

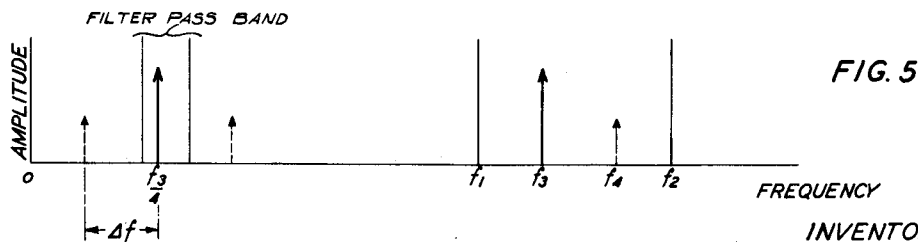
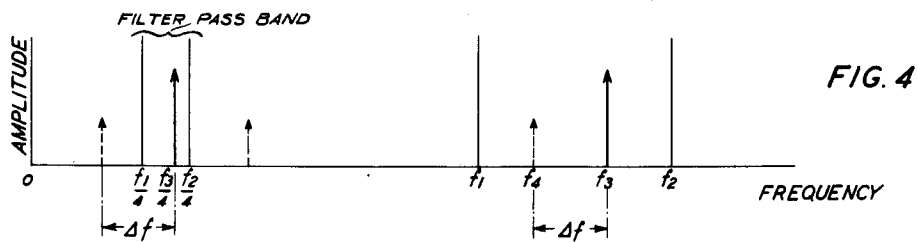
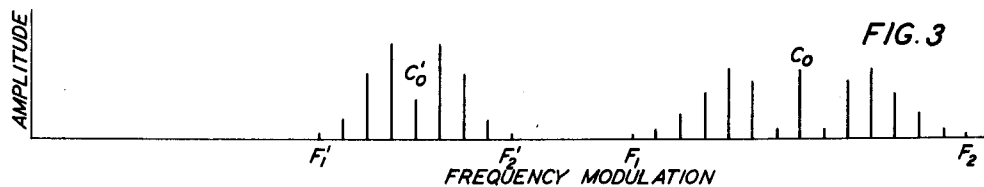
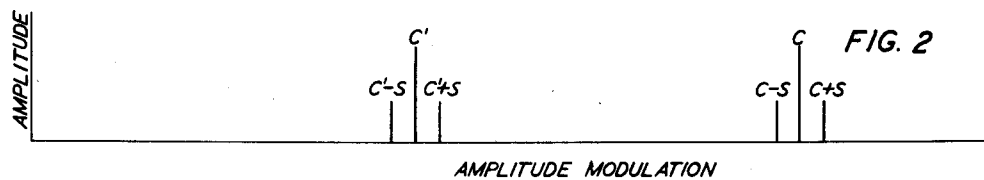
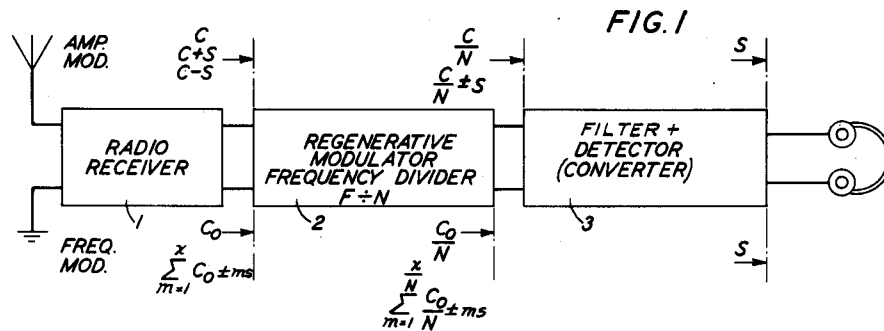
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CARRIER WAVE SIGNALING

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CARRIER WAVE SIGNALING

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1 Claim. (Cl. 250—20)

The present invention relates to the use of a frequency divider in the reception of complex waves such as speech and music waves, or high frequency carrier or radio waves modulated by speech or other signal.

A general object of the invention is to secure a more faithful translation of such waves into the desired output signal or wave component.

In the case of radio reception, an object is to step the frequency down to intermediate frequency level and secure an integral relation between the intermediate frequency wave and the incoming radio frequency wave.

These and other objects and features will be made more apparent in the following detailed description of representative embodiments together with the drawing.

In the drawing,

Fig. 1 is a block schematic diagram of a radio receiving system using this invention; and

Figs. 2, 3, 4 and 5 are diagrams of wave components to be referred to in the description.

In Fig. 1 the showing of the radio reception system is quite general and the row of symbols above the boxes indicates the wave transformations taking place when amplitude-modulated waves are received while the row of symbols below the boxes are for the case in which the received waves are frequency-modulated waves.

The first box, 1, may contain the usual tuning and radio-frequency amplifying equipment. The box 2 contains a regenerative-modulator type frequency divider circuit such as is disclosed in my Patent 2,159,595, granted May 23, 1939. The box 3 may include a band filter and it also includes a detector in the case of an amplitude-modulated wave and a converter followed by a detector in the case of a frequency-modulated wave. These are both well known in the art, the converter usually taking the form of a slope circuit or a pair of crossed slope circuits, each having an attenuation frequency characteristic which is sloped so that as the frequency sweeps over the band the wave is changed into a varying-amplitude wave dependent on the instantaneous frequency. Box 3 may also contain a limiter ahead of the converter in accordance with usual practice but in accordance with a feature of this invention the frequency divider circuit may be adjusted to provide a limiting effect so that the use of a limiter becomes unnecessary.

It is to be understood that box 2 may include one frequency divider or a plurality of frequency dividing stages working in tandem.

Considering first the case of reception of am-

plitude-modulated waves, I have found that if the carrier and both side-bands of an amplitude-modulated wave are applied to the input of a regenerative frequency dividing circuit of the type referred to, an output wave is secured of reduced frequency with its side-bands in proper amplitude and frequency in relation to the carrier. The carrier frequency is an exact submultiple of the original carrier and the side-bands retain all of the information contained in the original side-bands prior to subdivision of frequency. The original modulated wave may be considered as a sinusoidal wave with variable amplitude, which is subdivided in frequency by the regenerative frequency divider while retaining the correct amplitude relations. The frequency response characteristic of the dividing circuit must, of course, be sufficiently wide to allow the side-bands to be passed.

By this method the incoming radio wave can be stepped down in frequency to a desired intermediate frequency level and the stepped-down frequency will always bear a fixed relation to the original radio frequency. In the superheterodyne method using a beating oscillator the intermediate frequency varies if any variation occurs in the difference between the radio frequency and beating oscillator frequency. This can occur if either varies. Various means have been devised for holding the beating oscillator frequency as constant as possible. The invention avoids the necessity of using such means in view of the integral relation of the intermediate frequency to the radio frequency. Any submultiple of the radio frequency may be obtained within wide limits such as $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, etc., in a single stage. Larger reductions than are obtained in a single stage can be effected by use of stages in tandem, as above noted.

Fig. 2 shows at C a radio frequency wave with side-band frequencies C+S and C-S. By passage through a frequency dividing system the wave is translated down to the position shown and comprises a new carrier frequency C' and side frequencies C'+S and C'-S. In this figure C' is represented as having half the frequency of C. A single frequency modulation is assumed purely for simplicity of illustration. The spacing between the side frequencies and carrier in frequency is preserved and the relative amplitudes of side frequencies and carrier are preserved. This process is indicated by the symbols above the apparatus in Fig. 1 which denote the frequencies of interest at each of several points in the system. The symbol "N" denotes the nu-

merical ratio of the input frequency to the output or submultiple frequency in the case of the regenerative-modulator frequency dividing circuit.

A frequency modulated wave may be considered as a wave of constant amplitude whose instantaneous frequency varies according to the amplitude of the modulating wave. It is found that if the frequency response range of a regenerative modulator is sufficiently broad it will subdivide a frequency modulated wave to produce a frequency modulated wave situated at a frequency level which is a fractional part of the original level. The instantaneous frequency is subdivided. This results in both a lower mean frequency and a narrower band width since the index of modulation or absolute frequency swing is also subdivided in the same ratio as the mean frequency. This is indicated in Fig. 3 where the diagram shows a frequency modulated wave comprising components extending over a range F_1 to F_2 where the mean frequency is C_0 , subdivided (in this case halved) to produce a frequency modulated wave having a mean frequency component C_0' , but a lesser number of components occupying a band F_1' to F_2' which is approximately half as wide as F_1 to F_2 . The wave after frequency reduction can be detected by means of a converting circuit of half the range that would be required for the original wave or, if the converting circuit has a characteristic which is linear only over the range required for the reduced frequency wave, less distortion is produced than if a converter of the same shaped characteristic were used to derive the signal directly from the higher frequency wave.

The frequency transformations taking place in the case where a frequency modulated wave is received are indicated by the symbols below the boxes in Fig. 1. In these symbols, m is an integer representing the order of harmonic of the signal s , and C_0 is the mean or carrier frequency. The maximum limit of frequency swing, here approximately indicated by x in the input wave, is shown to be reduced to x/N in the subdivided frequency wave.

Since it is characteristic of modulators generally that they exert a limiting effect when overloaded, the regenerative modulators used for frequency dividing will serve also as limiters if overloaded and will thereby tend to suppress amplitude modulation in the frequency modulated waves, such as has commonly been done by limiters specially provided for that purpose.

Figs. 4 and 5 illustrate how the invention may be used to eliminate one or more unwanted frequency components in situations where filtering may be difficult or impossible.

Referring first to Fig. 4, let it be supposed that the high frequency band of interest is that between frequencies f_1 and f_2 and that there is a component shown at f_3 by solid line arrow which is wanted and another component that is not wanted shown by dotted arrow at f_4 . These components may be changing in frequency so that it would be impossible to separate them by filtering. If the wanted component exceeds in amplitude the unwanted component by 2 decibels or more, a frequency subdivision as disclosed herein will divide the frequency of the larger, wanted component but the unwanted, smaller component will be brought down to the lower frequency position as a modulation of the wanted component and will appear as a pair of side-band components having the same separation, Δf , from the wanted component as existed before the subdivision of

frequency. This is shown in the figure where a ratio of 4:1 is assumed in frequency reduction. Since the instantaneous frequency of the larger component is subdivided, its range of variation is also subdivided as in the case of a frequency modulated wave discussed above. If the two components should vary together, always maintaining the same separation Δf , and if the frequency reduction ratio can be made great enough in any case so that the range

$$\frac{f_1}{4} \text{ to } \frac{f_2}{4}$$

of the reduced frequency wave is greater than Δf , the unwanted component can under these circumstances be completely eliminated, by passing the reduced frequency band through a narrow band filter to exclude the unwanted side-band components. Comparison with Fig. 5 shows that the same is true if the unwanted component should shift to the upper side of the wanted component in frequency. The use of an oscillator to beat down the frequencies to a lower level might under certain specified conditions help to separate the components where straight filtering is used, to the extent that it would simplify the filtering problem as such. However, comparison of Figs. 4 and 5 shows that a beating oscillator if set to meet the conditions in one case would tend to eliminate the wrong component in the other case. This is not true of the method of the invention, which always subdivides the instantaneous frequency of the larger of the two components.

The question of how far the frequency division can be carried depends upon the nature of the original wave itself. Since the extent of frequency swing is reduced proportionally, a too great degree of frequency division may result in impairing the signal by loss of necessary frequency components. The width of band that is required to be passed through the separating filter must be great enough to accommodate the signal. For instance in reducing the frequency of a speech modulated wave, the eventual band must be broad enough to pass at least an upper and a lower side-band of speech width.

In the case where no fixed frequency spacing exists between wanted and unwanted components, the method of the invention is capable of eliminating the unwanted components except at certain instants when the two components approach each other too closely. Even this incomplete separation may be of advantage in some situations. If the distribution of the unwanted components is of random nature, the maximum degree of frequency division consistent with retention of wanted components should be used.

If in the situations illustrated in Figs. 4 and 5 it is desired to restore the

$$\frac{f_1}{4}$$

component to its original frequency position, f_3 , a frequency multiplier of suitable type known in the art may be used.

One application of this principle which has been proposed is to obtain the fundamental frequency of the human voice in a relatively pure form as well as having it occupy a much more limited range than it normally does. This should be possible because although it occupies a large frequency range the changes in pitch for a given voice are relatively slow, e. g., 10 cycles per second. As an example of this application

the pitch in normal speech might be considered as falling anywhere in the range of 75 cycles to 400 cycles. Thus, if the pitch is near the low end of the range as high as 5 harmonics of the speech wave might fall in the range of 75-400 cycles, while only the fundamental would appear if the pitch was over 200 cycles. By subdividing the fundamental frequency by a ratio of 5:1, however, only this submultiple component would fall in the reduced band. The fundamental frequency can be made the largest component by making use of an equalizer which has an increasing loss with frequency.

What is claimed is:

The method of eliminating an undesired fre- 15

quency component from a complex wave having a principal component of materially greater amplitude than the component that is to be eliminated comprising subdividing the complex wave to produce submultiple frequencies thereof the desired components of which occupy a reduced frequency band in proportion to the ratio of subdivision of the frequencies whereby said frequency component to be eliminated is made to appear in the reduced frequency wave as side-band components having the same frequency spacing from said principal component as in the original complex wave, and filtering the reduced frequency band from said side-band components.

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