

May 9, 1939.

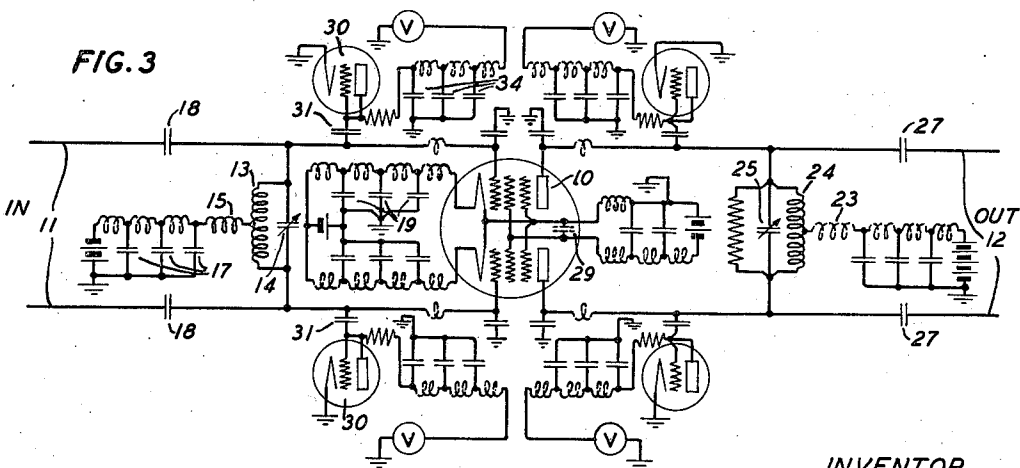
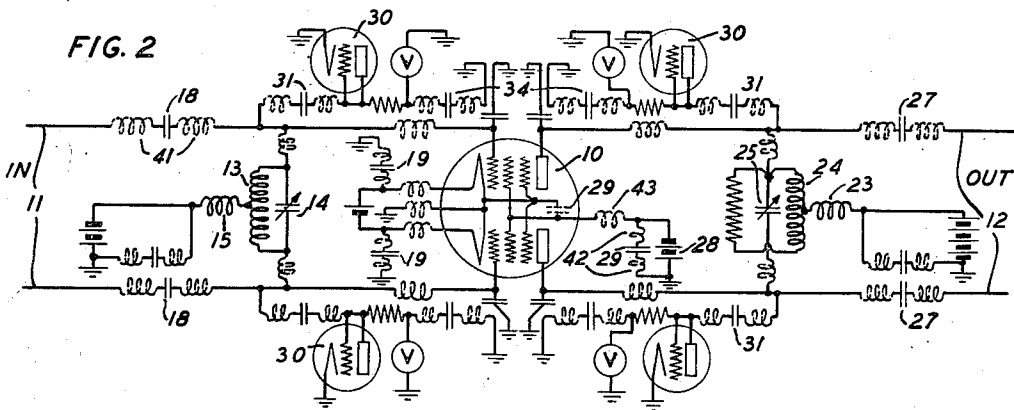
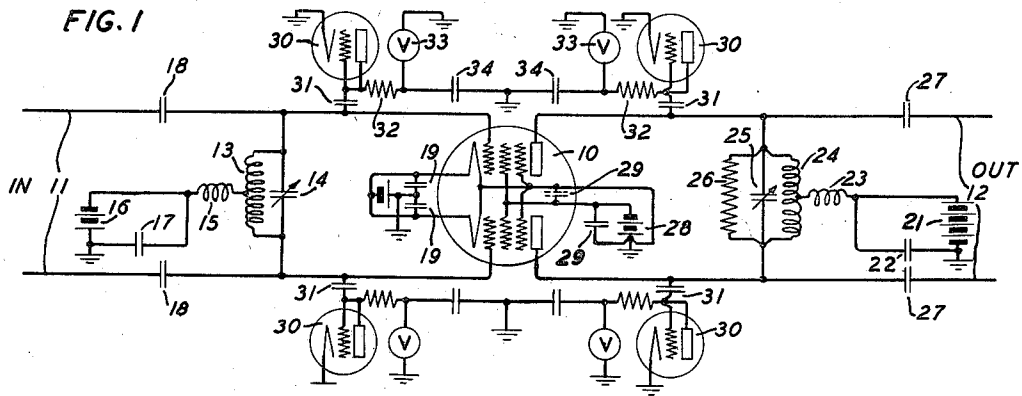
N. E. SOWERS

2,157,870

HIGH FREQUENCY CIRCUIT AND APPARATUS

Filed Aug. 21, 1936

4 Sheets-Sheet 1



INVENTOR
N. E. SOWERS
BY *H. A. Burgess*
ATTORNEY

May 9, 1939.

N. E. SOWERS

2,157,870

HIGH FREQUENCY CIRCUIT AND APPARATUS

Filed Aug. 21, 1936

4 Sheets-Sheet 2

FIG. 4

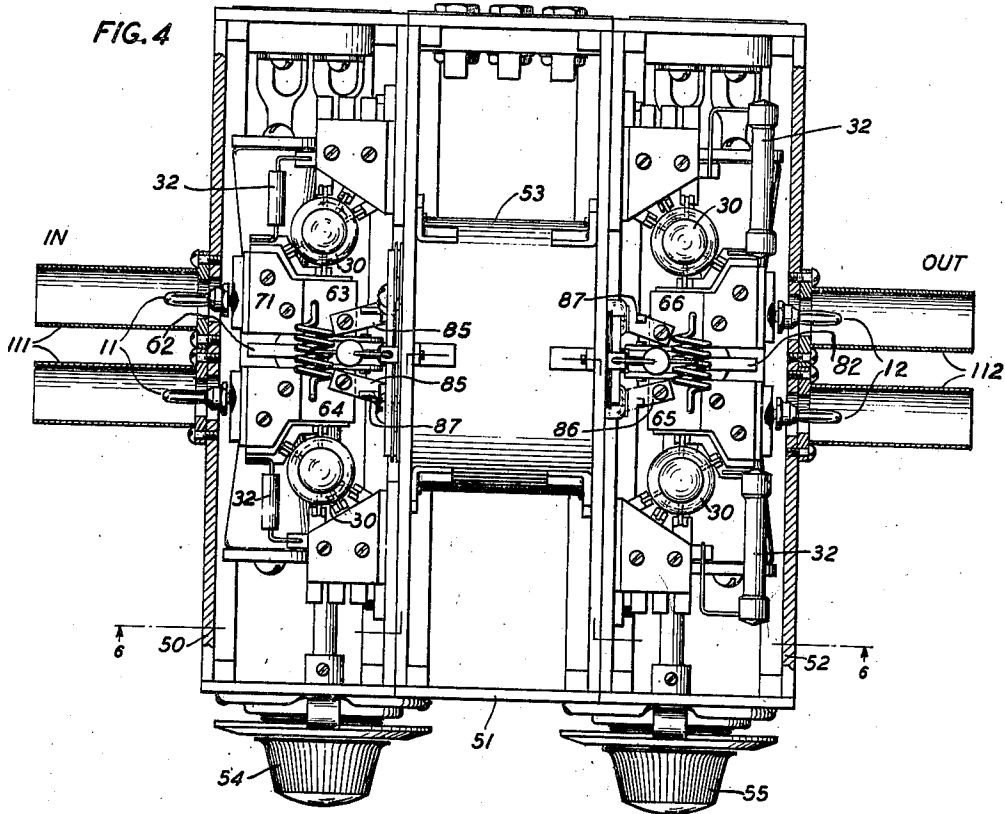
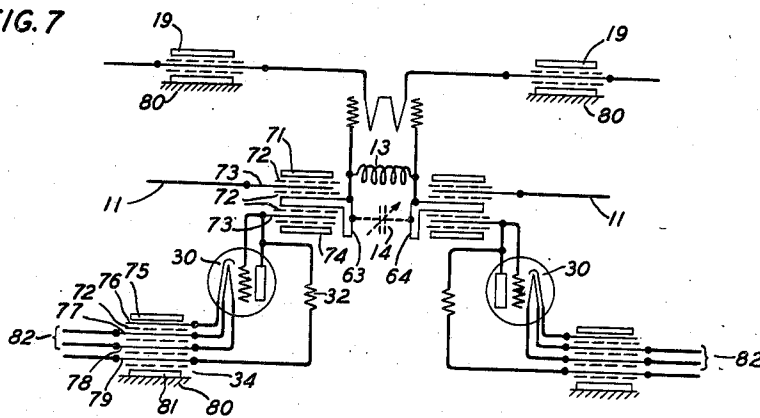


FIG. 7



INVENTOR
N.E. SOWERS
BY *J. A. Burgess*
ATTORNEY

May 9, 1939.

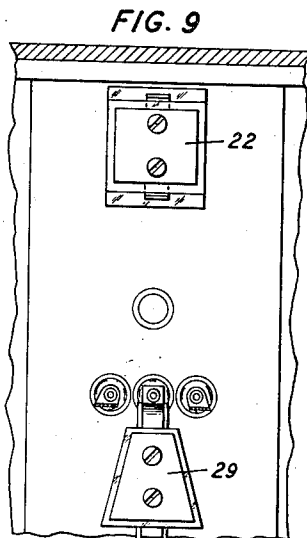
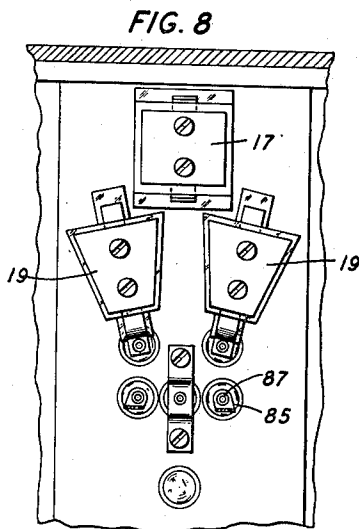
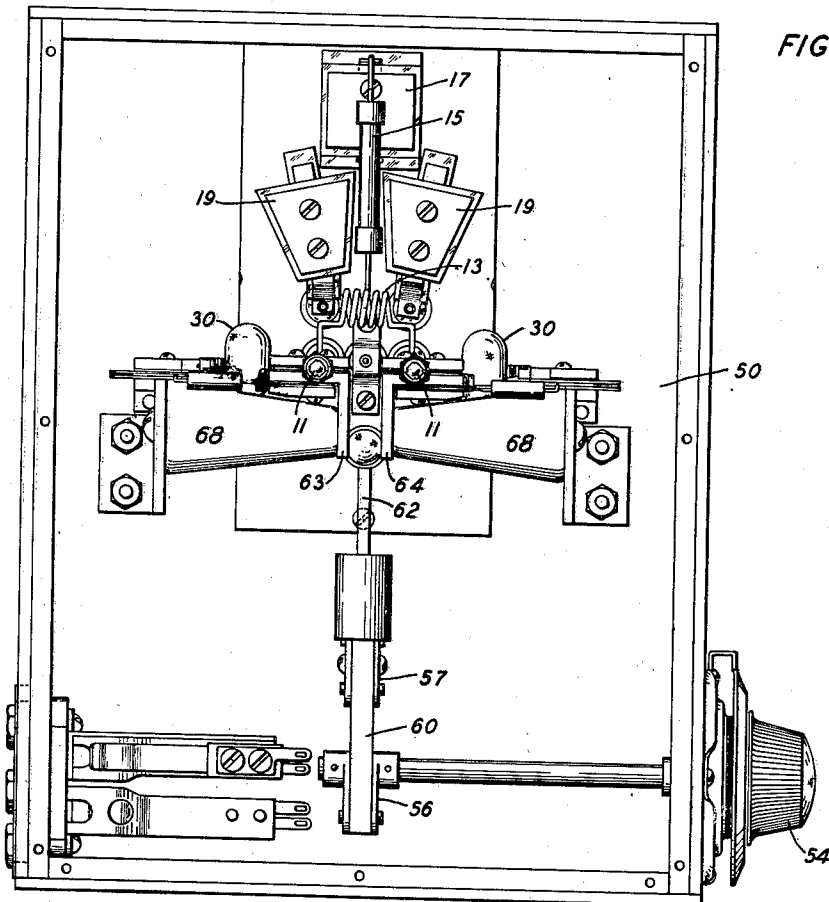
N. E. SOWERS

2,157,870

HIGH FREQUENCY CIRCUIT AND APPARATUS

Filed Aug. 21, 1936

4 Sheets-Sheet 3



INVENTOR
N. E. SOWERS
BY *H. A. Burgess*
ATTORNEY

May 9, 1939.

N. E. SOWERS

2,157,870

HIGH FREQUENCY CIRCUIT AND APPARATUS

Filed Aug. 21, 1936

4 Sheets-Sheet 4

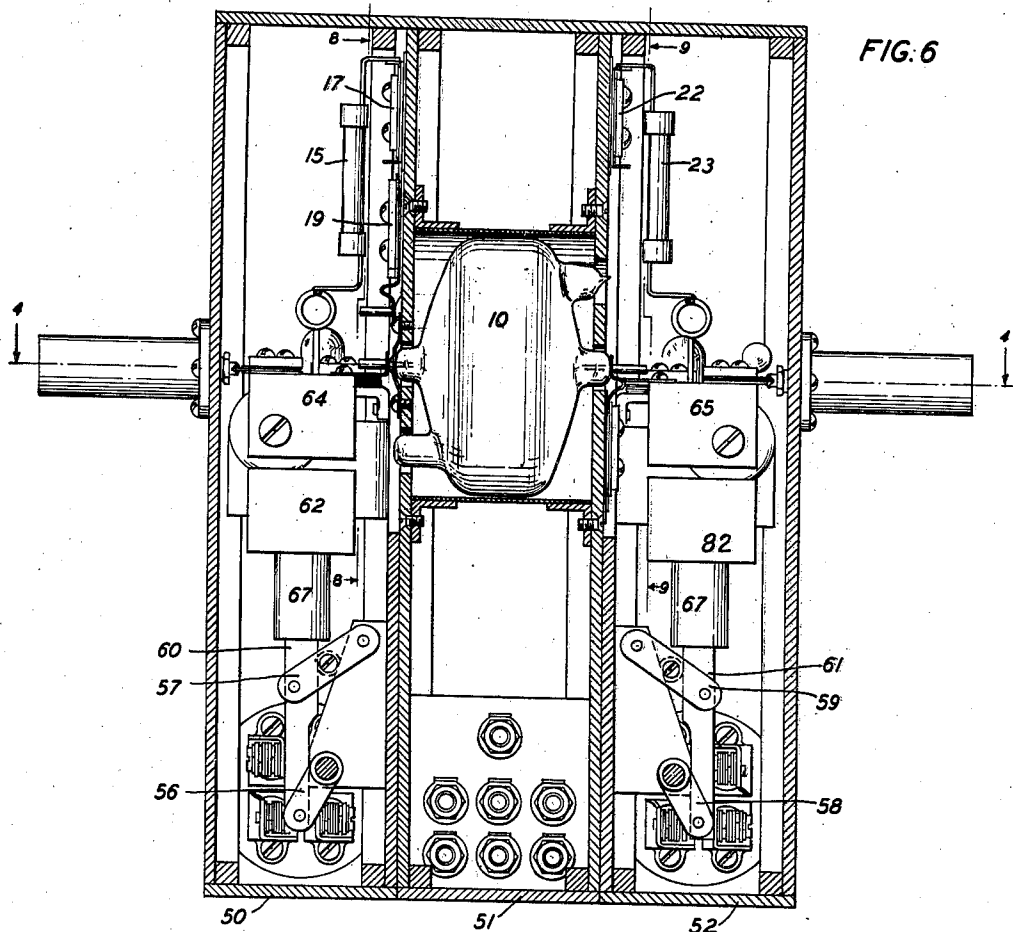


FIG. 6

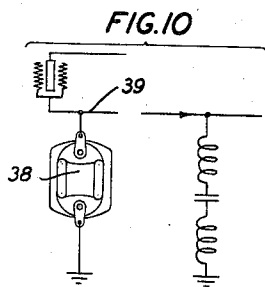


FIG. 10

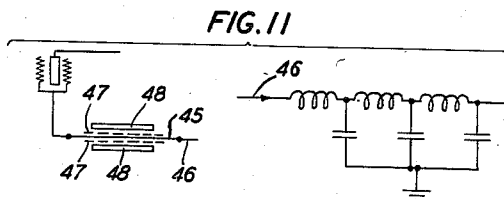


FIG. 11

INVENTOR
N. E. SOWERS
BY *H. A. Burgess*
ATTORNEY

UNITED STATES PATENT OFFICE

2,157,870

HIGH FREQUENCY CIRCUIT AND APPARATUS

Nelson E. Sowers, Red Bank, N. J., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application August 21, 1936, Serial No. 97,169

4 Claims. (Cl. 179—171)

The present invention relates to circuits and apparatus for use especially in ultra-high frequency transmission, and particularly in association with space discharge apparatus.

5 An object of the invention is to increase the effectiveness of an amplifier or similar circuit especially at ultra-high frequencies at which phantom resonances and other troublesome effects are encountered.

10 More specifically, an object of the invention is to minimize the deleterious effects of stray capacity or inductance on amplification at ultra-high frequency.

15 The study of operating characteristics of amplifier tubes at frequencies up to the order of 300 megacycles has brought up many new problems and greatly intensified those problems already existing at lower frequencies. The fundamental tube properties, transconductance, plate impedance, etc., no longer convey as much information as they do at lower frequencies, since the effects of stray inductances and capacities make it no longer possible to entirely separate tube problems from circuit problems. By considering the tube and its associated circuits as one piece of apparatus and using extreme care in the design, considerable improvement in result can be achieved.

20 In accordance with this invention, in one specific form, applicant has so constructed his circuit around the tube that certain resonance effects heretofore considered inherent in the circuit have been substantially avoided and other harmful effects have been greatly reduced.

25 The nature of the improvements constituting the invention and its various objects and features will be made clear from considering an illustrative embodiment of a preferred form as shown in the accompanying drawings and described in detail in the following specifications.

30 In the drawings, Fig. 1 is a schematic circuit diagram of an amplifier in which each symbol for capacity, inductance, etc., is assumed to be physically realizable at the frequencies at which the circuit is used;

35 Fig. 2 shows the same circuit but with the inherent inductances and capacities sketched as they would effectively exist in the circuit if an attempt were made to set up the circuit according to the Fig. 1 diagram using ordinary circuit elements arranged in the ordinary manner;

40 Fig. 3 shows the same circuit with the inherent inductances and capacities sketched as they effectively appear where the circuit diagram-

matically illustrated in Fig. 1 is built in accordance with this invention;

Fig. 4 is a plan view, partly in section, of apparatus embodying the circuit schematically shown in Fig. 1 in accordance with the invention;

Fig. 5 is an elevation of this apparatus from the input side;

Fig. 6 is a sectional elevation along the line 6—6 of Fig. 4; and

Fig. 7 is an explanatory apparatus and circuit diagram of condenser mountings;

Figs. 8 and 9 are fragmentary views taken along lines bearing the corresponding numerals in Figs. 5 and 6; and

Figs. 10 and 11 are fragmentary diagrams of condenser connections.

In Fig. 1 a single stage push-pull amplifier circuit is sketched for use at frequencies of one or several megacycles per second. The tube 10 has within it the tube elements for a push-pull circuit and is preferably constructed as disclosed in A. L. Samuel Patent 2,062,334, issued December 1, 1936. The input is shown at 11 and the output at 12. Across the input is an anti-resonant shunt comprising inductance 13 and condenser 14, the center of the inductance being connected through a radio frequency choke coil 15 and battery 16 to ground for biasing the grids. A by-pass condenser 17 is shown around this battery. Series condensers 18, 18 isolate the bias battery from the incoming circuit 11.

A somewhat similar circuit appears on the output side where plate battery 21 and by-pass condenser 22 are connected through choke 23 to the middle of inductance 24 which forms together with tuning condenser 25 and damping resistance 26 a suitably damped anti-resonant circuit impedance across the line. Stopping condensers 27 isolate the plate supply circuit from output leads 12.

40 Tube 10 is a double pentode, having its suppressor grids (as usual) connected to the cathodes and having its screen grids connected in common to battery 28, this connection being bypassed to ground by condensers 29, 29. Each side of the filament heating circuit is by-passed to ground by condenser 19, 19.

45 The circuit is shown as including voltmeter circuits comprising four tubes 30, 30, etc., acting as rectifiers having their anodes and grids connected through condensers 31, 31, etc., to the grid or plate lead as the case may be, and directly through resistances 32, 32, etc., and meters 33, 33, etc., to ground for measuring the high frequency voltage from desired circuit points to 55

ground. The meters are by-passed to ground by small condensers 34, 34, etc.

It is found, if one were to set up the circuit of Fig. 1 by connecting together the appropriate elements in the same manner as is done in comparatively low frequency work, that a circuit would result which at very high frequencies would resemble in effect that shown in Fig. 2. Thus, any lead, even short, has measurable inductance at very high frequency and an ordinary condenser if connected by its terminals between two points behaves as a series resonant circuit. This effect is illustrated in Fig. 10 in which an ordinary condenser 38 is connected between lead 39 and ground. Due to the inductance of the terminals and leads and of the condenser plates themselves, the circuit behaves not as a simple capacity but as a capacity accompanied with a certain amount of series inductance as shown in the equivalent schematic of this same figure.

With this in mind, if one substitutes for each capacity in Fig. 1 the effective schematic at ultra-high frequencies, the effect is as shown in Fig. 2 in which a large number of series resonant circuits appear, some in series in the transmission path and some in shunt to ground. For example, condensers 18 are indicated as including inductance 41. Similarly, condensers 29 in the screen grid lead are indicated as including inductance 42, and the lead from this combination to the screen grid is shown as including effective series inductance 43. Applicant has observed in an ordinary fixed mica condenser an inductive reactance of from 10 to 25 ohms at 300 megacycles. Use of condensers in this manner as by-pass condensers leads to the building up of sizable high frequency voltages between points in the circuit across which no high frequency difference of potential is supposed to exist, and tends to cause unsatisfactory circuit operation. Undesired resonances in a circuit due to inherent inductances or capacities, even where a tube of special design is used, such as that of the Samuel patent referred to above, may give rise to spurious impedance and voltage effects at 300 megacycles; for example, these undesired resonances may give rise to a high frequency voltage applied to the grids 25% higher than the voltage developed across the tuned grid circuit, and to a load impedance presented to the plates that is twice the load impedance actually present across the tuned plate circuit. These values were found even where the tuned plate and grid circuits (of the type indicated in Fig. 1) were placed as close as physically possible to the tube.

In accordance with the invention, condensers of special construction are used and are so associated physically with the other parts of the apparatus that the unavoidable inductive reactance is minimized and in the case of the by-pass condensers the inherent inductance is made to appear in the direct current path rather than in the alternating current path to ground. This effect is illustrated in Fig. 11 where the condenser comprises a flat sheet 45 (seen edgewise in this figure) included serially in the battery or ground lead 46 and separated by mica foil at 47, 47 from grounded plates 48, 48, the upper one of which may conveniently serve as a clamp acting against the lower one, which may be part of the frame or chassis on which the circuit elements are mounted. In this construction the inductance and capacity are both distributed along and in shunt to the lead 46 somewhat as shown in the schematic diagram of this figure. As a

consequence, substantially no high frequency difference of potential appears between lead 46 and ground.

The general effect of this mode of disposing the effective capacities and inductances may be seen from Fig. 3 in which the series resonant combinations in the by-pass connections of Fig. 2 appear for the most part as low-pass filters which serve to separate the direct current and alternating current paths in advantageous manner, 10 and in the case of the stopping condensers the inductance is reduced by the absence of lead wires or straps and by the condenser construction employed.

Moreover, in Fig. 3 the inherent or distributed inductance in the grid and plate leads of the tube 10 is shown greatly reduced as compared with Fig. 2. This reduction is secured by a special construction of connectors used between the tube pins and the apparatus parts to which they are connected as will be described hereinafter.

Referring now to the apparatus figures, and at first particularly to Figs. 4, 5 and 6, three metal boxes 50, 51 and 52 are combined into a compact structure by being screw-clamped together in suitable manner. Box 50 contains the input coupling and two of the voltmeter tubes 30 and their mountings; box 52 contains the corresponding output apparatus elements, and box 51 contains the tube 10 the terminals of which project through into the other boxes 50 and 52. A cylindrical shield 53 (Fig. 4) surrounds the tube 10. Jacks are provided on the rear of boxes 50 and 52 for battery and ground wire connections, and additional wiring terminals are provided on the rear of box 51.

The input and output tuning condensers 14 and 25, respectively, are operated by dials 54 and 55, respectively, which when rotated act through cranks 56, 57, 58 and 59 and rods 60 and 61 to move heavy brass plates 62 and 62 more or less in between fixed brass plates 63, 64 (in the case of input condenser 14) and a pair of plates 65, 66 (in the case of output condenser 25). That is, condenser 14 (Fig. 1) is comprised of fixed plates 63 and 64 and a movable plate 62 unconnected to anything but capable of movement in the field of the fixed plates 63 and 64 to change the effective dielectric of the condenser and hence its capacity. An analogous construction is used for output capacity 25. The actuating rods 60 and 61 each have mounted on them an insulator 67 for mechanically carrying plates 62 and 62 while insulating them from the chassis.

Each plate 63, 64 is carried on an insulating post 68 in turn supported from the chassis. The output tuned condenser 25 has its fixed plates similarly mounted.

Shields in the form of metal tubing 111 and 112 enclose the input terminals 11 and the output terminals 12 respectively.

Referring now to Fig. 7, this diagram in connection with Figs. 4 and 5 makes clear the manner of constructing and mounting the small fixed condensers in relation to the other apparatus parts on the input side of the amplifier. A similar construction and arrangement is used on the output side so that a detailed showing and description of the latter is deemed unnecessary. In Fig. 7 the fixed plates of the input tuning condenser 14 are shown at 63 and 64 as L-shaped. On the horizontal part of each there are built up the series condensers for the grid leads and for the coupling to the voltmeter rectifier tubes 30, 30, etc.

A clamping plate of brass 71 is placed above plate 63 and is held against plate 63 by screws. Between these plates are two sheets of mica 72 between which is a copper sheet 73 to which the input lead 11 is connected. Plates 71 and 63 are in effect one plate of the condenser 18 (of Fig. 1) and sheet 73 is the opposite plate.

On the underside of plate 63 is a clamping plate 74 secured against plate 63 by screws. Between them are mica sheets 72, one on each side of copper sheet 73 which leads to the anode of tube 30. This corresponds to condenser 31 of Fig. 1. The other plate 64 has similar condensers built up on it.

Building these auxiliary condenser plates onto the tuning condenser plates in this manner offers two important advantages. The unavoidable series inductance introduced by these condensers is reduced to a minimum and the stray capacity of the tuned circuit to ground is not increased appreciably.

Fig. 7 also shows the manner of constructing by-pass capacities 19 and 34 of Fig. 1 as well as others not shown in detail in Fig. 1. Tubes 30 are shown in Fig. 7 as of the heater type with their filaments supplied over circuit 82 from a source not shown. Plate 81 is mounted directly on the grounded chassis 80 and has brass plate 75 screwed to it. Clamped against plate 75 is copper strip 76 which directly grounds the cathode of tube 30. Copper sheets 77 and 78 are connected at one end to the tube filament and at their opposite ends to heating circuit 82. Copper sheet 79 is connected between resistor 32 and the lead to meter 33, not shown in this figure. Mica sheets 72 are interleaved with sheets 76, 77, 78, 79 and 81.

A similar construction is shown for each of the by-pass condensers 19 for the current supply leads to the filaments of tube 10 and it will be clear from this how the various other fixed condensers shown in the different figures are built up.

A further feature of the invention comprises the use of clips for making connection to the tube terminals with minimum stray inductance or capacity effects. These comprise short copper straps (shown at 85 and 86, Fig. 4) screwed on the top of plates 63, 64 on the input side and plates 65 and 66 on the output side. The opposite end of each copper strip is soldered to a brass sleeve 87 which is made to have a sliding fit over the tube terminal. When the parts are in position the sleeve 87 is pushed as far as possible over the tube terminal and is in contact with the glass envelope. This construction enables the tuned input and output circuits to be

placed in close proximity to the tube terminals so that in effect there are substantially no external tube leads at these points.

While a detailed disclosure of a preferred form of embodiment of the invention has been given, the invention itself is not to be construed to the details but its scope is defined in the claims.

What is claimed is:

1. In high frequency apparatus, a tuning condenser having a pair of fixed plates, an inductance coil mounted between and connected to said plates, a metallic shield adjacent said plates, a space discharge tube on the other side of said shield, having terminal pins projecting through apertures in said shield, one opposite each condenser plate, and connectors having a sliding fit over said pins for electrically connecting the pins to the respective condenser plates, said connectors being comparable in length to said pins.

2. In a high frequency system, a space discharge tube having contact pins protruding through the wall of the tube for connection to external apparatus, a tuned coupling circuit, an external circuit, said tuned coupling circuit including a condenser having a fixed plate, a metal strap secured to said plate and engaging one of said pins at the end of the pin adjacent the envelope, said strap being comparable in length to the protruding pin, a sheet of metal clamped against but insulated from said condenser plate, and a connection from the external circuit to said sheet of metal, said sheet of metal and plate forming the armatures of a series condenser in said connection from the external circuit.

3. In a push-pull high frequency amplifier, space discharge apparatus comprising two grids, two anodes and cathode means, a grounded chassis, a tuned input and a tuned output coupling, each including a tuning condenser having a pair of fixed end plates, an incoming and an outgoing circuit, series capacity in each side of the incoming and of the outgoing circuits comprising in each instance a metal sheet clamped against but insulated from a respective fixed plate of a respective tuning condenser, power supply leads for said cathode means and for said anodes, each lead including a by-pass condenser to ground comprising in each instance a metal sheet included serially in the respective lead and clamped against but insulated from said chassis.

4. Apparatus according to claim 3 including also a voltmeter rectifier connected between one of the fixed plates of a said tuning condenser and the chassis, through a series condenser comprising a metal sheet clamped against but insulated from the said fixed plate.

NELSON E. SOWERS.