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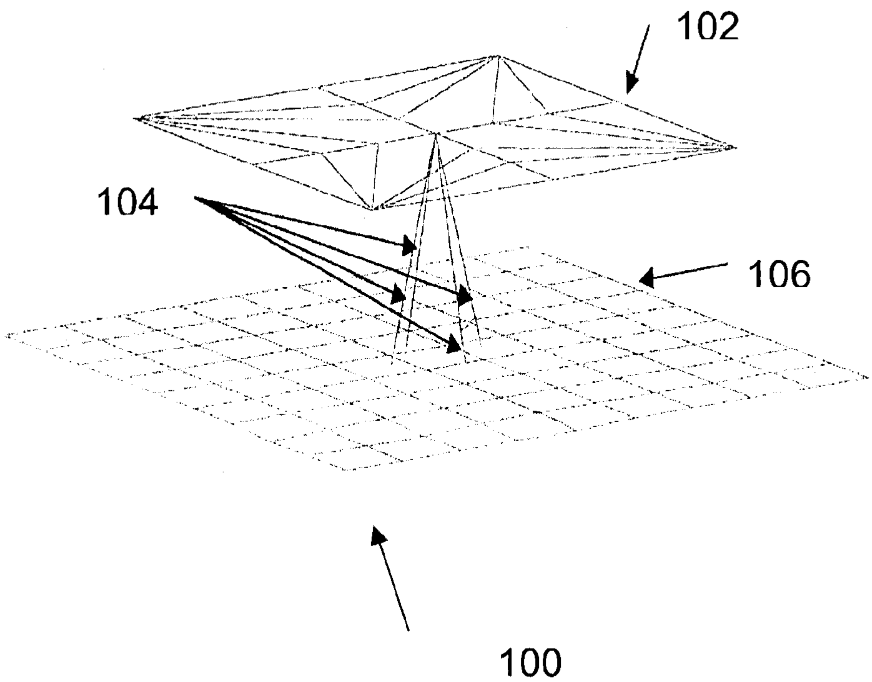

(57) Abstract: A broadband mesh antenna and a phased array broadband mesh antenna are provided. The antenna of the present invention is a mesh antenna system (102) that may be implemented with printed circuit board technology and wired technology that operates with increased bandwidth. The mesh antenna system (102) provides for a single mesh antenna to operate at a wide range of frequencies. The antenna may be employed as a high efficient broadband antenna for rockets, space vehicles and ships when placed inside a metallic open box.

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BROADBAND STARFISH ANTENNA AND ARRAY THEREOF

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to antenna systems. More particularly, the present invention relates to a starfish mesh antenna and array thereof with increase bandwidth implemented with printed circuit board technology.

Description of the Prior Art

Generally, patch antenna systems are implemented with printed circuit board technology. Patch antenna systems are typically one-resonance antenna systems, and thus, operate within a limited bandwidth, such as up to ten percent. Accordingly, patch antenna systems are typically designed to operate within a specific frequency band. These types of antenna systems typically require that an individual or single patch antenna is provided to operate at each frequency.

A prior art narrow-band mesh antenna as an extension of the loop antenna published in "IEEE Transactions on Antenna and Propagation", vol. AP- 49, pp. 715-723, May 2001 is illustrated in Fig. 1. The authors wrote in the abstract: "… [t]he frequency bandwidth for VSWR = 2 criterion is evaluated to be approximately 3%. … [t]he frequency bandwidth for a 3 dB axial ratio criterion is calculated to be approximately 1%." The feeding points *a,b,c,* and *d* are connected to coax.

There is a need for a mesh antenna system implemented with printed circuit board technology. There is a need for a mesh antenna system that operates at a bandwidth of more than one octave. There is a need for a mesh antenna system that is low cost. There is a need for a mesh antenna system that can be implemented for use with satellites, radars, space-vehicles and aircrafts.

SUMMARY OF THE INVENTION

According to embodiments of the present invention, a broadband mesh antenna and a phased array broadband mesh antenna are provided. The antennas of the present invention are mesh antenna systems implemented with printed circuit board technology that operates with increased bandwidth more than one octave. The simulated date presented in the disclosure of the present invention, illustrates a single mesh antenna operable at a wide range of frequencies, such as between 250 MHz to 730 MHz. The mesh antenna can be scaled to other frequency bands employing a 2.92 :1 coverage ratio.

According to an embodiment of the present invention, a broadband mesh antenna includes an element including a conductive surface. The conductive surface includes a) a symmetrically shaped conductive surface, such as a square loop, around a point corresponding to the center of the symmetrically shaped conductive surface, b) a first set of linear conductive surfaces extending away from the point corresponding to the center of the symmetrically shaped conductive surface, and c) a second set of linear conductive surfaces. Each linear conductive surface in the second set of linear conductive surfaces extends away from a point on a linear conductive surface in the first set of linear conductive surfaces to a corner of the symmetrically shaped conductive surface. The first set of linear conductive surfaces and second set of linear conductive surfaces enables the broadband mesh antenna to operate at a set of octaves.

According to an embodiment of the present invention, the broadband mesh antenna further includes a set of feed ports, such as four, symmetrically located around the point corresponding to the center of the symmetrically shaped conductive surface. A ground screen couples to the set of feed ports employing a corresponding set of feed lines, such as four coaxial lines. The ground screen is a distance h away from the element. The broadband mesh antenna can be provided within an box with an open top manufactured from structures such as wires and metal. The excitation of the broadband mesh antenna can be provided by coupling an inner conductor of each feed line to a feed port and coupling the outer conductors of each feed lines to the ground screen.

According to an embodiment of the present invention, a broadband mesh antenna includes an element including a conductive surface. The conductive surface includes a) a first symmetrically shaped conductive surface, such as a square loop, around a point corresponding to the center of the symmetrically shaped conductive surface, b) a first set of linear conductive surfaces extending away from the point corresponding to the center of the symmetrically shaped conductive surface, and c) a second symmetrically shaped conductive surface, such as a starfish, around a point corresponding to the center of the symmetrically shaped conductive surface. The first and second symmetrically shaped conductive surfaces enables the broadband mesh antenna operates at a first set of octaves.

According to an embodiment of the present invention, a broadband phased array mesh antenna includes a set of elements, each element in the set of elements including a conductive surface. Each conductive surface includes a) a symmetrically shaped conductive surface, such as a square loop, around a point corresponding to the center of the symmetrically shaped conductive surface, b) a first set of linear conductive surfaces extending away from the point corresponding to the center of the symmetrically shaped conductive surface, and c) a second set of linear conductive surfaces. Each linear conductive surface in the second set of linear conductive surfaces extends away from a point on a linear conductive surface in the first set of linear conductive surfaces to a corner of the symmetrically shaped conductive surface. The first set of linear conductive surfaces and second set of linear conductive surfaces enables the broadband mesh antenna to operate at a set of octaves.

According to an embodiment of the present invention, the broadband mesh antenna further includes each antenna element includes a set of feed ports, such as four, symmetrically located around the point corresponding to the center of the symmetrically shaped conductive surface. A ground screen couples to the set of feed ports employing a corresponding set of feed lines, such as four coaxial lines. The ground screen is a distance h away from the element. The broadband mesh antenna can be provided within an box with an open top manufactured from structures such as wires and metal.

According to an embodiment of the present invention, a phased broadband mesh array antenna includes a set of elements, each element in the set of elements including a conductive surface. Each conductive surface includes a) a first symmetrically shaped conductive surface, such as a square loop, around a point corresponding to the center of the symmetrically shaped conductive surface, b) a first set of linear conductive surfaces extending away from the point corresponding to the center of the symmetrically shaped conductive surface, and c) a second symmetrically shaped conductive surface, such as a starfish, around a point corresponding to the center of the symmetrically shaped conductive surface.

BRIEF DESCRIPTION OF THE INVENTION

Fig. 1a depict a prior art patch antenna;

Fig. 1b depicts an exemplary side view of Ultra Broadband Mesh Antenna according to an embodiment of the present invention;

Fig. 2a depicts an exemplary side view of feed coaxial lines according to an embodiment of the present invention;

Fig. 2b depicts an exemplary top view of a starfish antenna pattern diagram for the Ultra Broadband Mesh Antenna illustrated in Fig. 1 according to an embodiment of the present invention;

Figs. 3a-3b illustrate directivity plots for the Ultra Broadband Mesh Antenna illustrated in Fig. 1 according to an embodiment of the invention;

Figs. 4a-4b illustrate Axial Ratios for the Ultra Broadband Mesh Antenna illustrated in Fig. 1 according to an embodiment of the present invention;

Figs. 5a-5b illustrate Input impedance for the Ultra Broadband Mesh Antenna illustrated in Fig. 1. according to an embodiment of the present invention;

Fig. 6a illustrates a Ultra Broadband Mesh Antenna according to an embodiment of the present invention;

Fig. 6b illustrates an Ultra Broadband Mesh Antenna inside the metallic box open to the top and four coaxial lines according to an embodiment of the present invention;

Fig. 7 illustrates a Phased Array of Ultra Broadband Mesh Antennas according to an embodiment of the present invention;

Figs. 8a-8b illustrates Pattern Diagrams for the Array of Ultra Broadband Mesh Antennas illustrated in Fig. 7 according to an embodiment of the present invention;

Fig. 9 illustrates Axial Ratios for the Array of Ultra Broadband Mesh Antennas illustrated in Fig. 7 according to an embodiment of the present invention; and

Fig. 10 illustrates Input Impedance for the Array of Ultra Broadband Mesh Antennas illustrated in Fig. 7 according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is now described more fully hereinafter with reference to the accompanying drawings that show a preferred embodiment of the present invention. The present invention, however, may be embodied in many different forms and should not be construed as limited to embodiments set forth herein. Appropriately, embodiments are provided so that this disclosure will be thorough, complete and fully convey the scope of the present invention.

According to embodiments of the present invention, a broadband mesh antenna and a phased array broadband mesh antenna are provided. The antenna of the present invention is a mesh antenna system that may be implemented with printed circuit board technology and wired technology. The mesh antenna system operates with increased bandwidth more than one octave as prior art patch and mesh antenna operates with bandwidth 3% - 10% only. The mesh antenna of the present invention provides for a single mesh antenna to operate at a wide range of frequencies, such as between 250 MHz to 730 MHz or any other frequency band by scaling the antenna sizes with the same 2.92:1 frequency coverage. The antenna may be employed as a high efficient broadband antenna for rockets, and space vehicles or other applications when place inside a metallic open box, such as aluminum.

An exemplary side view of Ultra Broadband Mesh Antenna according to an embodiment of the present invention is shown in Fig. 1b. In the Fig. 1b embodiment of the present invention, the Ultra Broadband Mesh Antenna 100 includes an antenna element 102, feed ports 104, a ground plane 106 and 4 feed lines 108. The antenna element 102 may be provided as a conductive surface. The conductive surface includes, but is not limited to, wired technology. The antenna element 102 radiates electromagnetic waves. The antenna element includes feed ports 104 located symmetrically around the center of the antenna element 102. The feed ports 104 allow to connect antenna element to receiver (not shown) or transmitter (not shown).

The feed lines 108 couple to feed ports and ground plane 106. The feed lines 108 transmit and receive information for Ultra Broadband Mesh Antenna. The ground plane 106 may include a screen or a bottom of open top metallic box. The ground plane 106 includes holes or slots for feed lines 108. The ground plane prevents the reception or transmission of electromagnetic radiation from or to antenna element. Ultra Broadband Mesh antenna 100 may be considered as a superposition of set of electrical and magnetic dipoles connected in parallel to the feeding ports. In the Fig. 1 embodiment, the input impedance must keep almost stable for octave of one and more with some variation around $60\pi \cong 188$ Ohms.

An exemplary side view of broadband mesh antenna according to an embodiment of the present invention is shown in Fig. 2a. In the Fig. 2a embodiment of the present invention, feed lines 200a include a set of four feed lines 202a-202d.

The feed lines may be, but are not limited to, coaxial lines, waveguides, microstrip lines, and coplane lines. Each of the feed lines 202a includes a first free end, a second free, inner conductors and outer conductors. The inner conductors of the first free end of each feed line couples to a feed port of antenna element 102 shown in Fig. 1. The outer conductor of the second free end of each feed line couples to ground element 106 shown in Fig. 1. The broadband mesh antenna may be excited employing the connection of the feed lines in the manner mentioned above. In the Fig. 2 embodiment of the present invention, the height (h) between antenna element 102 and ground element 106 is $h = 0.125\lambda_{max}$ when the coaxial lines are coupled to an antenna element 102 and ground element 106, where λ_{max} is the wavelength for the lowest band frequency.

An exemplary top view of an antenna element illustrated in the Broadband Mesh Antenna illustrated in Fig. 1 is shown in Fig. 2b. In the Fig. 2b embodiment of the present invention, antenna element 200b is provided with symmetrically shaped configurations including a starfish and square. The antenna element 200b may be a conductive surface including wire technology and printed circuit board technology. In the Fig. 2b embodiment, a first symmetrically shaped conductive surface 202b, such as a square, is formed around a point 204b corresponding to the center of the first symmetrically shaped conductive surface 202b. A first set of linear conductive surfaces 206b extend away from the point 204b corresponding to the center of the symmetrically shaped conductive surface 202b to the midpoints of the sides of the first symmetrically shaped conductive surface. The first set of linear conductive surfaces form right angles with respect to one another.

In the Fig. 2 embodiment of the present invention, a second symmetrically shaped conductive surface 200b, such as a starfish, may be formed by providing a second set of linear conductive surfaces 208b. The second set of linear conductive surfaces extend away from points on the first set of linear conductive surfaces to a corner of the first symmetrically shaped conductive surface nearest the point on the first set of linear conductive surfaces. A plurality of starfish configuration may formed by providing second set of linear conductive surfaces 208b that extend away from points on the first set of linear conductive surfaces to a corner of the first symmetrically shaped conductive surface nearest the point on the first set of linear conductive surfaces. In the Fig. 2b embodiment of the present invention, each side of the symmetrically shaped conductive surface is $2s = 0.27\lambda$, where λ_{max} is the wavelength for the lowest band frequency.

Pattern diagrams for frequency bands from 250 MHz to 730 MHz are shown in Figs. 3a-3b according to an embodiment of the present invention for the Ultra Broadband Mesh Antenna illustrated in Fig. 1. In the graph of Fig. 3a, the peak directivity is 9.2 – 8.8 dB for frequency bands from 250 MHz to 490 MHz. In the graph of Fig. 3b, the peak directivity is 8.8 – 7.8 dB for frequency bands from 490 MHz to 730 MHz.

Axial Ratio for frequency bands from 250 MHz to 730 MHz are shown in Figs. 4a-4b according to an embodiment of the present invention for the Ultra Broadband Mesh Antenna illustrated in Fig. 1. In the graph of Fig. 4a, the axial ratio inside sector ± 20° is less than 0.5 dB for frequency bands from 250 MHz to 640 MHz. In the graph of Fig. 4b, the axial ratio inside the sector ± 20° increases and is less than 3 dB for frequency 730 MHz.

Input impedance for frequency bands from 250 MHz to 730 MHz are shown in Figs. 5a-5b according to an embodiment of the present invention for the Ultra Broadband Mesh Antenna illustrated in Fig. 1. In the graph of Fig. 5a, the input impedance form a well-shaped circle around the center of the Smith chart through the whole frequency band with 220 Ohms normalizing coefficient indicating compliance above 188 Ohms.

An Ultra Broadband Mesh Antennas, such as illustrated in Fig. 1, are shown in Fig. 6a-6b according to an embodiment of the present invention. In the Fig. 6a embodiment of the present invention for the Ultra Broadband Mesh Antenna 600a with box at Numerical Electromagnetic Code (NEC) is shown. The Ultra Broadband Mesh Antenna 600a with open top box NEC model includes an antenna element 602a, feed ports (not shown), feed lines (not shown) and a ground plane 604a inside an open top 606a. In the Fig. 6a embodiment of the present invention, the starfish configuration of antenna element 602a, feed ports (not shown), feed lines (not shown), and ground screen 604a are formed employing wired technology. The antenna element includes the feed ports which are symmetrically located around center of the antenna element 602a. Feed lines (not shown) couple to feed ports and ground plane 604a. In the Fig. 6a embodiment of the present invention, the ground plane is the bottom of an open wire box 606 in which mesh antenna is placed. This Ultra Broadband Mesh Antenna may be used as a low profile high efficient broadband antenna for radar and communication systems of vehicles including, but not limited to, rockets, spacecrafts, aircrafts, and ships.

In the Fig. 6b embodiment of the present invention an Ultra Broadband Mesh antenna is shown as a model in the Ansoft High-Frequency Structure Simulator (HFSS). Ultra Broadband Mesh Antenna 600b includes an antenna element 602b, feed ports (not shown) and feed line 604b, and ground plane 606b as the bottom of an open top metallic box. In the Fig. 6b embodiment of the present invention, the starfish configuration of the antenna element 602b is formed employing printed circuit board technology. The antenna element 602b includes the feed ports which are symmetrically located around center of the antenna element 602b. The feed lines 604b may be, but are not limited to, coaxial lines, waveguides, microstrip lines, and coplane lines. The ground plane within open top box 606b is made of metal such as copper, copper covered with gold or silver, aluminum, or any other material with high conductivity. This Ultra Broadband Mesh Antenna may be used, but not limited to, a low profile high efficient broadband antenna for radar and communication systems of rockets, spacecrafts, aircrafts, and ships.

An exemplary top view of an N x N Phased Array of Ultra Broadband Mesh Antennas according to an embodiment of the present invention is shown in Fig. 7. In the Fig. 7 embodiment of the present invention, the Phased Array of Ultra Broadband Mesh Antennas 700 is an 4 x 4 array of Ultra Broadband Mesh Antennas. The 4 x 4 array of Ultra Broadband Mesh Antennas includes 16 Ultra Broadband Mesh Antennas 702a-702n. Each Broadband Mesh Antenna 702 in the 4 x 4 array of Ultra Broadband Mesh Antennas includes an antenna element 704 and feed ports 706. Each Antenna element 704 may be provided with a set of starfish configurations. Each antenna element 704 may be a conductive surface including wires and printed antenna conductors. Each antenna element may be provided with symmetrically shaped configurations including a starfish and square as discussed above with respects to Fig. 2b. Each starfish configuration provided on an antenna element enables the broadband mesh antenna to operate at a particular octave. The feed ports 706 of each Broadband Mesh Antenna in the 4 x 4 phased array of Ultra Broadband Mesh Antennas are located symmetrically around the center of the antenna element 102 of each Broadband Mesh Antenna in the 4 x 4 phased array of Ultra Broadband Mesh Antennas.

A set of feed lines are provided for each Broadband Mesh Antenna in the 4 x 4 phased array of Ultra Broadband Mesh Antennas. Each set of feed lines couples to the feed ports of a respective Broadband Mesh Antenna in the 4 x 4 phased array of Ultra Broadband Mesh Antennas and the ground plane 708. The ground element 708 may include a screen or bottom of an open top metallic box.

In the Fig. 7 embodiment of the present invention, the separation between each Broadband Mesh Antenna in the 4x4 phased array of Ultra Broadband Mesh Antennas is defined by a distance of 0.8λmin where λmin is the wavelength at the highest frequency of the band. A separation of 0.8λmin between each Broadband Mesh Antenna in the 4x4 phased array of Ultra Broadband Mesh Array Antennas provides maximum peak directivity without grating lobes and sufficient mutual coupling at the highest frequencies. Each Broadband Mesh Antenna in the 4x4 phased array or any other number of Ultra Broadband Mesh Antennas is excited in phase when in boresight operation and with linear phase distribution to steer the beam.

Pattern diagrams are shown in Figs 8a-8b according to an embodiment of the present invention for the 4x4 phased array of Ultra Broadband Mesh Antennas illustrated in Fig. 7. The expected maximum peak directivity of this array is (10*log16 + 8.5) dB = 20.5 dB. According to the graph of Fig. 8a-8b of the NEC simulation the peak directivity is around 19.65 dB at the 1672 – 1871 MHz. The difference in peak directivity can be explained by single element aperture overlapping, which decreases the mesh element effective peak directivity in a phased array environment.

Axial Ratios for frequency bands from 1672 – 1871 MHz is shown in Fig. 9 according to an embodiment of the present invention for the 4 x 4 array of Ultra Broadband Mesh Antennas illustrated in Fig. 7.

Input impedance for frequency bands from 250 MHz to 730 MHz are shown in Fig. 10 according to an embodiment of the present invention for the 4 x 4 array of Ultra Broadband Mesh Antennas illustrated in Fig. 7. In the graph of Fig. 10, the input impedance is approximately 110 ohms at 1672 – 1871 MHz. The Smith chart demonstrates the broadband antenna performance for the 4 x 4 array of Ultra Broadband Mesh Antennas

While specific embodiments of the present invention have been illustrated and described, it will be understood by those having ordinary skill in the art that changes may be made to those embodiments without departing from the spirit and scope of the invention.

CLAIMS

What we claim is:

1. A broadband mesh antenna, comprising:

an element including a conductive surface; and

the conductive surface configured to form:

a symmetrically shaped conductive surface around a point corresponding to the center of the symmetrically shaped conductive surface;

a first set of linear conductive surfaces extending away from the point corresponding to the center of the symmetrically shaped conductive surface; and

a second set of linear conductive surfaces, each linear conductive surface in the second set of linear conductive surfaces extending away from a point on a linear conductive surface in the first set of linear conductive surfaces;

wherein the first set of linear conductive surfaces and second enables the broadband mesh antenna to operate at a set of octaves.

2. The broadband mesh antenna of claim 1, further comprising a set of feed ports coupled to the element at the point corresponding to the center of the symmetrically shaped conductive surface.

3. The broadband mesh antenna of claim 2, further comprising a ground screen coupled to the set of feed ports.

4. The broadband mesh antenna of claim 3, wherein the ground screen is a distance h away from the element.

5. The broadband mesh antenna of claim 2, further comprising an open metallic box coupled to the set of feed ports.

6. A phased broadband mesh array antenna, comprising:

a set of elements, each element in the set of elements including a conductive surface; and

the conductive surface configured to form:

a symmetrically shaped conductive surface around a point corresponding to the center of the symmetrically shaped conductive surface;

a first set of linear conductive surfaces extending away from the point corresponding to the center of the symmetrically shaped conductive surface; and

a second set of linear conductive surfaces, each linear conductive surface in the second set of linear conductive surfaces extending away from a point on a linear conductive surface in the first set of linear conductive surfaces;

wherein the second set of linear conductive surfaces enables the phased broadband mesh array antenna to operate at a set of octaves.

7. The phased broadband mesh array antenna of claim 6, further comprising a set of feed ports coupled to each element at the point corresponding to the center of the symmetrically shaped conductive surface.

8. The phased broadband mesh array antenna of claim 7, further comprising a ground screen coupled to each set of feed ports.

9. The phased broadband mesh array antenna of claim 6, further comprising an open metallic box coupled to each set of feed ports.

10. A broadband mesh antenna, comprising:

An element including a conductive surface; and

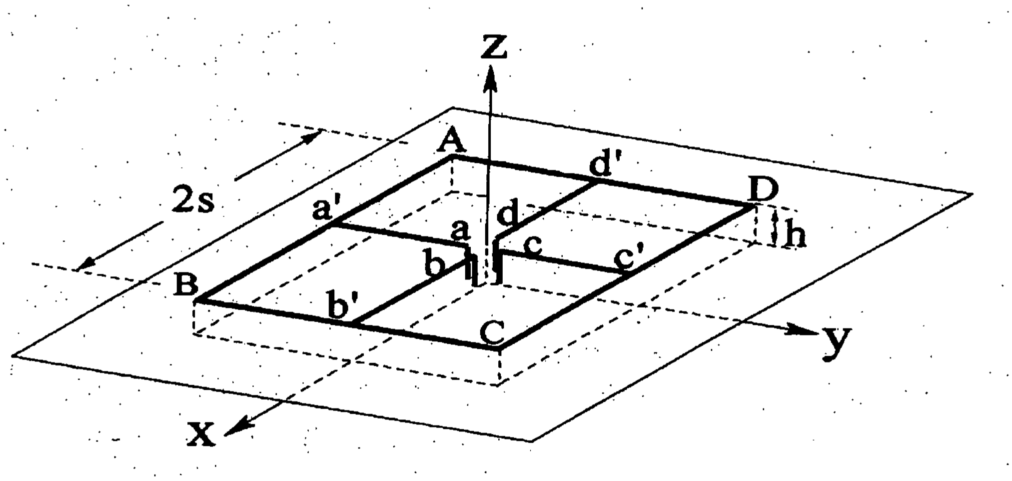
the conductive surface configured to form:

a symmetrically shaped conductive surface around a point corresponding to the center of the symmetrically shaped conductive surface;

a first starfish loop centered around the point corresponding to the center point of the symmetrically shaped conductive surface; and

a set of linear conductive surfaces extending away from the point corresponding to the center point of the symmetrically shaped conductive surface.

Fig. 1a



Prior Art

Fig. 1b

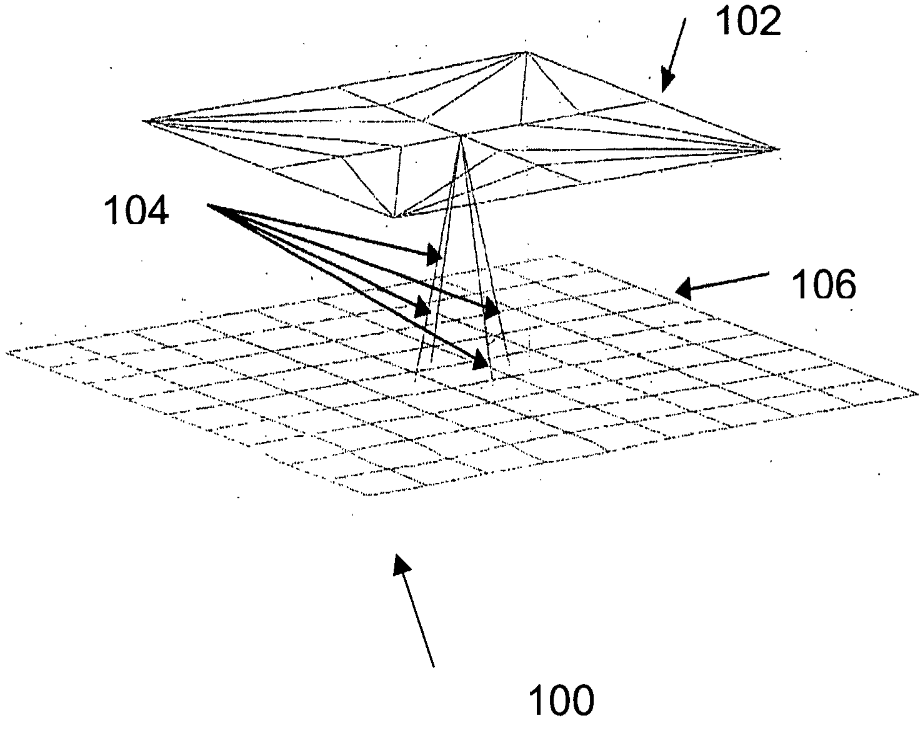
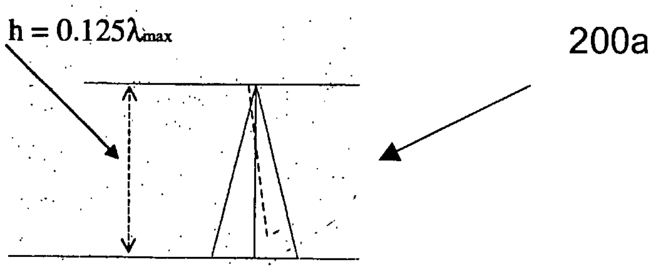


Fig. 2a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200a

Fig. 2b

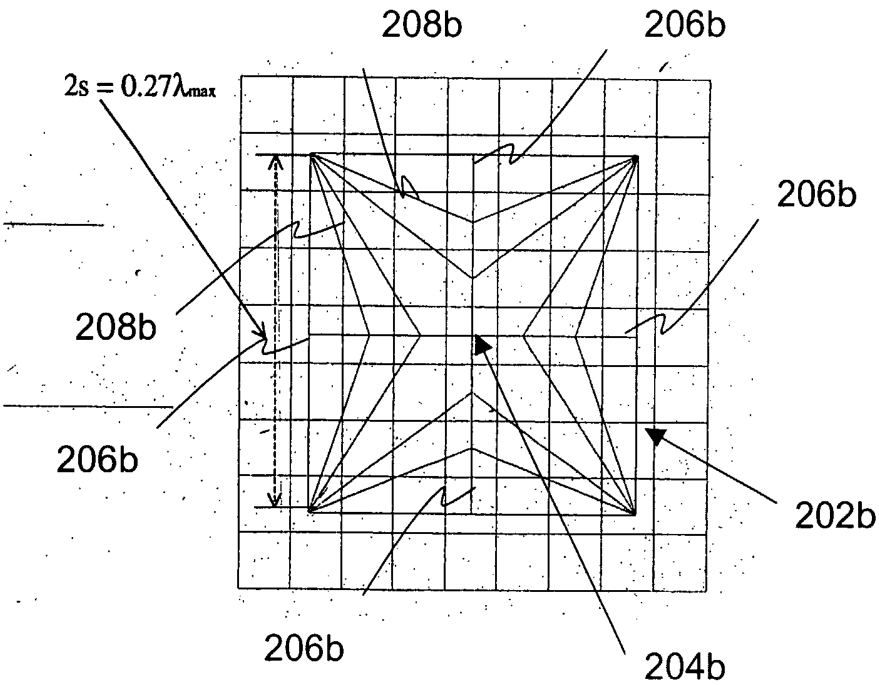

208b
206b
2s = 0.27λmax
206b
208b
206b
202b
206b
204b

Fig. 3a

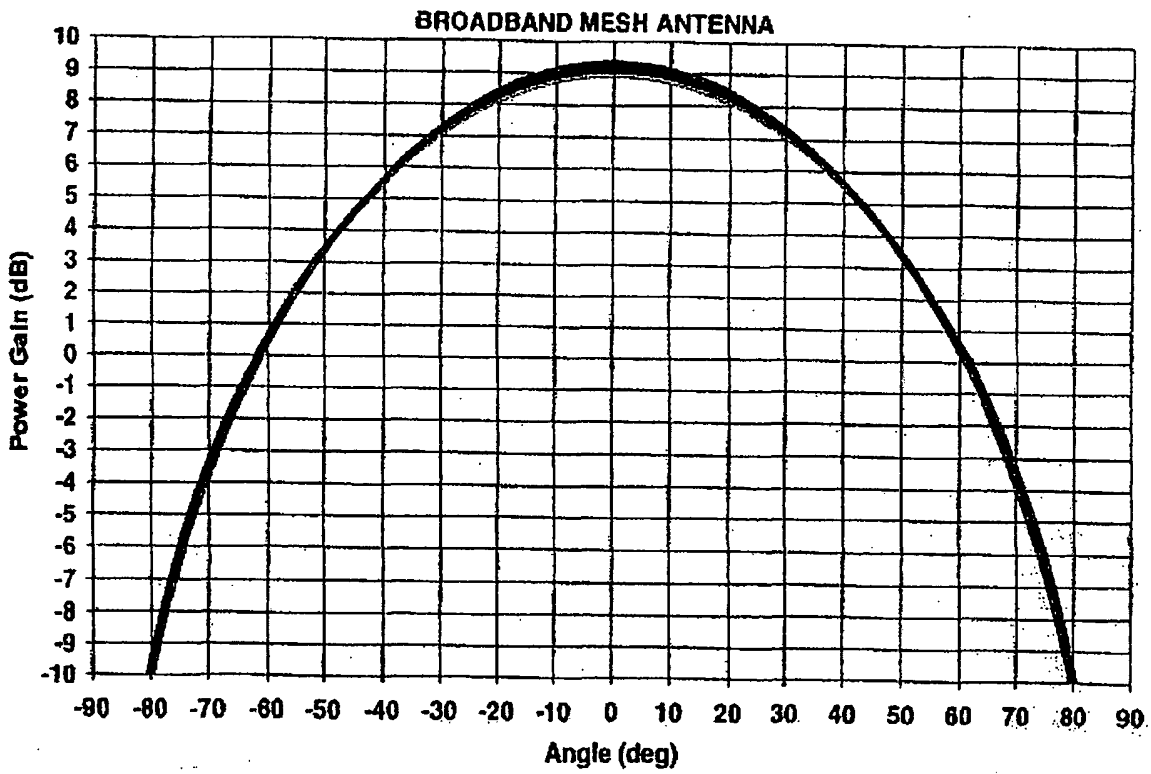

BROADBAND MESH ANTENNA
Power Gain (dB)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Fig. 3b

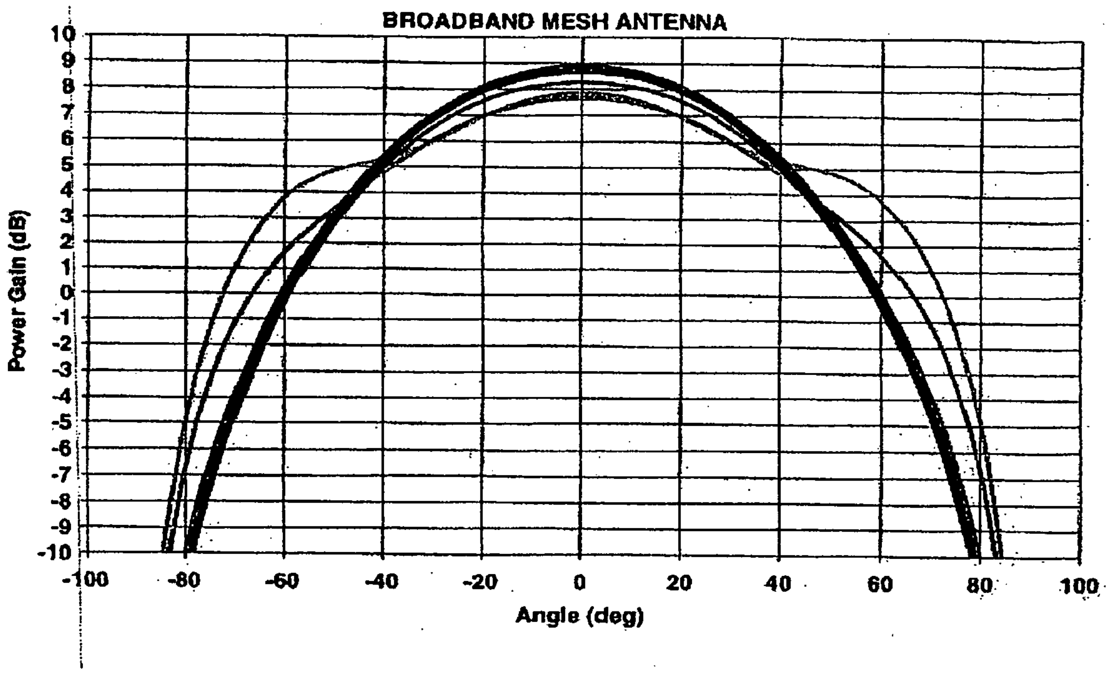
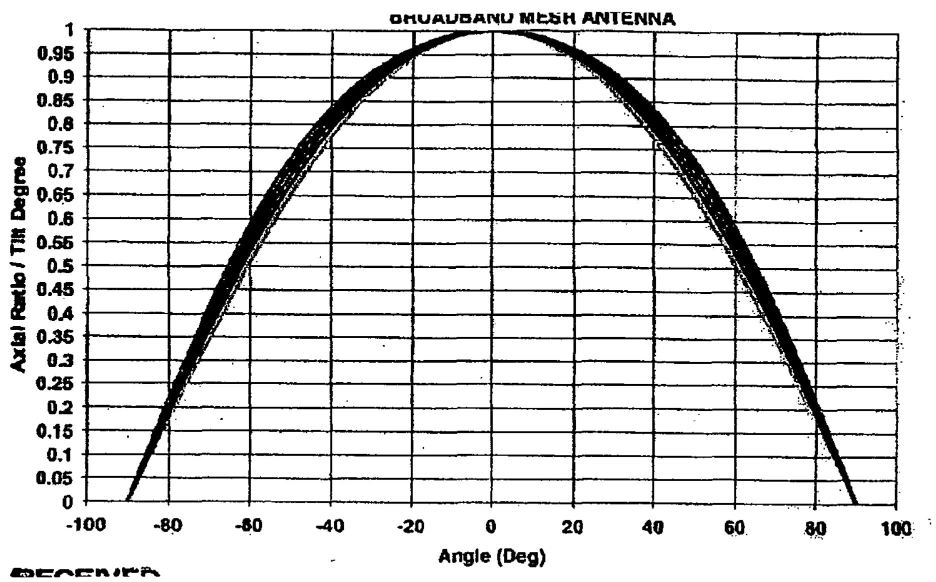

BROADBAND MESH ANTENNA
Power Gain (dB)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-100
-80
-60
-40
-20
0
20
40
60
80
100
Angle (deg)

Fig. 4a


BROADBAND MESH ANTENNA
Axial Ratio / Tilt Degree
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
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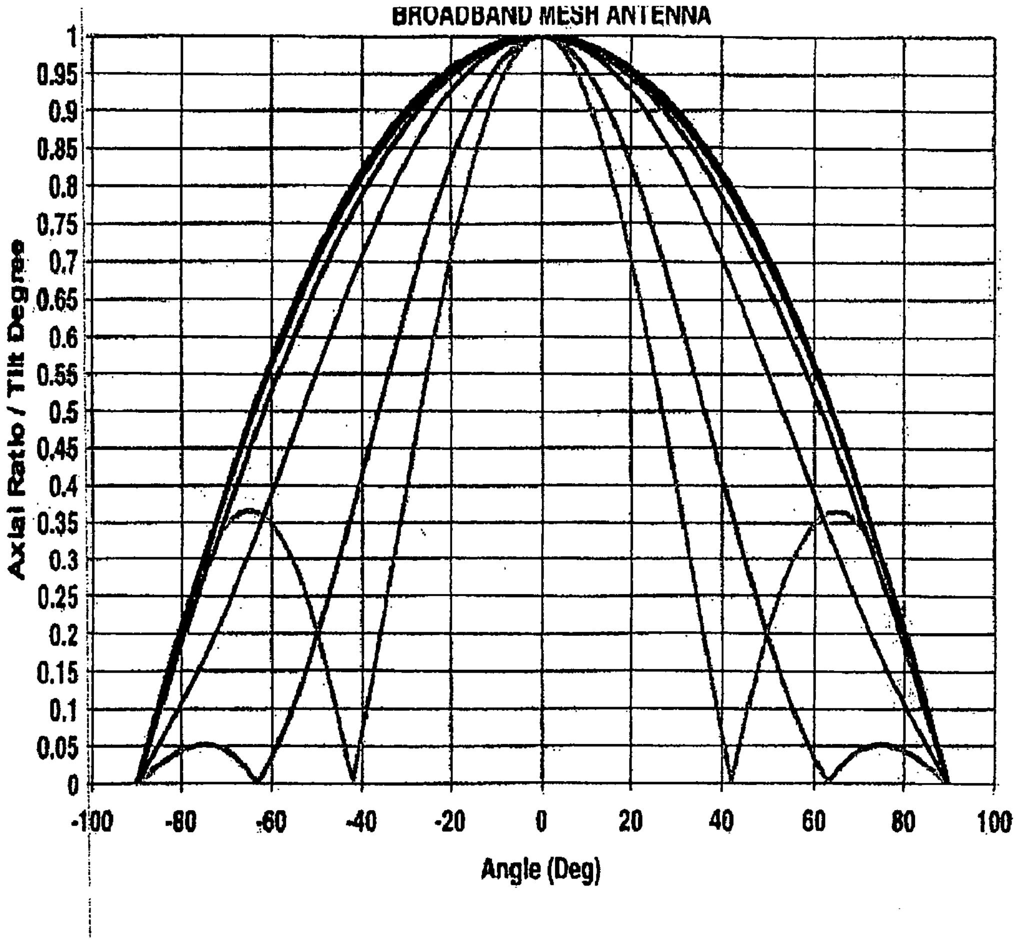
-80
-60
-40
-20
0
20
40
60
80
100
Angle (Deg)

Fig. 4b


BROADBAND MESH ANTENNA
Axial Ratio / Tilt Degree
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0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
Angle (Deg)

Fig. 5a

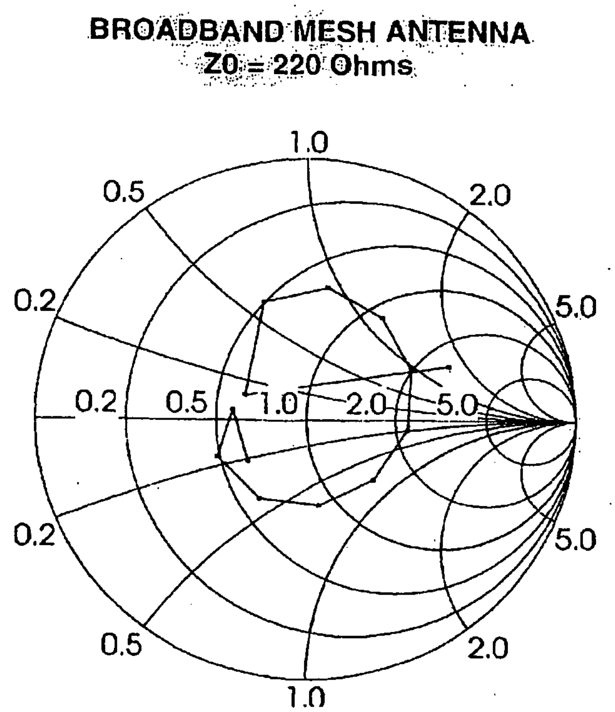
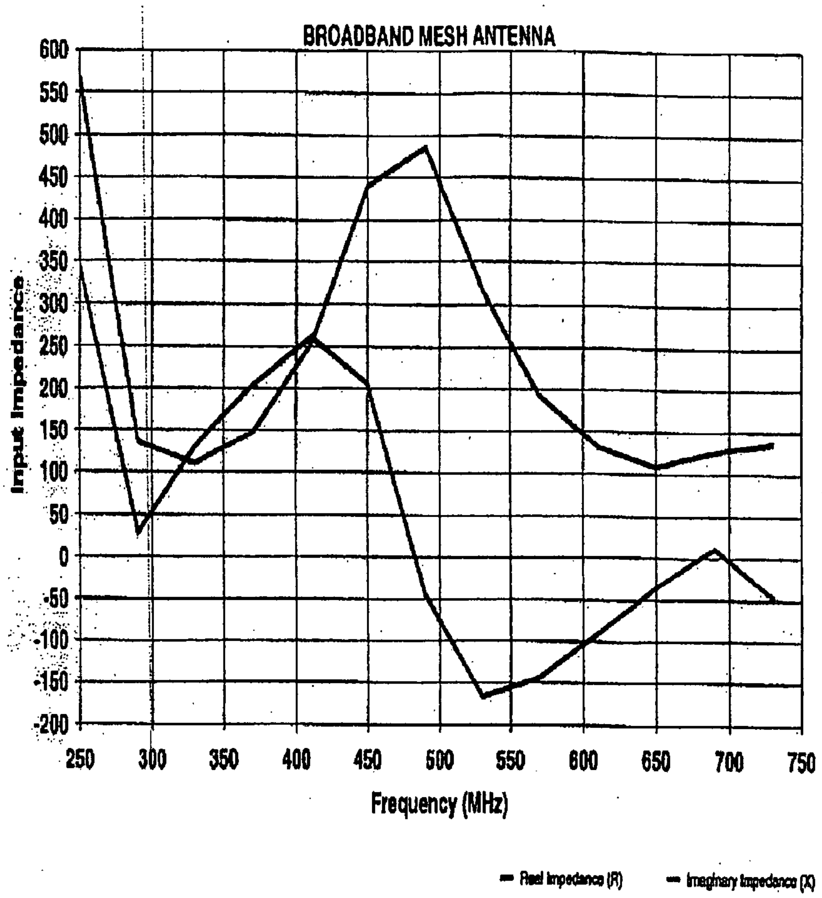

BROADBAND MESH ANTENNA
Z0 = 220 Ohms
1.0
0.5
2.0
0.2
5.0
0.2
0.5
1.0
2.0
5.0
0.2
5.0
0.5
2.0
1.0

Fig. 5b


BROADBAND MESH ANTENNA
Input Impedance
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550
500
450
400
350
300
250
200
150
100
50
0
-50
-100
-150
-200
250
300
350
400
450
500
550
600
650
700
750
Frequency (MHz)
Real Impedance (R)
Imaginary Impedance (X)

Fig. 6a

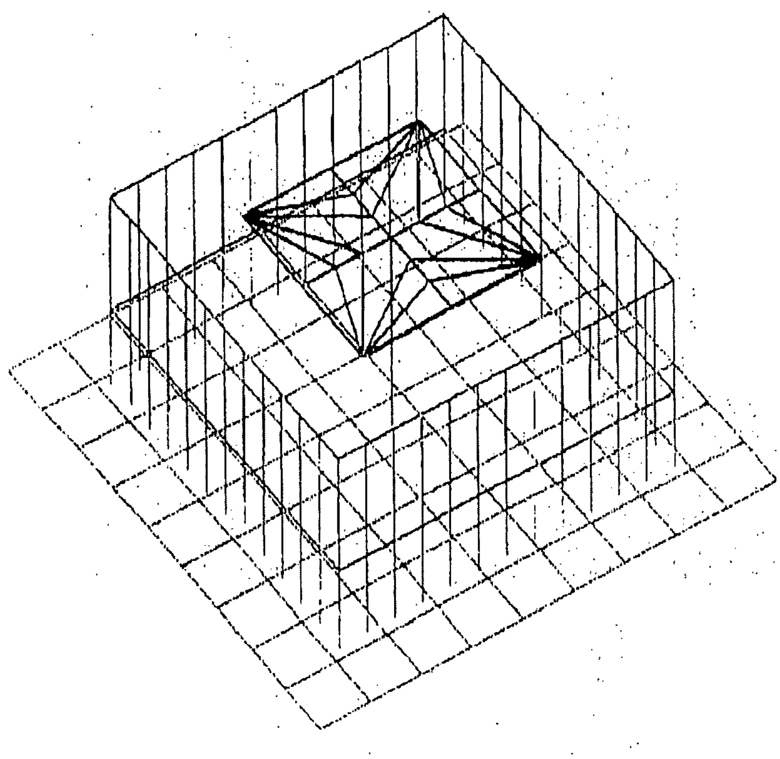


Fig. 6b

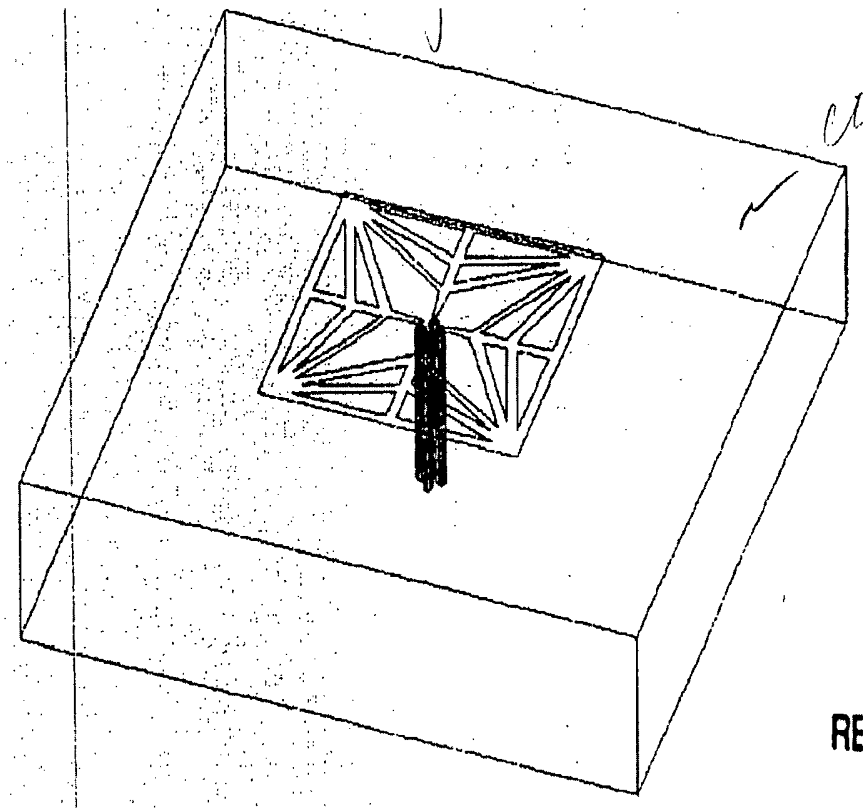


Fig. 7

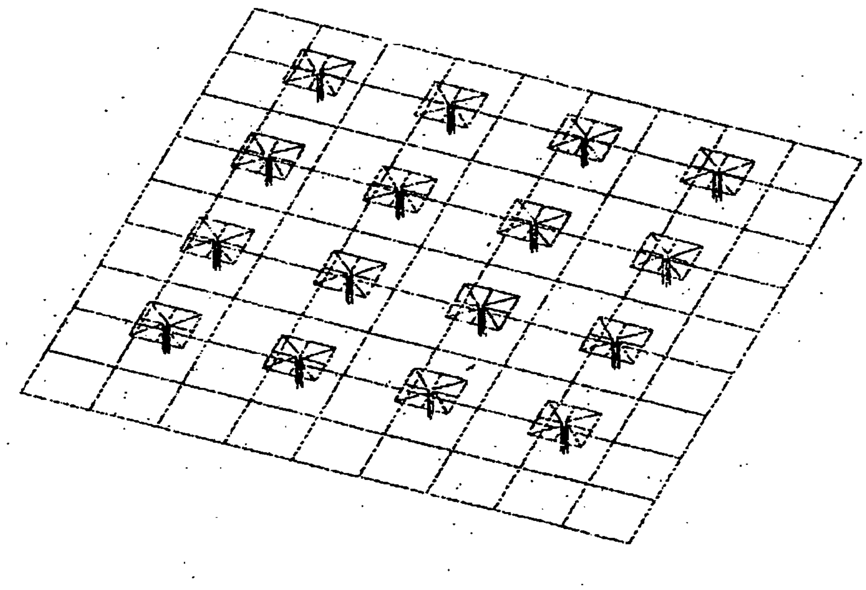


Fig. 8a

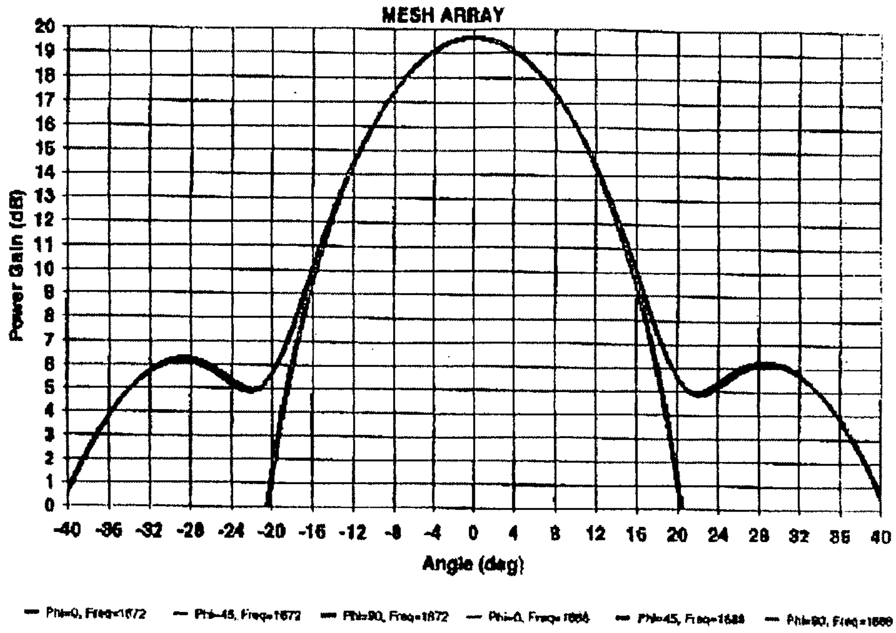

MESH ARRAY
Power Gain (dB)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
-40 -36 -32 -28 -24 -20 -16 -12 -8 -4 0 4 8 12 16 20 24 28 32 36 40
Angle (deg)
Phi=0, Freq=1672
Phi=90, Freq=1672

Fig. 8b

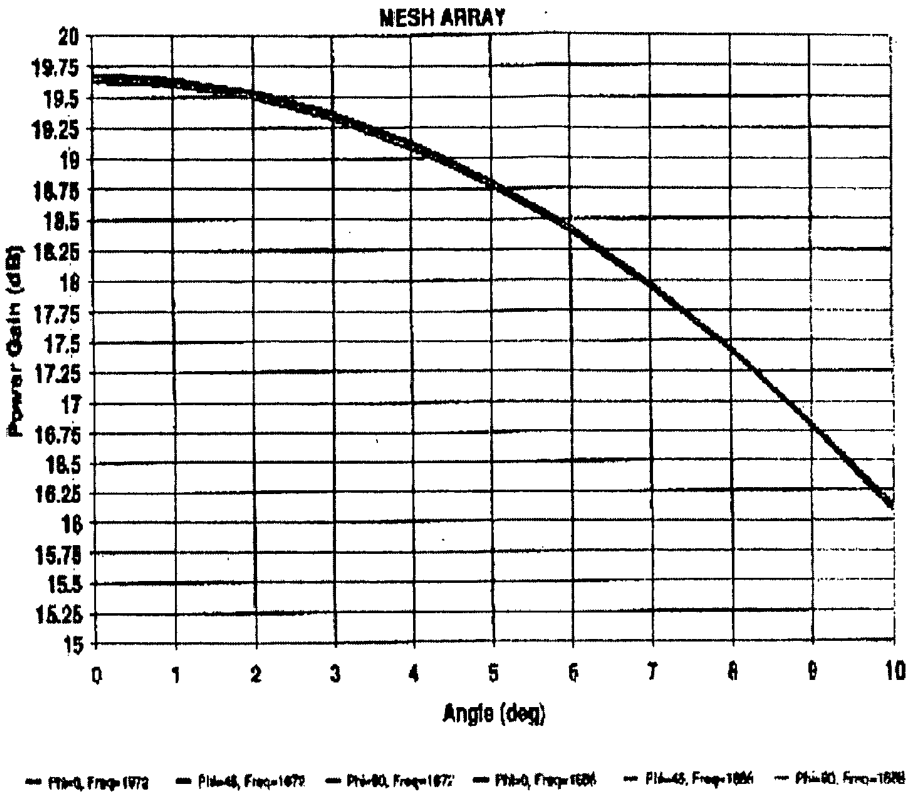

MESH ARRAY
Power Gain (dB)
Angle (deg)
20
19.75
19.5
19.25
19
18.75
18.5
18.25
18
17.75
17.5
17.25
17
16.75
16.5
16.25
16
15.75
15.5
15.25
15
0
1
2
3
4
5
6
7
8
9
10

Fig. 9

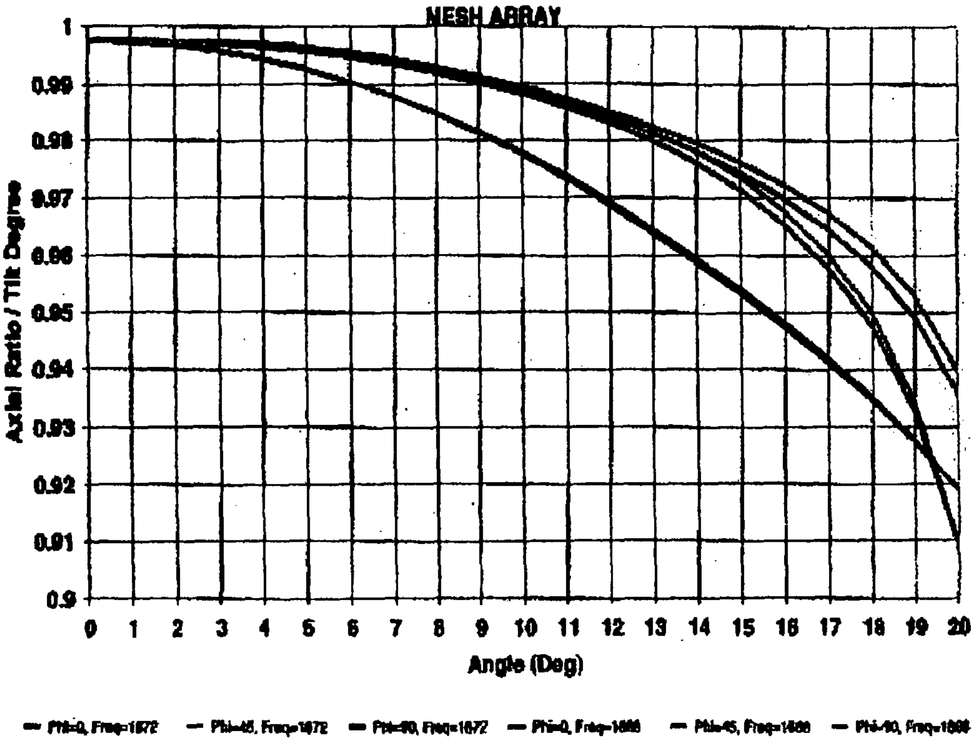
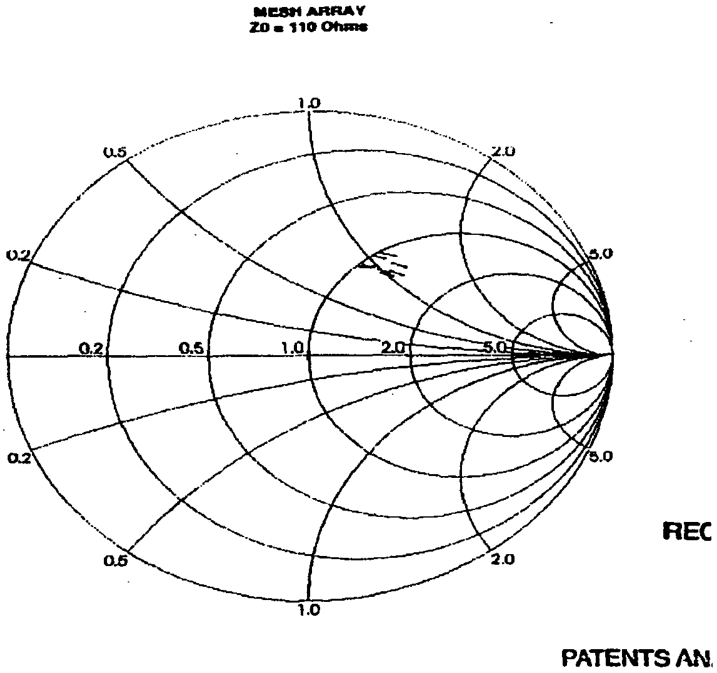

MESH ARRAY
Axial Ratio / Tilt Degree
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
0.9
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Angle (Deg)
Phi=0, Freq=1672
Phi=45, Freq=1672
Phi=90, Freq=1672

Fig. 10


MESH ARRAY
Z0 = 110 Ohms
1.0
0.5
2.0
0.2
5.0
0.2
0.5
1.0
2.0
5.0
0.2
5.0
REC
0.5
2.0
1.0
PATENTS AN

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US02/34866

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :H01Q 1/28, 1/36, 1/38, 11/12, 21/00
US CL :343/700ms, 705, 708, 741, 742, 795, 866, 867, 897
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, 705, 708, 741, 742, 795, 866, 867, 897

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO APS WEST
search terms: antenna, mesh, loop, feed

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,646,633 A (DAHLBERG) 08 July 1997 (08.07.1997), see entire document.	1-10
A	US 5,293,176 A (ELLIOT) 08 March 1994 (08.03.1994), see entire document.	1-10
A	US 6,014,107 A (WIESENFARTH) 11 January 2000 (11.01.2000), see entire document.	1-10
A,P	US 6,452,549 B1 (LO) 17 September 2002 (17.09.2002), see entire document.	1-10

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

* Special categories of cited documents:

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"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
09 FEBRUARY 2003	03 APR 2003

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