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MODULATED-CARRIER SIGNAL-TRANSLATING SYSTEM

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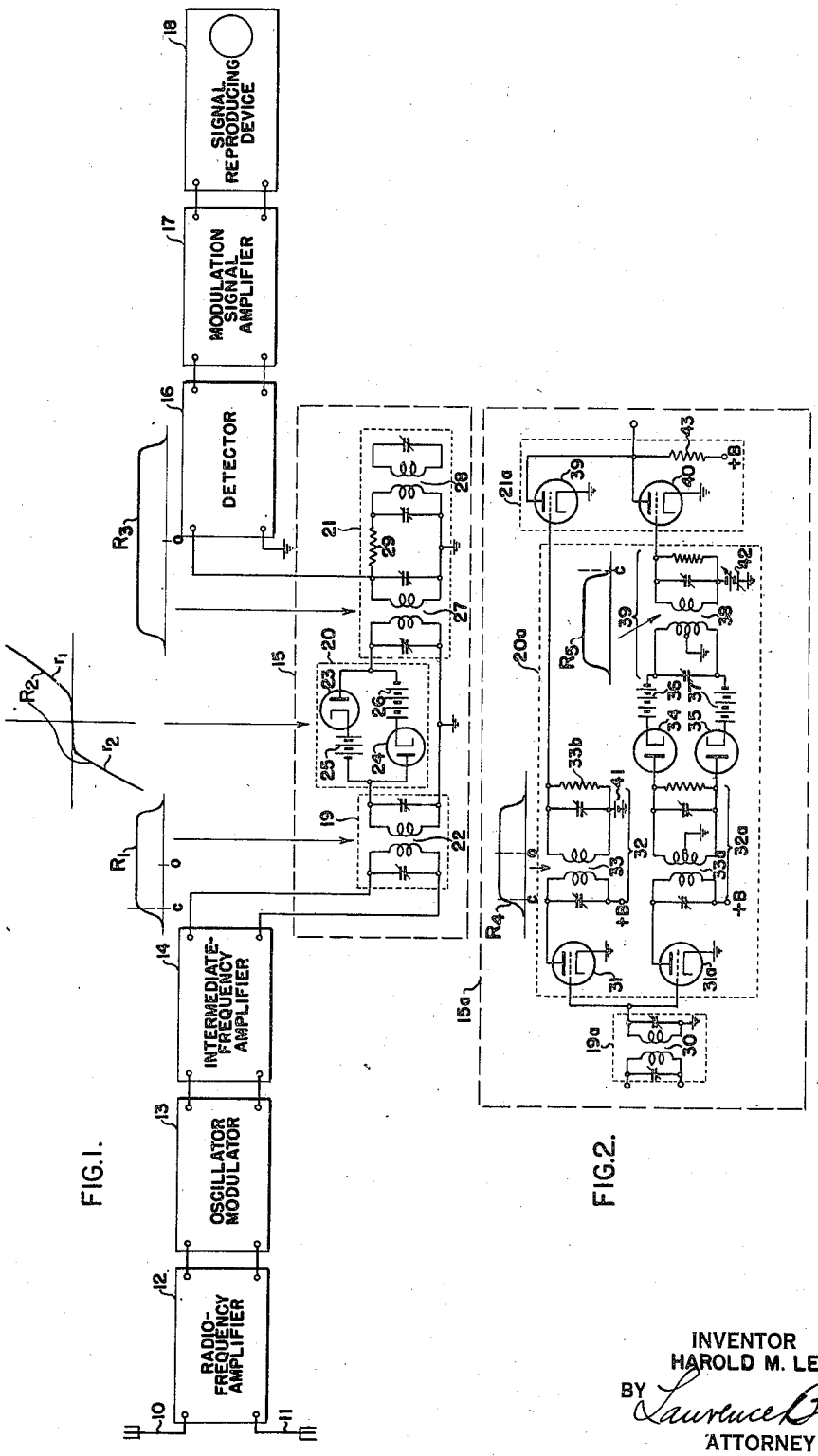


FIG. 1.

FIG. 2.

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MODULATED-CARRIER SIGNAL-TRANSLATING SYSTEM

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This invention relates to modulated-carrier signal-translating systems and is particularly concerned with systems of the single-sideband type utilizing a carrier wave and only one sideband of modulation frequencies or a carrier wave and a band of modulation frequencies excluding at least a major part of one of the sidebands of modulation frequencies.

In accordance with conventional practice in modulated-carrier signal-translating systems, at the transmitter there is developed a high-frequency carrier wave and a lower-frequency signal wave representing the information to be communicated. The signal wave is impressed as modulation on the carrier wave and there is thereby developed a modulated-carrier wave comprising the carrier-frequency component and upper and lower sideband modulation-frequency components having frequencies equal, respectively, to the sums of the carrier frequency and each signal frequency, and to the differences between the carrier frequency and each signal frequency. While the carrier-frequency component and each modulation sideband alone include components representative of all the information being transmitted, at the receiver, the carrier wave and both sidebands are generally detected to derive the original modulation signal for reproduction.

For various reasons it is frequently desirable to transmit the carrier wave and only one of the modulation sidebands. In television systems, for example, where the modulation-signal frequencies extend over an exceedingly wide range, of the order of four megacycles, the modulated carrier requires a relatively large portion of the limited part of the frequency spectrum which is available. For the purpose of economy with respect to the available part of the frequency spectrum, therefore, it has been proposed to develop and transmit single-sideband signals.

While in some systems single-sideband signals have been transmitted, received, and reproduced with satisfactory results, it is well known that such systems are both theoretically and practically imperfect. A perfect replica of the modulation signal cannot be derived from a single-sideband and carrier-wave under all conditions. This may be explained as follows: In detecting the usual modulated-carrier wave with its two modulation sidebands, the detector derives from the signal input thereto beat notes between the carrier wave and each of the sideband-frequency components. Corresponding upper and lower sideband-frequency components produce with the carrier wave the same beat notes which represent the modulation signal and they are cumulative in the output circuit of the detector. The detector also produces beat notes between each sideband-frequency component and all others which do not represent the modulation signal but constitute undesirable distortion components. Where both sidebands are present, however, the undesired beat notes due to one sideband cancel out those due to the other sideband. Where, however, the signal input to the detector comprises the carrier wave and only one modulation sideband, these undesired beat notes do not cancel but are present in the signal output and tend to destroy the fidelity of reproduction of the desired modulation components.

One manner of minimizing such undesirable results in single-sideband systems has been to develop and transmit a signal having a carrier wave of a substantially greater amplitude than any of the sideband-frequency components. Consequently, in such systems, the beat notes between the sideband-frequency components themselves are of substantially lesser amplitudes than the beat notes between the sideband-frequency components and the carrier wave, and the undesirable effects are reduced.

In certain single-sideband systems, however, it is desirable that certain sideband-frequency components be of such amplitude relative to that of the carrier wave that the beat notes therebetween are of appreciable values relative to the useful beat notes, rendering detection thereof highly unsatisfactory. For example, in television systems, where there is a sharp contrast between adjacent incremental areas of the image being transmitted, the boundary between these areas is represented in the signal by high-frequency modulation components comprising a relatively great percentage of modulation so that the beat notes between such sideband-frequency components are sufficiently great to impair the reproduction of a single-sideband signal under certain conditions.

It may be stated generally, therefore, that only where the signal impressed upon the detector comprises the carrier wave and both its modulation sidebands can the exact replica of the original modulation signal be derived under all conditions. For this reason, it has been conventional practice to utilize double sideband signals except where special considerations render expedient the compromise of utilizing single-sideband signals.

It is an object of the present invention to provide a modulated-carrier signal-translating system whereby there may be derived and utilized, from a signal comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the sidebands of modulation, the excluded modulation-frequency components.

It is another object of the invention to provide a modulated-carrier signal-translating system whereby there may be derived from an available single-sideband signal the modulation-fre-

quency components corresponding to the sideband components which are missing from the available signal.

It is a further object of the invention to provide a modulated-carrier signal-translating system whereby benefits incident to both conventional single-sideband transmission and double-sideband reception may be obtained.

In accordance with the present invention, there is provided a modulated-carrier signal-translating system comprising an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation-frequency sidebands. Non-linear signal translating means are coupled to the input circuit for distorting the impressed signal to derive therefrom signal-frequency components corresponding to the excluded portion of said sideband. An output circuit is coupled to the signal-translating means for utilizing the derived modulation-frequency 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 drawing and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a schematic diagram of a complete superheterodyne radio receiver including a signal- translating system embodying the present invention, while Fig. 2 is a circuit diagram of a modified form of the signal-translating system.

Referring now more particularly to Fig. 1, the system there illustrated comprises a receiver of the superheterodyne type including an antenna 10, 11 connected to a radio-frequency amplifier 12 to which there is connected in cascade, in the order named, an oscillator-modulator 13, an intermediate-frequency amplifier 14, a signal-translating system indicated generally at 15 and embodying the present invention, a detector 16, a modulation-signal amplifier 17 and a signal-reproducing device 18. Where the receiver of Fig. 1 comprises a television receiver, the signal-reproducing device may include scanning-wave generators, and a cathode-ray reproducing tube.

Referring briefly to the general operation of the system just described, a signal intercepted by the antenna 10, 11 is selected and amplified in the radio-frequency amplifier 12 and supplied to the oscillator-modulator 13, wherein it is converted into an intermediate-frequency signal which, in turn, is selectively amplified in intermediate-frequency amplifier 14 and delivered to the intermediate-frequency signal-translating system 15. The system 15 operates in accordance with the present invention, as will be presently fully explained, to deliver an intermediate-frequency signal to the detector 16 wherein the modulation signal is derived and from which it is supplied to the modulation-signal amplifier 17 which amplifies this signal and supplies it to the signal-reproducing device 18 for reproduction. It is to be noted that the receiver of Fig. 1 is adapted for the reception of a single-sideband signal, comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation-frequency sidebands. The intermediate-frequency amplifier 14, therefore, is designed to pass the intermediate-frequency components corresponding to the received signal and developed therefrom by the oscillator-modulator 13.

Referring now more particularly to the portion of the receiver of Fig. 1 which embodies the present invention, the intermediate-frequency signal-translating system 15 comprises an input circuit 19, a non-linear signal-translating device 20 and an output circuit 21. The input circuit is preferably a band-pass selector comprising a double-tuned transformer 22 having its primary circuit coupled to the output circuit of the intermediate-frequency amplifier 14 as shown. The response characteristic of the input circuit or selector 19 is indicated by curve R_1 shown above the selector in Fig. 1, the mean frequency of the selector being indicated at *o* and the location of the carrier being indicated at *c*. While any suitable elements may be utilized for the non-linear signal-translating device 20, such as properly biased multi-grid tubes, in the arrangement shown a pair of diodes 23 and 24 are connected in parallel in opposite senses with suitable biasing batteries 25 and 26, respectively, included in their cathode circuits. The device 20 interconnects the high-potential terminals of the input circuit 19 and the output circuit 21 which have a common low potential terminal. The response or repeating ratio characteristic of the device 20 is illustrated by curve R_2 shown above the device in Fig. 1. More particularly, the upper and lower halves r_1 and r_2 of curve R_2 represent the characteristics of the biased diodes 23 and 24, respectively, taken individually. For the purpose of clarity the curves r_1 and r_2 have been shown with the same zero base line but extending in opposite senses, since the diodes are connected in opposite senses and pass half-cycles of the signal of opposite polarities. It will be apparent that the device 20 has a non-linear response characteristic such that the signal translated thereby is distorted in a predetermined manner, as presently will be more fully explained.

The output circuit of the signal-translating system is preferably a band-pass selector of the dead-end filter type designed to pass a wide band of frequencies. This circuit may comprise two double-tuned transformers 27 and 28 and a terminating resistor 29 interposed therebetween. The detector 16 is connected across the secondary circuit of transformer 27. The response characteristic of the output circuit or selector 21 is illustrated by curve R_3 shown above the selector in Fig. 1 from which it is seen that the mean frequency of the pass band of the selector is the same as the frequency of intermediate-carrier wave and the selector is uniformly responsive over both the modulation sidebands.

In the operation of the signal-translating system 15, a single-sideband signal is impressed upon the input circuit 19 and is passed thereby with substantially uniform response over the single modulation-frequency sideband, as illustrated by curve R_1. The signal is then translated by the device 20 with a non-linear signal-repeating ratio, as illustrated by curve R_2, so as to effect a predetermined distortion of the wave form of the signal. By virtue of the non-linear characteristic of the device 15 it not only passes the impressed or input-signal frequency components but also it further functions to derive from the input signal the excluded or missing sideband-frequency components. The complete signal including the carrier wave and both the modulation-frequency sidebands are thus translated to the output circuit 21 and this circuit as just explained having a band-pass characteristic illustrated by curve R_3 passes all the frequency com-

ponents of the complete signal, including the carrier wave and its two sidebands, with substantially uniform response to the detector 16.

The operation of the system may be more fully appreciated from a consideration of the simple equations representing the signals passed by the system and the response characteristic of the non-linear translating means. Thus, assuming a carrier wave f_1 modulated by a sinusoidal modulation-frequency wave f_2, the carrier wave is represented by

$$E_1 \cos \omega_1 t \quad (1)$$

where

$$\omega_1 = 2\pi f_1$$

and the modulation-frequency wave is represented by

$$E_2 \cos \omega_2 t \quad (2)$$

where

$$\omega_2 = 2\pi f_2$$

and the modulated-carrier wave is represented by the formula:

$$e_m = E_1[1 + E_2 \cos \omega_2 t] \cos \omega_1 t$$

which when expanded gives:

$$e_m = E_1 \cos \omega_1 t + E_2/2 \cos (\omega_1 + \omega_2) t + E_2/2 \cos (\omega_1 - \omega_2) t \quad (3)$$

If the lower-frequency sideband is suppressed, the equation of the resultant carrier with only the upper-frequency sideband is:

$$e = E_1 \cos \omega_1 t + E_2/2 \cos (\omega_1 + \omega_2) t \quad (4)$$

Now the non-linear device 20 has an input voltage-output current characteristic which is represented by the general equation:

$$i = a_0 + a_1 e + a_2 e^2 + a_3 e^3 + a_4 e^4 + a_5 e^5 \ldots \text{ etc.} \quad (5)$$

It can be shown that only the odd power terms contribute to reproducing the sideband-frequency component missing from Equation 4. The characteristic of the non-linear device 20 of the present invention is of a form such that the even power terms cancel and its general equation (which also defines curve R_2 of Fig. 1 of the drawings) is:

$$i = a_1 e + a_3 e^3 + a_5 e^5 + a_7 e^7 + \ldots \text{ etc.} \quad (6)$$

The term $a_1 e$ represents the linearly repeated component of the applied signal while each of the other terms contribute to the production of the missing sideband-frequency components. For simplicity it will be shown that this is true for the term $a_3 e^3$ by rewriting Equation 4 as follows:

$$a_3 e^3 = a_3 \left[E_1 \cos \omega_1 t + \frac{E_2}{2} \cos (\omega_1 + \omega_2) t \right]^3 \quad (7)$$

This is of the form

$$(x+y)^3 = x^3 + 3x^2 y + 3xy^2 + y^3 \quad (8)$$

and it can be shown that only the second term is of interest as representing frequencies lower than the carrier. Hence

$$3x^2 y = 3E_1^2 \cos^2 \omega_1 t \frac{E_2}{2} \cos (\omega_1 + \omega_2) t =$$

$$3\frac{E_1^2 E_2}{4} \cos (\omega_1 + \omega_2) t + 3\frac{E_1^2 E_2}{4} \cos (3\omega_1 + \omega_2) t + 3\frac{E_1^2 E_2}{4} \cos (\omega_1 - \omega_2) t \quad (9)$$

Since E_1 is constant, the last term may be written in the form:

$$KE_2 \cos (\omega_1 - \omega_2) t \quad (10)$$

which is the third term of Equation 3 representing the suppressed sideband component.

In a manner similar to the above, it can be shown that, in case the upper or opposite sideband is suppressed and only the lower sideband is transmitted, the upper sideband may be derived by the apparatus of the present invention. Thus, in accordance with the system of the present invention, when a signal is impressed thereon comprising a carrier wave and a modulation-frequency sideband excluding one, or at least a major portion of one, of the modulation-frequency sidebands, the excluded sideband-freqency components are derived from this signal and reinserted in the output signal.

It can be shown that the device 20 develops from the input signal, in addition to the desired suppressed modulation sideband, modulation products corresponding to the higher order terms of its characteristic equation which constitute carrier waves of higher frequencies together with both their respective modulation-frequency sidebands. In certain cases it may be desired to utilize the higher-frequency carrier waves and their modulation sidebands. This may be readily accomplished by simply adjusting the output circuit 21 to be uniformly responsive over the desired higher band of frequencies.

Moreover, while the particular device 20 is so arranged that its characteristic equation includes only odd power terms, it will be appreciated that it is within the scope of the present invention to so design the device 20 that its characteristic equation includes only the even power terms or includes both the even and odd power terms, and to design the output circuit so that it is responsive to the modulated-carrier waves derived under these conditions, which waves include the carrier wave and its sideband frequency components at various harmonics of the original signal-input frequencies.

In Fig. 2 there is illustrated a signal-translating system 15a which is a modified form of the system 15 of Fig. 1 and may be substituted therefor in the receiver of Fig. 1. The system 15a comprises an input circuit 19a, a signal-translating section 20a, and an output circuit 21a. The input circuit comprises a double-tuned transformer 30 having its primary circuit adapted to be coupled to the output circuit of the intermediate-frequency amplifier 14.

The section 20a comprises two separate signal-translating channels. One channel includes a vacuum-tube amplifier 31, of the triode or other suitable type, and a band-pass selector 32 connected in cascade, as shown. The selector 32 may comprise a double-tuned transformer 33 preferably having its secondary circuit shunted by a damping resistor 33b and so adjusted as to have a band-pass characteristic as illustrated by curve R_4, its mean frequency being located at substantially the center frequency of the single sideband of frequencies of the input signal as indicated at o, and the carrier frequency being located near one edge of the pass band.

The other channel of the section 20a comprises a vacuum-tube amplifier 31a and selector 32a which may be substantially similar to the amplifier 31 and selector 32, respectively. Here, however, an intermediate tap on the secondary circuit of the double-tuned transformer 33a is grounded and its opposite terminals are connected, by way of non-linear signal-translating devices, for example, diodes 34 and 35 with suitable biasing batteries 36 and 37 in series therewith, to the opposite terminals of the primary circuit of a double-tuned transformer 38. The

latter transformer constitutes a band-pass selector 39 similar to the selectors 32 and 32a. An intermediate tap of the primary winding of the transformer 38 is grounded. The diodes 34 and 35 function similarly to the diodes 23 and 24 of Fig. 1, their general repeating ratio characteristic taken together being the same as that illustrated by curve R_2 of Fig. 1. Being connected to opposite terminals of the selectors 32a and 39, the diodes 34, 35 are connected in the same sense. Suitable adjustment of the batteries 36 and 37 serves effectively to shift the curves r_1 and r_2 laterally in opposite senses so that the desired over-all characteristic most suitable for developing the missing sideband-frequency components from the input signal may be obtained. The selector 39 has a band-pass characteristic illustrated by curve R_5 similar to that of the selector 32, but having a mean frequency substantially corresponding to the mean frequency of the missing sideband derived by the non-linear devices 34 and 35 so that it favors these derived frequencies. Also, the carrier frequency is located near the opposite edge of the pass band from that of selector 32.

The output circuit 21a may comprise a pair of combining amplifiers 39 and 40 having their input electrodes coupled across the secondary circuits of the transformers 33 and 38 by way of biasing batteries 41 and 42, respectively. A common output circuit comprising a resistor 43 is provided for the tubes 39 and 40, across which the input circuit of the detector 16 may be connected. This output circuit is adapted to translate the signal and both its modulation-frequency sidebands. The biasing batteries 41, 42 are adjusted so that the relative gains of the amplifiers 39 and 40 compensate for any difference in the amplitudes of the signals as translated by the two channels.

The operation of the system 15a is believed obvious from the above description. Briefly, the single-sideband signal is supplied to the input circuit 19a and the channel including the tube 31 and selector 32 amplifies and translates the carrier wave and its sideband-frequency components to the output circuit 21a. In the other channel, however, while the input signal is also amplified and translated by the tube 31a and selector 32a, the diodes 34 and 35 operate with a repeating ratio characteristic equivalent to that illustrated by curve R_2 of Fig. 1, that is, with a non-linear repeating ratio such as to distort the input signal and derive therefrom the missing side-band-frequency components. These derived frequency components are selectively translated by the selector 39 to the output circuit and the latter operates to combine them with the carrier wave and other sideband-frequency components translated by the channel 31, 32. There is thus developed in the output circuit the complete signal including the carrier wave and both modulation-frequency sidebands, which signal may thereafter be delivered to the detector for demodulation.

While there have been described what are at present considered 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 this invention, and, therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation sidebands, non-linear signal-translating means coupled to said input circuit for distorting said impressed signal to derive therefrom signal components corresponding to said excluded portion of said sideband, and an output circuit coupled to said signal-translating means for utilizing said derived signal components.

2. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation sidebands, non-linear signal-translating means coupled to said input circuit for distorting said impressed signal to derive therefrom said excluded portion of said sideband, and an output circuit coupled to said signal translating means for translating said carrier wave and both its sidebands of modulation frequencies including said derived excluded portion of said other sideband.

3. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation sidebands, non-linear signal-translating means coupled to said input circuit and having a non-linear signal-repeating ratio for translating said impressed signal with a predetermined distortion to derive therefrom said excluded portion of said sideband, and an output circuit coupled to said signal-translating means for utilizing said derived signal components.

4. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation sidebands, non-linear signal-translating means coupled to said input circuit and having a non-linear signal-repeating ratio for translating said impressed signal with a predetermined distortion to derive therefrom said excluded portion of said sideband, and an output circuit coupled to said signal-translating means for translating said signal-carrier wave and both its modulation sidebands including said derived excluded portion of said other sideband.

5. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation sidebands, said input circuit including a band-pass selector adapted to pass said signal with substantially uniform attenuation over said modulation band, non-linear signal-translating means coupled to said input circuit for distorting said impressed signal to derive therefrom said excluded portion of said sideband, and an output circuit coupled to said signal-translating means for translating said carrier wave and both its modulation sidebands including said derived excluded portion of said other sideband and including a band-pass selector having a substantially uniform response characteristic over said sidebands.

6. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major

portion of one of the modulation sidebands, said input circuit including a band-pass selector having a mean frequency at substantially the mean frequency of said band and adapted to pass said signal with uniform attenuation over said modulation band, non-linear signal-translating means coupled to said input circuit for distorting said impressed signal to derive therefrom said excluded portion of said sideband, and an output circuit coupled to said signal-translating means for translating said carrier wave and both its modulation sidebands and including a band-pass selector having a mean frequency equal to the carrier-frequency and a substantially uniformly responsive characteristic over said sidebands.

7. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation sidebands, non-linear signal-translating means including a pair of diodes coupled in opposite senses to said input circuit for non-linearly translating said impressed signal to effect a predetermined distortion thereof to derive therefrom said excluded portion of said sideband, and an output circuit coupled to said signal-translating means for utilizing said derived signal components.

8. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation sidebands, signal-translating means, including a pair of diodes coupled in opposite senses to said input circuit, and means providing predetermined biases for said diodes, for non-linearly translating said impressed signal to effect a predetermined distortion thereof to derive therefrom said excluded portion of said sideband, and an output circuit coupled to said signal-translating means for utilizing said derived signal components.

9. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation sidebands, a first channel for translating said signal, a second channel including signal-translating means coupled to said input circuit for distorting said impressed signal to derive therefrom said excluded portion of said sideband, and a common output circuit for said channels for translating said carrier wave and both its modulation sidebands including said derived excluded portion of said other sideband.

10. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation sidebands, a first channel for translating said signal, a second channel including signal-translating means coupled to said input circuit for distorting said impressed signal to derive therefrom said excluded portion of said sideband, a common output circuit for said channels for translating said carrier wave and both its modulation-frequency sidebands including said derived excluded portion of said other sideband, and means for adjusting the gain of one of said channels to adjust the relative amplitudes of said directly translated and said derived signals.

11. A signal-translating system comprising, an input circuit adapted to have a signal impressed thereon comprising a carrier wave and a modulation-frequency band excluding at least a major portion of one of the modulation sidebands, a first channel for translating said signal including a band-pass selector adapted to pass said signal with uniform response over said modulation-frequency band with said carrier wave at one edge of its pass band, a second channel including signal-translating means coupled to said input circuit for distorting said impressed signal to derive therefrom said excluded portion of said sideband, and a band-pass selector adapted to pass said excluded portion of said sideband with uniform response thereover and with said carrier at an opposite edge of its pass band, a common output circuit for said channels for translating said carrier wave and both its modulation-frequency sidebands including said derived excluded portion of said other sideband.

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