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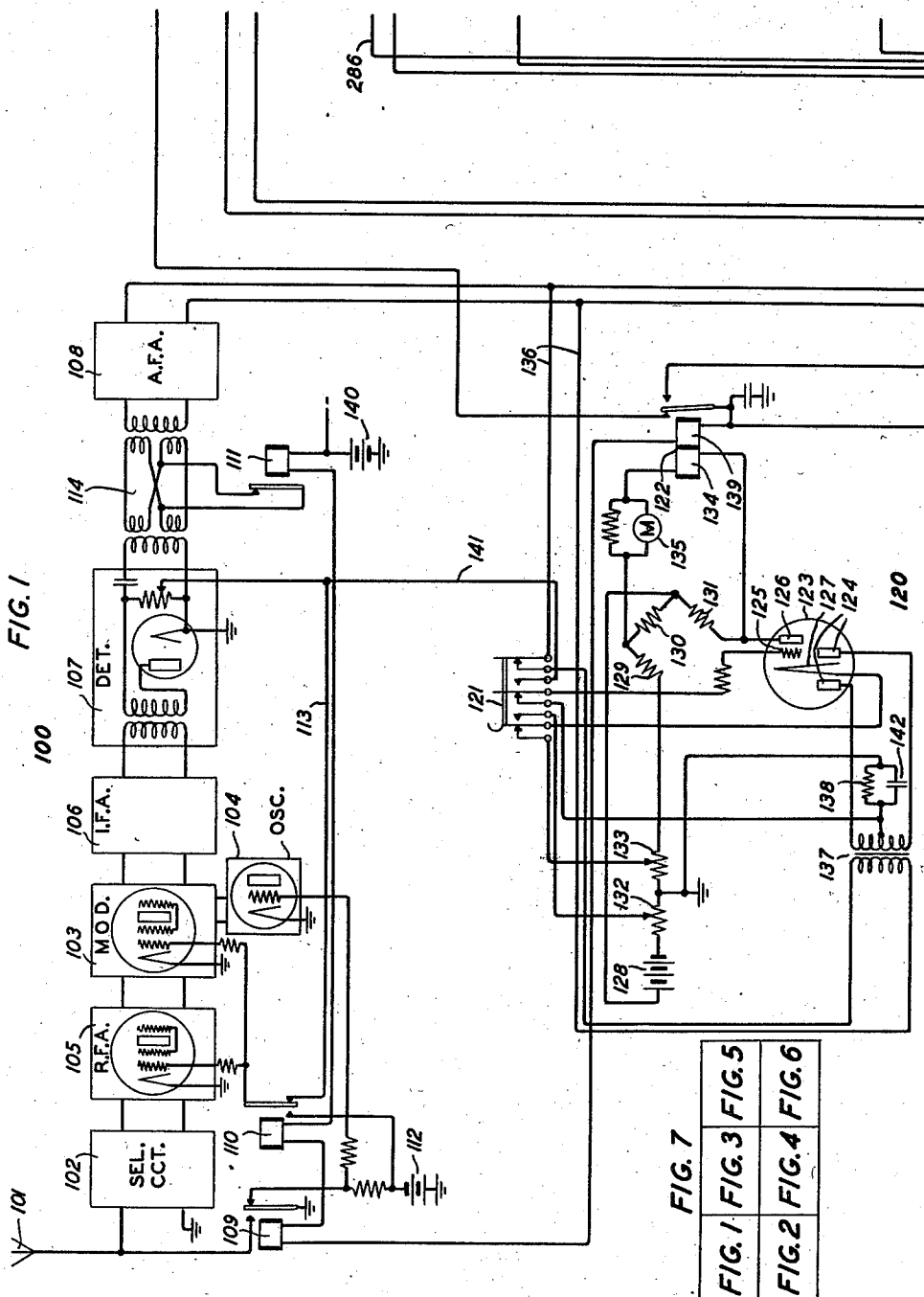
J. B. BISHOP ET AL

2,101,668

RADIO COMMUNICATION SYSTEM

Filed Sept. 26, 1935

6 Sheets-Sheet 1



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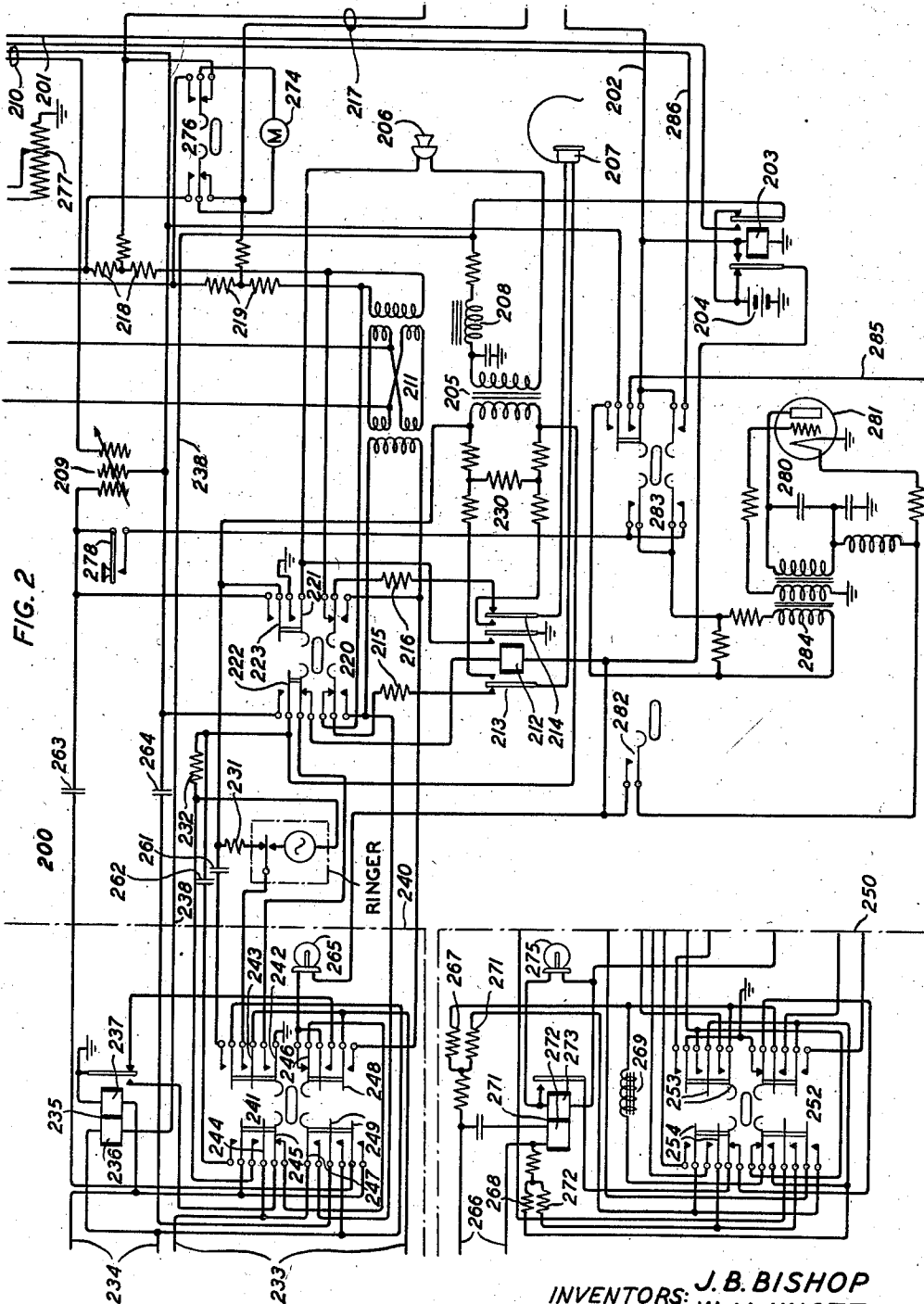
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RADIO COMMUNICATION SYSTEM

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6 Sheets-Sheet 2



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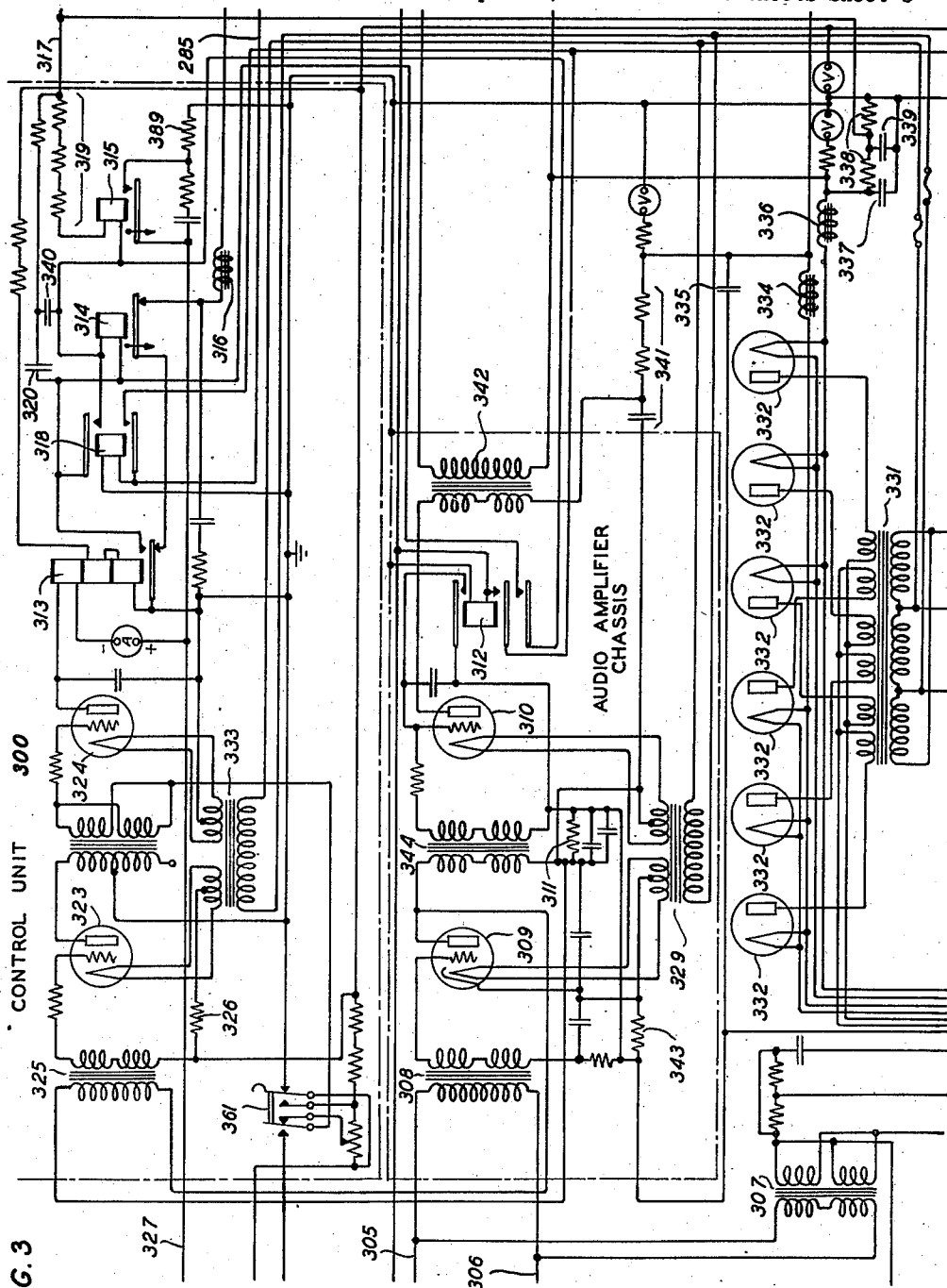
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RADIO COMMUNICATION SYSTEM

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6 Sheets-Sheet 3



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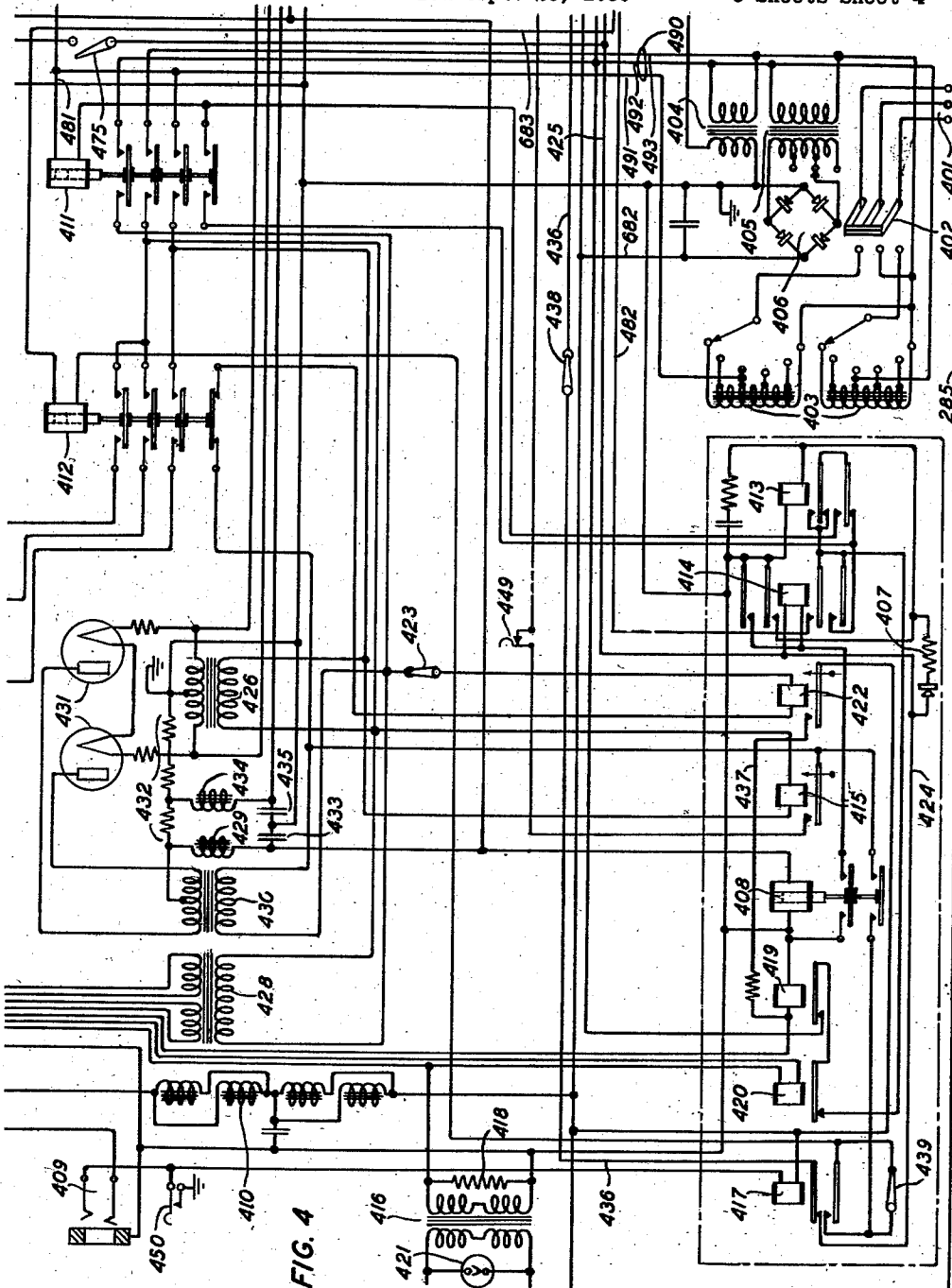
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RADIO COMMUNICATION SYSTEM

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6 Sheets-Sheet 4



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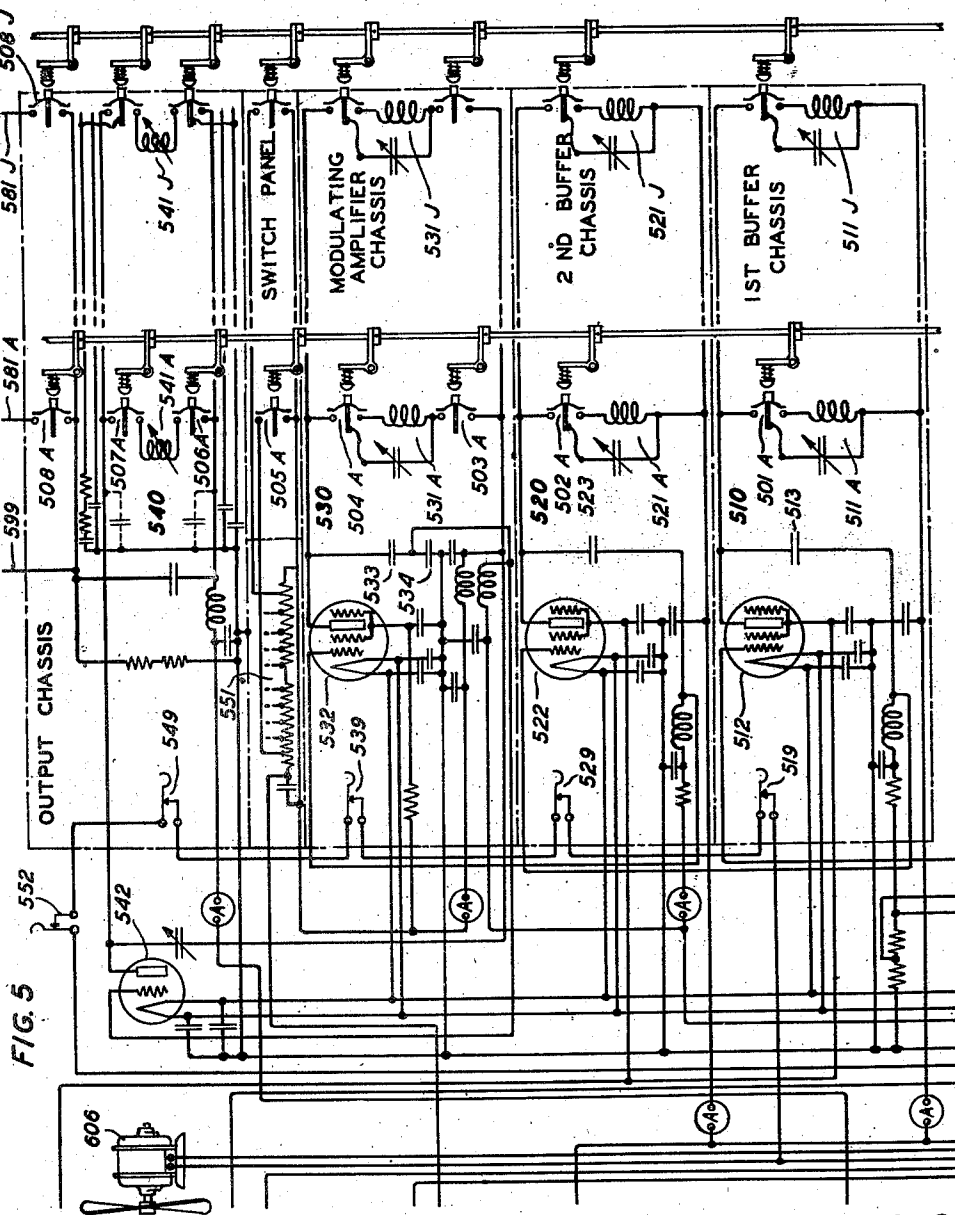
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RADIO COMMUNICATION SYSTEM

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6 Sheets-Sheet 5



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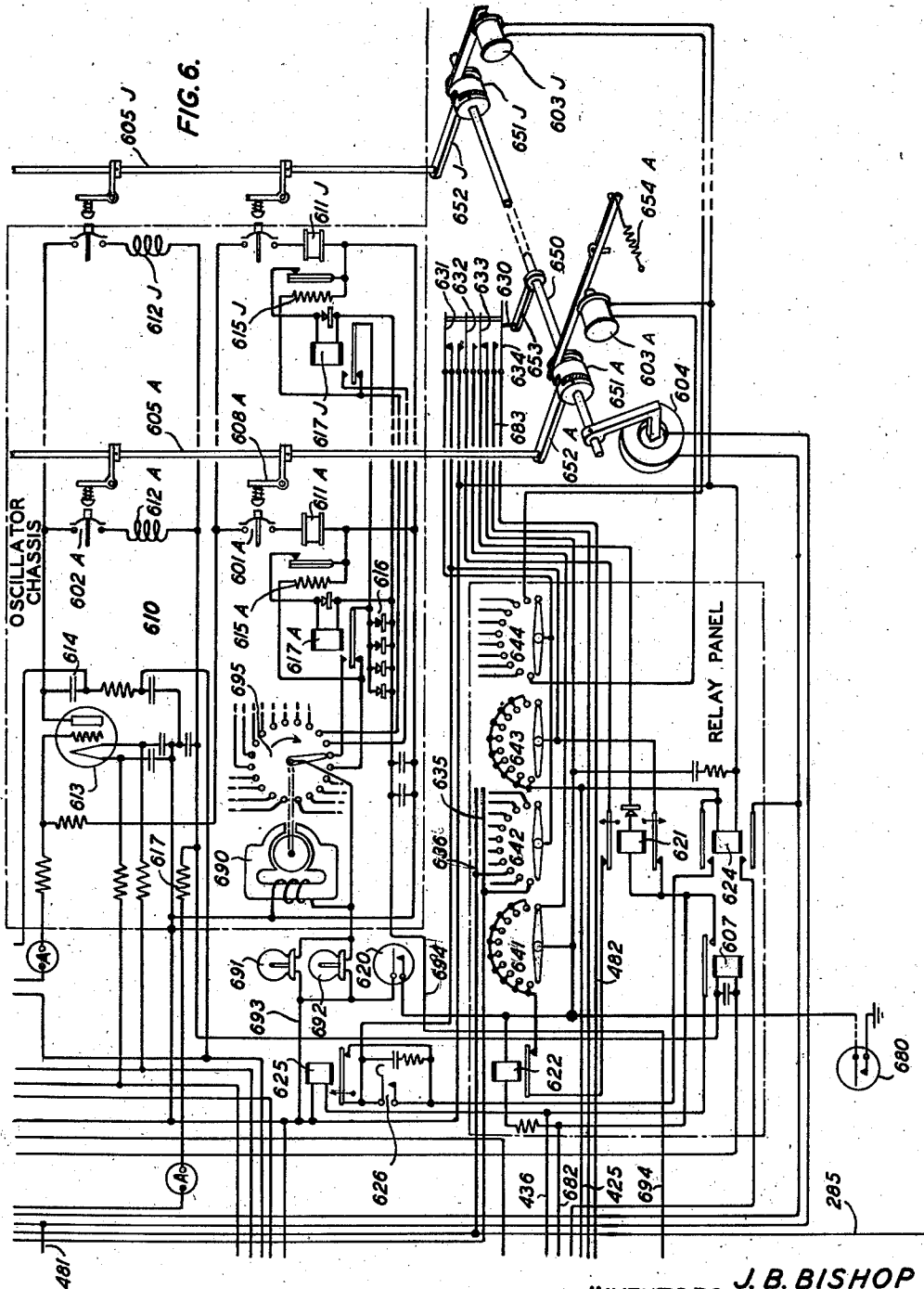
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RADIO COMMUNICATION SYSTEM

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6 Sheets-Sheet 6



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UNITED STATES PATENT OFFICE

2,101,668

RADIO COMMUNICATION SYSTEM

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Application September 26, 1935, Serial No. 42,172

12 Claims. (Cl. 178-44)

This invention relates to radio communication systems and particularly to two-way radio communication systems and control circuits therefor.

An object of the invention is to provide a system for two-way radio communication which will meet the requirements of reliability, economy of operation, simplicity of control and the like, essential to a two-way communication system for commercial operation.

One obstacle to the use of radio for communication is the lack of dependability. This fault is partially an inherent characteristic of radio transmission and is due to atmospheric disturbances, skip distance effects, and the like. Since as far as our present knowledge is concerned these difficulties must be accepted, it is necessary to adopt some method of overcoming their effects. It is well known that atmospheric disturbances while present to some degree at nearly all frequencies, do not affect all frequencies equally. Further, skip distance effects can be made to serve a useful purpose for carrying a signal over a maximum distance with a minimum of power. To take advantage of these conditions it is necessary to shift the frequency of the transmitter and receiver and if the service is to approach the reliability of other types of communication service such a shift of frequencies should be accomplished with the least possible delay.

A particular object of the invention is to provide a radio transmitter which may be operated on any of a number of frequencies and which can be readily shifted from one frequency to another in a minimum time and with a minimum of control operation.

Another object of the invention is to provide a radio transmitter which can be mounted at an isolated point and operated unattended except for controls from a remote point for turning on and off the power and automatically and rapidly controlling the frequency.

Another object of the invention is to provide means for reducing the consumption of power in remotely controlled radio transmitters.

Another object of the invention is to provide interlocking control means between a radio transmitter and a radio receiver so that two-way communication may be carried on without interference in the receiver from the local transmitter.

These and other objects of the invention have

been accomplished by the arrangement to be described in connection with the attached drawings, which, when arranged as shown in Fig. 7, show schematically one embodiment of the invention in a combined radio transmitter and receiver for two-way communication by telephone or telegraph.

Radio transmitter

The mechanical structure of the radio transmitter is of the type disclosed and claimed in the patent of H. D. Wilson, No. 2,077,160, issued April 13, 1937, and comprises five removable chassis located in a vertical arrangement from bottom to top as follows: Oscillator chassis 610, first buffer amplifier chassis 510, second buffer amplifier chassis 520, modulating amplifier chassis 530, and output circuit chassis 540. Each of these five removable chassis is equipped to accommodate as many as ten individual plug-in units which may be selected and adjusted to operate at any carrier frequency within the desired range. The oscillator chassis accommodates up to ten quartz crystal plates 611 and a like number of oscillator coils 612. (In each case only the first and last of the series of ten are shown). The first and second buffer amplifier and modulating amplifier chassis each accommodate up to ten tuning units, 511, 521 and 531, respectively. The output circuit chassis is arranged to provide for ten tuning coils 541.

In addition to these removable chassis the transmitter houses the mechanism which is actuated by the telephone dial 620 to select one of ten elevator rods 605. Each rod actuates a series of bell cranks such as 608 to close switches in the various chassis completing all the necessary circuits for setting up a particular frequency. The first and second buffer amplifier stages are sometimes used to amplify the frequency generated by the crystal oscillator and at other times one or both are used as frequency doublers, depending upon the carrier frequency desired. In this way, for example, crystal frequencies ranging from 2000 to 4525 kilocycles serve to yield a range in output frequency between 2 and 18.1 megacycles.

In addition to the radio transmitter circuit proper there is provided, as shown in the circuits of Figs. 3 and 4, a power supply, voice frequency

amplifier and control circuit. The power supply circuit includes necessary rectifiers for obtaining from an alternating current source all the power voltages including plate and grid bias and filament heating current together with a rectifier for obtaining direct current for the operation of the microphone and all control relays.

Radio frequency circuits

Before going into the details of the operation of the control circuit of the radio transmitter, the operation of the radio frequency circuit of the transmitter will be briefly considered. As indicated above, there is employed in this equipment a crystal oscillator, two successive stages of intermediate power amplification or frequency doubling, a modulating amplifier and a power amplifier. When M. C. W. telegraph or telephone transmission is employed the modulation electromotive force is applied to the plate and screen of the modulating amplifier tube 532 which immediately precedes the final or power amplifier stage employing a three-element amplifier tube 542. For convenience in describing the circuit let it be assumed that the switching equipment has been operated to select the first or A channel so that all of the switches 601—A, 602—A, 501—A, 502—A, 503—A, 504—A, 505—A, 506—A, 507—A and 508—A have been closed. Switch 601—A completes the grid circuit of the oscillator tube 613 while switch 602—A completes the plate circuit for the same tube. The plate circuit of this oscillator is coupled to the grid circuit of the first intermediate power amplifier tube 512 through the coupling condenser 614. The tuning unit 511—A connected in the plate circuit of the tube 512 serves as the complete tuned circuit in the plate circuit of the tube 512. If this stage is to function as an amplifier the circuit 511—A is tuned to the crystal frequency. If the stage is to function as a frequency doubler the circuit will, of course, be tuned to double the crystal frequency.

The output of this stage is coupled to the grid of the tube 522 in the second intermediate power stage through the condenser 513. Connected in the plate circuit of the tube 522 by means of a switch 502—A is the tuned circuit 521—A which functions for this stage in a similar manner to the circuit 511—A of the previous stage.

The output of this stage is coupled to the grid of the modulating-amplifier tube 532 through the coupling condenser 523. Connected in the plate circuit of this tube 532 by means of the switches 503—A and 504—A is a tuned circuit 531—A which, of course, is similar in its frequency characteristics to the circuit 521—A of the previous stage. The switching circuit of the modulating amplifier stage 530 differs from that of the intermediate power amplifier stages in that neither end of the tuning unit 531—A is at ground potential. This is occasioned by the fact that the power amplifier tube 542 is of the three-element variety and requires a neutralizing voltage which is supplied to the lower end of the tuning unit 531—A through the switch 503—A when closed, a neutralizing circuit of the capacity bridge type being used. When both switches 503—A and 504—A are closed excitation is applied to the grid of the power amplifier tube from the junction of condensers 533 and 534. Switch 505—A short-circuits a portion of the resistor 551 and leaves the correct amount of resistance in the plate supply in the modulating amplifier tube 532. The

power amplifier stage has its circuit completed by a tuning coil 541—A which is adjusted to properly tune this circuit when the switches 506—A and 507—A are closed.

Dialing channels B, C, D, etc. likewise serve to select the proper elevator rods which, in a similar manner to that described above, complete the entire tuning to the frequencies associated with these respective channels.

The transmitter is designed to work directly into a 500-ohm load and is equipped with ten independent output terminals which connect to the ten output circuits through the switches 508—A to 508—J. One additional output terminal 599 is common to all channels. This arrangement allows for ten independent 500-ohm transmission lines connected to terminals 581—A to 581—J and leading to ten antennae, or one 500-ohm transmission line common to all channels connected to terminal 599 and terminated in an antenna tuning unit.

In the crystal oscillator chassis 610 is located a self-starting synchronous motor 690 and in parallel with this motor on the left panel are two indicator lamps 691 and 692 which are lighted while the armature of the motor 690 is rotating. 12-volt alternating current is supplied to the oscillator chassis from the connection 694 to the grounded connection 693. This voltage serves to energize the heaters 615—A . . . 615—J for the quartz crystal plate and also to periodically operate the motor 690 and supply power through the rectifier 616 to operate the crystal heater relays 617—A . . . 617—J. As soon as power is supplied to the rectifier circuit by the closing of switch 402, 12-volts alternating current is supplied to the line 694 and the circuit of the motor 690 is initially completed through the upper contact of the crystal heater relay 617 and the commutator 695 associated with motor 690 and the commutator arm rotates to the lower of the two contacts associated with that particular crystal. It thus breaks its own circuit which is not again completed until the heater relay 617 operates. When the relay 617 operates the motor 690 is again started and the commutator arm moved to the first contact associated with the next heater relay where it remains until that crystal has gone through its heater cycle. In this way the indicator lights 691 and 692 function only when each and every crystal heater is properly operating. Should any one crystal fail to operate the motor 690 would stop and the indicator lights would remain permanently off. When the crystals are all properly functioning in their heater cycle the indicator lights periodically blink. Should any one crystal heater fail the indicator mark on the motor driven commutator 695 will show which crystal is at fault. In the event that a crystal is not used in one or more of the stages such stage or stages may have their leads going to the motor armature bridged so that the indicator clears that point immediately.

Operation of control circuits

Power is supplied from the three-phase alternating current mains 401. As soon as the main power supply switch 402 is closed the alternating current bus-bars of the transmitter are energized through the voltage regulating transformer 403 and the transformers 404 and 405 are energized, transformer 404 supplying 12-volt alternating current for heating the quartz plates in the transmitter over the connection 694. Transformer 405 furnishes 48-volt direct current for

relay operation as described later through the rectifier 408 to lead 682.

As the control circuit can probably best be understood by considering the sequence of operation of the relays, let us assume that the channel B is to be dialed, the telephone dial 620 or 680 being operated for this purpose. As the numeral 2 is dialed, the following sequence of events will take place at the dial contacts: First close, first open, second close, second open. The instance of the first close energizes relay 621, the 48-volt circuit for the operation of this relay being completed to ground through the contact 633 of the switch 630 and the contacts of the dial 620. A circuit is simultaneously closed from the 48-volt direct current source through the operating magnet 622 of the selector, thereby stretching its return spring.

The instant of first open releases the selector armature by opening the circuit of the operating magnet 622 so that the armature is then pulled back by the spring causing the brushes of the four contactor groups 641, 642, 643 and 644 to rotate to position 1. Relay 621 remains operated due to its slow release characteristic and nothing else happens.

The next instant is that of second close. When the selector operating magnet 622 and the relay 621 each again simultaneously receive a pulse of energy which pulls the selector operating magnet 622 up (relay 621 is already operated and thus remains unaltered in this position).

The next or second open period follows immediately whence the selector arm moves to position 2 and nothing further happens until relay 621 releases at the end of its slow release period (about one-quarter second). When relay 621 releases 48 volts is supplied through the lower armature of relay 621: (1) through the third selector bank 643 to relay 624 and through lead 425 to relay 413 which is simultaneously operated by current supplied through the rectifier-resistance network 407, and (2) through contact 631 of switch 630 and fourth selector bank 644 to energize the latching relay 603—B (not shown but identical to relay 603—A).

As soon as relay 624 has operated, its holding circuit through the contacts of the time delay relay 625 keeps it energized, and two results follow:

(1) Its lower armature completes a circuit to the elevator rod contactor 604 which is actuated and moves the rod 605—B, due to the operation of the latching relay 603—B, to its up position and also starts the ventilating fan 606 which is connected in parallel with the contactor 604.

(2) Through its upper armature 48-volt direct current circuit to the relay 413 is additionally closed thus forming a holding circuit for the relay 413. This circuit may be traced from lead 425, upper armature relay 624, armature relay 625, lower armature relay 621 to the 48-volt circuit 682.

When the elevator rod contactor 604 is actuated it mechanically operates a switch 630. The operation of the switch 630 results in the following simultaneous events:

(1) The holding circuit to the latching relay 603—A is broken at the contact 631, the armature of the latching relay 603—B being mechanically held in place due to the force exerted on the push rod 605—B.

(2) Arm 632 makes contact with its upper contacts completing a circuit through the selector operating winding 622 through the selector bank

641 so that the selector mechanism automatically notches itself back to its normal position.

(3) Contact arm 633 breaks its connection with its lower contact and makes connection with the upper contact preventing the relay 621 from receiving any pulse as the selector mechanism notches back to its normal position.

(4) Contactor arm 634 makes contact forming an interlock for the high voltage relay 412 as will be described in detail hereinafter. Thus the high voltage relay 412 can not be actuated until after the elevator rod contactor 604 has completed the setting up of one of the radio channels.

The 48-volt direct current supplied over the lead 425 by the operation of the circuits described above energizes the relay 413 through the network 407 as previously described. The operation of this relay 413 causes the operation of the filament heating circuit contactor 411 through the circuit completed from the alternating current bus-bars 490 through the inner contacts of the relay 413 and normally closed contacts of relays 419 and 420. The operation of the contactor 411 causes the simultaneous energization, from the alternating current bus-bars of the transformer 426 (all radio and grid bias rectifier tube filaments), transformer 428 (all high voltage rectifier tube filaments) and transformer 329 (the audio-amplifier tube filaments). The operation of the contactor 411 simultaneously with the energization of the transformer 426 energizes parallel connected winding of the time delay relay 415 which is timed to operate 35 seconds later. When relay 415 operates the bias plate supply transformer 430 for the grid bias rectifier is energized. This circuit may be traced from the alternating current bus-bar 491, lead 481, transmitter gate switches 519, 529, 539, 549 and 552, rectifier gate switch 449, contact and armature of relay 415 to primary of transformer 430 and upper armature of filament contactor 411 to bus-bar 492. This causes 200 volt direct current to be produced by the grid bias rectifier tubes 431 and this appears across the output resistance network 432. This rectified voltage is supplied to the marginal relay 408 and energizes it.

When relay 408 operates, its lower armature completes the circuit to one side of the high voltage contactor 412, provided the switch 439 is closed or provided relay 417 is energized by the operation of the microphone press to talk button 459 as described hereinafter. This circuit may be traced from the connection of the bus-bar 491 at the armature of relay 415, through lower armature of relay 408, switch 439 or lower armature of relay 417 to the lower terminal of the winding of high voltage contactor 412. The upper armature of the relay 408 completes the ground side of the 48-volt direct current circuit through the coil of the relay 414 and operates it.

As a result of the operation of relay 414 the following sequence of events takes place:

(1) Relay 413 is short-circuited through the upper inner armature of relay 414 and drops out.

(2) A holding circuit for relay 414 is completed through the upper outer armature.

(3) A holding circuit of the filament contactor 411 is completed through the lower outer armatures of the relay 414 and lower contact of the contactor 411.

(4) The lower inner armature of the relay 414 completes a circuit to the other side of the high voltage contactor 412. This circuit may be traced from the bus-bar 492, through armatures of re-

lays 419 and 420, lower inner armature of relay 414, lead 482, contact 634 of switch 630 and lead 683 to the upper terminal of the winding of the high voltage contactor 412.

When the high voltage contactor 412 is energized it operates to energize the high voltage transformer 331 which, in turn, completes the necessary high voltage to the plates of the high voltage rectifier tubes 432 and consequently to furnish direct current to the plate of the vacuum tube forming the circuit of the transformer proper. It also provides power to the filament transformer 333 of the voice operated control circuit 300 described later.

The operation just described sets up the circuit for the operation of the transmitter. The other relay circuits will be described later under the headings Automatic control features for push button, and Voice operated control, respectively.

Direct current power supply

The three-phase high voltage rectifiers delivering 2500 volts and 800 volts are employed to furnish direct current power to the plate circuits of the power amplifier and audio-amplifier tubes and to the low power radio frequency tubes respectively. Each high voltage rectifier uses three of the rectifier tubes 332, all of the tubes receiving their alternating current plate voltages from the single three-phase transformer 331. The 2500-volt supply is delivered through the filter circuit comprising the inductance coil 334 and the condenser 335 and the 800-volt supply through the filter comprising the inductance coil 336 and condensers 337. A potentiometer filter circuit consisting of the resistances 338 and condenser 339 serves to furnish approximately 200-volt direct current to the screen grid circuits of the tubes to the first and second buffer amplifier stages and to operate the hang-over relays of the voice frequency control circuit 300, to be described later.

As described earlier, an independent full wave rectifier employing two tubes 421 and delivering a total of 200-volt direct current is used to furnish grid bias to the power amplifier and modulating amplifier tubes through an appropriate filter circuit consisting of the inductance coil 429 and condenser 433. A potential divider 432 supplies 120-volt bias through the filter coil 434 and condenser 435 to the tubes of the buffer amplifier stages.

Speech input and monitoring circuit

Speech or tone input to the audio-amplifier is brought in over the lines 305—306, for example, from the operator's control circuit as will be described in detail hereinafter, or may be obtained from a local telephone set plugged into the jack 409 in which case it will be supplied through the transformer 307 to the connections 305—306. In any event such tone input is supplied to the primary of the transformer 308. When a local telephone set plugged into the jack 409 is used, direct current for the telephone transmitter is supplied from the 48-volt rectifier 406 through the filter 410 and the microphone transformer 307.

A transformer 416 has its primary circuit paralleled by a resistor 418 connected in series in the plate return of the power amplifier tube 542. The secondary winding of this transformer is terminated by the rectifier type voltmeter 421 for indicating the modulation level. The terminals to the secondary of the transformer 416 are also provided for connecting to the op-

erator's set as described hereinafter. For adjusting the modulation level a resistance pad attenuator (not shown) may be inserted in the leads to the primary of the transformer 308.

The audio-frequency amplifier comprises two tubes 309 and 310 connected in tandem. The circuit is so arranged that it receives its high voltage power from the 2500-volt rectifier supplied through the resistor-condenser filter 341. The grids of both tubes are biased by the drop in the plate current flowing through resistances connected in the returns to the cathodes. The tube 309 receives its entire plate and grid supply from the voltage drop across resistor 311 which also furnishes grid bias for the tube 310. The grid bias for tube 309 is supplied from the drop in the cathode return resistance 343.

A relay 312 is provided so that when operated it short-circuits the grid input to tube 310 through its upper armature and thus prevents the carrier from being modulated. This relay is for the purpose of C. W. telegraph control since its use allows for controlling the carrier by the method of keying the tone input without at the same time producing a modulated C. W. signal. The relay 312 may be controlled either locally when the transmitter is on any channel or automatically when a particular channel is dialed as will be described in detail hereinafter.

The output of the tube 310 is supplied through the transformer 342 to the plate and screen grid of the modulating amplifier tube 532 to modulate the radio frequency carrier in that tube.

Voice control circuits

A voice control circuit 300 comprising vacuum tubes 323 and 324 and associated relays and equipment is provided for controlling the operation of the transmitter, particularly for a combined transmitter and receiver circuit, by the voice or tone input. Speech input is supplied to the grid of the first tube 323 through the transformer 325 which has its primary winding connected in the plate circuit of the first audio-amplifier tube 309 in parallel with the primary winding of the interstage transformer 344. The tube 323 is self-biased by the cathode return resistor 326, the plate voltage being supplied from the 200-volt output of the rectifier tubes 431. The plate supply for the second tube 324 is furnished from the plate supply of the associated radio receiver through the connection 327, as will be described in detail in connection with the operation of the circuit.

Control unit 300 functions in the following manner: When the speech or tone supplied to the input terminals 305, 306 reaches a predetermined level, say minus 60 decibels, it then produces a sufficient increase in the plate current of the second stage tube 324 to operate the plate relay 313, plate current being supplied from the "B" battery supply of the radio receiver. When the relay 313 operates two events take place:

1—The grounded armature pulls away from the back contact which is connected through the armature and contact of relay 314 and retard coil 316, relay 607, to the plate supply for the oscillator tube 613.

2—When the grounded armature of the relay 313 touches its front contact, the circuit for the windings of relays 314 and 315 is closed to ground so that these relays are operated. The current flowing from the positive 250-volt terminal of the voltage divider 338 through connection 317, resistances 319, the windings of relays 315 and 314

in series, front contact and armature of relay 313 to ground and the negative pole of the 250-volt circuit.

The relays 314 and 315 are designed to provide "hang-over" in the operation of the voice control circuit. The relay 314 is held up for approximately 150 milliseconds after the armature of relay 313 has returned to its normal position by the discharge of the condenser 320 so that it serves when operated to insure that the oscillator control circuit does not become grounded until some 150 milliseconds after the last passage of speech. Relay 315 is given an additional time delay due to the discharge of condenser 340 to remain operated from 8 to 10 milliseconds after relay 314 has returned to normal and is used to prevent the associated radio receiver from returning to an operate condition before the carrier output of the transmitter has been completely suppressed.

Relay 318 which may be operated either locally or automatically on predetermined dialed channels is for the purpose of modulated C. W. carrier control. Its upper armature functions to disable the hang-over relay 314 by short-circuiting the winding thereof and thus allows the transmitter to produce a modulated C. W. signal by the method of keying the tone input.

Key clicks are eliminated by the use of the retard coil 316 placed in series with the oscillator control circuit thus preventing the carrier from dropping or bumping to zero when relay 314 returns to its normal position.

Automatic control features for push-button control of carrier

Two time delay relays 422 and 625 are provided by means of which full automatic operation of the transmitter may be secured. These relays are controlled by two switches 423 and 626. Switch 423 is known as the automatic filament release switch and 626 as the automatic high voltage release switch.

Switch 423 is in series with the winding of the relay 422 so that in the open position of the switch relay 422 cannot be energized. Switch 626 parallels the contacts of relay 625 so that even though this relay were operated no effect would result as long as switch 626 remained closed. For full automatic operation of the transformer therefore switch 626 is normally open and switch 423 is normally closed. Both time delay relays 422 and 625 may be timed to operate in a period such as 1 to 15 minutes.

When the transmitting equipment is arranged for push-button operation, it performs two operations. First, the outer armature, with the switch 439 open, is in series with the winding of the high voltage contactor 412 so that this contactor will only be closed when the relay 417 is operated by depressing the key 450. In other words for push-button control the key 450 controls the entire plate supply to the transmitter and hence the carrier output. Second, it will be observed that relay 417 in its normal unoperated condition, through its inner armature, allows the 48-volt direct current supply to be applied to the coil of the time delay relay 625 through connection 424, inner armature of relay 417, and connection 436. This would result in the operation of the relay 625 in from 1 to 15 minutes depending upon its adjustment after a channel has been dialed.

When relay 625 operates (switch 626 being in the open position) the opening of the contacts

of relay 625 opens the holding circuit to the relay 624 which results in two events:

1—Elevator contact 604 drops down, releasing the channel which had been dialed.

2—The return 48-volt circuit through connection 425 is broken and as the result relay 414 is deenergized and therefore dropped out. The holding circuit to the filament contactor 411 is still energized, however, through the back contact of relay 413 so that the filaments of all the tubes in both units still remain heated.

Summing up then, the action of relay 625 can serve only to drop down the channel which has been dialed in the transmitter and disrupt the 48-volt return circuit to the rectifier controls. It is important to note that in the normal operation of the equipment relay 422 receives its energy simultaneously with the application of energy to relay 625 and at the time when both relays receive their initial impulses starts from the last release operation of the push-button which breaks the circuit to the coil of the high voltage contactor 412.

The time delay relay 422 is energized through the normally closed back contact to the normally closed contact of the lower armature of the high voltage contactor 412. At the end of this 1 to 15 minute period relay 422 operates and in closing puts a pulse of current from the 48-volt source through the connection 437 to the winding of the overload relay 419, thus opening the circuit to the coil of the filament contactor 411 which immediately removes all filament voltage. As soon as the filament contactor 411 has dropped out, the alternating current circuit actuating the relay 422 is deenergized. Thus the momentary circuit made to the overload relay 419 is broken and relay 419 returns to its normal (closed) position, and providing relay 625 has previously operated, the transmitting equipment is back to the condition it originally was when only the main power supply switch 402 was closed.

It is important to note here that it is immaterial whether the relay 422 operates prior or subsequent to the relay 625. Each performs its function independently of the other. This is not true as will be evidenced in the later description, in the event that the use of the voice frequency control unit 300 is substituted for the push-button control. (In this latter event relay 422 must of necessity operate subsequent to relay 625.)

Returning to the case in point, namely the push-button operation, it is seen that the total elapsed time over which use may be made of these automatic shut-down features is confined to a time not exceeding fifteen minutes (with relays of the character described). Should it be desired to have the high voltage removed from the tubes of the transmitting equipment but have the filaments remain heated, it is necessary only to throw switch 423 to the open position in which case it would be necessary either to manually close the switch 423 and wait the delay period of the relay 422 or to momentarily open the main power supply switch 402.

Automatic control features for voice operated control of carrier

When voice control of the carrier is employed through the use of the control unit 300 switch 439 is closed and switch 438 is opened. Closing switch 439 by-passes the particular function of the relay 417 which for push-button control use exercises the final control of the high voltage

contactor 412. Opening switch 438 prevents the time delay relay 625 from being energized other than by the action of the relay 607.

Assuming as before that both switches 626 and 423 have been set for automatic operation, that is, 626 open and 423 closed, and that a number has been dialed to set up a radio frequency channel. Immediately that the high voltage has been applied to the radio tubes of the transmitting apparatus, current will flow from the 800-volt supply at the terminal of filter coil 336 through the oscillator plate resistor 617, relay 607, back to ground through the choke 316 and the armatures of relays 314 and 313. This current will operate relay 607 at once and cause the time delay relay 625 to be energized from the 48-volt supply lead 682. After the predetermined time of operation of the time delay relay 625, it will operate as earlier described, to drop down the channel and since the release of the channel opens the interlocks at contact 634 to the high voltage contactor 412, this contactor will be released. As soon as the high voltage contactor 412 drops out, the circuit will be completed through its lower armature to energize the relay 422 which will operate after its predetermined time has elapsed and as described in the section immediately preceding, will operate on the filament contactor 411 to remove all power from the transmitting equipment except the crystal heater circuit and the 48-volt rectifier supply.

Incoming speech, subsequent to dialing and having high voltage applied to the transmitting equipment, removes the ground return at the armature of the relay 313 and since no current flows in this circuit, relay 607 is released which in turn deenergizes the time delay relay 625 returning its timing mechanism to the initial position. Thus, the operation of the time delay relay 625 commences at the cessation of incoming speech or tone or from the last starting operation in the absence of an incoming signal.

It is important to note in this connection that the start of the time delay relay 422 commences from the operation of the time delay relay 625, rather than from the start of that relay as was the case with push-button control as described in the previous section.

Auxiliary control feature

The relay 312 associated with the audio-amplifier may be actuated by connecting the bus 635 to one or more of the ten points on the bank 642 of the selector. This relay is provided only for the purpose of converting the radio transmitter into a C. W. telegraph transmitter and is used only in conjunction with the control unit 300 as will be described hereinafter in the section entitled, C. W. and M. C. W. telegraph operation.

Similarly, the bus 636 when connected to appropriate terminals on the bank 642 of the selector actuates the relay 318 and is used to convert the radio transmitter into a M. C. W. telegraph transmitter. This connection also is used only in conjunction with the use of the control unit 300 and its operation will be described in detail in the section entitled, C. W. and M. C. W. telegraph operation.

Protective circuit

Protective gate switches are applied on the apparatus to insure that the operating personnel is adequately protected against coming in accidental contact with high voltage. For this

purpose there is provided a gate switch 552 on the door to the transmitting equipment and switches 548, 539, 529 and 519 which are opened when any of the respective chassis 540, 530, 520 or 510 are removed from their cradles. Similarly, gate switches 440 are associated with the rectifier assembly. All of these gate switches are connected in series in circuit from the armature and contact of relay 415 through which the grid bias rectifier transformer 430 is energized.

Two self-restoring overload relays 419 and 420 are provided to protect the vacuum tube against accidental overload. These relays are located in the return circuits of the 800-volt and 2500-volt power supplies, respectively, and when energized by amounts of current appreciably in excess of that required for normal operation of the transmitting equipment, operate to disable all supply circuits with the exception of the crystal heater and 48-volt direct current supply.

Switching mechanism

The switching mechanism as shown and described in detail in the copending application of H. D. Wilson, hereinbefore referred to, consists, in brief, of ten rods 605—A to 605—J running the vertical length of the transmitter. Cranks, such as 608—A, for example, one for each chassis switch, are located on horizontal cross shafts mounted normal to the elevator rod. A mechanism to operate the elevator rods is located at their lower ends.

This mechanism includes the shaft 650 mounted in self-aligning bearings. One end of this shaft passes through an adjusting block to the armature of the large alternating current operated solenoid 604. Mounted on the shaft 650 are a series of clutch collars 651—A to 651—J and associated lifting arms 652—A to 652—J. The clutch collars are pinned to the shaft 650 by taper pins while the lifting arms 652 are free to both slide and rotate on the shaft. Associated with the clutches are small latching relays 603—A and 603—J for actuating the clutches to engage the lifting arms.

The operation of the switching mechanism is briefly as follows: When the arm of the selector switch comes to rest momentarily on one of the off-normal contacts the voltage supplied to one of the small latching relays 603 causes the armature of the relay to close and draw with it its lifting arm, which slides along the shaft to engage the clutch collar. At the same instant that voltage is supplied to the latching relay 603, voltage is also supplied to relay 624 which picks up and in turn closes the 250-volt circuit to the large solenoid elevator contactor 604. The elevator contactor 604 now closes and in doing so rotates the shaft 650 with the clutch collar and the one lifting arm which has been previously engaged. The other nine lifting arms merely allow the shaft to rotate within them and remain in their non-operated positions.

The outer end of the lifting rod 652 which has been engaged to rotate with the shaft comes to bear on the lower end of its elevator rod 606 and in turn pushes it upward. The elevator rod 606 transmits its upward motion by means of the bell cranks, such as 608, to an axial thrust in line with the chassis switches such as 601.

At the same time that this is happening the switch arms of the switch 630 have been changed from their normal to their closed position by means of the lever arm mechanism 653. As hereinbefore described in more detail, this switch

performs several functions, one of which is to remove the voltage from the latching relay 603 by breaking the circuit at contact 631. These relays are designed for intermittent purpose only and their sole function is to engage the lifting arm with its clutch, the two being firmly held together by the frictional load when the elevator rod 605 is raised.

If another channel is dialed the circuit to the large solenoid 604 is broken on the first pulse of the dial and the armature of the solenoid falls back to the open position aided by a return spring (not shown) and the load of the operated elevator rod 605. This allows the lifting arm 652 to disengage from its clutch as soon as the elevator rod has reached its bottom stop at which point the return spring 654 on the armature of the latching relay draws the lifting arm along the shaft away from the clutch. The whole mechanism now having returned to its unoperated position is ready, as before, to set up another channel at the end of the slow-release period of relay 624.

Automatic C. W. or M. C. W. telegraph operation

When control unit 300 is employed the transmitting equipment may be made to function as a C. W. or a M. C. W. telegraph transmitter by operating either relay 312 or relay 318, respectively, and keying the tone input through the key 278 at the operator's control position as will be described in detail hereinafter. The relays may be operated by the control switch 203 at the operator's position, or may be operated automatically when predetermined numbers are dialed. In this latter case switch 475 must be closed and the buses 635 and 636 are connected to the proper terminals of the selector contactor 642. As illustrated contact 1 is connected to bus 635 and contact 3 to bus 636. Thus, when 1 is dialed, the set will operate for C. W. telegraph and when 3 is dialed, for M. C. W. telegraph. Switch 475 is closed only for operation of the telegraph features by dial control. When these features are controlled by the operator's switch 203, the switch 475 is kept open as illustrated.

When 1 is dialed the set will be conditioned for C. W. telegraph operation by the automatic operation of relay 312 through the closing of its operating circuit by the contacts on the selector bank 642. When the selector bank 642 returns to its normal position, relay 312 is maintained operated through a holding circuit from lead 428 through switch 475 and inner lower armature of relay 312. Thus, keyed tone input in this case will merely result in the starting and stopping of the unmodulated carrier in accordance with the key impulses.

In a similar manner when 3 is dialed, connection will be made through the selector bank 642 which will result in automatic operation of the relay 318, which also has a holding circuit through its lower armature similar to relay 312. Thus keyed tone input in this case will merely result in starting and stopping of the modulated carrier in accordance with the keyed impulses.

A more detailed description of the keying operation will be found under the title Radio telegraph communication in the following section on two-way operation.

Two-way operation

The complete system for two-way operation consists in addition to the radio transmitter and its control circuit just described, a radio re-

ceiver 100 and an operator's control unit 200 which are interconnected with the transmitter to permit two-way radio telephone or telegraph communication. As will be described in detail in the following sections, such operation is facilitated by interlocking controls between the receiver and the transmitter.

The radio receiver 100 which is shown in block diagram, only the parts essential to the interlocking control feature being shown in detail, is of the typical superheterodyne type employing an initial selector circuit 102 connected between the antenna 101 and the radio frequency amplifier 105. The output of the amplifier 105 is supplied through another selective circuit (not shown) to the high frequency detector or modulator 103, the latter being supplied with beating waves from an oscillator 104 for combining with the received waves to produce intermediate frequency waves which are selectively amplified in an intermediate frequency amplifier 106. The output of this amplifier is supplied to the input of the detector 107 which operates not only to detect the intermediate frequency waves to produce audio-frequency waves which are amplified in the audio-frequency amplifier 108, but also to rectify the intermediate frequency carrier to supply the automatic volume control circuit 113 of the conventional type. For the reception of continuous wave telegraph signals there may be provided a heterodyne oscillator and detector (not shown). For a more detailed description of a radio receiver of this type reference is made to the copending application of H. T. Budenbom, Serial No. 676,135, filed June 16, 1933.

While grid bias supply and plate supply are indicated as furnished by batteries 112 and 110 for simplification in illustration it is understood that such power supply would normally be derived from rectified alternating current in a well-known manner.

Associated with the radio receiver is a control circuit 120 which may be conditioned by the operation of the key 121 for operation for either Codan (carrier operated device anti-noise) control or Vodas (voice operated device anti-singing) control. In the case of both types of operation the control circuit 120 operates to block the output of the radio receiver to the connected telephone station at all times except when there is an incoming signal to the radio receiver as will be described in detail hereinafter. This control circuit also operates to prevent the use of the radio transmitter when a signal is being received and also, in effect, to disconnect the radio transmitter monitoring circuit from an extension telephone circuit when transmission is being carried on. In so doing it prevents feedback from the radio transmitter monitoring circuit to the speech input circuit by way of a two-conductor extension telephone line but allows the operator's telephone receiver to be connected at the same time to both the radio transmitter monitoring circuit and the radio receiver output circuit in order to permit monitoring in both directions of a radio telephone circuit.

The control of the radio receiver 100 to disable it for the reception of radio signals is accomplished by means of relays 109, 110 and 111. When operated, relay 109 grounds the antenna 101 through its front contact and opens the ground circuit for the grid of the tube of the oscillator 104 at its back contact thereby supplying negative blocking voltage to the grids from the battery 112. The operation of relay 110 opens

the connection through its back contact to the grids of the tubes of the radio frequency amplifier 105 and modulator 103 through the automatic volume control circuit 113 and instead closes a connection for the grids of those tubes to the battery 112 to block the tubes. The operation of relay 111 opens the connection to the coils of the Silent coil group 114 so that they act in series opposition preventing transmission therethrough. This transmission control is of the type disclosed and claimed in Silent Patent 1,749,851, March 11, 1930. Operated relay 111 opens the contacts and so arranges the connections between the interconnected windings of the transformers of the group 114 that these windings are mutually opposed. Thus, no transfer of energy between the circuits connected through the other windings of the transformers of the group 114 may be effected. Consequently, passage of audio-frequency current from detector 107 to the audio-frequency amplifier 108 is prevented.

A second Silent coil group 211 is employed in the operator's control equipment to permit the operator to monitor simultaneously both sides of a radio telephone conversation of a two-wire telephone extension circuit. This coil group 211 also serves as an added precaution against objectionable clicks and other circuit noise incidental to the operation of control relays which might otherwise reach the subscriber's telephone receiver. The control of this coil group is effected by the relay 122 of control circuit 120. The operation of the relays which control the two Silent coil groups 111 and 211 is so timed that the audio-frequency circuits are always disabled when other control relays are being operated.

Radio receiver control circuit 120

The control circuit 120 provides voice or carrier operated control of the radio receiver output circuit when it is interlocked with the voice operated control of the radio transmitter control circuit 300 in such a manner that operation of the radio receiver control relay 122 will prevent operation of the radio transmitter, as will be described in detail hereinafter.

Vacuum tube 123 is of the dual function type and comprises a full wave rectifier employing the anodes 124 and a three-element section comprising the grid 125 and anode 126, both sections having a common cathode 127. Space current for the amplifier section is supplied from a direct current supply such as battery 128 through a Wheatstone bridge circuit having as three arms thereof the resistors 129, 130 and 131 and as the fourth arm the cathode-anode path 127-126. The operating winding 134 of the relay 122 is connected across one diagonal of the bridge.

Two potentiometers 132 and 133 are provided for controlling the balance of the bridge, one potentiometer being for Codan operation and the other for Vodas operation. The conditioning of the circuit for either type of operation is controlled by the operation of key 121. When this key is in the left-hand position as shown the circuit is conditioned for Vodas operation.

In this condition, in the absence of a received signal in the radio receiver 100, the potentiometer 133 is adjusted to vary the bias on the grid 125 of the tube 123 until the bridge is balanced and no current flows through the winding 134 of relay 122. Under such conditions the relay 122 will be held in its normal position by the current in

the polarizing winding 139 which current is the normal space current of the tube 324 of the control unit 300 supplied from the battery 140; i. e., the plate current in the absence of a speech or tone input to the control unit 300. When a speech modulated carrier is received in the receiver 100 the speech output current is supplied through the lead 136 and transformer 137 to the full wave rectifier comprising the anode 124, cathode 127 and tube 123. The voltage produced across the resistance 138 by the rectified voice currents is impressed on the grid 125 of tube 123. The effect of this voltage will be to unbalance the bridge and cause current to flow through the winding 134 of the relay 122 to oppose the action of the polarizing winding 139. When the current through the winding 134 becomes sufficient to produce a flux greater than that produced in the relay by the polarizing winding 122, through which the normal (non-operating) space current of the amplifier tube 324 of the control circuit 300 is flowing, the relay armature will transfer from the left-hand contact to the right-hand contact.

In the operation of the control circuit 120 for the Vodas type of operation sufficient hang-over for the control relay 122 to prevent disabling of the Silent coil group between words of speech is provided by means of the condenser 142 which is charged by incoming speech to the potential developed across the rectifier load resistance 138. The condensers discharge slowly through the resistor 138 upon completion of a passage of speech to maintain the radio receiver control relay 122 in operated condition for say approximately 150 milliseconds after the last passage of speech.

This operation of the relay 122 performs two functions which are: (1) When the armature leaves its normal (left-hand) contact it breaks the circuit from the high voltage supply 140 of the radio receiver 100 through the receiver disabling relays 111, 110 and 109 and the control relay 313 of the control unit 300 to the tube 324. In this manner the radio transmitter is completely disabled until the bridge circuit regains its normal condition when the incoming signals cease; (2) when the armature of the relay 122 reaches its operated contact it connects together the four inner ends of the windings of the transformers of the Silent coil group 211. With the transformer windings so connected the audio-frequency output from the radio receiver may pass through the coil group 211 to the operator's control circuit 200.

When the relay 122 is in its normal condition the space current of the tube 324 passes through the polarizing winding 139. When voice currents are impressed on the transmitter circuit and also during the hang-over time for the transmitter control circuit 300, in the latter case through the operation of the relay 315, current through the winding 139 will be sufficient to hold the relay in its normal position so that the current produced in the winding 134 by the action of the voice output of the receiver will be insufficient to operate the relay. After voice currents in the transmitter ceases, the space current of the tube 324 falls, and consequently the polarizing current through the winding 139, to a comparatively small value so that the relay may be operated by the action of the currents in the winding 134.

The hang-over operation produced by relay 315 is such that the circuit 327 will be closed to ground through the armature of relay 315 and resistance 389 for 8 to 10 milliseconds after relays

313 and 314 release. This maintains the receiver control relays 109, 110 and 111 operated and relay 122 polarized to disable the receiver during this period.

For Codan operation of the radio receiver control circuit 120 the negative bias supplied to the grid 125 to cause the operation of the relay 122 with an incoming carrier, is obtained from the load circuit of the detector 107 through the lead 141. This negative voltage is supplied to the grid 125 through the middle contact of the switch 121 when in its right-hand position. In this position of the key 121 the grid 125 is initially biased by the voltage across the potentiometer 132. By the adjustment of this potentiometer the normal grid bias can be adjusted to a point where no current flows through the winding 134 of the control relay when no carrier is received by the radio receiver. In a sense this gives the relay 122 the power to discriminate between noise and a desired carrier signal.

For Codan operation no hang-over of the relay 122 is provided such as is provided for the Vodas operation by the action of the condenser 122 connected in parallel with resistance 138 as it is assumed that the radio transmitter from which the intermittent carrier receiver is equipped with suitable circuits to produce a carrier hang-over similar to that provided by the hang-over feature of the control circuit 300.

Operator's control circuit 200

The operator's control circuit comprises two alternative methods of connection, one with the control unit 240 connected as shown in the drawings, for connection to a four-wire extension or telephone subscriber's line 233—234, and the other with the control circuit 250 substituted for the circuit 240 for connection to a two-wire extension or telephone subscriber's line 266. These two types of operation will be separately described later.

The dial 680 (Fig. 6) really comprises part of the operator's control unit 200 so that the operator may select the desired radio frequency channel in the transmitter by the operation of the dial 680. The operation of this dial controls the selection mechanism in the same manner as the operation of the dial 620 previously described.

48-volt direct current from the rectifier 406 of the transmitter is supplied to the operator's control circuit 200 over two separate circuits. Filtered 48-volt direct current for the operation of the microphone circuit is supplied over connection 201. Unfiltered 48-volt for the operation of the tone generator supervisory lamp and certain of the relays is supplied over the connection 202. The purpose of this division of the 48-volt circuit is to permit the use of the highly effective filter 410 for the relatively small current supplied to the speech circuit.

Relay 203 is permanently connected directly to the unfiltered 48-volt supply circuit 202 and is therefore in an operated condition whenever the switch 402 is closed to connect the rectifier circuit to the main power source. In the operated condition of the relay 303 the 48-volt circuits in the control unit are connected through the relay armatures to the 48-volt circuits of the transmitter rectifier, the unfiltered supply 202 being connected through the left-hand armature and its front contact and the filtered supply 201 being connected through the right-hand armature and its front contact. In the unoperated condition of the relay 203, that is when the trans-

mitter-rectifier circuit is not operated, the 48-volt circuits of the control unit are connected to an emergency supply battery 204 which may be a battery as indicated, or a portion of a rectified supply for the receiver 100. Thus, whenever the transmitter-rectifier is not connected to the main power source as may be the case during long periods between the use of the radio equipment, operating voltage from the battery 304 is available for supervision of the extension telephone circuits and for interphone communication between the operator's position and any of the telephone extensions.

Radio telephone communication from operator's position

After the desired radio frequency channel has been dialed, radio communication may be carried on from the operator's position and from the extension telephone in the following manner: When the operator's key 220 is thrown to the "up" or "radio" position, the operator may use his telephone set comprising the telephone transmitter or microphone 206 and the telephone receiver 207 for the transmission and reception of radio telephone signals. The operation of the key 220 arranges the circuit for such use as follows:

1. One side of the operator's microphone 206 is connected through the contact 221 to ground. The other side of the microphone is permanently connected to the low impedance winding of the microphone transformer 205 and through the microphone choke coil 208 to the filtered 48-volt supply.

2. Both sides of the high impedance winding of the microphone transformer 205 are connected through the key arms 222 and 223 to the transmitter volume control attenuator 209 which is used to regulate the speech level supplied to the input circuit of the radio transmitter through the leads 210 connected to the primary winding of the transformer 208.

3. The operator's telephone receiver 207 which is connected to the armatures 213 and 214 of the relay 212 is connected through the back contacts of these armatures, resistors 215 and 216, lower arms of the key 220 to the input side of Silent coil group 211.

With the circuits arranged as just described, voice frequency currents in the high impedance winding of the microphone transformer 205 are applied to the speech input circuit of the transmitter and will cause operation of the voice operated carrier control circuit 300 in the transmitter-receiver interlock circuit.

When speech is impressed upon the radio transmitter a side tone signal is furnished to the operator's telephone receiver 206. The side tone is developed in the radio transmitter volume indicator circuit as described in a later section with the subtitle "Monitoring". The volume indicator circuit 217 from the output of the monitoring transformer 416 is connected to the radio receiver output circuit through the three-way impedance matching pads 218 and 219.

When no speech is impressed upon the radio transmitter an incoming signal to the radio receiver will reach the operator's telephone receiver through the pads 218 and 219.

Four-wire telephone extension

The operator's control unit 200 permits extension of the radio circuits to four-wire subscribers' extension telephones through units of the

type 240. While only one of these units is shown in the drawings, it is obvious that additional units with their corresponding keys like 241, may be similarly connected to permit selective connection of the radio system to any of a group of four-wire extension telephones.

With the extension key 241 thrown to the upper or "operator" position and the operator's key 220 in the neutral or "monitor" position, circuits between the subscriber's extension and the operator's telephone set are completed as follows:

1. The 48-volt circuit through the winding of relay 212 is completed to ground through the contact 224 of key 220, contact 242 of key 241 causing the relay 212 to operate. In the operated condition relay 212 completes to ground the 48-volt circuit for the operator's microphone through its inner right-hand armature, and transfers the operator's telephone receiver from the radio receiver output circuit to one side of the two-way path 230 through its armatures 213 and 214. The other side of the path 230 is connected to the output winding of the microphone transformer 205 and furnishes a side tone to the operator.

2. The output of the path 230 is also connected to the resistors 231 and 232 and contacts 243 and 244 of the key 241 to the subscriber's telephone receiver circuit 233 thus completing the talking circuit from the operator to the subscriber.

3. When the subscriber's extension telephone (not shown) is removed from its switch-hook the leads 234 are connected together through the extension microphone element and the primary winding of the extension telephone induction coil. Current from the filtered 48-volt source will then flow from lead 238 through winding 236 of relay 235 through the microphone of the subscriber's set returning to ground through the winding 237 of relay 235. Speech impressed upon the subscriber's microphone superimposes an alternating current upon the direct microphone current and speech voltages appear across the windings of relay 235. The subscriber's microphone circuit 234 will also be connected through the upper arms of the key 241, blocking condensers 261 and 262, through the resistors 231 and 232 and to the output side of the pad 230 and consequently through the front contacts and armatures 213 and 214 of relay 212 in the operator's receiver 207. The resistors 231 and 232 furnish a connection between the subscriber's talking circuit 234 and the subscriber's listening circuit 233 thus furnishing side tone to the subscriber.

The circuit just described completes the connection for two-way interphone connection between the subscriber and the operator.

The operator permits the subscriber to communicate over the radio circuit from the four-wire extension telephone connected to the circuits 233 and 234 by throwing the extension key 241 to the lower or "radio" position. In this position of the key the following circuit arrangement results:

1. The 48-volt circuit through the winding of relay 212 to ground is broken at the arm 242 of key 241 allowing the operator's telephone receiver to be reconnected to the radio receiver output circuit through the normally closed contacts of the operator's key 220, that is, with the key 220 in the neutral position.

The output of the radio receiver after passing through the Silent coil group 211 is connected through the arms 247 and 248 of the key 241 to the subscriber's telephone receiver circuit 233.

The speech circuits from the subscriber's telephone transmitter circuit 234 are applied through the arm 249 of the key 241 and the blocking condensers 263 and 264 to the transmitter volume attenuator 209 and thence to the speech input circuit of the radio transmitter.

For supervision of the four-wire telephone extension the key 241 is in its neutral position. When the subscriber's telephone set is removed from the switch-hook a direct current path is provided between the leads 234, as previously described. Current may then flow from the filtered 48-volt source to the subscriber's microphone circuit and through the windings of the supervisory relay 235 causing the relay 235 to operate. When the relay 235 operates, the grounded armature provides a path for current from the 48-volt circuit from ground, armature of relay 235, contacts 245 and 246 of the key 241 in its neutral position, supervisory lamp 265 to the positive 48-volt terminal, causing the lamp 265 to light indicating that the subscriber is calling.

When the operator answers the incoming call by throwing the key 241 to the upper position the indicator lamp circuit will be broken for as long as the key is in either upper or lower position and the extension set remains off the switch-hook. When the extension set is replaced on the switch-hook after completion of the call, the 48-volt circuit through the relay 35 is broken and the relay armature is released falling against its back contact. If the key 241 is then in the lower or "radio" position the armature of relay 235 will again supply ground to the indicator lamp indicating to the operator that the radio call has been completed.

Two-wire telephone extension

For operating the radio system with a subscriber's two-wire extension telephone circuit such as the usual commercial type telephone system, the unit 250 is substituted for the unit 240, the connections being made to the letter terminals as indicated. In this system the conventional commercial type of two-wire subscriber's telephone set (not shown) terminates in the line 266. With this circuit the operation of the key 252 permits interphone communication between the operator and subscriber and also radio telephone communication from the remote subscribers' stations.

With the operator's key 220 in the neutral position the operator may answer an incoming call from the two-wire extension by throwing the extension key 252 to the upper position arranging the circuit for interphone communication as follows:

1. Ground is connected to the winding of relay 212 through the arm 224 of switch 220, terminal H, upper right-hand arm of key 252 to ground, the operator being furnished a side tone and speech from his microphone appearing at the terminals D and G in a similar manner as in connection with the four-wire circuit.

2. The speech circuit terminating in the terminals D and G is connected through the contacts 253 of key 252 to the arms 267 and 268 of the three-way impedance matching pads allowing the operator's speech currents to go over the line 266 to the subscriber's set.

3. Additional contacts on the key 252 connect the retard coil 269 between the same terminals of the resistors 267 and 268 providing a low resistance path for direct current across the line 266. This direct current path is to complete supervisory circuits in commercial or private branch

exchange telephone office equipment to which the line 266 may be connected.

4. Speech currents originating in the subscriber's set and coming over the line 266 flow through the resistor arms 271 and 272 of the three-way pads and through closed contacts 254 of the key 252 to the terminals E and F and thence through the blocking condensers 262 and 261 to the operator's telephone receiver in the same manner as for the four-wire extension circuit. In this circuit no side tone connection for the subscriber is required in the operator's control circuit as such side tone circuit is furnished by the circuit of the subscriber's telephone set itself.

15 The two-wire telephone extension may be connected to the radio equipment by closing the key 252 to its lower or "radio" position. In that position of the key the extension subscriber's circuit is completed for radio telephone communication in the following manner:

1. The two lower left-hand closed contacts of the key 252 connect the extension line 266 through the resistors 271 and 272 of the three-way pad to the terminals A and B and thence through the blocking condensers 263 and 264 to the speech input to the radio transmitter.

2. The output of the radio receiver after passing through the Silent coil group 230 terminates in the terminals J and K and is then connected through the two lower right-hand closed contacts of the key 252, resistors 267 and 268 of the three-way pad to the subscriber's extension line 266. Incoming signals to the radio receiver may therefore go over the two-wire line 266 to the subscriber.

3. The resistors 267 and 268 of the three-way pad are also connected through contacts of the key 252 to induction coil 269 thus providing a direct current path between the conductors of the extension line 266 for holding up supervisory relays in an associated telephone exchange equipment.

For supervision of two-wire telephone extension the key 252 will be in the neutral position. The two-wire extension supervisory relay 271 is caused to operate in response to ringing current supplied to its winding 272 over the line 266 from the terminating subscriber's set or central office equipment. A second winding 273 on this relay is connected permanently through the +43-volt circuit of the operator's control equipment at the terminal I and to the relay front or holding contact. The armature of the relay 271 is connected to ground through a series connection including one pair of contacts on each side of the key 252. Thus, when a ringing current is supplied over the line 266, the relay 271 will be operated and locked up through its holding circuit in the operated position by the current from the 48-volt source through the holding winding 273 for as long a time as the key 252 remains in the neutral position.

The front contact of the relay 271 is also connected to the supervisory lamp 275 so that when the relay 271 is operated a circuit from the 43-volt supply at terminal I is provided through the lamp 275.

When the incoming call is answered by closing the key 252 to its upper or "operator" position, the ground return circuit from the supervisory relay holding winding is opened allowing the relay armature to fall back. At the same time ground is also removed from the indicator lamp 275 extinguishing the lamp.

75 No provision is made in the control unit where-

by the two-wire extension supervisory relay 271 will again operate upon completion of a call. However, the operator will know when a radio call has been completed by monitoring on the radio circuit.

Monitoring

With the operator's key 220 in the neutral or "monitor" position, the operator may listen for incoming calls in the output of the radio receiver. In this condition the operator's telephone receiver is also connected to the volume indicator circuit of the radio transmitter through the connection 217 permitting the operator to monitor speech both to and from a subscriber.

In the neutral position of the operator's key 220, the operator's telephone receiver is connected through closed contacts on the key and through back contacts on relay 212 to the input side of the Silent coil group 211. The input side of this coil group 211 connects both to the audio-frequency output circuit of the radio receiver 100 and to the radio transmitter monitoring circuit through the three-way pads 218 and 219. In this manner the operator may hear both sides of the radio conversation when the radio equipment is connected to a subscriber. When speech from a subscriber is impressed upon the radio transmitter, the Silent coil group 211 being disabled through the action of the control relay 122, the subscriber's speech in the monitoring circuit is prevented from getting back to the subscriber by the Silent coil group 211.

With the operator's key in the lower position the operator is permitted to hear the received signal exactly as it is heard by the subscriber. In this position of the key the operator's telephone receiver is transferred to the output side of the Silent coil group 211 enabling him to detect and correct any false operation of the radio receiver control relay 122.

Volume indicator

The volume indicator meter 274 may be used to indicate the speech or tone levels both into the radio transmitter and out of the radio receiver. With the volume indicator key 276 in the lower position, as shown in the drawings, the indicator is connected to the line 217 which connects the secondary of the monitoring transformer 416 of the transmitter, the primary winding of this transformer being connected in the plate return circuit of the radio transmitter power amplifier tube as previously described. The nature of the circuit is such that the potential across the volume indicator meter 274 is a function of the speech or tone components of the power amplifier plate current.

With the volume indicator key 276 in the upper position, the volume indicator meter 274 is connected directly across the output of the radio receiver 100. In that position of the key 276 the operator may adjust the level of the received speech always to the same predetermined level most satisfactory to the subscriber.

The potentiometer 277 is provided for regulating the sensitivity of the voice operated radio transmitter control unit 300 when the sensitivity control switch 361 is in the left-hand position. The purpose of this potentiometer 277 is to select the maximum permissible sensitivity of the radio transmitter voice operated control unit under varying conditions of room noise, speaker's voice level and line noises of any nature.

The transmitter sensitivity potentiometer 277

regulates the bias potential applied to the grid of the second amplifier tube 324 thereby controlling the magnitude of the plate current supplied to that tube through the operating winding on the transmitter carrier control relay 313.

Radio telegraph communication

The system may be used for radio telegraph transmission by supplying a tone to the radio transmitter speech input circuit by the operation of the telegraph key 278. The oscillator 280 which will supply a tone say of approximately 800 cycles for transmission of telegraph signals in the following manner:

The tube 281 of the oscillator receives filament heating current and plate supply from the unfiltered 48-volt circuit when the tone control key 282 is closed. With the oscillator made ready for use by closing the key 282 the operator may condition the circuit for either M. C. W. or C. W. transmission by closing the key 283 to either the upper or lower position, respectively. Thus, the key 282 may remain closed to energize the tube 281 during the radio telephone transmission period without interfering with the transmission of telephone signals provided the key 283 is in the neutral position.

With key 283 in the upper or M. C. W. position one terminal of the output winding 284 of the oscillator transformer is connected through the left-hand contact of the key 283 to the telegraph key 278 and the other side of the winding 284 is connected through the right-hand contact of key 283 to the other side of the input circuit 210 to the radio transmitter. At the same time +48-volt battery is applied through the right-hand contact of key 283, connection 285 through the winding of the relay 318 of the control unit 300. Relay 318 is therefore operated for as long a time as the key 283 is in the upper or M. C. W. position and its upper armature short-circuits the winding of relay 314 which if allowed to operate would hold open the ground circuit to the plate of the radio frequency oscillator tube 613 and maintain the oscillator in operated condition between tone impulses to the speech input circuit. With the transmitter hang-over thus removed, that is, by the shorting of the winding of the relay 314, tone may be supplied to the speech input circuit of the transmitter by pressing the telegraph key 278 to cause the carrier control relay 313 to operate each time the key is pressed and falling back to the unoperated condition each time the key is released. The impressed tone pulses are allowed to pass through the audio-amplifier comprising the tubes 309 and 310 and thus to modulate the interrupted carrier wave.

With the key 283 thrown to the lower or C. W. position the circuit is conditioned for the transmission of C. W. telegraph signals. Tone is again supplied through the telegraph key 278 to the radio transmission speech input circuit when the telegraph key is pressed. In this position, however, the key 283 connects +48 volts through the connection 286 to the ungrounded side of the winding of the relay 312 causing it to become operated in which condition it performs two functions, namely: (1) the input to the second audio-frequency amplifier tube 316 is shorted through the upper armature of the relay 312 preventing the impressed tone pulses from being amplified and applied to the carrier of the radio transmitter; (2) the outer lower armature of the relay 312 short-circuits the winding of hang-

over relay 314 removing the carrier hang-over between tone impulses applied to the speech input circuit as in the case for M. C. W. transmission.

What is claimed is:

1. A two-way radio communication system comprising a radio transmitter, a radio receiver, an electric discharge device having an input circuit connected to the signal input to the radio transmitter, a first relay having a winding connected in the space current path of said device and operated by the increased space current due to signal waves in the input, means responsive to the operation of said relay for enabling the transmitter for the generation and transmission of a carrier wave, a second relay responsive to the operation of the first relay for establishing an auxiliary circuit for enabling the radio transmitter, time controlled means for maintaining said second relay operated for a period after the release of said first relay sufficiently long to prevent undesired interruption of the carrier between syllables or words spoken in rapid succession, a third relay operated simultaneously with the first relay for disabling the radio receiver, and a fourth relay operated by the first relay for providing an auxiliary operating circuit for said third relay, and time controlled means for maintaining said fourth relay operated for an interval of the order of 8 to 10 milliseconds after the release of the second relay.

2. In a two-way radio communication system, a radio transmitter, a radio receiver, means for normally maintaining said transmitter in an inoperative condition and said receiver in an operative condition, an electric discharge device having an input circuit connected to the signal input circuit of said transmitter, a source of space current for said device, a plurality of relays having windings connected in series with said source in the space current path of said device and operated on the increased space current of said device due to signal waves in said input circuit, means responsive to the operation of one of said relays for rendering said transmitter operative, means responsive to the operation of another of said relays for rendering said receiver inoperative, a first and a second hang-over relay, means responsive to the operation of said one relay for operating said hang-over relays, means responsive to the operation of said first hang-over relay for establishing an auxiliary circuit arrangement for maintaining said transmitter in an operative condition irrespective of the condition of said one relay, means responsive to the operation of said second hang-over relay for establishing a circuit for maintaining said other relay operated irrespective of the condition of the space current path of said device, time controlled means for maintaining said first hang-over relay operated for a period after the release of said one relay sufficiently long to prevent undesired interruption of the transmission by said transmitter between syllables or words spoken in rapid succession, time controlled means for maintaining said second hang-over relay operated for a few milliseconds after the release of said first hang-over relay, and means responsive to waves received by said receiver for opening the space current circuit of said device.

3. In a two-way radio communication system, a radio transmitter, a radio receiver, means for normally maintaining said transmitter in an inoperative condition and said receiver in an operative condition, an electric discharge device hav-

ing an input circuit connected to the signal input circuit of said radio transmitter, a source of space current for said device, a plurality of relays connected in series with said source in the space current path of said device and operated on the increased space current of said device due to the signal waves in said input circuit, means responsive to the operation of one of said relays for rendering said transmitter operative, means responsive to the operation of another of said relays for rendering said receiver inoperative, a hang-over relay connected to be operated by the operation of said one relay, means responsive to the operation of said other relay for establishing an auxiliary circuit arrangement for maintaining said transmitter in an operative condition irrespective of the condition of said one relay, and time controlled means for maintaining said hang-over relay operated for a period after the release of said one relay sufficiently long to prevent undesired interruption by said transmitter between syllables or words spoken in rapid succession.

4. In a two-way radio communication system, a radio transmitter, a radio receiver, means for normally maintaining said transmitter in an inoperative condition and said receiver in an operative condition, an electric discharge device having an input circuit connected to the signal input circuit of said transmitter, a source of space current for said device, a radio transmitter controlling relay, a group of radio receiver controlling relays, connections for including the windings of said transmitter controlling relay and said receiver controlling relays in series with said source in the space current path of said device so that all of said relays are operated on the increased space current of said device due to the signal waves in said input circuit, means responsive to the operation of said radio transmitter controlling relay for rendering said transmitter operative, means responsive to the operation of said radio receiver controlling relays for rendering both the radio frequency circuit and the audio-frequency circuit of said radio receiver inoperative, a first and a second hang-over relay, means responsive to the operation of said transmitter controlling relay for operating said hang-over relays, means responsive to the operation of said first hang-over relay for establishing auxiliary circuit arrangements for maintaining said transmitter in an operative condition irrespective of the condition of said transmitter controlling relay, means responsive to the operation of said second hang-over relay for establishing a circuit for maintaining said radio receiver controlling relay operated irrespective of the condition of the space current path of said device, time controlled means for maintaining said first hang-over relay operated for a period after the release of said one relay sufficiently long to prevent undesired interruption of the operative condition of said transmitter between syllables or words spoken in rapid succession, time controlled means for maintaining said second hang-over relay operated for a few milliseconds after the release of said first hang-over relay, another relay, means for rendering the audio-frequency circuit of said radio receiver inoperative when the last-mentioned relay is in a normal condition, means responsive to waves received by said receiver for operating said last-mentioned relay, and means responsive to the operation of said last-mentioned relay for rendering the audio-frequency circuit of said radio receiver operative and for opening

the space current circuit of said discharge device.

5. In a two-way radio transmission system a radio receiver, a radio transmitter employing electric discharge devices, a source of power for energizing said devices, means responsive to the signal wave input of said transmitter for controlling an operative condition of said transmitter to render said transmitter operative for transmission of radio waves in the presence of a signal wave input and to prevent the transmission of radio waves in the absence of a signal wave input, time controlled means operative a predetermined time after the initiation of its operation to interrupt the supply of power from said source to said discharge devices, and means responsive to the cessation of signal input for initiating the operation of said time controlled means.

6. In a two-way radio transmission system, a radio receiver, a radio transmitter employing electric discharge devices, a source of cathode heating current and a source of space current for said devices, means responsive to the signal input to said transmitter for controlling an operative condition of said transmitter to render said transmitter operative for the transmission of radio waves in the presence of a signal wave input and to prevent the transmission of radio waves in the absence of a signal wave input, time controlled means operative a predetermined time after the initiation of its operation to interrupt the supply of space current from said source to said discharge device, means responsive to the cessation of the signal wave input for initiating the operation of said time controlled means, and a second time controlled means operative a predetermined time after the initiation of its operation to interrupt the supply of cathode heating current to said discharge devices, and means responsive to the final operation of the first time controlled means for initiating the operation of said second time controlled means.

7. In a two-way radio communication system, a radio receiver, a radio transmitter of the vacuum tube type, a power supply for said radio transmitter, a control circuit comprising a vacuum tube, a relay for controlling an operative condition of said radio transmitter, a second relay for controlling an operative condition of said radio receiver, and a series circuit including the windings of said relays and the anode-cathode circuit of said vacuum tube, means responsive to the signals to be transmitted for rendering said vacuum tube conductive whereby said relays operate to enable said transmitter and disable said receiver, time controlled means operative a predetermined time after the initiation of its operation to interrupt the supply of power to said radio transmitter, and means responsive to the operation of said first relay for initiating the operation of said time controlled means.

8. In a two-way radio transmission system, according to claim 7, a second time controlled means operative a predetermined time after the initiation of its operation to interrupt the supply of cathode heating current to the vacuum tubes of said radio transmitter, and means responsive to the final operation of the first-mentioned time controlled means for initiating the operation of said second time controlled means.

9. In a two-way radio communication system, a radio receiver, a radio transmitter, a plurality of sets of tuning units for said transmitter, each set being adapted for tuning said transmitter for transmitting at a different frequency, a selector switch control mechanism for selectively con-

necting said sets of tuning units in circuit in said transmitter, means operated by said selector switch control mechanism for connecting high voltage power to said transmitter, relay means operative in a normal condition for rendering said transmitter inoperative and in an operative position for rendering said transmitter operative for the transmission of radio waves, time controlled means operative a predetermined time after the initiation of its operation to release said selector switch control mechanism whereby the high voltage power supply and the sets of tuning units are disconnected from said transmitter, and means operated by the operation of said selector switch control mechanism or by the normal condition of said relay means for initiating the operation of said time controlled means.

10. In a two-way radio communication system, a radio receiver, a radio transmitter, a plurality of sets of tuning units for said transmitter, each set being adapted for tuning said transmitter for transmitting at a different frequency, a selector switch control mechanism for selectively connecting said sets of tuning units in circuit in said transmitter, means operated by said selector switch control mechanism for connecting high voltage power to said transmitter, means for normally maintaining said transmitter in an inoperative condition and said receiver in an operative condition, an electron discharge device having an input circuit connected to the signal input circuit of said transmitter, a source of space current for said device, a plurality of relays having windings connected in series with said source and the space current path of said device and operated on the increased space current of said device due to signal waves in said input circuit, means responsive to the operation of one of said relays for rendering said transmitter operative, means responsive to the operation of another of said relays for rendering said receiver inoperative, a first and a second hang-over relay, means responsive to the operation of said one relay for operating said hang-over relay, means responsive to the operation of said first hang-over relay for establishing an auxiliary circuit arrangement for maintaining said transmitter in an operative condition irrespective of the condition of said one relay, means responsive to the operation of said second hang-over relay for establishing a circuit for maintaining said other relay operated irrespective of the condition of the space current path of said device, time controlled means for maintaining said first hang-over relay operated for a period after the release of said one relay sufficiently long to prevent undesired interruptions of the transmission of said transmitter between syllables or words spoken in rapid succession, time controlled means for maintaining said second hang-over relay operated for a few milliseconds after the release of said first hang-over relay, means responsive to waves received by said receiver for opening the space current circuit of said device, time controlled means operative a predetermined time after the initiation of its operation to release said selector switch control mechanism whereby the high voltage power supply and the sets of tuning units are disconnected from said transmitter, and means operated by the means for normally maintaining said transmitter inoperative for initiating the operation of the last-mentioned time controlled means.

11. In a two-way radio communication system, a radio receiver, a radio transmitter employing

a plurality of vacuum tubes, a plurality of sets of tuning units for said transmitter, each set being adapted for tuning said transmitter for transmitting at a different frequency, a source for supplying space current to said vacuum tubes, a selector switch control mechanism for selectively connecting said sets of tuning units in circuit in said transmitter, means operated by said selector switch control mechanism for completing the circuit from said source for supplying space current to said vacuum tubes, a control vacuum tube having an input circuit connected to the signal input circuit of said transmitter, means for deriving space current from said source for said control vacuum tube including the means operated by said selector switch control mechanism for completing the circuit from said source to the vacuum tubes of said transmitter, a plurality of relays having windings connected in series with said source in the space current path of said control vacuum tube and operated on the increase in space current of said control vacuum tube due to the signal waves in said input circuit, a control circuit including contacts of one of said relays, an inductance coil and a resistor for grounding the anode of one of the vacuum tubes of said radio transmitter to render said transmitter inoperative when said one relay is in a normal condition, means responsive to the operation of another of said relays for rendering said receiver inoperative, a first and a second hang-over relay, said first hang-over relay having contacts in series in said circuit for grounding the anode of one of the vacuum tubes of said transmitter when said first hang-over relay is in a normal position, means responsive to the operation of said one relay for operating said hang-over relays whereby when said first hang-over relay is operated said circuit for grounding the anode of one of the vacuum tubes of said transmitter is open to render said transmitter operative, means responsive to the operation of said second hang-over relay for establishing a circuit for maintaining said other relay operated irrespective of the condition of the space current path of said control vacuum tube, time controlled means for maintaining said first hang-over relay operated for a period after the release of said one relay sufficiently long to prevent undesired interruption of the operative condition of said transmitter between syllables or words spoken in rapid succession, time controlled means for maintaining said second hang-over relay operated for a few milliseconds after the release of said first hang-over relay, means responsive to the waves received by said receiver for opening the space current circuit of said control vacuum tube, relay means having a winding connected in said control circuit for grounding the anode of one of the vacuum tubes of said transmitter and arranged to be operated a predetermined time after its initial energization, means responsive to the operation of said last-mentioned relay means to release said selector switch control mechanism whereby the power supply circuit for the space current of the vacuum tubes of said radio transmitter is interrupted and the set of tuning units is disconnected from the transmitter.

12. In a radio transmitter employing an electric discharge device having a thermionic cathode and an anode, means for supplying current for heating said cathode, means for supplying space current to said device, means for

supplying signal waves to said transmitter,
means responsive to the cessation of the supply-
ing of signal waves to said transmitter for initiat-
ing a time interval at the end of which in the
5 absence of another supply of signal waves said
supply of space current is interrupted and means

responsive to the end of said time interval for
initiating a second time interval at the end of
which said supply of cathode heating current is
interrupted.

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