Using Equalization on HF SSB

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Topics:

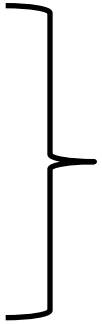
- **Some Commonly Used Methods for Improving HF SSB Comms**
- **Some key points about speech and hearing**
- **The W2IHY 8 Band Equalizer + Noise Gate**
  - What is it
  - When to use it
  - Where to use it
  - How to use it
  - What it can, and cannot do

What is “communication”?

- Communication ⇔ Transfer of Information

•What is “information transfer”?

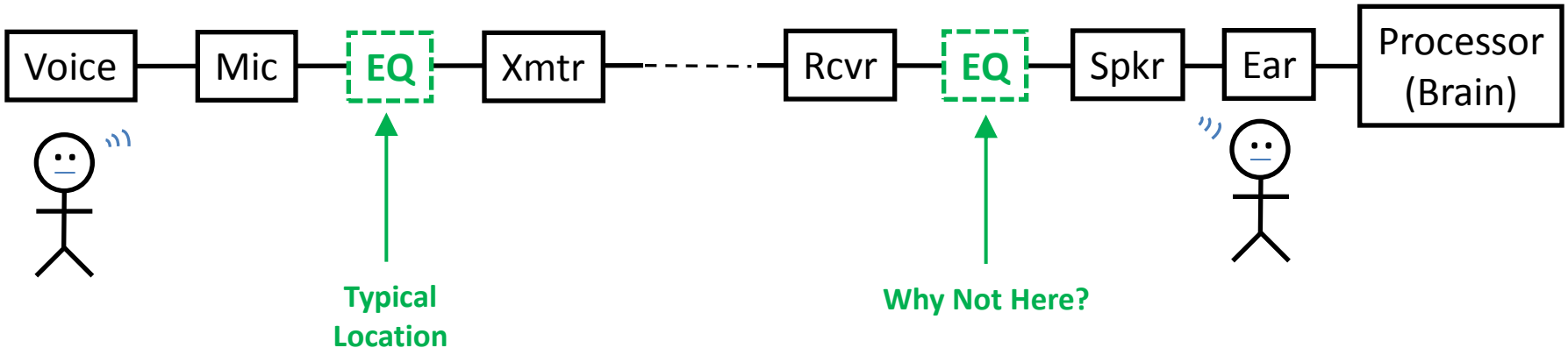
- CW
- Digital comms
- **SSB Voice**
  - **Rag-chew**
  - **Breaking DX pile-ups**
- FM Voice



Different modes require different methods to optimize information transfer

What can we do to improve our ability to communicate via HF SSB?

Typical communication path

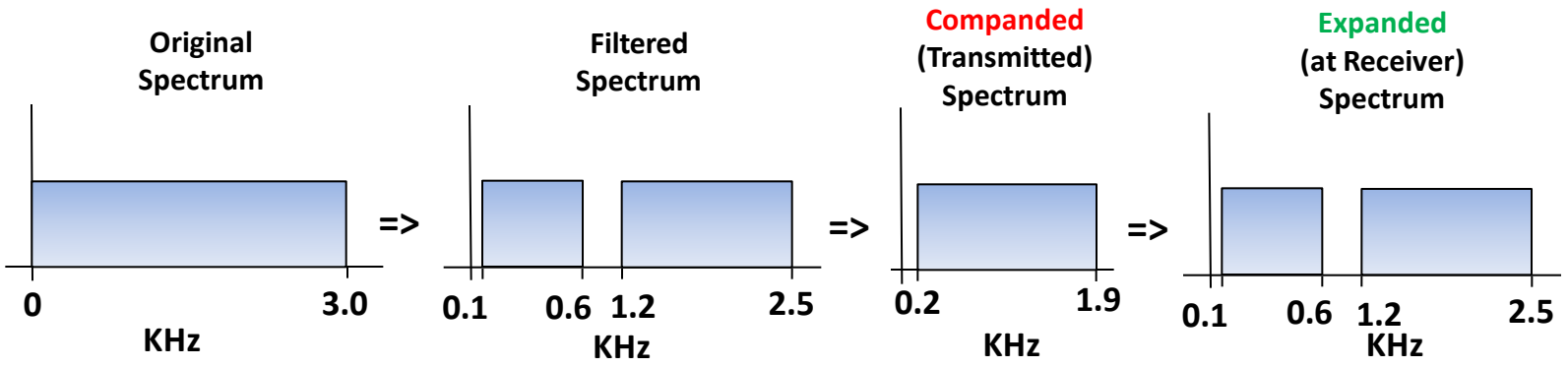


Some Commonly Used Methods for Improving HF SSB Comms:

1. **Improve received SNR:**
   - Use higher gain antennas
   - Use higher peak transmitter power
   - Raise **average** transmit power (compression)
     - There is a limit: trade-off between distortion vs. SNR improvement
     - Some (W2IHY) claim that straight compression can degrade transmit SNR
       - I question this claim (all limiters exhibit "small signal suppression")
       - Compression will increase background noise when ***no speech signal is present***
         - Use of a Noise Gate should mitigate this problem
   - "Matched Filter" detection:
     - "Matching" filters means more than just reducing bandwidth arbitrarily
     - There is a limit: trade-off between distortion vs. SNR improvement
       - A 10 Hz filter won't work very well with a 60 wpm CW signal
   - Reducing receiver noise figure will not help when atmospheric noise is dominant

Some Commonly Used Methods for Improving HF SSB Comms (continued):

1. **Improve received SNR** (continued):
   - Compander/expander (technology exists, but not in use on Ham bands):
     - 3KHz input signal => reduced to 1.7 KHz => 2.4 dB SNR improvement at receiver
       - http://people.wallawalla.edu/~Rob.Frohne/qex/qex-art.html
       - However, for 2.1 KHz input signal => only 0.9 dB improvement!



     - Complicates both transmit & receiver hardware
       - Adds significant hardware complexity to analog radios
       - Can be implemented totally in software in digital radios
         - Could start becoming available on future generation SDR radios
         - Standards for the companding/expanding algorithms will need to be agreed to ahead of time by all manufacturers
         - Manufacturers will need to offer more than 1 dB of improvement

Some Commonly Used Methods for Improving HF SSB Comms (continued):

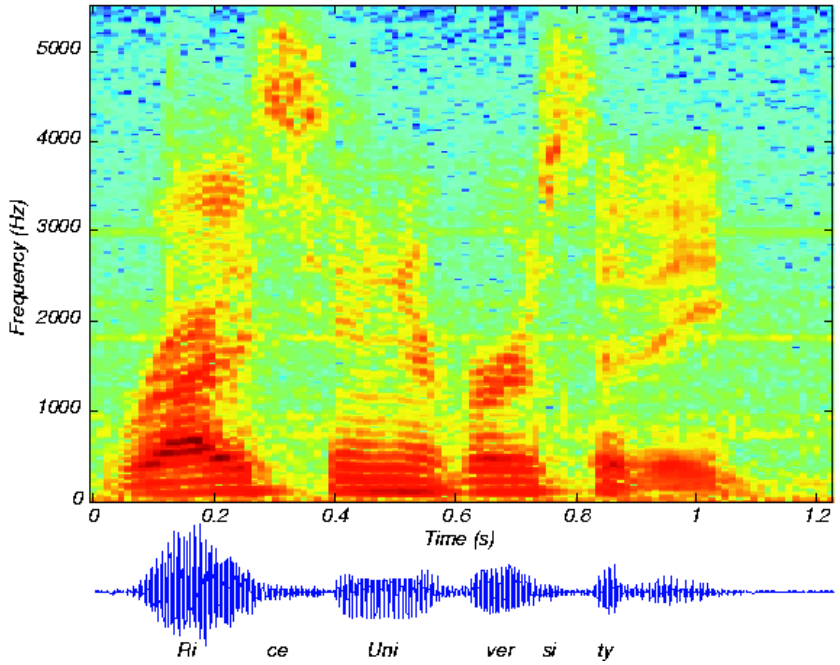
2. **Improve the ability to extract the information from the signal (Processing):**
   - Digital Signal Processing (DSP):
     - "Brick Wall" filters
     - Noise reduction algorithms
     - Interference cancelling algorithms

   } => **Better received SNR**

   - **Maximize the Brain's processing power by "Equalizing"**

Equalization is the process of shaping (ie, intentionally distorting) the frequency response curve to better match the brain's speech processing algorithm

Spectrogram:

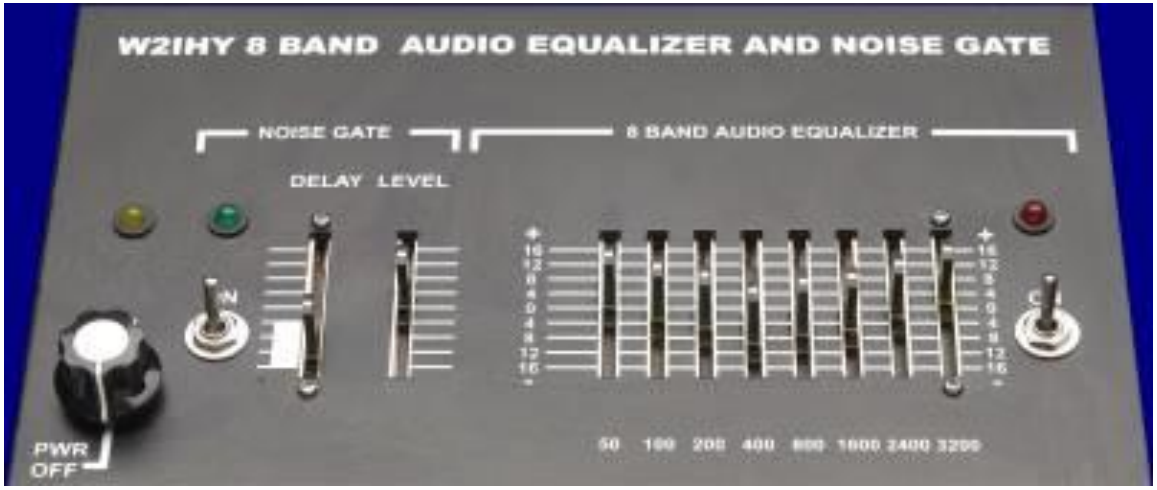


Speech frequency content varies with time, but some frequency ranges are more important than others to the Brain

The W2IHY 8 Band Equalizer + Noise Gate:

New: $270
Mic Cable: $30

Used(w/cable): $150-200



The W2IHY 8 Band Equalizer + Noise Gate (continued):

- The **8 Band Equalizer** breaks up the input audio spectrum from the microphone into 8 sub-bands with center frequencies of:

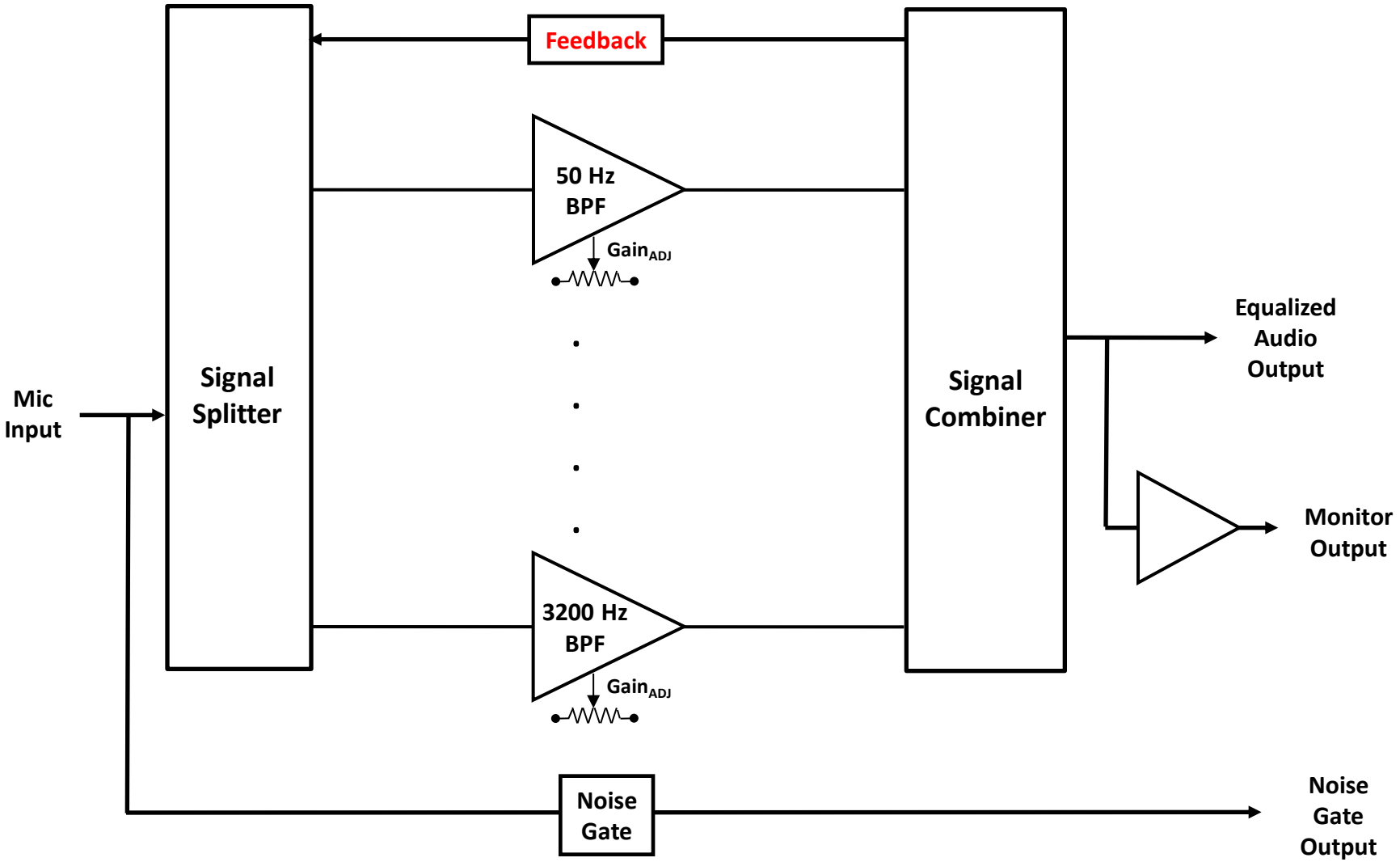
fo
50 Hz
100 Hz
200 Hz
400 Hz
800 Hz
1600 Hz
2400 Hz
3200 Hz

For each sub-band, mid-band gain adjustable: -16 to +16 dB:

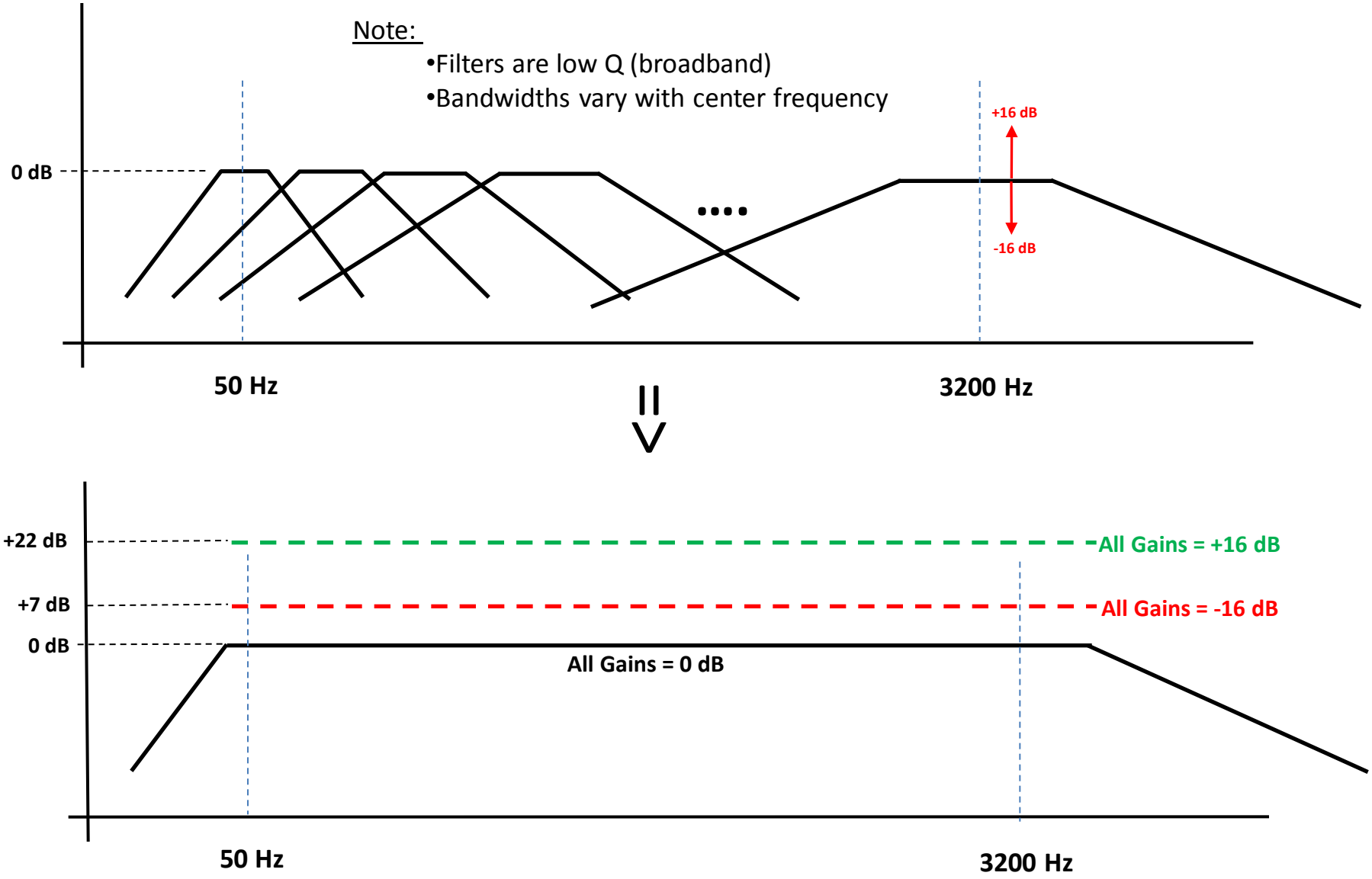
- The **Noise Gate** shuts off the audio to the transmitter during periods when there is no speech input:
  - This unit effectively eliminates the background noise from capturing the transmitter during pauses and between sentences
    - Most effective in stations with high background noise levels
    - Has adjustable delay and threshold
  - Does ***not*** improve communication capability
- A **Monitor** function included

The W2IHY 8 Band Equalizer (continued):

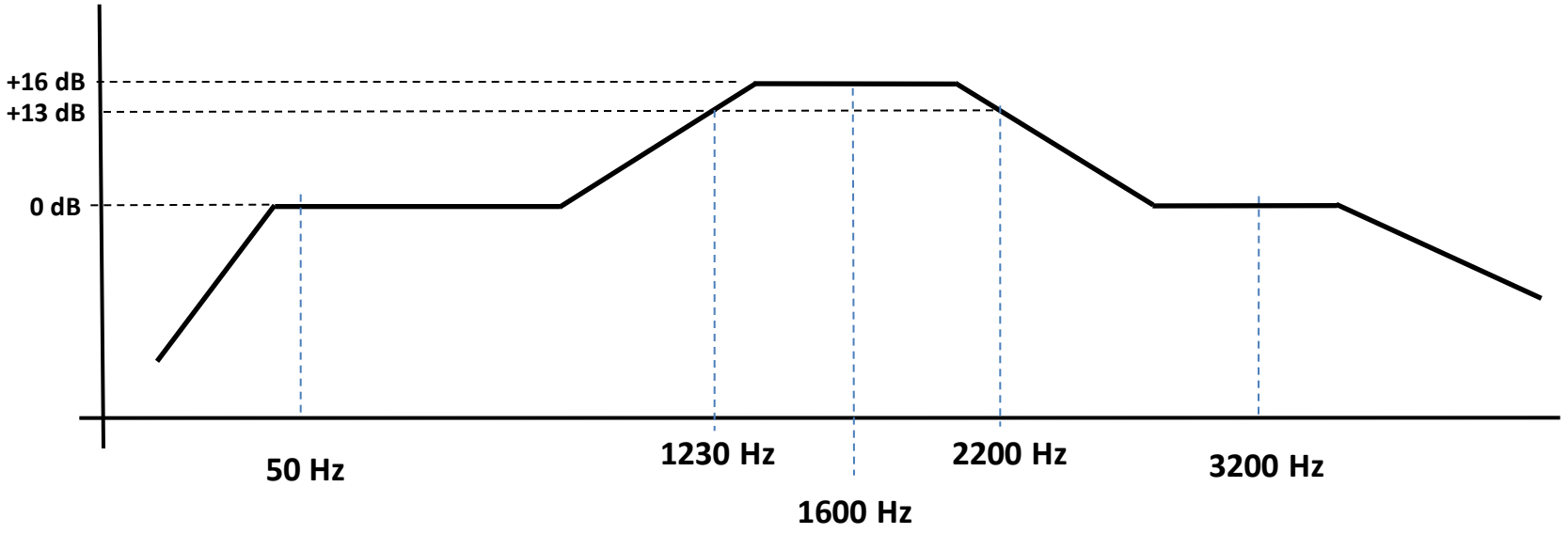
- Uses a parallel bank of 8, one-pole BPFs (centered at the above frequencies)



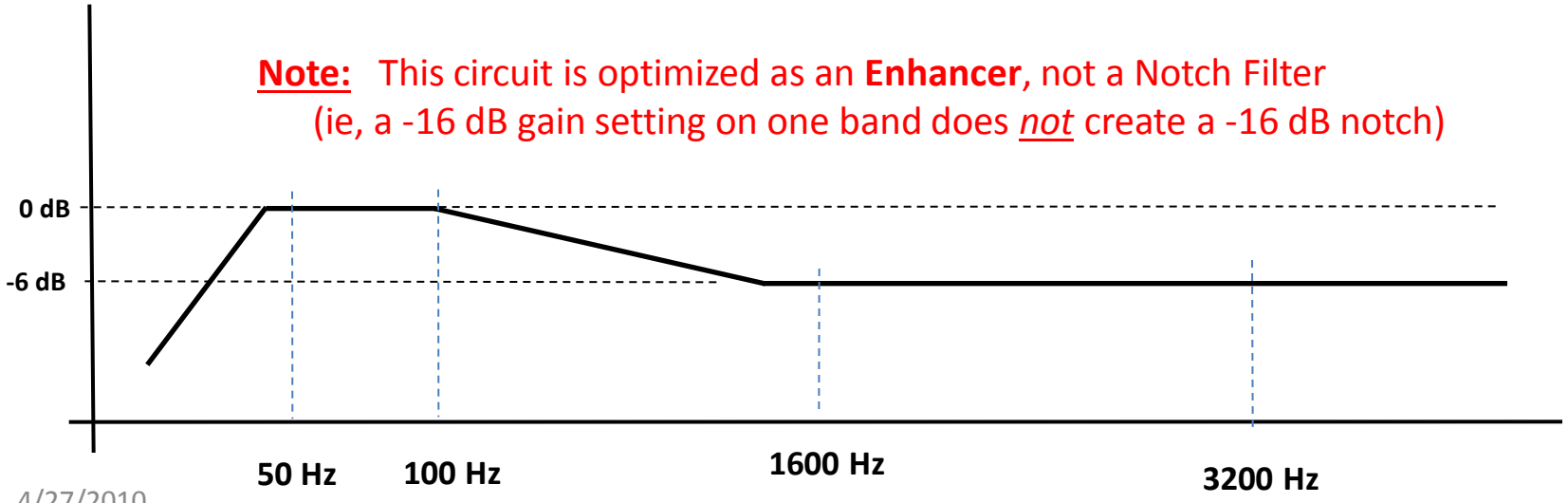
The W2IHY 8 Band Equalizer (continued):



The W2IHY 8 Band Equalizer (continued):



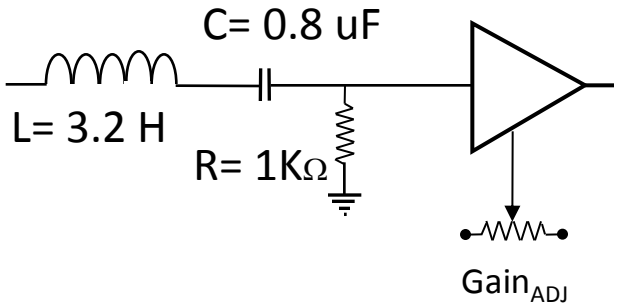
Note: This circuit is optimized as an **Enhancer**, not a Notch Filter
(ie, a -16 dB gain setting on one band does *not* create a -16 dB notch)



The W2IHY 8 Band Equalizer (continued):

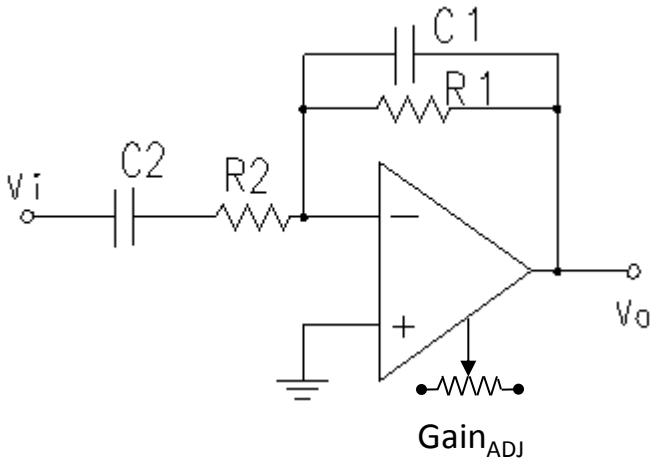
Two types of 1 Pole BPFs:

Passive/Active:



fo = 100 Hz
BW = 50 Hz
} Q = 2

Active RC:

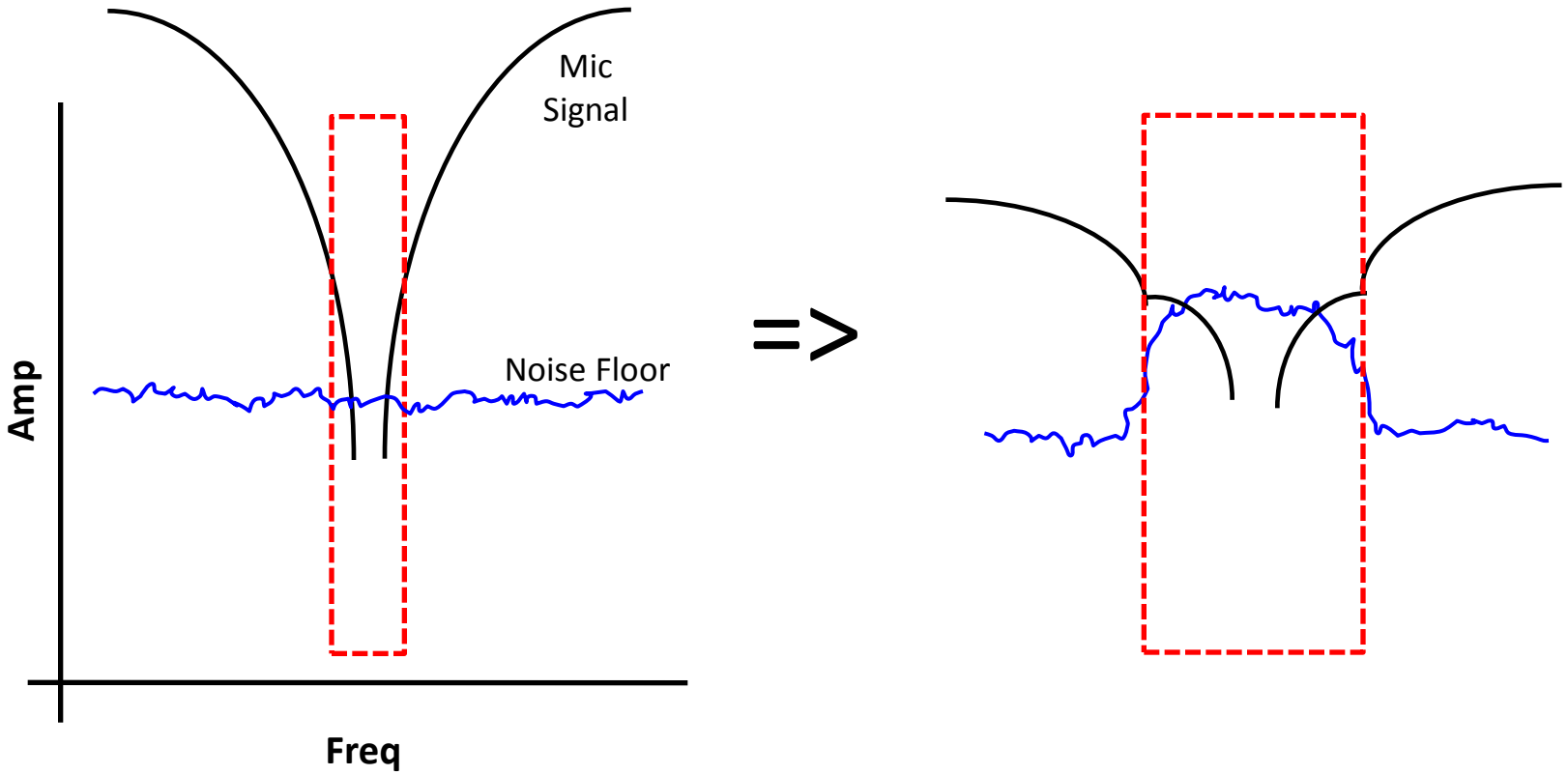


For the W2IHY design:

- Resistors: 3.3 kΩ to 1 MΩ
- Capacitors: 300 pF to 0.18 uF

Signals below the noise floor can*not* be recovered by use of an Equalizer!

- Negative SNR + Gain = Negative SNR



Where to Equalize?:

- At **Transmitter:** When the communications path uses only linear components (ie, no compressor, compander/expander, etc), an Equalizer can be placed anywhere along the path. However, since an Equalizer's effectiveness is affected by SNR, the best place to put it is at the output of the microphone

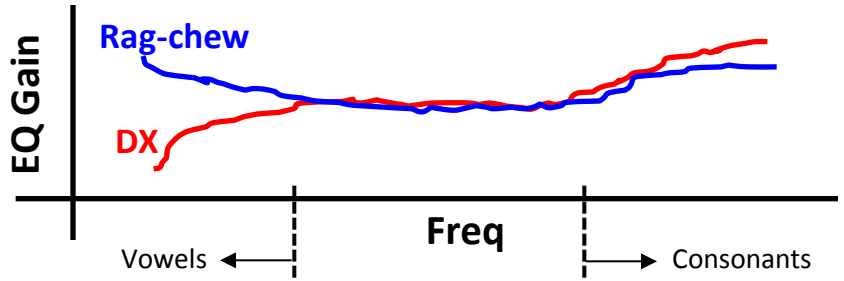
- At **Receiver:**
  - Theoretically, interchanging individual components of a "***linear***" system (ie, no compression, over-driven amps, etc,) will not affect the linear behavior of the system (ie, gain and phase)
    - Noise figure, IMDs, etc, will be affected
  - An Equalizer can be used at the receiver to improve copy of *high SNR* signals when:
    - They are missing critical frequencies
    - They there is a hearing deficiency on the receive end
  - Easy to do with the **W2IHY 8 Band Equalizer:**
    - Since the **Equalizer** is fully functional during receive:
      - Put a pair of headphones in the **Equalizer** monitor jack
      - Place the mic near the speaker
      - Turn the Noise Gate "off"

How an Equalizer is used depends on the application:

- **Music:**
  - Equalizers are used both to mitigate deficiencies in the electronics, and to emphasize or de-emphasize one or more instruments
  - The Brain's processor may, or may not be a factor in how the equalizer is used
- **Communications:**
  - The Brain uses different frequencies differently in the processing of speech waveforms => we should emphasize some ranges and de-emphasize others
  - Speech spectrum can be divided into ranges:
    - Two band:
      - **Lows:** vowels
      - **Highs:** consonants
    - Three band:

Lows: heaviness, weight & big bottom	0-200 Hz
Mids: warmth & naturalness	400-800 Hz
Highs: brilliance, sparkle, clarity & presence	1600-3200 Hz

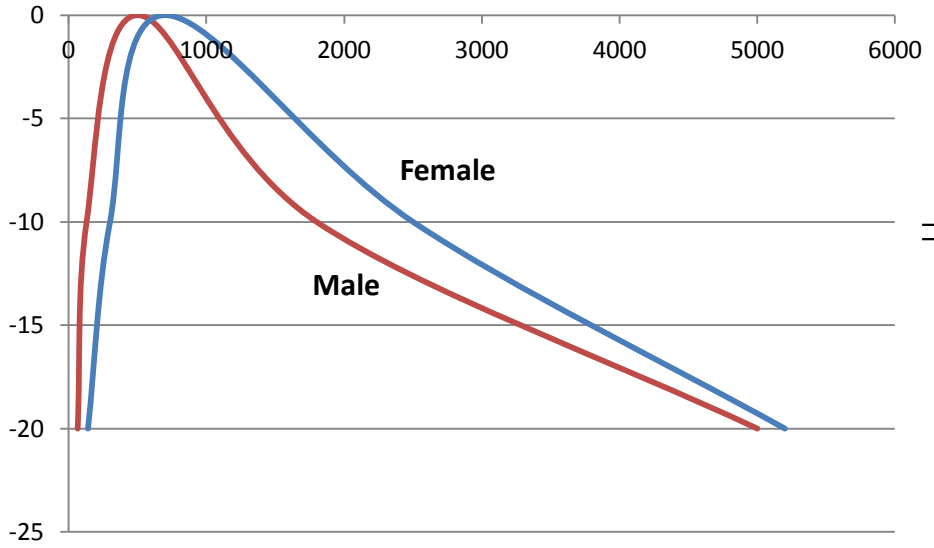
  - For HF SSB communications, two commonly used equalization profiles:



Equalizer Settings:

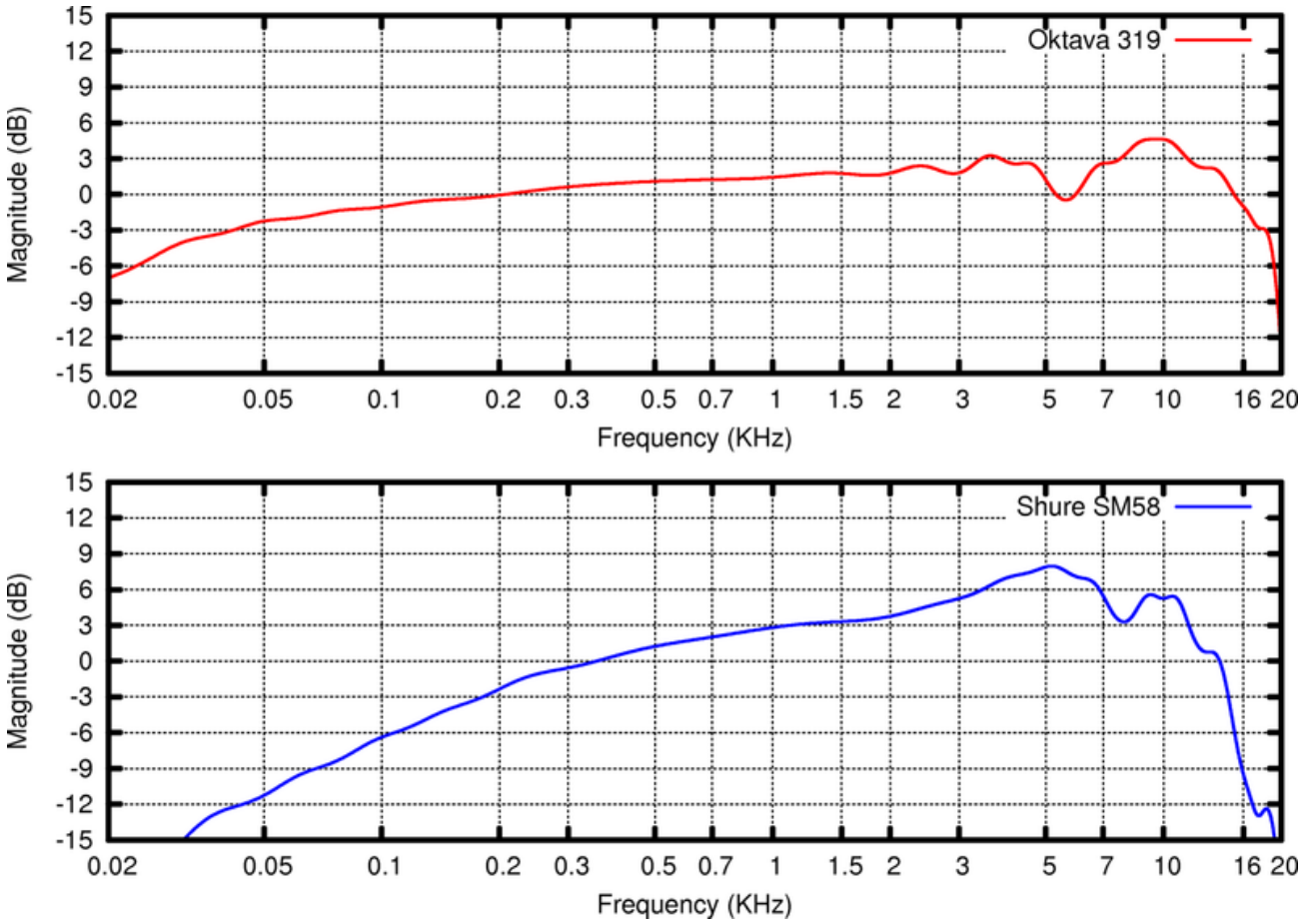
- ***Initial*** settings (based on microphone and rig) come from W2IHY table
- ***Final*** settings:
  - Usually arrived at via on-the-air-testing with several other Hams & varying conditions
  - Depend on numerous variables:
    - Frequency content of speech
    - Frequency response of the microphone
    - Frequency response through the hardware (transmitter + receiver)
    - Hearing response at the receiving end (the other Hams that are helping with the settings)

Frequency content of speech varies with gender:



⇒The optimum Equalizer shape is dependent upon the speaker

Speech frequency content varies with the microphone:

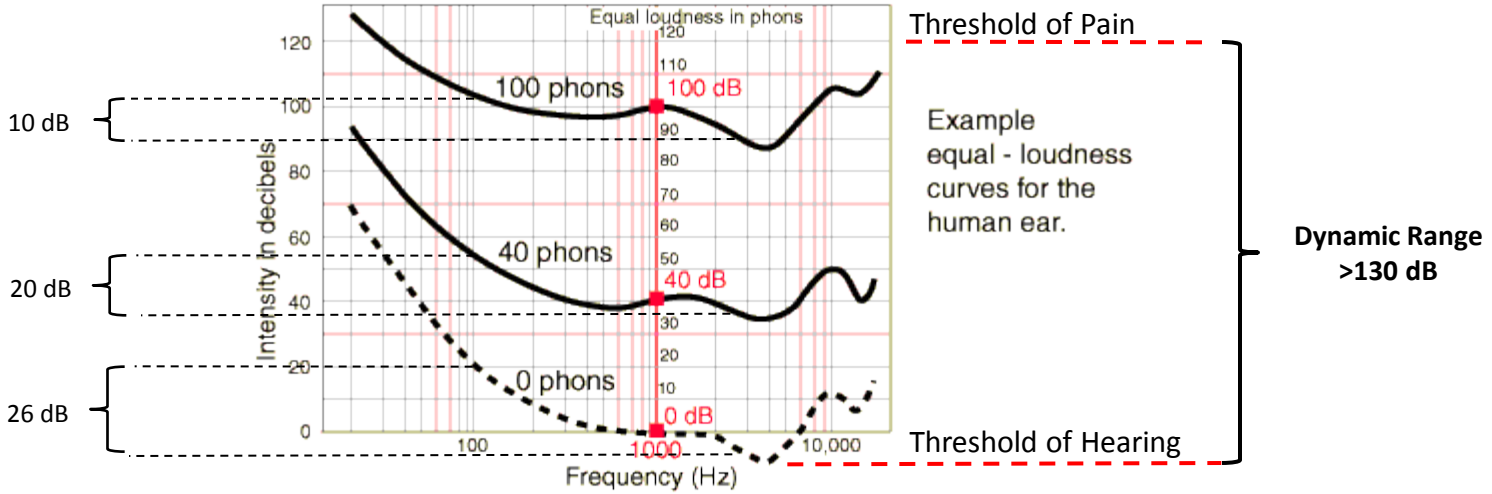


An **8 Band Equalizer** could make the bottom mic sound the same as the top mic (over the frequency range 50 Hz – 3.2 KHz)

Hearing frequency response is not flat:

- Varies with age
- Varies with gender
- **Varies with sound level**

Average "Equal Intensity (=1/Sensitivity)" Curves:



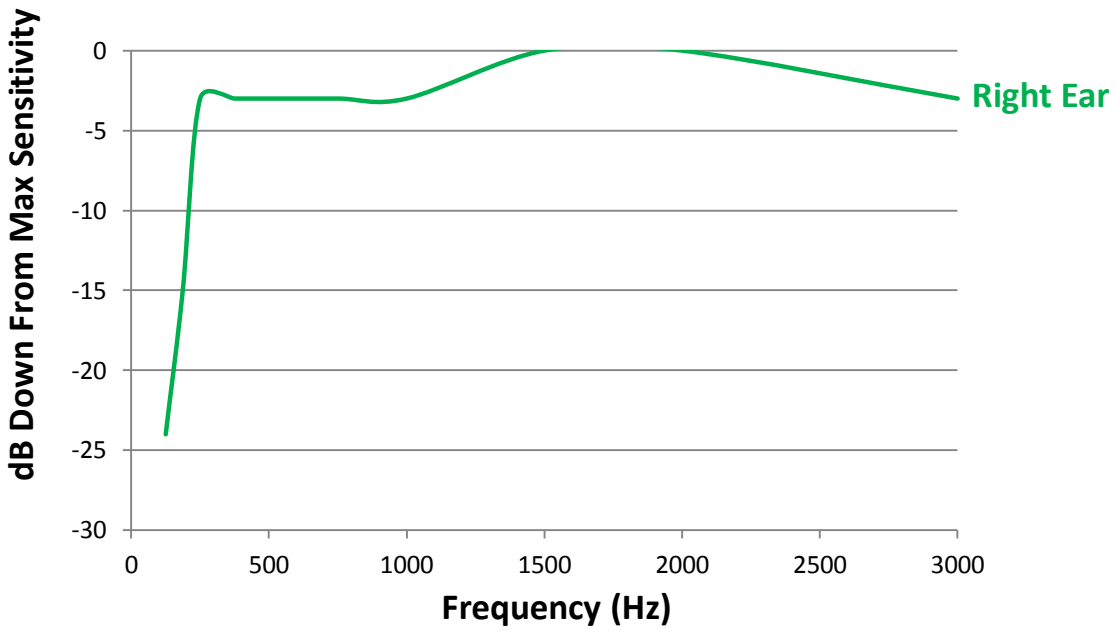
On-line hearing test: http://www.phys.unsw.edu.au/jw/hearing.html

Note:

- This test assumes that your sound card & speakers have a flat frequency response
- Earphones recommended over computer speakers, but that didn't work for me

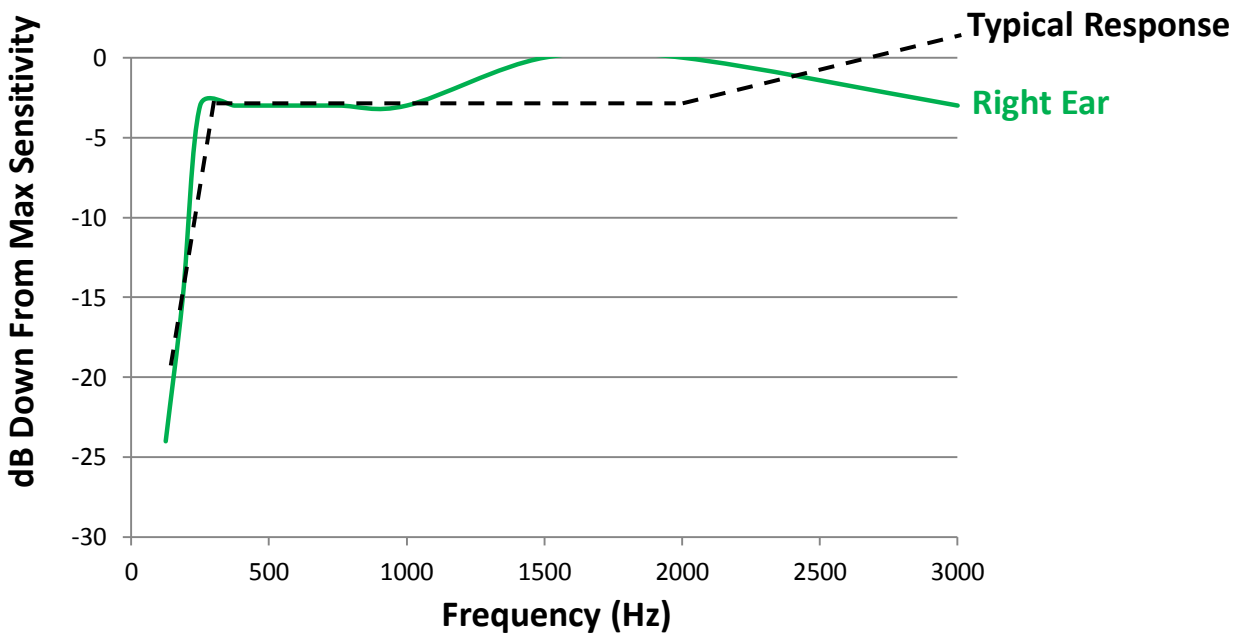
Hearing frequency response is not flat (continued)**:**

- My right ear looks reasonably close to the average response



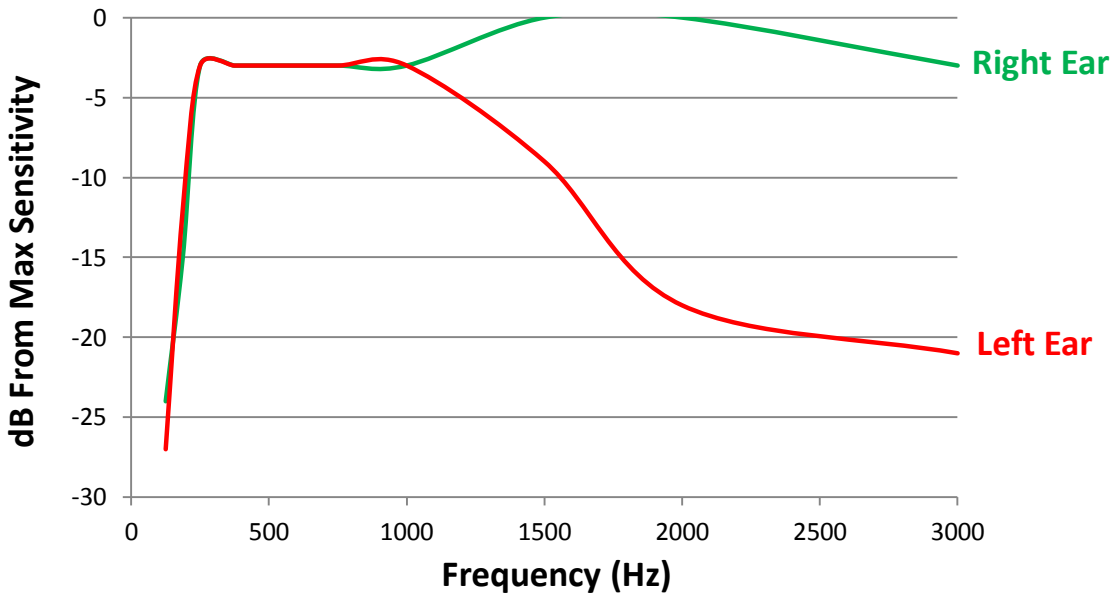
Hearing frequency response is not flat (continued)**:**

- My right ear looks reasonably close to the typical response



Hearing frequency response is not flat (continued)**:**

- My left ear has a significant deficiency above 1 KHz

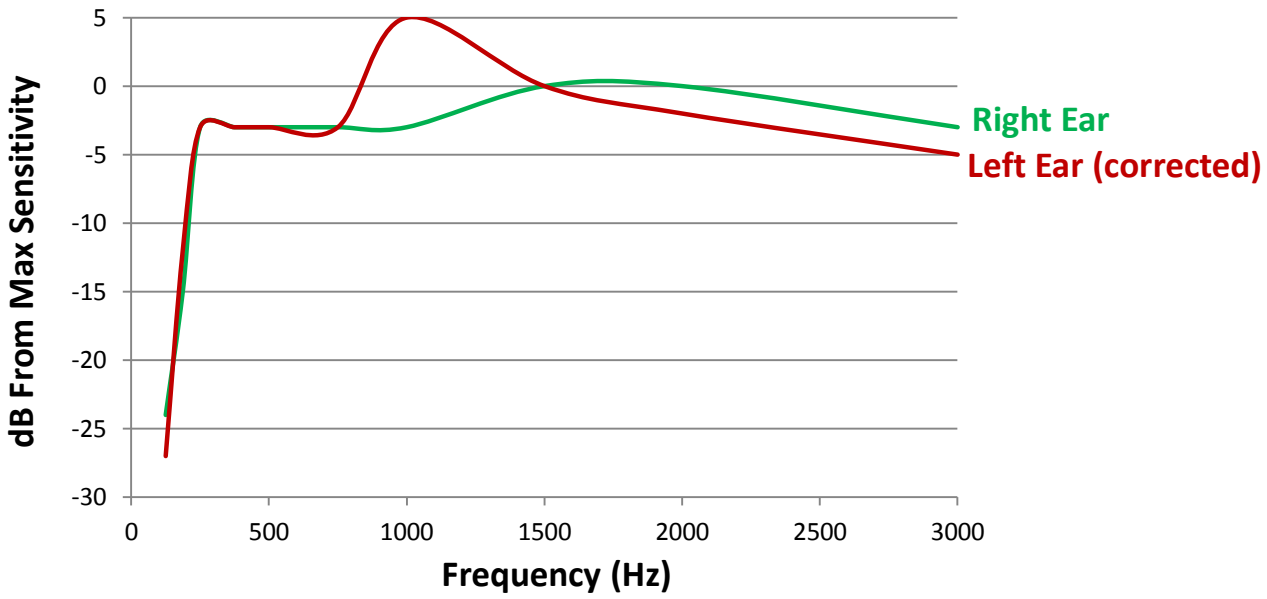


My Options:

1. Go monaural (ie, use only right ear)
   - The Brain is programmed for “Stereo” reception for direction info
   - Do we need “Stereo” reception for listening to speech from a speaker??
2. Use an **Equalizer** for my left ear only

Hearing frequency response is not flat (continued)**:**

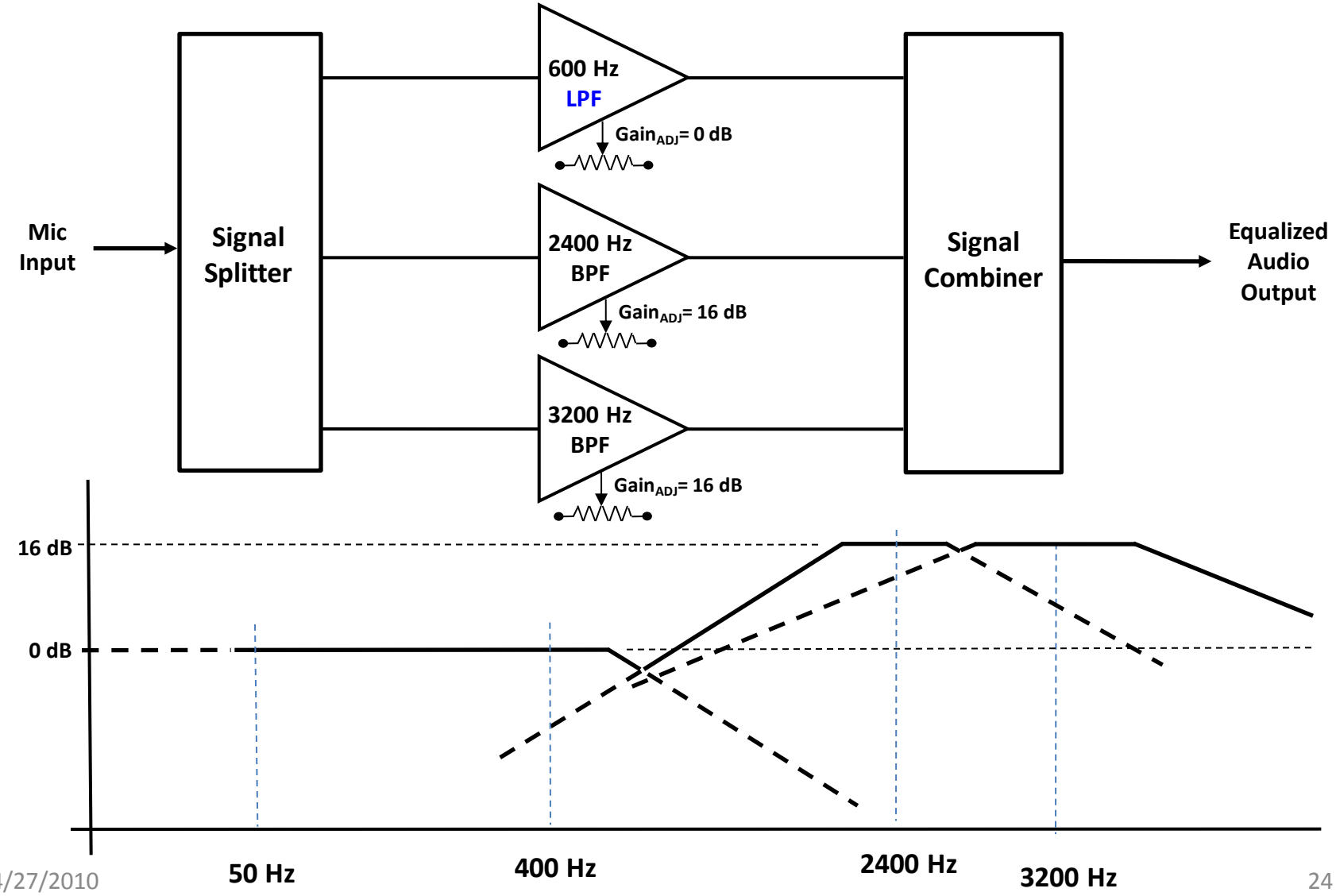
- My left ear after correction with an **8 Band Equalizer**:



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

Hearing frequency response is not flat (continued)**:**

- The solution=> ***3*** **Band Equalizer** (can be built with 2-3 ICs and < 30 R's & C's)
  - Does ***not*** require all of the features/complexity of the W2IHY 8 Band Equalizer



Wrap-up:

- Traditionally, Equalization is used at the transmit end to improve HF SSB communications by optimizing the frequency content of the speech waveform at the ear of the receiving station by:
  - Compensating for the transmitter operator's speech characteristics
  - Compensating for the transmitter microphone frequency response deficiencies
    - Can make an inexpensive mic sound like an expensive mic
  - Better matching the frequency content to the Brain's response
- An Equalizer can be used at the receiving end (with moderate to high SNR signals) to improve interpretation of speech from stations with sub-optimal transmit waveforms and/or to mitigate the effects of hearing deficiencies on the receive end
- Equalizers can***not*** improve signals with negative SNRs
- The optimal settings for an Equalizer are very subjective and dependent upon:
  - The speech characteristics of the transmitter station operator
  - The frequency response of the specific hardware being used
  - The hearing characteristics of the receiving station operator