Single Sideband Exciters

This is the fifth article from the training course written by Collins Radio Company for personnel concerned with single sideband communications.

The single sideband exciter must translate the incoming audiofrequency signal to a band of frequencies in the radiofrequency (RF) range. This article and the two that follow it describe the SSB exciter and how it functions.

A single sideband exciter is a complete transmitter in itself. It must generate an RF sideband from an audio input signal, translate this RF sideband to the final output frequency, and provide enough amplification to drive the RF power amplifier. Figure 1 is a functional diagram of a typical SSB exciter.

To generate the RF sideband of frequencies, the single sideband exciter makes use of low-level modulation and the desired output level is obtained through the use of linear amplifiers. Low-level modulation is used since the carrier and unwanted sideband must be suppressed. The best suppression is obtained at a fixed low frequency since the problems involved in building a high-level balanced modulator, that will work over a wide frequency range, appear to be insurmountable.

The most desirable performance characteristics of a single sideband exciter would be the ability to generate the desired sideband, completely suppress the undesired sideband, and suppress the carrier. In practical design, the undesired sideband and carrier frequencies may be suppressed by more than 40 decibels.

Careful consideration must be given to the amount of frequency spectrum space occupied by the generated signal. The band of side frequencies is normally held to 4 kilocycles in single sideband exciters for communication purposes.

The two basic systems for generating single sideband signals are the filter system, figure 2A, and the phase shift system, figure 2B.

Filter System

The filter system has a bandpass filter with enough selectivity to pass one sideband and reject the other. Filters having such characteristics are normally constructed for relatively low frequencies, below 500 kilocycles; but recent developments in crystal filter research have produced workable filters at 5 megacycles.

The carrier generator output is combined with the audio output of a speech amplifier in a balanced modulator. The upper and lower sidebands appear in the output, but the carrier is suppressed. One of the sidebands is passed by the filter and the other is rejected, so that a single sideband signal is applied to the mixer. The signal is mixed with the output of a high-frequency RF oscillator to produce the desired output frequency.

The problem of undesired mixer products arising in the frequency conversions of single sideband signals becomes important. Either balanced modulators or enough selectivity must be used to attenuate these frequencies in the output and minimize the possibility of unwanted radiations.

Phase Shift System

The principle involved in the generation of a single sideband signal by the phase shift method, figure 2B, is centered about two separate simultaneous modulation processes and the combination of the modulation products. The audio signal is split into two components that are identical except for a phase difference of 90°.

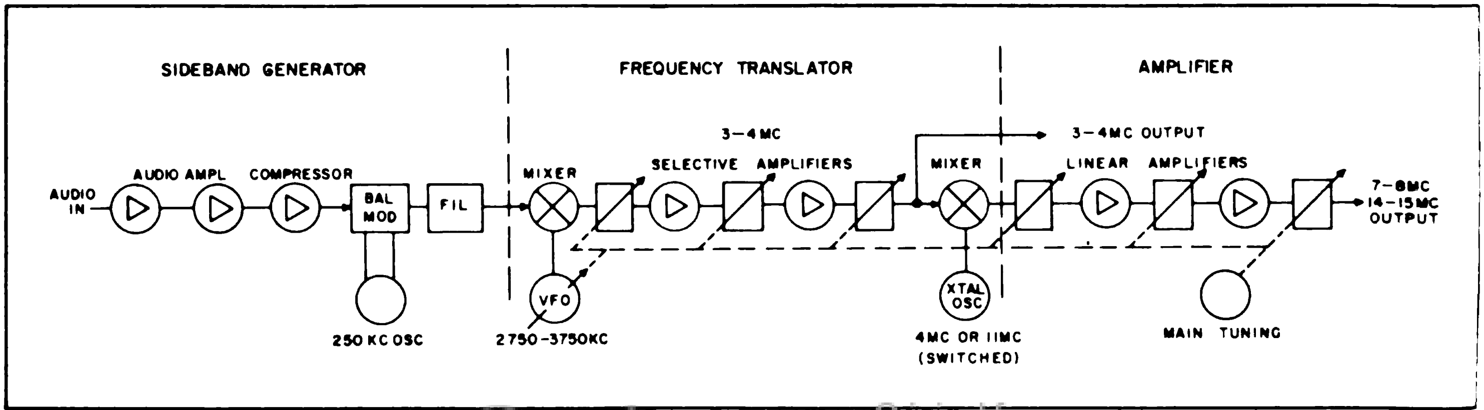
The output of the RF oscillator (which may be at the operating frequency, if desired) is also split into two separate components having a 90° phase difference. One RF and one audio component are combined in each of two separate balanced modulators. The carrier is suppressed in the modulators, and the relative phases of the sidebands are such that one sideband is balanced out while the other sideband is accentuated in the combined output.

If the output from the balanced modulator is of enough amplitude, such a single-sideband exciter can work directly into the antenna, or the power level can be increased in a following linear amplifier.

The SSB Generator

The sideband generator processes the input signal, generates the RF sideband in a modulator, selects the desired sideband while suppressing the unwanted sideband, and suppresses the carrier. The circuits used for these functions are shown in the single sideband generator portion of figure 1. The

Figure 1. Typical single-sideband exciter, functional diagram.



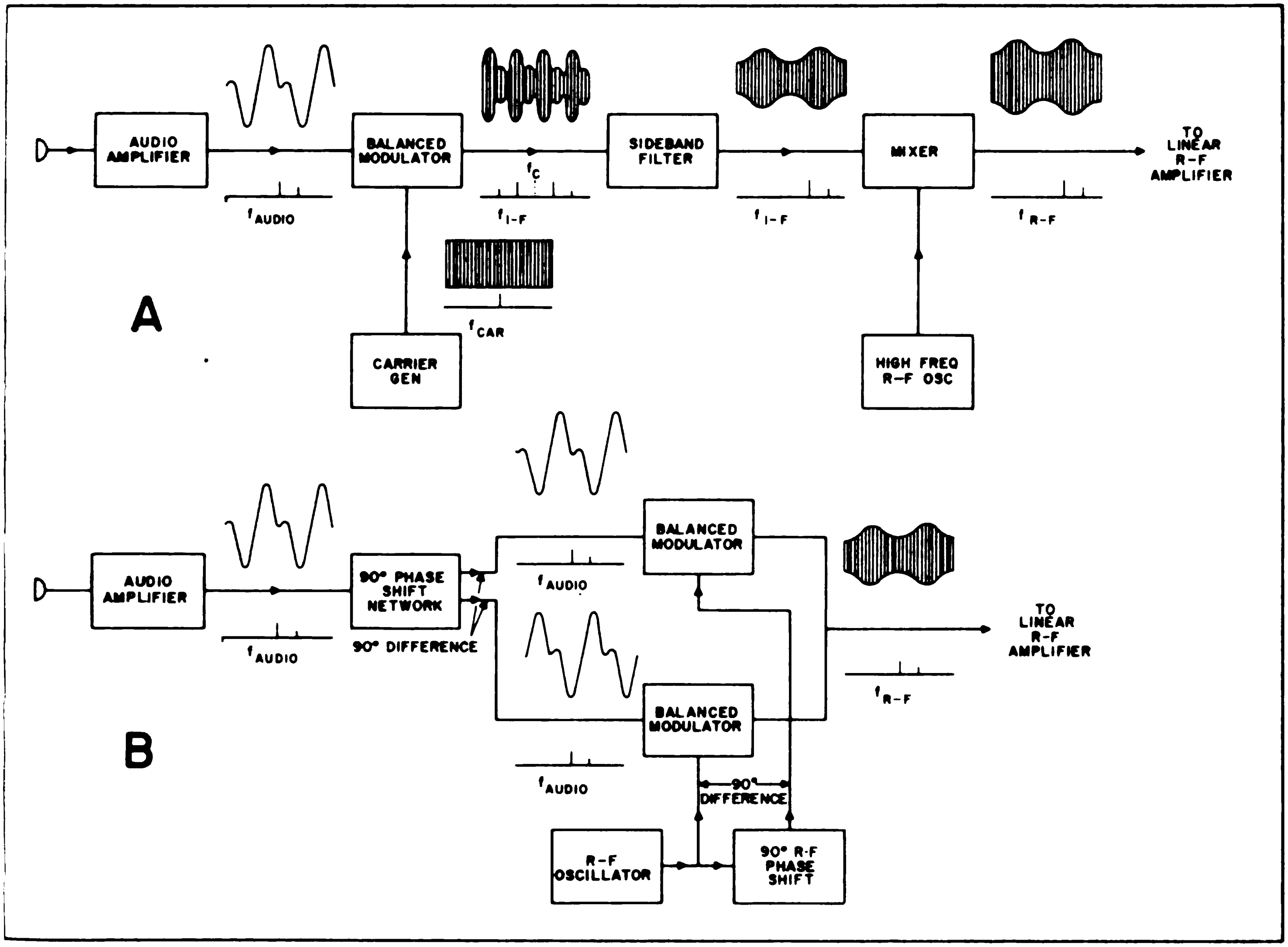


Figure 2. Basic single sideband generator, block diagram.

audio input wave must be amplified, amplitude limited, and shaped before being applied to the modulator circuits.

Sidebands are generated by using this audio input signal to vary the amplitude of a carrier wave in a modulator. The desired sideband is selected from the modulator output by using frequency discrimination or phase discrimination. The carrier wave is suppressed by using balanced modulators or rejection filters.

Input Signal Processing

Processing of the audio input signal is an important part of single sideband generating. If the input signal is a tone, or group of tones, of constant amplitude, such as the signal from a data gathering device, only a limited degree of processing will be required.

However, if the input audio signal is a voice signal, rather elaborate input processing circuits must be designed to obtain optimum results.

The amount of amplification required depends on the output capability of the source of the audio signal and the input signal requirements of the modulator. Modulators require an audio signal in the range of 0.1 to 1 volt at impedances of 200 ohms for diode modulators or several hundred thousand ohms for vacuum tube modulators.

The output of a microphone may be from 100 to 1,000 times less than the 0.1 to 1 volt range. Telephone line levels will also be considerably less than the required level.

To obtain efficient utilization of the transmitter power amplifier, the applied driving signal should be as close to maximum without exceeding the overload level. To avoid driving the power amplifier into overload, it is necessary to adjust gain to the point where maximum output is obtained with the maximum input signal.

When the input signal is made up of extreme variations, such as a peak level to average level of 4:1, the average transmitted power level will only be $\frac{1}{4}$ the maximum output that the transmitter can furnish. This analogy is illustrated in figure 3.

An effort must be made to compress the dynamic range of the human voice to make it more compatible with the electrical characteristics of a communications system. The two methods most commonly used to reduce these amplitude variations are compression and clipping circuits.

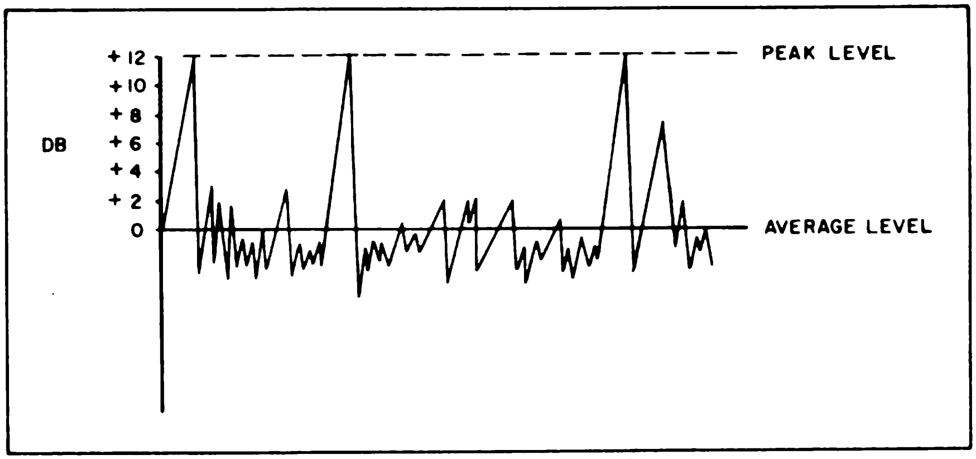


Figure 3. Peak-to-average level variations of speech.

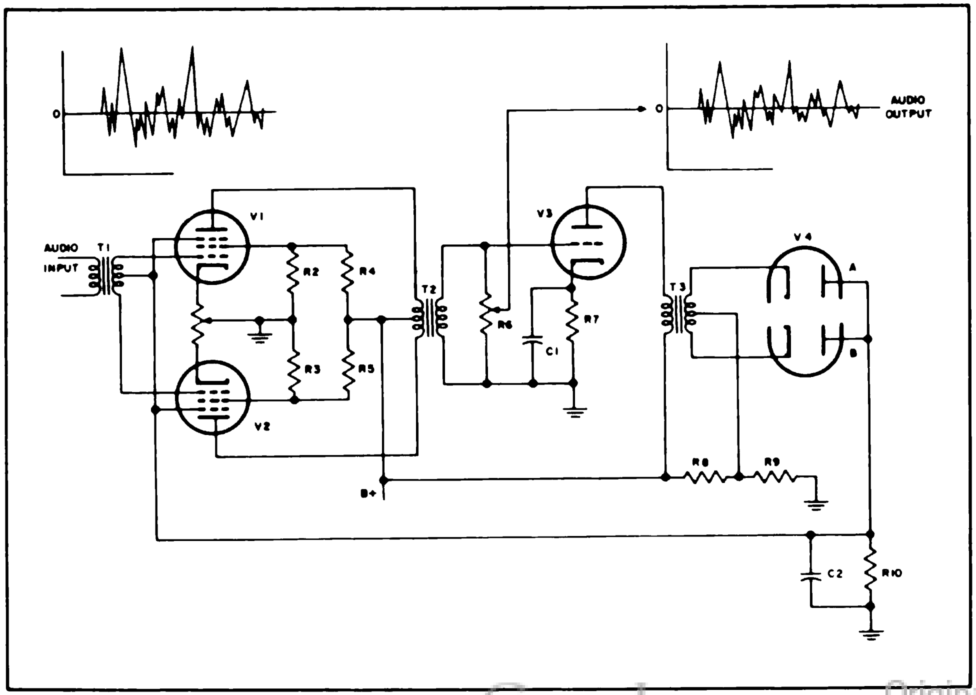
Compressor Circuit

A compressor is an automatic variable gain amplifier whose output bears some consistent relation to its input: For example, a 1-decibel rise in output for a 2-decibel rise in input. This circuit has very low steady state distortion. Common compressors have some type of feedback loop that samples the output of the amplifier and regulates the gain of the stage.

The time constants of this type of circuit are necessarily slow to prevent oscillation, motorboating, and distortion. The attack time, the time necessary to reach steady state condition after a sudden rise in input level, will be several milliseconds. The release time, the time necessary to reach steady state condition after a sudden drop in input level, will be several seconds. Compression of about 10 decibels is usually considered as an acceptable maximum value.

Operation of the compressor circuit, figure 4, is such that the d.c. bias voltage applied to the control and suppressor grids of the push-pull stage is in direct proportion to the amplitude of the signal passing through the circuit. If a large amplitude signal is impressed on the control grids of V1 and V2, such as a large amplitude low frequency, the signal is amplified and appears across transformer T3.

Figure 4. Compressor circuit.



As the audio signal swings positive at the top of the secondary of the transformer, tube V4B conducts, since the bottom of the secondary is negative with respect to ground, and the resulting current flow causes a bias voltage drop across resistor R10. The negative voltage on the control and suppressor grids of V1 and V2 reduces the gain of the tubes to limit the excursion of the audio signal.

Conversely, as the audio signal swings negative at the top of the secondary of transformer T3, tube V4A conducts. Since the plates of the rectifiers are in parallel, the bias voltage is produced on both positive and negative going portions of the audio signal.

Clipper Circuit

The clipper circuit, figure 5, prevents the amplitude of a signal from exceeding a preset level. Its time constants are practically instantaneous, and it functions on each cycle of a wave. Distortion is very high, which results in loss of individuality in speaking and broadens the spectrum occupied by the speech.

Low-pass filters are usually used in conjunction with clippers to limit the spectrum and reduce distortion.

The advantages of clipping are simplicity of circuit design and the prevention of overmodulation. Prevention of overmodulation results from the extremely fast attack on a wave after it exceeds the threshold. A well-designed clipper has no overshoot and an extremely fast release.

A weak signal following one cycle after a wave that is heavily clipped will not be limited. This means that a weak consonant that follows a loud vowel in human speech will be given full amplification, although the preceding vowel was severely clipped. This amplifying of weak sounds in relation to soft sounds is referred to as consonant amplification.

The clipper circuit serves as an instantaneous voltage amplitude limiter at a predetermined point on the positive and negative going portions of the audio signal. As the cathode of V1A swings positive, the tube will conduct until the potential on the cathode reaches the potential of the plate.

The current flow through resistor R3 causes a voltage drop across R3 which is alternately reinforcing and bucking the plate voltage in exact response to the applied audio signal. This action causes the current through V1B to vary as the plate voltage varies and the signal in the output, across resistor R2, will be the same as the signal at the input, across resistor R1.

When tube V1A is cut off, because of the cathode becoming more positive than the plate, there is no change of the plate voltage applied to V1B, and the current through the tube is held at a constant point. When the signal starts negative, the current variations through V1B will follow the current variations through V1A until the current through V1A becomes great enough to cause the negative voltage drop across resistor R3 to equal the applied d.c. plate potential.

At this point the plate of V1B is no longer positive with respect to the cathode, and V1B ceases to conduct. The net result of this action is the clipping (or limiting) of the positive and negative peaks of an audio signal at a value predetermined by the setting of potentiometer R4.

Frequency Response Shaping

The energy contained in a voice signal is confined principally to frequencies below 1000 cycles per second. Most of this energy is used to produce the vowel sounds that contribute little to intelligibility. The energy used to produce the consonant sounds is largely high frequency in content and is very important in intelligibility.

An improvement in intelligibility will result if the frequency response of the audio input signal circuits is modified to amplify the high frequencies more than the low frequencies.

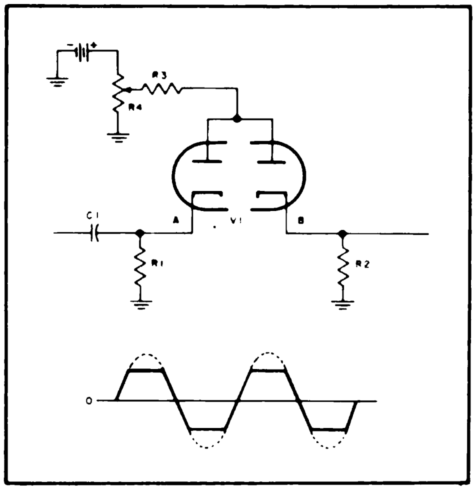


Figure 5. Clipper circuit.

Infrared

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Infrared radiation provides a new avenue of perception or a new sense like radio, radar, and sonar. The full development of this sense will give men the means to see at night. They will be able at night to communicate with friends and be aware of the presence of enemies.

Any sense has limitations as well as advantages. The senses compete in some instances, they work together in others. Infrared should be considered on its own merits and not primarily as a competitor of radar or sonar.

One of the principal characteristics of infrared is its security advantages. Radar is always an active system while sonar like infrared may be either active or passive.

The fact that infrared, whether active or passive, can be made highly directional makes it safe and difficult to jam. The passive infrared, of course, presents no additional hazard. Infrared like light trends in straight lines and its rays are only slightly bent by refraction as it passes through the atmosphere. This same desirable characteristic, however, also imposes a limitation, namely, the useful range is limited to the horizon.

Absorbed

Like light, infrared is absorbed by the atmosphere. Rain, snow, haze, and fog impose limitations just as they do in the visible region of the spectrum. Under some very special atmospheric conditions, infrared may have some advantage over visibility since it will usually penetrate artificial smoke screens and some kinds of fog. Its penetration potential is never worse than the visible.

Although infrared is primarily restricted to night operation, it can also be used in the daytime if certain precautions are taken. For daylight use, the visible region of the spectrum should be excluded. Usually energy below 3 microns in wavelength should be excluded. An infrared device should never be pointed directly at the sun.

Equipment of reasonable size and weight can now be designed that will perform at horizon ranges in average weather conditions. The applications include communication, search devices, and trackers. Also there is now equipment that can be used to determine the range of a cooperating (friendly) target.

Before proceeding to design and manufacture specific infrared actuated devices, minimum acceptable performance standards must be established.

With the exception of reconnaissance, missile guidance, and other similar applications, the need for the use of infrared is based on the assumption that in some tactical situations, when at war, it will be necessary, or at least desirable, to darken ship. Another assumption is that conditions will exist where radio and radar silence will also be necessary or desirable. The same would apply to active sonar.

Under these conditions, infrared services can be used for navigation, communication, and search.

Another assumption is that in wartime, particularly during action, the enemy will endeavor to jam all communication and search devices. Under such circumstances infrared, being difficult to jam, could be used to provide information urgently needed.