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(54) Improved antenna assembly

(57) An antenna assembly (1,50), a heated window incorporating such an antenna assembly and a method of heating such a window are disclosed. The antenna assembly (1,50) comprises at least two heating elements (3,5), each arranged to be in electrical communication with a direct current power supply. There is an antenna connection point (21,31) associated with each heating element that is in electrical communication with a respective heating element. An antenna decoupling means (24,34) is arranged to be in electrical communication on the one side with the antenna connection point and on the other side with a radio receiving means. There are means (19a,19b,29a,29b) of electrically isolating the heating element and the antenna connection point from the direct current power supply. At least one heating element is arranged to be in electrical communication with the direct current power supply via a smooth switching means, such as a MOSFET (37).

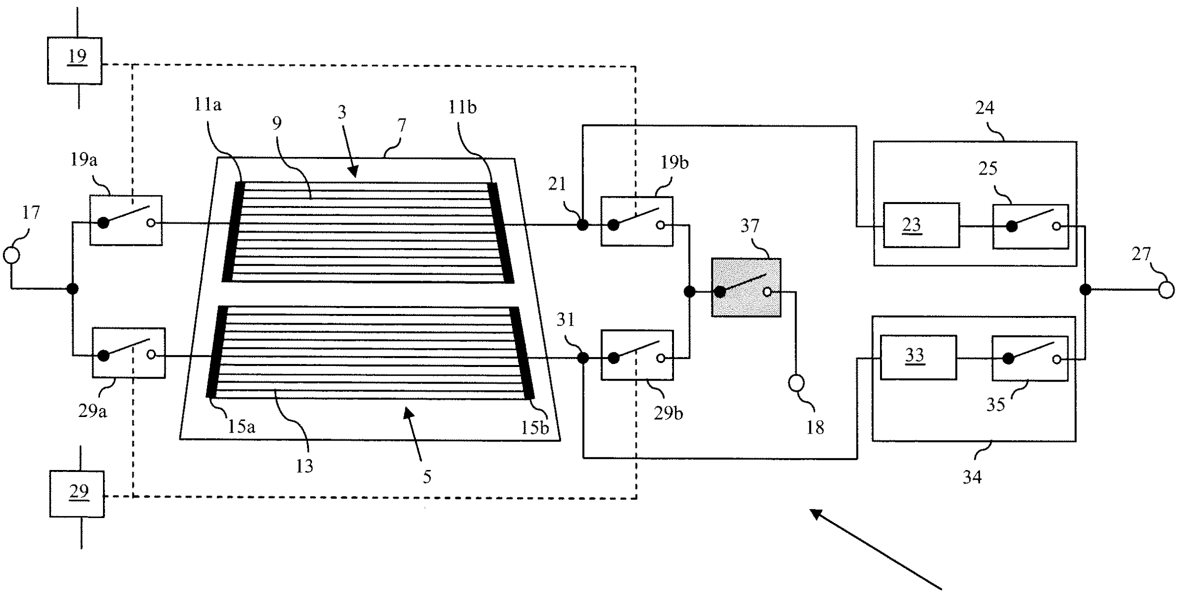

Figure 1

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Description

[0001] The present invention relates to an antenna assembly, a heated window incorporating such an antenna assembly and a method of heating such a window.

[0002] It is known to provide both an antenna and a heating element on a vehicle window. However in certain vehicles, for example compact or hatchback cars, there is a relatively small rear window and it is not possible to incorporate an antenna separate from the heating element because the available area is too small and radio reception would be poor, especially for the reception of AM radio.

[0003] In JP 51-19741 a solution to this has been proposed whereby the rear heated window of a vehicle has been arranged so that there are two separate heating elements, one at each side of the window. In operation, one heating element functions as a heater and can be used for defrosting or demisting purposes whilst the other heating element is used as an antenna. After a period of time the function of the two heating elements is switched so that the heating element that was heating the window becomes the antenna and the heating element that was functioning as an antenna becomes the heater and consequently the entire rear window can be defrosted or demisted while receiving a radio signal. A similar solution has been proposed in JP 62-020401. This disclosure describes a vehicle heated rear window antenna system wherein there are two heating elements, an upper and a lower, that can independently function either as a heater or as an antenna.

[0004] The problem with both systems is that there is electromagnetic interference noise introduced into the received signal when a heating element is switched between a heating function and an antenna function. In the case of a radio signal an audible click will be heard on the received broadcast.

[0005] It is therefore an object of the present invention to provide an improved antenna assembly for use in a heated window and suitable for the reception of amplitude modulated (AM) radio signals. It is a further object of the present invention to provide a heated window that incorporates such an improved antenna assembly. It is another object of the present invention to provide an improved method of heating a window wherein the window comprises an improved antenna assembly.

[0006] According to a first aspect the present invention provides an antenna assembly comprising at least two electrically conductive heating elements, each heating element arranged to be in electrical communication with a direct current power supply; an antenna connection point associated with each heating element, said antenna connection point being in electrical communication with a respective heating element; an antenna decoupling means arranged to be in electrical communication on the one side with the antenna connection point and on the other side with a radio receiving means; a means of electrically isolating each heating element and its associated antenna connection point from the direct current power supply, such that radio signals may be received from each heating element; characterised in that the antenna assembly includes a smooth switching means, and at least one heating element is arranged to be in electrical communication with the direct current power supply via the smooth switching means.

[0007] The smooth switching means should be capable of switching a large electrical direct current without producing electromagnetic interference. For a typical "on/off" switch designed to switch large currents, such as an electromechanical relay, switching between the "on" and the "off" position generates electromagnetic interference noise. By switching "on" it is meant actuating the switch so that direct electrical current can flow through it and by switching "off" it is meant actuating the switch so that direct electrical current does not flow through the switch. When a switch is turned off it is often referred to as being in the "open" position because there is no electrical connection between the terminals of the switch and the switch is effectively open circuit to direct electrical current. Conversely, when a switch is turned on it is often referred to as being in the "closed" position because there is an electrical connection between the terminals of the switch. Conventional "on/off" switches of the kind found in electromechanical relays can either be fully "on" or fully "off" with no intermediate position. In terms of electrical resistance, such switches have a very high resistance R_{hc} when turned off and a very low resistance R_{lc} when turned on. As a consequence, the resistance of conventional switches changes suddenly between the two values R_{lc} and R_{hc}. By comparison, a smooth switching means has a low resistance R_{ls} when turned on, and a high resistance R_{hs}, when turned off, but the resistance of the smooth switching means when switched on decreases gradually over a period of time from R_{hs} to R_{ls} in a smooth manner, for example exponentially. Suitably the time taken for the smooth switching means to switch on, T_s, is longer than the time taken for a conventional "on/off" switch to switch on, T_c.

[0008] For a particular heating element to function as an antenna, that heating element and antenna connection point must be electrically isolated from the direct current power supply. When the means of electrically isolating the heating element and antenna connection point is actuated, there is no direct electrical connection between the antenna connection point and either terminal of the direct current power supply. In addition there should be no indirect electrical connection between the antenna connection point associated with the heating element and either terminal of the direct current power supply. By an indirect electrical connection it is meant an electrical connection by capacitive or inductive coupling. Actuating the antenna decoupling means associated with a heating element that is directly or indirectly electrically connected to a direct current power supply prevents the received signal associated with a heating element that is functioning as an antenna from coupling to the direct current power supply such that the received signal is practically zero.

[0009] The heating element is electrically isolated after the electrical current flowing through the heating element has been reduced substantially to zero by the smooth switching means.

[0010] Suitably the smooth switching means comprises a semiconductor switching means. Preferably the semiconductor switching means comprises a transistor. The transistor could be part of a circuit that smoothly switches direct electrical current. Preferably the transistor is a field effect transistor. Preferably the field effect transistor is a MOSFET (metal oxide semiconductor field effect transistor).

[0011] The smooth switching means should be selected so that during the switching time T_s, the variation of direct electrical current with time through the smooth switching means varies in such a way that the generation of harmonics, preferably in the AM and FM radio ranges, and in the frequency range of other antennae in the vicinity of the antenna assembly, is reduced.

[0012] The antenna decoupling means is able to decouple the heating element from the radio receiving means so that the received signal associated with that heating element no longer reaches the radio receiving means. When a heating element is functioning as a heater and not as an antenna, the antenna decoupling means is able to prevent the received signal from any other heating element that is functioning as an antenna from being coupled to the heating element that is functioning as a heater so that the received signal is not coupled to the direct current power supply.

[0013] Preferably the antenna decoupling means comprises an antenna connection switch. Suitably the antenna connection switch comprises a relay, preferably an electromechanical relay, even more preferably a microelectromechanical relay. Preferably the antenna connection switch comprises a semiconductor switching means. The preferred semiconductor switching means comprises a PIN diode, for example the antenna switch could be an electrical circuit comprising a PIN diode. A PIN diode can be used as a radio frequency (RF) switch. In the forward direction a PIN diode can be biased sufficiently to ensure it has a low resistance to the RF that needs to be passed and can be considered to be switched on. When a reverse bias is applied the PIN diode it acts as an open circuit, with only a relatively small level of capacitance, and can be considered to be switched off.

[0014] The antenna decoupling means is electrically connected in series with the heating element such that the impedance of the antenna decoupling means when arranged to decouple the heating element from the radio receiving means must be much higher than that of the heating element to get an effective attenuation of the received signal in the heating element.

[0015] Preferably the antenna decoupling means comprises an impedance converter arranged to be in electrical communication with the antenna connection point. Preferably the impedance converter is electrically connected in series with the antenna connection point. Suitably the impedance converter changes the impedance of the heating element to which it is in electrical communication with by lowering the impedance of that heating element, preferably by lowering the impedance of the heating element by at least a factor of 10, more preferably by at least a factor of 100. Preferably the impedance converter reduces the impedance of the heating element to which it is connected so that that heating element has lower impedance than the antenna connection switch when turned off. When the antenna connection switch is turned on the impedance of the antenna connection switch should be as low as possible.

[0016] Suitably the means of electrically isolating the heating element from the direct current power supply comprises a first and second switching means, wherein one side of the first switching means is arranged to be in electrical communication with the heating element and on the other side with the first terminal of the direct current power supply, and the second switching means is arranged to be in electrical communication on the one side with the heating element and on the other side with the second terminal of the direct current power supply, so that when both the first and second switching means are switched off the heating element and the antenna connection point are electrically isolated from the direct current power supply. The first and second switching means are preferably relays, suitably electromechanical relays or microelectromechanical relays.

[0017] Suitably the first terminal of the direct current supply is arranged to be at a higher potential than the other terminal. Typically the direct current power supply is a battery, suitably at 12 volts or higher, for example 42 volts.

[0018] It is preferable to have the first and second switching means arranged so that they may be actuated at the same time. When using relays the first and second switching means can conveniently be part of the same component, for example a double pole double throw type electromechanical relay.

[0019] Suitably any or all of the switches or switching means can be switched directly by a microcontroller.

[0020] An antenna assembly of the present invention could be used for the reception of amplitude modulated (AM) radio signals and possibly for the reception of AM radio signals and frequency modulated (FM) radio signals. Suitably an antenna assembly of the present invention could be used in combination with one or more secondary antenna for the reception of other radio signals such as FM radio signals. The one or more secondary antenna will have an antenna connection point associated therewith which will be arranged to be in electrical communication with the radio receiving means.

[0021] According to the present invention in a second aspect, there is provided a heated window comprising at least one pane of optically transparent glazing material and an antenna assembly according to the first aspect of the present invention.

[0022] When the heated window is a rear heated window in a vehicle such as a car, the use of more than one heating element to demist the field of view of the window, and the fact that it is heated intermittently, means that more power has to be supplied to the heating element that is functioning as a heater, compared to a conventional rear heated window. Consequently a higher electrical current is needed to flow in the heating element of the present invention. At a set operating voltage, the electrical resistance of the two or more heater elements needs to be reduced, for example by using a more electrically conductive paint, or printing thicker lines.

[0023] However if a high voltage non-standard direct current power supply is available, for example a 42 volt supply instead of a 12 volt supply, the higher voltage means the electrical resistance of the heater elements need not be reduced so that standard methods of production of the heating elements can be used to produce the heated window.

[0024] According to the present invention in a third aspect, there is provided a method of heating a heated window according to the second aspect of the invention, said heated window comprising a first and second heating element wherein the first heating element is in electrical communication with the a direct current power supply; the second heating element is electrically isolated from the direct current power supply; the antenna connection point associated with the second heating element is in electrical communication with a radio receiving means and the antenna connection point associated with the first heating element is decoupled from the radio receiving means, the method comprising the steps of smoothly switching off the electrical current to the first heating element; electrically isolating the first heating element from the direct current power supply; coupling the first heating element to the radio receiving means, such that the first heating element is brought into electrical communication with the radio receiving means; decoupling the second heating element from the first radio receiving means; making the electrical connection between the second heating element and the power supply, such that the electrical current is switched on smoothly.

[0025] Smoothly switching off the electrical current to the first heating element reduces the amount of electromagnetic interference produced. If the first heating element is electrically isolated from the direct current power supply by a first and second switching means that comprise relays then the first and second relays are opened when little or substantially zero electrical current is flowing in the first heating element because the smooth switching means is switched off.

[0026] When there is no direct electrical current flowing in the first heating element and the first antenna connection point is decoupled from the direct current power supply, the first heating element can function as an antenna.

[0027] Suitably the step of bringing the antenna connection point associated with the first heating element into electrical communication with the radio receiving means takes place whilst the antenna connection point associated with the second heating element is still in electrical communication with the radio receiving means.

[0028] The present invention will now be described, by way of example only, with reference to the drawings that follow, in which;

Figure 1 is a schematic of one embodiment of an antenna assembly according to the first aspect of the present invention;
Figure 2 is a functional flow diagram of a method of operation of the heated window comprising the antenna assembly of figure 1;
Figure 3 is a timing diagram showing the sequence of switching when using a method of the invention;
Figure 4 is a graph showing the performance of a heated window incorporating an antenna assembly as shown in figure 1 when the first heating element is used as an antenna and the second heating element is used as a heater;
Figure 5 is a graph showing the suppression of electromagnetic interference when using a PIN diode;
Figure 6 is a graph showing the effect on the signal reception when using either the first or second heating element as an antenna with no heater function;
Figure 7 is a graph showing the improvement in signal reception by using an impedance converter; and
Figure 8 is a schematic of another embodiment of an antenna assembly of the present invention.

[0029] The antenna assembly 1 shown in figure 1 has two heating elements, a first heating element 3 and a second heating element 5. The heating elements could be one above the other as in this particular example, they could be side by side, or some other configuration. In this particular example the heating elements 3 and 5 are incorporated into a vehicle rear window 7. As an alternative, the heating elements may be incorporated into a vehicle windscreen. The antenna assembly shown in figure 1 was used to receive radio signals in the AM frequency range. The same antenna assembly may be used for the reception of radio signals in the FM frequency range. Alternatively, a separate antenna may be used for the reception of radio signals in the FM frequency range.

[0030] The first heating element 3 comprises a number of substantially horizontally spaced heating lines 9 connected by busbars 11a and 11 b. The second heating element 5 comprises a number of substantially horizontally spaced heating lines 13 connected by busbars 15a and 15b. The heating lines 9 and 13 are made of an electrically conductive paint. The heating lines 9 and 13 could also be thin wires, for example made of tungsten, or they could be formed from an electrically conductive coating, that may be transparent, which has been deposited onto an optically transparent glazing material.

[0031] Terminal 17 is connected to the positive terminal of a 12 volts direct current power supply (not shown) and terminal 18 is connected to ground.

[0032] Electromechanical relay 19 contains two switches 19a and 19b which can both be switched on or off at the same time (a double throw double pole type electromechanical relay). When switches 19a and 19b are switched off the first heating element 3 is electrically isolated from the direct current power supply and can function as an antenna for radio waves.

[0033] The first antenna connection point 21 is electrically connected via a first antenna decoupling means 24 to a radio receiving means (not shown) connected to terminal 27. The first antenna decoupling means comprises a first impedance converter 23 and a first antenna connection switch 25. The first impedance converter 23 and the first antenna connection switch 25 are able to decouple the first heating element 3 from the radio receiving means and the second heating element 5. The first antenna connection switch is a PIN diode. A GaAs transistor is an alternative. When the first antenna connection switch is turned on, then with the first heating element 3 electrically isolated from the direct current power supply, the first heating element is selected for use as an antenna for radio waves.

[0034] Electromechanical relay 29 contains two switches 29a and 29b which can both be switched on or off at the same time. When switches 29a and 29b are open the second heating element 5 is electrically isolated from the direct current power supply and can function as an antenna for radio waves.

[0035] The second antenna connection point 31 is electrically connected via a second antenna decoupling means 34 to a radio receiving means (not shown) connected to terminal 27. The second antenna decoupling means comprises a second impedance converter 33 and a second antenna connection switch 35. The second antenna connection switch is a PIN diode. A GaAs transistor is an alternative. For improved signal reception when the second heating element is functioning as a heater, the first heating element should be electrically isolated from the direct current power supply and the first antenna connection point 21 (which is in electrical communication with the radio receiver via the first antenna decoupling means 24), and the second antenna connection point 31 should be decoupled from the radio receiving means.

[0036] Electrical current flow to heating element 3 or 5 is controlled by the relays 19 and 29 and MOSFET 37. Typically between 10 and 30 amps flows through the heating element when it functions as a heater. The first and second switching means associated with a heating element and the smooth switching means must be able to switch such high electrical current. The relays 19 and 29 are switched on or off only when the MOSFET 37 is in the off position i.e the MOSFET 37 has been switched off. This reduces the amount of electromagnetic interference because no electrical current is flowing when the relay 19 or 29 is switched. All the switches were controlled by a microcontroller (not shown).

[0037] The one or more of the switches 19a, 19b, 29a and 29b could be replaced by a semiconductor switching means provided such switching means was able to adequately decouple the heating element from the direct current power supply and not couple to the direct current power supply by indirect means such as capacitive or inductive means. A capacitance of less than 50pF may be preferable. If one of the switches 19a or 19b and one of the switches 29a or 29b are replaced by semiconductor switching means, for example a MOSFET, then the MOSFET 37 is not required because the smooth switching is provided by the smooth switching means that has replaced switches 19a or 19b and 29a or 29b.

[0038] The switches 19a, 19b, 29a or 29b need to switch the heating current, which may be of the order of 10-30 amps. These switches could be replaced by micromechanical electromagnetic relays, when examples of the latter become available which are suitable for switching the currents involved.

[0039] Figure 2 shows a flow diagram illustrating the sequence of steps of the antenna assembly in operation. The start of the sequence of steps is at position 90. Prior to the start 90 of this sequence of steps, the relays 19 and 29, the PIN diodes 25 and 35 and the MOSFET 37 are switched off. No current is flowing in either heating element and neither heating element is functioning as an antenna because the PIN diodes 25 and 35 have decoupled the heating elements 3 and 5 from the radio receiving means.

[0040] In step 100 the first heating element is set to function as an antenna by switching PIN diode 25 on, connecting the first heating element 3 to the radio receiver. There is a short delay, typically 100ms, before the next step 102.

[0041] Step 102 is a decision step where it is determined if it heating is required. If no heating is required then path 101 is followed. If in step 102 it is found that heating is required, the sequence of steps follows path 103 and moves on to step 104.

[0042] In step 104 the relay 29 is switched on so that switches 29a and 29b are closed and electrical current can flow through the heating element 5 once the electrical circuit is completed. There is a short delay, typically 100ms, before moving to step 106.

[0043] In step 106 the MOSFET 37 is switched on. This completes the electrical circuit between the direct current power supply and the second heating element 5, allowing electrical current to flow in the second heating element 5 thereby generating heat in the heating lines 13. There is a delay of typically 100ms before moving on to step 108. The 100ms delay is used to ensure that the relays have switched securely, for example to ensure that the contacts have stopped bouncing.

[0044] In step 107 a timer is set to a time of 1000ms in the future. This 1000ms delay corresponds to the time the heating element is switched on and may be much longer.

[0045] Step 108 is a decision step where it is determined if the heating function is still required. If the heating function is required then the sequence follows path 110 and moves on to step 112. If the heating function is not required then the sequence follows path 109 and moves on to step 114.

[0046] Step 112 is another decision step. In step 112 the actual time is compared with the timer value set in step 107. If the actual time is less than the timer value set in step 107 then the sequence follows path 111 and moves back to step 108. This means that the second heating element 5 will be heating for a maximum of 1000ms (the value of the timer in step 107).

[0047] When the heating function is no longer required, either because of deliberate de-selection in the case of decision step 108 or because the time has exceeded the timer value set in step 107 the sequence moves on to step 114.

[0048] In step 114 the MOSFET 37 is switched off. This smoothly switches off the current to the second heating element 5 which reduces electromagnetic interference. There is a delay of typically 100ms before moving on to the next step 116.

[0049] In step 116 the relay 29 is switched off so that switches 29a and 29b are in the off position. This electrically isolates the second heating element from the direct current power supply. There is a delay of typically 100ms before moving on to step 118.

[0050] Step 118 is a decision step where it is determined if the heating function is required. If the heating function is not required then the sequence follows path 117 and moves back to step 102. If the heating function is still required then the sequence follows path 119 and moves on to step 120.

[0051] In step 120 the second PIN diode 35 is switched on so that the second heating element 5 can function as an antenna by connecting the second heating element 5 to the radio receiver. At this point, both heating elements 3 and 5 are functioning as antennae. There is a short delay, typically 100ms, before moving on to the next step 122.

[0052] In step 122 the first PIN diode 25 is switched off, disconnecting the first heating element 3 from the radio receiver so that heating element 3 no longer functions as an antenna. Switching off PIN diode 25 also decouples the first heating element from the second heating element so that there is no indirect path for the received radio signal to either terminal of the direct current power supply. At this point, only the second heating element functions as an antenna. There is a delay of typically 100ms before moving on to the next step 124.

[0053] In step 124 the first relay 19 is switched on so that switches 19a and 19b are in the on position and electrical current can flow through the first heating element once the electrical circuit between the first heating element and the direct current power supply has been completed. There is a short delay of typically 100ms before moving on to the next step.

[0054] In step 126 the MOSFET 37 is switched on. This completes the electrical circuit between the direct current power supply and the first heating element 3, allowing electrical current to flow in the first heating element 3 thereby generating heat in the heating lines 9. There is a delay of typically 100ms before moving on to step 127. In step 127 a timer is set to a time of 1000ms in the future.

[0055] Step 128 is a decision step where it is determined if the heating function is still required. If the heating function is required then the sequence follows path 130 and moves on to step 132. If the heating function is not required then the sequence of steps follows path 129 and moves on to step 134.

[0056] Step 132 is another decision step where the actual time is compared with the timer value set in step 127. If the actual time is less than the timer value set in step 127 then the sequence follows path 131 and moves back to step 128. This means that the first heating element 3 will be heating for a maximum of 1000ms the value of the timer in step 127. When the heating function is no longer required because the time has exceeded the timer value set in step 127 the sequence follows path 133 and moves on to step 134.

[0057] In step 134 the MOSFET 37 is switched off. This smoothly switches of the current to the first heating element which reduces electromagnetic interference. There is a delay of typically 100ms before moving on to the next step 136.

[0058] In step 136 the relay 19 is switched off so that switches 19a and 19b are in the off position. This electrically isolates the first heating element 3 from the direct current power supply. There is a delay of typically 100ms before moving on to step 138.

[0059] In step 138 the first PIN diode 25 is switched on so that the first heating element 3 can function as an antenna by connecting the first heating element to the radio receiver. At this point, both heating elements 3 and 5 are functioning as antennae. There is a short delay, typically 100ms, before moving on to the next step 140.

[0060] In step 140 the second PIN diode 35 is switched off, disconnecting the second heating element 5 from the radio receiver so that heating element 5 no longer functions as an antenna. This also decouples the second heating element from the first heating element so there is no indirect path for the received radio signals to either terminal of the direct current power supply. At this point, only the first heating element 3 functions as an antenna. Following a delay of typically 100ms, the sequence returns back to step 102.

[0061] Using this sequence of operations for the antenna assembly of shown in figure 1, the entire rear heated window was able to be demisted whilst functioning as an antenna with a reduced level of electromagnetic interference.

[0062] Figure 3 is a timing diagram showing the sequence of switching the relays 19 and 29, the PIN diodes 25 and 35 and the MOSFET 37 in the flow chart of figure 2. In this figure the time axis is represented by axis 198. A time of about one minute is represented by 200 and 202 represents a time of about one second. For clarity the time axis 198 has a break 206 to take into account the difference in the time periods 200 and 202. In this figure a low value for a particular switch means that switch is in the off position, and a high value means that that particular switch is in the on position. The sequence of switching may be controlled using a microprocessor.

[0063] For clarity, the corresponding steps in figure 2 have been marked on figure 3. Figure 3 starts just shortly after step 100 in figure 2. The point 204 corresponds to a point just after step 102 where is has been determined that heating is required and relay 29 is switched on (step 104). After a short delay the MOSFET 37 is switched on and smoothly connects the second heating element to ground (step 106). After a period of about a minute the MOSFET 37 is first switched off and smoothly disconnects the second heating element 5 from ground (step 114). After this, the relay 29 is switched off (step 116).

[0064] After a short delay the receiving antenna is changed from the first heating element to the second heating element. First PIN diode 35 couples the second heating element 5 to the radio receiving means so it can function as an antenna (step 120).

[0065] Next the first heating element 3 is decoupled from the radio receiving means and the second heating element (step 122). A similar sequence as described above starts for the first heating element 3. The relay 19 is switched on (step 124) following which the MOSFET 37 is switched on (step 126), smoothly connecting the first heating to the direct current power supply and heating begins. After about 1 minute, heating MOSFET 37 is switched off, smooth turning off the current to the first heating element (step 134). The relay 19 is then switched off (step 136).

[0066] Next, whilst the second heating element is still functioning as an antenna, the first PIN diode 25 couples the first heating element to the radio receiving means (step 136). The second heating element is then decoupled from both the radio receiving means and the first heating element by switching off PIN diode 35 (step 140). The timing sequence is then repeated as necessary.

[0067] At the end of heating all switches, except the first PIN diode 25, have to be switched off in the proper order. That is, the relays 19 and 29 are only switched off after the MOSFET 37 has been switched off.

[0068] Figures 4-7 show the sensitivity in various configurations of an antenna assembly of the present invention that was incorporated into a rear heated window of a vehicle. The heated window had a first upper and a second lower heating element. All measurements were compared to the level of a reference rod antenna at 0dB. The axis 296 represents frequency in MHz and the axis 298 represents the received signal strength in dB.

[0069] In figure 4, line 300 shows the performance of the antenna assembly shown in figure 1 when using the first upper heating element as an antenna and with the second lower one disconnected from the direct current power supply. The second heating element was decoupled from the radio receiving means. Line 302 shows the performance of the antenna assembly shown in figure 1 when using the first upper heating element as an antenna and when electrical current is passing through the second heating element and it is functioning as a heater. The second heating element was decoupled from the radio receiving means. Due to the capacitive coupling between the two heating elements there is a difference of around -2 to -3 dB, but both have better signal reception than a rod antenna.

[0070] Figure 5 shows the effect of using an antenna decoupling means in the form of a PIN diode in combination with an impedance converter to suppress electromagnetic interference noise. The first heating element was being used as an antenna and the second heating element was being used for heating. The second heating element was decoupled from the radio receiving means and the first heating element by the second antenna decoupling means. Line 304 shows the strength of the received radio signal when the first PIN diode is forward biased and switched on (otherwise known as being in the "on" state). Line 306 shows the signal strength when the first PIN diode is reverse biased and switched off (otherwise known as being in the "off" or "barricaded" state). The signal is suppressed 12-20dB because the first PIN diode is in the off state. When using the first heating element as an antenna and the second heating element for heating, electromagnetic interference noise can be introduced into the radio receiving means from the direct current power supply. When the second heating element functions as a heater it should be decoupled from the radio receiving means using the second antenna decoupling means for improved performance. The line 306 shows how effectively the PIN diode and impedance converter decouples the heating element from the direct current power supply.

[0071] Figure 6 shows a comparison of the response of the first and second heating elements when used as an antenna. Line 308 shows the response when the first heating element is used as an antenna and the second heating element is electrically isolated and decoupled from the radio receiving means. Line 310 shows the response when the second heating element is used as an antenna and the first heating element is electrically isolated and decoupled from the radio receiving means. For this particular heated window the first heating element gives about 3dB better signal reception. The combination of both heating elements being used as antennae when heating is not required gives no better performance so it is sufficient in this example to use only the upper heating element as an antenna.

[0072] Figure 7 shows the improvement in signal reception by using an impedance converter, in this particular case a FET transistor, as well as a PIN diode to decouple the heating element from the radio receiver. The first heating element was used as an antenna and the second heating element was electrically isolated from the direct current power supply and decoupled from the radio receiving means. Line 312 shows the signal at terminal 27 and line 314 shows the signal measured directly at the first antenna connection point of the first heating element. The signal strength is improved by about 2 to 3dB up to about 3MHz when using this particular impedance converter.

[0073] Figure 8 shows another embodiment of the present invention in which relays 19 and 29 and MOSFET 37 have been removed. Switches 19a, 19b, 29a and 29b have each been replaced with a MOSFET. The antenna assembly 50 shown in figure 8 has two heating elements, a first heating element 3 and a second heating element 5. The first heating element 3 comprises a number of horizontally spaced heating lines 9 connected by busbars 11a and 11b. The second heating element 5 comprises a number of horizontally spaced heating lines 13 connected by busbars 15a and 15b. Terminal 17 is connected to the positive terminal of a 12 volts direct current power supply not shown and terminal 18 is connected to ground. Electrically connected on one side of the first heating element 3 is a first MOSFET 40. Electrically connected to the other side of the first heating field is a second MOSFET 42. A first antenna connection point 21 is located along the electrical connection between the first heating element and the second MOSFET. When MOSFETs 40 and 42 are switched off the first heating element 3 is electrically isolated from the direct current power supply. The first antenna connection point 21 is electrically connected via a first antenna decoupling means 24 to a radio receiving means (not shown) connected to terminal 27.

[0074] Electrically connected on one side of the second heating element 5 is a third MOSFET 44. Electrically connected to the other side of the second heating field is a fourth MOSFET 46. A second antenna connection point 31 is located along the electrical connection between the second heating element and the fourth MOSFET. When MOSFETs 44 and 46 are switched off the second heating element 5 is electrically isolated from the direct current power supply. The second antenna connection point 31 is electrically connected via a second antenna decoupling means 34 to a radio receiving means (not shown) connected to terminal 27.

[0075] Better performance is achieved when the MOSFETs have low capacitance when switched off, preferably less than 100pF, more preferably less than 50pF. The capacitance associated with a MOSFET can couple high frequency radio signals to the direct current power supply via capacitive coupling and reduce the signal strength that reaches terminal 17. When the antenna decoupling means comprises an impedance converter there is little advantage in the MOSFET having a significantly lower capacitance than the impedance converter, which has an input impedance of about 15 pF.

[0076] Other suitable smooth switching means includes other transistors, or mechanical relays with an L-C network. Typically the resistance of the smooth switching means when switched on is low, suitably less than 10mOhms, so that a heat sink is not required.

Claims

1. An antenna assembly (1, 50) comprising

   at least two electrically conductive heating elements (3, 5)
   each heating element arranged to be in electrical communication with a direct current power supply;
   an antenna connection point (21, 31) associated with each heating element, said antenna connection point being in electrical communication with a respective heating element;
   an antenna decoupling means (24, 34) arranged to be in electrical communication on the one side with the antenna connection point and on the other side with a radio receiving means;
   a means of electrically isolating each heating element and its associated antenna connection point from the direct current power supply, such that radio signals may be received from each heating element;

   characterised in that the antenna assembly includes a smooth switching means, and at least one heating element is arranged to be in electrical communication with the direct current power supply via the smooth switching means.

2. An antenna assembly according to claim 1 wherein the smooth switching means comprises a semiconductor switching means.

3. An antenna assembly according to claim 2 wherein the semiconductor switching means comprises a transistor.

4. An antenna assembly according to claim 3, wherein the transistor is a field effect transistor.

5. An antenna assembly according to claim 4, wherein the field effect transistor is a MOSFET (37, 40, 42, 44, 46).

6. An antenna assembly according to any of the preceding claims, wherein the antenna decoupling means comprises an antenna connection switch (25, 35), preferably a relay, more preferably an electromechanical relay, even more preferably a micromechanical relay.

7. An antenna assembly according to claim 6, wherein the antenna connection switch comprises a semiconductor switching means.

8. An antenna assembly according to claim 7, wherein the semiconductor switching means comprises a PIN diode.

9. An antenna assembly according to any of the preceding claims, wherein the antenna decoupling means comprises an impedance converter (23, 33) arranged to be in electrical communication with the antenna connection point.

10. An antenna assembly according to claim 9, wherein the impedance converter changes the impedance of the heating element to which it is in electrical communication with by lowering the impedance of that heating element, preferably by lowering the impedance of the heating element by at least a factor of 10, more preferably by at least a factor of 100.

11. An antenna assembly according to either of claims 9 or 10 wherein the impedance converter changes the impedance of the heating element to which it is in electrical communication with by lowering the impedance of that heating element so that the heating element has lower impedance than the antenna connection switch.

12. An antenna assembly according to any of the preceding claims, wherein the means of electrically isolating the heating element from the direct current power supply comprises a first and second switching means, wherein one side of the first switching means is arranged to be in electrical communication with the heating element (3, 5) and on the other side with the first terminal of the direct current power supply (17), and the second switching means is arranged to be in electrical communication on the one side with the heating element (3, 5) and on the other side with the second terminal of the direct current power supply (18), so that when both the first and second switching means are switched off the heating element (3, 5) and the antenna connection point (21, 31) are electrically isolated from the direct current power supply.

13. An antenna assembly according to claim 12, wherein the first and second switching means are arranged to be actuated at the same time.

14. A heated window comprising at least one pane of optically transparent glazing material and an antenna assembly according to any of claims 1 to 13.

15. A method of heating the heated window of claim 14, said heated window comprising a first and second heating element (3, 5) wherein the first heating element (3) is in electrical communication with a direct current power supply; the second heating element (5) is electrically isolated from the direct current power supply; the antenna connection point (31) associated with the second heating element is in electrical communication with a radio receiving means and the antenna connection point (21) associated with the first heating element is decoupled from the radio receiving means, the method comprising the steps of smoothly switching off the electrical current to the first heating element;
electrically isolating the first heating element (3) from the direct current power supply;
coupling the first heating element (3) to the radio receiving means, such that the first heating element is brought into electrical communication with the radio receiving means;
decoupling the second heating element (5) from the first radio receiving means; and
making the electrical connection between the second heating element (5) and the direct current power supply, such that the electrical current is switched on smoothly.

16. A method of heating according to claim 15 wherein the step of bringing the antenna connection point (21) associated with the first heating element into electrical communication with the radio receiving means takes place whilst the antenna connection point (31) associated with the second heating element is still in electrical communication with the radio receiving means.

17. A method of heating according to either of claims 15 or 16, wherein the electrical connection between the second heating element (5) and the first and second terminals (17, 18) of the direct current power supply is made by actuating a first switching means associated with the heating element (5) and the first terminal (17) and a second switching means associated with the heating element (5) and the second terminal (18).

18. A method of heating according to claim 17, wherein the first and second switching means associated with the second heating element are actuated at the same time.

19. A method of heating according to any of claims 15 to 18, wherein the electrical current to the first heating element is smoothly switched off by actuating a first MOSFET (37, 40, 42).

20. A method of heating according to claim 19 wherein the electrical current to the second heating element is smoothly switched on by actuating a second MOSFET (37, 44, 46).

21. A method of heating according to claim 20, wherein the first and second MOSFET are the same.

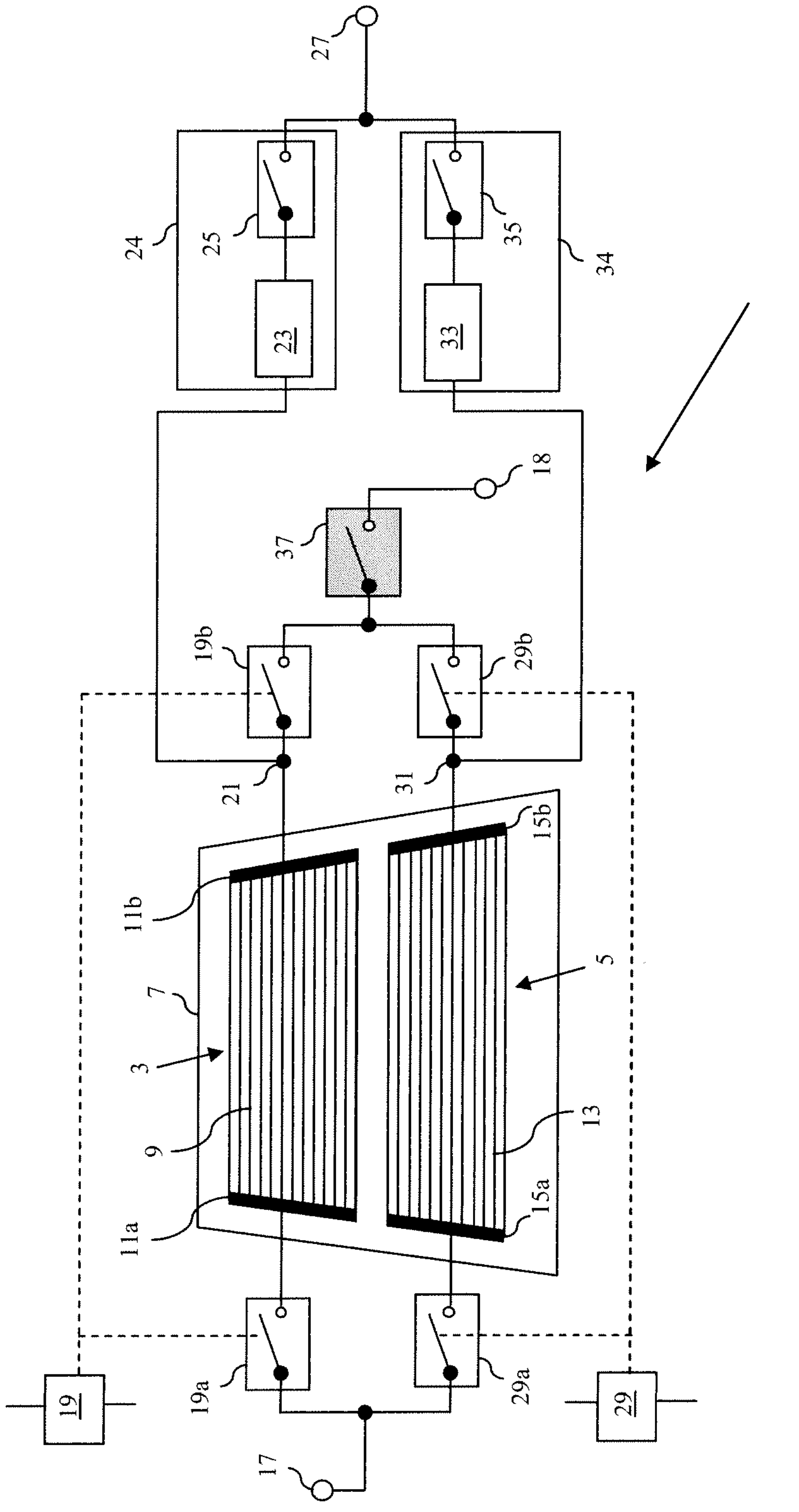
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Figure 1

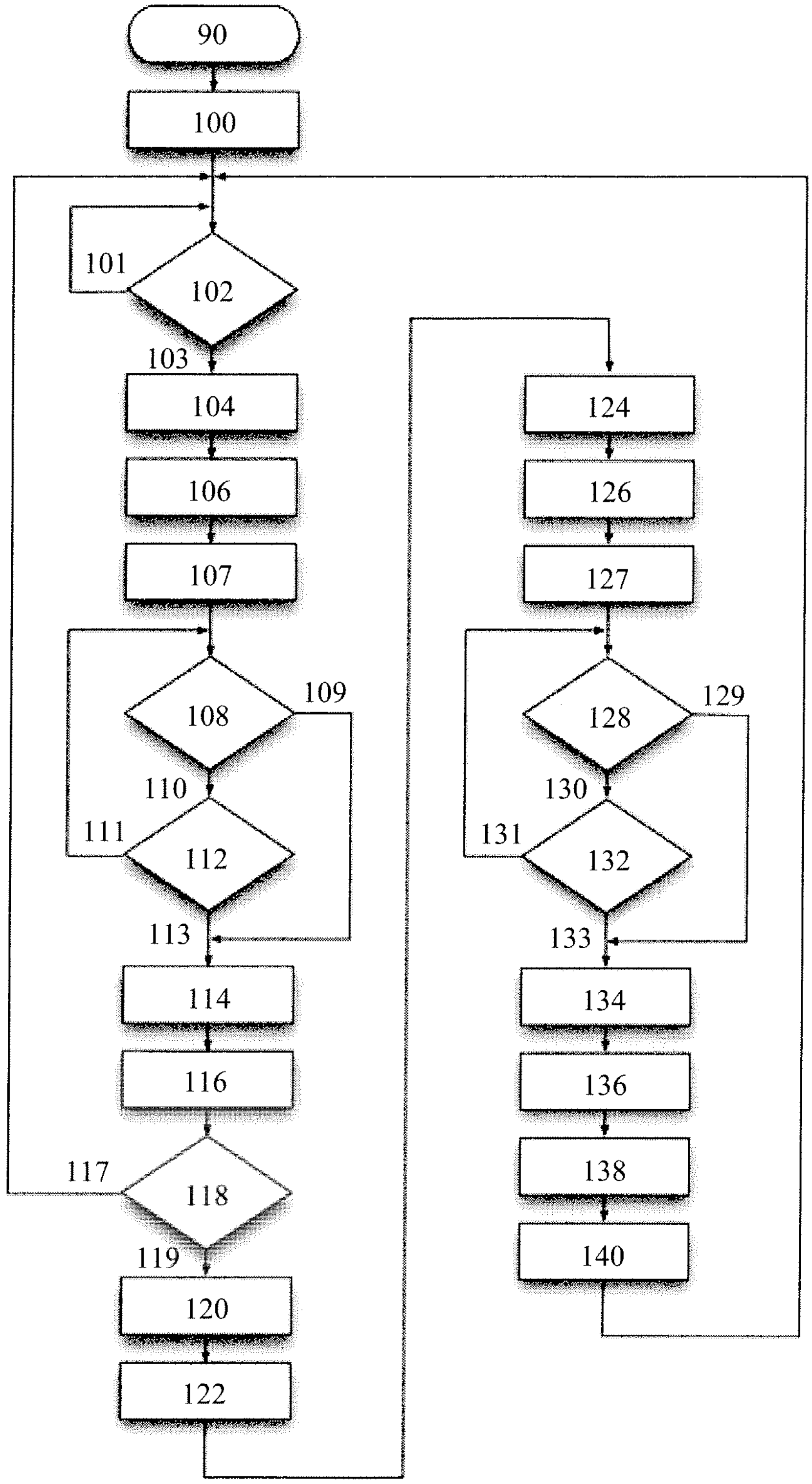
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Figure 2

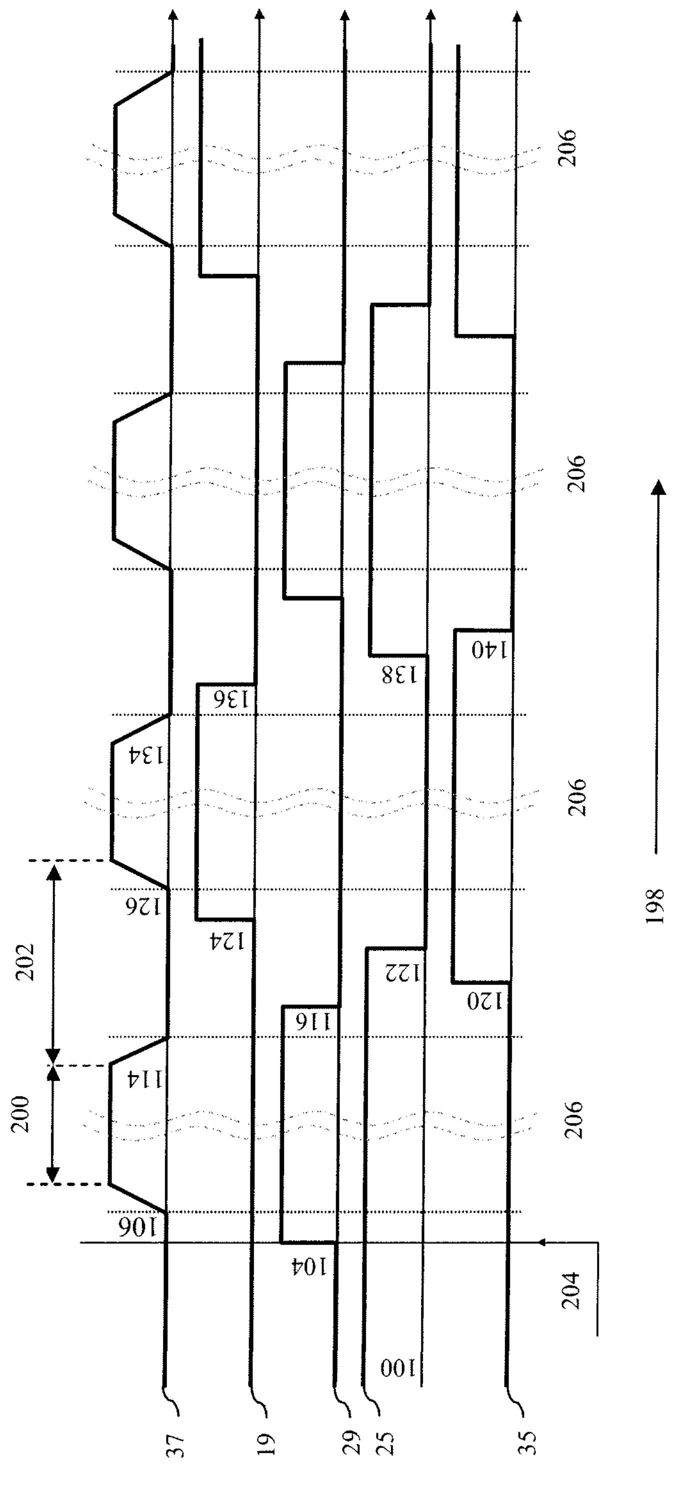
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Figure 3

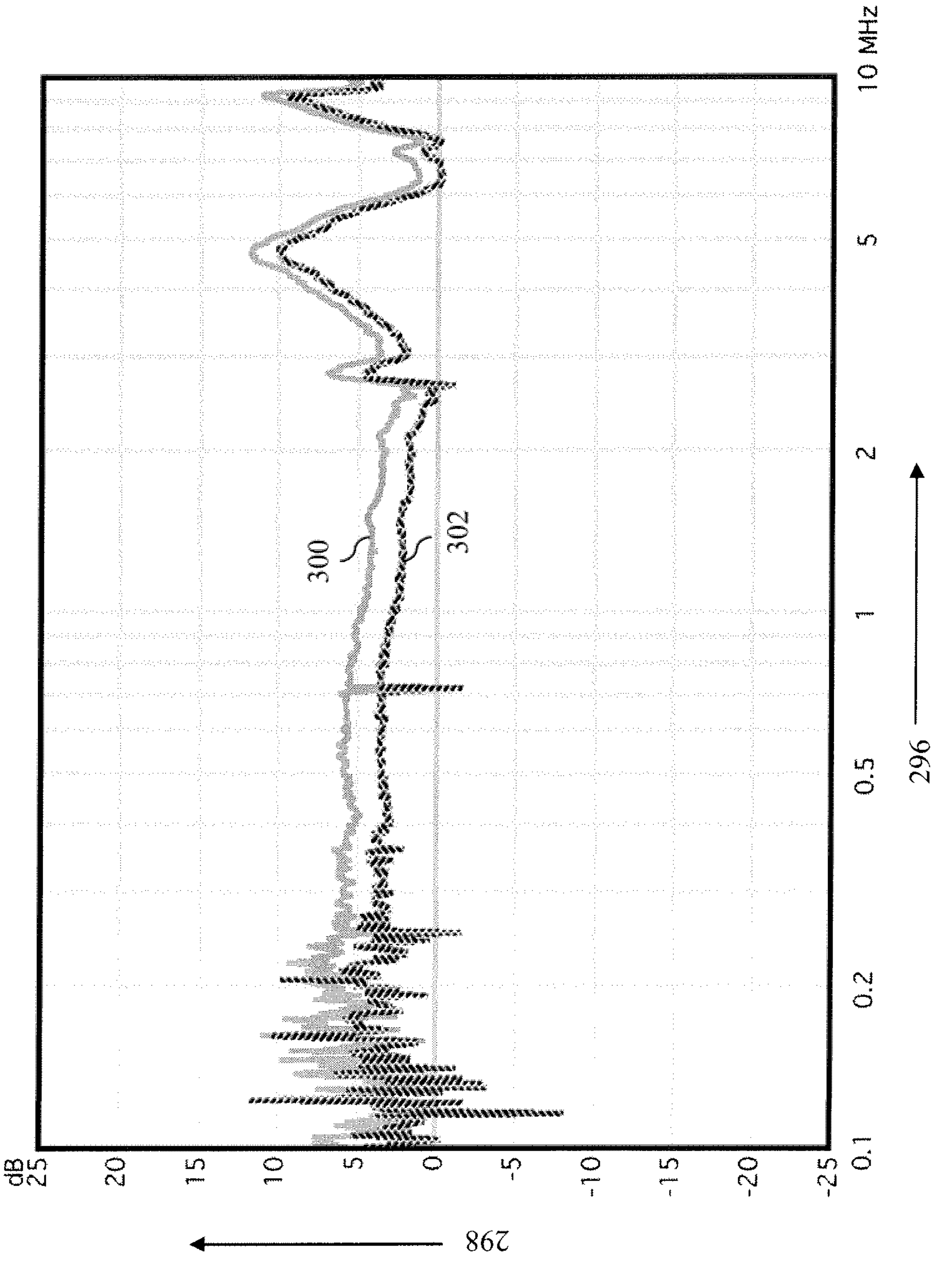

Figure 4

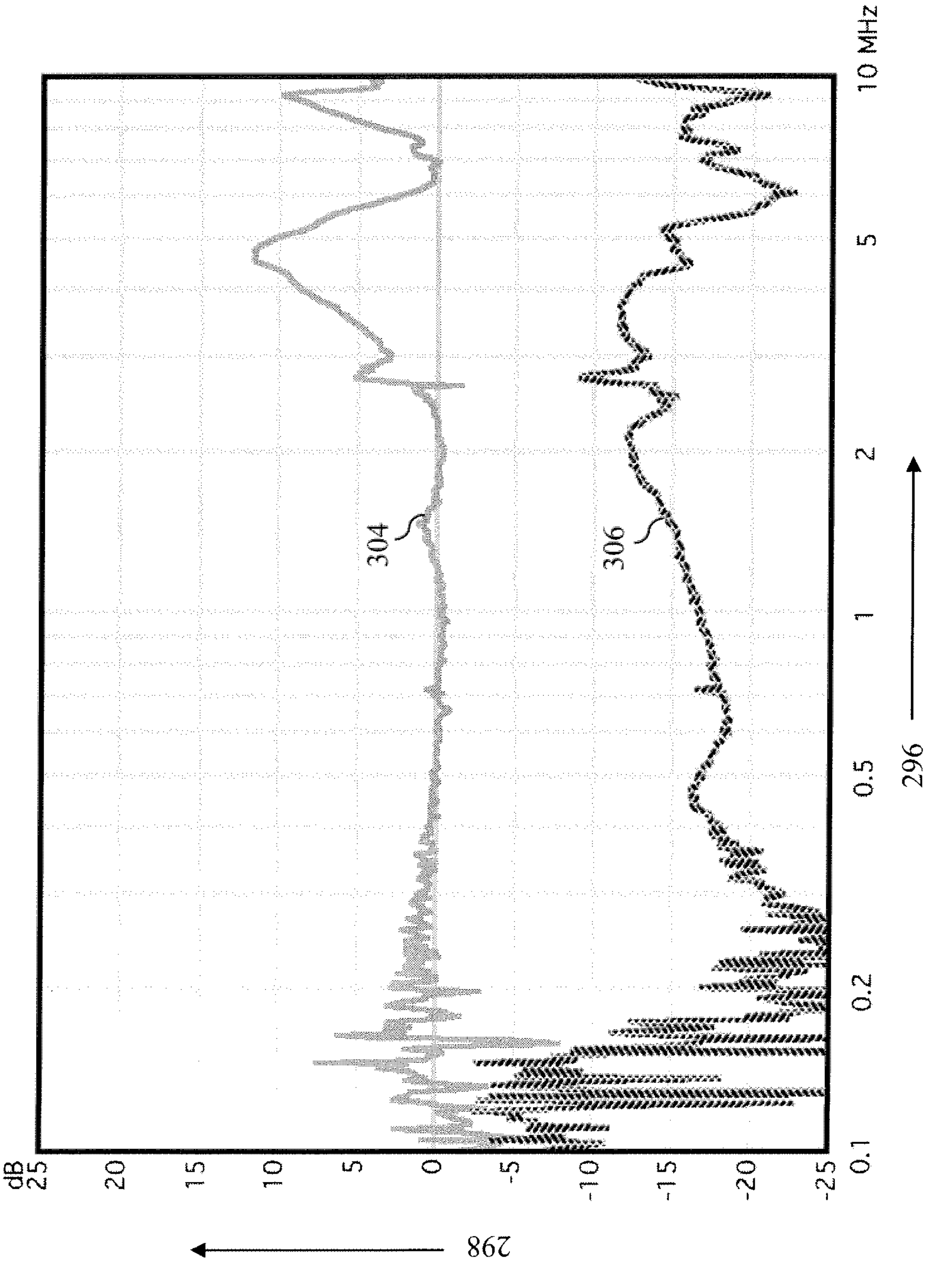

Figure 5

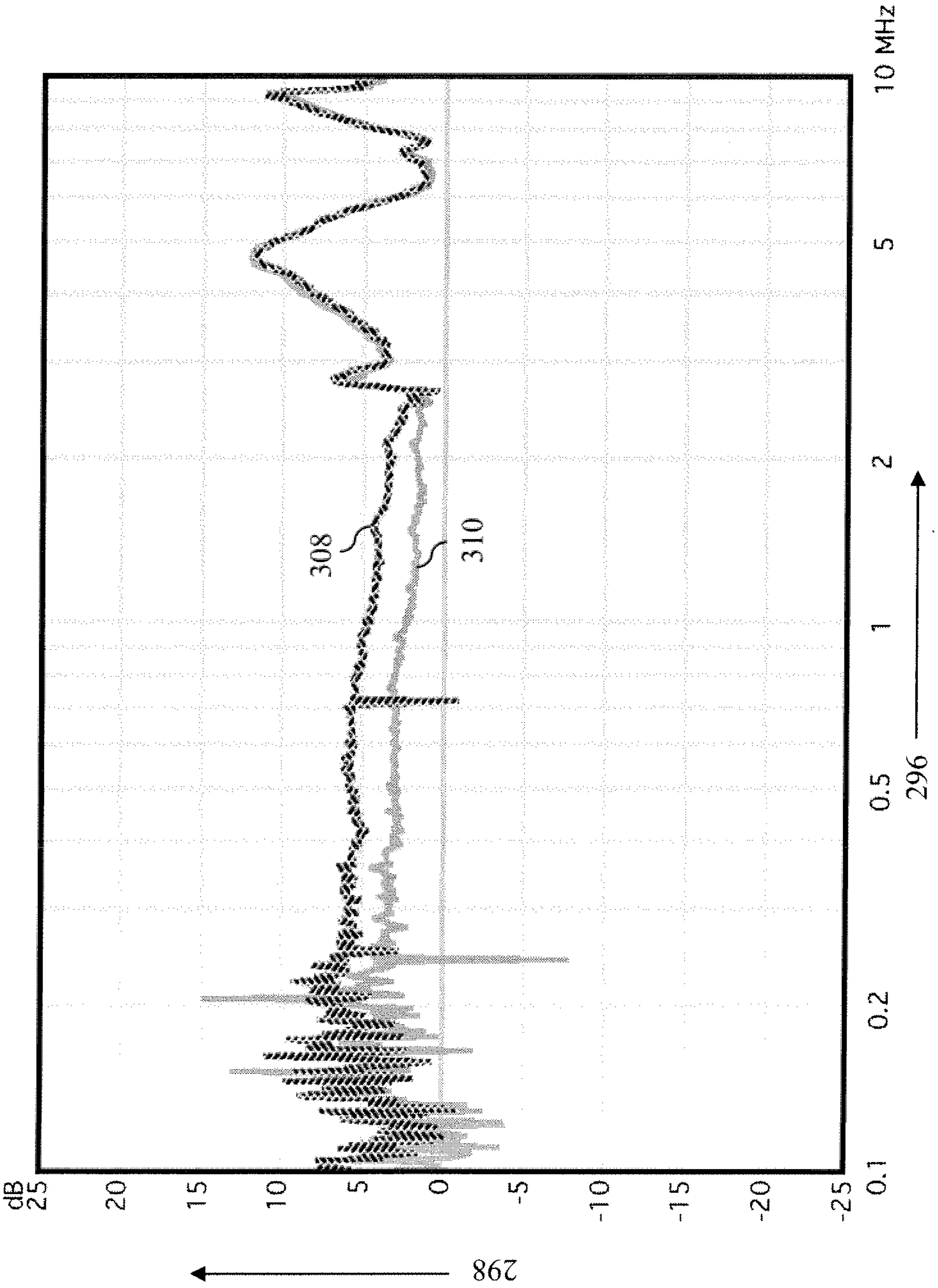

Figure 6

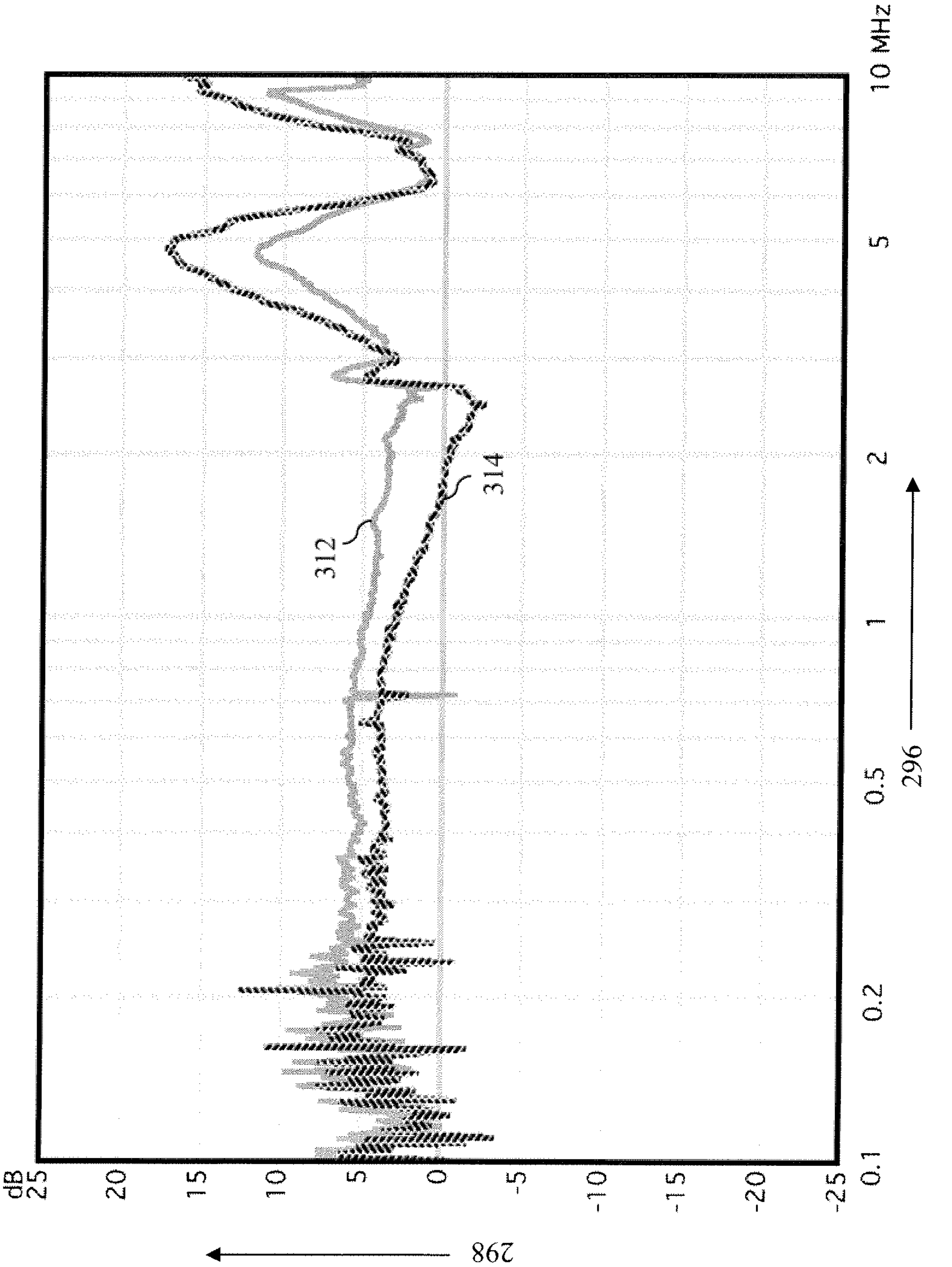

Figure 7

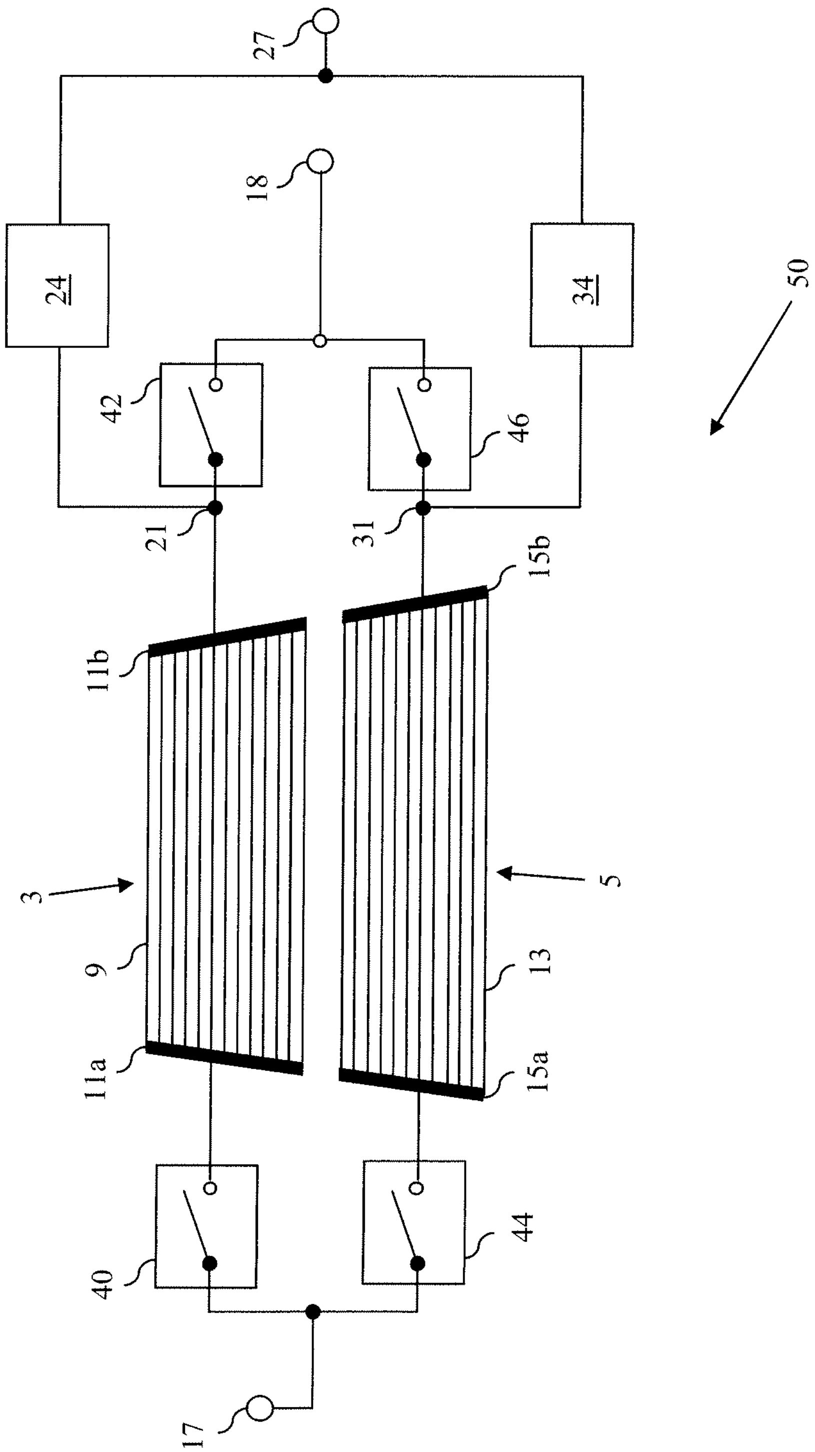

Figure 8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 10 4064

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D	JP 62 020401 A (MAZDA MOTOR) 29 January 1987 (1987-01-29) * abstract * * figure 1 *	1-15, 17-21	INV. H01Q1/12
A	DE 36 18 452 A1 (LINDENMEIER HEINZ [DE]; FLACHENECKER GERHARD [DE] LINDENMEIER HEINZ [D) 3 December 1987 (1987-12-03) * column 5, line 16 - column 11, line 21 * * figures 1-7 * * abstract *	1,14,15	
A	EP 0 446 684 A1 (FLACHGLAS AG [DE]) 18 September 1991 (1991-09-18) * column 4, line 43 - column 5, line 13 * * figures 1-6 * * abstract *	1,14,15	
			TECHNICAL FIELDS SEARCHED (IPC)
			H01Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 June 2007	von Walter, Sven-Uwe

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