FORM 1

600796

SPRUSON & FERGUSON

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

APPLICATION FOR A STANDARD PATENT

Siemens Aktiengesellschaft, incorporated in the Federal Republic of Germany, of Wittelsbacher Platz 2, 8000 Muenchen, FEDERAL REPUBLIC OF GERMANY, hereby apply for the grant of a standard patent for an invention entitled:

Microwave Polarisation Filters

which is described in the accompanying complete specification.

LODGED AT SUB-OFFICE
17 FEB 1988
Sydney

Details of basic application(s):-

Basic Applic. No:	Country:	Application Date:
P3705179.2	FEDERAL REPUBLIC OF GERMANY	18 February 1987

The address for service is:-

Spruson & Ferguson
Patent Attorneys
Level 33 St Martins Tower
31 Market Street
Sydney New South Wales Australia

DATED this SIXTEENTH day of FEBRUARY 1988

Siemens Aktiengesellschaft

By: M.J. Anderson

Registered Patent Attorney

TO: THE COMMISSIONER OF PATENTS
OUR REF: 48315
S&F CODE: 61890

FEE STAMP TO VALUE OF $192.00 ATTACHED
MAIL OFFICER

5845/2

APPLICATION ACCEPTED AND AMENDMENTS ALLOWED 14-6-90

PATENT OFFICE 100 ONE HUNDRED DOLLARS AUSTRALIA

LODGED AT SUB-OFFICE 17 FEB 1988 Sydney

FIFTY DOLLARS PATENT OFFICE 50 AUSTRALIA FORTY DOLLARS

SPRUSON & FERGUSON

AUSTRALIA
CONVENTION
STANDARD
& PETTY PATENT
DECLARATION

COMMONWEALTH OF AUSTRALIA
THE PATENTS ACT 1952

DECLARATION IN SUPPORT OF A CONVENTION APPLICATION FOR A PATENT

In support of the Convention Application made for a patent for an invention entitled:

Title of Invention: Microwave Polarisation Filters

Full name(s) and address(es) of Declarant(s)

I/~~We~~ John Gordon Hinde

of C/- Spruson & Ferguson
33rd Floor, St. Martins Tower, 31 Market Street,
Sydney 2000, New South Wales, Australia

do solemnly and sincerely declare as follows:-

Full name(s) of Applicant(s)

1. ~~I am/We are the applicant(s) for the patent~~

(or, in the case of an application by a body corporate)

1. I am/~~We are~~ authorised by

Siemens Aktiengesellschaft

the applicant~~(s)~~ for the patent to make this declaration on its/~~their~~ behalf.

2. The basic application~~(s)~~ as defined by Section 141 of the Act was/~~were~~ made

Basic Country(ies) in Federal Republic of Germany

Priority Date(s) on 18 February 1987

Basic Applicant(s) by Siemens Aktiengesellschaft

3. ~~I am/We are the actual inventor(s) of the invention referred to in the basic application(s)~~

Full name(s) and address(es) of inventor(s)

(or where a person other than the inventor is the applicant)

3. Eberhard Schuegraf

of Mauthaeuslstr 15, 8000 Muenchen 70
Federal Republic of Germany

~~(respectively)~~

is/~~are~~ the actual inventor~~(s)~~ of the invention and the facts upon which the applicant~~(s)~~ is/~~are~~ entitled to make the application are as follows:

Set out how Applicant(s) derive title from actual inventor(s) e.g. The Applicant(s) is/are the assignee(s) of the invention from the inventor(s)

The said applicant is the assignee of the actual inventor

4. The basic application~~(s)~~ referred to in paragraph 2 of this Declaration was/~~were~~ the first application~~(s)~~ made in a Convention country in respect of the invention~~(s)~~ the subject of the application.

Declared at Sydney this 15th day of February 19 88

J. Hinde
Signature of Declarant(s)

SFP4 To: The Commissioner of Patents

(12) PATENT ABRIDGMENT (11) Document No. AU-B-11794/88
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 600796

(54) Title
MICROWAVE POLARISATION FILTERS

International Patent Classification(s)
(51)[4] H01P 001/16

(21) Application No. : 11794/88 (22) Application Date : 17.02.88

(30) Priority Data

(31) Number (32) Date (33) Country
3705179 18.02.87 DE FEDERAL REPUBLIC OF GERMANY

(43) Publication Date : 25.08.88

(44) Publication Date of Accepted Application : 23.08.90

(71) Applicant(s)
SIEMENS AKTIENGESELLSCHAFT

(72) Inventor(s)
EBERHARD SCHUEGRAF

(74) Attorney or Agent
SPRUSON & FERGUSON

(56) Prior Art Documents
US 4700154
US 4293829
DE 2521956

(57) Claim

1. A microwave polarisation filter comprising a five-armed double junction of symmetrical construction which couples a waveguide of round or square cross-section, extending in the direction of the longitudinal axis, into a first pair and a second pair of diametrically-opposed rectangular waveguides, the first pair being fed by a first inherently symmetrical waveguide fork and the second pair being fed by a second inherently symmetrical waveguide fork, the first waveguide fork being formed by a symmetrical rectangular waveguide series junction consisting of two outwardly-directed E-bends, formed of a rectangular waveguide angled component bent along the waveguide broad side, and two straight rectangular waveguide arms each of which being connected to the series junction via an E-bend, extend parallel to one another, and continue into the two opposite rectangular waveguides of the first pair of diametrically-opposed rectangular waveguides, and second waveguide fork likewise comprising a symmetrical rectangular waveguide series junction, composed of two outwardly-directed E-bends, and two rectangular waveguide arms which are each connected to the series junction via an E-bend extend in parallel to

.../2

one another, and continue into the two opposite rectangular waveguides of the second pair of diametrically-opposed rectangular waveguides, the series junction of the second waveguide fork being arranged outside the first waveguide fork next to the external broad side wall of the first rectangular waveguide arm of the first waveguide fork, the two rectangular waveguide arms of the second waveguide fork each being provided with an H-bend, formed of a rectangular waveguide angled component bent along the waveguide narrow side, extending parallel in relation to the plane of symmetry of the waveguide fork, and continuing directly into the two oppositely-located rectangular waveguides of the assigned pair in the double junction, the internal width between the inner broad side walls of the two oppositely-located rectangular waveguide arms of the second waveguide fork being contrived to be at least somewhat greater than the broad side dimension of the two rectangular waveguide arms of the first waveguide fork, so that the rectangular waveguide arms which each lead via the H and E-bend to the series junction of the second waveguide fork, embrace the first rectangular waveguide arm and a subsidiary arm of the first waveguide fork which leads to the latter from the series junction.

600796

S & F Ref: 48315

FORM 10

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

COMPLETE SPECIFICATION

(ORIGINAL)

FOR OFFICE USE:

Class Int Class

Complete Specification Lodged:
Accepted:
Published:

Priority:

Related Art:

Name and Address of Applicant: Siemens Aktiengesellschaft
Wittelsbacher Platz 2
8000 Muenchen
FEDERAL REPUBLIC OF GERMANY

Address for Service: Spruson & Ferguson, Patent Attorneys
Level 33 St Martins Tower, 31 Market Street
Sydney, New South Wales, 2000, Australia

Complete Specification for the invention entitled:

Microwave Polarisation Filters

The following statement is a full description of this invention, including the best method of performing it known to me/us

5845/3

ABSTRACT:

MICROWAVE POLARISATION FILTERS:

The invention relates to a wide-band, compact polarisation filter with a symmetrical five-armed double junction (1) for coupling or branching a round or square waveguide (2) into two pairs of rectangular waveguides (3,4,5,6) arranged opposite one another. The first pair (3,4) is fed by an inherently symmetrical waveguide fork (7) formed by a first rectangular waveguide series junction (8) and two straight rectangular waveguide arms (9,10) connected to the series junction via E-bends (22,23). The second pair is likewise fed by an inherently symmetrical waveguide fork (11) constructed from a second rectangular waveguide series junction (12) and two rectangular waveguide arms (14,15) connected to the series junction (12) via E-bends (22,23) and angled at their narrow side with a respective H-bend (13). A polarisation filter constructed in accordance with the invention can be used in particular for supplying parabolic and conchoid antennae.

FIGURE 1

MICROWAVE POLARISATION FILTERS:

The invention relates to microwave polarisation filters with a five-armed double junction of symmetrical construction, which couples a waveguide of round or square cross-section, extending in the direction of its longitudinal axis, into two pairs of diametrically-opposed rectangular waveguides, where the two pairs are each supplied by a symmetrical waveguide fork, the first of which is formed by a symmetrical rectangular waveguide series junction, consisting of two outwardly-directed E-bends (rectangular waveguide angled component bent along the broad side of the waveguide) and two straight rectangular waveguide arms each connected to the series junction via an E-bend, extending parallel to one another, and leading into the two opposite rectangular waveguides of the first pair at their other end, and the second of which likewise comprises a symmetrical rectangular waveguide junction, consisting of two outwardly-directed E-bends, and two rectangular waveguide arms each connected to the series junction via an E-bend, extending parallel to one another, and leading into the two opposite rectangular waveguides of the other pair at their other end.

For operation with two polarisations, wide-band microwave antennae require corresponding wide-band polarisation filters. Large band widths are obtained only by means of polarisation filters in which both the polarisations are excited in the round or square waveguide spatially-symmetrically. Known wide-band polarisation filters of this type are disclosed in the DE-PS 26 51 935 and the DE-GM 69 24 060. They include an external waveguide network which

projects very substantially in the transverse direction and therefore produces a strong shadow in the radiation field of an antenna.

Other wide-band polarisation filters are disclosed in ~~the~~ U.S. 4,293,829 and U.S. 4,700,154 in ~~DE-PS 28 42 576 and the European Patent Application 0 196 065 in~~ which, however, no optimum solution is suggested in respect of minimising the shading surfaces, shortening the structural length and providing the possibility of rational series production. These two known polarisation filters each comprise a symmetrical five-armed double junction which branches a round or square waveguide, extending in the axial direction, into two pairs of mutually-opposed rectangular waveguides. In the case of the polarisation filter corresponding to ~~the European Patent Application 0 196 065~~ U.S. 4,700154, the first pair is fed by a symmetrical waveguide fork which is formed by a first rectangular waveguide series junction and two straight rectangular waveguide arms connected to the series junction. In this filter the second pair is fed by a waveguide fork formed by a second rectangular waveguide series junction and two rectangular waveguide arms connected thereto, which are straddled along their broad sides. In the case of the polarisation filter corresponding to ~~the DE-PS 28 42 576~~ U.S. 4,293,829 two oppositely-located subsidiary arms, extending from the double junction, are connected via identical filter arm sections to the subsidiary arms of one of two series junctions of identical design. Here two filter arm sections, located between the opposite subsidiary arms of the double junction and the subsidiary arms of the series junctions are formed on the one hand as E-offset components and on the other hand as H-offset components, where the

E-offset components each consist of rectangular waveguide components provided on both sides with a waveguide elbow, and the waveguide elbows are bent on both sides in opposite directions in each case along the waveguide broad side. The narrow sides of both the E-offset components are aligned obliquely to the longitudinal axis of the arrangement and extend in parallel to one another. The H-offset components consist of rectangular waveguide components, which are provided on both sides with a waveguide elbow and the waveguide elbows are bent on both sides in opposite directions, in each case along the waveguide narrow side. Here one of the E-offset components is accommodated between the H-offset components such that the subsidiary arms of the series junctions, which are connected to the E-offset components and the H-offset components, are free from inter-penetration.

One object of the present invention is to design a polarisation filter to be arranged in the radiation field of a microwave antenna, in such manner that it presents the smallest possible shading surface area in the radiation field, i.e. the dimensions of the polarisation filter transversely to its longitudinal axis are to be as small as possible. Furthermore the polarisation filter corresponding to the invention is required to have a large band breadth and a short structural length and by virtue of its favourable construction to be able to be rationally produced in series production.

In accordance with the present invention there is provided a microwave polarisation filter comprising a five-armed double junction of symmetrical construction which couples a waveguide of round or square cross-section, extending in the direction of the longitudinal axis, into a first pair and a second pair of diametrically-opposed rectangular waveguides, the first pair being fed by a first inherently symmetrical waveguide fork and the second pair being fed by a second inherently symmetrical waveguide fork, the first waveguide fork being formed by a symmetrical rectangular waveguide series junction consisting of two outwardly-directed E-bends, formed of a rectangular waveguide angled component bent along the waveguide broad side, and two straight rectangular waveguide arms each of which being connected to the series junction via an E-bend, extend parallel to one another, and continue into the two opposite rectangular waveguides of the first pair of diametrically-opposed rectangular waveguides, and second waveguide fork likewise comprising a symmetrical rectangular waveguide series junction, composed of two outwardly-directed E-bends, and two rectangular waveguide arms which are each connected to the series junction via an E-bend extend in parallel to one another, and continue into the two opposite rectangular waveguides of the second pair of diametrically-opposed rectangular waveguides, the series junction of the second waveguide fork being arranged outside the first waveguide fork next to the external broad side wall of the first rectangular waveguide arm of the first waveguide fork, the two rectangular waveguide arms of the second waveguide fork each being provided with an H-bend, formed of a rectangular waveguide angled component bent along the waveguide narrow side, extending parallel in relation to the plane of symmetry of the waveguide fork, and continuing directly

into the two oppositely-located rectangular waveguides of the assigned pair in the double junction, the internal width between the inner broad side walls of the two oppositely-located rectangular waveguide arms of the second waveguide fork being contrived to be at least somewhat greater than the broad side dimension of the two rectangular waveguide arms of the first waveguide fork, so that the rectangular waveguide arms which each lead via the H and E-bend to the series junction of the second waveguide fork, embrace the first rectangular waveguide arm and a subsidiary arm of the first waveguide fork which leads to the latter from the series junction.

The invention will now be described with reference to an exemplary embodiment illustrated in the drawings, in which:-

Figure 1 is a side view of a polarisation filter constructed in accordance with the invention; and

Figure 2 is a plan view of the polarisation filter embodiment shown in Figure 1.

The drawings illustrate a symmetrical, five-armed double junction 1 which, in accordance with Figure 1, branches from a round waveguide 2 extending in the axial direction - which can fundamentally also have a square cross-section - into two pairs of mutually-opposed rectangular waveguides, a first pair 3 and 4, and a second pair 5 and 6. The first pair, 3 and 4, is fed by a first inherently symmetrical waveguide fork 7 (framed in shorter broken lines) which is formed by a first rectangular waveguide series junction 8 and two straight rectangular waveguide arms 9 and 10 connected thereto. The second pair 5,6 of these rectangular

waveguides is fed by an inherently symmetrical waveguide fork 11 (indicated in a frame of long broken lines) formed by a rectangular waveguide series junction 12 and two rectangular waveguide arms, 14 and 15, each connected to the series junction 12 via a respective E-bend, 23 and 23', which are each angled at their narrow side by a H-bend, 13 and 13', respectively. In accordance with Figures 1 and 2 both the forks 7 and 11 comprise a symmetrical rectangular waveguide series junction 8 and 12 respectively, which can be of identical construction. The two series junctions 8 and 12 each divide a rectangular waveguide 16 and 17 respectively, which is to be branched, with dimensions of, for example, a = 2b, and having the correct surge impedance, into two subsidiary pairs of arms, 18,19 and 20,21 respectively, with the dimensions $a_T = 4b_T$ which they bend symmetrically to the right and to the left away from one another with an E-bend in each case at an angle of α. Here a and a_T are the breadth dimensions of the broad side walls and b and b_T are the breadth dimensions of the narrow side walls of the respective waveguides. The optimum bevelling height y_{Eopt} for the wide-band matching of the series junctions 8 and 12 is disclosed in the European Patent Application 0 196 065. The bevelling plane extends at right angles to the median lines Wh_E of each E-bend 22.

In accordance with the Figures, the series junctions 8 and 12 are adjoined in each subsidiary arm, 18,19 and 20,21 respectively, by an E-bend, 23 or 23', which has the same bend angle α in the opposite bending direction and the same bevelling

height y_{Eopt} as the preceding E-bend 22 of the series junctions 8 and 12 respectively. The distance l_K between these consecutive E-bends 22 and 23 is selected to be such that between their internal broad side walls the rectangular waveguide arms 9,10 and 14,15, which extend in parallel to one another, have an internal width W which is at least somewhat greater than the broad side a_T of the rectangular waveguide arms 9,10 and 14,15. Therefore the two waveguide forks 7 and 11 fit freely into one another without inter-penetration.

In the Figures, by way of an example the two H-bends 13 and (concealed) 13' of the angled waveguide fork 11 have a bend angle of 90° and are dimensioned for optimum wide-band matching, as is known from the DE-PS 28 56 733. Thus, by virtue of an increased bevel 24 of their outer corner and, as compensation for the latter by virtue of a capacitance on the median line Wh_H, these H-bends, 13 and 13', are low in reflection over a substantially wider band than conventional H-bends. This capacitance is formed by a metal cylinder 25 whose axis extends at right angles to the median line Wh_H.

It is of significance that consecutive waveguide bends in each of the two waveguide forks 7 and 11 must be spaced from one another by a distance which is adequate in respect of the respective requirements. A necessary criteria is the aperiodic attenuation of the line sections with the lengths l_{E11} and l_{H20} in Figure 1 for the respective interference wave-type (which consists of the E_{11}-wave in the case of the E-bend and the H_{20}-wave in the case of the H-bend) and at the highest critical operating frequency

in this respect. In the case of the straight waveguide fork 7 the aperiodic E_{11}-attenuation also defines the smallest possible length l_{E11min} of the two rectangular waveguide arms 9 and 10. This length l_{E11min} sufficiently weakens the interaction between the E-bend 23 of the fork 7 and the E-bend 26 at the input of the double junction 1. This E-bend 26 forms part of the double junction 1 which is present in the same way in all four arms of the double junction 1.

If the electric wavelength of the angled fork 11 is determined, for example, by l_{H20} and l_K, the length l_{E11} of the rectangular waveguide arms 9 and 10 of the straight waveguide fork 7 can be selected to be such that the two continuous paths of the polarisation filter are of the same electrical length at a predetermined frequency. For a rational series production it is favourable to divide the pair of forks corresponding to Figure 2 by a dividing plane T-T' into two mirror-inverted identical parts. The plane T-T' is the central plane of the first waveguide fork 7, which is free of reactive current.

Because of its large band-width (e.g. fmax/fmin = 1.7), the polarisation filter illustrated in the Figures is particularly suitable for a frequency filter to be directly connected to its polarisation-selective channels to the rectangular waveguides 16 and 17. Also the connection between the two channels to the rectangular waveguides 16 and 17 of the polarisation filter and the two frequency filters in accordance with the invention can be established by two long lines which consist, for example, of

over-modulated rectangular waveguides provided with corresponding transitions and which, by virtue of all conceivable measures to extend their transmission frequency range, are each suitable to transmit more than one radio relay frequency range of the same polarity from the location of the frequency filters, e.g. at the base of an antenna tower, with low-attenuation, low-reflection and low-transit distortion to the polarisation filter of the antenna arranged on the tower, and back.

The claims defining the invention are as follows:

1. A microwave polarisation filter comprising a five-armed double junction of symmetrical construction which couples a waveguide of round or square cross-section, extending in the direction of the longitudinal axis, into a first pair and a second pair of diametrically-opposed rectangular waveguides, the first pair being fed by a first inherently symmetrical waveguide fork and the second pair being fed by a second inherently symmetrical waveguide fork, the first waveguide fork being formed by a symmetrical rectangular waveguide series junction consisting of two outwardly-directed E-bends, formed of a rectangular waveguide angled component bent along the waveguide broad side, and two straight rectangular waveguide arms each of which being connected to the series junction via an E-bend, extend parallel to one another, and continue into the two opposite rectangular waveguides of the first pair of diametrically-opposed rectangular waveguides, and second waveguide fork likewise comprising a symmetrical rectangular waveguide series junction, composed of two outwardly-directed E-bends, and two rectangular waveguide arms which are each connected to the series junction via an E-bend extend in parallel to one another, and continue into the two opposite rectangular waveguides of the second pair of diametrically-opposed rectangular waveguides, the series junction of the second waveguide fork being arranged outside the first waveguide fork next to the external broad side wall of the first rectangular waveguide arm of the first waveguide fork, the two rectangular waveguide arms of the second waveguide fork each being provided with an H-bend, formed of a rectangular waveguide angled component bent along the waveguide narrow side, extending parallel in relation to the plane of symmetry of the waveguide fork, and continuing directly

into the two oppositely-located rectangular waveguides of the assigned pair in the double junction, the internal width between the inner broad side walls of the two oppositely-located rectangular waveguide arms of the second waveguide fork being contrived to be at least somewhat greater than the broad side dimension of the two rectangular waveguide arms of the first waveguide fork, so that the rectangular waveguide arms which each lead via the H and E-bend to the series junction of the second waveguide fork, embrace the first rectangular waveguide arm and a subsidiary arm of the first waveguide fork which leads to the latter from the series junction.

2. A polarisation filter as claimed in Claim 1, in which the two series junctions are formed with the correct surge impedance and indeed in each case with a normal rectangular waveguide profile of $a \approx 2b$ at the external polarisation filter terminal and with a profile of, in each case $a_T \approx 4b_T$ on the side of the two rectangular waveguide arms, where:

a) a_T is the breadth of the broad side walls; and

b) b_T is the breadth of the narrow side walls.

3. A polarisation filter as claimed in Claim 1 or Claim 2, in which the E-bends are symmetrically-bevelled at the outer corner.

4. A polarisation filter as claimed in any preceding Claim, in which the angle of the E-bends in the series junctions is identical to the angle of the E-bends at the transition to the connected parallel rectangular waveguide arms but in the opposite bending direction.

5. A polarisation filter as claimed in Claim 4, when dependent upon Claim 3, in which the E-bends in the series junctions and the E-bends at the transition to the connected rectangular waveguide arms have the same bevelling heights.

6. A polarisation filter as claimed in any preceding Claim, in which in the case of the second waveguide fork the distance between an E-bend in the series junction and the following E-bend at the transition to the connected rectangular waveguide arm is selected to be such that the parallel rectangular waveguide arms have the requisite internal width.

7. A polarisation filter as claimed in any preceding Claim, in which the two H-bends of the second waveguide fork have a bending angle of 90°.

8. A polarisation filter as claimed in any preceding Claim, in which the respective outer corner of the two H-bends of the second waveguide fork is provided with an increased bevel, and by way of a capacitive counter-compensating means to this bevel, a metal cylinder is provided which extends between the bevelling plane and the inner bending edge on the median line.

9. A polarisation filter as claimed in any preceding Claim, in which the mutual distances between consecutive waveguide bends in each waveguide fork are sufficiently great, in respect of the need for an aperiodic E_{11}-interference field attenuation in the case of the E-bends and an aperiodic H_{20}-interference field attenuation in the case of the H-bends at the highest critical operating frequency in this respect.

10. A polarisation filter as claimed in Claim 9, in which the smallest possible length of the two straight rectangular waveguide arms of the first waveguide fork is governed by the requisite aperiodic E_{11}-interference field attenuation.

11. A polarisation filter as claimed in Claim 10, ~~when dependent upon Claim 9,~~ in which following the determination both of the wavelength between the double junction and the H-bends in the second waveguide fork, and of the wavelength between the E-bends of the series junction and the E-bends in the transitions to the parallel rectangular waveguide arms of the same waveguide fork, the length of the two straight rectangular waveguide arms in the first waveguide fork is selected to be such that the two continuous paths of the polarisation filter are identical at a predetermined operating frequency.

12. A polarisation filter as claimed in any preceding Claim, in which a design is used consisting of two mirror-inverted identical components, where the mirror plane is formed by the central plane of the first waveguide fork, which is free of reactive current.

13. A polarisation filter as claimed in any preceding Claim, in which a frequency filter is directly connected to each of the two polarisation-selective rectangular waveguide supply channels.

14. A polarisation filter as claimed in any one of Claims 1 to 12, in which the two polarisation-selective rectangular waveguide supply channels are each connected to a frequency filter via a long line in the form of an over-modulated rectangular waveguide provided with corresponding junctions.

15. A polarisation filter substantially as described with reference to the drawings.

DATED this SIXTEENTH day of FEBRUARY 1988
Siemens Aktiengesellschaft

Patent Attorneys for the Applicant
SPRUSON & FERGUSON

FIG 1

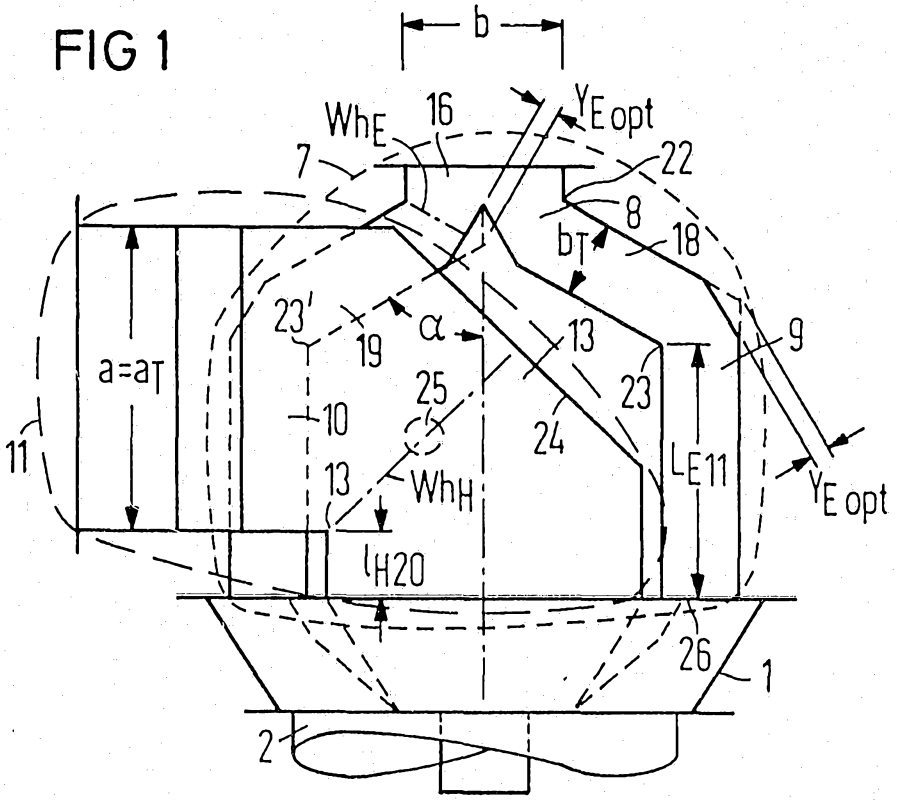
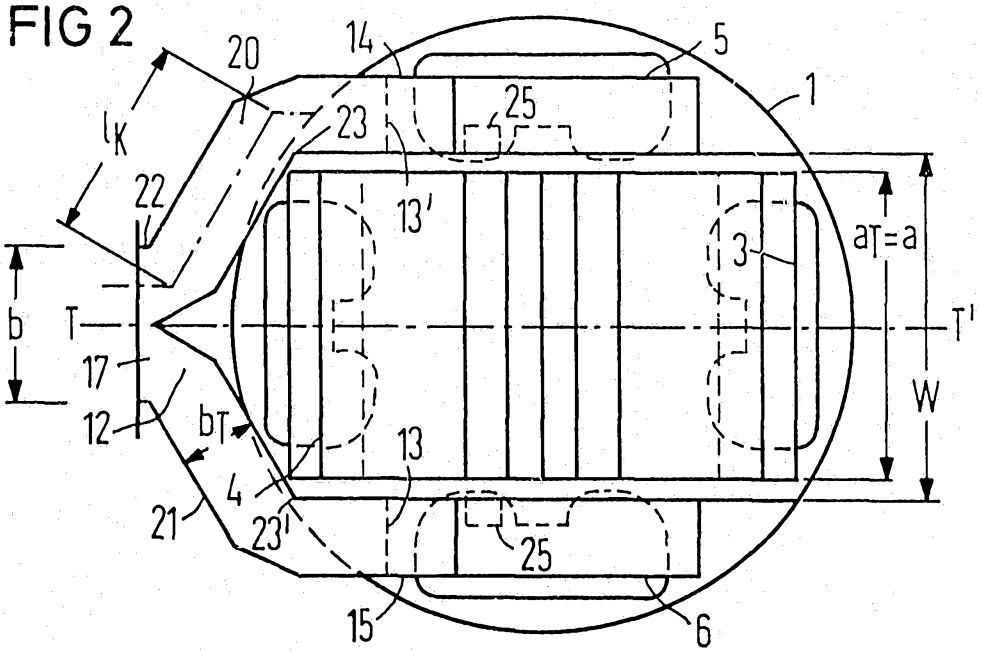

b
WhE
16
YE opt
7
22
8
bT
18
23'
19
α
13
9
a=aT
25
23
10
24
LE11
11
13
WhH
YE opt
lH20
26
1
2

FIG 2


20
14
5
1
lK
23
25
22
13'
aT=a
3
b
T
T'
17
W
12
bT
13
4
21
23'
25
15
6