

The invention relates to an amplifier system comprising an input transmission line, an output transmission line, a primary amplifier circuit and a back up amplifier circuit.

5 Communications systems require radio frequency amplification for increasing system sensitivity when receiving low-level signals from an antenna located at the top of a radio tower.

10 A tower-mounted preamplifier located at the base of an antenna may offer up to a ten decibel improvement in receiver sensitivity over preamplifier systems located at the base of the tower, in that the former preserves the signal-to-noise ratio existing at the base of the antenna by amplifying signals before they are reduced in amplitude by tower-to-ground transmission line losses. Unfortunately, tower-mounted preamplifiers are not readily accessible for maintenance in case of system failure. Therefore it
15 has been a practice to provide systems which permit the tower-mounted preamplifiers to be bypassed and signals to be carried by the transmission line to a backup or secondary preamplifier located at ground level. When the system is switched to the backup preamplifier, which is not located on top of the tower, the
20 improvement in system sensitivity achieved by using a tower-mounted preamplifier is lost.

Radio frequency amplifiers may be used in two-way repeater amplifiers, i.e. bidirectional amplifiers, or one-way amplifiers. In critical system applications where downtime caused by the
25 amplifier failure is a major concern, a backup circuit is usually incorporated in the system.

The use of an alternative amplifier circuit in the event of a primary circuit failure is well known, but all of the existing systems fail to provide a backup system suitable for a tower-mounted application with remote control. For instance, United States Patent
30 2 229 108 (J Maggio et al) entitled "Switching of Spare Repeater Sections" issued on 21 January 1941 discloses the broad concept of a spare amplifier circuit in combination with a plurality of amplifier circuits. The system requires an intricate array of relays to
35 provide a single spare circuit for a three-circuit system and the

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extensive hardware required to provide the switching increases the probability of failure to a point which far exceeds any benefits which may be derived in overall reliability from inclusion of the spare circuit. An even more serious shortcoming of the Maggio et al system is the fact that the multi-pole, multi-throw relays incorporated in the system are satisfactory for high-frequency operation, but completely unsatisfactory for use with preamplifiers where radio frequencies are encountered.

Other examples of backup amplifier circuits may be found in United States Patents 1 396 745 (Haddock), 1 472 455 (Blattner), 1 525 054 (Toomy), 2 647 176 (Daly) and 2 773 944 (Karlson). None of the techniques utilised by these references lends itself to the use in a remote tower or to preamplifier systems operating in the radio frequency (RF) range.

In the forgoing systems, the "standby" method has an advantage over the "common redundant preamplifier" method. The redundant method connects two preamplifiers in parallel with input and output 3 db hybrids. The theory behind this is that if one amplifier fails, the second amplifier will maintain system operation, although at a reduced performance level due to an increase in noise and reduction in gain. Another drawback of the redundant method is that both preamplifiers are active in the system and both are vulnerable to damage by lightning.

Many of the above problems are eliminated by the teaching of U. S. Patent 4 565 972 for a "Tower Mounted Preamplifier", namely a preamplifier backup system which is located in the tower but activated at ground level by interrupting the direct current (DC) voltage to the tower-mounted preamplifier assembly for a short time duration. This operates a latching relay which switches DC power and RF signals alternately between either of two identical preamplifiers each time the power is interrupted. This is usually done manually at the site after poor signal reception has been experienced, although the switching could be done remotely via a modem and telephone line or other radio link to the modem.

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Thus the teaching of U. S. Patent 4 565 972 requires an action to be taken by an individual to place the standby or secondary amplifier in operation.

5 In view of the apparent inability of prior art amplifier systems incorporating backup circuits to function satisfactorily in remote RF environments without human intervention, it is the primary objective of the present invention to provide an amplifier system which is capable of operating in the RF range and in which, through monitoring amplifier performance, a backup circuit amplifier
10 circuit can be automatically substituted for a primary amplifier circuit and a bypass circuit can be automatically substituted for the backup amplifier circuit.

A subsidiary objective is to provide, in such a system, a standby amplifier circuit which is switched out of the circuit in
15 both the DC power and RF signal inputs to eliminate exposure to lightning damage.

A further subsidiary objective is to provide a tower-mounted amplifier system including a spare, backup amplifier circuit and a amplifier bypass circuit, both automatically controllable in
20 response to the output of a voltage comparator circuit.

A still further subsidiary objective is to provide a tower-mounted amplifier system including a backup amplifier circuit and bypass circuit powered by a DC potential derived from an alternating current source.

25 According to the invention the primary objective is attained, in the case of an amplifier of the kind stated in the introduction, by the features stated in the characterising part of claim 1 or claim 4. The subsidiary objectives are attained by the features stated in the subclaims.

30 Preferably, the system is a remote preamplifier system which includes a primary preamplifier circuit, a backup preamplifier circuit which may be placed in service to bypass the primary preamplifier circuit, and a bypass circuit for circumventing both preamplifiers if they become inoperative. Circuit switching can be
35 achieved through automatic means which determine the need to switch

between the available circuits by monitoring the current draw of the preamplifier stages. The system may utilise four single-pole, double-throw RF coaxial relays to provide circuit routing through the primary preamplifier, the backup preamplifier or the bypass circuit. The RF coaxial relays can be controlled by a logical, series-connected DC comparator responsive to the primary preamplifier and a DC comparator responsive to the backup preamplifier.

Embodiments of the invention will now be described in more detail by reference to the accompanying drawings, in which:

Fig. 1 is a functional block diagram of a tower-mounted preamplifier system embodying the invention, including a base monitoring component;

Fig. 2 is a schematic diagram of interconnection and selection circuitry of a primary preamplifier circuit, backup preamplifier circuit and by-pass circuit of the system;

Fig. 3 is a schematic diagram of a DC comparator responsive to the primary preamplifier;

Fig. 4 is a schematic diagram of a DC comparator responsive to the backup preamplifier; and

Fig. 5 is a schematic diagram of a base monitor and control panel, including a voltage and current alarm system.

Referring now to the drawings, there is shown in Fig. 1 a tower-mounted amplifier system which is enclosed in a stainless steel, watertight housing 20, and a base monitor and control panel 30 located at the base of the tower. An antenna 10 is coupled via a preselector 11 to a RF relay assembly 12 which includes four single-pole, double-throw RF coaxial relays which are controlled to switch a primary preamplifier 13 and a backup preamplifier 14 in and out of the signal channel in a mutually exclusive manner. The relays are energised by outputs from a dual preamplifier monitor assembly 15 which compares functions of the input amplifiers and output amplifiers of the primary preamplifier 13 and backup preamplifier 14. The tower-mounted form of the system is a preferred mode, but the system is not limited thereto and may be used in any environment to eliminate the need for human intervention.

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5 The RF relay assembly 12 provides an RF signal output mutually and exclusively from the primary preamplifier 13, backup preamplifier 14 or a preamplifier bypass circuit as illustrated in Fig. 2. This signal passes through a polyphaser, surge suppressor and DC pick-off circuit 16 and then through a tower transmission line 17 to the base monitor and control panel 30.

10 The panel 30 includes an RF surge suppressor and DC injector 18. This circuit couples the RF signal to a receiver multicoupler and injects 15 volts DC onto the line 17 to provide power to the tower-mounted circuits via the DC pick-off section of the circuit 16.

15 A polyphaser surge suppressor 19 connects the monitor assembly 15 to the panel 30 via a 9-conductor alarm and control cable 21. This cable passes DC control and monitoring voltages through surge suppressor 22 to activate LED alarm 23 which indicates that the primary preamplifier is off line, LED alarm 24 which indicates that the backup preamplifier is off line, and LED alarm 25 which indicates low voltage in the tower-mounted assembly. LED alarm 26 indicates high current on the line 17 and is monitored by a circuit on the panel 30.

20 The panel 30 also includes a supervisory system terminal strip 27 which provides a means to connect the four signals that activate the panel alarms 23 to 26 to remote alarm relays, which use a floating ground completed via the terminal strip 27. A connection 29 for a backup battery power source to be used in the event of a power supply failure is located on the panel 30.

In the following description, a preferred embodiment incorporating relays is described. However, any one or all may be replaced by electronic circuits, such as flip-flops.

30 In Fig. 2, the signals received at the antenna 10 are applied through the preselector 11, namely a bandpass preselector filter, to the pole contact of a single-pole, double-throw RF coaxial relay 32 which is energised through connector J3 which is connected to connectors J3 of the primary and backup preamplifier DC comparator circuits illustrated in Figs. 3 and 4, respectively. While relay 32 is energised, it connects the signal to the pole of a single-pole,

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double-throw RF coaxial relay 34 which is energised via connector J7 which is connected to connector J7 of the backup preamplifier DC comparator illustrated in Fig. 4. The normally closed contact of relay 34 connects the signal to the primary preamplifier 13 which comprises two or more series-connected RF amplifier stages 35 and 36. When energised, relay 34 connects the signal to the backup preamplifier circuit 14 which similarly contains two or more series-connected RF amplifiers 37 and 38.

Connected in parallel with the coil of relay 34 is the coil of an RF coaxial relay 39, which is a single-pole double-throw relay. The normally closed contacts of relay 39 couple the output of the primary preamplifier, 36, to contact 41 of relay 40. Relay 40 is an RF coaxial single-pole, double-throw relay, the coil of which is in parallel with the coil of relay 32. When energised, the normally open set of contacts of relay 39 connect the output of the backup preamplifier, 38, to contact 41 of relay 40, so that the contact 41 is connected to the outputs of the primary and backup preamplifiers in a mutually exclusive manner. The pole contact 42 of relay 40 is connected to the transmission line to complete the signal path through either of the preamplifiers when it is energised and its normally open contacts are closed.

When relays 32 and 40 are de-energised, their normally closed contacts form a signal path through bypass cable 43.

The current draw of the input amplifiers, 35 and 37, and that of the output amplifiers, 36 and 38, of the primary and backup preamplifiers are monitored by their respective DC comparator circuits illustrated in Figs. 3 and 4. The low-noise stages or input amplifier stages are monitored via connector J5 for the primary preamplifier 35 and via connector J9 for the backup preamplifier. The high-level signals of the preamplifiers are monitored via connector J6 for the primary preamplifier 36 and via connector J10 for the backup preamplifier 38. If the current draw of either the low-noise or high-level stage changes by a preset amount above or below the norm for the active preamplifier circuit, it is switched out of the circuit and replaced, in particular the primary preamplifier is replaced by the backup preamplifier and the backup preamplifier by a bypass cable 43.

When the backup preamplifier is removed from the circuit and replaced by bypass cable 43, operation continues without system gain, but without added system loss due to a non-functional amplifier in the circuit.

5 The operational steps are sequential, i.e. the primary preamplifier 13 is active and monitored until a fault is detected by the DC comparator of Fig. 3, then the backup preamplifier 14 is activated in place of the primary preamplifier and it continues until a fault is detected by the DC comparator of Fig. 4, after
10 which it is deactivated and replaced by the bypass cable 43. If the DC power to the tower preamplifier assembly is interrupted, the system will reset, monitoring first the primary preamplifier. If it is operating within the preset current setting, it will remain in operation.

15 Fig. 3 shows ground-referencing, differential input circuits 51 and 52 and DC gain stages 53 and 54, which are individual operational amplifier circuits which, in the preferred embodiment, are found on LM158AJ integrated circuits. The high-level stage is a DC comparator formed by two amplifiers, 55 and 56, of a quad
20 comparator LM139AJ. The other two amplifiers, 57 and 58, of the quad comparator function as the low-noise stage comparator circuit. The basic circuits are well-known designs. The system is distinguished by its circuit interconnection methodology, the use of the time delay circuit and DC relays to control the DC power fed to
25 the preamplifiers, and the coaxial RF relays which select the primary preamplifier, backup preamplifier or preamplifier bypass cable, according to the output of the relevant DC voltage comparator circuit.

30 Fig. 3 illustrates the circuits which comprise the primary preamplifier control means. Resistors 61 and 62 are in series with the DC power to high-level and low-noise preamplifier stages 36 and 35 of Fig. 2, respectively via connectors J6 and J5. The value of these resistors is selected to provide a small voltage which is proportional to the current draw of the stages of the primary
35 preamplifier 13, which in the preferred embodiment is 300 to 350 millivolts.

This voltage is amplified and passed to the respective DC comparator, 55 and 56 or 57 and 58, for either the high-level or low-noise preamplifier stage. The DC gain stage, 54 or 53, is adjusted for a DC output of 10 volts to the appropriate comparator.
5 If the normal sample voltage is 350 millivolts, this is a gain of 28.57.

A current draw variance in the sampled preamplifier stage of $\pm 18\%$ indicates some fault in the amplifier, and the backup preamplifier 14 is to be selected by the RF relay action described
10 with respect to Fig. 2. If 10 volts is the norm to the comparator, a $\pm 18\%$ change in current draw will translate to 11.8 volts high trip and 8.2 volts low trip. These trip points are set by proper selection of resistors 63, 64 and 65 on the high-level comparator and resistors 66, 67 and 68 on the low-noise comparator.

15 An NPN transistor, 71, is used as a switch to control energising relay 72. The transistor circuit is a grounded emitter configuration so that the base voltage of the transistor must be positive relative to the emitter for collector current to flow from the grounded emitter to the collector and up through the coil of
20 relay 72 to energise the relay. If the voltages at the inputs to the comparators 55, 56, 57 and 58 are within the selected ranges, their high impedance outputs result in a positive voltage across resistor 73 which turns on transistor 71. As long as the comparator outputs present a high impedance to the base of transistor 71, a
25 positive voltage from resistor 73 will turn on the transistor and current will flow from the grounded emitter to the base and up through resistor 73. Current will also flow from emitter to collector to energise relay 72.

As long as relay 72 remains energised, the positive DC voltage
30 from relay 91 is supplied via contacts 74 to the primary operating voltage circuit. The primary operating voltage circuit supplies B+ voltage to the primary preamplifiers, the primary preamplifier comparator circuit and relays 32 and 40 which are energised via connector J3. The signal path is through the preamplifiers 13 or 14
35 as a function of the status of relays 34 and 39 of Fig. 2.

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If any one of the comparators 55, 56, 57 and 58 switches to a low impedance, it will turn off transistor 71, and de-energise relay 72. This causes the normally closed contact set 74 of relay 72 to close, disconnecting the DC potential to the primary voltage comparator circuit and connecting the positive DC potential to the secondary or backup operating preamplifier voltage comparator circuit. The backup operating preamplifier voltage comparator circuit provides B+ voltage to the backup preamplifiers, the backup preamplifier comparator circuit illustrated in Fig. 4 via connector J2, the relays 32 and 40 via connector J3 and the relays 34 and 39 via connector J7. If the backup preamplifier is operating properly, relays 32 and 40 will remain energised by the backup comparator circuitry and relays 34 and 39 will become energised to switch the backup preamplifier into the signal channel in place of the primary preamplifier.

De-energising relay 72 closes contact set 75 so that voltage B+ is supplied from the power supply source at the tower base to the primary alarm via connectors J4A and J4B and to the backup alarm relay via connectors J4C and J4D.

Closing switch 76 will turn off transistor 71 to disable the primary preamplifier as if one of the comparators had switched to low impedance. This can also be accomplished by applying a remote ground to the base of the transistor via connector J12.

Switching between preamplifiers or initialising the system can result in out-of-limit comparisons until the amplifiers stabilise. Therefore a delay circuit is required.

When the system is first activated and power applied to the tower-mounted preamplifier assembly, the active preamplifier requires a short period of time to stabilise in current and for control relay 72 to energise and close its normally open contact sets which control the flow of DC power to the backup preamplifier as well as the primary preamplifier comparator, the primary preamplifier, and the RF coaxial relays.

DC power is received from the polyphaser surge suppressor 16 of Fig. 1 via connector J1 at the primary power distribution delay circuit input of Fig. 3 to provide a B+ source to power the



operating voltage circuits of the system. The delay circuit is controlled by a delay transistor 81 which is turned on when capacitor 83 is charged and its base is positive (0.7 to 1.0 volts). The ratio of resistor 84 to resistors 84 + 85 is about 13 to 1, so the 15 volt input places 1.9 volts at the base of the delay transistor 81 when capacitor 83 is fully charged through resistor 85. The delay thus set by the RC time constant of capacitor 83 and resistor 84 delays the energisation of relay 82 which creates the settling time required by the preamplifier circuits by powering the primary operating voltage circuit until relay 72 energises. If relay 72 does not energise before relay 82, the primary preamplifier will not come on line.

Before the delay transistor starts to conduct, power is applied through the normally closed contacts of the de-energised relay 82 to the primary preamplifier comparator circuitry and coil of relay 72. When relay 72 is allowed to energise by the intolerance operation of comparators 55 to 58, energisation of relay 82 is no longer necessary because its contacts are bypassed by contact set 74 of relay 72. If the primary preamplifier comparators do not stabilise and turn on transistor 71 before the RC time constant of delay transistor 81 times out, the primary preamplifier will be considered defective and not allowed to be active.

Voltage to power the primary preamplifiers, comparator circuitry and RF coaxial relays 32 and 40 passes through the normally open contacts of relay 72 which are closed when it is energised. Since relay 72 is in a de-energised state when power is first applied, an alternative DC path must be provided around the relay to initially power up the primary comparators, preamplifiers, and relays 32 and 40. This is accomplished by relay 82 in its initial relaxed state, through diode 86. Within milliseconds, relay 82 activates and opens the path through diode 86, and the remaining DC path is now only through relay 72. If any comparator output grounds the base of transistor 71, relay 72 will be de-energised and remain in the de-energised state. Relay 72 sends DC power to the secondary preamplifier comparator/preamplifier circuitry and also

activates an alarm closure at connectors J4A and J4B, indicating that the primary preamplifier has been switched out. It should be noted that all DC power is removed from the primary preamplifier and comparator circuitry when a fault is detected. Diode 87 prevents
5 voltage present at relays 32 and 40 from powering up the primary preamplifier circuits when the backup preamplifier is on line.

Switches 88 and 76 are setup devices used to permanently deactivate relays 82 and 72, respectively.

If a power supply failure occurs and DC power is not available
10 at connector J1, relay 91 is de-energised and power is supplied from a battery and voltage regulator at the base through connector J16. Monitoring of the tower-mounted assembly voltage at the base permits the voltage regulator to be adjusted to the proper DC voltage at the tower-mounted assembly.

When the primary preamplifier fails, DC power is supplied to
15 connector J2 of Fig. 4 from the closed contact set 74 of the de-energised relay 72 of the primary amplifier circuit illustrated in Fig. 3. Connector J2 is the input to the backup power distribution delay circuit of Fig. 4 which provides a B+ source to power the
20 backup voltage comparator circuit. This circuit is controlled by the delay transistor 181 which is turned on when capacitor 183 is charged and its base is positive (0.7 to 1.0 volts). The ratio of resistor 184 to resistors 184 + 185 is about 13 to 1 so the 15 volt
25 input places 1.9 volts at the base of the delay transistor 181 when capacitor 183 is fully charged through resistor 185. The delay thus set by the RC time constant of capacitor 183 and resistor 184 delays the energisation of relay 182 which creates the settling time required by the preamplifier circuits by powering the backup
30 operating voltage circuit until relay 172 energises. If relay 172 does not energise before relay 182, the backup preamplifier will not come on line.

In the backup preamplifier comparator circuits of Fig. 4, resistors 161 and 162 are connected in series with the DC power to high-level and low-noise preamplifier stages, 38 and 37, of Fig. 2
35 respectively via connectors J10 and J9. The value of these



resistors is selected to provide a small voltage which is proportional to current draw of the stages of the backup preamplifier, 14, which in the preferred embodiment is 300 to 350 millivolts.

5 This voltage is amplified and passed to the respective DC comparator, 155 and 156 or 157 and 158, for either the high-level or low-noise preamplifier stage. The DC gain stage, 154 or 153, is adjusted for a DC output of 10 volts to the appropriate comparator. If the normal sample voltage is 350 millivolts, this is a gain of
10 28.57.

 A current draw variance in the sampled preamplifier stage of $\pm 18\%$ indicates some fault in the amplifier, and the bypass cable 43 is to be selected by the RF relay action described with respect to Fig. 2. If 10 volts is the norm to the comparator, a $\pm 18\%$
15 change in current draw will translate to 11.8 volts high trip and 8.2 volts low trip. These trip points are set by proper selection of resistors 163, 164 and 165 on the high-level comparator and resistors 166, 167 and 168 on the low-noise comparator.

 An NPN transistor 171 is used as a switch to control
20 energising relay 172. The transistor circuit is a grounded emitter configuration so the base voltage of the transistor must be positive relative to the emitter for collector current to flow from the grounded emitter to the collector and up through the coil of relay 172 to energise the relay. If the voltages at the inputs to the
25 comparators 155, 156, 157 and 158 are within the selected ranges, their high impedance outputs result in a positive voltage across resistor 173 which turns on transistor 171. As long as the comparator outputs present a high impedance to the base of transistor 171, a positive voltage from resistor 173 will turn on
30 the transistor and current will flow from the grounded emitter to the base and up through resistor 173. Current will also flow from emitter to collector to energise relay 172.

 As long as relay 172 remains energised, the RF coaxial relays 32, 34, 39 and 40 are energised via connectors J3 and J7 and the
35 signal path is through backup preamplifier 14 as a function of the

status of RF coaxial relays 34 and 39 of Fig. 2. If any one of the comparators 155, 156, 157 and 158 switches to a low impedance, that is, essentially ground, it will turn off transistor 171 and de-energise relay 172. This causes the normally closed contact set 174 of relay 172 to open and halt the positive DC potential applied to the coils of the relays 32, 34, 39 and 40 via connectors J3 and J7. This causes the bypass cable 43 to replace both the primary and backup preamplifiers in the RF signal channel.

De-energising relay 172 allows the normally closed contact set 175 to supply voltage B+ from the ground supply via connector J4A and contacts 75 of relay 72 to connector J4C and then to the backup alarm via connector J4C, so that an alarm on the backup preamplifier will not occur when the primary preamplifier is in operation. When the primary preamplifier is in operation, there is no DC power sent to the backup preamplifier circuitry to energise relay 172 and open the alarm circuit. Diode 187 prevents the activation of relays 34 and 39 when relays 32 and 40 are activated in the primary mode.

Closing switch 176 will turn off transistor 171 to disable the backup preamplifier as if one of the comparators had switched to low impedance.

The backup alarm signals routed through relay 72 and switches 188 and 176 are "setup devices" to prevent the energising of relays 182 and 172 respectively.

The tower-mounted assembly is functionally connected to the base unit, the base monitor and control panel 30 of Fig. 1, by a 9-conductor alarm and control cable 21 which transmits indicator and control functions between the two units. The base unit includes the low voltage and high current alarm systems illustrated in Fig. 5.

The low voltage alarm system includes a voltmeter 201 which monitors the DC voltage input to the tower-mounted circuitry via connector J15 and switch 202 which connects the voltmeter directly to the tower-mounted equipment or to the tower-mounted equipment via a potentiometer 203. The potentiometer permits the creation of a simulated low voltage observable on the voltmeter and provides a target voltage for adjustment purposes. The low voltage alarm

circuit, which comprises a voltage comparator including differential amplifiers 204 and 205, is initially adjusted by setting its operational threshold to the low voltage produced by potentiometer 203 via potentiometer 206.

5 With the low-voltage-simulating potentiometer 203 out of the circuit, the low voltage alarm circuit is connected directly to the tower-mounted equipment. When the monitored voltage is above the preset minimum, transistor 207 is held on, which causes relay 208 to be energised. When a low voltage situation occurs, transistor 207
10 is switched off and relay 208 is de-energised. This causes LED alarm 25 to illuminate and thus indicate a low voltage at the tower assembly. It also provides a signal to the tower assembly remote low voltage alarm.

 Fifteen volts DC is applied from the base power supply through
15 switch 210 and ammeter 212 to the tower-mounted assembly via the tower transmission line 17. An indicator 211 is provided at the output of switch 210 to signal that power is applied to the tower-mounted assembly. The current draw on the power supply is measured by a series of three differential amplifiers 213, 214 and 215 which
20 normally hold transistor 216 in a conducting state. However, when the current exceeds a preset limit, transistor 216 is turned off and relay 217 is de-energised. This causes LED alarm 26 to illuminate and thus provide a high current alarm. This action also causes a circuit connection to a remote over-current alarm indication.

25 An RF pick-off and bias injector 18 is located in the base unit side of the line 17 to provide a means to extract the RF signal to complete the RF channel and provide a means to supply DC power to the tower-mounted equipment. A similar circuit is located in the tower-mounted equipment to allow the RF signal to be injected onto
30 the DC-carrying line 17.

 The alarm and control cable 21 also provides a means to connect LED alarm 23 to the tower via connector J4B. This provides an alarm when the primary preamplifier is switched out of the circuit.

LED alarm 24 is connected to the tower-mounted equipment via connector J4D and it provides an indication when both the primary and backup preamplifiers are switched out of the RF signal channel and disconnected from their power source. Both alarms 23 and 24 may
5 be connected to remote indicators.

Switch 223 provides a remote ground to the delay circuit for the primary preamplifier via connector J11. This ground will cause that circuit to be turned off line, forcing a primary amplifier insertion and disabling secondary amplifier operation as a
10 troubleshooting aid.

Switch 224 is connected to the base of transistor 71 via connector J12 to switch that transistor off and de-energise relay 72 of the primary preamplifier circuit in a manner similar to that described for switch 76.

Switch 225 is connected to the backup preamplifier circuit via connector J13. This switch is in parallel with switch 188 and its purpose is to remotely turn off the delay transistor 181 of the backup preamplifier delay circuit in a manner similar to that described for switch 188. Grounding of the switches 224 and 225
15 will force secondary amplifier insertion into the system as a
20 troubleshooting aid.

CLAIMS

1. An amplifier system comprising an input transmission line, an output transmission line, a primary amplifier circuit (13) and a backup amplifier circuit (14), characterised by a bypass circuit (43), amplifier switching means (12) for mutually exclusively
5 connecting the primary amplifying circuit (13), the backup amplifying circuit (14) and the bypass circuit (43) between the lines, and generating means (15) for generating a primary failure signal in response to an abnormal current draw of the primary amplifier circuit (13) and a backup failure signal in response to an
10 abnormal current draw of the backup amplifier circuit (14), wherein the amplifier switching means (12) is operable to disconnect the primary amplifier circuit (13) from and connect the backup amplifier circuit (14) between the lines in response to the primary failure signal and to disconnect the backup amplifier circuit (14) from and
15 connect the bypass circuit (43) between the lines in response to the backup failure signal.
2. An amplifier system according to claim 1, characterised by an amplifier system power supply, a primary operating voltage comparator circuit (51 to 58), a backup operating voltage comparator
20 circuit (151 to 158), and operating voltage switching means responsive to the primary failure signal for mutually exclusively energising the comparator circuits with voltage supplied by the power supply.
3. An amplifier system according to claim 2, characterised in
25 that the generating means (15) is operable to generate the primary failure signal in response to the current draw of the primary amplifier circuit (13) exceeding a preset upper limit or lower limit when connected between the lines and to generate the backup failure signal in response to the current draw of the backup amplifier
30 circuit (14) exceeding a preset upper limit or lower limit when connected between the lines.



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4. An amplifier system, comprising an input transmission line, an output transmission line, a primary amplifier circuit (13) and a backup amplifier circuit (14), characterised by a bypass circuit (43), an amplifier system power supply, amplifier switching means (12) for mutually exclusively connecting the primary amplifying circuit (13), the backup amplifying circuit (14) and the bypass circuit (43) between the lines, generating means for generating a primary failure signal in response to the current draw of the primary amplifier (13) exceeding a preset upper limit or preset lower limit when connected between the lines, a primary operating voltage comparator circuit (51 to 58) for supplying operating voltage to the primary amplifier circuit (13) and the means for generating the primary failure signal, means for generating a backup failure signal in response to the current draw of the backup amplifier circuit (14) exceeding a preset upper limit or preset lower limit when connected between the lines, a backup operating voltage comparator circuit (151 to 158) for supplying operating voltage to the backup amplifier circuit (14) and the means for generating the backup failure signal, and operating voltage switching means for de-energising the primary operating voltage comparator circuit and energising the backup operating voltage comparator circuit in response to the primary failure signal, wherein the amplifier switching means (12) is operable to disconnect the primary amplifier circuit (13) from and connect the backup amplifier circuit (14) between the lines in response to the primary failure signal and to disconnect the backup amplifier circuit (14) from and connect the bypass circuit (43) between the lines in response to the backup failure signal.

5. An amplifier system according to claim 2 or claim 4, characterised by a primary power distribution delay circuit (81 to 85) for energising the primary operating voltage comparator circuit (51 to 58) for a predetermined period of time upon initial activation of the amplifier system with voltage supplied by the power supply.





5 6. An amplifier system according to claim 5, characterised by a backup power distribution delay circuit (181 to 185) for energising the backup operating voltage comparator circuit (151 to 158) for a predetermined period of time upon activation by voltage supplied in parallel to the backup operating voltage comparator circuit by the operating voltage switching means.

10 7. An amplifier according to claim 2 or claim 4, characterised in that the amplifier circuits (13, 14), bypass circuit (43), amplifier switching means (12), generating means (15), comparator circuits (51 to 58; 151 to 158) and operating voltage switching means are contained in a tower-mounted housing (20) and the power supply is located at the base of a tower supporting the housing.

15 8. An amplifier system according to claim 7, characterised by a tower transmission line (17) for conducting direct current power from the power supply to the primary operating voltage comparator circuit (51 to 58).

20 9. An amplifier system according to claim 8, characterised by a voltage comparator (204, 205) electrically connected to compare the voltage level of direct current power supplied by the tower transmission line (17) to the operating voltage switching means with a preset voltage level, low voltage switching means (207, 208) driven by the voltage comparator (204, 205) and arranged to change state in response to an output signal from the voltage comparator indicative of the compared voltage level falling below said preset level, and an alarm circuit (25) activated by the change in state of the low voltage switching means.

30 10. An amplifier system according to claim 8, characterised by a current monitor circuit (213 to 215) electrically connected to monitor current flow through the tower transmission line (17), high current alarm switching means (216, 217) driven by the current monitor circuit (213 to 215) and arranged to change state in response to an output signal from the current monitor circuit indicative of the monitored current exceeding a preset level, and a high current alarm circuit (26) activated by the change in state of the high current alarm switching means.

11. An amplifier system according to claim 8, characterised by a battery power source and means for substituting the battery power source for said direct current power.



ABSTRACT

AMPLIFIER SYSTEM

5 A communications amplifier system comprises a primary amplifier circuit (13), a backup amplifier circuit (14) and a bypass circuit mutually exclusively selectable through a relay switching means (12) which is automatically activated to bypass the primary amplifier circuit (13) with the backup amplifier circuit (14) or the backup amplifier circuit (14) with the bypass circuit in the event of malfunction. In the standby mode, the backup amplifier is not connected to DC power or RF signal input.

(Fig. 1)

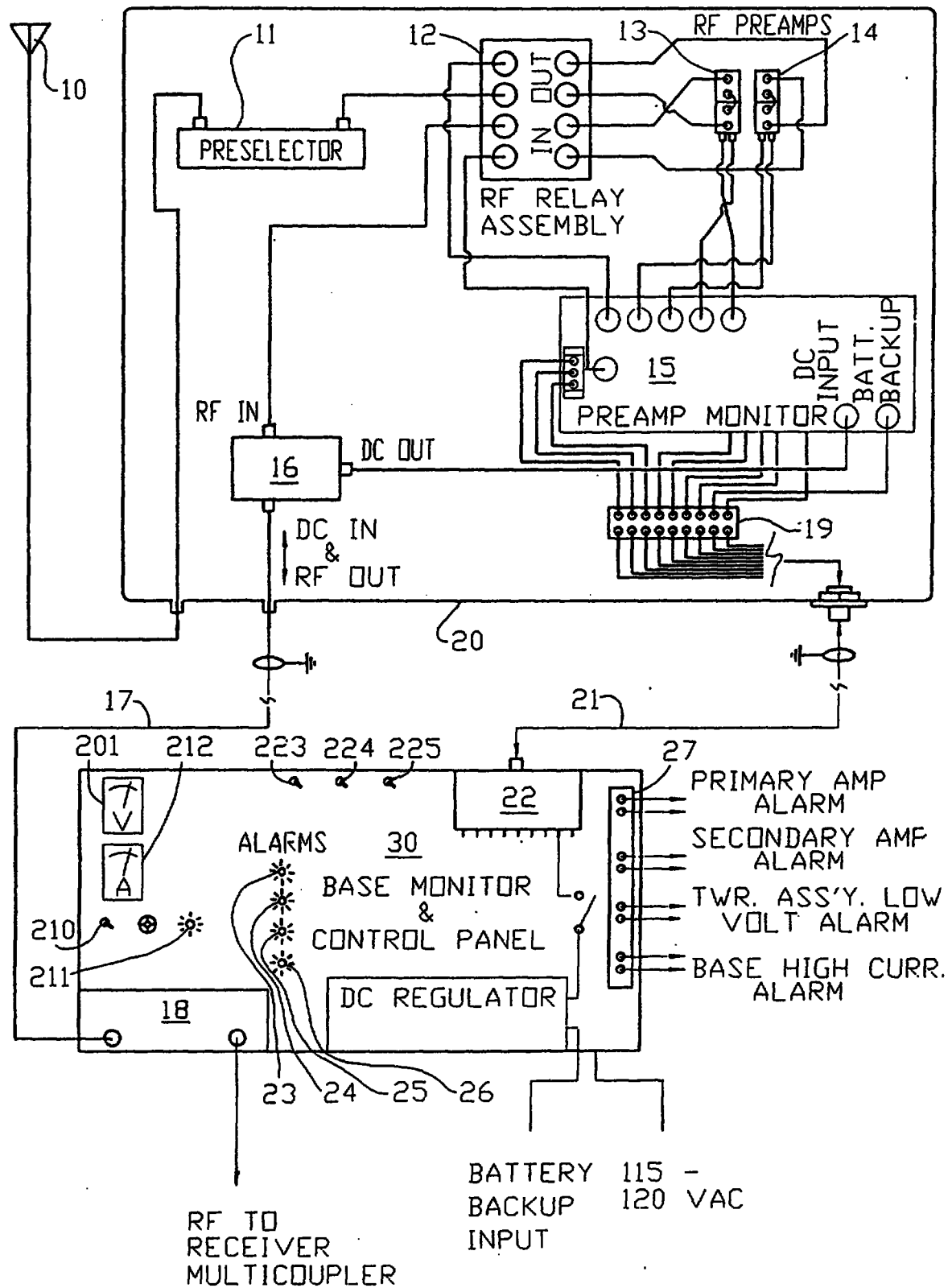


FIG. 1

RF TO SURGE SUPPRESSOR
/ DC PICKOFF AND
TRANSMISSION LINE

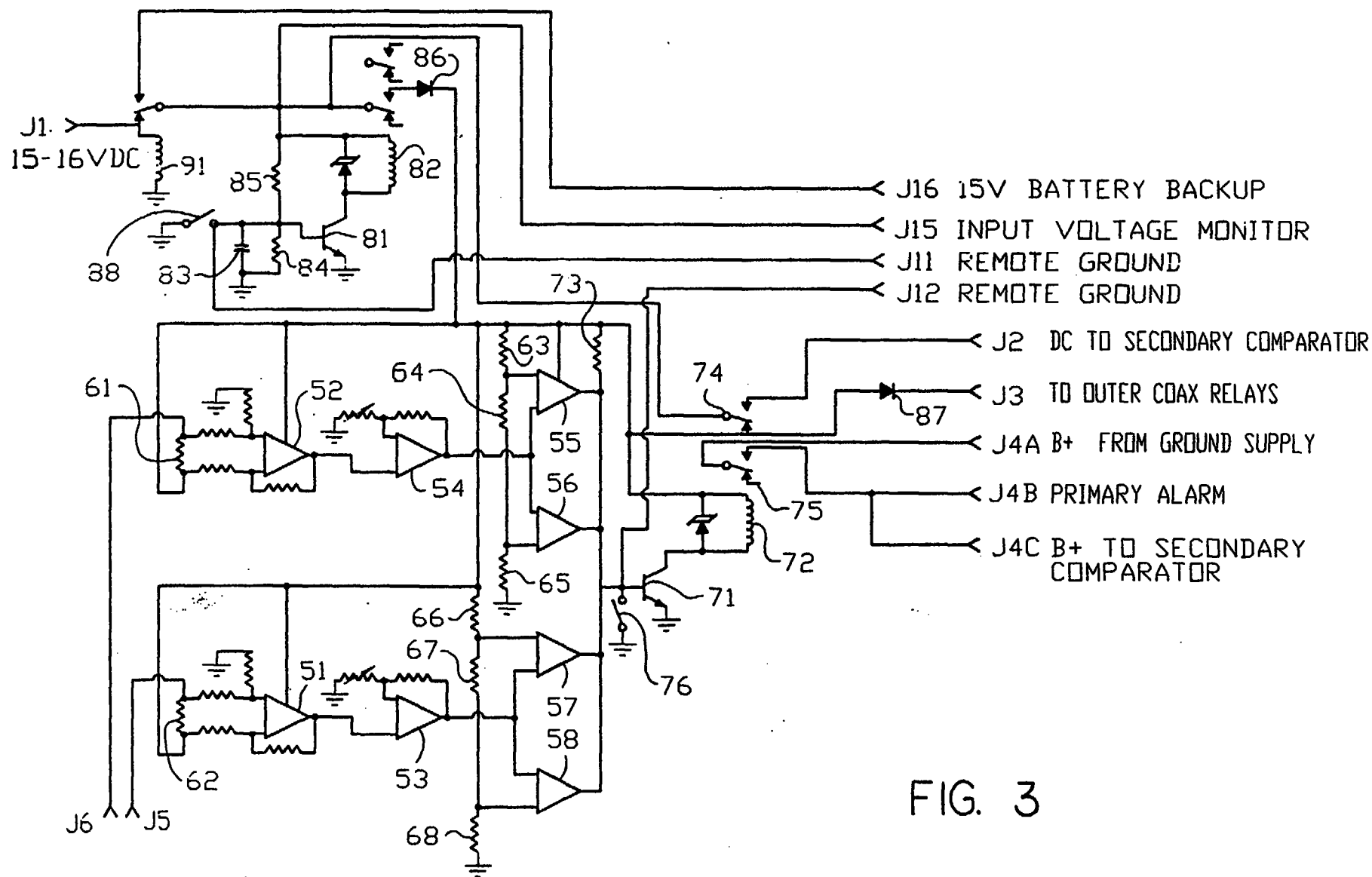


FIG. 3

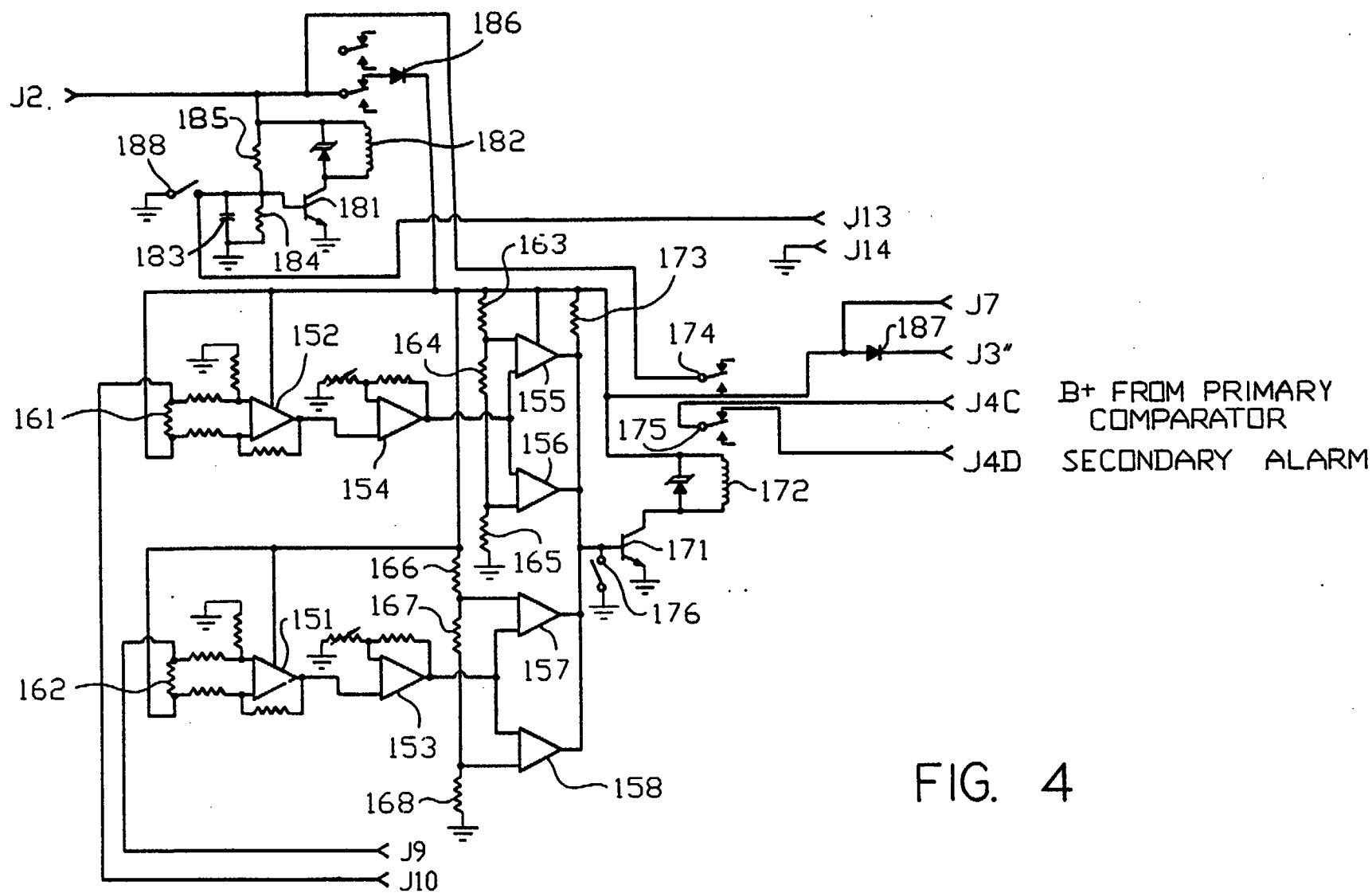


FIG. 4

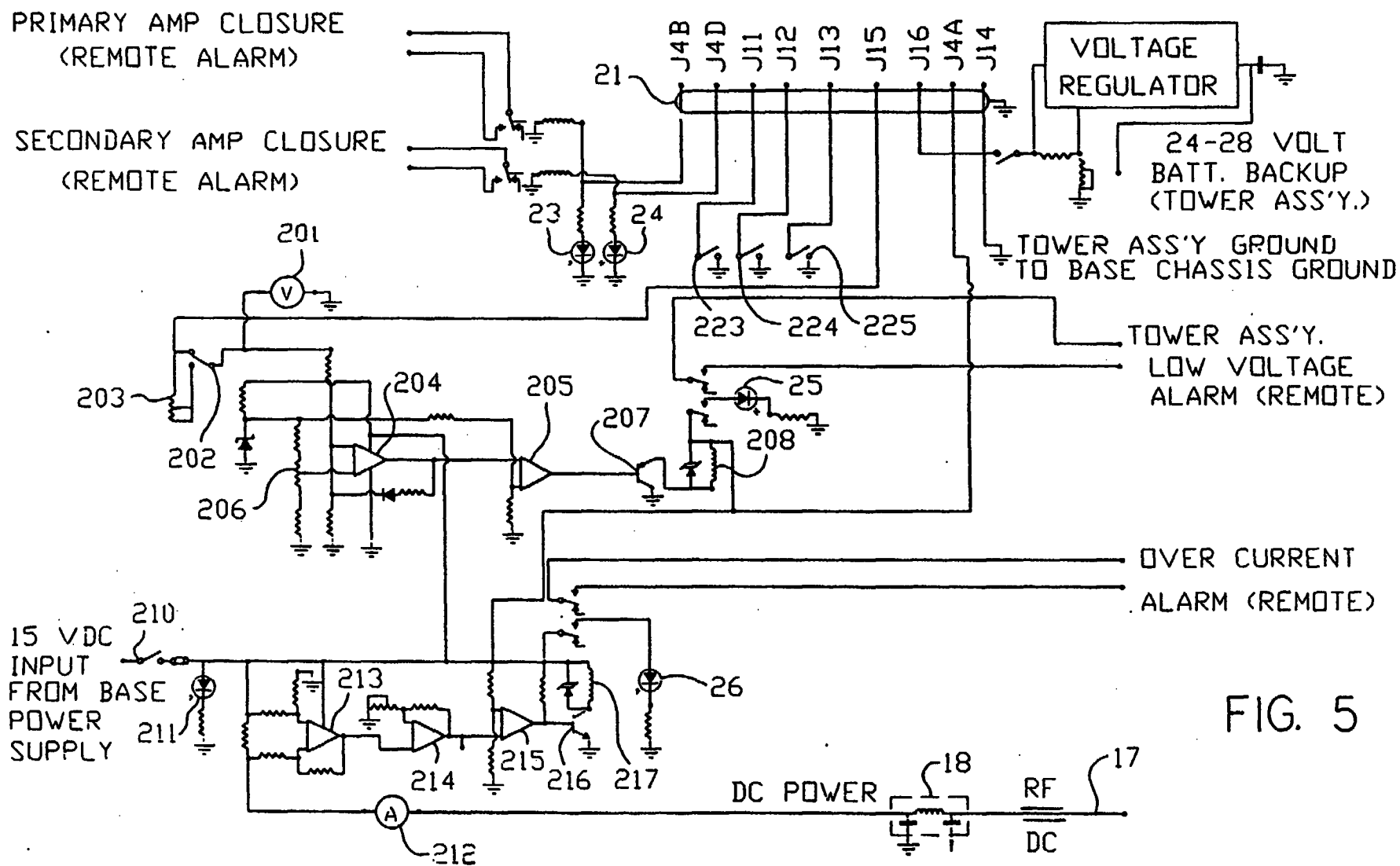


FIG. 5

extensive hardware required to provide the switching increases the probability of failure to a point which far exceeds any benefits which may be derived in overall reliability from inclusion of the spare circuit. An even more serious shortcoming of the Maggio et al system is the fact that the multi-pole, multi-throw relays incorporated in the system are satisfactory for high-frequency operation, but completely unsatisfactory for use with preamplifiers where radio frequencies are encountered.

Other examples of backup amplifier circuits may be found in United States Patents 1 396 745 (Haddock), 1 472 455 (Blattner), 1 525 054 (Toomy), 2 647 176 (Daly) and 2 773 944 (Karlson). None of the techniques utilised by these references lends itself to the use in a remote tower or to preamplifier systems operating in the radio frequency (RF) range.

In the forgoing systems, the "standby" method has an advantage over the "common redundant preamplifier" method. The redundant method connects two preamplifiers in parallel with input and output 3 db hybrids. The theory behind this is that if one amplifier fails, the second amplifier will maintain system operation, although at a reduced performance level due to an increase in noise and reduction in gain. Another drawback of the redundant method is that both preamplifiers are active in the system and both are vulnerable to damage by lightning.

Many of the above problems are eliminated by the teaching of U. S. Patent 4 565 972 for a "Tower Mounted Preamplifier", namely a preamplifier backup system which is located in the tower but activated at ground level by interrupting the direct current (DC) voltage to the tower-mounted preamplifier assembly for a short time duration. This operates a latching relay which switches DC power and RF signals alternately between either of two identical preamplifiers each time the power is interrupted. This is usually done manually at the site after poor signal reception has been experienced, although the switching could be done remotely via a modem and telephone line or other radio link to the modem.

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5 The RF relay assembly 12 provides an RF signal output mutually and exclusively from the primary preamplifier 13, backup preamplifier 14 or a preamplifier bypass circuit as illustrated in Fig. 2. This signal passes through a polyphaser, surge suppressor and DC pick-off circuit 16 and then through a tower transmission line 17 to the base monitor and control panel 30.

10 The panel 30 includes an RF surge suppressor and DC injector 18. This circuit couples the RF signal to a receiver multicoupler and injects 15 volts DC onto the line 17 to provide power to the tower-mounted circuits via the DC pick-off section of the circuit 16.

15 A polyphaser surge suppressor 19 connects the monitor assembly 15 to the panel 30 via a 9-conductor alarm and control cable 21. This cable passes DC control and monitoring voltages through surge suppressor 22 to activate LED alarm 23 which indicates that the primary preamplifier is off line, LED alarm 24 which indicates that the backup preamplifier is off line, and LED alarm 25 which indicates low voltage in the tower-mounted assembly. LED alarm 26 indicates high current on the line 17 and is monitored by a circuit on the panel 30.

20 The panel 30 also includes a supervisory system terminal strip 27 which provides a means to connect the four signals that activate the panel alarms 23 to 26 to remote alarm relays, which use a floating ground completed via the terminal strip 27. A connection 25 29 for a backup battery power source to be used in the event of a power supply failure is located on the panel 30.

In the following description, a preferred embodiment incorporating relays is described. However, any one or all may be replaced by electronic circuits, such as flip-flops.

30 In Fig. 2, the signals received at the antenna 10 are applied through the preselector 11, namely a bandpass preselector filter, to the pole contact of a single-pole, double-throw RF coaxial relay 32 which is energised through connector J3 which is connected to connectors J3 of the primary and backup preamplifier DC comparator circuits illustrated in Figs. 3 and 4, respectively. While relay 32 is energised, it connects the signal to the pole of a single-pole,

35

If any one of the comparators 55, 56, 57 and 58 switches to a low impedance, it will turn off transistor 71, and de-energise relay 72. This causes the normally closed contact set 74 of relay 72 to close, disconnecting the DC potential to the primary voltage comparator circuit and connecting the positive DC potential to the secondary or backup operating preamplifier voltage comparator circuit. The backup operating preamplifier voltage comparator circuit provides B+ voltage to the backup preamplifiers, the backup preamplifier comparator circuit illustrated in Fig. 4 via connector J2, the relays 32 and 40 via connector J3 and the relays 34 and 39 via connector J7. If the backup preamplifier is operating properly, relays 32 and 40 will remain energised by the backup comparator circuitry and relays 34 and 39 will become energised to switch the backup preamplifier into the signal channel in place of the primary preamplifier.

De-energising relay 72 closes contact set 75 so that voltage B+ is supplied from the power supply source at the tower base to the primary alarm via connectors J4A and J4B and to the backup alarm relay via connectors J4C and J4D.

Closing switch 76 will turn off transistor 71 to disable the primary preamplifier as if one of the comparators had switched to low impedance. This can also be accomplished by applying a remote ground to the base of the transistor via connector J12.

Switching between preamplifiers or initialising the system can result in out-of-limit comparisons until the amplifiers stabilise. Therefore a delay circuit is required.

When the system is first activated and power applied to the tower-mounted preamplifier assembly, the active preamplifier requires a short period of time to stabilise in current and for control relay 72 to energise and close its normally open contact sets which control the flow of DC power to the backup preamplifier as well as the primary preamplifier comparator, the primary preamplifier, and the RF coaxial relays.

DC power is received from the polyphaser surge suppressor 16 of Fig. 1 via connector J1 at the primary power distribution delay circuit input of Fig. 3 to provide a B+ source to power the

activates an alarm closure at connectors J4A and J4B, indicating that the primary preamplifier has been switched out. It should be noted that all DC power is removed from the primary preamplifier and comparator circuitry when a fault is detected. Diode 87 prevents
5 voltage present at relays 32 and 40 from powering up the primary preamplifier circuits when the backup preamplifier is on line.

Switches 88 and 76 are setup devices used to permanently deactivate relays 82 and 72, respectively.

If a power supply failure occurs and DC power is not available
10 at connector J1, relay 91 is de-energised and power is supplied from a battery and voltage regulator at the base through connector J16. Monitoring of the tower-mounted assembly voltage at the base permits the voltage regulator to be adjusted to the proper DC voltage at the tower-mounted assembly.

When the primary preamplifier fails, DC power is supplied to
15 connector J2 of Fig. 4 from the closed contact set 74 of the de-energised relay 72 of the primary amplifier circuit illustrated in Fig. 3. Connector J2 is the input to the backup power distribution delay circuit of Fig. 4 which provides a B+ source to power the
20 backup voltage comparator circuit. This circuit is controlled by the delay transistor 181 which is turned on when capacitor 183 is charged and its base is positive (0.7 to 1.0 volts). The ratio of resistor 184 to resistors 184 + 185 is about 13 to 1 so the 15 volt
25 input places 1.9 volts at the base of the delay transistor 181 when capacitor 183 is fully charged through resistor 185. The delay thus set by the RC time constant of capacitor 183 and resistor 184 delays the energisation of relay 182 which creates the settling time required by the preamplifier circuits by powering the backup
30 operating voltage circuit until relay 172 energises. If relay 172 does not energise before relay 182, the backup preamplifier will not come on line.

In the backup preamplifier comparator circuits of Fig. 4, resistors 161 and 162 are connected in series with the DC power to
35 high-level and low-noise preamplifier stages, 38 and 37, of Fig. 2 respectively via connectors J10 and J9. The value of these

5 6. An amplifier system according to claim 5, characterised by a backup power distribution delay circuit (181 to 185) for energising the backup operating voltage comparator circuit (151 to 158) for a predetermined period of time upon activation by voltage supplied in parallel to the backup operating voltage comparator circuit by the operating voltage switching means.

10 7. An amplifier according to claim 2 or claim 4, characterised in that the amplifier circuits (13, 14), bypass circuit (43), amplifier switching means (12), generating means (15), comparator circuits (51 to 58; 151 to 158) and operating voltage switching means are contained in a tower-mounted housing (20) and the power supply is located at the base of a tower supporting the housing.

15 8. An amplifier system according to claim 7, characterised by a tower transmission line (17) for conducting direct current power from the power supply to the primary operating voltage comparator circuit (51 to 58).

20 9. An amplifier system according to claim 8, characterised by a voltage comparator (204, 205) electrically connected to compare the voltage level of direct current power supplied by the tower transmission line (17) to the operating voltage switching means with a preset voltage level, low voltage switching means (207, 208) driven by the voltage comparator (204, 205) and arranged to change state in response to an output signal from the voltage comparator indicative of the compared voltage level falling below said preset level, and an alarm circuit (25) activated by the change in state of the low voltage switching means.

30 10. An amplifier system according to claim 8, characterised by a current monitor circuit (213 to 215) electrically connected to monitor current flow through the tower transmission line (17), high current alarm switching means (216, 217) driven by the current monitor circuit (213 to 215) and arranged to change state in response to an output signal from the current monitor circuit indicative of the monitored current exceeding a preset level, and a high current alarm circuit (26) activated by the change in state of the high current alarm switching means.



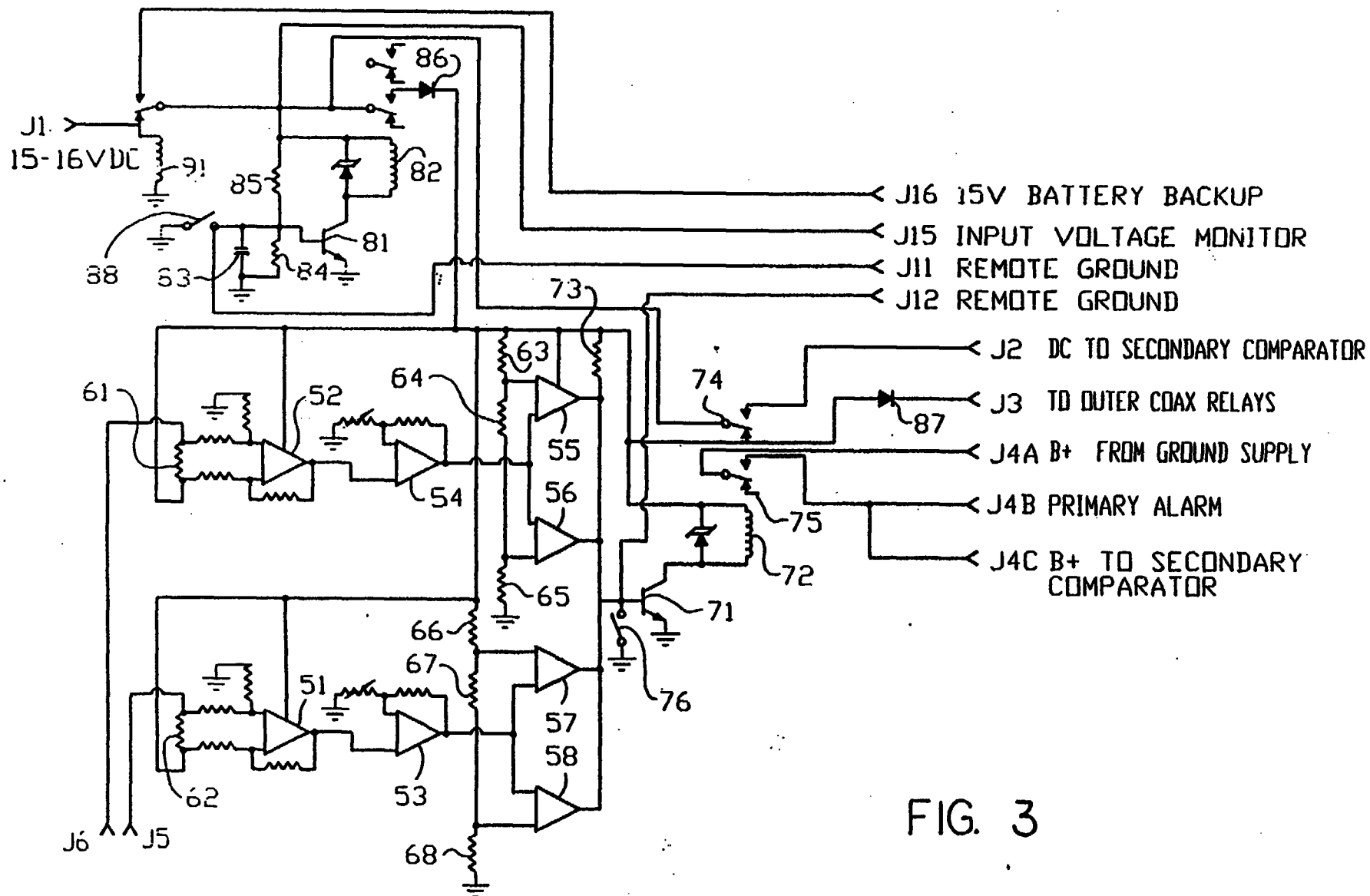


FIG. 3

CLAIMS

1. An amplifier system comprising an input transmission line, an output transmission line, a primary amplifier circuit (13) and a backup amplifier circuit (14), characterised by a bypass circuit (43), amplifier switching means (12) for mutually exclusively
5 connecting the primary amplifying circuit (13), the backup amplifying circuit (14) and the bypass circuit (43) between the lines, and generating means (15) for generating a primary failure signal in response to an abnormal current draw of the primary amplifier circuit (13) and a backup failure signal in response to an
10 abnormal current draw of the backup amplifier circuit (14), wherein the amplifier switching means (12) is operable to automatically disconnect the primary amplifier circuit (13) from and automatically connect the backup amplifier circuit (14) between the lines in response to the primary failure signal and to disconnect the backup amplifier circuit (14) from and
15 connect the bypass circuit (43) between the lines in response to the backup failure signal.
2. An amplifier system according to claim 1, characterised by an amplifier system power supply, a primary operating voltage comparator circuit (51 to 58), a backup operating voltage comparator
20 circuit (151 to 158), and operating voltage switching means responsive to the primary failure signal for mutually exclusively energising the comparator circuits with voltage supplied by the power supply.
3. An amplifier system according to claim 2, characterised in
25 that the generating means (15) is operable to generate the primary failure signal in response to the current draw of the primary amplifier circuit (13) exceeding a preset upper limit or lower limit when connected between the lines and to generate the backup failure signal in response to the current draw of the backup amplifier
30 circuit (14) exceeding a preset upper limit or lower limit when connected between the lines.

