CLAIMS

1. Electrosurgical apparatus (100) for resection of biological tissue, the apparatus comprising:

a radiofrequency (RF) signal generator (102) for generating RF electromagnetic (EM) radiation having a first frequency;

a microwave signal generator (104) for generating microwave EM radiation having a second frequency that is higher than the first frequency;

a probe (118) arranged to deliver the RF EM radiation and the microwave EM radiation separately or simultaneously from a distal end thereof;

a feed structure for conveying the RF EM radiation and the microwave EM radiation to the probe, the feed structure comprising an RF channel for connecting the probe (118) to the RF signal generator (102), and a microwave channel for connecting the probe (118) to the microwave signal generator (104);

an RF signal detector (1006) for sampling current and voltage on the RF channel and generating therefrom a RF detection signal (S_{RF}) indicative of the current and voltage;

a microwave signal detector (1012, 1014) for sampling forward and reflected power on the microwave channel and generating therefrom a microwave detection signal (S_{M1}, S_{M2}) indicative of the microwave power delivered by the probe (118); and

a controller (106) in communication with the RF signal detector (1006) and microwave signal detector (1012, 1014) to receive the RF detection signal and microwave detection signal,

wherein the controller (106) is operable to select an energy delivery profile for the RF EM radiation and the microwave EM radiation, the energy delivery profile for the RF EM radiation being for tissue cutting and the energy delivery profile for the microwave EM radiation being for haemostasis or sealing or coagulation or ablation of tissue,

characterised in that:

the controller (106) comprises a digital microprocessor (110) programmed to output an RF control signal (C_{RF}) for the RF signal generator (102) and a microwave control signal (C_M)

for the microwave signal generator (104), the RF control signal and the microwave control signal being for setting the energy delivery profile for the RF EM radiation and the microwave EM radiation respectively, and

the controller is arranged to determine a state for the RF control signal and the microwave control signal based on the received RF detection signal and microwave detection signal respectively.

2. Electrosurgical apparatus according to claim 1, wherein the feed structure includes a measurement channel for delivering energy at a power level of 10 mW or less.

3. Electrosurgical apparatus according to claim 2, wherein the measurement channel is connected to receive a measurement signal from the microwave signal generator, and wherein the apparatus is switchable so that microwave EM radiation is delivered to the probe either through the measurement channel or the microwave channel.

4. Electrosurgical apparatus according to claim 3, wherein the microwave signal detector includes a heterodyne or double heterodyne detector.

5. Electrosurgical apparatus according to claim 2, wherein, if the energy delivery profile for the RF EM radiation and/or the microwave EM radiation comprises a pulsed waveform, the apparatus is arranged to deliver energy to the probe along the measurement channel during the OFF time of the pulsed waveform.

6. Electrosurgical apparatus according to any preceding claim, wherein the controller is arranged to set the energy delivery profile by adjusting the waveform and/or power of the RF EM radiation and the microwave EM radiation.

7. Electrosurgical apparatus according to any preceding claim, wherein the distal end of the probe comprises a bipolar emitting structure comprising a first conductor (358) spatially separated from a second conductor (360), the first and second conductors being arranged to act:

as active and return electrodes respectively to convey the RF EM radiation by conduction, and

as an antenna to radiate the microwave EM radiation.

8. Electrosurgical apparatus according to claim 7 including a gas feed (124) connected to supply a flow of gas to the distal end of the probe, wherein, if the flow of gas is present, the RF EM radiation is controllable to strike a conducting gas plasma between the first and second conductors at the distal end of the probe and the microwave EM radiation is arranged to sustain the gas plasma.

9. Electrosurgical apparatus according to any preceding claim, wherein the RF channel and microwave channel comprise physically separate signal pathways from the RF signal generator (102) and microwave signal generator (104) respectively, the separate signal pathway on the RF channel being isolated from the microwave EM radiation and the separate signal pathway on the microwave channel being isolated from the RF EM radiation.

10. Electrosurgical apparatus according to claim 9, wherein the feed structure includes a combining circuit (114) having a first input connected to the separate signal pathway on the RF channel, a second input connected to the separate signal pathway on the microwave channel, and an output connected to a common signal pathway for conveying the RF EM radiation and the microwave EM radiation separately or simultaneously along a single channel to the probe.

11. Electrosurgical apparatus according to claim 10, wherein the combining circuit includes a switching device for connecting either the RF channel or the microwave channel to the common signal pathway.

12. Electrosurgical apparatus according to claim 10, wherein the switching device comprises a relay or coaxial switch.

13. Electrosurgical apparatus according to claim 10, wherein the combining circuit comprises a bi-directional diplexer arranged to permit:

forward RF EM radiation to be conveyed from the first input to the output,

reflected RF EM radiation to be conveyed from the output to the first input,

forward microwave EM radiation to be conveyed from the second input to the output, and

reflected microwave EM radiation to be conveyed from the output to the second input.

14. Electrosurgical apparatus according to claim 13, wherein the bi-direction diplexer comprising a T-shaped open microstrip circuit (546) having a low pass filter integrally formed therewith to prevent microwave EM radiation from leaking out of the first input.

15. Electrosurgical apparatus according to any preceding claim, wherein the RF detection signal from the RF signal detector is indicative of the voltage and current of the RF EM radiation.

16. Electrosurgical apparatus according to claim 15 comprising an RF tuner (138) connected on the RF channel for controlling the energy delivered into tissue by the RF EM radiation, wherein the RF tuner has an adjustable reactance that is controllable by the controller based on the RF detection signal.

17. Electrosurgical apparatus according to claim 16, wherein the adjustable reactance of the RF tuner comprises a plurality of reactive elements, each reactive element having a fixed reactance and being independently switchable into or out of connection with the RF channel according to a respective control signal from the controller.

18. Electrosurgical apparatus according to claim 16, wherein the adjustable reactance of the RF tuner comprises a plurality of reactive elements, each reactive element having a

variable reactance that is independently controllable according to a respective control signal from the controller.

19. Electrosurgical apparatus according to claim 16, wherein the adjustable reactance of the RF tuner is provided by a variable capacitor and/or variable inductor, and the controller comprises a self-adjusting feedback loop arranged to generate a signal for setting the reactance of the variable capacitor and/or variable inductor.

20. Electrosurgical apparatus according to any preceding claim, wherein the microwave detection signal is indicative of the magnitude of reflected power on the microwave channel.

21. Electrosurgical apparatus according to claim 20 including an impedance adjuster (158) connected on the microwave channel between the microwave signal generator (104) and the probe (118), the impedance adjuster having an adjustable complex impedance that is controllable by the controller based on the microwave detection signal.

22. Electrosurgical apparatus according to any preceding claim, wherein the RF signal generator comprises:

an oscillator (454) coupled to a switching unit (458) for generating a stable RF output;

an amplifier (456) for amplifying the stable RF output; and

an output transformer (462),

wherein the amplifier (456) is arranged to amplify a voltage across a primary coil of the transformer, and the switching unit (459) is arranged to switch ON/OFF a voltage across the primary coil of the output transformer.

23. Electrosurgical apparatus according to any preceding claim, wherein the first frequency is a stable fixed frequency in the range 10 kHz to 300 MHz and the second frequency is a stable fixed frequency in the range 300 MHz to 100 GHz.

24. Electrosurgical apparatus according to claim 7, wherein the bipolar emitting structure comprises a planar block of dielectric material, the first and second conductors

being conductive layers provided on opposite surfaces of the planar block.

25. Electrosurgical apparatus according to claim 7, wherein the bipolar emitting structure comprises two opposing clamping surfaces for clamping biological tissue therebetween, the first conductor being provided on one of the clamping surfaces and the second conductor being provided on the other clamping surface.

26. Electrosurgical apparatus according to any preceding claim for use in a clinical procedure relating to any one of Natural Orifice Transluminal Endoscopic Surgery (NOTES), Transanal Endoscopic Microsurgery (TEMS), and single port laparoscopic surgery.

CLAIMS

1. Electrosurgical apparatus for resection of biological tissue, the apparatus comprising:

a radiofrequency (RF) signal generator for generating RF electromagnetic (EM) radiation having a first frequency;

a microwave signal generator for generating microwave EM radiation having a second frequency that is higher than the first frequency;

a probe arranged to deliver the RF EM radiation and the microwave EM radiation separately or simultaneously from a distal end thereof;

a feed structure for conveying the RF EM radiation and the microwave EM radiation to the probe, the feed structure comprising an RF channel for connecting the probe to the RF signal generator, and a microwave channel for connecting the probe to the microwave signal generator;

an RF signal detector for sampling current and voltage on the RF channel and generating therefrom a RF detection signal indicative of the current and voltage;

a microwave signal detector for sampling forward and reflected power on the microwave channel and generating therefrom a microwave detection signal indicative of the microwave power delivered by the probe; and

a controller in communication with the RF signal detector and microwave signal detector to receive the RF detection signal and microwave detection signal,

wherein the controller is operable to select an energy delivery profile for the RF EM radiation and the microwave EM radiation, the energy delivery profile for the RF EM radiation being for tissue cutting and the energy delivery profile for the microwave EM radiation being for haemostasis or sealing or coagulation or ablation of tissue,

characterised in that:

the controller comprises a digital microprocessor programmed to output an RF control signal for the RF signal generator and a microwave control signal for the microwave signal generator, the RF control signal and the microwave control signal being for setting the energy delivery profile

for the RF EM radiation and the microwave EM radiation respectively, and

the controller is arranged to determine a state for the RF control signal and microwave control signal based on the received RF detection signal and microwave detection signal respectively.

2. Electrosurgical apparatus according to claim 1, wherein the feed structure includes a measurement channel for delivering energy at a power level of 10 mW or less.

3. Electrosurgical apparatus according to claim 2, wherein the measurement channel is connected to receive a measurement signal from the microwave signal generator, and wherein the apparatus is switchable so that microwave EM radiation is delivered to the probe either through the measurement channel or the microwave channel.

4. Electrosurgical apparatus according to claim 3, wherein the microwave signal detector includes a heterodyne or double heterodyne detector.

5. Electrosurgical apparatus according to claim 2, wherein, if the energy delivery profile for the RF EM radiation and/or the microwave EM radiation comprises a pulsed waveform, the apparatus is arranged to deliver energy to the probe along the measurement channel during the OFF time of the pulsed waveform.

6. Electrosurgical apparatus according to any preceding claim, wherein the controller is arranged to set the energy delivery profile by adjusting the waveform and/or power of the RF EM radiation and the microwave EM radiation.

7. Electrosurgical apparatus according to any preceding claim, wherein the distal end of the probe comprises a bipolar emitting structure comprising a first conductor spatially separated from a second conductor, the first and second conductors being arranged to act:

as active and return electrodes respectively to convey the RF EM radiation by conduction, and

as an antenna to radiate the microwave EM radiation.

8. Electrosurgical apparatus according to claim 7 including a gas feed connected to supply a flow of gas to the distal end of the probe, wherein, if the flow of gas is present, the RF EM radiation is controllable to strike a conducting gas plasma between the first and second conductors at the distal end of the probe and the microwave EM radiation is arranged to sustain the gas plasma.

9. Electrosurgical apparatus according to any preceding claim, wherein the RF channel and microwave channel comprise physically separate signal pathways from the RF signal generator and microwave signal generator respectively, the separate signal pathway on the RF channel being isolated from the microwave EM radiation and the separate signal pathway on the microwave channel being isolated from the RF EM radiation.

10. Electrosurgical apparatus according to claim 9, wherein the feed structure includes a combining circuit having a first input connected to the separate signal pathway on the RF channel, a second input connected to the separate signal pathway on the microwave channel, and an output connected to a common signal pathway for conveying the RF EM radiation and the microwave EM radiation separately or simultaneously along a single channel to the probe.

11. Electrosurgical apparatus according to claim 10, wherein the combining circuit includes a switching device for connecting either the RF channel or the microwave channel to the common signal pathway.

12. Electrosurgical apparatus according to claim 10, wherein the switching device comprises a relay or coaxial switch.

13. Electrosurgical apparatus according to claim 0, wherein the combining circuit comprises a bi-directional diplexer arranged to permit:

forward RF EM radiation to be conveyed from the first input to the output,

reflected RF EM radiation to be conveyed from the output to the first input,

forward microwave EM radiation to be conveyed from the second input to the output, and

reflected microwave EM radiation to be conveyed from the output to the second input.

14. Electrosurgical apparatus according to claim 11, wherein the bi-direction diplexer comprising a T-shaped open microstrip circuit having a low pass filter integrally formed therewith to prevent microwave EM radiation from leaking out of the first input.

15. Electrosurgical apparatus according to any preceding claim, wherein the RF detection signal from the RF signal detector is indicative of the voltage and current of the RF EM radiation.

16. Electrosurgical apparatus according to claim 15 comprising an RF tuner connected on the RF channel for controlling the energy delivered into tissue by the RF EM radiation, wherein the RF tuner has an adjustable reactance that is controllable by the controller based on the RF detection signal.

17. Electrosurgical apparatus according to claim 16, wherein the adjustable reactance of the RF tuner comprises a plurality of reactive elements, each reactive element having a fixed reactance and being independently switchable into or out of connection with the RF channel according to a respective control signal from the controller.

18. Electrosurgical apparatus according to claim 16, wherein the adjustable reactance of the RF tuner comprises a plurality of reactive elements, each reactive element having a variable reactance that is independently controllable according to a respective control signal from the controller.

19. Electrosurgical apparatus according to claim 16, wherein the adjustable reactance of the RF tuner is provided by a variable capacitor and/or variable inductor, and the

controller comprises a self-adjusting feedback loop arranged to generate a signal for setting the reactance of the variable capacitor and/or variable inductor.

20. Electrosurgical apparatus according to any preceding claim, wherein the microwave detection signal is indicative of the magnitude of reflected power on the microwave channel.

21. Electrosurgical apparatus according to claim 20 including an impedance adjuster connected on the microwave channel between the microwave signal generator and the probe, the impedance adjuster having an adjustable complex impedance that is controllable by the controller based on the microwave detection signal.

22. Electrosurgical apparatus according to any preceding claim, wherein the RF signal generator comprises:

an oscillator coupled to a switching unit for generating a stable RF output;

an amplifier for amplifying the stable RF output; and

an output transformer,

wherein the amplifier is arranged to amplify a voltage across a primary coil of the transformer, and the switching unit is arranged to switch ON/OFF a voltage across the primary coil of the output transformer.

23. Electrosurgical apparatus according to any preceding claim, wherein the first frequency is a stable fixed frequency in the range 10 kHz to 300 MHz and the second frequency is a stable fixed frequency in the range 300 MHz to 100 GHz.

24. Electrosurgical apparatus according to claim 7, wherein the bipolar emitting structure comprises a planar block of dielectric material, the first and second conductors being conductive layers provided on opposite surfaces of the planar block.

25. Electrosurgical apparatus according to claim 7, wherein the bipolar emitting structure comprises two opposing clamping surfaces for clamping biological tissue therebetween, the first conductor being provided on one of the clamping

surfaces and the second conductor being provided on the other clamping surface.

26. Electrosurgical apparatus according to any preceding claim for use in a clinical procedure relating to any one of Natural Orifice Transluminal Endoscopic Surgery (NOTES), Transanal Endoscopic Microsurgery (TEMS), and single port laparoscopic surgery.