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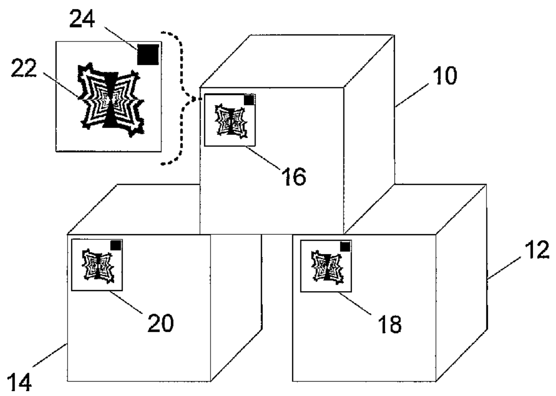
(54) Title: ANTENNA SYSTEM FOR RADIO FREQUENCY IDENTIFICATION



(57) Abstract: An antenna (22) including an electrically conductive portion (dark regions of element 22) defined substantially by a self-similar geometry present at multiple resolutions. The electrically conductive portion includes two or more angular bends and is configured to radiate broadband electromagnetic energy. The antenna further includes an electrically non-conductive portion (white regions of element 22) that structurally supports the electrically conductive portion.

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

ANTENNA SYSTEM FOR RADIO FREQUENCY IDENTIFICATION

RELATED APPLICATIONS AND TECHNICAL FIELD

[0001] This application is related to the following U.S. application, of common assignee, from which priority is claimed, and the contents of which are incorporated herein in their entirety by reference: "Wideband RFID Tag/Antenna," U.S. Provisional Patent Application Serial No. 60/513,497, filed October 22, 2003.

[0002] This disclosure relates to antenna systems and, more particularly, to an antenna system for radio frequency identification (RFID).

BACKGROUND

[0003] Antennas are used to radiate and/or receive typically electromagnetic signals, preferably with antenna gain, directivity, and efficiency. Practical antenna design traditionally involves trade-offs between various parameters, including antenna gain, size, efficiency, and bandwidth.

[0004] Antenna design has historically been dominated by Euclidean geometry. In such designs, the closed area of the antenna is directly proportional to the antenna perimeter. For example, if one doubles the length of an Euclidean square (or "quad") antenna, the enclosed area of the antenna quadruples. Classical antenna design has dealt with planes, circles, triangles, squares, ellipses, rectangles, hemispheres, paraboloids, and the like.

[0005] With respect to antennas, prior art design philosophy has been to pick a Euclidean geometric construction, e.g., a quad, and to explore its radiation characteristics, especially with emphasis on frequency resonance and power patterns. Unfortunately antenna design has concentrated on the ease of antenna construction, rather than on the underlying electromagnetics, which can cause a reduction in antenna performance.

[0006] This reduced antenna performance is evident in systems such as radio frequency identification (RFID) systems. RFID systems are used to track and monitor a variety of objects that range from commercial products and vehicles to even individual people. To track and monitor these objects an antenna and a radio frequency (RF) transceiver (together known as an RFID tag) are attached to the object. When an RF signal (usually transmitted from a handheld RF scanning device) is received by the RFID tag, the RF signal is used to transmit back another RF signal that contains information that identifies the object. However, an RFID tag's performance of can be affected by the environment in which it is placed. For example, performance of an antenna included in an RFID tag may be degraded by the object (e.g., a metallic shipping container, a car, etc.) to which it is attached. Due to this degradation, the RFID tag may need to be scanned multiple times and at a close range in order to activate the tag.

SUMMARY OF THE DISCLOSURE

[0007] In accordance with an aspect of the disclosure, an antenna includes an electrically conductive portion defined substantially by a self-similar geometry present at multiple resolutions. The electrically conductive portion includes two or more angular bends and is configured to radiate broadband electromagnetic energy. The antenna further includes an electrically non-conductive portion that structurally supports the electrically conductive portion.

[0008] In a preferred embodiment, the electrically conductive portion may include an element defined substantially by a V-shaped geometry or defined substantially by a rectangular geometry. The geometry of self-similarity at multiple resolutions may include a deterministic fractal.

[0009] In accordance with another aspect, a radio frequency identification system includes an antenna having an electrically conductive portion defined substantially by a self-similar geometry present at multiple resolutions. The electrically conductive portion includes two or more angular bends and is configured to radiate broadband electromagnetic energy. Further, the antenna includes an electrically non-conductive portion that structurally supports the electrically conductive portion. The radio frequency identification system further includes an integrated circuit in communication with the antenna, wherein the integrated circuit is configured to respond to an electromagnetic signal received by the antenna.

[0010] In one embodiment of the system, the broadband electromagnetic energy may radiate within a 10:1 ratio or a 50:1 frequency band. The antenna may includes a dipole geometry or a monopole geometry.

[0011] Additional advantages and aspects of the present disclosure will become readily apparent to those skilled in the art from the following detailed description, wherein embodiments of the present invention are shown and described, simply by way of illustration of the best mode contemplated for practicing the present invention. As will be described, the present disclosure is capable of other and different embodiments, and its several details are susceptible of modification in various obvious respects, all without departing from the spirit of the present disclosure. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as limitative.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram depicting RFID tags attached to a group of containers.

FIG. 2 is one embodiment of a wide band dipole antenna for use in an RFID tag.

FIG. 3 is one embodiment of a wide band monopole antenna for use in an RFID tag.

FIG. 4 is another embodiment of a wide band dipole antenna for use in an RFID tag.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] Referring to FIG. 1, a stack of shipping containers 10-14 are individually attached with RFID tags 16-20 so that each container can be tracked and monitored as it transits from one location (e.g., a warehouse, loading dock, stock yard, etc.) to a destination location (e.g., a retail store, personal residence, etc.). Each of the RFID tags, such as RFID tag 16 includes a surface-mounted antenna 22 that is capable of transmitting and receiving electromagnetic signals to and from an RFID scanner. Typically, an RFID scanner is used by personnel to check the identification of the containers such as container

10. In this example, RFID tags 16-20 are mounted to containers, however, in other arrangements tags may be mounted on and used to track other commercial or private objects and in some applications living bodies such as animals and humans. Furthermore, while RFID tags 16-20 are surface-mounted onto shipping contains 10-14, in other examples, each tags may extend off the container surface. For example, an RFID tag may be placed inside a rod or within another type of three-dimensional object that is attached to the container.

[0013] Referring to FIG. 2, antenna 26 is a dipole antenna that includes an upper portion 28 and a lower portion 30. To radiate and receive electromagnetic energy, antenna 26 includes conductive material that is represented by the color black and non-conductive material that is represented by the color white. Typical conductive materials that may be used to produce antenna 26 include metal, metallic paint, metallic ink, metallic film, and other similar materials that are capable of conducting electricity. Non-conductive materials may include insulators (e.g., air, etc.), dielectrics (e.g., glass, fiberglass, plastics, etc.), semiconductors, and other materials that impede the flow of electricity. Along with impeding current flow, the non-conductive material also typically provides structural support to the conductive portion of antenna 26. So, to provide such support, the non-conductive materials may include materials typically used for support (e.g., wood, plastic, etc.) that is covered by a non-conductive material on its outer surface.

[0014] In this embodiment, antenna 26 includes two traces 32, 34 of conductive material that are each triangular in shape and are positioned to mirror each other in orientation. Each portion 28, 30 of antenna 26 also includes series of traces 36 – 42 that extend radially from the center of the antenna and define an outer boundary. Each trace series 36 – 42 includes both conductive traces and non-conductive segments (between each pair of conductive traces) as represented by the black and white colors.

[0015] Focusing on trace series 36, the shape of each conductive trace and non-conductive segment are similar and include multiple bends. In particular each trace and segment is self-similar in shape and is similar at all resolutions. In general the self-similar shape is defined as a fractal geometry. Fractal geometry may be grouped into random fractals, which are also termed chaotic or Brownian fractal and include a random noise components, or deterministic fractals. Fractals typically have a statistical self-similarity at all resolutions and are generated by an infinitely recursive process. For example, a so-called Koch fractal may be produced with N iterations (e.g., N=1, N=2, etc.). However, in other arrangements trace series 36 may be produced using one or more other types of fractal geometries.

[0016] By incorporating the fractal geometry into the traces and segments of each series 36 – 42, the length and width of each conductive trace and non-conductive segment is increased due to the nature of the fractal pattern. However, while the length and width increase, the overall footprint area of the entire antenna 26 is relatively small. By providing longer conductive paths, antenna 26 can perform over a broad frequency band. For example, broad frequency bands with ratios, for example, of 10:1, 50:1, etc. can be achieved with antenna 26. Other frequency band ratio may be achievable. In one particular arrangement, antenna 26 can perform at frequencies within a broad frequency band of 400 Mega Hertz (MHz) to 6000 MHz. It should be appreciated that performance within other frequency bands can be achieved. Thus, antenna 26 is capable of transmitting and receiving electromagnetic signals over a broader frequency range. Since the RFID tag that includes antenna 26 may be mounted on an object that can affect the performance of the antenna, by extending the frequency coverage of the antenna, "detuning" of the antenna due to environmental effects is reduced. By reducing sensitivity to detuning, the RFID tag may not need to be scanned multiple times or scanned from a reduced distance to initiate a response from the IC included in the RFID tag.

[0017] Along with extending the frequency coverage of antenna 26 for broadband operations, by incorporating a fractal geometry to increase conductive trace length and width, antenna losses are reduced. By reducing antenna loss, the output impedance of antenna 26 is held to a nearly constant value across the operating range of the antenna. For example, a 50 – ohm output impedance may be provided by antenna 26 across a frequency band with a 10:1 or 50:1 ratio.

[0018] In this arrangement, when antenna 26 is transmitting an electromagnetic signal (in response to receiving an electromagnetic signal from a scanner), conductive traces 32, 34 primarily radiate the signal while the series of traces 36 – 42 load the antenna. By radiating and loading appropriately, both portions 28, 30 cause antenna 22 to produce a dipole beam pattern response.

[0019] Referring to Fig. 3, an antenna 44 is presented in which again conductive material is represented with the color black and non-conductive material is represented with the color white. Antenna 44 includes an upper portion 46 that is similar to the upper portion 28 of antenna 26. However, to provide a monopole antenna response, antenna 44 includes a lower portion 48 that simulates a ground plane. Similar to antenna 26, both upper and lower portions 46, 48 include conductive and non-conductive material. In particular, a V-shaped conductive trace 50 is included in upper portion 46 along with two series 52, 54 of conductive traces and non-conductive segments that radially extend from the intersection of the tip of V-shaped conductive trace 50 and lower portion 48. Similar to antenna 26, each series of traces and segments 52, 54 incorporate a self-similar geometry (e.g., a fractal) that is present at all resolutions of each trace. Each trace and segment in both series 52, 54 include multiple bends as part of the fractal geometry to increase the length and width of each trace and segment while not expanding the footprint area of antenna 44. By incorporating this geometry and the multiple bends, antenna 44 is capable of operating over a broad frequency band (e.g., such as the ranges associated with antenna 26) while providing a nearly constant impedance (e.g., 50 – ohms).

[0020] Referring to FIG. 4, an antenna 56, which is similar to the previous examples, includes conductive material that is represented with a dark color and non-conductive material that is represented with the color "white". Antenna 56 includes four portions 58 – 64, each incorporating a similar fractal pattern that was included in antenna 26 and antenna

44. However, rather than a V-shaped conductive trace, antenna 56 includes a nearly rectangular – shaped conductive trace 66 (highlighted by a dashed-line box) that extends from one end of the antenna, through the center of the antenna, and to the opposite end of the antenna. The rectangular – shaped conductive trace 66 has a relatively thin width and is relatively long in length. Due to this geometry, trace 66 provides a loading effect on antenna 56 rather than predominately providing the function of radiating electromagnetic energy, which was provided by the V-shaped traces 32, 34 and 50. When antenna 56 is put into a transmission mode, the extended lengths and widths of the conductive traces in the four portions 58 – 64 allow antenna 56 radiate the electromagnetic energy across a broad frequency band. Similarly, due to the fractal geometry incorporated into portions 58 – 64, the RFID tag is capable of receiving an electromagnetic signal across a broad frequency band.

[0021] A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made. Accordingly, other implementations are within the scope of the following claims.

WHAT IS CLAIMED IS:

1. An antenna comprising:

an electrically conductive portion defined substantially by a self-similar geometry present at multiple resolutions, wherein the electrically conductive portion includes two or more angular bends and is configured to radiate broadband electromagnetic energy; and

an electrically non-conductive portion that structurally supports the electrically conductive portion.

2. The antenna of claim 1, wherein the electrically conductive portion includes an element defined substantially by a V-shaped geometry.

3. The antenna of claim 1, wherein the electrically conductive portion includes an element defined substantially by a rectangular geometry.

4. The antenna of claim 1, wherein the geometry of self-similarity at multiple resolutions includes a deterministic fractal.

5. The antenna of claim 1, wherein the broadband electromagnetic energy radiates substantially within a 10:1 ratio frequency band.

6. The antenna of claim 1, wherein the broadband electromagnetic energy radiates substantially within a 50:1 ration frequency band.

7. The antenna of claim 1, wherein the broadband electromagnetic energy radiates between 400 MHz and 6000 KHz.

8. The antenna of claim 1, wherein the electrically conductive portion includes a ground plane.

9. The antenna of claim 1, wherein the conductive material is metallic.

10. A radio frequency identification system comprising:

an antenna including,

an electrically conductive portion defined substantially by a self-similar geometry present at multiple resolutions, wherein the electrically conductive portion includes two or more angular bends and is configured to radiate broadband electromagnetic energy, and

an electrically non-conductive portion that structurally supports the electrically conductive portion; and

an integrated circuit in communication with the antenna, wherein the integrated circuit is configured to respond to an electromagnetic signal received by the antenna.

11. The radio frequency identification system of claim 10, wherein the broadband electromagnetic energy radiates within a 10:1 ratio frequency band.

12. The radio frequency identification system of claim 10, wherein the broadband electromagnetic energy radiates within a 50:1 ratio frequency band.

13. The radio frequency identification system of claim 10, wherein the antenna includes a dipole geometry.

14. The radio frequency identification system of claim 10, wherein the antenna includes a monopole geometry.

15. The radio frequency identification system of claim 10, wherein the antenna is surface mounted.

16. The radio frequency identification system of claim 10, wherein the electrically non-conductive portion includes a dielectric material.

17. The radio frequency identification system of claim 10, wherein the antenna is configured to provide a substantially constant output impedance across a broad frequency band.

18. The radio frequency identification system of claim 10 wherein the integrated circuit is configured to initiate transmitting of an electromagnetic signal at the antenna.

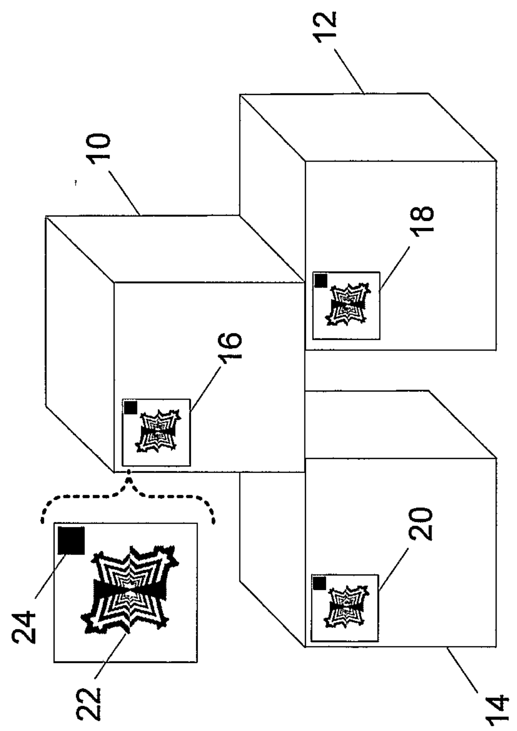

FIG. 1

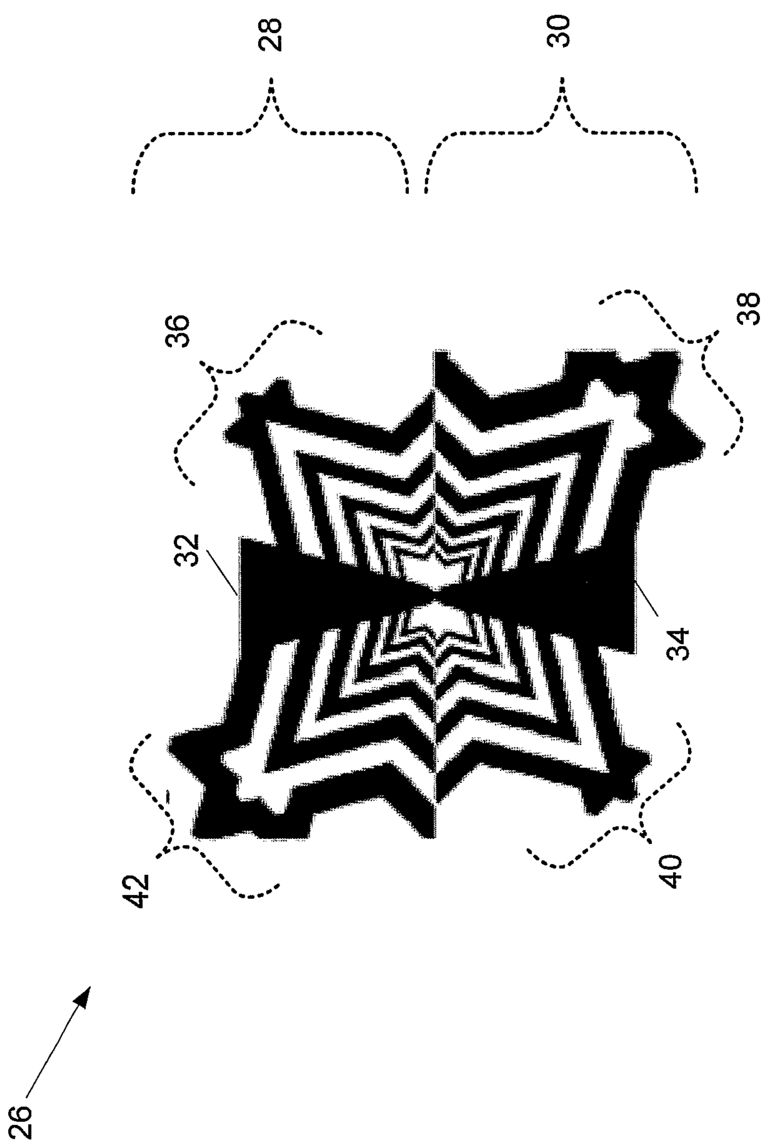

FIG. 2

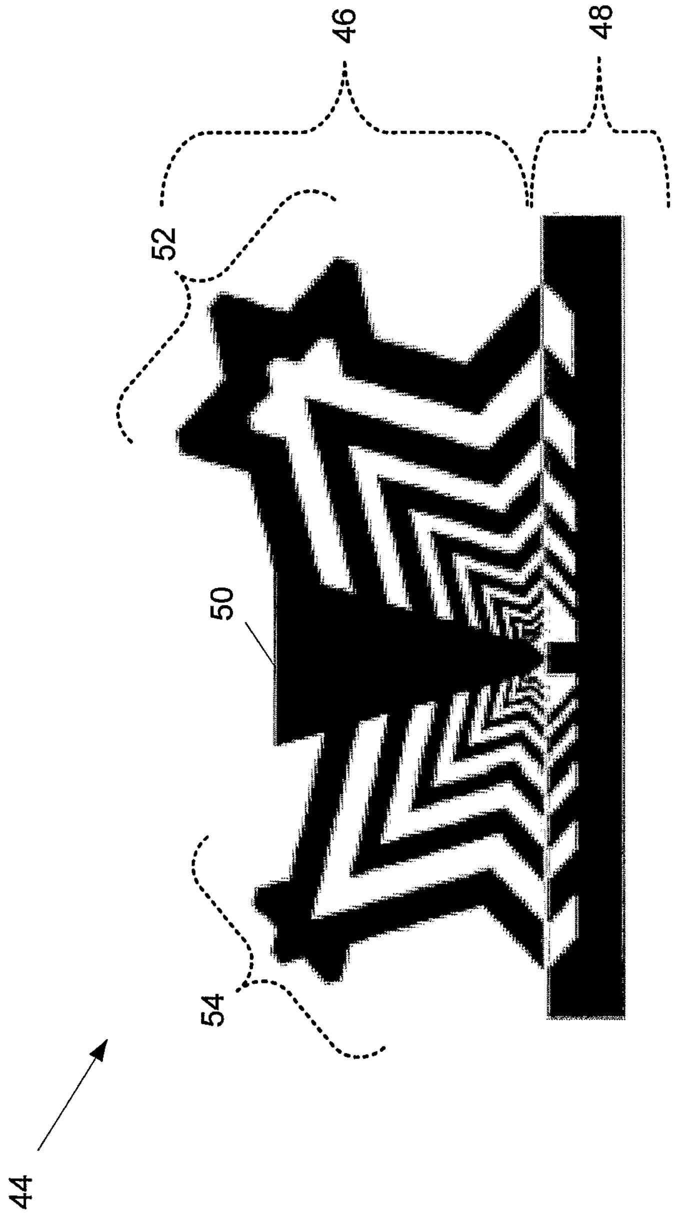

FIG. 3

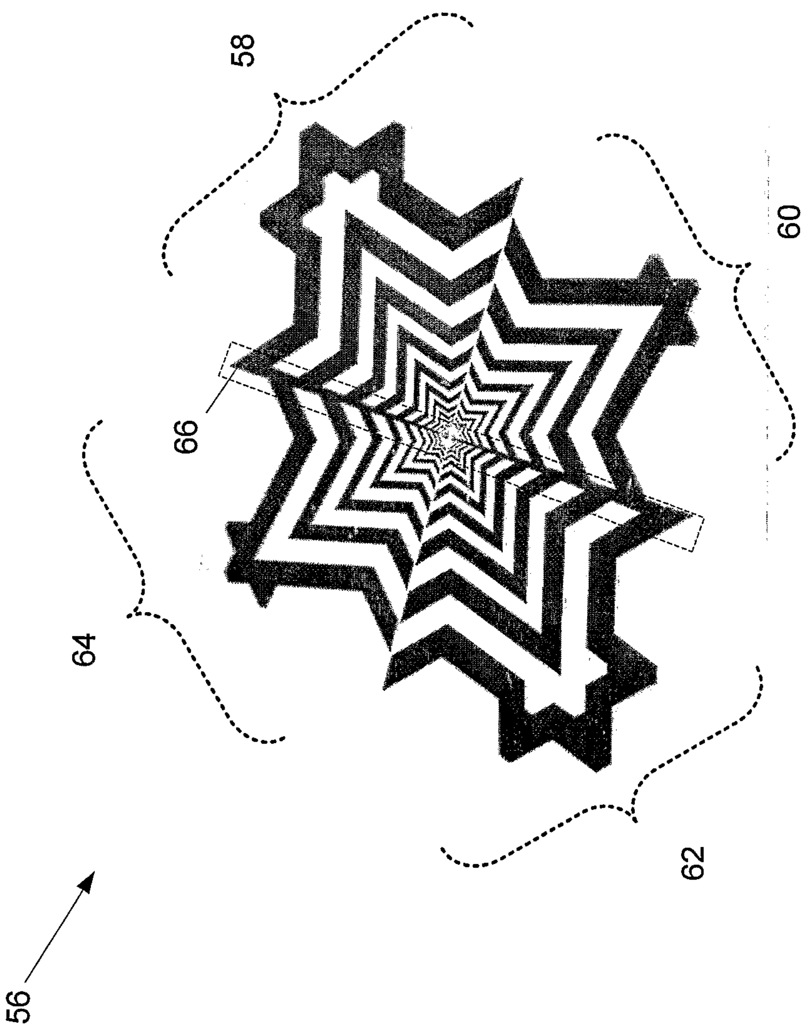

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US04/34942

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H01Q 9/16, 9/28, 21/20, 1/36
US CL : 343/700MS, 793, 795, 796, 895

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 343/700MS, 793, 795, 796, 895

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2002/0175874 A1 (EASON) 28 November 2002 (28.11.2002), figures 1-6, paragraphs 0036-0051	1-6, 8, and 9 ----------- 7, 10-18
Y	US 2003/0122713 A1 (MORRIS et al) 03 July 2003 (03.07.2003), figure 5	7, 10-18
Y	US 2003/0112196 A1 (WANG et al) 19 June 2003 (19.06.2003), figure 1a	14
A	US 2003/0160723 A1 (COHEN) 28 August 2003 (28.08.2003), entire document	1-18
A	US 6,525,691 B2 (VARADAN et al) 25 February 2003 (25.02.2003), entire document	1-18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
22 February 2005 (22.02.2005)

Date of mailing of the international search report
08 MAR 2005

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INTERNATIONAL SEARCH REPORT	International application No. PCT/US04/34942

Box No. I Nucleotide and/or amino acid sequence(s) (Continuation of item 1.b of the first sheet)

1. With regard to any nucleotide and/or amino acid sequence disclosed in the international application and necessary to the claimed invention, the international search was carried out on the basis of:
   a. type of material
      - ☐ a sequence listing
      - ☐ table(s) related to the sequence listing

   b. format of material
      - ☐ in written format
      - ☐ in computer readable form

   c. time of filing/furnishing
      - ☐ contained in the international application as filed
      - ☐ filed together with the international application in computer readable form
      - ☐ furnished subsequently to this Authority for the purposes of search

2. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

3. Additional comments:

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US04/34942

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.