About SSB

Hams new to HF face a challenge when tuning in single sideband voice signals.

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Many of us who are more experienced have forgotten how odd it was to us when we changed from AM (amplitude modulation) to single sideband (SSB). Our initial attempts at tuning were hesitant and error-prone, resulting in audio sounding more like *mezzo-sopranos* or *basso profundos* than natural speech. Eventually we developed a knack for it.

Figure 1 — One of the many "red-and-black" tutorials, *Single Sideband for the Radio Amateur* helped thousands understand and effectively use SSB modes.

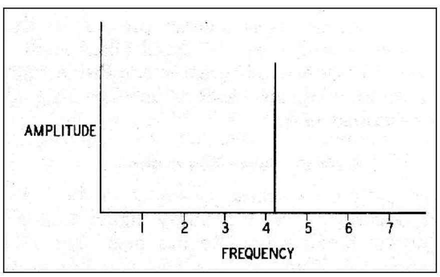

Figure 2 — A single RF signal is a zero-width line with a certain frequency and amplitude. This signal occupies no room in the spectrum, although a receiver will detect it as it tunes past the signal.

This article explains what an SSB signal is, how it occupies space on the band, and what an SSB receiver does when tuning across such a signal. The reader is encouraged to follow along on an actual receiver, and in so doing develop an appreciation for the physical nature of the signals, and gain more confidence in tuning and operation.

The transition from AM to SSB created confusion in the amateur ranks from the late 1940s well into the 1960s. Hams had gotten used to broadcast-style AM, for which tuning is not all that critical. SSB, on the other hand, was quite sensitive to tuning! Even an error of 100 Hz (cycles in those days) could render a familiar voice nearly unrecognizable.

To address the situation, ARRL created a book explaining SSB, how to use it, and provided a number of construction projects. Figure 1 shows the cover of this book, *Single Sideband for the Radio Amateur*.[1]

This article is based on two articles from Publication 20 — "How to Visualize a Phone Signal," and "How to Tune in a Single-Sideband Signal," by W1DX. Both are also available in the *QST* archives.[2, 3]

Visualizing a Phone Signal

Without a background in the theory of SSB, it is practically impossible to form a mental picture of "suppressed carriers" and "single sideband."

So let's start by visualizing signals. Any single RF signal can be represented by a vertical line on a graph of amplitude versus frequency, as in Figure 2. The taller the line, the greater the amplitude. This drawing represents what happens on the air when an SSB transmitter is modulated by a single audio tone or when a Morse code CW signal is transmitted.

The signal is shown here having zero width, meaning that it occupies a single frequency. If you tune a practical receiver across it, you will detect the signal across a range of frequencies. For example, if you place a receiver in its CW or SBB mode and slowly tune across a Morse code signal or steady tone, you will hear an

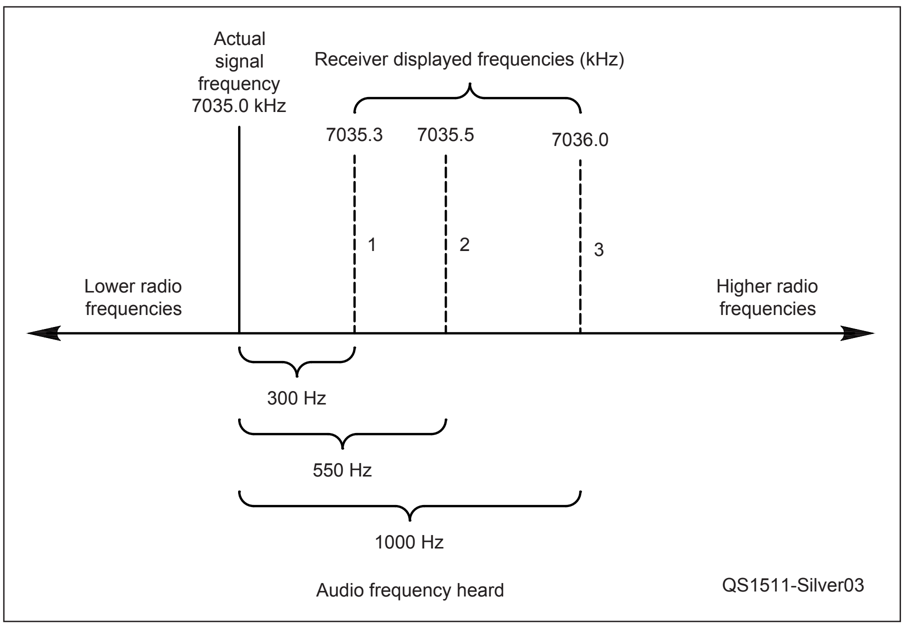

Figure 3 — Receiving a single-frequency RF signal such as for CW or a single audio tone on SSB. The audio frequency produced is the difference between the frequency displayed on the receiver and the frequency of the RF signal, shown as LSB received below the carrier frequency.

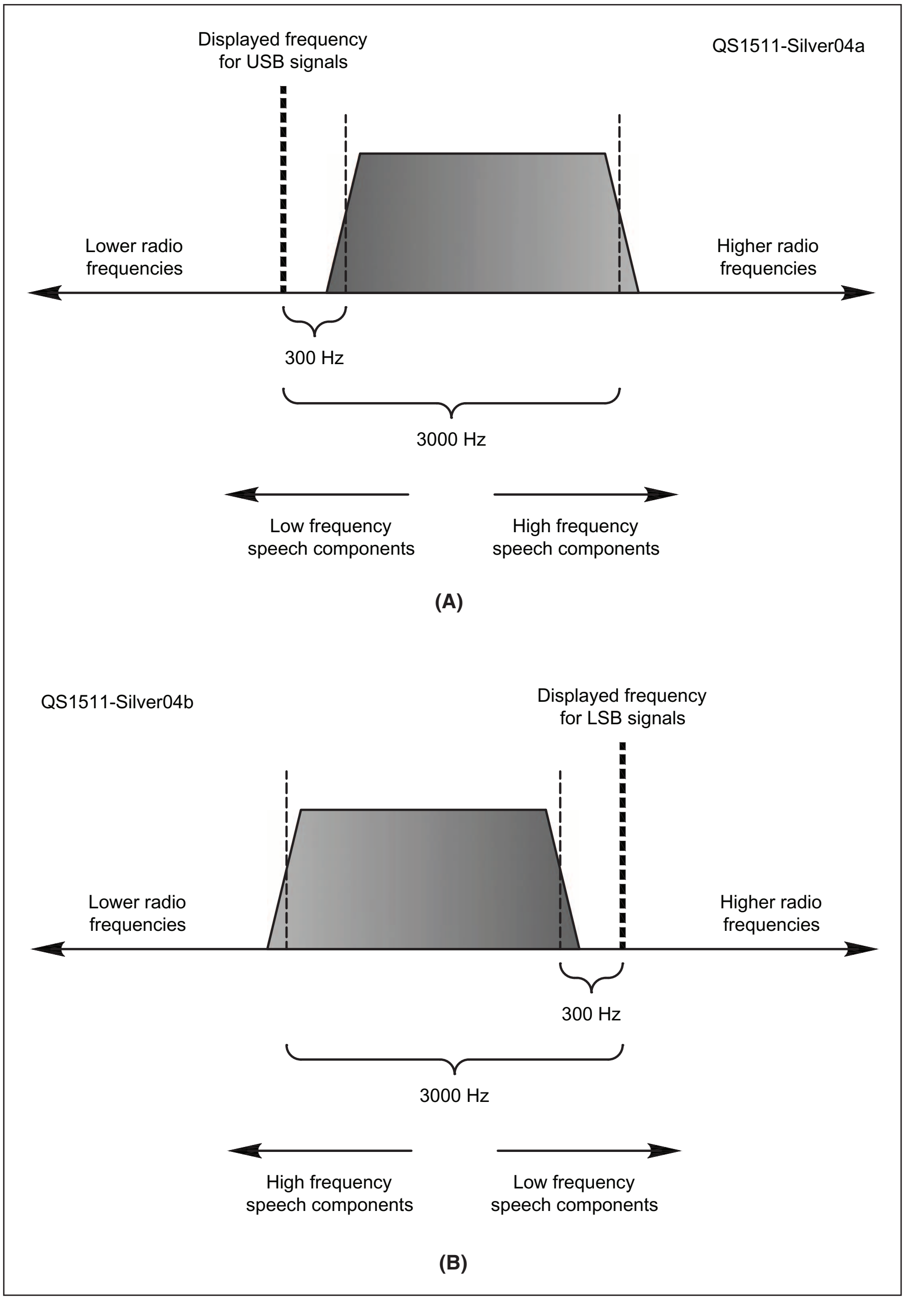

Figure 4 — The structure of a USB signal (A), and LSB signal (B), showing the displayed frequency of the suppressed carrier and the RF signal components representing the transmitted speech.

audio tone varying from very high to very low frequencies or vice versa. Why is a zero-width signal received at more than one frequency?

The audio output of the receiver consists of audio frequencies that are the difference between the frequency displayed on the receiver dial and the actual RF frequency of the on the air signal. As the displayed frequency of the receiver changes, so does the difference between the signal and displayed frequencies, causing the output audio frequency to change as well.

The solid line in Figure 3 is the actual signal at 7035.0 kHz. The dashed lines show three different displayed frequencies. The frequency of the audio tone produced by the receiver is the difference between the heavy line and a dashed line. If you set the receiver to LSB and tune to 7036.0 kHz, the receiver audio output tone frequency will be 7036.0 – 7035.0 = 1.0 kHz (or 1000 Hz). You hear the tone begin at a high frequency and smoothly drop lower and lower. Below 300 Hz, the signal rapidly becomes inaudible due to filters in the receiver.

For a CW signal, you tune the receiver by adjusting the VFO (variable frequency oscillator) until the audio tone for the *dits* and *dahs* is comfortable for your ear. Speech is more complex, but follows the same rule. Tuning changes the pitch of the received voice by shifting the frequencies of all speech components. To get the right pitch, you tune the VFO so that all of the speech components are recreated with the same frequencies as in the original speech. Speech components from a mistuned voice signal will have the wrong frequencies, creating the false soprano or basso effect.

Figure 4A shows a typical USB (upper sideband) signal in a receiver. You can find additional information about generating, transmitting, and receiving SSB signals in *The ARRL Handbook*.[4] Speech is filtered in the transmitter from approximately 300 to 3000 Hz. As explained in the sidebar, "What's Going On Inside," the radio will be properly tuned in when it displays the same frequency as is displayed by the SSB signal transmitter.

The displayed frequency corresponds to the frequency of the carrier that was removed (or *suppressed*) during the process of creating the SSB signal. Since this is a USB signal, the RF signal components representing speech are above the suppressed carrier or displayed frequency. RF signal components closer to the carrier frequency carry the lower frequency components of the original speech.

Figure 4B shows the same speech content transmitted as an LSB (lower sideband) signal. The displayed frequency is still the frequency of the missing carrier. The lower-frequency speech components are still closest to the carrier frequency but are now *below* the frequency of the carrier.

Visualizing Tuning in an SSB Signal

Figure 5 shows how the receiver filters create a "window" that you slide back and forth across the band when receiving USB signals. For LSB, flip the window around to the other side of the displayed frequency.

Your task is to align the receiver filter with the RF signals so the audio output frequencies are the same as the speech of the transmitting operator. Signals close to the displayed frequency become low audio

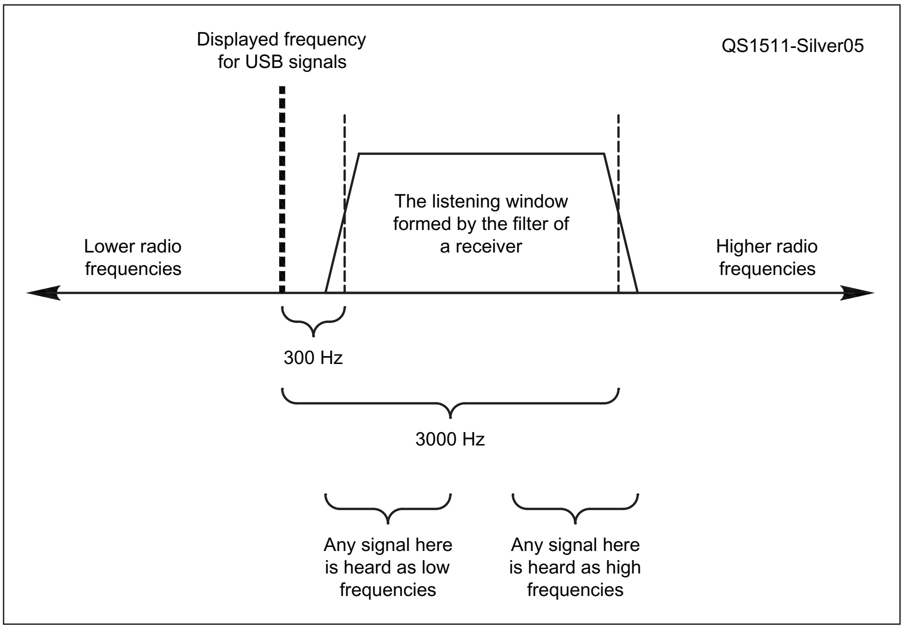

Figure 5 — The receiving window of an SSB receiver for USB signals shows the passband of the receiver filters and the receiver displayed (dial) frequency at the frequency of the suppressed carrier.

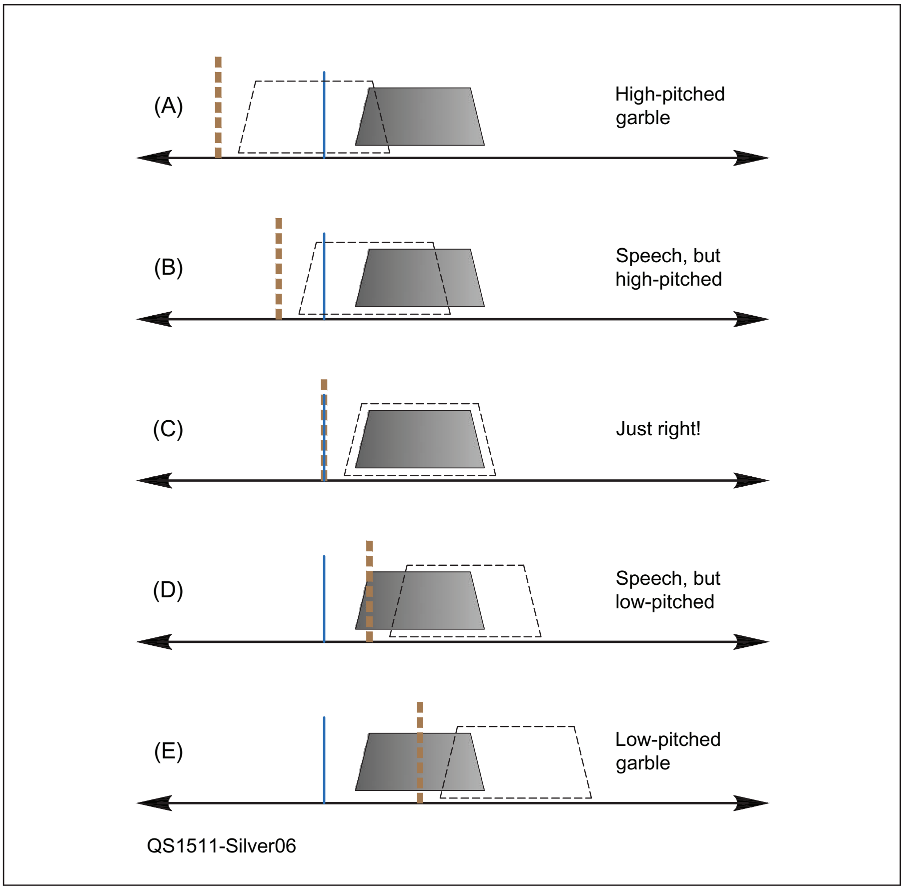

Figure 6 — The process of tuning in a USB signal from too low in frequency (A) through too high in frequency (E) shows the suppressed carrier frequency in blue and the displayed (dial) frequency in brown. A video of this process is on the *QST* in Depth web page.[5]

frequencies and signals farther from the displayed frequency become higher audio frequencies.

In Figure 6A, the receiving frequency is set too low at (A). If you have an HF receiver, tune to a band with USB voice signals (20 through 10 meters or 60 meters).

With the displayed receiver frequency set too low, the window captures what was transmitted as low-frequency speech components falls into the part of the receive window that is reproduced as high-frequency audio. You hear high-pitched garble.

Tuning higher (B) moves more of the transmitted signal into the receiving window. The voice you hear is still high-pitched, but probably recognizable. If you transmitted with this displayed frequency, the other station would hear you as being too low-pitched because your speech signal components would be offset in the opposite direction. Tune higher (C) so that the receiver displayed frequency matches the transmitter carrier frequency and natural-sounding speech results!

Keep tuning higher (D) and (E), and the transmitted signal will fall outside the lower edge of your receive window. The high-frequency speech will be received as a low-pitched garble results.

The sequence is similar on LSB. You can easily see and hear this by tuning to a band with LSB signals, such as 80 or 40 meters, and repeating the process of tuning past a signal in either direction.

If you select the "wrong" sideband, such as the LSB signal of Figure 4B with the USB receive window of Figure 5, low-frequency speech components would be received as high-frequency components and vice versa — making the speech completely unintelligible. Some voice scramblers work exactly this way, inverting the high- and low-frequency components to make the speech unintelligible to an eavesdropper.

Tuning in the Real World

Now that you understand what is going on as you tune in a signal, imagine what happens on a crowded band with "shoulder-to-shoulder" signals. Aside from simple ease of listening, tuning in a signal properly will also reduce the amount of unwanted speech components received from adjacent signals. A mistuned receiver will receive components of adjacent signals with their speech frequencies reproduced incorrectly.

Similarly, the signals often overlap to various degrees, creating unwanted speech components in your received audio, even if the desired signal is tuned in properly. Managing your receiver gain and filter settings is important to maintain a contact under crowded conditions. A narrower filter may reduce interference from adjacent signals significantly. Passband shift controls can offset your receiver filter window a bit higher or lower to avoid components from adjacent signals as well.

Other receiver functions can mimic interference by creating distortion or spurious signals in your receiver passband. For example, strong signals can overload your receiver, creating *intermodulation products* that are received as pops and scratchy noises. Reducing the sensitivity of your receiver by turning off preamps and turning down the RF gain control reduces background noise, and can help make sure the receiver is not being overloaded. Turning on an attenuator can also clean up a received channel considerably. Noise blankers may confuse strong signals with impulse noise, creating distortion often sounding like an overmodulated transmitter. You'll have a lot more fun on the bands if you learn to use all the features of your receiver.

As you get used to tuning in SSB signals, you will develop a "feel" for how much to spin the VFO knob between stations. You'll quickly be able to center a signal right into your passband, adjust the filters, and join the conversation or make a contest or DX contact while others are still hunting for the right tuning!

What's Going On Inside

It may help you tune in a signal if you understand what is going on inside the receiver to produce the audio output you hear. Without making this article a tutorial on *superheterodyne* (or *superhet*) receivers, the following describes what happens when you twist the *variable frequency oscillator* (*VFO*) tuning knob.

Adjusting the VFO knob (Figure A) changes the LO (local oscillator) frequency. The incoming RF signal mixes with the LO output and produces a signal at the IF (intermediate frequency), which is then filtered and amplified. A *product detector* combines the IF output signal with the BFO (*beat frequency oscillator*) signal to produce the audio signals called *beat notes* or *heterodynes*. In an SDR (software defined radio) or in radios that use DSP (digital signal processing) techniques, the DSP software performs the oscillator and mixer functions on the digitized RF signal.

Any signal passing through the IF filter and product detector will produce an audio output. If the RF signal consists of speech, which is made up of many different frequencies, or multiple tones (such as a digital signal), the audio output will also consist of many frequencies.

As the LO frequency is changed, so will the frequency of the mixer output signal that is input to the IF filter, which is centered at a fixed frequency. As long as the mixer output signal is within the IF filter passband, it will be amplified and passed to the product detector. Since the audio frequency is the difference between the IF output signal and the BFO, changing the LO frequency will also change the frequency of the audio output by moving it around in the IF filter passband.

Instead of moving the receiver IF passband to find RF signals, the RF signals are combined with the variable LO so the mixer output is within the IF filter passband. They are then amplified and converted to audio signals. In analogy, instead of moving a telescope to look at a star, the telescope remains stationary and the star moves into the telescope's field of view. That's what happens as you turn the VFO knob — the frequency of the signals from the IF amplifier changes while the BFO output stays fixed, creating an audio signal that also changes in frequency.

Note that nowhere in the superheterodyne receiver is there a signal generated at the same frequency as the RF signal! So what is the frequency shown on the radio display dial? It is the frequency at which all of the oscillators and IF filters and mixers combine to produce an audible output signal from the incoming RF signal. In the old days, a calibrated physical dial made the calculation — woe to the operator whose display dial slipped! Today a microprocessor makes the calculation and sends the resulting value to the front panel display.

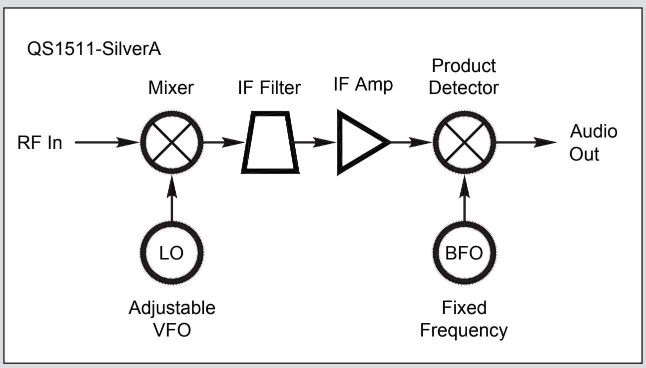

Figure A — Simplified block diagram of a superheterodyne receiver. Tuning the VFO of the receiver varies the frequency of the local oscillator (LO) so that the received RF signal appears to vary in frequency within the IF filter passband. This changes the audio frequency produced by the product detector.

A video showing the process of tuning in an SSB signal is available for download from the *QST* in Depth web page at **www.arrl.org/qst-in-depth**. It is also available for online viewing by devices that support Adobe Flash at **www.arrl.org/multimedia**.

Notes

[1] *Single Sideband for the Radio Amateur*, ARRL Publication No. 20, Fourth Edition, 1965.

[2] B. Goodman, W1DX, "How to Visualize a 'Phone Signal," *QST*, Jul 1950, pp 28 – 31, see **www.arrl.org/qst**.

[3] B. Goodman, W1DX, "How to Tune in a Single-Sideband Signal," *QST*, Aug 1954, pp 20, 110, see **www.arrl.org/qst**.

[4] *The ARRL Handbook,* 2016 Edition. ARRL Item no. 0413, available from your ARRL dealer, or from the ARRL Store, telephone toll-free in the US 888-277-5289, or 860-594-0355, fax 860-594-0303; **www.arrl.org/shop/**; **pubsales@arrl.org**.

[5] **www.arrl.org/qst-in-depth**

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