

Jan. 7, 1936.

J. B. KNIGHT, JR

2,026,944

MEANS FOR RECEIVING AND AMPLIFYING ELECTRIC SIGNALS

Filed Oct. 1, 1929

Fig. 1.

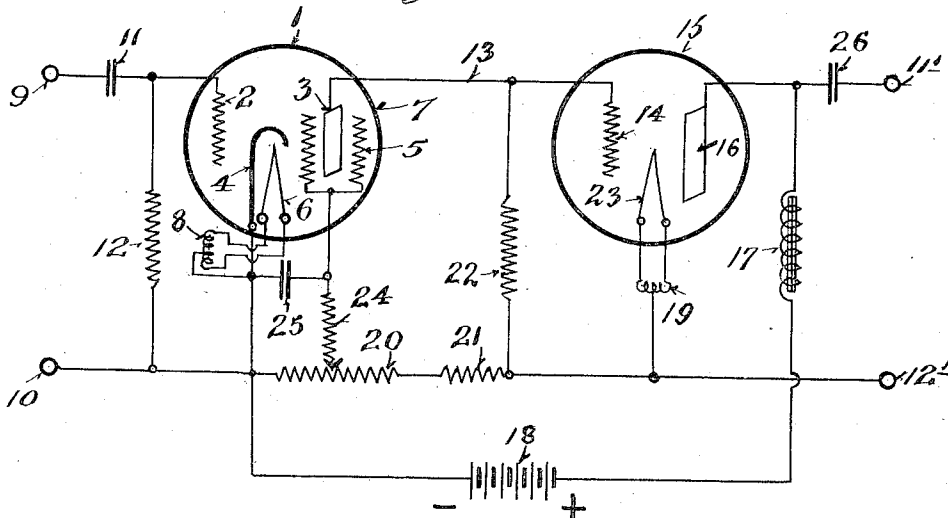
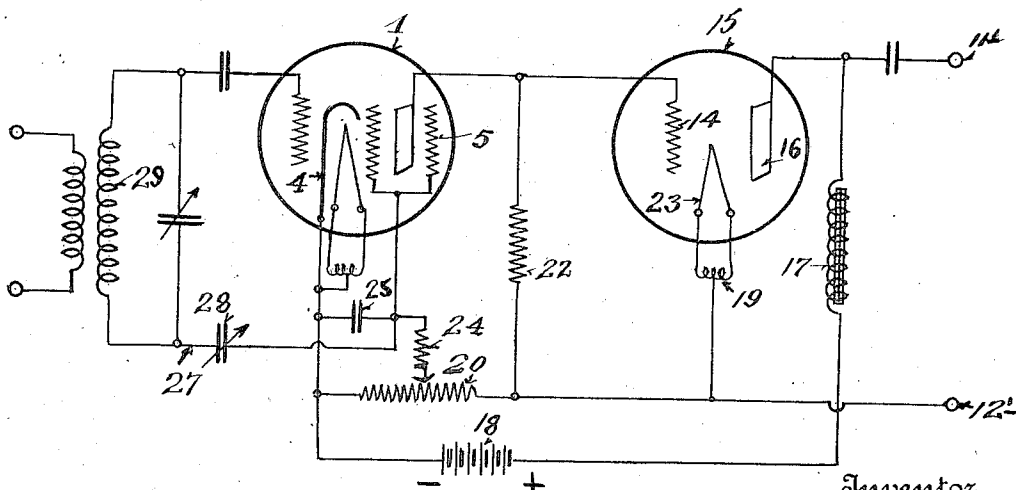


Fig. 2.



Inventor
John B. KNIGHT, Jr.
By his Attorneys
Darby & Darby

UNITED STATES PATENT OFFICE

2,026,944

MEANS FOR RECEIVING AND AMPLIFYING
ELECTRIC SIGNALS

John Broadus Knight, Jr., New York, N. Y., as-
signor, by mesne assignments, to Radio Corpo-
ration of America, a corporation of Delaware

Application October 1, 1929, Serial No. 396,469

32 Claims. (Cl. 250—20)

This invention relates to electrical transmis-
sion systems and with particularity to systems for
amplifying currents and voltages having a wide
frequency range, and also to systems for receiv-
ing modulated radio frequency signals.

A principal object of the invention is to pro-
vide an amplifier suitable for use in such systems
as television, picture transmission, etc., or in fact
in any system where the frequency spectrum to
be amplified is very wide and where a minimum
of successive amplifier stages is required.

Another object of the invention is to provide
an amplifier for electric currents or voltages
in which the frequency-gain transmission char-
acteristic is substantially uniform over a band of
frequencies of the order of 100 kilocycles.

Another object of the invention is to provide a
high-gain amplifier which is capable of regenera-
tion at audio frequencies without any noticeable
distortion in output.

Another object of the invention relates to an
amplifier system which is capable of simultane-
ously rectifying a modulated radio-frequency
carrier applied to the input terminals, and am-
plifying the audio frequency modulations and
also capable of amplifying an audio frequency
wave impressed upon said input terminals.

Another object of the invention is to provide a
high-gain direct coupled amplifier employing a
minimum of amplifier stages.

A further object of the invention is to provide
a high-gain amplifier having a uniform fre-
quency-gain characteristic over a wide range and
in which the anode potential of one stage is var-
ied in accordance with the output of a succeed-
ing stage.

A still further object of the invention is to
provide an improved amplifier system employing
a minimum of successive stages having a flat fre-
quency-gain characteristic over a wide range
wherein the successive stages are directly cou-
pled.

A still further object of the invention is to pro-
vide an amplifier stage in which the controlling
grid bias is varied in accordance with the anode
or output current.

A feature of the invention relates to the par-
ticular manner of coupling a so-called "shield-
grid" tube to a succeeding amplifier tube employ-
ing a direct coupling between the anode of the
"shield-grid" tube and the input circuit of the
amplifier tube.

Another feature of the invention relates to a
circuit arrangement whereby a so-called "shield-
grid" tube may be caused to rectify a radio fre-

quency modulated wave applied to the input cir-
cuit of the tube, and also to amplify the audio
frequency modulations of the carrier.

A further feature of the invention relates to a
circuit arrangement for enabling a so-called
"shield-grid" tube to function as a rectifier and
an audio frequency amplifier.

A further feature of the invention relates to a
plural stage amplifier in combination with a
source of anode potential which is applied di-
rectly to only one stage of the amplifier.

A further feature relates to the method of
causing a so-called "shield-grid" or four-element
tube to regenerate at radio-frequencies.

A further feature relates to a pair of electron
discharge devices in which the second device of
the pair is provided with circuit arrangements
enabling it to regenerate at audio frequencies
and wherein the regenerated output of said sec-
ond device controls the anode potential and the
output of the first device.

A still further feature relates to the manner
of coupling a screen grid tube to a three-element
tube whereby a maximum gain in amplification
is attained, which gain is disproportionately
greater than any gain that can be achieved with
a similar prior art circuit arrangement.

Other features and advantages not specifically
enumerated will be apparent after the following
detail descriptions and the appended claims.

While the invention will be disclosed herein-
after as applied to certain specific types of elec-
tron discharge devices, it will be understood that
the invention in its broad aspects is not limited
thereto, and is capable of application to other
forms of amplifier devices.

Referring to the drawing—

Figure 1 shows one preferred form of circuit
arrangement for carrying out the objects and
features of the invention;

Fig. 2 is a modification of the system disclosed
in Fig. 1 and adapted to produce radio frequency
oscillations.

Referring more particularly to Fig. 1 the nu-
meral 1 represents a space discharge device of
the thermionic type and includes a controlling
grid 2, an anode 3, a cathode 4, and a "shield-
grid" 5 surrounding anode 3. A suitable heater
filament 6 is provided for rendering the cathode
4 electronically active. All the above described
electrodes are mounted within the evacuated en-
velope 7 in the usual manner. Tubes of the
above described type have become generally
known in the art as "shield-grid" or four-element
tubes, and the amplifying qualities of such tubes

are recognized in the art. In accordance with the present invention it is proposed to take advantage in the highest degree of the inherent amplifying qualities of this type of tube.

Any well known means may be utilized for heating the filament 6. As shown in Fig. 1 the filament is heated by the secondary 8 of a suitable filament transformer, the midpoint of which is connected directly, or if desired through a suitable resistance to the cathode 4. The input terminals 9 and 10 of the system may be connected to a source of modulated radio-frequency carrier waves, or to a source of audio frequency waves. Interposed between the terminal 9 and the grid 2 of the first electron discharge device is a high capacity condenser 11 preferably of the order of two microfarads. A high resistance 12 is connected across the grid and cathode of the device 1 for the purpose of leaking off charges from the condenser 11 due to radio or audio frequency surges from the input terminals 9 and 10. The anode 3 is connected by means of conductor 13 directly to the grid 14 of a second electron discharge device 15, which may be of any well known construction, but preferably one having a low plate impedance.

The plate or anode 16 of this latter device is connected through a suitable choke coil 17 to the positive terminal of a high potential source 18, which may take the form of a battery, generator, or so-called "B eliminator". Source 18 is preferably of sufficiently high potential to enable tube 1 to act as a so-called "power detector" or "plate-rectifier". The negative terminal of the source 18 instead of being connected directly to the midpoint of the cathode transformer winding 19 is connected to the midpoint thereof through a pair of resistances 20, 21, the resistance 20 being preferably of lower value than the resistance 21. For example, one set of values that has been found to work with good results is 1000 ohms for resistance 20 and 2500 ohms for resistance 21. A coupling resistance 22 of the order of one megohm is connected directly across the grid 14 and the midpoint of the cathode secondary winding 8. The shield-grid 5 of device 1 is connected to the resistance 20 in series with a high resistance 24 of the order of 5 megohms, the lower end of said resistance being preferably adjustable along the resistance 20. By-pass condenser 25 of the order of one micro-farad is connected across high resistance 24. The output terminals 11' and 12' of the system are connected to the anode-cathode of device 15 through the high capacity condenser 26 in the well known manner. With the coupling resistance 22 properly proportioned in accordance with well-known principles, to the impedance of tubes 1 and 15, and with the circuit arrangements disclosed, the system is capable of amplifying audio-frequency waves impressed on terminals 9, 10 with a much greater gain than is attainable with corresponding equipment connected according to prior art arrangements. For example, in one arrangement the device 1 had a plate impedance of the order of 450,000 ohms and the coupling resistance was of the order of a megohm. It has been found that the system is capable of rectifying a modulated carrier wave which is impressed upon the terminals 9, 10, and at the same time amplifying the audio frequency modulations of such carrier wave. Furthermore it has been found that the system is capable of amplifying and transmitting variations having an extremely wide frequency variation, and with substantially uni-

form frequency gain characteristics. For example, with the arrangement shown in Fig. 1 frequencies occupying a band of the order of 100 kilocycles have been amplified with very little noticeable distortion in output. Consequently this system is of the highest practical value in connection with the transmission and reception of television signals, picture transmission signals, and any other signals requiring a wide frequency band. As a matter of fact by employing the two tubes in the circuit arrangement disclosed in Fig. 1 results have been obtained which are equivalent in faithfulness and gain with ordinary 5 and 6 tube amplifiers employing a greater number of stages, actual gain of the order of 1400 having been obtained without any noticeable distortion.

When a modulated radio-frequency carrier is impressed upon the terminals 9 and 10 the condenser 11 prevents the incoming signal from acting as a bias on the grid 2, and it has been found that the system acts as a rectifier-amplifier, and at the same time it is capable of amplifying audio frequency waves that are impressed upon the terminals 9, 10.

It has been found that the arrangement disclosed in Fig. 1 may be modified to oscillate at radio frequencies by connecting the grid return of device 1 to the screen-grid 5, instead of to the cathode 4. An arrangement for effecting this radio-frequency oscillation is disclosed in Fig. 2, wherein the same designation numerals are employed as are employed for corresponding parts of Fig. 1. It will be noted in connection with Fig. 2, however that the grid return conductor 27 is connected through a variable condenser 28 or other variable impedance to the screen-grid 5. It has been found that by varying the capacity of member 28 the amount of regeneration may be easily and accurately controlled. Thus there is provided a regenerative receiver having an extremely high gain wherein regeneration is produced without employing any tuned output circuit or inductive feed-back between the output and input circuits, and wherein a single coil, namely the coil 29 in the input circuit is required for producing such regeneration.

While the circuits disclose a so-called shield-grid tube for the first stage, it will be understood that advantageous results may be achieved with the ordinary three element tube. However, it has been found that the maximum benefits are derived when the output of the second tube causes a dual change in the anode and shield grid potential, and it is for this reason that a shield-grid tube is the preferred embodiment.

By the term "operating potential" for the various anodes as used in the claims is meant the ordinary high potential which is applied steadily to the anodes for the purpose of drawing off the electrons or producing the space current between the anode and its associated cathode. Also by the term "direct coupling" between the output of one tube and the input of the succeeding tube is meant a coupling of a substantially complete metallic type or its equivalent.

What is claimed is:

1. In combination a pair of electron discharge devices, each having a cathode, anode and control electrode, input and output circuits for said devices, a source of potential in the output circuit of the second device, and means for coupling the output circuit of the second device to the input circuit of the first device, to provide an amplifier of high gain and having a frequency-gain char-

acteristic suitable for use in television or like systems the last mentioned means including a resistance included serially between the anode and cathode of the second device, and means for impressing the potential drops across said resistance, due to the anode current of the second device, directly upon the anode of the first device.

2. In combination a pair of electron discharge amplifier devices, input and output circuits for said devices, a source of potential in the output circuit of the second device, a direct metallic coupling between the output circuit of the first device and the input circuit of the succeeding device, and means for varying the operating plate potential of the first device in accordance with relatively slow variations in plate potential of the succeeding device.

3. In combination a first audion device having an anode, a second electron discharge device having an anode and a cathode, means for impressing an operating potential on the anode of the first device, and means for directly varying said potential in accordance with slow variations only in the anode-cathode current of the second device.

4. A high gain amplifier comprising a first electron discharge device, a second electron discharge device each of said devices having an anode, cathode and a control electrode, and a connection between the anode of the second device and the anode of the first device, the operating anode potential of said first device being derived solely from the average anode-cathode current of said second device.

5. A high gain amplifier comprising a first electron discharge device having an anode, a second electron discharge device having an anode and a cathode, a serial circuit containing a source of potential, and a resistance connected in the anode-cathode system of the second device, and a connection from said resistance to the anode of the first device, whereby the operating anode potential of said first device is derived from the potential drop across said resistance.

6. A high gain amplifier comprising an electron discharge device, a source of potential and a resistance serially connected in the anode-cathode system of said device, and another electron discharge device having its anode-cathode system connected in shunt to said resistance.

7. A high gain amplifier comprising two tubes, each having a cathode, anode and control grid, a short circuit connection from the anode of the first tube to the grid of the second tube, a source of anode potential, a coupling resistance, a second resistance, one terminal of said coupling resistance being connected to said short circuit connection and the other terminal connected through said second resistance to the negative terminal of the anode supply, the positive terminal of said anode supply being connected only to the anode of the second tube.

8. In a high gain amplifier a first audion device, a second audion device, an ohmic resistance and a source of potential connected between the anode and cathode of the second device, a coupling resistance having one end connected to the grid of said second device and the other end to the cathode of said second device, and means for impressing the variations in potential across the first-named resistance upon the anode-cathode circuit of the first device.

9. In combination a first electron discharge device, having an electron emitting cathode, an

anode and an auxiliary electrode, means for impressing respective direct current potentials on both said anode and said auxiliary electrode, a second electron discharge device, and means for directly varying the operating potential of said auxiliary electrode and said anode in accordance with the variations in the anode system of the second device.

10. In combination a first electron discharge device having an electron emitting cathode, an anode and an auxiliary electrode, means for impressing respective direct current potentials on both said anode and said auxiliary electrode, a second electron discharge device, and means for directly varying the operating potentials of both said anode and said auxiliary electrode in accordance with the variations in the anode system of the second device.

11. In combination a first electron discharge device having an electron emitting cathode, an anode and an auxiliary electrode, a second electron discharge device having its control grid uni-potentially connected to the main anode of the first device, and a source of potential for the anode of said second device connected between the anode of the second device and said auxiliary electrode.

12. A high gain amplifier comprising a first electron discharge device having an electron emitting cathode, an anode and an auxiliary electrode, a second electron discharge device, and means for causing said amplifier to regenerate at audio frequencies including a source of potential, and a resistance connected in the anode-cathode system of the second device, and respective connections from said resistance to said anode and said auxiliary electrodes whereby the operating potentials for said main and auxiliary electrodes are derived entirely from the drop across said resistance.

13. In an amplifier system a combination of a low power electron discharge device, a high power electron discharge device uni-potentially connected to the low power device, and means for producing relatively large "grid-swings" on the grid of the high power device, corresponding to relatively low "grid-swings" on the grid of the low power device, said means including a resistance through which the space current of the high power device flows, and means for impressing drops across said resistance upon the anode-cathode circuit of the low power device.

14. In a high gain amplifier system the combination of a first electron discharge device having a main anode and a "shield-grid" therefor, a power amplifier tube having its control grid uni-potentially connected to the anode of the said first device, and means for producing a relatively large "grid-swing" on the grid of said power device, including means for causing relatively small "grid-swings" on the grid of the first device, said last mentioned means including a resistance through which the space current of the power device flows, and means for impressing the drop across said resistance upon the anode and shield grid of the first device.

15. A wave transmission system having input terminals and output terminals, an electron discharge device having a cathode, anode, control grid and auxiliary grid, a second electron discharge device having a grid and anode, a direct connection from the anode of the first device to the grid of the second device, means for deriving the operating anode potential of the first device from the anode-cathode current of the second de-

vice, and a high capacity condenser connected between one of said input terminals and the control grid of the first device, said condenser having sufficient capacity to pass radio frequency and audio frequency variations impressed on said input terminals.

16. An electrical transmission system capable of rectifying a modulated radio-frequency carrier, amplifying the audio frequency modulations of said carrier, and also capable of amplifying an audio frequency wave impressed on the system, including a first electron discharge device having a grid, a high capacity condenser connected between the input terminal of the system and the grid of the first device, means for leaking off the charge on said condenser, a second electron discharge device having a grid, and a direct connection between the first device and the grid of the second device.

17. A transmission system including an input terminal, a pair of electron discharge devices, a high capacity condenser connected between said input terminal and the first device, and means including said condenser for enabling said system to rectify and amplify a modulated radio frequency wave applied to said input terminal and also to amplify an audio frequency wave applied to said input terminal, said condenser having sufficient capacity to pass audio frequency currents.

18. A high-gain amplifier including a first electron discharge device having an anode, a cathode, a control electrode, and an auxiliary electrode, a second electron discharge device having an anode, a cathode, and a control electrode, a source of potential and a resistance serially connected, said resistance being connected in common to the anode-cathode systems of both said devices, and means for causing said first device to regenerate signals at radio frequencies, the last mentioned means including a feed-back connection from the auxiliary electrode to the control electrode of the first device.

19. In a high-gain amplifier the combination of a first electron discharge device having an input and an output circuit, a second electron discharge device having an input and an output circuit, means for feeding back audio frequency currents from the second device to the first device, and means for feeding back to the input of the first device energy in the output circuit of the first device to regenerate signals impressed upon said first device at radio frequencies.

20. In a high-gain amplifier, an electron discharge device having an electron emitting cathode, a control grid, an anode and an auxiliary electrode, means for impressing direct current potentials on both said anode and said auxiliary electrode, an input circuit for said device, and means exterior to said device for coupling the auxiliary electrode to the input circuit to provide regenerative feed-back.

21. A high-gain amplifier according to claim 20, comprising a succeeding electron discharge device having a grid, wherein the anode of said electron discharge device is connected to the grid of said succeeding electron discharge device, and means are provided for deriving the operating potentials of both the electrode and auxiliary anode of the said electron discharge device from the space current of the second electron discharge device.

22. In a high-gain amplifier, an electron discharge device having a cathode, a grid, a screen grid, and an anode, a second electron discharge

device having a cathode, grid and anode, a conductive connection between the anode of said first device and the grid of said second device, means for impressing operating potential on the anode of said second device, means for impressing operating potential on the anode of said first device through the anode-cathode circuit of said second device, a common resistance in the anode-cathode circuits of said devices, a second resistance connected at one end to the anode of said first device and the grid of said second device and at the other end to said common resistance, and means for feeding back radio frequency currents from the screen grid of said first device to the grid of said first device.

23. A high-gain amplifier comprising an electron discharge device having a cathode, grid, screen grid and anode, a second electron discharge device having a cathode, grid and anode, means for impressing anode operating potential on said devices in series, a resistance common to the anode-cathode circuits of said devices, means for causing signal potentials impressed upon the grid of said first device to be repeated in said second device and to have an effect upon the anode current of said first devices, and capacitive means for feeding back high frequency currents from the screen grid to the grid of said first device.

24. A radio receiving circuit comprising a screen grid tube having a tuned input circuit, an audio frequency amplifier connected in the anode circuit of said tube, and mutual impedance between the screen element circuit and the tuned input circuit of said tube, a potential supply potentiometer, the electrodes of said tube and amplifier being connected to the potentiometer, and means for adjustably connecting the screen element to the latter.

25. In a radio receiver, a detector stage including a screen grid tube provided with a tunable input circuit, an amplifier tube, a source of energizing current for the circuits of said tubes, means conductively coupling the anode of said detector tube and the control grid of the amplifier tube, additional means, including a high impedance, connecting said conductive coupling to said source, and means in the screen circuit of said detector tube to secure regeneration.

26. In a radio receiver, a detector stage including a screen grid tube provided with a tunable input circuit, an amplifier tube, a source of energizing current for the circuits of said tubes, means conductively coupling the anode of said detector tube and the control grid of the amplifier tube, additional means including an impedance, so high that there is insufficient anode current in the detector stage to produce regeneration satisfactorily, connecting said conductive coupling to said source, and means in the screen circuit of said detector tube to secure regeneration.

27. An electric circuit comprising an electron discharge tube having an emission cathode, an anode, a control grid, and a screen grid, a tunable input circuit connected between said cathode and said control grid, an output circuit connected between said cathode and said anode, a source of energizing current for the anode, control grid and screen grid circuits of said tube, said output circuit having an impedance so high that there is not enough anode current to produce regeneration satisfactorily, and means associated with said screen grid circuit for feeding energy to said input circuit in regenerative phase

with the energy transmitted from said input circuit to said output circuit.

28. In a high-gain amplifier, an electron discharge device having a cathode, a grid, a screen grid, and an anode, a second electron discharge device having a cathode, grid and anode, a conductive connection between the anode of said first device and the grid of said second device, means for impressing operating potential on the anode of said second device, means for impressing operating potential on the anode of said first device through the anode-cathode circuit of said second device, a common resistance in the anode-cathode circuits of said devices, and a second resistance connected at one end to the anode of said first device and the grid of said second device and at the other end to said common resistance.

29. A high-gain amplifier comprising an electron discharge device having a cathode, grid, screen grid and anode, a second electron discharge device having a cathode, grid and anode, means for impressing anode operating potential on said devices in series, a resistance common to the anode-cathode circuits of said devices, and means for causing signal potentials impressed upon the grid of said first device to be repeated in said second device and to have an effect upon the anode current of said first device.

30. An amplifier for providing uniform amplification over a wide range of frequencies, including in combination a first vacuum tube repeater having an anode, a cathode and a circuit connecting said anode and cathode, a second vacuum tube amplifier having input electrodes and output electrodes, said output electrodes comprising an anode and a cathode, a resistance in the anode-cathode circuit of the first repeater, means for directly connecting a potential drop derived from said resistance to the input electrodes of the second vacuum tube amplifier, an alternat-

ing current load circuit connected between the anode and cathode of said second amplifier, means for supplying operating current to the anode-cathode circuit of said second amplifier, an ohmic resistance traversed by said operating current, and means for inserting in the anode-cathode circuit of said first tube a potential drop derived from said last named resistance.

31. An amplifier including a first tube having cathode, grid, and anode electrodes, input and output circuits connecting said electrodes, means for impressing signals on the grid-cathode circuit of said tube, a resistance in the anode-cathode circuit of said tube traversed by the anode current, a second audio amplifier tube having an anode circuit and having input and output terminals, a utilization circuit, the input terminals of said second tube being connected to said resistance, and its output terminals being connected to said utilization circuit, means for energizing the anode circuit of said second tube, an ohmic resistance arranged to be traversed by at least a portion of the operating current of said second tube, and connections for energizing the anode circuit of said first tube from the voltage drop across said last named resistance.

32. A detector circuit including a vacuum tube having an anode, screen grid, control grid and cathode, circuits connecting said electrodes, a resonant circuit coupled to the input electrodes of said tube, an ohmic resistance in the anode circuit so high as to limit the anode current to a value too small to permit effective feed-back of energy at radio frequency from anode circuit to grid circuit, means for feeding back radio frequency energy from said screen circuit to said resonant input circuit, a second tube arranged to operate as an audio frequency amplifier, and direct connections from said resistance to the input electrodes of said second tube.

J. B. KNIGHT, JR.