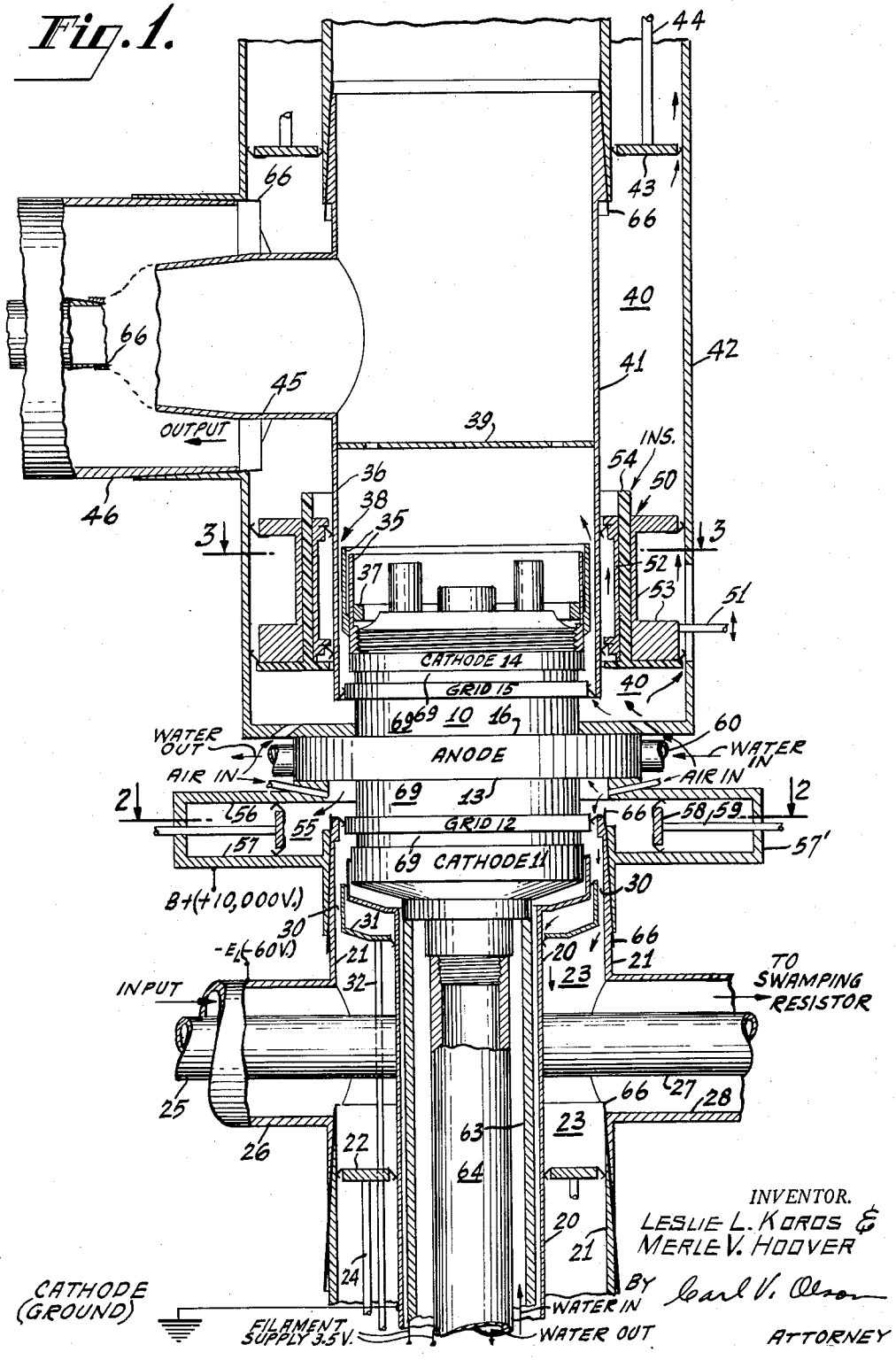
June 24, 1958 L. L. KOROS ET AL 2,840,647

INPUT AND OUTPUT COAXIAL-TYPE CIRCUITS FOR DOUBLE ENDED VACUUM TUBES

Filed May 23, 1956 3 Sheets-Sheet 1

Fig. 1.



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INPUT AND OUTPUT COAXIAL-TYPE CIRCUITS FOR DOUBLE ENDED VACUUM TUBES

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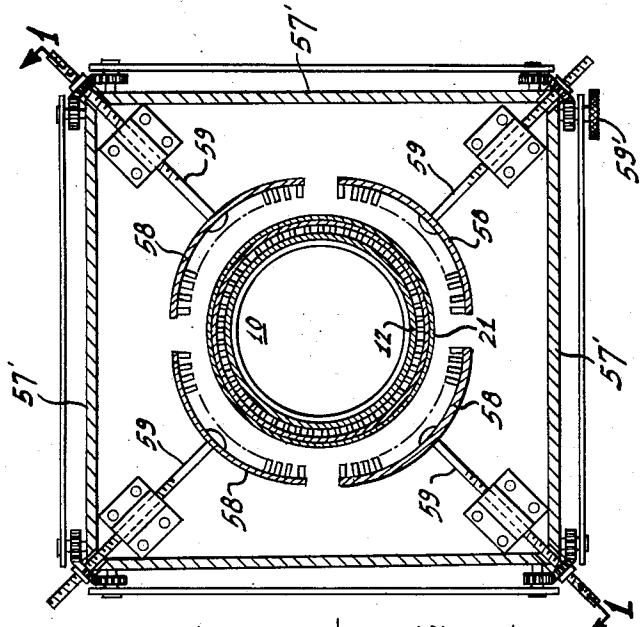


Fig. 2.

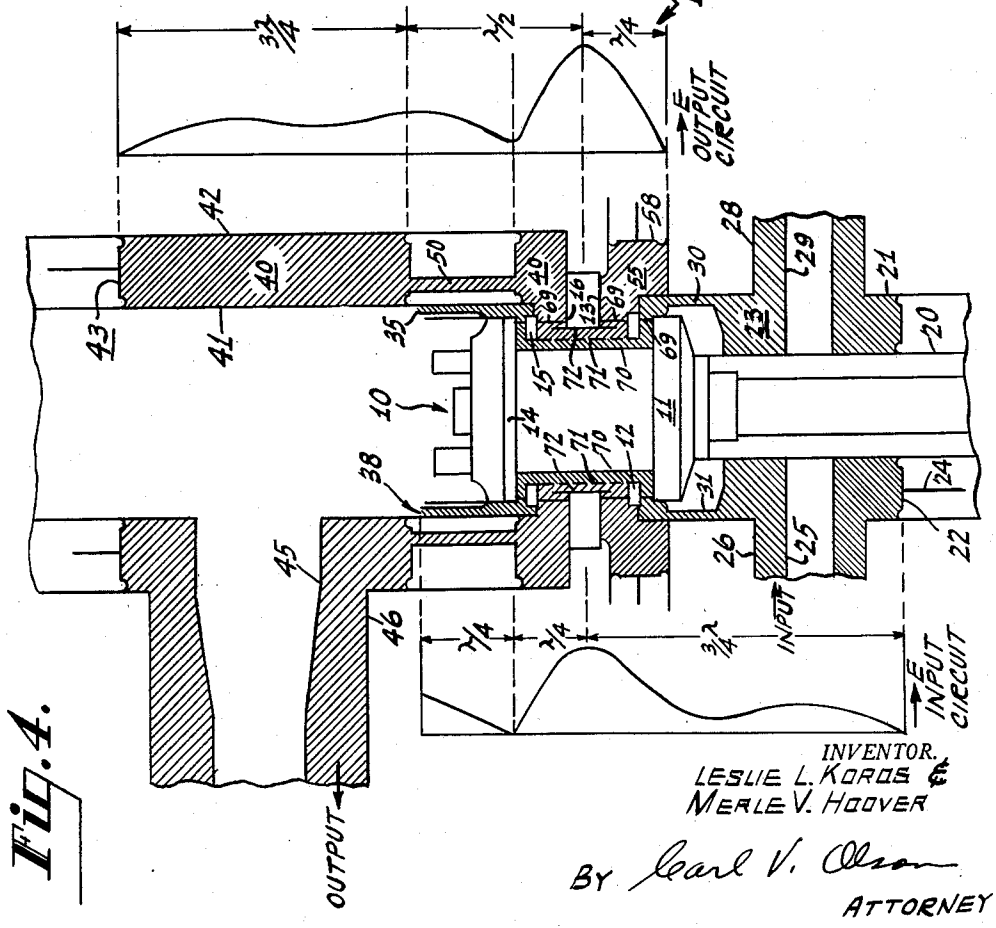


Fig. 4.

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Filed May 23, 1956 3 Sheets-Sheet 3

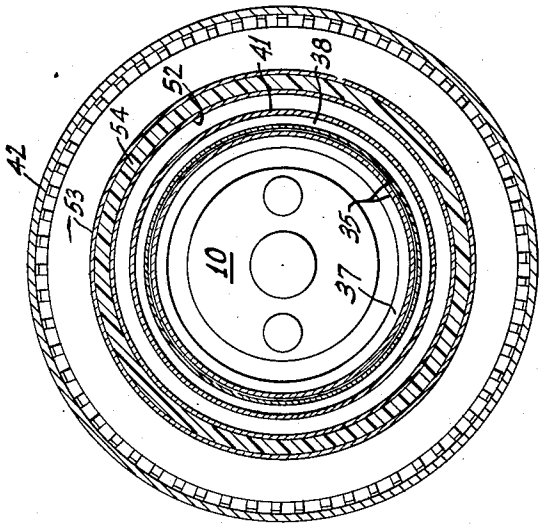


Fig. 3.

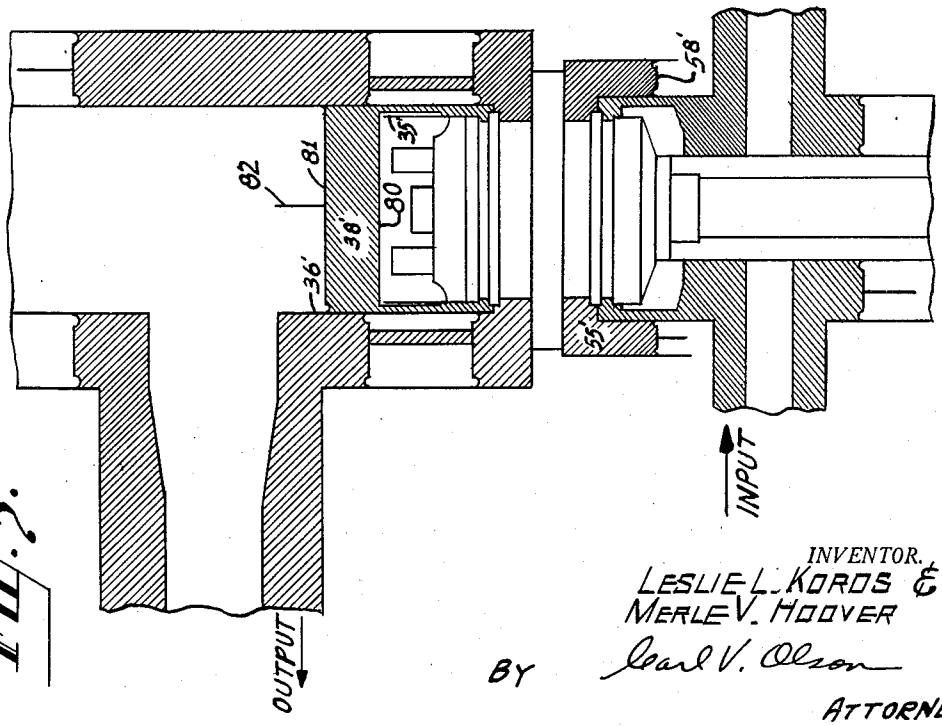


Fig. 5.

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2,840,647

INPUT AND OUTPUT COAXIAL-TYPE CIRCUITS FOR DOUBLE ENDED VACUUM TUBES

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Application May 23, 1956, Serial No. 586,690

12 Claims. (Cl. 179—171)

This invention relates to an improved arrangement of input and output circuits for double ended vacuum tubes, that is, vacuum tubes such as triodes or tetrodes constructed so that they may be physically and electrically inserted at axially or longitudinally intermediate points in coaxial line input and output circuits or cavities.

At very high and ultra-high frequencies, such as from about 150 megacycles to 1000 megacycles, it is difficult to construct high power vacuum tube circuits because certain physical dimensions necessarily related to the operating wavelength are small. The small physical dimensions limit the capacity of the tube and the associated circuits to handle high powers without voltage breakdown.

Another limitation at the high frequencies results from the fact that an appreciable portion of an electrical wavelength exists within the vacuum tube envelope. For example, when a coaxial line input circuit is coupled to the cathode and grid electrodes of the vacuum tube, the physical lengths of the cathode and grid electrodes may be a substantial portion of a quarter wavelength at the operating frequency. Therefore, when the input circuit is tuned to resonance, the electrodes at one end have maximum signal voltage thereacross and at the other end have a relatively low signal voltage thereacross. Thus, the electrodes are relatively inactive at one end.

The foregoing difficulties may be overcome by employing a double ended vacuum tube wherein a central cylindrical cathode is surrounded by a cylindrical control grid which is in turn surrounded by a cylindrical anode. A double ended tetrode may be employed having a cylindrical screen grid between the control grid and the anode. Electrode contact rings are connected from both ends of each cylindrical electrode to the exterior of the vacuum envelope. The large cylindrical surfaces of the electrodes provide correspondingly large power handling capacity while maintaining small dimensions between the electrodes.

The cylindrical configuration of the electrodes and the electrode contact rings at both ends of each electrode permit the cathode and grid electrodes to be inserted at an axially intermediate point in a coaxial line input circuit, and permit the grid and anode electrodes to be inserted at an axially intermediate point in a coaxial line output circuit. One end of the input circuit is terminated to provide a signal voltage distribution such that a radio frequency voltage maximum exists between the cathode and grid electrodes at the axial center of the electrodes, and high radio frequency voltages exist throughout the entire axial length of the electrodes. One end of the output circuit is terminated to provide an optimum signal voltage distribution between the grid and anode axially along the lengths thereof.

An object of this invention is to provide an improved vacuum tube circuit capable of translating very high radio frequency power at high frequencies.

Another object is to provide an improved vacuum tube circuit construction capable of being adjusted for operation at any desired frequency over a broad range of values.

A further object is to provide an improved vacuum tube circuit capable of uniformly amplifying broad band signals such as television radio frequency visual signals.

A still further object is to provide an improved double ended vacuum tube circuit construction having many advantageous practical features.

In one aspect, the invention comprises a circuit including a double ended vacuum tube having cathode, grid and anode electrodes constructed and arranged in the form of progressively larger concentric cylinders. Electrode contact rings are connected from the ends of each cylindrical electrode to the exterior of the vacuum envelope. A coaxial line input circuit is connected to the grid and cathode electrode contact rings at one end of the vacuum tube, and an open-circuited coaxial line input terminating line or circuit is coupled to the cathode and grid electrode contact rings at the other end of the vacuum tube. The input coaxial line and the input terminating line are adjusted to provide a signal voltage maximum at the axial center of the cylindrical cathode and grid electrodes. A coaxial line output line or circuit is coupled to the grid and anode electrode contact rings at one end of the vacuum tube, and a short-circuited coaxial line output terminating line or circuit is coupled to the grid and anode electrode contact rings at the other end of the vacuum tube. The output coaxial line and the output terminating line are adjusted to provide a signal voltage maximum at the axial center of the grid and anode electrodes within the vacuum tube. The input coaxial line and the output coaxial line extend from opposite ends of the double ended vacuum tube.

These and other objects and aspects of the invention will be apparent to those skilled in the art from the following more detailed description taken in conjunction with the appended drawings, wherein:

Figure 1 is a vertical sectional view of an amplifier constructed according to the teachings of this invention;

Figure 2 is a transverse sectional view taken on the line 2—2 of Figure 1;

Figure 3 is a transverse sectional view taken on the line 3—3 of Figure 1;

Figure 4 is a line diagram which will be referred to in describing the operation of the amplifier shown in Figures 1 thru 3; and

Figure 5 is a diagram illustrating an amplifier similar to that shown in Figures 1 thru 3 but having modified input and output terminating circuits.

Referring now in greater detail to the amplifier shown in Figures 1 thru 3 of the drawings, wherein all parts are figures of revolution, the amplifier includes a double ended vacuum tube designated 10 having, at the input end of the tube, a cathode contact ring 11, a grid contact ring 12, and an anode contact ring 13; and having at the output end of the tube, a cathode contact ring 14, a grid contact ring 15, and an anode contact ring 16. The anode contact rings 13 and 16 are actually two parallel surfaces of a single metallic structure. The various electrode contact rings are separated by means of ceramic portions 69 defining the vacuum envelope.

The double ended vacuum tube 10 may be an RCA Type A-2335 vacuum tube which is described in patent application Serial No. 534,971, filed by Lloyd P. Garner on September 19, 1955, and assigned to the assignee of the present application. The electrodes within the vacuum envelope are arranged in the form of concentric cylinders. An innermost cylindrical filamentary cathode is connected at its ends to the cathode contact ring 11 and the cathode contact ring 14. A cylindrical grid electrode surrounds the cathode electrode and has its ends connected to the grid contact ring 12 and the grid contact ring

15. An anode electrode within the tube is also of cylindrical form surrounding the grid electrode. The ends of the cylindrical anode electrode are effectively connected to the anode contact rings 13 and 16. The double ended vacuum tube construction is generally similar to that shown in Figure 1 of Patent No. 2,591,963 issued on April 8, 1952, to L. S. Nergaard. Since the double ended vacuum tube per se is not our invention, and since our invention can be understood with a general understanding of the double ended vacuum tube, it is unnecessary to here describe the constructional details of the tube.

Radio frequency energy is applied to the input electrodes of the vacuum tube 10 by means of an input coaxial line including an inner conductor 20 connected by means of spring fingers to the cathode contact ring 11 and an outer conductor 21 connected by means of spring fingers to the grid contact ring 12. An annular shorting plunger 22 between the conductors 20 and 21 defines one end of a coaxial input cavity or circuit designated 23. The position of the shorting plunger 22 is adjusted by means of a rod 24. The shorting plunger 22 is positioned to provide a three-quarter wavelength input cavity measured from the shorting plunger 22 to the center of the cylindrical input electrodes within the vacuum tube 10.

Radio frequency input energy is applied to the input circuit 23 by means of a branch coaxial line including an inner conductor 25 and an outer conductor 26. A second coaxial branch line 27, 28 is connected from the input circuit 23 to a swamping or broadbanding grid resistor (not shown). The inner conductors 25 and 27 of the two branch lines are directly connected to the inner conductor 20 of the input circuit 23, and the outer conductors 26 and 27 of the branch lines are directly connected to the outer conductor 21 of the input circuit.

The input circuit 23 includes an adjustable section designated 30 of low impedance coaxial line closely adjacent to the input electrode contact rings 11 and 12. The quarter wave section of low impedance line 30 is constituted in part by an apertured cup-shaped element 31 which is axially adjustable by means of a rod 32. The section 30 of low impedance line acts as an impedance transformer which permits high signal voltage within the vacuum tube 10 while maintaining a relatively low signal voltage between the inner and outer conductors of the input cavity 23. The resulting voltage distribution will be described in greater detail in connection with an explanation of the diagram of Figure 4.

The input circuit 23 does not terminate within the vacuum tube 10 but continues thru the vacuum tube, emerging out from between the cathode contact ring 14 and the grid contact ring 15, and continuing to an input terminating line or circuit 38 constituted by an inner conductor 35 connected to the cathode contact ring 14 and an outer conductor 36 connected to the grid contact ring 15. The inner conductor 35 includes two telescoping parts so that the axial length of the inner conductor 35 may be adjusted in accordance with the desired frequency of operation. An expansion ring 37 is provided to lock the two telescoping sections into any relative position in which they may be set.

The input terminating line 38 constituted by the cylindrical conductors 35 and 36 is open-circuited at the end. The telescoping inner conductor 35 is adjusted in length to provide the open circuit termination at a point one-half wavelength from the axial center of the cathode and grid electrodes within the vacuum tube 10. Although the outer conductor 36 of the input terminating line continues on and constitutes an inner conductor for the output circuit to be described, no energy from the input terminating line 36 is propagated beyond the end of the inner conductor 35. Energy is not propagated because the circumferential dimension of the outer conductor 36 is constructed to be less than a wavelength at the operating frequency. Under this condition, the outer conductor 36 constitutes a waveguide operated at a frequency below the cut-off frequency. However, a circular partition 39 is fixed at any convenient location to prevent the propagation of higher harmonics of the carrier frequency which may be present. It may be seen that the dimension of the input terminating line 38 parallel to the longitudinal axis of the tube is small compared to the similar dimension of input transmission line 23.

An output circuit generally designated 40 is constituted by an inner conductor 41 connected to the grid contact ring 15, and an outer conductor 42 connected to the anode contact ring 16. The end of the output cavity or circuit 40 remote from the vacuum tube 10 is terminated by means of an annular shorting plunger 43 adjustably positioned by means of a rod 44. Radio frequency energy is taken from the output circuit 40 by means of a branch coaxial line including an inner conductor 45 connected to the inner conductor 41 of the output circuit, and an outer conductor 46 connected to the outer conductor 42 of the output circuit. The inner conductor 45 of the output branch line is tapered to provide a smooth impedance transformation from the output cavity 40 to the output coaxial line used for conveying the radio frequency energy to an antenna or other utilization device.

The output circuit 40 includes a section 50 of low impedance coaxial line which is axially adjustable in position by means of a rod 51 extending thru a slot in the outer conductor 42. The section 50 of low impedance line is constituted by an inner conductive sleeve 52, having spring fingers engaging the inner conductor 41 of the output cavity, an outer conductive sleeve 53 having spring fingers engaging the outer conductor 42 of the output cavity, and a generally cylindrical insulating dielectric member 54 positioned between the sleeves 52 and 53. The insulating cylinder 54 may be constructed of "Teflon," a trade-name for tetrafluoroethylene, or it may be constructed of a ceramic dielectric material having a low radio frequency loss factor. The section 50 of low impedance line has an axial dimension of approximately a quarter-wavelength at the operating frequency, and the low impedance line section is positioned in the output cavity 40 near the vacuum tube 10 to provide an impedance transformation such that high radio frequency signal voltages are present between the electrodes within the vacuum tube and relatively low voltages exist between the inner and outer conductors of the output cavity 40.

The coaxial line output cavity or circuit 40 extends from the shorting plunger 43 thru the low impedance line section 50 and into the vacuum tube 10 thru the grid contact ring 15 and the anode contact ring 16. The circuit continues thru the vacuum tube 10 between the grid and anode electrodes therein and emerges from between the grid contact ring 12 and the anode contact ring 13 to an output terminating line or circuit designated 55. The output terminating line 55 is a radial line constituted by a square, transverse, apertured conductive plate 56, coupled at the edge of the aperture to the anode contact ring 13, and a parallel, square, transverse, apertured conductive plate 57 coupled at the edge of the aperture to the grid contact ring 12. The electrical length of the output terminating line 55 in the radial direction, as shown in Figure 2, is adjusted by means of four arcuate shorting strips 58 operated in unison by a knob 59' and four rods 59. Peripheral walls 57' prevent the escape of radio frequency energy. The output terminating line or cavity 55 thus consists of a radially extending transmission line having four arcuate shorting strips 58 which may be positioned to determine the electrical length of the output terminating line. The electrical field conditions within the output terminating line 55 are complex and difficult to analyze, but the effect of the terminating line is to provide a short circuit at a desired distance from the axial center of the grid-anode region within the vacuum tube 10. The short circuit termination is provided at a point a quarter wavelength (or three-quarters wavelength) removed from the axial center of the vacuum tube

electrodes so that a voltage maximum exists at the desired central region within the active portion of the vacuum tube. The output terminating line **55** constructed as shown and described is eminently satisfactory in electrical characteristics, and is especially advantageous in that it may be conveniently and economically manufactured from flat metal stock. A further practical advantage results from the radial arrangement whereby mechanical interference with the other circuit elements of the amplifier is avoided. It may be seen that the dimension of the output terminating line **55** parallel to the longitudinal axis of the tube is small compared to the similar dimension of output transmission line **40**.

A coolant such as water is applied to the anode of the vacuum tube thru a pipe **60**. The water is discharged from the tube thru a pipe labeled "Water Out." It will be noted that the arrangement for applying coolant to the anode of the vacuum tube **10** does not in any way interfere with the circuitry surrounding the vacuum tube. Coolant for other electrodes of the vacuum tube is inserted between a pipe **63** and a concentric pipe **64**. This coolant emerges from the vacuum tube thru the interior of the pipe **64**. The pipes **63** and **64** also serve to carry filament current supplying the filamentary cathode within the vacuum tube **10**. The cathode contact ring **11** is directly connected to the pipe **63**. The inner conductor **20** of the input circuit **23** is connected to the cathode contact ring **11** of the vacuum tube and is also connected to ground. The direct current potentials for the amplifier include a B+ potential having an order of magnitude of +10,000 volts with respect to ground connected to the anode of the vacuum tube **10**, and a negative potential with respect to ground of about −60 volts connected to the grid contact ring **12** thru the outer conductor **21** of the input circuit **23**. Most of the circuitry is thus at high direct current potentials with respect to ground and must be enclosed to prevent accidental contact by the operator.

Several direct current blocking and radio frequency by-passing capacitors **66** are required in the amplifier. These capacitors are constructed by compressing a frustroconical piece of dielectric material between tapered mating edges of the cylindrical conductors.

Reference will now be made to the line diagram of Figure 4 for an explanation of the operation of the amplifier of Figures 1 thru 3. The diagram of Figure 4 is representative of the structure shown in Figure 1 and includes diagonal cross-hatching of the spaces in communication with the input coaxial line **25**, **26**, and different diagonal cross-hatching of the spaces in communication with the output coaxial line **45**, **46**. The same reference numerals are used to identify corresponding elements in Figures 1 thru 4.

The space in communication with the input coaxial line **25**, **26** will be seen to extend from the shorting plunger **22**, thru the quarter wave section **30** of low impedance line, thru the ceramic seal **69** between the cathode contact ring **11** and the grid contact ring **12** to the interior of the vacuum tube **10**, thence thru the space between the cathode **70** and the grid **71**, and out of the vacuum tube between the cathode contact ring **14** and the grid contact ring **15** to the input terminating line **38** which terminates in an open circuit. The standing wave voltage distribution in the input circuit path described is plotted on the left-hand chart in Figure 4. It will be seen that the voltage at the shorting plunger **22** is zero, that the voltage between the cathode **70** and the grid **71** within the vacuum tube is high throughout the axial length of the electrodes, and that the voltage at the open circuited end of the input terminating line **38** is moderately high. The quarter wavelength section **30** of low impedance line provides an impedance and voltage transformation between the tube **10** and the input circuit **23** so that the signal standing wave voltage in the input circuit **23** is of moderate value. The loaded Q of the input circuit **23** is low, and therefore the input circuit possesses broadband characteristics.

The space in communication with the output coaxial line **45**, **46** will be seen from reference to Figure 4 to extend from the shorting plunger **43** in the output cavity **40**, thru the low impedance section **50** in the output cavity **40**, thru the vacuum seal **69** between the grid contact ring **15** and the anode contact ring **16** to the interior of the vacuum tube **10**, thence thru the vacuum tube between the grid electrode **71** and the anode electrode **72**, and out thru the vacuum seal **69** between the grid contact ring **12** and the anode contact ring **13** to the output radial terminating line **55**. The radial rectangular output terminating line **55** is terminated by a short-circuit provided by arcuate shorting members **58**.

The chart at the right in Figure 4 illustrates the voltage distribution at various points along the path described. It will be noted that the voltage is zero at the shorting plunger **43** and at the shorting plunger **58**. It will also be noted that the voltage is a maximum within the vacuum tube between the grid electrode **71** and the anode electrode **72**. The substantially quarter wave long section **50** of low impedance transmission line provides a voltage and impedance transformation such that the voltage existing in the output circuit **40** is of relatively low value. By this construction, the stored energy in the output circuit **40** is kept at a low value with the result that the output circuit has broadband characteristics, as required for handling television visual signals, and has good operational efficiency.

The amplifier of Figures 1 thru 4 is adjusted for operation at a given frequency as follows: The telescoping element **35** is adjusted in length to provide an open circuit at a point one-half wavelength removed from the axial center of the input electrodes within the vacuum tube. (All dimensions herein are given in terms of electrical wavelengths in the circuit, rather than in free space.) This insures that a voltage maximum exists at the axial center within the vacuum tube between the cathode **70** and the grid **71**. As a second step, the shorting plunger **22** at the end of the input circuit **23** is positioned at a point such that it is approximately three-quarters of a wavelength from the axial center of the vacuum tube **10**. The adjustable cup-shaped member **31** defining the length and position of the low impedance transmission line section **30** is then adjusted axially to the position at which maximum grid current is obtained. After this adjustment is made, the electrical length from the center of the vacuum tube to the tuning plunger **22** is exactly three-quarters of a wavelength.

Now referring to the output circuit, the shorting members **58** in the output terminating line **55** are positioned a quarter-wavelength removed from the axial center of the vacuum tube. This insures a voltage maximum within the vacuum tube at the axial center of the grid electrode **71** and the anode electrode **72**. The quarter wave section **50** of low impedance line is then positioned so that approximately a half-wavelength exists between the load end of the section **50** and the axial center of the grid and anode electrodes within the vacuum tube. Then the shorting plunger **43** is axially positioned to provide a proper impedance match between the output cavity **40** and the output coaxial line **45**, **46**, and the desired broadband characteristics.

Figure 5 is a diagram illustrating an amplifier similar to that shown in Figures 1 thru 4, but having a modified input terminating line **38'** and a modified output terminating line **55'** which differ in construction compared with the corresponding terminating lines **38** and **55**, respectively, in Figures 1 thru 4. The telescoping inner conductor **35'** of the input terminating line **38'** is provided with a circular conductive closure or wall **80**. A circular shorting plunger **81** is provided with spring fingers around its periphery which engage the outer conductor **36'** of the input terminating line **38'**. The short-

ing plunger 81 is operated by a rod 82. By this construction, the input terminating line 38' is in the form of a coaxial line 35', 36' which terminates in an inwardly directed radial transmission line formed by circular members 80 and 81. The radial transmission line is open-circuited at the axial center. The input terminating line 38' is adjusted so that the axial center of the radial transmission line portion is moved from the axial center of the vacuum tube an electrical distance equal to a multiple of half-wavelengths at the operating frequency. The diameter of the outer conductor 36' is selected to constitute a waveguide which will propagate energy at the operating frequency.

The output terminating line 55' in the embodiment of Figure 5 differs from that shown in Figures 1 thru 4 in that the line is of coaxial line configuration rather than radial configuration. It will be understood that one or both of the modifications illustrated in Figure 5 may be incorporated in the amplifier shown in Figures 1 thru 4.

An amplifier in accordance with Figures 1 thru 3 of the drawings was constructed for operation as the final stage of a U. H. F. television broadcasting transmitter. The amplifier was dimensioned for operation between 450 to 750 megacycles, and was tuned to 540 megacycles. A six kilowatt input signal was amplified to provide an output of 110 kilowatts with a continuous wave signal, and during another experiment, 200 kilowatts at the peak of sync of a television signal. With a B+ voltage of 10,000 volts, the amplifier uniformly amplified frequencies within a 12 megacycle bandwidth. The quarter wave section 50 of low impedance transmission line in the output circuit 40 had an axial length of 3.35 inches. The dielectric sleeve 54 was constructed of "Teflon" and had a mean diameter of 7.22 inches. The input terminating line 38 had a diameter of about 6 inches. This dimension is such that radio frequency energy below 1,170 megacycles cannot be propagated thru the circular waveguide constituted by the outer conductor 36. Therefore, no additional structure was needed to insure an open circuit termination at the end of the telescoping inner conductor 35. The dimensions of the various coaxial line conductors in the amplifier were such that the input line 25, 26 had a characteristic impedance of 50 ohms, the input cavity 23 had a characteristic impedance of about 40 ohms, the quarter wave section 30 had a characteristic impedance of about 4 ohms, the output circuit 40 had a characteristic impedance of about 35 ohms, the low-impedance section 50 had a characteristic impedance of about 3 ohms, and the output transmission line 45, 46 out beyond the tapered section had a characteristic impedance of 75 ohms.

As shown in Figure 1 of the drawings, the input and output circuit construction is such as to permit the flow of cooling air past all structural components at which excessive temperatures could cause failure. Air is directed under moderate pressure into the cavities near the anode contact ring of the vacuum tube from which the air flows thru the various spring contacts and thru the lines to the exterior of the equipment. The air flows past the quarter wave sections 30 and 50 and out past the shorting plungers 22, 43, and 58. The provisions for directing a coolant such as water thru the vacuum tube 10 have previously been described.

It is apparent that according to this invention there is provided an improved vacuum tube circuit capable of handling very high power at very high frequencies.

What is claimed is:

1. A vacuum tube circuit comprising a vacuum tube including cathode, grid, and anode electrodes generally arranged in the form of progressively larger concentric cylinders; an input transmission line having inner and outer conductors coupled at one end to one end of said cathode and grid electrodes, respectively, an input terminating line having inner and outer conductors coupled at one end to the other ends of said cathode and grid electrodes, respectively, the other end of said input terminating line being terminated to provide a voltage maximum between the cathode and grid electrodes in said vacuum tube at the axial center of said electrodes, an output transmission line having inner and outer conductors coupled at one end to one end of said grid and anode electrodes, respectively, and an output terminating line having first and second conductors coupled at one end to the other end of said grid and anode electrodes, respectively, the other end of said output terminating line being terminated to provide a voltage maximum between the grid and anode electrodes in said vacuum tube at the axial center of said electrodes.

2. A vacuum tube circuit comprising a vacuum tube including first, second, and third electrodes generally arranged in the form of progressively larger concentric cylinders; an input transmission line having inner and outer conductors coupled at one end to one end of said first and second electrodes, respectively, said input transmission line including a quarter wave section of relatively low characteristic impedance, an input terminating line having inner and outer conductors coupled at one end to the other ends of said first and second electrodes, respectively, the other end of said input terminating line being terminated to provide a voltage maximum between the first and second electrodes in said vacuum tube at the axial center of said electrodes, an output transmission line having inner and outer conductors coupled at one end to one end of said second and third electrodes, respectively, said output transmission line including a quarter wave section of relatively low characteristic impedance, and an output terminating line having first and second conductors coupled at one end to the other end of said second and third electrodes, respectively, the other end of said output terminating line being terminated to provide a voltage maximum between the second and third electrodes in said vacuum tube at the axial center of said electrodes, said input transmission line and said output transmission line being arranged to extend from opposite ends of said vacuum tube.

3. A vacuum tube circuit comprising a vacuum tube including cathode, grid, and anode electrodes generally arranged in the form of progressively larger concentric cylinders; an input transmission line having inner and outer conductors coupled at one end to one end of said cathode and grid electrodes, respectively, said input transmission line including a quarter wave section of relatively low characteristic impedance, an input terminating line having inner and outer conductors coupled at one end to the other ends of said cathode and grid electrodes, respectively, the other end of said input terminating line being terminated to provide a voltage maximum between the cathode and grid electrodes in said vacuum tube at the axial center of said electrodes, an output transmission line having inner and outer conductors coupled at one end to one end of said grid and anode electrodes, respectively, said output transmission line including a quarter wave section of relatively low characteristic impedance, and an output terminating line having first and second conductors coupled at one end to the other end of said grid and anode electrodes, respectively, the other end of said output terminating line being terminated to provide a voltage maximum between the grid and anode electrodes in said vacuum tube at the axial center of said electrodes.

4. A vacuum tube circuit comprising a vacuum tube including first, second, and third electrodes generally arranged in the form of progressively larger concentric cylinders; an input transmission line having inner and outer conductors coupled at one end to one end of said first and second electrodes, respectively, said input transmission line including a substantially quarter wave long section of relatively low characteristic impedance, an input terminating line having inner and outer conductors

coupled at one end to the other ends of said first and second electrodes, respectively, the other end of said input terminating line being terminated to provide a voltage maximum between the first and second electrodes in said vacuum tube at the axial center of said electrodes, an output transmission line having inner and outer conductors coupled at one end to one end of said second and third electrodes, respectively, said output transmission line including a substantially quarter wave long section of relatively low characteristic impedance, and an output terminating line having first and second conductors coupled at one end to the other end of said second and third electrodes, respectively, the other end of said output terminating line being terminated to provide a voltage maximum between the second and third electrodes in said vacuum tube at the axial center of said electrodes, the outer conductor of said input terminating line and the inner conductor of said output transmission line being constituted in part by a common conductive cylindrical wall, the inner conductor of said input terminating line having an end uncoupled from the outer conductor thereof to provide an open circuit termination.

5. A vacuum tube circuit as defined in claim 4 wherein said common conductive cylindrical wall is dimensioned to constitute a waveguide having a cut-off frequency higher than the operating frequency of said circuit.

6. A vacuum tube circuit comprising a vacuum tube including first, second, and third electrodes generally arranged in the form of progressively larger concentric cylinders; an input transmission line having inner and outer conductors coupled at one end to one end of said first and second electrodes, respectively, said input transmission line including a substantially quarter wave long section of relatively low characteristic impedance, an input terminating line having inner and outer conductors coupled at one end to the other ends of said first and second electrodes, respectively, the other end of said input terminating line being terminated to provide a voltage maximum between the first and second electrodes in said vacuum tube at the axial center of said electrodes, an output transmission line having inner and outer conductors coupled at one end to one end of said second and third electrodes, respectively, said output transmission line including a substantially quarter wave long section of relatively low characteristic impedance, and a radial output terminating line having first and second parallel apertured conductors coupled at said apertures to the other end of said second and third electrodes, respectively, the peripheral edge of said output terminating line being terminated by radially movable arcuate shorting elements to provide a voltage maximum between the second and third electrodes in said vacuum tube at the axial center of said electrodes.

7. A vacuum tube circuit comprising a vacuum tube including first, second, and third electrodes generally arranged in the form of progressively larger concentric cylinders; an input transmission line having inner and outer conductors coupled at one end to one end of said first and second electrodes, respectively, said input transmission line including a quarter wave section of relatively low characteristic impedance, an input terminating line having inner and outer conductors coupled at one end to the other ends of said first and second electrodes, respectively, the other end of said input terminating line being terminated to provide a voltage maximum between the first and second electrodes in said vacuum tube at the axial center of said electrodes, an output transmission line having inner and outer conductors coupled at one end to one end of said second and third electrodes, respectively, said output transmission line including a quarter wave section of relatively low characteristic impedance, and a radial output terminating line having first and second parallel apertured conductors coupled at said apertures to the other end of said second and third electrodes, respectively, the peripheral edge of said output terminating line being terminated by radially movable arcuate shorting elements to provide a voltage maximum between the second and third electrodes in said vacuum tube at the axial center of said electrodes, the outer conductor of said input terminating line and the inner conductor of said output transmission line being constituted in part by a common conductive cylindrical wall, the inner conductor of said input terminating line having an end uncoupled from the outer conductor thereof to provide an open circuit termination.

8. A vacuum tube circuit comprising a vacuum tube including first, second, and third electrodes generally arranged in the form of progressively larger concentric cylinders; an input transmission line having inner and outer conductors coupled at one end to one end of said first and second electrodes, respectively, said input transmission line including a quarter wave section of relatively low characteristic impedance, an input terminating line having inner and outer conductors coupled at one end to the other ends of said first and second electrodes, respectively, the other end of said input terminating line being terminated as an inwardly extending radial transmission line to provide a voltage maximum between the first and second electrodes in said vacuum tube at the axial center of said electrodes, an output transmission line having inner and outer conductors coupled at one end to one end of said second and third electrodes, respectively, said output transmission line including a quarter wave section of relatively low characteristic impedance, and an output terminating line having first and second conductors coupled at one end to the other end of said second and third electrodes, respectively, the other end of said output terminating line being terminated to provide a voltage maximum between the second and third electrodes in said vacuum tube at the axial center of said electrodes.

9. A vacuum tube circuit comprising a vacuum tube including cathode, grid, and anode electrodes generally arranged in the form of progressively larger concentric cylinders; an input transmission line having inner and outer conductors coupled at one end to one end of said input electrodes, respectively, a cathode and grid terminating line having inner and outer conductors coupled at one end to the other end of said input electrodes, respectively, the other end of said cathode and grid terminating line being terminated by an open circuit positioned to provide a voltage maximum between said cathode and grid electrodes at the longitudinal center thereof, said open circuit termination being formed by terminating said inner conductor and extending said outer conductor, said outer conductor having a diameter dimensioned to constitute a waveguide which will not propagate at the operating frequency of the vacuum tube circuit, an output transmission line having inner and outer conductors coupled at one end to one end of said output electrodes, respectively, and a grid and anode terminating line having first and second conductors coupled at one end to the other end of said grid and anode electrodes, respectively, the other end of said output terminating line being terminated to provide a voltage maximum between said grid and anode electrodes at the longitudinal center thereof.

10. A vacuum tube circuit comprising a vacuum tube including cathode, grid, and anode electrodes generally arranged in the form of progressively larger concentric cylinders; an input transmission line having inner and outer conductors coupled at one end to one end of said input electrodes, respectively, a cathode and grid terminating line having inner and outer conductors coupled at one end to the other end of said cathode and grid electrodes, respectively, an output transmission line having inner and outer conductors coupled at one end to one end of said output electrodes, respectively, and an output terminating line having first and second conductors coupled at one end to the other end of said output electrodes, respectively, the other end of said grid and anode

terminating line being terminated to provide a voltage maximum between said grid and anode electrodes at the longitudinal center thereof, one of said terminating lines being concentrically inside one of said transmission lines and being terminated by an open circuit at the end of the inner conductor of said one terminating line, the outer conductor of said one terminating line being dimensioned beyond said open circuit termination to constitute a non-propagating waveguide at the operating frequency of the vacuum tube circuit.

11. A vacuum tube circuit comprising a vacuum tube including first and second electrodes generally arranged in the form of concentric cylinders; a transmission line having inner and outer conductors coupled at one end to one end of said first and second electrodes, respectively, and a terminating line having inner and outer conductors coupled at one end to the other end of said first and second electrodes, respectively, the other end of said terminating line being terminated by an open circuit positioned to provide a voltage maximum between said first and second electrodes at the longitudinal center portion thereof, the outer conductor of said terminating line extending beyond said open circuit termination and having a diameter such as to constitute a waveguide which will not propagate at the operating frequency of the vacuum tube circuit.

12. A vacuum tube circuit comprising a vacuum tube including cathode, grid, and anode electrodes generally arranged in the form of progressively larger concentric

cylinders; an input transmission line having inner and outer coductors coupled at one end to one end of said cathode and grid electrodes, respectively, an input terminating line having inner and outer conductors coupled at one end to the other ends of said cathode and grid electrodes, respectively, the dimension of said terminating line parallel to the axis of said cylinders being small compared to the similar dimension of said transmission line, an output transmission line having inner and outer conductors coupled at one end to one end of said grid and anode electrodes, respectively, and an output terminating line having first and second conductors coupled at one end to the other end of said grid and anode electrodes, respectively, the dimension of said output terminating line parallel to the axis of said cylinders being small compared to the similar dimension of said output transmission line.

References Cited in the file of this patent

UNITED STATES PATENTS

2,153,728	Southworth	Apr. 11, 1939
2,169,396	Samuel	Aug. 15, 1939
2,207,846	Wolff	July 16, 1940
2,289,846	Litton	July 14, 1942
2,410,109	Schelling	Oct. 29, 1946
2,425,748	Llewellyn	Aug. 19, 1947
2,727,950	Wise	Dec. 20, 1955