

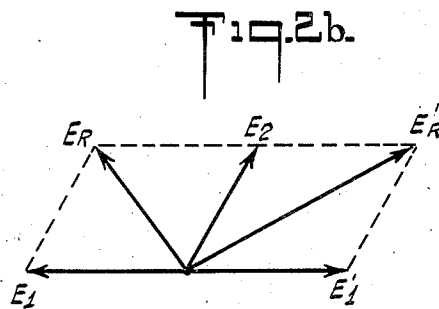
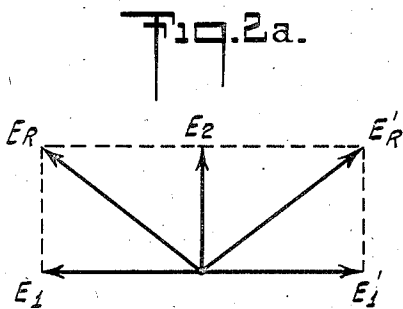
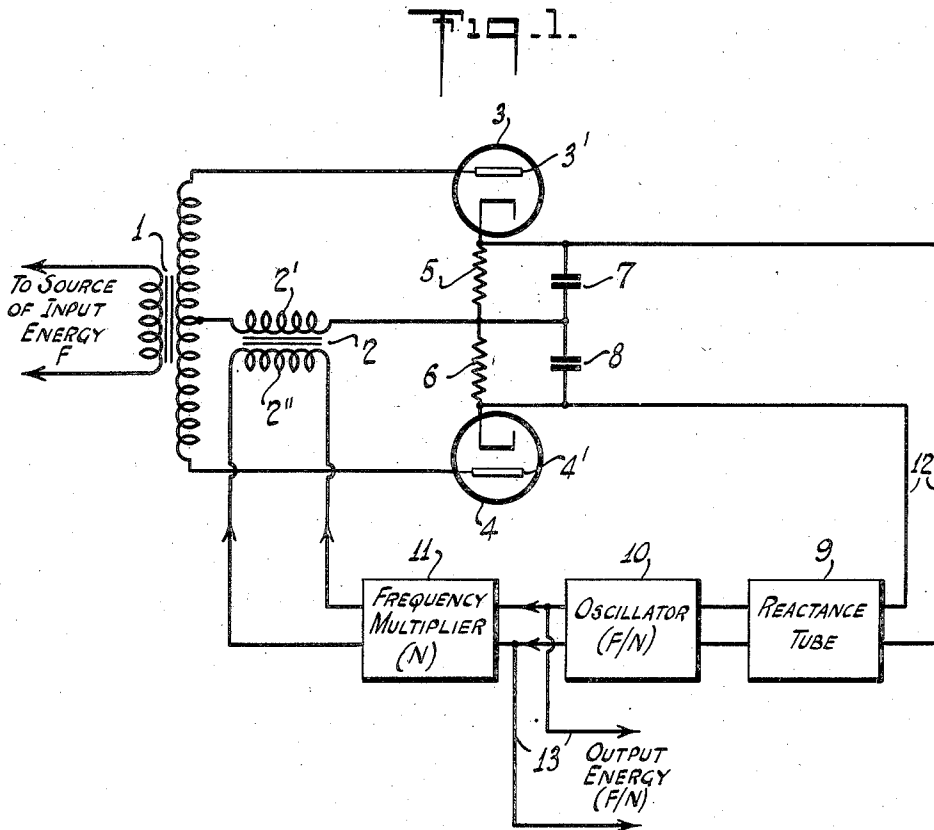
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FREQUENCY MODULATION DIVIDER

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FREQUENCY MODULATION DIVIDER

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1 Claim. (Cl. 250—20)

My present invention relates to frequency divider circuits, and more particularly to a frequency divider circuit of the type employing an oscillator operating at a sub-harmonic of the frequency to be divided.

In the past frequency division has been effected either by self-synchronization of an oscillator, as for example one of the multi-vibrator type, or by means of a regenerative converter system as described in my application Serial No. 385,800, filed March 29, 1941, patented March 21, 1944, as U. S. Patent No. 2,344,678.

One of the main objects of my present invention is to provide a frequency divided circuit which is somewhat like the arrangement in which a self-synchronized oscillator is used, but in which automatic phase control is used in place of self-synchronism.

Another important object of the invention may be stated to reside in the provision of a frequency divider in which an oscillator, operating at a sub-harmonic of the frequency to be divided, is synchronized with the frequency to be divided by means of an automatic phase control circuit.

Yet another object of my invention is to provide a frequency divider system wherein the ratio of frequency division may be increased to any desired value by merely increasing the degree of frequency multiplication subsequent to an oscillator, which is operating at the desired sub-harmonic frequency of the input energy frequency, and which oscillator is under automatic phase control.

Still other objects of my invention are to improve generally the efficiency and reliability of frequency divider networks, and to provide the latter in an economical and readily manufacturable manner.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description taken in connection with the drawing in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

In the drawing:

Fig. 1 shows a frequency divider circuit, portions of which are schematically shown, according to my invention;

Figs. 2a and 2b show vector diagrams to explain the operation of the phase control network of the system.

Referring, now, to Fig. 1 there is applied to the primary winding of the transformer 1 input energy of a predetermined frequency. The input energy may be of any desired frequency range.

For example, I have shown the transformer 1 as an iron core transformer, which indicates that the input energy is in the audio frequency range. On the other hand, by replacing the iron core transformer 1 by tuned transformers, input energy of higher frequencies may be subjected to frequency division. For example, the input energy can readily be angular velocity-modulated carrier wave energy whose center frequency is in the megacycle range. As is well known, and as described in my aforesaid U. S. Patent No. 2,344,678, the center or carrier frequency of an angular velocity-modulated carrier wave, such as a frequency modulated carrier wave, is deviated at the transmitter in dependence upon the amplitude of the modulation signal, and the rate of deviation is dependent upon the modulating frequencies themselves. It is emphasized that the present divider system is independent of the magnitude of the frequency of the input energy. The secondary winding of transformer 1 has its opposite ends connected to the anodes 3' and 4', respectively, of diode rectifiers 3 and 4. The cathodes of the two diodes are connected by series-arranged resistors 5 and 6. The junction of the resistors is connected to the midpoint of the secondary winding of transformer 1 by the secondary winding 2' of the iron core transformer 2. Each of resistors 5 and 6 is shunted by a respective by-pass condenser 7 and 8.

The diodes 3 and 4 and associated circuits thereof provide a phase detector network. To the primary winding 2'' of transformer 2 there is fed oscillatory energy from an oscillator 10. The oscillatory output of oscillator 10 is subjected to frequency multiplication at the frequency multiplier 11. The output energy of the multiplier 11 is applied to the primary winding 2'' of transformer 2. As indicated in Fig. 1, the oscillator 10 is constructed and arranged to produce oscillations at a frequency

$$\frac{F}{N}$$

The multiplier 11 is constructed to multiply the frequency of the oscillatory output of oscillator 10 N times. It will be understood that N is the desired frequency division ratio.

Those skilled in the art will readily understand how to construct the oscillator 10 and the fre-

quency multiplier 11. Any well known devices in the prior art may be utilized for each of these networks. The oscillator 10, operating at the predetermined sub-harmonic frequency of the input energy frequency, may be of any well known stabilized type. The automatic phase control circuit comprises a reactance tube network 9 arranged in well known manner to control the frequency of oscillator 10. The reactive impedance of network 9 is regulated in accordance with the rectified voltage developed across resistors 5 and 6. The rectified voltage is applied to the reactance tube by leads 12. The leads 13, connected to the output of oscillator 10, supply the output energy whose frequency is

$$\frac{F}{N}$$

In other words, there is derived from the leads 13 the frequency divided energy. Where the energy applied to transformer 1 is frequency modulated, the frequency deviation ratio is proportionately reduced.

The multiplication factor of multiplier 11 is adjusted to be equal to the frequency division ratio N . Without the aid of the automatic phase control action, the energies fed to transformers 1 and 2 will be of approximately the same frequency. When the automatic phase control voltage transmitted over leads 12 is applied, the energies fed to transformers 1 and 2 are held in phase synchronism. To produce this phase synchronism the oscillator 10 is maintained at that sub-harmonic frequency and phase which gives the proper frequency and phase for the output energy of multiplier 11.

Figs. 2a and 2b respectively show vector diagrams explaining the operation of the phase detector. For the condition of phase in which the two voltages applied at transformers 1 and 2 respectively are 90 degrees out of phase, the vector relations in Fig. 2a apply. The voltages appearing across the two halves of the secondary winding of transformer 1 are indicated by E_1 and E'_1 respectively. The voltage from transformer 2 is indicated by E_2 which is normal to the voltages across the secondary portions of transformer 1. These voltages combine to form the resultants E_R and E'_R . These resultant voltages are fed to the two detectors 3 and 4. With these equal amplitude voltages fed to the detectors, the differential detector output voltage will be zero. This follows from the fact that the detector resistors 5 and 6 are connected so that the difference between the outputs of the two rectifiers is utilized.

When the phase departs from the condition of 90 degrees relationship, the vector diagram of Fig. 2b applies. For this condition it will be seen that the resultant voltages E_R and E'_R have lost the balanced amplitude relationship that they had in Fig. 2a. The differential detected output voltage will, therefore, be a finite amount which is either positive or negative depending upon the direction of phase departure. Hence, the detectors produce zero voltage output for the 90 degrees condition, and plus or minus output as the phase deviates to either side of 90 degrees.

When such detector potentials are applied to the reactance tube 9, a departure of the oscillator from the 90 degree phase condition causes the detector automatically to develop potential which tunes the oscillator back approximately to eliminate the departure. In this way a phase synchronism is maintained which is equivalent to a

frequency synchronism of within a fraction of a cycle. Such a synchronism is to the same degree obtainable in the type of frequency divider which uses a multi-vibrator which is locked in step with the frequency to be divided.

The reactance 9 may be of any well known type. For example, there may be employed the cathode to plate impedance of a tube. The impedance is connected across the tank circuit of the oscillator, and there is derived by means of an appropriate phase shifter network from the tank circuit an alternating voltage which is in phase quadrature with the alternating voltage across the tank circuit. This phase quadrature voltage is applied to the control grid of the reactance tube. In this way, the impedance of the reactance can be made to simulate a reactive effect whose sign is a function of the reactive nature of the phase shifter network across which the quadrature voltage is derived. Such a circuit is disclosed for example in my U. S. Patent No. 2,278,429, granted April 7, 1942. Those skilled in the art will realize that any other type of variable reactance device commonly employed for automatic frequency control of an oscillator, or for frequency modulation of an oscillator circuit, may be employed at network 9.

It will be seen that the ratio of frequency division may be increased to any desired value by merely increasing the degree of frequency multiplication and tuning the oscillator 10 to the proper lower frequency. Thus, the automatic phase control and oscillator serve for large degrees of division. This is an advantage over the prior types of frequency dividers in which the degree of division for one multi-vibrator stage is limited. Synchronism is also possible at ratios which are not integral, such as 3:2. One way to do this would be to eliminate the multiplier 11. Then, simultaneous detection and harmonic generation take place at the rectifiers.

These non-integral ratios could be more easily generated by inserting an harmonic generator in the input leads to transformer 1. For instance, assume that $F=3$ mc. (megacycles). The input harmonic generator (or multiplier) would then have a multiplication factor of n (for example 4) thereby giving nF (or 12 mc.) output. The oscillator 10 would in that case be tuned to nF/N , assuming N to be a factor of 6, and the multiplier 11 would have a factor of N . The resulting division is, therefore, N/n .

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made without departing from the scope of my invention, as set forth in the appended claim.

What I claim is:

In a frequency divider system, a source of frequency modulated wave energy of a given frequency deviation range, said wave energy having its center or carrier frequency deviated in dependence on the amplitude of modulating signals, a rectifier network having a pair of input circuits connected and arranged in quadrature phase relation, means for applying energy from said source to one of said input circuits, means to provide oscillatory energy at a desired sub-harmonic frequency of the mean frequency of said wave energy, means for multiplying the mean frequency of said oscillatory energy to substantially the mean frequency of said wave energy, means for

applying the multiplied energy to the second of said input circuits, means, responsive to unidirectional voltage developed by said rectifier network in response to substantially instantaneous phase deviations from said phase quadrature relation, for substantially instantaneously controlling said sub-harmonic frequency energy in a sense to

maintain synchronism between the frequency deviations of said modulated wave energy and the latter and means to derive from said oscillatory means said sub-harmonic frequency energy with a frequency deviation range which is reduced relative to said given range.

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