Using Equalization on HF SSB

Bill Leonard
NØCU
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

Voice -> Mic > EQ < Xmtr <--- <--- Rcvr > EQ < Spkr < Ear < (Processor (Brain))

Typical Location

Why Not Here?
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](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
   • Maximize the Brain’s processing power by “Equalizing”

   => Better received SNR

**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:

\[
\begin{array}{c}
50 \text{ Hz} \\
100 \text{ Hz} \\
200 \text{ Hz} \\
400 \text{ Hz} \\
800 \text{ Hz} \\
1600 \text{ Hz} \\
2400 \text{ Hz} \\
3200 \text{ Hz}
\end{array}
\]

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):

Note:

- Filters are low Q (broadband)
- Bandwidths vary with center frequency

![Diagram of equalizer settings]

- All Gains = 0 dB
- All Gains = +16 dB
- All Gains = -16 dB
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:

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 cannot 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:


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 in a **significant** 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 cannot 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