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CARRIER WAVE CIRCUIT PROTECTION

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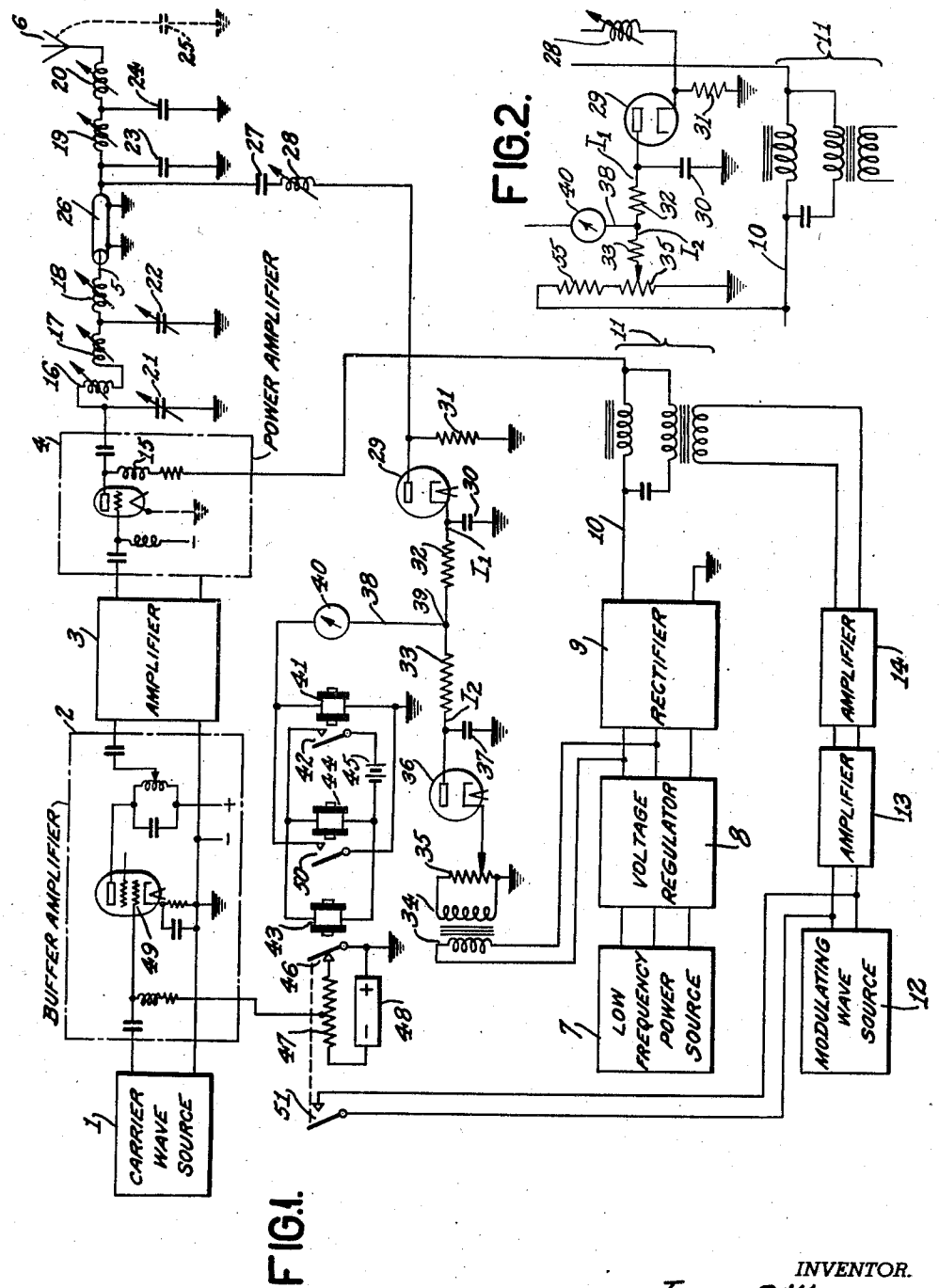


FIG. 1.

FIG. 2.

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CARRIER WAVE CIRCUIT PROTECTION

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This invention relates to a method of and a means for protecting a radio or other carrier wave transmitting system from prolonged interruption or injury as a result of a lightning disturbance or other abnormal discharge of current.

When a lightning discharge, or other impulse, or cause, starts a sustained arc or short circuit between parts of a radio transmitter circuit, a prolonged interruption is likely to occur in the radio signal or program transmission, or said transmission is likely to be objectionably mutilated. Furthermore, the equipment is likely to be permanently injured or destroyed unless the arc is quickly extinguished or the short circuit quickly removed.

Some of the objects of the present invention are to protect a radio or other carrier wave system from the difficulties referred to above, to prevent prolonged or unnecessary interruption of wave transmission in such a system, and to prevent injury or destruction of equipment in such a system, when an arc or other short circuit path occurs between different parts of the system.

Another object is to restore normal transmission of carrier waves automatically and promptly after stopping an arc or other short circuit path in the system.

In a radio transmitting system employing a power amplifier having such a negative grid bias that the space current flows during a portion only of each cycle of the carrier wave impressed on the grid, and the modulating wave is impressed directly on the space current circuit, any sudden stoppage of the carrier wave excitation during modulation, may cause a very objectionable and injurious transient disturbance which may destroy the modulating equipment or cause serious damage thereto. An object of the present invention is to protect the system under these circumstances, when the carrier wave excitation of the power amplifier grid is suddenly interrupted.

When a radio transmitting antenna is supplied with carrier wave power over a transmission line circuit having a substantial amount of distributed reactance so that the line has a length of the order of one-quarter or more of the wavelength of the carrier wave, an arc started at one place on the line may cause a decrease in the normal carrier wave voltage level at some other points in the line, whereas an arc at some other place on the line may cause an increase in level at said points.

An object of the present invention is to protect a radio transmitting system by quickly cutting off the carrier wave transmission when the level of the carrier in the transmission circuit between the output terminals of a power amplifier tube and an antenna, substantially increases or decreases above or below normal, without, however, cutting off the carrier in response to the ordinary signal modulations of the carrier wave.

In accordance with one aspect of the present invention, a carrier wave transmitting system, such as a radio transmitter, for example, including a carrier wave amplifier, is protected by a method of and means for quickly and automatically terminating an undesirable short circuit of the carrier wave output current, such as that caused by an arc started by a lightning flash or other disturbance, or caused by some other abnormal discharge path, the carrier wave being automatically cut off from the power amplifier in response to a departure of the average amplitude of the carrier wave in the output of the amplifier from its normal relation to a definite reference standard, and being quickly and automatically restored to normal condition as soon as the short circuit path is removed. Provision is also made for automatically cutting off modulating wave energy from the power amplifier when the carrier wave is cut off therefrom, and for automatically restoring the modulating wave when the carrier wave is restored.

These and other objects and features of the invention will be apparent from the following detailed description and from the accompanying drawings relating to a radio transmitting system illustrative of the invention.

In the drawing, Fig. 1 is a schematic diagram of a radio transmitting system, and

Fig. 2 is a circuit diagram showing a modification of a portion of the Fig. 1 circuit.

In the drawing, the source of oscillations 1, such as a crystal controlled carrier wave oscillator, supplies radio frequency waves to the buffer amplifier stage 2, having its output coupled with the pre-amplifier stage 3, the output of which in turn supplies carrier wave excitation to the control grid of the power amplifier stage 4, which, in the particular instance shown, is of the "class C" type, characterized by the flow of space current through the tube for less than one-half the period of each carrier wave cycle. The successive stages 2, 3 and 4, thus constitute a multistage amplifier of well known form, coupled to the master carrier wave oscillator source 1 which

provides carrier wave excitation for the input of the amplifier.

The low frequency commercial power source 7 may have a frequency, for example, of 60 cycles per second, and may have the usual fluctuations in voltage of such a source. The regulator 8, coupled to source 7, has its substantially constant voltage output coupled with the rectifier 9 for supplying substantially constant high voltage direct current over conductor 10 to the anode of amplifier 4, the current path returning from the cathode of amplifier 4 by way of ground to rectifier 9. Included in conductor 10, is the modulating wave transformer coupling arrangement 11, the source of signal modulating waves 12 transmitting the modulating waves through amplifiers 13 and 14 in succession, and through coupling 11 to the anode-cathode circuit of amplifier 4. It will be understood that the control grid of power amplifier 4, is normally biased so negatively that space current flows during less than one-half the period of the carrier wave cycle. It will be understood, however, that the invention is applicable to amplifiers wherein the space current flows during the whole or any part of said cycle. The high frequency choke coil 15 keeps the carrier wave frequency current from reaching coupling 11 and other parts of the modulating frequency circuit.

The output conductor 5, includes in series therewith, the adjustable inductive reactance elements 16, 17, 18, 19 and 20, while in shunt between conductor 5 and ground, are the capacitive reactance elements 21, 22, 23, 24 and 25, the reactance 25 being that between the antenna 6 and ground. Reactances 16, 17, 21 and 22 form a tank or resonant output circuit, which may be adjustably tuned by variable capacitance 21 or the variable inductances 16 or 17. It will be seen that inductances 17 and 18 with the capacitance 22, constitute a T-type of network while inductance 19 together with reactances 23 and 24 constitute a π type of network. The conductor 5 passes through a cylindrical shield 2 between the inductances 18 and 19. The transmission line between amplifier 4 and antenna 6, may have a length of one-quarter of a wavelength or more at the carrier wave frequency, so that one or more voltage nodes may exist along the conductor with respect to ground.

In the case of a lightning discharge striking the antenna or transmission line 5, an arc discharge may be initiated which would continue to exist until removal of the carrier wave power or destruction of the circuit. Since such an arc discharge has the effect of a short-circuit on the transmission line 5, the carrier wave supply to the antenna ordinarily would be interrupted or seriously disturbed, depending upon the particular point along the line at which the arc occurred. The effect of such a relatively low impedance path between parts of the output circuit of the power amplifier 4 may have the effect of raising or lowering the radio frequency output voltage at the antenna or in the line, depending upon the location of the short circuit path with reference to a voltage node of the output circuit.

In order to prevent injury or destruction to the output circuit and various other parts of the transmitter, the carrier wave voltage at a point in the output conductor 5, is made to control the application or removal of a high negative biasing potential on the grid of the buffer amplifier 2, thereby to cut off or block the transmission of carrier waves to the power amplifier 4 and thus to terminate the arc or other abnormal discharge of current in the output circuit of the power amplifier. The carrier wave for controlling the operation of the protective device may be taken from any desired point along conductor 5 and in the particular instance shown, is taken from the conductor 5 at a point on the antenna side of the grounded shield 26, the path of the current being traced through condenser 27, and variable inductance 28 to the anode of rectifier 29, the heated cathode of which is connected to ground through the capacitance 30 which is of relatively low impedance at the carrier wave frequency and at all frequencies above the lowest modulating wave frequency, for example, 20 cycles. A resistance 31 is provided for stabilizing the potential of the anode of rectifier 29 with respect to ground.

Rectification of the carrier wave current produces a direct current, indicated as I_1, which is transmitted through the resistance element 32 forming one arm of a bridge. The other arm 33 of the bridge is supplied with direct current indicated as I_2, derived from rectification of the low frequency relatively low voltage wave from power source 7.

The low frequency current is tapped off from a pair of the output conductors of voltage regulator 8, and is transmitted to the primary of transformer 34, the secondary of which has a potentiometer 35 in shunt therewith, a sliding contact on the potentiometer leading to the cathode of rectifier 36, the anode of which is connected with the arm 33 of the bridge. A condenser 37 connects between the anode of rectifier 36 and ground, forming a return path for the low frequency current passing through the rectifier from potentiometer 35 which is grounded at its lower end. Condenser 37 is of such low impedance that the low frequency wave from source 7 and the harmonics thereof, are effectively suppressed and kept from reaching arm 33, so that a substantially constant direct current derived from the substantially constant voltage from regulator 8, is provided in arm 33 to serve as a reference standard. By adjustment of potentiometer 35 and adjustment of inductance 23 in the carrier wave circuit, currents I_1 and I_2 in resistances 32 and 33, respectively, may be adjusted to such values as to balance, so that no current passes to the conductor 38, from the neutral point 39 of bridge 32, 33, over a path traced to ground through meter 40 and the high speed relay 41, having a quick pull-up and quick release armature.

A relatively small current, for example, of the order of 5 milliamperes or more, may be sufficient to close the contacts 42 of relay 41, thereby energizing relays 43 and 44 in parallel from the source of energy 45. Both relays 43 and 44 pull up their armatures at high speed, but are slow to release. Energization of relay 43 opens contacts 46, thereby disconnecting the right end of potentiometer 47 from the positive terminal of the direct current source 48, thereby increasing the negative bias on control grid 49 of the buffer amplifier 2 by an amount equal approximately to one-half the voltage of source 48, this increase in negative bias being sufficient to completely stop the flow of space current in amplifier 2 and stop the transmission of the carrier wave to the output of stage 2 and to stages 3 and 4 of the multi-stage amplifier.

When a disturbance is caused by lightning striking the antenna system 5, 6, causing an arc,

or when any other abnormal path in the nature of a short circuit, is produced between parts of the antenna system 5, 6, the resulting change in amplitude of the carrier waves transmitted through rectifier 29 from conductor 5, produces a change of direct current in bridge arm 32, thereby upsetting the balance of the bridge current I_1 with respect to the more constant current I_2 in arm 33. Relay 41 then closes contacts 42, and relay 43 opens contacts 46, immediately terminating transmission of the carrier waves to power amplifier 4, thus extinguishing the arc, or terminating the carrier wave power in any abnormal path between parts of the antenna system, such as might be produced for example by snow, or moisture causing a short circuit path between such parts. At the same time energization of relay 44 closes contact 50 which establishes a short circuit around relay 41, thereby releasing relay 41 and causing contacts 42 to open. Relays 43 and 44, however, being slow to release, provide a sufficient delay before restoring to normal and causing the re-establishment of the carrier wave in the antenna system, to allow of dissipation of the effect of the lightning in the antenna system 5, 6.

When relays 43 and 44 release, contacts 46 close and permit the transmission of normal carrier wave power to antenna 6, so that the balance of bridge 32, 33, is re-established. The radio transmitter is then in condition for normal operation, the various circuits having been restored automatically to normal without requiring any monitoring or special attention by an operator. In the event that a lightning discharge were to persist, or repeat at the instant of restoration of relays 41, 43 and 44 to normal, relay 41 would again immediately energize and the protective operation previously recited would be repeated until the external source of disturbance had disappeared.

Because of the abrupt cessation of carrier wave potentials on the grid of power amplifier 4 of the class C type, serious transient disturbances would ordinarily tend to take place in the carrier wave circuit and the modulating wave circuit. In order to prevent such transient disturbances, relay 43 is arranged to close its contacts 51 and produce a short circuit across the input of modulating amplifier 13 when the carrier wave is cut off by contacts 46, thus preventing the transmission of modulating waves to amplifiers 13, 14 and 4, and safeguarding the circuits from the damaging effects of interruption of the high power modulating waves on the power amplifier 4 and circuits connected therewith. Contacts 46 are preferably adjusted to open before contacts 51 close. It will be seen that upon the de-energization of relay 43 after the disturbance to the antenna system 5, 6 has been cleared, the modulating wave source amplifiers 13 and 14 are restored to normal operation, so that modulating waves may be then transmitted to power amplifier 4.

One advantage of the present invention, is that the voltage output from regulator 8 which is normally of constant amplitude may be adjusted to any desired value, or may vary due to causes beyond control, without disturbing the balance of the currents in bridge 32, 33, provided the voltage applied to the anode of the power amplifier 4 and the voltage amplitude of the carrier wave output from the amplifier are in linear relation. This will be clear from the fact that the current I_2 in arm 32 will be directly proportional to the normal average carrier wave amplitude in the output of the amplifier and the fact that amplifier 4, operating as an amplifier of the class C type, produces a carrier wave output voltage in linear relation to the voltage applied to the anode circuit of the amplifier, the normal average voltage applied to the anode circuit being directly proportional to the voltage output of rectifier 9 and regulator 8, so that the current I_1 is directly proportional to the voltage output of regulator 8, while the current I_2 is also obviously directly proportional to the voltage output of regulator 8. Any change in I_1 is therefore, exactly balanced by a corresponding change in I_2. Any short circuit path in the carrier wave output of the amplifier disturbs the above linear relation and unbalances the currents in bridge 32, 33, thereby causing the described protective circuits to operate.

The condenser 27 serves merely as a direct current blocking condenser for use in cases where it is desired to maintain direct current insulation between the antenna conductors and ground, and may be omitted if desired.

In Fig. 2, the bridge circuit resistance arm 33 is supplied with direct current directly from the high voltage direct current conductor 10 in the output of rectifier 9, the high resistance 55 being provided in series with potentiometer 35 to adjust the voltage across the potentiometer to the same value as in the Fig. 1 circuit. Since the voltage across potentiometer 35 and the current in arm 33 of Fig. 2, is reversed from that in Fig. 1, the voltage across condenser 30 is also reversed in Fig. 2 by reversing the electrodes of rectifier 29 so that the anode thereof connects directly with resistance 32 while the cathode connects with conductor 5 by way of inductance 28. The currents I_1 and I_2, in the Fig. 2 circuit, are thus in a direction permitting of balancing of the bridge with respect to conductor 36 leading to relay 41. It will be seen that the Fig. 2 modification makes it possible to omit rectifier 36 and condenser 37. In most cases, however, the Fig. 1 form of circuit is preferable to the Fig. 2 modification, since the problem of providing a relatively low voltage for potentiometer 35 from the secondary coil of transformer 34 or a similar transformer coil, avoids the usually more difficult problem of constructing and suitably insulating the resistance 55 for absorbing the greater part of the high voltage between conductor 10 and ground. The main features of the operation of the Fig. 2 modification are the same as in the Fig. 1 circuit and will be clear in view of the description of the operation of Fig. 1.

Various modifications of the invention will be apparent to those skilled in the art without departing from the invention, as claimed hereinafter. For example, various other types of antenna from that shown by the system 5, 6, could be used, or a conductively grounded antenna system could be provided, instead of the system shown, in which the conductor 5 and antenna 6, have no conductive connection with ground. It will also be seen that various other types of connection for applying the modulated waves to the carrier wave could be employed. The features of the invention for which protection is desired, are set forth in the following claims.

What is claimed is:

1. In a carrier wave transmitting system, a carrier wave amplifier, a source of carrier waves for exciting the input of said amplifier, a source of energy for the output of said amplifier, a network having two arms, means for producing in one of said arms a current proportional to the

normal average voltage of said source of energy, means for producing in the other of said arms a current proportional to the normal average amplitude of the carrier wave in the output of said amplifier, means for balancing the currents in said arms, and means responsive to an unbalance of the currents in said arms for interrupting the carrier wave excitation of the input of said amplifier.

2. In a carrier wave system, a carrier wave amplifier having an input circuit and an output circuit, energy supply means for said output circuit including a source of normally constant direct current voltage and a source of signal modulating voltage in series therewith, a source of carrier waves for exciting said amplifier input circuit, said amplifier having a characteristic in accordance with which the amplitude of the carrier wave produced in said output circuit normally varies linearly with the voltage from said modulating source, a bridge network including two arms, means for producing in one of said arms a current proportional to said normally constant voltage, means for producing in the other of said arms, a current proportional to the normal average amplitude of the carrier wave in said amplifier output circuit, means for balancing the currents in said arms, and means responsive to an unbalance of the currents in said arms for interrupting the excitation of said amplifier input circuit from said carrier wave source.

3. In a carrier wave transmitting system according to claim 1, the combination in which each of said arms includes a resistance, and said unbalance responsive means includes a relay.

4. In a carrier wave transmitting system according to claim 1, the combination in which said means for producing a current in said other arm includes a rectifier for the carrier wave produced in the output of said amplifier and also includes means for preventing the transmission to said arm of any signal modulating component derived from rectification of said carrier wave.

5. In a carrier wave transmitting system according to claim 1, the combination in which said amplifier has a plurality of stages of amplification, and said unbalance responsive means responds to prevent the transmission of carrier waves beyond the input of the first stage of said amplifier.

6. In a carrier wave transmitting system according to claim 1, the combination in which said energy supply source includes a low frequency source of alternating current and means for deriving a high voltage rectified current therefrom for utilization in the output of said amplifier, and said means for producing a current in said one arm includes means for deriving from said alternating current source and producing in said arm a low voltage rectified current, substantially free from alternating components.

7. In a carrier wave transmitting system, a carrier wave amplifier of the space current type, a carrier wave source for exciting the input of said amplifier, means for normally blocking the flow of space current in the output of said amplifier except for periods of less than one half the carrier wave period, a bridge network having two arms, means for producing in one of said arms a direct current proportional to the average voltage of the space current energy supplied to the output of said amplifier, means for producing in the other of said arms a direct current proportional to the normal average amplitude of the carrier wave output of said amplifier, means for adjusting the balance of the currents in said arms, and means responsive to an unbalance of the currents in said arms for interrupting the transmission of carrier waves from said source to the input of said amplifier.

8. In a carrier wave transmitting system, the combination according to claim 2, in which there is provided means, responsive to an unbalance of the currents in said arms, for interrupting said signal modulating voltage in said output circuit.

9. In a carrier wave transmitting system, a carrier wave amplifier, a source of carrier waves for exciting the input of said amplifier, a source of energy including a source of modulating waves for the output of said amplifier, a network having two arms, means for producing in one of said arms a current proportional to the normal average voltage of said source of energy, means for producing in the other of said arms a current proportional to the normal average amplitude of the carrier wave in the output of said amplifier, means for balancing the currents in said arms, and means responsive to an unbalance of the currents in said arms for interrupting said source of modulating waves.

10. In a radio transmitter, including a radio frequency amplifier having an output circuit including an antenna and connections therefor, the method of protecting the transmitter from a disturbance of the type produced by an abnormal shunt such as that produced by an arc across a part of said output circuit, said method including producing a direct current proportional to the normal average voltage supplied to the output of the amplifier, producing a direct current proportional to the normal average amplitude of the radio frequency output current of the amplifier, balancing said two direct currents, and interrupting the amplification of radio frequency current in the amplifier in response to an unbalance of said direct currents resulting from a disturbance of the type referred to.

11. The method according to claim 10 in which the amplification of radio frequency current in the amplifier is resorted in response to removal of said disturbance.

12. The method according to claim 10 in which the carrier wave is modulated in accordance with a modulating wave transmitted to the output of the amplifier, and the transmission of said modulating wave to the output of the amplifier is interrupted in response to said unbalance of direct currents.

13. The method according to claim 10 in which the carrier wave is modulated in accordance with a modulating wave transmitted to the output of the amplifier, the transmission of said modulating wave to the output of the amplifier is interrupted in response to said unbalance of direct currents, and the amplification of radio frequency current in the amplifier and the modulation of the carrier wave is restored in response to removal of said disturbance.

14. In a carrier wave transmitter, including a carrier wave amplifier of the space current type in which a modulating wave is directly transmitted to the output circuit of the amplifier over a discrete modulating path independent of the carrier wave input path of said space current amplifier, said amplifier having an output circuit subject to abnormal discharges of the carrier wave produced therein, the method of op-

eration which includes interrupting said direct and discrete transmission of the modulating wave to the output of the amplifier in response to an abnormal discharge of the carrier wave current in the output circuit of the amplifier.

15. In a carrier wave transmitter, a carrier wave amplifier having an output circuit subject to abnormal discharges of the carrier wave produced therein, means for transmitting a modulating wave directly to the output circuit of said amplifier over a discrete path independent of the carrier wave input circuit of said carrier wave amplifier, and means responsive to an abnormal discharge of the carrier wave current in said output circuit for interrupting the direct and independent transmission of the modulating wave to the output of the amplifier.

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