The AEROVOX Research Worker

The Aerovox Research Worker is edited and published by the Aerovox Corporation to bring to the Radio Experimenter and Engineer, authoritative, first hand information on capacitors and resistors for electrical and electronic application.

VOL. 26, NO. 1 | JANUARY, 1956 | Subscription By Application Only

Recent Trends in Single-Sideband Communication

By the Engineering Department, Aerovox Corporation

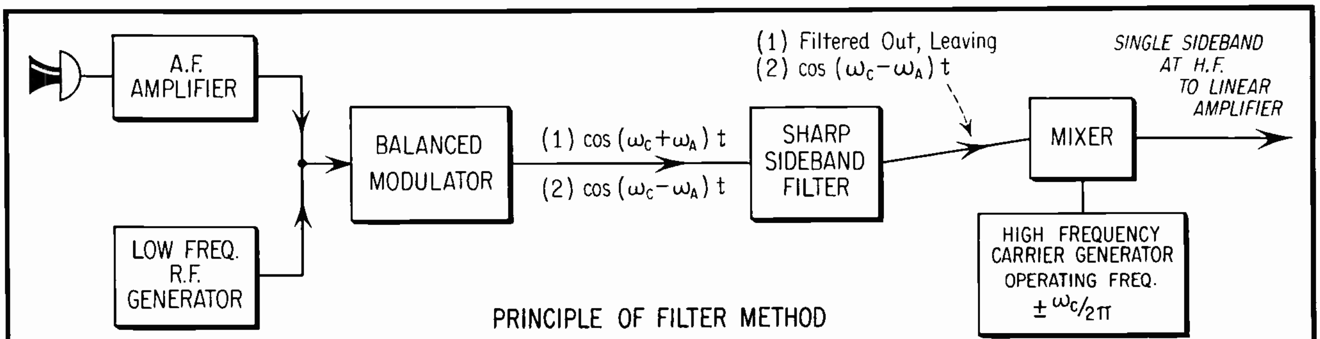
FROM the days of the earliest radiotelephone transmissions, radio engineers and experimenters have been impressed with the fact that a conventional amplitude-modulated signal contains all its necessary intelligence in one of its sidebands. Yet associated with the transmission of this sideband is an identical additional sideband and a carrier component, so the total transmitted power amounts to six times that of a single sideband, which contains all the necessary intelligence. At the same time, the conventional amplitude-modulated signal takes up twice as much precious frequency spectrum bandwidth as a single sideband.

It has been found that certain types of fading, common with amplitude-modulated signals, are either eliminated or greatly reduced in single-sideband transmissions. This is particularly true of *selective* fading, which results from propagational phase variations between carrier and sidebands or between the two sidebands themselves. Elimination of the heavy and expensive high-level audio-frequency components of the conventional a-m transmitter is a powerful argument in favor of the single-sideband system.

Radio transmission with supressed carrier and a single sideband has been used almost as long as the conventional double-sideband amplitude-modulated type. It was employed for transatlantic radiotelephony at low frequencies as long ago as the early nineteen twenties. Because at that time the direct filter method was the only one generally applied, the inconvenience of heterodyning, instability of oscillator components and other factors limited practical use of such a system to the lower radio frequencies. In the last few years, development of high grade components and new techniques of circuitry have made single-sideband-suppressed-carrier (sssc) communication at higher frequencies more attractive. Improved stability and selectivity in receivers and receiving systems have also been helpful in this development.

The Filter Method of Generating SSB Signals

Two main methods of generating single-sideband signals are generally employed: the filter method and the phasing method. The filter method is the older of the two, and in principle is simpler and more direct. This principle is illustrated in Fig. 1. The carrier is removed from the composite modulated signal by means of a



PRINCIPLE OF FILTER METHOD
FIG. 1

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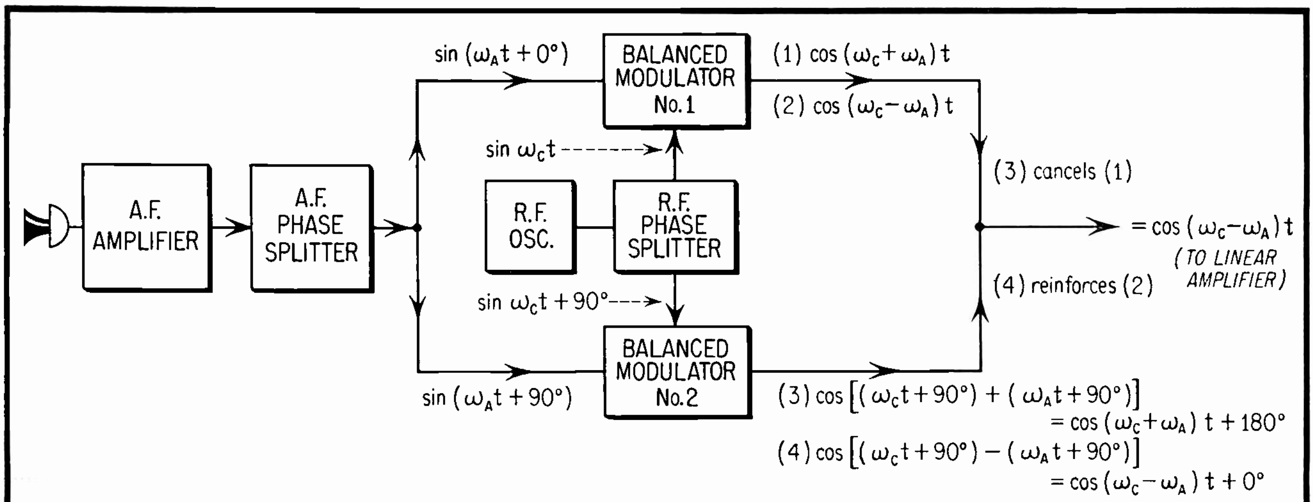


PRINCIPLE OF PHASING METHOD

FIG. 2

balanced modulator. Then a filter with a sharp frequency characteristic, connected at the output circuit of the balanced modulator, removes the unwanted sideband.

In the filter method, the carrier must be generated at a relatively low radio frequency. If the radio frequency is too high, the percentage frequency spacing between the two sidebands is too small. Filters sharp enough to isolate the desired sideband would introduce too much phase distortion. Some amateur installations are using generated r-f carriers as high as nearly 500 kc for the filter method. Crystal lattice filters are used. However, in commercial practice it is common to keep the generated carrier between 20 kc and 100 kc. to ensure high filter efficiency and best attenuation of the unwanted sideband.

The single-sideband signal from the balanced modulator and filter is then transposed to the desired higher operating frequency by heterodyning with higher frequency carriers in one or more successive mixers. If the operating frequency is many times that of the carrier of the sideband generator (as is ordinarily the case in high-frequency transmitters of the filter type), more than one stage of mixing is necessary. This is because when the mixer output frequency is very much higher than its input frequency, and the frequencies of the sum and difference heterodyne products are close, it is difficult to attenuate the unwanted heterodyne. The necessity for one or more mixing stages and lack of flexibility in switching from one sideband to the other are disadvantages of the filter method as applied to the higher communications frequencies.

The Phasing Method

In most cases, the need for mixer stages can be eliminated by use of the phasing method of single-sideband generation. In this method, the r-f carrier can be generated at the transmitter's output operating frequency. The principle is illustrated in Fig. 2. The mathematical expressions for the various signals, assuming a single-tone modulation signal, are given alongside their respective paths. Both the audio-frequency modulating signal and the carrier are divided, each into two components in quadrature. As shown, each phase component of the a-f signal is combined with one phase component of the carrier in a balanced modulator. In each case, the balanced modulator removes the carrier, leaving two sidebands in the output from each modulator. In the example given, assuming the use of a single modulation frequency, there would be just a single-frequency side-component on either side of the carrier frequency (but no carrier) in each case.

After the balanced modulators, their outputs are combined. The phase relations of the four sidebands (or single-frequency components) is such that one sideband is canceled while the other is reinforced. In the example illustrated, the carrier component which was shifted 90 degrees is modulated by the a-f component which was shifted 90 degrees. As can be seen by the mathematical expressions, combination in such phases results in cancelling of the high frequency sideband and reinforcement of the low frequency sideband. The phase of either the a-f or the carrier component can be reversed to provide high frequency sideband output instead of low frequency sideband output.

One of the critical sections of the phasing type transmitter is the audio phase shifter, which must provide two a-f signals 90 degrees apart at all frequencies in the modulation range. For the normal voice-communication frequency range, a simple RC network will accomplish this. A typical phase shift network for this purpose is illustrated in Fig. 3. One of the problems connected with such a circuit, of course, is the odd values required for most of the components. Special, non-standard components would have to be obtained.

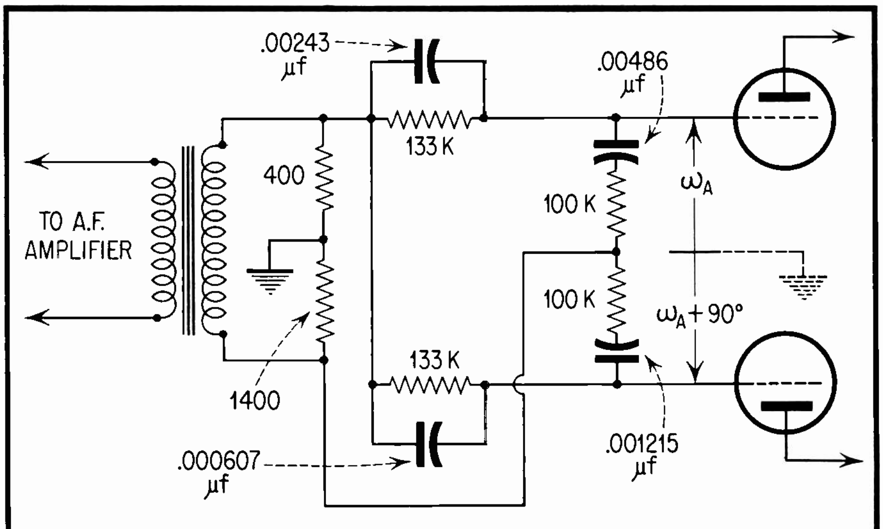
However, a big step forward in making the phasing type of transmitter more practical was the provision by several manufacturers of complete phase shifting networks in very compact form. One of these standard commercially-available networks is completely enclosed in a metal tube envelope, of the same size as a 6J5 tube, and plugs into an octal socket[1]. It provides a 90-degree phase shift constant to within ± 1.5 degrees over an audio frequency range of 300 to 3,000 cps, adequate for voice communication purposes.

Linear Amplifiers

Use of sssc communication has spurred renewed attention to linear amplifier design. Two factors are important in these amplifiers: (1) low distortion, and (2) maximum power gain. Stability, which is very important, is interrelated with distortion, so is not classified separately.

Realization of the full advantages of the limited bandwidth of single-sideband transmission requires that

[1]Barker & Williamson Model 350



TYPICAL AUDIO PHASE SHIFT NETWORK

FIG. 3

distortion be well controlled. This is especially true in services in which each sideband is used for transmission of different intelligence, in which case distortion manifests itself as splatter and noise effects between channels. Thus, low distortion can be considered even more important in ssb linear amplifiers than in the conventional carrier systems.

On the other hand, high power gain is also an important consideration. Single-sideband generators must be operated at relatively low levels. Thus, if linear amplifiers which follow do not have a high power gain, a large number of stages must be used and this is uneconomical and leads to unreasonable maintenance and adjustment requirements.

Under ordinary conditions, very low distortion and high power gain are not compatible. High power gain is seldom obtained with best linearity and lowest distortion. It is the reconciliation of these two factors which is the objective of most modern linear amplifier development.

The conventional grounded-cathode linear amplifier exemplifies the high-power-gain type, especially those circuits employing tetrodes and beam tubes. However, in the latter, optimum power gain is not consistent with minimum distortion. When the screen voltage is raised to a high enough level to minimize grid drive requirements, the static plate current becomes so high that the plate dissipation is likely to become excessive. On the other hand, when the static plate current is kept low, distortion is introduced. One way to maintain the low grid drive requirement and still keep static plate current limited is to use negative feedback.

One popular way to introduce feedback to improve linearity and stability is to use the grounded-grid circuit. Although this does provide excellent linearity, the power gain is low.

Two-Stage Feedback

A somewhat different arrangement for obtaining high power gain with low distortion has recently been suggested.[2] In this arrangement, feedback around both stages is introduced. The first stage is operated class AB_1 and the second either AB_1 or AB_2. A power gain of 5,000 with distortion reduction of up to 16 db over conventional circuits is claimed.

[2] "Linear Power Amplifier for SSB Transmitters" by W. B. Bruene, Electronics, August 1955, p. 124.

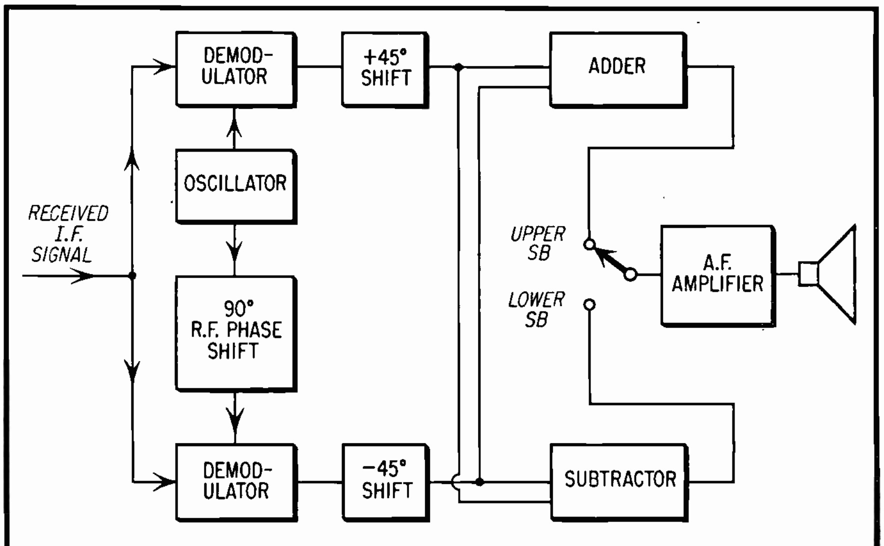
Even though tetrodes are used, neutralization is provided; this is desirable to minimize single-stage instabilities. Less circuit "swamping" is then required.

SSB Reception

The most efficient method of reception of SSB signals is the *phasing* arrangement, which is the reverse of the transmission method illustrated in Fig. 2. A block diagram of the front end of the phasing type receiver is shown in Fig. 4. In applications in which a "pilot" carrier level is transmitted, automatic frequency control is employed in connection with the local oscillator. Otherwise, a suitable vernier adjustment of oscillator frequency must be available to facilitate manual control.

General improvement in component and material quality have contributed greatly in bringing ssb receivers to a relatively high state of development. The narrow pass band (usually about 3 kc) and steep skirt selectivity desirable in this service can now be provided by crystal lattice filters or by the new mechanical i-f filters. These go a long way toward full realization of the full advantages of the single-sideband system, which include improved signal-to-noise ratio, interference-rejection, and fuller use of valuable frequency spectrum. These are in addition to the propagational and economic advantages previously mentioned.

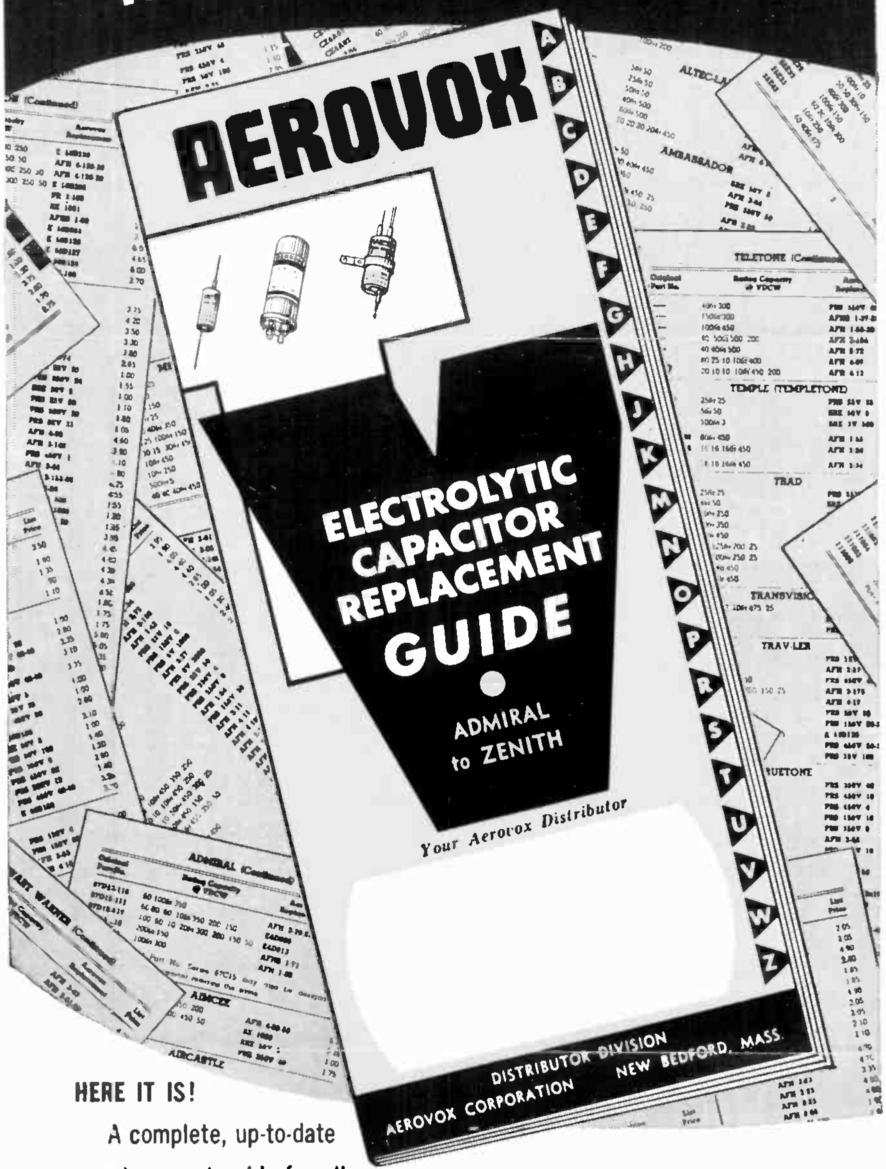
In conclusion it may be said that present trends certainly indicate that before many years most communication services will have converted to single-sideband operation.



BLOCK DIAGRAM OF PHASING-TYPE SSB RECEIVER

FIG. 4

let THIS be your guide



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