Aug. 10, 1943. D. G. BURNSIDE 2,326,519

ULTRA HIGH FREQUENCY COUPLING MEANS

Filed Feb. 28, 1941 2 Sheets-Sheet 1

Fig. 1

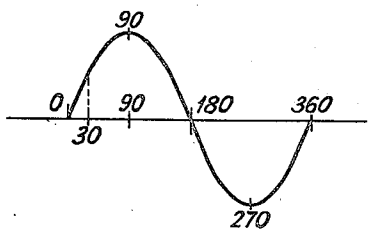


Fig. 2

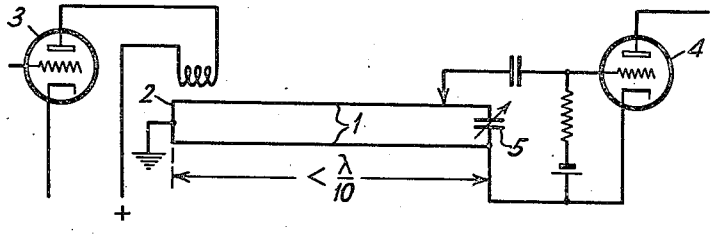
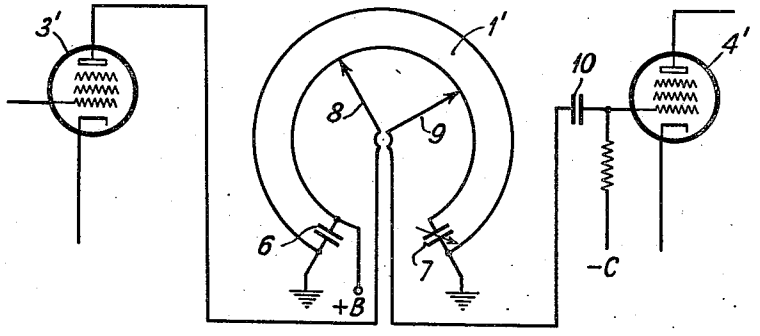


Fig. 3



INVENTOR
DON. G. BURNSIDE
BY H. S. Grover
ATTORNEY

Aug. 10, 1943. D. G. BURNSIDE 2,326,519

ULTRA HIGH FREQUENCY COUPLING MEANS

Filed Feb. 28, 1941 2 Sheets-Sheet 2

Fig. 4

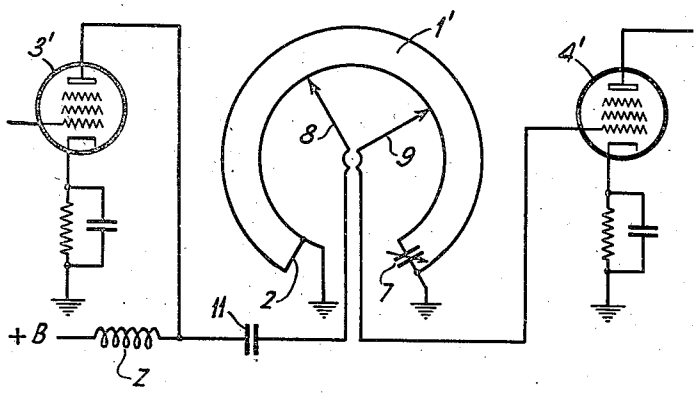
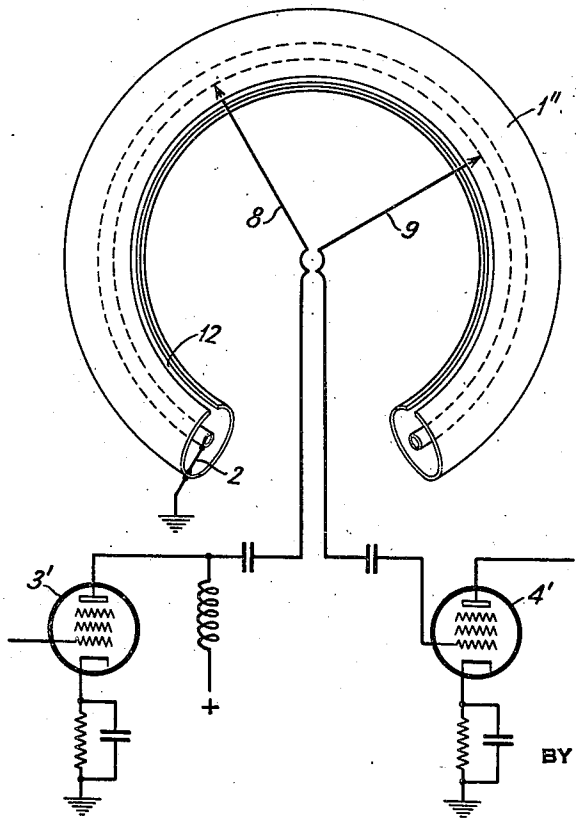


Fig. 5



INVENTOR
DON G. BURNSIDE
BY H. S. Brower
ATTORNEY

Patented Aug. 10, 1943

2,326,519

UNITED STATES PATENT OFFICE

2,326,519

ULTRA HIGH FREQUENCY COUPLING MEANS

Don G. Burnside, East Orange, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application February 28, 1941, Serial No. 381,161

14 Claims. (Cl. 178—44)

This invention relates to ultra short radio wave apparatus, and particularly to an improved ultra high frequency coupling unit for use in such apparatus.

It is known to use interstage coupling units of both the lumped circuit and resonant line types. The lumped circuit type includes a coil, while the resonant line type is a section of uniform transmission line. By making the connections from the input and output circuits adjustable over the coupling unit, the impedances of the coupled circuits can be matched to the impedance of the coupling unit in order to attain maximum gain. It has been found, however, that such known coupling units do not lend themselves readily to easy and accurate adjustment of the circuit connections in order to attain the desired matching of impedances, mainly because of the difficulty of obtaining smooth, variable, vernier adjustments of the tapping points throughout the length of the coupling unit. The physical dimensions of the uniform transmission line circuit used as a coupling unit are generally large relative to the dimensions of the coupled apparatus, such as the vacuum tube stages. Another difficulty to be found in the use of the known type of uniform transmission line as a coupling unit resides in the fact that the line has maximum and minimum voltage points when longer than a quarter wavelength, or unless terminated by such an impedance that standing waves are suppressed, and which must be considered in tapping the input circuits to the coupling unit.

The foregoing difficulties are overcome in the present invention, which provides a shortened and compact coupling unit in the form of a uniform section of transmission line having a substantially linear voltage distribution throughout its length. Briefly, the coupling unit of the invention consists of a uniform section of transmission line whose physical length is less than one-quarter wavelength such that the voltage distribution from one end to the other varies linearly. In the preferred embodiment of the invention, the uniform section of line comprising the coupling unit, is of the order of one-tenth to one-twelfth of the length of the operating wave, or less. It will be appreciated, however, that sections of line greater than the above-mentioned preferred lengths but less than one-quarter wavelength will give usable substantially linear voltage distributions, it being understood that the departure from linearity will become greater as the length of the line approaches one-quarter wavelength. Thus, as an example, a section of line having a length equal to one-eighth of a wavelength, constructed in accordance with the principles of the invention, will provide a substantially linear voltage distribution which can be used for many purposes.

A more detailed description of the invention follows in conjunction with drawings, wherein Fig. 1 graphically illustrates a voltage distribution curve given to aid in an understanding of the principles of the invention, and Figs. 2, 3, 4 and 5 illustrate different embodiments of the present invention.

Throughout the drawings, the same reference numerals represent the same parts.

Referring to Fig. 1, there is shown a typical sine curve E which illustrates the voltage distribution on a line one wavelength long. From the angular markings on this figure, it will be noted that the voltage varies from zero to a maximum at 90°, i. e., $2\pi/4$. The change in voltage from zero to 90° is representative of the voltage distribution of the length of a line which is one-quarter of the length of the operating wave; i. e., $\lambda/4$, where λ is the length of the operating wave. Over the range from zero to 30° on the curve E (equivalent to one-twelfth of a wavelength) the voltage varies substantially linearly and there is a greater and greater departure from linearity as the curve approaches the 90° point. The present invention is based on an appreciation of this fact and contemplates the use of a transmission line having such a length less than one-quarter wavelength that its voltage distribution is linear.

Fig. 2 illustrates, by way of example only, one embodiment of the present invention. This figure shows a section of transmission line consisting of a pair of parallel conductors 1 short-circuited and grounded at one end 2, and whose length is one-tenth of the operating wave or less. This section of line is shown as a coupling unit between vacuum tube stages 3 and 4. The output of vacuum tube stage 3, which may be an amplifier or any other suitable circuit, is shown inductively coupled to the section of line 1 at a suitable location near the low potential end, while the input of the following stage 4 is shown coupled to the section of line 1 near the other or high potential end of the line 1. Because of the short length of the line 1, it will be obvious that the voltage distribution throughout the line will be linear. Although the output of vacuum stage 3 has been shown to be inductively coupled to the line, it should be understood that this type of coupling is merely illustrative, and that if desired a direct or a capacitive connection can be used between the line 1 and the stage 3. Because of the relatively short dimensions of the line, the circuit is one of minimum dimensions and provides a compact arrangement not easily obtainable by other structures. Where it is desired to tune the coupling unit 1 to the resonant frequency, there may be provided a variable condenser 5 across the high potential end. The

variable condenser (of the low loss type) has the effect of tuning the line to resonance, without greatly affecting the tuned impedance at the open end. By "open end" is meant the end across which the variable condenser is connected. With a given line length, the condenser may be used to tune over a wide frequency range, thus being useful to permit of a physically shorter line without reducing its electrical length. In order to match the impedance of the coupling unit 1 to the input impedance of the stage 4, the tapping point of the connection to the grid of the vacuum tube 4 may be moved over the line 1 to a suitable location on the line.

Figs. 3 and 4 illustrate how the coupling unit of the invention can be bent into circular form in order to obtain a more compact arrangement than that shown in Fig. 2 and one which lends itself to greater ease of adjustment. The conductors of the coupling unit are preferably not merely parallel wires, but one of those conductors (namely, the lower or grounded one) is, for simplicity of construction, a surface which while not forming a concentric line is intended to approach it. It may be a flat plate back of the upper curved conductor and spaced from it a distance equal to two or three times the diameter of the conductor. Or it may be a curved narrow strip having a width four or five times the diameter of the conductor and spaced from it as above. The voltage variation should occur on the upper conductor, the plate or lower conductor being at ground potential at all points. In Fig. 3 the coupling unit is designated 1', and couples the output of a suitable vacuum tube amplifier stage 3' to the input of another amplifier vacuum stage 4'. The low potential end of line 1' is electrically short circuited by condenser 6 while the high potential end is shown bridged by a tuning condenser 7 for tuning the line. The ground connection is provided, as shown, at the low potential side of the coupling unit. The output or anode circuit of amplifier stage 3' and the input or grid circuit of amplifier stage 4' are individually connected to rotatable contact shafts 8 and 9, respectively, which slide over the lengths of the inner circular conductor of the coupled unit. These contact shafts may, if desired, be linked to separate adjustment dials, and preferably are arranged to engage opposite sides of the inner circular conductor of the line 1' in order that they may pass one another. Because the two conductors of the coupled unit are insulated from one another from a direct current standpoint, the polarizing potential for the anode of the vacuum tube 3' may be directly applied to the inner conductor of the coupling unit, as shown. A blocking condenser 10 in the grid circuit of the amplifier stage 4' serves to isolate this grid from this positive polarizing potential. In Fig. 4 the low potential end of the line 1' is shown short circuited at its low potential end by a direct connection 2, this end being grounded. In this figure, the positive polarizing potential for the anode of the vacuum stage 3' is prevented from being applied to the inner conductor of the line 1' by the blocking condenser 11. The impedance Z of the radio frequency choke allows the voltage set up in the plate circuit of tube 1 to be applied to the coupling element. The vacuum tubes shown in Figs. 3 and 4 are merely illustrative of any type of tube that can be used and may have any number of electrodes. The differences in applying bias to the electrodes of the vacuum tubes in Figs. 3 and 4 merely illustrate different ways by which this may be done and are not to be considered as limitative of the invention.

Fig. 5 illustrates how the coupling unit of the present invention can take the form of a concentric resonant line 1''. Such an arrangement is preferred. This concentric resonant line is shown bent into circular form in a manner generally similar to the coupling units of Figs. 3 and 4. A slot 12 is provided in the outer conductor of the concentric line to permit access to the inner conductor for contact shafts 8 and 9. These contact shafts enter the interior of the line 1'' through slot 12 and are so arranged that they do not touch the outer conductor of the line. As in the case in Figs. 2, 3 and 4, the low potential end of the coupling unit is short circuited and grounded.

Although the coupling units of Figs. 2, 3 and 4 have been shown as interstage coupling elements, it should be understood that they are not limited merely to connecting together a pair of vacuum tubes, since they can be used to couple together any two input and output circuits, such, for example, as the antenna of a suitable high frequency receiver to the first radio frequency stage, or the last stage of a transmitter to a suitable load. The present invention finds particular application to ultra high frequency radio circuits operating in a range from 50 megacycles to much higher frequencies. It is preferred that the overall length of the coupling unit be less than one-tenth of the length of the operating wave, for example one-twelfth, although as mentioned before for many purposes, lengths of the order of one-eighth of the operating wave can be used without departing from the principles of the invention.

The term "ground" used in the description and appended claims is not limited to an actual earthed connection but is deemed to include any point or surface of zero or fixed alternating current potential.

What is claimed is:

1. A coupling circuit for use between a source of high frequency waves and a load, comprising a pair of parallel conductors connected together at one end by a path of low impedance to energy of the operating frequency, the physical length of said conductors being appreciably less than and substantially of a different order than one-quarter of the length of the operating wave, whereby the voltage distribution varies substantially linearly over the entire length of said line, one of said conductors being a surface with open edges and whose width is at least twice the width of the other conductor.

2. A coupling circuit for use between a source of high frequency energy and a load, comprising a section of two-conductor transmission line short-circuited at one end for energy of the operating frequency, the physical length of said line being not substantially greater than one-eighth of the length of the wave of said source, whereby the voltage distribution varies linearly over the entire length of said line, a pair of slidable taps contacting one conductor of said line and movable over the length thereof, one of said taps being adapted to be connected to a source of high frequency energy, and the other of said taps being adapted to be connected to a load.

3. A coupling circuit for use between a source of high frequency waves and a load, comprising a section of two-conductor transmission line short-circuited at one end for energy of the operating frequency and having a length of the

order of one-twelfth of the length of the wave of said source, whereby the voltage distribution varies linearly over the entire length of said line, one of said conductors being a surface with open edges and whose width is at least twice the width of the other conductor.

4. A coupling circuit for use between a source of high frequency waves and a load, comprising a section of uniform two-conductor transmission line short-circuited at one end for energy of the operating frequency and having a physical length appreciably less than and substantially of a different order than one-quarter of the length of the wave of said source, and a variable capacitor bridged across the other end of said line for tuning the same, whereby the voltage distribution varies substantially linearly over the entire length of said line, one of said conductors being a surface with open edges and whose width is at least twice the width of the other conductor.

5. A coupling circuit for use between a source of high frequency waves and a load, comprising a section of uniform two-conductor transmission line short-circuited at one end for energy of the operating frequency and having a physical length appreciably less than and substantially of a different order than one-quarter of the length of the wave of said source, the voltage distribution over said line being substantially linear, a connection from ground to said short-circuited end, and a variable capacitor bridged across the other end of said line for tuning the same, one of said conductors being a surface with open edges and whose width is at least twice the width of the other conductor.

6. A coupling circuit for use between a source of high frequency waves and a load, comprising a pair of parallel conductors bent into circular form and connected together at one end by a path of low impedance to energy of the operating frequency, the physical length of said conductors being appreciably less than and substantially of a different order than one-quarter of the length of the operating wave, the voltage distribution over said line being substantially linear, and connections from one of said conductors to said source and load, said connections being movable over said one conductor.

7. A coupling circuit for use between a source of high frequency waves and a load, comprising a section of uniform transmission line bent into circular form and short-circuited at one end from a high frequency standpoint, the physical length of said line being not substantially greater than one-eighth of the length of the wave of said source, whereby the voltage distribution varies substantially linearly over the entire length of said line, means grounding said line at said short-circuited end, a pair of electrically conducting shafts contacting one conductor of said line and slidable over the length thereof, a connection from one of said shafts to said source and a connection from the other shaft to said load.

8. Apparatus in accordance with claim 7, characterized in this that said line consists of a pair of wires.

9. Apparatus in accordance with claim 7, characterized in this that said line is a coaxial arrangement, there being a slot in the outer conductor of said line for enabling said shafts to contact the inner conductor.

10. A coupling circuit for use between the output of a high frequency vacuum tube stage and the input of a following vacuum tube stage, comprising a section of uniform two-conductor transmission line short-circuited and grounded at one end, one of the conductors of said line being a surface with open edges and whose width is several times the width of the other conductor, the physical length of said line being appreciably less than and substantially of a different order than one-quarter of the length of the operating wave in order to obtain a substantially linear voltage distribution over the entire length of said line, and connections from said stages to different points on one conductor of said line.

11. A coupling circuit for use between the output of a high frequency vacuum tube stage and the input of a following vacuum tube stage, comprising a section of uniform two-conductor transmission short-circuited and grounded at one end, one of the conductors of said line being a surface with open edges and whose width is at least twice the width of the other conductor, the physical length of said line being appreciably less than and substantially of a different order than one-quarter of the length of the operating wave in order to obtain a substantially linear voltage distribution over the entire length of said line, a variable tuning capacitor across the other end of said line, and connections from said stages to different points on one conductor of said line.

12. A coupling circuit for use between the output of a high frequency vacuum tube stage and the input of a following vacuum tube stage, comprising a section of uniform two-conductor transmission line short-circuited from a high frequency standpoint and grounded at one end, one of the conductors of said line being a surface with open edges and whose width is several times the width of the other conductor, the physical length of said line being appreciably less than and substantially of a different order than one-quarter of the length of the operating wave in order to obtain a substantially linear voltage distribution over the entire length of said line, and connections from said stages to different slidable taps on opposite sides of the width of one conductor of said line.

13. An ultra high frequency coupling circuit for use with frequencies of the order of fifty megacycles and much higher comprising a section of uniform transmission line bent into circular form and short circuited for radio frequency waves at one end, the physical length of said line not exceeding substantially one-eighth of the length of the operating wave, and a pair of slidable taps contacting one conductor of said line and movable over the length thereof, said taps being adapted to be connected one to a source of high frequency current and the other to a load.

14. A coupling circuit for use between a pair of translating circuits one of which comprises a source of high frequency energy and the other of which is a load, comprising a section of two-conductor transmission line short-circuited at one end for energy of the operating frequency, the physical length of said line being not substantially greater than one-eighth of the length of the wave of said source, whereby the voltage distribution varies linearly over the entire length of said line, a slidable tap contacting one conductor of said line and movable over the length thereof, said slidable tap being adapted to be connected to one of said translating circuits, and another connection to said same one conductor of said line and adapted to be connected to the other translating circuit.

DON G. BURNSIDE.