Feb. 24, 1925. 1,527,228

J. C. SCHELLENG

METHOD OF HARMONIC OR SUBHARMONIC FREQUENCY PRODUCTION

Filed Dec. 29, 1923

Fig. 1

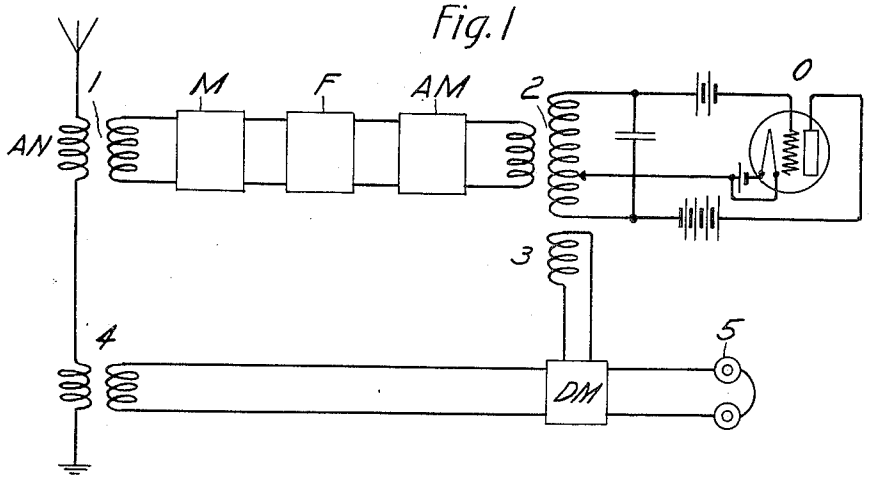
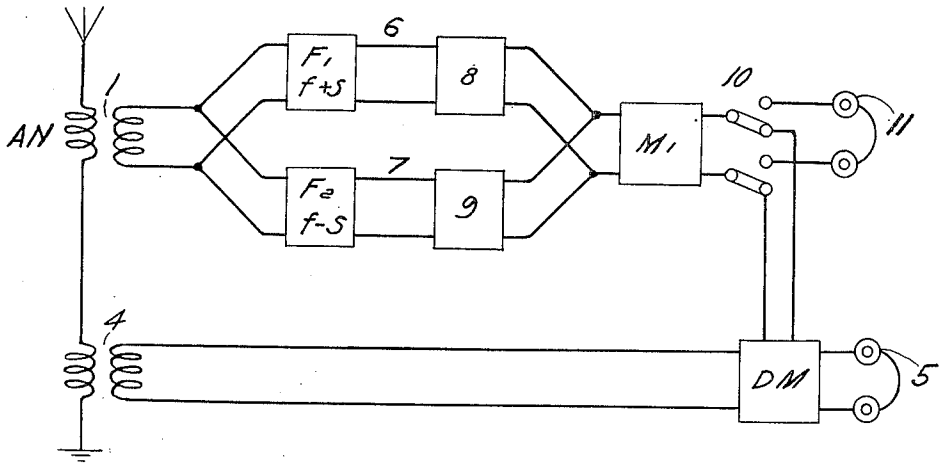


Fig. 2



Inventor:
John C. Schelleng
by E. W. Adams Atty

Patented Feb. 24, 1925. 1,527,228

UNITED STATES PATENT OFFICE.

JOHN C. SCHELLENG, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

METHOD OF HARMONIC OR SUBHARMONIC FREQUENCY PRODUCTION.

Application filed December 29, 1923. Serial No. 683,303.

To all whom it may concern:

Be it known that I, JOHN C. SCHELLENG, a citizen of the United States of America, residing at East Orange, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Methods of Harmonic or Subharmonic Frequency Production, of which the following is a full, clear, concise, and exact description.

This invention relates to the production of oscillations and particularly to methods of and systems for the production of oscillations the frequency of which has a definite relation to the frequencies of the currents from one or more different sources.

An object of the invention is to generate a wave whose frequency is a desired multiple or sub-multiple of a given frequency.

Another object of the invention is to produce a wave which has a frequency equal to the average of the frequencies of the upper and lower side bands of a modulated carrier wave, that is, to produce a wave whose frequency is the arithmetic means of the frequencies of the two side bands.

A still further object is to provide an efficient circuit for the reception of a pure modulated wave, including improved means for locally producing and maintaining at the desired frequency, the unmodulated carrier wave required for signal detection.

The objects of the invention are realized in circuit arrangements utilizing an oscillator for producing a complex wave whose fundamental frequency is normally approximately that of the desired sub-harmonic frequency and having a harmonic approximately equal to the reference frequency. The current of the reference frequency is caused to coact with the current of the harmonic frequency in the oscillation circuit of the oscillator. The effect of such coaction on the oscillator is to pull it into step with the frequency of the impressed current, that is, to cause the reference and harmonic frequencies to become identical. The fundamental frequency is thus correspondingly automatically adjusted to exact sub-harmonic relationship with the reference frequency.

The above described principle has particular application in a system for deriving a carrier frequency wave from upper and lower side bands based upon the carrier frequency wave and especially in a carrier wave receiving system characterized by the transmission of a pure modulated wave, that is, a wave having no unmodulated component. The use of this type of transmission has pronounced advantages in the way of efficiency, and secrecy. Its most serious limitation has been the difficulty that attends the production at the receiver of a wave having at all times the frequency of the unmodulated carrier used at the transmitter.

The production of the unmodulated carrier may be accomplished by means of the present invention by combining the received side bands, selecting the resulting component of double carrier frequency and causing it to operate upon a local oscillator in the manner described above to produce the first even sub-harmonic, i. e., the desired carrier frequency.

An alternative method involves the step of first producing currents whose frequencies are sub-harmonics of the respective side band frequencies and then combining these currents to produce a current of the carrier frequency.

It should be noted that the method of harmonic or sub-harmonic frequency production of the invention is not based on an analysis of the reference wave as in common forms of harmonic or sub-harmonic producers. It differs essentially also from a type of harmonic producer illustrated for example, by U. S. patent to Affel, No. 1,450,966 issued April 10, 1923, in which interaction between the reference current and the current derived from a harmonic generator tends to produce a component proportional to the difference in frequency, which, in turn, produces a proportional effect on the frequency of the generator by actuating mechanical impedance varying means, or the like. The method of the invention is marked by simplicity, sensitivity, positiveness of control, direct result, and inherent accuracy.

A better understanding of the invention

both in its broad and specific aspects will be afforded by the following description in which typical embodiments and other objects will be pointed out as the description proceeds.

In the drawing to which reference will now be made,

Fig. 1 illustrates a sub-harmonic frequency producing arrangement of the invention and also a system in which it may be practically applied and

Fig. 2 illustrates another form of arrangement designed to produce the same ultimate result as that of Fig. 1.

The system of Fig. 1, as a whole, will be described in connection with the particular sub-harmonic producer which constitutes a part thereof.

The system of Fig. 1 is designed to receive two side bands of a modulated wave from which the unmodulated component has been suppressed and to reproduce therefrom signal modulations. The received waves constituting side bands which are incident on antenna AN are impressed through transformer 1 on modulator M. This modulator may be of any type capable of distorting the impressed waves to produce components whose frequencies are the sums and differences of the frequencies of the impressed components. A practical example of vacuum tube modulator adapted for use in the system of Fig. 1 is described in U. S. patent to Wold, No. 1,424,866, issued August 8, 1922. In this patent the modulator indicated in the drawing by M combines the received side bands in a manner similar to that of the present invention to similarly produce, among other components, a double carrier frequency component.

Filter F selects the resultant double carrier frequency component to the exclusion of all of the other components. Filters whose design is appropriate to the function here described, are described in Campbell Patent No. 1,227,113, issued May 22, 1917. Amplifier AM amplifies the selected double carrier frequency component and impresses it through transformer 2 on oscillator O. The oscillator illustrated is of the type described in detail in the patent to Hartley, 1,356,763 issued Oct. 26, 1920. Any other type of oscillator may be used provided only that its frequency is determined by the impedance characteristic of a circuit which is adapted to be coupled with external circuits from which control waves may be impressed.

Oscillator O is designed to generate a wave whose fundamental or a harmonic thereof is approximately the desired frequency and which has a harmonic which has a frequency approximately equal to that impressed from transformer 2. If the harmonic frequency is sufficiently near the frequency of the impressed current, this current can, under certain conditions, pull the oscillator, through this harmonic, into step with the impressed wave. The fundamental frequency of oscillator O together with the other harmonics will undergo a corresponding adjustment so as finally to have a frequency corresponding to an exact sub-harmonic of the impressed current, the order of this sub-harmonic being determined by the particular harmonic of the fundamental on which the pulling-in effect is exerted.

In the system illustrated, oscillator O is pulled into step with the double carrier frequency by means of its first even harmonic so that the resultant sub-harmonic has a frequency corresponding to that of the unmodulated carrier. This carrier frequency current is transmitted through transformer 3 to demodulator DM where it is combined with side band currents incident on the antenna and impressed on the modulator from the secondary of transformer 4, to reproduce the modulated component in indicator 5. Demodulator DM in its essential principle of operation is similar to a modulator and may utilize a circuit arrangement identical with that used for modulator M.

The theoretical reasons for the function of the control wave in pulling the oscillator into step with its own frequency is more or less obscure and is incapable of simple mathematical analysis. It is true that this action cannot arise in a system all of whose electrical characteristics are linear. No interaction between fundamental and harmonics, or between any of the two frequencies is possible except through this distorting action of some element of the circuit, such as a space discharge device.

It is old to cause two oscillators to be pulled into step with other oscillators or for one current to pull an oscillator into step with its own frequency. See, for example, U. S. patent to Hazeltine, No. 1,379,184 issued May 24, 1921. Important features of the invention are the utilization of a harmonic of the generated wave in performing the function of pulling an oscillator into step and the utilization of one frequency component for the pulling-in function in order to produce another frequency component of either higher or lower frequency than the first mentioned, and the utilization of the principle of sub-harmonic frequency production in producing an unmodulated carrier component from its modulated side bands.

One of the conditions that must be present to insure the success of the pulling-in function is a sufficiently close initial degree of synchronization. Also, since the effect of the impressed current is similar to that of an actuating means in a system for producing forced ocillations, the coupling should preferably be close. The method of operat-

ing the system of Fig. 2 is similar to that of Fig. 1 but the order of steps is different. A portion of the incident wave is impressed through transformer 1 on circuits 6 and 7. The two side bands are each constrained to flow in an individual one of these two circuits by selective circuits F_1 and F_2 which may be similar in design to filter F of Fig. 1. In the particular case illustrated, the upper side band, $f+S$ is made individual to circuit 6 and the lower side band $f-S$, to circuit 7. The first even sub-harmonics of these side bands, that is, currents of frequencies

$$\frac{f+S}{2}$$

and

$$\frac{f-S}{2},$$

respectively, are produced by the circuits indicated by blocks 8 and 9. These circuits may comprise a combination identical with the combination of amplifier AM, transformer 2, oscillator O and transformer 3, of Fig. 1.

The resultant sub-harmonic frequency currents are combined in modulator M to yield a component frequency equal to the sum of these frequencies, that is, the unmodulated carrier frequency f. This carrier is utilized in demodulator DM to reproduce the signal component which is indicated in telephones or the like 5 as in Fig. 1, the switch 10 being in its lower position.

In the operation of the system of Fig. 2, it is apparently required that the controlled oscillator be kept in step with a variable frequency control current. To the extent that this result is actually realized, that is, that the fundamental frequency has all values of

$$\frac{f+S}{2}$$

and

$$\frac{f-S}{2},$$

modulation in modulator M will yield the difference frequency component S, as well as the carrier f. Accordingly, the desired signal may under some conditions be reproduced directly from indicator 11 by actuating switch 10 to its upper position. Obviously a single indicator could be used to perform the functions of indicators 5 and 11.

As a matter of fact, it is impossible to cause the control oscillator to follow the multiplicity of frequencies in their complex variations of amplitude if speech signals, for example are used. In general, however, this failure of the control oscillators to follow rapid variations of the impressed frequencies is not detrimental to the success of the function of producing the unmodulated carrier.

If the frequency of the carrier wave is so high as to make separation of its side band by filters F_1 and F_2 difficult, the frequency of the incoming side bands may be stepped down by conventional methods. After the separation of the corresponding side bands of the reduced frequency, they may be stepped up to the original high frequencies. Means for accomplishing this function are common in the art, being described, for example, in U. S. patent to Affel, No. 1,353,698 issued September 21, 1920. A similar means may be used in connection with filter F of Fig. 1 in order to separate the frequency $2f$ from the component $2f+2S$, although it is probable that if both of these components were present in the control circuit, the oscillator would tend to keep in step with the constant frequency $2f$ rather than with the variable frequency.

Although the invention has been described as applied in a radio receiving system, it may equally well be applied in any other system employing modulated carrier waves.

In the claims the word "harmonic" will be used to define a quantity, which is an integral multiple of another quantity including unity.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. The method which consists in generating a reference frequency wave, generating another wave having a plurality of harmonically related frequency components, the frequency of one of which is approximately that of the reference frequency, synchronizing one of the harmonic frequencies with the reference frequency by interaction between the energies corresponding to said frequencies, and utilizing one of the other harmonic frequency components.

2. The method using a source of reference frequency currents and a source of complex currents having harmonically related components and including a frequency determining resonant circuit, which consists in transducing energy from the first source to the frequency determining circuit of the second source to pull the frequency of one of the harmonics of said complex current into step with the frequency of the current from the first source, and utilizing the energy of one of the other harmonics.

3. The method of frequency division, which consists in generating a current having a plurality of harmonics, synchroniz-

ing one of the harmonic frequencies with the reference frequency by interaction of the energies corresponding to said frequencies, and utilizing another harmonic which corresponds to the desired fraction of the reference frequency.

4. The method of deriving an unmodulated carrier component from its modulated side bands which comprises combining said side bands to produce a double carrier frequency component and producing the first even sub-harmonic of said double frequency component.

5. The method which comprises producing a carrier wave of relatively high frequency and a speech wave, modulating the carrier wave by the speech wave to produce side bands and eliminating the unmodulated carrier component, transmitting the side bands to a distant point and there utilizing their energy to control the reproduction of a wave of the carrier frequency.

6. The method which comprises producing a wave of a given frequency from two side-bands resulting from the modulation of a wave of said given frequency by a speech wave.

7. The method of deriving an unmodulated carrier component from its modulated side bands, which consists in combining said side bands, selecting the resultant double carrier frequency component, generating a wave having a pronounced first even harmonic, and synchronizing the double carrier frequency component with the said harmonic, whereby the fundamental wave has the frequency of the unmodulated carrier.

8. The method of receiving a modulated wave from which the unmodulated carrier has been suppressed, comprising intermodulating a portion of the side bands of said wave, selecting the resultant double carrier frequency component, generating a wave having a pronounced first even harmonic, synchronizing the frequency of the double carrier frequency wave with said hormonic, and combining the fundamental with another portion of the side bands to reproduce the modulated component.

9. The method of receiving a signal modulated suppressed carrier wave, which comprises independently generating two waves, each of which has a pronounced first even harmonic, synchronizing a portion of each of the side bands of said wave with the even harmonic of one of said generated waves, combining the resultant fundamental component to produce the carrier frequency, and combining said carrier frequency with another portion of each of the side bands to reproduce the signal.

10. The method of frequency division, using an electrical oscillating circuit having a plurality of degrees of freedom, the frequencies of vibration differing from each other at all times by fixed ratios, and a source of reference currents, which consists in using the current of reference frequency to force said circuit into vibration at said reference frequency, and utilizing the energy of other modes of vibration.

11. In combination, a source of current, a harmonic oscillator having a resonant frequency determining circuit, means for impressing the current from said source on said circuit to force it into oscillation at a harmonic frequency equal to the frequency of said current, and means for obtaining from said oscillator a current of a different harmonic frequency.

12. A carrier wave system comprising means for producing and transmitting a signal modulated suppressed carrier wave, a receiving conductor therefor, means for combining a portion of the received components of said wave, means for selecting the resultant double carrier frequency component, a harmonic electric discharge oscillator having a resonant frequency determining circuit, means for impressing said double carrier component on said circuit to pull said oscillator into step therewith with reference to the first even harmonic frequency, means for obtaining the fundamental frequency component from said oscillator, and means for combining said fundamental frequency component with another portion of the received components to reproduce the signal.

13. The method of obtaining a wave whose frequency is the arithmetic mean of the mean frequencies of two frequency bands each containing at least one frequency, which comprises combining said frequency bands to produce a resultant component whose frequency is the sum of said mean frequencies and producing the first even sub-harmonic of said resultant component.

14. The method of obtaining a wave whose frequency is the arithmetic mean of the mean frequencies of two frequency bands each containing at least one frequency, which comprises combining said frequency bands to produce a resultant component whose frequency is the sum of said mean frequencies, generating a current having a plurality of harmonics, synchronizing one of the harmonic frequencies with the frequency of said resultant component by interaction of the energies corresponding to said frequencies, and utilizing another harmonic which corresponds to the first even sub-harmonic of said resultant component.

In witness whereof, I hereunto subscribe my name this 26 day of December, A. D. 1923.

JOHN C. SCHELLENG.