

**Claims**

1. A power receiver, comprising:

- (i) a first electrode arranged to be electrically coupled to a body of a living being, the first electrode operable to receive an electrical signal via the body; and
- 5 (ii) a rectifier for converting the received electrical signal into a rectified electrical signal, the rectifier having a plurality of rectifier switches and operable in a bulk biasing mode in which selected rectifier switches of the plurality of rectifier switches are forward bulk biased.

2. A power receiver according to claim 1, wherein the rectifier is operable selectively  
10 between the bulk biasing mode and a non-bulk biasing mode in which the selected rectifier switches are not forward bulk biased, in dependence on an amplitude of the rectified electrical signal.

3. A power receiver according to claim 2, wherein second selected rectifier switches of the plurality of rectifier switches are reverse bulk biased in the bulk biasing mode, and wherein the second rectifier switches are not reversed bulk biased in the non-  
15 bulk biased mode.

4. A power receiver according to claim 3, wherein the selected rectifier switches and the second selected rectifier switches are alternately forward and reversed bulk biased in the bulk biasing mode, in dependence on a phase of the electrical signal.

20 5. A power receiver according to any one of claims 2 to 4, wherein the rectifier is operable in the bulk biasing mode at amplitudes of the rectified electrical signal less than or equal to 0.4V and in the non-bulk biased mode otherwise.

6. A power receiver according to any one of the preceding claims, wherein the power receiver has an input load impedance; the power receiver further comprising an L-C  
25 circuit, the input load impedance being dependent on a resonance response of the L-C circuit.

7. A power receiver according to claim 6, wherein the L-C circuit comprises a parallel L-C circuit.

8. A power receiver according to any one of the preceding claims, wherein the electrical signal has a power level, the power receiver further comprising:

5           (iii)       a DC-DC converter for converting the rectified electrical signal to an output electrical signal, the DC-DC converter having a number of selectable discontinuous mode (DCM) times and operable between a power transmission operation mode in which the electrical signal is transmitted by a power transmitter; and a power harvesting operation mode in which the electrical  
10           signal is harvested ambient energy, in dependence on the power level of the electrical signal; and

          (iv)       a controller arranged to select a discontinuous mode (DCM) time from the number of selectable discontinuous mode (DCM) times for the DC-DC converter in response to the operation mode of the DC-DC converter.

15    9.    A power receiver, comprising:

          (i)       a first electrode arranged to be electrically coupled to a body of a living being, the first electrode operable to receive an electrical signal via the body, the electrical signal having a power level;

          (ii)       a rectifier for rectifying the electrical signal into a rectified electrical signal;

20           (iii)       a DC-DC converter for converting the rectified electrical signal to an output electrical signal, the DC-DC converter having a number of selectable discontinuous mode (DCM) times and operable between a power transmission operation mode in which the electrical signal is transmitted by a power transmitter; and a power harvesting operation mode in which the electrical  
25           signal is harvested ambient energy, in dependence on the power level of the electrical signal; and

- (iv) a controller arranged to select a discontinuous mode (DCM) time from the number of selectable discontinuous mode (DCM) times for the DC-DC converter in response to the operation mode of the DC-DC converter.
10. A power receiver according to claim 8 or claim 9, wherein the controller is arranged
- 5 to select between a plurality of power transmission discontinuous mode (DCM) times in response to the power transmission operation mode, and between a plurality of power harvesting discontinuous mode (DCM) times in response to the power harvesting operation mode, in dependence of a voltage of the rectified electrical signal.
- 10 11. A power receiver according to any one of claims 8 to 10, wherein a switching frequency of the DC-DC converter in the power transmission operation mode is in the range 10 kHz to 500 kHz and a switching frequency of the DC-DC converter in the power harvesting operation mode is in the range 500 Hz to 6 kHz.
12. A power receiver according to any one of claims 8 to 11, wherein the controller is
- 15 further arranged to adjust an inductor charging time of the DC-DC converter within a predetermined range until an input power of the DC-DC converter reaches a maximum value for the predetermined range.
13. A power receiver according to claim 12, wherein the controller is arranged to
- 20 determine a direction of adjustment of the inductor charging time based on a corresponding inductor discharging time of the DC-DC converter.
14. A power receiver according to claim 12 or claim 13, wherein the inductor charging time of the DC-DC converter is between 100ns and 500ns.
15. A power receiver according to any one of the preceding claims, being formed as an integrated circuit (IC) chip.
- 25 16. A power receiver according to any one of the preceding claims, further comprising a floating ground node operable as a parasitic capacitive return path via an external ground for the electrical signal.

17. A power receiver according to any one of claims 1 to 15, wherein the first electrode comprises a receiving coil, the receiving coil being operable to receive the electrical signal via the body through magnetic resonance coupling with a transmitting coil.
- 5 18. A power receiver according to any one of claims 1 to 15, further comprising a second electrode arranged to be electrically coupled to the body of the living being, wherein the electrical signal is galvanic current.
19. A power transmitter, comprising:
- 10 (i) a signal generator having a variable output impedance; the signal generator operable to generate an electrical signal;
- (ii) a first electrode arranged to be electrically coupled to a living being body for transmission of the electrical signal via the living being body;
- 15 (iii) an amplitude detector configured to measure an amplitude of the electrical signal; and
- (iv) a controller operable to adjust an impedance of the variable output impedance based on the amplitude of the electrical signal to enable the amplitude of the electrical signal to at least reach a threshold amplitude for transmission by the first electrode.
- 20 20. A power transmitter according to claim 19, wherein the controller is operable to determine that the electrical signal has at least reached the threshold amplitude when a magnitude of a difference between the amplitude of the electrical signal and a half open circuit amplitude of the transmitter is less than a predetermined value.
- 25 21. A power transmitter according to claim 20, wherein the variable output impedance comprises a resistive component and a capacitive component, the controller being operable to adjust the impedance of the variable output impedance based

on a multichotomic search of the amplitude of the electrical signal within a two-dimensional space described by the capacitive component and the resistive component of the variable output impedance to enable the amplitude of the electrical signal to at least reach the threshold amplitude for transmission by the first electrode.

22. A power transmitter according to claim 21 wherein the multichotomic search of the amplitude of the electrical signal within two-dimensional space described by the capacitive component and the resistive component of the variable output impedance comprises dividing the two-dimensional space into a plurality of areas and determining the amplitude of the electrical signal at a single point in each of the plurality of areas; and selecting the area for which the amplitude of the electrical signal at the single point is closest to the half open circuit output amplitude of the transmitter to be searched in a following stage of the multichotomic search.

23. A power transmitter according to any one of claims 19 to 22, wherein the signal generator comprises a first capacitor bank having a first, variable configuration, the capacitive element of the variable output impedance being dependent on the first configuration of the first capacitor bank; and a second capacitor bank having a second, variable configuration, the resistive component of the variable output impedance being dependent on the second configuration of the second capacitor bank, the controller being operable to change at least one of the first configuration and the second configuration to adjust the impedance value of the variable output impedance.

24. A power transmitter according to any of claims 19 to 23, being formed as an integrated circuit (IC) chip.

25. A power transmitter according to any one of claims 19 to 24, further comprising a floating ground node operable as a parasitic capacitive return path via an external ground for the electrical signal.

26. A power transmitter according to any one of claims 19 to 24, wherein the first electrode comprises a transmitting coil, the transmitting coil being operable to transmit the electrical signal via the body through magnetic resonance coupling with a receiving coil.
- 5 27. A power receiver according to any of claims 19 to 24, further comprising a second electrode arranged to be electrically coupled to the body of the living being, wherein the electrical signal is galvanic current.
28. Energy transfer apparatus, comprising:
- 10 (i) a power transmitter comprising: a signal generator operable to generate an electrical signal, and an electrode arranged to be electrically coupled to a living being body for transmission of the electrical signal via the living being body; and
- (ii) a power receiver according to any one of claims 1 to 18.
29. Energy transfer apparatus according to claim 28, wherein the signal generator has  
15 an output load impedance, the power transmitter further comprising an L-C circuit, the output load impedance being dependent on a resonance response of the L-C circuit.
30. Energy transfer apparatus according to claim 28, wherein the power transmitter is a power transmitter of any one of claims 19 to 24.
31. Energy transfer apparatus, comprising:
- 20 (i) a power transmitter according to any of claims 19 to 27; and
- (ii) a power receiver comprising: an electrode arranged to be electrically coupled to a body of a living being, the electrode operable to receive an electrical signal via the body, and a rectifier for rectifying the received electrical signal into a rectified electrical signal.

32. Energy transfer apparatus of claim 31, wherein the power receiver includes an input load impedance; the power receiver further comprising an L-C circuit, the input load impedance being dependent on a resonance response of the L-C circuit.
- 5 33. A method of receiving electrical power via an electrode coupled to a body of a living being, the method comprising:
- receiving an electrical signal from the body via the electrode;
  - rectifying the received electrical signal into a rectified electrical signal using a rectifier, the rectifier having a bulk biasing mode in which selected rectifier switches
  - 10 of a plurality of rectifier switches are forward bulk biased.
34. A method according to claim 33, wherein the rectifier includes a non-bulk biased mode in which the selected rectifier switches are not forward bulk biased, and the method includes:
- 15 selectively operating the rectifier between the bulk biasing mode and the non-bulk biasing mode, in dependence on an amplitude of the rectified electrical signal.
35. A method of receiving electrical power via an electrode coupled to the body of a living being according to claim 33 or 34, further comprising:
- 20 varying an input load impedance for receiving the electrical signal in accordance with a resonance response of an L-C circuit.
36. A method of receiving electrical power via an electrode coupled to the body of a living being according to any one of the preceding claims 33 to 35, further
- 25 comprising:
  - measuring a power level of the electrical signal;
  - converting the rectified electrical signal to an output electrical signal using a DC-DC converter, the DC-DC converter having a number of selectable discontinuous mode (DCM) times and operable between a power transmission operation mode

in which the electrical signal is transmitted by a power transmitter; and a power harvesting operation mode in which the electrical signal is harvested ambient energy, in dependence on the power level of the electrical signal; and selecting a discontinuous mode (DCM) time from the number of selectable discontinuous mode (DCM) times for the DC-DC converter in response to the operation mode of the DC-DC converter.

37. A method of receiving electrical power via an electrode coupled to a body of a living being, the method comprising:

receiving an electrical signal from the body via the electrode;  
measuring a power level of the electrical signal;  
rectifying the electrical signal to obtain a rectified electrical signal;  
converting the rectified electrical signal to an output electrical signal using a DC-DC converter, the DC-DC converter having a number of selectable discontinuous mode (DCM) times and operable between a power transmission operation mode in which the electrical signal is transmitted by a power transmitter; and a power harvesting operation mode in which the electrical signal is harvested ambient energy, in dependence on the power level of the electrical signal; and selecting a discontinuous mode (DCM) time from the number of selectable discontinuous mode (DCM) times for the DC-DC converter in response to the operation mode of the DC-DC converter.

38. A method of receiving electrical power according to claim 36 or claim 37, further comprising: adjusting an inductor charging time of the DC-DC converter within a predetermined range to until an input voltage of the DC-DC converter reaches a maximum value for the predetermined range.

39. A method of receiving electrical power according to claim 38, further comprising:  
determining an inductor discharging time of the DC-DC converter;  
determining a direction of adjustment of the inductor charging time, based

on the inductor discharging time; and adjusting the inductor charging time of the DC-DC converter in the direction of adjustment.

40. A method of transmitting electrical power via an electrode coupled to a body of a living being, the method comprising:

- 5       generating, by a signal generator having a variable output impedance, an electrical signal;  
measuring an amplitude of the electrical signal;  
adjusting an impedance value of the variable output impedance based on the amplitude of the electrical signal to enable the amplitude of the electrical signal  
10       to at least reach a threshold amplitude; and  
transmitting the electrical signal via the electrode to the living being body.

41. A method of transmitting electrical power according to claim 40, wherein the variable output impedance having a resistive and a capacitive component, the  
15       method further comprising:

- performing a multichotomic search of the amplitude of the electrical signal within a two-dimensional space described by the capacitive component and the resistive component of the variable output impedance; and  
adjusting the impedance value of the variable output impedance based on the  
20       multichotomic search.

42. A method of transmitting electrical power according to claim 41, wherein  
performing the multichotomic search of the amplitude of the electrical signal further comprises dividing the two-dimensional space into a plurality of areas  
25       and determining the amplitude of the electrical signal at a single point in each of the plurality of areas; and selecting the area for which the amplitude of the electrical signal at the single point is the highest to be searched in a following stage of the multichotomic search.

43. A method of transferring power between a power transmitter and a power receiver; the power transmitter including a signal generator and a first transmitter electrode electrically coupled to a living being body; the power receiver including a rectifier and a first receiver electrode electrically coupled to the living being, the method comprising:

generating an electrical signal by the signal generator, the signal generator having an output impedance circuit, wherein an impedance of the output impedance circuit is adjusted based on one of resonance response of an L-C circuit, and an amplitude of the generated electrical signal;

transmitting the electrical signal via the first transmitter electrode to the living being body;

receiving the transmitted electrical signal, by the first receiver electrode, via the living being body;

rectifying the received electrical signal to produce a rectified electrical signal.

44. A method according to claim 43; wherein the output impedance circuit further includes a floating transmitter node; and the power receiver further includes a floating receiver node; the first transmitter electrode arranged to cooperate with the first receiver electrode to form a transmission path via the living being body for the electrical signal, and the floating transmitter node being arranged to cooperate with the floating receiver node to form a parasitic capacitive return path via an external ground for the electrical signal.

45. A method according to claim 43, wherein the first transmitter electrode includes a transmitting coil and the first receiver electrode includes a receiving coil, wherein the power transmitter is operable to transmit the electrical signal to the power receiver via the living being body through magnetic resonance coupling between the transmitting and the receiving coil.

46. A method according to claim 43, wherein the power transmitter further includes a second transmitter electrode coupled to the living being body, and the power receiver further includes a second receiver electrode, wherein the electrical signal being transmitted by the first transmitter electrode is galvanic current.

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47. A method according to any one of claims 43 to 45, further comprising adjusting an input load impedance of the power receiver in dependence on a predetermined resonance response.

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48. A method of any one of claims 43 to 47, wherein the rectifier has a bulk biasing mode in which first selected rectifier switches of a plurality of rectifier switches are forward bulk biased, and a non-bulk biased mode in which the first selected rectifier switches are not forward bulk biased, and wherein rectifying the electrical signal comprises:

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selectively operating the rectifier between the bulk biasing mode and the non-bulk biasing mode, in dependence on an amplitude of the rectified electrical signal.

49. A method of any one of claims 43 to 48, further comprising:

converting the rectified electrical signal to an output electrical signal using a DC-DC converter, the DC-DC converter having a number of selectable discontinuous mode (DCM) times; and

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selecting a discontinuous mode (DCM) time from the number of selectable discontinuous mode (DCM) times for the DC-DC converter in dependence of a voltage of the rectified electrical signal.

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50. A method of any one of claims 43 to 49, wherein adjusting an impedance of the output impedance of the signal generator, comprises:

measuring an amplitude of the electrical signal; and

adjusting the output impedance of the signal generator based on the amplitude of the electrical signal to enable the amplitude of the electrical signal to at least reach a threshold amplitude.

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