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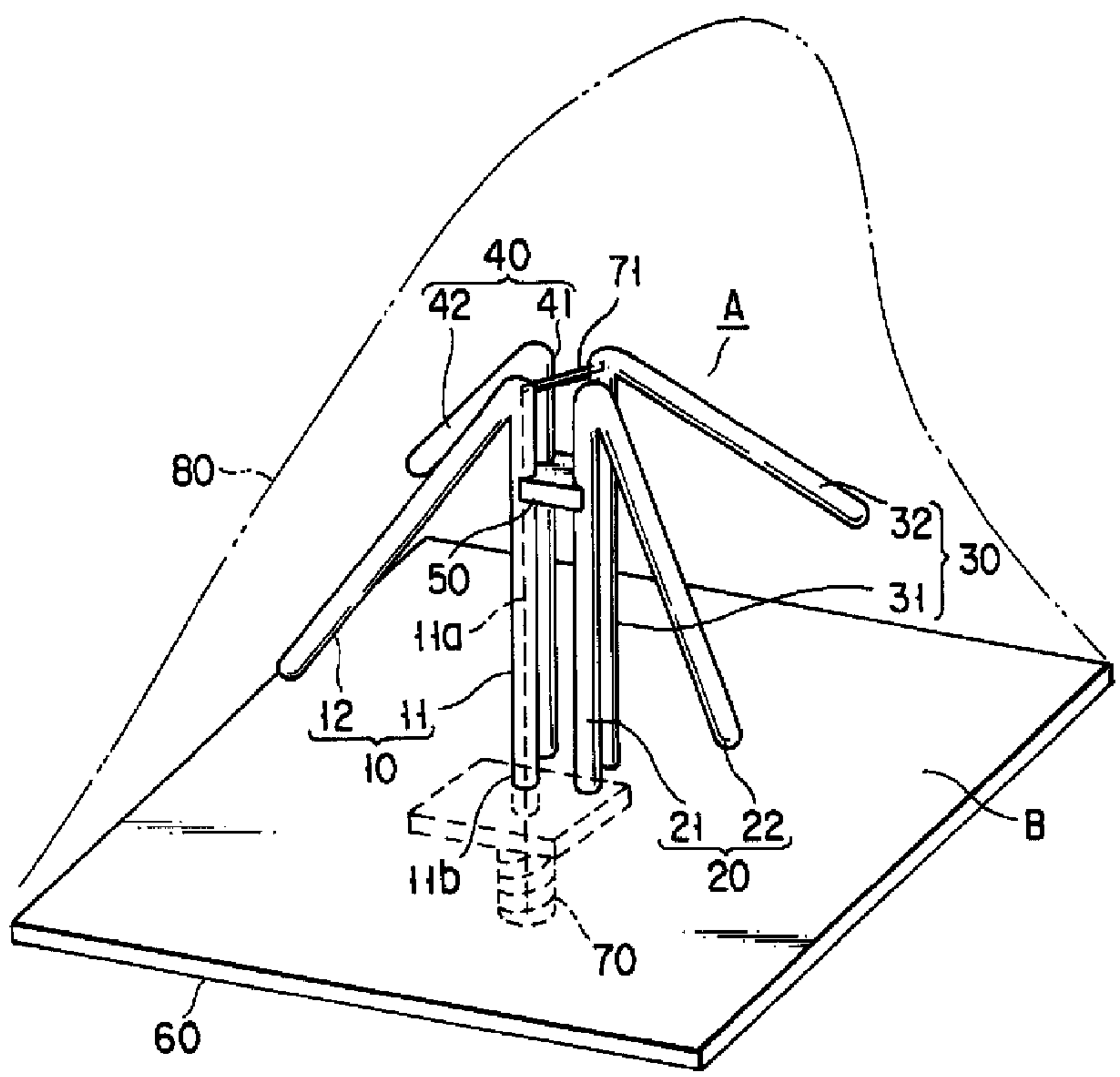
(54) Title: CIRCULARLY POLARIZED CROSS DIPOLE ANTENNA



(57) Abrégé/Abstract:
A circularly polarized cross dipole antenna according to the present invention includes a cross dipole antenna element formed of two pairs of inverted-V-shaped dipole antenna elements, which are bent like an inverted "V" at a set angle, so as to cross each other on a ground plane, and a feeding mechanism provided to perform a single-point feed through a feeding section common to the inverted-V-shaped dipole antenna elements of the cross dipole antenna element.

CIRCULARLY POLARIZED CROSS DIPOLE ANTENNA

ABSTRACT OF THE DISCLOSURE

A circularly polarized cross dipole antenna according to the present invention includes a cross dipole antenna element formed of two pairs of inverted-V-shaped dipole antenna elements, which are bent like an inverted "V" at a set angle, so as to cross each other on a ground plane, and a feeding mechanism provided to perform a single-point feed through a feeding section common to the inverted-V-shaped dipole antenna elements of the cross dipole antenna element.

CIRCULARLY POLARIZED CROSS DIPOLE ANTENNA

BACKGROUND OF THE INVENTION

The present invention relates to a circularly polarized cross dipole antenna which is favorably used as a mobile communication antenna for a GPS wave receiving system, a transmitting/receiving system of a satellite communications cellular phone, and the like.

Referring to Figs. **10**A and **10**B, illustrations for describing an overview of a prior art circularly polarized cross dipole antenna are shown. Fig.**10**A illustrates a dipole antenna, while Fig. **10**B illustrates a cross dipole antenna. The dipole antenna shown in Fig. **10**A is assembled by forming a single dipole antenna element **101** on a ground plate **100**, whereas the cross dipole antenna shown in Fig. **10**B is assembled by forming a pair of dipole antennas **101** and **102** on the ground plate **100** so as to cross each other. The cross dipole antenna excites a circularly polarized wave by shifting its phase **90** degrees.

An axial ratio characteristic is important to an antenna for exciting a circularly polarized wave. In the cross dipole antenna illustrated in Fig. **10**B, the axial ratio characteristic of each of the dipole antenna elements **101** and **102** crossing each other is unsuitable. The axial ratio characteristic improves when a gain characteristic of an E plane (where an electric field is generated) in each of the dipole antenna elements **101** and **102** is equal to that of an H plane (where a magnetic field is generated) therein. When these gain characteristics differ from each other, the axial ratio characteristic becomes worse by an amount corresponding to the difference.

Fig. **11** is a chart of the comparison of a gain characteristic of the E plane (C**1** indicated by the solid line) and that of the H plane (C**2** indicated by the broken line) in the single dipole antenna element **101** shown in Fig. **10**A. It is seen from Fig. **11** that the gain characteristics C**1** and C**2** are widely different.

If a cross dipole antenna is assembled by simply crossing two dipole antenna elements having the above characteristics, an axial ratio of them is satisfactory in the vicinity of 0° but it is unsatisfactory at other angles. It is thus difficult to obtain a circularly polarized cross dipole antenna having a wide-angle axial ratio characteristic even though it is assembled by simply combining two dipole antenna elements having a conventional structure.

BRIEF SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, there is provided a circularly polarized cross dipole antenna comprising a cross dipole antenna element formed of two pairs of inverted-V-shaped dipole antenna elements, which are bent like an inverted "V" at a set angle and arranged so as to cross each other on a ground plane. The antenna further comprises a feeding mechanism provided to perform a single-point feed through a feeding section common to the inverted-V-shaped dipole antenna elements of the cross dipole antenna element. Each of the inverted-V-shaped dipole antenna elements includes a pole portion standing vertically on the ground plane, an arm portion one end of which is rotatably coupled to a top of the pole portion by a pivot mechanism and another end of which is provided so as to move close to or away from the ground plane in a region closer to the ground plane than the one end of the arm portion. Each of the inverted-V-shaped dipole antenna elements further may include a plate-shaped insulating support member slidably fitted on the pole portion and fixed at a predetermined level of the pole portion, for supporting the arm portion at a predetermined angle by supporting the arm portion from below on a periphery of the insulating member.

In accordance with another aspect of the present invention there is provided a circularly polarized cross dipole antenna having an excellent axial ratio characteristic across a wide angle.

In accordance with aspect of the invention there is provided a circularly polarized cross dipole antenna. The antenna may comprise two pairs of inverted V-shaped dipole antenna elements arranged to cross each other on a ground plane and a feeding mechanism having a feeding section common to the dipole antenna elements, for providing a single point feed to the antenna elements. Each of the antenna elements may comprise a pole portion extending at right angles to the ground plane, an arm portion having an end pivotally connected to the pole portion such that an opposite end thereof can be moved toward and away from the ground plane to cause the arm to have an inclination angle relative to the ground plane and an angle adjustment mechanism for variably setting the inclination angle of the arm portion.

The angle adjustment mechanism may comprise an insulating support member slidably fitted on the pole portion and may further comprise a device for securing the insulating support member to the pole portion.

The insulating support member may have a plate shape.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description given above and the detailed description below serve to explain the principles of the invention.

Fig. **1** is a perspective view showing a circularly polarized cross dipole antenna according to a first embodiment of the present invention;

Fig. **2** is a top view of the circularly polarized cross dipole antenna according to the first embodiment of the present invention;

Fig. **3** is a side view of the circularly polarized cross dipole antenna according to the first embodiment of the present invention;

Fig. **4** is a chart for describing a function of an inverted-V-shaped dipole antenna element of the circularly polarized cross dipole antenna according to the first embodiment of the present invention;

Fig. **5** is a graph showing conditions for acquiring a wide-angle axial ratio characteristic of the circularly polarized cross dipole antenna according to the first embodiment of the present invention;

Fig. **6** is a graph showing the optimum-structure data acquired when an inclination angle of the circularly polarized cross dipole antenna according to the first embodiment of the present invention is varied;

Fig. **7** is a graph showing a relationship between the **3**dB width (half-value angle) of axial ratio and gain and the input impedance with respect to the inclination angle when the circularly polarized cross dipole antenna according to the first embodiment of the present invention has a particular structure;

Fig. **8** is a chart showing a typical example of the axial ratio characteristic and the gain characteristic of the circularly polarized cross dipole antenna according to the first embodiment of the present invention;

Fig. **9** is a partly cutaway side view of the main part of a circularly polarized cross dipole antenna according to a second embodiment of the present invention;

Figs. **10**A and **10**B are illustrations for describing an overview of a prior art circularly cross dipole antenna; and

Fig. **11** is a chart of the comparison of a gain characteristic of E plane and that of H plane in the prior art circularly polarized cross dipole antenna.

DETAILED DESCRIPTION OF THE INVENTION

(First Embodiment)

As illustrated in Figs. **1** to **3**, a circularly polarized cross dipole antenna according to a first embodiment of the invention includes a cross dipole antenna element A comprised of four inverted-V-shaped dipole antenna elements **10**, **20**, **30** and **40** which are integrated as one unit. The dipole antenna elements **10**, **20**, **30** and **40** have respective pole portions **11**, **21**, **31** and **41**, and the pole portions **11**, **21**, **31** and **41** have respective arm portions **12**, **22**, **32** and **42** at their tops. The "inverted-V-shaped" means that the arm portions **12**, **22**, **32** and **42** are each inclined from the top toward the ground at a given angle θ s.

A first of the dipole antenna elements **10** includes a pole portion **11** standing vertically on a ground plane B (the surface of ground member **60**) and having a height H and an arm portion **12**, one end of which is coupled to the top of the pole portion **11** and the other end of which is held in a position where it is closer to the ground plane B than the one end of the arm portion **12**. The arm portion **12** is thus inclined at the given angle θ s.

The other elements **20**, **30** and **40** also include pole portions **21**, **31** and **41** and arm portions **22**, **32** and **42**, respectively.

The pole portions **11**, **21**, **31** and **41** of the dipole antenna elements **10**, **20**, **30** and **40** are coupled to each other by a short-circuit member **50** at a distance Hs from their tops. The pole portions **11**, **21**, **31** and **41** are therefore electrically short-circuited at the coupling portion to achieve a single-point feed structure. In other words, the dipole antenna elements **10**, **20**, **30** and **40** are so designed as to perform a single-point feed through the short-circuit member **50** which acts as a common feeding section of a feeding mechanism F.

As illustrated in Fig. **1**, one of the pole portions **11**, **21**, **31** and **41** of the dipole antenna elements **10**, **20**, **30** and **40**, for example, the pole portion **11**, is constructed so that its core wire **11**a and conductive pipe **11**b are arranged coaxially with each other. The proximal end of the conductive pipe **11**b is connected to the ground member **60**, while that of the core wire **11**a insulatively penetrates the ground member **60** and then connects to the central conductor of a coaxial feeder-connecting connector **70** attached to the underside of the ground member **60**.

The distal end of the core wire **11**a is connected to that of the conductive pipe **11**b at the top of the pole portion **11**. The top of the pole portion **11** is short-circuited by a conductor **71** with another pole portion **31**, which stands diagonally with respect to the pole portion **11**.

In order to mount the above-described antenna on an object such as an automobile, it is preferable that the ground member **60** be used as a mount plate and the entire antenna be covered with a cover **80** having a streamlined shape or other desired shape.

If, as described above, the dipole antenna elements **10**, **20**, **30** and **40** are each shaped like an inverted "V", the gain characteristics of E and H planes in each of the antenna elements are similar over a wide angle. This situation is specifically shown in Fig. **4**.

In Fig. **4**, characteristic curve C**11** indicates the gain characteristic of the E plane when the inclination angle θ s is **0**°, curve C**12** indicates the gain characteristic of H plane when the inclination angle θ s is **0**°, curve C**13** indicates the gain characteristic of E plane when the inclination angle θ s is **45**°, and curve C**14** indicates the gain characteristic of H plane when the inclination angle θ s is **45**°.

It is apparent from Fig. **4** that the gain characteristics of E and H planes are different from each other so widely when the angle θ s is **0**°. In contrast, they are considerably closer to each other when the angle θ s is **45**°.

If, therefore, the four inverted-V-shaped dipole antenna elements **10**, **20**, **30** and **40** are combined by properly setting the inclination angle θ s, the circularly polarized cross dipole antenna having an axial ratio characteristic can be obtained as shown in Fig. **1**.

A condition for acquiring an excellent axial ratio characteristic across a wide angle will now be described. If the gain characteristics of E and H planes of the dipole antenna elements **10**, **20**, **30** and **40** are set equal to each other, the axial ratio characteristic is satisfied. By varying the height H of each of the pole portions **11**, **21**, **31** and **41** of the dipole antenna elements **10**, **20**, **30** and **40**, the length L of each of the arm portions **12**, **22**, **32** and **42**, and the inclination angle θ s, a difference between the gain characteristics of E and H planes in the range from **0**° to **60**° can be minimized.

If the real part R and imaginary part X of input impedance Z does not satisfy the following relationship: R = -X, a difference between gains of E and H planes at an inclination angle of **0**° does not become zero and thus no polarized waves are obtained. The structure for satisfying the above condition may be obtained by simulation.

Fig. **5** is a graph showing results of such a simulation. In Fig. **5**, the horizontal axis represents the inclination angle θ s and the vertical axis represents the length L of each of the arm portions **12**, **22**, **32** and **42** on a wavelength basis. C**21** to C**25** indicate a relationship between the inclination angle θ s and the length L of each of the arm portions **12**, **22**, **32** and **42** when the above height H is used as a parameter. Further, C**20** indicates a relationship between the inclination angle θ s and the length L of each of the arm portions **12**, **22**, **32** and **42** to satisfy the second condition: R = -X for obtaining a circularly polarized wave.

If both the condition of R = -X in the impedance X and that of the length L of each of the arm portions **12**, **22**, **32** and **42** corresponding to variations in the height H of the pole portions **11**, **12**, **31** and **41** are satisfied simultaneously, an excellent axial ratio characteristic can be obtained. In Fig. **5**, therefore, intersection points of the curves C**21** to C**25** and the curve C**20** correspond to the conditions for obtaining the excellent axial ratio characteristic.

Next, a distance Hs from the top of each of the pole portions **11**, **21**, **31** and **41** to the short-circuit member **50** will be described. When the cross dipole antenna has a single-point feed structure, the axial ratio characteristic greatly depends upon how the height of the short-circuit member **50** for short-circuiting the pole portions **11**, **21**, **31** and **41**, i.e., the distance Hs is determined. The input impedance Z(X/R) of the dipole antenna, the height H of the pole portions **11**, **21**, **31** and **41**, the height of the short-circuit member **50**, i.e., the distance Hs may be expressed by the following equation:

$$X/R = \sin\beta(H + Hs) / \sin\beta(H - Hs) \quad \ldots \quad (1)$$

where β is a phase constant.

Hereinafter the above equation will be referred to as an Hs design equation (**1**). By setting the distance Hs based on equation (**1**), a good axial ratio characteristic can be obtained.

The structure of a cross dipole antenna having good axial ratio characteristic will now be described.

As described above referring to Fig. **5**, the height H of each of the pole portions **11**, **21**, **31** and **41** and the length L of each of the arm portions **12**, **22**, **32** and **42** corresponding to the height H can be measured by the inclination angle θ s. The cross dipole antenna having a single-point feed structure can be optimized from the input impedance Z and the Hs design equation (**1**).

Fig. **6** is a graph showing the optimum-structure data of the cross dipole antenna which is acquired when the inclination angle θ s is varied, that is, the optimum interrelationship among the height H of each of the pole portions **11**, **21**, **31** and **41**, the length L of each of the arm portions **12**, **22**, **32** and **42**, and the distance Hs from the top of each of the pole portions to the short-circuit member **50** with respect to the inclination angle θ s.

Fig. **7** is a graph showing a relationship between the 3dB width (half-value angle) of axial ratio and gain and the input impedance with respect to the inclination angle θ s when the cross dipole antenna has an optimum structure.

Fig. **8** is a chart showing the gain and axial ratio characteristics, when the inclination angle θ s is varied from **0**° to **45**° and from **45**° to **80**°. Unless a distance d between opposing pole portions is sufficiently small, an error of the Hs design equation (**1**) is increased. For this reason, d is set equal to $10^{-4}\lambda$. When the inclination angle θ s of each of the arm portions **12**, **22**, **32** and **42** is set to approximately **5**° as shown in Fig. **8**, the 3dB width of the axial ratio is considerably increased.

It is thus seen from Fig. **8** that the distance Hs from the top of each of the pole portions **11**, **21**, **31** and **41** to the short-circuit member **50** is uniquely determined for the inclination angle θ s and, if the inclination angle θ s is determined without being set to an extreme value, the length L of each of the arm portions and the distance Hs produce an excellent axial ratio characteristic.

The circularly polarized cross dipole antenna according to the first embodiment of the present invention has a single-point feed structure in which the dipole antenna elements **10**, **20**, **30** and **40** are bent and shaped like an inverted "V" and the pole portions **11**, **21**, **31** and **41** are employed. A circularly polarized dipole antenna having a simple feed structure and a wide-angle axial ratio characteristic can thus be attained. The structure of the antenna can be achieved easily and accurately by setting the height H of each of the pole portions **11**, **21**, **31** and **41**, the length L of each of the arm portions **12**, **22**, **32** and **42**, the inclination angle θ s of each of the arm portions **12**, **22**, **32** and **42**, the height Hs of the short-circuit member **50**, and impedance Z, so as to approximate the gain characteristics of E and H planes of each of the dipole antenna elements **10**, **20**, **30** and **40** to each other. Consequently, a circularly polarized cross dipole antenna for fulfilling a desired function can stably be provided.

(Second Embodiment)

Fig. **9** is a side view showing a major part of a circularly polarized cross dipole antenna according to a second embodiment of the present invention. This embodiment differs from the first embodiment in that it includes an angle adjustment mechanism **93** for variably setting the inclination angle θ s of an arm portion **92**. More specifically, one end of the arm portion **92** is coupled to the top of a pole portion **91** such that it can be moved up and down, as indicated by double-headed arrow y in Fig. **9**, by means of a shaft mechanism **94**.

In order to stabilize the adjusted inclination angle θ s, the arm portion **92** can be supported by an insulating support member **95** which is slidably fitted on the pole portion **91** as indicated by double-headed arrow z. Thus, the inclination angle of the arm portion **92** can be set variably.

In general, there is provided a circularly polarized cross dipole antenna wherein paired dipole antenna elements (**10**, **30**; **20**, **40**) are each bent like an inverted "V" to control a gain characteristic of the antenna and an axial ratio characteristic thereof.

The antenna allows a circularly polarized wave to be excited by arranging paired dipole antenna elements (**10**, **30**; **20**, **40**) so as to cross each other, wherein the paired dipole antenna elements (**10**, **30**; **20**, **40**) are inverted-V-shaped antenna elements each of which is bent like an inverted "V" at a set angle.

The inverted-V-shaped antenna elements may have pole portions (**11**, **21**, **31**, **41**) standing vertically on a ground plane (B) and arm portions (**12**, **22**, **32**, **42**) inclined at a set inclination angle (Os) s) such that one end of each of the arm portions is coupled to a top of each of the pole portions and another end thereof is held in a position closer to the ground plane (B) than the one end of each of the arm portions. The pole portions (**11**, **21**, **31**, **41**) of the inverted-V-shaped antenna elements may be coupled to one another by a short-circuit member (**50**) to have a single-point feed structure.

The antenna may have an angle adjustment mechanism (**93**) for variably setting the inclination angle (θ s) of an arm portion (**92**).

(Modifications)

The dipole antenna element may have a gently-curved or acute-angled L-shaped arm portion and may be formed by adhering a thin-film conductor onto a substrate.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention, in its broader aspects, is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A circularly polarized cross dipole antenna comprising:

a cross dipole antenna element formed of two pairs of inverted V-shaped dipole antenna elements, which are bent like an inverted "V" at a set angle and arranged so as to cross each other on a ground plane; and

a feeding mechanism provided to perform a single-point feed through a feeding section common to the inverted V-shaped dipole antenna elements, each of the inverted V-shaped dipole antenna elements including:

a pole portion standing vertically on the ground plane;

an arm portion, one end of which is rotatably coupled to a top of the pole portion by a pivot mechanism and another end of which is provided so as to move close to or away from the ground plane in a region closer to the ground plane than the one end of the arm portion; and

a plate-shaped insulating support member slidably fitted on the pole portion and fixed at a predetermined level on the pole portion, for supporting the arm portion at a predetermined angle by supporting the arm portion from below on a periphery of the insulating member.

2. A circularly polarized cross dipole antenna comprising:

two pairs of inverted V-shaped dipole antenna elements arranged to cross each other on a ground plane; and

a feeding mechanism having a feeding section common to the dipole antenna elements, for providing a single point feed to the antenna elements;

each of said antenna elements comprising:

a pole portion extending at right angles to the ground plane;

an arm portion having an end pivotally connected to said pole portion such that an opposite end thereof can be moved toward and away from the ground plane to cause said arm to have an inclination angle relative to the ground plane; and

an angle adjustment mechanism for variably setting the inclination angle of said arm portion.

3. The antenna of claim **2** wherein said angle adjustment mechanism comprises an insulating support member slidably fitted on said pole portion.

4. The antenna of claim **3** wherein said angle adjustment mechanism comprises a device for securing said insulating support member to said pole portion.

5. The antenna of claim **3** wherein said angle adjustment mechanism comprises securing means for securing the insulating support member to said pole portion.

6. The antenna of claim 3, 4 or 5 wherein said insulating support member has a plate shape.

7. A circularly polarized cross dipole antenna comprising:

two pairs of inverted V-shaped dipole antenna elements arranged to cross each other on a ground plane; and

a feeding mechanism having a feeding section common to the dipole antenna elements, for providing a single point feed to the antenna elements;

each of said antenna elements comprising:

a pole portion extending at right angles to the ground plane;

an arm portion having an end pivotally connected to said pole portion such that an opposite end thereof can be moved toward and away from the ground plane to cause said arm to have an inclination angle relative to the ground plane; and

angle adjustment means for variably setting the inclination angle of said arm portion.

8. The antenna of claim 7 wherein said angle adjustment means comprises an insulating support member slidably fitted on said pole portion.

9. The antenna of claim 8 wherein said angle adjustment means comprises a device for securing said insulating support member to said pole portion.

10. The antenna of claim **8** wherein said angle adjustment means comprises securing means for securing the insulating support member to said pole portion.

11. The antenna of claim **8**, **9** or **10** wherein said insulating support member has a plate shape.

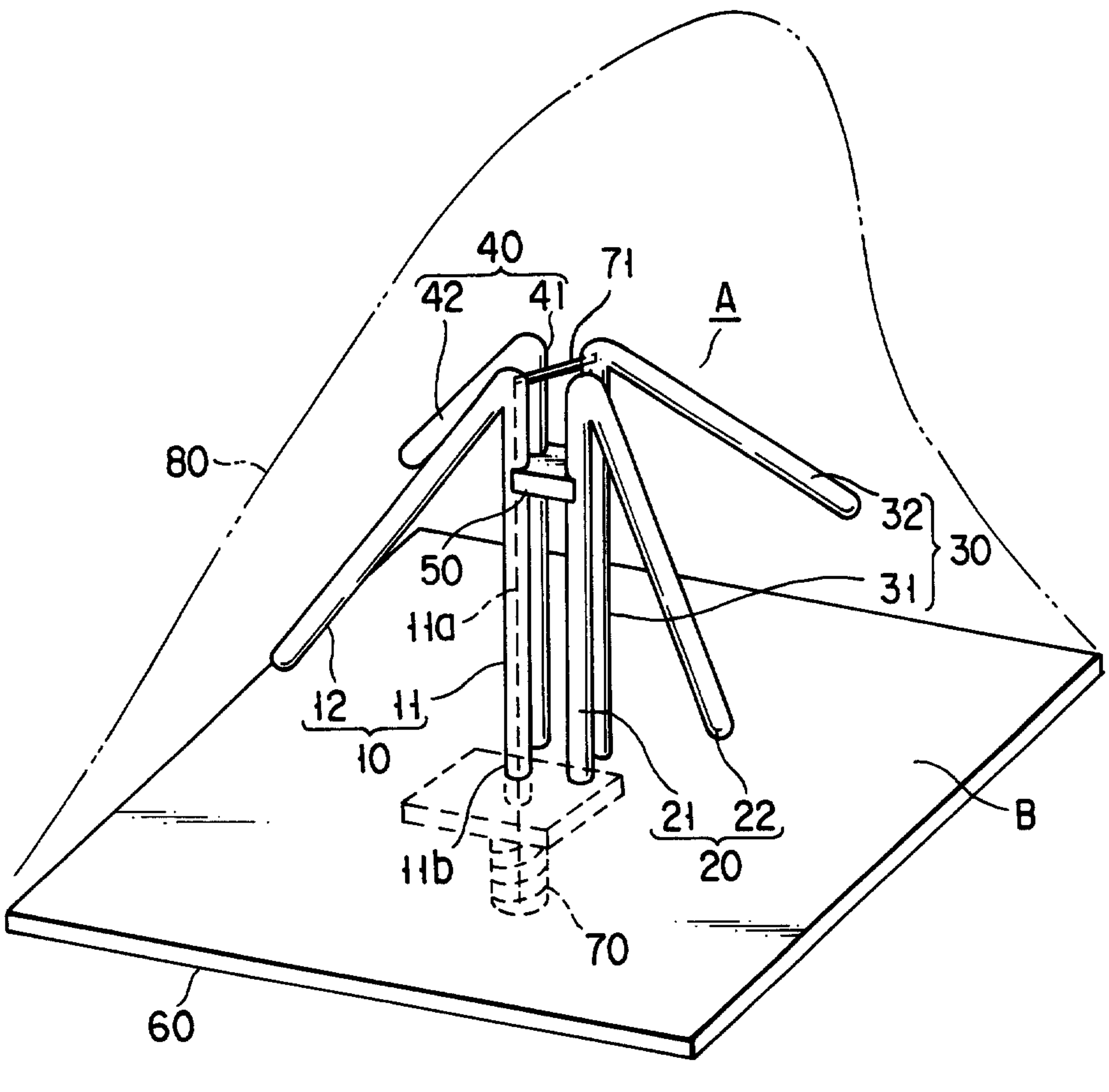


FIG. 1

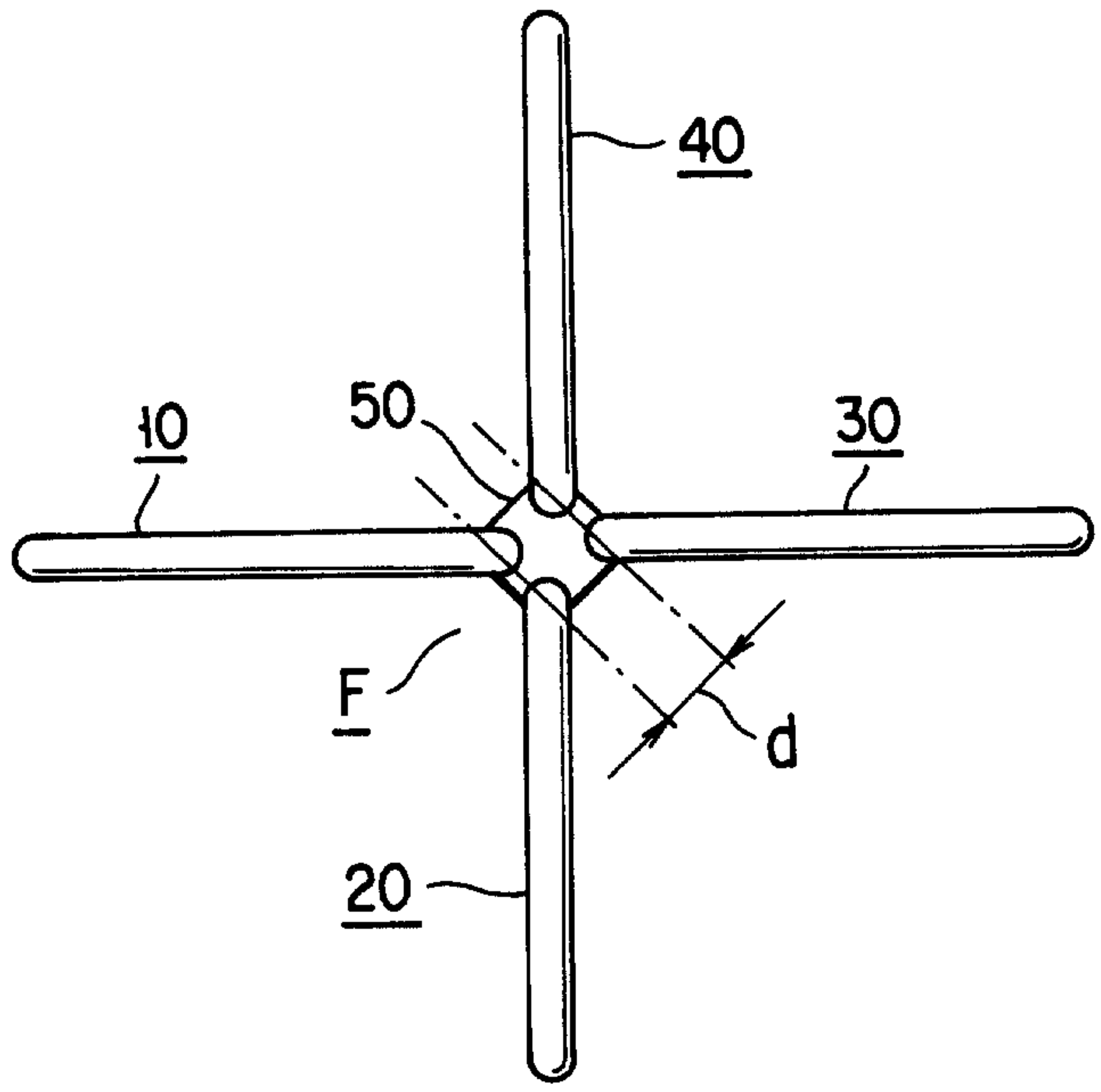


FIG. 2

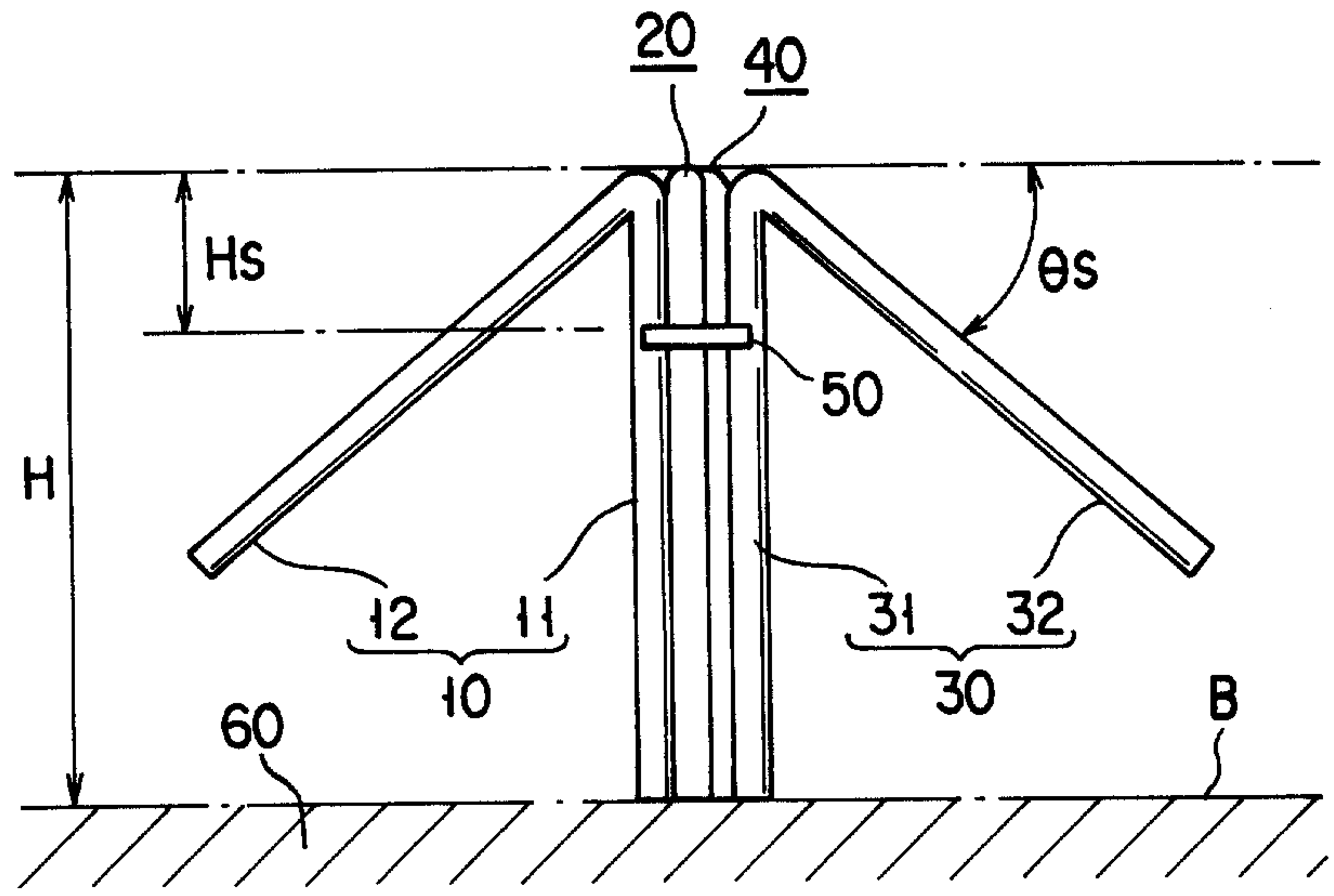


FIG. 3

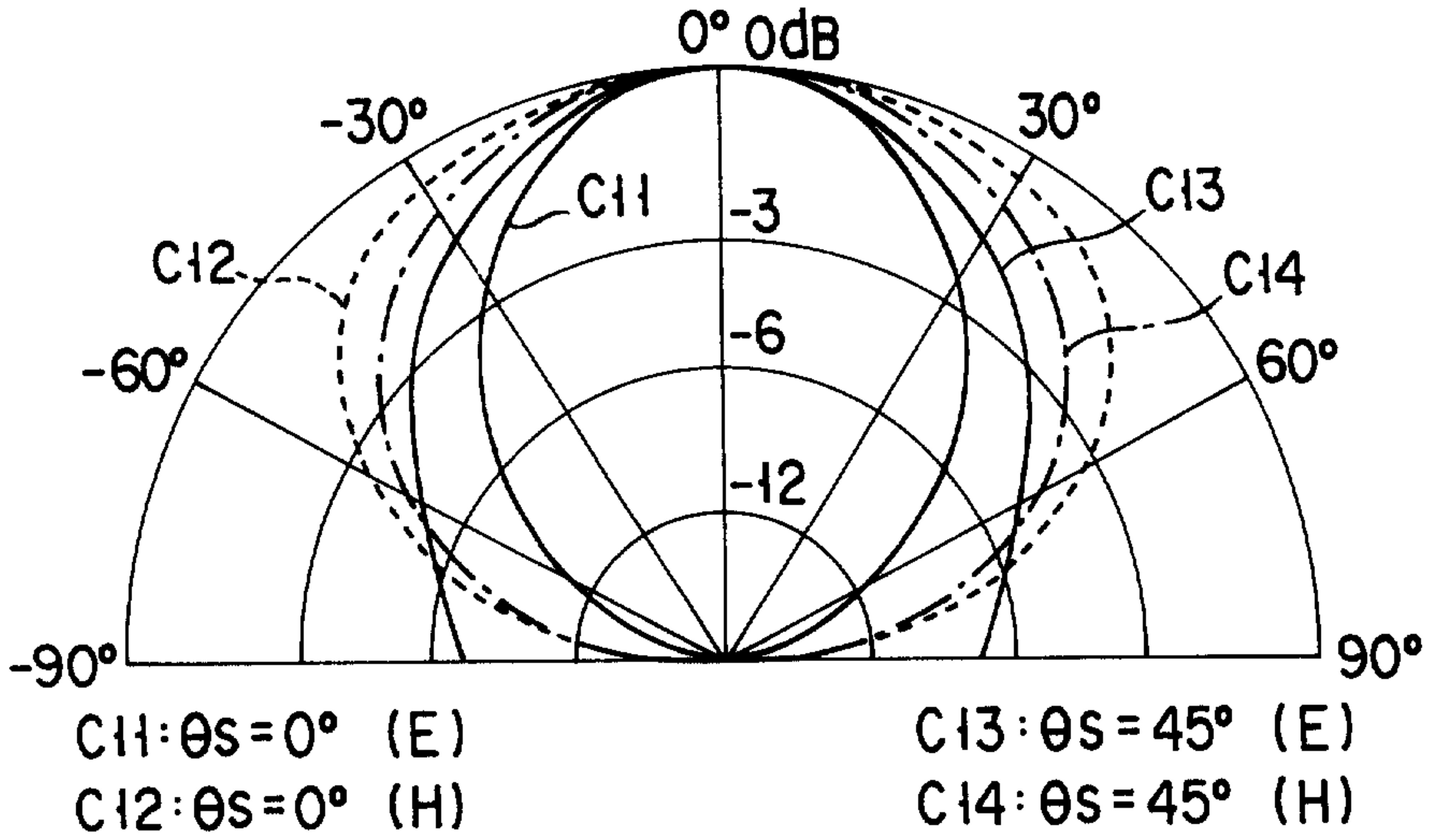

0° 0dB
-30°
30°
C11
-3
C13
C12
C14
-6
-60°
60°
-12
-90°
90°
C11: θs=0° (E)
C12: θs=0° (H)
C13: θs=45° (E)
C14: θs=45° (H)

FIG. 4

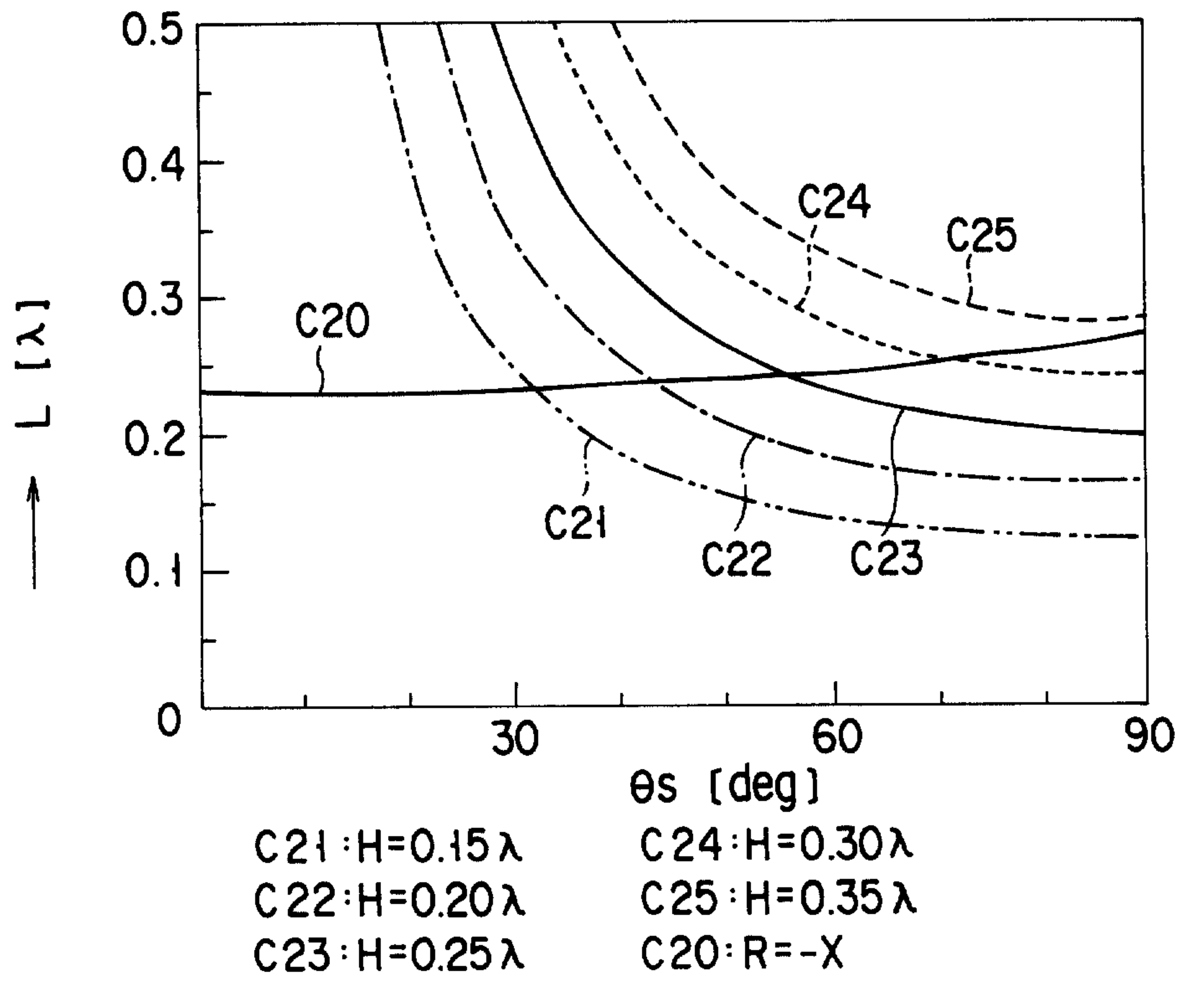

0.5
0.4
0.3
0.2
0.1
0
L [λ]
C24
C25
C20
C21
C22
C23
30
60
90
θs [deg]
C21: H=0.15λ
C22: H=0.20λ
C23: H=0.25λ
C24: H=0.30λ
C25: H=0.35λ
C20: R=-X

FIG. 5

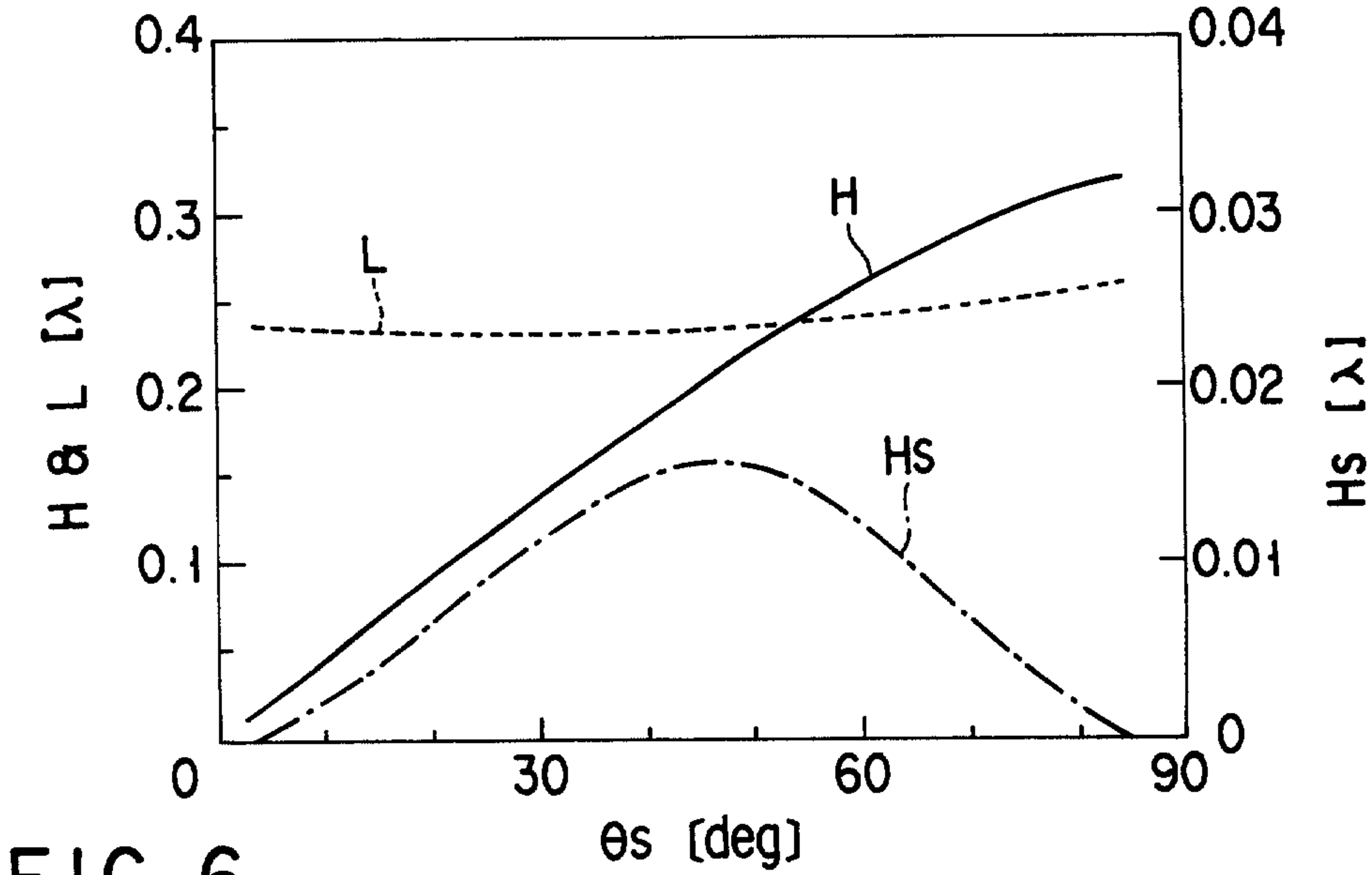

0.4
0.3
0.2
0.1
0
H & L [λ]
0.04
0.03
0.02
0.01
0
Hs [λ]
H
L
Hs
30
60
90
θs [deg]

FIG. 6

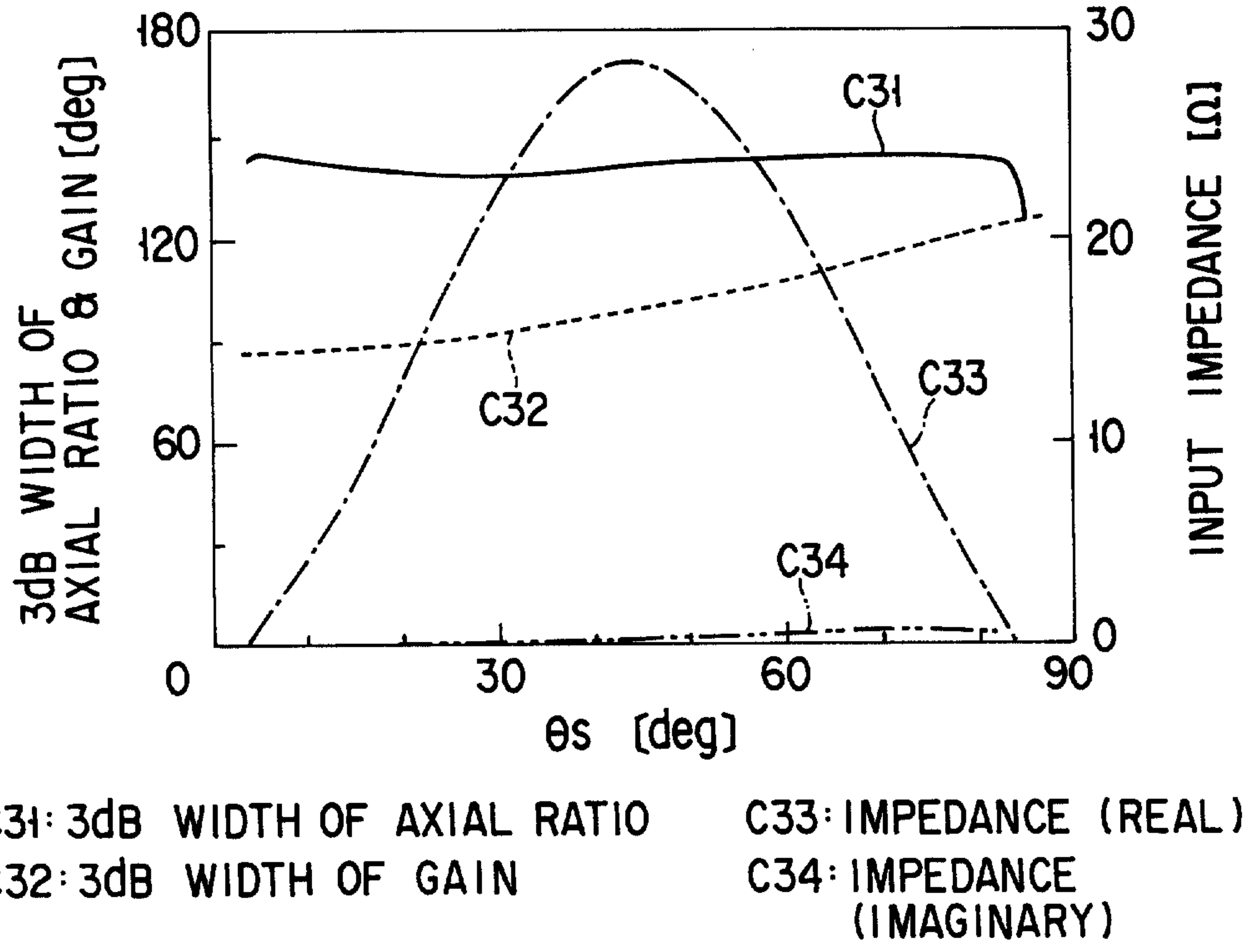

180
120
60
0
3dB WIDTH OF AXIAL RATIO & GAIN [deg]
30
20
10
0
INPUT IMPEDANCE [Ω]
C31
C32
C33
C34
30
60
90
θs [deg]
C31: 3dB WIDTH OF AXIAL RATIO
C32: 3dB WIDTH OF GAIN
C33: IMPEDANCE (REAL)
C34: IMPEDANCE (IMAGINARY)

FIG. 7

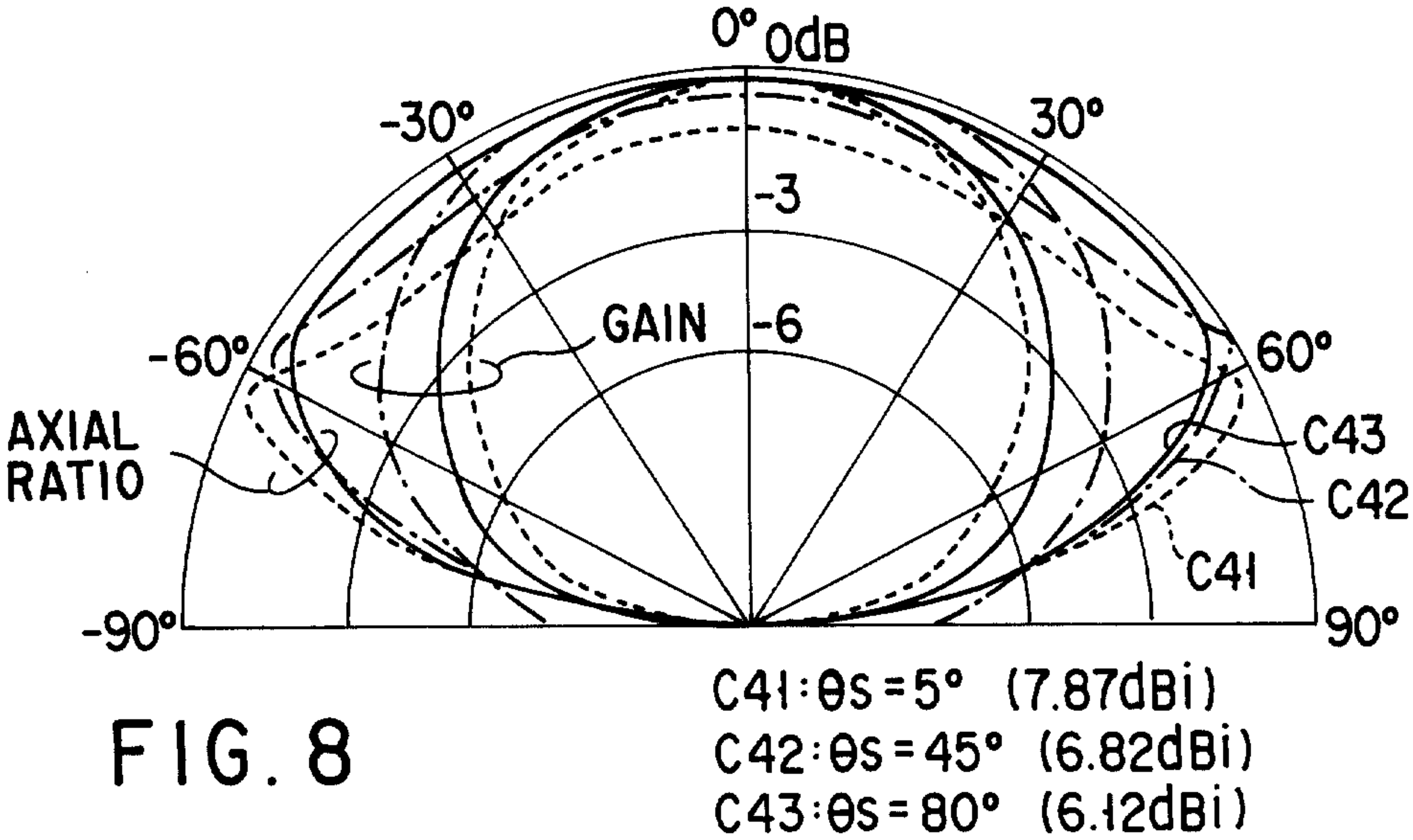

0°
0dB
-30°
30°
-3
GAIN
-6
-60°
60°
AXIAL
RATIO
C43
C42
C41
-90°
90°
C41:θs=5° (7.87dBi)
C42:θs=45° (6.82dBi)
C43:θs=80° (6.12dBi)

FIG. 8

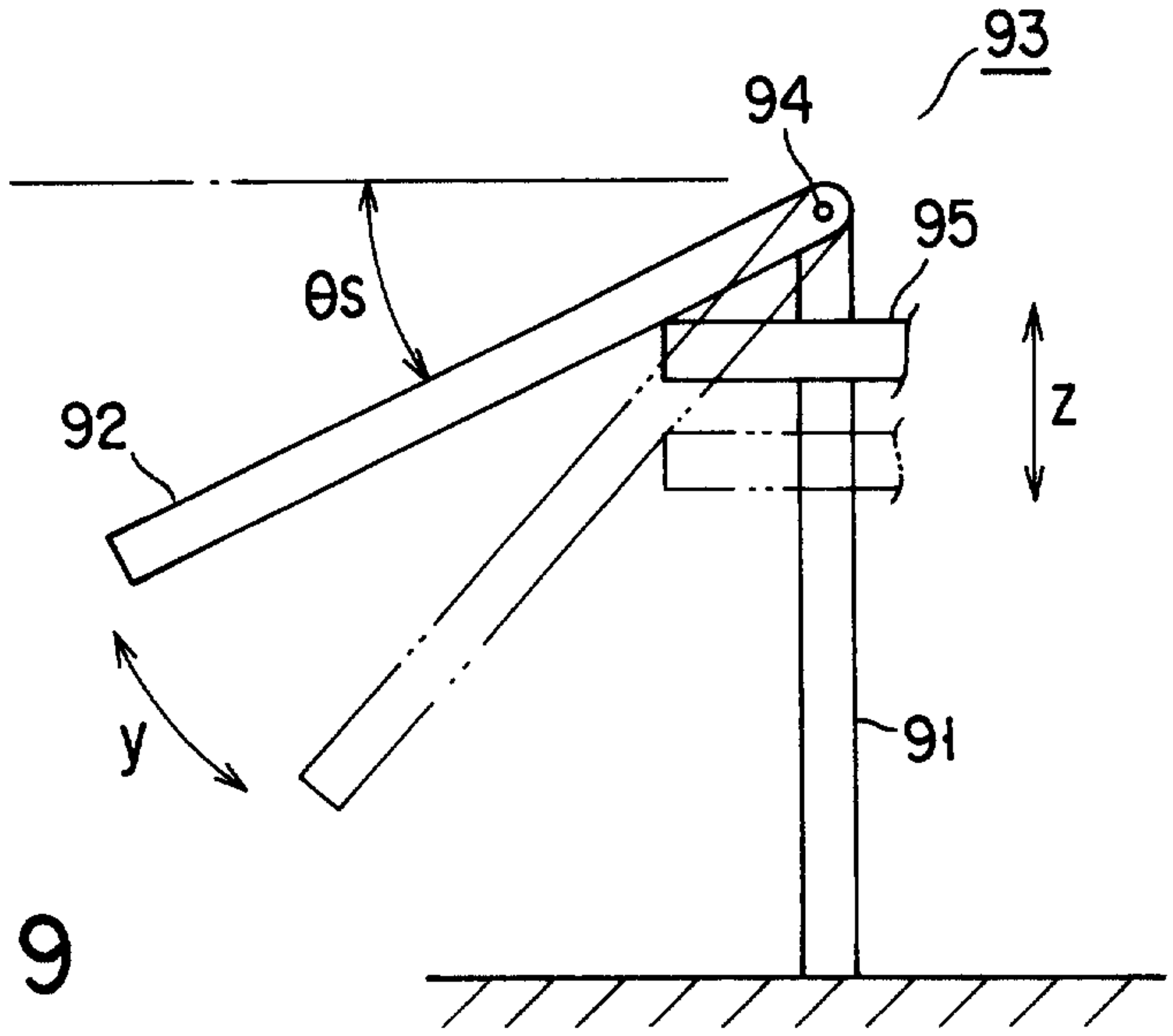

93
94
95
θs
Z
92
y
91

FIG. 9

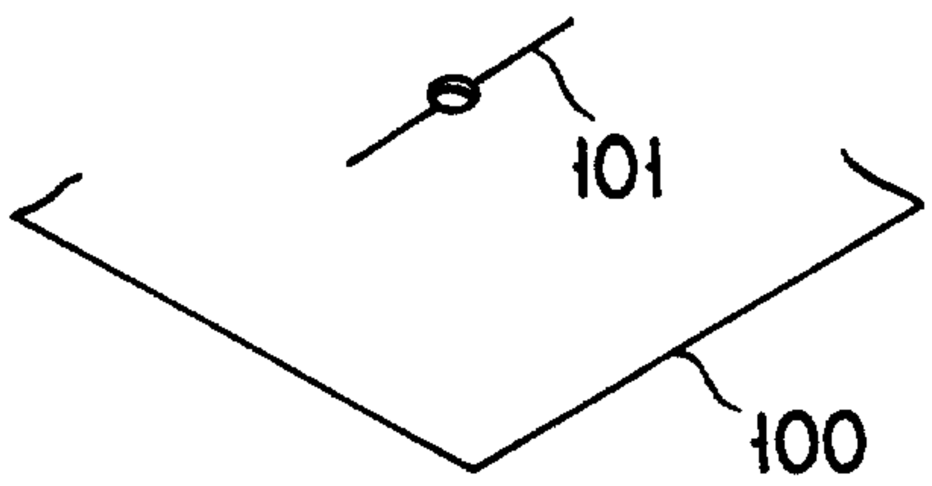


FIG. 10A

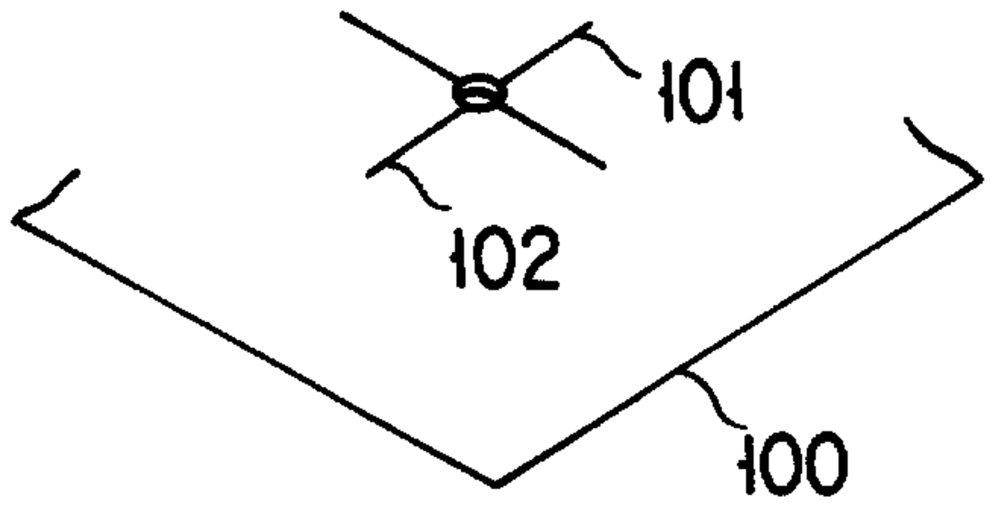


FIG. 10B

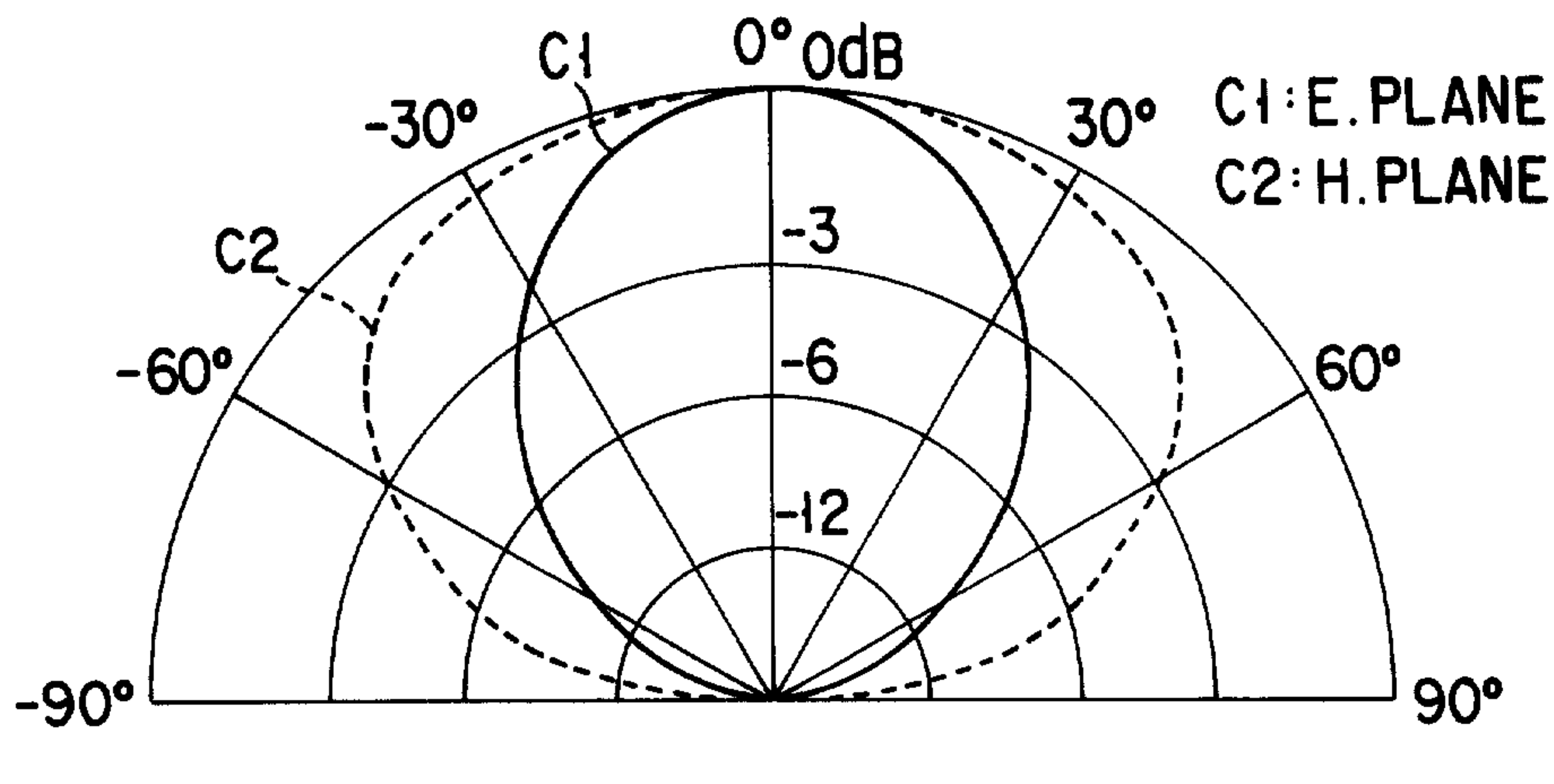
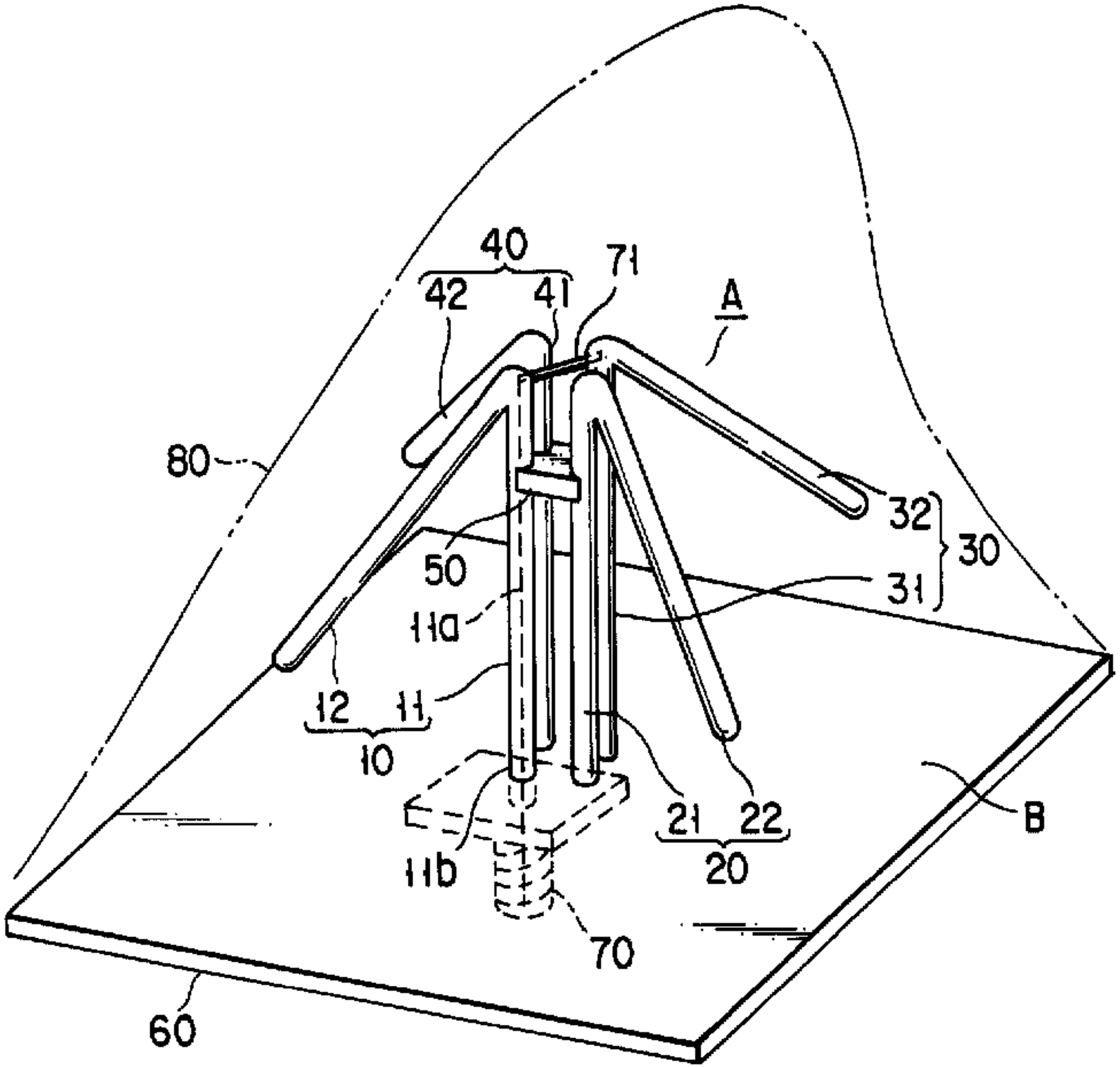


FIG. 11



40
42
41
71
A
80
32
30
50
31
11a
12
11
10
21
22
20
B
11b
70
60