July 2, 1946. B. D. LOUGHLIN 2,403,385

SIGNAL-TRANSLATING SYSTEM

Filed Sept. 20, 1943 4 Sheets-Sheet 1

FIG. 1

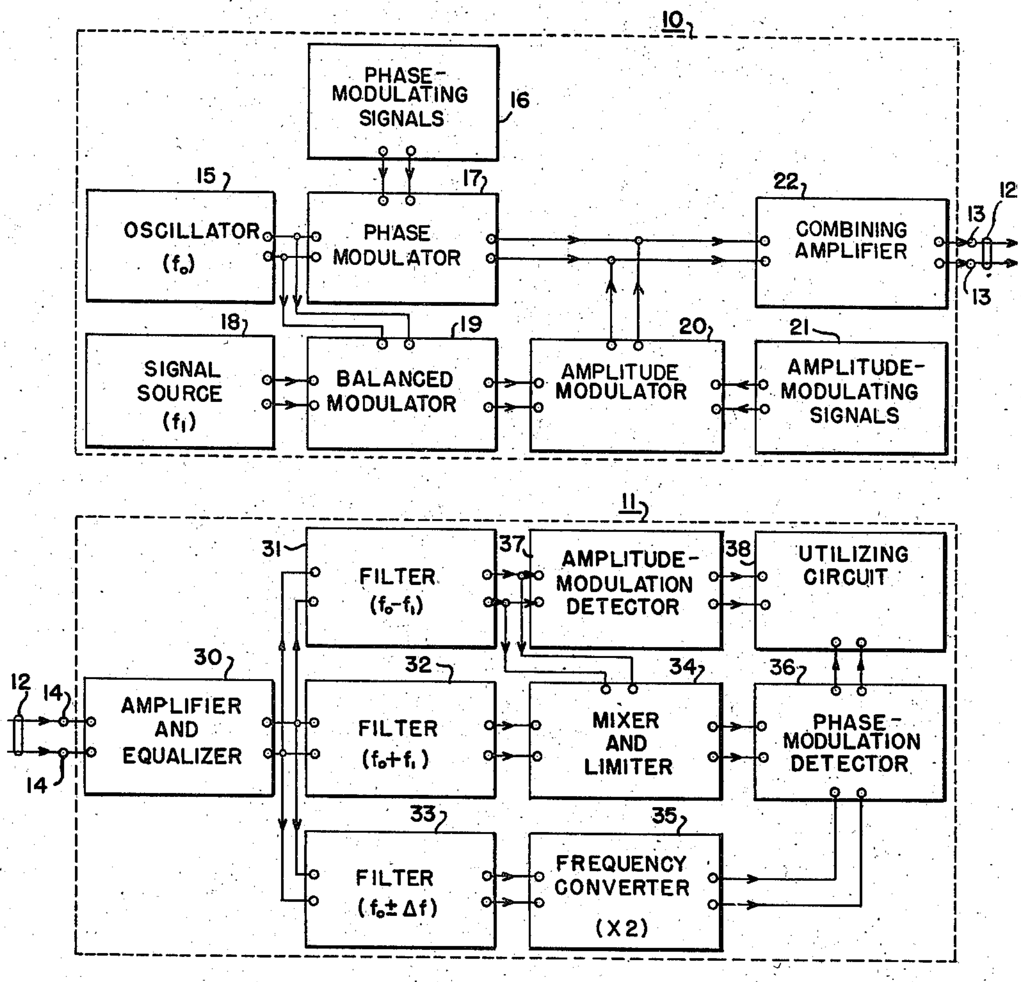

FIG. 2

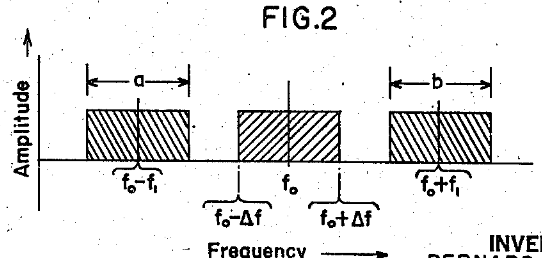

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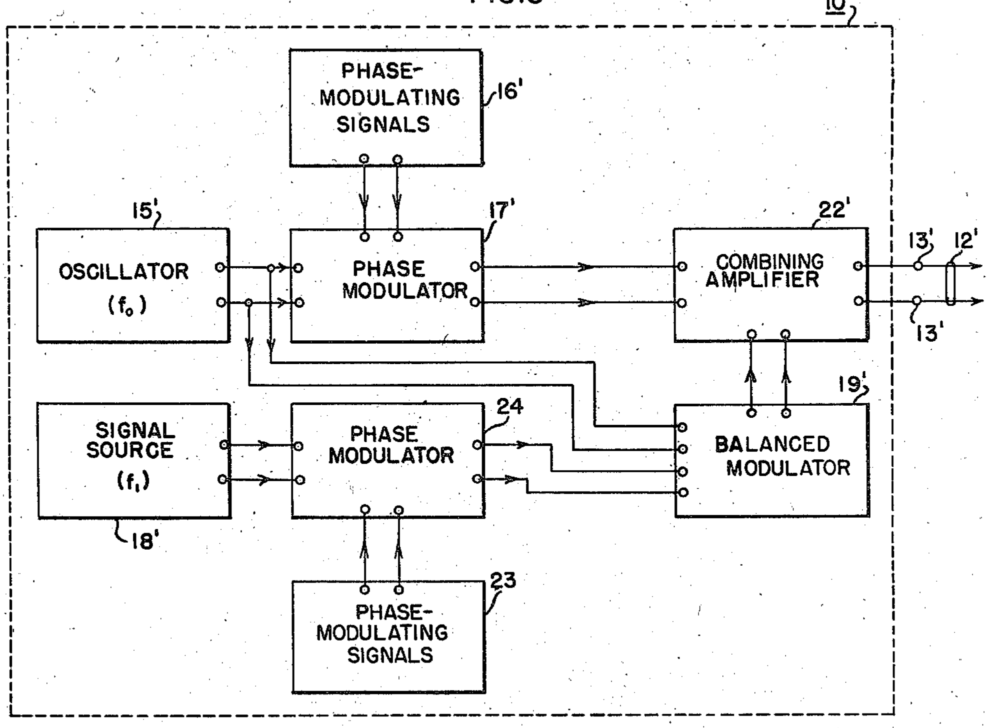
FIG. 3



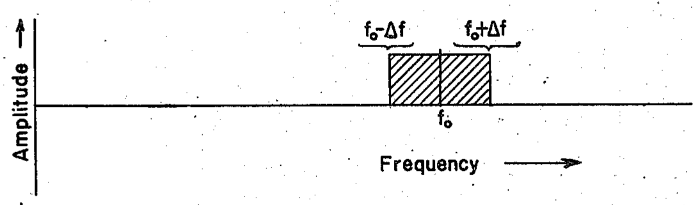


FIG. 3a

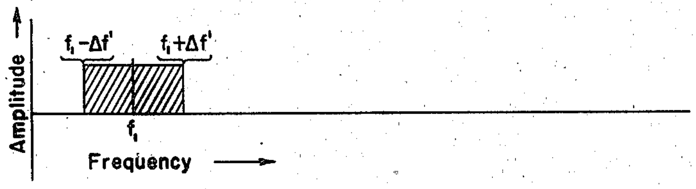


FIG. 3b

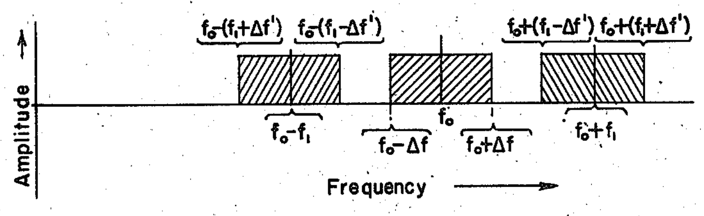


FIG. 3c

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FIG. 4

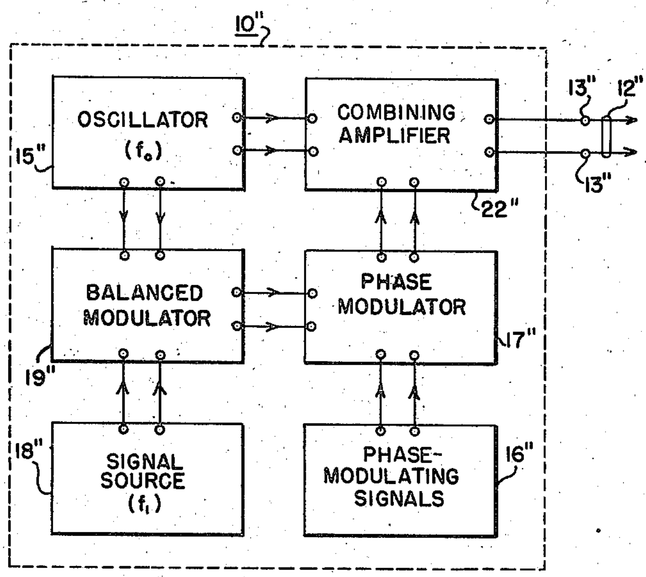
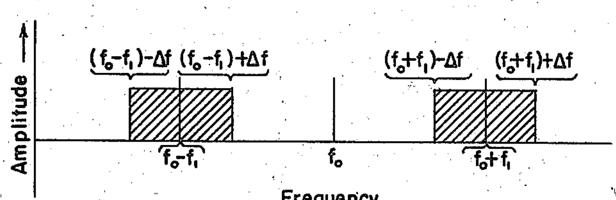


FIG. 4a



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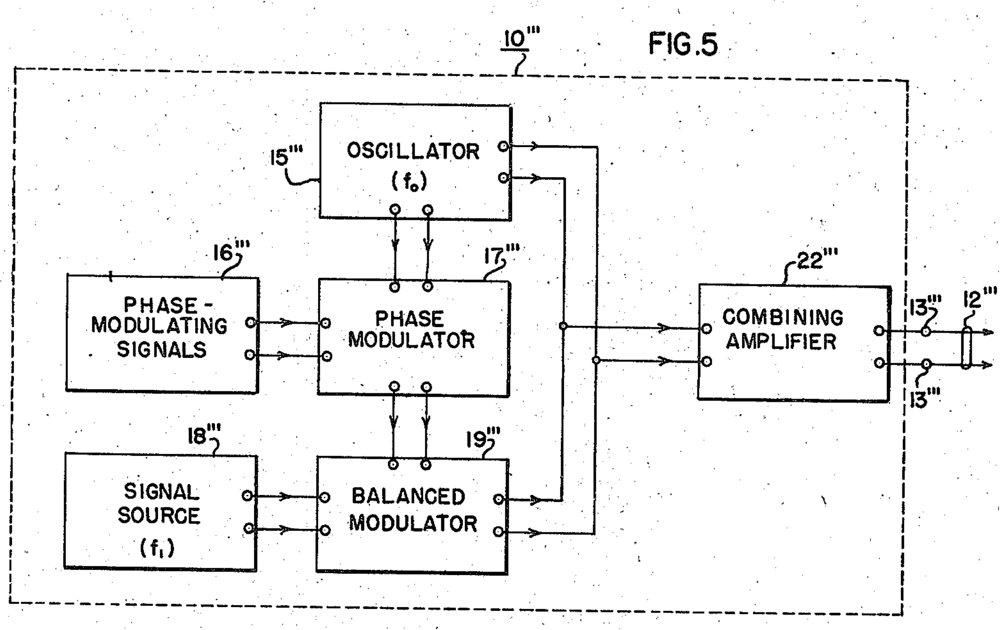

FIG. 5

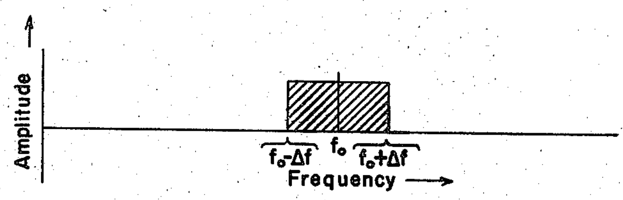

FIG. 5a

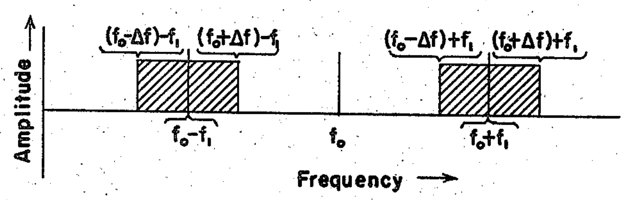

FIG. 5b

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Patented July 2, 1946

2,403,385

UNITED STATES PATENT OFFICE

2,403,385

SIGNAL-TRANSLATING SYSTEM

Bernard D. Loughlin, Bayside, N. Y., assignor, by mesne assignments, to Hazeltine Research, Inc., Chicago, Ill., a corporation of Illinois

Application September 20, 1943, Serial No. 503,071

32 Claims. (Cl. 179—15)

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The present invention relates, in general, to a signal-translating system and is particularly directed to such a system for translating an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies. While the invention is to be particularly described in connection with a phase-modulation system, it is equally applicable to a frequency-modulation system and, accordingly, the term "angular-velocity-modulated carrier signal" is used in this specification and in the appended claims to include the modulated carrier signal translated in each such system.

In a phase-modulation system it is desirable to have at the receiver a phase-reference signal representing the absolute phase of the carrier component of the received modulated carrier signal. Where such a reference signal is available, all of the modulation components of the received signal may be derived directly by a method of comparison. In certain prior art arrangements a phase-reference signal, comprising the unmodulated carrier signal, is transmitted to the receiver over one channel while the modulated carrier signal is transmitted thereto over a separate and independent channel. Although such arrangements provide the desired phase-reference signal, they require at least two transmitting channels which, for many installations, is an undesirable limitation.

Other prior art arrangements utilize some harmonic or subharmonic of the original carrier signal as a reference which is transmitted over a single channel along with the modulated carrier signal and separated therefrom at the receiver. However, these other arrangements are subject to the limitation that the reference signal and modulated carrier signal are widely separated in the frequency spectrum. This is undesirable since the wave propagation characteristics of a transmission channel are frequently quite different for signals of widely separated frequencies, which effect introduces distortion into the detected signal.

Still other arrangements utilize a reference oscillator at the receiver, synchronized from the transmitter, to supply a phase-reference signal. Obviously, such arrangements are objectionable in that they require a duplication of equipments and introduce an exacting synchronizing problem.

Arrangements have also been proposed which include a sharply selective filter for selecting a signal having the average phase of a received phase-modulated signal, the signal so selected being thereafter compared with the instantaneous phase of the received signal for the purpose of obtaining its modulation components. However, arrangements of this type require an extremely selective filter to derive low-frequency modulation components and in any event are unable to derive modulation components down to and including direct current components.

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It is, therefore, an object of the invention to provide an improved angular-velocity-modulated carrier signal-translating system which is not subject to one or more of the above-mentioned limitations of prior art arrangements.

It is another object of the invention to provide an improved signal-translating system for translating over a single channel an angular-velocity-modulated carrier signal and a suitable reference signal.

It is a specific object of the invention to provide an improved signal-translating system for translating over a single channel a phase-modulated carrier signal and a phase-reference signal.

In accordance with the invention, a signal-translating system comprises means for supplying a first signal and means for effectively supplying a second signal, the second signal comprising a pair of signal components having predetermined phase relations with reference to the first signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values. This system also includes means for modulating the angular velocity of one of the first and second signals in accordance with information to be transmitted to develop a modulated carrier signal having predominant modulation components within a modulation band that is located only in a portion of the frequency spectrum adjacent its carrier frequency. The width of one modulation sideband thereof is less than one of the aforesaid values. Further, the system includes a signal-translating channel having input and output terminals and means for applying to the input terminals thereof the modulated carrier signal and the other one of the first and second signals. Additionally, means are coupled to the output terminals for utilizing the modulated carrier signal and the other one of the first and second signals to derive the modulation components.

Also in accordance with the invention, a signal-translating system comprises means for supplying a first signal and means for effectively supplying a second signal, the second signal comprising a pair of signal components having predetermined phase relations with reference to the first-mentioned signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values. The system also includes means for modulating the angular velocity of one of the aforementioned first and second signals in accordance with information to be transmitted to develop a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of the aforesaid values. Further, the system includes a signal-translating channel and means for applying to the channel the modulated carrier signal and the other one of the aforesaid signals.

Also in accordance with the invention, a receiver is provided in a system for translating a composite signal which includes a first signal and a second signal, the second signal including a pair of signal components having predetermined phase relations with reference to the first signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values. Also, one of the first and second signals is angular-velocity-modulated in accordance with information to be translated so as to provide a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of the aforesaid values. The receiver comprises a pair of input terminals for receiving the composite signal, frequency-selective means coupled to the input terminals for individually separating the modulated carrier signal and the other one of the first and second signals, and means coupled to the frequency-selective means for utilizing the separated signals to derive the modulation components.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Referring to the drawings, Fig. 1 is a schematic circuit diagram of a complete signal-translating system in accordance with the invention; Fig. 2 is a graph utilized in explaining the operation of the system of Fig. 1; Figs. 3, 4 and 5 represent modifications of a portion of the signal-translating system of Fig. 1; and Figs. 3*a* to 3*c*, Fig. 4*a* and Figs. 5*a* and 5*b* comprise graphs used in describing the operation of the arrangements of Figs. 3, 4 and 5, respectively.

Referring now more particularly to Fig. 1 of the drawings, there is represented schematically a complete signal-translating system, in accordance with the invention, composed of elements which, individually, are of well-known construction and design. As represented, the system comprises a sending station 10 and a receiving station 11, interconnected by a single signal-translating channel 12 having input terminals 13, 13 and output terminals 14, 14. Channel 12 may be a direct wire connection as, for example, a telephone cable, or it may consist of a conventional radio link. The sending station includes means for supplying an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies. This means comprises an oscillator 15 having a mean operating frequency f_0 for supplying a carrier signal to be modulated, a source of phase-modulating signals 16 representing the information to be translated, and a phase modulator 17 having one input circuit coupled to oscillator 15 and another input circuit coupled to signal source 16.

There is also included in the sending station means for supplying a pair of reference-signal components having predetermined phase relations with reference to the carrier signal applied to phase modulator 17. This means comprises means for supplying a second carrier signal having predetermined phase and frequency relations with reference to the first carrier signal, namely, that applied to modulator 17. It is preferred that the second carrier signal have substantially the same frequency and phase as that of the first carrier signal and, consequently, it is expedient to derive the second carrier signal directly from oscillator 15, as illustrated, although an auxiliary oscillator may be provided if desired. The means for supplying a pair of reference-signal components also comprises a signal source 18 which supplies a modulating signal having a predetermined frequency f_1, to be defined more particularly hereinafter, and a balanced amplitude modulator 19 having one input circuit coupled to oscillator 15 and another input circuit coupled to signal source 18. The output circuit of modulator 19 is arranged to select only the upper and lower sideband components of amplitude modulation which are utilized as the reference-signal components, the second carrier signal being suppressed.

Other information, in addition to that represented by signal source 16, may also be transmitted from sending station 10 to receiving station 11 over the channel 12. For this purpose, means, comprising an amplitude modulator 20, are included in the sending station for modulating each of the reference-signal components produced in balanced modulator 19 in accordance with such additional information. Modulator 20 has one input circuit which is coupled to balanced modulator 19 and another input circuit coupled to a signal source 21, representing the additional information to be translated. The frequencies of the signals developed by source 21 are included in a predetermined band of frequencies, defined more particularly hereinafter.

The output circuits of modulators 17 and 20 are connected to the input circuit of a combining amplifier 22. The output circuit of this amplifier, in turn, is connected to input terminals 13, 13 of signal-translating channel 12, thereby to provide means for applying the phase-modulated carrier signal developed in unit 17 and the amplitude-modulated reference-signal components developed in unit 20 to channel 12 for translation to the receiving station 11.

The receiving station comprises means coupled to the output terminals of channel 12 for utilizing the reference-signal components to derive the modulation components of the translated phase-modulated carrier signal. This means includes an amplifier and equalizer 30, such as an amplifier having a frequency-response characteristic selected to compensate for any nonuniform frequency-response characteristics of channel 12, coupled to output terminals 14, 14 of the channel and frequency-selective means or filters 31, 32 and 33 connected to the amplifier and equalizer 30 for individually selecting the received modulated carrier signal and each of the reference-signal components. Filters 31 and 32 are designed to have pass bands with mean frequencies corresponding to individual ones of the reference-signal components and sufficiently wide to pass the band of amplitude-modulation components associated with each such reference-signal component. Filter 33 has a pass band having a mean frequency which corresponds to that of the carrier component of the phase-modulated signal and a pass band effective to pass the band of phase-modulatiton components associated therewith. A mixer, or modulator, and limiter 34 is coupled to the output circuits of filters 31 and 32 for the purpose of effectively combining the separated reference-signal components. The output circuit of mixer 34 is designed to select that upper sideband modulation component which comprises a reference carrier signal having a predetermined phase relation with reference to the carrier signal generated in oscillator 15 at sending station 10, but of twice the frequency. The limiter of unit 34 is provided to remove all amplitude modulation from this reference carrier signal.

In order to utilize the derived reference carrier signal for the purpose of detecting all of the phase-modulation components of the received phase-modulated carrier signal, it is desirable to convert the frequency of the carrier component of one of these signals to that of the other. Accordingly, a frequent converter or multiplier 35 is provided in receiving station 11, coupled to the output circuit of filter 33.

The output circuits of mixer 34 and frequency converter 35 are coupled to input circuits of a phase-modulation detector 36 designed to derive the desired phase-modulation components by effectively comparing the applied phase-modulated carrier signal and reference carrier signal. This detector may be generally similar to that included in the phase-control system disclosed in Fig. 1 of United States Letters Patent 2,231,704, issued on February 11, 1941, to Leslie F. Curtis. Such a detector comprises a pair of diodes to which the phase-modulated carrier signal is applied with like phase and to which the reference carrier signal is applied with opposite phase. The unidirectional voltages developed in the load circuits of the diodes are differentially combined and the resultant output voltage comprises the modulation components of the phase-modulated signal. The derived phase-modulation components are supplied for utilization to a suitable utilizing circuit 38 connected to the output circuit of detector 36.

An amplitude-modulation detector 37 is connected to the output circuit of filter 31 for deriving the modulation components of the amplitude-modulated reference-signal component selected by this filter. The output circuit of detector 37 is coupled to utilizing circuit 38 so that the detected amplitude-modulation components may be supplied thereto for utilization in any desired manner. For convenience of illustration, a single utilizing circuit 38 has been shown. It will be understood that this unit includes circuit arrangements for utilizing the modulation components derived in each detector 36 and 37. In the most general case, unit 38 comprises two circuit arrangements individually designed to utilize the signal output of one of detectors 36 and 37.

In considering the operation of the described system, it will be seen that the angular velocity of the carrier signal applied by oscillator 15 to modulator 17 is modulated in accordance with the signals supplied by signal source 16 or, expressed in other words, the carrier signal is phase-modulated in accordance with information to be translated. A mathematical analysis indicates an infinite number of modulation components or sidebands to be produced through such a modulating process, the sidebands being spaced in the frequency spectrum on opposite sides of the carrier component. However, where the frequency deviation of the carrier signal is large with reference to the frequency of the modulating signal, it is found that the energy of those side-band components which are spaced from the carrier component by an amount exceeding the maximum deviation of the carrier signal is so small that such components may be neglected. Therefore, in such a case the developed phase-modulated signal may be defined as having modulation components predominantly in a predetermined band of frequencies, which band is determined by the maximum deviation of the carrier signal. Thus, for the arrangement under consideration which employs such a mode of modulation, the phase-modulated signal produced in unit 17, as represented by the graph of Fig. 2, has a carrier component of frequency f_0 corresponding to the operating frequency of oscillator 15 and a band of phase-modulation components having the limiting frequencies of $f_0+\Delta f$ and $f_0-\Delta f$, where Δf is the maximum deviation of the carrier signal.

The carrier signal f_0 supplied by oscillator 15 is also amplitude-modulated in modulator 19 with a modulating signal having a frequency f_1 to produce upper and lower sideband components having the frequencies f_0+f_1 and f_0-f_1, respectively. These components, being derived through an amplitude-modulation process, have such phase relations with reference to their carrier components f_0 as to combine in phase therewith and, hence, are suitable reference-signal components for providing a phase-reference signal representing the absolute phase of the carrier signal f_0 modulated in unit 17. To facilitate separating the phase-reference signal components from the phase-modulated carrier signal at the receiving station, the modulating frequency f_1 is so chosen that the reference-signal components f_0+f_1 and f_0-f_1 have frequencies spaced from the carrier component f_0 by equal and opposite increments of such magnitude that the band of frequencies $f_0-\Delta f$ to $f_0+\Delta f$ containing the phase-modulation components is located therebetween. This frequency relation is clearly shown by the graph of Fig. 2.

The developed reference-signal components f_0-f_1 and f_0+f_1 are individually amplitude-modulated in unit 20 in accordance with signals from source 21, or in accordance with additional information to be transmitted. The resulting signal output of modulator 20 comprises a pair of amplitude-modulated reference-signal components, having modulation components contained in different predetermined bands of frequencies. In Fig. 2 these bands of modulation components are designated by reference characters *a* and *b*. The frequencies of the modulating signals from signal source 21 are located in such a predetermined band of frequencies that these different predetermined bands of modulation components *a*, *b* are spaced in the frequency spectrum from the band of phase-modulation components $f_0\pm\Delta f$ produced in unit 17, as illustrated by the graph of Fig. 2.

The described signals produced in the sending station, after amplification in amplifier 22, are applied to channel 12 for translation to the receiver. This channel has a pass-band characteristic sufficiently wide to pass the reference-signal components and their associated bands of modulation components *a*, *b*. At the receiving station these signals are selectively amplified in unit 30 to compensate for any nonuniform frequency-response characteristics of the translating channel and are thereafter individually separated by filters 31–33, inclusive, their separation being facilitated by virtue of the aforementioned frequency relationships established at the sending station. The separated reference-signal components, upon being combined in mixer 34, produce a phase-reference carrier signal having a predetermined phase relation with reference to the carrier signal of oscillator 15 included in the sending station, but of twice the frequency. This may be seen from the following consideration. The signals applied to mixer 34 include, among others, the carrier components of the amplitude-modulated carrier signals selected by filters 31 and 32. Such components have the frequencies f_0+f_1 and f_0-f_1 and their sum frequency, obtained in the output circuit of unit 34, is $2f_0$, where f_0 is the operating frequency of oscillator 15. Thus, the reference signal derived in unit 34 is harmonically related to the carrier component f_0 of the received phase-modulated carrier signal and, specifically, the reference signal corresponds to the second harmonic of such carrier component. However, the separated phase-modulated carrier signal is doubled in frequency by frequency multiplier 35, so that detector 36, by comparing therewith the phase-reference carrier signals from mixer 34, is effective to derive all of the phase-modulation components for utilization in utilizing circuit 38. Further, the amplitude-modulation components of the particular reference-signal component f_0-f_1 selected by filter 31 are derived in detector 37 and are also supplied to circuit 38 for utilization in any desired manner.

It will be apparent that the aforedescribed system is especially suited for translating a phase-reference signal to be utilized in deriving the modulation components of a phase-modulated carrier signal. In the described arrangement, modulator 20 functions merely as an amplifier in the event that the only information to be translated between stations 10 and 11 comprises the signals from source 16.

It will also be apparent that a pair of amplitude-modulation detectors may be utilized in the receiving station 11 for individually deriving the amplitude-modulation components of each reference-signal component. This arrangement is particularly advantageous in those applications where there is an undesired frequency distortion in the signal-translating channel. In such a case, by combining the derived amplitude-modulation components from each of the detectors a compensation may be effected.

The described signal-translating system may be further extended by individually modulating the reference-signal components from unit 19 with additional information desired to be translated to receiving station 11. To accomplish this result, modulator 20 at sending station 10 may be replaced by a pair of amplitude modulators individually coupled to unit 19 through frequency-selective circuits so that one reference-signal component f_0+f_1 is applied to one such modulator while the other f_0-f_1 is applied to the other such modulator. It is then possible individually to couple a pair of different signal sources to the modulators, thereby separately to amplitude-modulate the reference-signal components with information to be translated. When the sending station is modified as herein suggested, corresponding modifications are necessary at receiving station 11. In particular, an additional amplitude-modulation detector is required to be coupled to filter 32 so that the modulation components of each received amplitude-modulated reference-signal component may be derived. However, in deriving the modulation components of the received phase-modulated carrier signal, the modified system operates substantially as hereinbefore described. The graph of Fig. 2 again illustrates the frequency relations to be maintained for the signals translated by the suggested modification. Accordingly, the expression "means for modulating each of the reference-signal components in accordance with additional information to be translated" as used in this description and in the appended claims is intended to include the specific arrangement of Fig. 1 and the aforementioned modification thereof.

In any case where information is translated between stations 10 and 11 by amplitude modulation of the reference-signal components, it may be convenient to limit the percentage modulation to less than 100 per cent. Where this operating condition is established, the signal outputs from filters 31 and 32 may be supplied to mixer 34 through limiter stages, adjusted to remove all amplitude modulation therefrom and thus supply to unit 34 only signals having the frequencies f_0+f_1 and f_0-f_1. Such an arrangement materially reduces the filtering problem otherwise presented when the signals applied to unit 34 comprise the amplitude-modulated reference-signal components.

In the foregoing description of receiving station 11 it was shown that mixer 34, by combining two reference-signal components having the frequencies f_0+f_1 and f_0-f_1, respectively, produces the desired phase-reference signal having the frequency $2f_0$. This reference signal will be seen to be independent of the phase and freqency of the signal f_1 utilized in generating the reference-signal components at the sending station 10. Thus, signal f_1 may be variously modulated without affecting the desired phase-reference signal derived at the receiving station. Specifically, information may be translated by amplitude modulation of the reference-signal components, as particularly described in connection with the arrangement of Fig. 1, or by modulating the angular velocity of the reference-signal components in synchronism and in opposite senses, as in the arrangement of Fig. 3 presently to be described.

Fig. 3 represents a modification of the sending station 10 of Fig. 1 and corresponding components thereof are identified by like reference numerals primed. Sending station 10′ comprises means for supplying a first signal and means for modulating the angular velocity of the first signal in accordance with information to be translated to develop a first modulated carrier signal having components predominantly in a first predetermined band of frequencies. Such means are provided by an oscillator 15′ having a mean operating frequency f_0, a signal source 16′ representing the information to be translated, and a phase modulator 17′ interconnected as corresponding units of sending station 10 of Fig. 1 described above.

Sending station 10′ also includes a signal source 18′ for supplying a second signal and means for modulating the angular velocity of such second signal in accordance with additional information to be translated to develop a second modulated carrier signal having components predominantly in a second predetermined band of frequencies. This last-named means comprises a phase modulator 24 having input circuits individually coupled to signal source 18′ and to a source of phase-modulating signals 23 representing such additional information.

A balanced amplitude modulator 19′ is included in sending station 10′ having one input circuit coupled to oscillator 15′ and another input circuit coupled to phase modulator 24. Thus, unit 19′ comprises means for amplitude-modulating the first signal, i. e. the signal from oscillator 15′, with the modulated carrier signal of modulator 24 to develop only a pair of angular-velocity-modulated signals having predetermined phase relations with reference to the aforesaid first signal. A combining amplifier 22′ serves to apply the phase-modulated carrier signal produced in unit 17′ and the pair of phase-modulated signals produced in unit 19′ to a signal-translating channel 12′ for translation to the receiving station 11.

Receiving station 11, when the above-described sending station 10′ is utilized in the signal-translating system of the invention, may be substantially as represented in Fig. 1. However, it will be necessary to substitute a phase-modulation detector for unit 37 thereof and filters 31, 32 must have band widths sufficiently wide to accommodate a band of frequencies containing the predominant modulation components of one of the above-mentioned pair of modulated signals produced in modulator 19′ at sending station 10′.

In considering the operation of the signal-translating system of Fig. 3, reference is made to the graphs of Figs. 3a, 3b and 3c. Let it be assumed for the moment that the only information to be translated between stations 10′ and 11 comprises the signals from source 16′. For the assumed condition, phase modulator 17′ develops a first angular-velocity-modulated carrier signal having components predominantly in a first predetermined band of frequencies as represented by the graph of Fig. 3a; modulator 24 functions as an amplifier; and balanced modulator 19′ produces reference-signal components having the frequencies f_0+f_1 and f_0-f_1. These signals are translated over channel 12 to the receiving station 11 where they are utilized to derive the modulation components of the translated modulated carrier signal. This operation of stations 10′ and 11 is precisely as described hereinbefore in connection with the arrangement of Fig. 1.

When signals from source 23 are also to be translated, modulator 24 develops a second angular-velocity-modulated carrier signal, Fig. 3b, having a carrier component of frequency f_1 and modulation components predominantly in a second predetermined band of frequencies having the limiting values of $f_1+\Delta f'$ and $f_1-\Delta f'$, where $\Delta f'$ is the maximum deviation of signal f_1 in such modulation. In this respect the operation of modulator 24 is similar to that of modulator 17′. However, for the operating conditions under consideration, modulator 19′ produces, as reference signals, a pair of angular-velocity-modulated signals having predetermined phase relations with reference to the carrier signal f_0 supplied by oscillator 15′ and having modulation components corresponding to those of the modulated carrier signal from modulator 24 but located in different individual predetermined bands of frequencies. This may be readily understood from a consideration of the signal components involved.

The signal applied to unit 19′ to be modulated has the frequency f_0 and the modulating signals supplied from unit 24 may be represented as $f_1+\Delta f'$. The resulting modulation products obtained from the output circuit of unit 19′ are:

$$f_0+(f_1\pm\Delta f')\text{; and } f_0-(f_1\pm\Delta f') \qquad (1)$$

This expression may be rewritten as:

$$f_0+f_1\pm\Delta f'\text{; and } f_0-f_1\mp\Delta f' \qquad (2)$$

It will be apparent from expression (2) that the pair of modulated signals, utilized in the instant modification of the invention to translate a phase reference to receiver station 11, are angular-velocity-modulated in synchronism and in opposite senses. It will be further apparent that the sum frequencies of such modulated signals is equal to $2f_0$ which is harmonically related to both the signal produced by oscillator 15′ and the carrier component of the modulated carrier signal developed in modulator 17′.

Thus, the signal transmitted to receiving station 11 from station 10′ for the assumed conditions, is as represented by the graph of Fig. 3c. In order that the several signals may be conveniently separated at the receiving station, the frequencies of the first and second signals supplied by units 15′ and 18′, respectively, are so chosen and their angular-velocity modulation is such that the predetermined band of frequencies $f_0\pm\Delta f$ containing the predominant modulation components produced in unit 17′ is located in the frequency spectrum between the different individual bands of frequencies $f_0+f_1\pm\Delta f'$ and $f_0-f_1\mp\Delta f'$ containing the predominant modulation components of the pair of modulated signals from modulator 19′. The operation of the receiving station in deriving the modulation components from the translated signals is substantially as described in connection with the arrangement of Fig. 1.

A further modification of the invention is represented in Fig. 4 which comprises a sending station 10″ having a construction generally similar to that of sending station 10, already described, corresponding parts thereof being identified by like reference numerals double primed. Sending station 10″ includes an oscillator 15″ for supplying a first signal of frequency f_0 and means for supplying a second signal which comprises a pair of signal components having predetermined phase relations with reference to the first-named signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values. Such means comprise a balanced amplitude modulator 19″ having one input circuit coupled to oscillator 15″ and another input circuit coupled to a signal source 18″. A phase modulator 17″ having input circuits individually coupled to balanced modulator 19″ and to a signal source 16″ representing information to be translated, constitutes means for modulating the angular velocity of the second-named signal in accordance with information to be translated to develop a pair of modulated carrier signals, described more particularly hereinafter. A combining amplifier 22'' has input circuits coupled to modulator 17'' and to oscillator 15'', being provided as a means for applying to a signal-translating channel 12'' the pair of modulated carrier signals developed in modulator 17'' and a phase-reference signal obtained from oscillator 15''.

Receiving station 11 of Fig. 1 may also be utilized with sending station 10'' to complete the signal-translating system. However, in such an arrangement the amplitude-modulation detector 37 will not be required at the receiving station and filter 33 may be sharply selective to the frequency f_0 of oscillator 15''.

In the arrangement of Fig. 4, a signal from oscillator 15'' having the frequency f_0 and a signal from source 18'' having the frequency f_1 are modulated in unit 19'' producing in the output circuit thereof a signal which comprises a pair of components having the frequencies, respectively, f_0+f_1 and f_0-f_1. Since these components are produced through an amplitude modulation process they have predetermined phase relations with reference to the signal from oscillator 15'' as mentioned hereinbefore and the frequency relationships of such signals are as indicated by the graph of Fig. 4*a*. The signal components from modulator 19'' are phase-modulated in unit 17'' in accordance with information to be translated to develop a pair of angular-velocity-modulated carrier signals. These modulated carrier signals may be defined as:

$$(f_0+f_1)\pm\Delta f;\ (f_0-f_1)\pm\Delta f \qquad (3)$$

where Δf represents the maximum deviation of each carrier component. It will be apparent from expression (3) that the carrier signals are angular-velocity modulated in synchronism and in the same sense and therefore their sum frequency, as obtained in a modulator, is equal to $2f_0\pm2\Delta f$. In other words, by combining such modulated carrier signals a third angular-velocity-modulated carrier signal is obtained which has a carrier component harmonically related to the signal from oscillator 15'' and having modulation components which correspond to the modulation components of each of the pair of modulated carrier signals produced in unit 17''. In order that the pair of modulated carrier signals translated from sending station 10'' to receiving station 11 may be readily separated and then modulated at the receiving station to derive the above-mentioned third angular-velocity-modulated carrier signal, the frequency relationships indicated by the graph of Fig. 4*a* must be established. In particular, the angular-velocity modulation in unit 17'' must be such that each modulated carrier signal obtained therefrom has predominant modulation components within an individual modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency. Also, the width of one modulation sideband of each of the pair of modulated carrier signals is to be less than the separation between the frequency f_0 and the particular carrier frequency.

The operation of receiving station 11 in combining the translated pair of modulated carrier signals to derive the aforementioned third angular-velocity-modulated carrier signal and the manner of utilizing the reference signal of frequency f_0 translated from oscillator 15'' will be apparent.

Fig. 5 represents a still further modification of a signal-translating system in accordance with the invention, this modification being generally similar to that of Fig. 4 and corresponding components are identified by like reference numerals triple primed. This modification includes an oscillator 15''' for supplying a first signal, a phase modulator 17''' and a source of phase-modulating signals 16''' representing information to be transmitted, interconnected as described in connection with the arrangement of Fig. 1 to develop a first modulated carrier signal having predominant modulation components in a predetermined band of frequencies.

Sending station 10''' further includes means for amplitude-modulating the aforementioned first modulated carrier signal to develop a pair of angular-velocity-modulated signals described more particularly hereinafter. Such means consists of a balanced amplitude modulator 19''' having an input circuit coupled to phase modulator 17''' and another input circuit coupled to a signal source 18''' which supplies a second, or modulating, signal of frequency f_1. Additionally, station 10''' is provided with means for supplying a third signal having predetermined phase and frequency relations with reference to the aforementioned first signal, namely, that applied to modulator 17''' from oscillator 15'''. It is preferred that these signals have substantially the same phase and frequency characteristics and, accordingly, the third signal is derived from a second output circuit of oscillator 15''' as illustrated. Such third-named signal, as well as the pair of modulated signals produced in modulator 19''', is applied to a signal-translating channel 12''' by way of a combining amplifier 22''' having input circuits individually coupled to units 15''' and 19'''.

Receiving station 11 of Fig. 1 may be utilized in connection with the described sending station 10''' to complete a signal-translating system, it being only necessary to modify the receiving station as above mentioned in connection with the Fig. 4 embodiment.

In considering the operation of the Fig. 5 arrangement, reference is made to the graphs of Figs. 5*a* and 5*b*. The carrier signal of frequency f_0 supplied from oscillator 15''' to modulator 17''' is phase-modulated in accordance with information to be translated to develop a first angular-velocity-modulated carrier signal having predominant modulation components in a predetermined band of frequencies. This modulated signal, which is represented graphically in Fig. 5*a*, is amplitude-modulated in unit 19''' with the signal supplied from source 18'''. There results from such modulation a pair of angular-velocity-modulated carrier signals having predetermined phase relations with reference to the modulated carrier signal from modulator 17''' and having modulation components corresponding to those of the modulated carrier signal from 17''' but contained in different individual predetermined bands of frequencies as indicated in Fig. 5*b*. This may be clearly understood from the following:

The signals applied to unit 19''' to be modulated may be expressed as $f_0\pm\Delta f$ while the modulating signal may be defined as f_1. The modulation products derived from unit 19''' are:

$$(f_0\pm\Delta f)+f_1;\ \text{and}\ (f_0\pm\Delta f)-f_1 \qquad (4)$$

By rearranging terms this expression becomes:

$$(f_0+f_1)\pm\Delta f;\ \text{and}\ (f_0-f_1)\pm\Delta f \qquad (5)$$

It will be apparent from a comparison of expressions (3) and (5) that the pair of modulated carrier signals developed in the arrangements of Figs. 4 and 5 are identical. Hence, the reference signal from oscillator 15''' which is translated along with such pair of modulated carrier signals may be utilized at the receiving station as previously described for deriving the desired modulation components. However, the frequency relationships represented by the graph of Fig. 5b must be maintained at the sending station in order that such signals may be conveniently separated. This may be achieved by selecting the frequency of modulating signal f_1 such that the signal f_0 from oscillator 15''' is located in the frequency spectrum between the different predetermined bands of frequencies $[(f_0+f_1)\pm\Delta f]$ and $[(f_0-f_1)\pm\Delta f]$ containing the predominant modulation components of each of the pair of modulated signals, respectively.

Inasmuch as the arrangements of Figs. 4 and 5 operate in substantially the same manner and translate identical signals, the expressions "means for effectively supplying a second signal comprising a pair of signal components" and "means for modulating the angular velocity of said second signal to develop a pair of modulated carrier signals" as used in the specification and in the appended claims are intended to include both such arrangements.

To simplify the explanation, the reference signal transmitted from the sending station in both the Figs. 4 and 5 embodiments has been disclosed as an unmodulated signal of frequency f_0. If desired, the utility of either arrangement may be enhanced by translating additional information as amplitude modulation on such reference signal. So long as the percentage modulation is limited to less than 100 per cent., the carrier component required as a phase-reference signal at the receiving station may be derived through the use of a limiter stage, as hereinbefore suggested.

In each of the described embodiments of the invention a signal-translating system comprises means for supplying a first signal and means for supplying, or effectively supplying, a second signal which comprises a pair of signal components having predetermined phase relations with reference to the first signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values. Also, in each case, the system includes means for modulating the angular velocity of one of the aforesaid first and second signals in accordance with the information to be transmitted to develop a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of the aforementioned values. Further, each system comprises a signal-translating channel, and means for applying to that channel the modulated carrier signal and the other of the aforesaid first and second signals.

For a specific application of a phase-modulation system in accordance with the teachings of this invention, reference may be had to copending application, Serial No. 503,069, filed concurrently herewith in the name of Bernard D. Loughlin and assigned to the same assignee as the present invention. Furthermore, the signal-translating system is especially suited for application to a frequency-modulation system of the type which employs a so-called zero-beat method of

frequency discrimination, proposed by C. F. Shaeffer, and described in the Proceedings of the I. R. E., vol. 30, No. 8, August, 1942, page 365-367, inclusive. When adapted to such a system, the reference signal derived at the receiving station may be utilized as the reference oscillations supplied to the zero-beat frequency-discriminator system. Such a frequency-modulation system has the advantages that the system utilizes in the discriminator no resonant circuits which may become detuned; that the reference oscillations determine the balance or center frequency of the discriminator, thereby facilitating its adjustment; and that the linearity of the system is improved.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A signal-translating system comprising, means for supplying a first signal, means for effectively supplying a second signal comprising a pair of signal components having predetermined phase relations with reference to said first signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for modulating the angular velocity of one of said first and second signals in accordance with information to be transmitted to develop a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of said values, a signal-translating channel having input and output terminals, means for applying said modulated carrier signal and the other one of said first and second signals to said input terminals, and means coupled to said output terminals for utilizing said modulated carrier signal and said other one of said first and second signals to derive said modulation components.

2. A signal-translating system comprising, means for supplying a first signal, means for effectively supplying a second signal comprising a pair of signal components having predetermined phase relations with reference to said first signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for modulating the angular velocity of one of said first and second signals in accordance with information to be transmitted to develop a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of said values, a signal-translating channel having input and output terminals, means for applying said modulated carrier signal and the other one of said first and second signals to said input terminals, frequency-selective means coupled to said output terminals for individually separating said modulated carrier signal and said other one of said first and second signals, and means coupled to said frequency-selective means for utilizing the separated signals to derive said modulation components.

3. A signal-translating system comprising, means for supplying a first signal, means for ef-

fectively supplying a second signal comprising a pair of signal components having predetermined phase relations with reference to said first signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for modulating the angular velocity of one of said first and second signals in accordance with information to be transmitted to develop a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of said values, a signal-translating channel having input and output terminals, means for applying said modulated carrier signal and the other one of said first and second signals to said input terminals, frequency-selective means coupled to said output terminals for individually separating said modulated carrier signal and said other one of said first and second signals, means for deriving from the separated other one of said first and second signals a reference signal having predetermined phase and frequency relations with respect to the carrier component of the separated modulated carrier signal, and means for utilizing said reference signal and said separated modulated carrier signal to derive said modulation components.

4. A signal-translating system comprising, means for supplying a first signal, means for effectively supplying a second signal comprising a pair of signal components having predetermined phase relations with reference to said first signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for modulating the angular velocity of one of said first and second signals in accordance with information to be transmitted to develop a modulated carrier signal having predominant modulation components with a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of said values, a signal-translating channel having input and output terminals, means for applying said modulated carrier signal and the other one of said first and second signals to said input terminals, frequency-selective means coupled to said output terminals for individually separating said modulated carrier signal and said other one of said first and second signals, means for deriving from the separated other one of said first and second signals a reference signal of substantially the same phase and frequency as the carrier component of the separated modulated carrier signal, and means for utilizing said reference signal and said separated modulated carrier signal to derive said modulation components.

5. A signal-translating system comprising, means for supplying an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies, means for supplying a pair of reference-signal components having predetermined phase relations with reference to the carrier component of said signal, the frequencies of said reference-signal components being spaced in the frequency spectrum from said carrier component by equal and opposite increments of such magnitude that said predetermined band of frequencies is located therebetween, a signal-translating channel having input and output terminals, means for applying said modulated carrier signal and said reference-signal components to said input terminals, frequency-selective means coupled to said output terminals for individually separating said modulated carrier signal and each of said reference-signal components, means for combining the separated reference-signal components to derive a reference carrier signal which is harmonically related to the carrier component of the separated modulated carrier signal, and means for utilizing said reference carrier signal and the separated modulated carrier signal for deriving said modulation components.

6. A signal-translating system comprising, means for supplying an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies, means for supplying a pair of reference-signal components having predetermined phase relations with reference to the carrier component of said signal, the frequencies of said reference-signal components being spaced in the frequency spectrum from said carrier component by equal and opposite increments of such magnitude that said predetermined band of frequencies is located therebetween, a signal-translating channel having input and output terminals, means for applying said modulated carrier signal and said reference-signal components to said input terminals, frequency-selective means coupled to said output terminals for individually separating said modulated carrier signal and each of said reference-signal components, means for combining said separated reference-signal components to derive a reference carrier signal which is harmonically related to the carrier component of the separated modulated carrier signal, a frequency converter, means for applying one of said carrier signals to said frequency converter to convert the frequency of the carrier component of said one carrier signal to that of the other, a detector, and means for applying the carrier signal of converted frequency and said other carrier signal to said detector to derive said modulation components.

7. A signal-translating system comprising, means for supplying an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies, means for supplying a pair of reference-signal components having predetermined phase relations with reference to the carrier component of said signal, the frequencies of said reference-signal components being spaced in the frequency spectrum from said carrier component by equal and opposite increments of such magnitude that said predetermined band of frequencies is located therebetween, a signal-translating channel having input and output terminals, means for applying said modulated carrier signal and said reference-signal components to said input terminals, frequency-selective means coupled to said output terminals for individually separating said modulated carrier signal and each of said reference-signal components, means for combining the separated reference-signal components to derive a reference carrier signal corresponding to the second harmonic of the carrier component of the separated modulated carrier signal, a frequency doubler, means for applying said separated modulated carrier signal to said frequency doubler to double the frequency thereof, a detector, and means for applying said reference carrier signal and the double-frequency

modulated carrier signal to said detector to derive said modulation components.

8. A signal-translating system comprising, means for supplying an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies, means for supplying a pair of reference-signal components having predetermined phase relations with reference to the carrier component of said signal, means for modulating each of said reference-signal components in accordance with additional information to be translated thereby to develop a pair of modulated reference-signal components having modulation components in different predetermined bands of frequencies, the frequencies of said reference-signal components being spaced in the frequency spectrum by equal and opposite increments from said carrier component and the frequencies of said modulation components of said reference-signal components being such that said first-named band of frequencies is located between said different predetermined bands of frequencies, a signal-translating channel having input and output terminals, means for applying said modulated carrier signal and said modulated reference-signal components to said input terminals, frequency-selective means coupled to said output terminals for individually separating said modulated carrier signal and each of said modulated reference-signal components, means coupled to said frequency-selective means for utilizing the separated signals to derive said modulation components of said modulated carrier signal, and additional means coupled to said frequency-selective means for deriving said modulation components of at least one of said modulated reference-signal components.

9. A signal-translating system comprising, means for supplying a first signal, means for effectively supplying a second signal comprising a pair of signal components having predetermined phase relations with reference to said first-named signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for modulating the angular velocity of said second signal in accordance with information to be translated to develop a pair of modulated carrier signals each having predominant modulation components within an individual modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband of each of said pair of modulated carrier signals being less than one of said values, a signal-translating channel having input and output terminals, means for applying said first-named signal and said pair of modulated carrier signals to said input terminals, frequency-selective means coupled to said output terminals for individually separating said first-named signal and each of said pair of modulated carrier signals, means for combining the separated modulated carrier signals to derive a third angular-velocity-modulated carrier signal having a carrier component harmonically related to said first-named signal and having modulation components corresponding to said modulation components of each of said pair of modulated carrier signals, and means for utilizing the separated first-named signal to derive said modulation components of said third modulated carrier signal.

10. A signal-translating system comprising, means for supplying a first signal, means for effectively supplying a second signal comprising a pair of signal components having predetermined phase relations with reference to said first-named signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for modulating the angular velocity of said second signal in accordance with information to be translated to develop a pair of modulated carrier signals each having predominant modulation components within individual modulation bands located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband of each of said pair of modulated carrier signals being less than one of said values, a signal-translating channel having input and output terminals, means for applying said first-named signal and said pair of modulated carrier signals to said input terminals, frequency-selective means coupled to said output terminals for individually separating said first-named signal and each of said pair of modulated carrier signals, means for combining the separated modulated carrier signals to derive a third angular-velocity-modulated carrier signal having a carrier component which corresponds to the second harmonic of said first-named signal and having modulation components corresponding to said modulation components of each of said pair of modulated carrier signals, and means for utilizing the separated first-named signal to derive said modulation components of said third modulated carrier signal.

11. A signal-translating system comprising, means for supplying a first signal, means for effectively supplying a second signal comprising a pair of signal components having predetermined phase relations with reference to said first-named signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for modulating the angular velocity of said second signal in accordance with information to be translated to develop a pair of modulated carrier signals each having predominant modulation components within an individual modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation side band of each of said pair of modulated carrier signals being less than one of said values, a signal-translating channel having input and output terminals, means for applying said first-named signal and said pair of modulated carrier signals to said input terminals, frequency-selective means coupled to said output terminals for individually separating said first-named signal and each of said pair of modulated carrier signals, means for combining the separated modulated carrier signals to derive a third angular-velocity-modulated carrier signal having a carrier component which corresponds to the second harmonic of said first-named signal and having modulation components corresponding to said modulation components of each of said pair of modulated carrier signals, means for doubling the frequency of the separated first-named signal to derive a reference signal of substantially the same phase and frequency as the carrier component of said third modulated carrier signal, a detector, and means for supplying said reference signal and said third modulated carrier signal to said detector to derive said modulation components.

12. A signal-translating system comprising, means for supplying a first signal, means for ef-

fectively supplying a second signal comprising a pair of signal components having predetermined phase relations with reference to said first signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for modulating the angular velocity of one of said first and second signals in accordance with information to be transmitted to develop a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of said values, a signal-translating channel, and means for applying to said channel said modulated carrier signal and the other one of said first and second signals.

13. A signal-translating system comprising, means for supplying a first signal, means for effectively supplying a second signal comprising a pair of signal components having predetermined phase relations with reference to said first signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for phase-modulating one of said first and second signals in accordance with information to be transmitted to develop a phase-modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of said values, a signal-translating channel, and means for applying to said channel said phase-modulated carrier signal and the other one of said first and second signals.

14. A signal-translating system comprising, means for supplying a first signal, means for effectively deriving from said first signal a second signal comprising a pair of signal components having predetermined phase relations with reference to said first signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for modulating the angular velocity of one of said first and second signals in accordance with information to be transmitted to develop a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of said values, a signal-translating channel, and means for applying to said channel said modulated carrier signal and the other one of said first and second signals.

15. A signal-translating system comprising, means for supplying an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies, means for supplying a pair of reference-signal components having predetermined phase relations with reference to the carrier component of said signal, the frequencies of said reference-signal components being spaced in the frequency spectrum from said carrier component by equal and opposite increments of such magnitude that said predetermined band of frequencies is located therebetween, a signal-translating channel, and means for applying to said channel said modulated carrier signal and said reference-signal components.

16. A signal-translating system comprising, means for supplying a first signal, means for modulating the angular velocity of said first signal in accordance with information to be translated to develop a modulated carrier signal having components predominantly in a predetermined band of frequencies, means for supplying a second signal having predetermined frequency and phase relations with reference to said first signal, means for amplitude-modulating said second signal to develop reference-signal components comprising upper and lower sideband components of amplitude modulation, the frequency of said second signal and the modulation frequency of said amplitude modulation being such that said predetermined band of frequencies is located between said reference-signal components in the frequency spectrum, a signal-translating channel, and means for applying to said channel said modulated carrier signal and said reference-signal components.

17. A signal-translating system comprising, means for supplying a first signal, means for modulating the angular velocity of said first signal in accordance with information to be translated to develop a modulated carrier signal having components predominantly in a predetermined band of frequencies, means for supplying a second signal of substantially the same phase and frequency as said first signal, means for amplitude-modulating said second signal to develop reference-signal components comprising upper and lower sideband components of amplitude modulation, the modulation frequency of said amplitude modulation being such that said predetermined band of frequencies is located between said reference-signal components in the frequency spectrum, a signal-translating channel, and means for applying to said channel said modulated carrier signal and said reference-signal components.

18. A signal-translating system comprising, means for supplying a carrier signal, means for modulating the angular velocity of said carrier signal in accordance with information to be translated to develop a modulated carrier signal having components predominantly in a predetermined band of frequencies, means for amplitude-modulating said carrier signal to develop reference-signal components comprising upper and lower sideband components of amplitude modulation, the modulation frequency of said amplitude modulation being such that said predetermined band of frequencies is located between said reference-signal components in the frequency spectrum, a signal-translating channel, and means for applying to said channel said first-named modulated carrier signal and said reference-signal components.

19. A signal-translating system comprising, means for supplying a carrier signal, means for modulating the angular velocity of said carrier signal in accordance with information to be translated to develop a modulated carrier signal having components predominantly in a predetermined band of frequencies, means for supplying a modulating signal of a predetermined frequency, a balanced amplitude modulator, means for applying said carrier signal and said modulating signal to said modulator to produce reference-signal components comprising upper and lower sideband components of amplitude modulation, the frequency of said modulating signal being such that said predetermined band of frequencies is located between said reference-signal components in the frequency spectrum, a signal-

translating channel, and means for applying to said channel said first-named modulated carrier signal and said reference-signal components.

20. A signal-translating system comprising, means for supplying an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies, means for supplying a pair of reference-signal components having predetermined phase relations with reference to the carrier component of said signal, means for modulating each of said reference-signal components in accordance with additional information to be translated to develop a pair of modulated reference-signal components having modulation components in different predetermined bands of frequencies, the frequencies of said reference-signal components being spaced in the frequency spectrum by equal and opposite increments from said carrier component and the frequencies of said modulation components of said reference-signal components being such that said first-named band of frequencies is located between said different predetermined bands of frequencies, a signal-translating channel, and means for applying said modulated carrier signal and said modulated reference-signal components to said channel.

21. A signal-translating system comprising, means for supplying an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies, means for supplying a pair of reference-signal components having predetermined phase relations with reference to the carrier component of said signal, means for amplitude-modulating each of said reference-signal components in accordance with additional information to be translated to develop a pair of modulated reference-signal components having amplitude-modulation components in different predetermined bands of frequencies, the frequencies of said reference-signal components being spaced in the frequency spectrum by equal and opposite increments from said carrier component and the frequencies of the components of said amplitude-modulation being such that said first-named band of frequencies is located between said different predetermined bands of frequencies, a signal-translating channel, and means for applying said modulated carrier signal and said modulated reference-signal components to said channel.

22. A signal-translating system comprising, means for supplying a first signal, means for modulating the angular velocity of said first signal in accordance with information to be translated to develop a first modulated carrier signal having components predominantly in a first predetermined band of frequencies, means for supplying a second signal, means for modulating the angular velocity of said second signal in accordance with information to be translated to develop a second modulated carrier signal having components predominantly in a second predetermined band of frequencies, means for amplitude modulating said first signal with said second modulated carrier signal to develop a pair of angular-velocity-modulated signals having predetermined phase relations with reference to said first signal and having modulation components corresponding to said components of said second modulated carrier signal but located in different individual predetermined bands of frequencies, the frequencies of said first and second signals being so related and their angular-velocity modulation being such that said first-named predetermined band of frequencies is located in the frequency spectrum between said different individual predetermined bands of frequencies, a signal-translating channel, and means for applying said first-named modulated carrier signal and said pair of modulated signals to said channel.

23. A signal-translating system comprising, means for supplying a first signal, means for effectively supplying a second signal comprising a pair of signal components having predetermined phase relations with reference to said first-named signal and being individually spaced therefrom in the frequency spectrum by equal and opposite values, means for modulating the angular velocity of said second signal in accordance with information to be translated to develop a pair of modulated carrier signals each having predominant modulation components within an individual modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband of each of said pair of modulated carrier signals being less than one of said values, a signal-translating channel, and means for applying to said channel said first-named signal and said pair of modulated carrier signals.

24. A signal-translating system comprising, means for supplying a first signal, means for modulating the angular velocity of said first signal in accordance with information to be translated to develop a first modulated carrier signal having predominant modulation components in a predetermined band of frequencies, means for supplying a second signal, means for amplitude-modulating said first modulated carrier signal with said second signal to develop a pair of angular-velocity-modulated signals having predetermined phase relations with reference to said first modulated carrier signal and having modulation components corresponding to those of said first modulated carrier signal but contained in different individual predetermined bands of frequencies, the frequency of said second signal being such that said first signal is located in the frequency spectrum between said different individual predetermined bands of frequencies, means for supplying a third signal having predetermined phase and frequency relations with reference to said first signal, a signal-translating channel, and means for applying to said channel said pair of modulated signals and said third signal.

25. A signal-translating system comprising, means for supplying a first signal, means for modulating the angular velocity of said first signal in accordance with information to be translated to develop a first modulated carrier signal having predominant modulation components in a predetermined band of frequencies, means for supplying a second signal, means for amplitude-modulating said first modulated carrier signal with said second signal to develop a pair of angular-velocity-modulated signals having predetermined phase relations with reference to said first modulated carrier signal and having modulation components corresponding to those of said first modulated carrier signal but contained in different individual predetermined bands of frequencies, the frequency of said second signal being such that said first signal is located in the frequency spectrum between said different individual predetermined bands of frequencies, means for supplying a third signal of substan-

tially the same phase and frequency as said first signal, a signal-translating channel, and means for applying to said channel said pair of modulated signals and said third signal.

26. A signal-translating system comprising, means for supplying a first signal, means for modulating the angular velocity of said first signal in accordance with information to be translated to develop a first modulated carrier signal having predominant modulation components in a predetermined band of frequencies, means for supplying a second signal, means for amplitude-modulating said first modulated carrier signal with said second signal to develop a pair of angular-velocity-modulated signals having predetermined phase relations with reference to said first modulated carrier signal and having modulation components corresponding to those of said first modulated carrier signal but contained in different individual predetermined bands of frequencies, the frequency of said second signal being such that said first signal is located in the frequency spectrum between said different individual predetermined bands of frequencies, a signal-translating channel, and means for applying to said channel said pair of moduated signals and said first signal.

27. In a system for translating a composite signal including a first signal and a second signal which includes a pair of signal components having predetermined phase relations with reference to said first signal and individually spaced therefrom in the frequency spectrum by equal and opposite values, one of said first and second signals being angular-velocity-modulated in accordance with information to be translated so as to provide a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of said values, a receiver comprising, a pair of input terminals for receiving said composite signal, frequency-selective means coupled to said terminals for individually separating said modulated carrier signal and said other one of said first and second signals, and means coupled to said frequency-selective means for utilizing the separated signals to derive said modulation components.

28. In a system for translating a composite signal including a first signal and a second signal which includes a pair of signal components having predetermined phase relations with reference to said first signal and individually spaced therefrom in the frequency spectrum by equal and opposite values, one of said first and second signals being angular-velocity-modulated in accordance with information to be translated so as to provide a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of said values, a receiver comprising, a pair of input terminals for receiving said composite signal, frequency-selective means coupled to said terminals for individually separating said modulated carrier signal and said other one of said first and second signals, means for deriving from the separated other one of said first and second signals a reference signal having predetermined phase and frequency relations with reference to the carrier component of the separated modulated carrier signal, and means for utilizing said reference signal and said separated modulated carrier signal to derive said modulation components.

29. In a system for translating a composite signal including a first signal and a second signal which includes a pair of signal components having predetermined phase relations with reference to said first signal and individually spaced therefrom in the frequency spectrum by equal and opposite values, one of said first and second signals being angular-velocity-modulated in accordance with information to be translated so as to provide a modulated carrier signal having predominant modulation components within a modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband thereof being less than one of said values, a receiver comprising, a pair of input terminals for receiving said composite signal, frequency-selective means coupled to said terminals for individually separating said modulated carrier signal and said other one of said first and second signals, means for deriving from the separated other one of said first and second signals a reference signal of substantially the same phase and frequency as the carrier component of the separated modulated carrier signal, and means for utilizing said reference signal and said separated modulated carrier signal to derive said modulation components.

30. In a system for translating a composite signal which includes a first signal comprising an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies and a second signal including a pair of reference-signal components having predetermined phase relations with reference to the carrier component of said first signal, the frequencies of said reference-signal components being spaced in the frequency spectrum from said carrier component by equal and opposite increments of such magnitude that said predetermined band of frequencies is located therebetween, a receiver comprising, a pair of input terminals for receiving said composite signal, frequency-selective means coupled to said terminals for individually separating said modulated carrier signal and each of said reference-signal components, means for combining the separated reference-signal components to derive a reference carrier signal which is harmonically related to said carrier component of said modulated carrier signal, and means for utilizing said reference carrier signal and the separated modulated carrier signal for deriving said modulation components.

31. In a system for translating a composite signal which includes a first signal comprising an angular-velocity-modulated carrier signal having modulation components determined by information to be translated and predominantly in a predetermined band of frequencies and a second signal including a pair of reference-signal components having predetermined phase relations with reference to the carrier component of said first signal, the frequencies of said reference-signal components being spaced in the frequency spectrum from said carrier component by equal and opposite increments of such magnitude that said predetermined band of frequencies is located therebetween, a receiver comprising, a pair of input terminals for receiving said composite signal, frequency-selective means coupled to said terminals for individually separating said modulated carrier signal and each of said reference-signal components, means for combining the separated reference-signal components to derive a reference carrier signal which is harmonically related to said carrier component of said modulated carrier signal, and means for utilizing said reference carrier signal and the separated modulated carrier signal for deriving said modulation components.

nals and individually separating said modulated carrier signal and each of said reference-signal components, means for combining the separated reference-signal components to derive a reference carrier signal which is harmonically related to said carrier component of said modulated carrier signal, a frequency converter, means for applying one of said carrier signals to said frequency converter to convert the frequency of the carrier component of said one carrier signal to that of the other, a detector, and means for applying the carrier signal of converted frequency and said other carrier signal to said detector to derive said modulation components.

32. In a system for translating a composite signal which includes a first signal and a second signal comprising a pair of angular-velocity-modulated carrier signals the carrier components of which have predetermined phase relations with reference to said first signal and are individually spaced therefrom in the frequency spectrum by equal and opposite values, said pair of carrier signals each including predominant modulation components within an individual modulation band located only in a portion of the frequency spectrum which is adjacent its carrier frequency, the width of one modulation sideband of each of said pair of carrier signals being less than one of said values, a receiver comprising, a pair of input terminals for receiving said composite signal, frequency-selective means coupled to said terminals for individually separating said first signal and each of said pair of modulated carrier signals, means for combining the separated modulated carrier signals to derive a third angular-velocity-modulated carrier signal having a carrier component harmonically related to said first signal and having modulation components corresponding to said modulation components of each of said pair of modulated carrier signals, and means for utilizing the separated first signal to derive said modulation components of said third modulated carrier signal.

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