A Third Method of Generation and Detection of Single-Sideband Signals

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Summary—This paper presentes third method of generation and detection of a single-sideband signal. The method is basically different from either the conventional filter or phasing method in that no sharp cutoff filters or wide-band 90° phase-difference networks are needed. This system is especially suited to keeping the signal energy confined to the desired bandwidth. Any unwanted sideband occupies the same band as the desired sideband, and the unwanted sideband in the usual sense is not present.

THE PURPOSE of this paper is to present a third basic method of generation and detection of slngle-sideband signals   Two methods are commonly used today   A block diagram of the first of these, the filter method, is shown in Fig.1. The input signal(a speech waveform, for example) is applid to a balanced modulator along with the first translating or carrier frequency. The two normal sidebands appear in the output of the balanced modulation, but the carrier frequency is balanced out. The purpose of the filter is to select one sideband and reject the other. When the desired frequency location of the single-sideband signal is high compared with the original location of the input signal(e.g., translating speech to the hf region), it becomes very difficult to obtain filters that will pass one sideband and reject the other. To avoid this, the translation is done in several steps so as to ease the filter requirement.

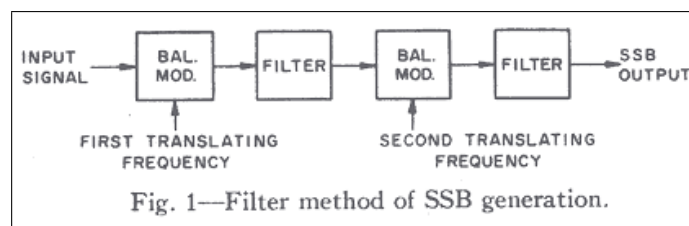Fig. 1—Filter method of SSB generation.

Fig.1 shows a system using two translational steps. In many radio transmission systems, three to five translational steps may be used. The detection problem is simply an inverse operation; that is, the arrows in Fig.1 could be reversed. In detection, balanced modulators are not necessary, and ordinary converter circuits are satisfactory.

The second method, generally called the phasing method, is shown in Fig.2. The input signal is applied to a wide-band 90 ° phase-difference network. This network passes all frequencies of the input signal uniformly in amplitude. However, the phase response is such that a sinusoidal input whose frequency falls anywhere within the input signal frequency band will result in two equal amplitude sinusoidal signals whose phases differ by 90 ° . These quadrature signals are applied to a pair of balanced modulators. The translating carrier frequency is also divided into two 90 ° components. When the output signals from these two balanced modulators are added,

one set of sidebands will add in phase, generating the desired signal, while the other sideband will cancel itself out. By subtracting instead of adding, it is possible to change sidebands.
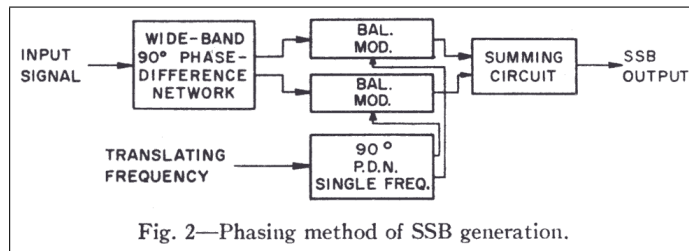

Fig. 2—Phasing method of SSB generation.

As this is a balancing method and does not require any sharp cutoff filters, it is possible to generate the desired sideband in a single translational step regardless of how high the final signal frequency maybe. However, the degree to which the undesired sideband may be suppressed depends upon accurate balancing and requires very careful control of amplitudes and phases. As a practical matter it is quite easy to realize 20-db suppression, reasonable to expect 30 db, and quite difficult to go beyond 40 db. Suppression of 60 to 80 db or more can be realized using the filter method, but extreme care in maintaining low intermodulation in linear amplifiers is necessary if this degree of suppression is to exist in the final radiated signal.

The design and construction of a wide-band $90°$ phase-difference network is not a familiar art withmost circuit designers, and this often acts as a roadblock to using the phasing method.

A block diagram showing the new method of single-sideband signal generation is shown in Fig.3. The input signal e_i is confined to a banddwidth W with the lower band limit f_L as shown in Fig.4. The band center is f_0

$$f_0 = f_L + W/2. \tag{1}$$

For convenience let the input signal be expressed as a summation of sinusoidal terms.

$$e_i(t) = \sum_{n=1}^{N} E_n \cos(\omega_n t + \phi_n). \tag{2}$$
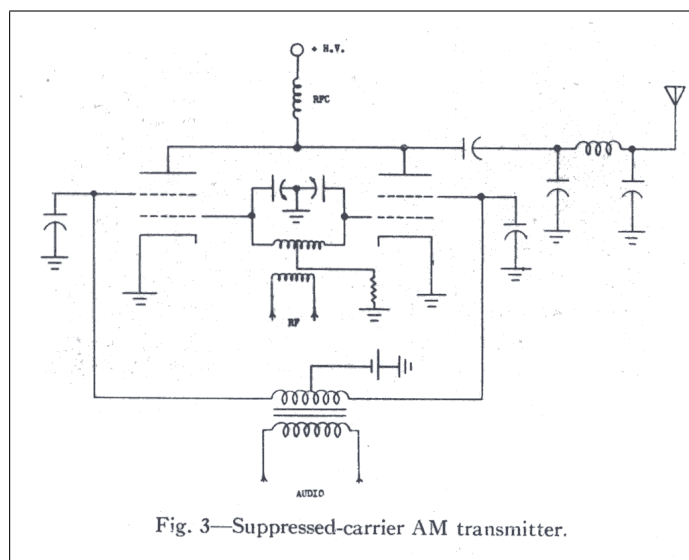

Fig. 3—Suppressed-carrier AM transmitter.

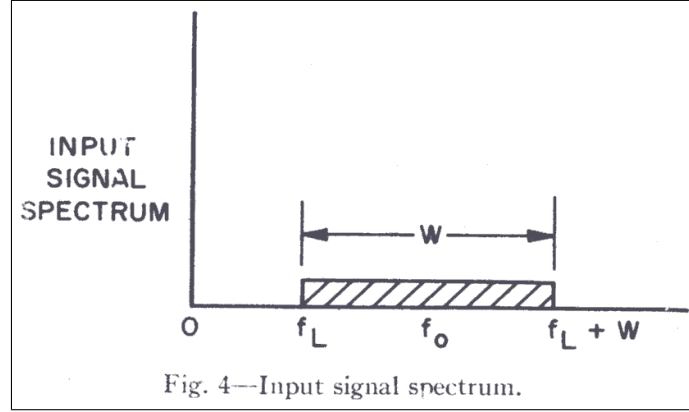Note that the modulating of carrier frequency of the first pair of balanced modulators is the

center frequency of the input spectrum. The outputs of the first two balanced modulators are

$$e_{a1} = 2e_i(t)\cos\omega_0 t \tag{3}$$

$$e_{b1} = 2e_i(t)\sin\omega_0 t, \tag{4}$$

where

$$\omega_0 = 2\pi f_0 \tag{5}$$

Fig. 4—Input signal spectrum.

The coefficient 2 is used for convenience and can be considered a property of the balanced modulators. Substituting (2) into (3) and (4) and expanding gives

$$e_{a1} = \sum_{n=1}^{N} E_n \cos[(\omega_n - \omega_0)t + \phi_n] + E_n \cos[(\omega_n + \omega_0)t + \phi_n] \tag{6}$$

$$e_{b1} = \sum_{n=1}^{N} -E_n \sin[(\omega_n - \omega_0)t + \phi_n] + E_n \sin[(\omega_n + \omega_0)t + \phi_n]. \tag{7}$$

The frequencies $f_n = \omega_n/2\pi$ are restricted to the original bandwidth W

$$f_L \leq f_n \leq f_L + W. \tag{8}$$

Hence the spectrum of the signals e_{a1} and e_{b1} is as shown in Fig.5. The low-pass filter passes the frequencies from *zero* to W 2. From $W/2$ to $2f_0 - W/2$ there should be no signal energy which provides a convenient transition region for the filter. Above $2f_0 - W/2$ the filter should have adequate attenuation to eliminate the high-frequency components from the balanced modulators. Using such a filter the expressions for the filter output voltages are

$$e_{a2} = \sum_{n=1}^{N} E_n \cos[(\omega_n - \omega_0)t + \phi_n] \tag{9}$$

$$e_{b2} = \sum_{n=1}^{N} E_n \sin[(\omega_n - \omega_0)t + \phi_n]. \tag{10}$$

Fig. 5—Spectrum from first balanced modulators.

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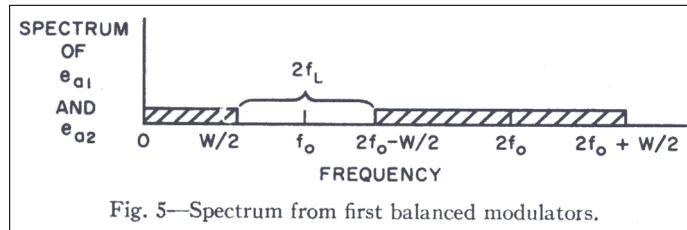
These two low-frequency functions are then applied to another pair of balanced modulators. However, in this case the translating frequency ω_c is the band center of the desired single-sideband signal. This is generally a high frequency compared with any of the frequencies of the original signal. The expressions for the outputs of this second pair of modulators are

$$e_{a3} = e_{a2} \cos \omega_c t \tag{11}$$

$$e_{b3} = e_{b2} \sin \omega_c t. \tag{12}$$

Substituting (9) and (10) into (11) and (12), and expanding gives

$$e_{a3} = \sum_{n=1}^{N} \frac{E_n}{2} \cos[(\omega_c + \omega_n - \omega_0)t + \phi_n] + \frac{E_n}{2} \cos[(\omega_c - \omega_n + \omega_0)t - \phi_n] \tag{13}$$
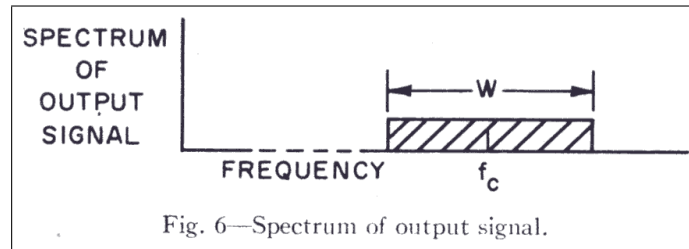
$$e_{b3} = \sum_{n=1}^{N} \frac{E_n}{2} \cos[(\omega_c + \omega_n - \omega_0)t + \phi_n] - \frac{E_n}{2} \cos[(\omega_c - \omega_n + \omega_0)t - \phi_n]. \tag{14}$$

Finally, adding (13) and (14) gives the desired single-sideband output.

$$e_0 = e_{a3} + e_{b3} \tag{15}$$

$$e_0 = \sum_{n=1}^{N} E_n \cos[(\omega_c + \omega_n - \omega_0)t + \phi_n]. \tag{16}$$

Note that the frequency normally referred to as the carrier corresponds to $\omega_c - \omega_0$ and that the frequency ω_c is the center of the singlesideband. Fig.6 shows the spectrum of e_0.
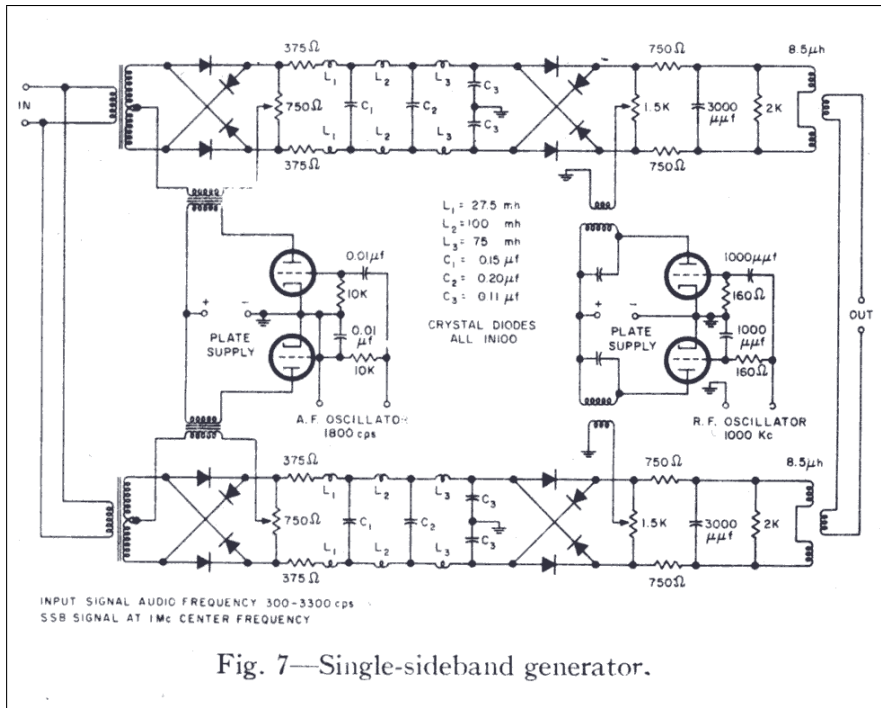

Fig. 6—Spectrum of output signal.

This method of single-sideband generation does not need either sharp cutoff filters or wideband 90 ° phase-difference networks. Imperfections in the phasing or balancing do not result in the presence of the unwanted sideband in its usual location. Instead, the unwanted sideband occupies the same band of frequencies as the desired sideband, except that it is inverted. This is a very useful property of this system when channel conservation is an important reason for using single-sideband signals.

Fig.7 shows the circuit of a single-sideband generator using this method. The input signal is a typical speech signal whose energy is confined to a band from 300 to 3300 cps. Care must be taken in the first pair of balanced modulators to keep the input signal component (linear term) from appearing in the output. The two low-pass filters pass all frequencies up to 1500 cps and provide adequate attenuation above 2100 cps. In the second pair of balanced modulators the rf oscillator signal must be accurately balanced out to keep it from appearing in the output.

Two tone tests indicated that undesired signal components were all more than 30 db below the desired sinals. The input signal level was in the range 0.1 to 1.0 volt. Listening tests using speech

and music indicated good quality. No difficulty was encountered in balancing the modulators or in phasing the translating signals. The balanced modulators, filters, and transformers can be packaged in a very small unit. As the circuit is bilateral, it can be used in demodulation as well as in generation of single-sideband signals. The lack of critical or expensive elements, combined with the ease of adjustment and the ruggedness and reliability of a passive circuit (such as the one shown in Fig.7) makes this method attractive for application in future single-sideband systems.

Fig. 7—Single-sideband generator.

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