CLAIMS

1. An electrosurgical instrument configured for delivering microwave frequency energy having a predetermined operating frequency into tissue having a predetermined characteristic impedance in contact with a distal end of the instrument, the instrument comprising:

a proximal coaxial transmission line for conveying microwave frequency energy comprising a first inner conductor, a first outer conductor formed coaxially with the first inner conductor, and a first dielectric layer separating the first inner conductor and the first outer conductor;

a distal coaxial transmission line for conveying microwave frequency energy comprising a second inner conductor connected to the first inner conductor, a second outer conductor formed coaxially with the second inner conductor and connected to the first outer conductor, and a second dielectric layer separating the second inner conductor and the second outer conductor;

wherein a ratio of an inner diameter of the second outer conductor to the outer diameter of the second inner conductor is such that a characteristic impedance of the distal coaxial transmission line is intermediate between a characteristic impedance of the proximal coaxial transmission line and a load impedance at the distal end of the distal coaxial transmission line when the distal end of the instrument is in contact with the tissue; ~~and~~

wherein a length of the distal coaxial transmission line is such that the distal coaxial transmission line is an impedance transformer that improves the impedance match between the proximal coaxial transmission line and the load impedance at the distal end of the distal coaxial transmission line when the distal end of instrument is in contact with the tissue, at the predetermined operating frequency~~.~~; and

wherein the electrosurgical instrument comprises a further distal coaxial transmission line comprising a third inner conductor connected to the second inner conductor, a third outer conductor formed coaxially with the third inner conductor and connected to the second outer conductor, and a

third dielectric layer separating the third inner conductor and the third outer conductor.

2. The electrosurgical instrument according to claim 1, wherein a length of the distal coaxial transmission line is substantially equal to $(2n+1)\lambda/4$, where λ is the wavelength in the distal coaxial transmission line of microwave frequency energy having the predetermined operating frequency and n is an integer greater than or equal to 0.

3. The electrosurgical instrument according to claim 1 or claim 2, wherein the electrosurgical instrument is for coagulating tissue.

4. The electrosurgical instrument according to any one of the previous claims, wherein the ratio of the inner diameter of the second outer conductor to the outer diameter of the second inner conductor is such that a characteristic impedance of the distal coaxial transmission line is substantially equal to $\sqrt{Z_{in}Z_L}$, where Z_{in} is the characteristic impedance of the proximal coaxial transmission line and Z_L is the load impedance at the distal end of the distal coaxial transmission line when the distal end of the instrument is in contact with the tissue.

5. The electrosurgical instrument according to any ~~one of the previous claims, wherein the second inner conductor, second outer conductor and second dielectric layer are exposed at a distal end face of the distal coaxial transmission line for contacting the tissue.~~

~~6. The electrosurgical instrument according to any one of claims 1 to 4,~~ preceding claim ~~wherein the electrosurgical instrument comprises a further distal coaxial transmission line comprising a third inner conductor connected to the second inner conductor, a third outer conductor formed coaxially with the third inner conductor and connected to the second outer conductor, and a third dielectric layer separating the third inner conductor and the third outer conductor.~~

~~7. The electrosurgical instrument according to claim 6~~, wherein a characteristic impedance of the further distal coaxial transmission line is the same as a characteristic impedance of the proximal coaxial transmission line.

~~8~~6. The electrosurgical instrument according to any preceding claim ~~6 or claim 7~~, wherein a length of the further distal coaxial transmission line is such that the further distal coaxial transmission line substantially cancels out a reactive part of the predetermined characteristic impedance of the tissue at the predetermined operating frequency.

~~9~~7. The electrosurgical instrument according to any ~~one of claims 6 to 8~~preceding claim, wherein the further distal coaxial transmission line is rigid.

~~10~~8. The electrosurgical instrument according to any ~~one of claims 6 to 9~~preceding claim, wherein the electrosurgical instrument comprises:

an open-circuited or short-circuited stub connected in parallel to the further distal coaxial transmission line.

~~11~~9. The electrosurgical instrument according to claim ~~10~~8, wherein a characteristic impedance of the stub is the same as a characteristic impedance of the further distal coaxial transmission line.

~~12~~10. The electrosurgical instrument according to claim ~~10~~8, wherein a characteristic impedance of the stub is not the same as a characteristic impedance of the further distal coaxial transmission line.

~~13~~11. The electrosurgical instrument according to any one of claims ~~10~~8 to ~~12~~10, wherein the electrosurgical instrument comprises a plurality of the open-circuited or short-circuited stubs connected in parallel to the further distal coaxial transmission line.

~~14. The electrosurgical instrument according to any one of the previous claims, wherein the distal coaxial transmission line is rigid.~~

~~15. The electrosurgical instrument according to any one of the previous claims, wherein the predetermined operating frequency is 5.8 GHz.~~

~~16~~12. The electrosurgical instrument according to any one of the previous claims, wherein a separation between the outer diameter of the second inner conductor and the inner diameter of the second outer conductor is less than a separation between an outer diameter of the first inner conductor and an inner diameter of the first outer conductor.

~~17~~13. The electrosurgical instrument according to any one of the previous claims, wherein the second dielectric layer has a higher relative permittivity than the first dielectric layer.

~~18~~14. The electrosurgical instrument according to any one of the previous claims, wherein ~~the characteristic impedance of~~at least one of the following apply:

(a) the ~~proximal~~distal coaxial transmission line is ~~50 Ohms.~~rigid;

~~19. The electrosurgical instrument according to any one of the previous claims, wherein the proximal coaxial transmission line is a coaxial cable.~~

~~20. The electrosurgical instrument according to any one of the previous claims, wherein~~(b) the distal coaxial transmission is tapered from a wider proximal end thereof to a narrower distal end thereof~~.~~;

~~21. The electrosurgical instrument according to any one of the previous claims, wherein:~~

~~the instrument is configured for delivering microwave frequency energy having the predetermined operating frequency~~

~~into tissue having a predetermined characteristic impedance in the range of 45 to 180 Ohms.~~

~~22~~(c) the proximal coaxial transmission line is a coaxial cable.

15. The electrosurgical instrument according to any one of the previous claims, wherein the electrosurgical instrument comprises a plurality of the distal coaxial transmission lines for improving the impedance match between the proximal coaxial transmission line and the tissue at the predetermined operating frequency.

~~23. An electrosurgical system comprising:~~

~~an electrosurgical instrument according to any one of the previous claims; and~~

~~an electrosurgical generator connected to a proximal end of the proximal coaxial transmission line;~~

~~wherein the electrosurgical generator is configured to supply the proximal coaxial transmission line with microwave frequency energy having the predetermined operating frequency.~~

~~24. The electrosurgical system according to claim 23, wherein:~~

~~the electrosurgical system comprises a controller for controlling the electrosurgical generator; and~~

~~the controller is configured to control the power and/or duration of the microwave frequency energy supplied by the generator to limit the amount of microwave frequency energy delivered to the tissue to below a predetermined amount.~~

~~25. The electrosurgical system according to claim 24, wherein the electrosurgical system comprises a sensor for sensing information indicative of the amount of microwave frequency energy delivered to the tissue.~~

~~26. The electrosurgical system according to claim 24 or claim 25, wherein the controller is configured to control the generator to provide a power of 15 W for a period of up to four seconds.~~

27. A method of manufacturing an electrosurgical instrument according to any one of claims 1 to 22, the method comprising:

determining the ratio of the inner diameter of the second outer conductor to the outer diameter of the second inner conductor that results in the characteristic impedance of the distal coaxial transmission line being intermediate between a characteristic impedance of the proximal coaxial transmission line and the load impedance at the distal end of the distal coaxial transmission line when the distal end of the instrument is in contact with the tissue;

setting the ratio of the inner diameter of the second outer conductor to the outer diameter of the second inner conductor to be the determined ratio;

determining a length of the distal coaxial transmission line that results in the distal coaxial transmission line being an impedance transformer that improves the impedance match between the proximal coaxial transmission line and the load impedance at the distal end of the distal coaxial transmission line when the distal end of the instrument is in contact with the tissue, at the predetermined operating frequency; and

setting the length of the distal coaxial transmission line to be the determined length.

28. The method according to claim 27, wherein the method comprises:

determining the wavelength λ in the distal coaxial transmission line of microwave frequency energy having the predetermined operating frequency; and

setting the length of the distal coaxial transmission line to be substantially equal to $(2n+1)\lambda/4$, where n is an integer greater than or equal to 0, based on the determined wavelength λ.

29. The method according to claim 27 or claim 28, wherein the method comprises:

determining the ratio of the inner diameter of the second outer conductor to the outer diameter of the second inner

conductor that results in the characteristic impedance of the distal coaxial transmission line being substantially equal to $\sqrt{Z_{in}Z_L}$, where Z_{in} is the characteristic impedance of the proximal coaxial transmission line and Z_L is the load impedance at the distal end of the distal coaxial transmission line when the distal end of the instrument is in contact with the tissue; and

setting the ratio of the inner diameter of the second outer conductor to the outer diameter of the second inner conductor to be the determined ratio.

30. The method according to claim 29, wherein the method comprises:

calculating $\sqrt{Z_{in}Z_L}$; and

calculating the ratio of the inner diameter of the second outer conductor to the outer diameter of the second inner conductor that results in a characteristic impedance of the distal coaxial transmission line equal to $\sqrt{Z_{in}Z_L}$.

31. The method according to claim 28, wherein the method comprises calculating the wavelength in the distal coaxial transmission line of the microwave frequency energy having the predetermined operating frequency based on the relative permittivity of the second dielectric layer.

32. The method according to any one of claims 27 to 31, in which the electrosurgical instrument comprises the further distal coaxial transmission line, wherein the method comprises:

determining a length of the further distal coaxial transmission line that results in the reactive part of the predetermined characteristic impedance of the tissue being cancelled out; and

setting the length of the further distal coaxial transmission line to be substantially equal to the determined length.