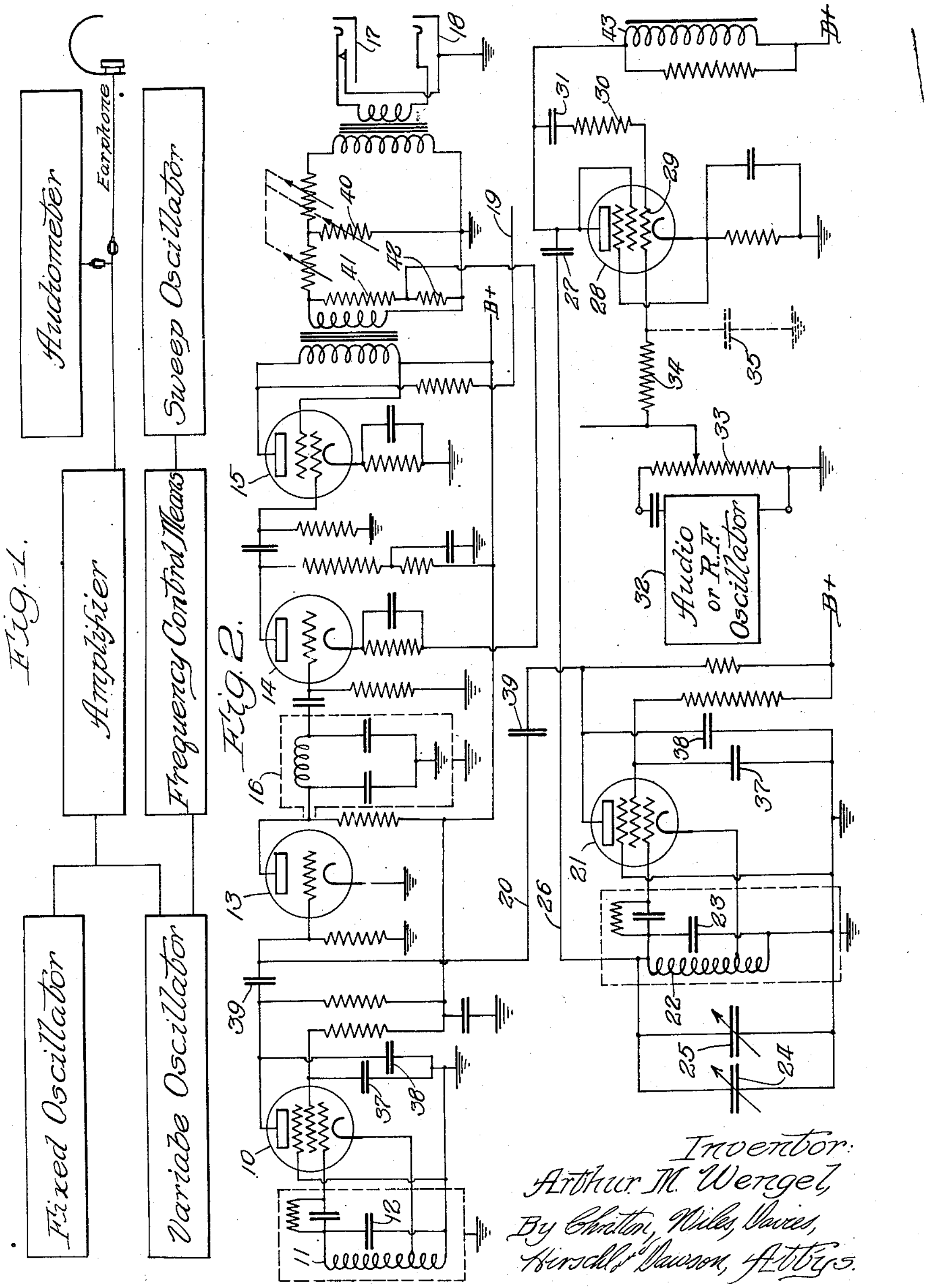
June 23, 1942. A. M. WENGEL 2,287,401

ALL-FREQUENCY GENERATOR

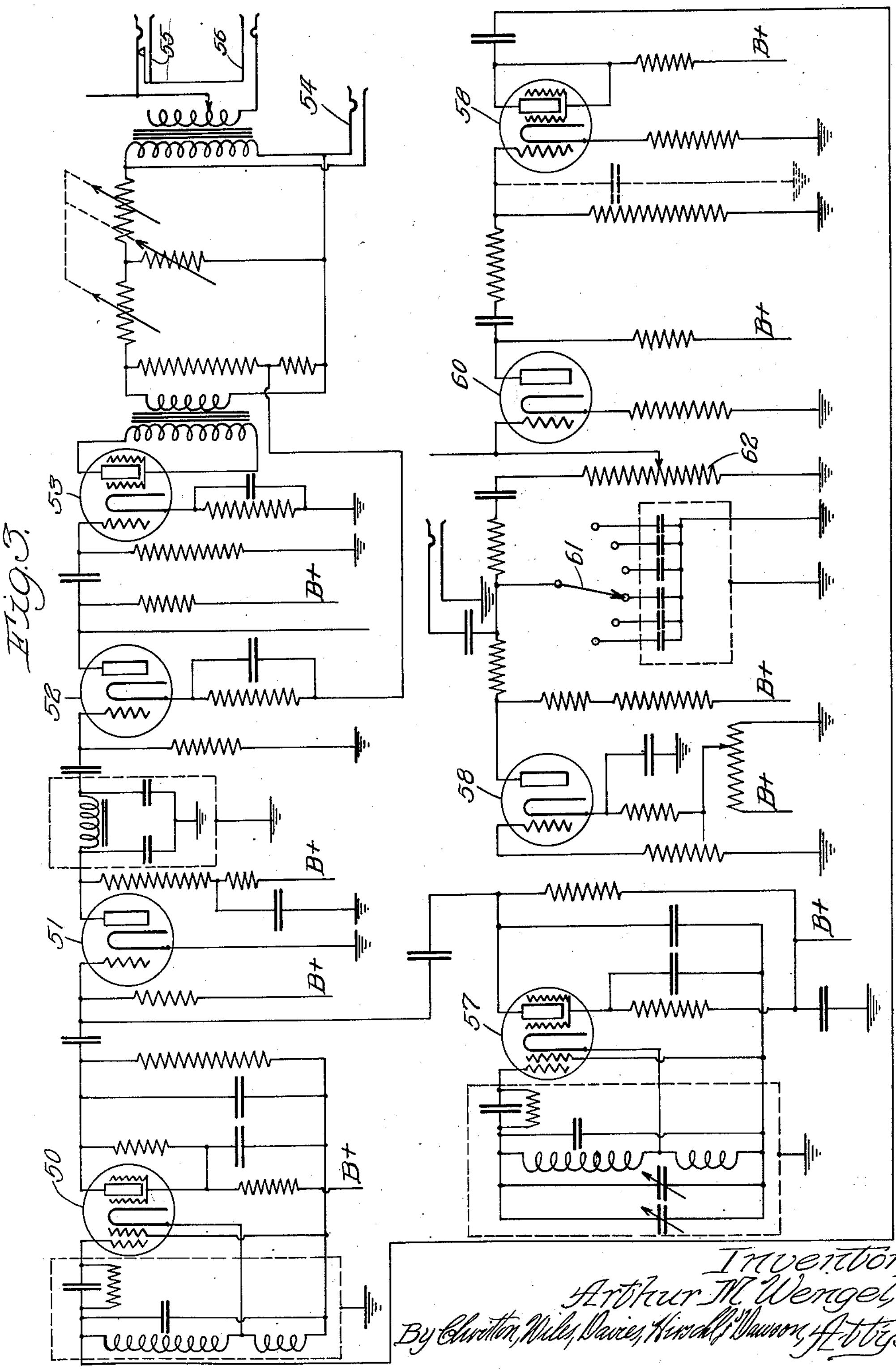
Filed June 17, 1940 2 Sheets-Sheet 1



June 23, 1942. A. M. WENGEL 2,287,401

ALL-FREQUENCY GENERATOR

Filed June 17, 1940 2 Sheets-Sheet 2



Inventor:
Arthur M. Wengel
By Chritton, Wiles, Davies, Hirschl & Dawson, Attys.

Patented June 23, 1942 2,287,401

UNITED STATES PATENT OFFICE

2,287,401

ALL-FREQUENCY GENERATOR

Arthur M. Wengel, Madison, Wis., assignor to Ray-O-Vac Company, a corporation of Wisconsin

Application June 17, 1940, Serial No. 341,015

6 Claims. (Cl. 179—1)

This invention relates to an all-frequency generator for producing a wave output comprising a substantially uniform distribution of frequencies throughout a desired band, and more particularly to a generator for test purposes, as for producing a background sound for use with a separate substantially single frequency test note for hearing testing purposes.

This application is a continuation-in-part of my co-pending application, Serial No. 254,931, filed February 6, 1939. One feature of this invention is that it provides apparatus for generating a complex wave having a desired band width and frequency distribution; another feature is that it provides apparatus enabling optimum design of an amplifier, with respect to its frequency-amplification characteristics in particular, and the conditions of use normally encountered by a hard-of-hearing person; yet another feature of this invention is that testing of ear response to a particular test note is done under laboratory conditions which closely approximate conditions of actual normal use of a hearing aid device; a further feature of this invention is that, at least insofar as ear response is concerned, it provides a background sound comprising a substantially uniform distribution of frequencies, of uniform intensity, throughout a given desired audible band; another feature of this invention is that the width and location of the background sound band, as well as its intensity, are readily controllable; still another feature of this invention is that new and improved means are provided for varying the resonance frequency of a tuned circuit without mechanical movement of any of the elements thereof; other features and advantages of this invention will be apparent from the following specification and the drawings, in which:

Figure 1 is a block diagram of apparatus embodying my invention; Figure 2 is a wiring diagram of apparatus embodying this invention; and Figure 3 is a wiring diagram of another embodiment of my invention.

It is known that the hearing response of the ear of a hard-of-hearing person differs for pure notes of various frequencies, and some effort has heretofore been made to design the amplifier of a hearing aid device to have a frequency-amplification curve inverse to the frequency-response curve of the ear. That is, the amplifier is designed to accentuate those frequencies to which the ear is least responsive and to amplify to a lesser extent those frequencies to which the ear is particularly responsive. A hearing aid device having an amplifier of this type has been disclosed in my earlier Patent 2,192,669, which issued March 5, 1940.

Heretofore, however, audiometers or test apparatus used to determine the frequency-response curve of the ear of a hard-of-hearing person have all been capable of determining only the threshold curve or the pain curve. That is, such previously used test apparatus has had means for producing notes of any desired frequency in the audio range and means for varying the intensity of such notes, generally combined with a meter or the like for measuring such intensity. With such apparatus, at any given frequency, the lowest (threshold) intensity audible to the person could be determined and the intensity which produced pain or discomfort. This enabled plotting of the two curves representing the extremes of hearing response; but gave no information as to the intermediate area bounded by such curves.

The threshold and pain curves seldom, if ever, have the same form; and I have found that hearing response at intermediate points may differ from the shape of both curves. In the normal affairs of every day life it is the intermediate area, and not the threshold curve, which is important. That is, the ears of a person are practically always exposed to a background of sound comprising practically all frequencies; and sounds which it is desired to hear must make themselves audible above such background. A person sitting in an office in the business area of a city, for example, will have his ears exposed to a background of noise produced by street cars, trains, motor traffic, typewriters, telephone conversations at other desks and a number of other sources. Under such circumstances the threshold audibility curve determined in a laboratory under sound insulated conditions is of little value in designing a hearing aid device.

My present invention comprises apparatus for electrically producing a complex electrical wave or waves having a substantially uniform distribution of frequencies, of the same intensity, throughout a given band in the audible range, the complex wave being controllable in respect to intensity level, band width, and band location. When used for hearing aid work this wave is translated into a corresponding background sound, and this provides improved apparatus for use with an audiometer producing a substantially single frequency test note controllable as to frequency and intensity, preferably by calibrated dials, in order to design the frequency-amplification curve of a hearing aid amplifier with proper corrections for the ear response under normal usage conditions, rather than threshold or pain level conditions. An audiometer satisfactory for such use with the all-frequency generator disclosed herein is shown, for example, in the lower half of Figure 1 of my application, Serial No. 254,931, mentioned above.

In the particular embodiment of my invention illustrated herewith in Figures 1 and 2, referring first to Figure 1, a fixed oscillator generates a single fixed frequency, as for example one hundred kilocycles. The variable oscillator is adapted to have the frequency generated by it varied through a band close to the frequency generated by the fixed oscillator, as for example through a band of ninety to one hundred kilocycles. This is accomplished electrically by frequency-control means which is put through a rapid periodic cycle, as for example two hundred or five hundred or one thousand times per second, by a sweep oscillator. The outputs of the fixed and variable oscillators are combined to produce a beat frequency wave or note which is then passed through an amplifier which preferably includes a low-pass filter to remove the higher frequencies and leave only the beat note frequencies.

This beat note frequency goes through the desired band the desired number of times per second, so that the ear hears only a background sound comprising a substantially uniform distribution of frequencies of the same intensity. That is, if the variable oscillator swings from ninety to one hundred kilocycles five hundred times a second, a few waves of each of the frequencies from substantially zero frequencies up to ten thousand cycles per second would be generated five hundred times a second, so that the ear would not be able to distinguish, but would merely hear the desired all-frequency background. The sweep oscillator frequency can be made below normal audibility, if desired, or can be filtered out of the output by a sharp single frequency rejection tuned circuit in the amplifier.

The resultant background sound output is combined with a substantially single-frequency test note generated by an audiometer, and the combined electrical waves are translated into actual sound waves by an earphone, and thus delivered to the defective ear being tested. If calibrated frequency intensity and band width control dials are used, as is preferable, intensities and frequencies of all desired types can be applied to the ear for test purposes to determine the best amplifier prescription for that particular ear in order to enable it to hear best under normal every-day conditions.

Referring now more particularly to Figure 2, the fixed oscillator is shown as comprising the tube 10 with its associated tuned circuit (the inductance 11 and condenser 12) to determine its frequency of oscillation. The circuit constants may be so chosen, for example, as to have this oscillator generate a frequency of one hundred kilocycles per second.

It is here shown as resistance coupled to the first tube 13 of an amplifier comprising the tubes 13, 14 and 15. These various tubes of the amplifier are also resistance coupled, a low-pass filter 16 being in the circuit path between two of the tubes. The output of the amplifier is coupled, through appropriate transformers and a calibrated T-pad or resistance network, to the jacks 17 and 18. The jack 17 is intended to have the output of an audiometer plugged into it; and the jack 18 is intended to have an earphone plugged into it, so that the earphone delivers to the ear being tested both the output of the amplifier and the substantially single frequency test note from the audiometer. A portion of the output of the amplifier may be diverted through the wire 19 to an electronic tuning eye, milliammeter, or other means for determining zero beat conditions.

The input of the amplifier also has delivered to it, through a wire 20 connected to the grid circuit of the tube 13, the waves generated by a variable oscillator comprising the tube 21 and its associated circuits. The tuned circuit associated with the tube 21 to determine the frequency at which it oscillates includes the inductance 22 and a plurality of parallel condensers. These condensers are the fixed condenser 23, the main variable condenser 24, and the zero beat adjustment condenser 25. The values of the tuned circuit constants are so chosen that with the condenser 24 at minimum capacity the condenser 25 can be adjusted to make the frequency generated by the tube 21 exactly equal to that generated by the fixed oscillator tube 10, so that it will be zero beats. The condenser 24 is preferably calibrated in the cycles of the beat note resulting from its adjustment, so that movement of this condenser to a particular position determines the low frequency boundary of the sound band which is to be generated.

A lead 26 and condenser 27 couple the grid end of the inductance 22 to the plate of a control tube 28. This tube has at least three elements, and is preferably a multielement tube, as shown. Its control grid 29 is coupled through a resistor 30 and a condenser 31 to its plate; and the control grid also has impressed thereon a sweep frequency voltage, as from an audio or radio frequency oscillator 32 of conventional type. The sweep voltage from this source is impressed across a potentiometer 33, and any desired portion of it delivered to the control grid 29 through a resistor 34. Adjustment of the variable arm on the potentiometer 33 determines the maximum amount of sweep voltage to be impressed on the grid, and thus the maximum swing frequency generated by the tube 21. That is, the lower boundary of the all-frequency band is determined by adjustment of the condenser 24; and its width by adjustment of the sliding arm of the potentiometer 33.

The purpose of the tube 28 is to provide a readily electrically variable impedance in a control circuit having the current flow therein out of phase with the voltage in the tuned circuit of the oscillator tube 21. Current flow through this tube parallels that through the inductance 22; and if it lags the voltage in the tuned circuit of the tube 21, it acts as an additional effective inductance in such tuned circuit. The shift in phase relation is generally sufficiently effected by the capacity between tube elements and wiring, here indicated in dotted lines as the capacity 35. This should be between fifteen and fifty micro-microfarads where the tubes 21 and 28 are of the 6J7 type; and must be low in impedance compared to the resistor 30.

Assuming the condenser 24 to be so set that the lower margin of the band, or the beat note produced in the amplifier output when the sweep voltage is zero, was one thousand cycles per second, rise in sweep voltage would increase current flow through the tube 28, and thus increase the effective inductance in the tuned circuit of the variable oscillator 21. This would in turn decrease the frequency generated by it, so that it would drop on down from ninety-nine kilocycles to ninety-six kilocycles, for example, as the sweep voltage rose to maximum. The beat note frequency generated by the combination of the two oscillators would thus swing through all of the frequencies in the range from one thousand to four thousand cycles in the length of time required for the sweep voltage to rise from zero to maximum; and the intensity of all of these waves would be substantially the same, and their distribution with respect to time also substantially uniform. If the sweep frequency were fifty cycles per second, each of the various frequencies throughout the desired band would be generated for a brief instant fifty times per second; and the resultant effect on the ear would be that of a background sound comprising a substantially uniform distribution of frequencies, of uniform intensity, in the audible band between one thousand and four thousand cycles.

While the majority of the circuit constants follow conventional amplifier and oscillator practice, it is believed desirable to mention specifically a few of the others. Oscillator condensers **37**, for example, should be about .1 mf.; and condensers **38** should be .01 mf. Oscillator coupling condensers **39** may be .0005 mf., as may also condenser **27**. Each of the three resistors **40** of the T-pad network may be five hundred ohms; the resistor **41** should be a number of times the value of the resistor **42**, as for example two thousand ohms as against fifty ohms. The potentiometer **33** preferably has a resistance in the neighborhood of fifty thousand ohms, and that of the coupling resistor **34** in the neighborhood of 250,000 ohms. The condenser **31** used by me has a capacity of .0002 mf.; and the resistor **30** a value of fifty thousand ohms. The inductance of the choke **43** should have a value of at least 85 millihenries, preferably higher.

Another embodiment of my invention is illustrated herewith in Figure 3. The tube **50** and its associated tuned circuits form the fixed oscillator; the tubes **51**, **52** and **53** comprise the amplifier, the output again being delivered through a T-pad to jacks adapted to be connected to a source of a single frequency note (the jack **54**) and to a pair of earphones, through the jacks **55** and **56**, provision being made to connect the phones in parallel or in series. The tube **57** and its associated circuits comprise the variable oscillator; the tube **58** is the control tube for varying the flow of out of phase current drawn from one of the oscillators, in this case the so-called fixed oscillator; the tube **59** and its associated circuits form the sweep oscillator, in this case the tube being of the 884 type, and generating a sawtooth wave with a lineal change of voltage; and the tube **60** is merely a simplifying tube connecting the sweep oscillator to the control tube.

Instead of being a continuously variable control, the sweep frequency oscillator is here arranged with step-by-step control, means being provided for switching any of a plurality of condensers into the circuit by switch means **61**. The capacitance of the fixed condensers is preferably so chosen as to provide a sweep frequency of five, ten, fifteen, thirty, sixty and one hundred twenty cycles per second. Control of the sweep width is again provided by a potentiometer, here identified as **62**. In this embodiment of my invention it is the oscillator provided with a fixedly tuned circuit which is swung by the control tube; and the variably tunable oscillator, including the tube **57**, remains at the frequency to which it has been set. The resultant beat note swing is, of course, the same as in the previously described modification. The use of a sawtooth generator provides a lineal change of voltage and an exceedingly uniform distribution of frequencies in the desired output wave.

While I have described and claimed certain embodiments of my invention it is to be understood that it is capable of many modifications. Changes, therefore, in the construction and arrangement may be made without departing from the spirit and scope of the invention as disclosed in the appended claims.

I claim:

1. Apparatus of the character described for producing, for hearing testing purposes, a background sound comprising a substantially uniform distribution of frequencies and a separate single-frequency test note, including: an oscillator having a tuned circuit determining the frequency generated; means for rapidly periodically varying the effective inductance in the tuned circuit through a predetermined range; means for generating a substantially single-frequency note; and means for simultaneously impressing the background sound and the note on the ear being tested.

2. Apparatus of the character described for producing, for hearing testing purposes, a background sound comprising a substantially uniform distribution of frequencies and a separate single-frequency test note, including: an oscillator having a tuned circuit determining the frequency generated; a control circuit operatively connected with the tuned circuit and arranged to have variations in the flow of current therethrough effect variations in the effective reactance of the tuned circuit; means for rapidly periodically varying the impedance of the control circuit to vary the frequency generated; means for generating a substantially single-frequency note; and means for simultaneously impressing the background sound and the note on the ear being tested.

3. Apparatus of the character described for producing, for hearing testing purposes, a background sound comprising a substantially uniform distribution of frequencies and a separate single-frequency test note, including: a first oscillator having a tuned circuit determining the frequency generated; a second oscillator having a tuned circuit determining the frequency generated; means for combining the outputs of the two oscillators to produce beat frequency waves within the audible range; a control circuit in parallel with the tuned circuit of the second oscillator and arranged to have variations in the flow of current therethrough effect variations in the effective reactance of the tuned circuit it parallels; means for rapidly periodically varying the impedance of the control circuit to vary the frequency generated by the second oscillator, and the beat frequency; means for generating a substantially single-frequency note; and means for simultaneously impressing the background sound and the note on the ear being tested.

4. Apparatus of the character claimed in claim 3, including means for predetermining one boundary of the desired band.

5. Apparatus of the character claimed in claim 3, including means for predetermining the width of the desired band.

6. Apparatus of the character claimed in claim 3, wherein the control circuit includes a vacuum tube having at least three elements therein and the cathode-plate impedance of the tube is varied by periodically varying the voltage on the grid of the tube.

ARTHUR M. WENGEL.