

the pair of jaw elements adjacent to the gap; a second conductive element mounted in the other one of the pair of jaw elements adjacent to the gap opposite the first conductive element; a coaxial cable for conveying microwave energy, having a specific frequency; and a signal transition portion at a distal end of the coaxial cable, the signal transition portion being arranged to connect the first conductive element to an outer conductor of the coaxial cable and to connect the second conductive element to an inner conductor of the coaxial cable, wherein the first conductive element and the second conductive element and the gap between the pair of jaws constitute a ~~form a~~ non-uniform ~~unbalanced lossy~~ transmission line to support the microwave energy as a travelling wave, and wherein the transmission line formed by the first conductive element and the second conductive element is designed to couple electrical energy into biological tissue in the gap between the pair of jaw elements to prevent multiple reflections of the travelling wave, whereby the transmission line is ~~a~~ non-resonant for the microwave energy along the travelling wave, in the presence of biological tissue, and wherein the transmission line has a geometry selected to exhibit a return loss of better than 7db at the specific frequency of the microwave energy when the biological tissue is present in the gap, whereby power received at the proximal end of the transmission line is efficiently delivered into the biological tissue in the gap during a single transit of the travelling wave along the transmission line.

Herein the term "non-resonant" ~~may means~~ that multiple reflections of the electrical length of the transmission line ~~(along the microwave energy travelling wave)~~ do not occur on the transmission line, is set to inhibit multiple reflections of the travelling wave, i.e. to prevent or inhibit the creation of a radiating standing wave is not created. In practice this may mean that the electrical length of the transmission line is substantially different from a multiple of a quarter wavelength of the microwave energy (an odd or even multiple needs to be avoided depending on whether the distal end of the transmission line is an open circuit or a short circuit). It is particularly desirable for the transmission line to be non-resonant when there

is biological tissue in the gap, i.e. in contact with the jaw elements. Thus, the electrical length of the transmission line may be set to avoid a multiple of a quarter wavelength of the microwave energy when the transmission line is loaded by the biological tissue in this way. Preferably the distal end of the transmission line is an open circuit, as this may enable the device to operate with radiofrequency (RF) energy as well as microwave energy.

Forming a non-resonant transmission line may prevent the device from radiating. The microwave energy is therefore delivered into tissue through leakage from the transmission line structure. By setting the length of the transmission line with knowledge of the loss level into biological tissue at the frequency of the microwave energy, the electrosurgical forceps of the invention ~~can be~~ is arranged to deliver substantially all of the power received at the proximal end of

for the patient when in use in the environment found inside the patient's body.

The magnitude of the field may be controlled e.g. by controlling the power delivered to the forceps based on the size of the gap. This control may ~~be~~ permit the magnitude of the electric field to be independent of the size of the vessel or the thickness of the tissue located in the gap. This may present an advantage over conventional bipolar RF forceps.

Herein, ~~"microwave frequency" may be used broadly to indicate~~ the microwave energy may have a specific frequency within a frequency range of 400 MHz to 100 GHz, but preferably within the range 1 GHz to 60 GHz, more preferably 2.45 GHz to 30 GHz or 5 GHz to 30 GHz. Specific frequencies that have been considered are: 915 MHz, 2.45 GHz, 3.3 GHz, 5.8 GHz, 10 GHz, 14.5 GHz and 24 GHz.

The electrosurgical forceps of the invention may be configured for insertion down an instrument channel of an endoscope, or may be arranged for use in laparoscopic surgery or in a NOTES procedure or in a general open procedure.

Herein, the term "non-uniform" transmission line is used to designate an arrangement in which the conductive elements on opposing surfaces of the jaws are not in a uniform spatial relationship with each other along the length of the pair of jaw elements. For example, the conductive elements may comprise a first conductive plate mounted in one of the pair of jaw elements and a second conductive plate mounted in the other one of the pair of jaw elements, wherein the signal transition portion is arranged to connect the first conductive plate to an outer conductor of the coaxial cable and to connect the second conductive plate to an inner conductor of the coaxial cable. The conductive plates may each include a flat surface at or aligned with the surface of one of the jaw elements facing into the gap. This configuration may ensure an optimal power density in the gap between the plates, to ensure that the energy is delivered into biological tissue present in the gap.

The transmission line may form a parallel transmission line or parallel plate transmission line when the opposing

surfaces of the conductive plates are parallel. However, this is not essential. Over a wide range of angles between the jaws, e.g.  $\pm 20^\circ$  or more, the power will travel up between the jaws. The jaws might not be parallel for a number of reasons,

in one of the pair of jaw elements adjacent to the gap; a second transmission line structure mounted in the other one of the pair of jaw elements adjacent to the gap opposite the first transmission line structure; a coaxial cable for conveying microwave ~~frequency energy~~, having a specific frequency; and a power splitter at a distal end of the coaxial cable, the power splitter being arranged to divide the microwave frequency energy conveyed by the coaxial cable between the first transmission line structure and the second transmission line structure, wherein each of the first transmission line structure and the second transmission line structure consists of ~~an unbalanced lossy~~ a transmission line arranged to support the microwave energy as a travelling wave, and wherein the transmission line of each of the first transmission line structure and the second transmission line structure have an electrical length along the is designed to couple electrical energy into biological tissue in the gap between the pair of jaw elements to prevent multiple reflections of the travelling wave, whereby the transmission line that is non-resonant for the microwave energy, in the presence of biological tissue, and wherein the transmission line has a geometry selected to exhibit a return loss of better than 7 db at the specific frequency of the microwave energy when the biological tissue is present in the gap, whereby power received at the proximal end of the transmission line is efficiently delivered into the biological tissue in the gap during a single transit of the travelling wave along the transmission line.

Each of the first transmission line structure and the second transmission line structure is a parallel transmission line or a coaxial transmission line. The power splitter may comprise an arrangement of flexible microstrip transmission lines or coaxial transmission lines. For example, the signal transition may comprise any of a Wilkinson power divider, an arrangement of two quarter wavelength transformers, a 3 dB power splitter or the like. If a Wilkinson power divider is

used to split the power available at the distal end of the coaxial cable into two equal parts, then the signal transition may comprise two semi-circular or straight sections that are each a quarter wavelength long at the frequency of operation, i.e. the overall length of the splitter is a half wavelength at the operating frequency. In this arrangement the impedance of the transmission lines that form the two semi-circular or straight sections is set as

$$Z_W = \sqrt{2}Z_0,$$

where  $Z_W$  is the impedance of the line that forms the Wilkinson power divider and  $Z_0$  is the characteristic impedance of the coaxial cable. In a preferred embodiment, the impedance of the coaxial cable is set to be the same as the transmission line inside the jaws, ~~which in turn is set to be the same as the~~ when loaded with the biological tissue to be treated.

CLAIMS

1. Electrosurgical forceps comprising:

a pair of jaw elements pivotable relative to each other  
to open and close a gap therebetween;

a first conductive element mounted in one of the pair of  
jaw elements adjacent to the gap;

a second conductive element mounted in the other one of  
the pair of jaw elements adjacent to the gap opposite the  
first conductive element;

a coaxial cable for conveying microwave energy having a  
specific frequency; and

a signal transition portion at a distal end of the  
coaxial cable, the signal transition portion being arranged to  
connect the first conductive element to an outer conductor of  
the coaxial cable and to connect the second conductive element  
to an inner conductor of the coaxial cable,

wherein the first conductive element and the second  
conductive element and the gap between the pair of jaws  
constitute a non-uniform transmission line to support the  
microwave energy as a travelling wave,

~~wherein the conductive elements on opposing surfaces of the  
pair of jaw elements are not in a uniform spatial  
relationship with each other along the length of the pair of  
jaw elements,~~

wherein the transmission line formed by the first  
conductive element and the second conductive element is  
designed to couple electrical energy into biological tissue in  
the gap between the pair of jaw elements to prevent multiple  
reflections of the travelling wave, whereby the transmission  
line is non-resonant for the microwave energy along the  
travelling wave in the presence of biological tissue, and

wherein the transmission line has a geometry selected to  
exhibit a return loss of better than 7 dB at the specific  
frequency of the microwave energy when the biological tissue

8. Electrosurgical forceps according to any preceding claim, wherein the signal transition portion includes an outer connector that extends from the outer conductor of the coaxial cable and electrically connects the outer conductor of the coaxial cable to the first conductive element.

9. Electrosurgical forceps according to claim 8, wherein the outer connector tapers in width as it extends away from the outer conductor of the coaxial cable.

10. Electrosurgical forceps comprising:  
a pair of jaw elements pivotable relative to each other to open and close a gap therebetween;  
a first transmission line structure mounted in one of the pair of jaw elements adjacent to the gap;  
a second transmission line structure mounted in the other one of the pair of jaw elements adjacent to the gap opposite the first transmission line structure;  
a coaxial cable for conveying microwave energy having a specific frequency; and  
a power splitter at a distal end of the coaxial cable, the power splitter being arranged to divide the microwave frequency energy conveyed by the coaxial cable between the first transmission line structure and the second transmission line structure,  
wherein each of the first transmission line structure and the second transmission line structure consists of a transmission line arranged to support the microwave energy as a travelling wave,  
wherein the transmission line of each of the first transmission line structure and the second transmission line structure is designed to couple electrical energy into biological tissue in the gap between the pair of jaw elements to prevent multiple reflections of the travelling wave, whereby the transmission line is non-resonant for the microwave energy in the presence of biological tissue, and