Feb. 3, 1948. A. V. WURMSER 2,435,262

SELF-MODULATED OSCILLATOR

Filed Jan. 26, 1944 2 Sheets-Sheet 1

FIG. 1

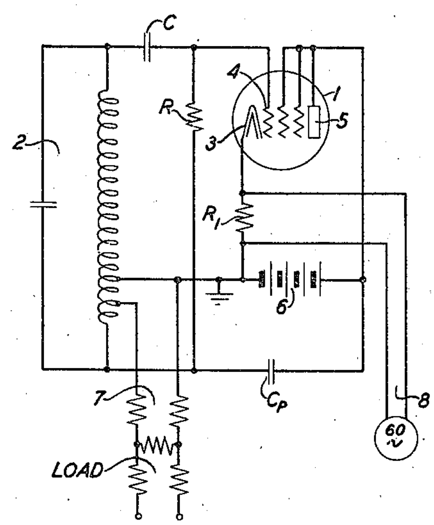
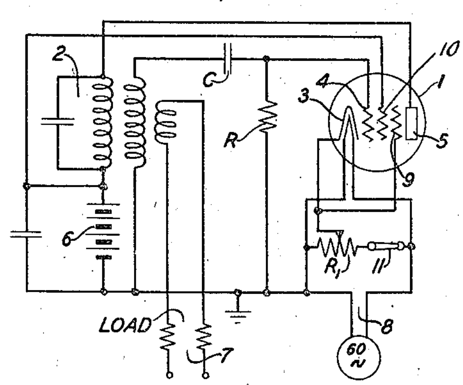


FIG. 2



INVENTOR
A. V. WURMSER
BY Guy T. Morris

ATTORNEY

FIG. 3

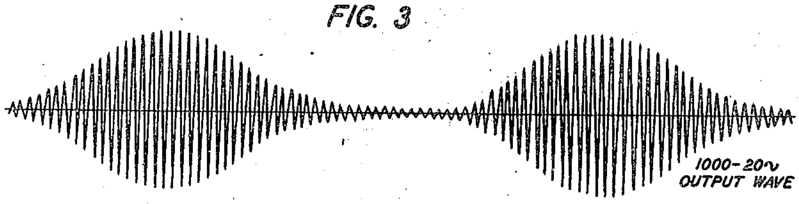


FIG. 4

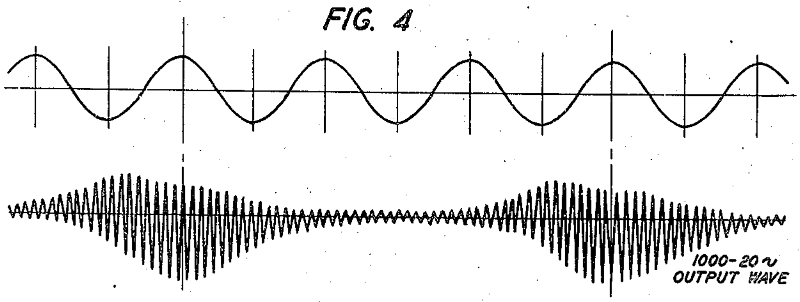


FIG. 5

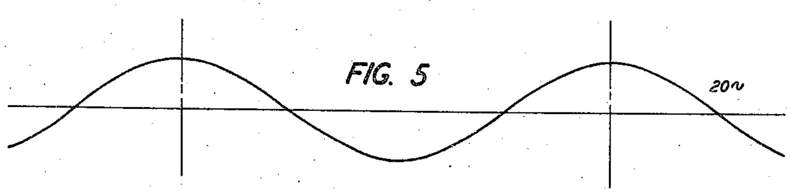
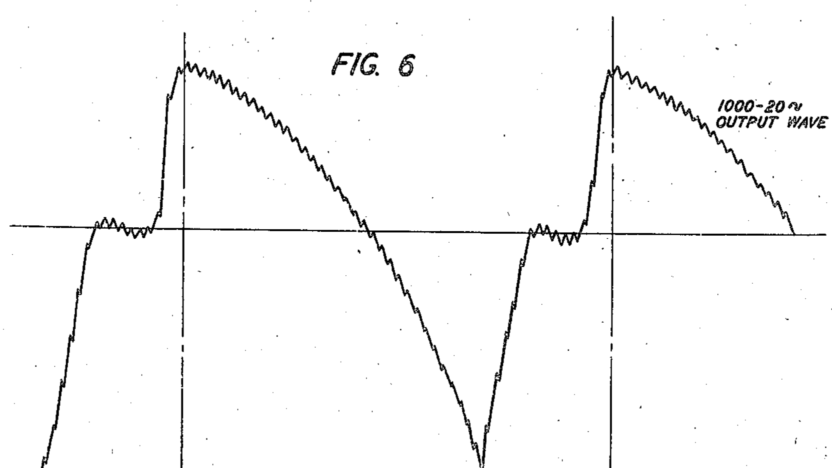


FIG. 6



INVENTOR
A. V. WURMSER
BY Harry T. Morris

ATTORNEY

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SELF-MODULATED OSCILLATOR

Alphons V. Wurmser, Bogota, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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7 Claims. (Cl. 250—36)

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This invention relates to an oscillator-moderator and particularly to an electric discharge oscillator of this type and therefore to an electric discharge oscillator which is self-modulating. That is, the organization of the invention comprehends in a single electric discharge device and its immediately associated circuits, means for generating the higher frequency wave, that is, the carrier wave, and the relatively low frequency wave, that is, the modulating wave, together with means for intermodulating the same so as to effectuate the intermodulation products, namely, the side-band frequency waves. As a corollary, to indicate the comprehensibility and versatility of the invention, the organization is capable of being used as a source for either of the component frequencies per se.

The primary object of the invention is to achieve the above functions with the simplest possible circuit organization consistently with the adequate performance of such functions; with respect, for example, to the production of adequate power at each of the frequencies for which the organization is apt to be used, with respect to adequate constancy of frequencies in the device, and the like.

A specific object, the corollary of the above object, is to achieve the complex result implied by, to as large an extent as possible, utilizing circuit elements necessarily present in an organization to achieve generation of the wave of one of the component frequencies only, so that, to as great an extent as possible, the complexity of result is not the function of a corresponding complexity of circuit organization.

Certain difficulties have attended organizations of this generic class in the prior art, these largely having to do, for example, with undesirable and unstable interactions of the two component frequencies, leading, for instance, to overmodulation or interruption of the carrier wave at the modulating frequency when a true modulation is desired.

Another specific object of the invention is to achieve the above functions without inducing any other function and, therefore, so that the output waves (either the intermodulation products or waves of the component frequencies themselves) have no impurities which are not inherently characteristic of the function.

In what follows, it will be assumed, partly by way of illustration but also having in mind an organization in which the invention is well adapted to be used and which has been experimentally used, that the two component frequencies have

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particular values, within the audible frequency range, namely, 1,000 and 20 cycles. It should be understood, however, that the inventive principle is not at all limited to use at these frequencies or even to frequencies within the audible range. The organization assumed is sometimes described as a 1,000–20-cycle oscillator or as an oscillator which gives a 1,000–20-cycle output. Such an oscillator constitutes a 1,000–20-cycle ringing source in a well-known signaling system. This means that the output wave is an audible frequency wave having primarily a 1,000-cycle frequency but which is interrupted or modulated (strictly a modulation, that is, a sine wave modulation, in the present instance) at 20 cycles. Such a source elaborated, as in the present instance, to make possible the capability also of deriving a 1,000-cycle and/or a 20-cycle wave per se has additional practical applications which are not of present concern.

The above objects are achieved in the above practical example by an organization comprising primarily a 1,000-cycle electric discharge feedback oscillator of the conventional conductance-capacitance type, although the particular type is relatively immaterial, which by the injection of a small 60-cycle synchronizing frequency produces a 1,000–20-cycle output wave which is, accordingly, locked in and controlled by the injection frequency. Instead of the above modulating and injection frequencies any other two frequencies may be used provided there is a commensurable relation between them. The exemplary 20-cycle frequency determining elements comprise a small resistance and a very small condenser instead of the alternative large condenser and inductance that would be conventionally used if the circuit generated a 20-cycle wave as an LC prime source or even instead of the large resistance and condenser of an alternative RC prime source. The organization is not a prime source as to this frequency, that is, a source as distinctive as the 1,000-cycle prime source, because the resistance and capacitance elements are adapted from existing elements of the 1,000-cycle wave oscillator, being in fact the grid resistance and capacitance elements normally used although differently evaluated in accordance with the specific function. While such a resistance-capacitance circuit is not fundamentally as stable a frequency-determining circuit as an inductance-capacitance combination, the use of the injection frequency, which itself is stable, obviates any difficulty of this kind. The necessity for the use of the injection frequency source, considered as added to the necessary elements of the prototype organization, has no implications as to an increase in the size of plant or of the complexity of the circuit, since the 60-cycle (for example, having in mind the most commonly available frequency) source may be used to excite the cathode of the tube. The result in fact is a comparatively very simple, inexpensive, organization, very well adapted to produce the desired side-band frequency or frequencies. Further, by an analogous demodulation action a 20-cycle wave, as such, may be easily derived from the circuit. This last feature is important because, consistently with the simplest and least expensive organizations as above, the circuit would not ordinarily be capable of generating this 20-cycle wave directly. Of course, a 1,000-cycle wave may likewise be derived from the circuit because of the amplifier aspects of the tube, as in any other conventional modulating device.

A more complete understanding of the invention will be facilitated by the following detailed description of the oscillator as exemplified in two specific forms, especially with reference to the drawing, in which:

Figs. 1 and 2 are circuit exemplifications of the two species, or at least alternative forms, of the invention; and

Figs. 3, 4, 5 and 6 are scale representations of oscillograms made from a Fig. 1 circuit and intended here to be of assistance to the description in teaching the function and operation of the invention.

With reference to the circuit of Fig. 1, tube 1 in cooperation with tuned, frequency-determining circuit 2, together with attendant circuit elements, each performing a conventional function, comprises a well-known type of negative grid, feedback, space discharge oscillator, commonly described as a Hartley type oscillator. Therein the necessary phase-reversing feedback or coupling between the output and input circuits of the electric discharge tube is achieved by the tuned circuit since the cathode 3 of the tube is connected to a point in the inductance constituting a part of said circuit at a point intermediate the connections from said inductance to the control electrode 4 and the anode 5, this cathode connection passing through cathode lead resistor R_1, the function of which will be indicated later. The electric discharge tube that has been used in this circuit, and is intended to be represented in this Fig. 1, is an RCA tube designated 6SJ7. This is a standard pentode tube but has been used in the Fig. 1 circuit, as is here indicated, as a triode, the suppressor and shield grids being directly connected to the anode so as to effectively constitute a portion thereof, the connection, of course, being made externally of the tube. It should be emphasized at this place that the choice of tube is not very critical and that the tube could be employed as a pentode tube, quite analogously as in Fig. 2 to be described. Similarly, the Fig. 2 circuit could employ the triode connection illustrated by Fig. 1. Of course, a filamentary cathode, instead of the indirectly heated cathode as shown, would be appropriate.

The accessory or attendant electrical elements of the oscillator not so far described are quite conventional. The oscillator is presumed to generate the carrier frequency wave, that is, the 1,000-cycle wave, in the particular instance in mind. The anode is supplied by potential source 6, the circuit to cathode being completed through ground and the above resistance R_1. The connection of circuit 2 to the anode is through a capacitor C_p which, as a blocking condenser, serves to prevent the impression of potential from source 6 on the frequency-determining circuit which, among other things, would result in a near short-circuit of said source through a part of the inductance of said frequency-determining circuit. The capacitor C and resistor R cooperate in the usual way, in relation to the associated circuit and tube elements to insure the correct control electrode bias for efficient operation. In the present instance, as will be more apparent later, since the tube functions not only as the amplifier element of a feedback oscillator, but also as the modulating or combining device, with respect to the two frequencies concerned, the control electrode bias would determine a potential on a non-linear portion of the tube characteristic. The output of the circuit, considered either as a 1,000-cycle oscillator or, anticipating a later description, as an oscillator-modulator, may be taken off by circuit 7 connected to the frequency-determining circuit as shown. The impedances into which the output circuit looks at this point makes this connection appropriate for either of these purposes, although since the potentials at this point partake of those at both the control electrode and anode, the connection could, although less effectively, be made at either one of these elements alternatively.

The elements C and R, while functioning as above, have another function which is an important feature of the invention. These elements play a primary role as the frequency-determining circuit for the modulating frequency, 20 cycles in the example in mind. It is obvious that an RC circuit, as here exemplified, can perform such function because of its time constant analogously as the more customary LC circuit which is here illustrated as determining the 1,000-cycle frequency. This RC circuit could be otherwise placed and, if especially placed, it quite possibly could determine a modulating frequency by a self-sustained oscillator action. However, consistently with its double role, as above, which is very greatly in the interest of simplicity and economy of plant, it would not ordinarily serve such a function. Accordingly, an injection frequency, and action are required. This is achieved by the injection circuit 8 whereby an injection frequency, 60 cycles in the example in mind, tends to coerce the circuit as a whole to which it is connected to oscillate at its own frequency or, in the alternative and as in the circuit of the invention, at a commensurable frequency invited by a particular tuning or time constant of an impressed circuit. In the present instance such impressed circuit is the RC circuit which has a time constant close to 20 cycles and is made to promote an oscillation of exactly 20 cycles since this is the closest commensurable frequency with relation to the injection frequency. It is obvious that the injection frequency potential, which is applied across the cathode lead resistance R_1, is impressed, although indirectly, on the RC circuit.

The operation of the organization as a whole should now be quite plain. The organization as a whole tends to oscillate at the respective component frequencies, that is, 1,000 cycles and 20 cycles, and the tube, by the non-linear relationship between control electrode potential and anode current, achieves intermodulation of these two frequencies. The action, in the present instance, is quite conventional in triode tubes or in tubes illustrating conventional triode functions, and is sometimes known as the Van der Bijl type of modulation. The action may be thought of as changing the control electrode potential by the modulating waves so as to correspondingly modify the amplification characteristics of the tube, since the characteristic relationship between control electrode potential and anode current at a given point on the characteristic curve expresses the amplification at the corresponding point. The final result is that a modulating frequency envelope is impressed on the carrier frequency wave occurring in the anode-cathode circuit. It is apparent that with the ultimate result achieved in the particular way illustrated by Fig. 1 there is a comparative simplicity and economy of plant. Because of the injection action this achievement is attended by no sacrifice of frequency stability because of the use of an RC, instead of an LC, frequency-determining circuit. This, of course, assumes that the injection frequency is itself stable, which can easily be achieved in practice.

Figs. 3, 4, 5 and 6 are scale reproductions of actual oscillograms illustrating features of operation and in particular illustrating, quantitatively, the presence of both the component frequencies per se and their intermodulation products. These oscillograms were made with the Fig. 1 circuit. In particular they illustrate how the desired functions are achieved without depreciation of the alternative functions of the organization as generators of sine wave component frequencies. That is, intermodulation is not attended by any extraneous distortion, so that there is a smooth, sine wave modulation of the 1,000-cycle frequency by the 20-cycle frequency as distinguished from a mere interruption at that frequency, or even of an unstable modulation short of actual interruption as might be expressed as an occasional overmodulation, either of which would not as well subserve all of the desired purposes.

Fig. 3 is an oscillogram of a voltage taken in the output circuit of Fig. 1. As in each of the other oscillograms and as has been assumed by way of example all along, the two component frequencies are 1,000 cycles and 20 cycles with a 60-cycle injection frequency. In this oscillogram the injection potential was 1 volt and this oscillogram was one of several illustrating the effect of varying the injection potential. This particular oscillogram of the series shows nearly the optimum injection potential, although a variation in either direction of as much as 40 per cent or thereabouts was found not to greatly change the purity of the modulated product. At greater divergences of injection potential the 20-cycle envelope becomes more ragged and then tends to break first into 30 cycles and then into 60 cycles, that is, into the injection frequency. The Fig. 3 oscillogram is significant as showing a nearly perfect modulation in that the envelope accurately reproduces a 20-cycle sine wave. Also, although perhaps not quite so significant, there is complete modulation as indicated by the envelope coming all the way down to the axis.

Fig. 4 is an oscillogram like that of Fig. 3 but taken across resistance R. Otherwise the conditions are exactly as for Fig. 3, for example the same injection potential is used, and, therefore, are closest to optimum. A 60-cycle sine wave was superposed on the original of the oscillogram and is accordingly included in Fig. 4. This oscillogram shows, in comparison with Fig. 3, that there is a choice of places from which to derive the output side-band waves and also that it is possible to exercise a considerable discrimination in this choice since the wave at this point has nowhere nearly as great purity as if taken at the indicated output point in Fig. 1, as shown in Fig. 3. The conditions across this resistance R would tend to be nearly the same as across the input electrodes of the tube. The reason for good wave form as shown in Fig. 3, as compared with Fig. 4, is that it is taken from the tuned circuit, which allows the side-band frequencies to flow and in turn suppresses any low frequency from flowing due to low impedance to the 20-cycle component and the like. That is, it removes the distortion shown in Fig. 4.

Fig. 5 is, similarly as Fig. 4, like Fig. 3. It differs in that the oscillogram was taken across the plate condenser C_p. The wave is very evidently a 20-cycle wave, showing that although a 20-cycle wave is not self-sustaining as is the 1,000-cycle wave, it may be derived from the circuit in all of the purity that would attend, for example, the use of an LC self-sustained oscillator to generate such a wave, as in the instance of the 1,000-cycle wave. That is, the use of the injection frequency insures, with as gross a frequency-determining circuit as the RC circuit in question, as perfect a result as could be desired. Of course, this 20-cycle wave results from a demodulation of the side-bands illustrated in the two above oscillograms.

Fig. 6 is an oscillogram of a voltage taken across condenser C of Fig. 1. This voltage is the effective grid bias voltage of the oscillator tube. The oscillogram shows that the bias is varied at a 20-cycle rate and that this effect changes the gain of the tube to produce the 1,000–20-cycle output. This is not a pure 20-cycle wave due to distortion. For a fairly good 20-cycle wave form the best position would be across condenser C_p is in Fig. 5 because at that point there is high impedance to 20-cycle current and low impedance for the higher extraneous frequency currents present in the distorted 20-cycle wave existing in the grid circuit. It was one of a series illustrating the effect of the use of different injection potentials, as in the instance of Fig. 3 and which series as a whole showed the same sort of evolution. That is, with increase of injection voltage from zero there was first a 60-cycle wave with a 1,000-cycle ripple superposed on it, followed by an imperfect 30-cycle wave and then by the 20-cycle wave that is characteristic of the circuit. For this oscillogram, as for those of Figs. 3, 4 and 5, the injection voltage was 1.

As has been before stated, the Fig. 1 circuit has been used to demonstrate the efficacy of the circuit of the invention, as shown by the above oscillogram. The following are the actual specifications of electrical values used in that circuit:

Tuning inductance=0.169 henry
Tuning capacitance=0.15 microfarad
C=0.02 microfarad
R=1.8 megohms
R_1=100 ohms
C_p=1 microfarad
Battery voltage=130

Fig. 2 illustrates an alternative form of the invention as to the circuit for generating the 1,000-cycle wave and the connections of the tube elements to associated circuits. In these respects the figure merely indicates the versatility of the invention since, having in mind the ultimate result, there is very little choice as between these two figures or between the different specific expedients illustrated in them, and of which a great many others could have been illustrated by additional figures. The particular purpose of Fig. 2, however, is to indicate the reason for the choice of the 60-cycle injection frequency and to justify the seemingly increased complication required by the use of such injection frequency. This teaching, of course, is as applicable to the Fig. 1 circuit as to the Fig. 2 circuit. Except for this teaching the Fig. 2 circuit differs from that of Fig. 1 specifically in the use of what is sometimes called a reversed feedback or tuned output feedback oscillator which is only a slight variant from the Hartley oscillator of Fig. 1, in its last analysis, and itself is known as one form of the Hartley oscillator, and in the use of a pentode tube as such as against the (effective) triode of Fig. 1. The tube is the same as in Fig. 1 but here the suppressor grid 9 and shield grid 10 are separated from the anode and exercise their normal functions. The same tube arrangement and connections of its electrodes to associated circuits could have been used in the Fig. 1 circuit. The elements of Fig. 2 not specifically mentioned above are the same as in Fig. 1 and are similarly identified in the drawing. The injection feature, which distinguishes the teaching of this figure, will be explained in greater detail below.

In Fig. 2 the injection potential resistance R_1 has been placed across the heater circuit of the tube with a switch 11 interposed in its circuit. It is evident that this injection resistance has precisely the same relationship otherwise to the circuit as a whole, as in Fig. 1, just as the RC circuit has the same relationship. However, when switch 11 is closed, the 60-cycle current which is assumed to be used for exciting the heater, as it could have been assumed with respect to Fig. 1, takes on the new function of also supplying the injection potential. This indicates that by the use of the expedient of the invention calling for the use of an injection frequency, there is no implication whatever of the necessity for use of any additional circuit or plant, similarly as in the instance of elements RC. The switch 11 makes possible the use of the circuit either to generate the 1,000–20-cycle wave with its attendant possibilities of deriving the 1,000-cycle and 20-cycle waves per se, or the generation of the 1,000-cycle wave only uncomplicated by the existance of other frequencies. This last function may be efficiently achieved even though the use of elements RC adapted for the 20-cycle modulation would tend to somewhat affect the operation since a different choice of values of these elements would be desirable for the most efficient use of the circuit as a 1,000-cycle oscillator. In practice, however, this has been found to be of minor importance.

What is claimed is:

1. A self-modulated electric discharge tube oscillator comprising, an electric discharge tube having input and output electrodes and associated circuits all so interrelated as to cause the organization to generate a steady, substantially pure, wave of relatively high frequency, a relatively low frequency modulating wave source comprising a resistance-capacitance combination specific to said input electrodes for determining the modulating frequency, and an injection frequency means connected to said associated circuits adapted to coerce said low frequency combination and lock its frequency into a commensurable relation with its own frequency, said tube having a modulating as well as an amplifying characteristic whereby the organization as a whole is adapted to generate steady, pure, waves of both said relatively high and relatively low frequencies together with intermodulation products of the same.

2. A self-modulated electric discharge tube oscillator comprising, an electric discharge tube having input and output electrodes and associated circuits all so interrelated as to cause the organization to generate a steady, substantially pure, carrier wave, a resistance-capacitance combination specific to said input electrodes and having a time constant corresponding approximately to the desired modulating frequency, an injection frequency source adapted to generate a wave having a commensurable relation to said modulating frequency, and coupling means between said injection frequency source and said resistance-capacitance combination whereby said injection wave may coerce said modulating frequency circuit as in accordance with said commensurable relation, said tube having an amplifier-modulator characteristic whereby the organization as a whole is adapted to generate steady, pure, waves of both the carrier and modulating frequencies as well as their intermodulation products.

3. An oscillator-modulator comprising an amplifier-modulator electric discharge tube having input and output electrodes, a feedback circuit interconnecting said electrodes and including an inductance-capacitance combination for determining the frequency of carrier oscillation thereby generated, a resistance-capacitance combination specific to said input electrodes and having a time constant corresponding approximately to a desired modulating frequency, and an injection frequency source adapted to generate a wave having a commensurable frequency relation to said desired modulating wave, and means coupling the same to said resistance-capacitance combination, whereby the organization as a whole is adapted to generate a steady, pure, wave of the carrier frequency as well as to generate, by modulating and demodulating action, respectively, waves of combination frequencies and a steady pure wave of the modulating frequency.

4. The organization specified in claim 3 in which said resistance-capacitance combination also constitutes an electrode-biasing-potential determining means for said carrier wave generating means.

5. An oscillator-modulator comprising an electric discharge amplifier-modulator tube having a cathode, control electrode, and anode, a feedback circuit including a carrier-frequency-determining circuit between the anode-cathode and control electrode-cathode pairs of tube elements, a capacitance in circuit with said control electrode cooperating with a resistance also in said control electrode circuit but at least partially in shunt to said capacitance, to bias said control electrode for effective operation of said tube as an amplifier or modulator, the time constant of the resulting resistance-capacitance combination also corresponding approximately to a desired modulating frequency, an injection frequency source adapted to generate a steady wave whose frequency has a commensurable relation to said desired modulating frequency, and means cou-

pling said source to said resistance-capacitance combination for coercing same at the commensurable frequency approximately corresponding to said time constant, whereby the organization as a whole is adapted to generate, by oscillator action, a carrier frequency and, by modulator and demodulator action, respectively, a wave having combination frequencies and a pure sine wave corresponding to the modulating frequency.

6. The organization specified in claim 5 including additionally means whereby said injection frequency source energizes the cathode of said tube.

7. The organization specified in claim 5 in which said carrier, modulating and injection frequencies are of the order, respectively, of 1000, 20 and 60 cycles and in which there is additionally a means for energizing the cathode of the

tube from the 60-cycle injection frequency source.

ALPHONS V. WURMSER.

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