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Vaiser et al.

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(45) **Date of Patent: Apr. 22, 2003**

(54) **SUPER-TOROIDAL ELECTRIC AND MAGNETIC FIELD GENERATOR/ DETECTOR, AND SAMPLE ANALYSER AND TREATMENT APPARATUS USING SAME**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **08/949,760**

(22) Filed: **Oct. 14, 1997**

Related U.S. Application Data

(63) Continuation-in-part of application No. 08/586,909, filed as application No. PCT/HU93/00043 on Jul. 27, 1993, now abandoned.

(51) **Int. Cl.**^{7} **G01N 27/74**; H01Q 11/08; A61N 2/04; G01R 33/00

(52) **U.S. Cl.** **324/204**; 324/226; 324/260; 324/239; 335/299; 336/229; 600/409

(58) **Field of Search** 324/204, 228, 324/226, 342, 239, 244, 253–255, 260, 262, 127, 445; 335/299; 336/229; 600/409

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Primary Examiner—Jay Patidar
(74) *Attorney, Agent, or Firm*—Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P.

(57) **ABSTRACT**

A field generator/detector including at least one super-toroidal conductor and a device to energize the super-toroidal conductor to generate varying electric and magnetic fields. Where conductor has a length l, the super-toroidal conductor is energized with at least one frequency component equal to or greater than 2c/l, where c is the speed of light in free space. Then the near field generated at this frequency close to the super-toroidal conductor has a strongly inhomogeneous spatial distribution similar or more complex than that generated by four or more electric charges and/or current loops. At any particular moment in time, the amplitudes of the electric and magnetic fields components of such a complex field change significantly over a distance comparable with the smallest winding feature of the super-toroidal conductor. The field generator/detector may be used in a sample analyzer having a chamber and a sample holder within the chamber. The chamber contains at least a first super-toroidal conductor having at least the length l. This super-toroidal conductor is energized to generate oscillating electric and magnetic field in the region of a sample in the chamber. The response of the generated field to the presence of a sample on the sample holder is determined, so that an analysis can be made. The field generator/detector may used also as a treatment apparatus for treating a desired component of a specimen. The treatment super-toroidal conductor is energized at a frequency or set of frequencies or continuous band of frequencies greater than 2c/1 to produce strongly inhomogeneous electric and magnetic fields.

22 Claims, 13 Drawing Sheets

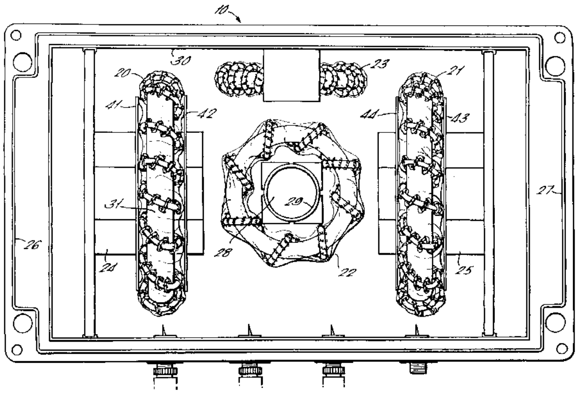


FIG. 1a.

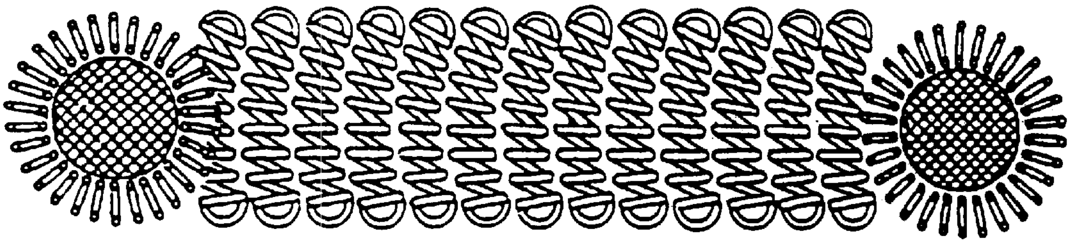
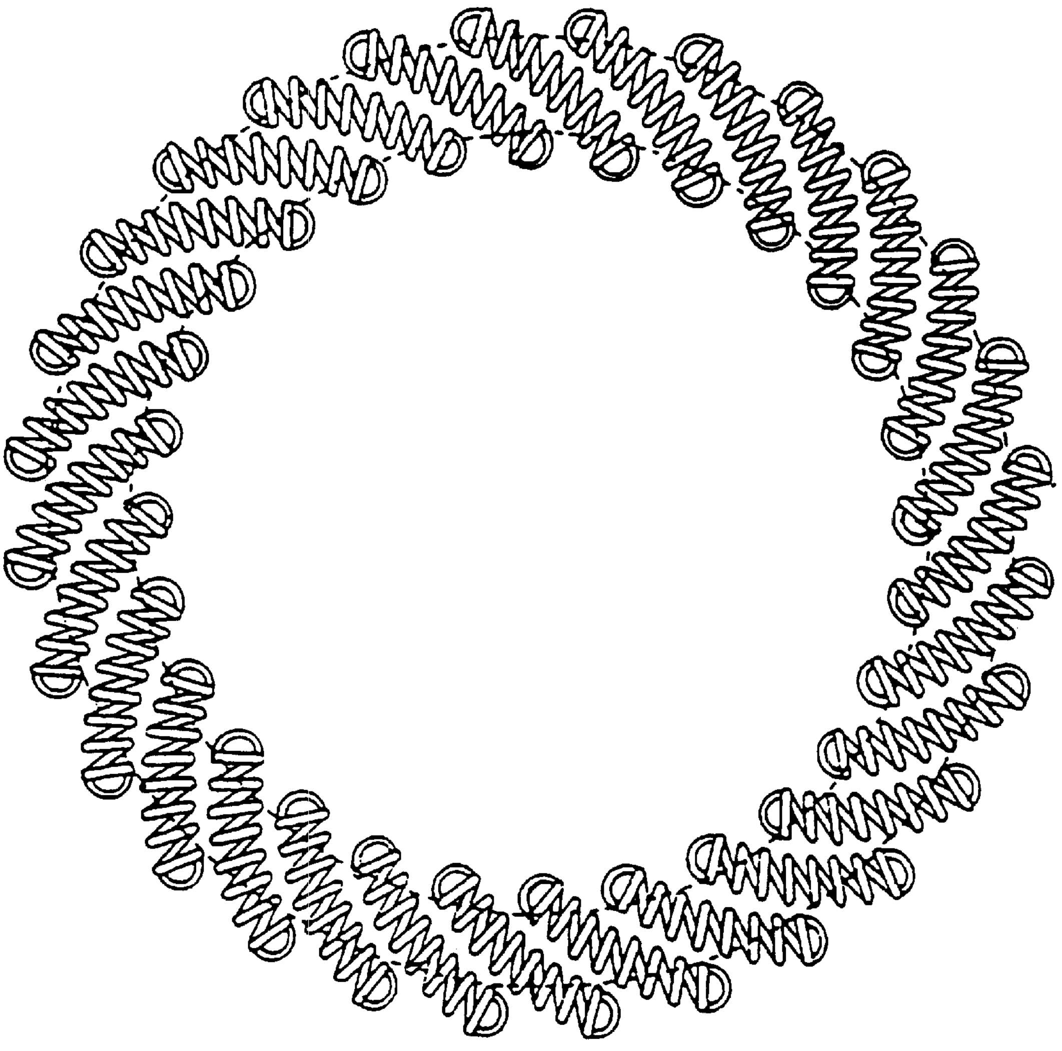


FIG. 1b.



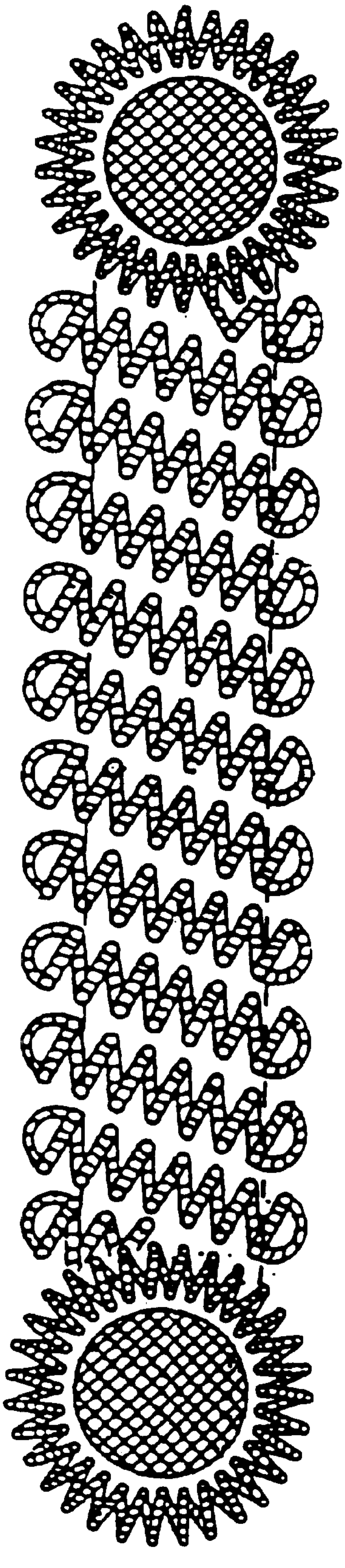


FIG. 1C.

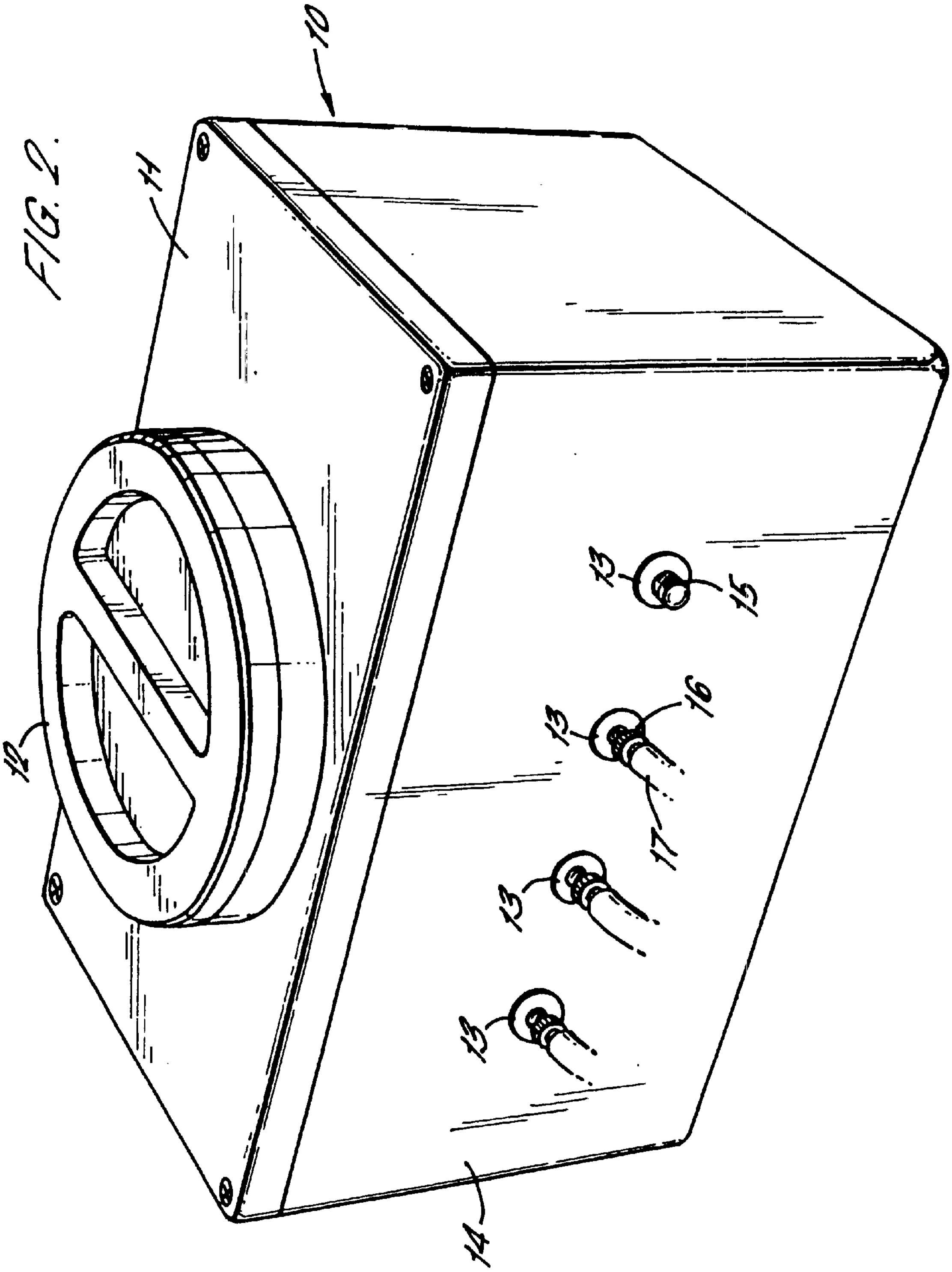


FIG. 2.

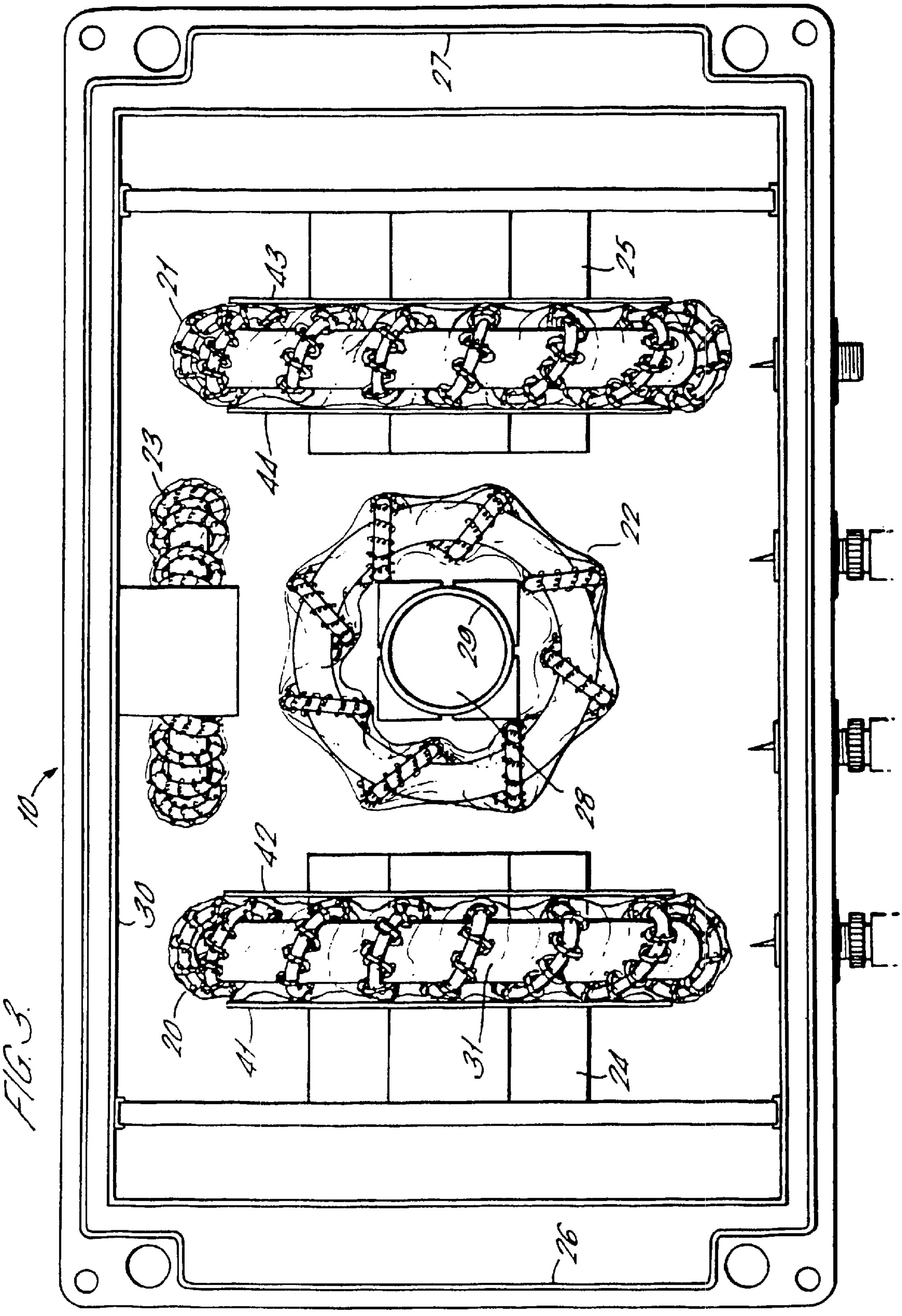


FIG. 3

FIG. 4

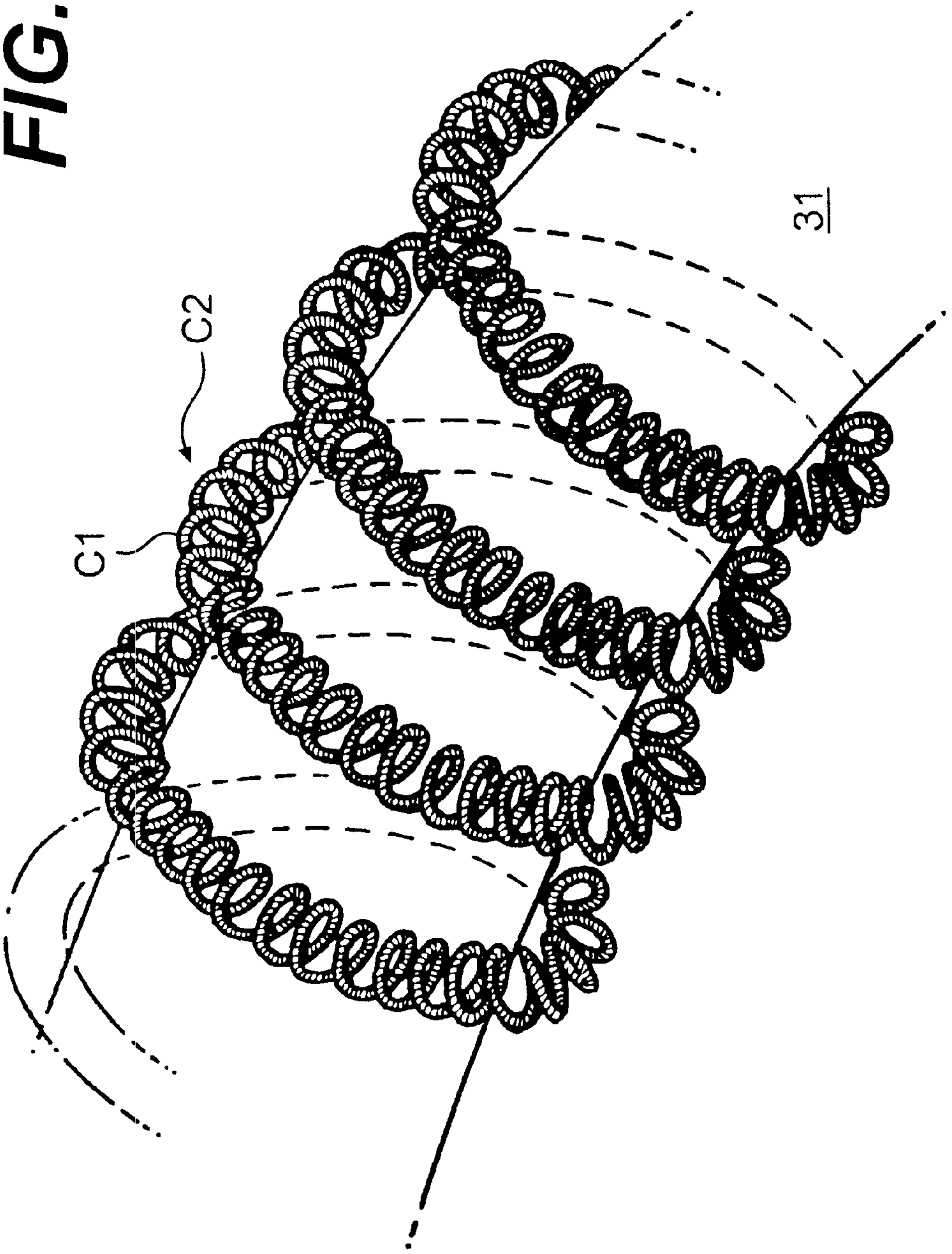


FIG. 5

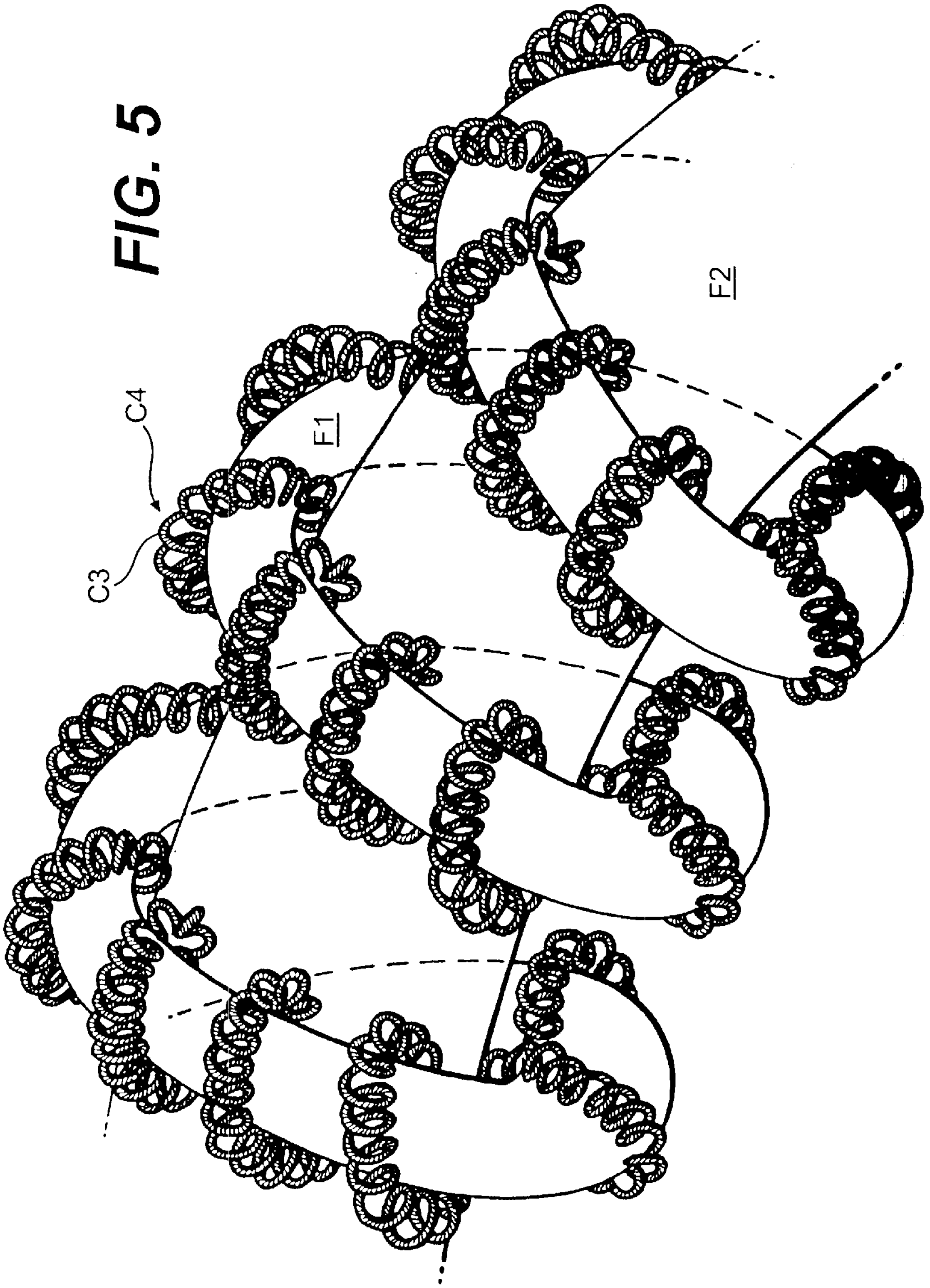


FIG. 6.

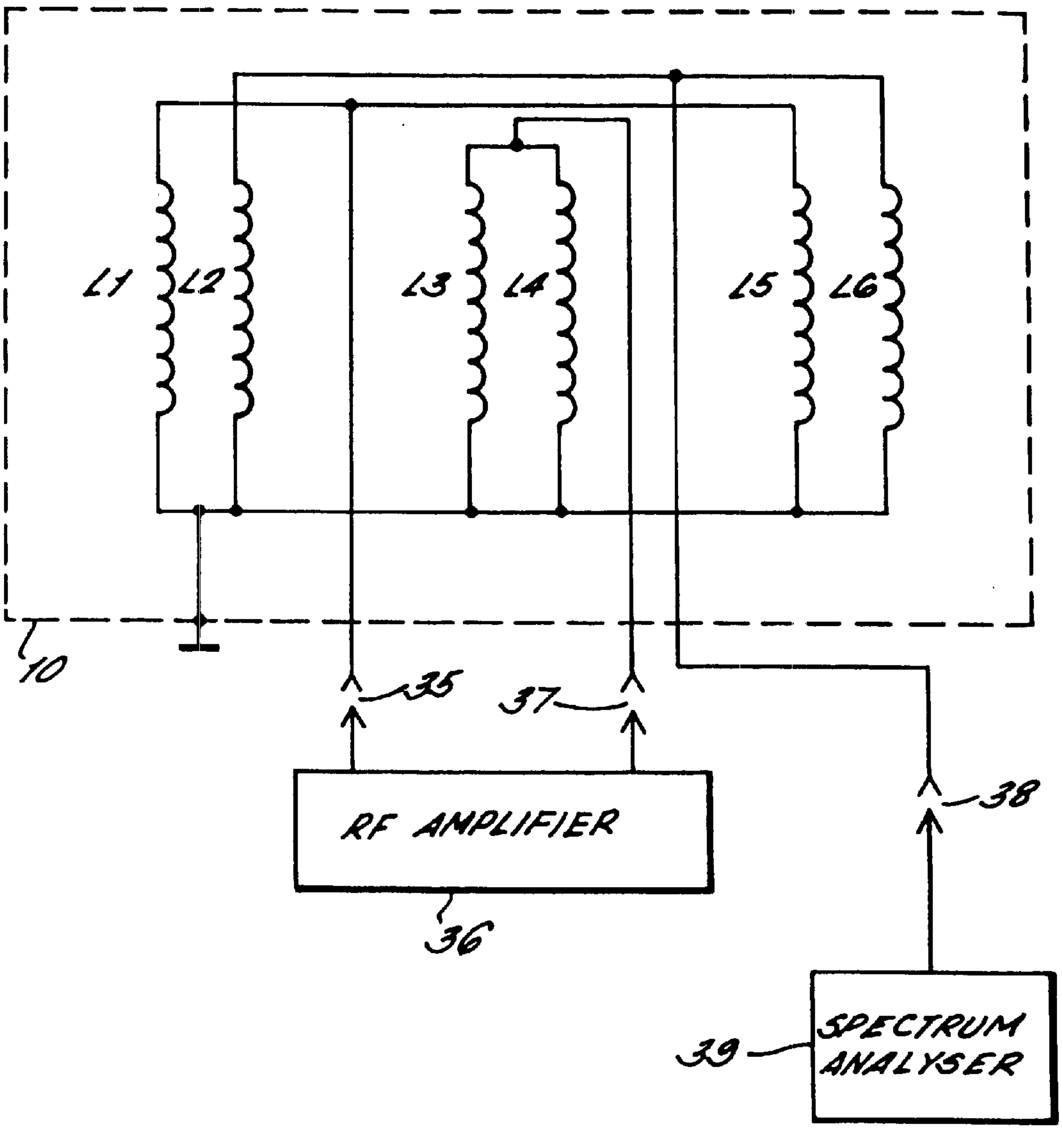
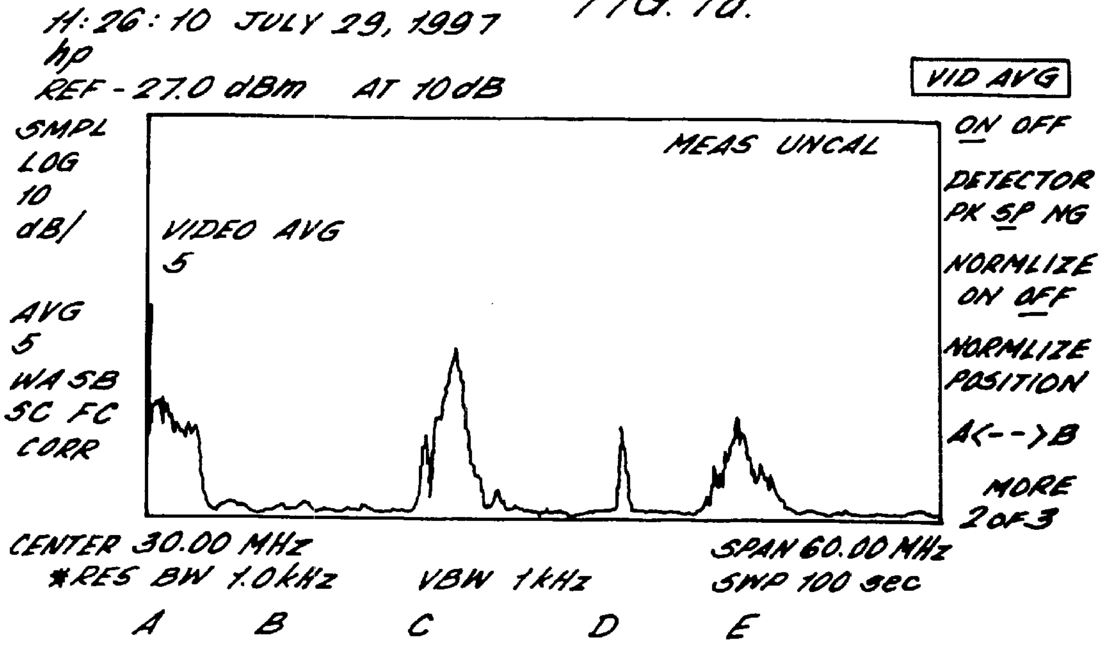

L1
L2
L3
L4
L5
L6
10
35
37
RF AMPLIFIER
36
38
39
SPECTRUM ANALYSER

FIG. 7a.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hp
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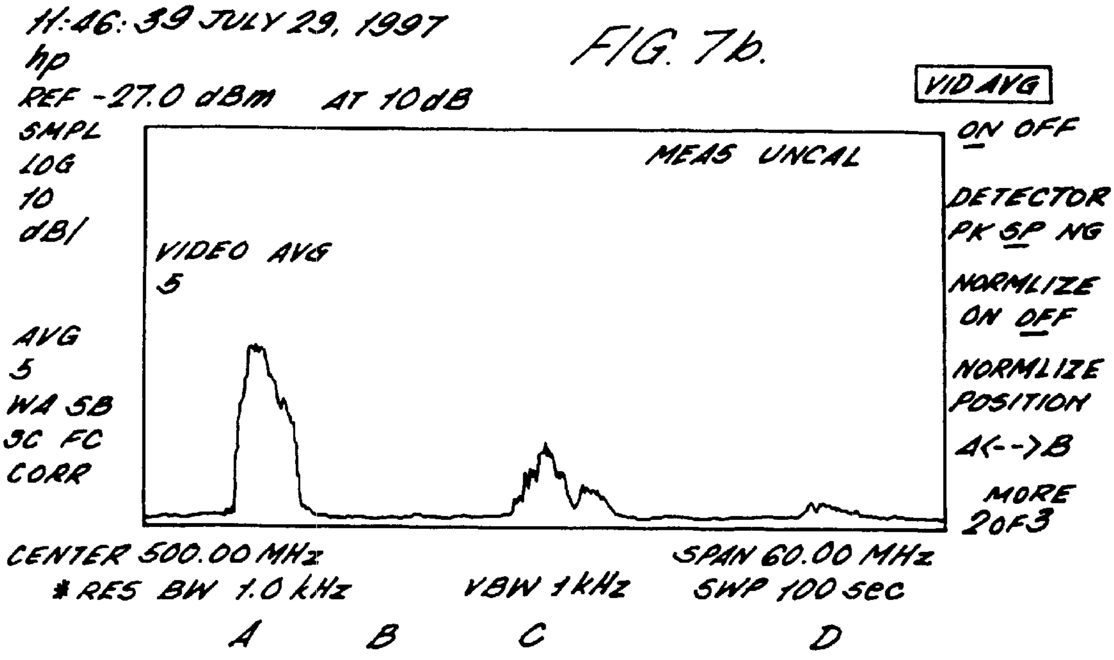
VID AVG
SMPL
LOG
10
dB/
MEAS UNCAL
VIDEO AVG
5
ON OFF
DETECTOR
PK SP NG
NORMLIZE
ON OFF
NORMLIZE
POSITION
A<-->B
MORE
2 OF 3
AVG
5
WA SB
SC FC
CORR
CENTER 30.00 MHz
*RES BW 1.0 kHz
VBW 1 kHz
SPAN 60.00 MHz
SWP 100 sec
A
B
C
D
E

FIG. 7b.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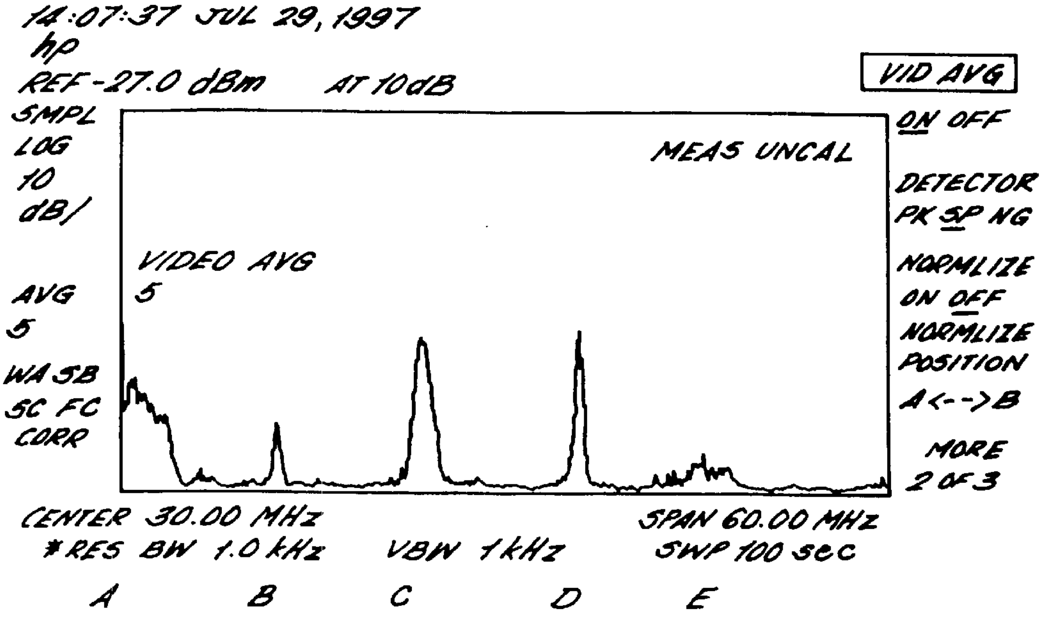
VID AVG
SMPL
LOG
10
dB/
MEAS UNCAL
VIDEO AVG
5
ON OFF
DETECTOR
PK SP NG
NORMLIZE
ON OFF
NORMLIZE
POSITION
A<-->B
MORE
2 OF 3
AVG
5
WA SB
SC FC
CORR
CENTER 500.00 MHz
*RES BW 1.0 kHz
VBW 1 kHz
SPAN 60.00 MHz
SWP 100 sec
A
B
C
D

FIG. 8a.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VID AVG
SMPL
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10
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MEAS UNCAL
ON OFF
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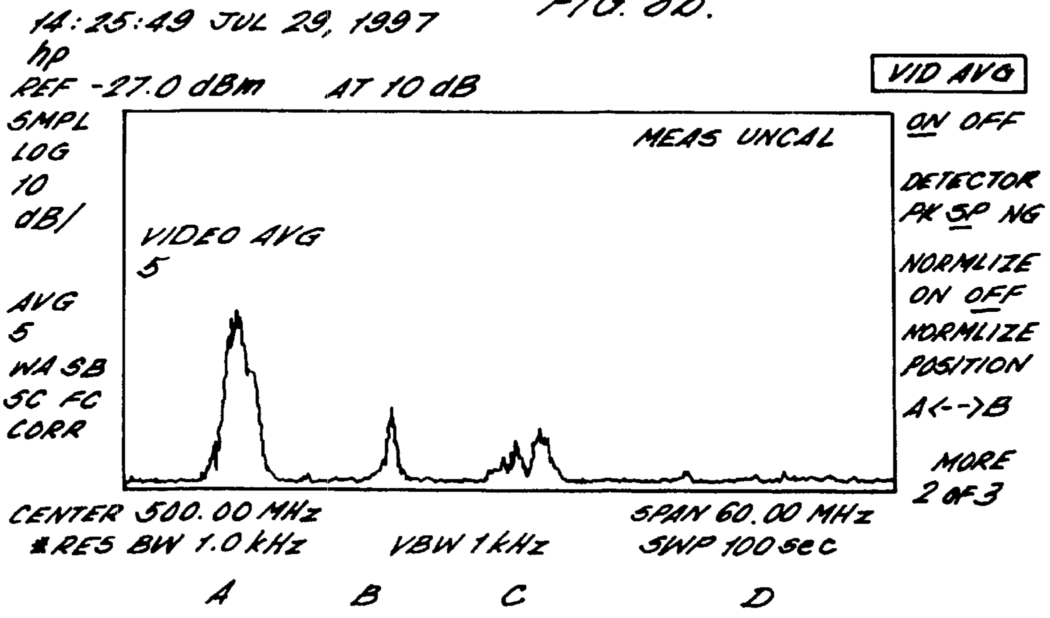
VIDEO AVG
5
NORMLIZE
ON OFF
AVG
5
NORMLIZE
POSITION
WA SB
SC FC
CORR
A<-->B
MORE
2 OF 3
CENTER 30.00 MHz
SPAN 60.00 MHz
*RES BW 1.0 kHz
VBW 1 kHz
SWP 100 sec
A
B
C
D
E

FIG. 8b.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hp
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VID AVG
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10
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MEAS UNCAL
ON OFF
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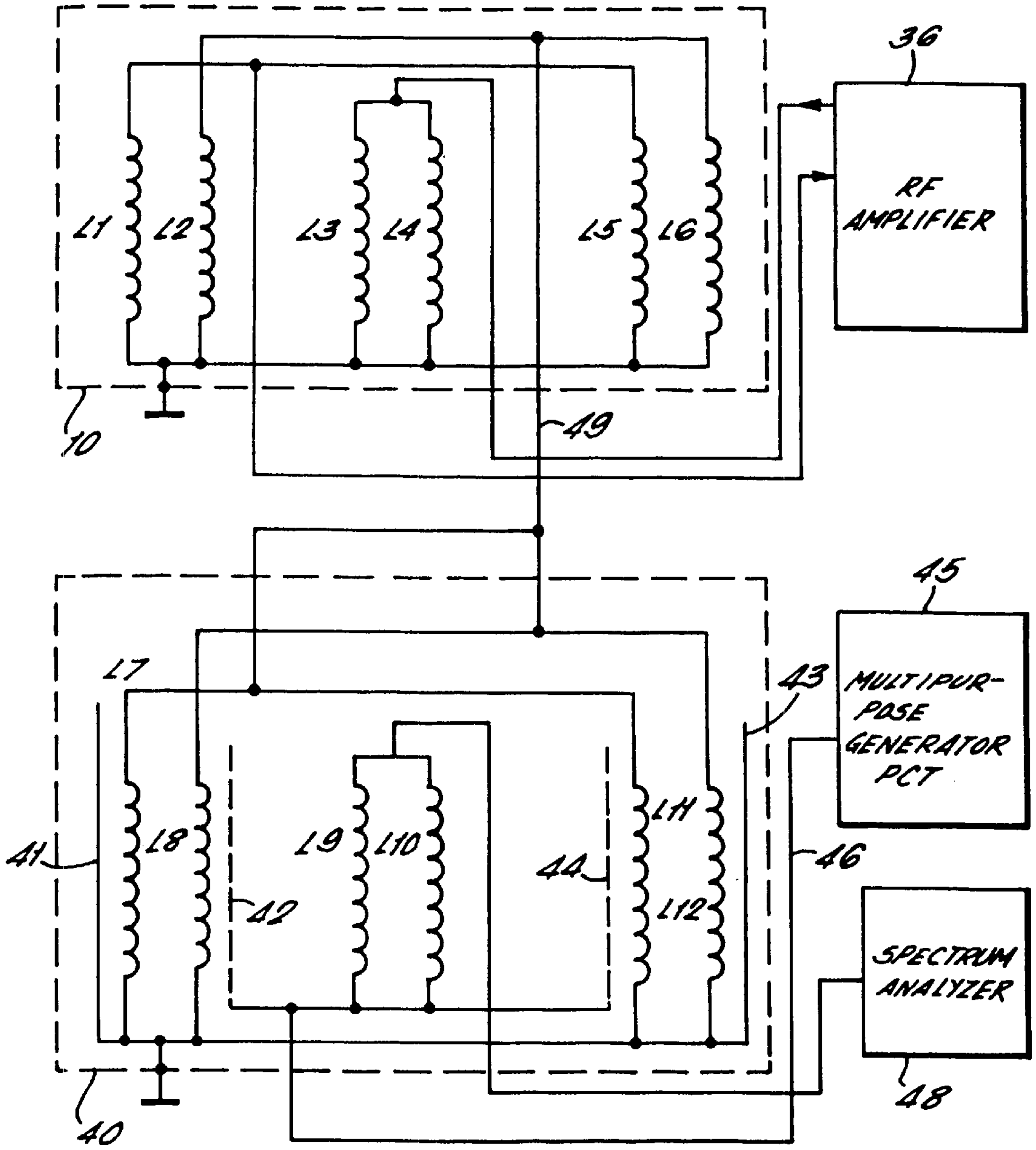
5
NORMLIZE
ON OFF
AVG
5
NORMLIZE
POSITION
WA SB
SC FC
CORR
A<-->B
MORE
2 OF 3
CENTER 500.00 MHz
SPAN 60.00 MHz
*RES BW 1.0 kHz
VBW 1 kHz
SWP 100 sec
A
B
C
D

FIG. 9.


36
RF AMPLIFIER
L1
L2
L3
L4
L5
L6
10
49
45
MULTIPURPOSE GENERATOR PCT
L7
43
41
L8
L9
L10
L11
44
L12
42
46
SPECTRUM ANALYZER
48
40

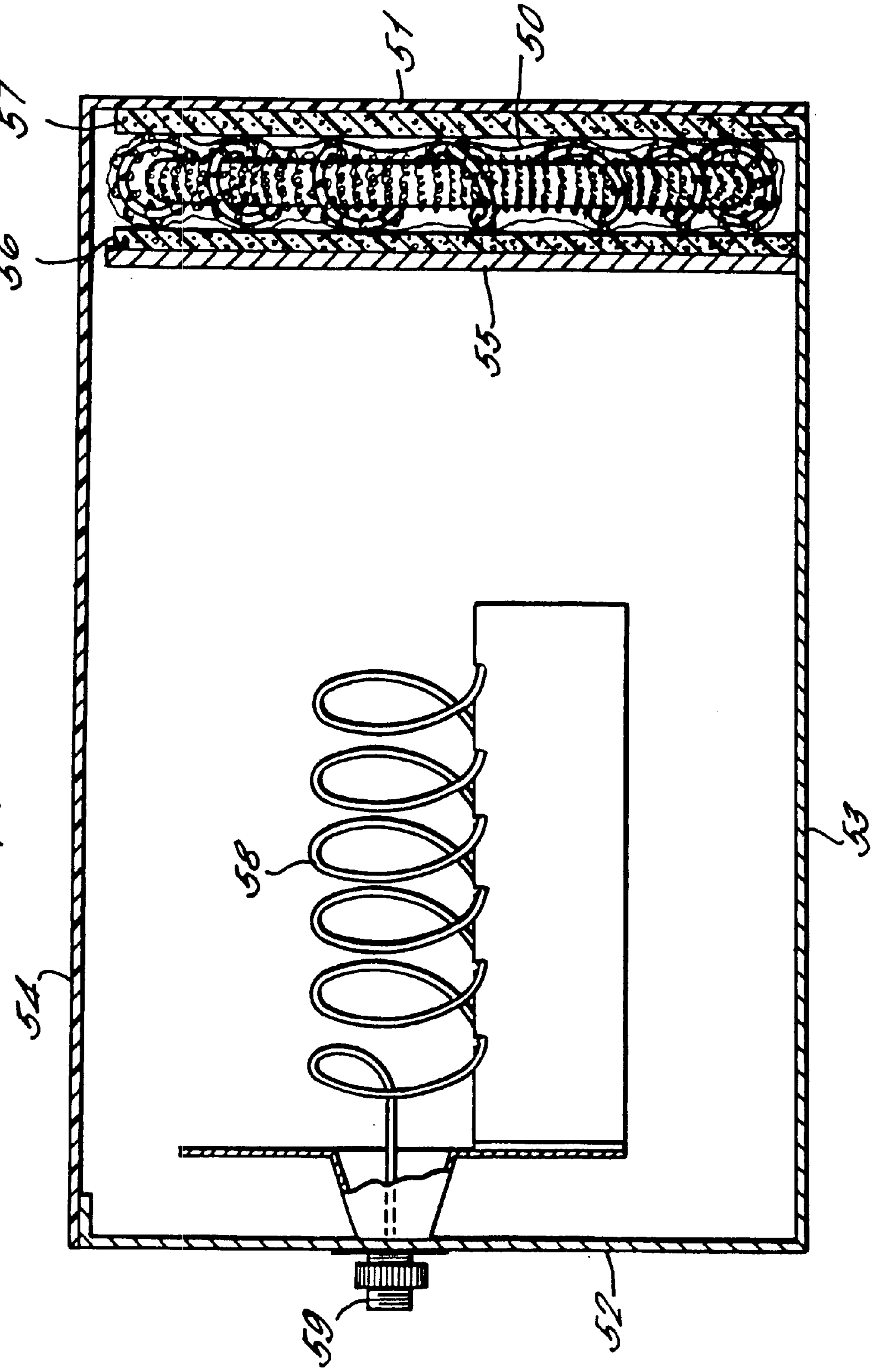


FIG. 10

FIG. 11.

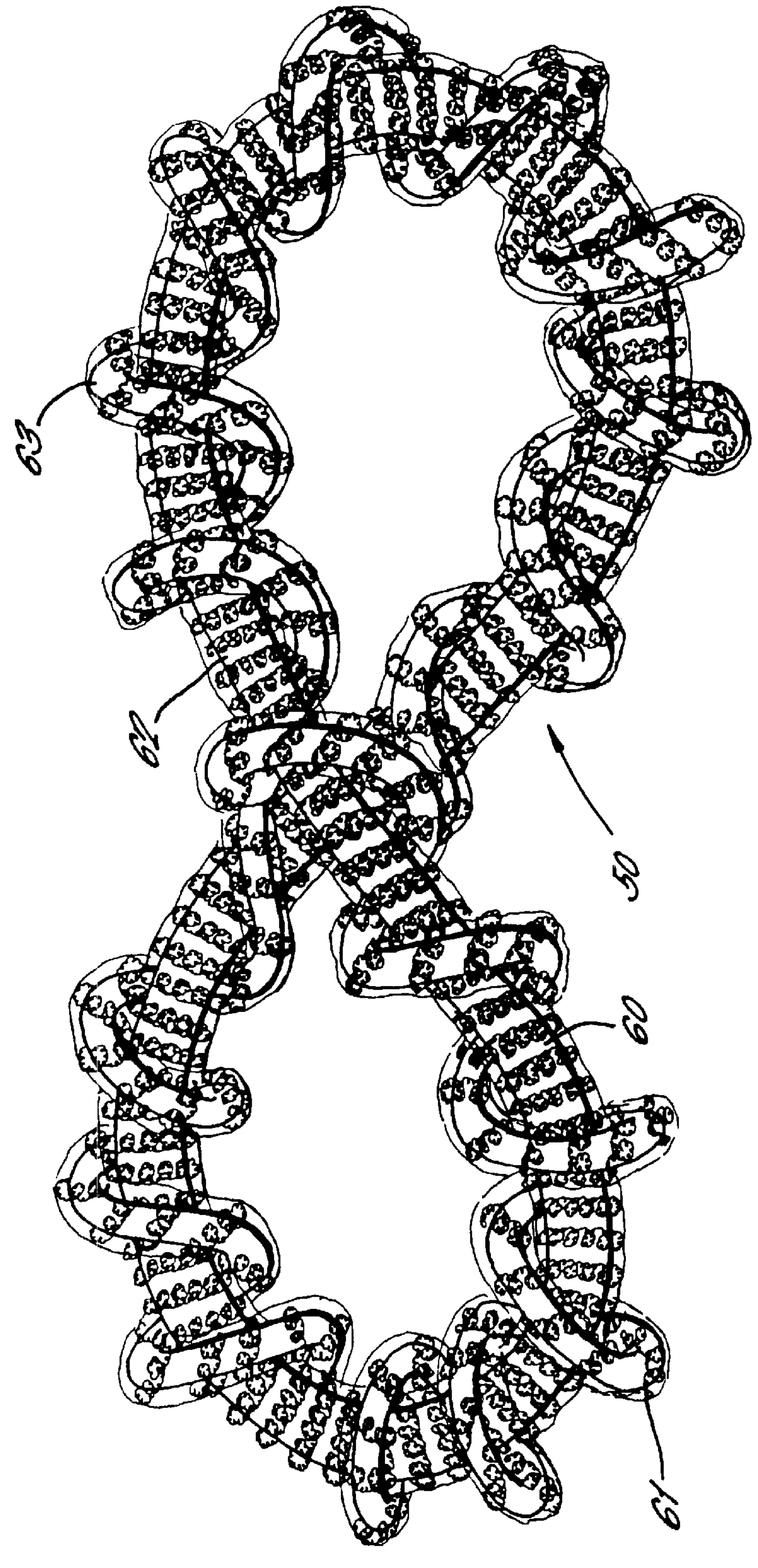
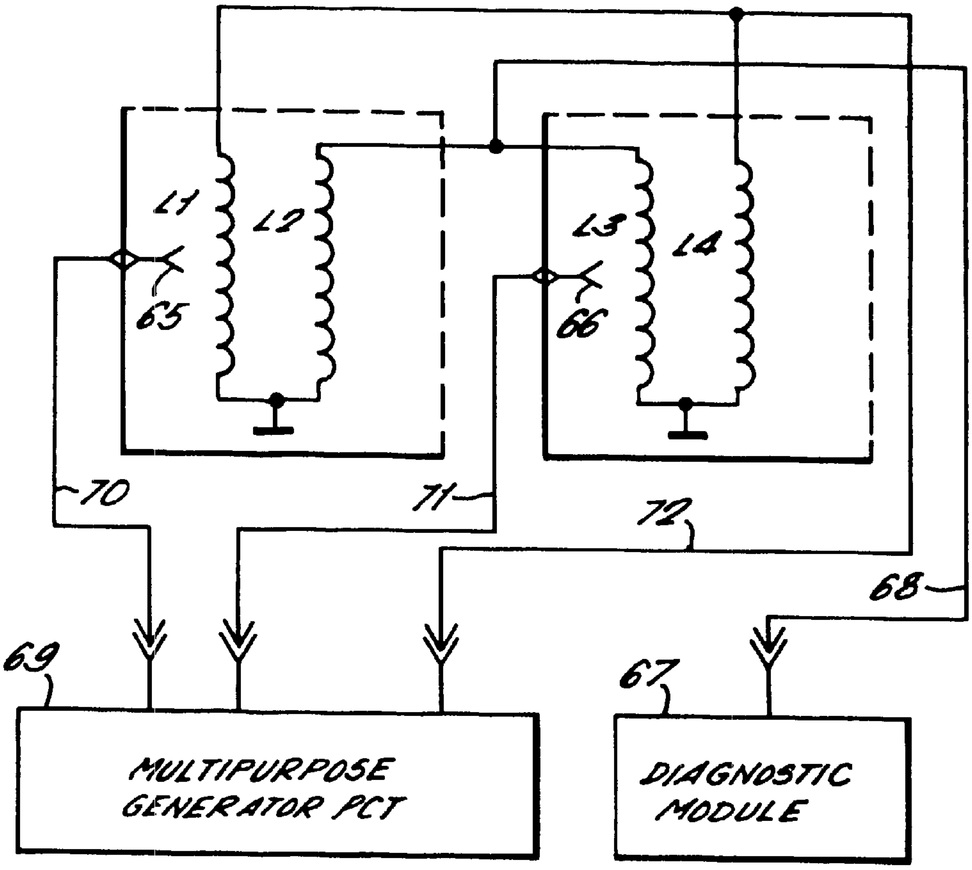


FIG. 12.


L1
L2
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L3
L4
66
70
71
72
68
69
67
MULTIPURPOSE GENERATOR PCT
DIAGNOSTIC MODULE

SUPER-TOROIDAL ELECTRIC AND MAGNETIC FIELD GENERATOR/ DETECTOR, AND SAMPLE ANALYSER AND TREATMENT APPARATUS USING SAME

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of application Ser. No. 08/586,909, filed Jan. 26, 1996, now abandoned which was filed as PCT/HU93/00043 Jul. 27, 1993.

TECHNICAL FIELD OF INVENTION

The invention relates to a generator of electric and magnetic fields, particularly incorporating a super-toroidal conductor. The invention also relates to a corresponding detector of electric and magnetic fields and to a sample analyzer and treatment apparatus incorporating the field generator and/or detector.

BACKGROUND ART OF THE INVENTION

The use of toroidal windings as electromagnetic radiating antennas is known, e.g. from U.S. Pat. Nos. 4,622,558, 4,751,515, 5,442,369 and 5,654,723. However, none of these prior patents contemplate the use of a super-toroidal winding for generating an electromagnetic field. Further, the last two patents are particularly concerned with ensuring that a toroidal antenna can be designed to operate at a particular frequency to produce an electromagnetic field, equivalent to that produced by classic electric or magnetic dipole antennas.

DISCLOSURE OF THE INVENTION

An object of the present invention is the generation of a varying electric and magnetic fields using a super-toroidally wound conductor. In this context, a super-toroidal conductor is one in which the windings of a toroidally wound conductor are constituted by helical windings. Further explanation of super-toroidal conductors of various orders will be given later herein.

Another object of the present invention is the generation of periodically varying electric and magnetic fields with strong spatial inhomogeneousity, that is fields with high spatial gradients of the field's amplitudes by comparison with the typical dipole electric or magnetic field produced by a radiating antenna. A further object of the present invention is the detection of electric and magnetic fields of this kind using a super-toroidal conductor as a detecting element.

A still further object of the present invention is the analysis of samples using strongly inhomogeneous fields generated by super-toroidal conductors.

A still further object of the present invention is the treatment of specimens using such strongly inhomogeneous periodically varying fields.

Accordingly, the present invention provides a field generator comprising at least one super-toroidal conductor and means to energize the super-toroidal conductor to generate varying electric and magnetic fields. Where conductor has a length l, the super-toroidal conductor should be energized with at least one frequency component equal to or greater than 2c/l, where c is the speed of light in free space. Then the near field generated at this frequency close to the super-toroidal conductor will have a strongly inhomogeneous spatial distribution similar or more complex than that generated by four or more electric charges and/or current loops. At any particular moment in time, the amplitudes of the electric and magnetic fields components of such a complex field change significantly over a distance comparable with the smallest winding feature of the super-toroidal conductor. Such a strongly inhomogeneous field can be distinguished from the classic electromagnetic fields produced in the prior art.

The invention also provides a detector for electric and magnetic fields comprising at least one super-toroidal conductor and means responsive to electrical currents generated in said conductor by varying electric and magnetic fields.

Examples of the invention provide a sample analyzer comprising a chamber, and a sample holder within the chamber. The chamber contains at least a first super-toroidal conductor having at least the length l. This super-toroidal conductor is energized to generate oscillating electric and magnetic field in the region of any sample on the sample holder. The electromagnetic field varies with a frequency component equal to or greater than 2c/l to produce a strongly spatial inhomogeneous field. Then the response of the generated field to the presence of a sample on the sample holder is determined, so that an analysis can be made.

The invention also provides treatment apparatus for treating a desired component of a specimen. The apparatus comprises a treatment super-toroidal conductor having a length l. The treatment super-toroidal conductor is energized at a frequency or set of frequencies or continuous band of frequencies greater than 2c/l to produce strongly inhomogeneous electric and magnetic fields. The specimen is exposed to this field and the frequency or set of frequencies or continuous band of frequencies is selected to provide the required treatment of the desired component of the specimen. In order to select the required frequency or set of frequencies or continuous band of frequencies for treatment, a sample corresponding to the desired component of the specimen to be treated may be analyzed in the above described sample analyzer. The treatment frequency or set of frequencies or continuous band of frequencies is then selected in accordance with the response determined in the sample analyzer. In this way, treatment of predominantly or only selected components of a specimen can be ensured by incorporating a sample of the desired component in the associated sample analyzer.

For treatment purposes the electromagnetic field may be modulated by a low frequency signal within a band of from 0.001 to 1000 cycles per second.

Examples of the present invention will now be described with reference to the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1***a*, **1***b*, and **1***c* show designs of a super-toroidal conductor for use in the invention.

FIG. **2** is a perspective view of an enclosure which may embody the present invention, either for sample analysis or specimen treatment.

FIG. **3** is a plan view of the interior of the enclosure of FIG. **2**.

FIG. **4** is an illustration of part of a second order super-toroidal winding.

FIG. **5** is an illustration of part of a third order super-toroidal winding.

FIG. **6** is a circuit diagram illustrating how the windings in the enclosure of FIG. **3** may be connected together to provide sample analysis.

FIGS. **7***a* and **7***b* are graphical representations of radio frequency spectra obtained for a sample of distilled water at different center frequencies.

FIGS. **8***a* and **8***b* are graphical representations of the spectra at frequencies corresponding to those in FIGS. **7***a* and **7***b*, but for sea water.

FIG. **9** is a circuit diagram illustrating the connections of the windings of a combined analysis and treatment apparatus.

FIG. **10** is a view in elevation of the interior of an alternative form of the present invention.

FIG. **11** illustrates the super-toroidal winding assembly used in the assembly of FIG. **10**.

FIG. **12** is a circuit diagram illustrating how the components of the embodiment of FIG. **10** are connected in a treatment application.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The super-toroidally wound conductor shown in FIGS. **1***a* to **1***c* is an example of field generator for effecting the method proposed in the invention.

A toroidal winding comprises a conductor wound helically around a toroidal former. In a first order super-toroidal winding, the conductor of the toroidal winding is replaced by a long helically coiled conductor which is itself wound around the toroidal former. In a second order super-toroidal winding, the conductor of the first order super-toroidal winding is itself wound into a long helically coiled conductor. In a third order super-toroidal winding, the conductor of the second order super-toroidal winding is itself wound into a long helically coiled conductor, and so forth up to higher orders. In the examples of the present invention to be described below, super-toroidal windings of second and third order are included.

In practice it is possible to make super-toroids of the twelfth or even the fifteenth order.

In general, one or more such super-toroidal conductors are energized to produce an electromagnetic field having two different frequencies: a high frequency component in the band from 1 kHz to 1000 GHz modulated by a low frequency component between 0.001 lines and 100 Hz.

Efficiency of operation can improve, if the low and frequency modulating signal is chopped at a predetermined phase angle. Experience shows that to provide a field having a stimulating effect on a sample, the low frequency modulating signal should be chopped at a phase angle $0.33\times2\pi$, and to provide a field having an inhibiting effect, the low frequency signal should be chopped at a phase angle$\times2\pi$.

FIG. **2** is an external view of an enclosure used in a sample analyzer embodying the present invention. The enclosure comprises a box **10** having a removable lid **11** constituting one face of the box. A hatch **12** is provided in the lid for easy access to the interior of the enclosure. The enclosure is made of metal and is intended to provide electromagnetic screening of the interior of the box. Feedthroughs **13** are provided for electrical signals through a front face **14** of the box and include coaxial electrical sockets **15** for selective engagement with corresponding coaxial plugs **16** on coaxial connecting cables **17**.

FIG. **3** illustrates the interior of the box **10** with the lid **11** removed. The box contains four super-toroidal conductor assemblies **20**, **21**, **22** and **23**. The toroidal conductor assemblies **20** and **21** are mounted on respective dielectric mounting blocks **24** and **25**, so as to be essentially parallel to opposite upright end faces **26** and **27** of the box **10**.

Substantially midway between the toroidal assemblies **20** and **21** a sample tray **28** is mounted on the bottom face of the box **10**. Sample tray **28** provides a flat base with an upstanding rim **29** sized so as accurately to locate a removable sample holder on the tray **28** within the box. As shown in the figure, the toroidal conductor assembly **22** is located around the base of the sample tray **28**, so that any sample placed in a container upon the tray **28** lies substantially on the axis of the super-toroidal conductor **22**.

The fourth super-toroidal conductor assembly **23** is mounted so as to be parallel to the rear face **30** of the enclosure, and midway between the opposed conductor assemblies **20** and **21**.

Each of the super-toroidal conductor assemblies **20** and **21** comprises a combination of a second order super-toroidal conductor and a third order super-toroidal conductor. In effect, the third order super-toroidal conductor is formed on a toroidal former constituted by a second order super-toroidal conductor. Thus, a toroidal former **31** for each of the assemblies **20** and **21** comprises a second order super-toroidal conductor such as illustrated in FIG. **4**. As illustrated in FIG. **4**, the second order super-toroidal conductor may be formed from a tightly wound helical spring C**1** of insulated wire, which is itself then wound round in a helix C**2** of greater diameter. The resulting double helical conductor C**2** is then wound around the toroidal (ring shaped) former **31** to form the second order super-toroidal winding.

In constructing the assemblies **20** and **21**, the second order super-toroidal winding is stabilised by wrapping in a heat shrinkable material and then used as the toroidal former for a third order super-toroidal winding such as illustrated in FIG. **5**. The winding of FIG. **5** may be formed from a tightly wound helical spring C**3** of insulated wire, which spring is itself wound into a helix C**4** of greater diameter. This doubly wound helical formation C**4** is then wound around a helical dielectric former F**1** which is in turn wound around the toroidal former F**2** of the third order super-toroidal conductor. Although not detailed in FIG. **3**, in the combination of a second order super-toroidal conductor and a third order super-toroidal conductor in the assemblies **20** and **21**, the toroidal former F**2** in FIG. **5** is replaced by the toroidal former **31** wound by the double helical conductor C**2** of FIG. **4**.

The super-toroidal conductor assembly **22** comprises a simple third order super-toroidal conductor wound on a dielectric toroidal former, and the super-toroidal conductor assembly **23** is a second order super-toroidal conductor also wound on a dielectric toroidal former.

The various windings of the super-toroidal assemblies within the enclosure formed by the box **10** are illustrated diagrammatically in FIG. **6** In the Figure, L**1** represents the third order super-toroidal winding of super-toroidal assembly **20**, and L**2** represents the second order super-toroidal winding forming the toroidal former of the third order winding in assembly **20**. Similarly, L**6** represents the third order winding of assembly **21** on the toroidal former constituted by the second order winding L**5**. L**3** represents the third order super-toroidal conductor winding **22** and L**4** represents the second order super-toroidal conductor winding **23**.

As can be seen, the outer third order winding L**1** of the assembly **20** is connected in parallel with the inner second order winding L**5** of assembly **21** and fed via a feedthrough **35** from the box **10** to the input of a broad band rf amplifier **36**. The output of the broad band amplifier **36** is fed back through a second feedthrough **37** into the box **10** to the third order winding L**3**, forming the assembly **22** connected in parallel with the second order winding L**4** forming the assembly **23**.

The inner second order winding L2 of the assembly **20** is connected in parallel with the outer third order winding L**6** of the assembly **21** and fed via a further feedthrough **38** to an analyzer **39**.

With the above construction, the windings within the box **10** together with the high gain broad band radio frequency amplifier **36** form a closed loop. If the gain of the rf amplifier is sufficient, the loop gain at particular frequencies will exceed unity producing oscillation at these frequencies. Also, oscillation at other frequencies may be generated due to nonlinearity of the circuit. The frequencies at which oscillation is occurring can be monitored by the analyzer **39** which is preferably a spectrum analyzer. In a particular embodiment, the broad band radio frequency amplifier is type HP8347A from HewlettPackard and the spectrum analyzer **39** is type 8599E also from Hewlett-Packard.

It has been found that the arrangement disclosed above produces rf oscillations over a wide spectrum extending from a relatively low frequency up to 3 GHz or more. The system produces a spectrum of oscillations, detected by the analyzer **39**. Depending on the tuning of the system, which may be achieved by adjustments of the positions of the super-toroidal antennas, lengths of the rf leads and the amplifier gain the spectrum has peaks at discrete frequencies over this frequency range or comprises of a combination of discrete frequencies and continuous bands of frequencies. It has been found that the distribution of these frequency peaks and/or bands is dependent on the nature of a sample material located in a container on the tray **28** in the center of the box **10**. Typically, the sample may be a fluid sample and the quantity (volume) of the fluid sample and the dimensions of the container to be located on the tray **28** are maintained constant so that the features in the output spectrum dependent on the internal geometry of the enclosure **10** remain consistent for different samples.

The following example illustrates the different spectra which may be obtained from the above described instrument for different sample materials. The various samples were all liquid and were placed in identical polyethylene containers having internal diameter 30 mm, external diameter 32 mm, and height 50 mm. For each sample, the containers were completely filled.

FIGS. **7***a* and **7***b* respectively show the traces obtained from the spectrum analyzer **39** for distilled water, over the spectral regions 0 to 60 MHz and 470 to 530 MHz. The spectra were averaged over five readings each using the analyzer's built-in averaging function and then hard copied at the end of each acquisition period. As can be seen, the frequency span in each trace is 60 MHz, the analyzer resolution bandwidth is 1 kHz and the sweep time is 100 seconds. The frequency scales in all spectra are linear. The vertical scales show spectral power density of the signal in arbitrary logarithmic units.

FIGS. **8***a* and **8***b* show corresponding spectra at similar frequency ranges for sea water.

As can be seen by comparison of FIGS. **7***a* and **8***a*, the sea water sample has an additional line at B at about 12 MHz and a more pronounced line D at about 36 MHz. The 25 MHz line C for sea water is narrower than the equivalent for distilled water.

Comparing FIGS. **7***b* and **8***b*, sea water shows a new line B at approximately 491 MHz while line D which can be seen in distilled water appears suppressed for sea water.

The sample analyzer instrument described above can therefore produce spectra which can distinguish one sample from another. By comparing the spectrum obtained for an unknown sample with a library of previously recorded spectra, the nature of an unknown sample may be determined. The comparison may be performed using correlation techniques known in the art.

More significantly, the spectrum obtained from the instrument may be used to control the electric and magnetic fields produced in a material treatment apparatus (to be described later) in such a way as to confine the effect of the electromagnetic field specifically or predominantly to a desired component in a material or body being treated.

The process going on in the above described sample analysis instrument is believed to be similar, though at radio frequencies, to the technique of inter resonator laser spectroscopy. In inter resonator laser spectroscopy, an absorbing sample to be analysed is located inside the resonator of a laser. Absorption by the sample has the effect of removing or suppressing some of the resonator modes so that the resulting spectral content of the light output from the laser is changed in a way which is specific to the nature of the absorbing substance under test. It should be understood that for this laser spectroscopy technique, a laser which has a large number of resonator modes, or natural output frequencies in laser emission, may be used. The missing or suppressed lines in the output spectrum can be indicative of the nature of the absorbing substance located in the resonator region of the laser.

In the instrument described above, the box **10** containing the super-toroidal conductors may be equivalent to the resonator region of a laser. As a result, in the absence of any absorbing material located in the box, it can be expected that the closed loop comprising the windings in the box and the rf amplifier **36** will cause resonant oscillation at a larger number of frequencies over the frequency range for which the amplifier **36** has sufficient gain. The different frequencies of resonance correspond to a multiplicity of resonant modes within the box, in combination with the phase delays represented by the leads to and from the rf amplifier **36** together with delays in the amplifier itself. Therefore it also can be expected that the material located in the box will cause a change in the pattern of the resonant oscillation frequencies due to the phase delay in the material. Nonlinearities in the loop may also cause, through redistribution of the energy circulating in the loop, appearance of new spectral components as a reaction to the suppression of other spectral components or/and shift of their frequencies.

Importantly, the super-toroidal windings of the conductors within the box **10** can operate over a very broad frequency band, since the length of wire in any one super-toroidal winding may be many times the free space wavelength of the relevant frequency. For example, the length of wire in a first order super-toroidal winding having a diameter (of the toroidal former itself) of say 10 cms may be 20 metres or more. The length of wire in similarly sized super-toroidal windings of third order may be several hundred metres. Thus, the length of wire in a super-toroidal winding in the instrument may be several times the free space wavelengths for frequencies above about 5 Mhz.

The super-toroidal windings of the conductors within the box **10** can operate over a very broad frequency band, because, due to the complexity of the winding the supertoroidal antennas have remarkably low inductances and capacitances at high frequencies.

As mentioned above, in the absence of a sample, the instrument illustrated would produce an output spectrum from feedthrough **38** to the spectrum analyzer **39** containing a large number of peaks over a wide frequency range. The presence of a sample in a container on the sample tray **28** within the instrument is believed to change the output spectrum from the instrument.

Importantly also, interaction with a sample within the instrument is not solely dependent on the electric dipole mechanism of absorption. Hitherto, conventional radio frequency spectroscopy has depended upon the effect of the incident radio frequency energy on dipoles formed by the molecules of the sample. Whereas some molecules are significantly dipolar (including water) many other molecules exhibit substantially no dipole moment so that they are substantially unaffected by homogeneous electromagnetic fields.

The super-toroidal windings used in the above instrument, when energized at frequencies greater than 2c/l, where l is the length of wire in a super-toroidal winding, generate electromagnetic fields which are strongly spatial inhomogeneous, at least in the near field region close to the torus of the winding. Where as a quadrupolar molecule, for example, is substantially unaffected by a dipole field, such a molecule can be rotated (excited) by a strongly inhomogeneous magnetic and electric fields. Importantly, some molecules may have no electric dipolar moment, or not only dipolar moment, but also show electric and magnetic multipolar moments which interact with strongly inhomogeneous electric and magnetic fields created within the device.

When operating at relatively high frequency, the super-toroidal windings used in the above instrument can generate highly inhomogeneous fields which should be absorbed/refracted in samples comprising molecules with electric and magnetic multipolar moments.

In this way, liquid samples which would produce only uninformative broad radio frequency absorption spectra in purely dipole electromagnetic fields, can produce much more informative absorption spectra in the strongly spatially inhomogeneous fields generated in the instrument described above.

A desired specimen may be treated by exposing the specimen to the electromagnetic fields generated by super-toroidal windings in an enclosure similar to that described above with reference to FIG. **3**. Referring to FIG. **9**, for treatment of a specimen, a second enclosure, here shown schematically at **40** is connected to the enclosure **10** as illustrated. The second enclosure **40** may have the identical components as described above for the sample analyzer enclosure and illustrated in FIG. **3**. In the treatment enclosure **40**, the left hand super-toroidal assembly (corresponding to assembly **20** in enclosure **10**) is formed by an outer third order super-toroidal winding L7 on an inner second order super-toroidal winding L**8**. Similarly, the right hand super-toroidal assembly (corresponding to assembly **21** in the enclosure **10**) is formed of a third order super-toroidal winding L12 on a second order super-toroidal winding L11. The super toroidal windings L9 and L**10** correspond to the windings L3 and L4 of the enclosure **10**.

The enclosure **40** for treatment of a specimen further includes conductive foil plates **41** and **42** on opposite sides of the toroidal assembly comprising windings L7 and L**8**, and **43** and **44** on opposite sides of the toroidal assembly comprising the windings L**11** and L12. These plates are in fact illustrated in FIG. **3**, but it should be understood that these plates are employed only in the enclosure used for treatment of a specimen and not in the enclosure used for sample analysis as first described with reference to FIG. **3**. The conductive plates **41**, **42** and **43**, **44** may be made of flexible copper film and are annular in form having an inner radius similar to the inner radius of the super-toroidal assembly and an outer radius which is rather less than the outer radius of the super-toroidal assembly.

The pair of plates **41**, **42** and **43**, **44** function to couple energy capacitatively to the windings of the assembly located between the respective pairs, so that the windings may be energized more uniformly.

Referring to FIG. **9**, the treatment enclosure is connected in circuit as illustrated. A broad band rf noise generator **45** produces pulses of broad band rf noise on an output line **46**. The modulation may comprise pulses at either 1 Hz or 4 Hz repetition rate, with a duty cycle of 1:3. These pulses are used to modulate the wide band rf noise signal on line **46**.

The outer third order and inner second order conductors L7 and L**8** of the left hand super-toroidal assembly are connected in parallel with each other and with the inner second order and outer third order conductors L**11** and L12 of the right hand assembly, and all together fed directly from the sample analysing enclosure **10**. As can be seen, the signal from the sample analysing enclosure **10** which is supplied to the spectrum analyzer in FIG. **6** is, in the specimen treatment example illustrated in FIG. **9**, fed to the windings L7, L**8** and L**11**, L12 of the treatment enclosure **14**.

The outer plate **41** and **43** on each of the supertoroidal assemblies is connected to ground and the inner plate **42** and **44** are supplied with the pulsed wide band rf noise signal on line **46** from the generator **45**.

Signal from the remaining two super-toroidal windings L9 and L**10** in the treatment enclosure **40** may be fed to a spectrum analyzer **48** for monitoring.

In operation, a specimen to be treated is located on the specimen tray (corresponding to the tray **28** of enclosure **10**) in the treatment enclosure **40**. A liquid sample is made up of the component in the specimen which is particularly to be treated and this sample is located on the tray **28** in the analyzer enclosure **10**. The rf amplifier **36** is then energized to produce an rf spectrum on the line **49** from the analyzer chamber **10**, which is in turn supplied to energize the windings L7, L**8** and L**11**, L12 in the treatment chamber **40**. At the same time, the generator **45** is energized to apply modulated wide band noise to the windings by capacitative coupling.

It has been observed that this process can provide effective treatment of the designated component of the specimen located in the treatment chamber **40**. If the generator **45** is selected to produce pulses of wide band rf noise at 1 Hz, the treatment appears to be beneficial to the designated component of the specimen, so that if the component is a living organism, growth of the organism in the specimen is promoted. However, if the wide band rf noise applied by the generator **45** is modulated at 4 Hz, then the treatment is deleterious to the designated component, with the effect that the component can be destroyed or inactivated in the specimen.

Treatment has been performed of biological samples whereby only selected biological components of the sample have been effected by the treatment with no apparent effects on the remaining components of the sample.

Apparatus using super-toroidal windings was used in an experiment for the treatment in vitro of cells chronically infected with HIV-1. Samples were made up for the analyzer enclosure comprising p24 antigen, p120 antigen (proteins contained in HIV virus) and also genetically engineered pro viral HIV DNA.

Treatment specimens were then also made up.

The samples treated were:

1) Non infected cells including fresh peripheral white blood cells and human T-cells.

2) Chronically HIV-1 infected cells.

For treatment of the different specimens selected samples were located in an analyzer chamber and the equipment was energized as described above.

For the treatment of non-infected cells these were counted before exposure and treatment in the apparatus and then treated cells as well as a non-treated control set of cells were counted every other day for the following two weeks. The treated cells were exposed in the apparatus twice for 30 minutes with the rf noise generator providing pulses at 1 Hz and twice for 30 minutes with the generator providing pulses at 4 Hz. This was repeated during the following two days. Subsequently cells were counted over the next two weeks and the cell count revealed that there was no difference in the growth rate of either the exposed fresh white blood cell cultures or the T-cell line when compared with cultures which had not been treated.

For chronically HIV infected cells, these were exposed for one hour to emissions generated by a sample of p24 antigen only located in the sample analyzer chamber, and subsequently for a total of two hours with only gp120 antigen located in the sample analyzer chamber. Both treatments were conducted with the generator **45** providing pulses at 4 Hz. This treatment was repeated during the following four days and the cells were then counted. There was no difference in the growth rate of the exposed cells when compared with those which had not been treated.

Five days after the treatment, the cell suspensions of the treated and non treated chronically infected cells were spun separately at 1500 rpm for ten minutes. The supernatant was collected separately, followed by a serial ten-fold dilution and titration for virus yield in the non infected T-cells, which are highly susceptible to the HIV-1 strain used. Following titration, the cell culture was monitored for cytopathic effect (CPE) over the following ten days. It was then established that while the HIV-1 yield in the non exposed cell culture fluid was 10^6 infectious particle per ml, in the fluid of the exposed cells there was only a yield of 10^5 infectious particles per ml. Thus, treatment for chronically infected cells had led to ten-fold reduction in HIV-1 yield of the chronically infected cells.

In a further procedure, cells which were acutely infected with HIV-1 were also exposed twice for 30 minutes with each of p24 antigen and gp120 antigen in the sample analyzer chamber, with the rf noise generator providing pulses at 4 Hz, followed by a further exposure each for 45 minutes again at 4 Hz. This exposure was repeated over a three day period both with HIV-1 infected non exposed T-cells as well as T-cells which were exposed before the acute infection. Thereafter the HIV-1 infected and exposed cell culture as well as to control non exposed HIV-1 infected cell cultures were pipetted forcefully to disrupt the infected cells in order to maximise HIV-1 release into the fluid. This was followed by centrifugation at 1500 rpm for 10 minutes and the supernatant from each cell culture was then separated. Virus titration with ten-fold dilution followed. The two non exposed HIV-1 infected cultures were found to contain 10^6 HIV-1 infectious particles per ml, while in the fluid of the exposed culture there was only 10^4 HIV-1 infectious particles per ml. Thus, there was a 100-fold reduction in the virus yield. One of the two cell cultures which were not treated in the above process was previously treated in the apparatus prior to infection. However, the culture treated prior to infection, and not treated after infection, had a similar infectious particle count as the infected cultures which had not been treated either before or after infection. Thus, treatment prior to infection does not reduce the rate of HIV-1 production.

Alternative Embodiments

Other embodiments of the apparatus described above can be contemplated. FIGS. **10**, **11** and **12** illustrate an embodiment of apparatus which can be used for the treatment of specimens externally of a screened container. In FIG. **10** a super-toroidal assembly **50** is located against a front wall **51** of a container. The container comprises rear and bottom walls **52** and **53** made of metal, and upper and front walls **54** and **51** made of dielectric material. The super-toroidal assembly **50** is located against the front wall **51** by means of a dielectric retaining plate **55**. The assembly **50** is secured between the plate **55** and the wall **51** by dielectric foam material **56** and **57**. A single wire helical antenna **58** is also mounted within the enclosure on the front wall **52**. A feedthrough **59** enables radio frequency energy to be supplied to the helical antenna **58**. Connections to the super-toroidal conductor assembly **50** are provided through side walls of the container which are not illustrated in FIG. **10**. The side walls (parallel to the plane of the paper) are also made of dielectric material.

FIG. **11** illustrates the form of the super-toroidal conductor assembly **50** shown in FIG. **10**. The assembly **50** comprises a second order super-toroidal winding which forms the toroidal former for a third order super-toroidal winding **61**. The toroidal former **62** of the second order winding **60**, and the helical former **63** of the third order winding **61** are themselves sufficiently flexible to allow the assembly **50** to be twisted into a figure of eight as illustrated in the drawing. This figure of eight arrangement is then mounted in the container illustrated in FIG. **10** against the front wall **51** as described above. Separate connections can be made to the inner second order and the outer third order toroidal windings of the assembly **50**.

For treatment of an external body, for example, two treatment assemblies such as illustrated in FIG. **10** may be used, e.g. by placing one on opposite sides of the body to be treated, with the body located between respective front faces **51** of the treatment assemblies.

FIG. **12** illustrates the electrical connections for the elements in the treatment assemblies, with **L1** and **L2** representing the inner second order and outer third order toroidal windings of the toroidal assembly in one container, and **L3** and **L4** representing respectively the inner second order and outer third order windings of the other container. The helical antenna **58** in each treatment container is represented in FIG. **12** at **65** and **66** for the two containers respectively.

The outer third order winding **L2** of one assembly and the inner second order winding **L3** of the other assembly are connected together in parallel and supplied with the rf spectrum signal generated by an analyzer assembly such as illustrated in FIG. **7**. Thus, the Diagnostic Module **67** illustrated in FIG. **12** may be constituted by a sample analyzer assembly as described with reference to FIG. **6** and as illustrated in the upper part of FIG. **9**. The signal supplied by the Diagnostic Module **67** on line **68** in FIG. **10** corresponds to the signal supplied via feedthrough **38** to the spectrum analyzer in FIG. **6**, and the signal supplied along lines **49** to the treatment chamber **40** in FIG. **9**.

The wide band rf noise generator **69**, corresponding to generator **45** described with reference to FIG. **9**, provides a pulsed wide band rf noise signal on lines **70** and **71** to each of the helical antennae **65** and **66**. The rf noise signal on each of lines **70** and **71** may be pulsed at 1 Hz or 4 Hz as described above. Preferably, the pulses on line **71** are phased to occur during the spaces between pulses on line **70**. The pulse signal itself is supplied from the generator **69** on line **72** directly to windings L2 and L3 in parallel.

The above apparatus has been found effective in the treatment of relatively larger bodies of material. As before, a sample of the component which is to be specifically treated in the body is prepared and placed in the sample analyzer enclosure. The apparatus is then activated with the body to be treated located between the super-toroidal assemblies **50** of the two treatment units shown in FIG. **12**.

In the above described embodiments, an rf spectrum is obtained from a sample analyzer, by the use of an rf resonator comprising a high gain wide band rf amplifier feeding output and input windings in a resonator region. Instead, a wide band signal could be generated externally of the sample analyzer chamber and fed to one or more super-toroidal winding within the chamber. A second sensing winding or windings would then be used to monitor the effect on the electromagnetic field produced by the first winding by a sample to be analysed. For example, the externally generated wide band rf signal might comprise a series of relatively closely spaced rf frequencies, and the detection arrangement could monitor changes in amplitude of these rf frequencies as a result of the presence within the electromagnetic field generated of a sample to be analysed.

In another arrangement, a single super-toroidal winding could be used, energized by an externally generated rf signal. The impedance of the super-toroidal winding could then be monitored and changes in that impedance detected resulting from the presence within the electromagnetic field generated by the winding of a sample to be analysed.

Although the super-toroidal winding could be supplied with a wide band rf signal comprising a range of frequencies simultaneously, instead the antenna could be energized at a single rf frequency which is swept over a desired band. Alternatively, a predetermined selection of rf frequencies could be generated one after the other and supplied to the super-toroidal winding.

A further method of energizing the super-toroidal winding would be to apply a pulse to the winding and monitor modifications to the frequency content of the resulting electromagnetic field due to the presence in the field of a sample to be analysed. It will be understood that a short duration pulse (impulse) is in effect a wide band signal.

In the above described examples, super-toroidal windings are energized by direct connection of rf signals across the ends of the windings. Instead, any other method could be used for energizing the windings, including multy-terminal connections, capacitive links, inductive links etc.

Although an example is described above of an application of the treatment process of the invention to the treatment of HIV-1 in vitro, the invention may also be applicable to in vivo treatment.

A large scale chamber has been constructed containing super-toroidal windings as discussed above, with the chamber being large enough to accommodate a human being. By energizing the super-toroidal windings in the chamber with radio frequency signals having spectral content determined by a sample analyzer, e.g. of the kind described above with reference to FIG. **11**, it has proved possible to treat an entire human patient and substantially reduce, if not eliminate infection, specifically including HIV-1.

What is claimed is:

1. A field generator comprising at least one super-toroidal conductor having a dielectric former core and means for supplying electric current to the super-toroidal conductor to generate varying electric and magnetic fields.

2. A generator as claimed in claim **1** wherein said conductor includes a length l and said means for supplying electric current is operative to generate an electromagnetic field varying with at least one frequency component at a frequency which is equal to or greater than 2c/l, where c is the speed of light in free space.

3. A generator as claimed in claim **2** wherein said means for supplying electric current is operative to generate an electromagnetic field having a plurality of frequency components at frequencies greater than 2c/l.

4. A generator as claimed in claim **3** wherein said frequency components include frequencies greater than 10c/l.

5. A field generator comprising at least one super-toroidal conductor and means for supplying electric current to the super-toroidal conductor to generate varying electric and magnetic fields, wherein said at least one super-toroidal conductor comprises a super-toroidal conductor of an odd-number order and a super-toroidal conductor of an even-number order.

6. A field generator comprising at least one super-toroidal conductor and means for supplying electric current to the super-toroidal conductor to generate varying electric and magnetic fields, wherein said at least one super-toroidal conductor comprises a super-toroidal conductor of a first predetermined order and a super-toroidal conductor of a second predetermined order higher than said first predetermined order, said super-toroidal conductor of said first predetermined order providing a toroidal former and said super-toroidal conductor of said second predetermined order being wound on said toroidal former.

7. A detector for a variable electromagnetic field comprising at least one super-toroidal conductor having a dielectric former core and means for detecting electrical current generated in said conductor by the varying electromagnetic field.

8. A detector for a variable electromagnetic field comprising at least one super-toroidal conductor and means for detecting electrical current generated in said conductor by the varying electromagnetic field, wherein said at least one super-toroidal conductor comprises a super-toroidal conductor of odd-number order and a super-toroidal conductor of even-number order.

9. A detector for a variable electromagnetic field comprising at least one super-toroidal conductor and means for detecting electrical current generated in said conductor by the varying electromagnetic field, wherein said at least one super-toroidal conductor comprises a super-toroidal conductor of a first predetermined order and a super-toroidal conductor of a second predetermined order higher than said first predetermined order, said super-toroidal conductor of said first predetermined order providing a toroidal former and said super-toroidal conductor of said second predetermined order being wound on said toroidal former.

10. A sample analyser comprising a chamber, a sample holder within the chamber, at least a first super-toroidal conductor in the chamber and including a length l of the conductor wound continuously in the same direction throughout the length l, means for supplying a variable electric current to said first super-toroidal conductor to generate, in the region of any sample on the sample holder, a variable electromagnetic field varying with at least one frequency component at a frequency which is equal to or greater than 2c/l, where c is the speed of light in free space, and means for detecting the generated field in the presence of a sample on the sample holder.

11. A sample analyser as claimed in claim **10**, wherein said means for detecting includes at least a further super-toroidal conductor in the chamber and means for detecting electrical currents generated in said further conductor by said field generated by said first super-toroidal conductor.

12. A sample analyser as claimed in claim **10**, wherein said means for supplying electric current comprises at least a second super-toroidal conductor in the chamber, and a high gain broad band radio frequency amplifier having an input connected to receive signals corresponding to electrical currents generated in said second conductor by a varying electromagnetic field in said chamber and having an output connected to energise the first conductor to form a closed radio frequency loop, said high gain amplifier having sufficient gain that the loop gain exceeds unity at frequencies within the band width of the amplifier.

13. A sample analyser as claimed in claim **12** wherein said means for detecting includes at least a third super-toroidal conductor in the chamber and means responsive to electrical currents generated in said further conductor by said field generated by said first super-toroidal conductor.

14. A sample analyser as claimed in claim **13** wherein the chamber contains at least two super-toroidal conductor assemblies, each said assembly comprising an inner super-toroidal conductor of a first predetermined order providing a toroidal former, and an outer super-toroidal conductor of a second predetermined order wound on said toroidal former provided by said inner super-toroidal conductor, the inner conductor of one toroidal assembly and the outer conductor of the other toroidal assembly together forming said second toroidal conductors connected to the input of said high gain amplifier, and the outer conductor of said one toroidal assembly and the inner conductor of said other toroidal assembly together forming said third toroidal conductors.

15. A sample analyser as claimed in claim **14** wherein said chamber contains a further said super-toroidal conductor assembly, the inner and outer conductors of said further assembly together forming said first toroidal conductors connected to the output of said high gain amplifier.

16. A sample analyser as claimed in claim **15** wherein said sample holder holds the sample substantially on the axis of said further super-toroidal conductor assembly.

17. A sample analyser as claimed in claim **14** wherein said two super-toroidal conductor assemblies are located coaxially on opposite sides of said sample holder.

18. Treatment apparatus for treating a desired component of a specimen, comprising at least one treatment super-toroidal conductor having a length l of the conductor which is wound continuously in the same direction throughout the length l, means for supplying electric current to the treatment super-toroidal conductor at at least one selected frequency which is equal to or greater than 2c/l, where c is the speed of light in free space, so as to generate strongly spatial inhomogeneous electric and magnetic fields at said frequency, and means to expose the specimen to said generated inhomogeneous field.

19. Treatment apparatus as claimed in claim **18** and including a sample analyser comprising a chamber, at least a first super-toroidal conductor in the chamber which includes a length l of the conductor which is wound continuously in the same direction, means for supplying electric current to said first super-toroidal conductor to generate, in the region of any sample on the sample holder, an electromagnetic field varying with at least one frequency component at a frequency which is equal to or greater than 2c/l, where c is the speed of light in free space, and means for detecting the generated field in response to a sample on the sample holder, wherein said means for supplying electric current to said treatment super-toroidal conductor is arranged so that said at least one selected frequency is selected in accordance with said generated field detected by said detecting means in response to the presence on the analyser sample holder of a sample corresponding to the desired component of the specimen to be treated.

20. Treatment apparatus as claimed in claim **19** wherein said detecting means in said analyser includes at least a further super-toroidal conductor in the chamber and means responsive to electrical currents generated in said further conductor by said field generated by said first super-toroidal conductor.

21. Treatment apparatus as claimed in claim **20**, further comprising a treatment chamber of similar dimensions to said chamber of said analyser, and, in said treatment chamber, first and second super-toroidal toroidal conductor assemblies, each said assembly comprising an inner super-toroidal conductor of a first predetermined order providing a toroidal former, and an outer super-toroidal conductor of a second predetermined order wound on said toroidal former provided by said inner conductor, the inner conductor of one toroidal assembly and the outer conductor of the other toroidal assembly forming said treatment super-toroidal conductors and being connected to be energised by electrical currents derived from said currents generated in said further super-toroidal conductor in said analyser.

22. Treatment apparatus as claimed in claim **21** and including a broad band radio frequency noise generator and/or a modulator providing pulses of said broad band noise at a selected pulse rate and having a selected pulse width, and means to energise said toroidal assemblies with said pulses from said modulator.

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