Internal distribution code:
(A) [ ] Publication in OJ
(B) [ ] To Chairmen and Members
(C) [ ] To Chairmen
(D) [X] No distribution

Datasheet for the decision
of 26 October 2012

Case Number:	T 1310/11 - 3.3.09
Application Number:	03749246.9
Publication Number:	1587670
IPC:	B32B 1/00, H01Q 19/06
Language of the proceedings:	EN

Title of invention:
Indefinite materials

Applicant:
The Regents of the University of California

Headword:
–

Relevant legal provisions:
EPC Art. 123(2), 84, 83

Keyword:
"Support in the application as filed (yes)"
"Clarity of claims (yes)"
"Sufficiency (yes)"

Decisions cited:
–

Catchword:
–

EPA Form 3030   This datasheet is not part of the Decision.
                     It can be changed at any time and without notice.
C8663.D

Case Number: T 1310/11 - 3.3.09

D E C I S I O N
of the Technical Board of Appeal 3.3.09
of 26 October 2012

Appellant:
(Applicant)

The Regents of the University of California
1111 Franklin Street
Oakland, CA 94607-5200   (US)

Representative:

Gill, David Alan
WP Thompson
55 Drury Lane
London WC2B 5SQ   (GB)

Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 9 December 2010 refusing European patent application No. 03749246.9 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman: W. Sieber
Members: M. O. Müller
                  K. Garnett

Summary of Facts and Submissions

I.   European patent application No. 03 749 246.9, filed on
        29 August 2003 as international application
        PCT/US2003/027194 in the name of THE REGENTS OF THE
        UNIVERSITY OF CALIFORNIA was refused by a decision of
        the examining division, which was announced orally on
        28 October 2010 and issued in writing on 9 December
        2010.

II.   The examining division's decision was based on a main
        request containing claims 1 and 2 filed on 18 January
        2010 and claims 3 to 14 filed with entry into the
        regional phase before the EPO and on an auxiliary
        request containing claims 1 and 2 filed on 5 October
        2010 and claims 3 to 14 filed with entry into the
        regional phase before the EPO.

        Claim 1 of the main request read as follows:

        "1. A compensating multilayer material comprising:

        —   an indefinite anisotropic first layer having
             material properties of ε_1 and μ_1, both ε_1 and μ_1
             being tensors, and a thickness d_1;
        —   an indefinite anisotropic second layer adjacent to
             said first layer, said second layer having
             material properties of ε_2 and μ_2, both ε_2 and μ_2
             being tensors, and having a thickness d_2; and,

        wherein ε_1, μ_1, ε_2 and μ_2 are simultaneously
        diagonalizable in a diagonalizing basis that includes a
        layer normal to said first and second layers, and

$$\varepsilon_2 = \psi \varepsilon_1$$

$$\mu_2 = \psi \mu_1$$

where

$$\psi = \quad - \begin{bmatrix} d_1/d_2 & 0 & 0 \\ 0 & d_1/d_2 & 0 \\ 0 & 0 & d_2/d_1 \end{bmatrix}$$

and ψ is a tensor represented in the diagonalizing basis with a third basis vector that is normal to said first and second layers.

Claim 1 of the auxiliary request differed from claim 1 of the main request in that ε_1, μ_1, ε_2 and μ_2 were at least closely approximately simultaneously diagonalizable and in that ε_1, μ_1, ε_2 and μ_2 at least closely approximately satisfied the equations $\varepsilon_2 = \psi \varepsilon_1$ and $\mu_2 = \psi \mu_1$.

III.   The examining division argued essentially as follows:

The main request does not meet the requirements of Article 83 EPC.

Claim 1 requires the first and second layers to have permittivity and permeability tensors ε and μ that can be simultaneously diagonalized. It is however nowhere mentioned in the application as to how this diagonalization can be achieved, and whether physical materials exist that have permittivity and permeability tensors ε_1, μ_1, ε_2 and μ_2 that are indeed simultaneously

diagonalizable. Even more so, the application actually states that such materials do not exist, by mentioning on page 6 that "metamaterials" can be constructed that closely approximate these μ and ε tensors rather than having exactly these tensors. From this statement it has to be concluded that materials having the required diagonalization property do not exist and that hence also the materials used in the embodiment of figure 5 do not fulfil this requirement of claim 1. Since, furthermore, this embodiment of figure 5 is the only way indicated in the application as filed as to how to carry out the invention, the requirements of Article 83 EPC in conjunction with Rule 42(1)(e) EPC are not met.

In addition, claim 1 is not restrictive as to the values of the thickness ratio d_1/d_2 and thus covers ratios with very small thicknesses d_1, such as 0.001λ. For such a thickness, the invention cannot be carried out, since there are no materials that constitute an indefinite anisotropic first layer having the assumed properties with a thickness d_1 equal to 0.001λ. For example, when split ring resonators are used in one of the layers, the minimum thickness of such a layer would be at least in the order of $\lambda/4$, since this would be the length of a side of said split ring.

The auxiliary request was not admitted into the proceedings under Rule 137(3) EPC because it was filed late and was clearly not allowable under Articles 84, 123(2) and 83 EPC.

IV.   On 9 February 2011, the applicant (in the following "appellant") filed a notice of appeal against the above decision and paid the prescribed fee on the same day. A

statement setting out the grounds of appeal was filed
on 19 April 2011 together with a main and an auxiliary
request, which were identical to the requests before
the examining division; and

D5:   Affidavit by Professor Sir J. B. Pendry dated
       15 April 2011.

Further, reference was made to

D6:   J. B. Pendry et al, "Magnetism from conductors and
       enhanced nonlinear phenomena", IEEE Transactions
       on microwave theory and techniques, volume 47(11),
       1999, pages 2075-2084 (a copy of this article was
       filed by the then-applicant on 5 October 2010
       during examination proceedings).

V.   By communication dated 12 March 2012, the board issued
       its preliminary opinion, in which the main request was
       objected to under Articles 83 and 84 EPC.

       As to the requirements of Article 84 EPC, the board
       questioned the clarity of *inter alia* the following
       expressions:

       –   "indefinite anisotropic layer";
       –   "that may be defined as" and "generally planar";
              and
       –   "Never Cutoff property".

       As to sufficiency of disclosure the board raised the
       following objections:

—   Claim 1 covers multilayer materials with any type
        of building blocks provided only that they meet
        the mathematical requirements defined in this
        claim. The application as filed discloses however
        only one way of carrying out the invention, namely
        a composite material containing two specific
        building blocks, namely one being composed of
        straight wires and the other being composed of
        split ring resonators. There is no information at
        all in the application as filed as to how a
        multilayer material with building blocks different
        from these two specific ones can be constructed
        that meets the mathematical requirements of
        claim 1.

—   The elements of the tensor ψ and linked thereto
        the elements of the tensors ε and μ are defined in
        claim 1 by the thickness ratio d_1/d_2. For
        infinitely small thicknesses d_2, this ratio can be
        infinitely large such that the tensors ε and μ can
        have infinite values though no materials with
        infinite permittivity and permeability exist.

—   Claim 1 requires ε_1, μ_1, ε_2 and μ_2 to be
        "simultaneously diagonalizable" while according to
        the penultimate paragraph of page 6 of the
        application as filed, simultaneous
        diagonalizability is achievable only approximately.

VI.   By letter of 28 September 2012, the appellant submitted
        a new main and a new auxiliary request together with

D7: D. R. Smith et al, "Partial focusing of radiation
     by a slab of indefinite media", Applied Physical
     Letters, volume 84(13), 2004, pages 2244- 2246;

D8: D. Schurig et al, "Metamaterial electromagnetic
     cloak at microwave frequencies", Science,
     volume 314, 2006, pages 977-980;

D9: R. A. Shelby et al, "Experimental verification of
     a negative index of refraction", Science,
     volume 292, 2001, pages 77-79;

D10: J. B. Pendry et al, "Controlling Electromagnetic
     Fields", Science, volume 312, 2006, pages 780-782;
     and

D11: R. A. Shelby et al, "Microwave transmission
     through a two-dimensional, isotropic, left-handed
     metamaterial, Applied Physics Letters,
     volume 78(4), 2001, pages 489-491.

VII. By letter of 2 October 2012, the appellant filed

      D12: Supplemental affidavit of Professor Sir
           J. B. Pendry, dated 30 September 2012.

VIII. On 26 October 2012, oral proceedings were held before
      the board. During the oral proceedings, the appellant
      presented background information on "metamaterials" and
      addressed the objections raised by the board in its
      preliminary opinion. In this context, the following
      document was filed

D13: "Indefinite materials - EPO Oral Proceedings 26 Oct. 2012", pages 1-30.

The appellant also filed a new main request as sole request. Claim 1 of the new main request is reproduced in point 2.1 below.

IX.   The appellant's position, in as far as relevant to the present decision, can be summarised as follows:

Clarity

-      The term "indefinite anisotropic layer" in claim 1 is clear in that it implies that the tensors defining the layer must be indefinite, ie must have negative and positive eigenvalues.

-      The term "Never Cutoff property" in claim 3 does not lack clarity as it is clearly defined by the mathematical equations present in this claim.

Sufficiency of disclosure

-      Straight wires create negative permittivity while split ring resonators lead to negative permeability. By combining the two structural elements in one layer, indefinite permittivity and permeability tensors as required by claim 1 can be realised.

-      The straight wire and split ring resonator structures of claim 1 have well-defined permittivity and permeability values and these translate into well-defined thickness ratios. The

thickness ratio is therefore inherently restricted in claim 1 by way of these structures.

–	As confirmed by point 12 of the supplemental affidavit D12 of Professor Sir J. B. Pendry, simultaneous diagonalizability is achievable by the straight wire and split ring resonator structures as shown in figure 5 of the application as filed. As to the passage on page 6 of the application as filed, this does not say that simultaneous diagonalizability cannot be reached but only states that approximate simultaneous diagonalizability is achievable.

X.	The appellant requested that the decision under appeal be set aside and a patent be granted on the basis of the main request filed during the oral proceedings.

Reasons for the Decision

1.	The appeal is admissible.

Main request (sole request)

2.	*Amendments - Article 123(2) EPC*

2.1	Claim 1 refers to "A compensating multilayer material comprising:

–	an indefinite anisotropic first layer having material properties of ε_1 and μ_1, both ε_1 and μ_1 being tensors, and a thickness d_1;

–   an indefinite anisotropic second layer adjacent to
       said first layer, said second layer having
       material properties of ε_2 and μ_2, both ε_2 and μ_2
       being tensors, and having a thickness d_2;

each of said first and second layers comprising a
composite material including a host dielectric medium
with split ring resonators and straight wires embedded
in said host medium in a periodic spatial arrangement;

wherein ε_1, μ_1, ε_2 and μ_2 are simultaneously
diagonalizable in a diagonalizing basis that includes a
layer normal to said first and second layers, and

$\varepsilon_2 = \psi\varepsilon_1$

$\mu_2 = \psi\mu_1$

where

$$\psi = -\begin{bmatrix} d_1/d_2 & 0 & 0 \\ 0 & d_1/d_2 & 0 \\ 0 & 0 & d_2/d_1 \end{bmatrix}$$

and ψ is a tensor represented in the diagonalizing
basis with a third basis vector that is normal to said
first and second layers."

2.1.1 Claim 1 is identical to claim 1 as filed except that:

(a)   the symbol ψ is consistently used throughout the
       equations and the corresponding passages of the
       text (originally, mixed symbols had been used,
       namely the symbols ψ, φ and Φ); and

(b)   each of the first and second layers now comprise a
       composite material including a host dielectric
       medium with split ring resonators and straight
       wires embedded in said host medium in a periodic
       spatial arrangement.

2.1.2   The first amendment (a) represents a correction of an
        obvious error allowable under Rule 139 EPC. Firstly, it
        is obvious that original claim 1 contains an error as
        three different symbols ψ, φ and Φ are used in the same
        context. Secondly, the first paragraph on page 3 of the
        application as filed uses in all equations and the
        corresponding text exclusively the symbol ψ so that the
        only possible correction in claim 1 is the consistent
        use of the symbol ψ.

2.1.3   The second amendment (b) is based on claim 12 as filed
        in conjunction with claim 14 and page 12, lines 1-2 as
        filed.

        Claim 12 as filed refers to "A compensating multi-layer
        material as defined by claim 1 wherein each of said
        layers comprises a composite material including a host
        dielectric and one of an artificial electric or
        magnetic medium embedded in said host medium."
        (emphasis added). Claim 14 as filed is directed to "A
        compensating multi-layer material as defined by
        claim 12 wherein said artificial electric or magnetic
        medium comprises one or both of split ring resonators
        and substantially straight wires in a periodic spatial
        arrangement." (emphasis added). Finally, page 12,
        lines 1-2 as filed states that "Also, combination of
        conductors may be made, with lengths of straight wires

and split ring resonators being one example combination
[sic]." (emphasis added).

In particular, the underlined text of the above-cited
passages of the application as filed clearly and
unambiguously discloses the combination of split ring
resonators and straight wires in the context of the
invention.

2.2   Dependent claim 2 refers to "A compensating multi-layer
       material as defined by claim 1 wherein said first and
       second layers are planar and of equal thickness ... and
       wherein each of said material properties ε and μ for
       both of said layers are tensors that are defined
       as: ..." (emphasis added by the board).

       Claim 2 is identical to claim 2 as filed except that
       "generally planar" has been replaced by "planar" and
       the wording "that may be defined" has been replaced by
       "that are defined" (see highlighted terms above).

       The terms "generally" and "may be" in the original
       claim imply that apart from the explicit embodiments,
       eg planar, other options may exist. The deletion of
       these terms hence merely removes this optionality which
       is not objectionable under Article 123(2) EPC.

2.3   Dependent claims 3 and 4 are based on a combination of
       claims 3 and 4 and of claims 5 and 6 as filed,
       respectively. The fact that claims 3 and 4 as filed and
       claims 5 and 6 as filed are combined does not add any
       new subject-matter, as claim 4 as filed refers back to
       claim 3 as filed and claim 6 as filed refers back to
       claim 5 as filed.

2.4   Dependent claim 5 is based on claim 7 as filed.

2.5   Dependent claim 6 refers to "A compensating multi-layer
        material as defined by claim 1 wherein $\varepsilon_1 = \mu_1$, $\varepsilon_2 = \mu_2$
        and $d_1 = d_2$".

        The feature "A compensating multi-layer material as
        defined in claim 1 wherein $\varepsilon_1 = \mu_1$, $\varepsilon_2 = \mu_2$" is based on
        claim 8 as filed and the feature "and $d_1 = d_2$" is based
        on claim 11 as filed. There is at least a pointer to
        the combination of the two features in the paragraph
        bridging pages 16 and 17 of the application as filed.
        This paragraph deals with the case where the ε and μ
        tensors are equal to each other and where, in a
        particular embodiment, also the layer thickness is
        equal.

        Thus, the subject-matter of claim 6 is clearly and
        unambiguously derivable from the application as filed.

2.6   Claims 7-10 refer to preferred compensating multi-layer
        materials, spatial filter and antenna embodiments and,
        by way of back-reference to any of the preceding claims,
        combine these with the specific first and second layer
        features of the preceding claims.

        The compensating multi-layer material, spatial filter
        and antenna embodiments of claims 7-10 are based on
        claims 16, 19 and 22 as well as the paragraph bridging
        pages 21 and 22 of the application as filed,
        respectively. The combination of these embodiments with
        the specific first and second layer features of the
        preceding claims is based on the same paragraph

bridging pages 21 and 22 of the application as filed.
More particularly, this paragraph discloses the multi-
layer designs, spatial filters and antennae of claims
7-10 in general terms such that it is clear that this
disclosure applies to any first and second layer
embodiments disclosed in the application as filed.

2.7   The main request thus meets the requirements of
        Article 123(2) EPC.

3.   *Clarity (Article 84 EPC)*

3.1   As regards the term "indefinite anisotropic layer" in
        claim 1, it has been convincingly explained by
        Professor Sir J. B. Pendry in his supplemental
        affidavit D12 that the terms "indefinite tensor" and
        "indefinite matrix" are elementary mathematical
        concepts and mean that the tensor or matrix is neither
        "positive definite" (ie all elements having positive
        eigenvalues) nor "negative definite" (ie all elements
        having negative eigenvalues). The term "indefinite
        anisotropic layer" in claim 1 can thus only mean that
        the tensors defining the layer must be indefinite, ie
        must have negative and positive eigenvalues. This means
        eg for the permittivity tensor ε_1 of the first layer

$$\varepsilon_1 = \begin{bmatrix} \varepsilon_1^{xx} & 0 & 0 \\ 0 & \varepsilon_1^{yy} & 0 \\ 0 & 0 & \varepsilon_1^{zz} \end{bmatrix}$$

        that the eigenvalues ε_1^{xx}, ε_1^{yy} and ε_1^{zz} are not all
        positive or negative. The term "indefinite anisotropic
        layer" in claim 1 thus is clear.

3.2   The board's objection raised in its preliminary opinion
        against the wordings "that may be defined as" and
        "generally planar" of the then-pending claim 2 has been
        met by the appellant's amendment of claim 2, ie the
        replacement of "that may be defined as" by "that are
        defined as" and by deletion of the term "generally".

3.3   As regards the term "Never Cutoff property" in claim 3,
        the appellant has convincingly argued during the oral
        proceedings that this term is exhaustively defined by
        the immediately following mathematical equations
        present in claim 3. Therefore, no clarity objection
        arises in this context.

3.4   The main request thus meets the requirements of
        Article 84 EPC.

4.   *Sufficiency of disclosure (Article 83 EPC)*

4.1   In its preliminary opinion, the board took the view
        that guidance was missing for structures different from
        those specifically disclosed in the present application,
        namely layers comprising split ring resonators and
        straight wires. By restricting claim 1 to these
        specific structures (point 2.1 above), this objection
        has been met.

4.2   While there is still no explicit limitation present in
        claim 1 with regard to the thickness ratio d_1/d_2, the
        limitation in claim 1 that the first and second layers
        of this material contain split ring resonators and
        straight wires introduces an implicit limitation to
        physical values that are actually achievable by these
        two elements. More particularly, as pointed out by the

appellant during the oral proceedings, the properties
of metamaterials composed of split ring resonators and
straight wires are accurately characterised by
Maxwell's equations, and therefore highly predictable.
Accordingly, there is a predictable, well-defined range
of achievable permittivity and permeability for a given
implementation of the metamaterial building blocks and
this translates into a predictable, well-defined range
of achievable thickness ratios (in this context see
also lines 3-7 of paragraph 10 of D12).

This is in line with the examining division's argument
that split ring resonators must have a side length of
at least a fourth of the incoming radiation's
wavelength ($\lambda/4$) and that thicknesses below this value
thus are not possible.

In view of the above, the board's objection raised in
the preliminary opinion with regard to the thickness
ratio in claim 1 no longer applies.

4.3   One reason for the examining division's refusal of the
        application was that the requirement "simultaneously
        diagonalizable" could not be achieved (point III above).
        Since according to the penultimate paragraph of page 6
        of the application as filed, this requirement was
        achievable only "closely approximately", the board
        upheld this objection in its preliminary opinion.

4.3.1   However, in its supplemental affidavit D12, Professor
        Sir J. B. Pendry resists this argument. More
        specifically, in point 12 of D12, he makes the
        following statement:

"With respect to the Board's statement that "no material is available for which the permittivity and permeability tensors are simultaneously diagonalizable", I believe that this statement is incorrect. As I explained in my earlier affidavit at points 9-14, a simultaneously diagonalizable metamaterial can be constructed by positioning wires and split rings along orthogonal axis. The inventors of the current application have followed this prescription, as seen in Figure 5 of the application, which shows various arrangements of wires and split rings along x, y, and z axes. Based upon my earlier work, cited in paragraph 10 of the prior affidavit, it can be stated with certainty that the arrangements depicted in Figure 5 of the current application satisfy the condition of simultaneous diagonalizability. This certainty follows from the fact that the structures behave according to Maxwell's equations, which are predictable and solvable." (emphasis added by the board).

In view of this clear and unequivocal statement made by a leading expert in the field, the board accepts that with the specific straight wire and split ring structures to which claim 1 has now been restricted, simultaneous diagonalizability rather than an approximate simultaneous diagonalizability is indeed achievable. This is also not in contradiction to the above cited passage on page 6 of the application as filed as this passage only states that approximate simultaneous diagonalizability is achievable which does not necessarily imply that simultaneous diagonalizability is not achievable.

4.3.2   Furthermore, it is stated in point 13 of D12 that there
        have been experimental demonstrations of simultaneously
        diagonalizable media.

4.3.3   The board is therefore persuaded that the invention
        underlying the main request is sufficiently disclosed
        with regard to the diagonalizability requirement of
        claim 1.

4.4   The main request thus meets the requirements of
        Article 83 EPC.

5.   *Remittal*

        In view of the fact that novelty and inventive step
        have not yet been dealt with by the examining division,
        remittal to the examining division for further
        prosecution is appropriate.

Order

For these reasons it is decided that:

1.   The decision under appeal is set aside.

2.   The case is remitted to the examining division for further prosecution on the basis of claims 1-10 of the main request filed during the oral proceedings before the board.

The Registrar: The Chairman:

D. Hampe   W. Sieber