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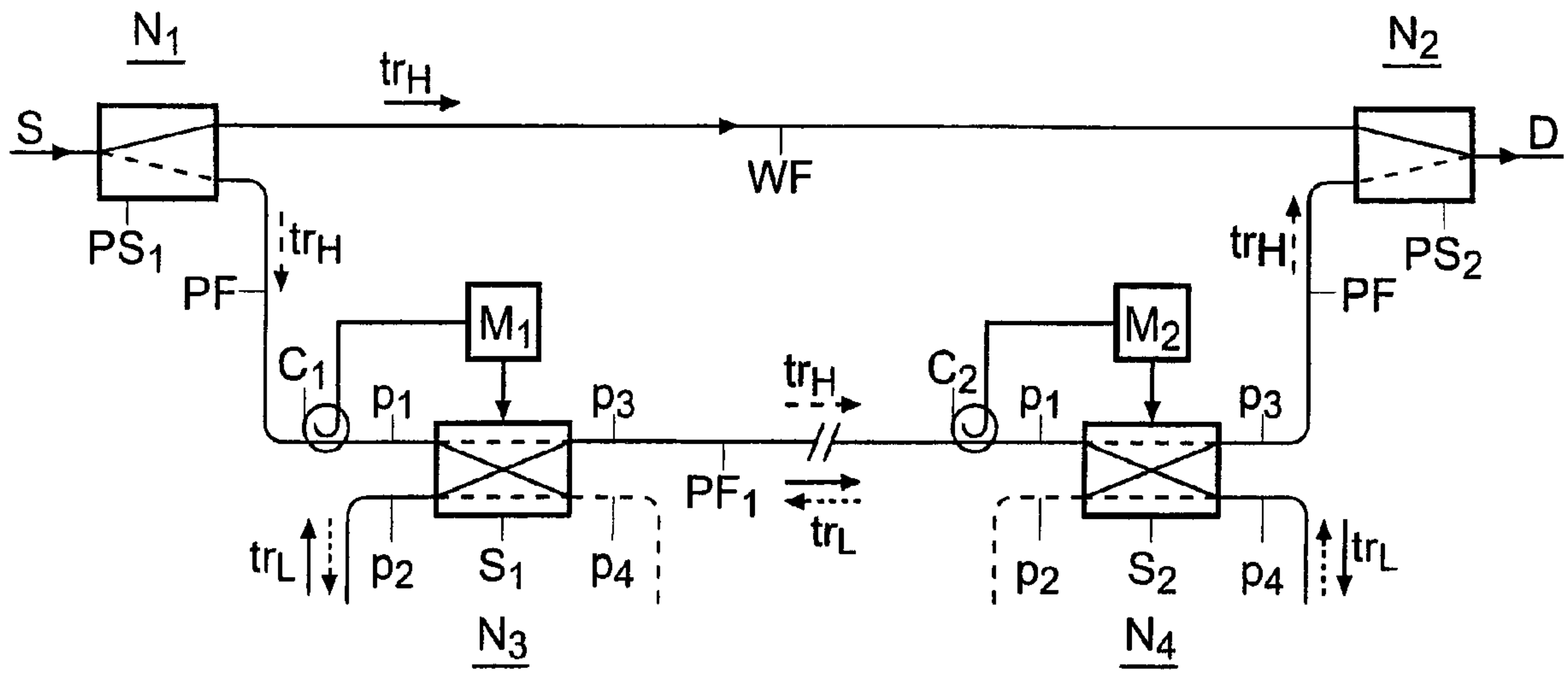
(54) Title: OPTICAL TRANSMISSION NETWORK HAVING A PROTECTION CONFIGURATION



(57) Abrégé/Abstract:
An optical transmission network with protection configuration comprises an operational connection (WF) for signals having a high priority (tr_H) and a protection connection (PF) for the transmission of high-priority signals (tr_H) in the event of an error condition of the operational connection (WF). In the protection connection (PF), switching elements (S_1, S_2) are located having therebetween a section (PF_1) over which, in the event of undisturbed operation, a signal of low priority (tr_L) is conducted. The switching means are controlled by detection means (M_1/C_1, M_2/C_2). In the event of an error condition, the high-priority signal on the protection connection is detected, and the switching means are switched in such a manner that a low-priority signal transmission is no longer possible. The low- and high-priority signals may be WDM signals, and the section may be part of an optical annular network.

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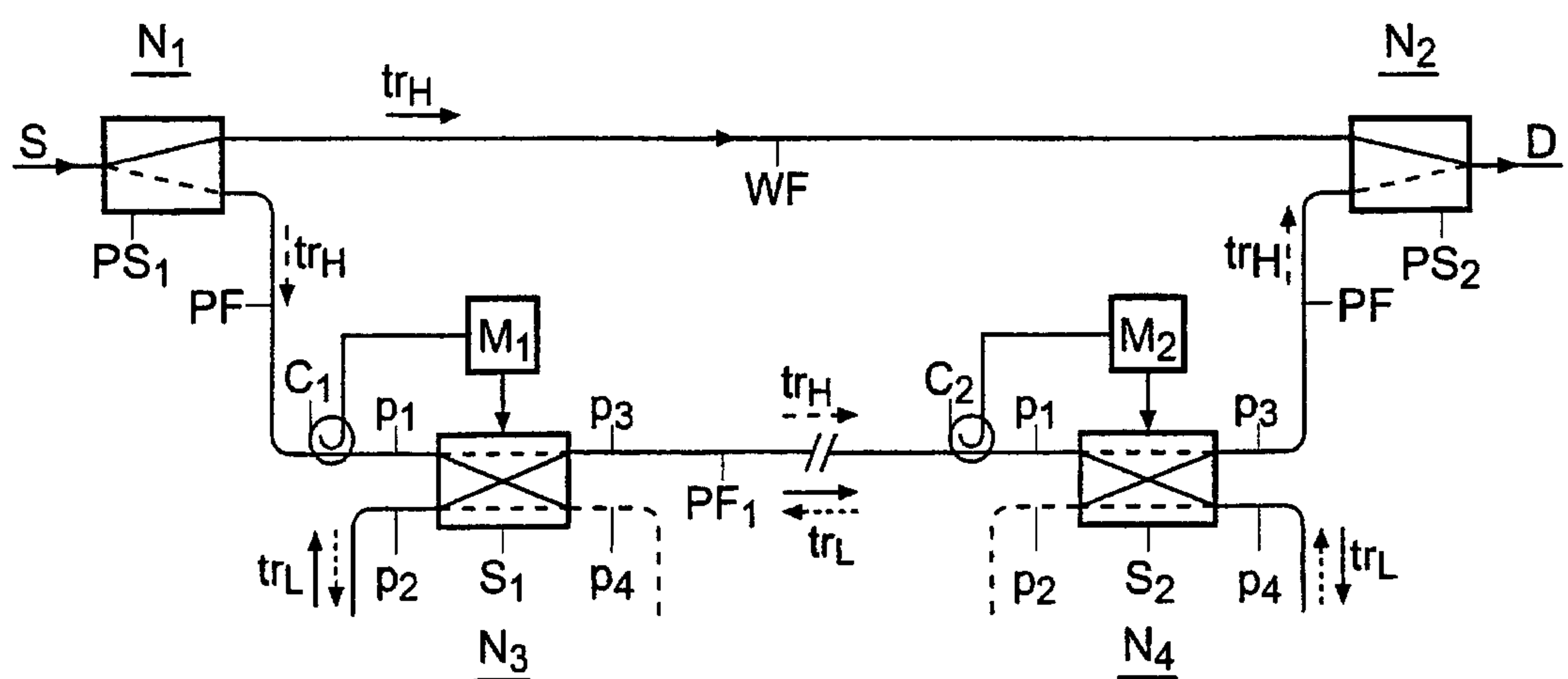
(54) Title: OPTICAL TRANSMISSION NETWORK HAVING A PROTECTION CONFIGURATION



(57) Abstract: An optical transmission network with protection configuration comprises an operational connection (WF) for signals having a high priority (tr_H) and a protection connection (PF) for the transmission of high-priority signals (tr_H) in the event of an error condition of the operational connection (WF). In the protection connection (PF), switching elements (S_1, S_2) are located having therebetween a section (PF_1) over which, in the event of undisturbed operation, a signal of low priority (tr_L) is conducted. The switching means are controlled by detection means (M_1/C_1, M_2/C_2). In the event of an error condition, the high-priority signal on the protection connection is detected, and the switching means are switched in such a manner that a low-priority signal transmission is no longer possible. The low- and high-priority signals may be WDM signals, and the section may be part of an optical annular network.

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Optical transmission network having a protection configuration.

A. BACKGROUND OF THE INVENTION

The invention lies in the area of optical transmission networks. More in particular, it concerns an optical transmission network having a protection configuration for transmitting optical signals having a low and a high priority, according to the preamble of claim 1.

Such an optical transmission network is disclosed in reference [1] (for more bibliographical detail, see below under C.).

For a protection configuration in optical transmission networks, basically four schemes are known, which are denoted by 1+1 protection, 1:1 protection, 1:N protection and M:N protection, respectively. Said schemes relate to signal transmission over one (schemes 1+1 and 1:1) or more (schemes 1+N and M:N) operational fibre connection(s) ("working fibre(s)") and one (schemes 1+1, 1:1 and 1:N) or more (sheme M:N) protection fibre connection(s) ("protection fibre(s)"), hereinafter to be referred to as an operational connection and a protection connection, respectively. In the 1+1 scheme, the signal transmission takes place over the operational connection and the protection connection simultaneously, the destination side selecting either of the two connections for receipt. In the 1:1 scheme and in its more general forms - the schemes 1:N and M:N - a protection connection is basically taken into use for signal transmission only in the event that the signal transmission over an operational connection is disturbed, such as, e.g., due to fibre rupture. With said three schemes, under normal, i.e., undisturbed operation, the protection connection is therefore not in use. Such connections, which are not used under normal circumstances, may be used for traffic having a low priority, as is known (see reference [1]), to increase the total traffic capacity , which traffic has to make way, however, for protection traffic which, in the event of a disturbed operational connection, is led via the protection connection, and which is assigned a high priority. In order not to disturb the protection traffic having a high priority, or at least to disturb it as little as possible, said making way must take place as fast as possible. In optical transmission networks, to which such protection schemes are being applied, switching over to a protection connection in most cases occurs under the control of a central operating system, or by way of a signalling protocol. The removal of the traffic having a low priority from a protection connection to be taken into use for protection traffic, too, might take place by intervention of a central control or by way of a signalling protocol expanded for that purpose. This would take place much too slowly, however. Therefore, there is the desire in a transmission network of the type referred to above to have the low-priority traffic on a protection connection give way to the high-priority traffic without intervention of a central control, or without applying any signalling protocol.

B. SUMMARY OF THE INVENTION

The object of the invention is to provide for an optical transmission network of the type referred to above, which accommodates the desire referred to above. For this purpose, the transmission system of the type referred to above according to the invention is characterised as in claim 1. In this connection, the invention makes use of the fact that, by means of optical detection of the presence of protection traffic on the protection connection it may be decided, in the optical domain itself, when the low-priority traffic of a relevant part of the protection connection must make way. In general, for the detection may be applied detection means may be applied which are selective for one or more signal characteristics in which the signals having high and low priorities differ from one another, such as, e.g., in wavelength, in transmission direction, or also via a signal component specific to the high-priority signal, such as a pilot signal. For this purpose, in preferred embodiments the invention has the characteristics of claim 2, claim 3 and claim 4, respectively.

Annular optical networks are typically suitable to the application of protection configurations according to a 1:1 scheme or, in the event of WDM rings (WDM = Wavelength Division Multiplex) according to a 1:N scheme or an M:N scheme. In this connection, the protection may take place at the level of an optical-multiplex section (= OMS) of such a ring, such as, e.g., disclosed in reference [2], or at the level of an optical channel (= OCH). A further object of the invention therefore is to also provide for an annular optical network whose capacity of signal transmission may be increased by applying low-priority traffic over protection connections present in such rings. An annular optical network according to the preamble of claim 13, known per se from reference [2], for this purpose is characterised, according to the invention, as in claim 13.

Other preferred embodiments of the invention have been summarised in further subclaims.

The invention makes possible a more effective use of the capacity of optical networks in general, and annular optical WDM networks in particular. By applying low-priority traffic over protection connections according to a 1:1 scheme during undisturbed operation, the capacity of the network may even be substantially doubled. The reaction time for having the low-priority traffic give way to the high-priority traffic is substantially restricted only by the switching time of optical switches which, for the current prior art, lies in the range of several microseconds to several milliseconds. The decision to switch over is taken locally in the optical domain, therefore requires no central control or any other signalling in the optical network, and may be carried out relatively fast. Nodes of an optical network may basically be arranged identically for adding or dropping low-priority traffic, not only for such traffic between adjacent nodes, but also for transit traffic.

C. REFERENCES

[1] R. Ramswami & K.N. Sivarajan, "Optical Networks: A Practical Perspective", Morgan Kaufmann Publishers, Inc., San Francisco, California, 1998; more particularly Chapter

10 "Control and Management", Section 10.4.1 "Protection Concepts", pp. 430-434;

[2] F. Arecco et al., "A transparent, all-optical, metropolitan network experiment in a field environment: The "PROMETEO" self-healing ring", J. Lightwave Technol., Vol. 15, No. 12, December 1997, pp. 2206-2213.

D. BRIEF DESCRIPTION OF THE DRAWING

The invention will be explained in greater detail by reference to a drawing comprising the following figures:

FIG. 1 schematically shows a first exemplary embodiment of the invention;

FIG. 2 shows a first variant for a component of the exemplary embodiment according to FIG. 1;

FIG. 3 shows a second variant for an identical component as the one shown in FIG. 2;

FIG. 4 shows a first variant for a component of the exemplary embodiment shown in FIG. 1 for application in a WDM connection;

FIG. 5 shows a second variant for an identical component as the one shown in FIG. 4;

FIG. 6 schematically shows an annular optical network to which the invention is applied;

FIG. 7 schematically shows a node of the network according to FIG. 6;

FIG. 8 shows a scheme for wavelength allocation for WDM channels for transmitting WDM signals over the network of FIG. 6;

FIG. 9 schematically shows a component of the node shown in FIG.7.

E. DESCRIPTION OF EXEMPLARY EMBODIMENTS

The exemplary embodiments described below are restricted, only for reasons of simplicity of description, to a protection configuration according to a 1:1 scheme. The principle of the invention, however, is also applicable to protection connections in protection configurations according to the more general schemes 1:N and M:N.

FIG. 1 schematically shows a protection configuration according to a 1:1 scheme, to which the invention is applied. The configuration comprises a point-to-point connection between a (signal) source S and a (signal) destination D, which may be part of a more extensive optical network, the source and the destination being located in different nodes N_1 and N_2 of the network, as drawn, but which may also be separate. Between the source S in node N_1 and the destination D in node N_2, two physically separated, optical signal connections are located, namely, an operational connection WF ("working fibre") and a protection connection PF ("protection fibre") which runs by way of, e.g., network nodes N_3 and N_4. Said two connections are placed between a first protection switch PS_1 in node N_1 at the side of the source, and a second protection switch PS_2 in node N_2 at the side of the destination. In normal, i.e., undisturbed operation, the protection switches are in switch modes such that signal traffic between the source S and the destination D takes place by way of the operational connection WF. In the event of a disturbance of the operational connection WF, e.g., due to fibre rupture, in both protection switches switching over to the protection connection PF takes place. The control of the protection switches, which are not further denoted in the figure, takes place in the known way and is not per se part of the invention. In the protection connection PF, two optical switches S_1 and S_2 are included, which enclose a section PF_1 of the protection connection between network nodes N_3 and N_4. The switches S_1 and S_2 may be switched between a first switch mode (parallel mode in the figure, having interrupted lines), in which first and second ports p_1 and p_2 are interconnected with third and fourth ports p_3 and p_4, respectively, and a second switch mode (cross mode in the figure, having drawn lines), in which the first and second ports p_1 and p_2 are interconnected with the fourth and third ports p_4 and p_3, respectively. The switches S_1 and S_2 are controlled by control signals given off by signal-detecting means M_1 and M_2, respectively, which are coupled to the optical signal-tapping means C_1 and C_2, respectively, placed at the first port p_1 of the switches S_1 and S_2. The signal-tapping means are measured and orientated in such a manner that they tap a fraction, e.g., 10%, of the power of an optical signal entering at the port p_1 of the switch in question, and conduct it to the detection means coupled to the tapping means.

The configuration operates as follows. A distinction is made between signal traffic having a high priority and signal traffic having a low priority. The signal traffic between the source S and the destination D is traffic having a high priority, denoted in the figure by tr_H, and hereinafter is also denoted by high-priority signal tr_H. In the event of undisturbed operation, the signal traffic having a high priority, tr_H, is conducted over the operational connection WF. Only in the event of disturbance on the operational connection, the protection switches PS_1 and PS_2 are switched over, and the traffic tr_H between the source S and the destination D is conducted by way of the protection connection PF. In order not to leave the protection connection unused in the event of undisturbed operation, in order to increase the signal-transport capacity in the network, signal traffic is conducted over at least a portion of the protection connection PF, in this case section PF_1. Said traffic, which is referred to as signal traffic having a low priority or low-priority signal, denoted by tr_L, must disappear from the protection connection, however, as soon as use is to be made of the protection connection by the signal traffic having a high priority. In the undisturbed situation, the switches S_1 and S_2 both are in the cross mode indicated above. Now, there are two options for conducting the signal traffic having a low priority û tr_L û over the section PF_1 of the priority connection PF in question. According to the first option, referred to as the co-directional variant, the signal traffic tr_L (continuous arrow) is added, via the second port p_2 of the switch S_1, to the connection section PF_1, and is dropped therefrom at the fourth port p_4 of the second switch S_2. According to the second option, referred to as the counter-directional variant, said signal traffic is added to the connection section PF_1 in the opposite direction (interrupted arrow) by way of the fourth port p_4 of the switch S_2, and dropped from it at the second port p_2 of the first switch S_1. Due to the cross mode of the switches, section PF_1 is disconnected, as it were, from the total protection connection for the benefit of use for signal traffic having a low priority. As soon as the high-priority signal tr_H is conducted over the protection connection PF by switching over the protection switch PS_1, however, the protection connection must be restored as soon as possible. For this purpose, as soon as the arrival of the high-priority signal at the port p_1 of the switch S_1 in node N_3 is detected by the detecting means M_1, the switch S_1 is set to the parallel mode. The high-priority signal tr_H propagates over the section PF_1, further in the direction of the second switch S_2 in node N_4. There, the arrival of said signal at the port p_1 of the second switch S_2 is detected by the detection means M_2, and the switch S_2 is set to the parallel mode. After switching over the switches S_1 and S_2 to the parallel mode, the protection connection PF is restored, and the low-priority signal tr_L, in the co-directional variant at switch S_1 in node N_3 and in the counter-directional variant at switch S_2 in the node N_4 is no longer added to the section PF_1, and the high-priority signal tr_H is conducted to the destination D. The counter-directional variant has the advantage that the detection means M_1 and M_2, due to a direction-selective arrangement of the signal-tapping means C_1 and C_2, do not require any further measures to be capable of detecting the arrival of the high-priority signal tr_H. The counter-directional variant, however, is less simple to combine with optical amplifiers. In the co-directional variant, it is a requirement that, at any rate in the node N_4, with the detection means M_2 together with the tapping means C_2, a selective differentiation is possible between states in which, at the port p_1, the high-priority signal tr_H is, and is not, present. This may be achieved, e.g., by having the high-priority and low-priority signal traffic take place at various wavelengths, more generally at various wavelength spectra, and, e.g., render the tapping means C_2 or the detection means M_2 wavelength-selective for the wavelength, or (part of) the wavelength spectrum in which the wavelength spectrum of the high-priority signal differs from that of the low-priority spectrum, as the case may be. In order to keep the configuration unequivocal, the tapping means C_1 or the detection means M_1 preferably have one and the same wavelength selectivity. A detection mechanism which is based on wavelength selectivity is very efficient in the event that the high-priority and/or low-priority signals are WDM signals (see below).

In either variant - the co-directional and the counter-directional - instead of wavelength or directional selectivity, use maybe made of detection means which are selective for a signal which is typical for the high-priority signal, and which is not present in the low-priority signal, such as a pilot signal having a specific modulation which may be recognised by the detection means.

The protection connection PF may be broken down into several sections, similar to the section PF_1, for the benefit of still more low-priority traffic, e.g., in the event that the protection connection runs by way of still other network nodes. In this case, the priority connection PF includes three or more switches, similar to the switches S_1 and S_2, having associated detection means. In this connection, transit traffic is also possible by setting interim switches in the parallel mode, as required. Upon arrival of the high-priority signal, these need no longer be switched over.

The application of tapping means at the first port p_1 of the switches S_1 and S_2, for the benefit of the detection of the high-priority signal, has the drawback that, in the event of use of the protection connection PF, the signal is weakened too much when passing a number of switches. This may be prevented by placing the tapping means at the fourth port p_4 of each switch. This is shown in FIG. 2 for a switch S_3 and tapping means C_3.

If for a switch the port p_4 is not in use for adding or dropping the low-priority signal, in the counter-directional and the co-directional variant, respectively, the detection means may also be connected directly to the port p_4. This is shown in FIG. 3 for a switch S_4 and detection means M_4.

In the exemplary embodiments described so far, both the high-priority and the low-priority signal may be an optical WDM signal, which signals are completely switched by the various switches. If, however, the high-priority signal is a WDM signal comprising a number of n WDM channels, each WDM channel corresponding to a separate wavelength λ_i (i=1,-,n) in the WDM signal, basically any WDM channel may also be utilised separately over one or more sections of the protection connection, for signal transmission having a low priority. For this purpose, an Optical Add/Drop Multiplexer is added, hereinafter to be referred to as OADM, at the beginning and at the end of each section, instead of a singular switch with associated detection means, such as the switches S_1 and S_2 in FIG. 1. The individual WDM channels are further denoted by their wavelength λ_i (i=1,-,n). FIG. 4 shows a first variant thereof in a counter-directional embodiment, an OADM 40 being included in a protection connection. The OADM comprises a bidirectional (de)multiplexer 42 having an I/O port 44 and a bidirectional (de)multiplexer 46 having an I/O port 48, for splitting off and rejoining a number of n WDM channels λ_1,-,λ_n in either signal-transmission direction. In the WDM channels λ_1,-,λ_n, optical 2x2 switches SP_1,-,SP_n are included, provided with detection means MM_1,-,MM_n, all this for each WDM channel in a similar way as the switch S_1 or S_2 with associated detection means in FIG. 1. For adding or dropping signals having a low priority û tr_L û at the fourth and the second port of the switches, respectively, in the event of undisturbed operation the switches SP_1,ûSP_n are in the cross mode. As soon as the high-priority tr_H enters the I/O port 44 of the (de)multiplexer 42 as a WDM signal, said signal is split up into signal components in the various WDM channels λ_1,-,λ_n. Subsequently, in each channel the possibly present signal component of the high-priority signal is detected separately and, after switching over the switch associated with the channel, passed on to the (de)multiplexer 46, and finally rejoined, together with signal components of the high-priority signal passed on in other channels, to form a WDM signal of the high-priority signal tr_H which propagates itself further over the protection connection by way of I/O port 48.

In a similar way as in FIG. 4, FIG. 5 shows a second variant for a WDM application, this time in a co-directional embodiment. In said variant, the high-priority signal tr_H is a WDM signal which, apart from the number of n WDM channels still comprises an additional WDM channel having a specific wavelength λ_s, which has a recognition function for the high-priority signal on the protection connection, and whose presence of the high-priority signal on the protection connection is therefore unequivocally capable of being detected. This additional WDM channel, which hereinafter will also be referred to as signature channel λ_s, may already be associated with the high-priority signal over the operational connection, but may also be added to the signal only upon transition to the protection connection. The high-priority signal including the signature channel is denoted by $tr_H(\lambda_s)$. FIG. 5 shows an OADM 50 included in a protection connection at the beginning or the end of each section of said connection which is used for low-priority traffic. The OADM 50 comprises a demultiplexer 52 having an input port 54 and a multiplexer 56 having an output port 58, respectively, for splitting off and rejoining a number of n WDM channels $\lambda_1,-,\lambda_n$ and the additional WDM channel λ_s. In the WDM channels $\lambda_1,-,\lambda_n$, optical 2x2 switches $SQ_1,-,SQ_n$ are included, all this for each WDM channel in a similar way as the switches S_1 or S_2 in FIG. 1, this time without the associated detection means. Detection means MM are coupled to the additional WDM channel λ_s, for simultaneously driving the switches $SQ_1,-,SQ_n$ in the WDM channels $\lambda_1,-,\lambda_n$. For adding or dropping signals having a low priority tr_L, at the second and the fourth port of the switches, respectively, the switches $SQ_1,-,SQ_n$ in the event of undisturbed operation are in the cross mode. The recognition channel λ_s in this connection is not used for low-priority traffic. As soon as the WDM signal of the high-priority signal $tr_H(\lambda_s)$ enters the input port 54 of the demultiplexer 52, it is split up into signal components in the various WDM channels $\lambda_1,-,\lambda_n$ and λ_s. Subsequently, the presence of the high-priority signal is detected with the detection of the signal component in the recognition channel λ_s and the switches SQ_1,-,SQ_n in the WDM channels λ_1,-,λ_n are switched over, as a result of which the signal components are passed on to multiplexer 56. There, the signal components in the various WDM channels are rejoined to form a WDM signal of high priority $tr_H(\lambda_s)$, which may propagate via the output port 58 over a protection connection coupled thereto.

Both the OADM 40 in FIG. 4 and the OADM 50 in FIG. 5 may be arranged to still process signals in other WDM channels, denoted in the figures by $\{\lambda_w\}$, which relate to operational signal traffic having a protection path by way of another part of the network (not shown). For this purpose, there may also be utilized the operational connection WF of FIG. 1 itself, provided the nodes N_1 and N_2 are equipped with fitting OADMs for that purpose. Such a protection principle is applied, inter alia, in annular optical transmission networks having a protection configuration for the transmission of WDM signals. In such networks, hereinafter to be denoted, for briefness' sake, by WDM rings, three or more nodes are included in, and mutually connected by, (at least) two optical connections forming two rings, hereinafter to be referred to as a double ring, for the transmission of WDM signals between the nodes in two transmission directions opposite to one another. In this connection, each node is provided with protection-switching means for switching over from signal transmission over an operational connection in a first or in a second transmission direction to signal transmission over a protection connection by way of the double ring in the second or in the first transmission direction, respectively. In this connection, an operational connection by way of a section of the double ring between each pair of adjacent nodes in the double ring always has a protection connection by way of a portion of the double ring which is complementary to said section, in the event that the operational connection over said section of the double ring ends up in an error condition. In WDM rings having so-called optical multiplex section protection (= OMS protection), the entire complementary portion belongs to the protection connection. In WDM rings having optical channel protection (= OCH protection) the complementary part is not necessarily part, as a whole, of the protection connection, all of this depending on which nodes of the double ring have the high-priority traffic over the operational connection as its source and its destination. In either type of WDM ring, it is basically possible to conduct low-priority traffic over the protection connections present in the rings, both in the co-directional and in the counter-directional embodiment, in a way as described above.

Below, on the basis of the figures FIG. 6 to 9 inclusive, a specific form of WDM ring is described having OMS protection, to which the invention is applied. FIG. 6 shows such a network RN having four nodes RN1, RN2, RN3 and RN4, which are included in a double ring DR, comprising an outer ring R1 and an inner ring R2, respectively, having signal traffic between the nodes in a first transmission direction (clockwise in the figure), and having signal traffic in a second transmission direction (anticlockwise). As schematically shown in FIG. 7, a node 70, such as a node RNi (with i=1,-,4) of the double ring DR, comprises a first OADM 71 and a second OADM 72, included in the outer ring R1 and in the inner ring R2, respectively, for adding and dropping (arrows A/D) of WDM channels on the double ring DR in either transmission direction. Furthermore, the node 70 comprises protection switches 73 and 74, included on either side of the OADMs in the double ring DR. The protection is such that, in the event of normal operation, the rings R1 and R2 are intact. However, in the event of an error condition, in an operational connection over a section between two adjacent nodes or in a node itself, the protection switches, e.g., under the control of a central operating system, or also with the help of detection means in the optical domain, on either side of the section in question of the double ring, or on either side of the node in question, are switched in such a manner that the section, or the node having the error condition, is disconnected from the double ring. In this connection, the operational signal traffic in question over the double ring in the one transmission direction in the protection switch is reversed in direction for the disconnected part of the double ring, and conducted over the double ring in the other transmission direction as protection signal traffic.

Over both the inner ring and the outer ring, signal traffic is possible of WDM signals comprising 2n+2 different WDM channels. FIG. 8 shows a diagram of the wavelength allocation of the various WDM channels. To the outer ring R1, belongs a first set {W1} of n+1 WDM channels, i.e., n channels λ_1,-,λ_n and a recognition channel λ_{s1}, which form operational channels for operational signal connections by way of the outer ring. To the inner ring R2, belongs, similarly, a first set {W2} of n+1 WDM channels, i.e., λ_{n+1},û,λ_{2n}, and a recognition channel $\lambda_{\sigma 2}$, which form operational channels for operational signal connections by way of the inner ring. Furthermore, both the outer ring R1 and the inner ring R2 are associated with a second set, or the set {P2} of the WDM channels λ_{n+1},-,λ_{2n}, as the case may be, and the recognition channel λ_{s1} and the set {P1} of the WDM channels λ_1,-,λ_n and the recognition channel λ_{s1}, which form protection channels for protection traffic, on the outer ring R1 in the event of an error condition of an operational connection on the inner ring R2, and on the inner ring R2 in the event of an error condition of an operational connection on the outer ring R1, respectively. Over the sections of both the outer ring R1 and the inner ring R2 between each pair of adjacent nodes, such as, e.g., the pair RN2 and RN3, or the pair RN4 and RN1, over the recognition channels λ_{s1} and λ_{s2} from the first sets {W1} and {W2}, respectively, of operational channels, permanent, so-called next-door-neighbour connections nb are maintained, such as, e.g., the next-door-neighbour connections nb over the section of the outer ring R1 between the nodes RN1 and RN2, and over the section of the inner ring R2 between the nodes RN1 and RN4. In the event of an undisturbed operation, the protection channels of the second sets {P1} and {P2}, with the exception of the recognition channels λ_{s1} and λ_{s2} on the outer and inner rings, may be reused for signal traffic having a low priority, which must make way upon the appearance of signal traffic having a high priority, i.e., protection traffic originating from operational channels corresponding to the protection channels in question of the first sets {W1} and {W2}. For this purpose, in each OADM of each node, the protection channels are provided with switching means and with detection means for controlling the switching means, all of this in a simular manner as in the OADM 50 (see FIG. 5). FIG. 9 schematically shows an OADM 90, included in the outer ring R1. The OADM 90 includes a demultiplexer 92 having an input port 93 and a multiplexer 94 having an output port 95, between which the channels of the first set {W1} of operational channels and of the second set {P2} of protection channels are split up. In the operational channels, A/D switching means are included 96 for adding/dropping or switching through signals in each channel separately. In the recognition channel λ_{s1} of the set {W1} of operational channels, an A/D switch 98 is included, which in the figure is shown separately to indicate that it is permanently in the cross mode for the benefit of the next-door-neighbour connections nb in the incoming and outgoing directions. In the protection channels, with the exception of the recognition channel λ_{s2}, switching means SQ are included for adding/dropping or switching through signals having a low priority $tr_L(1)$ in each protection channel separately over the outer ring R1. To the recognition channel λ_{s2} of the set {P2} of protection channels, detection means MM are coupled for collectively controlling the switching means SQ. When the presence of a high-priority signal $tr_H(\lambda_{s2})$ is detected on the input port 93 of the demultiplexer 92 in the recognition channel λ_{s2}, all protection channels are switched through by the switching means SQ, in such a manner that no low-priority signals $tr_L(1)$ can be added or dropped any longer.

Such a WDM ring has the great advantage that, as a result of the permanent presence of a next-door-neighbour connection between each pair of adjacent nodes over a WDM channel having the same wavelength, i.e., the recognition channels λ_{s1} and λ_{s2} on the outer ring and the inner ring, respectively, in the event of an error condition on a signal connection over any operational channel whatsoever, the protection signal, anywhere on a protection connection over the double ring, always comprises the recognition channel in question and is capable of being detected thereon in the optical area.

In the event of the exemplary embodiments described, the coûoperation of the detection means and the switching means preferably is such that, if the high-priority signal is no longer detected on the protection connection, the switching means are switched back to switch modes in which low-priority traffic is once again possible.

Set of Amended CLAIMS

1. Method for transmitting optical signals having several priorities via a transmission network with protection, comprising steps of:

- transmitting an optical signal carrying traffic with a high priority, hereinafter called high priority signal (tr_H), via an operational connection (WF; R1, R2) through the network,
- transmitting an optical signal carrying traffic with a low priority, hereinafter called low priority signal (tr_L), via at least a part (PF1) of a protection connection (PF; R2, R1),
- protection switching for switching the traffic with high priority from being carried by an optical signal transmitted via the operational connection to being carried by an optical signal transmitted via the protection connection in the event of an error condition, and
- giving way the transmission of the low priority signal via at least said part of the protection connection in the event of said error condition under control of a detection of an optical signal signalling that a protection switching has occurred,

characterised in that

the transmission network is an optical network, in which the step of protection switching is carried out in such a way that the high priority signal (tr_H) is switched by optical switching means (PS1; 73, 74) from the operational connection (WF; R1, R2) to the protection connection (PF; R2, R1), and

the step of giving way is carried out upon detection of a signal characteristic of the high priority signal (tr_H) on the protection connection (PF; R2, R1).

2. Transmission method according to claim 1, characterised in that the transmission of the low priority signal is carried out at a first wavelength spectrum (λ1,-,λn), the transmission of the high priority optical signals is carried out at a second wavelength spectrum (λ1,-,λn,λs), which differs from the first wavelength spectrum, and the optical detection is carried out on the optical characteristic which corresponds to a difference spectrum (λs), in which the second wavelength spectrum differs from the first one.

3. Transmission method according to claim 1, characterised in that the transmission of the low priority signal being carried out in a direction opposite to the one of the transmission of the high priority signal in the event of an error condition of the operational connection, and the optical detection is carried out in a direction-selective manner.

4. Transmission method according to claim 1, characterised in that the high priority signal includes a signal which is specific for the high priority signal, and the optical detection is carried out in a manner selective for said specific signal.

5. Transmission method according to claim 2, 3 or 4, characterised in that the switching is carried out by switching means (S1; S2; S3; S4) between a first switching mode, in which the low-priority signal is added or dropped, respectively to and from the protection connection, and a second switching mode, in which the high-priority signal passes on over the protection connection.

6. Transmission method according to claim 5, characterised in that the optical detection includes optical-power splitting by optical-power splitting means (C1) for tapping a part of the optical power present on a port (p1) of the switching means (S1) to which an incoming end of the protection connection (PF) is coupled.

7. Transmission method according to claim 5, characterised in that the optical detection includes optical-power splitting by optical-power splitting means (C3) for tapping a portion of the optical power present on a port (p4) of the switching means (S3) which, in the first switching mode, are connected through to a further port (p1) of the switching means to which an incoming end of the protection connection (PF) is coupled.

8. Transmission method according to claim 5, characterised in that the optical detection is carried out directly on a port (p4) of the switching means (S4), which, in the first switching mode, is connected through to a further port (p1) of the switching means to which an incoming end of the protection connection (PF) is coupled.

9. Transmission method according to any of the claims 1,-,8, characterised in that: the high- and/or low-priority signals are optical WDM signals ($\lambda 1,-,\lambda n$, λs; {W1}, {W2}, {P1}, {P2}).

10. Transmission method according to claim 1, 2 or 3, characterised in that:
the high- and low-priority signals are WDM signals, with the WDM signal of the low-priority signal comprising a number of WDM channels ($\lambda 1,-,\lambda n$) which is at least a subset

of the number of WDM channels (λ1,-,λn; λ1,-,λn,λs) in the WDM signal of the high-priority signal,

on either side of said part (PF1) of the protection connection, an OADM (40; 50) is included of which the switching means (SP1,-,SPn; SQ1,-,SQn) and detection means (MM1,-,MMn; MM) are part,

and in that, per OADM, the optical detection is carried out on at least one (λ1,-,λn; λs) of the WDM channels of the high-priority signal, and the switching is carried out per WDM channel of the low-priority signal through switching means (SP1,-,SPn; SQ1,-,SQn) under control of the optical detection (MM1,-,MMn; MM), the switching means having a first switching mode for adding and dropping a low priority signal and a second switching mode for passing on a high priority signal.

11. Transmission method according to claim 10, characterised in that the high-priority signal includes a WDM channel having a wavelength (λs) which is specific to the high-priority signal, and that the optical detection is carried out by detection means (MM) coupled to the WDM channel having said specific wavelength.

12. Transmission method according to claim 10, characterised in that the optical detection is carried out per WDM channel (λ1,-,λn) by means of an optical signal detector (MM1,-,MMn) for controlling the switching means (SP1,-,SPn) associated with the WDM channel in question.

13. Annular optical transmission network with protection, for the transmission of optical WDM signals, comprising: a number of nodes (RN1,…,RN4) included in, and mutually connected by, two optical connections forming two optical rings, hereinafter separately also referred to as first

ring (R1) and second ring (R2), for optical signal transmission of WDM signals in two mutually opposite transmission directions between the nodes,

each node (70) comprising a first OADM (71) included in the first ring (R1) and a second OADM (72) included in the second ring (R2), and optical protection-switching means (73, 74) included between the two rings on either side of the first and second OADM's for optical protection-switching of WDM-signals between the two optical rings,

<u>characterised in that</u>

- each (R1;R2) of the two rings includes:
  + a first set of WDM channels ({λw};{W1};{W2}), called operational channels, for forming operational connections over a concerned one (R1; R2) of the two rings for the transmission of optical signals of high priority, and
  + a second set of WDM channels ((λ1,-,λn); (λ1,-,λn,λs); {P2}; {P1}), called protection channels, for the transmission of optical signals of low priority (tr_L; $tr_L(1)$) in normal operation, and for forming protection connections over said concerned one (R1; R2) of the two rings for high priority signals (tr_H; $tr_H(\lambda s2)$) upon occurrence of protection-switching in the event of an error condition of an operational connection over the other one (R2; R1) of the two rings, and
- each OADM (40; 50; 90) includes:
  + optical switching means ((SP1,-,SPn); (SQ1,-,SQn); SQ) for switching on and off low priority signals (tr_L; $tr_L(1)$) over any of the protection channels of a ring concerned (R1;R2), and
  + optical detection means ((MM1,-,MMn); MM) for detecting a high priority signal on at least one

protection channel ((λ1,-,λn); λs; λs2) of the set of protection channels.

14. Annular optical transmission network according to claim 13, characterised in that the first set ({W1}; {W2}) of WDM channels of each (R1; R2) of the two rings includes a recognition channel (λs; λs1, λs2), which corresponds to a recognition channel having the same specific wavelength (λs; λs1, λs2) included in the second set ({P1}; {P2}) of WDM channels of the other one (R2; R1) of the two rings, the and the optical detection means (MM) of each OADM have been coupled to the recognition channel (λs; λs1, λs2) of the second set of WDM channels for driving the switching means (SQ1,-,SQn; SQ) of the WDM channels of the second set, the recognition channel of the first set of operations channels of one (R1; R2) of the two rings having a specific wavelength (λs; λs1, λs2) for recognising the high priority signal on the corresponding recognition channel of the second set of WDM channels of the other one (R2; R1) of the two rings.

15. Annular optical transmission network according to claim 14, characterised in that each OADM includes an add/drop means (98) for adding and dropping the recognition channel (λs1) of the first set ({W1}) of WDM channels.

16. Annular optical transmission network according to claim 15, characterised in that the detection means include an optical-signal detector (MM1,-,MMn) per WDM channel (λ1,-,λn) for controlling the switch (SP1,-,SPn) associated with the WDM channel in question.

CA 02379046 2002-01-10

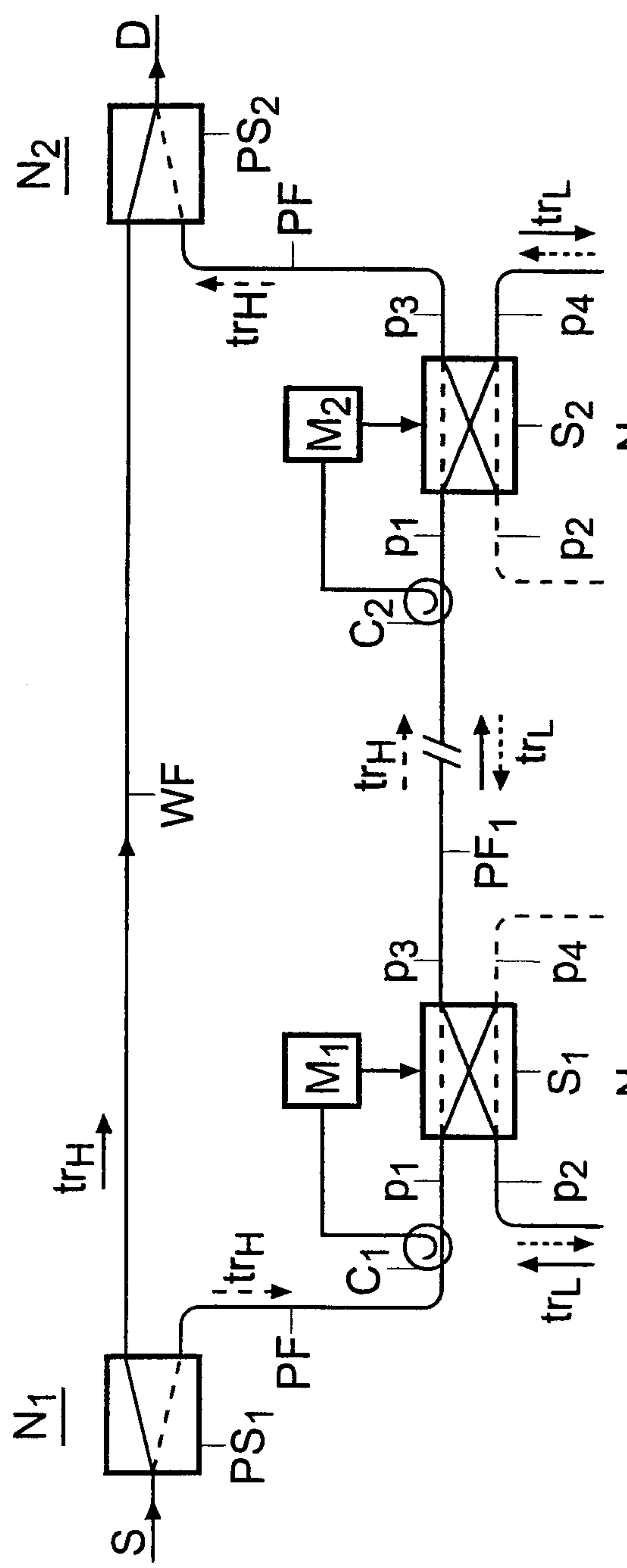


FIG. 1

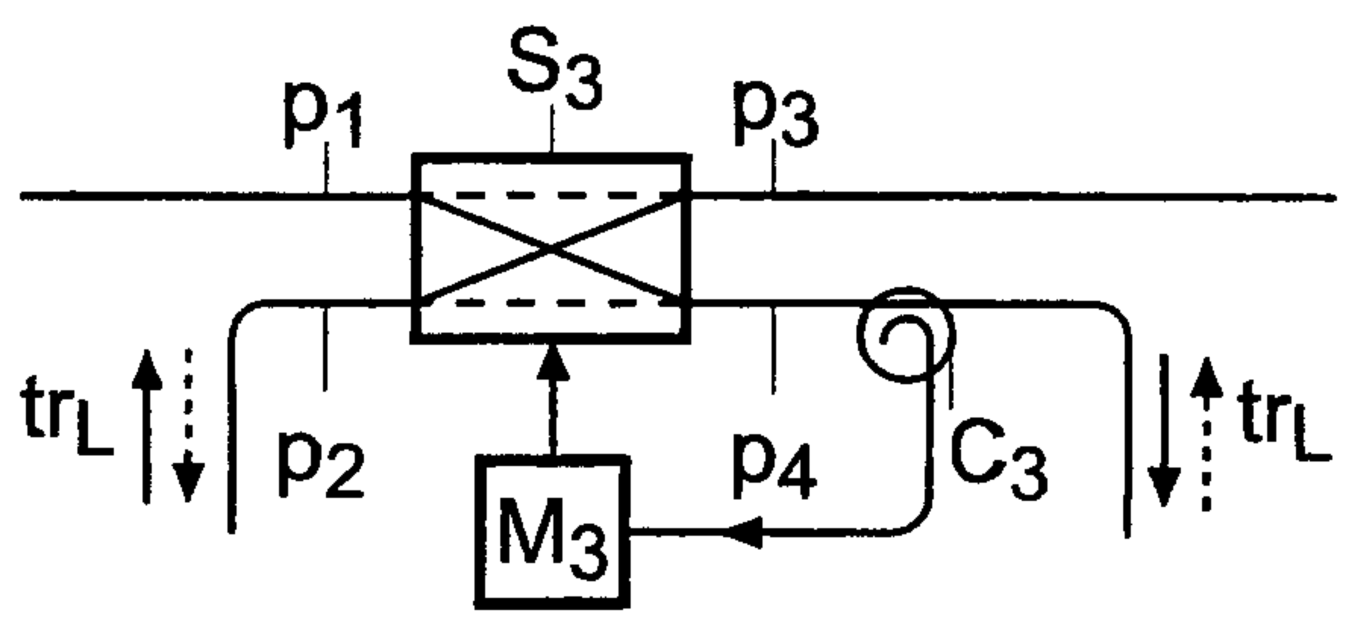


FIG. 2

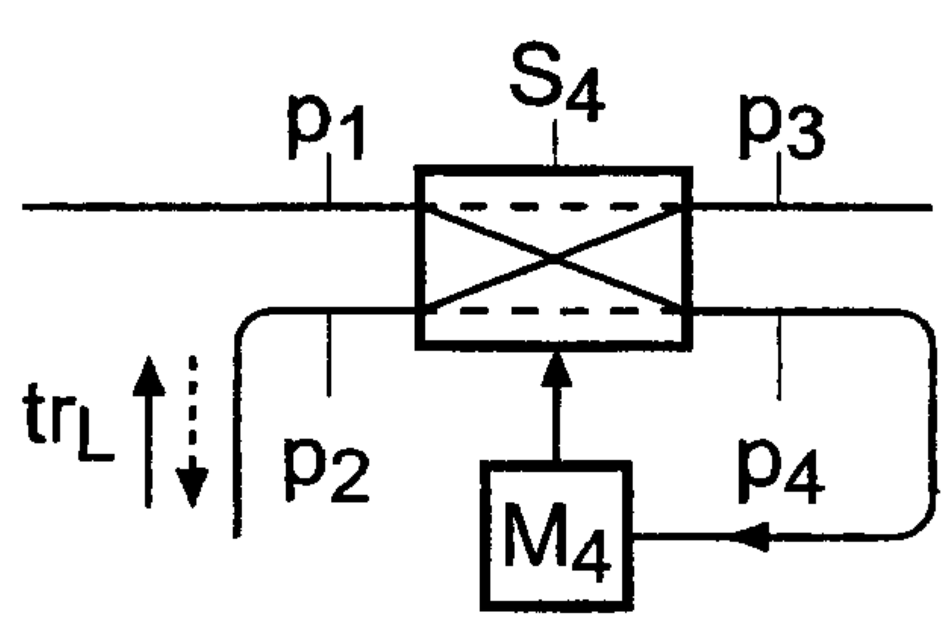


FIG. 3

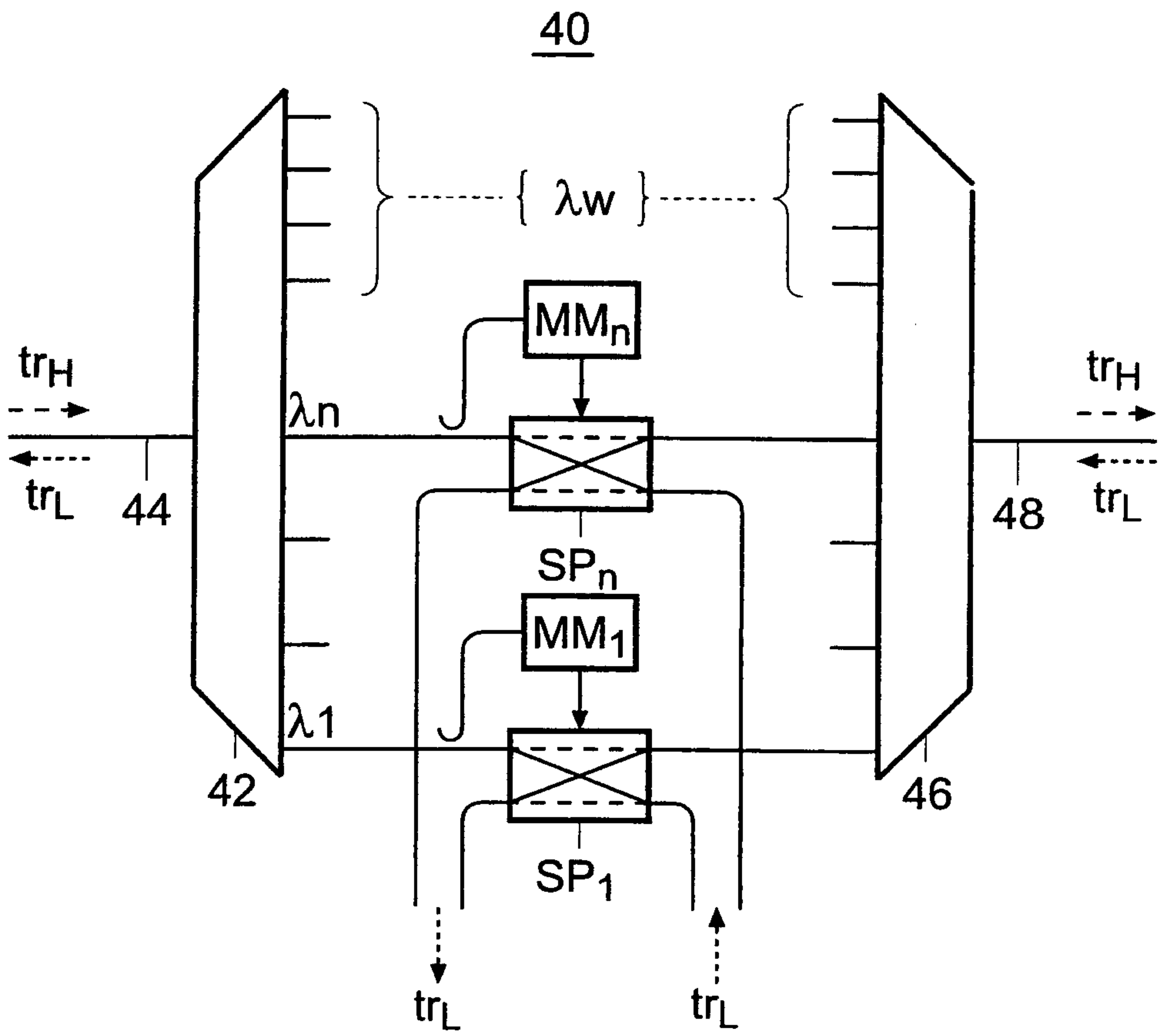


FIG. 4

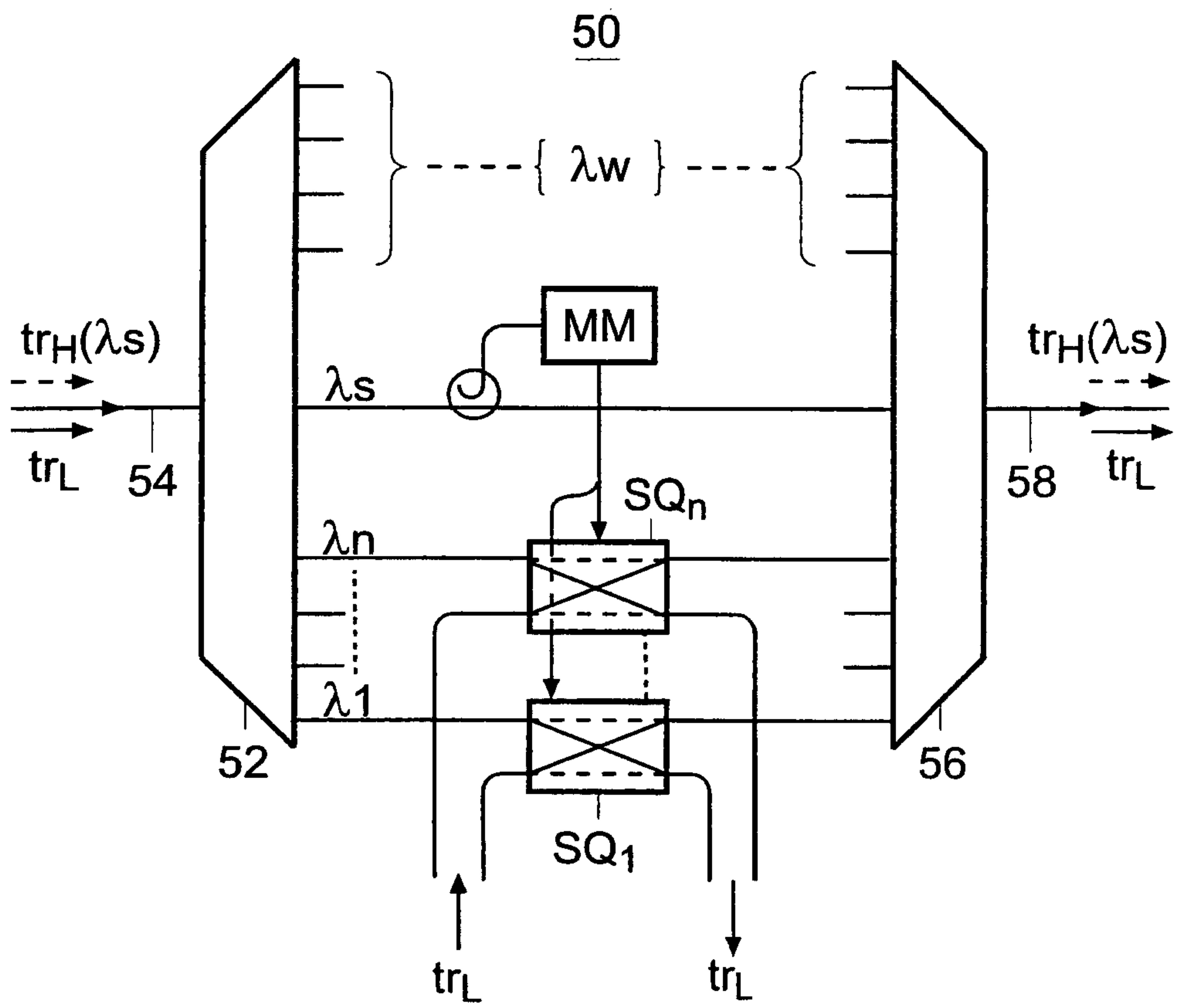


FIG. 5

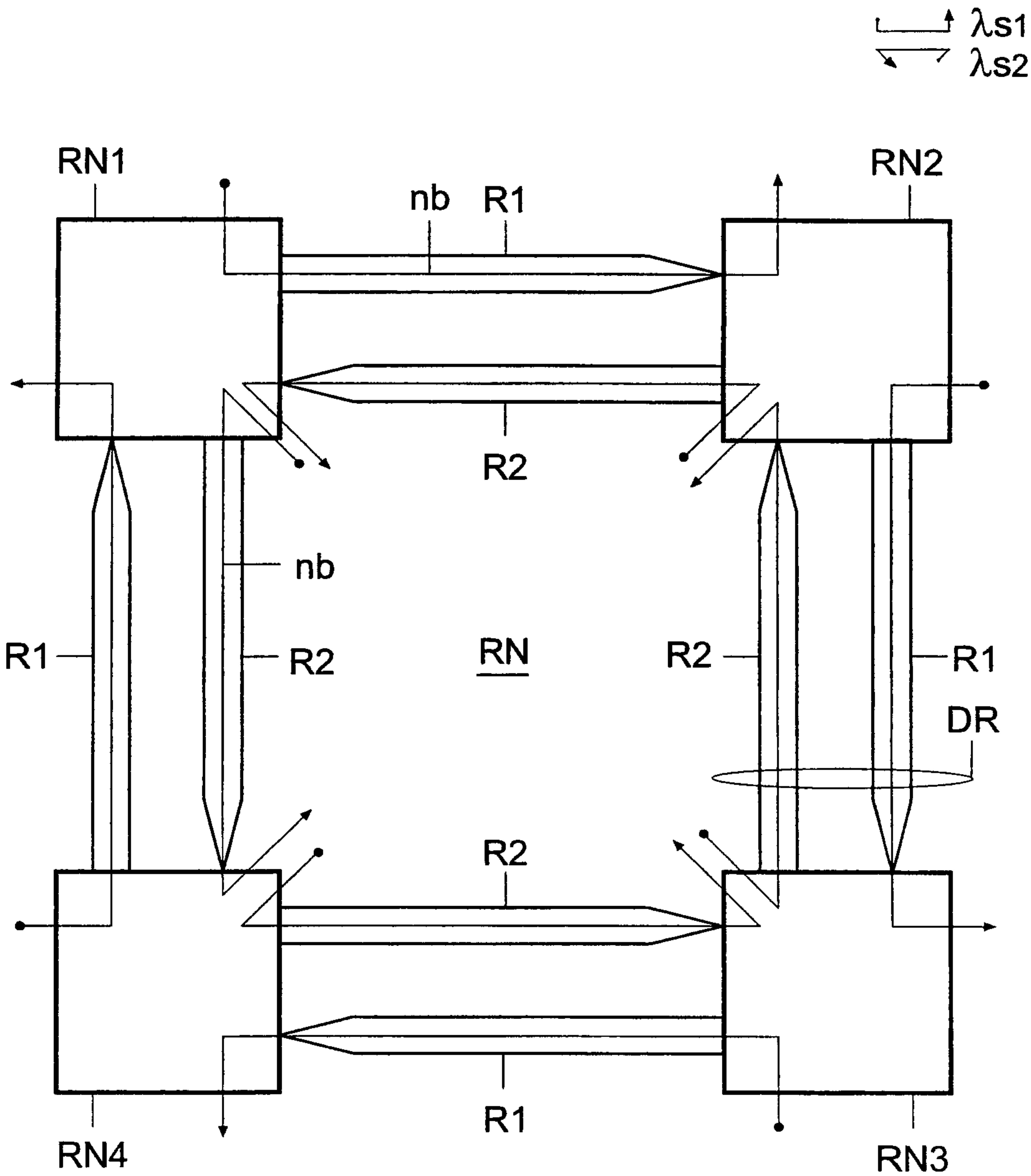


FIG. 6

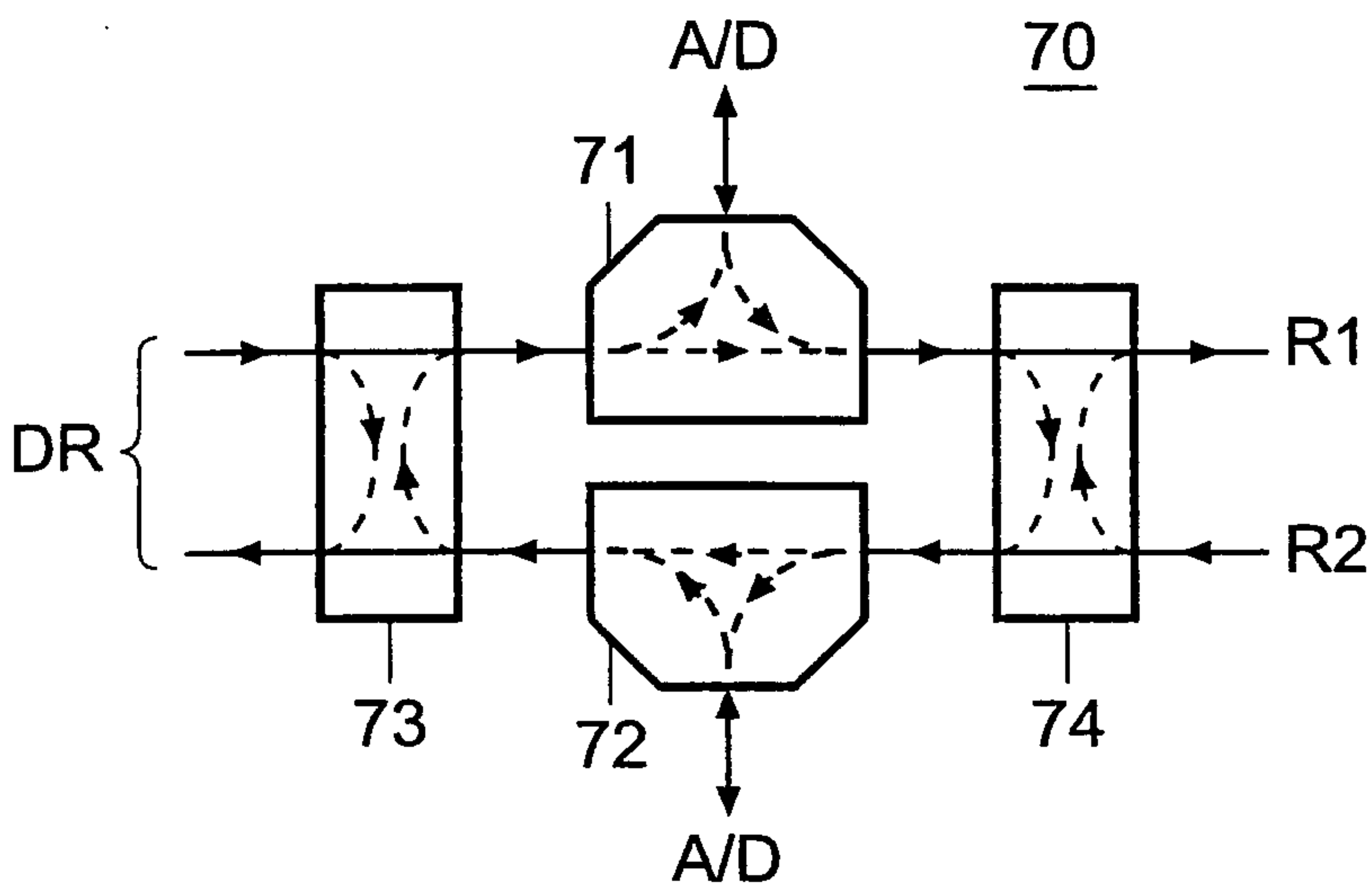


FIG. 7

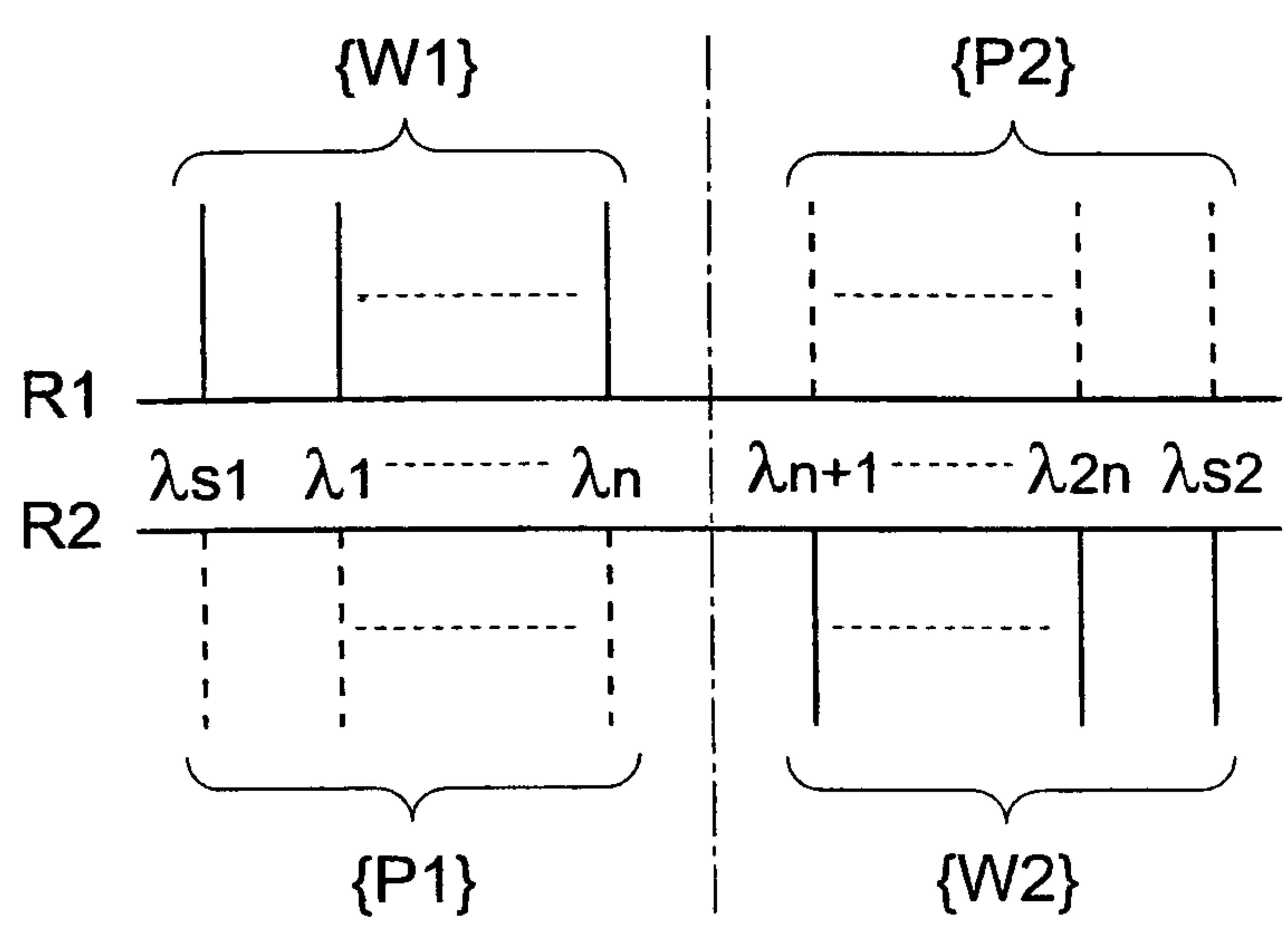
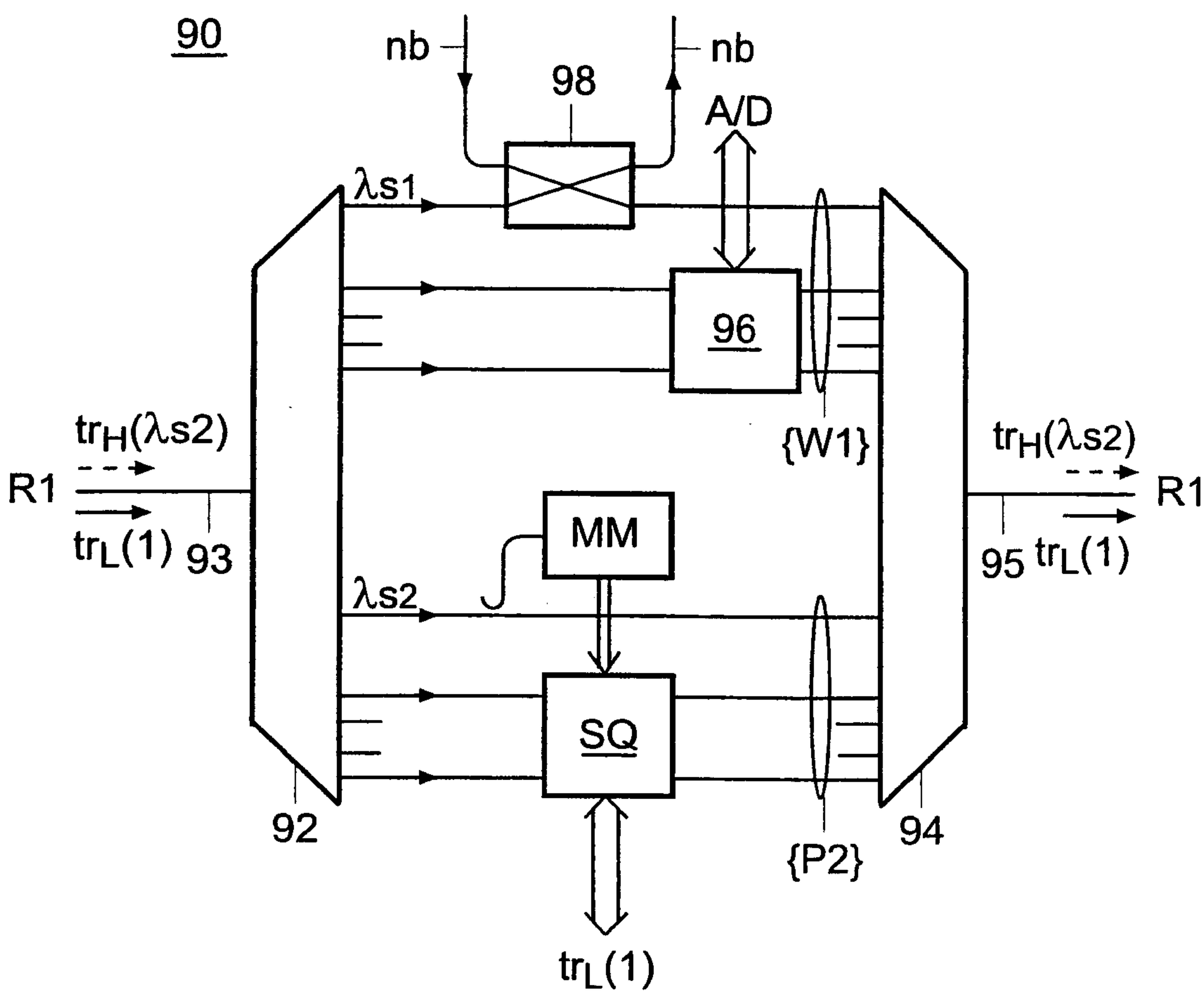


FIG. 8


90
nb
98
nb
A/D
λs1
96
{W1}
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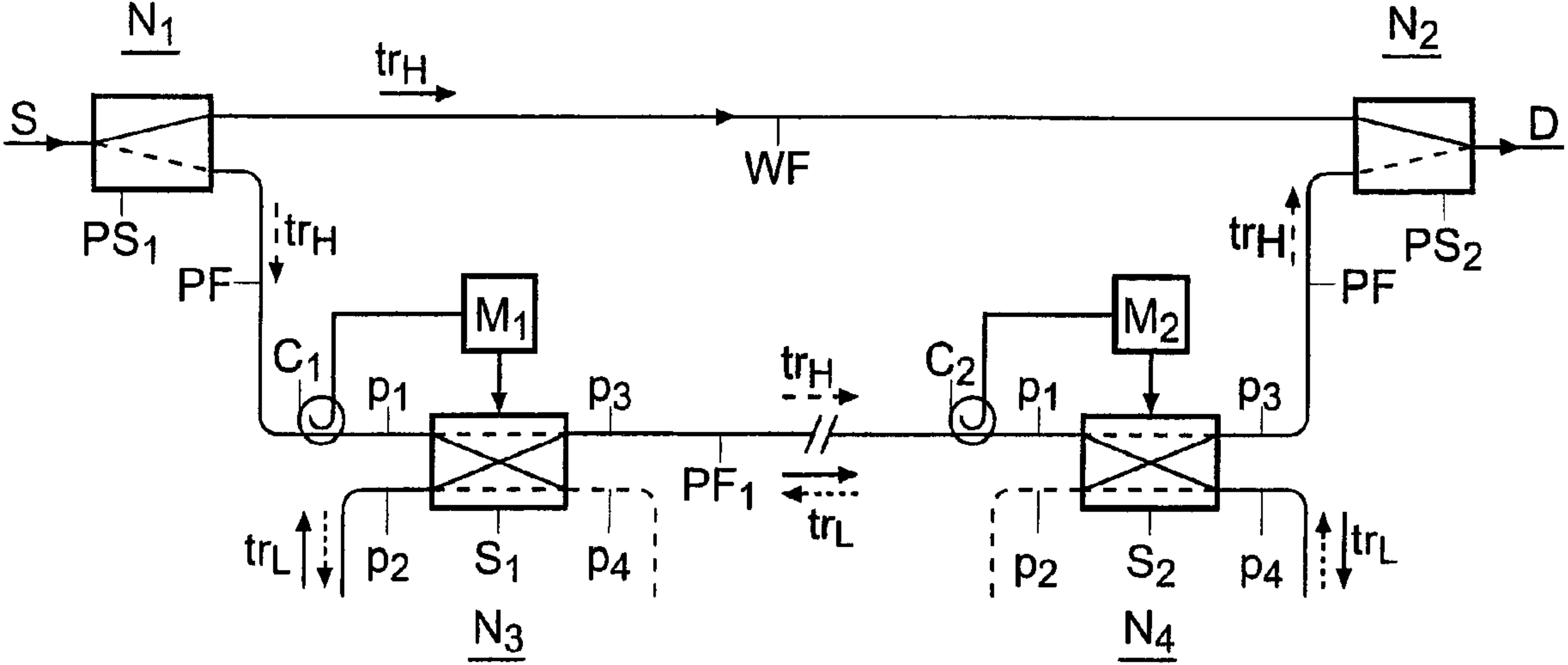
R1
trL(1)
93
trH(λs2)
R1
95 trL(1)
MM
λs2
SQ
92
{P2}
94
trL(1)

FIG. 9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trH
S
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PF
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p1
p3
p1
p3
PF1
trL
trL
trL
p2
S1
p4
p2
S2
p4
N3
N4