(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 003 235 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
24.05.2000 Bulletin 2000/21

(51) Int Cl.[7]: H01P 1/17

(21) Application number: 99308849.1

(22) Date of filing: 05.11.1999

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 20.11.1998 JP 33126598

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(54) Linear/circular polarization converter utilizing elliptical waveguide

(57) The linear/circular polarizing converter of the present invention uses an elliptical waveguide (1) having elliptical cross-section which receives supply of a linearly polarized signal at one end of elliptical waveguide and outputs a circularly polarized signal from the other end of elliptical waveguide (1) When the application frequency wavelength of polarized signal supplied to the elliptical waveguide is λ_0, length of elliptical waveguide is L, cutoff wavelength of polarizing plane in the long axis direction of polarized signal is λ_{CH}, cutoff wavelength of the polarizing plane in the short axis direction of polarized signal is λ_{CV}, phase of the basic mode polarization signal in the long axis direction for the polarized signal is $\theta_{H,}$ phase of basic mode polarization in the short axis direction is θ_V and phase difference of these phases θ_H and θ_V is $\Delta\theta$, θ_H is expressed using λ_0, λ_{CH} and L, while θ_V is expressed using λ_0, λ_{CV} and L, and long axis size a, short axis size b and length L in the tube axis direction are selected to meet $\Delta\theta = 90°$.

FIG. 1A

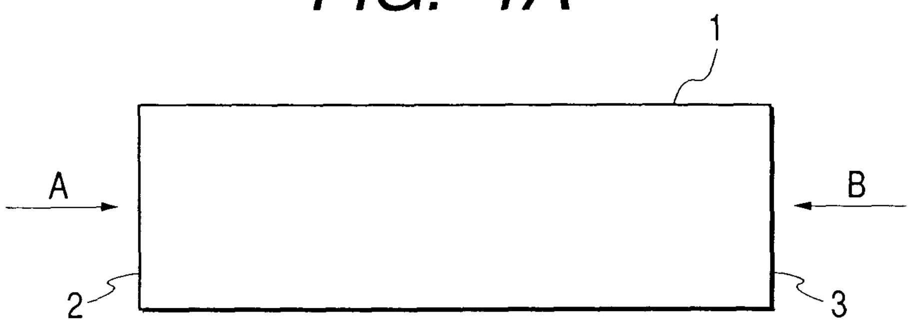

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FIG. 1B

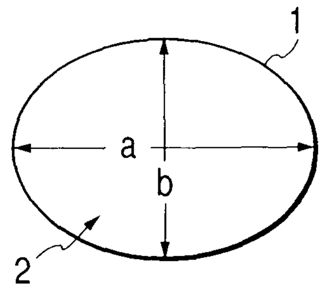
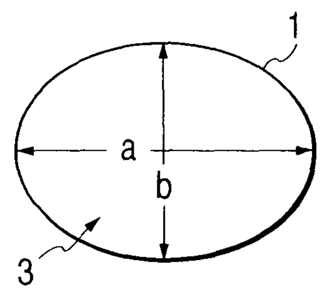


FIG. 1C



Description

[0001] The present invention relates to a linear/circular polarization converter and particularly to a linear/circular polarization converter to realize linear polarization-circular polarization conversion by using an elliptical waveguide having an elliptical cross-section consisting of long axis and short axis and selecting the long axis size, short axis size and length in the tube axis direction of the elliptical waveguide.

[0002] As linear/circular polarization converter for converting a linearly polarized signal to a circularly polarized signal, a converter in which a dielectric material plate is arranged in the angle of 45 degrees at the input polarizing plane of the linearly polarized signal (hereinafter, this converter is called an existing first linear/circular polarization converter) and a converter in which a plurality of screws are projected in the angle of 45 degrees at the input polarizing plane of the linearly polarized signal toward the internal side of the circular waveguide (hereinafter, this converter is called an existing second linear/circular polarization converter) are well known.

[0003] Here, Figs. 2A, 2B, 2C illustrate a structure of an example of the existing first linear/circular polarization converter. Fig. 2A is a cross-sectional view in the longitudinal direction. Fig. 2B is a side elevation seen in the direction A (input end side) and Fig. 2C is a side elevation seen in the direction B (output end side).

[0004] As illustrated in Fig. 2A to Fig. 2C, the first linear/circular polarization converter is composed of a circular waveguide 21 having the circular cross-section and a dielectric material plate 22 arranged in the diameter direction within the circular waveguide 21 and an input end 23 is formed at one end of the circular waveguide 21, while an output end 24 is formed at the other end of the circular waveguide 21. The dielectric material plate 22 is arranged in the angle of 45 degrees for the linear polarizing plane of the linearly polarized signal supplied to the input end 23 and the cutout portions 22a, 22b for preventing reflection which are cut deeply as it approaches the center area are formed in the side of the input end 23 and output end 24.

[0005] In a preferred embodiment of the linear/circular polarization converter the linearly polarized signal supplied to the input end 23 of the circular waveguide 21 is converted in its polarizing plane to the circular polarization from the linear polarization by the dielectric material plate 22 arranged in the angle of 45 degrees for the linear polarizing plane when it is transmitted within the circular waveguide 21 from the input end 23 and thereby the circularly polarized signal can be extracted from the output end 24. As explained above, the first linear/circular polarization converter performs conversion to circularly polarized signal from the linearly polarized signal.

[0006] Next, Figs. 3A, 3B, 3C illustrate a structure of an example of the existing second linear/circular polarization converter. Fig. 2A illustrates a cross-sectional view in the longitudinal direction. Fig. 2B illustrates a side elevation seen in the direction A (input end side) and Fig. 2C is a side elevation seen in the direction B (output end side).

[0007] As illustrated in Fig. 3A to 3C, the second linear/circular polarization converter is composed of a circular waveguide 31 having the circular cross-section 31 and a plurality of screws projected in the diameter direction toward inside of the circular waveguide 31. At one end of the circular waveguide 31, an input end 33 is formed and at the other end of circular waveguide 31, an output end 34 is formed. A plurality of screws 32 are projected in the angle of 45 degrees to the linear polarizing plane of the linearly polarized signal supplied to the input end 23 and length of projection of these screws are sequentially reduced as it approaches the input end 23 and output end 24 in order to prevent reflection by a plurality of screws 32.

[0008] In another embodiment of the linear/circular polarization converter the linearly polarized signal supplied to the input end 33 of the circular waveguide 31 is converted to the circularly polarized signal from the linearly polarized signal at its polarizing plane by a plurality of screws projected in the angle of 45 degrees for the linear polarizing plane when it is transmitted within the circular waveguide 31 from the input end 33 and is then extracted from the output end 34. As explained above, the conversion to circularly polarized signal from the linearly polarized signal is conducted in the second linear/circular polarization converter.

[0009] Since the dielectric material plate 22 is arranged within the circular waveguide 21 to convert the linearly polarized signal to the circularly polarized signal in the first linear/circular polarization converter, number of parts increases and the total structure is rather complicated, resulting in the problem that it is difficult to assure the stable operation and higher reliability.

[0010] Moreover, the linear/circular polarization converter performs the conversion to the circularly polarized signal from the linearly polarized signal by projecting a plurality of screws 32 within the circular waveguide 31. Accordingly, the number of parts also increases and total structure is complicated, resulting in the problem that it is difficult to assure stable operation and higher reliability.

[0011] The present invention has been proposed to solve such problems and it is therefore an object of the present invention to provide a linear/circular polarization converter which can simplify the total structure by reducing the number of parts and assures higher reliability by improving stability of the operation.

[0012] In view of attaining the objects explained above, the linear/circular polarization converter of the present invention uses an elliptical waveguide and when wavelength of the application frequency of polarized signal supplied to the elliptical waveguide is defined as λ_0, length of the elliptical waveguide as L, cutoff wavelength of the plane polarized in the long axis direction of the polarized signal as λ_{CH}, cutoff wavelength of the plane polarized in the short axis direction of the polarized signal as λ_{CV}, phase of basic mode polarization in the long axis direction for the polarized signal as θ_H, phase of basic mode polarization in the short axis direction as θ_V and phase difference between phase θ_H of basic mode polarization in the long axis direction and phase θ_V of basic mode polarization in the short axis direction as $\Delta\theta$, following expression is satisfied,

[Expression 1]

$$\Delta\theta = |\theta_V - \theta_H| = \frac{2\pi L}{\lambda_0} \left| \sqrt{1-\left(\frac{\lambda_0}{\lambda_{CV}}\right)^2} - \sqrt{1-\left(\frac{\lambda_0}{\lambda_{CH}}\right)^2} \right| = 90^\circ$$

by selecting the long axis size a, short axis size b and length L in the tube axis direction of the elliptical waveguide.

[0013] The linear/circular polarization converter respectively selects the long axis size a, short axis size b and length L of tube direction of the elliptical waveguide to obtain 90 degrees of phase difference between the basic mode polarization in the long axis direction and basic mode polarization in the short axis direction by utilizing that the cutoff wavelength of the polarizing plane in the long axis direction in the elliptical waveguide is different from the cutoff wavelength of the polarizing plane in the short axis direction and that transmission rate of polarization in the long axis direction is different from that of polarization in the short axis direction.

[0014] According to the means explained above, the linear/circular polarization converter is formed only of an elliptical waveguide and dielectric material plate and a plurality of screws are never arranged within the waveguide. Therefore, number of parts can be reduced and total structure can also be simplified and moreover stable operation can be assured through higher reliability.

[0015] According to one aspect of the present invention, the linear/circular polarization converter uses an elliptical waveguide having elliptical cross-section including long axis and short axis to receive supply of the linearly polarized signal or circularly polarized signal at one end of the elliptical waveguide and output the circularly polarized signal or linearly polarized signal from the other end of the elliptical waveguide, and when wavelength of the application frequency of polarized signal supplied to said elliptical waveguide is defined as λ_0, length of said elliptical waveguide as L, cutoff wavelength of the plane polarized in the long axis direction of said polarized signal as λ_{CH}, cutoff wavelength of the plane polarized in the short axis direction of said polarized signal as λ_{CV}, phase of basic mode polarization in said long axis direction for said polarized signal as θ_H, phase of basic mode polarization in said short axis direction as θ_V and phase difference between phase θ_H of basic mode polarization in said long axis direction and phase θ_V of basic mode polarization in said short axis direction as $\Delta\theta$, following expression is satisfied;

[Expression 1]

$$\Delta\theta = |\theta_V - \theta_H| = \frac{2\pi L}{\lambda_0} \left| \sqrt{1-\left(\frac{\lambda_0}{\lambda_{CV}}\right)^2} - \sqrt{1-\left(\frac{\lambda_0}{\lambda_{CH}}\right)^2} \right| = 90^\circ$$

by selecting the long axis size a, short axis size b and length L in the tube axis direction of the elliptical waveguide.

[0016] In a preferred embodiment of the linear/circular polarization converter of the present invention, the short axis size b of the elliptical waveguide is selected to satisfy the condition $\lambda_{CH} \fallingdotseq 1.1\ \lambda_1$ for the cutoff wavelength of the polarizing plane in the long axis direction of the polarized signal when the polarized signal wavelength of the lowest frequency in the frequency band supplied to the elliptical waveguide is defined as λ_1.

[0017] In the linear/circular polarization converter , the long axis size a of the elliptical waveguide is detected to attain (a/b) ≒ 1.2 between the long axis size a and short axis size b of the elliptical waveguide.

[0018] The linear/circular polarization converter is formed of only an elliptical waveguide, the long axis size, short axis size and length in the tube axis direction of the elliptical waveguide are selected as explained above and structural elements such as dielectric material plate and a plurality of screws are never arranged within the elliptical waveguide. Therefore, number of structural parts of the linear/circular polarization converter is reduced, total structure can be very much simplified and stability in operation of the linear/circular polarization converter is much improved to remarkably enhance the reliability.

[0019] Embodiments of the present invention, will now be described, with reference to the accompanying drawings, in which:

[0020] Figs. 1A to 1C are structural diagrams illustrating an embodiment of the linear/circular polarization converter of the present invention.

[0021] Figs. 2 A to 2C are structural diagrams illustrating an example of the linear/circular polarization converter of the related art.

[0022] Figs. 3A to 3C are structural diagrams illustrating the other example of the linear/circular polarizing converter of the related art.

[0023] Figs. 1A, 1B, 1C illustrate a structure of a preferred embodiment of the linear/circular polarization converter of the present invention. Fig. 1A is a cross-sectional view in the longitudinal direction. Fig. 1B is a side elevation seen in the direction A (input end side) and Fig. 1C is a side elevation seen in the direction B (output end side).

[0024] As illustrated in Fig. 1, the linear/circular polarization converter of the present embodiment is composed of an elliptical waveguide 1 having an elliptical cross-section having the length (diameter) a in the short axis direction, length (diameter) b in the long axis direction and length L in the tube axis direction. At one end of the elliptical waveguide 1, an input end 2 is formed and at the other end of the elliptical waveguide 1, an output end 3 is formed.

[0025] In this embodiment, the fact that when the polarized signal is transmitted within the elliptical waveguide 1, the cutoff wavelength λ_{CH} of the polarizing plane in the long axis direction in the elliptical waveguide 1 is different from the cutoff wavelength λ_{CV} of the polarizing plane in the short axis direction and the transmission rate of polarized signal in the long axis direction is different from that of the polarized signal in the short axis direction.

[0026] Here, the polarized signal transmitted in the waveguide has the phase θ expressed below when the free space wavelength of the frequency of the polarized signal is defined as λ_0 and the wavelength in the waveguide of the frequency of polarized signal as λ_g.

[Expression 2]

$$\theta = \frac{2\pi}{\lambda_g} L, \qquad \lambda_g = \frac{\lambda_0}{\sqrt{1 - (\frac{\lambda_0}{\lambda_C})^2}}$$

[0027] Here, L is the length in the tube axis direction of the waveguide as explained above.

[0028] In the case of waveguide, when phase of the polarized signal in the long axis direction is defined as θ_H, phase of the polarized signal in the short axis direction as θ_V, the phase θ_H of the polarized signal in the long axis direction and phase θ_V of the polarized signal in the short axis direction can be expressed as follow.

[Expression 3]

$$\theta_H = \frac{2\pi}{\lambda_{gH}} L, \qquad \theta_V = \frac{2\pi}{\lambda_{gV}} L$$

[0029] In the above expression, λ_{gH} is the wavelength in the waveguide of the desired application frequency of the polarized signal in the long axis direction and λ_{gV} is the wavelength in the waveguide guide of the desired application frequency of the polarized signal in the short axis direction.

[0030] Here, the condition to form the linear/circular polarization converter with an elliptical waveguide 1, namely the condition to attain 90 degrees of a phase difference $\Delta\theta$ between the phase θ_H of the polarized signal in the long axis direction at the output end 3 of the polarized signal and the phase θ_V of the polarized signal in the short axis direction

[Expression 1]

$$\Delta\theta = |\theta_V - \theta_H| = \frac{2\pi L}{\lambda_0}\left|\sqrt{1-\left(\frac{\lambda_0}{\lambda_{CV}}\right)^2} - \sqrt{1-\left(\frac{\lambda_0}{\lambda_{CH}}\right)^2}\right| = 90^\circ$$

will be obtained.

[0031] In the elliptical waveguide 1, there lies a relationship of $\lambda_{CH} \neq \lambda_{CV}$ between the cutoff wavelength λ_{CH} of the polarizing plane in the long axis direction and the cutoff wavelength λ_{CV} of the polarizing plane in the short axis direction and moreover, when length in the long axis direction of the elliptical waveguide 1 is defined as a and length in the short axis direction as b, the cutoff wavelength λ_{CH} of the polarizing plane in the long axis direction and the cutoff wavelength λ_{CV} of the polarizing plane in the short axis direction are expressed as follow.

[Expression 4]

$$\lambda_{CH} \fallingdotseq 3.41 \cdot \left(\frac{b}{2}\right)$$

$$\lambda_{CV} \fallingdotseq 3.41 \cdot \left(\frac{a}{2}\right)$$

[0032] Moreover, when the free space wavelength of lowest frequency of the frequency band of the polarized signal is defined as λ_1, the length b in the short axis direction of the elliptical waveguide 1 is selected to provide $\lambda_{CH} \geqq \lambda_1$, preferably $\lambda_{CH} \fallingdotseq 1.1\ \lambda_1$ for the cutoff wavelength λ_{CH} of the polarizing plane in the long axis direction.

[0033] Moreover, length a on the long axis direction of the elliptical waveguide 1 is selected to provide the result, $(a/b) \fallingdotseq 1.2$, between the length a in the long axis direction and the length b of short axis direction of the elliptical waveguide 1.

[0034] Next, an example of the designing means of the elliptical waveguide 1 forming the linear/circular polarization converter of the present embodiment will be explained as follow.

[0035] First, frequency band (lowest frequency f_1 and highest frequency f_h) of the linearly polarized signal for linear/circular polarization conversion with the elliptical waveguide 1 are determined.

[0036] Next, the length b in the short axis direction of the elliptical waveguide 1 is set from the following expression among the cutoff wavelength λ_{CH}, of the polarizing plane in the long axis direction, length a in the long axis direction of the elliptical waveguide 1, free space wavelength λ_1 of the lowest frequency and lowest frequency f_1,

$$\lambda_{CH} \fallingdotseq 3.41\ (b/2) = 1.1\ \lambda_1 = 1.1(c/f_1)$$

(where, c is velocity of light).

[0037] Next, length a in the long axis direction of the elliptical waveguide 1 is set from the expression between the length a in the long axis direction of the elliptical waveguide 1 and length b in the short axis direction,

$$(a/b) \fallingdotseq 1.2.$$

[0038] Subsequently, length L in the tube axis direction of the elliptical waveguide 1 is set from the following expression 1 to determine the wanted shape of the elliptical waveguide 1.

[Expression 1]

$$\Delta\theta = |\theta_V - \theta_H| = \frac{2\pi L}{\lambda_0}\left|\sqrt{1-\left(\frac{\lambda_0}{\lambda_{CV}}\right)^2} - \sqrt{1-\left(\frac{\lambda_0}{\lambda_{CH}}\right)^2}\right| = 90^\circ$$

[0039] In the linear/circular polarization converter of this embodiment of the structure explained above, when the wavelength λ_0 of linearly polarized signal of the application frequency is supplied to the input end 2 of the elliptical waveguide 1, such linearly polarized signal is transmitted to the elliptical waveguide 1. In this case, since the elliptical waveguide 1 is structured by selecting the sizes such as length a in the long axis direction, length b in the short axis direction and length L in the tube axis direction to satisfy each expression explained above, the linearly polarized signal supplied to the input end 2 is converted in its polarizing plane to the circularly polarized signal from the linearly polarized signal and the circularly polarized signal can be extracted from the output end 3 to form the linearly/circular polarization converter for conversion to the circularly polarized signal from the linearly polarized signal. Meanwhile, when the circularly polarized signal is supplied to the input end 2, the linearly polarized signal can be extracted from the output end 3.

[0040] In this case, the linear/circular polarization converter of this embodiment is structured only by the elliptical waveguide 1, long axis size a, short axis size b and length L of tube axis direction of the elliptical waveguide 1 are selected and structural elements such as dielectric material plate and a plurality of screws, etc. are never arranged within the elliptical waveguide 1. Therefore, number of structural parts of linear/circular polarization converter can be reduced, total structure can be extremely simplified and structural parts other than the elliptical waveguide 1 are never used. As a result, stable operation of the linear/circular polarization converter is much improved and reliability of this converter can be much enhanced.

[0041] The length b in the short axis direction of the elliptical waveguide 1 is selected to satisfy $\lambda_{CH} \geqq \lambda_1$, preferably, $\lambda_{CH} \fallingdotseq 1.1\ \lambda_1$ between the wavelength λ_1 of the lowest frequency signal in free space and cutoff wavelength λ_{CH} of the polarizing plane in the long axis direction of the elliptical waveguide 1, particularly in the lowest frequency area of the frequency band in which transmission loss for the polarized signal of the elliptical waveguide 1 increases sharply. Therefore, rapid increase of transmission loss in the lowest frequency area can be eliminated.

[0042] Moreover, since length a of long axis direction of the elliptical waveguide 1 is selected in the linear/circular polarization converter of this embodiment to provide the result $(a/b) \fallingdotseq 1.2$ between the long axis size a and short axis size b of the elliptical waveguide 1, increase in size of the elliptical waveguide 1 can be prevented and generation of high order mode can also be eliminated.

[0043] As explained above, the present invention structures a linear/circular polarizing converter only with an elliptical waveguide and never arranges structural elements such as dielectric material plate and a plurality of screws or the like within the elliptical waveguide, resulting in the effect that number of parts of the linear/circular polarizing converter is reduced, total structure is extremely simplified, stable operation of the linear/circular polarizing converter can be much improved and reliability of converter can be enhanced.

Claims

1. A linear/circular polarization converter comprising an elliptical waveguide having elliptical cross-section including a long axis and a short axis to receive supply of a linearly polarized signal or circularly polarized signal at one end of said elliptical waveguide and output the circularly polarized signal or linearly polarized signal from the other end of said elliptical waveguide, wherein a size of long axis of an elliptical waveguide is selected as a, size of short axis thereof as b and length in the tube axis direction as L, so that the following expression (1) can be satisfied;

[Expression 1]

$$\Delta\theta = |\theta_V - \theta_H| = \frac{2\pi L}{\lambda_0}\left|\sqrt{1-\left(\frac{\lambda_0}{\lambda_{CV}}\right)^2} - \sqrt{1-\left(\frac{\lambda_0}{\lambda_{CH}}\right)^2}\right| = 90^\circ$$

when wavelength of the application frequency of polarized signal supplied to said elliptical waveguide is defined as λ_0, length of said elliptical waveguide as L, cutoff wavelength of the plane polarized in the long axis direction of said polarized signal as λ_{CH}, cutoff wavelength of the plane polarized in the short axis direction of said polarized signal as λ_{CV}, phase of basic mode polarization in said long axis direction for said polarized signal as θ_H, phase of basic mode polarization in said short axis direction as θ_V and phase difference between phase θ_H of basic mode polarization in said long axis direction and phase θ_V of basic mode polarization in said short axis direction as $\Delta\theta$.

2. The linear/circular polarization converter according to claim 1, wherein the short axis size b of said elliptical waveguide is selected to satisfy the condition $\lambda_{CH} \fallingdotseq 1.1\ \lambda_1$ for the cutoff wavelength λ_{CH} of the plane polarized in the long axis direction of said polarized signal when the free space wavelength of polarized signal of the minimum frequency in the frequency band supplied to said elliptical waveguide is defined as λ_1.

3. The linear/circular polarization converter according to claim 1 or 2, wherein the long axis size a of said elliptical waveguide is selected so that $(a/b) \fallingdotseq 1.2$ can be obtained between the long axis size a and short axis size b in said elliptical waveguide.

FIG. 1A

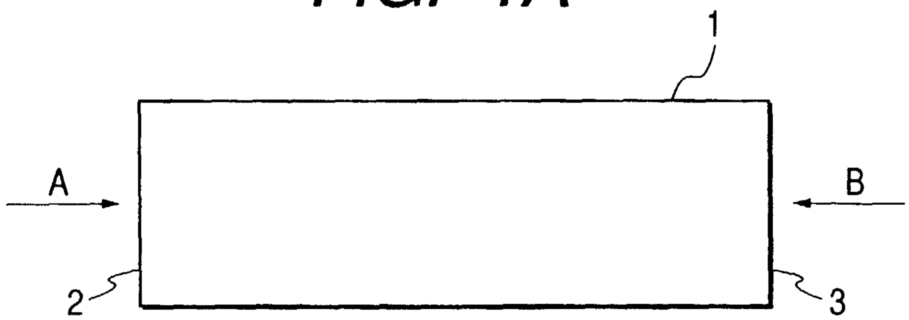


FIG. 1B

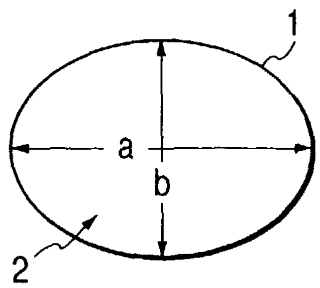


FIG. 1C

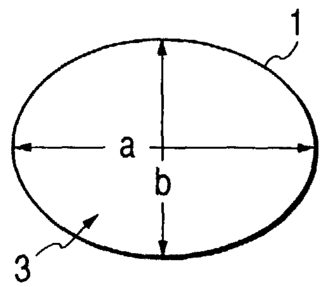


FIG. 2A
PRIOR ART

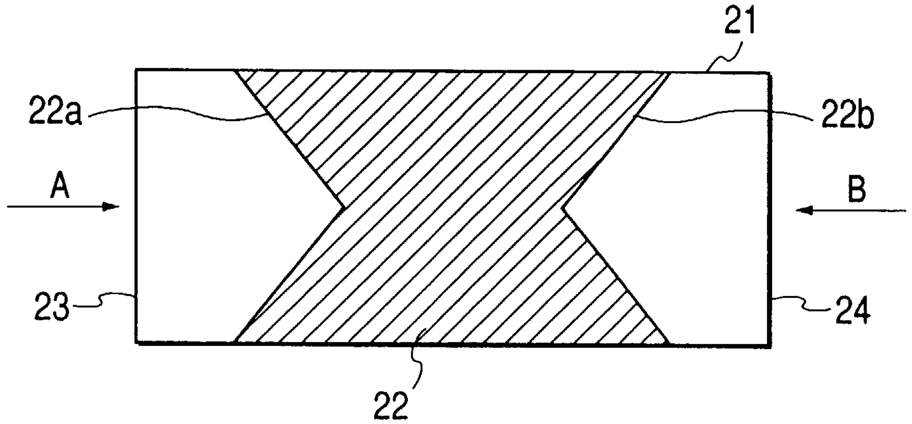


FIG. 2B
PRIOR ART

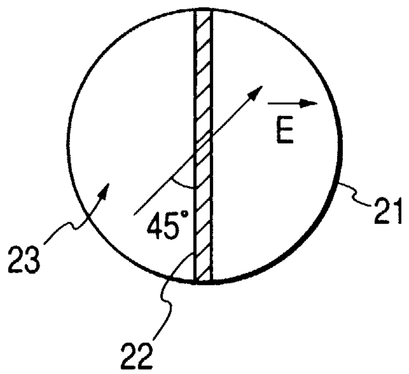


FIG. 2C
PRIOR ART

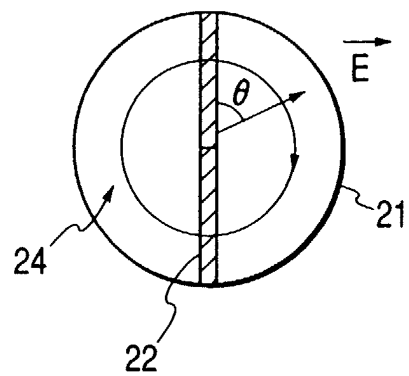


FIG. 3A
PRIOR ART

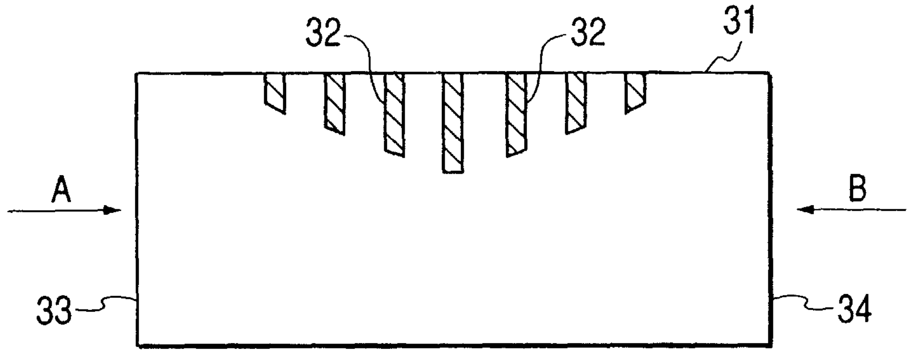


FIG. 3B
PRIOR ART

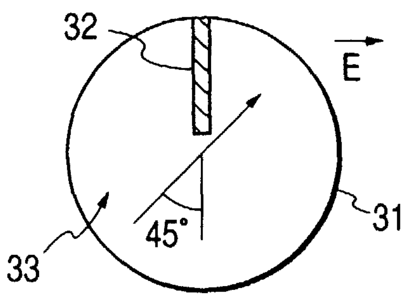
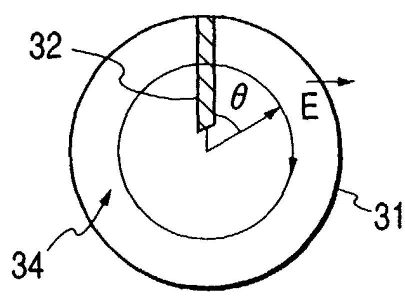


FIG. 3C
PRIOR ART



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EUROPEAN SEARCH REPORT

Application Number
EP 99 30 8849

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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A	J. DESCHAMPS ET AL.: "ÉTUDE ET RÉALISATION D' UN POLARISEUR CIRCULAIRE D' ONDES HYPERFRÉQUENCE A FORTE TENUE EN PUISSANCE" REVUE DE PHYSIQUE APPLIQUEE., vol. 5, no. 2, April 1970 (1970-04), pages 283-286, XP002131486 LES EDITIONS DE PHYSIQUE. PARIS., FR * page 283, right-hand column, line 16 - page 284, left-hand column, line 5 * * page 286, left-hand column, line 12 - line 20; figures 1,2,4 *	1,3	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H01P
A	US 2 607 849 A (PURCELL ET AL.) 19 August 1952 (1952-08-19) * column 4, line 51 - column 5, line 11; figure 2 *	1	
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 333 (E-794), 26 July 1989 (1989-07-26) & JP 01 097001 A (MITSUBISHI ELECTRIC CORP.), 14 April 1989 (1989-04-14) * abstract *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	24 February 2000	Den Otter, A

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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