RF COUPLED, IMPLANTABLE MEDICAL DEVICE WITH RECHARGEABLE BACK-UP POWER SOURCE

The RF coupled implantable medical system comprises: a transmitting unit (12); a receiving unit (14) including an implantable, electrically operated, medical device; the transmitting unit including RF energy transmitting circuitry (64), RF signal receiving circuitry (38) and first control circuitry (25) coupled to the RF energy transmitting circuitry and to the RF signal receiving circuitry for controlling the amount of RF energy transmitted to the receiving unit; the receiving unit including RF energy receiving circuitry (60), RF signal transmitting circuitry, a rechargeable power supply (44) coupled to the RF energy receiving circuitry and second control circuitry for adjusting the charging current flowing into the rechargeable battery coupled to the rechargeable power supply, to the RF energy receiving circuitry, to the RF signal transmitting circuitry and to the implanted medical device; and mode selection circuitry for setting the receiving unit to operate in one of the following modes: (1) "RF only", (2) "battery only" or (3) "combination of both".
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RF COUPLED, IMPLANTABLE MEDICAL DEVICE WITH
RECHARGEABLE BACK-UP POWER SOURCE
BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates to an implantable medical device including a rechargeable back-up power source and a charging unit for recharging the back-up power source via RF coupling.

2. Description of the Prior Art.

The concept of using an implantable, electrically operated medical device for treating specific diseases or physical disorders is well known. Examples of implantable, electrically operated medical devices are: cardiac pacemakers which restore a sick human heart to a normal rhythm, neural stimulators which control nerve or brain response (such as pain or epileptic seizures), infusion pumps for subcutaneously drug delivery (such as insulin pump), and diagnostic devices for monitoring a patient's condition.

With respect to all of these implantable, electrically operated devices, it is necessary to provide power to the device implanted below the skin. Since the medical device is subcutaneously implanted in the patient, the power source must supply electrical energy for a reasonable period of time in order to reduce further surgical trauma to the patient and financial cost to the medical provider.

Several examples of such previously proposed implantable devices are disclosed in the following U.S. Patents:

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<td>3,942,535</td>
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<td>5,480,415</td>
<td>Cox et al.</td>
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SUMMARY OF THE INVENTION

According to the present invention there is provided an RF coupled implantable medical system comprising: a transmitting unit; a receiving unit including an implantable, electrically operated, medical device; the transmitting unit including RF energy transmitting circuitry, RF signal receiving circuitry and first control circuitry coupled to the RF energy transmitting circuitry and to said RF signal receiving circuitry for controlling the amount of RF energy transmitted to the receiving unit; the receiving unit including RF energy receiving circuitry, RF signal transmitting circuitry, a rechargeable power supply coupled to the RF energy receiving circuitry and second control circuitry for adjusting the charging current flowing into the rechargeable battery coupled to the rechargeable power supply, to the RF energy receiving circuitry, to the RF signal transmitting circuitry and to the implanted medical device; and mode selection circuitry for setting the receiving unit to operate in one of the following modes: (1) "RF only", (2) "battery only" or (3) "combination of both".

Further, if desired, circuitry can be provided in the receiving unit for measuring the charge level of the rechargeable battery and, upon sensing a fully charged battery, automatically up-linking a coded signal which commands the transmitting unit to "stop" transmitting RF energy.
BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block electrical, schematic circuit diagram of the overall system including a transmitting unit and an implanted receiver unit configured for an implantable, rechargeable tissue stimulator system.

FIG. 2A is a block electrical schematic circuit of a digital to analog converter in the receiver unit

FIG. 2B is a detailed electrical schematic circuit diagram of the digital to analog converter with current output shown in FIG. 2A which is used, under control of a micro controller, to regulate the constant current rate for recharging the back-up power source within the implanted receiver unit.

FIG. 3 is a block electrical schematic circuit diagram of the overall system as configured for an implantable, rechargeable drug delivery system.

FIG. 4 is a block electrical schematic circuit diagram of the overall system as configured for an implantable, rechargeable cardiac pacemaker system.

FIG. 5 is a block electrical schematic circuit diagram of the overall system as configured for an implantable, rechargeable cardioverter/defibrillator.

FIG. 6 is a block electrical schematic circuit diagram of the overall system as configured for an implantable, rechargeable monitor and diagnostic system.
DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring to the drawings in greater detail, there is illustrated in FIG. 1 a block electrical schematic circuit diagram of an implantable, rechargeable tissue stimulator system 10. The system 10 includes a transmitter 12 and a receiver 14, the latter being surgically implanted beneath a patient's skin 16. The receiver 14 is connected, via lead connector 18, to an implanted medical device, which in this embodiment, is an implanted lead 19 which contains, at it's distal end 20, stimulating electrodes 21-24. These electrodes 21-24 are implanted adjacent to the target tissue to be stimulated (i.e., a specific nerve or a nerve bundle, a specific area of the brain or a specific muscle within the human body). The implanted receiver 14 receives therapy values, transmitted by the transmitter 12 via RF signals, which are decoded by decoder 25 and then stored in a non-volatile memory (EPROM) 27.

Referring again to FIG. 1, the major components of the transmitter 12 are a micro controller 26 which is used, via software, to: 1) control the output of a programmable DC to DC converter 28 in order to regulate the amount of RF energy to be coupled into the receiver 14; 2) read data and command inputs inputted via a keyboard 30, display messages and menus via a display 32, transmit therapy parameter values, via a programming encoder 34, a transmit driver 36 and an antenna 38, to the implanted receiver 14; 3) and receive commands and patient's diagnostic data, transmitted from the implanted receiver 14, via the antenna 38, an amplifier 39 and a decoder 40.

As shown in FIG. 1, when the transmitter 12 is powered up via a switch 41 and a "start therapy" key 42 on the keyboard 30 is pressed, the transmitter 12 will transmit the "start" command to the receiver 14 which will initiate delivery of therapy by the receiver 14. Likewise, if a "stop therapy" key 43 on the keyboard 30 is pressed, the transmitter 12 will transmit the "stop" command to the receiver 14 which will cease delivery of therapy.

The implanted receiver 14 of FIG. 1 can be programmed by the physician or patient to obtain it's operating power from
one of three sources: 1) RF coupled energy only; 2) back-up rechargeable power supply/source 44 only; or 3) a combination of both whereby the implanted receiver 14 alternates automatically from one to the other according to a preset schedule programmed via the transmitter 12.

When "RF only" is selected from a menu displayed by the display 32 of the transmitter 12, an output port 45 of a micro controller 46 in the receiver 14 is switched to a "0" and a port 47 is switched to a "1" which places pmos transistor P2 in a conducting state and pmos transistor P1 in a non-conducting state. This effectively connects a line conductor 50 to a line conductor 52, making VDD equal to the output of a voltage regulator 54 which is at + 3.0 vdc.

When "battery only" is selected from the same menu, the output port 47 is switched to a "0" and the port 45 is switched to a "1", thus effectively connecting line conductor 56 to line conductor 52 and making VDD equal to the voltage level at the rechargeable power source 44.

As shown in FIG. 1, when "combination" is selected from the same menu, the system 10 will automatically switch the source of VDD to the output of the voltage regulator 54 (line conductor 50) when the transmitter 12 is proximal to the receiver 14, or to the rechargeable power source 44 when the transmitter 12 is removed away from the receiver 14. The automatic switching is performed by the micro controller 46 in response to the state of line conductor 50 which is at +3.0 volts when RF energy is being coupled into an inductor 60 (the transmitter 12 is proximal to the receiver 14) or is 0 volts in the absence of RF energy (the transmitter 12 is away from the receiver 14).

When the receiver 14 is programmed to "battery only" power acquisition mode, it's exclusive source of operating power becomes the rechargeable power source 44. After prolonged use, the rechargeable power source 44 will reach a near depleted level, at which point the receiver 14 will transmit, via an RF communication link 61, a "recharge" command to the transmitter 12. This will cause the transmitter 12 to generate, via the battery 62, the DC/DC converter 28 and an output inductor 64, high energy RF waves which are coupled into the inductor 60.
contained within the receiver 14. The actual level of RF energy generated by the inductor 64 is regulated by an output port 70 of the micro controller 26 as a real-time response to data transmitted by the receiver 14 via the micro controller 46, the data representing the voltage level E1 at the output of the rectifier 74 in the receiver 14 which is measured via an attenuator 76 and an analog to digital converter 78. This feedback system extends the life of the battery 62 within the transmitter 12, by adjusting, as a function of distance between the inductors 64 and 60, the RF energy required to quickly recharge the rechargeable power source 44. A close proximity requires much less RF energy to recharge the rechargeable power source 44 than a longer distance would, in the same time. During this recharging operation, the micro controller 46 regulates, as a function of temperature, the current level used to recharge the rechargeable power source 44. The temperature is measured by a thermistor 80 which is adhered to the rechargeable power source 44 during manufacturing. The junction between the thermistor 80 and a resistor 82 form a voltage divider which is fed through an analog switch 84 to an analog to digital converter 86 and, via a line conductor 88, to the micro controller 46. As the voltage rises, the ohmic value of the thermistor 80 drops proportionally to the temperature, thus reducing the voltage at the line conductor 88 to the micro controller 46. This loop forms a temperature-controlled, current-regulated charging system which restricts the temperature rise of the rechargeable power source 44 during recharging, thus preventing the power source 44 from suffering electrolyte starvation and gas generation. Both of these phenomena will, if left unchecked, dramatically reduce the reliability and service life of the power source 44. Also, during recharging of the power source 44, the micro controller 46 will monitor the voltage level of the power source 44 via a line conductor 90, analog switch 92, the A/D converter 86 and, finally, the line conductor 88. Upon sensing a fully charged state, the micro controller 46 will telemeter to transmitter 12, via the RF communications link 61, a "stop" recharging command and simultaneously will turn off a D/A converter 94 which will cut off the current needed to charge the
rechargeable power source 44. In this manner, the power source 44 cannot be overcharged, even if the "stop" command was not received by the transmitter 12 due to electromagnetic interference.

Referring to FIG. 1, when the receiver 14 is programmed to "RF only", the power acquisition mode, it's exclusive source of operating power is the low level RF energy generated by transmitter 12 and coupled into the inductor 60 within the receiver 14. The actual level of RF energy generated by the inductor 64 is regulated by the output port 70 of the micro controller 26 to the minimum level required to operate the receiver 14 and the rechargeable power source 44 is trickle charged, as a real-time response to data transmitted by the receiver 14 via the micro controller 26, i.e., the data representing the voltage level E1 at the output of the rectifier 74 which is measured via the attenuator 76 and the analog to digital converter 78. This feedback system extends the life of the battery 62 within the transmitter 12, by adjusting the RF energy required to operate the receiver 14 and maintain a trickle charge to the rechargeable power source 44, as a function of the distance between the inductors 64 and 60. At close proximity, much less RF energy is required to accomplish these functions than at a longer distance.

During trickle charging, the micro controller 46 regulates, as a function of temperature, the current level used to trickle charge the power source 46, by the same method already explained in the previous paragraph. Again, this prevents electrolyte starvation and gas generation within the rechargeable power source 44. Also, during trickle charging, the micro controller 46 will monitor the charge level of the power source 44, and upon sensing a fully charged state, the receiver 14 will telemeter to the transmitter 12 the "stop" recharging command and simultaneously will turn off the D/A converter 94 which will cut off the current needed to charge the power source 44. In this manner, the power source 44 cannot be overcharged, even if the "stop" command was not received by the transmitter 12 due to electromagnetic interference.

When the receiver 14 is programmed to "combination" power
acquisition mode, the micro controller 46 will automatically switch delivery of operating power to the receiver 14 to RF coupled energy upon detection of RF induced voltage at E1. Likewise, the micro controller 46 will switch delivery of operating power to the rechargeable power source 44 upon loss of RF induced voltage at E1. The patient may select, via a menu shown in the transmitter's display 32, fast or trickle charge to the rechargeable power source 44.

Upon sensing that the charge in the rechargeable power source 44 is below a predetermined level, the micro controller 46 signals the patient, via an audible alarm 96 and/or a vibrating alarm 98, that the rechargeable power source 44 should be recharged.

Referring to FIG. 2B, a detailed electrical schematic of the digital to analog (D/A) converter 94 is provided. The D/A converter 94 is software programmable, precision current source whose output is regulated by the micro controller 46. It should be noted that this type of D/A converter is best implemented into an integrated circuit where the electrical characteristics of the transistors can be precisely matched.

Referring again to FIG. 2B, resistor R1 is used to set the base bias current for the converter 94. Transistors N17 and N1 form a 1:1 current mirror where the current into the transistor N17 equals the current through the transistor N1, since both transistors have equal channel width and length. However, the channel width for the transistors N2 through N8 are binary weighted, so that the transistor N2 has twice the width of the transistors N1, N3 has twice the width of N2, and so forth. This binary scaling results in transistor N2 conducting twice the current of transistor N1 (assuming equal bias current), the transistor N3 conducting twice the current of the transistor N2, and so forth. The transistors N9 through N16 are used as pass devices to allow the current available at the transistor N1 through the transistor N8 to pass to the current sum line 1.

The on-off state for the transistors N9 through N16 is governed by inputs i1 through i8 which, in one embodiment, are output ports from the micro controller 46 (bus line 100 in FIG. 1). In this manner, the micro controller 46 is able to select any value of current between 1 and 256 times that of the current
flowing through the resistor R1 (bias current) to pass to the current sum line 1.

Input line "enable.n" is used to turn on and off the D/A converter. When "enable.n" is a "0", the transistor P1 conducts connecting VDD to the sources of the transistors P2 and P3 which form a 1:1 current mirror. Therefore, the current source by the transistor P3 equals the current flowing through the transistors P2, P3 being the output current device ("iSOURCE") for this D/A converter 94.

In FIG. 3 is shown a block diagram for an implantable, rechargeable drug delivery system. The block diagram for the transmitter 12 is the same as for the transmitter 12 shown in FIG. 1.

The block diagram for the receiver 14 contains the same power supply system, supply switching means and method for recharging the rechargeable power source 44 that has been already described above in connection with the description of FIG. 1, but has been modified to incorporate the components required to assemble an implantable drug delivery system.

These components are: 1) a drug reservoir 104 which contains the drug to be delivered by the receiver 14; 2) a refill septum 106 used to percutaneously, via a hypodermic needle, refill the drug reservoir 104; 3) a portioning pump 108 used to dispense a precise volume of drug to a catheter 110 by making one or more small injections (portions); 4) a pump inlet tube 112; 5) a pump outlet tube 114; 6) the drug delivery catheter 110 which is used to carry and deliver to the target tissue the drug volume dispensed by the pump 108; and 7) a multi-wire cable 118 which carries the electrical signals for driving the pump 108.

Referring again to FIG. 3, the wire conductors 121-123 are used to drive the pump 108 and the wire conductors 131-133 are used to sense when a portion has been delivered. The micro controller 46 measures the time required for delivering each drug portion, and based on this time determines if the pump 108 is empty or contains fluid, since the former condition results is a faster time than the latter. Upon sensing a "pump empty" condition, the micro controller 46 signals the patient, via an audible alarm 140 and/or a vibrating alarm 142, that the reservoir 104 is empty. It should be noted that the titanium
housing 150 of the receiver 14 should be in close proximity to the audible alarm 140 in order to transmit the sound waves to outside the human body.

FIG. 4 is a block diagram of an implantable, rechargeable cardiac pacemaker system. The block diagram for the transmitter 12 is the same as for the block diagram of the transmitter 12 shown in FIG. 1.

The block diagram for the receiver 14 contains the same power supply system, supply switching means and method for recharging the rechargeable power source 44 that already have been described above in connection with the description of FIG. 1, but has been modified to incorporate the components required to assemble an implantable, rechargeable cardiac pacemaker system. These components are: 1) a pulse amplitude D/A converter 202 which is used to regulate, under command of the micro controller 46, the amplitude of the stimulating pulses delivered to the human heart; 2) a bus 204 which carries the binary value for the amplitude from the micro controller 46 to the D/A converter 202; 3) an amplifier and filter 206 which detects and amplifies the cardiac depolarization waves (such as R or P waves) and filters out other signal frequencies not related to cardiac activity; 4) an implanted lead 210 containing electrodes 211-212 which is used to deliver stimulating pulses to the heart in order to regulate the heart's rhythm, but which is used also to pick-up and carry the cardiac depolarization waves to the amplifier/filter 206. These cardiac waves are used by the micro controller 46 to measure the intrinsic rate of the heart. The measurement is utilized to determine if electrical stimulation pulses are needed to speed-up the heart.

Upon sensing that the charge in the rechargeable power source 44 is below a predetermined level, the micro controller 46 signals the patient, via an audible alarm 220 and/or a vibrating alarm 222, that the rechargeable power source 44 should be recharged.

In FIG. 5 is illustrated a block diagram of an implantable, rechargeable cardioverter/defibrillator. The block diagram for the transmitter 12 is the same as the block diagram for the transmitter 12 shown in FIG. 1.
The block diagram for the receiver 14 contains the same power supply system, supply switching means and method for recharging the rechargeable power source 44 that already have been described above in connection with the description of FIG. 1, but has been modified to incorporate the components required to assemble an implantable, rechargeable cardioverter/defibrillator system. These components are: 1) a high voltage output, DC to DC converter 302 used to convert the low voltage available at the rechargeable power source 44 to a relatively higher voltage required to cardiovert a fibrillating human heart; 2) a bus 304 which carries the binary value for the voltage amplitude from the micro controller 46 to the D/A converter 302; 3) an amplifier/filter 306 used to detect the presence of a cardiac arrhythmia such as fibrillation or tachycardia; and, 4) an implanted cardioverting lead 310 containing cardioverting electrodes 311-312.

As shown in FIG. 5, the DC/DC converter 302 is used to generate either low voltage pulses to pace the human heart when needed or high voltage pulses to shock a large number of cardiac cells into synchrony, thereby restoring a normal cardiac rhythm. The micro controller 46, via the bus 304, regulates the timing and amplitude of low voltage pulses or high voltage shocks, depending if an arrhythmia is detected or not. Upon sensing that the charge in the rechargeable power source 44 is below a predetermined level, the micro controller 46 signals the patient, via an audible alarm 320 and/or a vibrating alarm 322, that the rechargeable power source 44 should be recharged.

In FIG. 6 there is illustrated a block diagram of an implantable, rechargeable monitor and diagnostic system. The block diagram for the transmitter 12 is the same as the block diagram for the transmitter 12 shown in FIG. 1.

The block diagram for the receiver 14 contains the same power supply system, supply switching means and method for recharging the rechargeable power source 44 that already have been described in connection with the description of FIG. 1, but has been modified to incorporate the components required to assemble an implantable, rechargeable monitor and diagnostic system. These components are: 1) an amplifier/filter 406 used
to amplify the desired biological signals and to filter out other undesirable signals; 2) an analog to digital converter 408 which is used to convert the biological signal into a digital value representative of frequency and amplitude of the biological signal; 3) a monitoring lead 410 containing electrodes 411-412 which are used to pick-up and carry the biological signals to the amplifier/filter 406.

The mission of the monitor and diagnostic system shown in FIG. 6 is to monitor and record, in a non-volatile memory 414, specific biological signals and events occurring adjacent to the monitoring electrodes 411-412. Later, at a convenient time, these recordings can be telemetered to the transmitter 12 which will produce, via a graphic recorder 416, a hard copy of the biological signals for the physician's examination and eventual diagnosis. Any time biological signals occur, they are scrutinized by the micro controller 46 for specific morphology which would cause the event to be stored into the memory 27 for later examination by the physician. An example of a typical use, would be to record dysfunctional endocardiac signals which, when inspected by a trained physician, may reveal the origin of a cardiac dysfunction not detected by conventional means, such as a surface EKG.

From the foregoing description, it will be apparent that the RF coupled, implantable medical system 10 with the rechargeable back-up power supply/source 44 of the present invention has a number of advantages, some of which have been described above and others of which are inherent in the invention. Also it will be understood that modifications can be made to the RF coupled, implantable medical system including the rechargeable back-up power supply/source 44 described above without departing from the teachings of the present invention. Accordingly, the scope of the invention is only to be limited as necessitated by the accompanying claims.
CLAIMS

We claim:

1. An RF coupled implantable medical system comprising:
   a transmitting unit;
   a receiving unit including an implantable, electrically
   operated, medical device;
   said transmitting unit including RF energy transmitting
   means, RF signal receiving means and first control means
   coupled to said RF energy transmitting means and to said RF
   signal receiving means for controlling the amount of RF energy
   transmitted to said receiving unit;
   said receiving unit including RF energy receiving means,
   RF signal transmitting means, a rechargeable power supply
   coupled to said RF energy receiving means and second control
   means for adjusting the charging current flowing into said
   rechargeable battery coupled to said rechargeable power supply
   means, to said RF energy receiving means, to said RF signal
   transmitting means and to said implanted medical device; and
   mode selection means for setting said receiving unit to
   operate in one of the following modes: (1) "RF only", (2)
   "battery only" or (3) "combination of both".

2. The system of claim 1 wherein said receiving unit, when
   said transmitting unit is set to operate in said "RF only"
   mode, is operable to supply electrical energy to said
   implantable device, so long as said transmitting unit is
   located proximate to said receiving unit and said receiving
   unit is sensing transmitted RF energy.

3. The system of claim 1 wherein said receiving unit, when
   said transmitting unit is set to operate in said "battery only"
   mode, is operable, periodically, to supply electrical energy to
   said implantable device from said rechargeable power supply for
   a period of at least 24 hours.

4. The system of claim 1 wherein said RF energy
   transmitting means of said transmitting unit includes mode
   selection means for recharging said rechargeable battery at a
   "fast" rate or at a "trickle" rate.

5. The system of claim 1 wherein said receiving unit, when
   said transmitting unit is set to operate in said "combination"
   mode, is operable to supply electrical energy to said
implantable device through a rectifier directly to said implanted medical device, so long as said transmitting unit is located proximate to said receiving unit, and, separately, to "trickle charge" said rechargeable power supply.

6. The system of claim 1 wherein said receiving unit further comprises means for measuring the charge level of said rechargeable battery and, upon sensing a fully charged battery, automatically up-linking a coded signal which commands said transmitting unit to "stop" transmitting RF energy.

7. The system of claim 1 wherein said receiving unit includes a titanium housing enclosing said RF energy receiving means, said RF signal transmitting means, said rechargeable battery and said second control means.

8. The system of claim 1 wherein said RF energy transmitting means of said transmitting unit is constructed to transmit energy at a frequency as low as 10 Hz and up to at least 20,000 Hz.

9. The system of claim 1 wherein said rechargeable battery has a temperature sensor which is mounted closely adjacent thereto and which is coupled via said RF signal transmitting means to said first control means of said transmitting unit whereby the level of transmitted RF energy can be reduced proportionally to the reduction in charging rate of the rechargeable battery in said receiving unit, in order to reduce the power consumption from said power source powering said transmitting unit.

10. The system of claim 1 wherein said first control means of said transmitting unit includes means for controlling the level of RF energy transfer from the transmitting unit to the receiving unit relative to one or more of the following parameters; (a) the charge level of said rechargeable battery, (b) selected charging rate and (c) the selected power supply for said receiving unit.

11. The system of claim 1 wherein said transmitting unit includes a visual display coupled to said first control means.

12. The system of claim 1 wherein said transmitting unit includes a keyboard coupled to said first control means including keys to start and stop recharging of said rechargeable battery within the implantable medical device.
13. The system of claim 1 wherein said transmitting unit includes a battery, whereby said transmitting unit is portable and not dependent upon an a.c. power source.

14. The system of claim 1 wherein said implanted medical device is selected from the group consisting essentially of a tissue stimulator, a drug delivery system, a cardiac pacemaker system, and a cardioverter/defibrillator.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) A61N 1/08
US CL. 607/61
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S.: 607/61, 33-35
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>US 5411537 A (MUNSHI ET AL) 2 MAY 1995, SEE ENTIRE DOCUMENT</td>
<td>1-14</td>
</tr>
<tr>
<td>A</td>
<td>US 5713939 A (NEDUNGADI ET AL) 3 FEBRUARY 1998, SEE ENTIRE DOCUMENT</td>
<td>1-14</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

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*A* document defining the general state of the art which is not considered to be of particular relevance
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Date of mailing of the international search report 14 JUL 1998

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer
GEORGE EVANISKO
Telephone No. (703) 308-2612

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