

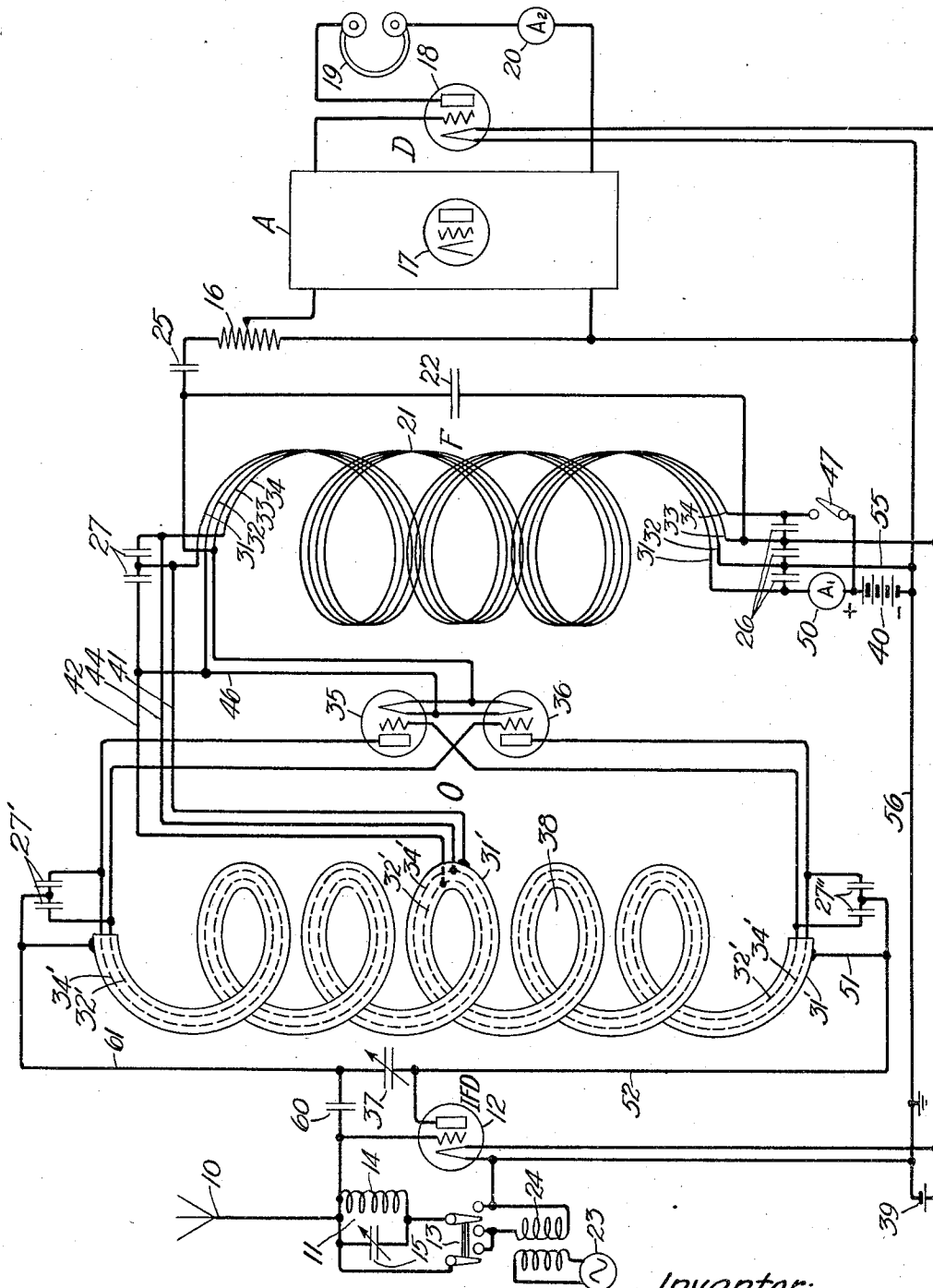
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H. T. FRIIS

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ELECTRIC WAVE TRANSLATING SYSTEM

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② Inventor:
Harald T. Friis

by W. Briggs

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UNITED STATES PATENT OFFICE

HARALD T. FRIIS, OF RED BANK, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

ELECTRIC WAVE TRANSLATING SYSTEM

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This invention relates to translating electric waves and relates also to electrical testing.

An object of the invention is production of electrical oscillations, especially oscillations of high frequency.

It is an object of the invention to couple a wave source to a space discharge tube so as to prevent undesired flow of oscillatory or other waves through specified paths in the tube circuit.

It is also an object of the invention to receive and detect electric waves, as, for example, radio telephone signals.

It is also an object of the invention to quantitatively determine the electrical characteristics or condition of a medium, as for example, to determine electrical field intensities produced by electromagnetic waves, or to measure electromotive forces, or the amplification produced by the resonance of a resonant path.

As a specific example of applications of the invention, there is described herein the operation of a double detection radio signal receiving system, embodying one form of the invention, for receiving and detecting radio telephone signals and for measuring radio field strengths. This system is suitable for use in making accurate measurements at high frequencies, for example, radio frequencies in a range extending up to at least a frequency of the order of forty megacycles per second.

In the specific form of the invention shown in the accompanying drawing the heterodyne oscillator of the double detection radio receiver is a vacuum tube oscillator of push-pull type and is coupled to the anode circuit of the first detector tube. The oscillator tuned circuit is connected directly in the anode circuit and the tuning coil performs the added function of a balancing inductance, the middle of the coil being connected to the oscillator filaments, one terminal of this coil

being connected to the anode of the first detector and its opposite terminal being connected through a balancing condenser to the grid of this detector. By the balance thus obtained between the beating oscillator and the input circuit of the detector, reaction between the oscillator and the input circuit of the first detector is prevented and radiation from the antenna as well as tuning difficulties are avoided.

The beating oscillator circuit includes a tuning coil adapted to have very low resistance. This coil comprises a hollow conducting tube inside of which several other insulated conductors are placed for supplying direct current paths to the anodes and grids of the respective tubes of the oscillator. The several conductors function as a single inductance and are connected together at their terminals by means of condensers having small reactance for high frequencies.

The resonant circuit provided for selecting the intermediate frequency waves also includes an inductance coil having a plurality of insulated conductors wound together to form a single coil. The terminals of these conductors are connected through low reactance condensers and the coil functions at high frequencies as a single inductance, but provides a plurality of direct current paths for current supplied to the space paths of the first detector, the oscillator tubes and to the filament of the oscillator tubes.

When the connection of the filaments of the beating oscillator tubes to their heating current source is made by way of the coil conductors just mentioned, the heating source may be grounded for direct current and yet these filaments will be maintained at a high intermediate frequency potential.

The double detection receiver, including the push-pull beating oscillator having the balancing arrangement and the special coils as described, is suitable for general use.

To adapt it for use, in a manner described

hereinafter, as an extremely sensitive vacuum tube system for measuring, for example, voltages or radio field strengths, a direct current microammeter is included in the anode circuit of the first detector. The detector and the meter are calibrated as an ordinary vacuum tube voltmeter. A direct current microammeter is included in the last detector tube of the double detection receiving system, and an adjustable, calibrated voltage attenuator is connected in the circuit, preferably between an intermediate frequency filter and an intermediate frequency amplifier which are comprised in the system.

Other objects and features of the invention will be apparent from the following description and claims.

The single figure of the drawing is a diagrammatic representation of the system referred to above.

In the system shown in the drawing, an antenna circuit including an open antenna 10 and a circuit 11 may be connected to an intermediate frequency detector tube 12 of a double detection receiver, through a double throw switch 13. The circuit 11 includes an inductance 14 in parallel with a variable tuning condenser 15. The double detection receiver includes in addition to the tube 12 a beating or heterodyne oscillator O of a push-pull type, an intermediate frequency filter F, an attenuating or gain control device 16, an intermediate frequency amplifier A indicated by an electron space discharge tube 17, a low frequency detector 18, and indicating devices shown as a telephone receiver 19 and a direct current microammeter 20. This ammeter is designated A₂, the intermediate frequency detector tube 12 is designated IFD. The filter F comprises an inductance 21 and a condenser 22. For use in connection with the receiver when voltage measurements are to be made as described hereinafter, a source of alternating electromotive force, 23, which may be, for example, an electron discharge tube oscillator, is provided. This oscillator is coupled to a coil 24. When the system is to be used for receiving incoming radio signals, the switch 13 should be closed to the left, and the oscillator 23 should be stopped from oscillating or its circuit 23 should be so arranged that the coil 24, which is inserted in series with the loop 11 by this closure of switch 13 has no electromotive force induced in it from the oscillator circuit.

The intermediate frequency filter F is shown as a parallel resonant circuit tuned to the intermediate frequency and connected across the input side of the attenuator 16 through a large capacity coupling condenser 25 which prevents steady potentials from being impressed on the grid of the intermediate amplifier from the filter. The coil 21 comprises a wire having four insulated strands 31, 32, 33 and 34 closely magnetically coupled

and connected together at their lower ends by condensers 26 and at their upper ends by condensers 27 and the low impedance path provided by the filaments of the oscillator tubes. For alternating current, the coil with the four strands constitutes one coil or winding, although the several strands are used as several paths for direct currents for supplying heating current to the filaments of electron discharge tubes (described below) employed in the oscillator O, and for supplying direct current to the plate circuits of those tubes and of the intermediate frequency detector tube 12.

The oscillator O is of the general type disclosed in R. V. L. Hartley Patent 1,356,763 October 26, 1920. However, it comprises two electron discharge tubes 35 and 36 connected in push-pull relationship and has a frequency determining circuit for the oscillator which comprises a variable condenser 37 connected in parallel with a multi-strand coil 38 somewhat similar to the coil 21. Filament current is supplied from a source 39 through the strands 32 and 33 of coil 21, and space current for tubes 35 and 36 is supplied from a source 40 through a switch 47 and the strand 34 of coil 21. Plate current for tube 35 passes between the strand 34 and the plate of that tube through a conductor 44 and the upper half of an insulated wire strand 34' of coil 38. Plate current for tube 36 passes between strand 34 and the plate of that tube through the conductor 44 and the lower half of strand 34'.

The coil 38 comprises, in addition to the strand 34', an insulated wire strand 32' and a coil or helix of copper tubing 31' inclosing the wires 34' and 32' and forming a conductor of very low resistance for high frequency waves. Coils 31', 32', and 34' have their mid-points interconnected by condensers 27 and conductors 41, 42 and 44, their upper ends interconnected by condensers 27', and their lower ends interconnected by condensers 27''. For alternating current the coil with the three direct current paths constitutes one coil or winding the strands of which are closely coupled electromagnetically. The upper and lower ends of strand 32' are connected to the grids of tubes 36 and 35 respectively, and the mid-point of this strand is conductively connected, through conductors 42 and 46, to the filaments of these tubes. Thus the upper half of coil 32' forms part of a conductive path for fixing the average potential of the grid of tube 36 with reference to its filament, and the lower half of coil 32' forms part of a conductive path for fixing the average potential of the grid of tube 35 with reference to its filament.

Regarding the frequency determining circuit of the oscillator, the coil 38 across which the condenser 37 is connected extends between the plate and grid of tube 35 and between

the plate and grid of tube 36, and for alternating current the filaments of these tubes are connected to the mid-point of this coil by lead 46 the connection to certain of the strands being through one or more of the condensers 27. The by-pass condensers 26, 27, 27' and 27'' are all of low or negligible impedance at the intermediate frequency, to which filter F is tuned which may be, for example, of the order of 300,000 cycles per second, as well as for the frequency of the oscillator O, which may be, for example, of the order of forty million cycles per second. The resistance and the inductance of the coil 38 for alternating current are substantially the resistance and the inductance of coil 31'; and the resistance and inductance of each half of coil 38 for alternating current are substantially the resistance and induction of half of coil 31'.

Direct plate current for the tube 12 of the intermediate frequency detector is supplied from source 40 through a direct current milliammeter or microammeter 50 designated A₁, the strand 31 of coil 21, conductor 41, coil 31', conductors 51 and 52 to the plate of tube 12, the filament of this tube being grounded as indicated. If desired the meter 50 and the switch 47 may be connected to points of different potential on source 40, so that the direct current plate voltage for the oscillator tubes will be different from that for the tube 12.

The lower half of coil 38 is serially included in the alternating current output circuit of tube 12. Waves received by the antenna are supplied to the input circuit of detector tube 12 and are repeated in the output circuit of this tube. The alternating current output circuit of tube 12 may be traced as follows; From the grounded filament of tube 12, through its space path to the anode, conductors 52 and 51, the lower half of coil 38, conductors 41, 42 and 44 in parallel, condensers 27, conductor 46 coil 21 and condenser 22 in parallel, and the condensers 26 at the lower end of coil 21, which are directly grounded through leads 55 and 56.

Thus, in the operation of the system for receiving modulated signal waves incident upon the antenna 10, the modulated wave received from the antenna circuit and amplified by tube 12 modulates or is modulated in the anode circuit of tube 12 by the waves supplied by the beating oscillator. One of the modulation products, the so called intermediate frequency, is a signal modulated carrier wave of a frequency equal to the difference between the carrier frequency and the oscillator frequency. This difference will ordinarily be small compared to the carrier frequency received by the antenna. This intermediate frequency in the output circuit of tube 12 passes through the intermediate frequency filter F substantially without attenu-

ation and is supplied to the attenuator 16, whereas other frequencies are attenuated by the filter F and hence are not transmitted to the intermediate frequency amplifier. The intermediate frequency waves, attenuated to the desired extent by the attenuator, are supplied to the input circuit of the intermediate frequency amplifier A, which may be of any suitable type, and the amplified waves are transmitted from the output circuit of amplifier A to the input circuit of the low frequency detector 18. The device 18 operates to detect the intermediate frequency wave and produce the audible frequency signal currents which are supplied to the telephone 19 and the direct current milliammeter 20. This meter serves to indicate the average value of the signal currents.

Although in the ordinary Hartley oscillator the phase difference between the voltages on the grid and plate is not exactly 180°, the phase difference between the grid and plate voltages of each tube of the oscillator disclosed herein is 180°. In the circuit shown in the drawing, advantage is taken of this 180° phase difference to obtain a balance between the input circuit to the tube 12 and the beating oscillator or in other words to balance out the coupling between the beating oscillator circuit and the input circuit to tube 12. This results in simplifying the tuning operation, preventing the radiation of locally supplied oscillations from the antenna, and reducing the tendency of tube 12 to sing. This balancing is accomplished by connecting a balancing condenser 60 between the grid of tube 12 and a conductor 61 leading to the upper end of coil 38, the voltage of which is opposite in phase to the voltage of the lower end of the coil.

The condenser 60 has such capacity that in spite of the internal plate to grid capacity of tube 12 and any other inherent coupling between the plate and grid circuits of tube 12, no appreciable voltage from the beating oscillator appears between the grid and filament of the intermediate detector. Under these conditions changes in the input circuit impedance do not react on the beating oscillator. The single inductance coil 38 serves as an element of the frequency determining circuit, as a coupling coil for connecting the oscillator to the output circuit of tube 12, and as a balancing coil.

The connection of the filaments of the oscillator tubes to the grounded heating current source 39 through the conductors 32 and 33 of coil 21 maintains these filaments at the required high potential above ground for the waves of the intermediate frequency, since the reactive voltage drop in coil 21 is high for the intermediate frequency.

To facilitate use of the system as an extremely sensitive vacuum tube system for measuring voltages, the tube 12 and direct

current microammeter A_1 is calibrated as an ordinary vacuum tube voltmeter, and the attenuator 16 is calibrated directly in voltage ratios. Thus, for example a reading of 10,000 on the attenuator indicates that the voltage impressed on the input terminals of the attenuator is 10,000 times larger than the attenuator output voltage. The attenuator is preferably made of resistance units wound with reversed loops on a thin card. Maximum attenuation may be, for example, one million times.

To facilitate explanation of the use of the system for measuring voltages, it will be assumed, as an example, that the voltage to be measured is the voltage across coil 14 or circuit 11 when the set is being used as a receiver. It will be clear from such explanation that other unknown voltages which can be applied across tube 12 may be measured in the manner to be explained with regard to the voltage across circuit 11.

To measure the voltage across circuit 11, which may be designated as an unknown voltage E_x , and which may have a frequency f of, for example, forty million cycles per second, switch 13 is closed to the left, and the frequency of the beating oscillator O may be adjusted to a value f' of say $f \pm 300$ kilocycles. The attenuator 16 is adjusted to such a setting that a convenient deflection appears in meter A_2 , with the local comparison oscillator 23 delivering no input to coil 24. This attenuation may be designated as an attenuation of a times, and the voltage of frequency f' delivered to the output circuit of tube 12 by the lower half of coil 38 may be designated E_B , and the voltage of frequency 300 kilocycles then present across the filter F may be designated E_1 . From well known modulation theory, $E_1 = kE_xE_B$ where k is a constant depending upon the constants of the system, provided the load on the intermediate frequency detector is not too great. Therefore, designating the attenuator output voltage under these conditions as E_A ,

$$E_A = \frac{kE_xE_B}{a}$$

Then the comparison oscillator 23 is caused to produce in the input circuit of tube 12 a voltage which may be designated E_o and which is identical in frequency with the voltage E_x but is sufficiently large to be measurable when using the tube 12 and meter A_1 as an ordinary vacuum tube voltmeter with the switch 47 open (that is, with E_B turned off). This voltage E_o is so large in comparison to the voltage E_x that, without material error, E_o may be regarded as substituted for the voltage E_x in the input circuit of tube 12, and therefore it is not necessary to stop the transmitter supplying radio waves to antenna 10 or to disconnect the antenna during this measurement. With E_o substituted for E_x

in the input circuit of tube 12, and with switch 47 closed and E_B at the same value it had for the first reading of meter A_2 , the setting of attenuator 16 is changed to give an attenuation such that the reading of meter A_2 has the same value as its first reading. This attenuation may be designated b times. Under this last condition of the system E_A is the same as previously. Therefore

$$E_A = \frac{kE_oE_B}{b}$$

Equating the two expressions given above for E_A gives

$$\frac{kE_xE_B}{a} = \frac{kE_oE_B}{b},$$

whence

$$E_x = E_o \frac{a}{b},$$

which gives the unknown voltage E_x in terms of E_o . Now to determine the value of E_o the switch 47 is opened, so that the beating oscillator stops oscillating, and the voltage E_o is read from the meter A_1 which, as stated above, has been calibrated for use with the tube 12 acting as an ordinary vacuum tube voltmeter. The value of E_o being now known, the value of E_x , which was desired, is also known, from the last equation above.

The intermediate frequency amplifier A may be of any suitable type, and with f and f' having values as given above, the resonant frequency of the intermediate frequency amplifier may be 300 kilocycles and its band width about 30 kilocycles. This broad band eliminates "hair line" tuning at high signaling frequencies.

The voltage measuring operations described above may be extended to the measurement of radio field strength, with the system shown in the drawing, by measuring the voltage step up obtained by virtue of the fact that the voltage, say E_v induced in the antenna circuit by the incoming signaling wave produces a higher voltage across the reactance 14, 15, since that reactance is an inductive reactance in series with the capacity of the antenna to ground. When this voltage step up ratio, which may be designated r , has been measured; the voltage induced in the antenna circuit by the incoming signaling waves can be found by dividing the above mentioned voltage E_x by r ; and then the radio field strength at the antenna can be calculated by dividing this induced voltage by the effective height of the antenna.

To measure the voltage step up ratio r , the switch 47 is closed again, and the switch 13 is closed to the right to connect the grid and filament of the tube 12 in parallel with the coil 14 and condenser 15 and across coil 24. With this condition of the circuit, the setting of the attenuator 16 is changed to give

an attenuation which makes the reading of the meter A , the same as its first or second reading. This attenuation may be designated c . The voltage step up ratio r is then given as

$$r = \frac{b}{c}$$

Therefore the voltage induced in the antenna circuit by the incoming signaling wave, which may be designated E_Y is

$$E_Y = \frac{X}{r} = \frac{E_o b}{r}$$

In making this last measurement, switch 13 being closed to the right, the circuit 11 and the antenna capacity to earth and the grid to filament capacity of the tube 12 are all in parallel across coil 24 as stated above. With this arrangement the voltage between the grid and filament of tube 12 is substantially the desired true value of the voltage induced in coil 24, since the circuits terminating at the coil 24 constitute a high impedance anti-resonant circuit in series with coil 24 which prevents the flow of an appreciable current through the coil and hence prevents the production of an applicable drop of potential across the coil. So far as the present invention is concerned, however, the antenna and circuit 11 may be disconnected and only the coil of the comparison oscillator connected to the grid and filament of tube 12 when obtaining an indication of the comparison electromotive force. The improved circuit shown in the drawing and described above is the invention of Edmond Bruce and is disclosed and claimed in his application bearing Serial No. 104,608, filed of even date herewith.

The method described above for measuring the voltage step up ratio of the antenna circuit is applicable to tuned circuits generally, for measuring step up of voltage produced in the circuit due to resonance.

With the voltage attenuator located in the output of the intermediate frequency detector, the attenuator operates at a relatively low and fixed frequency, and therefore great accuracy is possible without elaborate attenuator design, regardless of the signal frequency. Moreover, any interfering waves entering the system ahead of the attenuator and passing on to the attenuator are subjected to attenuation therein.

With regard to accuracy, the measurement of the comparison voltage directly by means of the tube voltmeter, as described above, is more satisfactory than obtaining the value of this voltage as the product of a current passed through an impedance, at very high frequencies.

What is claimed is:

1. A translating device having input and output circuits, and means comprising an

oscillator including two electric space discharge devices connected in push-pull relation to each other and coupling the circuits of said translating device to each other.

2. In combination a space discharge detector tube having interelectrode capacity, a tuned circuit including an inductance coil and a condenser in shunt thereto, a space discharge oscillator, said tuned circuit constituting the frequency determining element of the space discharge oscillator, and means adapted to cause said circuit to function as a balancing circuit for said space discharge tube detector to prevent energy supplied by said oscillator from reacting upon the detector input circuit.

3. In combination, a space discharge tube detector having grid, anode and cathode electrodes, a space discharge tube oscillator including a resonant circuit comprising an inductance coil and a condenser, said coil having one terminal connected to the anode of said detector tube, the opposite terminal being connected through a capacity to the grid electrode of said detector, and an intermediate point of said coil being connected to the cathode, whereby said detector is balanced for the prevention of undesired reaction of the energy supplied by the oscillator on the detector input circuit.

4. In combination, a detector having an output circuit, a beating source of electric waves forming a part of said output circuit, means included in said output circuit for selecting waves of a beat frequency produced by said detector and said beating source, and an attenuating device connected to receive said waves of said selected frequency from said means.

5. A double detection radio receiver comprising a beat frequency detector, a beating oscillator, an intermediate frequency filter, connected directly in series circuit with said oscillator to said detector, a meter in the output circuit of said beat frequency detector, and an adjustable attenuating device connected to said filter to receive waves therefrom, said beat frequency detector and said meter being calibrated as a voltmeter.

6. The method of measuring the voltage of an electric wave of a low unknown voltage which comprises combining the wave of unknown voltage with a second wave of different frequency to obtain a lower frequency wave, causing said lower frequency wave to produce an indication of its amplitude, combining said second wave with a comparison wave of the frequency of said unknown wave but of relatively larger voltage to produce a second low frequency wave, causing said second low frequency wave to produce an indication of its amplitude, and controlling the amplitude of at least one of said low frequency waves in such manner as to render said indications equal, whereby the relative

values of said voltages producing said equal indications may be determined.

7. The method of using a resonant path to measure the intensity of electric waves which comprises causing said waves to induce a voltage in the resonant path in such manner as to cause the path to amplify said induced voltage, inducing a comparison voltage in said resonant path in such manner that the latter voltage is amplified by said resonant path in the same ratio as said first induced voltage, measuring said second amplified voltage and the ratio of said first and second amplified voltages, and measuring the amplification of said second induced voltage produced by said resonant circuit whereby the field intensity may be determined.

8. The method of using a resonant path to measure the intensity of electric waves which comprises causing said waves to induce a voltage in the resonant path in such manner as to cause the path to amplify said induced voltage, combining said amplified voltage with a second wave of different frequency to obtain a wave of lower frequency, causing a comparison wave to induce a voltage, of the frequency of said first voltage but of greater amplitude, in said resonant path in such manner that the latter voltage is amplified by said resonant path in the same ratio as said first induced voltage, combining said second wave with said second amplified voltage to obtain a second low frequency wave, causing each of said low frequency waves to produce an indication of its amplitude and relatively controlling the amplitude of said indicated voltages in such manner as to render said indications equal and determine the relative values of said voltages producing said equal indications, and measuring said amplification produced by said resonant circuit in said second induced voltage.

9. The method of measuring voltage amplification produced in a resonant path due to resonance in the path, which comprises inducing in the path a voltage of the resonant frequency thereof to cause the resonance of the path to amplify said induced voltage, causing said amplified voltage to produce an indication of its amplitude, causing a voltage equal to said induced voltage to produce an indication of its amplitude and relatively controlling the amplitude of said indicated voltages in such manner as to render said indications equal and determine the relative values of said voltages producing said equal indications.

10. In combination, a space discharge device having input and output circuits, an oscillator connected to said space discharge device, said oscillator having a grid, filament and an anode element, and means for maintaining said filament at ground potential for direct current and at a substantially different potential for alternating current.

11. In combination, a detector tube having input and output circuits, an oscillator comprising two tubes in push pull relationship connected to said detector tube, each of said oscillator tubes having a grid, filament and anode element, and means for maintaining the filaments of said oscillator tubes at ground potential for direct current and at a substantially different potential for alternating current.

12. In combination, a thermionic tube having interelectrode capacity, a tuned circuit having an induction coil shunted by a condenser, a space discharge oscillator, said tuned circuit constituting the frequency determining element of the space discharge oscillator, and means including said tuned circuit for balancing the capacity of said thermionic tube to prevent energy supplied by said oscillator from reacting upon the thermionic tube input circuit.

13. In combination, a thermionic tube having interelectrode capacity, a tuned circuit having a coil shunted by a condenser, an oscillator comprising two space discharge tubes connected in push pull relationship, said tuned circuit constituting the frequency determining element of the oscillator, and means including said tuned circuit for balancing the capacity of said thermionic tube to prevent energy supplied by said oscillator from reacting upon the thermionic tube input circuit.

14. A regenerative space discharge system comprising two space discharge tubes, means for coupling said tubes in push-pull relationship, each of said tubes having a grid, filament and anode element, input and output circuits for said tubes, means for coupling said input and output circuits regeneratively, and means for maintaining the filaments of said tubes at ground potential for direct current and at a substantially different potential for alternating current.

In witness whereof, I hereunto subscribe my name this 22 day of April, A. D. 1926.

HARALD T. FRIIS.