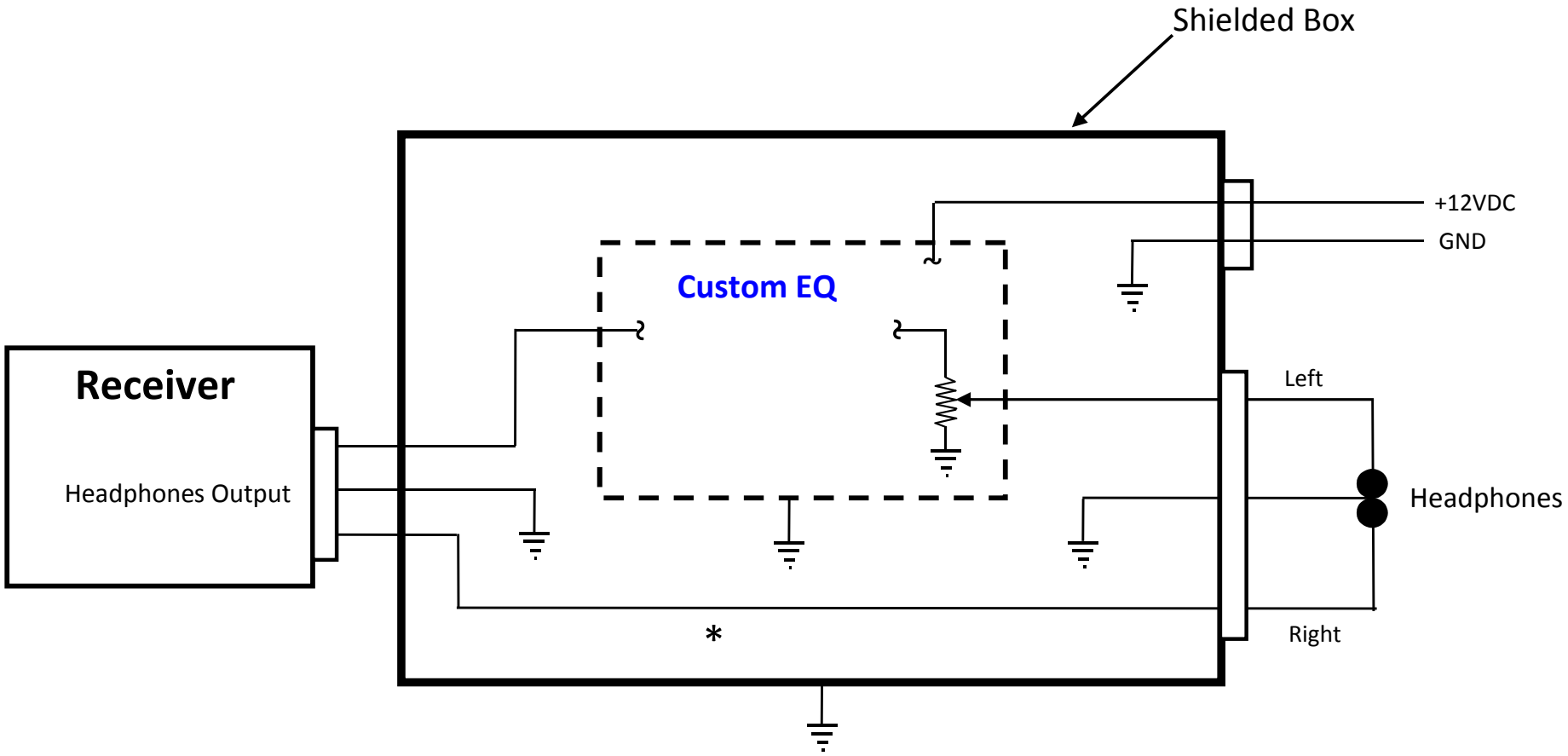


Custom Homebrew Equalizer:

- Equalizing my left ear response only requires a **2 Band Equalizer**
- Can be made with parts readily available at Radio Shack
  - 2-3 ICs and < 30 R's & C's (<$50)



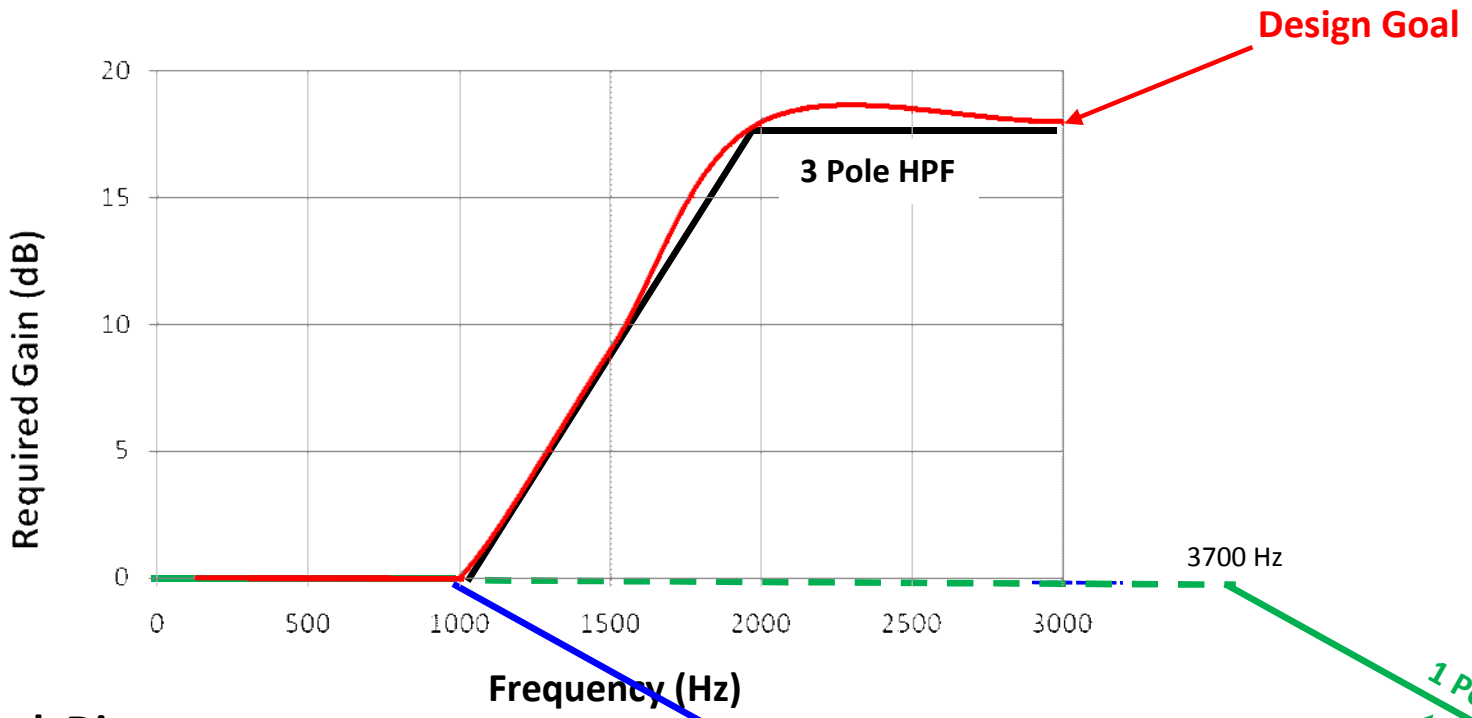
Custom Homebrew Equalizer (continued):



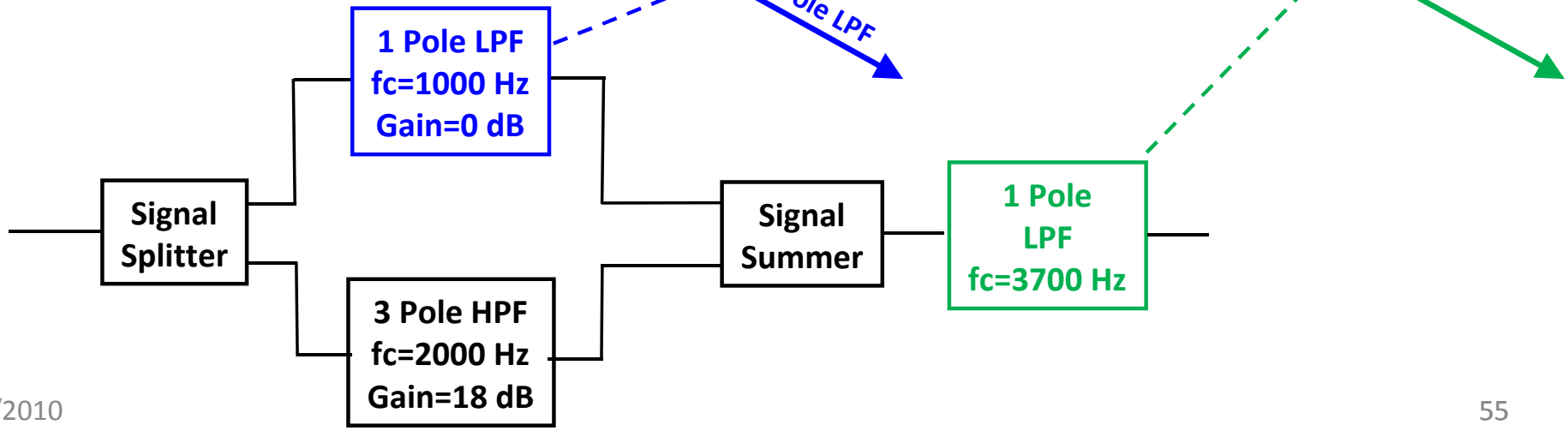
*A second **Custom EQ** could also be used in the right channel if needed

Custom Homebrew Equalizer (continued):

- Design

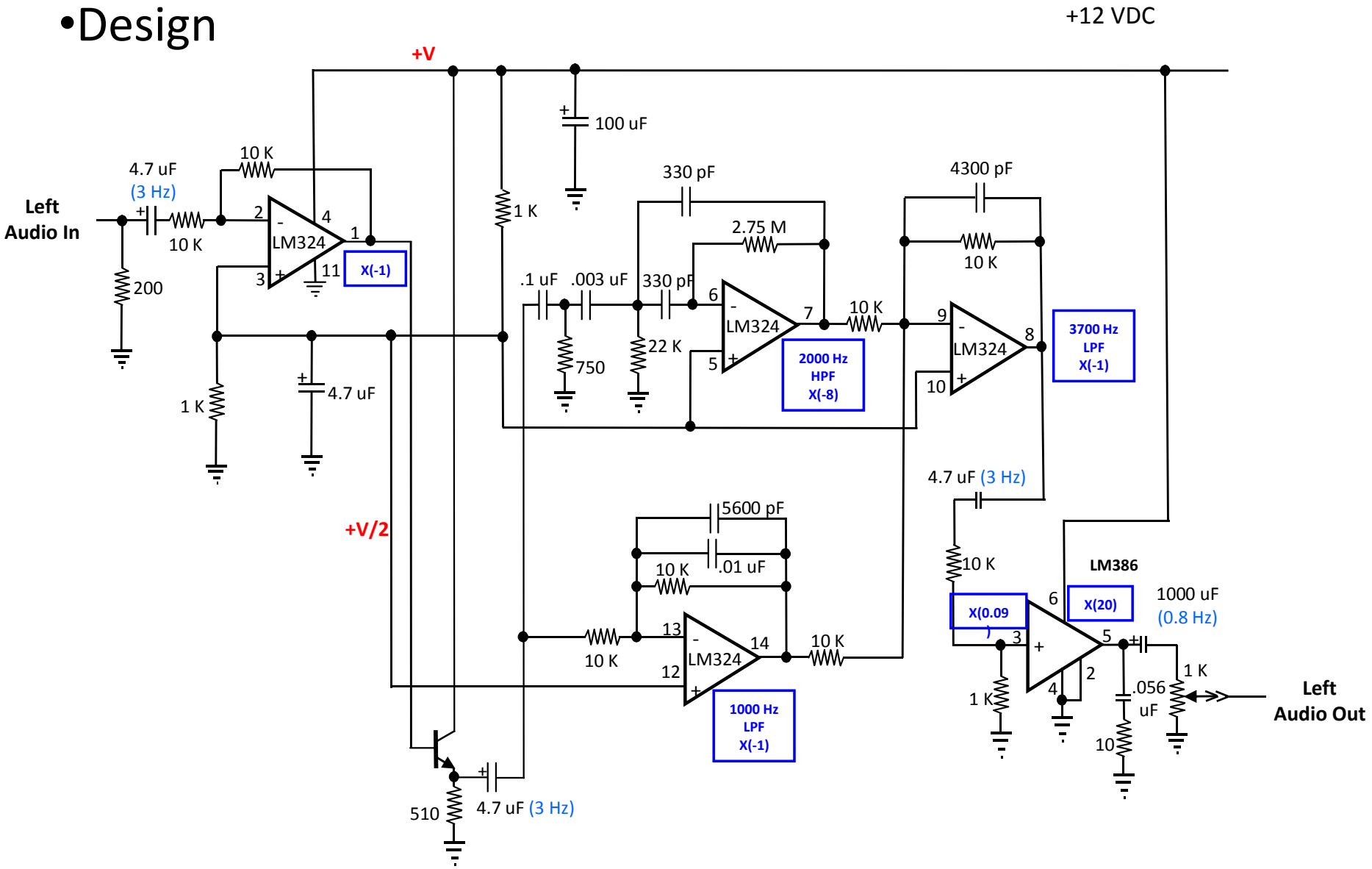


Functional Block Diagram:



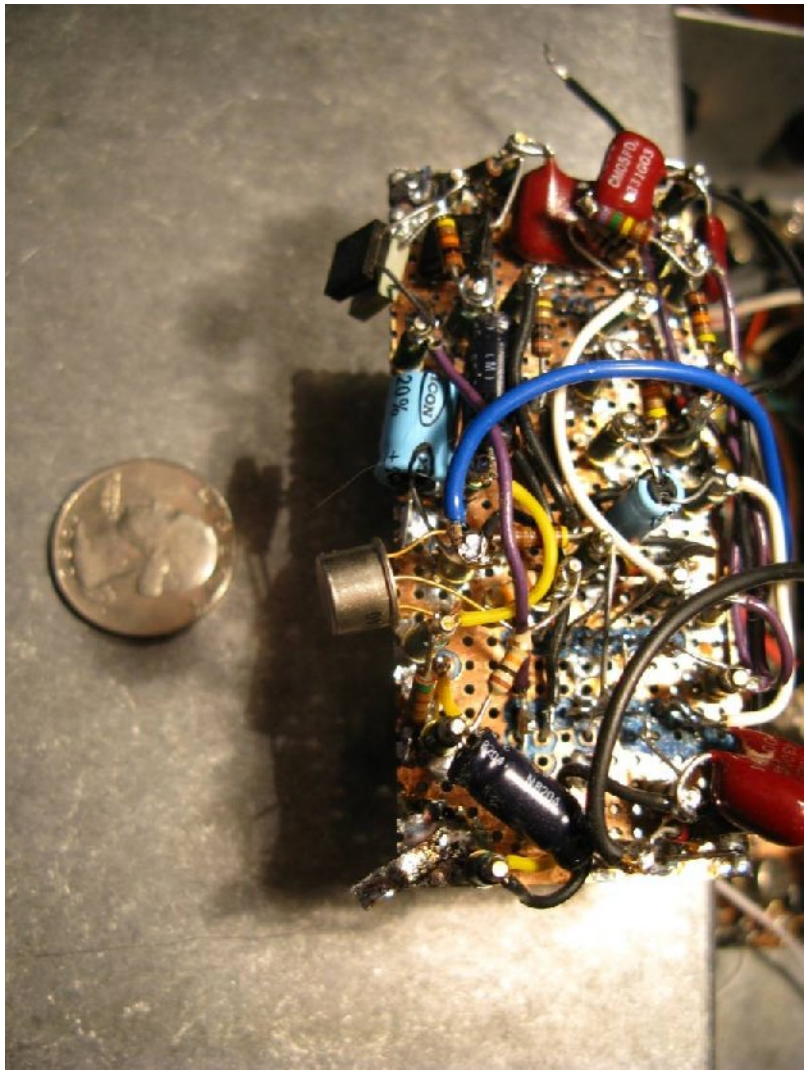
Custom Homebrew Equalizer (continued):

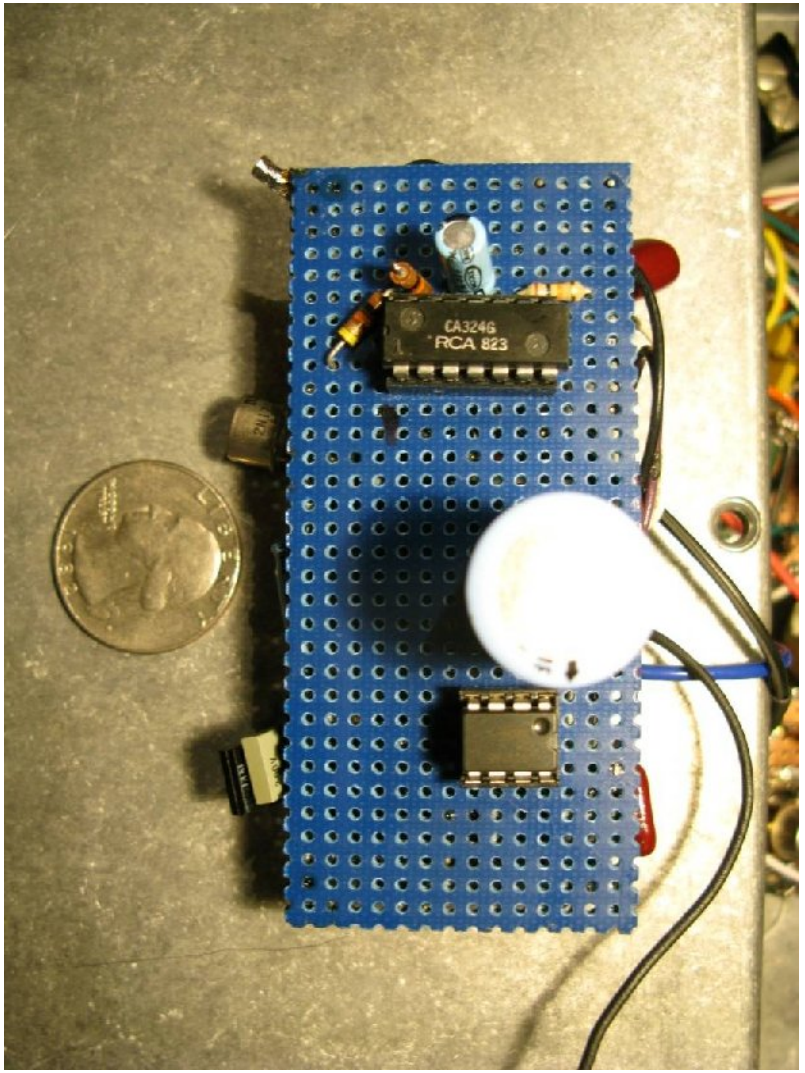
- Design



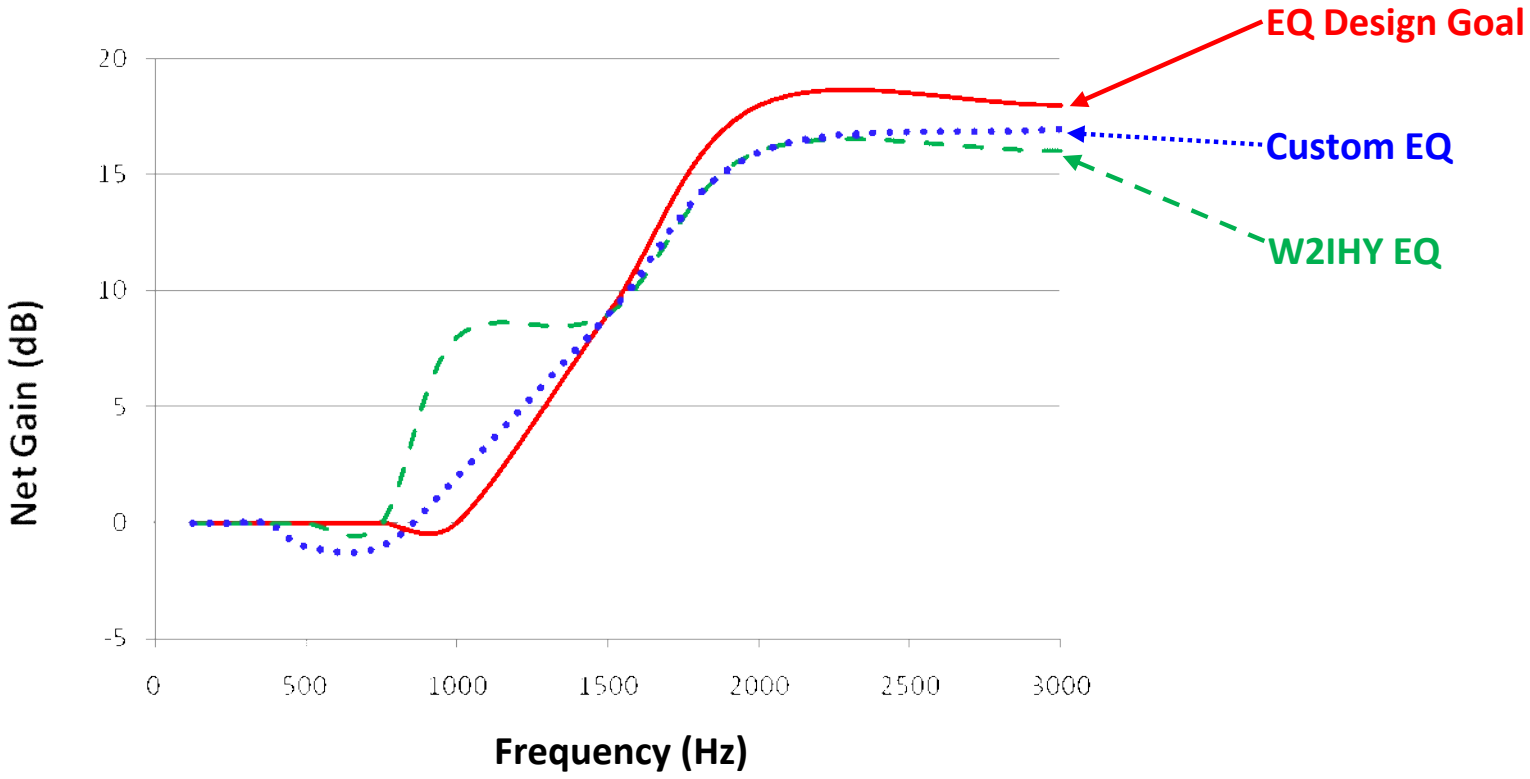
Custom Homebrew Equalizer (continued)**:**

- Layout





Comparison of results:



Both Equalizers provide a <u>significant</u> improvement in my ability to copy SSB signals with the left ear!

- *Signals with <50% copy => ~100% copy*

Wrap-up:

- Audio equalizers can be used to improve SSB communications:
  - Transmit end:
    - Adding "Punch" to the transmitted signal
    - Compensating for the transmitter operator's speech characteristics
    - Improving the frequency response of the transmitter hardware
  - Receive end:
    - Adding "Punch" to the received signal (SNR dependent)
    - Compensating for the transmitter operator's speech characteristics (SNR dependent)
    - Compensating for the non-ideal responses of the transmitter and/or receiver hardware (may be SNR dependent)
    - Compensating for the effects of hearing deficiencies on the receive end
- Equalizers will not improve intelligibility of signals with negative SNRs
- Equalizers are becoming standard equipment on new transceivers
  - For transmit and receive
- No benefit to using an equalizer for narrowband modes
  - CW, PSK31, etc

Wrap-up (continued)**:**

- **The optimal settings for TRANSMIT applications are *very subjective* and dependent upon:**
  - **The application (rag-chew, DX, etc)**
  - **The voice characteristics of the transmitter operator**
  - **The frequency response of the hardware (transmitter & receiver)**
  - **The hearing response of the operator on the *receive* end**
  - **The best settings are achieved via spectral analysis of the output signal**
    - **The analysis can be done at the receive end**
- **Don't need "Studio" quality audio components (20 Hz – 20 KHz)**
  - **Only need 150 Hz – 3 KHz**
  - **Big $$$**
  - **Sometimes they don't sound as good as components designed for "communications" applications**