

May 21, 1946.

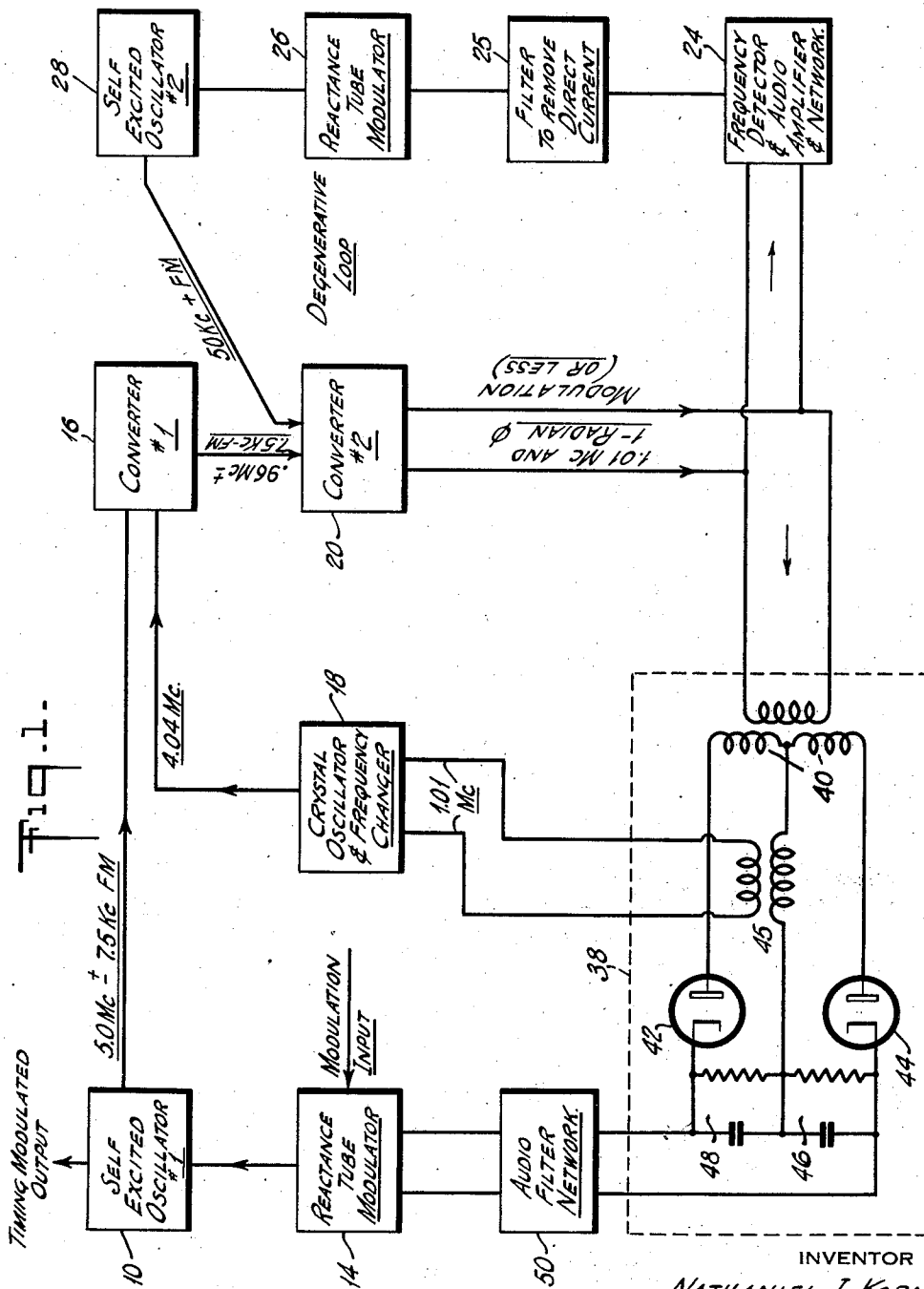
N. I. KORMAN

2,400,648

TIMING MODULATION

Filed June 30, 1943

2 Sheets-Sheet 1



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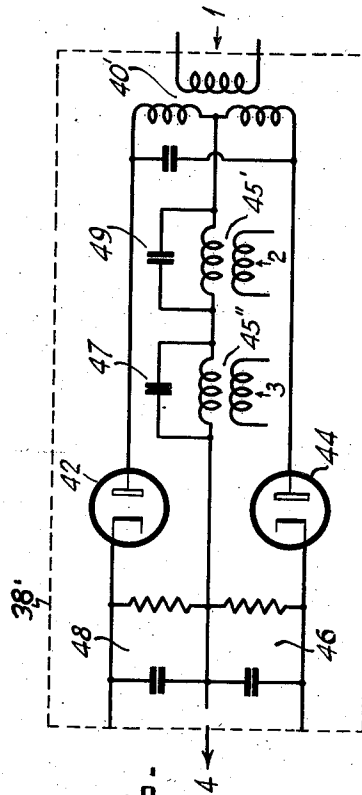
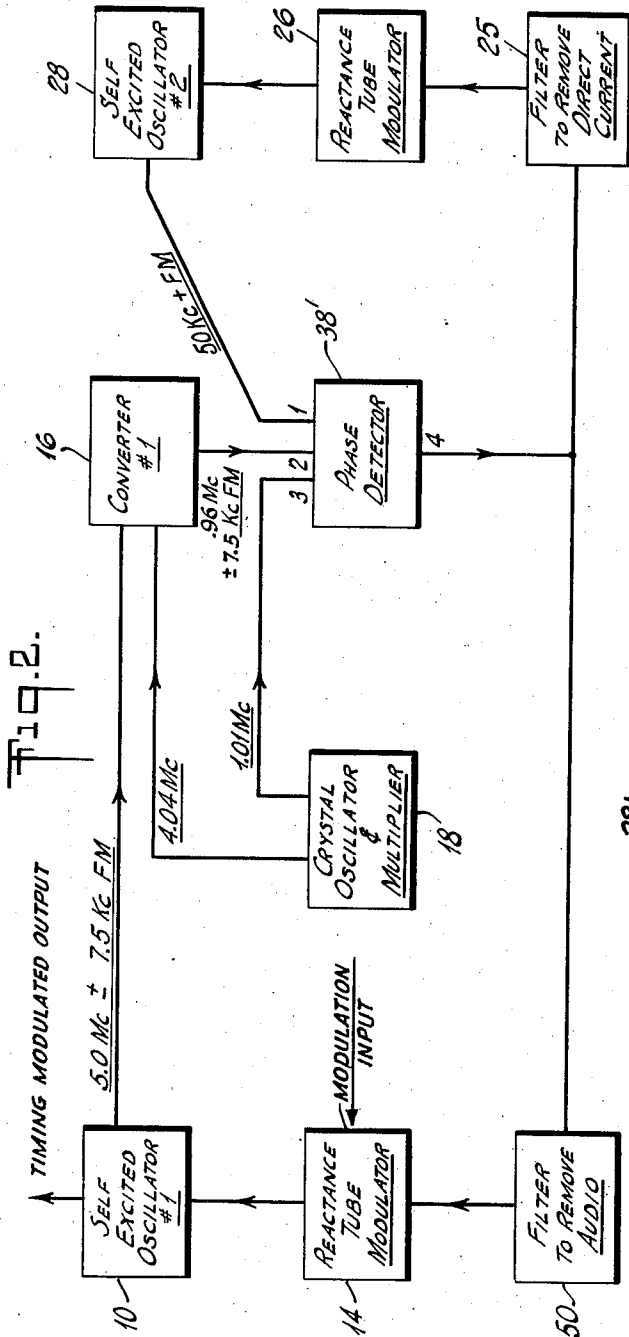
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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,400,648

TIMING MODULATION

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Application June 30, 1943, Serial No. 492,841

18 Claims. (Cl. 179—171.5)

A requirement in a frequency or phase modulator is that the mean carrier stay within its assigned place in the frequency spectrum. The Federal Communication Commission requires that the carrier frequency must be maintained within prescribed limits, the present limits requiring a stability of ± 2000 C. P. S. in the 42–50 mc. band or better.

Two frequency modulation systems have attracted considerable attention in the radio art. In one of these systems a crystal controlled oscillator supplies a carrier which is modulated in amplitude in accordance with modified signals, the side bands are selected and recombined with the carrier which has been shifted 90° in phase. This resulting built up wave has a characteristic of a wave which has been frequency modulated. The carrier frequency stability is that of the crystal oscillator but in order to have low harmonic distortion a small phase variation only may be obtained in the built up wave. In order to obtain the wider deviation desirable this built up wave is multiplied in frequency, say five or six thousand times and the multiplication steps are broken up by heterodyning down steps.

This sort of system is obviously complicated and uses a large amount of apparatus. Moreover, the use of the beating down oscillations affects the frequency stability of the final carrier because it is no longer that of the crystal controlled oscillations nor the beating oscillations. It is a modulation product of the several oscillations. The stability of the crystal controlled oscillations and the beating oscillations and all of the other factors including temperature variations, vacuum tube dissimilarity, operating voltages and other circuit elements enter in the problem, thereby rendering it more difficult to obtain the stability required.

In the second method or system which was devised by M. G. Crosby (Crosby Patent #2,279,659, dated April 14, 1942) direct timing modulation is used. A generator of the self-generation type, has its frequency modulated directly by a reactance tube and its mean frequency is stabilized by selecting some of its output, subjecting the same to discrimination and rectification and using the output obtained by rectification to regulate the bias on a control electrode of the reactance tube in a sense to offset or nullify tendencies of the oscillator frequency to drift from its assigned frequency.

This second method and means has been widely accepted and has numerous advantages. The initially modulated oscillations may be of higher

frequency thereby necessitating less multiplication and resulting in simplification of the entire arrangement. By careful attention to the frequency discriminator circuit used to derive the control potentials the carrier frequency can readily be maintained within the assigned limits. However, in any system where a large frequency deviation is used, the modulated wave consists of a large number of side bands of considerable energy content and a carrier of relatively small energy content. This renders more difficult selection and linear conversion of the same by the discriminator (sloping circuit) to obtain control potentials truly characteristic of carrier drift. If the frequency deviation or excursions are reduced to a large degree, say for example, to a degree less than the lowest signal frequency, the modulation then consists of a strong carrier or mean frequency component and a few upper and lower side bands of relatively negligible amplitude. It has been suggested that this reduction of deviation be accomplished by frequency division. This, however, entails a large number of frequency divider stages and again the system becomes unwieldy due to the large number of divider stages and apparatus used with the same.

In my present system direct frequency modulation, as illustrated in said Crosby patent, is used, and in my new improved means and method, to reduce the deviation to derive substantially mainly carrier energy with reduced modulation components for control purposes, I make use of the principle of degeneration.

An object of my invention then is to stabilize the frequency of generated oscillations.

A particular object of my invention is to stabilize the mean frequency of generated oscillations the timing of which is modulated extensively in accordance with signals.

The above objects are attained in accordance with my invention by diverting wave energy from the generator, subjecting the diverted energy to degeneration to an extent such that frequency or phase deviations thereof are reduced to a low value such that they may be subjected to phase detection and the demodulation components used to control the mean frequency of the generator in a sense to wipe out undesired drifts or variations in its mean frequency.

Details of the manner in which the above objects are attained, as well as other objects and the manner of attaining the same, will appear from the detailed description which follows. In this detailed description reference will be made to the attached drawings wherein Figs. 1 and 2

each illustrates schematically and mainly by block diagram, embodiments of timing modulation systems arranged in accordance with my invention, while Fig. 3 illustrates details of the phase detector used in the modification of Fig. 2.

10 is a self-excited oscillation generator designated hereinafter as oscillator #1. This oscillator generator is modulated as to its timing by signals fed to the modulation input of a modulator 14 coupled to the oscillation generator 10. This modulator may be of any approved type and herein is assumed to be of the reactance tube type similar to that shown, for example, in Crosby Patent #2,279,659, dated April 14, 1942.

The timing modulated oscillations are supplied to an output and also to a frequency converter 16 designated hereinafter as converter #1. In this converter, which may be of any well known type, the timing modulated oscillations are heterodyned with oscillations of constant frequency derived from an oscillator 18 which may be of the crystal controlled type.

The timing modulated oscillations are reduced in frequency in converter 16 and supplied to a converter 20 designated hereinafter as converter #2. In this converter oscillations of a reduced frequency are mixed with oscillations from a self-excited oscillation generator 28, designated hereinafter as self-excited oscillator #2.

The output of converter #2, which may be the sum or difference frequency, is supplied to a frequency modulation detector 24 wherein the timing modulations on the wave energy are detected so that at the output from 24 is derived potential variations characteristic of the timing modulation and of the slow changes or drifts in the mean frequency of the intermediate frequency out of the converter in 20. This frequency modulation detector may be of any approved type, such as, for example, as shown in Crosby Patent #2,279,659, dated April 14, 1942, or in Seeley Patent #2,121,103, dated June 21, 1938.

The output selected from 24 is fed through a filter 25, wherein the direct current is removed, and acts through a reactance tube modulator such as, for example, used at 14 to control the self-excited oscillator in 28. Units 20, 24, 26 and 28 comprise a degenerative loop wherein, as will be set forth more in detail hereinafter, the modulations on the wave energy are reduced considerably such as, for example, to a phase amplitude of less than one radian. This degenerative loop utilizes the principle involved in Hansell Patent #2,205,762, dated June 25, 1940, and Crosby Patent #2,197,518, dated April 16, 1940.

In the output of converter #2 due to this degeneration the frequency of the carrier is substantially unchanged while the swing is reduced to a small phase amplitude and the output is fed to a phase detector 38 which also is supplied with oscillations from stable oscillator 18, the output frequency of which is the same as the average frequency of the output of converter #2. A network 50 is provided between the output of the phase detector and the modulator 14 to filter out all audio frequency currents.

The phase detector 38 may be of any approved type and, as illustrated, utilizes the principle involved in Crosby Patent #2,229,640, dated January 28, 1941. In the phase detector it will be noted that the output of converter #2 is impressed by a transformer 40 differentially on a pair of diodes 42 and 44, while the oscillations of constant frequency from 18 are impressed in parallel

by transformer 45 on these diodes. The voltages supplied by transformer 45 to the diode anodes are of like phase and those supplied by transformer 40 are of opposed phase. The phases of the latter swing with changes in phase of the output from 20 so that the resultants on the anodes change differentially in amplitude as do the potential drops in resistance and condenser units 46 and 48. This produces across 46 and 48 a potential which represents the changes in frequency of the carrier in 10. The demodulated components are filtered by resistance condenser units 46 and 48 and, if necessary, by additional filtering circuits in 50 and supplied to the reactance tube modulator 14 in a sense to tend to oppose undesired changes in the mean frequency of the oscillations generated in 10.

The operation of the timing modulation system including self-excited oscillator #1 and modulator 14 is well known in the art, and is described in the Crosby Patent #2,279,659, referred to above.

Some of the timing modulated output energy is fed to 16 and heterodyned with oscillations from crystal oscillator 18 and the difference frequency is selected in converter #1 and fed to converter #2. The difference frequency is taken here in preference to the sum frequency in order that the self-excited oscillator #2 may operate at a low frequency and a relatively low frequency output may be derived from converter #2. The second intermediate frequency output of converter #2 may be at the sum or difference frequency and this output is fed to the phase detector 38 and to the frequency detector 24. The detected modulation out of the detector in 24 controls the reactance tube in 26 to modulate the self-excited oscillator #2 in a degenerative sense, so that when the output of 28 is mixed with the output of 16 in converter #2 the timing modulation is reduced to an extent such that it is represented by not more than one radian phase amplitude. When the sum intermediate frequency is selected at the output of converter 20 the self-excited oscillator #2 is to be modulated in such a direction that the modulation envelope thereof is opposed in phase with respect to the modulation envelope on the energy at the output of converter #1 in 16. By the expression modulation envelope used here I use the term somewhat in the same manner in which it is used in connection with intensity modulation.

When the difference frequency is selected at the output of converter 20, the self-excited oscillator #2 in 28 is timing modulated in such a sense that the modulation envelope of the output thereof is in phase with the modulation envelope of the energy in the output of the converter #1, i. e., the frequency deviations are in the same direction instead of being opposed, as is the case when the sum frequency is selected from converter #2.

The proper polarity of the control potentials supplied to the reactance tube modulator in 26 to obtain the desired sense of control of the self-excited oscillator #2 in 28 to make the loop degenerative, may be obtained in various manners. For example, reversal of the detector 24 output leads reverses the polarity of the control potentials. The use of an additional modulation amplifier coupling stage between detector 24 and 26 will also reverse the polarity of the control potentials. In this respect, it is noted that if the control potentials are of insufficient amplitude to accomplish the desired degeneration to obtain not more than one radian phase swing in the output

of converter #2, an amplifier may be included in the regenerative loop and this amplifier may be at the output of detector 24 and serve the double purpose of correcting the control potential polarity and increasing its amplitude the required amount. The output of converter #2 of reduced phase swing is then fed to phase detector 38, as is output from source 18 and the detected components are filtered and used to control the modulator 14 to tune the oscillator #1.

In the modification of Fig. 2, the phase detector 38' is coupled to converter #1 in 16, to carrier source 18 and also to oscillator #2 in 28. The output of the phase detector 38' is coupled through the audio filter 50 to the reactance tube modulator in 14 and through the direct current filter to the modulator in 26.

The phase detector 38' in the embodiment of Fig. 2, performs the functions of the converter #2 in 16, the detector 24 and the phase detector 38 of Fig. 1. As shown in Fig. 3, a phase detector somewhat as used in Fig. 1, modified to meet the requirements of Fig. 2, is satisfactory. The input supplied at the terminals marked 1 in Figs. 2 and 3, from oscillator #2, is applied differentially to the diodes 42 and 44 by transformer 40'. This input is mixed in 38' with the input 2 from converter #1 applied in parallel to the diodes by transformer 45'. Moreover, this combination or mixing is in a degenerative sense and the polarity of control of modulator 26 is made such by steps described above to insure degeneration in the loop. The sum or difference frequency, say the sum 1.01 mc., plus the radian or less phase modulation resulting from this mixing in the degenerative sense, is also detected in 38'.

The output from 18 is also supplied at the leads marked 3 in Figs. 2 and 3, and fed in parallel by transformer 45' to the diodes 42 and 44. The phase detector 38' therefore, in addition to mixing the outputs of converter #1 and oscillator #2 in a degenerative sense and detecting the resulting current of reduced phase swing, also detect the phase relation of the demodulation components so that the direct current components used in modulator 14, as well as the audio components used in modulator 26, appear in the output leads marked 4 in Figs. 2 and 3. The diodes 42 and 44, which are non-linear circuit elements, form all possible beats between the various signals impressed on them. All the beats with frequencies greater than audio frequencies are bypassed by the capacitors of resistance and condenser units 46 and 48. The net result is that output 4 contains only the audio corresponding to the difference in frequency modulation from the output of the converter in 16 and the output from the oscillator in 28 and a direct current component corresponding to the drift of the oscillations generated in 10 relative to those generated in 18. The condensers 47 and 49 are to tune to resonance the coils across which they are connected. This is not essential but is helpful in obtaining good efficiency.

Referring again to Fig. 1, it is obvious that the output of the phase detector 38 contains audio as well as direct current. This audio may be used to feed the circuits in 25, thereby dispensing with the need of the frequency detector in 24. In addition, as explained above, the #2 converter in unit 20 and the phase detector 38 may be combined as shown in Figs. 2 and 3.

Although I do not propose to limit my system to waves of particular frequencies, I have, merely for purposes of example, indicated on the draw-

ings appropriate frequencies for the various waves used in the various parts of the circuit.

It is noted that the crystal oscillator 18 supplies to the converter #1 in unit 16 a 4.04 megacycle wave and to the phase detectors 38 and 38' a 1.01 megacycle wave. This unit 18 accordingly includes in addition to a crystal oscillator the necessary frequency multipliers or dividers to supply appropriate outputs to obtain the desired frequency for the #1 converter in 16, and the desired frequency for the phase detectors 38 and 38'.

I claim:

1. The method of generating oscillations the timing of which is varied in accordance with signals, and of compensating variations in the mean frequency of the timing modulated oscillations to obtain timing modulated oscillations of substantially constant mean frequency which includes these steps, heterodyning oscillatory energy characteristic of said timing modulated generated oscillations with other oscillatory energy characteristic of said timing modulated generated oscillations in a degenerative sense to derive resultant energy the timing of which varies within small limits in a manner corresponding to variations in the timing of said generated oscillations, detecting said resultant energy and varying the mean frequency of said generated oscillations in a sense to oppose and nullify said first variations in the mean frequency thereof.

2. The method of generating oscillations the frequency of which is varied in accordance with signals, and of compensating variations in the mean frequency of the frequency modulated oscillations to obtain frequency modulated oscillations of substantially constant mean frequency which includes these steps, heterodyning oscillatory energy characteristic of said frequency modulated generated oscillations with other oscillatory energy characteristic of said frequency modulated generated oscillations in a degenerative sense to derive resultant energy the frequency of which varies within about 1 radian in a manner corresponding to variations in the frequency of said generated oscillations, detecting said phase variations and varying the mean frequency of said generated oscillations in a sense to oppose and nullify said first variations in the mean frequency thereof.

3. The method of generating oscillations the phase or frequency of which is varied extensively in accordance with signals and of compensating variations in the mean frequency of the phase or frequency varied oscillations to obtain oscillations of substantially constant mean frequency which includes these steps, heterodyning oscillatory energy characteristic of said phase or frequency varied generated oscillations with other oscillatory energy characteristic of said phase or frequency varied generated oscillations in a degenerative sense to derive resultant energy the phase of which varies within the limits of about one radian in a manner corresponding to variations in the phase or frequency of said generated oscillations, detecting said phase variations of said resultant energy and varying the mean frequency of said generated oscillations in accordance with said detected phase variations and in a sense to oppose and nullify said first mentioned variations in the mean frequency thereof.

4. The method of generating oscillations the frequency of which is modulated extensively in accordance with signals and of compensating variations in the mean frequency of the frequency varied oscillations to obtain oscillations of sub-

stantially constant mean frequency which includes these steps, heterodyning oscillatory energy characteristic of said frequency modulated generated oscillations with other oscillatory energy characteristic of said frequency modulated generated oscillations in a degenerative sense to derive resultant energy the phase of which varies within the limits of one radian in a manner corresponding to variations in the frequency of said generated oscillations, beating said derived phase varied resultant energy against oscillations of a fixed frequency which is the same as the mean frequency of said resultant energy to detect said phase variations, and varying the mean frequency of said generated oscillations in accordance with said detected phase variations and in a sense to oppose and nullify said first mentioned variations in the mean frequency thereof.

5. In a timing modulation system comprising a self-generating generator and a modulator for modulating the timing of the generated oscillations in accordance with signals, a mean frequency stabilizing circuit for said generator including a degenerative loop to which said modulated energy is fed and from which energy comprising primarily carrier energy is selected, a timing modulation detector coupled to said loop and responsive to said selected energy and a control circuit coupling said detector to said generator for controlling its mean frequency of operation in a sense to nullify tendencies of the mean frequency of operation thereof to drift.

6. In a timing modulation system comprising a self-generating generator and a reactance tube modulator for modulating the timing of the generated oscillations in accordance with signals, a frequency stabilizing circuit for said generator including a degenerative loop to which said modulated energy is fed and wherein degeneration is carried out to an extent such that the timing modulation is reduced to not more than one radian deviation, a selecting circuit for selecting the energy of reduced deviation, a phase detector coupled to said selective circuit and responsive to said selected energy and a control circuit coupling said detector to said reactance tube for controlling the mean frequency of operation of said generator in a sense to nullify tendencies of the mean frequency of operation thereof to drift.

7. In a frequency modulation system comprising a self-generating generator and a reactance tube modulator for modulating the frequency of the generated oscillations in accordance with signals, a frequency stabilizing circuit for said generator including a degenerative loop to which said frequency modulated energy is fed and from which energy comprising primarily carrier and signal variations represented by phase deviations within one radian is selected, a phase modulation detector coupled to said loop and responsive to said selected energy and a control circuit coupling said detector to said reactance tube for controlling the mean frequency of operation of said generator in a sense to nullify tendencies of the mean frequency of operation thereof to drift.

8. In a timing modulation system comprising a self-generating generator and a modulator for modulating the timing of the generated oscillations in accordance with signals, a frequency stabilizing circuit for said generator including a degenerative loop to which said modulated energy is fed and from which energy comprising primarily carrier energy is selected, said degenerative loop including a converter wherein said oscillations are heterodyned to a low frequency,

a timing modulation detector, for deriving the modulation, a second generator modulated by the output of the detector and a second converter for heterodyning said low frequency oscillations against the output of said second generator in a degenerative sense, a timing modulation detector coupled to said loop and responsive to said selected energy and a control circuit coupling said timing modulation detector to said first generator for controlling its mean frequency of operation in a sense to nullify tendencies of the mean frequency of operation thereof to drift.

9. In apparatus of the class described, a frequency modulated oscillation generator the mean frequency of operation of which may change, a source of oscillations of fixed frequency and a first converter for deriving corresponding modulated and changing oscillations, means for combining said derived oscillations and said frequency modulated oscillation in degenerative sense to obtain oscillatory energy wherein the modulations have been reduced to phase librations of the order of one radian, a phase detector coupled to said last named means, and a control circuit coupling said phase detector to said first generator to change its mean frequency of operation in a sense to nullify said changes in its frequency of operation.

10. In apparatus of the class described, a frequency modulated oscillation generator the mean frequency of operation of which may change, connections for deriving corresponding modulated oscillations from said generator, other means for deriving other oscillatory energy the frequency variations of which corresponds to modulation of the frequency of said generated oscillation, means for combining said two derived oscillations in degenerative sense to obtain oscillatory energy wherein the modulations have been reduced to phase librations within one radian, a phase detector coupled to said last named means, and a control circuit coupling said phase detector to said first mentioned generator to change its frequency of operation in a sense to nullify said changes in its mean frequency of operation.

11. In apparatus of the class described, an oscillation generator and modulator wherein the generated oscillations are modulated through a wide range and wherein the mean frequency of operation may change, connections for deriving oscillations correspondingly modulated and changed in mean frequency from said generator, other means for deriving other oscillatory energy the frequency modulations of which corresponds to modulations in the frequency of said generated oscillation, means for combining said two derived oscillations in degenerative sense to obtain oscillatory energy wherein the modulations have been reduced to phase librations with one radian, a source of oscillations of a fixed frequency equal to the mean frequency of said last mentioned oscillatory energy, a phase detector coupled to said last named means and to said last named source, and a control circuit coupling said phase detector to said first mentioned generator to change its frequency of operation in a sense to nullify said changes in its mean frequency of operation.

12. In apparatus of the class described, a frequency modulated oscillation generator the mean frequency of operation of which may change, connections for deriving corresponding oscillations from said generator, other means for deriving other oscillatory energy the frequency variations

of which corresponds to changes in the frequency of said generated oscillation, a phase detector for combining said two derived oscillations in degenerative sense to obtain oscillatory energy wherein the modulations have been reduced to phase librations within one radian and for detecting said phase librations, connections between said phase detector and said other means to control the same by the detected audio component to derive said other oscillations, and a control circuit coupling said phase detector to said first mentioned generator to control its frequency of operation in accordance with the direct current component obtained by said phase detection.

13. The method of compensating variations in the mean frequency of timing modulated oscillations to obtain timing modulated oscillations of substantially constant mean frequency which includes these steps, heterodyning oscillatory energy characteristic of said timing modulated oscillations with other oscillatory energy characteristic of said timing modulated oscillations in a degenerative sense to derive resultant energy the timing of which varies within small limits in a manner corresponding to variations in the timing of said oscillations, detecting said resultant energy and varying the mean frequency of said first mentioned timing modulated oscillations in a sense to oppose and nullify said first variations in the mean frequency thereof.

14. The method of compensating variations in the mean frequency of phase or frequency varied oscillations to obtain oscillations of substantially constant mean frequency which includes these steps, heterodyning oscillatory energy characteristic of said phase or frequency varied oscillations with other oscillatory energy characteristic of said phase or frequency modulated generated oscillations in a degenerative sense to derive resultant energy the phase of which varies within the limits of about one radian in a manner corresponding to variations in the phase or frequency of said first mentioned oscillations, detecting said phase variations of said resultant energy and varying the mean frequency of said first mentioned oscillations in accordance with said detected phase variations and in a sense to oppose and nullify said first mentioned variations in the mean frequency thereof.

15. In wave frequency stabilizing apparatus to be used to stabilize the mean frequency of wave energy the instantaneous frequency of which is modulated in accordance with signals and the mean frequency of which may change in an undesired manner, a current frequency converter, means to feed to said converter currents of different frequencies, the instantaneous frequencies of which are modulated in a manner corresponding to the modulations on the said wave energy and the mean frequencies of which may change in said undesired manner, in a degenerative sense such that the modulations on a beat note result-

ing from mixing said currents in said converter are reduced to a small phase amplitude, and means for selecting said beat note and opposing said changes in the mean frequency of said first mentioned wave energy in accordance with the phase changes of the selected beat note.

16. In wave frequency stabilizing apparatus to be used to stabilize the mean frequency of wave energy the instantaneous frequency of which is modulated in accordance with signals and the mean frequency of which may change in an undesired manner, a current frequency converter, means controlled by said wave energy to feed to said converter currents of a first frequency the instantaneous frequency of which is modulated in a manner corresponding to the modulations on the said wave energy, means controlled by said currents of said first frequency to feed to said converter currents of a second frequency the instantaneous frequency of which is modulated in a manner corresponding to the modulations on said wave energy, the two currents being fed to said converter in a degenerative sense such that the modulations on a beat note resulting from mixing said currents in said converter are reduced to a small phase amplitude, and means for selecting said beat note and opposing said changes in the mean frequency of said first mentioned wave energy in accordance with the phase changes of the selected beat note.

17. Apparatus as recited in claim 16, wherein said first means includes a current mixer excited by oscillations of fixed frequency and by said first mentioned wave energy with a coupling between the mixer and converter, and wherein said second means includes an oscillation generator with a wave frequency demodulator excited by the selected beat note, a modulator coupling the demodulator to the oscillation generator, and a coupling between the generator and the converter.

18. In a signalling system comprising a source of oscillations the timing of which is modulated in accordance with signals and the mean frequency of which may drift, a circuit for stabilizing the mean frequency of said oscillations including a degenerative loop to which said modulated energy is fed, and in which the timing modulation on said energy is reduced, and from which energy comprising primarily carrier energy, with reduced timing modulation, is selected, a phase modulation detector coupled to said loop and excited by said selected energy to produce a control potential and a control circuit coupling said detector to said source of oscillations for controlling the mean frequency of said timing modulated oscillations in a sense to nullify tendencies of the mean frequency thereof to drift.

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