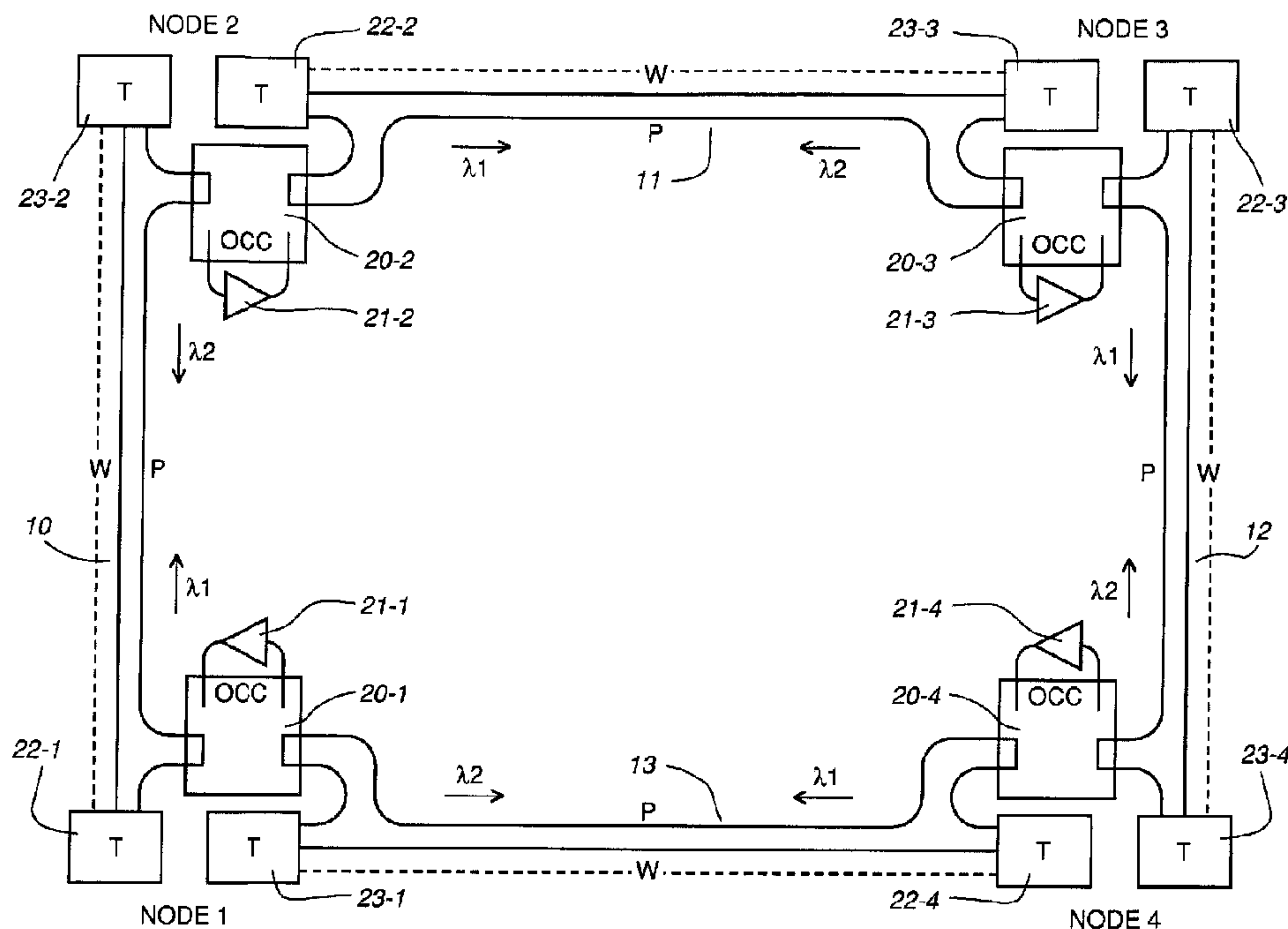




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 (72) Inventeurs/Inventors:  
 Flanagan, Thomas P. J., US;  
 Elahmadi, Siraj E., US  
 (73) Propriétaire/Owner:  
 NORTEL NETWORKS LIMITED, CA  
 (74) Agent: SMART & BIGGAR

(54) Titre : SYSTEME DE COMMUNICATION OPTIQUE  
 (54) Title: OPTICAL COMMUNICATION SYSTEM



(57) **Abrégé/Abstract:**

A discontinuous ring is formed by separate bidirectional optical communication links, with possibly different transmission speeds, synchronous or asynchronous transmission, and ratios of working to protection channels, each linking a pair of terminals in different nodes of a communication system. To protect protection-switched traffic on a communication link from a link failure, it is routed around the ring via the protection channel of the other communication links. To this end, an optical switch is provided between the protection channel of each link and the associated terminals in each node, and is controlled differently in nodes adjacent the link failure and in nodes not adjacent the link failure to route the protection-switched traffic accordingly. Rapid protection switching is facilitated by controlling the optical switches using wavelength detectors directionally coupled to the protection channel at each node.

Abstract of the Disclosure

A discontinuous ring is formed by separate bidirectional optical communication links, with possibly different transmission speeds, synchronous or asynchronous transmission, and ratios of working to protection channels, each linking a pair of terminals in different nodes of a communication system. To protect protection-switched traffic on a communication link from a link failure, it is routed around the ring via the protection channel of the other communication links. To this end, an optical switch is provided between the protection channel of each link and the associated terminals in each node, and is controlled differently in nodes adjacent the link failure and in nodes not adjacent the link failure to route the protection-switched traffic accordingly. Rapid protection switching is facilitated by controlling the optical switches using wavelength detectors directionally coupled to the protection channel at each node.

## 1 TITLE OF THE INVENTION

2 STEERING SYSTEM FOR WORKING VEHICLE AND THE METHOD THEREOF

3  
4 BACKGROUND OF THE INVENTION

## 5 1. Field of the Invention

6 The present invention relates to a steering system  
7 and method of a working vehicle and specifically to a steer-  
8 ing system and method of a working vehicle used for lawn  
9 mowing, agricultural works, construction works and the like.

## 10 2. Prior Arts

11 Generally, it is desirable that a turning radius  
12 of a working vehicle is as small as possible from the view-  
13 point of the working efficiency and handlingability. There  
14 are so many techniques for reducing the turning radius of  
15 vehicles used for miscellaneous indoor or outdoor works.  
16 Among them, Japanese Unexamined Patent Application Toku-Kai-  
17 Sho 59-6170 discloses a steering linkage mechanism by which  
18 when a steering wheel is turned, an axle housing is swung in  
19 the steering direction and at the same time each wheel pro-  
20 vided at the both ends of the axle housing is pivotably  
21 turned for steering.

22 Further, Japanese Unexamined Patent Application  
23 Toku-Kai-Sho 63-203473 discloses a steering mechanism in  
24 which, when a steering wheel is turned, an axle housing is  
25 swung in the steering direction so as to increase the steer-  
26 ing angle of wheels after front wheels are turned at a speci-

1       fied angle.

2               Further, Japanese Unexamined Patent Application  
3 Toku-Kai-Sho 61-18567 proposes a mechanism in which, when a  
4 steering wheel is turned, front wheels are turned and at the  
5 same time a vehicle body is folded at the middle portion  
6 thereof so as to increase the steering angle of the front  
7 wheels.

8               Furthermore, Japanese Unexamined Patent Applica-  
9 tion Toku-Kai-Hei 1-108909 presents a steering control mecha-  
10 nism, or a so-called "fourwheel steering mechanism" in which  
11 both front and rear wheels are pivotably turned in the ad-  
12 verse direction to each other so as to reduce a turning  
13 radius of the vehicle.

14              In recent years, autonomous running type lawn  
15 mowing vehicles which can mow the lawn of golf courses un-  
16 mannedly have been proposed. These vehicles are required to  
17 mow the lawn in such a way that the going pass and the  
18 returning pass come alternately with an exactly equal inter-  
19 val and that no uncut lawn is left. Further, since they must  
20 run about in a vast area, quick directional turnings are re-  
21 quired. Further, when those vehicles make U-turns, they are  
22 required to be operated so as not to damage the lawn by  
23 turning wheels.

24              However, in the steering mechanisms according to  
25 Toku-Kai-Sho 59-6170, Toku-Kai-Sho 63-203473 and Toku-Kai-Sho  
26 61-18567, when the axle housing is swung in the horizontal

1 plane with the front wheels held at an angle, the front  
2 wheels give a damage to the lawn due to the side slip. Fur-  
3 ther, since first the front wheels are pivotably turned and  
4 then the axle housing is swung in the horizontal plane, it is  
5 difficult to make a quick turn on the lawn. Furthermore, the  
6 fourwheel steering mechanism according to Toku-Kai-Hei 1-  
7 108909 contains defects that it needs a sophisticated tech-  
8 nology and its manufacturing cost is high. Further, the  
9 weight of the vehicle is so heavy that the high ground pres-  
10 sure gives a damage to the lawn.

#### 11 12 SUMMARY OF THE INVENTION

13 Accordingly, the present invention is intended to  
14 obviate the abovementioned problems and disadvantages of the  
15 prior arts and the objects of the present invention will be  
16 summarized as follows.

17 An object of the present invention is to provide a  
18 steering system of a working vehicle capable of making a turn  
19 with a minimal turning radius and of quickly moving to the  
20 next pass.

21 Another object of the present invention is to  
22 provide a steering system of a working vehicle capable of  
23 entering the next pass with a high precision.

24 Further object of the present invention is to  
25 provide a steering system of a working vehicle capable of  
26 making a U-turn without damaging the lawn.

1            Still further object of the present invention is  
2 to provide a steering system having a simple construction and  
3 a right weight.

4            To achieve these objects mentioned above, the  
5 steering system according to the present invention comprises:

6            means for swinging an axle housing in a horizontal  
7 plane about an axis provided in a vehicle at a specified  
8 swinging angle and for fixing the axle housing at the swing-  
9 ing angle while a steering wheel rotatably connected with a  
10 king pin provided in the axle housing is fixed at a neutral  
11 position;

12           means for rotating said the wheel about the king  
13 pin at a specified steering angle according to an Ackermann's  
14 steering condition and for fixing the steering wheel at the  
15 specified steering angle while the axle housing is fixed at  
16 the specified swinging angle;

17           means for rotating the steering wheel according to  
18 the Ackermann's steering condition from the specified steer-  
19 ing angle back to a neutral position and fixing the steering  
20 wheel at the neutral position;

21           means for swinging the axle housing from the  
22 specified swinging angle to a position where the axle housing  
23 and a lengthwise center line of the vehicle meet orthogonally  
24 and for fixing the axle housing at the position; and

25           means for rotating the steering wheel about the  
26 king pin discretionally while the axle housing is fixed at

1 the position.

2

3 BRIEF DESCRIPTION OF THE DRAWINGS

4 A specific embodiment of the present invention  
5 will be described with reference to the accompanying draw-  
6 ings, in which:

7 Fig. 1 is a side view showing a chassis construc-  
8 tion of a working vehicle equipped with a steering system  
9 according to the present invention;

10 Fig. 2 is a rear view showing a rear axle housing  
11 according to the present invention;

12 Fig. 3 is a plan view showing a rear axle housing  
13 according to the present invention;

14 Fig. 4 is a side view showing a rear axle housing  
15 according to the present invention;

16 Fig. 5 is a longitudinal sectional view showing a  
17 hydraulic cylinder for swinging a rear axle housing according  
18 to the present invention;

19 Fig. 6 is a diagram showing a hydraulic circuit  
20 for controlling a rear wheel steering cylinder and a rear  
21 axle housing swinging cylinder;

22 Fig. 7 is a block diagram showing a steering  
23 control according to the present invention;

24 Fig. 8 is a flowchart of a steering control when a  
25 vehicle makes a U-turn;

26 Fig. 9 and Fig. 10 are flowcharts of a steering

1 control when a vehicle makes a U-turn to the right;

2 Fig. 11 is a plan view showing a state of a rear  
3 axle housing swung to the left at a specified angle with  
4 rear steering wheels fixed at a neutral position;

5 Fig. 12 is a plan view showing a state of a rear  
6 axle housing swung to the left at a specified angle with rear  
7 steering wheels rotated about a king pin in the same direc-  
8 tion as the rear axle housing at a specified angle.

9 Fig. 13 is a plan view showing a working vehicle  
10 when making a U-turn with a minimal turning radius in a state  
11 of a rear axle housing swung to the left at a specified angle  
12 with rear steering wheels rotated about a king pin in the  
13 same direction as the rear axle housing at a specified angle;  
14 and

15 Fig. 14 is a flowchart of an operation of hydrau-  
16 lic control valves when the steering is returned to the  
17 neutral position.

#### 18 19 DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

20 Referring now to Fig. 1, numeral 1 denotes an  
21 autonomous running type lawn mowing vehicle which can mow the  
22 lawn in a golf course unmannedly and autonomously according  
23 to a navigation method comprising a position recognition  
24 using a GPS (Global Positioning System) navigation method, an  
25 earth magnetism sensor, an encoder for detecting the wheel  
26 speed or the like, a trace running using a boundary detecting



1 sensor for detecting a boundary between the mowed and unmowed  
2 areas, and a course selection according to a running program.

3 A driving force generated in an engine 3 which is  
4 installed at the rear of a chassis frame 2 is transferred to  
5 a HST (Hydraulic Static Transmission) type transmission 5  
6 through a propeller shaft 4. The driving force subjected to a  
7 speed change in the transmission 5 is transmitted to a dif-  
8 ferential gear provided in a front axle housing 6 to drive  
9 left and right front wheels 7. On the other hand, a driving  
10 force picked up from a gear box 8 provided in the front axle  
11 housing 6 is transmitted to a differential gear provided in a  
12 rear axle housing 10 through a propeller shaft 9 to drive  
13 left and right rear wheels 11. That is to say, the vehicle 1  
14 is a fourwheel drive type working vehicle driven by both the  
15 pairs of front wheels 7 and rear wheels 11 (since in this  
16 embodiment rear wheels are rotatable for steering the vehi-  
17 cle, referred to as "steering wheels" hereinafter). Further,  
18 in this working vehicle 1 a lawn mowing machine 12 is sus-  
19 pended from a suspension mechanism (not shown) provided at  
20 the front of the chassis frame 2.

21 Referring to Fig. 2, a pair of bevel knuckles, a  
22 left one 14L and a right one 14R are pivotably connected  
23 about a king pin 13 with a left and right end of the rear  
24 axle housing 10. The left and right rear wheels 11L and 11R  
25 are respectively connected with left and right hubs 15 driven  
26 by a gear mechanism built in the bevel knuckles 14L and 14R.

1 Further, as shown in Fig. 3 and Fig. 4, the rear axle housing  
2 10 is connected at the lower portion thereof with a lower  
3 plate 17 and a control plate 19 is connected with the lower  
4 plate 17 swingably about a pivot 18 in the transversal  
5 direction of the vehicle on the horizontal plane. Further, a  
6 pair of left and right tie-rods 20 are connected at one end  
7 thereof with the front end of the control plate 19 and con-  
8 nected at the other end thereof with the left and right bevel  
9 knuckles 14L and 14R respectively. Generally, this mechanism  
10 is called "Ackermann steering mechanism".

11 Further, the rear axle housing 10 is connected at  
12 the upper portion thereof with an upper plate 21 and an arm  
13 22 is fixed to the upper portion of the right bevel knuckle  
14 14R. Between the upper plate 21 and the arm 22 there is  
15 provided a hydraulic cylinder 23 for steering the rear steer-  
16 ing wheels. Thus, when the hydraulic cylinder 23 is expanded,  
17 the rear right steering wheel 11R is turned around the king  
18 pin 13 to the right and at the same time the rear left steer-  
19 ing wheel 11L is turned around the king pin 13 to the right  
20 with respect to the rear axle housing 10 by means of the  
21 above Ackermann steering mechanism. On the contrary, when the  
22 hydraulic cylinder 23 is contracted, the rear steering wheels  
23 11R and 11L are turned to the left with respect to the rear  
24 axle housing 10. Since this working vehicle 1 introduces a  
25 rear wheel steering method, when the rear steering wheels 11  
26 are steered to the right, the working vehicle 1 is turned to

1 the left and when the rear steering wheels 11 are steered to  
2 the left, the working vehicle 11 is turned to the right.

3 Further, as shown in Fig. 3, a steering angle  
4 sensor 25 is disposed at the left end of the rear axle hous-  
5 ing 10. The steering angle sensor 25 is operated by a rod 28  
6 connecting a lever 26 fixed to the steering angle sensor 25  
7 and a lever 27 fixed to the left bevel knuckle 14L. The  
8 purpose of the steering angle sensor 25 is to detect a rela-  
9 tive steering angle of the rear left steering wheel 11L with  
10 respect to the rear axle housing 10, i.e., an inclination  
11 angle formed by an axle line RC of the rear axle housing 10  
12 and a wheel axle line WL of the rear left steering wheel 11L.

13 Further, as shown in Fig. 4, the rear axle housing  
14 10 is pivotably connected at the upper portion thereof with a  
15 rear cross member 31 fixed to the rear part of the chassis  
16 frame 2 through an upper ball-and-socket joint 32. On the  
17 other hand, the chassis frame 2 is connected at the rear end  
18 thereof with a trailing rod 34 extended in the obliquely  
19 forward and downward direction through a pair of rubber  
20 bushings 35 and the trailing rod 34 is connected at the other  
21 end thereof with the lower plate 17 through a lower  
22 ball-and-socket joint 36 whose ball-with stud is bolted on  
23 the lower surface of the rear axle housing 10. Since the  
24 upper ball-and-socket joint 32 and the lower ball-and-socket  
25 joint 36 share a common axis extended vertically, the rear  
26 axle housing 10 swings on the horizontal plane or yaws about

1 the common axis, that is, a yawing axis 37 in the steering  
2 (yawing) direction. Further, since the rear axle housing 10  
3 is pivotably connected with the chassis frame 2 through the  
4 ball-and-socket joint 32, the rear axle housing 10 can make  
5 rolling motions around the ball-and-socket joint 32 so as to  
6 be able to follow up the running on uneven roads. When the  
7 rear axle housing 10 makes rolling motions, the end of the  
8 trailing rod 34 swings pivotably about the rubber bushings 35  
9 in the widthwise direction of the vehicle.

10 On the other hand, as illustrated in Fig. 2 and  
11 Fig. 3, there is provided a hydraulic cylinder 40 for apply-  
12 ing a yawing motion to the rear axle housing 10 between the  
13 upper plate 21 and the bracket 29 fixed to the vehicle body.  
14 As shown in Fig. 5, the hydraulic cylinder 40 comprises a  
15 pair of cylinders 42 and 43 having the same stroke. The  
16 hydraulic cylinder 40 is constituted by a pair of the left  
17 and right cylinders 42, 43 connected with each other on the  
18 same axis through a partition wall 41, a pair of stoppers 44,  
19 45 for closing an open end of each cylinder, a pair of pis-  
20 tons 48, 49 slidably inserted in the cylinder 42, 43, a pair  
21 of pressure chambers 46, 47 provided inside of the cylinders  
22 42, 43 and a pair of piston rods 50, 51 connected at an end  
23 thereof with the pistons 48, 49. The end of the piston rod  
24 50 is connected with the aforementioned upper plate 21  
25 through a ball-and-socket joint 52 and the end of the piston  
26 rod 51 is connected with the bracket 29 grounded on the

1 vehicle body through a ball-and-socket joint 53.

2 Pressure oil is supplied to the hydraulic cylinder  
3 40 through ports A, B, C and D provided in the cylinders 42,  
4 43 and the partition wall 41. When pressure oil is fed to the  
5 ports A and B, the pistons 48 and 49 travel inward and final-  
6 ly come into contact with the partition wall 41 respectively.  
7 With this movement of the pistons, the rods 50, 51 are in-  
8 truded into the cylinders 42, 43 and the total length L of  
9 the cylinder 40 becomes shortest (most contracted condition).  
10 When pressure oil is fed to the ports C and D, the pistons  
11 48, 49 travel outward and finally come into contact with the  
12 stoppers 44, 45 respectively. Being accompanied with this,  
13 the rods 50, 51 are protruded out of the cylinders 42, 43  
14 respectively and the total length L of the cylinder 40 be-  
15 comes longest (most expanded condition). On the other hand,  
16 when pressure oil is supplied to the ports A and C, the rod  
17 50 is intruded into the cylinder 42 and the rod 51 is pro-  
18 truded from the cylinder 43. Further, when pressure oil is  
19 supplied to the ports D and B, the rod 50 is protruded from  
20 the cylinder 42 and the rod 51 is intruded into the cylinder  
21 43. In these conditions, the total length L of the hydraulic  
22 cylinder 40 becomes medium (intermediate condition). Thus,  
23 according to the way of supplying pressure oil, the hydraulic  
24 cylinder 40 for yawing the rear axle housing can be retained  
25 and fixed in any condition among "most contracted condition,  
26 "most expanded condition" and "intermediate condition".

1           When the hydraulic cylinder 40 is fixed in "most  
2 contracted condition", the rear axle housing 10 is yawed  
3 about the yawing axis 37 clockwise on the plan view at a  
4 specified angle (in this embodiment 15 degrees) and fixed at  
5 that position. When the hydraulic cylinder 40 is fixed in  
6 "most expanded condition", the rear axle housing 10 is yawed  
7 about the yawing axis 37 counterclockwise on the plan view at  
8 a specified angle (15 degrees) and fixed at that position. On  
9 the other hand, when the hydraulic cylinder 40 is fixed in  
10 "intermediate condition", the rear axle housing 10 is fixed  
11 in a "not yawed state", namely at a state where the axle line  
12 RC of the rear axle housing 10 is extended orthogonally with  
13 respect to the longitudinal direction of the vehicle.

14           Further, there is provided an L-shaped bracket 54  
15 on the cylinders 42, 43 of the hydraulic cylinder 40 respec-  
16 tively. Further, a stop plate 55 is connected with the rod  
17 50, 51 respectively. Further, at the bracket 54 on the left  
18 side there are provided limit switches 56 and 57 for detect-  
19 ing "most expanded condition" and "most contracted condition"  
20 of the rod 50 respectively by the contact of the stop plate  
21 55 with these limit switches. Similarly, at the bracket 54 on  
22 the right side there are provided limit switches 58 and 59  
23 for detecting "most expanded condition" and "most contracted  
24 condition" respectively.

25           Next, a hydraulic circuit to control the hydraulic  
26 cylinder 23 for steering the rear wheels and the hydraulic

1 cylinder 40 for yawing the rear axle housing will be de-  
2 scribed with reference to Fig. 6.

3 An operation of the hydraulic cylinder 23 is  
4 controlled by a solenoid operated directional control valve  
5 61 of the 4 ports-3 positions type. Further, an operation of  
6 the hydraulic cylinder 40 is controlled by a pair of solenoid  
7 operated directional control valves 62, 63 of the 4 ports-3  
8 positions type. Pressure oil is supplied to these directional  
9 control vales 61, 62 and 63 from a hydraulic pump 64 driven  
10 by the engine 3.

11 On the other hand, referring to Fig. 7, the steer-  
12 ing angle sensor 25, the limit switches 56, 57, 58 and 59 are  
13 connected with a hydraulic controller 65 respectively. Fur-  
14 ther, there is provided an autonomous running controller 66  
15 to send miscellaneous instruction signals for controlling the  
16 autonomous running of the working vehicle 1 to the hydraulic  
17 controller 65. The hydraulic controller 65 acts as selecting  
18 these directional control valves 61, 62 and 63 based on those  
19 instruction signals so as to determine the running direction  
20 of the working vehicle 1 by controlling the hydraulic cylin-  
21 der 23 for steering the rear steering wheels and the hydrau-  
22 lic cylinder 40 for yawing the rear axle housing.

23 The abovementioned steering control by the hydrau-  
24 lic controller 65 is performed according to a U-turn control  
25 routine as shown in Fig. 8. That is to say, when the auto-  
26 nomous controller 66 recognizes that the working vehicle 1

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1 reaches an end of a mowing pass and it is judged that the  
2 vehicle must make a U-turn, either a right U-turn switch 67  
3 is turned on or a left U-turn switch is turned on. That is,  
4 at S71 it is judged whether or not the state of the U-turn  
5 switch is changed. If it is judged to be YES, the program  
6 goes to S72 where it is judged whether or not the right U-  
7 turn switch 67 is turned on. If the right U-turn switch 67 is  
8 turned on, the program goes to S73 in which an operation of  
9 the right U-turn is executed.

10 On the other hand, if the right U-turn switch 67  
11 is turned off, the program steps to S74 where it is judged  
12 whether or not the left U-turn switch 68 is turned on. If the  
13 left U-turn switch 68 is turned on, the program goes to S75  
14 where the left U-turn is executed.

15 When the right U-turn is executed at S73 or when  
16 the left U-turn is executed at S75, the program is returned  
17 to S71 where it is judged whether or not the state of the U-  
18 turn switch is changed. If No, the step S71 is repeated at a  
19 specified interval of time until the state of the U-turn  
20 switch is changed.

21 On the other hand, if it is judged at S76 that  
22 the state of the U-turn switch has been changed and both of  
23 the right and left U-turn switches 67, 68 are turned off, the  
24 program steps to S77 where a returning operation to the  
25 neutral position is started.

26 First, an operation of the right U-turn will be



1 described by referring to Fig. 9 and Fig. 10.

2        When the operation of the right U-turn is started,  
3 the hydraulic controller 65 reads the data of the steering  
4 angle sensor 25 and detects a relative steering angle of the  
5 rear left wheel 11L with respect to the rear axle housing 10.  
6 If it is detected at S82 that the rear wheel 11L is deviated  
7 to the right compared to the neutral position, at S83 the  
8 hydraulic controller 65 energizes a solenoid at the terminal  
9 "a" of the directional control valve 61. As a result, the  
10 hydraulic cylinder 23 for steering the rear wheels is con-  
11 tracted so as to correct the rear wheels 11L and 11R to the  
12 left.

13        On the other hand, if it is detected at S84 that  
14 the rear wheel 11L is deviated to the left with respect to  
15 the neutral position, at S85 the hydraulic controller 65  
16 energizes a solenoid at the terminal "b" of the directional  
17 control valve 61, whereby the hydraulic cylinder 23 is ex-  
18 panded so as to correct the rear steering wheels 11L and 11R  
19 to the right.

20        These corrections of the rear steering wheels 11L  
21 and 11R are continued to be made until the relative steering  
22 angle becomes zero with respect to the neutral position. That  
23 is, the steps S81, S82 and S84 are executed until when it is  
24 judged that the steering angle is neither deviated to the  
25 right at S82 nor deviated to the left at S84. When the rela-  
26 tive steering angle is zero with respect to the neutral

1 position, the axle line RC of the rear axle housing 10 is in  
2 parallel with the rotational axis WL of the rear wheel 11L.  
3 At this moment, at S86 the current is stopped to be fed  
4 neither to the terminal "a" nor to the terminal "b" so as to  
5 render the directional control valve 61 to fix at the neutral  
6 position. Thus, the hydraulic cylinder 23 is fixed so as not  
7 to change the length thereof and the rear steering wheels  
8 11R, 11L are fixed at the relative steering angle "zero".

9 Next, when at S87 the current is fed to the termi-  
10 nal "a" of the directional control valve 62 and to the termi-  
11 nal "b" of the directional control valve 63, the rods 50 and  
12 51 of the hydraulic cylinder 40 both are gradually protruded  
13 from the cylinders 42, 43 to give a yaw motion about the  
14 yawing axis 37 to the rear axle housing 10 in the counter-  
15 clockwise direction. At S89 and S90, when it is confirmed  
16 that both the limit switches 56 and 59 are turned on and the  
17 hydraulic cylinder 40 is in "most expanded condition", at S92  
18 and S93, the directional control valves 62 and 63 are posi-  
19 tioned at the neutral position so as to hold the hydraulic  
20 cylinder 40 at "most expanded condition". Thus, the rear axle  
21 housing 10 is yawed by  $\theta$  (in this embodiment 15) degrees  
22 counterclockwise on the plan view as shown in Fig. 10 and is  
23 fixed in this state.

24 In the working vehicle 1 according to this embodi-  
25 ment, after the axis line RC of the rear axle housing 10 is  
26 let to be in parallel with the rotational axes WL and WR of

1 the rear steering wheels 11L and 11R respectively, then the  
2 rear axle housing 10 is yawed about the yawing axis 37.  
3 Therefore, when the rear axle housing 10 is yawed, a side  
4 slip does not occur at the left and right rear steering  
5 wheels 11L and 11R. Further, since the differential gears  
6 absorb a rotational difference between the left and right  
7 steering wheels 11L, 11R, there is no side slip in the rota-  
8 tional direction of the wheels. Thus, according to the work-  
9 ing vehicle 1 of the embodiment the rear axle housing 10 can  
10 be yawed without damaging the lawn.

11 When the rear axle housing 10 finishes the yaw  
12 motion and is fixed at "most expanded condition", at S93 of  
13 Fig. 10 the hydraulic controller 65 feeds current to the  
14 terminal "a" of the directional control valve 61 to contract  
15 the hydraulic cylinder 23 for steering the rear wheels. Thus,  
16 the left and right rear steering wheels 11L and 11R are  
17 steered gradually to the left with the help of the Ackermann  
18 steering mechanism. Since the rear steering wheels 11L and  
19 11R are steered with the rear axle housing fixed, it is  
20 possible to know accurately the steering angle (absolute  
21 steering angle) against the vehicular center line C from the  
22 steering angle sensor 25, therefore the steering angle of the  
23 left and right rear steering wheels 11L and 11R can be con-  
24 trolled precisely. This enables the working vehicle to move  
25 accurately from the mowed pass to the neighboring unmowed  
26 pass. When the rear steering wheels 11L and 11R are steered,

1 since the Ackermann steering mechanism does not produce a  
2 side slip at the left and right steering wheels 11L and 11R,  
3 the lawn is saved from being damaged.

4 At S94, the relative steering angle of the left  
5 rear steering wheel 11L with respect to the rear axle housing  
6 10 is read and when it is judged at S95 that this relative  
7 steering angle is fully steered to the left, at S96 the  
8 hydraulic controller 65 lets the directional control valve 61  
9 in the neutral condition to fix the length of the hydraulic  
10 cylinder 23. Thus, the left and right rear steering wheels  
11 11L and 11R are fixed in a state fully steered to the left.  
12 This state is shown in Fig. 13 by a relative angle  $\alpha$  for the  
13 left rear steering wheel 11L and a relative angle  $\beta$  for the  
14 right rear steering wheel 11R. Further, as referred to Fig.  
15 13, the rotational axis WL of the left rear wheel 11L and the  
16 rotational axis WR of the right rear steering wheel 11R both  
17 are met at a point P with the rotational axis FC of the front  
18 wheels 7. That is to say, the working vehicle 1 makes a turn  
19 around the point P. As can be known from Fig. 13, in the  
20 working vehicle 1 according to the embodiment, when the  
21 vehicle makes a U-turn (turn by 180 degrees) around the point  
22 P, the width of mowing overlaps the next width of mowing and  
23 therefore there is no portion left unmowed.

24 When the right U-turn is finished, the steering  
25 must be returned to the neutral position (a returning opera-  
26 tion to the neutral position). Next, this returning operation

1 will be described with reference to a routine for the return-  
2 ing operation to the neutral position in Fig. 14.

3 Referring to Fig. 14, the autonomous running  
4 controller 66 detects a running direction of the working  
5 vehicle 1 by use of a magnetic direction sensor D mounted on  
6 a mast M of the working vehicle 1. When the vehicle makes a  
7 U-turn to the right and it is detected that the longitudinal  
8 direction of the vehicle is turned by 180 degrees approxi-  
9 mately, the autonomous running controller 66 turns the right  
10 U-turn switch 67 off. Then, at S76 of Fig. 8 the hydraulic  
11 controller 65 detects that both the left and right U-turn  
12 switches 67, 68 are turned off and then a returning operation  
13 to the neutral position is executed at S77.

14 When this returning operation is started, the  
15 hydraulic controller 65 reads the data of the steering sensor  
16 25 at S101 shown in Fig. 14. When the right U-turn operation  
17 is switched to the returning operation, since the steering  
18 angle of the rear wheels is still deviated to the left, the  
19 program goes from S104 to S105 where the terminal "b" of the  
20 directional control valve 61 is energized so as to expand the  
21 cylinder 23 and as a result the rear steering wheels 11 are  
22 steered to the right to reduce the steering angle thereof. At  
23 this moment, no side slip occurs at the left and right rear  
24 steering wheels 11L, 11R with the help of the Ackermann  
25 steering mechanism.

26 When it is confirmed through S101, S102 and S104

1 that the steering angle of the rear steering wheels 11 is  
2 zero, at S106 the directional control valve 61 is set to the  
3 neutral position. As a result of this, the hydraulic cylinder  
4 23 is fixed at the neutral position and the relative steering  
5 angle of the left and right rear steering wheels 11L, 11R is  
6 held to be zero with respect to the rear axle housing 10, as  
7 shown in Fig. 11.

8 When the relative steering angle is returned to  
9 zero, at S107 the hydraulic controller 65 feeds current to  
10 the terminal "b" of the directional control valve 62 so as to  
11 intrude the rod 50 into the cylinder 42. As a result, the  
12 rear axle housing 10 is yawed about the yawing axis 37. At  
13 this moment, since the relative angle of the rear steering  
14 wheels 11 is kept zero with respect to the rear axle housing  
15 10, the lawn is never damaged by the rear steering wheels. In  
16 performing a returning operation of the rear axle housing 10,  
17 the terminal "a" of the directional control valve 63 may be  
18 energized. In this case, the rod 51 is intruded into the  
19 cylinder 43.

20 At S108, when it is confirmed that the limit  
21 switch 57 is operated, the program steps to S109 where the  
22 directional control valve 62 is set to the neutral position,  
23 whereby the hydraulic cylinder 40 for yawing the rear axle  
24 housing 10 gets into "intermediate condition" that the rod 50  
25 at one side has been intruded to the full into the cylinder  
26 42 and the rod 51 at the other side has been protruded to the

1 full from the cylinder 43. Therefore, the rear axle housing  
2 10 is fixed in the neutral position in which the axle line RC  
3 of the rear axle housing 10 is met orthogonally with the  
4 longitudinal center line C of the vehicle.

5 With respect to the left U-turn, the operation is  
6 done in a similar way to the aforementioned right U-turn  
7 operation.

8 Since the working vehicle 1 runs about anywhere in  
9 the field, it must have a function for sometimes going  
10 straight and sometimes making a turn. According to the embod-  
11 iment of the present invention, when the working vehicle 1  
12 makes a small turn other than a U-turn, the steering opera-  
13 tion is performed only by steering the left and right rear  
14 steering wheels 11L, 11R with the rear axle housing held in  
15 "intermediate condition". In this case, the hydraulic con-  
16 troller 65 fixes the rear axle housing 10 at "intermediate  
17 condition" and controls the hydraulic cylinder 23 only.

18 In this embodiment, the yawing and steering mecha-  
19 nisms are all provided on the rear wheel side, however these  
20 may be furnished on the front wheel side. Further, in this  
21 embodiment, the hydraulic cylinder for yawing the rear axle  
22 housing is constituted by a pair of cylinders integrally  
23 connected with each other on a common axis, however this pair  
24 of cylinders may be connected integrally in parallel with  
25 each other.

26 Summarizing the steering system of the working

1 vehicle according to the present invention, since the steer-  
2 ing system is constituted such that the wheels are steered  
3 according to the Ackermann steering mechanism while the axle  
4 housing having those wheels is in a yawed condition against  
5 the longitudinal center line of the vehicle, it is possible  
6 to acquire a substantially large absolute steering angle and  
7 a minimal turning radius. Further, since the axle housing is  
8 yawed by the expansion force or contraction force of the  
9 hydraulic cylinder, the axle housing can make a quick yaw  
10 motion, thereby the working vehicle can perform a swift U-  
11 turn. Further, since the hydraulic cylinder comprises a pair  
12 of cylinders each of which is operated independently, the  
13 length of the hydraulic cylinder can be selected at three  
14 positions, a most expanded condition, a most contracted  
15 condition and an intermediate condition and fixed at these  
16 three positions respectively, whereby the absolute steering  
17 angle of the wheels can be controlled accurately and a cor-  
18 rect steering operation can be attained. The correct steering  
19 operation is important when the working vehicle attempts to  
20 catch the next mowing pass properly. Further, since the axle  
21 housing is yawed while the relative steering angle of the  
22 wheels is zero, the wheels never produce side slips damaging  
23 the lawn, when the axle housing is yawed. Furthermore, since  
24 the steering system according to the present invention has a  
25 simple construction, the weight of the vehicle can be reduced  
26 and therefore less damages are provided on the lawn.



1           While the presently preferred embodiment of the  
2 present invention has been shown and described, it is to be  
3 understood that this disclosure is for the purpose of illus-  
4 tration and that various changes and modifications may be  
5 made without departing from the scope of the invention as set  
6 forth in the appended claims.

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## WHAT IS CLAIMED IS:

1. A steering system for a vehicle having a chassis and an engine mounted on said vehicle for driving said vehicle, comprising:

an axle housing rotatably jointed with said vehicle for swinging about a swinging axis fixed to said chassis in a horizontal plane so as to steer said vehicle;

a king pin axis connected with a left and right end of said axle housing respectively;

a steering wheel rotatably connected about said king pin axis with said axle housing so as to steer said vehicle;

swinging means for swinging said axle housing in a horizontal plane about said swinging axis while said steering wheel is fixed at a neutral position so as to reduce a turning radius of said vehicle; and

rotating means for rotating said steering wheel about said king pin axis so as to steer said vehicle while said axle housing is fixed about said swinging axis.

2. A steering system for a vehicle having a chassis and an engine mounted on said vehicle for driving said vehicle, comprising:

an axle housing rotatably jointed with said vehicle for swinging about a swinging axis fixed to said chassis

in a horizontal plane so as to steer said vehicle;

a king pin axis connected with a left and right end of said axle housing respectively;

a steering wheel rotatably connected about said king pin axis with said axle housing so as to steer said vehicle;

first swinging means for swinging said axle housing in a horizontal plane about said swinging axis at a specified swinging angle and for fixing said axle housing at said swinging angle while said steering wheel is fixed at a neutral position so as to reduce a turning radius of said vehicle;

first rotating means for rotating said steering wheel about said king pin axis at a specified steering angle and for fixing said steering wheel at said specified steering angle while said axle housing is fixed at said specified swinging angle;

second rotating means for rotating said steering wheel from said specified steering angle back to a neutral position and fixing said steering wheel at said neutral position;

second swinging means for swinging said axle housing in a horizontal plane from said specified swinging angle to a position where said axle housing and a lengthwise center line of said vehicle meet orthogonally and for fixing said axle housing at said position; and

third rotating means for rotating said steering wheel about said king pin axis discretionally while said axle housing is fixed at said position.

3. A steering system for a vehicle having a chassis and an engine mounted on said vehicle for driving said vehicle, comprising:

an axle housing rotatably jointed with said vehicle for swinging about a swinging axis fixed to said chassis in a horizontal plane so as to steer said vehicle;

a king pin axis connected with a left and right end of said axle housing respectively;

an Ackermann steering mechanism provided in said axle housing for steering said vehicle according to an Ackermann's steering condition so as to turn said vehicle smoothly without causing a side slip;

a steering wheel rotatably connected about said king pin axis with said axle housing so as to steer said vehicle according to said Ackermann steering mechanism;

swinging means for swinging said axle housing in a horizontal plane about said axis while said steering wheel is fixed at a neutral position so as to reduce a turning radius of said vehicle; and

rotating means for rotating said steering wheel about said king pin axis so as to steer said vehicle while said axle housing is fixed.

4. A steering system for a vehicle having a chassis and an engine mounted on said vehicle for driving said vehicle, comprising:

an axle housing rotatably jointed with said vehicle for swinging about a swinging axis fixed to said chassis in a horizontal plane so as to steer said vehicle;

a king pin axis connected with a left and right end of said axle housing respectively;

an Ackermann steering mechanism provided in said axle housing for steering said vehicle according to an Ackermann's steering condition so as to turn said vehicle smoothly without causing a side slip;

a steering wheel rotatably connected about said king pin axis with said axle housing so as to steer said vehicle according to said Ackermann steering mechanism;

first swinging means for swinging said axle housing in a horizontal plane about said swinging axis at a specified swinging angle and for fixing said axle housing at said swinging angle while said steering wheel is fixed at a neutral position;

first rotating means for rotating said steering wheel about said king pin axis at a specified steering angle and for fixing said steering wheel at said specified steering angle while said axle housing is fixed at said specified swinging angle;

second rotating means for rotating said steering wheel from said steering angle back to a neutral position and fixing said steering wheel at said neutral position;

second swinging means for swinging said axle housing in a horizontal plane from said specified swinging angle to a position where said axle housing and a lengthwise center line of said vehicle meet orthogonally and for fixing said axle housing at said position; and

third rotating means for rotating said steering wheel about said king pin axis discretionally while said axle housing is fixed at said position.

5. The steering system according to claim 1, wherein said swinging means for swinging said axle housing comprise a hydraulic cylinder for applying a force to swing said axle housing about said swinging axis, a solenoid operated directional control valve for controlling said hydraulic cylinder and an electronic control apparatus for controlling said directional control valve.

6. The steering system according to claim 2, wherein said first swinging means for swinging said axle housing and for fixing said axle housing at said swinging angle comprise a hydraulic cylinder for swinging said axle housing about said axis and for fixing said axle housing at said swinging angle, a solenoid operated directional control

valve for controlling said hydraulic cylinder and an electronic control apparatus for controlling said directional control valve.

7. The steering system according to claim 2, wherein said second swinging means for swinging said axle housing from said specified swinging angle to said position and for fixing said axle housing at said position comprise a hydraulic cylinder for swinging said axle housing about said axis and for fixing said axle housing at said swinging angle, a solenoid operated directional control valve for controlling said hydraulic cylinder and an electronic control apparatus for controlling said directional control valve.

8. A steering method of a vehicle having a chassis and an engine mounted on said vehicle for driving said vehicle, an axle housing rotatably jointed with said vehicle for swinging about a swinging axis fixed to said chassis in a horizontal plane so as to steer said vehicle, a king pin axis connected with a left and right end of said axle housing respectively and a steering wheel rotatably connected about said king pin axis with said axle housing so as to steer said vehicle, comprising the steps of:

swinging said axle housing in a horizontal plane about said swinging axis while said steering wheel is fixed at a neutral position so as to reduce a turning radius of

said vehicle; and

rotating said steering wheel about said king pin axis so as to steer said vehicle while said axle housing is fixed about said swinging axis.

9. A steering method of a vehicle having a chassis and an engine mounted on said vehicle for driving said vehicle, an axle housing rotatably jointed with said vehicle for swinging about a swinging axis fixed to said chassis in a horizontal plane so as to steer said vehicle, a king pin axis connected with a left and right end of said axle housing respectively and a steering wheel rotatably connected about said king pin axis with said axle housing so as to steer said vehicle, comprising the steps of:

swinging said axle housing in a horizontal plane about said swinging axis at a specified swinging angle and for fixing said axle housing at said swinging angle while said steering wheel is fixed at a neutral position so as to reduce a turning radius of said vehicle;

rotating said steering wheel about said king pin axis at a specified steering angle and for fixing said steering wheel at said specified steering angle while said axle housing is fixed at said specified swinging angle;

rotating said steering wheel from said specified steering angle back to a neutral position and fixing said steering wheel at said neutral position;



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swinging said axle housing in a horizontal plane from said specified swinging angle to a position where said axle housing and a lengthwise center line of said vehicle meet orthogonally and for fixing said axle housing at said position; and

rotating said steering wheel about said king pin axis discretionally while said axle housing is fixed at said position.

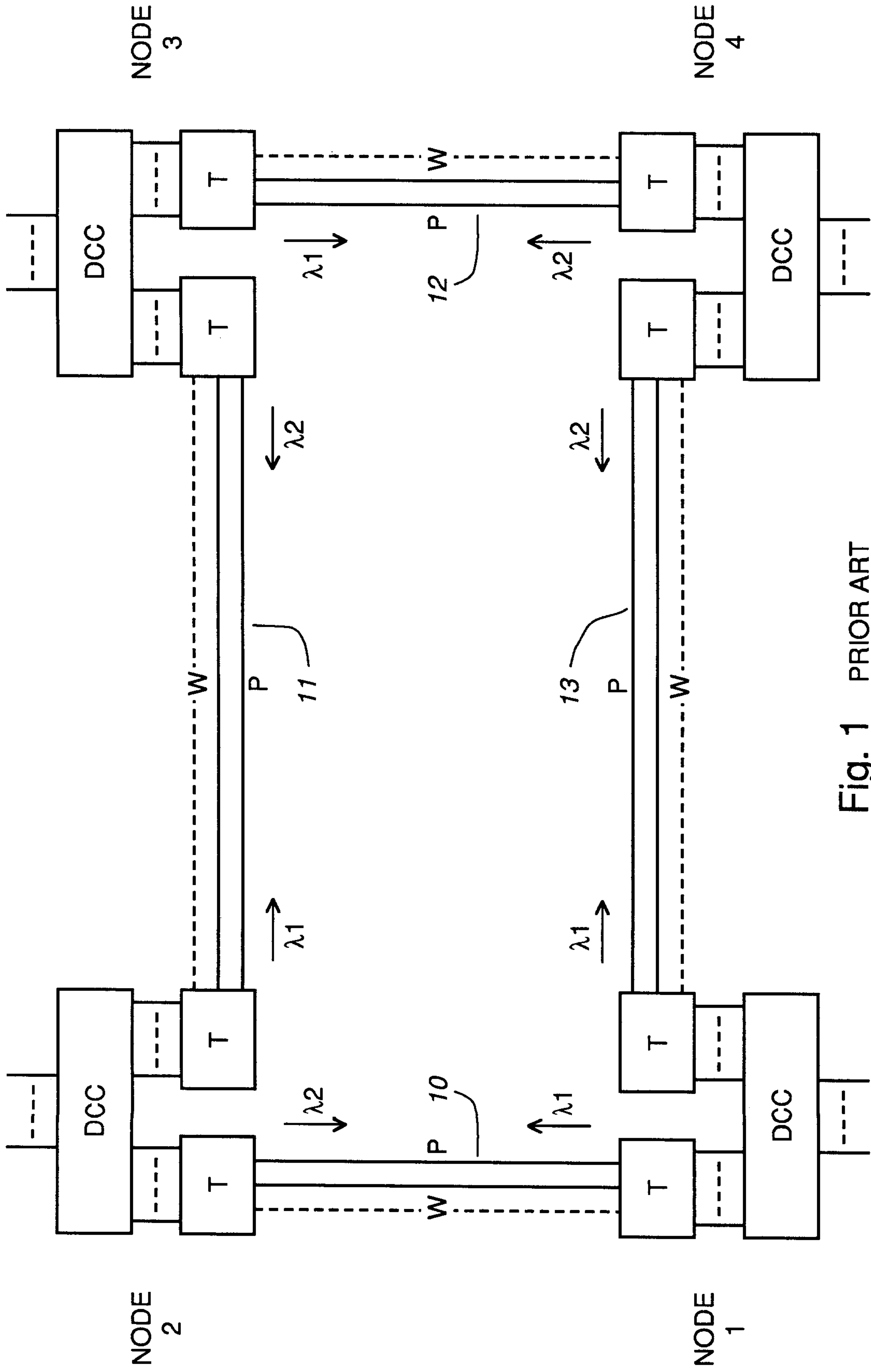


Fig. 1 PRIOR ART



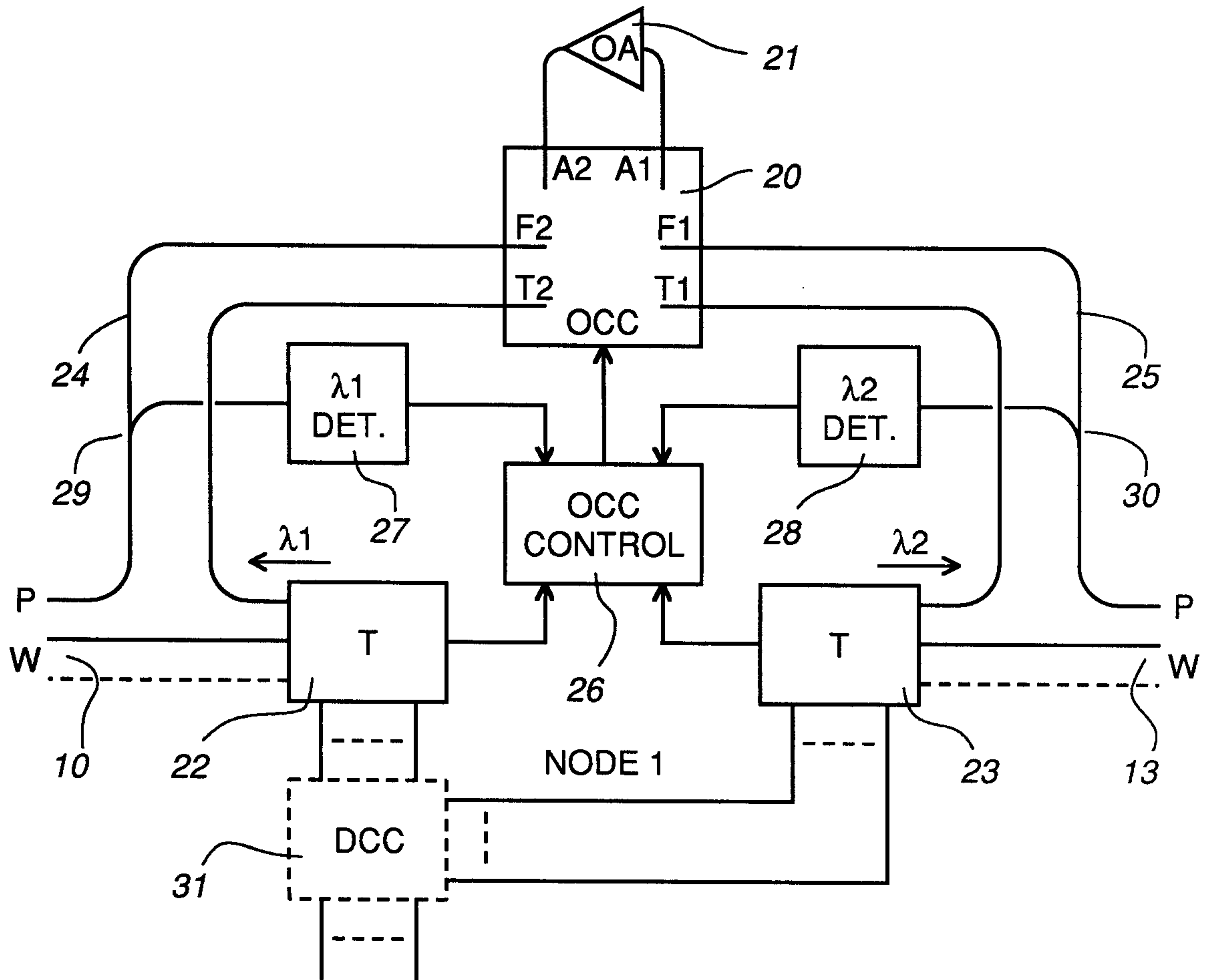


Fig. 2

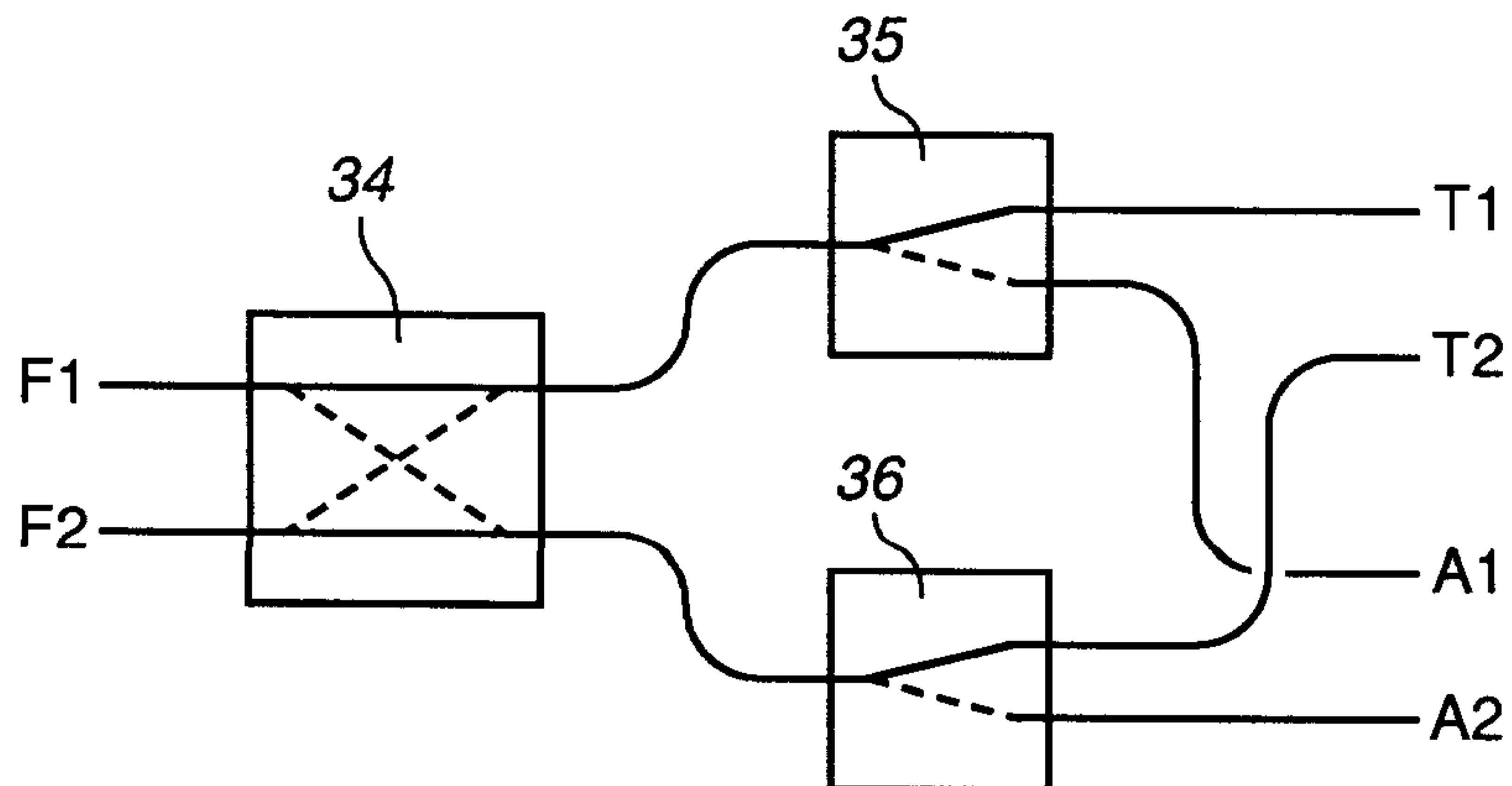


Fig. 3

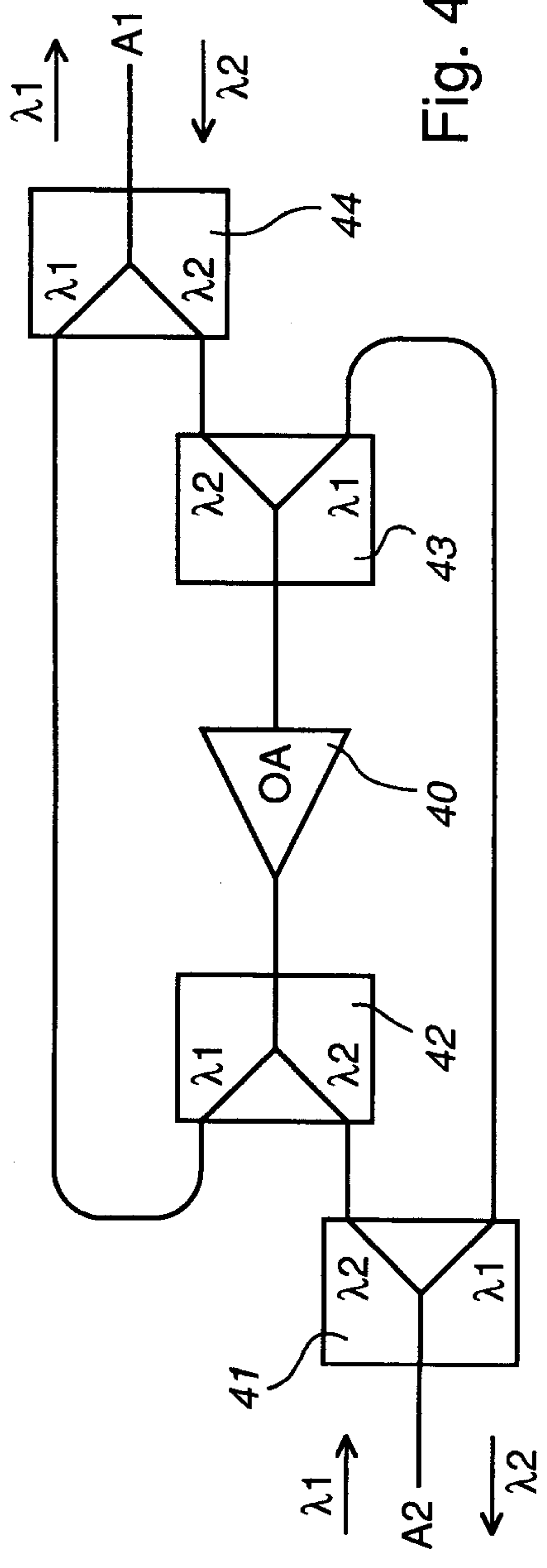


Fig. 4

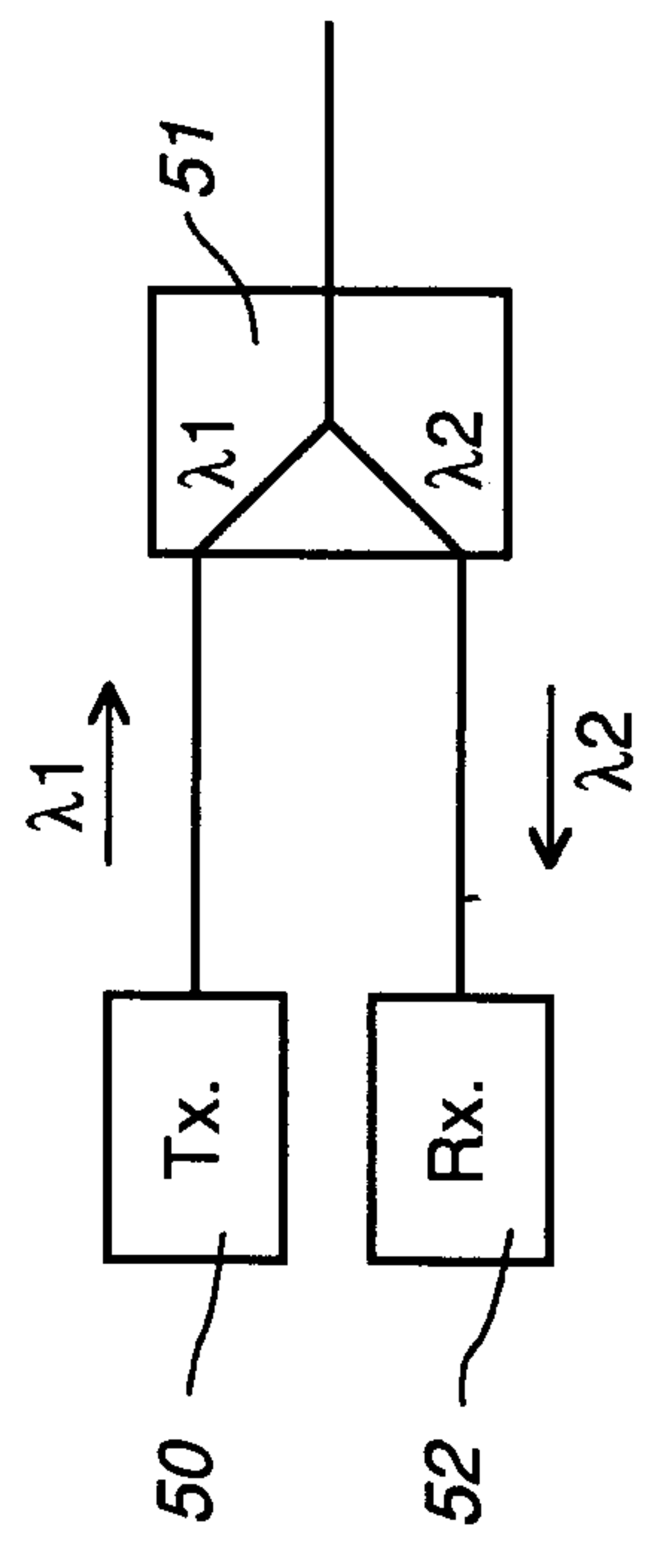


Fig. 5

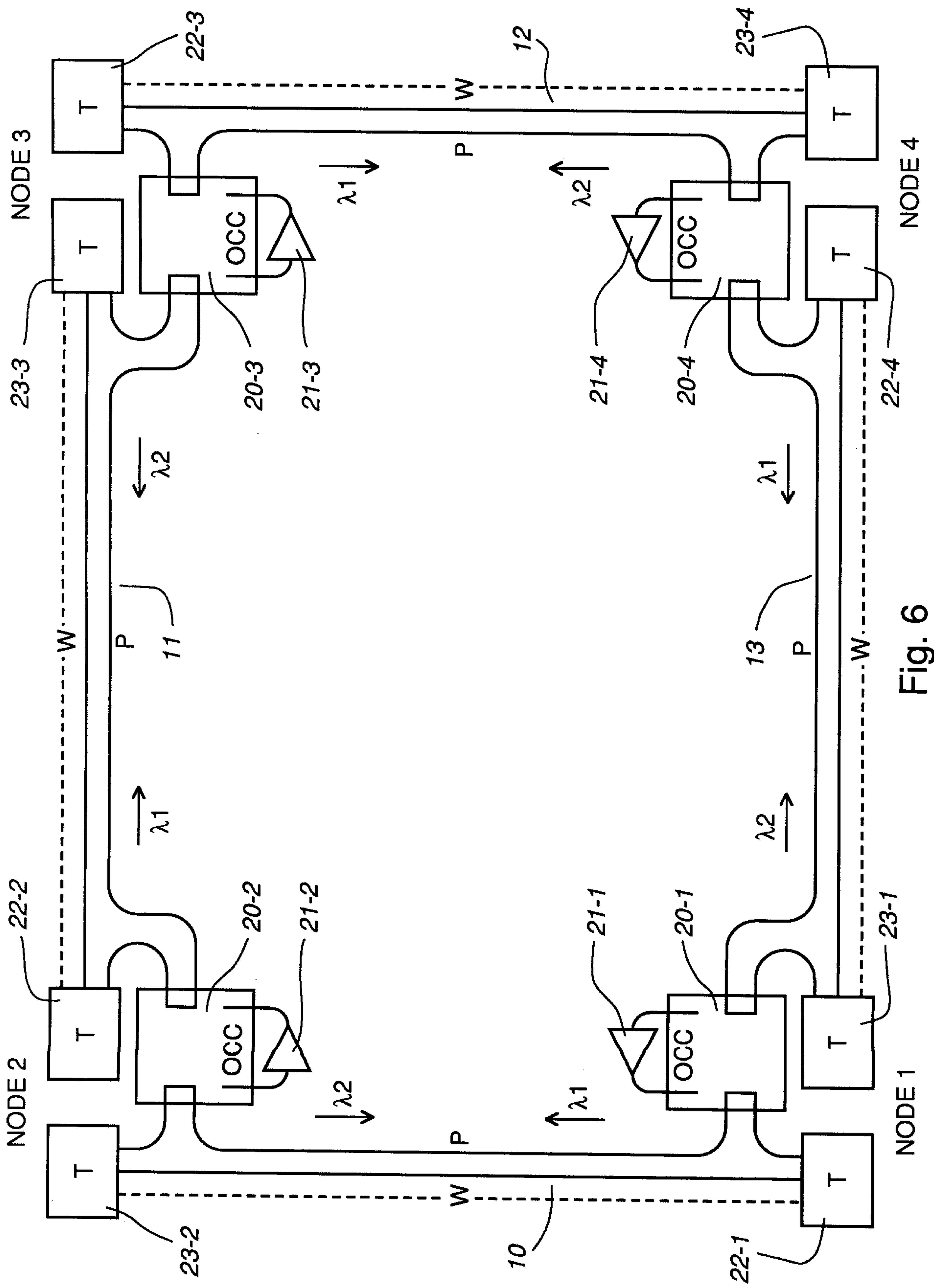


Fig. 6

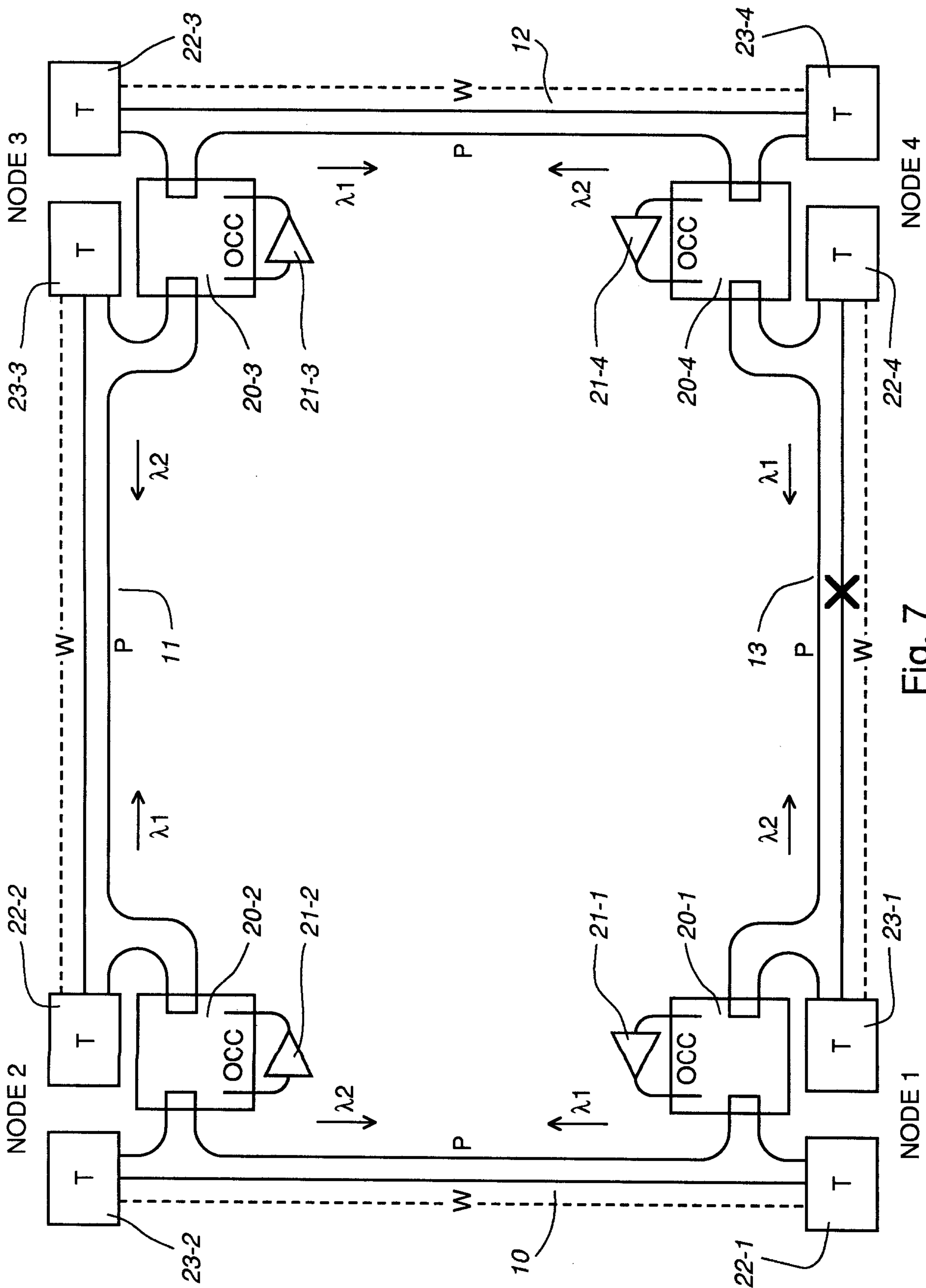


Fig. 7

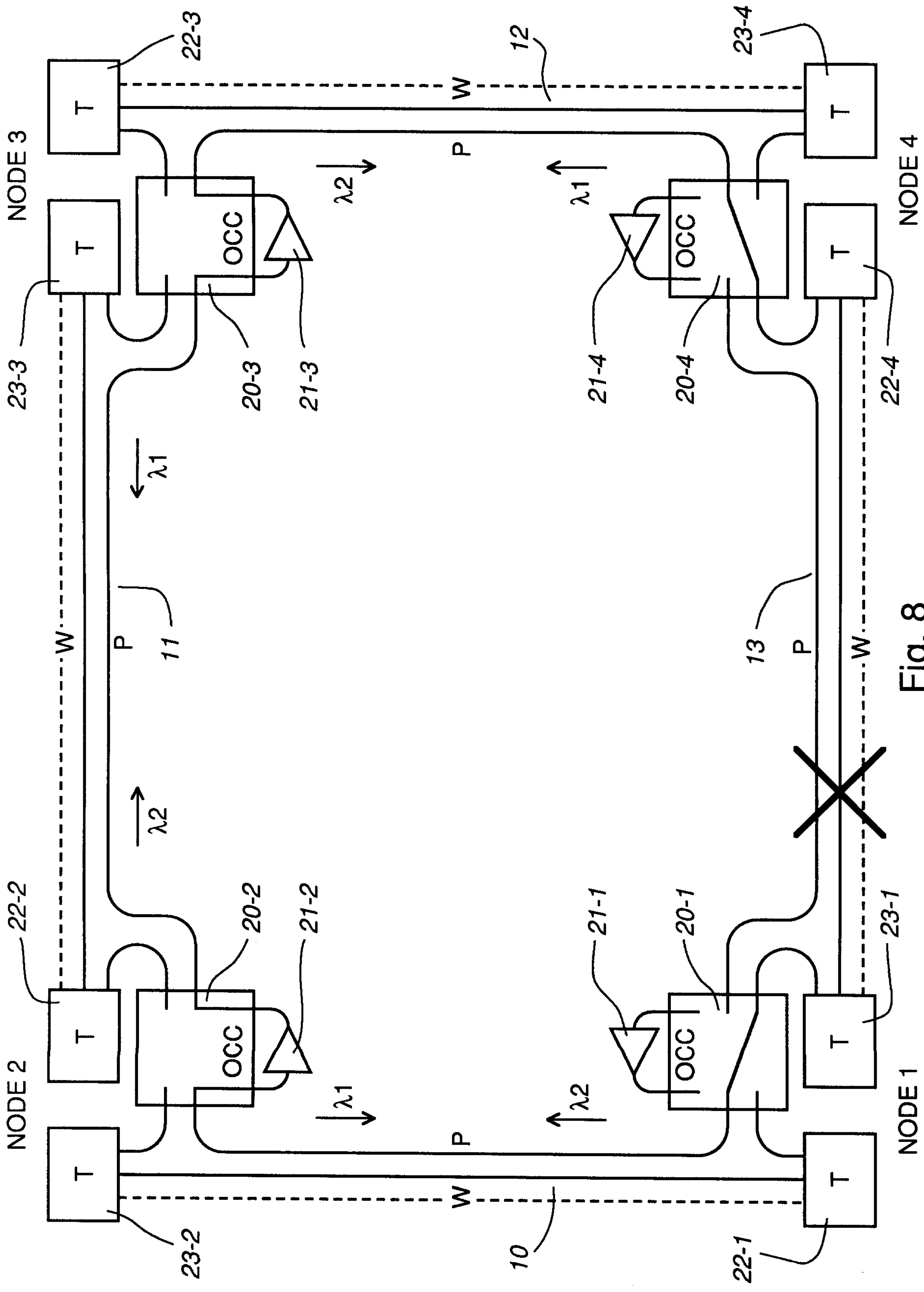


Fig. 8

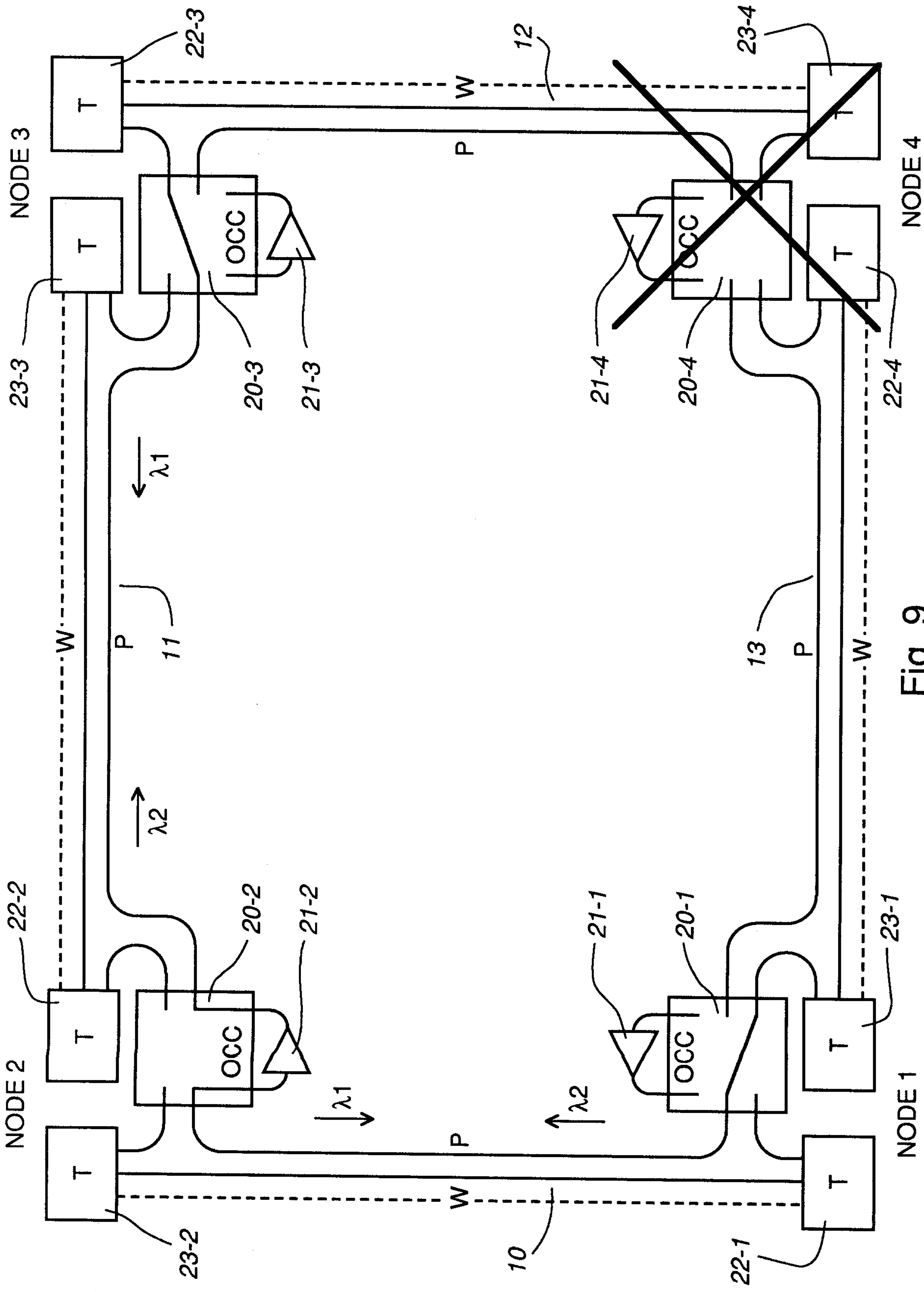


Fig. 9



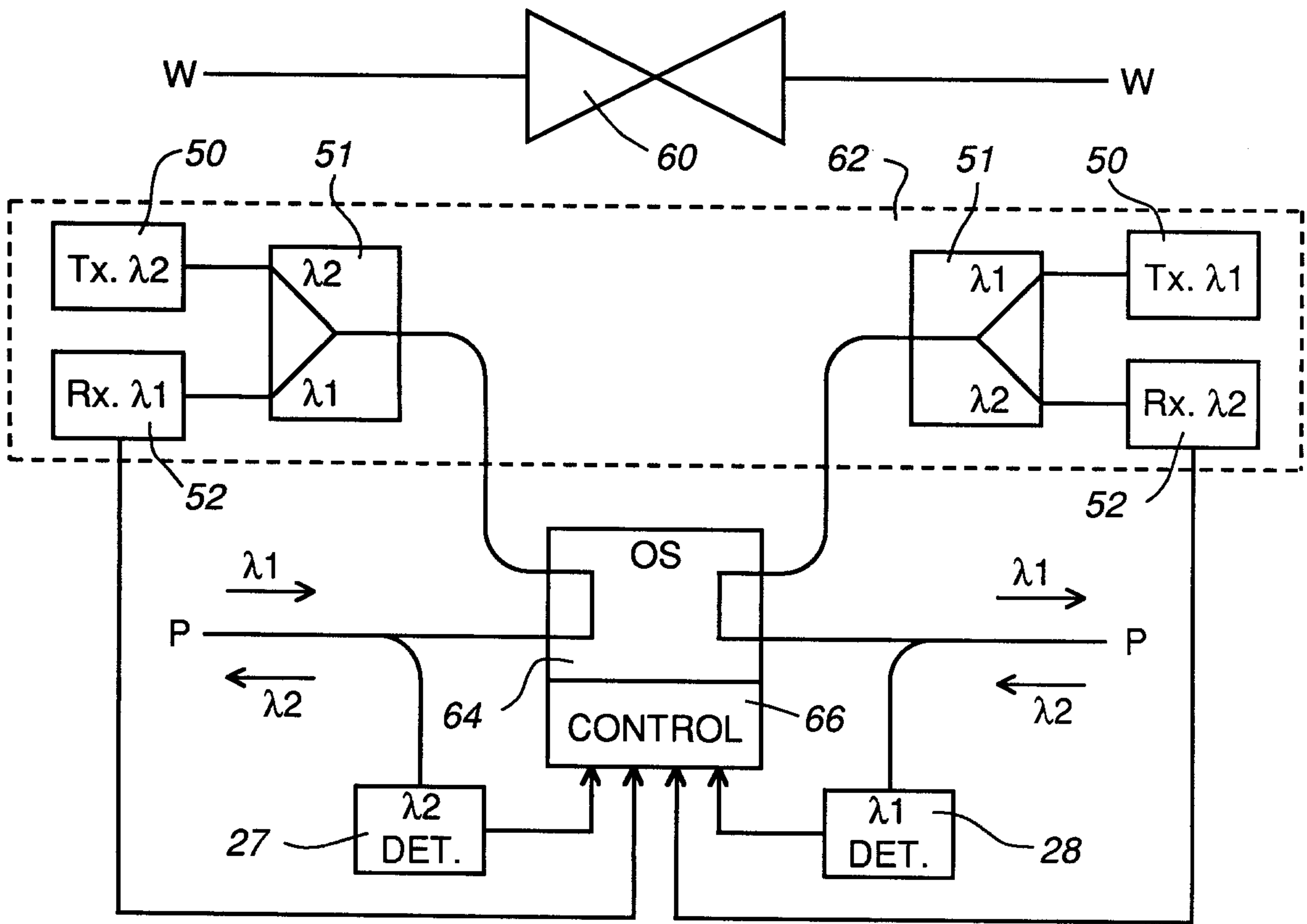


Fig. 10

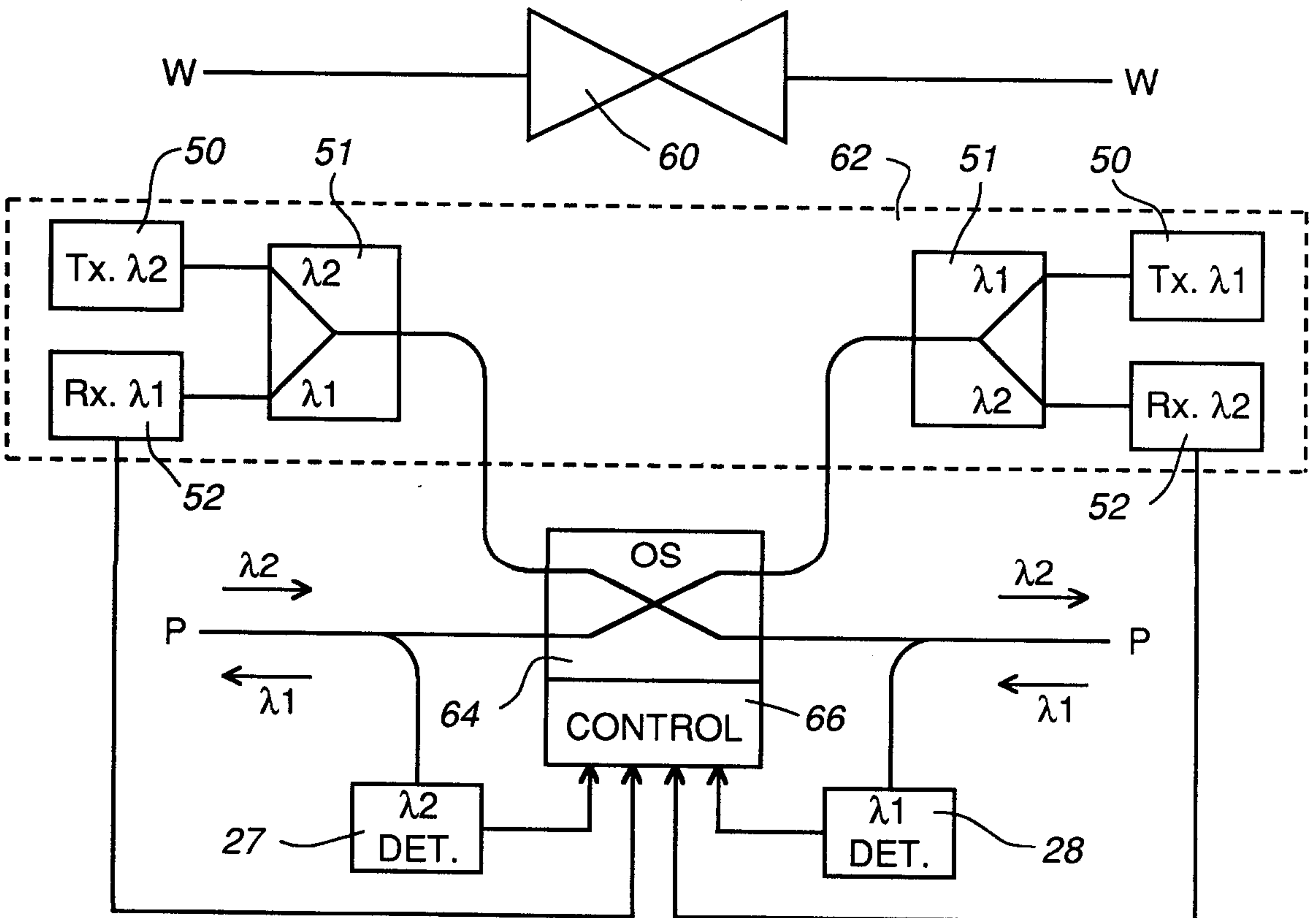


Fig. 11

