Communication Circuits Design

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Lecture 3.3: Single-Sideband (SSB) Communications

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Single-Sideband Characteristics (1)

- When a carrier is amplitude modulated by a single sine wave, it generates three different frequencies:
  1) the original carrier with amplitude unchanged;
  2) a frequency equal to the difference between the carrier and the modulating frequencies, with an amplitude up to one-half (at 100% modulation) the modulating signal; and
  3) a frequency equal to the sum of the carrier and the modulating frequencies, with an amplitude also equal to a maximum of one-half that oldie modulating signal.
- The two new frequencies, of course, are the side frequencies.

Single-Sideband Characteristics (2)

- Upon recognition of the fact that sidebands existed, further investigation showed that after the carrier and one of the sidebands were eliminated, the other sideband could be used to transmit the intelligence.
- Since its amplitude and frequency never change, there is no information contained in the carrier.
- Further experiments proved that both sidebands could be transmitted, each containing different intelli-gence, with a suppressed or completely eliminated carrier.

Types of Sideband Transmission (1)

- A number of single-sideband systems have been developed. The major types include the following:
  1) In the standard single sideband, or simply SSB, system the carrier and one of the sidebands are completely eliminated at the transmitter; only one sideband is transmitted. This is quite popular with amateur radio operators. The chief advantages of this system are maximum transmitted signal range with minimum transmitter power and the elimination of carrier interference.
  2) Another system eliminates one sideband and suppresses the carrier to a desired level. The suppressed carrier can then be used at the receiver for a reference, AGC, automatic frequency control (AFC), and, in some cases, demodulation of the intelligence-bearing sideband, known as single-sideband suppressed carrier (SSBSC). This system retains fidelity of the received signal and minimizes carrier interference.

Types of Sideband Transmission (2)

3) The type of system often used in military communications is referred to as twin-sideband suppressed carrier, or independent sideband (ISB) transmission. This system involves the transmission of two independent sidebands, each containing different intelligence, with the carrier suppressed to a desired level.
4) Vestigial sideband is used for television video transmissions. In it, a vestige (trace) of the unwanted sideband and the carrier are included with one full sideband.
5) A more recently developed system is called amplitude-compandored single sideband (ACSSB). It is actually a type of SSBSC because a pilot carrier is usually included. In ACSSB the amplitude of the speech signal is compressed at the transmitter and expanded at the receiver.

Advantages of SSB (1)

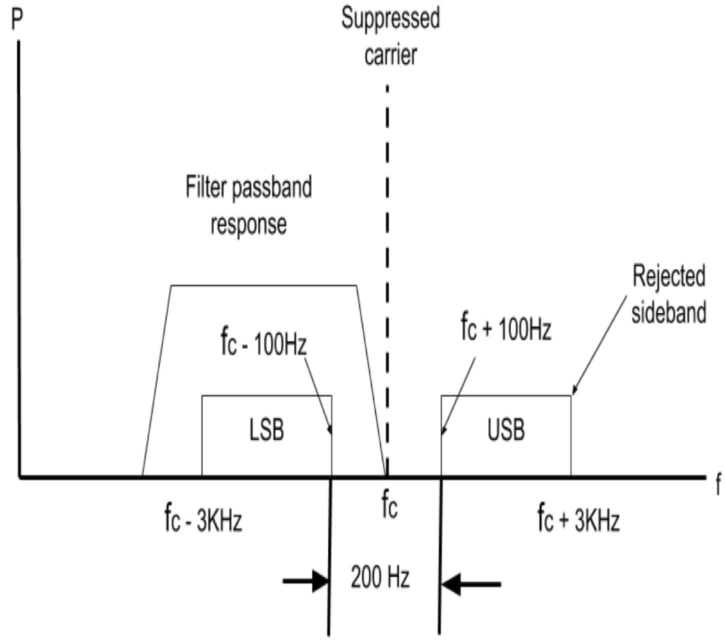
- The most important advantage of SSB systems is a more effective utilization of the available frequency spectrum. The bandwidth required for the transmission of one conventional AM signal contains two equivalent SSB transmissions. This type of communications is especially adaptable, therefore, to the already overcrowded high-frequency spectrum.
- Another major advantage of SSB is the power saved by not transmitting the carrier and one sideband. The resultant lower power requirements and weight reduction are especially important in mobile communication systems.
- The SSB system has a noise advantage over AM due to the bandwidth reduction (one-half). Taking into account the selective fading improvement, noise reduction, and power savings, SSB offers about a 10- to 12-dB advantage over AM.

Advantages of SSB (2)

- Another advantage of this system is that it is less subject to the effects of selective fading. In the propagation of conventional AM transmissions, if the upper-sideband frequency strikes the ionosphere and is refracted back to earth at a different phase angle from that of the carrier and lower-sideband frequencies, distortion is introduced at the receiver. Under extremely bad conditions, complete signal cancellation may result. The two sidebands should be identical in phase with respect to the carrier so that when passed through a nonlinear device (i.e., a diode detector), the difference between the sidebands and carrier is identical. That difference is the intelligence and will be distorted in AM systems if the two sidebands have a phase difference.

SSB Filters (1)

- Once the carrier has been eliminated, it is necessary to cancel one of the sidebands without affecting the other one.
- This requires a sharply defined filter as shown in this figure.
- Voice Transmission requires from about 100Hz up to 3KHz.
- Therefore, the upper and lower SBs generated by the balanced modulator are separated by 200 Hz (see Fig.)



SSB Filters (2)

- As we know, the required Q factor depends on three elements:
  - the centre or carrier frequency, fc
  - the separation between, ∇f
  - The desired attenuation level of the unwanted sideband

- It can be calculated as:

$$Q = \frac{f_c(\log^{-1} \mathrm{dB}/20)^{1/2}}{4\Delta f}$$

here, dB is the suppression if the unwanted sideband

Example 1

- Calculate the required Q for the situation depicted in the following figure for the carrier frequency of 100KHz and 80-dB sideband suppression. (Use the figure on the first slide)

- Solution:

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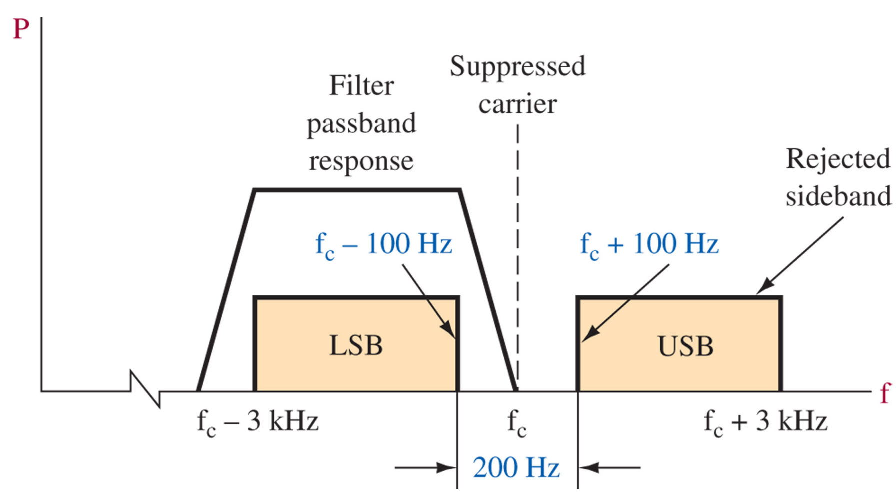
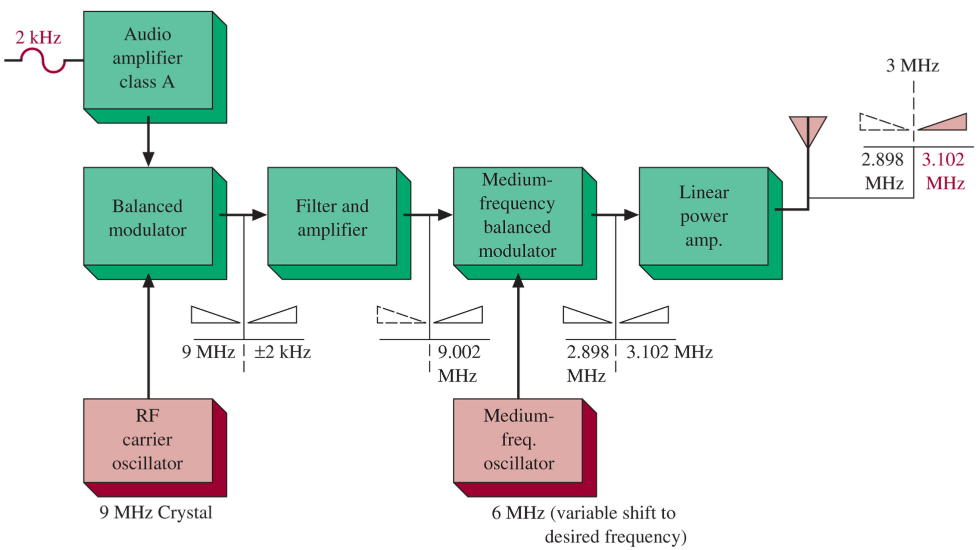
$$Q = \frac{f_c\left(log^{-1}\frac{db}{20}\right)^{\frac{1}{2}}}{4\Delta f} = \frac{100KHz\left(log^{-1}\frac{80}{20}\right)^{\frac{1}{2}}}{4\times 200Hz} = \frac{10^7}{8\times 10^2} = 12{,}500$$



SSB Transmitters (1)

- Figure below is a block diagram of a modern single-sideband transmitter using a balanced modulator to generate DSB and the filter method of eliminating one of the sidebands.
- For illustrative purposes, a single-tone 2000-Hz intelligence signal is used, but it is normally a complex intelligence signal, such as that produced by the human voice.
- A 9-MHz crystal frequency is used because of the excellent operating characteristics of monolithic filters at that frequency.

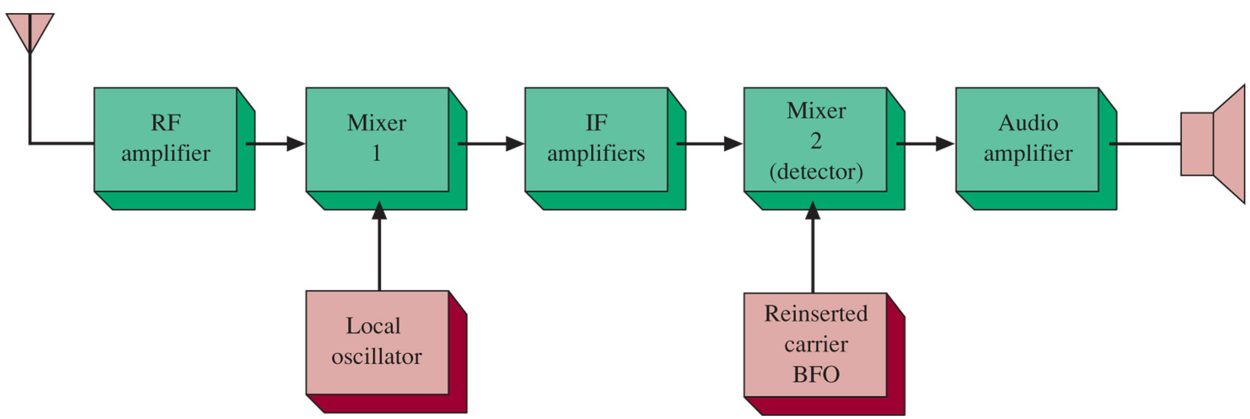


SSB Transmitters (2)

- The 2-kHz signal is amplified and mixed with a 9-MHz carrier (conversion frequency) in the balanced modulator. Remember, neither the carrier nor audio frequencies appear in the output of the balanced modulator; the sum and difference frequencies (9 MHz $\pm$ 2 kHz) are its output.
- As illustrated in Figure, the two sidebands from the balanced modulator are applied to the filter. Only the desired upper sideband is, passed. The dashed lines show that the carrier and lower sideband have been removed.
- The output of the first balanced modulator is filtered and mixed again with a new conversion frequency to adjust the output to the desired transmitter frequency.
- After mixing the two inputs to get two new sidebands, the balanced modulator removes the new 3-MHz carrier and applies the two new sidebands (3102 kHz and 2898 kHz) to a tunable linear power amplifier.

SSB Receivers (1)

- Block diagram of SSB receiver is given below, the receiver is similar to an ordinary AM super-heterodyne receiver; that is, it has RF and IF amplifiers, a mixer, a detector, and audio amplifiers.
- To permit satisfactory SSB reception, however, an additional mixer (demodulator) and oscillator must replace the conventional diode detector.
- The carrier frequency was suppressed at the transmitter; thus, for proper intelligence detection, a carrier must be inserted by the receiver.



SSB Receivers (2)

- The receiver illustrated in Figure inserts a carrier frequency into the detector, although the carrier frequency may be inserted at any point in the receiver before demodulation.
- When the SSB signal is received at the antenna, it is amplified by the RF amplifier and applied to the first mixer.
- By mixing the output of the local oscillator with the input signal (heterodyning), a difference frequency, or IF, is obtained.
- The IF is then amplified by one or more stages. Of course, this is dependent upon the type of receiver. Up to this point it is identical to an AM superheterodyne receiver.
- The IF output is applied to the second mixer (detector). The detector output is applied to the audio amplifier and then on to the output speaker.

References

- Chapter 4, Beasley and Miller, Modern Electronic Communication, 9^{th} Edition.