TUBES AT WORK

Including INDUSTRIAL CONTROL

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Single-Signal Single-Sideband Adaptor

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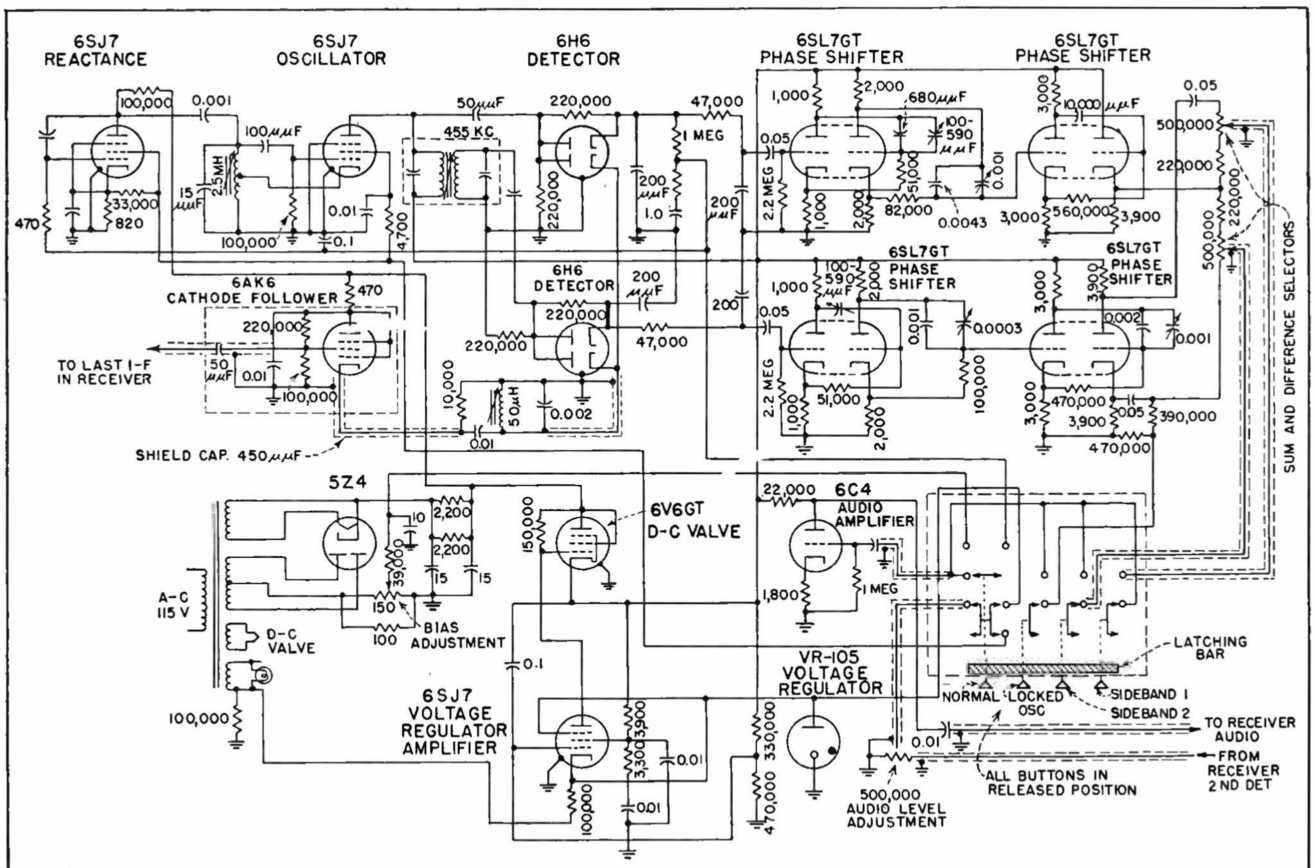
An ordinary superheterodyne receiver will demodulate a single sideband signal and its accompanying carrier so long as the ratio of carrier amplitude to sideband amplitude is kept sufficiently large, though not without distortion. If, however, the carrier is attenuated below a critical value, complete unintelligibility will result. Commercial single-sideband transmitters now in operation attenuate the carrier 20 db below the sideband level to conserve power and simplify equipment.

If a communications type of receiver is used to demodulate this type of signal some means of carrier reinforcement in the receiver is necessary. This can be done conveniently at the intermediate frequency by using the receiver's beat frequency oscillator to exalt the carrier. Exact tuning is required, as well as excellent stability of transmitter frequency, receiver local oscillator frequency and beat frequency oscillator. If the frequency of any of these varies, an audio beat will be produced.

If the carrier is completely suppressed, then the received single-sideband signal can be satisfactorily demodulated only if the beat frequency oscillator supplies the missing carrier. The critical value between the synthetic carrier and the signal must be maintained or exceeded for acceptable results. Since it is difficult to control accurately the frequencies of the oscillators in both transmitter and receiver, other arrangements usually are resorted to in conventional single-sideband receivers.

Figure 1 shows in block form a simple receiver system using low-frequency filters. With this ar-



Complete circuit of the General Electric Selector for single sideband reception with a conventional communications receiver

rangement, double conversion is necessary to change the higher radio frequencies used for communications down to the frequency of the filter.

The purpose of the two oscillators is to enable the pass-band filter to accept the desired side-

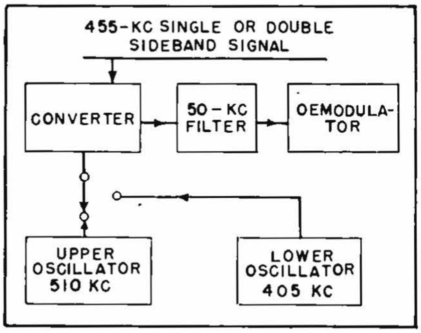


FIG. 1—Filter type of single-sideband receiver

band, whether it be upper or lower. This is done by switching one or the other oscillator into the second converter circuit.

Another single-sideband system, relatively simple in circuit elements, is shown in Fig. 2. This arrangement is used in the General Electric Single Sideband Selector. Reception of a single-sideband signal with or without carrier, and selection of one or the other sideband in a conventional a-m signal, are among the types of transmission which the system handles.

Principle of Operation

Assume that a conventional a-m, double sideband signal is being received. Referring to Fig. 2, the signal from the receiver i-f channel, containing carrier and both sidebands, is fed into two special detectors; 1 and 2. Voltage from an oscillator operating at the same frequency as the i-f channel is also fed into the two detectors. A fixed phase shift of 90 degrees exists between the oscillator voltage applied to detector 1 and detector 2.

The oscillator voltage, or synthetic carrier, is many times greater in magnitude than the incoming signal voltage. Thus the two detectors demodulate the incoming signals at an effective low modulation factor and distortion products are small. Identical audio signals, corresponding to the sideband intelligence are obtained from the two detectors, except for a 90-degree phase difference between them. The amplitude of these signals is directly proportional to the amplitude of the sideband intelligence.

The audio voltages are fed into phase-shift networks A and B, where they undergo an additional 90-degree relative phase shift. The two outputs are fed into a sum and difference circuit, where they are added or substracted algebraically. It can be shown that the sum contains only upper sideband information, for example, and that the difference contains only lower sideband information. (See: Simplified Single-Sideband Reception O. G. Villard, Jr. ELECTRONICS, May 1948.) Selection of one or the other is easily done by a switch, which selects the additive or subtractive process. The same switch also selects an output containing both sidebands.

Lattice Networks

Since the oscillator operates at one frequency only, it is quite simple to create and maintain a 90-degree phase shift of its voltage for application to detector 2. To be of any practical value, the sidebands must be wide enough to carry the desired intelligence. Suppose for instance that an audio voice frequency range of 100 cycles to 4,000 cycles is desired. Then the two sidebands will each be up to 4,000 cycles wide, so that the A and B networks must maintain a 90-degree phase difference over the full 100 to 4,000-cycle audio band. The wideband phase-shift networks were devised by R. B. Dome, and were described in detail in ELECTRONICS, December 1946. Briefly, the manner in which they function is that phase shift increases nearly linearly with the logarithm of the frequency. Thus

$$\text{Phase A} = K + \log f$$
$$\text{Phase B} = K + \log tf$$

Substracting phase B from phase A

$$\phi A - \phi B = K + \log f - K - \log tf$$
$$= \log f - \log f - \log t$$
$$= -\log t$$

where K and t are constants and f is the frequency. Thus the difference in phase shifts between A Network and B Network is a constant, regardless of frequency.

With two networks composed of three RC lattices as shown in Fig. 3 and through proper choice of component values, a frequency coverage ratio of 100 to 1 may be accomplished. Figure 4 shows that although the applied voltages undergo total phase shifts up to several hundred degrees, depending on frequency, the difference in phase shift between the two outputs is approxi-

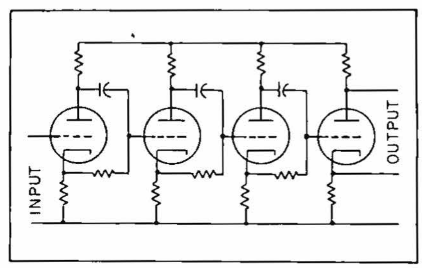


FIG. 3—Three-lattice A or B phase-shift audio network

mately 90 degrees over a very wide range. This difference can be made to extend from 50 to 5,000 cycles per second, or it may be from 250 to 25,000 cycles per second, for example.

The choice of frequencies of say 50 to 5,000 cycles per second does not mean that the phase-shift networks will not pass frequencies beyond this range (higher or lower in frequency). It means simply

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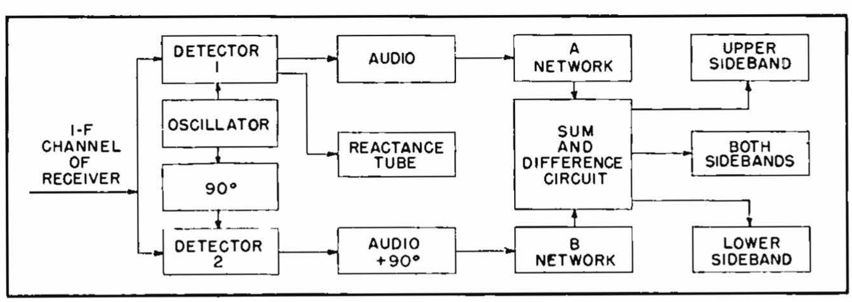

FIG. 2—Stage arrangement of the General Electric Selector unit for adding to a conventional communications receiver

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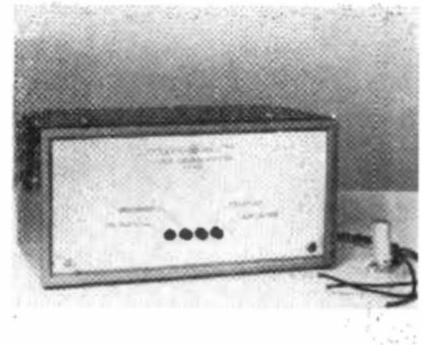


Sideband selector unit and probe for connection to the receiver

that the 90-degree phase difference is not preserved outside this range. Frequencies above or below will have a phase difference other than 90 degrees and consequently, when applied to the sum and difference circuits, they will not combine algebraically to add or cancel completely. Incomplete suppression of the unwanted sideband corresponding to these extreme frequencies is the result.

Operating Unit

A single-sideband selector unit embodying the method shown in Fig. 2 and 3 is built for use in conjunction with existing a-m receivers having a nominal i-f frequency of approximately 455 kc.

The unit is attached to the receiver by means of a small probe which is connected to the last i-f stage of the receiver through a short length of low-capacitance shielded cable. The high-impedance i-f signals are transformed to low-impedance level by means of the probe, and are then fed into the selector. The only other connections between the receiver and the unit are two shielded wires for audio.

The selector permits reception of single-sideband signals with carrier, single-sideband signals without carrier, conventional a-m signals (selecting the upper or lower sideband or both), dual single-sideband signals, that is, intelligence A on one sideband or intelligence B on the other sideband with carrier or attenuated carrier and conventional shortwave broadcasts employing exalted carrier.

Selection of any of these is done by four pushbuttons on the front panel. The phase-shift networks

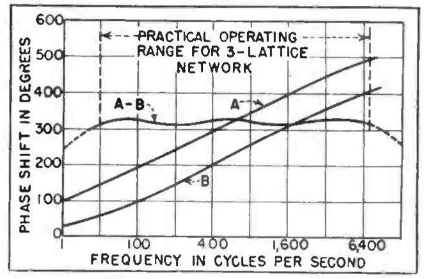


FIG. 4—Characteristics of three-lattice phase-shift network

cover a frequency range of 70 to 7,000 cycles per second. Therefore, the quality of reproduction is usually only dependent upon the i-f pass-band characteristics of the receiver.

Locked Oscillator

Should the carrier frequency delivered by the receiver tend to deviate from that of the selector's oscillator, a d-c control voltage will be delivered by the combination of oscillator frequency, intermediate frequency, and detector.

This d-c control voltage, applied in a feedback loop back to the oscillator through a reactance tube, then serves to restore the i-f carrier and oscillator to frequency synchronism. Moreover, the time constant in the d-c circuit provides the equivalent of memory; should the i-f carrier temporarily disappear because of selective fading or transmitter troubles, the locked oscillator will not get away. This is especially useful in weak-signal, transoceanic communications, and a must when the receiver is unattended over long time intervals.

This feature minimizes the need for retuning against change in transmitter frequency, change in receiver local oscillator frequency, change in selector voltages or temperatures that normally would cause frequency drift.

Satisfactory locking action is produced when the carrier of the received signal, either because of suppression at the transmitter, or because of selective fading, is as much as 20 db below sideband level. When no carrier is transmitted, no locking or control voltage is generated, so that retuning of the receiver will be necessary from time to time. For this reason a small amount of carrier, say 1 or 2 percent of the sideband energy, should always be transmitted in single-sideband systems for use with this type of receiver.

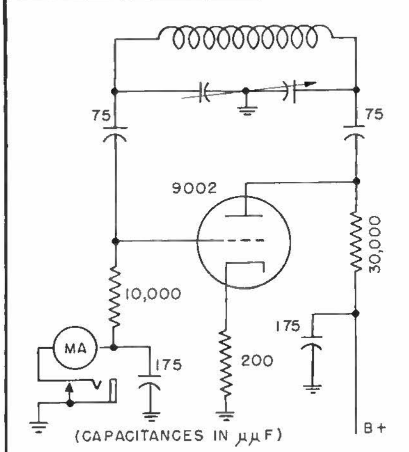
The locking circuit permits listening to a weak signal, even though a strong signal is nearby (in frequency), without the selector oscillator being captured by the stronger signal. The degree of selectivity which this makes possible cannot be fully appreciated by anything short of an actual listening test in a band of crowded signals.

Grid-Dip Oscillator

ONE of the most useful instruments in an electronic laboratory is the grid-dip oscillator with a vhf frequency range. Strangely enough, however, these have not been generally available as a commercial product until recently. Since the early days of radio, however, they have been constructed by the individual engineer to fit particular applications when needed.

The grid-dip oscillator consists of a variable-frequency oscillator with an indicating milliammeter in its grid circuit. When the oscillator tank circuit is coupled to a second resonant circuit, usually by holding the tank inductance near the second tuned circuit, a dip in the grid current indicates the frequency at which power is drawn from the oscillator. A frequency-calibrated dial on the oscillator then indicates the frequency at which resonance occurs.

The resonant frequency of any coil and capacitor combination,



Circuit of the probe portion of the De Vine grid-dip oscillator