

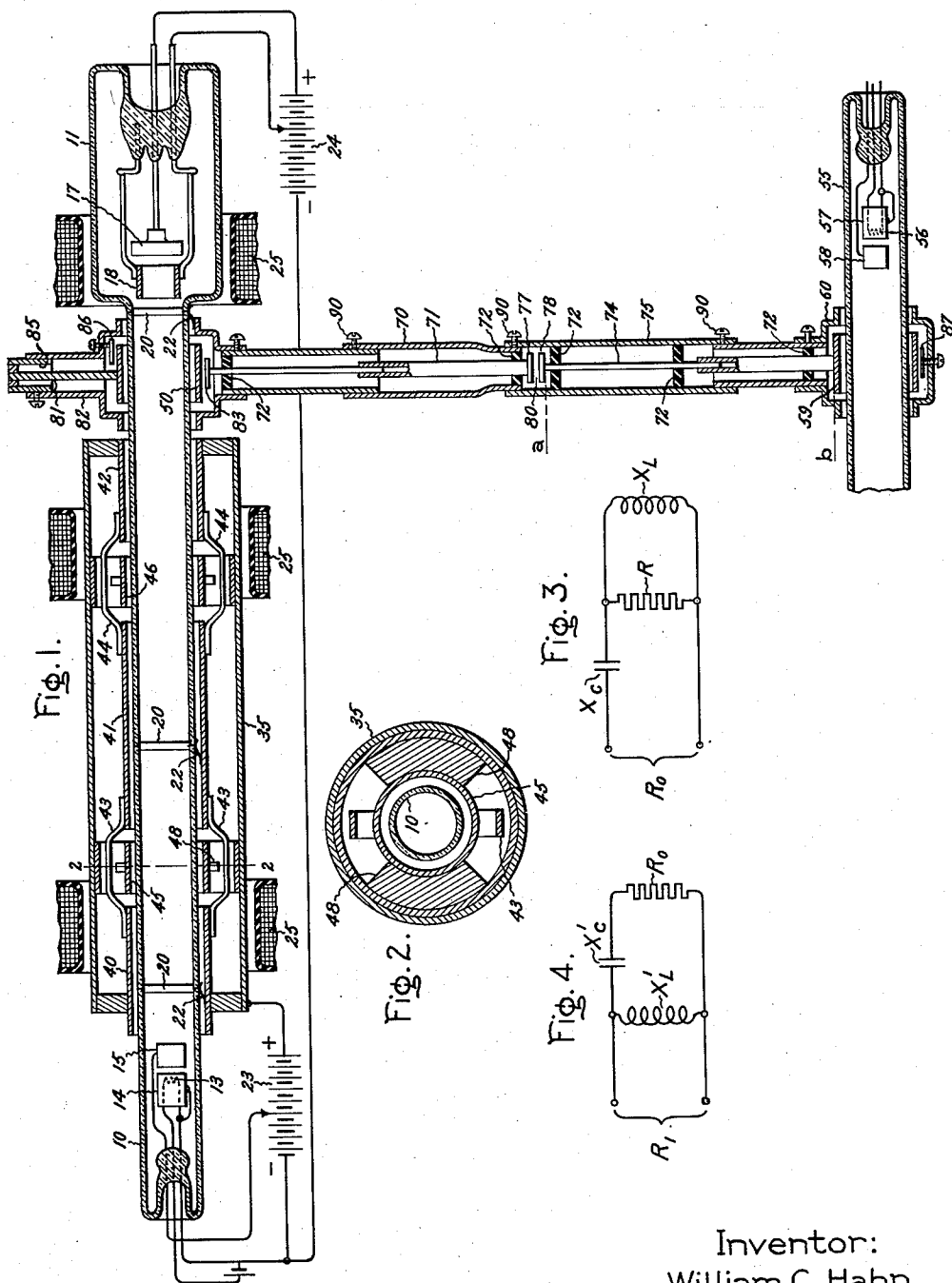
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MEANS FOR TRANSFERRING HIGH FREQUENCY POWER

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MEANS FOR TRANSFERRING HIGH
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eral Electric Company, a corporation of New
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The present invention relates to improved means for transferring high frequency power from a generating apparatus to a utilization apparatus. In particular the invention is concerned with the provision of an effective system for transmitting ultra-short waves from an oscillator or other source to an amplifier, modulating device, or the like.

It is known that in order to assure efficient transmission of electrical power from one point to another, the various elements of the transmitting system must be properly matched in impedance. Absence of such matching results in loss of power due to reflection at junction points and to other causes.

It is an object of the present invention to provide means useful at wave lengths on the order of from 1 meter to 5 centimeters or less for effectively matching the impedances of dissimilar circuit elements which are to be joined in a common circuit.

It is my further object to utilize in the foregoing connection, means which can be readily adjusted to meet the requirements of numerous conditions of use and which are characterized by a simple and readily usable construction.

The features which I desire to protect herein will be pointed out in appended claims. The invention itself together with further objects and advantages thereof, may best be understood by referring to the following description taken in connection with the drawing, in which Fig. 1 represents an ultra-short wave system embodying the invention; Fig. 2 is a sectional view taken on line 2—2 of Fig. 1, and Figs. 3 and 4 are diagrammatic representations useful in explaining the invention.

Referring to the drawing, there is shown at the upper part thereof on ultra-short wave oscillator of a type which is fully described in my co-pending application, Serial No. 211,123, filed June 1, 1938. The oscillator includes a tubular glass envelope which consists of an elongated shaft portion 10 and an enlarged anode-containing portion 11. At one extremity of the shaft portion there is provided means for producing an electron beam, such means comprising any known type of "electron gun." The particular combination illustrated includes a cathode 13, shown in dotted outline, a focusing cylinder 14 surrounding the cathode and electrically connected thereto and an accelerating electrode 15 positioned adjacent to the focusing cylinder and maintained at a high potential with respect to the cathode.

At the opposite end of the envelope there is provided an anode 17 which receives electrons projected toward it from the cathode 13 and which may consist of graphite or an equivalent heat-resisting material. Adjacent to the discharge-receiving face of the anode, there is a cylinder 18 which is adapted to serve as a suppressor grid for intercepting secondary electrons emitted from the anode during operation. This cylinder is preferably maintained at a negative potential with respect to the anode.

In the intermediate portion of the envelope there are provided a series of electrode elements 20 which serve to fix the potential of the interior surface of the envelope wall. These may suitably comprise bands of conducting material, for example, resistance paint applied circumferentially to the interior wall surface. They are provided with lead-in connections and spring contacts 22 which make it possible to apply a definite potential to the electrodes 20. With circuit connections such as those shown, the electrodes 20 are at ground potential, while the cathode is maintained several thousand volts negative by means of a battery 23. The accelerating electrode 15 is biased to a potential intermediate that of cathode and ground, and the anode 17 is held several thousand volts above the cathode by the use of a battery 24. These potentials are, of course, exemplary and may be varied within wide limits.

In order to maintain the electron beam in focus during its passage through the envelope, there are provided a series of magnetic coils 25 (shown partly broken away) mounted co-axially with the envelope. These may be excited with direct current and function in a known manner to prevent dispersion of the beam. In some cases, they may advantageously be replaced by electrostatic beam-focusing means.

The electrode combination which has been so far described comprises means for producing a unidirectional electron beam of constant average intensity and velocity. The remaining structure comprises means for producing ultra high frequency oscillations in accordance with the principles set forth in my aforementioned prior application, Serial No. 211,123.

In my said application it is pointed out that an electron stream may be modulated either as to electron velocity or as to charge density. The first type of modulation involves the creation of systematic irregularities in electron velocity from point to point along the stream. The second involves the production of variations in

charge density, such variations being manifested as systematic irregularities in the electron grouping.

In the conventional design of electronic discharge devices, no distinction is made between these two types of modulation. I have found, however, that with reference to ultra short wave devices improved results are obtained by using constructions in which velocity modulation and charge density modulation are produced separately. The oscillator shown herein embodies this principle.

In the arrangement illustrated the electron beam proceeding from the cathode is caused to traverse a space enclosed by an outer conducting shell 35 and an inner tubular structure which is within the shell and extends longitudinally thereof. The inner structure includes a series of conducting tubes numbered 40, 41, and 42 respectively, the tubes being relatively spaced so as to provide gaps between them. These gaps are conductively bridged by means of metallic elements 43, 44 connecting with the various tubes. In the gaps there are provided tubular electrodes 45, 46 which are connected to the shell 35 by means of metallic members 48, extending between them. (See Fig. 2.)

Assuming that the shell 35 is grounded as shown, the electrodes 45 and 46 may be considered to maintain a constant potential. The tubular members 40, 41, and 42, however, may be considered as forming the inner conductor of a concentric transmission line, of which the cylinder 35 forms the outer conductor. Under these conditions standing waves may be caused to exist along the tubular conductors. The frequency of such waves is determined by the length of the conductor 35, which is preferably so adjusted as to produce waves of a frequency corresponding to the desired oscillation frequency. This may be done by making the length of the conductor 35 approximately equal to some multiple number of half wave lengths of the desired frequency.

With the arrangement specified, potential variations occurring at those portions of the transmission line which are in the vicinity of the extremities of electrode 45 are effective to cause longitudinal velocity variations in the electron beam. Within the field free space enclosed by the tubular conductor 41, these variations may be converted into charge density variations by virtue of a sorting process by which the faster electrons become grouped with the slower electrons. Subsequently, the charge density modulated beam passing through the electrode 46 gives up energy to the transmission line system so that energy feed-back to the region of the electrode 45 is accomplished. By this means the system is maintained in continuous and self-sustained oscillation.

After leaving the space enclosed by the electrode 35 the charge density modulated portion of the beam is caused to traverse an output electrode 50. This electrode is preferably of a length which corresponds to a spacing between adjacent charge density maxima and minima in the modulated stream. If this condition is fulfilled, current pulses will be produced in the electrode by virtue of inequalities in the charges approaching toward and receding from it. These pulses will have a frequency determined by the oscillation frequency of the transmission line system previously traversed by the beam.

In use, the high frequency energy abstracted

from the beam by electrode 50 must be supplied to a suitable utilization device, such as an amplifier or modulator. A fragmentary portion of such a device is illustrated at 55 at the lower portion of Fig. 1. This comprises a glass envelope enclosing a cathode 56, a focusing electrode 57, an accelerating anode 58, and a high frequency input electrode 59. The output elements are not shown since their character is not material to my present invention. However, if the utilization device is to be an amplifier, it may suitably be of the type described in my prior application S. N. 211,124, filed June 1, 1938.

In order that energy may be effectively transmitted between electrode 50 and the control or input element 59 of the device 55 there is provided a non-dissipating transmission system, illustrated as a concentric conductor transmission line. The main body of the line comprises an outer conductor 70 and an inner conductor 71, these being insulatingly separated by means of spacers 72.

In order to assure the most effective transfer of power along the transmission line, it is necessary that its impedance be properly matched both to the impedance of the oscillator and to the impedance of the utilization device 55. As to the latter, the condition desired to be fulfilled for optimum or most effective cooperation of the device 55 and the transmission line is that the impedance presented to the transmission line by the device shall be substantially equal to the characteristic impedance of the transmission line. At the frequencies here under consideration, the characteristic impedance of the line may be taken as equal to its surge impedance Z_0 , which in turn is equal to

$$\sqrt{\frac{L}{C}}$$

This quantity is substantially a pure resistance of value R_0 and for practical dimensions of the line will have a magnitude on the order of about 70 ohms. It is necessary to match this to the impedance of the control electrode 59, which may be on the order of 100,000 ohms.

In order that the input impedance of the amplifier may be made to assume a purely resistive character, it is connected to an appropriate resonant circuit. Such a circuit may be provided by means of a resonant transmission line comprising an inner conductor 74 and an outer conductor 75, these conductors being assumed to extend from the point marked "a" to the point "b" of Fig. 1. Assuming that the distance $a-b$ corresponds to a half wave length at the frequency involved less the amount required to tune out the stray capacity of 59 to the outer shell 60, the resonant line will present a high impedance at both ends, such impedance being approximately determined by the formula

$$\frac{8Z_0 f}{rc}$$

(see Electrical Engineering, vol 53, pages 1046-1053). In this formula Z_0 (which is the same as R_0 above referred to) is the characteristic impedance of the line, f is its resonant frequency, r is the resistance of the line per unit of length and c is the velocity of the line. The input impedance thus determined is substantially of resistive character. Its value, however, is on the order of one thousand times the characteristic impedance of the transmission line which is formed by the conductors 70 and 71.

In order properly to match these two impedances my invention provides a series condenser of adjustable value interposed between the line 70, 71, and the line 74, 75. This condenser, which is shown at 80, may comprise, for example, a pair of metallic disks 77, 78 whose spacing can be varied at will. As will be shown in the following, such a condenser can be made to modify in a desired fashion the impedance presented to the extremity of the transmission line 70, 71, by the circuit containing the conductors 74 and 75 and the electrode 59. Referring particularly to the requirements of the present case, it can be made to cause the composite impedance presented to the line 70, 71 to assume a value equal to R_0 , the characteristic impedance of the line.

This may be better understood by referring to the schematic representation of Fig. 3 in which X_c represents a capacitive reactance equal to the reactance of the condenser 80 (Fig. 1), R represents the composite impedance of the line 74, 75 and the electrode 59, and X_L represents an inductive reactance provided by slightly detuning the transmission line 74, 75. This can be done, for example, by slightly shortening the line to a length than one-half wave length so that its inductance becomes predominant. It is desired that the inductance X_L be approximately equal to the value of the capacitive reactance X_c in which case the reactive component of the composite circuit impedance becomes negligible. Since the value of inductance required to accomplish this result is relatively small, it can be obtained without seriously detuning the resonant line 74, 75.

It can readily be shown that the composite resistance of the circuit of Fig. 3 is approximately equal to

$$\frac{X_c^2}{R}$$

This becomes equal to R_0 , the characteristic impedance of the line 70, 71 if the value of the capacitive reactance X_c is approximately equal to

$$\sqrt{R_0 R}$$

that is to say, to the geometric means of the said characteristic impedance and the input impedance of the device 55. When this condition is fulfilled, as it may readily be by proper adjustment of the condenser 80 (Fig. 1) the transmission line 70, 71 will be terminated in its characteristic impedance and there will be no possibility of wave reflection at the junction between this line and the line 74, 75. In other words, proper impedance matching at the line extremity under consideration is assured.

At the other end of the line the condition desired to be fulfilled is that the oscillator shall work into its optimum load impedance. This latter quantity is ordinarily on the order of from 3000 to 20,000 ohms and is determined by the following considerations.

The peak A. C. voltage developed across the gaps bounding the electrode 50 has to be limited to a value above which the electrons in the beam underneath would be actually brought to rest. Practically this limit must be set still lower by reason of heat generated in the glass envelope directly below the gaps and by the danger of arc-over. The peak induced current is limited to a value approximately equal to or less than the D. C. beam current. For maximum utilization of the power capacity of a tube, the voltage limit should be reached at the same time that the current limit is reached. Consequently the

optimum load impedance can be taken as being approximately equal to the voltage limit divided by the current limit.

In order to cause the transmission lines 70, 71 to present the desired impedance to the oscillator, an expedient similar to that used at the other end of the transmission line is employed. Thus, there is provided in connection with the electrode 50, a resonant type transmission line adapted to provide a tuned tank circuit for the electrode. This may comprise either a half-wave line of the character used in connection with the electrode 59, or a quarter wave line short circuited at its extremity. The latter arrangement is that shown in Fig. 1, wherein the resonant line comprises the concentric conductors 81 and 82.

There is also provided a variable capacitive coupling between the transmission line 70, 71 and the electrode 50. This coupling is obtained for example, by means of a movable disk 83 having its surface directly opposed to, but spaced from the surface of electrode 50.

The manner in which the condenser disk 83 serves as a matching device is indicated in Fig. 4 which represents the reactance of the condenser as the quantity X'_c , and the characteristic impedance of the transmission line 70, 71 as the quantity R_0 . The reactance X'_L is an inductive component provided by slightly de-tuning the resonant line 75, 76 as by shortening its length. It should be of approximately the same value as the capacitive reactance X'_c so as to give the circuit as a whole an essentially resistive characteristic.

Assuming that the optimum load impedance of the oscillator has a value R_1 , the illustrated network can provide this impedance if the quantity X'_c is made approximately equal to

$$\sqrt{R_0 R_1}$$

that is, to the geometric mean of the two impedances to be matched. (This is true on the assumption that R_0 is small with respect to R_1). Thus, by adjusting the condenser 83 (Fig. 1) to give the indicated value of X'_c , the transmission line 70, 71 can be properly matched to the oscillator.

In adjusting the apparatus in accordance with the principle described in the foregoing, I prefer first to compute an approximate setting for the coupling condensers 80 and 83 and to adjust the condensers to this setting. (It will be noted that the various sections of the transmission line are provided with mutually slidable elements so as to permit this adjustment.) Thereafter the resonant transmission lines associated with the electrodes 50 and 59 are respectively adjusted to resonance. As to the former, a preliminary adjustment may be made by moving the sliding element 85 until resonance is attained. A more delicate tuning of the system can be reached by means of a vernier condenser comprising a small metal disk 86 which is movable toward and away from the electrode 50. The transmission line 74, 75 is adjusted by appropriate movement of its telescoping parts. Another vernier condenser 87 provided in connection with the electrode 59 makes finer tuning possible.

After this initial setting is made the coupling condenser 80 may be more precisely adjusted by trial and error to give optimum output from the utilization device 55. The same thing may be done with the condenser 83. After each such change the resonant lines associated with the

electrodes 50 and 59 will need to be slightly re-tuned (primarily to control the values of the inductive impedance components referred to in connection with Figs. 3 and 4). Proceeding thus by a method of successive approximations it is a relatively simple matter to obtain optimum adjustment of the system in a short time.

It will be understood that various known mechanical expedients may be employed for facilitating accurate adjustment of the various parts. For example, I have shown set-screws 90 provided at appropriate points for rigidly fixing the various slidable joints after a satisfactory adjustment has been reached. Alternatively, these joints may be given a screw-threaded construction which will permit fine adjustments to be made.

The coupling system described in the foregoing is especially advantageous in that a single combination of elements may be made to work satisfactorily over a fairly wide range of frequencies. That is to say, if the operating frequency of the oscillator is changed, the coupling system can be adapted to the change simply by appropriate readjustment of the variable condensers 80 and 83 and of the resonant lines 70, 71 and 74, 75.

While I have described my improved transmission system as applied as a connection between an oscillator and an amplifier or the like, it will be understood that it may be used with equal facility in any connection where the transmission of ultra high frequency energy is desired. For example, it may be employed between a power tube and a load device such as an antenna. Other uses will occur to those skilled in the art.

I aim in the appended claims to cover all such variations of structure and use as fall within the true spirit of the foregoing disclosure.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, a device for delivering power at ultra high frequency, a system for receiving power at such frequency, the impedance of the system being materially different from the impedance which it ought to present to the device for optimum cooperation therewith and means for matching the impedances of the device and system, said means including a lumped capacitance serially interposed between the device and the system and having a capacitive reactance the value of which approximates the geometric mean of the impedances of the device and system.

2. An impedance-matched system including a device for delivering power at high frequency, a utilization device adapted to be energized by the first-named device, a transmission line of indeterminate length connected between the devices for transferring power between them, and separate condensers respectively providing lumped capacitances serially interposed between opposite terminals of the transmission line and the devices, the capacitive reactance of each condenser being approximately equal to the geometric mean of the characteristic impedance of the transmission line and of the impedance which the line ought to present to the associated device for most effective cooperation therewith.

3. In combination, a device capable of supplying power at a plurality of different operating frequencies within an ultra high frequency band, a utilization device adapted to be energized by the first named device, a transmission line of indeterminate length connected between the devices for transferring power between them, and separate condensers respectively providing

lumped capacitances serially interposed between opposite terminals of the transmission line and the devices, the capacitive reactance of each condenser being adjustable through a range such that for each operating frequency of the power supplying device an adjustment can be found at which the capacitive reactance of such condenser is approximately equal to the geometric mean of the characteristic impedance of the transmission line and of the impedance which the line ought to present to the associated device for most effective cooperation therewith.

4. In combination, a first discharge device having an output electrode adapted to deliver power at high frequency, a second discharge device having an input electrode adapted to receive power at the said high frequency, a transmission line for transmitting power between the two electrodes, a condenser serially interposed between one terminal of the transmission line and the said output electrode, said condenser having such a value as to match the characteristic impedance of the transmission line to the optimum load impedance of the first discharge device, and a second condenser serially interposed between the line and the said input electrode, the said second condenser being of such value as to match the characteristic impedance of the line to the input impedance of the said second discharge device.

5. In combination, a device for supplying power at ultra high frequencies, a power-transmitting system connected to the device and having an impedance materially different from the optimum load impedance of the device, the said system impedance being of substantially resistive character, a condenser providing a lumped capacitance serially interposed between the device and the transmitting system, and adjustable circuit means connected across the device for providing an inductive component substantially equal to the capacitive reactance of the said condenser, the value of such capacitive reactance being approximately equal to the geometric mean of the characteristic impedance of the transmission line and of the optimum load impedance of the said device, whereby the said line and device are brought into impedance matched condition.

6. In combination, a device adapted to be energized at ultra high frequency, a transmission system for supplying power at ultra high frequency to the device, said system having a characteristic impedance which is materially different from the input impedance of the device, a condenser providing a lumped capacitance serially connected between the transmission system and the device, and adjustable circuit means connected across the device and providing an inductive component substantially equal to the capacitive reactance of said condenser, the value of said capacitive reactance being approximately equal to the geometric mean of the impedances of the device and of the system, whereby the device and system operate in impedance matched condition.

7. In combination, a discharge device adapted to supply power at ultra-high frequency, a concentric conductor transmission line connected to the output circuit of the device for receiving power therefrom, and means for matching the characteristic impedance of the line to the optimum load impedance of the device, said means comprising a condenser serially connected between the line and the device and having a capacitive reactance which approximates the geometric mean of the said impedances, and a resonant-type transmission line connected across

the output circuit of the device, said last-named line being adjusted to provide an inductive component which is at least approximately equal to the capacitive reactance of the said condenser.

5 8. In combination, a device adapted to be energized at ultra-high frequency, a concentric conductor transmission line connected to the device for supplying power thereto, said line comprising an outer and a spaced inner conductor, and
10 means for matching the characteristic impedance

of the line to the impedance of the device, said means comprising capacitance-providing elements serially interposed in the said inner conductor at a point relatively near its connection with the said device, the lumped capacitance provided by said elements being approximately equal to the
5 geometric mean of the impedances of the said device and of the transmission line.

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