(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 356 545 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
17.05.2006 Bulletin 2006/20

(21) Application number: **02701471.1**

(22) Date of filing: **31.01.2002**

(51) Int Cl.:
H01Q 9/30 *(2006.01)* ***A61N 5/04*** *(2006.01)*

(86) International application number:
PCT/IB2002/000299

(87) International publication number:
WO 2002/061880 (08.08.2002 Gazette 2002/32)

(54) **INTERSTITIAL MICROWAVE ANTENNA WITH MINIATURIZED CHOKE FOR HYPERTHERMIA IN MEDICINE AND SURGERY**

MASCHEN-MIKROWELLENANTENNE MIT MINIATURISIERTER DROSSEL FÜR DIE HYPERTHERMIE IN DER MEDIZIN UND CHIRURGIE

ANTENNE INTERSTITIELLE A MICRO-ONDES AVEC ETRANGLEMENT MINIATURISE POUR HYPERTHERMIE EN MEDECINE ET CHIRURGIE

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **31.01.2001 IT PI20010006**

(43) Date of publication of application:
29.10.2003 Bulletin 2003/44

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EP 1 356 545 B1

Description

Field of the invention

[0001] The present invention relates to minimally invasive surgery techniques, for interstitial, percutaneous, laparoscopic, endoscopic and intrasurgery applications in medicine and surgery, especially in oncology.

[0002] More precisely, it relates to a microwave antenna, for hyperthermia, operating from 37C up to over 100C, of the monopole or dipole co-axial type equipped with "trap", commonly called choke, for blocking the propagation of the reflecting wave that turns back towards the generator.

[0003] Furthermore the invention relates to a method of construction of such an antenna.

Description of the prior art

[0004] Hyperthermia in oncology is method used for over 30 years for treatment of cancer (Hahn GM, Hyperthermia and Cancer, Plenum Press, in the York, 1982). It consists in heating the cancer cells to obtain their necrosis directly or with additional use of other methods such as radiotherapy, chemotherapy or other surgery techniques.

[0005] For heating tissues, in particular for treatment of surface lesions, firstly electromagnetic waves have been used produced by a source located out of the human body.

[0006] More recently thin appliances have been used among which microwave antennas, operating between some hundreds of MHz and some thousands of MHz, typically at 2450 MHz, executed in co-axial tube, for interstitial, percutaneous, laparoscopic, endoscopic and intrasurgery applications, suitable to the local treatment of deep lesions (Iskander MF & Tumeh AM, Design Optimization of Interstitial Antennas, IEEE Transactions on Biomedical Engineering, 1989, 238-246).

[0007] Such antennas are usually inserted in the lesion to treat using catheters or metal needles, under echographic guide, TAC, NMR or other computerised imaging techniques. They are suitable to be used in association with drugs, ionizing waves and/or with surgery ablation.

[0008] These microwave antennas, normally, are manufactured using a flexible or semi-rigid co-axial tube, suitably modified at one end, for conveying microwave power into the tissues to cause hyperthermia.

[0009] In Figure 1 an axial cross section is shown of an antenna inserted in a biopsy needle 1. The antenna, in its active portion at the right of the drawing, is suitably configured as radiating dipole or monopole. More precisely, 2 is the external conductor of the co-axial tube, 3 is the dielectric layer that insulates the external conductor from the central conductor 4. The point indicated with 7 is the feeding point, i.e, the active portion of the antenna, commonly called "feed", where the emitted power, normally, is maximum.

[0010] The isothermal surfaces that can be obtained by heating a biological tissue (not crossed by large blood vessels) with a normal antenna, that for example is made by cutting at an end a portion of the external conductor 2 of the co-axial tube and leaving dielectric layer 3 uncovered, as described in Figure 1, have a rotationally symmetric configuration. Their projection on the plane of the figure is elliptical, with a central maximum of transmission, as above said, near feeding point 7 of the antenna, where the distal portion of the external conductor 2 of the co-axial tube is cut. The surface of dotted projection 8 indicates an isothermal surface of the tissue that is being radiated by this type of antenna in a purely theoretical case.

[0011] Actually, the impedance of the antenna is never perfectly adapted with that of the medium in which it operates, owing to the variation of the dielectric characteristics of the medium same when heating, and for other reasons connected with the guided propagation of an electromagnetic wave. During the delivery of microwave power there is always an backward wave that returns along the external conductor of the antenna, from the active end towards the generator, causing an backward elongation of the heating figure. The dashed curve 9 indicates the projection of an backwardly elongated isothermal surface corresponding to this effect. This drawback prevents from suitably concentrating the heat production near the active portion of the antenna and is a big limit to the use of this technique.

[0012] For overcoming this drawback normally the antenna is equipped with a device, called choke, or trap, often used in radio-broadcasting antennas (see for example Reintjes JF & Coate GT, Principles of Radar, McGraw-Hill Book Company, in the York 1952, p 851) that blocks the backwards propagation of the reflected power.

[0013] This device, indicated with 11 in figure 2, consists in a co-axial guiding portion, $\lambda/4$ long, being λ the wavelength of the emitted waves, obtained by arranging at an end the external conductor of the co-axial tube of the antenna, near the feed 7, a short circuit metal tube 12. In Figure 2, 1 is the needle guide of the antenna, 2 is the external conductor of the antenna, 3 is the insulating material and 4 is the central conductor.

[0014] In this case the backwards reflecting wave, indicated with 13, runs the external surface of the antenna, enters choke 11, reflects itself at its end in a short circuit and, after a total path of $\lambda/2$ is again at the entrance of the choke but in phase opposition with respect to that that at inlet, with a result of a null intensity. The isothermal surface that is obtained when the antenna is equipped with choke 11 is indicated by the continuous curve 10 of Figure 2.

[0015] Actually, as it can be seen, the introduction of the choke 11 causes a substantial increase of the diameter of the antenna, and then of needle 1, thus limiting its applications when a minimum invasive operation is required, such as for example in out-patient's departments, in the repeated treatments, etc..

[0016] For manufacturing reasons, and because of the resistance limits of the material, the radial dimension of the choke cannot be reduced under certain limits.

[0017] Furthermore, in case of change of the dielectric characteristics of the medium caused by the variation of the temperature during the treatment, or in case of variation of the frequency of the antenna, as when a microwave generator with adjustable frequency, the choke cannot be lengthened or shortened, in order to be always about a fourth of the wavelength long. The impedance of the existing chokes is therefore fixed, whereby the elimination of the returning wave can not be totally effective when the operating temperature is changed.

[0018] An application of hyperthermia is, furthermore normally associated to a measure of the local temperature. In fact, it is necessary for measure the heating temperature of the cancer lesions, or other lesions to treat, to preserve the adjacent healthy tissues and for controlling the actual heating power of the antenna.

[0019] Usually, in the operation region a sensor of temperature is inserted (indicated with 20 in figure 2) For example, metal thermocouples are used. However, they cannot be introduced during the delivery of energy by the antenna, owing to eddy currents in the metal of thermocouple, that overheats thus affecting the measure. Furthermore the presence of a thermocouple changes the distribution of the microwave field, changing the heating cannot be introduced during the delivery of energy by the antenna, owing to eddy currents in the metal of thermocouple, that overheats thus affecting the measure. Furthermore the presence of a thermocouple changes the distribution of the microwave field, changing the heating pattern. Therefore, the temperature measure with a metal thermocouple must be done with the drawback of stopping often the delivery of energy. Alternatively, optical-fibre sensors are known to have no metal and are not affected by the field or do not perturbate it, but have the drawback of being expensive and fragile. In both cases of metal thermocouples or optical-fibre sensors, there is the further drawback of introducing a further catheter for guiding the sensor into the operation region.

Summary of the invention

[0020] It is object of the present invention to provide an co-axial mic'rowave antenna for applications in medicine and surgery that is provided with trap, or choke, for blocking the backwards propagation of the reflecting wave towards the generator, wherein a miniaturisation of this trap with respect to the prior art is possible, in order to allow the use for minimally invasive applications.

[0021] It is another object of the present invention to provide an antenna that, in case of variation of the medium wavelength, allows the choke to be lengthened or shortened for a more correct operation.

[0022] It is a further object of the present invention to provide an antenna that allows a measure of temperature operation region.

[0023] It is a further object of the present invention to provide a method for the production of a such an antenna that allows this miniaturisation with simple construction.

[0024] These and other objects are achieved by the antenna according to the present invention, that can be inserted in a metal needle necessary for the introduction of the antenna in the target tissue, the antenna having:

- an inner conductor,
- a dielectric layer that coats the inner conductor for all its length,
- an external conductor that covers coaxially the dielectric layer except from an end portion,
- a choke mounted outside the external conductor near the end portion, the choke comprising a co-axial conducting portion of diameter higher than the external conductor,
- a conducting collar for connecting the co-axial conductor to the external conductor, the conducting collar being arranged along the co-axial conducting portion opposite to the end portion,
- the characteristic of the antenna being that the co-axial conducting portion of the choke consists in the metal needle same.

[0025] Advantageously, the collar is in sliding contact with the needle, whereby the length of the choke can be changed.

[0026] Preferably, next to the collar and adjacent to the end portion, the antenna has a plastics sheath that is a dielectric layer in the choke.

[0027] The sheath can be of antiadhesive material and of length that protrudes from the needle, preventing the outer portion to adhere to tissues during the high temperature heating treatment.

[0028] Advantageously, a thermocouple is provided put through the choke and the sheath, said thermocouple being in contact with the external conductor of said co-axial tube and having the sensitive end that comes out from said sheath protruding into the zone of feed of the antenna.

[0029] According to another aspect of the invention, a method of construction of a choke with variable length on a co-axial antenna, the antenna being inserted in a metal needle necessary for the introduction of the antenna in the target tissue, the antenna having:

- an inner conductor,
- a dielectric layer that coats the inner conductor for all its length,
- an external conductor that covers coaxially the dielectric layer except from an end portion,

the characteristic being that of providing on the antenna a conducting collar near the end portion, whereby the conducting collar slides in the metal needle.

[0030] Preferably, next to the collar adjacent to the end portion a plastics sheath is arranged on the antenna that

is a dielectric layer in the choke.

[0031] The sheath and the dielectric layer of the antenna are advantageously of PTFE.

[0032] The collar can be made of metal welded to the external conductor of the antenna.

Brief description of the drawings

[0033] Further characteristics and advantages of the interstitial microwave antenna and of the method for its production, according to the present invention, will be made clearer with the following description of an embodiment thereof, exemplifying but not limitative, with reference to the further attached drawings wherein:

- figure 3 shows a sectional axial view of an antenna second invention;
- figure 4 shows an exploded view of the antenna of figure 3;
- figure 5 shows the antenna of figure 3 to which a thermocouple is added that crosses the choke and protrudes into the zone of feed.

Description of a preferred embodiment

[0034] In Figure 3 an axial cross section is shown of an antenna according to the invention inserted in a metal tube that consists in an biopsy needle 1, for example a 14 Gauge, outer diameter = 2.1 mm needle.

[0035] The antenna, in its active portion at the right of the figure, is a radiating dipole or monopole. More precisely, the antenna is formed by a co-axial tube having an external conductor 2, by a dielectric layer 3 and by a central conductor 4 immersed in the dielectric layer 3 that insulates it from the external conductor 2. The external conductor 2, as well known, has an end point indicated with 7, which is the feeding point, i.e. the active portion of the antenna, normally called "feed", where the emitted power, normally, is maximum.

[0036] According to the invention, a plastics insulating sheath 5 and a metal collar 6 are provided. More precisely, this can be obtained:

- welding on the external conductor of the antenna 2 the metal collar 6 in a predetermined position,
- by arranging the sheath 5 of plastics that coats the external conductor 2 in the portion that goes from feed 7 up to collar 6,
- using the wall inner of the same metal needle 1 wherein the antenna is inserted for containing and guiding the collar 6 and the sheath 5, in particular, the collar 6 being in electrical contact with the wall inner of the metal needle 1.

[0037] The invention allows to make in a easy and not expensive way a miniaturized microwave antenna equipped with choke, suitable for local treatment of deep lesions in medicine and surgery. In fact, in combination with the metal needle 1, the collar 6 and the sheath 5 allow to obtain a choke of variable length and made reducing to the minimum the increase of the outer diameter of the antenna.

[0038] Like the choke of figure 2, in fact, in figure 3 the wave 13 is reflected back starting from the feed 7 and runs the external surface of the antenna, enters the choke formed between the needle 1 and the external conductor 4, reflects itself on the collar 6 in short circuit and, after a total $\lambda/2$ path is again at the inlet of the choke in phase opposition with respect to the wave at the inlet, obtaining a null intensity. The variation of wavelength in case of temperature rise, or other cause, can be corrected by varying the position of the collar 6 with respect to needle 1, so that the choke is always $\lambda/4$ long. Within a certain range the variation of impedance of the antenna during the operation can be compensated in the same way changing the length of the choke and then of the portion between the choke and the feed.

[0039] The isothermal surface that is obtained when the antenna is equipped with the choke according to the invention is shown also in this case by the dashed curve axial tube of the antenna, and the inner wall 1 of the needle guide through which the antenna is inserted.

[0040] More precisely, the metal collar 6 keeps the electrical contact with the inner wall of the needle guide 1 and is thus a mobile by-pass.

[0041] Sheath 5 has, then, the following functions:

- is a co-axial wave guide $\lambda/4$ long supplying an effective choke for the antenna,
- it is a centering element for the sliding in the antenna needle,
- in the portion outer to the choke the adhesion of tissues is avoided during the high temperature heating treatment, and it does not allow their contact with metal surfaces different from the needle guide within which the antenna slides.

[0042] With reference to figure 5, according to a different embodiment of the invention, a thermocouple is provided 21 put through the collar 6 and the sheath 5 that forms the choke. Thermocouple 21 is in contact with the external conductor 2 of the co-axial tube that forms the antenna, and has its sensitive end 22 that comes out from the sheath 5 protruding into the zone 10 of feed of the antenna. The other end of thermocouple is connected to the a temperature measuring instrument not shown by means of a plug 23.

[0043] According to the invention thermocouple 21 does not affects the operation of the antenna. In fact, the thermocouple is integral to the metal of the outer co-axial conductor 2. Therefore, thermocouple 22 is practically shielded.

[0044] Thermocouple 21 can be a common metal thermocouple, formed by a metal sheath in which are metal different conductors are joined at the sensitive end 22. Such a metal thermocouple not much expensive, much

less than in optical fibre sensors (for example fluoride-optical sensors).

[0045] A further advantage of thermocouple 21 is that of an external thermocouple has not to be inserted through an additional catheter to part and, especially, the measure can be made directly in the operation region during the feeding delivery that produces the hyperthermia.

[0046] Thermocouple 21 can be put also in hyperthermia antennas different from that shown in figures from 3 to 5.

Claims

1. Co-axial microwave antenna for applications interstitial, percutaneous, laparoscopic, endoscopic and intrasurgery in medicine and surgery, in species for acute hyperthermia in oncology, that can be inserted into a metal needle for introduction into a target tissue, said antenna having:

   - an inner conductor,
   - a dielectric layer that coats the inner conductor for all its length,
   - an external conductor that covers coaxially the dielectric layer except from an end portion,
   - a choke mounted outside the external conductor near said end portion, said choke comprising a co-axial conducting portion of diameter higher than the external conductor,
   - a conducting collar for connecting said axial conductor to the external conductor, said conducting collar being arranged along said co-axial conducting portion opposite to said end portion,

   characterised in that
   the co-axial conducting portion of the choke consists in said metal needle.

2. Antenna according to claim 1, wherein said collar is in sliding contact with said needle, whereby the length of the choke can be changed.

3. Antenna according to claim 1, wherein next to said collar adjacent to said end portion a plastics sheath is provided that is a dielectric layer in the choke.

4. Antenna according to claim 1, wherein said sheath is of antiadhesive material and has a length that protrudes from the needle, preventing the outer portion to adhere to tissues during the high temperature heating treatment.

5. Antenna according to claim 1, wherein a thermocouple is provided put through the collar and the sheath that forms the choke, said thermocouple being in contact with the external conductor of said co-axial tube and having the sensitive end that comes out from said sheath protruding into the zone of feed of the antenna.

6. A method of construction of a choke with variable length on a co-axial microwave antenna for interstitial, percutaneous, laparoscopic, endoscopic and intrasurgery applications in medicine and surgery, in species for acute hyperthermia in oncology, said antenna being inserted into a metal needle necessary for introduction into a target tissue, said antenna having:

   - an inner conductor,
   - a dielectric layer that coats the inner conductor for all its length,
   - an external conductor that covers coaxially the dielectric layer except from an end portion,

   characterised in that said antenna is provided with a conducting collar near said end portion, whereby said conducting collar slides in said metal needle.

7. Method according to claim 6, wherein next to said collar adjacent to said end portion a plastics sheath is provided on the antenna that is a dielectric layer inner to said choke.

8. Method according to claim 6, wherein said sheath and the dielectric layer of the antenna are of PTFE.

9. Method according to claim 6, wherein said collar is made of metal welded to the external conductor of the antenna.

Patentansprüche

1. Koaxiale Mikrowellenantenne für interstitiale, perkutane, laparoskopische, endoskopische und intrachirurgische Anwendungen in der Medizin und Chirurgie bei Spezies für eine akute Hyperthermie in der Onkologie, die in eine Metallnadel zum Einführen in ein Zielgewebe eingesetzt werden kann, wobei die Antenne aufweist:

   - einen inneren Leiter,
   - eine dielektrische Schicht, welche den inneren Leiter über seine gesamte Länge beschichtet,
   - einen externen Leiter, der die dielektrische Schicht außer einem Endabschnitt koaxial bedeckt,
   - einer Drossel, die außerhalb des externen Leiters nahe dem Endabschnitt angebracht ist, wobei die Drossel einen koaxial leitenden Abschnitt mit einem größeren Durchmesser als der externe Leiter umfasst,
   - einem leitenden Kragen zum Verbinden des

axialen Leiters mit dem externen Leiter, wobei der leitende Kragen entlang dem koaxial leitenden Abschnitt gegenüber dem Endabschnitt angeordnet ist,

dadurch gekennzeichnet, dass
der koaxiale leitende Abschnitt der Drossel in der Metallnadel besteht.

2. Antenne nach Anspruch 1, wobei der Kragen sich in Gleitkontakt mit der Nadel befindet, und die Länge der Drossel geändert werden kann.

3. Antenne nach Anspruch 1, wobei nahe dem Kragen angrenzend an den Endabschnitt eine Kunststoffhülse vorgesehen ist, die eine dielektrische Schicht in der Drossel ist.

4. Antenne nach Anspruch 1, wobei die Hülse aus nichthaftendem Material ist, und eine Länge aufweist, die aus der Nadel vorsteht, wobei ein Anhaften des äußeren Abschnitts an Geweben während der Hochtemperatur-Wärmebehandlung verhindert wird.

5. Antenne nach Anspruch 1, wobei ein Thermoelement, welches die Drossel bildet, den Kragen und die Hülse durchsetzend vorgesehen ist, wobei das Thermoelement in Kontakt mit dem externen Leiter des koaxialen Rohrs steht, und das empfindliche Ende aufweist, welches aus der Hülse austritt und in die Vorschubzone der Antenne vorsteht.

6. Verfahren zum Aufbau einer Drossel mit variabler Länge an einer koaxialen Mikrowellenantenne für interstitiale, perkutane, laparoskopische, endoskopische und intrachirurgische Anwendungen in der Medizin und Chirurgie bei Spezies für eine akute Hyperthermie in der Onkologie, wobei die Antenne in eine Metallnadel eingesetzt ist, die zum Einführen in ein Zielgewebe notwendig ist, wobei die Antenne aufweist:

- einen inneren Leiter,
- eine dielektrische Schicht, welche den inneren Leiter über seine gesamte Länge beschichtet,
- einen externen Leiter, der die dielektrische Schicht außer einem Endabschnitt koaxial bedeckt,

dadurch gekennzeichnet, dass die Antenne mit einem leitenden Kragen nahe dem Endabschnitt versehen ist, wodurch der leitende Kragen in der Metallnadel gleitet.

7. Verfahren nach Anspruch 6, wobei nahe dem Kragen angrenzend an den Endabschnitt eine Kunststoffhülse an der Antenne vorgesehen ist, die eine dielektrische Schicht innerhalb der Drossel ist.

8. Verfahren nach Anspruch 6, wobei die Hülse und die dielektrische Schicht der Antenne aus PTFE sind.

9. Verfahren nach Anspruch 6, wobei der Kragen aus einem an den externen Leiter der Antenne geschweißten Metall hergestellt ist.

Revendications

1. Antenne micro-onde coaxiale pour des applications interstitielles, percutanées, laparoscopiques, endoscopiques et de chirurgie interne en médecine et chirurgie, en particulier pour l'hyperthermie aiguë en oncologie, qui peut être insérée dans une aiguille métallique pour une introduction dans un tissu cible, ladite antenne comportant :

- un conducteur interne,
- une couche diélectrique qui recouvre le conducteur interne sur toute sa longueur,
- un conducteur externe qui recouvre de manière coaxiale la couche diélectrique sauf à partir d'une partie d'extrémité,
- un étranglement monté en dehors du conducteur externe près de ladite partie d'extrémité, ledit étranglement comprenant une partie conductrice coaxiale d'un diamètre plus grand que le conducteur externe,
- une bague conductrice pour connecter ledit conducteur axial au conducteur externe, ladite bague conductrice étant disposée le long de ladite partie conductrice coaxiale à l'opposé de ladite partie d'extrémité,

caractérisée en ce que
la partie conductrice coaxiale de l'étranglement est constituée de ladite aiguille métallique.

2. Antenne selon la revendication 1, dans laquelle ladite bague est en contact coulissant avec ladite aiguille, moyennant quoi la longueur de l'étranglement peut être modifiée.

3. Antenne selon la revendication 1, dans laquelle près de ladite bague adjacente à ladite partie d'extrémité, une gaine en plastique est prévue qui est une couche diélectrique dans l'étranglement.

4. Antenne selon la revendication 1, dans laquelle ladite gaine est faite d'un matériau antiadhésif et présente une longueur qui fait saillie à partir de l'aiguille, empêchant que la partie externe adhère aux tissus lors du traitement à chaud à haute température.

5. Antenne selon la revendication 1, dans laquelle un

thermocouple est fourni, placé à travers la bague et la gaine qui forme l'étranglement, ledit thermocouple étant en contact avec le conducteur externe dudit tube coaxial et ayant l'extrémité sensible qui sort de ladite gaine faisant saillie dans la zone d'alimentation de l'antenne.

6. Procédé de construction d'un étranglement avec une longueur variable sur une antenne micro-onde coaxiale pour des applications interstitielles, percutanées, laparoscopiques, endoscopiques et de chirurgie interne en médecine et chirurgie, en particulier pour une hyperthermie aiguë en oncologie, ladite antenne étant insérée dans une aiguille métallique nécessaire pour l'introduction dans un tissu cible, ladite antenne comportant :

- un conducteur interne,
- une couche diélectrique qui recouvre le conducteur interne sur toute sa longueur,
- un conducteur externe qui recouvre de manière coaxiale la couche diélectrique sauf à partir d'une partie d'extrémité,

caractérisé en ce que ladite antenne est pourvue d'une bague conductrice près de ladite partie d'extrémité, moyennant quoi ladite bague conductrice coulisse dans ladite aiguille métallique.

7. Procédé selon la revendication 6, dans lequel près de ladite bague adjacente à ladite partie d'extrémité, une gaine en plastique est prévue sur l'antenne qui est une couche diélectrique interne audit étranglement.

8. Procédé selon la revendication 6, dans lequel ladite gaine et la couche diélectrique de l'antenne sont en PTFE.

9. Procédé selon la revendication 6, dans lequel ladite bague est faite de métal soudé au conducteur externe de l'antenne.

Fig. 1
(prior art)

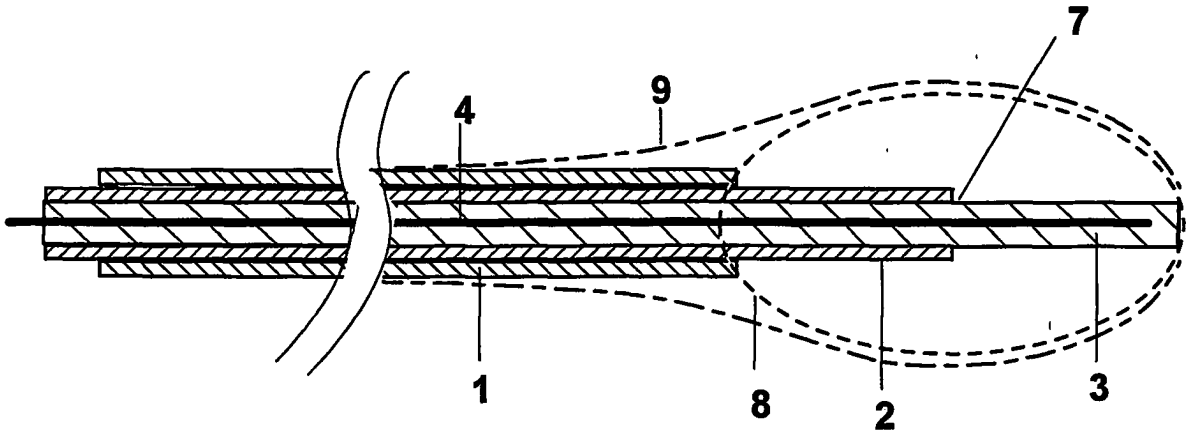


Fig. 2
(prior art)

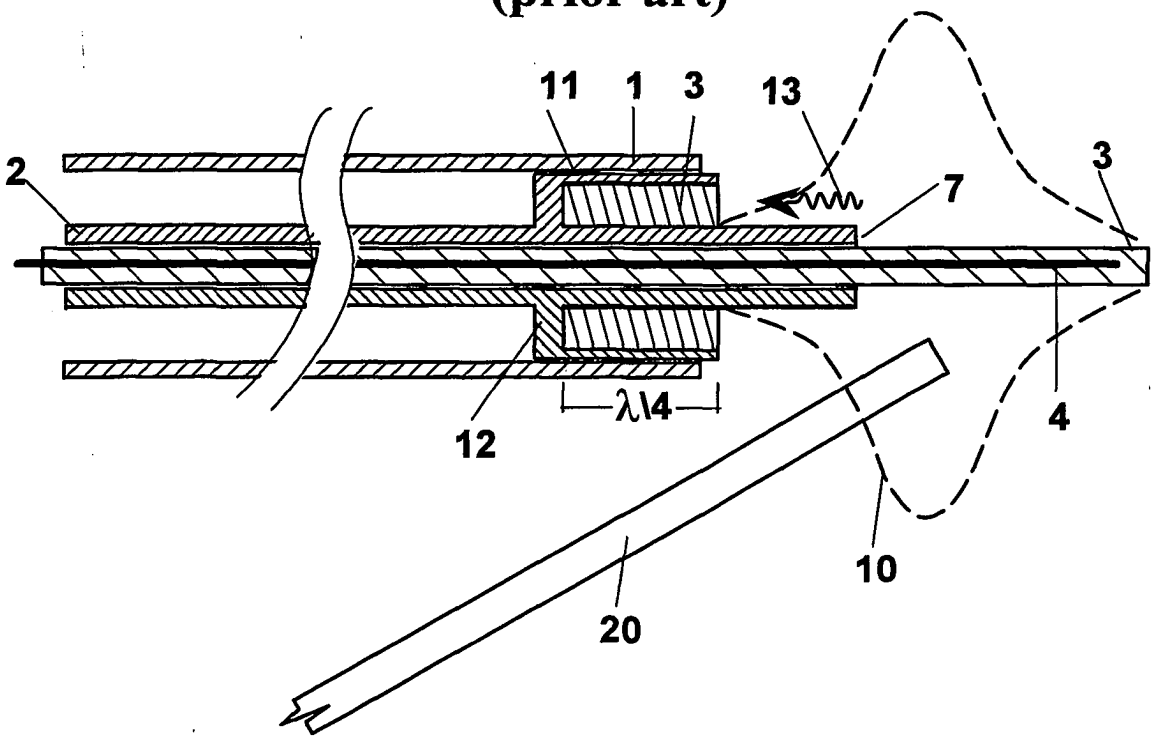


Fig. 3

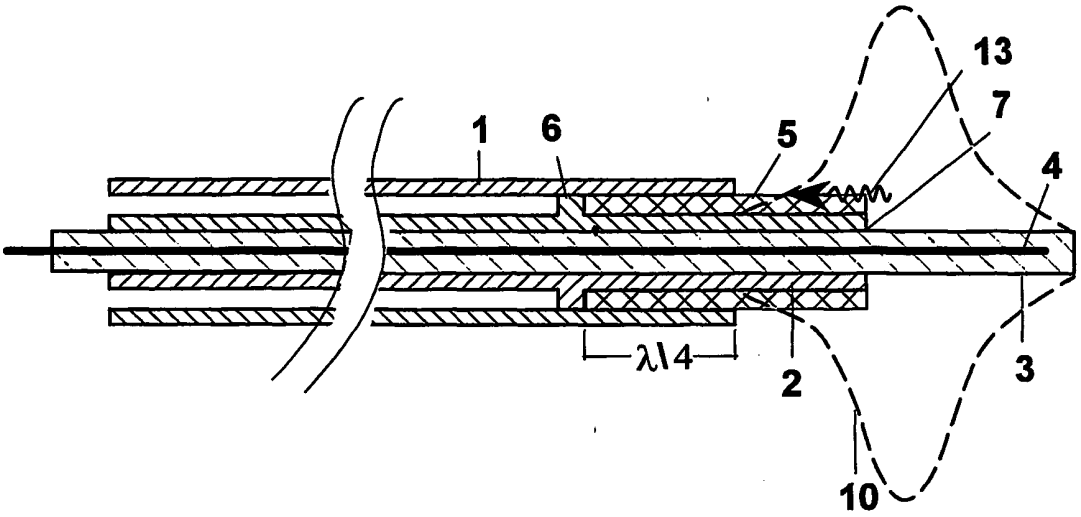


Fig. 4

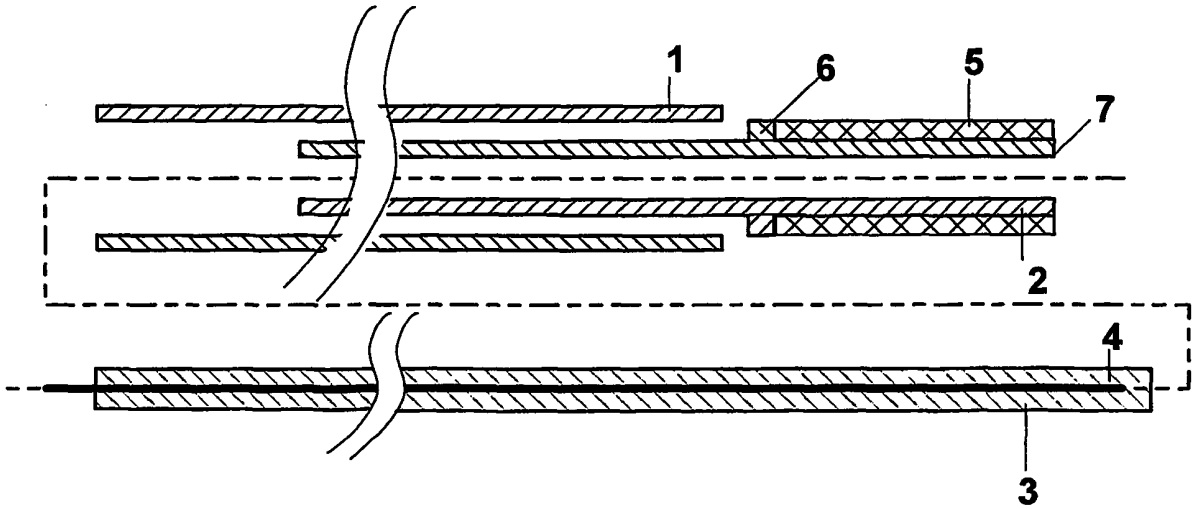
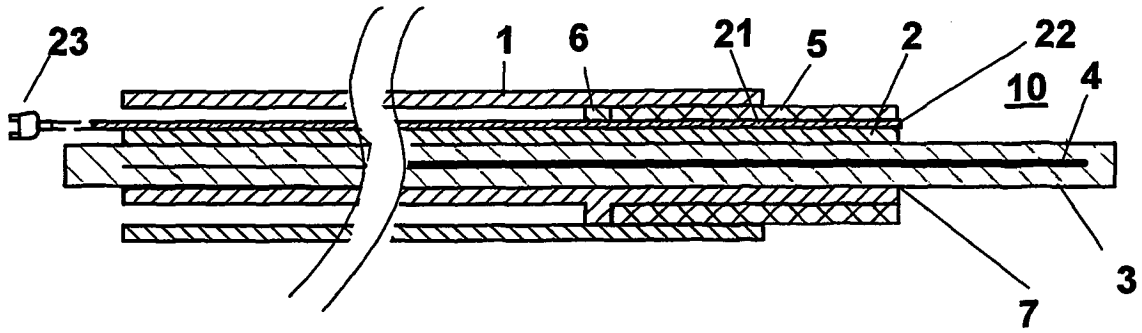


Fig. 5



专利名称(译)	具有微型扼流圈的间质微波天线，用于医学和外科手术中的热疗		
公开(公告)号	EP1356545B1	公开(公告)日	2006-05-17
申请号	EP2002701471	申请日	2002-01-31
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IPC分类号	H01Q9/30 A61N5/04 A61B18/18 H01Q1/44 H01Q9/26		
CPC分类号	H01Q9/30 A61B18/18 A61B18/1815		
优先权	PI2001000006 2001-01-31 IT		
其他公开文献	EP1356545A2		
外部链接	Espacenet		

摘要(译)

本发明涉及微创手术技术。它提供了一种制造用于经皮急性热疗微波应用的天线的方法，该微波应用是单极或偶极同轴型，具有陷阱，通常称为扼流圈，用于阻止向后反射波向发生器的传播。该装置的小型化允许在医学和外科手术中，特别是对于肿瘤学中使用微创的间质热疗。制造天线的方法提供了金属针（1），用于在目标组织中引入天线（2,3,4）。在天线（2）的外导体（4）上，金属套环（6）连接在预定位置;施加塑料护套（5）以便在进料（7）和轴环（6）之间的部分中覆盖外部导体（2）;然后，用于插入天线的金属针（1）的内壁用于容纳和引导轴环（6）和护套（5）;特别地，套环（6）与金属针（1）的内壁电接触。因此获得具有可变长度和小直径的扼流圈的天线。热电偶可以通过扼流圈引入，该扼流圈直接伸入“进料”区域。（图3）