Oct. 25, 1949. T. J. BOERNER ET AL 2,485,856

HIGH-FREQUENCY APPARATUS

Original Filed June 17, 1943

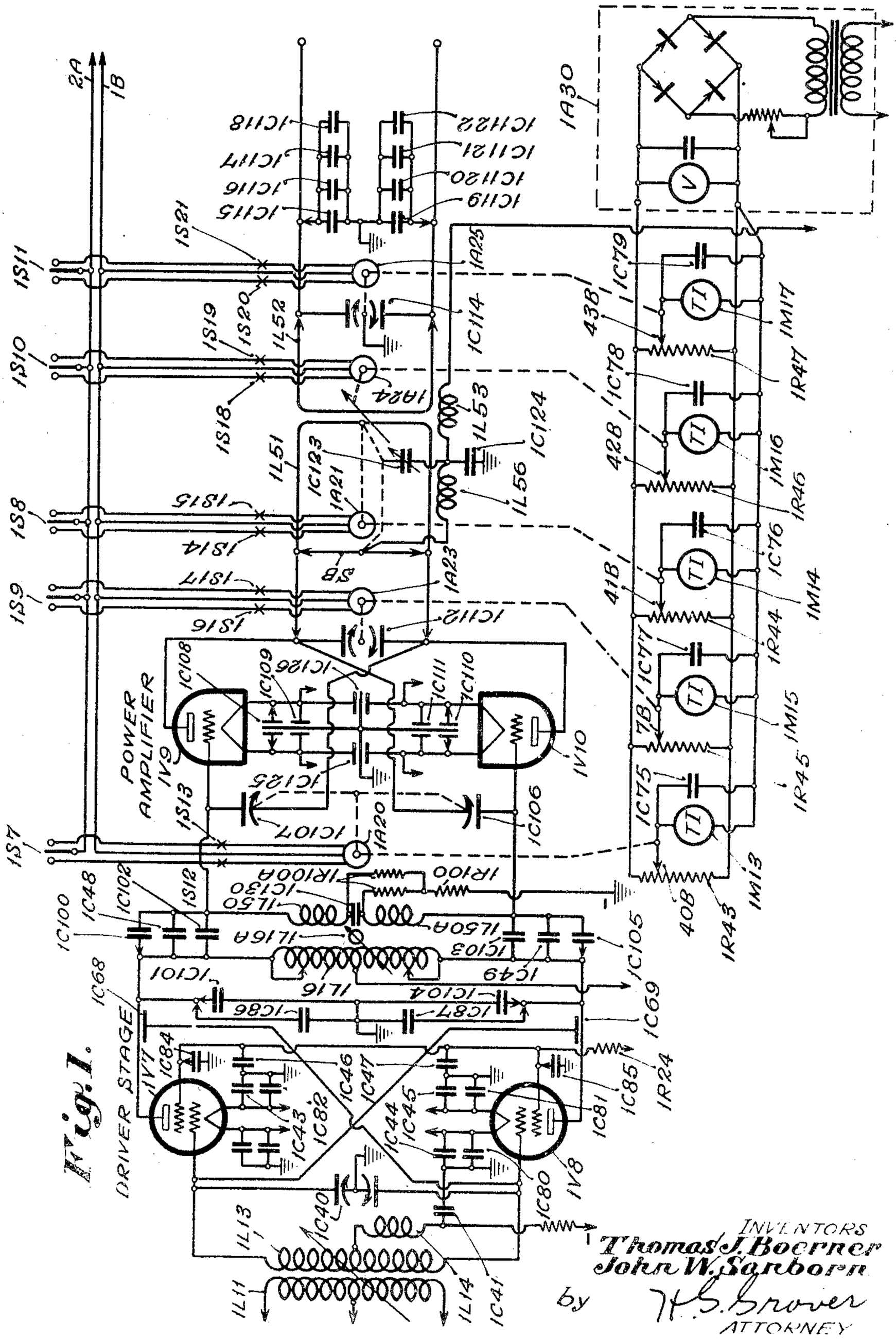

Fig. 1.

INVENTORS
Thomas J. Boerner
John W. Sanborn
by H. S. Grover
ATTORNEY

Patented Oct. 25, 1949

2,485,856

UNITED STATES PATENT OFFICE

2,485,856

HIGH-FREQUENCY APPARATUS

Thomas James Boerner, Collingswood, and John W. Sanborn, Merchantville, N. J., assignors to Radio Corporation of America, a corporation of Delaware

Original application June 17, 1943, Serial No. 491,164. Divided and this application March 28, 1944, Serial No. 528,416

6 Claims. (Cl. 318—3)

1

This is a division of our copending application Serial No. 491,164, filed June 17, 1943, now Patent No. 2,412,314 issued December 10, 1946, and describes an invention which relates to high frequency apparatus and especially to the power amplifier stages of high frequency transmitters.

One object of the invention is to provide improved high frequency vacuum tube power amplifying apparatus and circuits which shall operate at high efficiency and in which spurious effects such as parasitic oscillations are minimized. A further object of our invention is to provide high frequency amplifying apparatus wherein the frequency of operation may readily and conveniently be changed.

In brief, certain features of the present invention may be outlined as follows:

A push-pull connected vacuum tube driver stage is coupled through a condenser-divider arrangement to a push-pull connected vacuum tube power amplifier. The condenser-divider operates in such a way that over a wide range of operating frequencies substantially constant radio frequency excitation is applied to the grids of the power amplifier with constant direct current voltage impressed upon the plates of the driver tubes. In this connection it may also be mentioned that biasing circuits are provided for the grids of the power amplifier tubes which operate so as to secure flow of equal grid currents over a wide operating range.

Reversible electric motors are provided for adjusting neutralizing and tuning condensers of the power amplifier stage and output circuit. Further instrumentalities under control of other reversible electric motors are provided for adjusting other circuits, etc., as will be explained more fully later. Limit switches are provided for the motors so as to prevent them from over-running in either direction. Instrumentalities are also provided whereby each reversible electric motor drives the variable arm of a potentiometer. Each potentiometer supplies voltage to a separate tuning indicator which may be in the form of a volt meter. In this way the tuning indicators give a measure, by the respective volt meter readings, of the capacity in circuit and in other cases the amount of coupling or the amount of inductance in the power amplifier tank circuit.

The drawing is a wiring diagram of a push-pull connected driver-amplifier stage feeding through a condenser-divider arrangement the grids of a pair of push-pull connected vacuum tube amplifiers of a high frequency power amplifier. As illustrated, reversible electric motors

2

are provided for varying neutralizing and tuning condensers, the inductance of the tank circuit, and the coupling between the tank circuit of the power amplifier and the final output circuit to which the tank circuit is coupled.

Referring to the drawing, any carrier frequency within a range of, say, for example, 6 to 22 megacycles is fed into the primary coil 1L11 and thence into the secondary 1L13, exciting the control grids of tubes 1V7 and 1V8 in phase opposition. The carrier may be generated by any suitable vacuum tube generator followed by amplifiers and frequency multipliers. The secondary 1L13 is tuned by the split stator condenser 1C40. The amplified output of the driver stage consisting of tubes 1V7 and 1V8 appears in the tuned output circuit comprising coil 1L16 and condensers 1C101, 1C86, 1C87 and 1C104. The condensers are switched into the circuit as needed, depending upon the frequency employed.

In order to prevent spurious oscillations, the screen grids of the driver tubes 1V7 and 1V8 are by-passed to ground by condensers 1C46 and 1C47. For a range of lower frequencies, additional by-passing condensers 1C84 and 1C85 are also switched into the circuit, but are switched out of circuit in the range of higher frequencies. That is to say, condensers 1C47 and 1C46 will serve to give sufficient by-passing to ground at the higher frequencies since these condensers may be constructed integrally with the screen grid connections to the tubes.

Over the entire range of frequencies, however, neutralizing condensers 1C68 and 1C69, which may consist of sections of copper strap adjacent the anodes, are also employed. That is, these neutralizing condensers are employed in addition to the screen grids and their by-passing circuits to ground, over the entire operating range of frequencies. The use of such neutralizing circuits in addition to the screening circuits insures freedom from spurious oscillations and similar effects.

Coupling from the driver stage, including tubes 1V7 and 1V8, to the final power amplifier stage comprising water cooled tubes 1V9 and 1V10, is accomplished through capacitors 1C100, 1C48, 1C102, 1C103, 1C49 and 1C105.

The condensers 1C100, 1C48 and 1C102 are equal in value, respectively, to condensers 1C103, 1C49 and 1C105. The values of the upper three capacitors in parallel and the lower three are therefore equal; or, they may be used singly or in pairs so that the coupling capacities on both sides of the plate coil 1L16 are equal. In this

way, proper voltage will be applied to the grids of the final power amplifier tubes for different operating conditions.

From the foregoing, it will be observed that the input capacity of the power amplifier tubes 1V9 and 1V10 form the low voltage legs of a condenser divider. Hence, as long as the radio frequency plate voltage of the driver stage is held constant, the condenser divider serves to maintain a correspondingly constant excitation voltage to the power amplifier across the power tubes of 1V9 and 1V10 over a very wide frequency range.

By virtue of the condenser divider tuning of the driver output stage can be adjusted over the entire frequency range without affecting the ratio of driver plate to power amplifier grid radio frequency voltage. Actually some fixed adjustment of the coupling capacitors of the voltage divider arrangement may be required. We have found that the entire range from six to twenty-two megacycles can be covered with three combinations of the condensers in the voltage divider with wide non-critical points of overlap. Further adjustment in the circuits may be made by means of the taps on coil 1L16 and by changing the position and coupling of a short-circuited turn 1L16A with respect to the turns of coil 1L16.

The grids of the power amplifier tubes are subjected to biasing action through the action of a common resistor 1R100 and the further resistors 1R100A. As indicated, one of the latter is connected in series with the grid of tube 1V9 and the other in series with the grid of the other tube 1V10 of the power amplifier. Also, it will be noted that chokes 1L50 and 1L50A and radio frequency by-pass condenser 1C130 have been provided in the grid circuit of the power amplifier stage. The grid circuit as described provides balanced grid currents over the entire range of frequencies employed.

Neutralizing condensers 1C107 and 1C106, which will be described in greater detail hereinafter, are provided for the power amplifier tubes 1V9 and 1V10. Also, as will be described more fully hereinafter, the tank circuit of the power amplifier comprises the inductance 1L51, tuning condenser 1C112, short-circuiting strap SB, condenser 1C123, by-passing condenser 1C124 and choke 1L56.

The loading or output circuit, which also will be described more fully hereinafter, comprises the inductor 1L52, tuning condenser 1C114 and fixed condensers 1C115 to 1C1122 inclusive.

Motor-driven adjustment or tuning of various elements in the power amplifier stage and output circuit are provided. Thus, reversible electric motor 1A20 drives neutralizing condensers 1C106 and 1C107. Direction of rotation is controlled by switch 1S7. Limiting switches, diagrammatically indicated at 1S12 and 1S13, limit the amount of rotation of the motor in either direction. The angular position of motor 1A20 is indicated on a tuning indicator 1M13 which is in effect a voltmeter, the voltage of which depends upon the position of tap 40B upon potentiometer 1R43. The tap 40B is moved along the potentiometer 1R43 by the action of motor 1A20. In other words, motor 1A20 simultaneously varies condensers 1C106 and 1C107 and the position of tap 40B along potentiometer 1R43.

Similarly, reversible driving motors 1A23, 1A21, 1A24 and 1A25, switches 1S9, 1S8, 1S10, and 1S11, limiting switches 1S16, 1S17, 1S14, 1S15, 1S18, 1S19, 1S20 and 1S21, and indicators 1M15, 1M14, 1M16 and 1M17 are provided for adjusting and indicating the adjustment of condensers 1C112, coupling between inductors 1L51 and 1L52 and condenser 1C114. Supply voltage for the tuning indicating system is derived from the rectifier arrangement 1A30. Motor driving power is furnished through leads 1B and 2A. The power supply to these leads may be, for example, 220 volts 60 cycles A. C. current.

The limit switches, such as 1S12 and 1S13, may be operated by cams, in turn operated or driven by reduction gearing coupled to the motor 1A20, so that after a given number of revolutions in one direction, limit switch 1S12 will be opened and after a given number of revolutions in the other direction limit switch 1S13 will be opened. Similarly, the potentiometer and tap arrangement 1R43 and 40B may be controlled by reduction gearing also coupled to the motor 1A20, the tap being in contact with and moved over a circularly shaped potentiometer winding. Similar comments are applicable to the other limit switches and potentiometers controlling the tuning indicators T1. The latter are provided with by-passing condensers 1C75 to 1C79 inclusive.

Having thus described our invention, what we claim is:

1. A control system for high frequency apparatus having a push-pull connected vacuum tube power amplifier, comprising a variable condenser arrangement including at least two variable condensers, each one of said condensers connected to the respective vacuum tubes of said amplifier, a reversible electric motor, switching apparatus for controlling the direction of rotation of said motor in either direction, and mechanical linkage between the armature of said motor to a variable element on each one of said variable condensers, whereby movement of said motor simultaneously varies each condenser capacity.

2. A control system for high frequency apparatus, comprising a plurality of variable condenser and inductor impedance elements connected to said high frequency apparatus, a plurality of reversible electric motors there being a motor individual to each condenser and inductor element, switching apparatus for controlling the direction and the amount of rotation of each one of said motors, and mechanical linkage between said motors and the respective condensers and inductors, whereby the movement of said motors varies the reactance of the impedance element linked thereto.

3. A motor control system including a push-pull connected vacuum tube amplifier, comprising a variable condenser arrangement including at least two variable condensers, each one of said condensers being connected to the respective vacuum tubes of said amplifier, a source of voltage, a reversible electric motor, a potentiometer, a meter, connections from said source of voltage to said potentiometer, a movable tap on said potentiometer, said meter being connected to one side of said potentiometer and its movable tap, switching apparatus for controlling the direction of rotation of said motor and mechanical linkage between the armature of said motor and each one of said variable condensers and also said movable tap, whereby the movement of said motor varies the values of said condensers and simultaneously the position of said tap, and the meter indicates the angular position of said motor.

4. A control system for high frequency appa-

ratus having a plurality of variable condensers and inductors connected to said high frequency apparatus, comprising a source of voltage, a plurality of electric motors, there being a motor controlling each condenser and a motor controlling each inductor, a plurality of meters, a plurality of potentiometers each having a movable tap, each one of said potentiometers being connected across said source of voltage, each one of said meters being connected to one side of each potentiometer and its movable tap, there being a potentiometer associated with each condenser and with each inductor, a link between the tap on each potentiometer and its associated motor, switching apparatus for controlling the direction and the amount of rotation of each one of said motors, whereby the movement of any motor varies the reactance of the condenser or inductor linked thereto and simultaneously causes the meter associated with its respective potentiometer to measure the change in said reactance.

5. A control system for high frequency apparatus having a plurality of variable condensers and an inductor connected to said high frequency apparatus comprising a source of voltage, a movable short-circuiting strap across a portion of said inductor, a plurality of electric motors, a plurality of meters, a potentiometer individual to each condenser and to said inductor, each potentiometer having a movable tap, said potentiometers being connected across said source of voltage, each one of said meters being connected to one side of each potentiometer and its movable tap, switching apparatus for controlling the direction of the amount of rotation of each one of said motors, and mechanical coupling apparatus coupling said motors respectively to different condensers and to said short-circuiting strap, and linkage between each motor and the movable tap

on its associated potentiometer, whereby the movement of one of said motors varies the capacity of a condenser and another motor moves said short-circuiting strap simultaneously, and the meters indicate the degree of movement of said motors.

6. A control system for high frequency apparatus including vacuum tube amplifiers connected in push-pull relationship comprising two vacuum tubes each having at least an anode, a grid and a cathode, two neutralizing condensers each in circuit connection between the anode of one tube and the grid of another tube, a source of voltage, a reversible electric motor linked to both neutralizing condensers for simultaneously varying the same, a potentiometer connected in shunt with said source of voltage, a variable tap for said potentiometer, said variable tap being linked to said motor, and a meter in shunt with said potentiometer.

THOMAS JAMES BOERNER.
JOHN W. SANBORN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,539,168	Dresser	May 26, 1925
1,872,155	Masek	Aug. 16, 1932
1,959,494	Nyquist	May 22, 1934
2,096,072	Spagnola	Oct. 19, 1937
2,098,587	Markowitz	Nov. 9, 1937
2,147,486	Fyler	Feb. 14, 1939
2,191,606	Butler	Feb. 27, 1940
2,347,523	Suksdorf	Apr. 25, 1944
2,376,667	Cunningham et al.	May 22, 1945