Oct. 29, 1946. W. M. KELLOGG 2,410,080

HIGH FREQUENCY APPARATUS

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FIG. 2

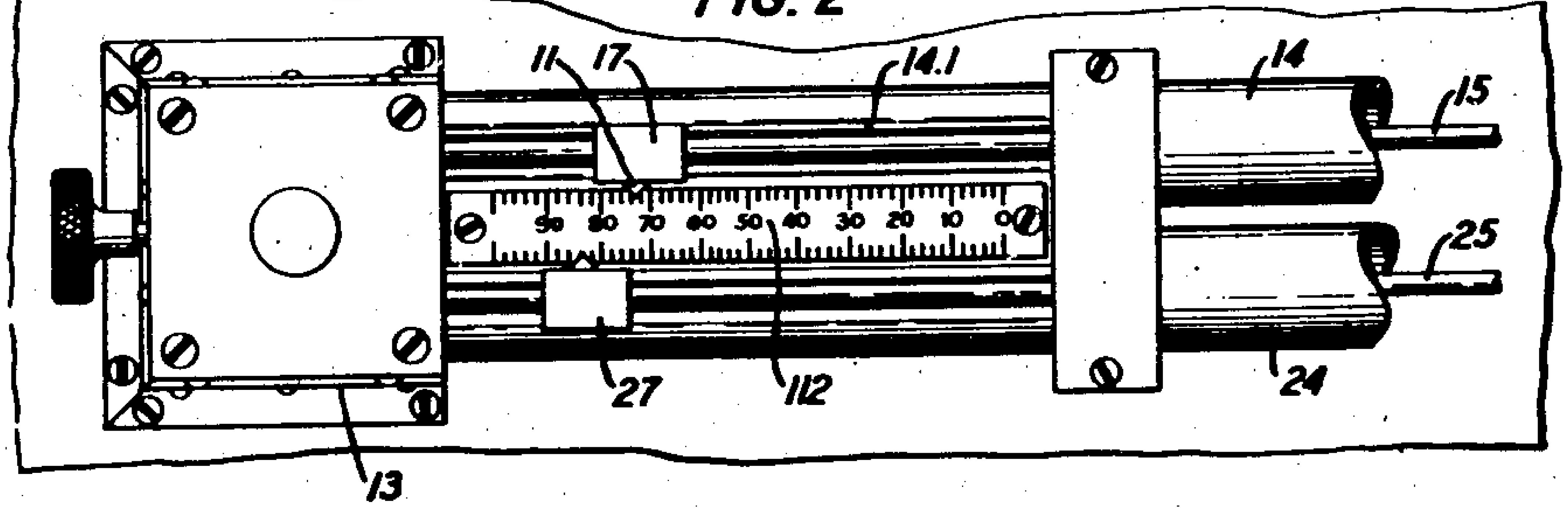

FIG. 3

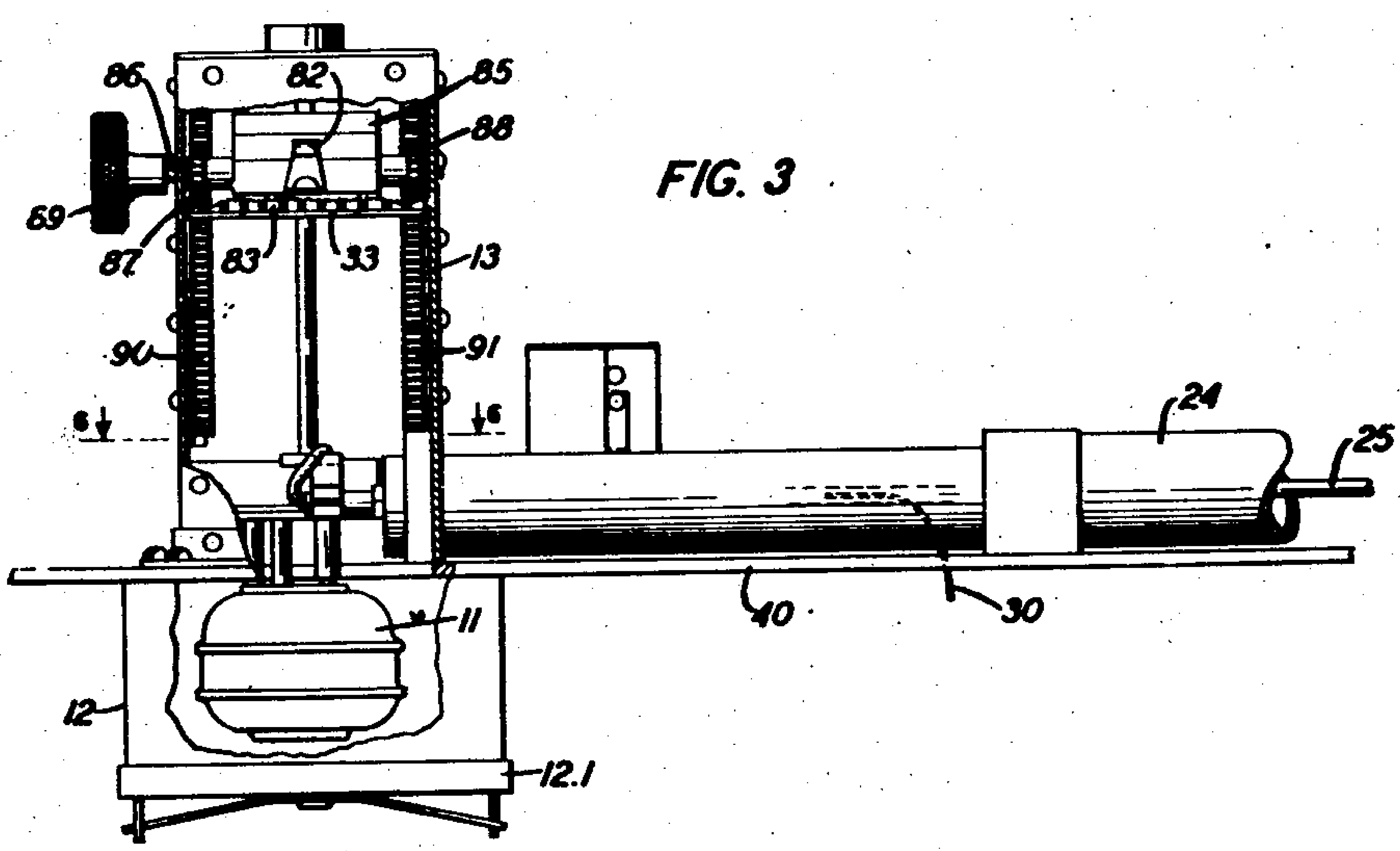

FIG. 1

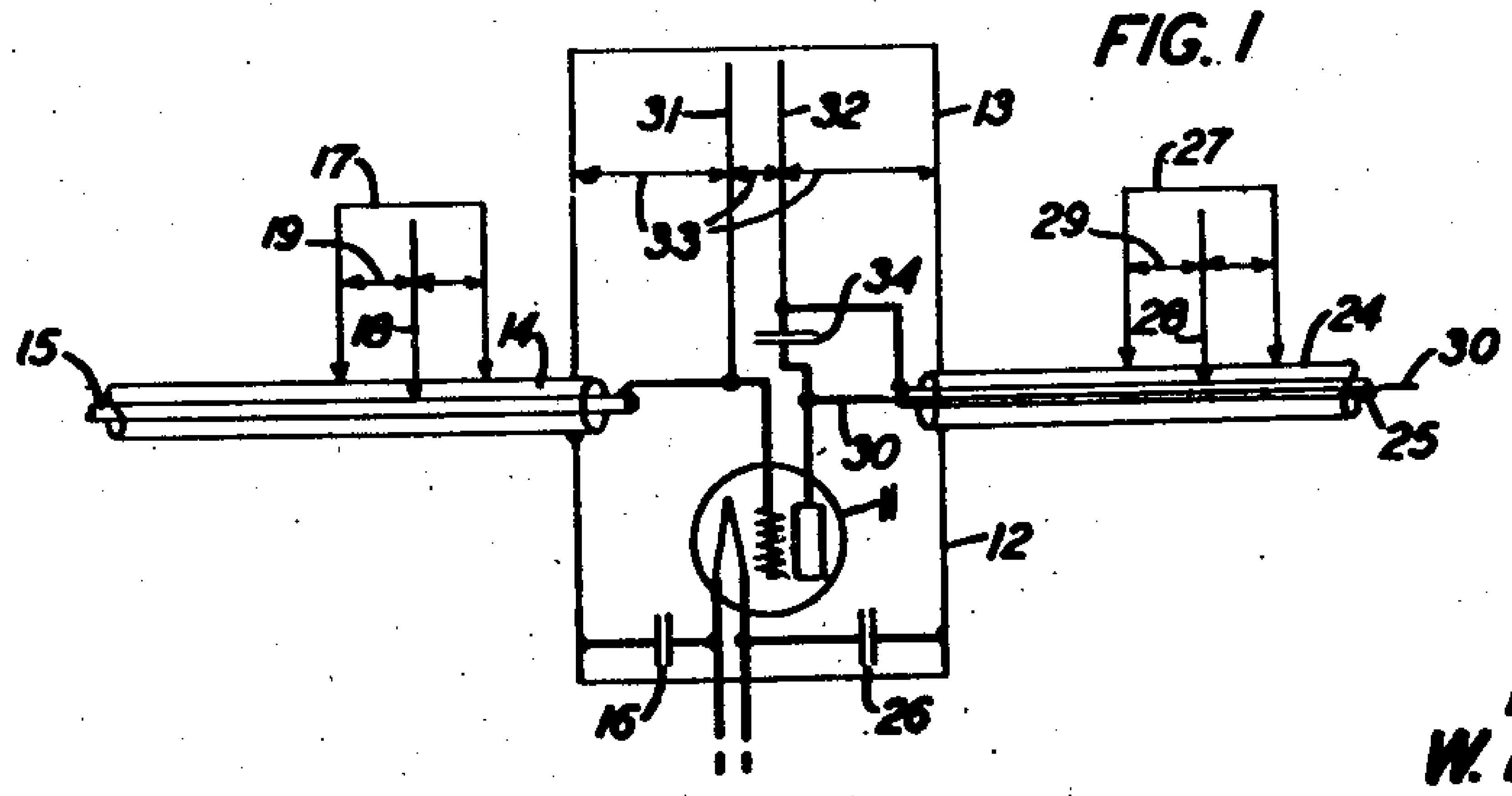

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FIG. 4

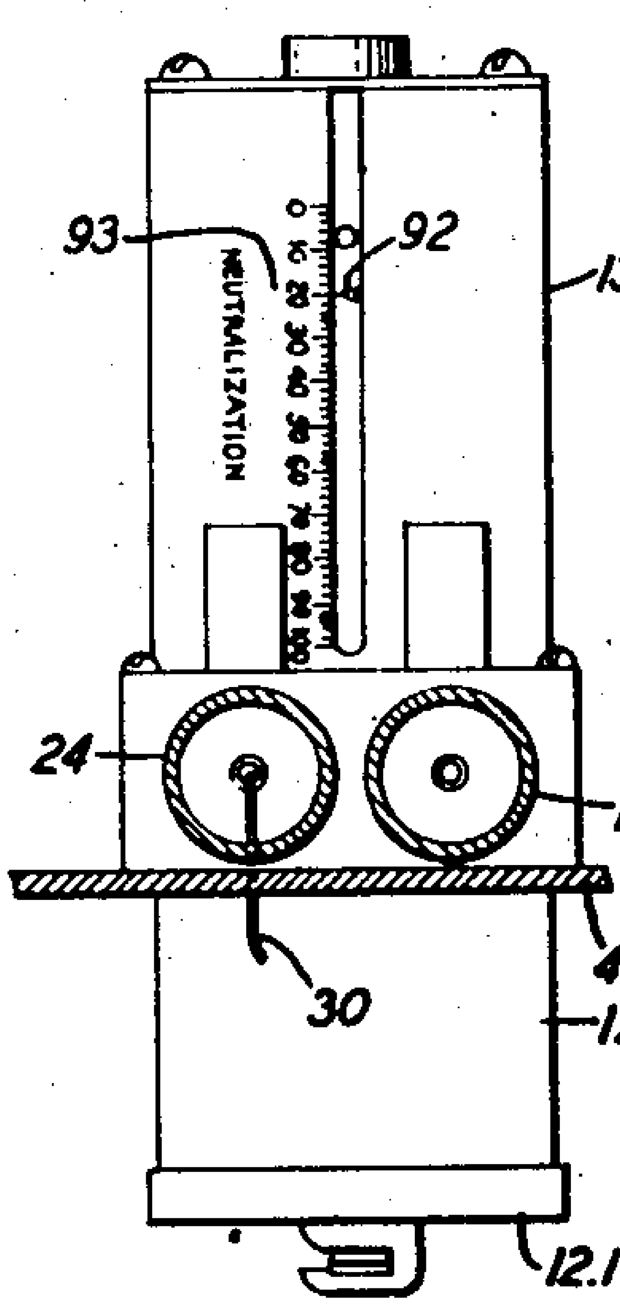


FIG. 5A

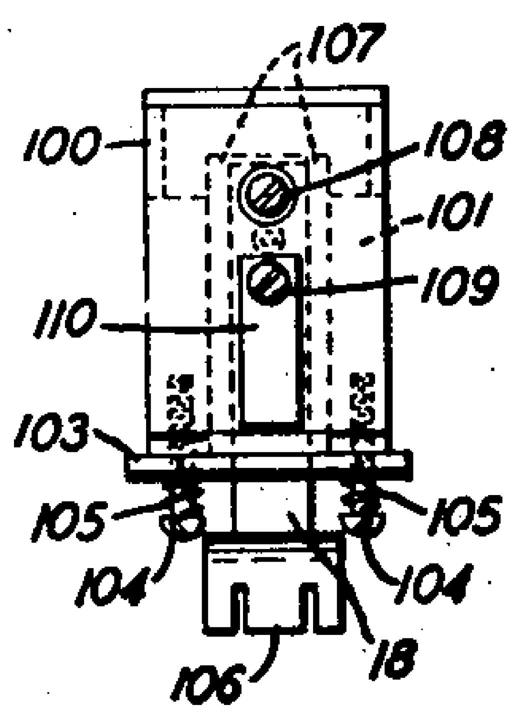


FIG. 5

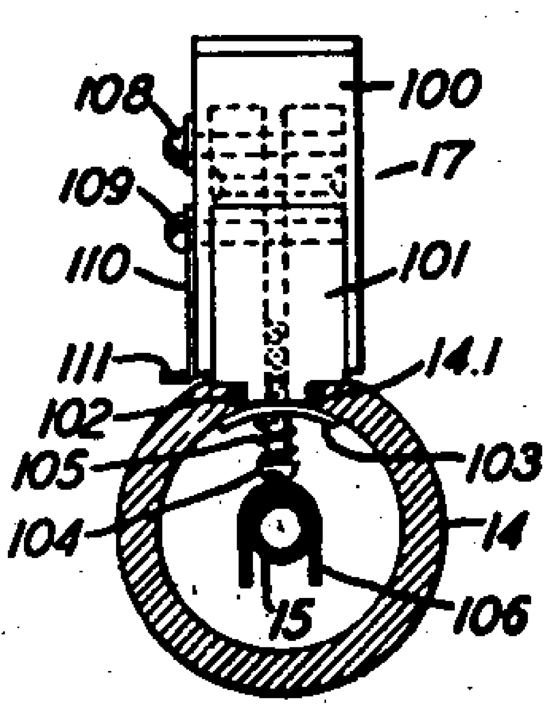


FIG. 10

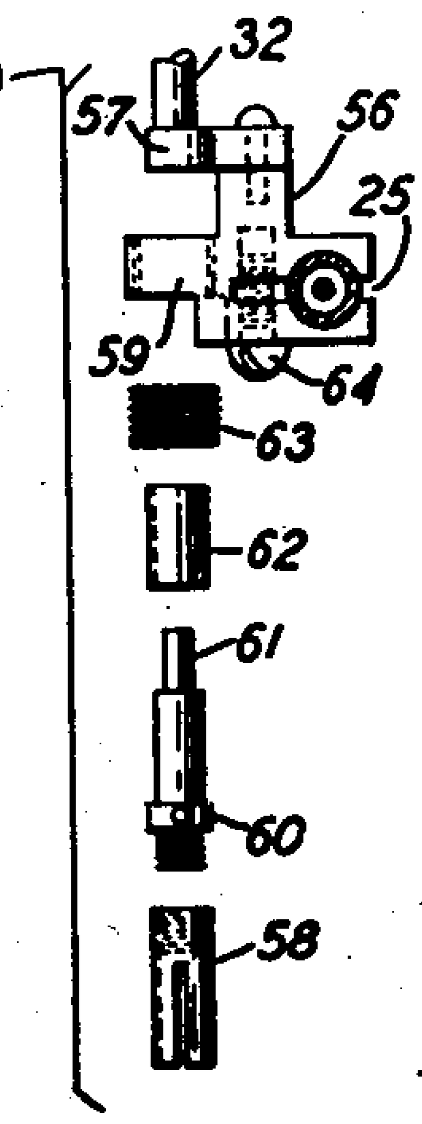


FIG. 6

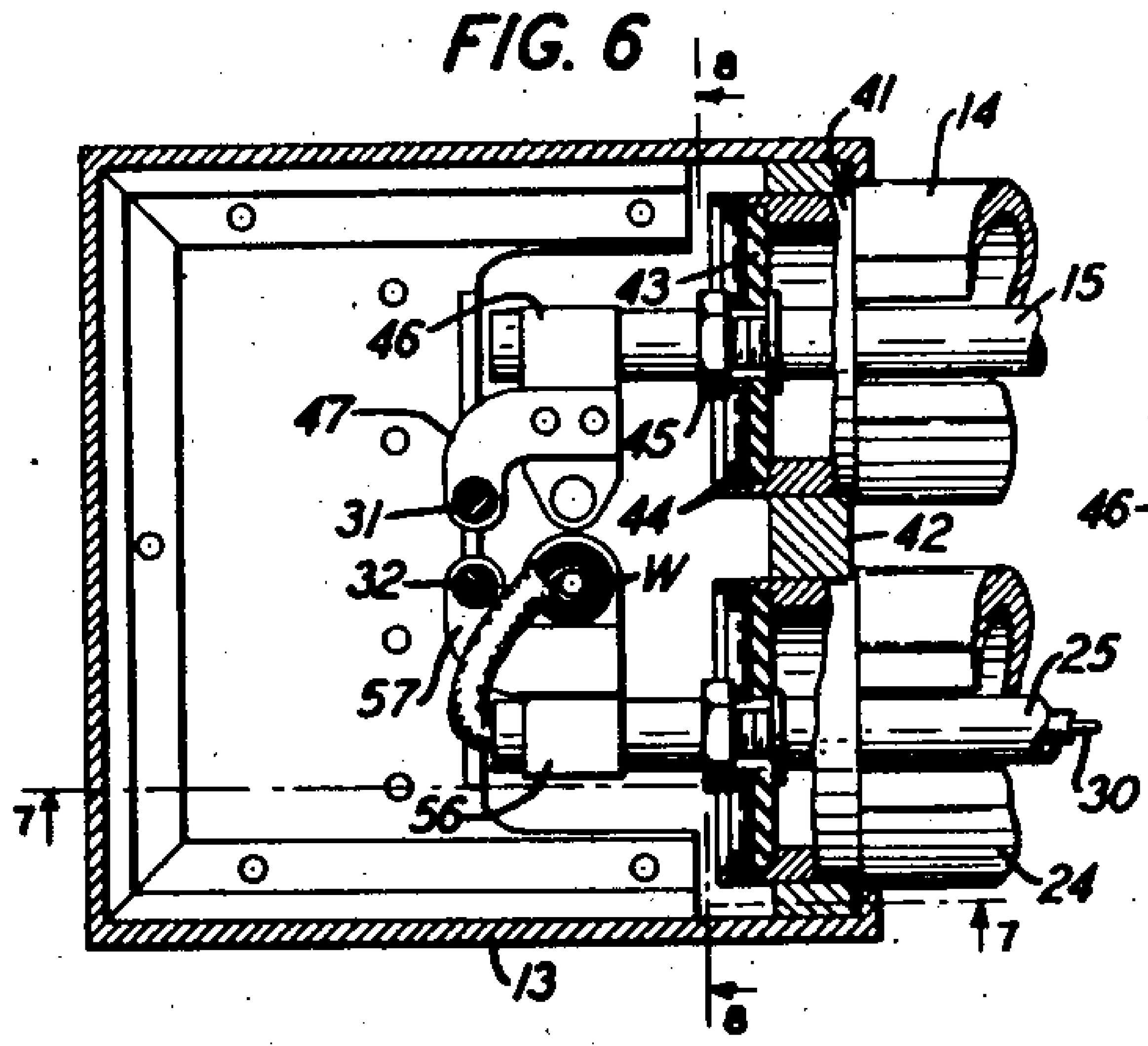


FIG. 8

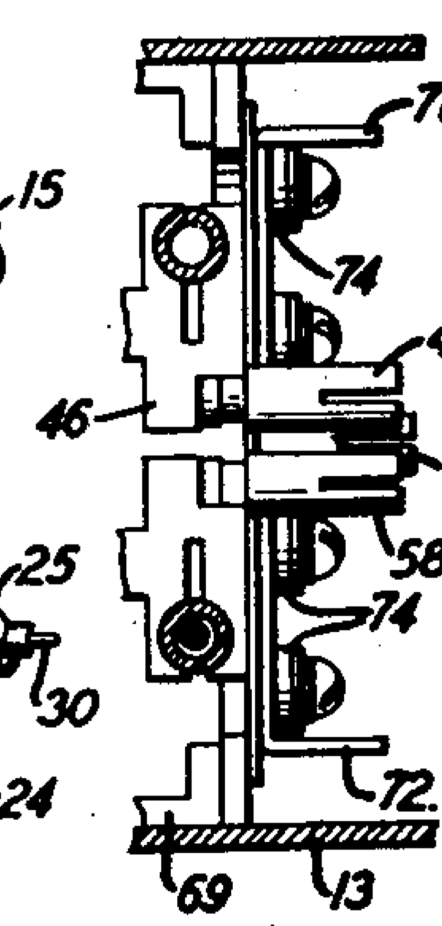


FIG. 9

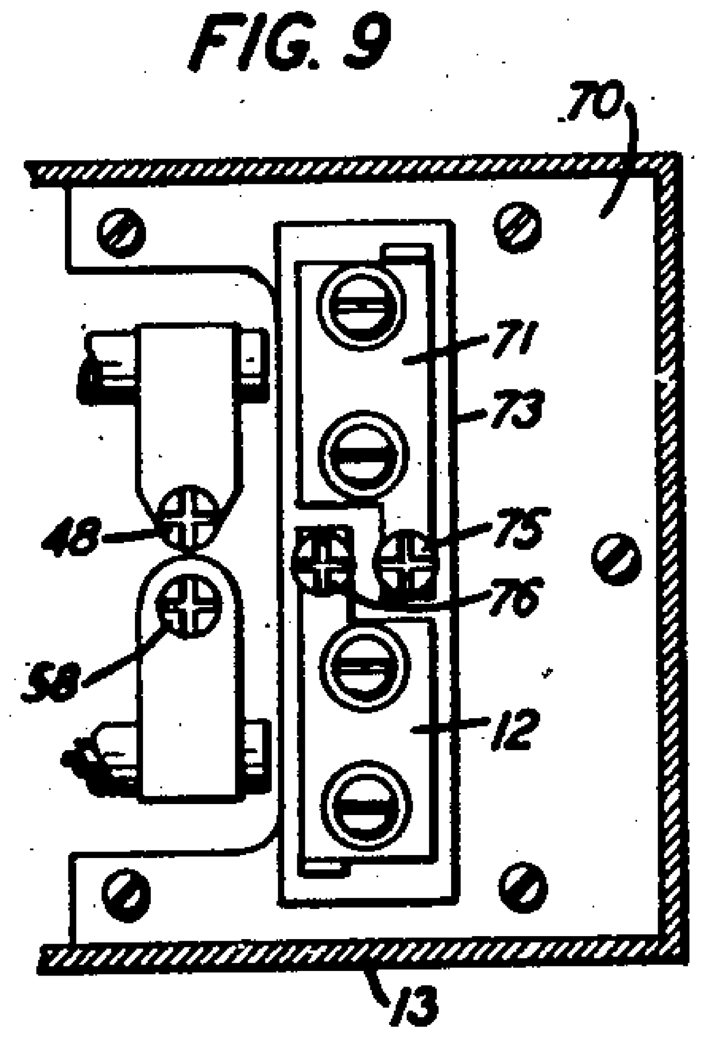
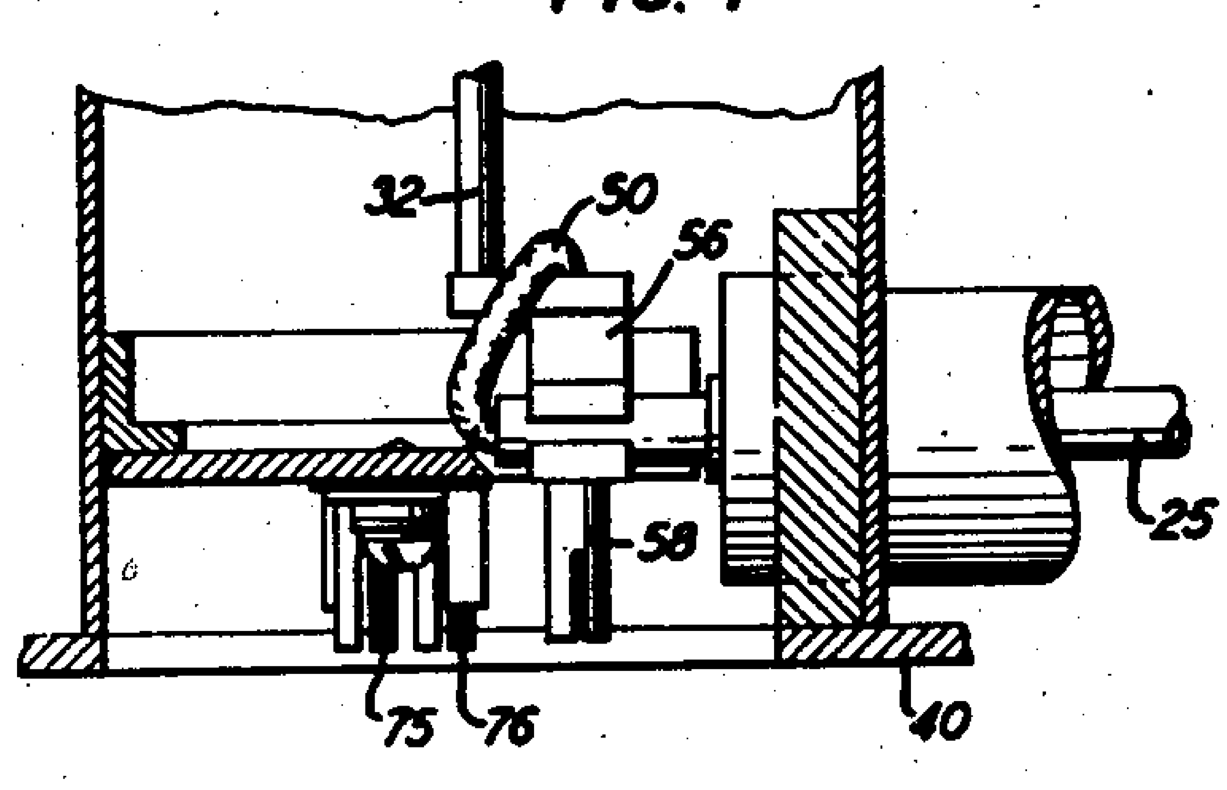


FIG. 7



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Patented Oct. 29, 1946

2,410,080

UNITED STATES PATENT OFFICE

2,410,080

HIGH-FREQUENCY APPARATUS

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Application December 11, 1941, Serial No. 422,510

4 Claims. (Cl. 179—171)

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This invention relates to amplifiers for use at ultra-high frequencies and particularly to tuning, impedance matching and neutralizing circuits therefor.

An object of the invention is to provide an amplifier for ultra-high frequency radio waves which is simple in construction and readily adjustable for operation at different frequencies.

A further object of the invention is to provide a neutralizing system for ultra-high frequency amplifiers.

In the operation of amplifiers and similar circuits in the ultra-high frequency range, it has been found that circuits having distributed constants are superior to lumped constant circuits for use for tuning, impedance matching, neutralizing and the like. For example, one method of tuning the input of an amplifier and matching its impedance to the incoming line is to connect to the amplifier input a short-circuited section of transmission line the length of which is so adjusted that in combination with the input impedance of the amplifier it acts as a quarter wave-length line at the frequency of the waves to be amplified. With such an arrangement the incoming line may be tapped onto the short-circuited line at a point where the two impedances are equal. Electrically, such a system operates very satisfactorily. Also where the amplifier is to be used only at a single frequency the apparatus can be quite readily constructed and adjusted for such satisfactory operation. However, where the system is to be adjustable to permit operation at any of a number of frequencies, there are certain structural difficulties. Among these is the problem of providing for the variable connection between the incoming line and the quarter wave line particularly since flexible lines are not entirely satisfactory for waves in the ultra-high frequency range.

In accordance with a feature of the present invention there is provided a system in which the incoming line is connected directly to the amplifier input and there is further provided a stub line of adjustable length which may be connected to the incoming line at various points along the length of the latter. The characteristic impedance of this section of input line is the same as that of the line from which the amplifier signal is derived. In this system the amplifier is tuned by the line formed by the portion of the incoming line between the amplifier and the tapping point of the stub line in series with the stub line and at the same time impedance matching is achieved by the adjustment of the tapping point. Such a system is the electrical equivalent of the system

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just described and at the same time is readily capable of adjustment for operation at different frequencies. Such systems are not only suitable for coupling to the input of an amplifier but also for output and interstage coupling.

In accordance with another feature of the invention the grid to plate capacity of an ultra-high frequency amplifier is neutralized by means of a short-circuited two-wire line connected to the grid and plate. This line is surrounded by a cylindrical shield which forms on each side of the two-wire line a substantially concentric line.

This invention can be more readily understood by reference to the following detailed description of one embodiment of the invention in an ultra-high radio frequency amplifier as shown in the drawings in which:

Fig. 1 is a schematic circuit diagram thereof;

Fig. 2 is a plan view;

Fig. 3 is a front elevation, partly in section;

Fig. 4 is an end view partly in section;

Figs. 5 and 5A are detailed views of the stub line 17, Fig. 5 being an end elevation and Fig. 5A a side elevation;

Fig. 6 is a detailed plan view (in enlarged scale) taken along the line 6—6 of Fig. 3;

Fig. 7 is a detailed front elevation of the portion shown in Fig. 6;

Fig. 8 is a detailed end elevation taken along the line 8—8 of Fig. 6 and showing the construction of the filament by-pass condensers;

Fig. 9 is a detailed inverted plan view of the filament by-pass condensers; and

Fig. 10 is a detailed exploded view of the blocking condenser 34.

Fig. 1 shows in a somewhat conventional schematic circuit form the ultra-high frequency amplifier of the present invention, the construction of which is illustrated in the other figures. This amplifier comprises a triode vacuum tube 11 enclosed in a shield comprising a portion 12 surrounding the tube itself and a section portion 13 enclosing the top of the tube shield and also enclosing the neutralizing line, to be described later. The radio frequer input to the tube is brought in through a concentric line comprising an outer conductor or sheath 14 and a tubular inner conductor 15. The outer conductor is grounded to the shield 12 and connected to the cathode of the tube 11 through the direct current blocking condensers 16 and 26. A short-circuited stub line 17 is provided to tune the input circuit and provide proper impedance matching for the input.

The stub line comprises an outer conductor or shield 17, an inner conductor 18 and a short-circuiting member 19. (This latter member 19 is shown adjustable in Fig. 1 for purposes of explanation though in the actual construction of the other figures it is fixed, thus fixing the length of the stub line.) The shield 17 contacts the outer conductor 14 of the input line and the inner conductor 18 contacts the inner conductor 15 of the input line.

The stub line 17 is movable along the input line so that the length of the short-circuited section from the grid of tube 11 to the shorting member 19 may be adjusted. This provides a tuning section between the grid connection and the short-circuited terminal which when adjusted to the equivalent quarter wave-length of the input oscillations in effect tunes the amplifier input circuit. At the same time the input portion of the line 14—15 is in effect tapped into this resonant line section at the junction of the line 14—15 and the stub line 17. By adjusting the reactance of the stub line 17, i. e., its length is determined by the position of the shorting member 19, it is also possible to obtain a proper impedance match for the efficient termination or coupling of the input line.

Since the latter adjustment for impedance match is somewhat less critical than the tuning adjustment, it is possible, particularly where the amplifier is intended for operation over a narrow frequency range, to determine by preliminary calculation and trial the necessary length of the stub line 17 and fix the position of the member 19. This is done in the embodiment shown in the other figures, though, of course, applicant's invention is not limited to such an arrangement.

The equivalent electrical circuit, that is a quarter wave-length line for tuning with an intermediate tap for impedance matching, is familiar to those skilled in the art. However, applicant's structure avoids a serious handicap of the previous arrangements in which it was necessary in order to make the impedance matching adjustment to use a flexible section of incoming line. Such an arrangement is undesirable, particularly when operating in the higher frequency ranges.

The plate or output circuit of the amplifier is tuned and efficiently coupled to the outgoing coaxial line 24—25 by a similar arrangement. This comprises the coaxial line having an inner tubular conductor 24 connected at the inner end to the plate of the tube 11 through a blocking condenser 34 and an outer conductor 25 connected to the grounded shield 12. The blocking condensers 16 and 26 serve to connect the cathode of tube 11. The adjustable stub line 27, which is similar to the line 17, is also provided and comprises a shield 27 contacting the outer conductor 24, an inner conductor 28 contacting the inner conductor 25 and a shorting member 29. The direct current plate supply is brought in through the insulated wire 30 carried within the tubular inner conductor 25. The line 24—25 may be used for interstage coupling in which case it leads to a second amplifier and is terminated in a similar manner to the input line 14—15.

The tube 11 is neutralized to prevent the generation of spurious oscillations by means of the balanced line 31—32. One side 31 of this line is connected to the grid of tube 11. The other side is connected to the plate of tube 11 through the blocking condenser 34. The line 31—32 is adjustably short-circuited by the member 33 so that its inductance can be adjusted to give a reactance equal to that of the grid to plate capacity, thus neutralizing the effect of the latter.

The adjustment may also be made to cause the amplifier to operate as a regenerative amplifier, if desired.

The line 31—32 is enclosed in the shield 13. Each side of the line 31—32 acts as the center conductor of an approximately concentric line of which the cylindrical shield 13 is the sheath. This presents an impedance from the plate and from the grid to the sheath 13 that is determined by the characteristic impedance and length of these concentric lines. The length is determined by the shorting member 33 which is extended to contact the sheath 13. Since the cathode and sheath are at substantially the same radio frequency potential the grid and plate circuits are additionally tuned by this system. Therefore, these concentric lines should be self-resonant or have sufficient inductive reactance to partially or wholly resonate the grid-sheath and plate-sheath capacitances with the shorting member 33 in the position that permits the balanced line 31—32 to tune the grid-plate capacitance to resonance. These requirements place a restriction on the diameters of the neutralizing rods 31 and 32 and the inner diameter of the sheath or shield 13. It is preferable that there be approximate equality of the characteristic impedance of the rods as a balanced line or as individual unbalanced (concentric) lines. Accordingly, at any setting of the member 33 less than a quarter wave-length a triangle of approximately equal inductive reactances is presented to the tube 11. This provides the reactances desired for a tube such as the Western Electric 703A vacuum tube, the interelectrode capacitances of which are approximately equal. For a tube of different characteristics, different line parameters would be preferred.

In neutralizing the amplifier, the plate voltage is removed and with a high signal input the input and output stub lines 17 and 27 are set for maximum output while the member 33 is adjusted for the maximum ratio of input to output. When so neutralized, the input and output circuits can be retuned independently by a readjustment of the stub lines 17 and 27.

For the actual structure of a practical embodiment of my invention reference is made to Figs. 2 to 10 of the drawings in which the same reference numerals are used throughout for like elements. Referring first to Figs. 2 and 3, the amplifier is built on a panel or base 40. Above this base and secured thereto by screws is a shielding housing 13. This shield 13 is made square in cross section for mechanical reasons but is the substantial electrical equivalent of a circular shield as regards its cooperation with the neutralizing rods 31 and 32 in tuning the grid and plate circuits.

The amplifier is supported mainly by the housing 13 as is more clearly shown in Figs. 6 to 9. The input concentric line comprising the sheath 14 and the inner conductor 15 is supported in the right wall of the housing 13. For this purpose the inner end 41 is turned down forming a reduced portion and a shoulder which is mounted in a hole in the wall 42 by a press fit. A disc insulator 43 is mounted in a recess in the inner end of the sheath 14 by means of a spring retaining ring 44. The inner hollow tubular conductor 15 is mounted in a centrally located hole in the disc 43 and secured there by the nut 45. Clamped on the end of the conductor 15 is a clamping block 46.

The clamping block 46 carries an L-shaped bracket 47 and the plate terminal socket 48. The neutralizing rod 31 is carried by the bracket 47.

The plate circuit concentric line 24—25 is similarly mounted in a second hole in the wall 42. An insulated wire 30 forming the direct current connection to the plate is run through the hollow inner conductor 25. The wire 30 is brought out of the conductor 25 at a point of low radio frequency impedance as shown in Fig. 3 thus simplifying the filtering of the direct current circuit. A clamping block 56 is mounted on the inner end of the conductor 25. Like the block 46, this block 56 carries a neutralizing rod 32 and the socket 58 for the plate terminal of the tube 11. However, the socket 48 is directly mounted in block 46, while terminal 58 is mounted in the block 56 through the medium of an insulating bushing to form the blocking condenser 34. Fig. 10 shows this construction.

Referring to Fig. 10, which is an exploded view of the condenser 34, the socket 58 is screwed onto the threaded end of rod 60. The other end 61 is of reduced size forming a soldering terminal for the direct current lead 30. A bushing 62 fits over the intermediate portion of the rod 60. This bushing 62 is of a lava type insulating material which is first coated with silver and then copper plated, both inside and out. An externally threaded metallic bushing 63 fits over the insulating bushing 62. The rod 60 and bushings 62 and 63 are sweated together. Then the bushing 63 is screwed into the tapped hole 59 in the block 56. In this way the plate of the tube 11 is capacity coupled to the neutralizing rod 32 and the inner conductor 25. The rod 60 and bushings 62 and 63 form the blocking condenser 34.

It will be observed that the conductor 25 is clamped in a split portion of the block 56 by means of the screw 64. A similar construction is used for clamping the block 46 to the conductor 15.

An assembly of cathode circuit condensers 16 and 26 is also mounted in the shield 13. These comprise a mounting plate 70 screwed to angles 69 suitably mounted on the inner walls of the shield 13. Two irregularly shaped plates 71 and 72 are screwed to the plate 70 and separated therefrom by the sheet of mica 73. Insulating washers 74 prevent the screw heads from making electrical contact with the plates 71 and 72. Soldering terminals 71.1 and 72.1 are provided on the plates 71 and 72 respectively, for connecting the leads which furnish heating current to the cathode of the tube 11. Cathode terminal sockets 75 and 76 for the tube 11 are mounted on the plates 71 and 72 respectively.

The tube 11 is mounted below the panel 40, being supported from the sockets 48, 58, 75 and 76 by its electrode terminals. The shield 12 surrounds the tube 11 and is provided with a removable cover 12.1 for access to the tube.

The short-circuit member 33 is mounted in the shield 13. This is provided with a wiper 82 which contacts the rod 32. A similar wiper, not visible in the drawings, contacts the rod 31. The plate member 33 is also provided with brushes 83 which make contact with the inner surface of the shield 13. A block 85 is attached to the plate 33. A shaft 86 is journaled in this block 85 and carries two pinions 87 and 88 within the shield 13 and a knurled knob 89 outside. The pinions 87 and 88 mesh with the teeth of the respective racks 90 and 91 secured to the inside of the shield 13. Thus by turning the knob 89 the position of the plate 33 and consequently the effective length of the balanced neutralizing line and the unbalanced plate and grid lines may be adjusted. A pointer 92 and scale 93 give an indication of the adjustment.

Figs. 5 and 5A show the construction of the stub line 17, the stub line 27 being identical thereto. This comprises an outer housing or shield 100 formed largely of sheet metal but having two solid end blocks 101 soldered to the sheet metal portion. The lower end of each of these end blocks 101 is machined to form a tongue 102, which rides in the slot 14.1 in the top of the outer conductor 14. Riding on the inside of the conductor 14 is a shoe 103 that is fastened to the end blocks 101 by means of the machine screws 104 and springs 105. A wiper 106 contacts the inner conductor 15. This wiper is carried by a stem 18 forming the inner conductor of the stub line 17. The stem 18 is carried by two guide blocks 107 to which it is riveted. The assembly of blocks 107 and stem 18 are secured to the casing 100 by means of machine screws 108 and 109. The screw 109 in addition carries a strip 110 the lower end of which is bent outwardly and pointed to form an indicator 111. This indicator cooperates with the scale 112 to indicate the adjustment of the stub lines 17 and 27.

What is claimed is:

1. In a high frequency amplifier, a vacuum tube having a cathode, an anode and a control grid, a two-wire line, a shield surrounding said line and so spaced with respect thereto and to the spacing between the two wires of said line that each of said wires forms a substantially concentric line with said shield, means for connecting one set of terminals of said two-wire line to said anode and control grid, means for connecting the corresponding end of said shield to said cathode, and an adjustable device forming a short circuit at the other set of terminals of said two wires and a point on said shield spaced from said corresponding end thereof, the spacing of the wires of said two-wire line with respect to each other and to said shield being such that said adjustable device simultaneously controls the length of said substantially concentric lines to tune the grid and anode circuits to the operating frequency and the length of said two-wire line to prevent the generation of spurious oscillations.

2. In a high frequency amplifier, a vacuum tube amplifier having a cathode, an anode, and a control grid, a two-wire line having a set of terminals connected to said anode and control grid, an adjustable short-circuiting element for said line whereby the regenerative action of said tube may be controlled to prevent the generation of spurious oscillations, a shield surrounding said line and so spaced therefrom relative to the spacing of the wires of said line that each of said wires forms a substantially concentric line with said shield, and an adjustable device for short-circuiting said wires to said shield to tune the grid and anode circuits to the operating frequency of the amplifier.

3. In an ultra-high frequency amplifier according to claim 2, means for simultaneously adjusting said adjustable short-circuit element and said adjustable device.

4. In a high frequency amplifier, a vacuum tube having a cathode, an anode and a control grid, a two-wire line, a shield surrounding said line and so spaced relative to said line and to the spacing between the two wires thereof as to form a substantially concentric line with each

of said two wires, electrical connections between corresponding ends of said two wires and said anode and said control grid, respectively, electrical connections between the corresponding end of said shield and said cathode, a plunger element making electrical contact with said shield and each of said two wires and having such electrical characteristics as to form a substantial short circuit between said two wires and between each of said two wires and said shield, and con-

trol means for adjusting the position of said plunger in said shield to simultaneously adjust the length of said two-wire line to prevent the generation of spurious oscillations and the substantially concentric lines formed between each of said two wires and said shield to tune the grid and anode circuits to the operating frequency.

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