Oct. 4, 1938. F. W. DUNMORE 2,132,208

ULTRAHIGH FREQUENCY RADIO AMPLIFIER

Filed Dec. 27, 1935 4 Sheets-Sheet 1

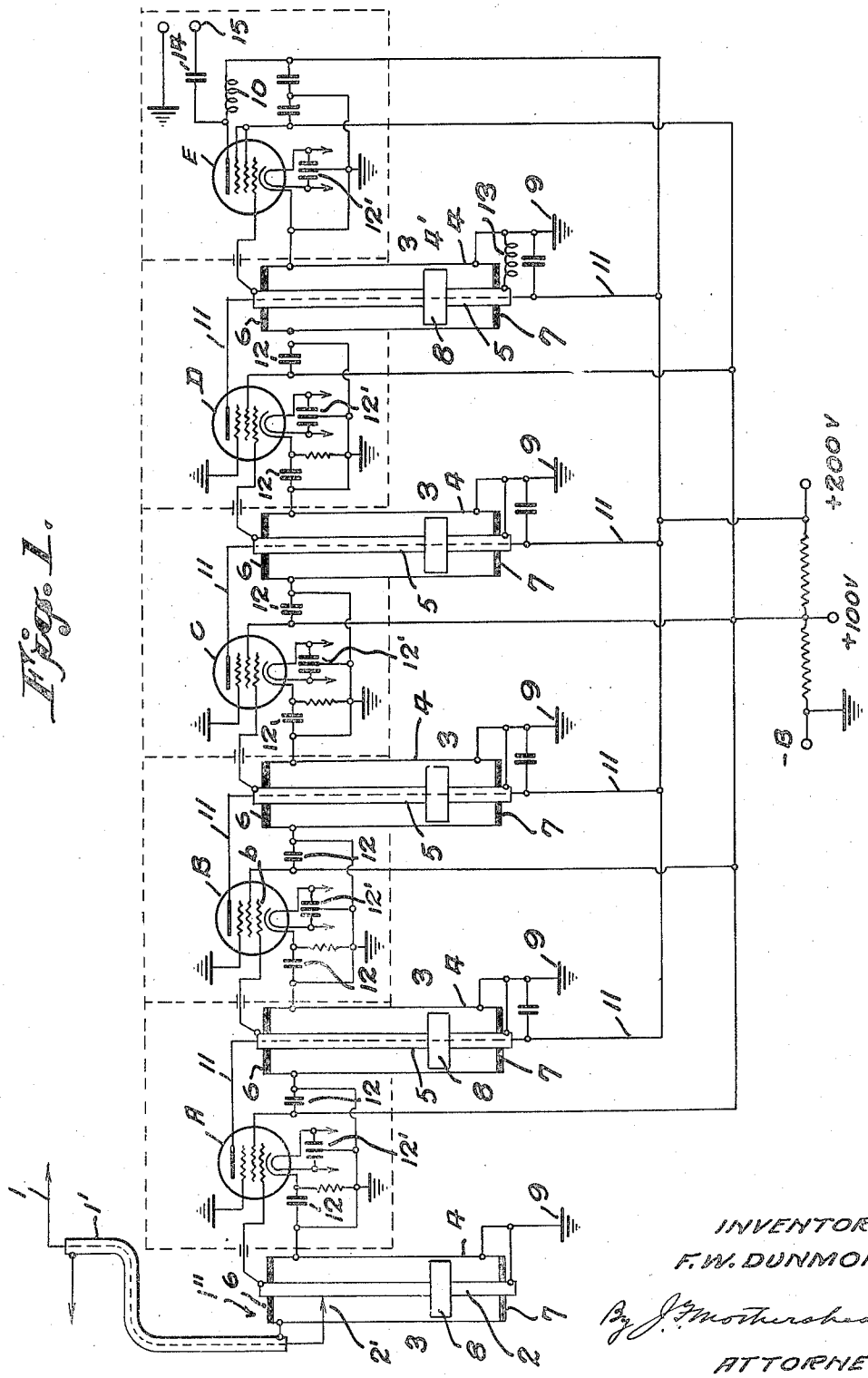


Fig. 1.

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ULTRAHIGH FREQUENCY RADIO AMPLIFIER

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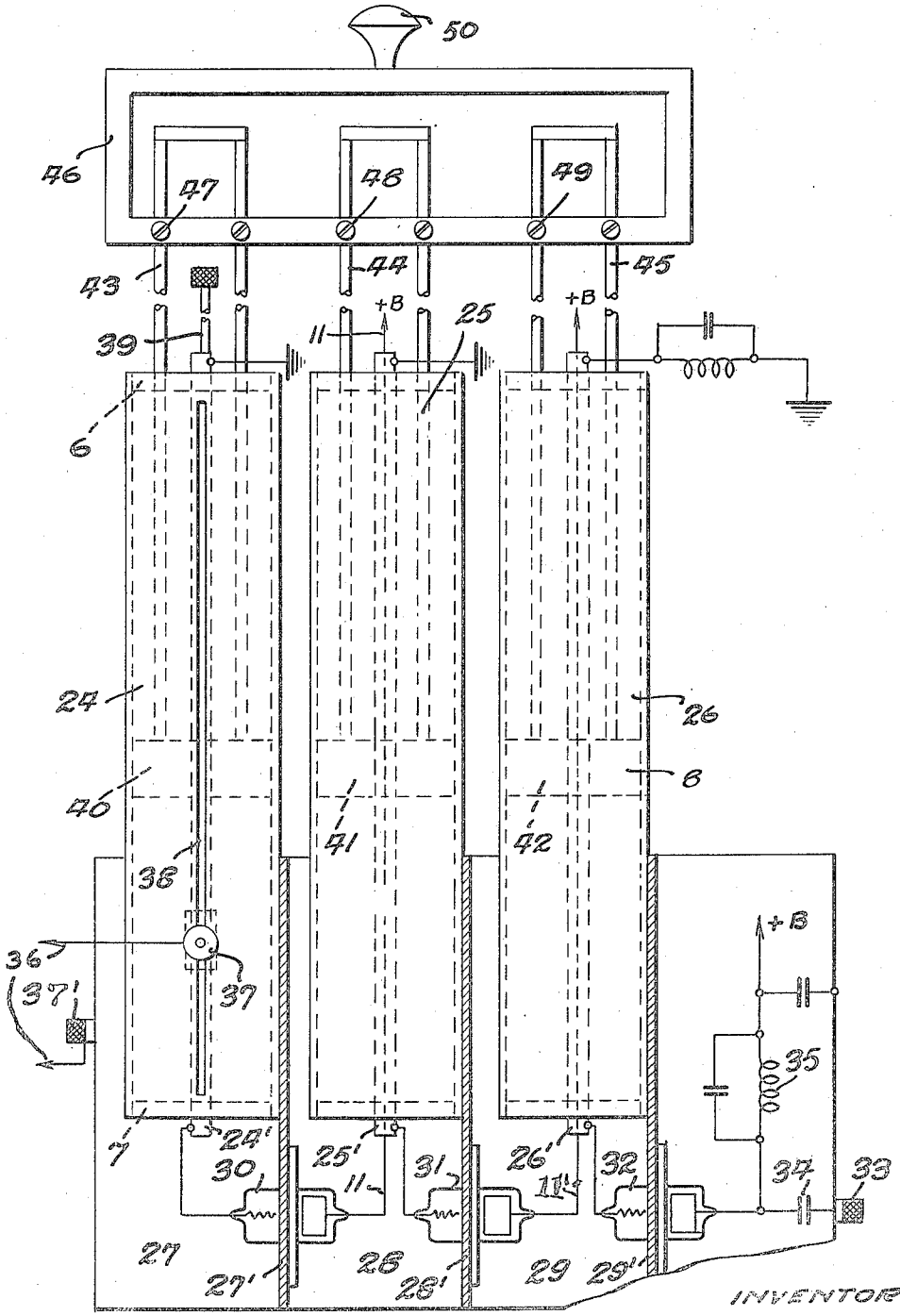


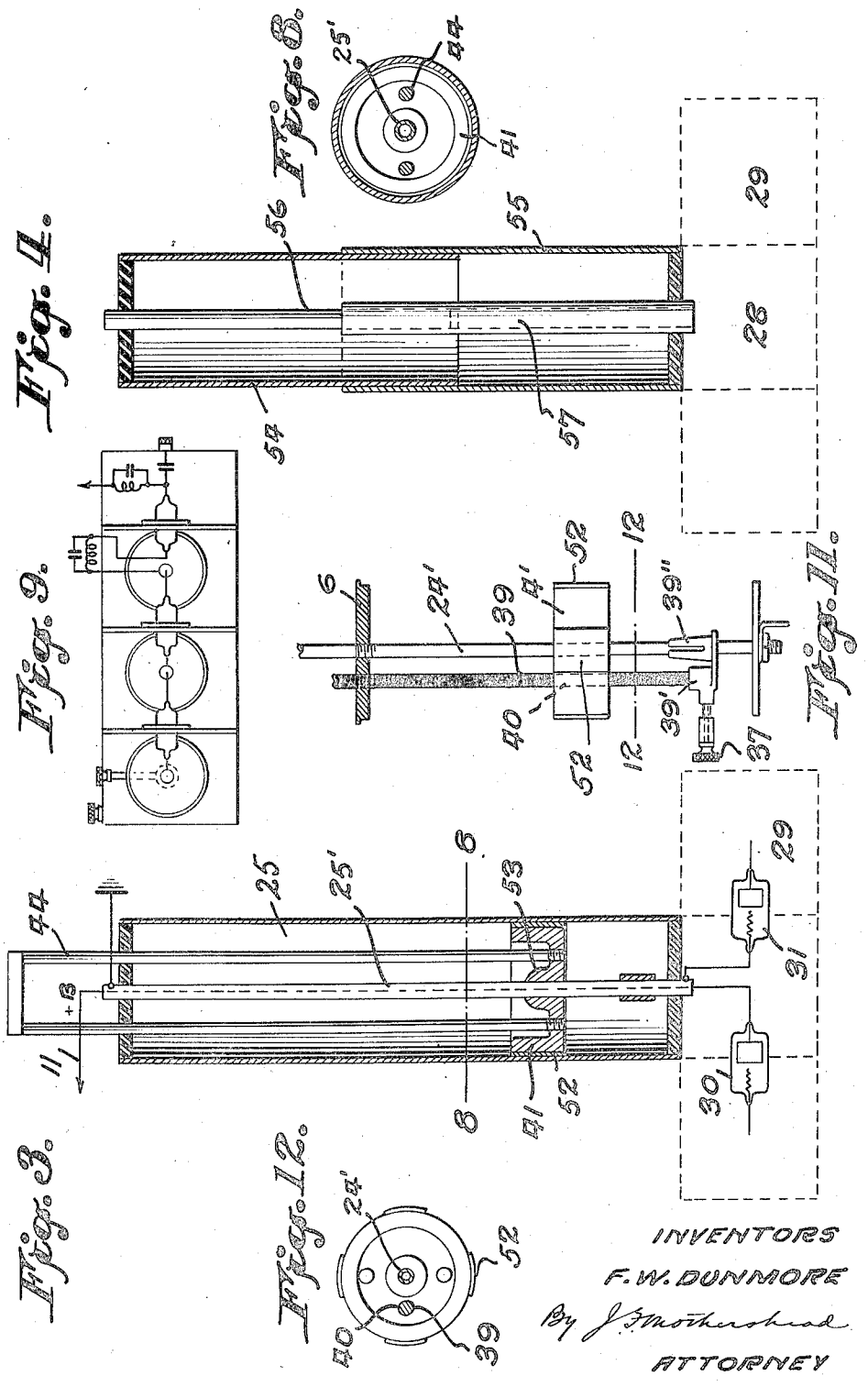
Fig. 2.

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ULTRAHIGH FREQUENCY RADIO AMPLIFIER

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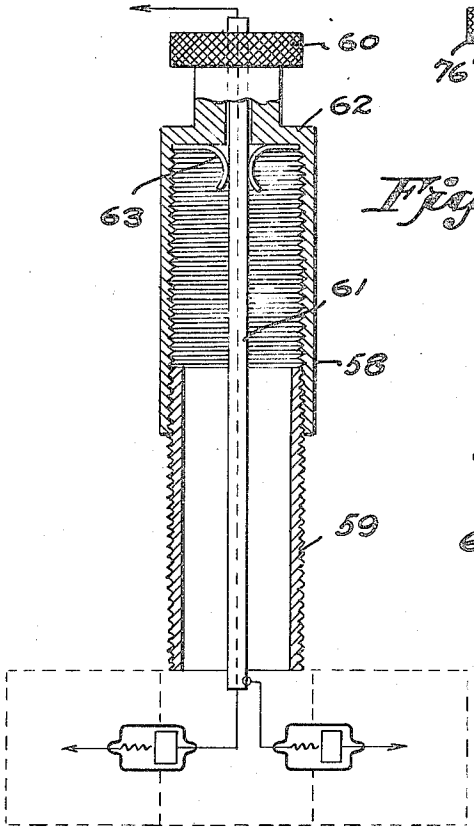


Fig. 5.

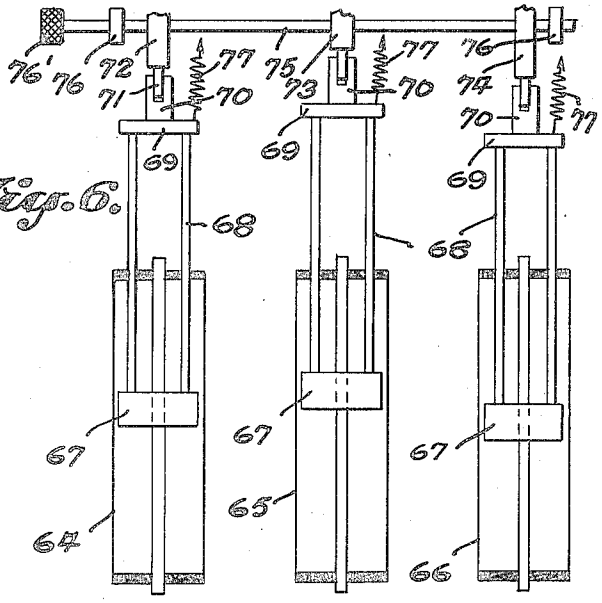


Fig. 6.

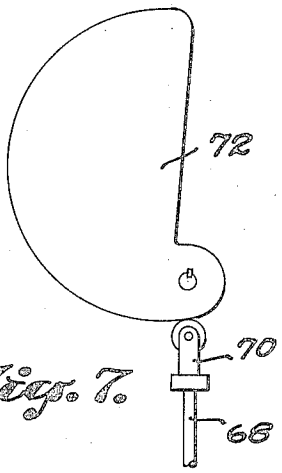


Fig. 7.

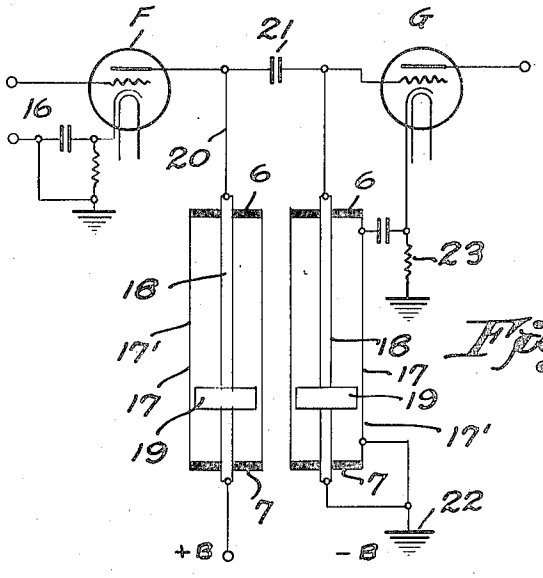


Fig. 10.

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Patented Oct. 4, 1938 2,132,208

UNITED STATES PATENT OFFICE

2,132,208

ULTRAHIGH FREQUENCY RADIO AMPLIFIER

Francis W. Dunmore, Washington, D. C., assignor to the Government of the United States, represented by the Secretary of Commerce

Application December 27, 1935, Serial No. 56,349

15 Claims. (Cl. 250—20)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

The invention described herein, if patented, may be manufactured and used by or for the Government for governmental purposes without the payment to me of any royalty thereon.

This invention relates to improvements in ultra high frequency radio amplifiers, and more particularly to the kind using quarter wave concentric line impedance coupling between the stages. The concentric lines as interstage coupling impedance, about to be described, involves certain new circuits and means for tuning in order to obtain maximum voltage step-up and ease of operation.

The primary object of the invention is to provide novel ways of connecting the electron tube elements to their respective circuits through concentric line interstage tuning impedances; and a further object is to provide simple means for tuning to a quarter wave length when using such impedance coupling. Another object is to provide certain novel construction and arrangement of apparatus for carrying out the objects first above mentioned.

Briefly the first object involves a novel way of transferring the R. F. voltage on the plate of one amplifying tube to the grid of the next tube. The method consists of a cylindrical concentric transmission line tuned to a quarter wave length. The outer line is grounded over its whole length. The inner line is grounded at one end. It is hollow with an insulated wire running through it connecting the +B to the plate of the preceding electron tube. The R. F. voltage in this wire built up due to the tuning of the line, is transferred through the capacity formed between the wire and the inner line, to the grid of the following electron tube which is connected to the ungrounded end of the inner line.

The second stated object involves means for varying the electrical length of the concentric lines, so that they will be equivalent to a quarter wave length long, thus building up maximum voltage on the grid and plate. Actually the line length, when tuned, is somewhat shorter than the theoretical quarter wave, due to the capacitance of the leads and the electron tube elements connected to the high voltage end of the line. This shortening effect is greater the higher the frequency.

Heretofore it has been customary to build up coupling impedance between stages by means of lumped capacity and inductance. At ultra high radio frequencies it is not possible to build up as high an impedance in this way as with my invention, due to greater losses and radiation in the inductance and capacity arrangement. Furthermore, my invention makes possible the use of a single transmission line per stage of amplification in an ultra high radio frequency amplifier using a single electron tube per stage, with simple means of varying electrical lengths of the lines, not only independently, but by a single control as will appear from the following description of illustrated circuits, and apparatus, it being understood that the drawings are for the purpose of illustration only and not as defining the elements of my invention.

In the drawings—

Figure 1 illustrates a circuit in which it is possible to keep both grid and plate at high R. F. voltage and at the same time supply each with its proper D. C. potential.

Figure 2 shows an arrangement of mounting the concentric lines adjacent each other whereby to shorten leads and make possible convenient and expeditious uni-control.

Figure 3 is a sectional view of a concentric line, showing means for adjusting the line to one quarter wave length, there being shown in a possible position, and diametrically, two electron tubes and shielding compartments.

Figures 4, 5 and 6 show several different forms involving different means for adjusting the length of the line.

Figure 7 is a detail view of a part of a mechanism for adjusting the line length, in the form shown in Figure 6.

Figure 8 is a cross section of a concentric line taken on the line 8—8 of Figure 3.

Figure 9 is a bottom view more or less schematic, of the line and electron tubes of the arrangement shown in Figure 2.

Figure 10 illustrates another circuit employing two concentric lines between stages.

Figure 11 is a detail showing more clearly the manner of connecting one of the terminals of the input line to the antenna.

Figure 12 is a section taken on line 12—12, Figure 11.

Referring to the drawings more in detail, and particularly to Figure 1, wherein is shown a multistage amplifier using the concentric lines as interstage couplings, the numeral 1 designates the antenna; 1' the transmission line for transferring the signal from the antenna to the input concentric line 1''. This input line 1'' differs somewhat from the others as will appear, and comprises an outer cylindrical line 3 and an inner concentric line 2, which in this line may be a solid rod.

Conventional ultra high frequency electron tubes are designated by the letters A, B, C, D and E. The numeral 3 designates the lines as a whole throughout, and each line with the exception of the input line, includes an outer metallic tube 4 and an inner concentric metallic tube 5, the latter being hereinafter referred to as the inner line. All of the inner lines which include the inner line 5, as well as the inner line 2, Figure 1, are held concentric within their re-

spective lines by means of insulating spacers 6 and 7, and for each line 3 there is a metallic plunger 8 in metallic contact with the inner lines 2 and 5, but capacitively connected to the outer part 4 of the lines—that is to say, the plunger is in close proximity to the inner wall of the tube 4, but does not touch it at any point, and in fact means is provided, as will appear, for insulating the plunger from the outer part of the line. The plunger slides upon the inner line and is for the purpose of tuning the whole line to quarter wave length, or in other words, varying the electrical length of the transmission line. By means of the plunger in the input line 1'' this line may be adjusted to give maximum impedance. The inner line 2 of this input line is grounded at its lower end at 9 and connected to the control grid of the electron tube A at its upper end. This is true of each of the inner lines 5, except for the last line 4' where it is grounded through a suitable choke 13. The signal on antenna 1 is supplied to the control grid of tube A through line 1'' by way of contact 2' sliding on inner conductor 2 and connected to antenna 1. The output circuit of tube A is connected to a transmission line 3 which is similar to line 1'', except that the center line 5 in this case is made of tubing and the plate connection with the electron tube A is made by means of an insulated wire 11 which is run from the B supply through this central line to the plate of tube A. The concentric line 3 is tuned to resonance by means of the plunger 8 as in the case of the input line 1'', and when so tuned the voltage built up on or in the plate of the tube A is passed on to the control grid of tube B by means of the capacity formed between wire 11 and the inner line 5. As lead 11 is in close proximity to inner line tube 5, the plate of electron tube A may be considered as connected to grid of tube B for the ultra high frequency used, but insulated for D. C. This feature forms an important part of my invention for it provides a novel way in which the plates of the electron tubes may be supplied with their proper D. C. voltage and at the same time provide means for coupling the radio frequency voltage on them (through the capacitance formed between the wire or lead 11 and the concentric line 5) to the grid of the following tube without grounding the ultra high radio frequency voltage. By means of this circuit arrangement the plate of the electron tube A and the control grid of the tube B are each supplied with their proper direct current voltages, yet are maintained at the radio frequency voltage developed on the plate of tube A, due to the high impedance to ground offered by transmission line 3, when plunger 8 is so adjusted as to tune the line. Suitable by-pass condensers 12 and 12' are provided for the various electron tube elements. Electron tubes C and D function in a similar fashion to the electron tube B, but the tube E, however, is a detector tube, and with this tube the control grid instead of being grounded directly at the lower end of the inner line 5, is grounded through the choke 13, which offers a high impedance to the modulation frequencies and for a similar reason the choke 10 is provided in the plate circuit of the detector tube E so that the modulation frequencies are supplied through condenser 14 to terminal 15. As this type of receiver is designed to tune to ultra-high radio frequencies it is possible to have the ultra-high radio-frequency carrier modulated at frequencies within the broadcast band, i. e. 1500 to 500 k. c., which in turn may carry an audio modulation. In this case the detector output of the receiver will supply the 1500–500 k. c. signal with its audio modulation. An ordinary broadcast receiver may therefore (in this case) be connected between terminal 15 and ground and serve to amplify the detector output, reproducing the original audio modulation.

Under the circumstances it is thought best to now pass over for a moment a description of Figures 2–9, which more particularly illustrate apparatus, and describe the circuit illustrated in Figure 10, which is closely related to that shown in Figure 1. Fig. 10 differs from Fig. 1 only in that two transmission lines are used between each stage of amplification, in place of the one line used between each stage in Fig. 1. In Fig. 10 the output of one stage and the input of the next are each separately tuned by different concentric lines, while in Fig. 1 one transmission line forms a common tuning element between the output of one stage and the input to the next. Due to the greater flexibility of adjustment, the circuit arrangement of Fig. 10 may give slightly greater gain, but for most purposes the added expense in construction does not warrant it.

Referring now to Figure 10, the numeral 16 represents a source of ultra high radio frequency; F and G represent conventional ultra high frequency electron tubes; 17 a concentric line, in most respects like the line 3 of Figure 1 circuit, and 18 the center or inner portion of the line, in this case like the input line 2 of Figure 1 circuit, in that these parts of the lines are rods instead of tubes. A metallic plunger 19 is provided and is in metallic or capacitive contact with the rods 18 and capacitively connected to the outer line portion 17' for varying and adjusting the line length. The portion of the whole line between the plunger and the end connected to the electron tubes is the operative section. The plate of tube F is connected through rod 18 and wire 20 to the proper D. C. voltage. A coupling condenser 21 passes to the grid of tube G the radio frequency voltage generated, when the first line is tuned to quarter wave length. In order to ground the grid of tube G for D. C., a second concentric line 17 is added. The inner line or rod 18 of this second line is grounded for D. C. This second line 17 is tuned to one quarter wave length by its plunger 19, thus holding the grid of tube G at the R. F. potential of the plate in tube F, yet allowing grid of tube G proper D. C. bias by means of resistor 23.

As maximum voltage is built up when the concentric line is one-quarter wave length long (or some length less than one-quarter due to lead and tube capacitances on the end of the line), simple means for varying the electrical length of such a line is necessary in order to tune to the different ultra high radio frequencies.

Referring to Figure 2, there is shown what I believe to be a novel way of arranging the concentric lines, adjacent each other in such a way that the leads to the grids and plates of the electron tubes are kept very short and so that the input of the electron tube is well shielded from its output, which arrangement makes uni-control possible and convenient. In this figure, 24, 25 and 26 designate three concentric lines arranged side by side and a suitable distance apart with R. F. voltage ends terminating in shielding compartments 27, 28 and 29, respectively, each line having an inner center line therein, respectively designated 24', 25' and 26'. Each shield 27', 28' and

29' carries an electron tube 30, 31 and 32, respectively. The tube 30 is the first R. F. stage with control grid connected to the line 24' and the plate connected to the line 25, while tube 31 is the second R. F. stage, with its control grid connected to the line 25 and its plate connected to line 26. The plates of tube 30 and 31 are connected to the insulated wires 11 and 11' respectively, which extend through the inner tubes 25' and 26' respectively, and connect to the source of D. C. plate potential B+. Tube 32 is the detector with its control grid connected to line 26 and its plate connected to output terminal 33, through blocking condenser 34, there being also employed a choke 35 for the modulation frequency used.

The ultra high radio frequency input is designated by the numeral 36. One terminal of this input 37' goes to the chassis ground and the other goes to a binding post 37 that extends through an elongated slot 38 in the outer tubular portion of line 24. This binding post is fixed to a rod 39 of insulating material that passes through an opening in the insulating spacer disk 6 in the top of line 24, and through a similar opening in the plunger 40, below which the rod carries a bracket 39', Figure 11, a part 39'' of which surrounds and has sliding contact with the center line 24' of the line 24, the upper part of the rod 39 being available above the line for moving the bracket and consequently the binding post to different positions on the line 24' for the purpose of matching the input impedance of concentric line 24 to the antenna and transmission line connected to the terminals 36.

In the input line 24 the center line 24' is a rod like 2 in Figure 1, and the center lines 25' and 26' are tubular like lines 5 in same figure. In order to obtain uni-control operation, the tuning plungers designated by 40, 41 and 42 are ganged by having their control rods 43, 44 and 45, respectively, connected to a common control bracket 46, the connection being by means of set screws 47, 48 and 49, there being provided centrally of the bracket a knob 50 whereby the rods and consequently the tuning plungers may be moved in unison. Each plunger is initially set when a signal is received and adjusted independently, and when properly adjusted the set screws for the respective rods are tightened, obviously so fastening the rods to the bracket that a movement of the bracket will move all the rods and plungers in unison.

Figure 3 may be taken as a central longitudinal section of the concentric line 25 in Figure 2. Here the plunger 41 is shown in close proximity to the inner walls of the outer portion of the line 25, but not touching them, there being provided around the plunger thin pieces of insulating material 52, Figure 11, which may be placed at intervals around it, or the whole of the inside wall of the line may be covered with insulating material, the former arrangement, however, being preferred. This arrangement practically connects the plunger to the inside wall of the outer portion of the line 25 so far as ultra high frequencies are concerned, but insulates the plunger from said outer portion so far as D. C. voltage is concerned.

By the arrangement shown in Figures 2 and 3 it will be seen that the plunger may be moved to any position within the line, thus tuning the line to any frequency within its range. The plunger makes metallic contact with the inner line through its central boss or hub 53.

As in Figure 2, the plate lead wire 11 of electron tube 30 is run through the inner line 25' which is connected to the grid of electron tube 31 at its high R. F. voltage end and grounded at its low voltage end.

There are several ways of varying electric length of the central lines. For instance, as shown in Figure 4, both the inner and outer portions of the line are made in two pieces, the outer designated by 54 and 55 and the inner by 56 and 57, the sections 54 and 56 being arranged to telescope with relation to sections 55 and 57, the line length being changed by a push-pull action of the section 54, which must move in unison with the inner line 56.

Another form for varying the line length is shown in Figure 5. Here, the outer portion of the line is made in two pieces 58 and 59, the former being internally threaded and the latter externally threaded, there being a knob 60 on the part 58 by which it may be convenienty turned to feed it on to or off the section 59 to shorten or lengthen the over-all length of the line, as may be desired. The inner concentric line 61, of course, in this form remains stationary and the metal end 62 keeps in electrical contact with the inner line 61 by means of sliding contacts 63.

In Figures 6 and 7 another means for varying the electrical length of the lines is shown. The lines are designated by the numerals 64, 65 and 66, and each is provided with a plunger 67 to which are connected rods 68, a pair of rods for each plunger, and which extend through the insulating spacers in the ends of the lines as before. Each pair of rods is fitted with a cross piece 69 and each piece carries a bifurcated stud 70 in each of which is journaled a roller 71. Cams 72, 73 and 74 are mounted on a common shaft 75 supported in suitably positioned bearings 76 and provided with a knob 76' by which it may be conveniently turned. This arrangement has advantages in case the settings of the plungers should differ when each line is tuned to resonance. By suitably shaping or positioning each cam the proper simultaneous movement of all of the plungers to keep the lines in tune may be obtained by rotating the shaft, the rollers meanwhile being held against the cams by springs 77 attached to the cross pieces of the rods, with their other ends connected to any suitable support.

I claim:

1. A multistage ultra high radio frequency amplifier with a single concentric transmission line as the only coupling impedance between each stage, each of said coupling impedances being arranged with its longest dimension in parallel planes, means for independently adjusting the electrical length of each of said concentric transmission lines including a metallic plunger concentric with each line and movable along the length of each line and additional means for varying the electrical length of all of said concentric transmission line in unison, by simultaneously varying the position of each of said plungers.

2. A multistage ultra high radio frequency amplifier with an impedance coupling unit between each stage consisting of a concentric transmission line with the outer line grounded, and with adjustable means for varying its electrical length to give maximum voltage transfer between stages, said adjustable means comprising an electrically conductive cylindrical plunger concentric with the inner line of said transmission line and movable along its length and making electrical and mechanical contact thereto, and insulated for direct current from the outer line of said concentric line but forming by virtue of its prox-

imity to said outer line a capacitive contact thereto of low impedance to ultra high radio frequencies.

3. In a multistage ultra high radio frequency amplifier with an output detector having input and output circuits, adapted to receive modulated ultra-high radio frequencies said amplifier using concentric transmission line type of coupling impedance between stages with adjustable tuning plunger means for varying the electrical length of said transmission lines, means whereby each of said plungers forms a metallic contact with the inner line of said concentric transmission line and a capacitive contact to the outer line of low impedance to ultra high radio frequencies but of high impedance to said modulation frequencies, means coupling the detector input circuit on the low ultra high radio frequency end of the transmission line in said detector input circuit, for offering high impedance to ground for said modulations frequencies.

4. In a multistage ultra high radio frequency amplifier with output detector with input and output circuits, said amplifier using concentric transmission line type of coupling impedance between stages with adjustable tuning plunger means for varying the electrical length of said transmission lines, means whereby each of said plungers forms a metallic contact with the inner line of said concentric transmission line and a capacitive contact to the outer line of low impedance to ultra high radio frequencies but of high imepdance to all lower frequencies, inductive means associated in the low ultra high radio frequency end of the detector input circuit whereby the capacitance formed by said plunger and said transmission line constitutes a circuit of high impedance to ground to a band of frequencies lower than said ultra high radio frequency, and means in the detector output circuit offering a high impedance to the said band of frequencies lower than said ultra high radio frequency.

5. In a multistage ultra high radio frequency amplifier a plurality of amplifier stages using concentric transmission line type impedance coupling units between stages, input and output circuits for said amplifier, a source of modulated ultra high radio frequency applied to the input circuit of said amplifier, a detector for detecting the modulation frequencies carried by said ultra high radio frequency, with input and output circuits, the input circuit of said detector being coupled to the output circuit of said amplifier, inductive means located in the low ultra high radio frequency voltage end of the inner line of the concentric transmission line in the detector input circuit whereby said inner line and said detector input circuit have between them and ground a high impedance to the modulation frequency voltages developed in the detector, but a low impedance to direct current.

6. In a multistage ultra high radio frequency amplifier with input and output circuits, and with a single concentric transmission line as the only coupling impedance between stages consisting of an outer tubular grounded conductor and an inner concentric tubular conductor, an additional concentric transmission line consisting of and outer tubular grounded conductor and an inner concentric tubular conductor and associated with the input circuit to said amplifier, a movable means connected to an antenna and connected with and movable along the inner conductor of said additional concentric transmission line for matching the antenna impedance to that of the input circuit of said amplifier such that the input circuit is held at a high ultra radio frequency potential.

7. In a multistage ultra high radio frequency amplifier with input and output circuits, and with a single concentric transmission line as the only coupling impedance between stages consisting of an outer tubular grounded conductor and an inner concentric tubular conductor, an additional concentric transmission line consisting of an outer tubular grounded conductor and an inner concentric tubular conductor and associated with the input circuit to said amplifier, a movable means connected to an antenna and connected with and movable along the inner conductor of said additional concentric transmission line for matching the antenna impedance to that of the input circuit of said amplifier, and tuning means associated with each interstage concentric transmission line and with said additional concentric transmission line for varying their electrical length.

8. In a multistage ultra high radio frequency amplifier, a first amplifier stage with input and output circuits, a source of ultra high radio frequency applied to the input of said first amplifier stage, a transmission line comprising concentric tubular conductors connected to the output of said first amplifier stage and of such length as to build up the ultra high radio frequency voltage in the output of said first amplifier stage, means for supplying the proper direct current voltage to the output circuit of said first stage through an insulated wire running through the inner conductor of said transmission line, without loss of ultra high radio frequency voltage, a second amplifier stage with input and output circuits, means for transferring said ultra high radio frequency voltage to the input circuit of said second stage consisting of the capacitive connection formed between said insulated wire and said inner line and means consisting of said inner concentric conductor for supplying the proper direct current voltage to the input circuit of said second stage without loss of ultra high frequency voltage.

9. In a multistage ultra-high radio frequency amplifier, a first amplifier stage with input and output circuits, a source of ultra-high radio frequency applied to the input circuit of said first amplifier stage, a second amplifier stage with input and output circuit, a concentric transmission line with tubular outer conductor and concentric tubular inner conductor said outer conductor being grounded throughout its length and one end of said inner conductor being capacitively coupled at ultra-high radio frequencies to the output of said first amplifier stage and directly connected to the input of said second amplifier stage, said transmission line being of such length as to build up the ultra-high radio frequency voltage in the output of said first stage and apply it to the input of the said second stage, means for supplying the proper direct-current voltage to the output circuit of said first amplifier stage consisting of an insulated wire extending through the inner tubular conductor and forming a capacitive connection thereto at ultra-high radio frequencies, said wire being directly connected to a source of direct current at one end and to the output of said first amplifier stage at the other end, means for maintaining the proper direct-current voltage on the input circuit of said second stage by connecting the low ultra-high radio-frequency voltage end of the inner line to

ground, said direct-current voltages being supplied to said output and said input circuits without loss of ultra-high radio-frequency voltage in said output and said input circuits.

10. In a multistage ultra-high radio-frequency amplifier, a first amplifier stage with input and output circuits, a source of ultra-high radio frequency applied to the input circuit of said first amplifier stage, a second amplifier stage with input and output circuit, a concentric transmission line with tubular outer conductor and concentric tubular inner conductor said outer conductor being grounded throughout its length and one end of said inner conductor being capacitively coupled at ultra-high radio frequencies to the output of said first amplifier stage and directly connected to the input of said second amplifier stage, said transmission line being of such length as to build up the ultra-high radio-frequency voltage in the output of said first stage and apply it to the input of the said second stage, means for supplying the proper direct-current voltage to the output circuit of said first amplifier stage consisting of an insulated wire extending through the inner tubular conductor and forming a capacitive connection thereto at ultra-high radio frequencies, said wire being directly connected to a source of direct current at one end and to the output of said first amplifier stage at the other end, means for maintaining the proper direct-current voltage on the input circuit of said second stage by connecting the low ultra-high radio-frequency voltage end of the inner conductor to ground, said direct-current voltages being supplied to said output and said input circuits without loss of ultra-high radio-frequency voltage in said output and said input circuits, detecting means having an input circuit and means connecting said input circuit to a point on said inner conductor at a substantial radio frequency voltage above ground.

11. In a multistage ultra-high radio-frequency amplifier using concentric-transmission line type of coupling impedance between stages, transmission lines consisting of an outer tubular conductor and an inner tubular conductor concentric with the outer line, said outer line being grounded over its full length, said inner line being insulated for direct current from the said outer line at one end and directly connected at the other end to its associated interstage input circuit, an insulated wire inside each of said inside tubular conductors connected at one end to a source of direct current and at the other end to its associated output circuit and forming a capacitive connection at ultra-high radio-frequencies to its associated inner conductor, means for supplying each input circuit with proper direct-current voltage by connecting its associated inside conductor to ground at one end.

12. In a multistage ultra-high radio-frequency amplifier using concentric-transmission line type of coupling impedance between stages, transmission lines consisting of an outer tubular conductor and an inner tubular conductor concentric with the outer conductor, said outer conductor being grounded over its full length, said inner conductor being insulated for direct current from the said outer conductor at one end and directly connected at the other end to its associated interstage input circuit, an insulated wire inside each of said inside conductors connected at one end to a source of direct current and at the other end to its associated output circuit and forming a capacitive connection at ultra-high radio frequencies to its associated inner conductor, means for supplying each input circuit with proper direct-current voltage by connecting its associated inside conductor to ground at one end, plunger tuning means associated with each of said inner conductors and concentric thereto and movable.

13. In a multistage ultra-high radio-frequency amplifier using a single concentric transmission-line type of coupling impedance between stages, transmission lines each consisting of an outer grounded tubular conductor the length of which determines the frequency to which said radio-frequency amplifier is tuned, and an inner tubular conductor concentric with its associated outer conductor and insulated for direct current therefrom, insulated wire conductor means extending through the tubular conductor of each of said concentric transmission lines for supplying the proper direct-current voltage to the associated output circuit of the associated amplifier stage, means for supplying the proper direct-current voltage to the associated input circuit of the associated amplifier stage using the associated inner tubular conductor as this conducting means.

14. A multistage ultra-high radio-frequency amplifier with input and output circuits in each stage and using a single concentric transmission line consisting of an outer grounded conductor and an inner hollow concentric conductor insulated for direct current but grounded at one end for ultra-high radio frequencies as the only coupling impedance between each stage, and means associated with each of said inner concentric conductors consisting of an insulated wire running through its center for supplying the proper direct current voltages to each one of said output circuits, and means consisting of the inner tubular conductor for supplying the proper direct-current voltages to each one of said input circuits, tuning plunger means movable along and concentric with each of said inner conductors for varying the electrical length of each of said concentric transmission lines.

15. A multistage ultra-high radio-frequency amplifier with input and output circuits in each stage and using a single concentric transmission line consisting of an outer grounded conductor and an inner hollow concentric conductor insulated for direct current but grounded at one end for ultra-high radio frequencies as the only coupling impedance between each stage, and means associated with each of said inner concentric conductors consisting of an insulated wire running through its center for supplying the proper direct-current voltages to each one of said output circuits, and means consisting of the inner tubular conductor for supplying the proper direct-current voltages to each one of said input circuits, tuning plunger means movable along and concentric with each of said inner conductors for varying the electrical length of each of said concentric transmission lines, said tuning plunger means being ganged for unicontrol operation.

FRANCIS W. DUNMORE.