

CLAIMS

1. An electrosurgical instrument for delivering electromagnetic (EM) energy and ultrasonic vibrations for treating biological tissue, the electrosurgical instrument comprising:

an instrument shaft arranged to convey EM energy and an electrical signal for driving a magnetostrictive ultrasound transducer;

a distal end assembly arranged at a distal end of the instrument shaft to receive the EM energy from the instrument shaft and deliver the EM energy from the distal end assembly for tissue treatment; and

a magnetostrictive ultrasound transducer arranged to receive the electrical signal from the instrument shaft and generate ultrasonic vibrations around the distal end assembly for tissue treatment.

2. The electrosurgical instrument of claim 1, wherein the instrument shaft comprises a coaxial transmission line having an inner conductor, an outer conductor, and a dielectric material separating the inner conductor from the outer conductor, the coaxial transmission line being arranged to convey the EM energy and the electrical signal.

3. The electrosurgical instrument of claim 2, wherein the magnetostrictive ultrasound transducer has first and second input terminals for receiving the electrical signal from the coaxial transmission line, the first input terminal being connected to the inner conductor by a first connection means, and the second input terminal being connected to the outer conductor by a second connection means.

4. The electrosurgical instrument of claim 3, wherein the magnetostrictive ultrasound transducer is mounted on or in the distal end assembly.

5. The electrosurgical instrument of claim 4, wherein the distal end assembly is a radiating tip portion arranged to radiate an EM field for tissue treatment, the radiating tip portion comprising:

a dielectric tip,

a distal conductive portion of the inner conductor, which extends longitudinally into the dielectric tip,

an intermediate dielectric element surrounding a proximal part of the distal conductive portion and separating the dielectric material of the coaxial transmission line from the dielectric tip, and

wherein the magnetostrictive ultrasound transducer is mounted on or in the intermediate dielectric element.

5 6. The electrosurgical instrument of claim 4, wherein the distal end assembly comprises:
 a pair of jaws that are movable relative to each other to open and close a gap between opposing inner surfaces thereof, the pair of jaws comprising an energy delivery structure arranged to emit the EM energy into the gap between the opposing inner surfaces,
10 wherein the energy delivery structure comprises a microstrip antenna mounted on the inner surface of one or both of the pair of jaws.

 7. The electrosurgical instrument of claim 6, wherein the distal end assembly further comprises:
15 a blade comprising the magnetostrictive ultrasound transducer for cutting through biological tissue, the blade being slidably disposed within the distal end assembly to be movable through the region between the pair of jaws.

 8. The electrosurgical instrument of claim 6, wherein the
20 magnetostrictive ultrasound transducer is housed in or on one of the pair of jaws.

 9. The electrosurgical instrument of claim 8, wherein the microstrip antenna is a coplanar microstrip antenna comprising:
 a planar dielectric substrate having a top surface that is exposed at the gap
25 between the opposing inner surfaces, and an under surface on an opposite side of the planar dielectric substrate from the top surface;
 a ground conductor layer on the under surface;
 a ground conductive strip on the top surface and electrically connected to the ground conductor layer; and
30 an active conductive strip on the top surface, the active conductive strip being spaced from the ground conductive strip,
 wherein the active conductive strip and the ground conductive strip are positioned to have a uniform closest spacing within the region between the pair of jaws, and
35 wherein the magnetostrictive ultrasound transducer is positioned on the top surface of the planar dielectric substrate and in-between the active conductive strip and the ground conductive strip.

 10. The electrosurgical instrument of claim 8, wherein the pair of jaws
40 comprises a first jaw having the energy delivery structure mounted therein, and a

second jaw which does not receive an EM energy feed, and wherein the magnetostrictive ultrasound transducer is housed in or on the second jaw.

5 11. The electrosurgical instrument of any of claims 1 to 3, wherein the magnetostrictive ultrasound transducer is mounted on or in the instrument shaft.

 12. The electrosurgical instrument of any preceding claim, wherein the magnetostrictive ultrasound transducer comprises a magnetostrictive element made of Terfenol-D.

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 13. An electrosurgical generator comprising:
 an electromagnetic (EM) signal supply unit for generating EM energy;
 an electrical signal supply unit for generating an electrical signal for driving a magnetostrictive ultrasound transducer;
15 an output port configured to be connectable to an electrosurgical instrument for delivering the EM energy from a distal end thereof and for generating ultrasonic vibrations using the electrical signal; and
 a feed structure for conveying the EM energy from the EM signal supply unit to the output port, and for conveying the electrical signal from the electrical signal supply unit to the output port, wherein the feed structure has a common signal
20 pathway for conveying the EM energy and the electrical signal to the output port.

 14. The electrosurgical generator of claim 13 wherein the EM signal supply unit comprises a microwave signal generator for generating microwave EM
25 radiation having a first frequency, and
 wherein the feed structure comprises an electrical signal channel for connecting the output port to the electrical signal supply unit, and a microwave channel for connecting the output port to the microwave signal generator, the electrical signal channel and microwave channel comprising physically separate
30 signal pathways from the electrical signal supply unit and microwave signal generator respectively,
 wherein the feed structure includes a first combining circuit having a first input connected to receive the electrical signal from the electrical signal channel, a second input connected to receive the microwave EM radiation from the microwave channel,
35 and an output in communication with the first and second inputs for transferring the electrical signal and the microwave EM radiation to the common signal pathway.

 15. The electrosurgical generator of claim 14, wherein the microwave channel comprises a first filter arranged to permit the passage of microwave EM
40 radiation from the microwave signal generator to the first combining circuit, but

prevent the passage of the electrical signal from the first combining circuit to the microwave signal generator.

5 16. The electrosurgical generator of claim 13 or 14, wherein the electrical signal channel comprises a second filter arranged to permit the passage of the electrical signal from the electrical signal supply unit to the first combining circuit, but prevent the passage of the microwave EM radiation from the first combining circuit to the electrical signal supply unit.

10 17. The electrosurgical generator of any one of claims 13 to 16, wherein the electromagnetic signal supply unit comprises:
 a radiofrequency (RF) signal generator for generating RF EM radiation having a second frequency that is lower than the first frequency,
 wherein the feed structure comprises an RF channel for connecting the output
15 port to the RF signal generator, the RF channel and microwave channel comprising physically separate signal pathways from the RF signal generator and microwave signal generator respectively,
 wherein the feed structure includes a second combining circuit connected to the electrical signal channel and having a first input connected to receive the
20 electrical signal from the electrical signal supply unit and a second input connected to receive the RF EM radiation from the RF channel, and an output in communication with the first and second inputs for transferring the RF EM radiation and the electrical signal to the first combining circuit.

25 18. The electrosurgical generator of claim 17, wherein the electrical signal channel comprises a third filter arranged to permit the passage of the electrical signal from the electrical signal supply unit to the second combining circuit, but prevent the passage of the RF EM radiation from the second combining circuit to the electrical signal supply unit.

30 19. The electrosurgical generator of claim 17 or 18, wherein the RF channel comprises a fourth filter arranged to permit the passage of the RF EM radiation from the RF signal generator to the second combining circuit, but prevent the passage of the electrical signal from the second combining circuit to the RF
35 signal generator.

 20. The electrosurgical generator of any one of claims 13 to 19, wherein the electrical signal supply unit comprises:
 a first power supply for outputting a first supply signal;
40 a signal source for outputting a first control signal;

a first switching circuit having a control input coupled to the signal source for receiving the first control signal, a supply input coupled to the first power supply for receiving the first supply signal, and an output, wherein the first switching circuit is operable to provide at the output at least part of the electrical signal based on the first supply signal and the first control signal.

21. The electrosurgical generator of claim 20, wherein the first power supply comprises a filtering circuit for blocking an alternating current signal received by the first power supply at its output.

22. The electrosurgical generator of claim 20 or 21, wherein the first switching circuit comprises a current source for generating the at least part of the electrical signal from the first supply signal and in accordance with a characteristic of the first control signal.

23. The electrosurgical generator of claim 20, 21 or 22, wherein the first switching circuit comprises a signal conditioner coupled to a switch, the signal conditioner being operable to convert the control signal into a driving signal for operating the switch.

24. The electrosurgical generator of any one of claims 20 to 23, wherein the signal source is operable to output a second control signal, and wherein the electrical signal supply unit further comprises:

a second power supply for outputting a second supply signal;

a second switching circuit having a control input coupled to the signal source for receiving the second control signal, a supply input coupled to the second power supply for receiving the second supply signal, and an output, wherein the second switching circuit is operable to provide at the output a second part of the electrical signal based on the second supply signal and the second control signal, and

a common signal pathway coupled the output of the first switching circuit for receiving a first part of the electrical signal, and coupled to the output of the second switching circuit for receiving the second part of the electrical signal, and for combining the first and second parts to form the electrical signal.

25. An electrosurgical apparatus comprising:

an electrosurgical instrument as claimed in any of claims 1 to 12, and

an electrosurgical generator as claimed in any of claims 13 to 24,

wherein the output of the electrosurgical generator is configured to be connectable to a proximal end of the instrument shaft of the electrosurgical instrument.