Reduction of HETERODYNE

REDUCTION of constant-frequency interference such as is caused by heterodyne signals can be accomplished by utilizing the principle that heterodyne waves both amplitude and phase modulate the carrier of the desired signal. This method of interference reduction involves simultaneous detection of amplitude and quadrature modulation components of an interfering wave and subsequent canceling of the two detected outputs by balancing them against each other. The reception of desired signals, which are modulated in only one manner, remains unaffected.

The system is of particular advantage for communications in crowded bands where interference due to carrier heterodynes is objectionable, and increases the number of stations that can occupy a given frequency band without producing cross interference. In operation, the system to be described has attenuated strong interference heterodyne signals to below audibility with no apparent effect on the desired signal.

Principle of System

It is an accepted fact[1] that the sum of two waves is a wave which varies in both amplitude and phase. If one of the waves is taken as a reference, the second wave can be said to produce amplitude and phase modulation of this reference wave. In Fig. 1 let e_0 be the reference wave, which may be the carrier wave of a desired signal, and let e_1 be the second wave, which may be an interfering and undesired signal. The combination of these waves can be resolved into a component e_2 which is in phase with the reference wave and produces pure amplitude modulation and a component e_3 which is in phase quadrature and produces pure phase modulation.

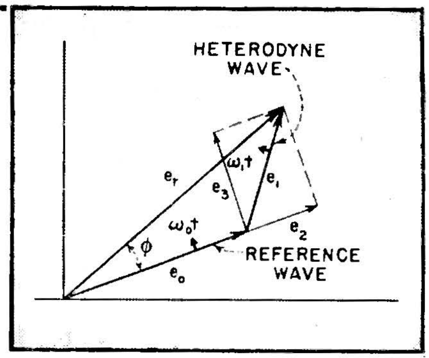

FIG. 1—Vector relations of two waves show phase and amplitude modulation of one by the other

A heterodyne interference wave thus produces effects which differ from either those of a pure amplitude-modulated wave in which the resultant modulating vector is always exactly in phase with the carrier, or those of a narrow-band phase or frequency-modulated wave in which the resultant modulating vector may be in phase quadrature with the carrier.

The inherent characteristic of a heterodyne interference wave can be utilized to eliminate the interfering effects of the undesired wave in the reception of amplitude-modulated, or narrow-band phase or frequency-modulated signals, provided that suitable detection circuits as assumed in Fig. 2 can be devised. These detectors must be such that the amplitude-modulation detector responds only to sidebands which are in phase with a carrier, and the phase-modulation detector responds only to sidebands which are in phase quadrature with the carrier.

Principle of Detectors

Detectors devised by Crosby,[2] in which carrier segregation and amplification are utilized, are adaptable for this purpose. Referring to Fig. 3, the carrier, which has been derived from the desired signal by filtering or other means

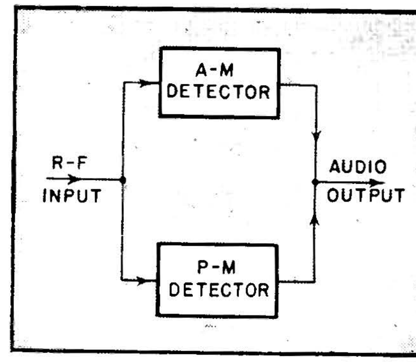

FIG. 2—System by which amplitude and phase, modulation components are independently detected

and then amplified, is applied to the balanced detector as shown. Also the entire received signal is applied in a balanced manner to the rectifiers.

In the absence of the carrier, there is no detection of the received signals, and in the presence of the carrier, only those resultant signal vectors which have components directly in phase or 180 degrees out of phase with the carrier are detected. For the a-m detector the segregated and amplified carrier should be in phase with the signal carrier, while for the p-m detector the segregated carrier should be in phase quadrature.

Basic Circuit

A more complete diagram of the system is shown in Fig. 4. The receiver i-f voltage is fed in parallel to a crystal filter for segregation of the signal carrier, and to two detectors through isolating amplifiers. The segregated carrier from the filter is amplified and fed to the two detectors, with the carrier voltage to one detector being shifted 90 degrees in phase.

One of the detectors detects amplitude modulation and the other detects quadrature modulation. For equal applied voltages, the outputs of the amplitude and quadrature detectors are equal. Thus, in the simultaneous reception, for example, of a pure a-m

INTERFERENCE

Adjacent-channel signals produce both amplitude and phase modulation of the desired carrier. From separate detection of these two modulations, two interference signals are obtained which cancel each other leaving only the desired signal

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wave and a heterodyne interference wave, the amplitude-modulation detector will respond to both the a-m signal and to the heterodyne signal, while the quadrature detector will respond only to the heterodyne signal. Consequently if the output of the quadrature detector is combined in the proper phase with the output of the amplitude-modulation detector, cancellation of the detected heterodyne signal will result. The output of the quadrature detector must be shifted an additional 90 degrees to bring its output signal into opposition to the heterodyne signal from the other detector. Also the output of the quadrature detector must be shifted an additional 180 degrees when the heterodyne interference wave changes frequency from above to below that of the carrier.

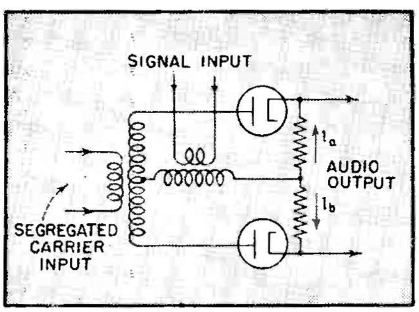

FIG. 3—Balanced rectifier is used to detect either a-m or p-m components of input, but not both

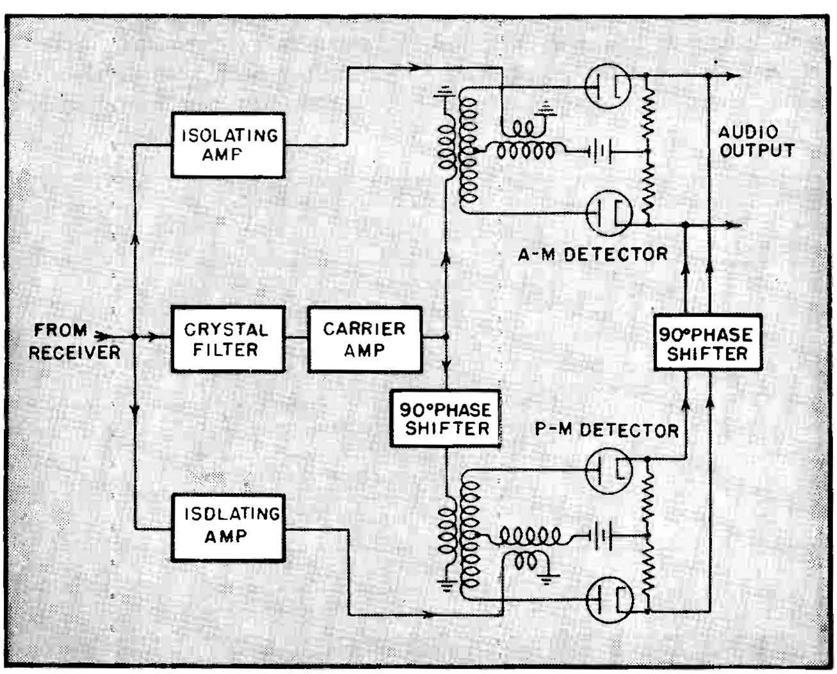

FIG. 4—By means of filters and phase shifters, the interfering carrier heterodyne can be eliminated in the detector stage, leaving only the desired signal

Effect of Segregated Carrier

Detecting systems, other than that described, are also usable. For example, a single diode to which the segregated carrier and received signal are applied will detect substantially only those signal components in phase with the segregated carrier, provided that the voltage of the segregated carrier greatly exceeds that of the total signal.

It is interesting to note the effects of the large phase shifts which occur in the crystal filter when the incoming carrier is slightly off resonance. One such effect causes detection of amplitude-modulated signals by the phase-modulation detector, because if the carrier is not at exactly 90 degrees phase difference with the amplitude-modulation components some detection of these components will result. This effect of carrier phase shift can be overcome by biasing the detectors so that the segregated carrier voltage will exceed the bias voltage only when the phase shift in the crystal filter is less than a predetermined amount which should be less than 45 degrees, at which condition the outputs from the two detectors are equal.

REFERENCES

(1) H. J. Reich, "Theory and Application of Electron Tubes", McGraw-Hill Book Co., New York, 1944, (2nd Ed.), p. 314.

(2) M. G. Crosby, Communication by Phase Modulation, *Proc. I.R.E.*, 27, p. 126, Feb., 1939.