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1,963,726

SINGLE SIDEBAND MODULATOR

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FIG. 1

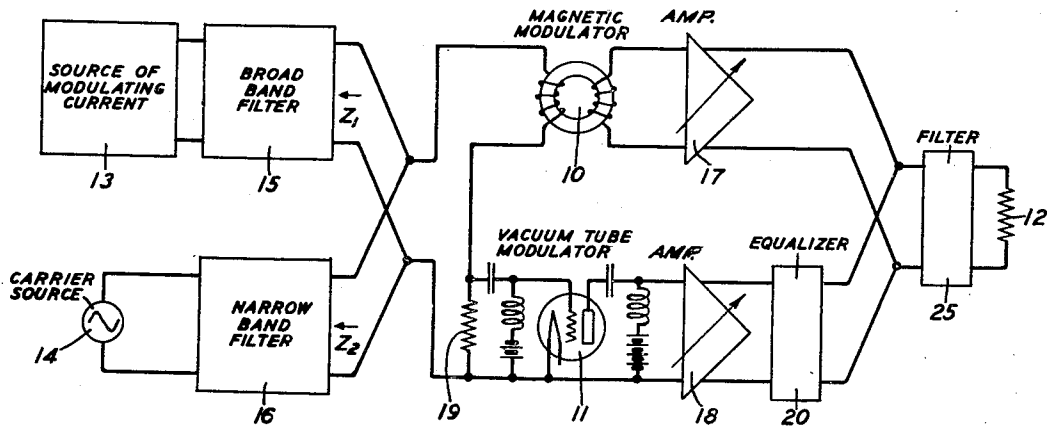


FIG. 2

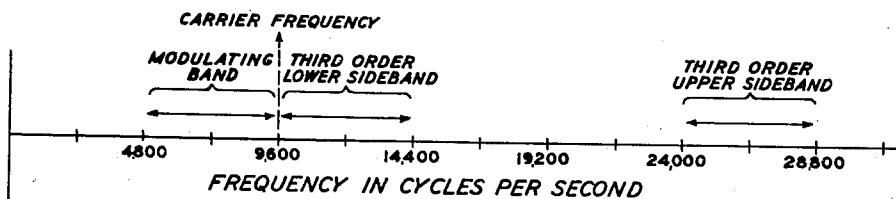
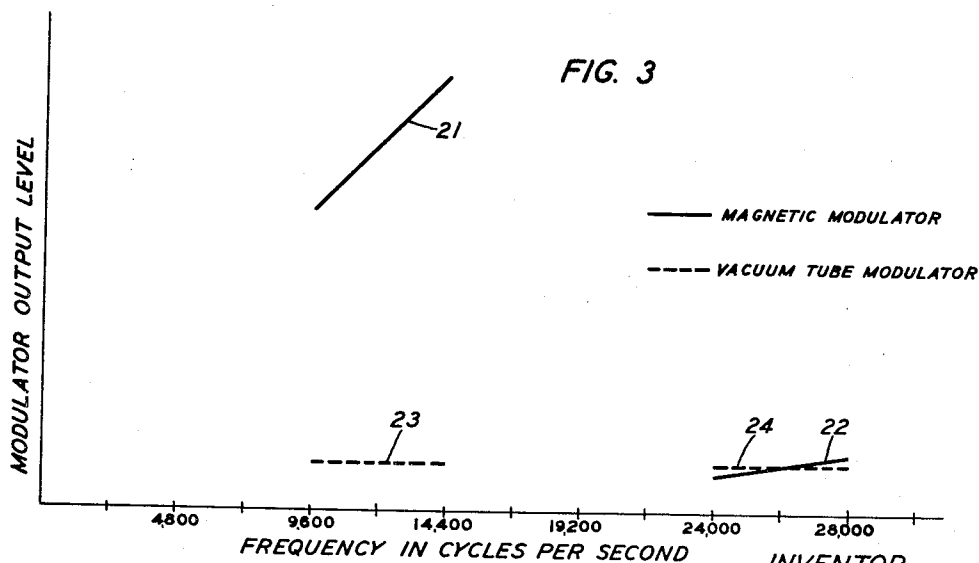


FIG. 3



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SINGLE SIDEBAND MODULATOR

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5 Claims. (Cl. 179—171)

This invention relates to modulating arrangements for producing a single sideband and more particularly to systems in which one sideband is balanced out by phase opposition rather than by suppression in a selective circuit or filter.

An object of the invention is to improve the economy of single sideband producing systems by simplification of the apparatus required.

Another object is to avoid the use of elaborate filters or other frequency selective devices as far as possible in the separation of one sideband from the other.

In accordance with the present invention, a pair of modulators differing from each other distinctly in their mode of operation and output are combined to secure the desired suppression of one sideband. The modulators, one of which may be of the magnetic type and the other of the vacuum tube type, are actuated by the same carrier wave and modulating current and deliver their outputs simultaneously into a common load circuit. The lower sideband output of the magnetic type modulator is found to be much more pronounced than the upper sideband. In the other modulator, both sidebands are of substantially the same strength. The outputs of the two modulators are adjusted to equal levels of upper sideband and combined differentially, thereby causing the upper sideband to be balanced out or neutralized while the lower sideband passes to the load circuit.

The invention is described in detail hereinafter with reference to the accompanying drawing, in which

Fig. 1 is a schematic representation of a circuit embodying the invention;

Fig. 2 is a frequency spectrum for a particular selection of currents that might be impressed upon the system of Fig. 1, and

Fig. 3 is a graph of the relative output levels of sidebands in a system embodying the invention.

Fig. 1 shows a magnetic modulator 10 and a vacuum tube modulator 11 differentially connected to a load circuit 12. The inputs of both modulators are supplied with modulating currents from a common source 13 and carrier waves from a common carrier source 14. Intermingling of the impressed carrier and modulating currents elsewhere than in the modulators is prevented by the insertion of filters 15 and 16 as shown. Filter 15 has a broad band to accommodate the range of modulating currents while filter 16 has a narrow band adapted to pass only the carrier. The filters 15 and 16 serve also to prevent the feeding back of modulation products from the

modulators to the sources. To avoid interaction between the output circuits of the respective modulators, adjustable amplifiers 17 and 18 are inserted which transmit only in the direction from the modulators to the load. These also serve to provide means for adjusting the relative amplitudes of the modulation products of the two modulators. A fairly low resistance shunt 19 is placed across the input of the vacuum tube modulator to reduce the effect of reactance therein, which would otherwise be introduced into the input circuit of the magnetic modulator, and an equalizer 20 is used in the output circuit to improve the action of the system as hereinafter described. A filter 25 is inserted to freely pass the desired sideband and to discriminate against undesired frequencies in general.

In the operation of the system of Fig. 1, the modulating current from source 13 and the carrier wave from source 14 are impressed simultaneously upon the two modulators 10 and 11. The magnetic modulator 10, in common with modulators of its type, produces, primarily, modulation of the third order, that is, a lower sideband at a frequency of twice the carrier diminished by the modulating frequency, and an upper sideband at twice the carrier increased by the modulating frequency. If the carrier frequency is designated by p and the modulating frequency by q , then the upper sideband is $(2p+q)$ and the lower is $(2p-q)$. The vacuum tube modulator 11 also produces third order sidebands $(2p+q)$ and $(2p-q)$ although these are less prominent usually than the second order sidebands $(p+q)$ and $(p-q)$. The upper and lower sidebands of third order in the vacuum tube modulator are of approximately equal strength, in other words the output level of this modulator is substantially the same for the two sidebands of equal order. In the case of a magnetic modulator, however, I have found experimentally that there is a striking difference in output level between the upper and lower sidebands; the lower being much stronger than the upper. This observed difference is believed to be accountable to the hysteresis effect which is present in the magnetic modulator and not in the vacuum tube modulator. It is this marked inequality of sideband levels which is utilized in the system of Fig. 1 to effect a separation of upper and lower sidebands, the upper being suppressed and the lower greatly accentuated. In the circuit illustrated the modulator outputs are adjusted to have equal levels of third order upper sideband

and are combined differentially as to this sideband.

Fig. 2 shows the frequency relations of impressed waves and sidebands in an illustrative case. The modulating frequencies lie in a band from approximately 5200 to 9200 cycles per second. These frequencies may be a carrier and two sidebands obtained originally by modulating a 7200 cycle carrier with a band of signal frequencies from zero to 2000 cycles. If it is desired to translate this 5200-9200 cycle band to a new place in the frequency spectrum, for example to a position of 10000-14000 cycles. This shift may be accomplished by using a 9600 cycle carrier and producing a third order lower sideband which will be in the range from 10000 to 14000 cycles. The upper sideband which is to be suppressed, in this case will lie between 24400 and 28400 cycles.

Fig. 3 shows in graphical form the relative output levels of the sidebands in the two varieties of modulators. The full lines 21 and 22 represent the output levels in decibels which have been observed in experimental work with magnetic modulators. The lower sideband line 21 shows a much higher level than the upper sideband level 22. The approximately equal sideband levels of the vacuum tube modulator are represented in broken lines 23 and 24. The relative levels have been adjusted to make lines 22 and 24 substantially coincide. If desired, the equalizer 20 may be designed to tilt the line 24 to coincide more exactly with 22. In such case the equalizer will attenuate low frequencies more than high frequencies. It need exhibit the required attenuation characteristic, however, only within the relatively narrow frequency band occupied by the upper sideband. No phase adjustment of sidebands, other than a possible transposition of leads, is required to secure suppression of the upper sideband in the load, but merely an adjustment of the amplitude of the upper sidebands in the two modulators to substantial equality. This amplitude adjustment is readily secured by regulating the gain of either or both of the amplifiers 17 and 18 by any suitable means.

The impedance Z_1 looking into filter 15 from the output end should preferably be as high as possible for all frequencies outside the pass band. This will reduce any shunting effect of filter 15 upon the filter 16 or upon the modulator input circuits. Similarly, the impedance Z_2 looking into filter 16 from the output end should be as high as possible for all frequencies except in the immediate neighborhood of the carrier frequency.

Magnetic modulators suitable for use in the system of Fig. 1 are disclosed in a variety of forms in U. S. Patent 1,678,163, issued July 24, 1928, to E. Peterson. The opposing modulator 11 need not necessarily be a vacuum tube device but may be of any type in which the amplitudes of the upper and lower sidebands are in a ratio materially different from the amplitude ratio of corresponding sidebands in the first modulator. Any two modulators inherently different in respect to the amplitude ratio of sidebands may be used.

The modulator outputs may be combined in any form of output circuit which is designed to avoid interaction between the modulators, for example, a hybrid coil or bridge type output circuit of which several are known in the art. If a circuit of this type is used it is then unnecessary to use one-way amplifiers 17 and 18 to prevent interaction but such amplifiers may still

be required to conveniently adjust the relative output levels of the two modulators.

It is to be understood that the equalizer 20 may be placed in the output branch containing the modulator 10 and amplifier 17 equally well as in the position shown. If associated with modulator 10, the equalizer should attenuate high frequencies more than low ones, which is the reverse of the requirement when the equalizer is located in the path with modulator 11.

The filter 25, while it may aid in suppressing the upper sideband, need not exert great selectivity in this regard as the main action of the remainder of the system is to give the desired suppression.

What is claimed is:

1. In combination, two modulators differing from each other materially in respect of the ratio of the amplitude of upper sideband to the amplitude of lower sideband produced in the same modulator, common sources of carrier waves and modulating current for the two modulators, means for adjusting the relative output levels of the modulators to secure substantially equal amplitudes of one of the sidebands in said modulators, a common output circuit, and means for differentially combining therein the outputs of the respective modulators to balance out the sideband of substantially equal amplitudes while leaving the other sideband substantially uncompensated.

2. A single sideband producing system comprising a modulator of a type inherently producing materially unequal amplitudes of upper and lower sidebands, a second modulator of a type inherently producing substantially equal amplitudes of upper and lower sidebands, common sources of carrier waves and modulating current connected simultaneously to both modulators, means for adjusting the relative output levels of the modulators to secure substantially equal amplitudes of one of the sidebands in the respective modulators, a common output circuit, and means for differentially combining the adjusted modulator outputs therein to balance out the sideband of substantially equalized amplitude while leaving the other sideband materially uncompensated.

3. A single sideband producing system comprising a magnetic modulator, a vacuum tube modulator, means for impressing a carrier wave and a modulating current simultaneously upon both of said modulators, means to adjust the output of at least one of said modulators to secure substantially equal amplitudes of one sideband from the two modulators, and means for differentially combining the adjusted outputs of said modulators to neutralize the sideband of substantially equal amplitude from the two modulators while leaving the other sideband substantially uncompensated.

4. In combination, a magnetic modulator, a vacuum tube modulator, means for impressing the same carrier wave and modulating current simultaneously upon both modulators, means to adjust the output of at least one of said modulators to secure substantially equal amplitudes of upper sideband from the respective modulators, and means for differentially combining the adjusted outputs of said modulators to neutralize the upper sideband while leaving a substantial uncompensated output of lower sideband.

5. In combination, a magnetic modulator, a vacuum tube modulator, means for impressing

a carrier wave and a modulating current simultaneously upon both of said modulators, said modulating currents occupying an extended band of frequencies, means to adjust the outputs of said modulators to substantially equal amplitude of upper sideband from the respective modulators at one frequency in the upper sideband range, means for equalizing the output level of upper sideband in the two modulators over substantially the whole frequency range of the upper sideband, and means for differentially combining the adjusted outputs of said modulators to neutralize the upper sideband over substantially its whole range while leaving the lower sideband substantially uncompensated.

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