June 18, 1929. W. SCHÄFFER 1,717,630

AMPLIFIER

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Fig. 1

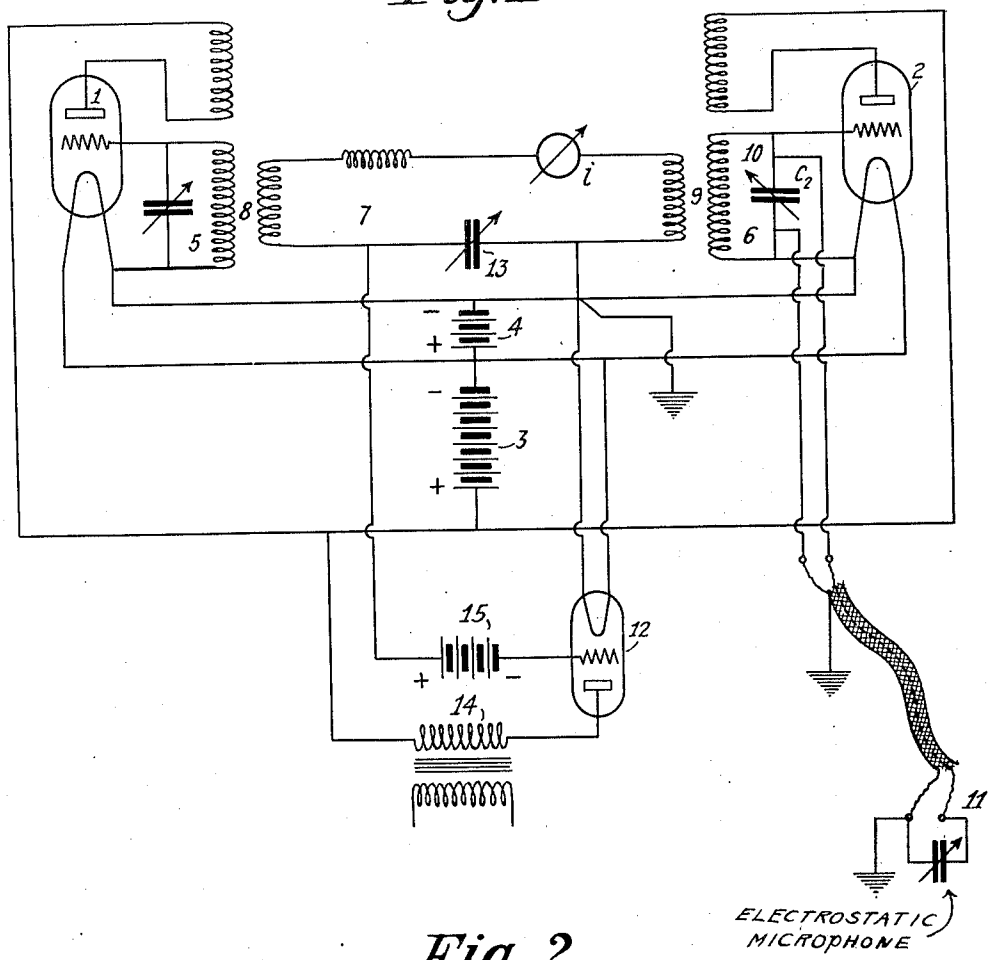
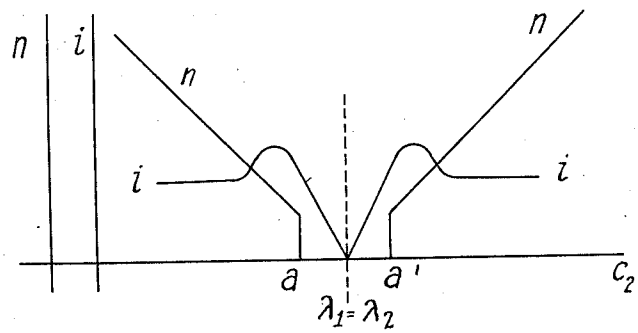


Fig. 2



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AMPLIFIER.

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If two self-excited tube generators are connected together in such a way that they are coupled with a common or joint circuit, the high frequency currents arising in the tube generators may influence one another in such a manner that the currents delivered by them are displaced in phase by 180 degrees in the coupling circuit. The natural frequencies of the circuits determining or governing the frequency must be of equal value in the tube generators. If the coupling factor of one of said generators with the common circuit has the same value as that of the other generator tube, no current will flow in said joint circuit, since the potential impressed by the two tube generators are phase-displaced by 180 degrees, and that their amplitudes are of equal value. Upon the frequency-governing circuit of one of said generator tubes being untuned slightly, beats will not be produced at once, because one of the generators is so to speak "entrained" by the other. However, there arises incidentally a current in the joint coupling circuit which rises from zero value at the instant when the natural waves of the frequency-governing generator circuits were of equal value. Such rise occurs in proportion to the untuning of the two generator circuits with relation to one another. The rise of the resultant current in the joint coupling circuit proceeds to about twice the value of the current which arises in the joint circuit when only one generator is connected. It is only shortly before the said two-fold value of the current is reached that beats are produced. In other words, the state of entraining is no longer present. One of the tubes has "detached" or liberated itself from the other. Inside the range in which the current in the joint circuit starts to rise from zero up to the instant where beats are initiated, the variation of the currents within a wide range takes place rectilinearly in dependence upon a capacity variation in the frequency-governing circuit of one of the generators. The steepness of the rise is a function of the coupling factor of the generators with the joint circuit.

According to the present invention, the range of the rectilinear current variation is utilized to great advantage for the transmission of signals, for instance, for the microphonic transmission of pictures or similar purposes. If a capacitive microphone is disposed in parallel with the condenser of one of the generator circuits, or if the condenser is replaced by such a microphone, variations of the high frequency current in the common circuit are obtained on speaking into the microphone. After rectification of this high frequency current there is thus obtained a low frequency current which varies at the rhythm of the speech. Of course, the current can be used, for instance, in the same manner for the controlling of a telephony transmitter as a microphone current produced in any other manner.

In the accompanying drawing

Fig. 1 illustrates a preferred embodiment of the invention, and

Fig. 2 illustrates the current characteristic of the coupling circuit 7.

In Fig. 1 the numerals 1 and 2 denote the two generator tubes fed with the requisite current from plate battery 3 and heating battery 4. With tubes 1 and 2 are connected in any of the well-known oscillation-generator arrangements the frequency-determining circuits 5 and 6. Both circuits, for instance, are inductively coupled with the joint circuits 7 and 8. Connected in parallel with condenser 10 of the frequency-governing circuit is the capacitive (electrostatic) microphone 11 which may be disposed and constructed in any convenient manner, or which may be replaced by some other signal element. According to what has been pointed out above the current conditions as described are set up in the joint coupling circuit 7. The current in circuit 7, when speaking into the microphone, is a high frequency current whose amplitude is varied or modulated at the rhythm of the speech. The amplifier-detector tube 12 has its cathode and grid connected in parallel with a condenser 13 of circuit 7 by way of a battery 15 furnishing a steady potential. From the secondary winding of the plate transformer 14, the low frequency speech currents can be taken off while operations are going on. Its heating and plate current is supplied to the rectifier-amplifier tube 12 likewise from the batteries 3 and 4. The connections as here indicated have merely been cited by way of example, and they could be modified in an analogous manner. For instance, the circuit 7 could

be made oscillatory just as well as aperiodic. Its coupling with the circuits 5 and 6 could also be made capacitive and direct. The electrostatic microphone could also be of the bilateral kind provided with a movable diaphragm which at the same time influences the frequency-governing circuits 5 and 6 in contrary sense. Instead of the unilaterally acting rectifier-amplifier tube 12, for instance, also two such tubes operating differentially could be employed, while furthermore the low frequency current, instead of through the transformer coupling 14 as here shown, could be taken off through a resistance coupling. For the purpose of oscillation generation and normal amplification, there may finally be used also all usual modes of connection.

Fig. 2 shows a diagram in which the dependence of the current i in the coupling circuit upon the change of capacity c^2 in the frequency-governing circuit 6 is shown. If the natural wave of the circuit 6 is equal to the natural wave of the circuit 5, in other words, if $\lambda 1 = \lambda 2$, the current i in the common circuit is equal to zero, if the couplings 8 and 9 are equally close. Both in the case of decrease as well as of increase in capacity c^2, there occurs a rise of the current which upon either side by way of a certain maximum changes over into a value which arises when beats are produced in the circuit 7. The frequency of the beats is illustrated by the curve n. In the neighborhood of tuned conditions of the two circuits 5 and 6, or when $\lambda 1 = \lambda 2$, the tone frequency is of zero value, until suddenly it sets in at a and a', from that instant it changes normally in proportion to c^2, in proportion to the detuning. The rectilinear variation of the current shape, starting from $i = 0$ in one direction up till the instant when beats are initiated, constitutes the working range to be used for microphone purposes. The shape of the curve is in reality not quite as symmetrical as illustrated in the graph, in fact, the shape of curve here shown is merely a diagrammatic illustration of the conditions.

If the impedances, i. e., the condensers and self-inductances indicated in Fig. 1 are suitably proportioned, and if the coupling factors to be used are suitably chosen, an extremely slight amount of detuning in circuit 6, and an extremely small change in the capacity by speaking into the electrostatic microphone 11 will suffice to produce adequate action, because the ascending branch of the current curve from zero to the corresponding value can be rendered very steep. Practical experiments have shown that, on changing the total capacity of circuit 6 by only a small percentage, the total working range of the current in circuit 7 can be passed through. By means of this assembly arrangement it is possible to render the speech energies independent of the low frequency. The electrical variations occur proportionally with the sound pressure variations, and the speech-energy to be taken from the high frequency circuit is so large that, compared with other capacitive microphone devices, only disproportionately small amplification is necessary in order to obtain such speech currents as are required for the modulation of a transmitter. It goes without saying that noises will not be produced at all in this sort of microphone arrangement.

The construction of the capacitive microphone may be of any of the well known kinds. What is suitable, for instance, is a movable diaphragm consisting of a metal foil as light as feasible held between silk surfaces. The silk surfaces may be disposed in front of a stationary coat, the silk being tautened only so much that no creases or folds are produced. The said stationary coat may consist of a brass plate or disk of from 2 to 3 mm. thickness in which slits ranging between 1 and 2 mms. in width are formed spaced ½ mm. apart. If, then, sound waves impinge upon the brass plate by speaking into the microphone, the resultant sound pressures come to act through said slits upon the movable coat held between the silk, that is to say, upon the metal foil. The result is that the distance between the stationary and the movable coats is changed, and that as a consequence capacity changes are occasioned. A good plan is furthermore to provide in well known manner a compression space in the rear of the movable coat, by the proper proportioning of which the acoustic conditions may be rendered particularly favorable. Of course, as pointed out before, the microphone could also be of the so-called bilateral-action kind, with the motion of the movable coat taking place between two stationary coats, each of the latter being united with the respective grids of the two oscillation tubes, while the movable coat is united with the common "K" point of the two tubes.

The generator connection is suitably so chosen that the grid circuit is made the oscillation circuit. This offers two advantages, to wit (1) the voltage at the microphone is prevented from exceeding a certain value and (2) the circuit capacity is comparatively high so that the capacitance in the flexible lead to the microphone which may be relatively long, will become of a permissible value. One of the poles of the said lead, namely, the one connected with the K-point of the tube, should, of course, be suitably grounded, and be connected with the microphone casing. This grounded lead may have the shape of a flexible metal tube, while the conductor sensitive to capacity may be disposed therein.

It may be finally mentioned that the cou-

pling of the tube may be so chosen and ascertained that one thereof is given a closer grid coupling, and the other one a closer anode coupling; this favors and promotes the entrainment by one tube of the other tube. The same end is attained by that both, or at least one tube, is caused to operate inside the negative range.

If the conditions are so chosen that the tube to which the unilateral-action microphone is connected is stable, while the other one is unstable in its operation, it will be found that also the wave will change in proportion to the sound pressure variations coming to act upon the microphone. If the coupling circuit between the two oscillation systems is adapted to be tuned and subject to little damping, it will present a correspondingly sharp resonance curve. If the adjustment is so chosen that operations take place either upon the rising or the drooping branch of the resonance curve of the said joint coupling circuit, current variations can be obtained in the common coupling circuit with still greater sensitivity than corresponds only to the entrainment phenomenon. Apart from the current variation due to the steepness of the entrainment process, as will be seen, amplified current variations are produced, and these, as will be understood, are due to the working on the steep branch of the resonance curve on which the working point is moving up and down. Of course, those branches of the resonance curve of the entrainment range must be chosen in which the actions are added to one another.

As can be seen from the description, what is important in any given case is that the natural wave of the circuit of the generator tubes 1 and 2 governing and determining the frequency is changed. It goes without saying that the detuning can be brought about in a way as hereinbefore set forth also in another way than by capacitive means. It is feasible to cause such detuning also by inductive means or by the insertion of variable resistances, for instance, selenium cells, disposed at convenient points.

Having thus described my invention, what I claim is:—

1. In combination, two synchronously tuned oscillators coupled to a common circuit, means for detuning one of said oscillators and at the same time maintaining synchronization whereby current change is produced in said common circuit.

2. In combination a pair of synchronously tuned oscillators having 180 degree phase relation, means for coupling the oscillators, detecting means associated with said means, means for detuning one of the oscillators consisting of an electrostatic microphone coupled to a tuning element of said oscillator whereby one oscillator will be detuned but entrained by the other oscillator thereby producing definite current flow in the detecting means in direct ratio to the change in the microphone.

3. In combination, a plurality of synchronous oscillators having tuned circuits and operable in opposition to each other, a rectifier, means for coupling the oscillators with the rectifier, means for detuning one of the oscillators, said means being coupled to a tuning element whereby one oscillator will be detuned but entrained by the other, thereby producing definite current flow in the rectifier in direct ratio to the change in the microphone.

4. A method of amplifying sound signals by means of an electrostatic microphone and a pair of generators of oscillations which consists in causing said generators to produce oscillations of substantially the same frequency combining said effects in opposition and causing said electrostatic microphone to vary the tuning frequency of a circuit of one of said oscillators at the frequency of said signals maintaining the frequency of oscillations generated thereby due to the entraining effect between the oscillators, and detecting the resultant combined effects to produce amplified sound signals.

5. In a system for amplifying sound signals the combination of a pair of synchronously tuned oscillators, a circuit for combining the oscillations produced thereby, a condenser microphone associated with one of the oscillators and adapted to vary the tuning frequency of a circuit thereof, said other oscillator being adapted to entrain the last mentioned oscillator whereby the frequency of the oscillations generated by the first oscillator is maintained despite the change in the tuning frequency, and means for detecting electrical variations in said combining circuit for the production of amplified sound signals.

6. In combination, a plurality of three element vacuum tube oscillators having input and output circuits tuned and coupled for generation of oscillations of the same frequency, a circuit coupled to a tuned circuit of each of said oscillators and having an impedance therein, a three-element vacuum tube having its input circuit connected across said impedance and its output circuit associated with a device to be controlled and modulating means connected to one only of said oscillators for slightly detuning a tuned circuit thereof, said oscillators being entrained through said coupling circuit whereby said modulating means produces amplified electrical variations in said coupling circuit.

7. In combination, a pair of synchronously tuned oscillators, means comprising a common tuned circuit for combining the oscillations produced by said oscillators, means associated with one of the oscillators adapt-

ed to vary the tuning frequency of a circuit thereof, said other oscillator acting through said common tuned circuit to entrain the last mentioned oscillator whereby the frequency of the oscillations generated by the first oscillator is maintained despite the change in the tuning frequency, and means for detecting electrical variations in said combining circuit for the production of amplified sound signals.

8. A method of amplifying sound signals which consists in transferring sound pressures to electrostatic capacities, causing the capacities to vary the magnitude of difference between two synchronous series of oscillations while maintaining synchronization, and detecting the said difference to secure amplified sound signals.

9. A method of amplifying sound signals wherein sound pressures are transferred to electrical constants; the variation of said constants is caused to vary the magnitude of diflerence between two synchronous series of oscillations while maintaining synchronization, thereby modulating them in accordance with the sound pressures.

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