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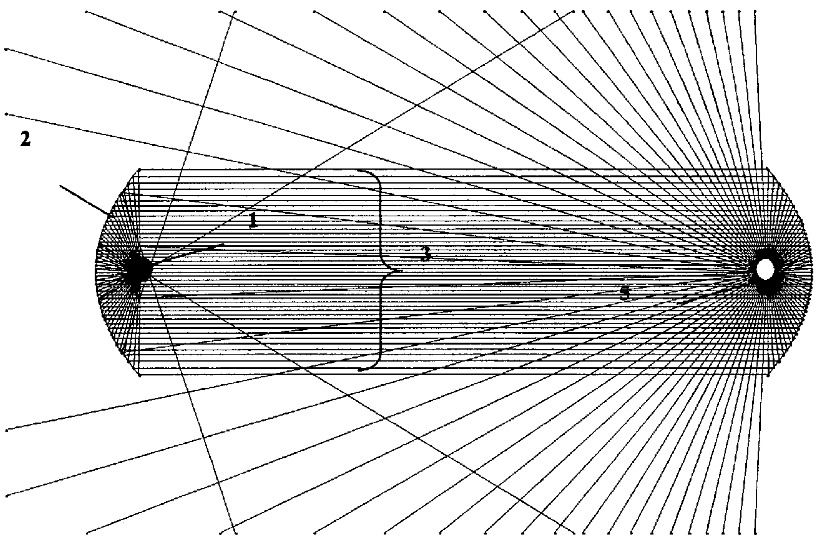
(54) Title: APPARATUS FOR PROVIDING A RECONFIGURABLE DISTRIBUTION NETWORK



(57) Abstract: Apparatus for providing a reconfigurable distribution network, which apparatus is of a monolithic construction, and which apparatus comprises at least one input port (1), at least one output port (5), and control means (2) for modifying the transfer characteristics of electromagnetic signais between the input (1) and output (5) ports whereby the transfer function of the electromagnetic signals between the input (1) and output (5) ports is able to be àontrolled, and the control means (2) being electronic control means, photonic control means, or electromechanical control means.

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APPARATUS FOR PROVIDING A RECONFIGURABLE DISTRIBUTION NETWORK

Field of the Invention

This invention relates to apparatus for providing a reconfigurable distribution network. This invention also relates to the reconfigurable distribution network when provided with the apparatus.

Description of the Prior Art

Prior art relating to localised control of electromagnetic signals within a parallel plate structure is described in PCT/GB01/02813, PCT/GB02/05915 and GB-A-0224724.

Brief Description of the Invention

It is an aim of the present invention to provide a monolithic compact apparatus that acts as a programmable transfer network for electromagnetic signals.

Accordingly, in one non-limiting embodiment of the present invention there is provided apparatus for providing a reconfigurable distribution network, which apparatus is of a monolithic construction, and which apparatus comprises at least one input port, at least one output port, and control means for modifying the transfer characteristics of electromagnetic signals between the input and output ports whereby the transfer function of the electromagnetic signals between the input and output ports is able to be controlled, and the control means being electronic control means, photonic control means, or electromechanical control means.

The electromechanical means may be in the form of miniature electromechanical devices.

The electronic control means may cause filamentary volumes of electronic carriers to be generated through the injection of electrical current.

Alternatively, the photonic control means may cause filamentary volumes of electronic carriers to be generated through the optical illumination of a semi-conducting material.

The miniature electromechanical devices may be micro-electromechanical actuators which stress, strain or otherwise modify a local medium and thereby affect the passage of the electromagnetic signals.

Alternatively, the miniature electromagnetic devices may be micro-electromechanical actuators which controllably reflect, refract, attenuate or otherwise modify the passage of the electromagnetic signals.

The electromagnetic signals may be transmitted and subsequently received between essentially parallel planar conducting surfaces, the energy being distributed and collected by means of locally controllable regions of modified media within the apparatus. The passage of the electromagnetic signals may be directed in such a manner that the transfer function of the apparatus performs the function of a filter, a delay line, a finite impulse response filter, a splitter or combiner, or any other class of transfer function.

The apparatus of the present invention may be such that the input and output ports are in the form of waveguide, transmission line, coaxial cable, or any combination thereof.

The input and output ports may be attached to discrete antennas. Alternatively, the output ports may be antennas directly mounted on a substrate. The input and output ports may be antennas arranged radially to provide full circular coverage.

The apparatus may be one which is conformal apparatus which is so shaped as to follow surface contours of some other object. Such a conformal apparatus may have application to aerodynamic shapes such for example as occurs in aerospace, nautical and other vehicular applications.

The present invention also extends to a plurality of pieces of apparatus of the invention, the pieces of apparatus acting in unison to provide complex and controllable functionality.

The apparatus of the present invention may be designed by calculation and material properties to perform in specific applications relating to, for example, telecommunications, radar, guidance, aerospace, medical scanning, inspection or other forms of imaging.

As indicated above, the invention also extends to a reconfigurable distribution network when including the apparatus of the invention.

Due to the ability of the apparatus to configure a parallel plate structure using both wafer and discrete micro-electromechanical electronic systems devices, and plasma devices, applications of parallel plate, reconfigurable distribution networks exist at both apparatus level and sub-system level. At a microwave/millimeter wave device level, applications include programmable time delays, programmable attenuators, programmable filters, and programmable cavity resonators. At a sub-system level, applications include programmable waveform synthesizers, wideband signal routers, and electronically directed antennas.

The reconfigurable distribution network may enable electromagnetic signals to be connected between a plurality of input and output ports, with the network typically causing the transmitted signals to be selectively combined, split, delayed and attenuated. Through combination, in series or in parallel, of the transmitted signals, the network is able to perform the function of spatial and temporal filtering. The network may be in the form of a twin plate structure through which the electromagnetic signals are transmitted between the input and output ports.

Mathematical Description of the Transfer Characteristics

In order to fully appreciate the general purpose nature of the apparatus of the present invention, it is useful to understand the spatial and temporal operations that an embodiment of the apparatus performs in mathematical terms.

More specifically, the transfer characteristic of a general purpose distribution network of the type described herein is defined by the Gabor/Kolmogorov equation written for the output y_s:

$$y_s = \sum a_r x_s + \sum\sum a_{r1r2t} x_{s1} x_{s2} + \sum\sum\sum a_{r1,r2,r3} x_{s1} x_{s2} x_{s3} + \text{.......high order terms}$$

where the coefficients $a_{r1r2r3...}$ are the *Gaussian/Sommerfield* Diffraction Integral Operators performed coherently for all possible paths lengths (the paths being constrained between twin plates) and all reflective, absorptive and refractive boundary conditions encountered between the *sth* output (y_s) and all '*n*' input feeds (x_r). For most devices, only the linear terms are significant and the quadratic and cubic terms only become needed if the inputs are mutually coupled. It is noted that the *Gabor/Kolmogorov* equation is totally general in terms of its functionality and represents all *finite impulse* interpolative and extrapolative temporal and spatial filters.

The constrained Diffraction Integrals are essentially due to Gauss and further developed by Sommerfield.

$$a_r(u,v,t) = \int_{-\pi}^{\pi} \int_{-\pi}^{\pi} F_{r-in}(\psi).F_{s-out}(\theta-\psi).A_{r,s}(\psi,\theta,u,v,t).d\psi d\theta$$

$$a_{r1,r2,s}(u,v,t) = \int_{-\pi}^{\pi} \int_{-\pi}^{\pi} \int_{-\pi}^{\pi} F_{r1-in}(\psi) F_{r2-in}(\theta-\psi).F_{s-out}(\vartheta-\psi-\theta).A_{r,s}(\psi,\theta,\vartheta,u,v,t).d\psi d\vartheta d\theta$$

The "F" terms are feed Directivity Functions, and the "A" terms are complex exponential terms that take into account wave number, traversed optical path lengths (Fermat's principle applies), propagation constants and angular frequency for Fresnel boundary conditions on the conformal surface g(u, v), further constrained by the active and passive regions sandwiched between the parallel plates. The integrals can be greatly simplified if a thin parallel plate guide is assumed, (where only the *TEM* wave-guiding properties apply), as this requires only one propagation constant to be introduced, (i.e. only one modal solution is possible) for each dielectric material used. This means that for planar configurations, ray trace solutions are sufficient in predicting to a first order, the performance of the apparatus and the rules of Euclidean geometry apply, especially those related to conic sections.

General Description of the Drawings

Embodiments of the invention will now be described solely by way of example and with reference to the accompanying drawings in which;

Figure 1 shows a one-to-one distribution network;

Figure 2 shows a multi-way splitter/combiner network;

Figure 3 shows a finite impulse response filter;

Figures 4a and 4b show a reconfigurable distribution network;

Figures 5a and 5b show radially symmetric distributors;

Figure 6 shows a one-to-one selector;

Figure 7 shows a one-to-many selector;

Figure 8 shows a resonator device;

Figure 9 shows a parallel plate, general purpose, reconfigurable network;

Figure 10 shows a bi-planar construction;

Figure 11 shows a conformal construction;

Figure 12 shows an anti-symmetric variable time delay configuration;

Figure 13 shows an elliptical surface time delay;

Figures 14a and 14b shows two FIR filter configurations;

Figure 15 shows a programmable waveform synthesizer;

Figure 16 shows a wideband signal router;

Figure 17 shows an electronically directed antenna;

Figure 18 shows a radial distributor with twin line output;

Figure 19 shows a twin line radial distributor with Vivaldi antenna elements; and

Figure 20 shows a radial distributor feeding re-orientated radial distributors.

Referring to Figure 1, there is shown a reconfigurable distribution network in its most fundamental form, namely a one-to-one distribution network. As shown in Figure 1, an omni-directional input feed 1 illuminates a parabolic primary reflector 2 to produce a collimated beam 3 directed towards a parabolic sub-reflector 4. The sub-reflector 4 focuses the received beam to an omni-directional output feed 5.

Through the control of the optical path lengths, a variable time delay apparatus is provided. The optical path length may be affected through control of the intervening medium, or through modification of the focal length of the reflecting parabolas. Furthermore, the magnitude of the signal received may be controlled through influence of the size of the primary reflector 2, the size of the sub-reflector 4, their reflectivity, and by control of the propagation medium.

It will be understood that in a practical implementation of the described delay line, some energy may be directed at such angles that the energy is not intercepted by the receiving parabolic sub-reflector 4, and is thereby lost. This unused energy may advantageously be absorbed at the boundaries of the apparatus in order to preclude the possibility of interference through subsequent reflections.

It will also be appreciated that the described delay line is fully reciprocal in its operation. In other words, the input and output ports may be interchanged.

Figure 2 illustrates the manner in which the previously described one-to-one network of Figure 1 may be extended to implement a one-to-four network. As shown in Figure 2, a signal is launched through an input feed point 7 and illuminates a parabolic primary reflector 8, in order to produce a collimated reflected beam 9. The collimated reflected beam 9 in turn illuminates four separate sub-reflectors 10, 11, 12, 13. The four sub-reflectors, 10, 11, 12, 13 receive differing amounts of energy but the optical path lengths, or time delays, are equal. The described apparatus acts as a four-way splitter or combiner. By modification of the reflecting properties of the antenna 8 or the sub-reflectors 10, 11, 12, 13, the apparatus of the invention is able to act as a multi-way switch, wherein one, two, three or four channels may be selected.

In a further extension of the apparatus and concept shown in Figure 1, Figure 3 shows how the invention may be used to implement a finite impulse response filter. More specifically, the apparatus shown in Figure 2 is replicated in a reciprocal manner. Energy is transferred between feed points 92, 93 and primary reflectors 90, 91 via sub-reflector pairs 18, 19, 20, 21 and interconnectors 14, 15, 16, 17. Time delays and amplitude weightings are influenced by control of the characteristics of the sub-reflector pairs 18, 19, 20, 21. In network terms, the transfer function may be represented as a summation of time and amplitude elements as illustrated by the reference number 22. This configuration represents a general four tap, finite impulse response (FIR) filter.

Figure 4a and 4b are respectively plan and side elevational views of apparatus of the present invention. More specifically, Figures 4a and 4b show solid state plasma diodes used between a guiding structure in order to create reflecting surfaces, refracting boundaries and attenuating regions. By control of the level of carriers injected (electrons and hole) absorption and reflection regions are created and modified.

The positioning of plasma diodes is shown in magnified form 25. An input port 26 and an output port 27 have been shown as co-axial cables, the ends of which act as feed points between the parallel plates. Four co-axial cables 28 are used to connect the left and right sub-reflector systems together. Control lines 29 control the absorbing region composed of an array of "slightly on" plasma diodes, typically producing a carrier concentration of 10^15cm^-3. Control lines 30 control the main reflector composed of two curved lines of the "fully on" plasma diodes, typically producing a carrier concentration of 10^17cm^-3. Control lines 31 control the reflecting regions composed of eight curved lines of "fully on" plasma diodes.

An alternative implementation of the present invention is to use micro-actuator devices to change the position of reflecting, refracting and absorbing elements. Alternative geometries for such elements are discussed in UK Patent No. 0224724 entitled An Electromagnetic Switch. Essentially, the geometric layout shown in Figure 4 remains the same, except that the plasma devices are replaced by micro-actuators which can physically move different permittivity materials into regions between a parallel plate waveguide. In both cases, the elements and their spacing should be small with respect to a wavelength. The micro-actuator realisation has the advantage of requiring much less latching power, but it is unlikely to change state as quickly as the plasma diode approach.

Figure 5 shows two radial distribution networks where a central omni-directional feed 32 distributes a signal equally amongst a circular array of electrical reflector systems 33 that share a common focus at the centre of the circular array. Figure 5a shows twelve elliptical reflectors with a small number of rays intersecting each reflector. Figure 5b shows twenty four elliptical sub-reflectors, with many rays intersecting each reflector. The rays are only shown as an aid to understanding the design process and choice of geometry. By switching-off sub-reflectors or replacing them with absorbing material rather than reflecting surfaces, the radial network may be used as a multi-way switch. By changing distances and reflection co-efficients in the way described above for Figure 4, a wide range of functions may be realised.

Figure 6 shows how an elliptical system 34 may be rotated to perform a one-to-one distribution system. The system shown in Figure 6 is similar to that shown in Figure 1, except that the single focus parabolic reflectors have been replaced in Figure 6 by a dual foci ellipse. The choice between ellipse and parabola will normally be made largely in terms of feed geometries and the relative insertion losses introduced. It should be noted that, because no refracting surfaces have been introduced, there are no lens aberrations, and the family of conic section reflectors are appropriate.

Figure 7 illustrates how a hyperbola 35 may be used to distribute and weight an associated electromagnetic beam across a set of appropriately orientated elliptical reflectors 36 that share a common focus 37. This common focus 37 may also be shared with a second focus of the hyperbola 35 in order to help equalise the power received by each sub-reflector (not shown). The exact choice of geometry depends upon the desired weighting across the set of sub-reflectors. This weighting and the time delays become important when the radial distribution system is used to feed a set of external antennas (not shown) in order to provide a circularly scanned array.

By way of further example of the range of possible applications for the reconfigurable distribution network, a tuneable resonant cavity is shown in Figure 8. In Figure 8, a central feed 38 is at a first focus of a set of ellipses 39. The reflected optical path lengths can be adjusted such that either destructive or constructive interference occurs at the single central feed for a particular wavelength. By changing either the dielectric properties of the material between the plates, or the geometry of the reflectors, the outward and inward optical distances may be changed and hence the resonant and filtering properties of the cavity.

Figure 9 shows a general purpose reconfigurable distribution network capable of performing a wide range of spatial and temporal filtering operations. The reconfigurable distribution network may be fabricated either on a single semi-conductor wafer, or it may employ discrete devices, or it may be a combination of both. If the network is a single semi-conductor wafer, then upper and lower surfaces of the semi-conductor wafer may be metalised and thus the dielectric between the plates becomes the semi-conductor material. In the case of the use of the discrete devices, the discrete devices may be sandwiched between the metal plates, and the dielectric may then be mostly air.

Synthetic dielectrics with both positive and negative refractive indices may be synthesized by generating regular arrays of metal and dielectric on the inner surfaces of parallel plates, and in volumes in between the parallel plates. The synthetic dielectrics may be reconfigured using plasma diodes and micro-electromechanical electronic systems (MEMS) devices.

The apparatus shown in Figure 9 comprises a central input port 40 surrounded by two active regions 41, where various refracting and reflecting elements may be generated or switched in (or out). Ideally, the amount of high density plasma generated and/or the distance moved by the micro-actuators needs to be kept small to improve switching times. To facilitate switching times and minimise insertion losses, quarter-wavelength impedance transformers may be used to vary the distance between the parallel plates. Generally, inter-plate spacing may be used in regions of active absorption 42 where less dense absorptive plasmas need to be generated. A number of fixed position output ports 43 have been included in the outer active region 41. These output ports 43 have been positioned concentric to the central input port 40. Input and output ports 40, 43 may be either mono-poles, patches, cavities or combinations thereof. The network is reciprocal (i.e. perfectly bi-directional) and inputs can be exchanged with outputs. The exact choice of feed geometry and disposition will depend on many factors which can only be determined by electromagnetic modelling wherein the required reflection parameters and insertion losses are taken into account. An outer passive region 44 has also been included in order to absorb any undesired electromagnetic radiation and to prevent unwanted secondary reflections.

In order to control the plasma/MEMS dedicated shape 45 and material permittivity 46, controls have been introduced which set up plasma/MEMS element states via X and Y element address control circuitry 47, 48. A further level of control is also allowed for in terms of changing the bandwidth and beamwidth of the input and output ports 49. This can be achieved by reconfiguring the input and output port geometries using either MEMS or plasma diode devices.

Figure 10 illustrates how one device may be stacked above another in a bi-planar construction to provide a compact realisation of a reconfigurable distribution network. A signal is fed via an upper input feed 50 in an upper twin plate waveguide 51, through a set of cross over feeds 52 to a lower twin plate waveguide 53, and then out through a lower output port 54. For many applications which have reflective (i.e. one-fold) symmetry, such as the finite impulse response filter shown in Figure 3, the same control circuitry may be shared between the upper and lower waveguide structures.

Figure 11 illustrates the possibility of producing a conformal structure. As shown in Figure 11, as with a planar construction, a conformal twin plate waveguide 55 is fed through co-axial cables 56 and associated impedance transformers 57. The conformal waveguide 55 contains both active regions 58 and passive regions 59. The conformal waveguide 55 also contains appropriately positioned output ports 60. The active regions may contain either plasma diode or micro-actuator devices.

Due to the ability to configure parallel plate structures using both wafer and discrete MEMS and plasma devices, applications of parallel plate, reconfigurable distribution networks exist at both the device and the sub-system level. At the microwave/millimeter wave device level, applications include programmable time delays, programmable attenuators, programmable filters and programmable cavity resonators. The operation of these devices has been generally explained above and different device geometries will now be referred to with reference to Figures 12, 13 and 14.

Figure 12 shows an anti-symmetric, variable time delay configuration having an input port 61 at the focus of a parabolic primary reflector 62. This enables the production of a collimated beam with an output port 63 at the focus of a parabolic sub-reflector 64. In order to change the delay, the focal length of the sub-reflector 65 is changed. The input and output feed positions remain unchanged. The change in focal length can be effected using either plasma diodes or micro-actuators.

Figure 13 shows an elliptical design of variable time delay with a directional input port 66, a reconfigurable elliptical reflector 67, and a directional output port 68. This design benefits from having only one elliptical reflector 67 that can be reconfigured without moving the two focal points at which the input/output feeds are placed. The design may also act as an attenuator by changing the reflectivity of the reconfigurable reflector.

Figure 14 shows two alternative designs for an eight element finite impulse response filter, configured using two different designs of reconfigurable distribution network. In Figure 14a, a bi-planar system 69 is used, the mechanism for which has already been explained above with reference to Figures 3 and 11. In Figure 14b, there is used a single plane system 70 with slightly inclined flat mirrors that give rise to displaced input and output ports. The individual time delays due to the eight individual parabolic sub-reflectors and the eight inclined flat sub-reflectors may be contrasted in graphs 71 and 72. The losses through the system may be contrasted in graphs 73 and 74. The harmonic frequency performance may be compared between graphs 75 and 76. By placing a weighted cosine taper across the collimated beam, the side-band levels may be reduced and the effects are shown in graphs 77 and 78.

At a sub-system level, applications of the invention include programmable waveform synthesizers, wideband signal routers, and electronically directed antennas.

Figure 15 shows a programmable waveform synthesizer where a Gaussian impulse function 79 is presented at the input to configuration shown in Figure 9. The device can generate simultaneously a set of different output functions 80, which are the weighted sum of the input function displaced by different time delays (see the Gabor-Kolmogorov equation above for a more mathematical description of what can be synthesized).

Figure 16 shows a wideband signal router where certain combinations of microwave input signals 81 can be selected and output at 82. Complete cross-over capabilities would require interconnected versions of what is shown in Figure 9.

Figure 17 shows an electronically directed antenna with a single input port 83 and eight output ports that have been connected to eight directional antenna elements 84. The eight output ports may be selected and weighted as shown in Figure 7, using a combination of reconfigurable elliptical and hyperbolic reflectors.

Figure 18 shows a radial distributor where twin plates have been tapered at 85 into sixteen "twin line" output ports 86. This configuration removes the need for a second reflecting surface.

Figure 19 shows the same "twin line" radial distributor 89 being used to drive upper and lower halves 87 of radially arranged Vivaldi antenna arrangements, where only four of the sixteen are shown, in order to form a steerable horizontally polarised antenna. The configuration shown in Figure 19 has the advantage of being totally planar in its construction. Other antenna elements can provide different polarisations and capabilities, for example bandwidths and elevation coverage.

Figure 20 illustrates how a radial distributor 90 may feed into differently orientated radial, linear or sectoral distributors 91 that in turn drive antenna elements. In Figure 20, for clarity, only a radial distributor has been shown with a few Vivaldi elements 92. Various torroidal, cylindrical and spherical elements may be configured to provide a full 360° antenna beam pointing in both azimuth and elevation. All polarisations may be achieved using appropriately orientated antenna elements.

It will be noted from the above that Figures 4 and 9 show the geometric layout of the inputs, outputs, controllable and fixed surfaces which are sandwiched between a thin parallel plate wave-guiding structure that may be either planar or conformal. The wave-guiding structure is divided into regions containing either active or passive dielectric materials. The active regions are composed of either arrays of solid state through-thickness, plasma-generating devices that are either photonically or electronically controlled. Alternatively arrays of micro-electromechanical electronic systems (MEMS) can be used. The passive regions are composed of any appropriate dielectric materials, and may also contain fixed reflective, refractive and absorptive functions. In all cases, these through-thickness arrays perform reflective, refractive or absorptive functions, and form reflectors, lenses and baffles, that for the active regions may be reconfigured. Active and passive regions may be linked by transformers that allow the thickness of the parallel waveguide to be varied either continuously or stepped. By varying the thickness of the parallel plate waveguide, the insertion losses may be minimised over a band of frequencies.

It is to be appreciated that the embodiments of the invention described above with reference to the accompanying drawings have been given by way of example only and that modifications may be effected.

CLAIMS

1. Apparatus for providing a reconfigurable distribution network, which apparatus is of a monolithic construction, and which apparatus comprises at least one input port, at least one output port, and control means for modifying the transfer characteristics of electromagnetic signals between the input and output ports whereby the transfer function of the electromagnetic signals between the input and output ports is able to be controlled, and the control means being electronic control means, photonic control means, or electromechanical control means.

2. Apparatus according to claim 1 in which the electromechanical control means is in the form of miniature electromechanical devices.

3. Apparatus according to claim 1 in which the electronic control means causes filamentary volumes of electronic carriers to be generated through the injection of electrical current.

4. Apparatus according to claim 1 in which the photonic control means causes filamentary volumes of electronic carriers to be generated through the optical illumination of a semi-conducting material.

5. Apparatus according to claim 2 in which the miniature electromechanical devices are micro-electromechanical actuators which

stress, strain or otherwise modify a local medium and thereby affect the passage of the electromagnetic signals.

6. Apparatus according to claim 2 in which the miniature electromagnetic devices are micro-electromechanical actuators which controllably reflect, refract or attenuate or otherwise modify the passage of the electromagnetic signals.

7. Apparatus according to claim 1 in which the electromagnetic signals are transmitted and subsequently received between the substantially parallel planar conducting surfaces, the energy being distributed and collected by means of locally controllable regions of modified media with the apparatus.

8. Apparatus according to claim 7 in which the passage of the electromagnetic signals is directed in such a manner that the transfer function of the apparatus performs the function of a filter, a delay line, a finite impulse response filter, a splitter or combiner, or any other class of transfer function.

9. Apparatus according to any one of the preceding claims in which the input and output ports are in the form of waveguide, transmission line, co-axial cable, or any combination thereof.

10. Apparatus according to any one of the preceding claims in which the input and outputs are attached to discrete antennas.

11. Apparatus according to any one of claims 1 – 9 in which the outputs are antennas directly mounted on a substrate.

12. Apparatus according to claim 10 or claim 11 in which the input and output ports are antennas arranged radially to provide full circular coverage.

13. Apparatus according to any one of the preceding claims and which is conformal apparatus which is so shaped as to follow surface contours of some other object.

14. A plurality of pieces of apparatus according to any one of the preceding claims, the pieces of apparatus acting in unison to provide complex and controllable functionality.

15. A reconfigurable distribution network when including apparatus according to any one of the preceding claims.

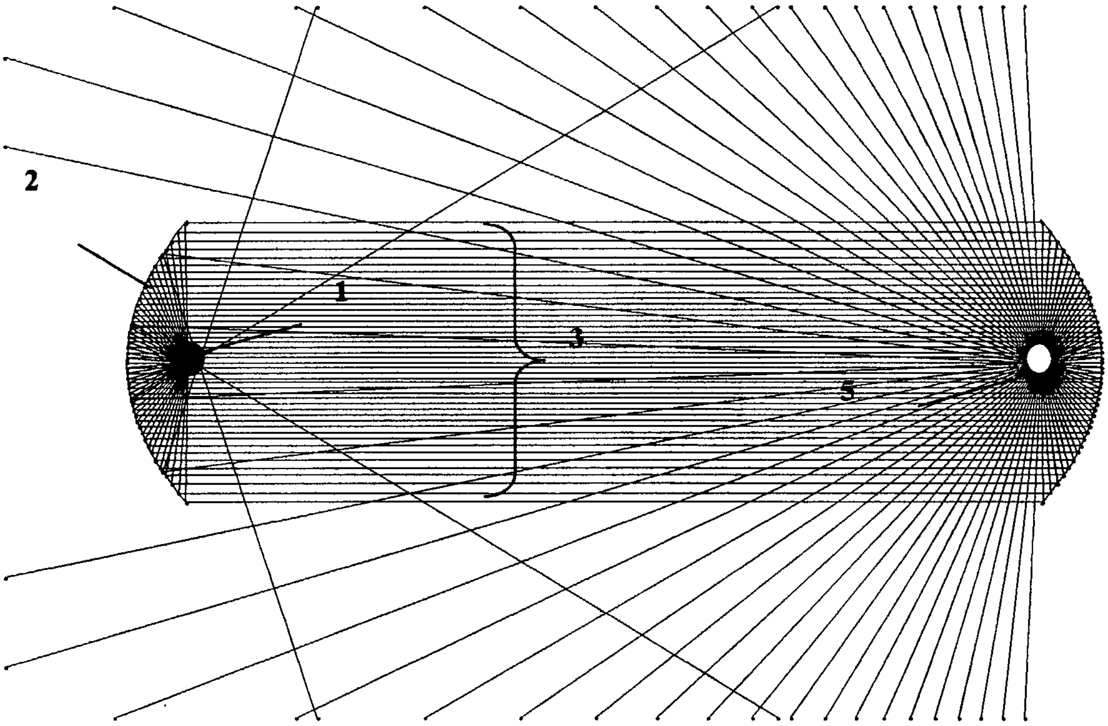


FIG 1

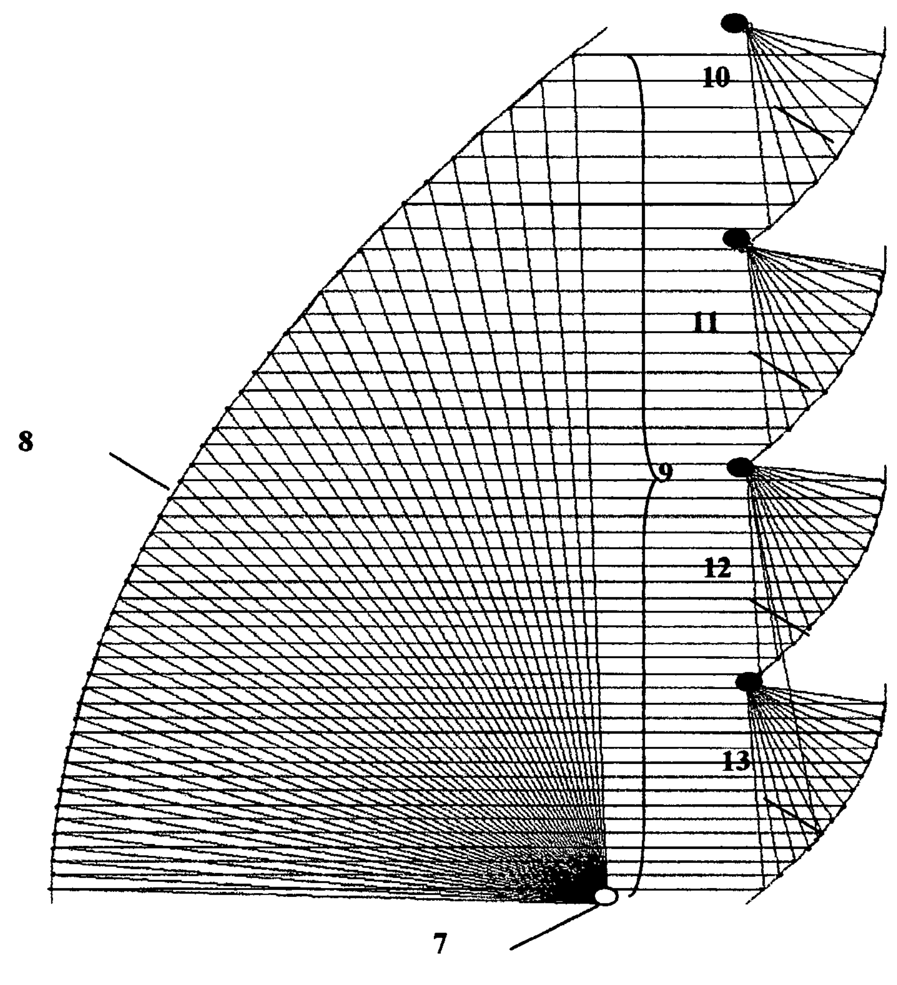
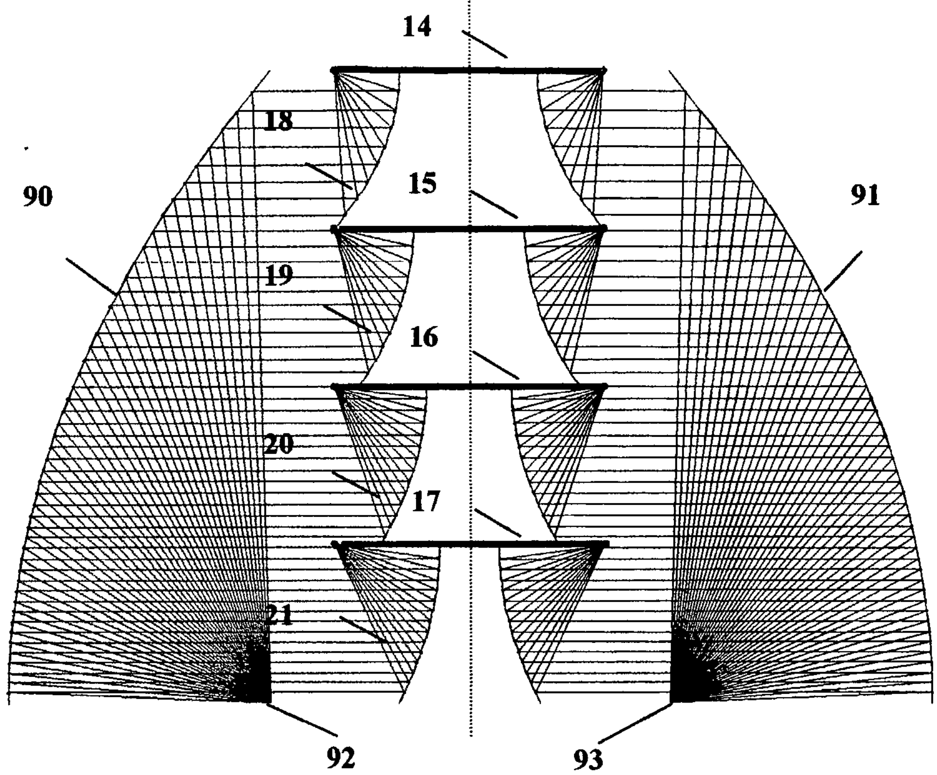


FIG 2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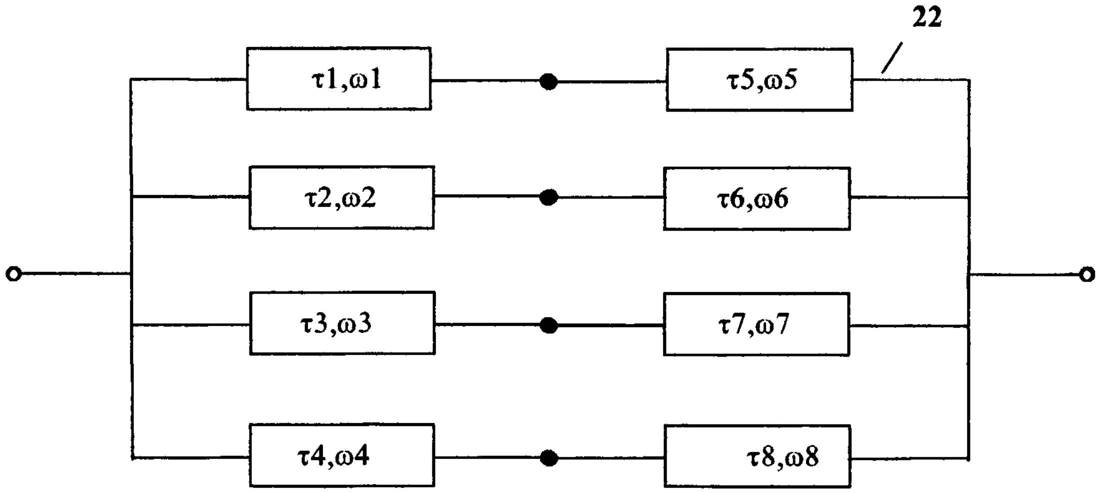
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τ4,ω4
τ8,ω8

FIG 3

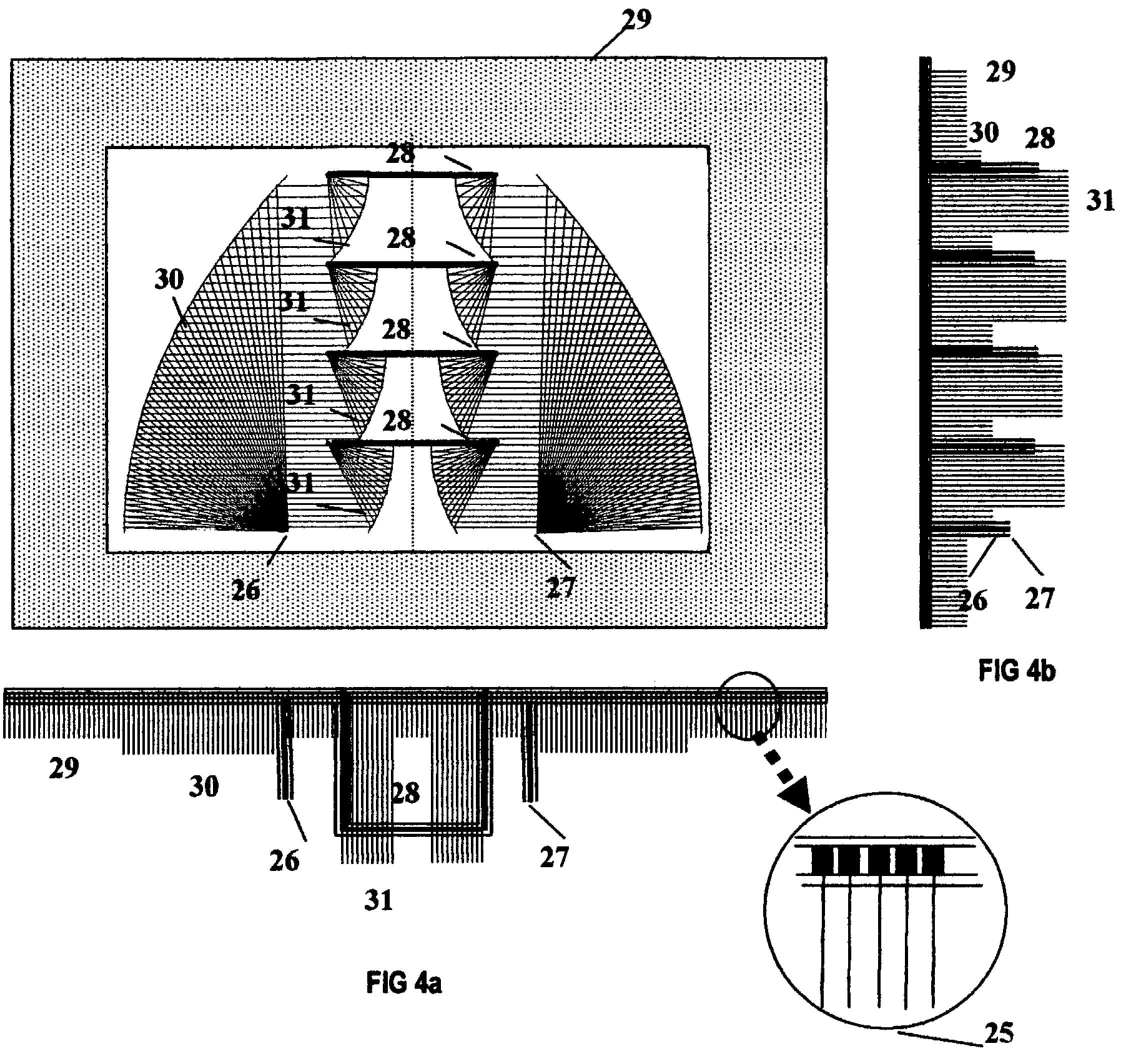
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FIG 4b

FIG 4a

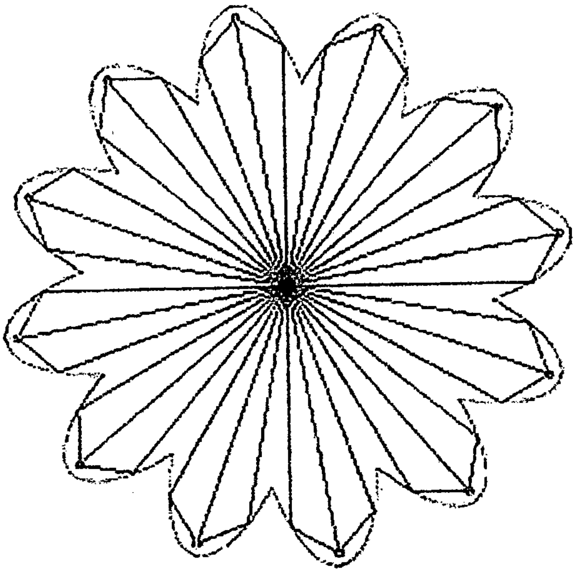

FIG 5a

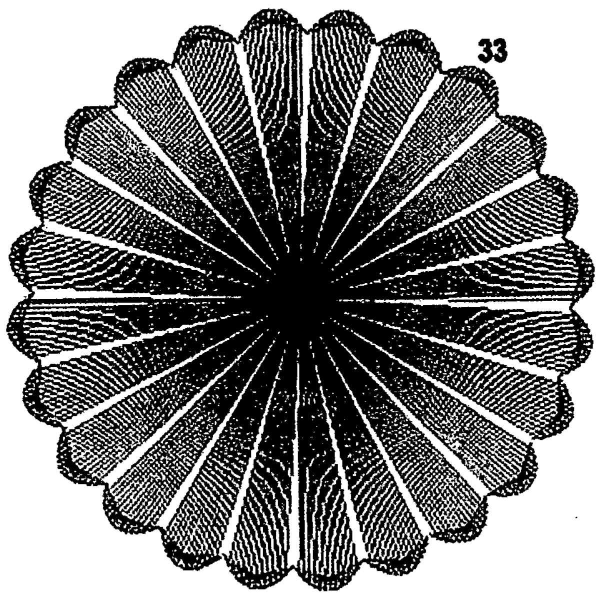

FIG 5b

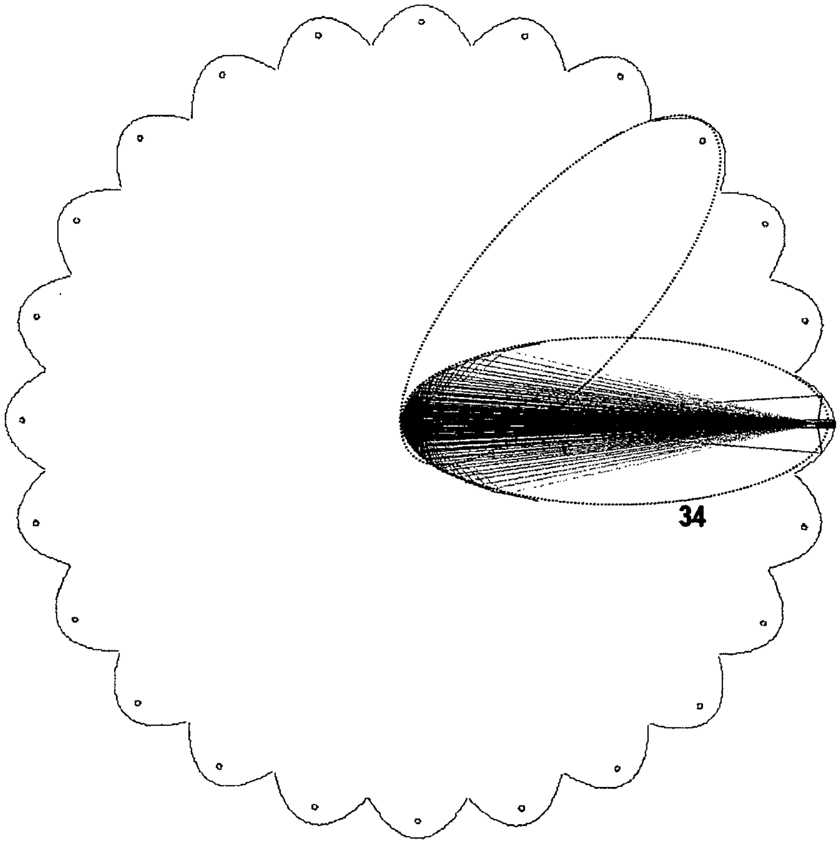

FIG 6

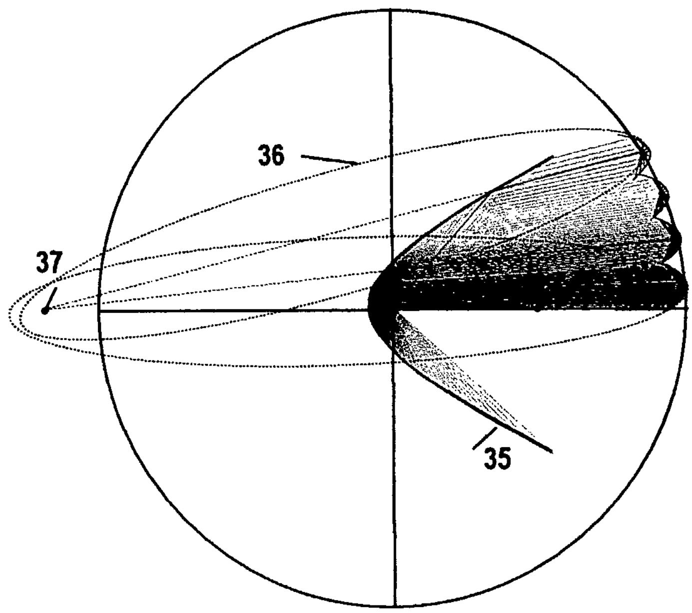

FIG 7

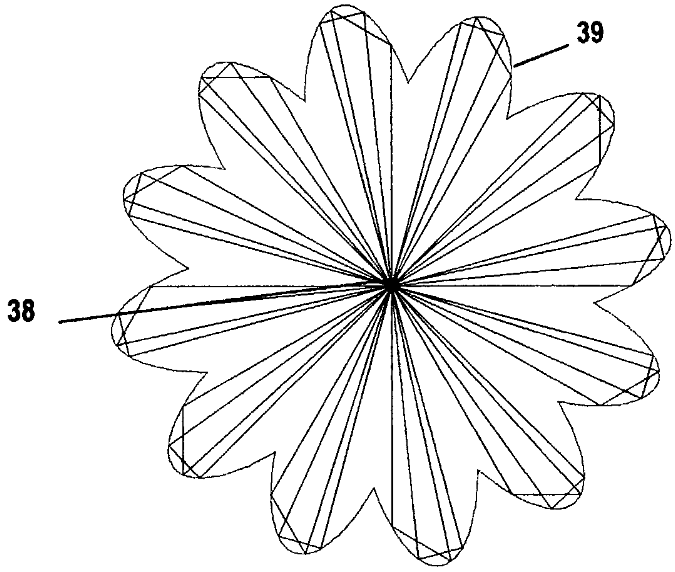

FIG 8

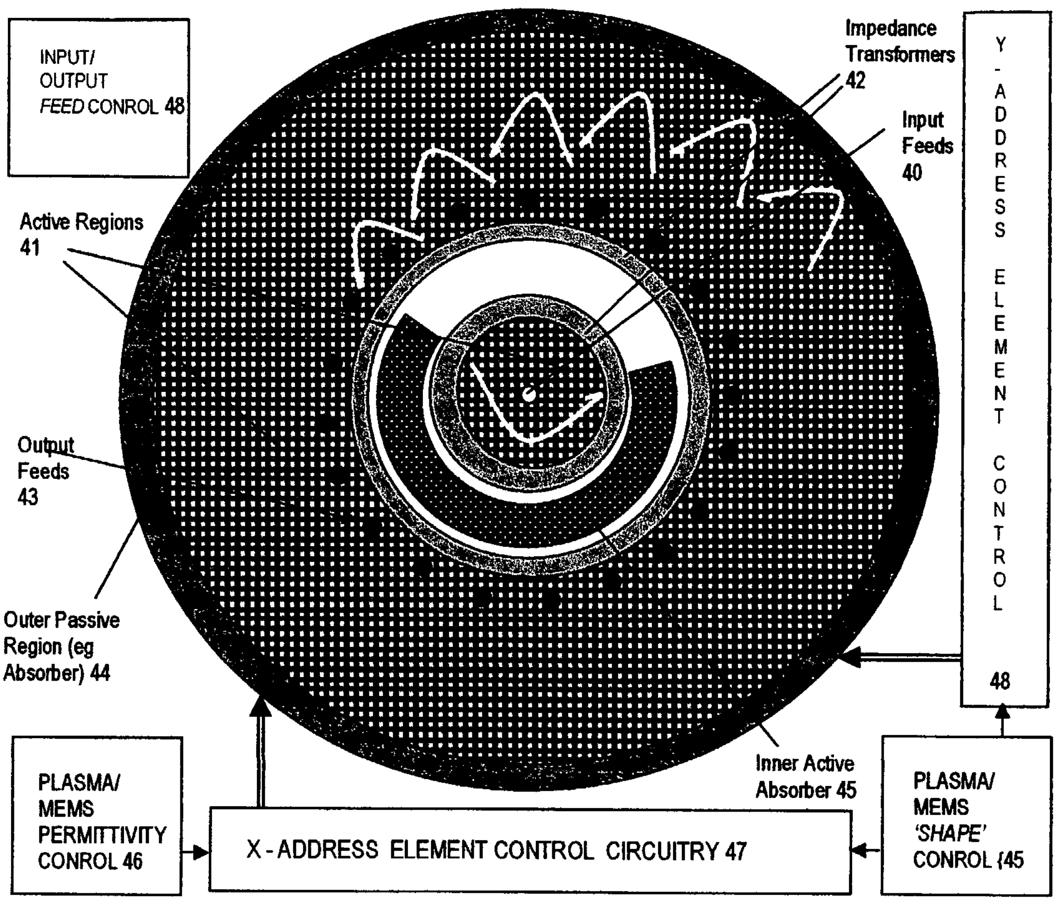
INPUT/
OUTPUT
FEED CONROL 48
Impedance
Transformers
42
Input
Feeds
40
Y-ADDRESS ELEMENT CONTROL
48
Active Regions
41
Output
Feeds
43
Outer Passive
Region (eg
Absorber) 44
Inner Active
Absorber 45
PLASMA/
MEMS
PERMITTIVITY
CONROL 46
X-ADDRESS ELEMENT CONTROL CIRCUITRY 47
PLASMA/
MEMS
'SHAPE'
CONROL {45

FIG 9

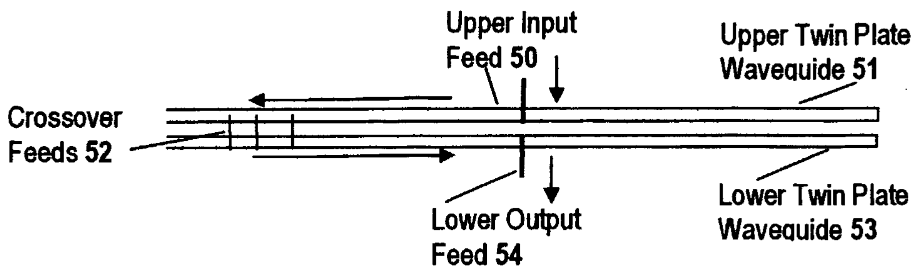
Upper Input
Feed 50
Upper Twin Plate
Waveguide 51
Crossover
Feeds 52
Lower Output
Feed 54
Lower Twin Plate
Waveguide 53

FIG 10

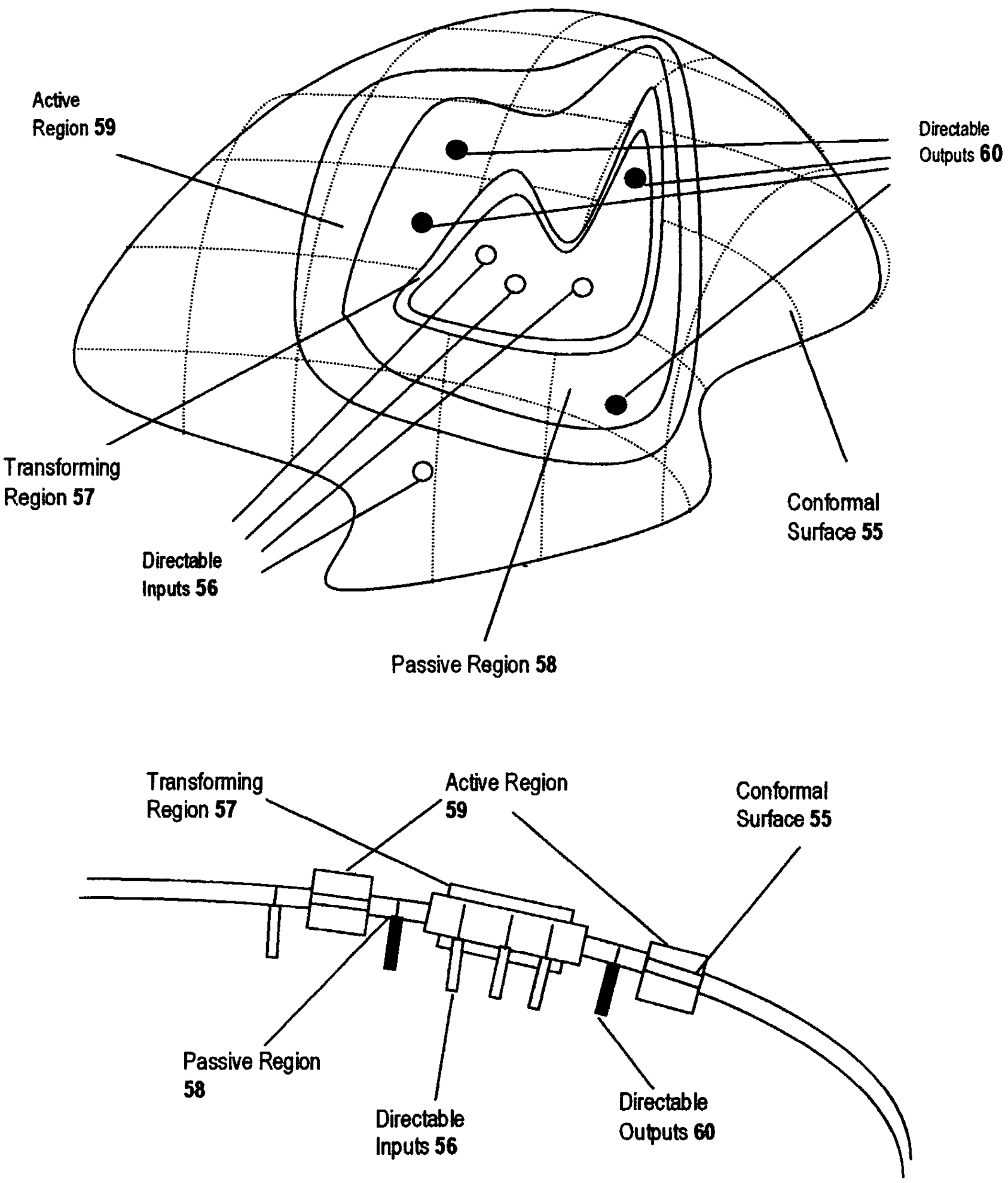
Active
Region 59
Directable
Outputs 60
Transforming
Region 57
Directable
Inputs 56
Conformal
Surface 55
Passive Region 58
Transforming
Region 57
Active Region
59
Conformal
Surface 55
Passive Region
58
Directable
Inputs 56
Directable
Outputs 60

FIG 11

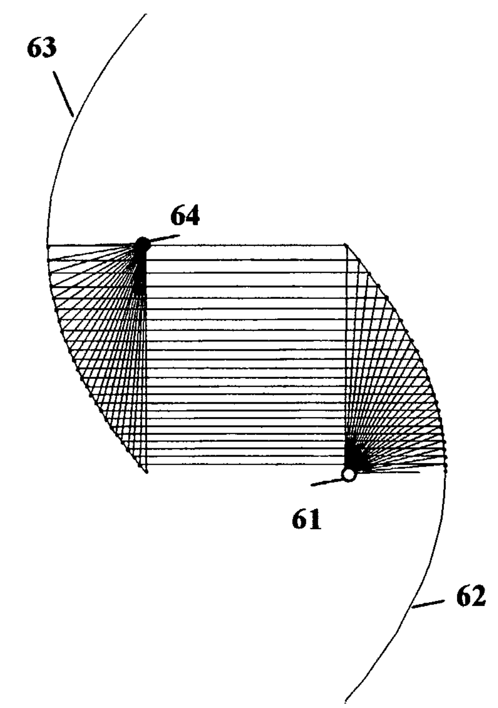

Figure 12

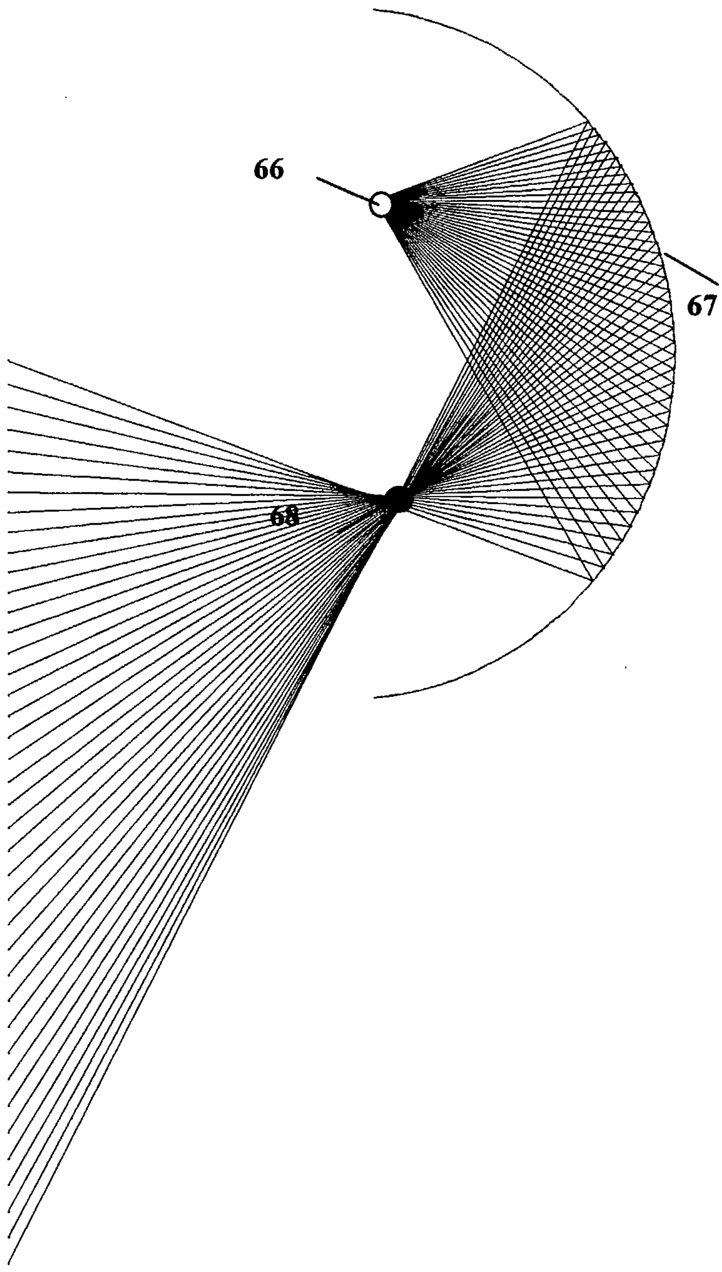

FIG 13

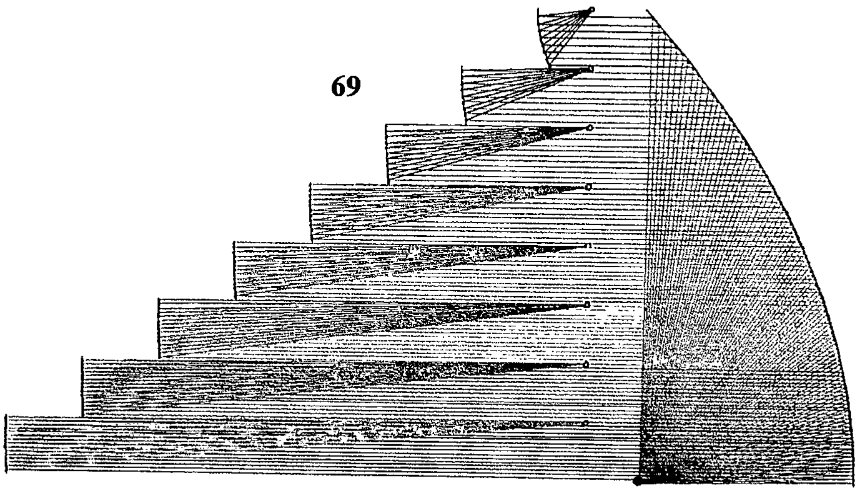

FIG 14a

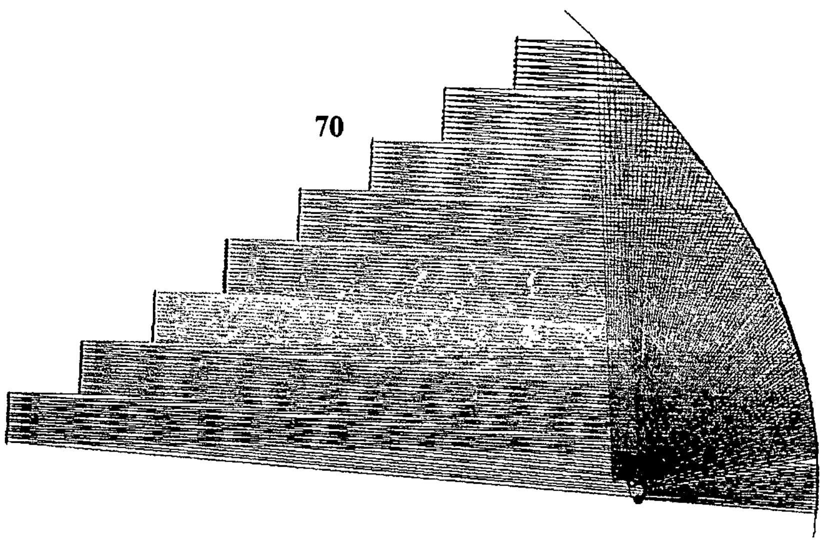

FIG 14b

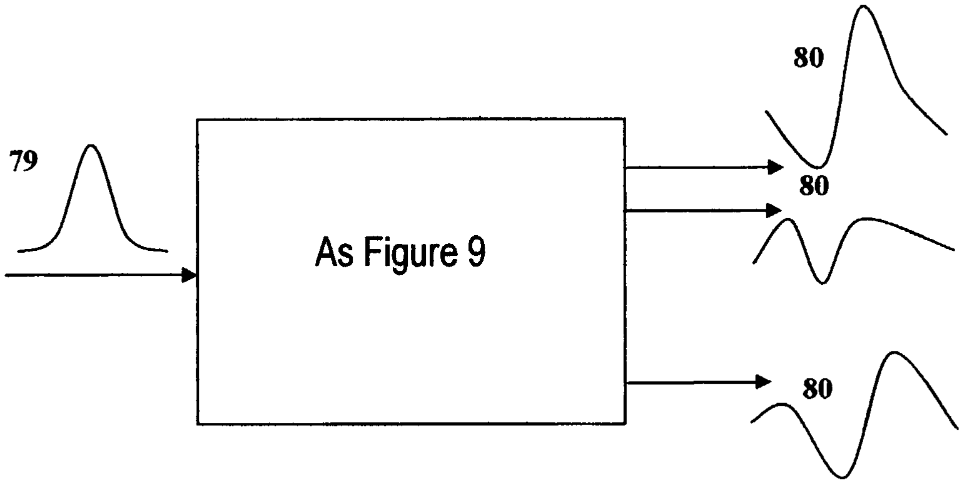

FIG 15

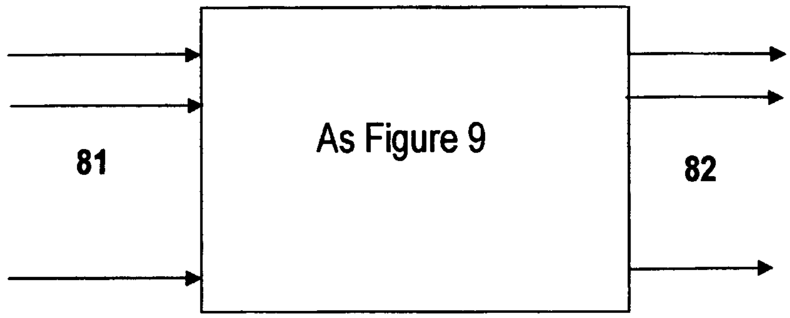

FIG 16

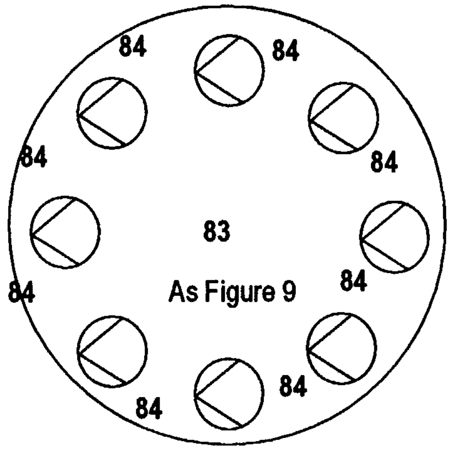

FIG 17

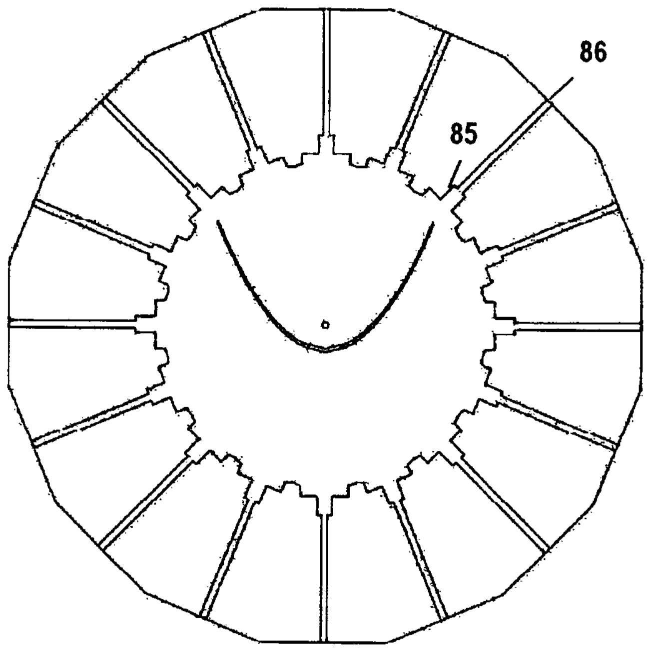

FIG 18

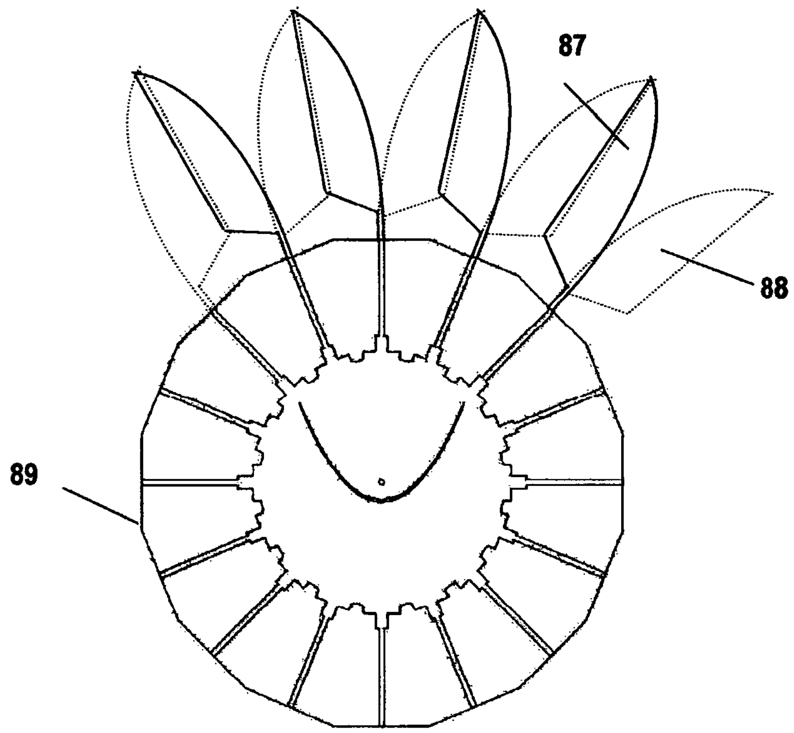

FIG 19

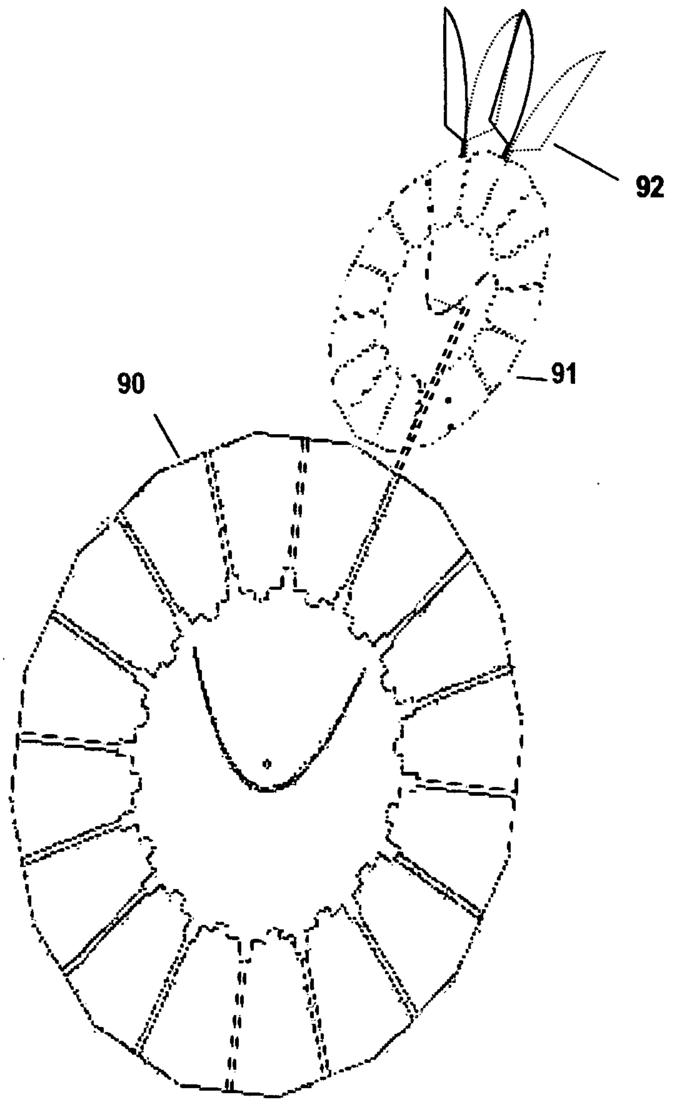

FIG 20

INTERNATIONAL SEARCH REPORT

PCT/GB2004/003152

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01Q1/36 H01P3/00

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)
IPC 7 H01Q H01P

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 practical, search terms used)

EPO-Internal, WPI Data, INSPEC, COMPENDEX, IBM-TDB, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 02/01671 A (PLASMA ANTENNAS LTD ; HAYES DAVID (GB)) 3 January 2002 (2002-01-03) cited in the application page 11, line 23 - page 15, line 25 figures 1-15 abstract -----	1,3,4, 7-15
X	WO 02/089250 A (PLASMA ANTENNAS LTD ; HAYES DAVID (GB)) 7 November 2002 (2002-11-07) page 6, line 12 - page 11, line 2 figures 1-10 abstract ----- -/--	1,3,4, 7-11,14, 15

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"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

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"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	Date of mailing of the international search report
5 October 2004	13/10/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	von Walter, S-U

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 305 123 A (SADOVNIK LEV S ET AL) 19 April 1994 (1994-04-19) column 6, line 9 - line 60 figures 6,7 abstract	1,4
X	US 2002/101300 A1 (KUDRLE THOMAS D ET AL) 1 August 2002 (2002-08-01) page 2, paragraph 25 - page 3, paragraph 29 figures 1,5,6 abstract	1,2,5-9, 14,15
X	US 4 525 693 A (OHKI HAJIME ET AL) 25 June 1985 (1985-06-25)	1
A	column 4, line 8 - column 5, line 9 figures 6-8 abstract	2,5-9
X,P	WO 2004/038850 A (KEETON RICHARD BROOKE ; PLASMA ANTENNAS LTD (GB); HAYES DAVID (GB)) 6 May 2004 (2004-05-06) page 12, line 3 - line 16 page 13, line 3 - page 14, line 6 figures 10,13,14 abstract	1,2,5-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

[redacted]T/GB2004/003152

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WO 2004038850 A	06-05-2004	WO 2004038850 A1	06-05-2004