(12) UK Patent Application (19) GB (11) 2 389 261 (13) A

(43) Date of A Publication 03.12.2003

(21) Application No: 0212500.3

(22) Date of Filing: 30.05.2002

(51) INT CL[7]:
H04B 10/00 // H04J 14/02 , H04Q 11/00

(52) UK CL (Edition V):
H4B BKR BN

(56) Documents Cited:
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JP 030126334 A
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WO 2000/057583 A1
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(58) Field of Search:
UK CL (Edition T) **H4B**
INT CL[7] **G02B, H04B, H04J, H04Q**
Other: **Online: WPI, EPODOC, JAPIO, INSPEC**

(71) Applicant(s):
Bookham Technology Plc
(Incorporated In the United Kingdom)
90 Milton Park, ABINGDON, Oxfordshire,
OX14 4RY, United Kingdom

(72) Inventor(s):
Ian Day
Patrick Grant

(74) Agent and/or Address for Service:
Marks & Clerk
4220 Nash Court,
Oxford Business Park South, OXFORD,
OX4 2RU, United Kingdom

(54) Abstract Title: **Optical protective switching modules**

(57) A protective switching arrangement incorporates a splitter 11 and a 1 X 2 switch 12 and is connected to input and output fibres by input and output waveguides 13, 14. The input optical signal is split between a branch waveguide 15 connected to a master cross-connect (OXO) switch 17 and a branch waveguide 16 connected to an input of a backup cross-connect switch 18. The inputs of the switch 12 are connected to a branch waveguide 19 connected to an output of the master cross-connect and a branch waveguide 20 connected to an output of the backup cross-connect. The input signal is supplied to both cross-connects with the switch 12 normally connected to receive an output from the master cross-connect. In the event that the photodiode of a coupler 22 does not sense the presence of an optical signal, indicating a failure, an electrical signal is supplied to the switch to receive an output from the back-up cross-connect. Other protective switching embodiments are disclosed (e.g. fig 2B) including multiple or arrayed modules integrated on a single chip (e.g. figs 2C & 2D). Application is to unidirectional path switch ring (UPSR) and bidirectional line switch ring (BLSR) arrangements.

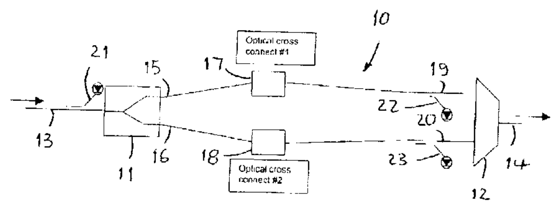

Fig. 2A

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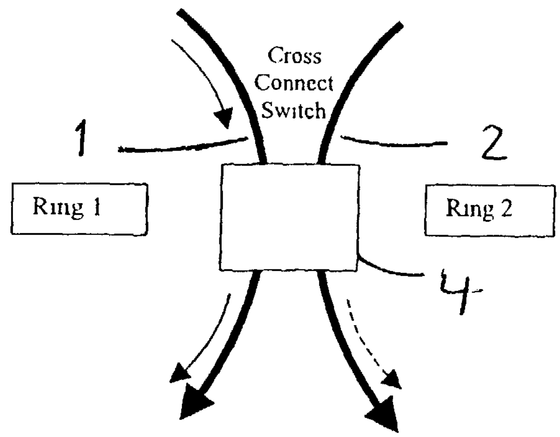

Fig. 1

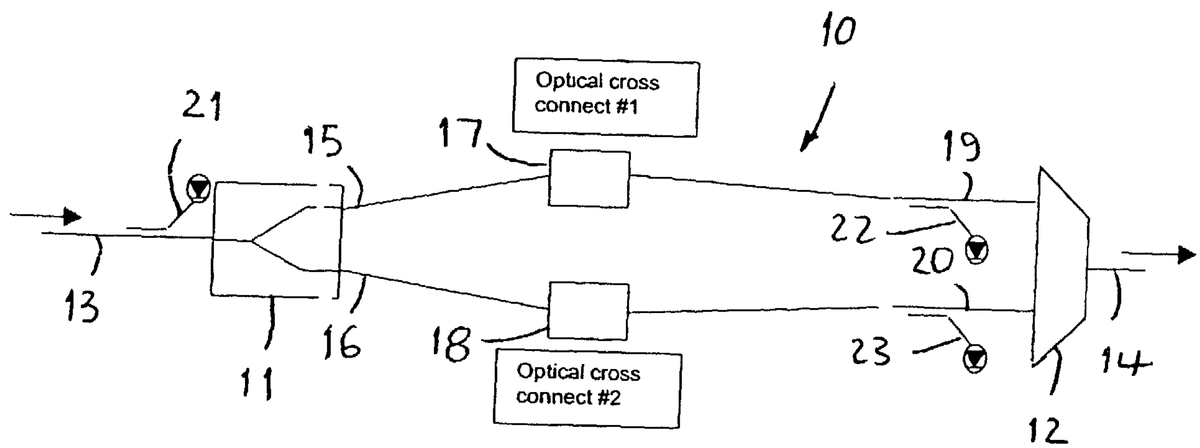

Fig. 2A

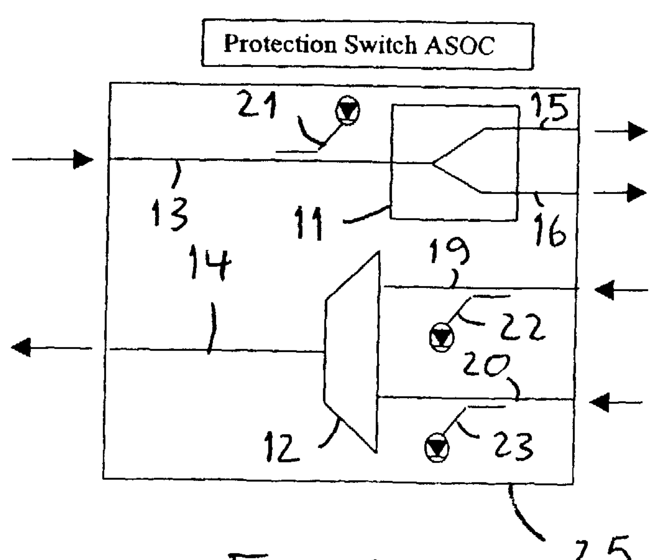

Fig. 2B

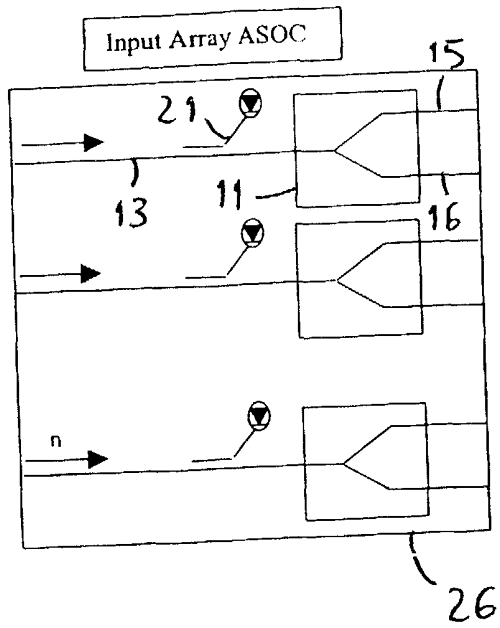
Input Array ASOC
15
21
13
11
16
n
26

Fig. 2c

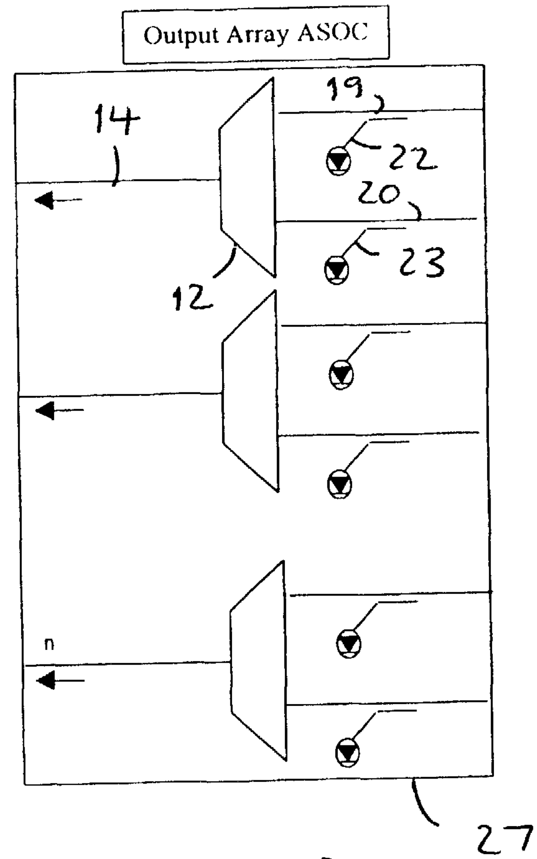
Output Array ASOC
19
14
22
20
23
12
n
27

Fig. 2D

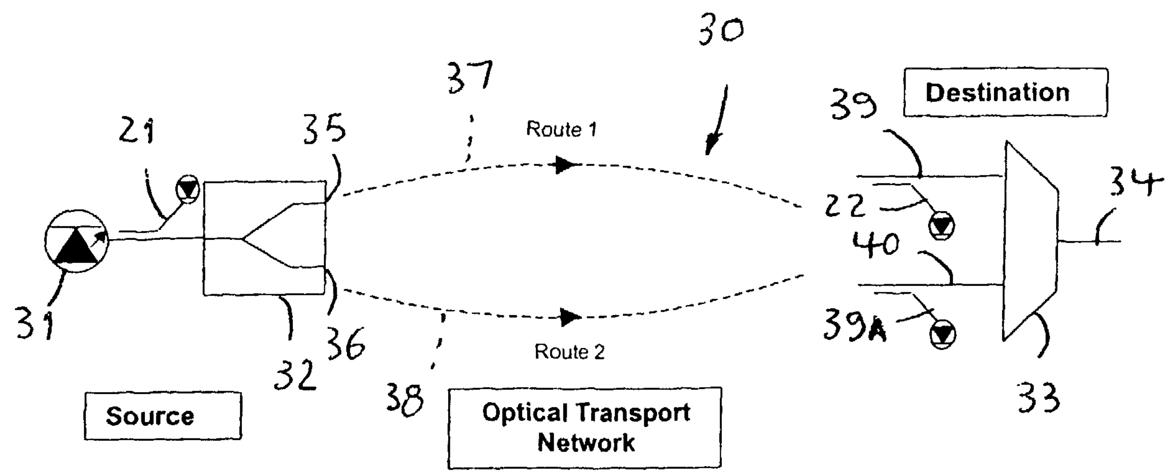

Fig. 3A

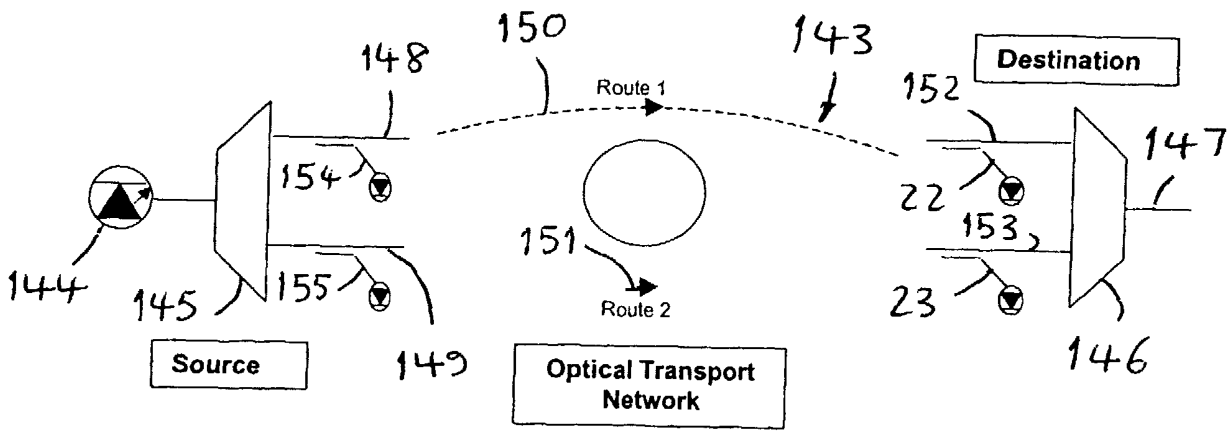

Fig. 4A

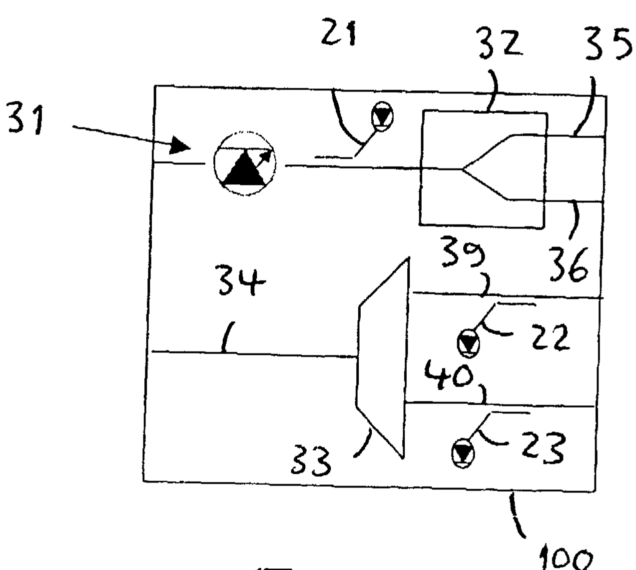

Fig. 3B

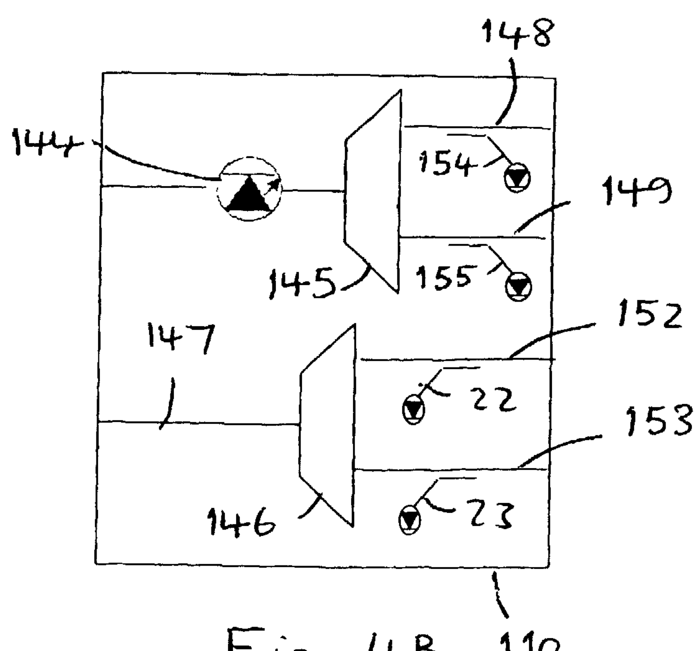

Fig. 4B

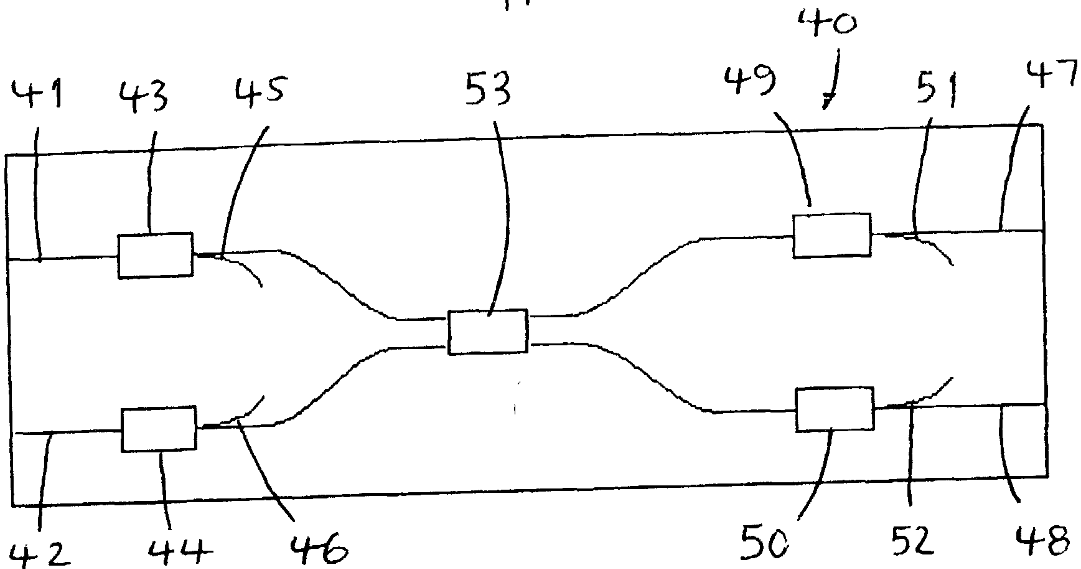

Fig. 5A

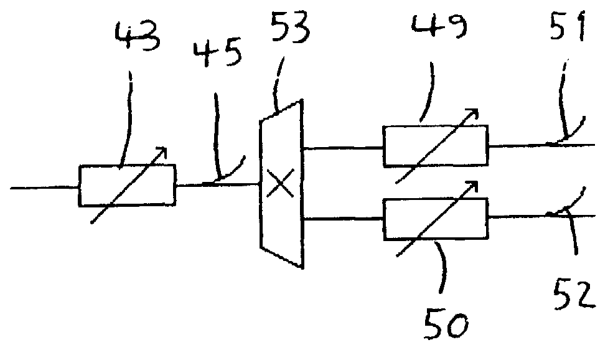

Fig. 5B

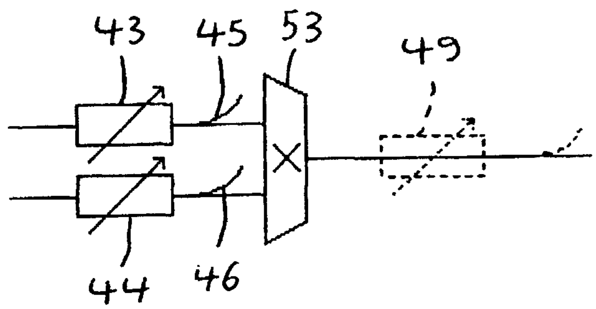

Fig. 5C

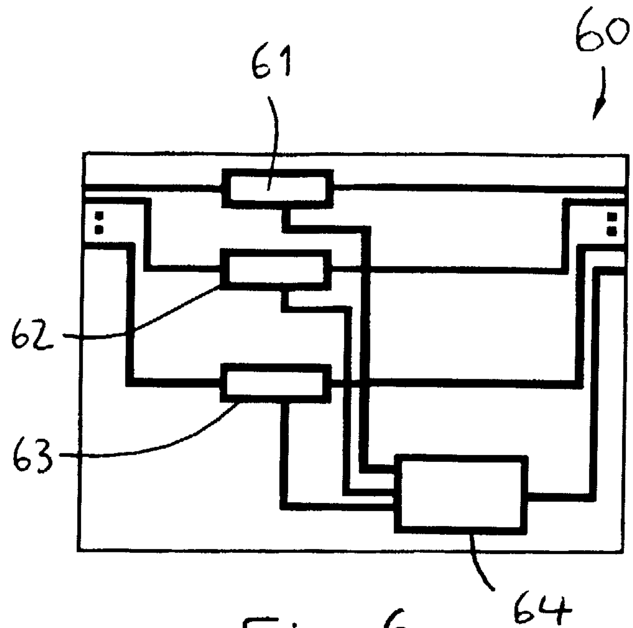

Fig. 6

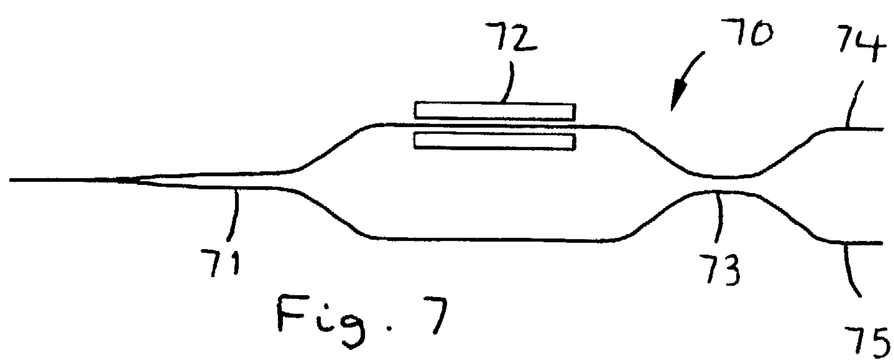

Fig. 7

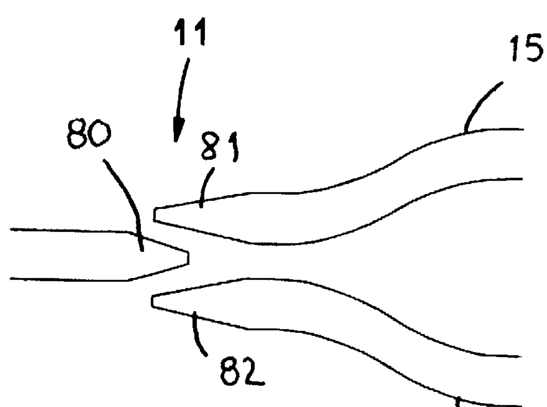

Fig. 8

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"Optical Protective Switching Modules"

This invention relates to optical protective switching modules for providing protective switching within an optical fibre communication system.

As is well understood in the field of optical communications, it is common practice for a protective switching arrangement to be provided for switching an optical signal to an alternative route in the event of a line failure. One such arrangement comprises a unidirectional path switch ring (UPSR) to which optical signals are supplied so that they are permanently transmitted in both directions around the ring between two points spaced around the ring. A switch is provided at one end of the line connection for switching to receive the optical signal transmitted the other way around the ring in the event that the optical signal travelling in the one direction around the ring is no longer being received due to line failure. In such an arrangement the usable bandwidth of the system is permanently reduced by the fact that the optical signal is at all times transmitted around the ring in both directions whilst the benefit of this is only seen in the event of a line failure.

Another arrangement comprises a bidirectional line switch ring (BLSR) to which optical signals are supplied so that the optical signals are normally transmitted only one way around the ring. In this case switches are generally provided at both ends of the line connection so that, in the event of a line failure, the optical signal can be rerouted by operating both switches so that it travels around the ring in the opposite direction. In this arrangement the two switches at opposite ends of the line are required to be operated in synchronism in the event of a failure and this involves additional control circuitry.

It is also common practice to provide a cross-connect switching arrangement between two rings in an optical communication network. In the event of a fault being detected either within or at the output of a cross-connect switch of such an arrangement, the signals are transferred to the other cross-connect switch of the arrangement. A selector switch may be operated so as to route the optical signal by way of a different switch.

It is an object of the invention to provide an optical protective switching module which is particularly reliable in providing protective switching in the event of a fault within an optical fibre communication network and which can be fabricated in a straightforward manner.

According to one aspect of the present invention there is provided an optical protective switching module for providing protective switching in the event of a fault within an optical fibre communication system, the module comprising an input waveguide for receiving an input optical signal, an output waveguide for supplying an output optical signal, first and second branch waveguides, optical coupling means for supplying the input optical signal to the first and second branch waveguides, first optical connection means for connection of the first and second branch waveguides to two optical transmission paths, third and fourth branch waveguides, second optical connection means for connection of two optical transmission paths to the third and fourth branch waveguides, selection means for supplying the output optical signal from a selected one of the third and fourth branch waveguides to the output waveguide, and photodetector means for detecting the presence of the optical signal in at least one of the third and fourth branch waveguides and for supplying an electrical control signal to the selection means for selecting one of the third and fourth branch waveguides for the supply of the output optical signal.

Such a module can be produced as an integrated chip which is both compact and reliable in operation, and enables fast protective switching to be applied in a straightforward manner in either a cross-connect switching arrangement or in a UPSR or a BLSR arrangement, that is either in an arrangement in which the optical signal is permanently present in both of the first and second transmission routes or an arrangement in which the optical signal is normally present in only one of the first and second transmission routes (and is switched to the other route only in the event of a fault being detected).

In one embodiment of the invention, for providing protective switching in a unidirectional path switch ring (UPSR) arrangement, the optical coupling means comprises a splitter for splitting the input optical signal between the first and second branch waveguides so as to supply optical signals to the two optical transmission paths at the same time.

In another embodiment of the invention, for providing protective switching in a bidirectional line switch ring (BLSR) arrangement, the optical coupling means comprises an optical switch for directing the input optical signal to a selected one of the first and second branch waveguides so as to supply an optical signal to only one of the optical transmission paths at a time.

In another embodiment of the invention, for providing protective switching in the event of a switch failure within an optical fibre communication system utilising cross-connect switches, the optical coupling means comprises a splitter for splitting the input optical signal between the first and second branch waveguides so as to supply optical signals to first and second cross-connect switches at the same time, the selection means serving to select the optical signal supplied by the second cross-connect switch in the event of failure of the first cross-connect switch.

The invention also provides an optical protective switching module for providing protective switching in the event of a fault within an optical fibre communication system, the module comprising a substrate, two input waveguides on the substrate for receiving at least one input optical signal, two output waveguides on the substrate for supplying at least one output optical signal, selection means on the substrate for supplying an optical signal from one of the input waveguides to one of the output waveguides in dependence on an electrical selection signal supplied to the selection means by control means, and detector means on the substrate for detecting the presence of an optical signal in at least one of the waveguides and for supplying an electrical control signal to the control means, whereby the switching module is adapted to switch an optical signal from a first optical transmission path to a second optical transmission path in response to detection of a fault.

Furthermore optical attenuation means, such as one or more VOAs, may be provided for attenuating the optical signal supplied along at least one of the waveguides. In this manner the optical signals may be equalised.

According to another aspect of the present invention there is provided an optical protective switching module for providing protective switching in the event of a fault within an optical fibre communication system, the module comprising an input waveguide for receiving an input optical signal, first and second branch waveguides, optical coupling means for supplying the input optical signal to the first and second branch waveguides, optical connection means for connection of the first and second branch waveguides to two optical transmission paths for transmitting the input optical signal, and photodetector means for detecting the presence of the input optical signal and for supplying an electrical output signal to subsequent selection means for selecting one of the optical transmission paths for the supply of an output optical signal.

According to another aspect of the present invention there is provided an optical protective switching module for providing protective switching in the event of a fault within an optical fibre communication system, the module comprising an output waveguide for supplying an output optical signal, optical coupling means for supplying the input optical signal to the first and second branch waveguides, two branch waveguides for receiving input optical signals from two alternative optical transmission paths, optical connection means for connection of the branch waveguides to the optical transmission paths, selection means for supplying the output optical signal from a selected one of the branch waveguides to the output waveguide, and photodetector means for detecting the presence of the optical signal in at least one of the branch waveguides and for supplying an electrical control signal to the selection means for selecting one of the branch waveguides for the supply of the output optical signal.

In order that the invention may be more fully understood, reference will be made to the accompanying drawings, in which:

Figure 1 is a diagram of a cross connect optical circuit arrangement;

Figure 2A is a diagram of a first embodiment in accordance with the invention, Figures 2B, 2C and 2D showing possible integrated circuit arrangements which may be used with such an embodiment;

Figure 3A is a diagram of a second embodiment in accordance with the invention, Figure 3B showing a possible integrated circuit arrangement which may be used with such an embodiment;

Figure 4A is a diagram of a third embodiment in accordance with the invention, Figure 4B showing a possible integrated circuit arrangement which may be used with such an embodiment;

Figures 5A, 5B and 5C are diagrams of possible integrated circuit arrangements which may be used in variants of the invention;

Figure 6 is a diagram of a fourth embodiment in accordance with the invention; and

Figures 7 and 8 are diagrams of components which may be incorporated in embodiments of the invention.

Figure 1 shows a cross-connect arrangement for an optical fibre communication network comprising a cross-connect switch 4 interconnecting two optical rings 1 and 2 of an optical communication network. The optical rings 1 and 2 serve for the transmission of optical signals between transmit/receive nodes within the network. The function of the cross-connect switch 4 is to control routing of the optical signals between nodes within the network, and the network incorporates several of these switches to allow the signal capacity between the network nodes to be managed. Such management may involve the setting up of the route for signal transmission between two nodes, the increasing or decreasing of the signal bandwidth over an established route, and the re-directing of the route for signal transmission between two nodes to avoid a network failure point. Each ring may contain multiple fibres with each fibre carrying optical signals of different wavelengths. In principle the switch 4 may be adapted to transfer a signal of a single wavelength from the ring 1 to the ring 2 whilst leaving signals of other wavelengths on the ring 2.

Because of the vital importance of these cross-connect switches to the proper functioning of optical communication networks, it is advantageous to duplicate the cross-connect functionality so that, in the event of a failure within the cross-connect hardware, a back-up system can be used with minimal loss of customer traffic. To this end a protective switching arrangement may be provided as will now be described in more detail with reference to Figure 2A.

Figure 2A diagrammatically shows a protective switching arrangement 10 in accordance with a first embodiment of the invention. Such a protective switching arrangement 10 incorporates a splitter 11 and a 1X2 switch 12 and intended to be connected to input and output optical fibres respectively by way of input and output waveguides 13 and 14. The splitter 11 splits the input optical signal between a first branch waveguide 15 connected to an input of a master cross-connect switch 17 and a second branch waveguide 16 connected to an input of a backup cross-connect switch 18. The inputs of the 1X2 switch 12 are connected to a third branch waveguide 19 which is in turn connected to an output of the master cross-connect switch 17 and a fourth branch waveguide 20 which is in turn connected to an output of the backup cross-connect switch 18. The backup cross-connect switch 18 is thus a redundant switch which can be used in the event of failure of the master cross-connect switch 17, to perform all the cross-connect functionality previously performed by the master cross-connect switch 17.

The optical signal transmitted along the input waveguide 13 is tapped off by a coupler 21 and sensed by an associated pin photodiode which provides an electrical output signal providing information on the light level in the waveguide 13. Furthermore respective couplers 22 and 23 and associated pin photodiodes are provided for determining light levels in the third and fourth branch waveguides 19 and 20. The couplers may be tap-off couplers, for example 90/10 tap-off couplers, and are optionally provided with further inputs coupled to integral lasers or external connectors.

In use of such a protective switching arrangement 10 in a cross-connect network, the optical input signal is supplied to both cross-connect switches 17 and 18 by the splitter 11. The 1X2 switch 12 will normally be switched to receive an optical output signal from the master cross-connect switch 17 by way of the third branch waveguide 19. However, in the event that the photodiode of the coupler 22 does not sense the presence of an optical signal in the waveguide 19 indicating failure of the master cross-connect switch 17, an electrical signal is supplied to the 1X2 switch 12 so as to switch the output waveguide 14 to receive an optical signal from the backup cross-connect switch 18 by way of the fourth branch waveguide 20. Clearly the provision of the coupler 23 associated with the fourth branch waveguide 20 would also enable switching of the output waveguide 14 to receive an optical signal from the third branch waveguide 19 in the event that no optical signal is detected by the photodiode of the coupler 23.

It should be appreciated that a separate protective switching arrangement is required for each optical fibre connection to the cross-connect switches. Thus the protective switching arrangement described above with reference to Figure 2A may serve to receive an input signal from a first fibre of the ring 1 and to send this optical signal to both the master cross-connect switch 17 and the backup cross-connect switch 18. Furthermore the output signal from the cross-connect arrangement, which may be an optical signal from the ring 2 destined for the first optical fibre of the ring 1, may be supplied from both switches 17 and 18 to the 1X2 switch 12 such that the signal received from one of the switches may selected for supply to the output waveguide 14. Clearly further protective switching arrangements are required for the signals from other fibres of the ring 1.

Figure 2B shows such a protective switching arrangement for a single fibre connection integrated on a SOI chip 25 for connection to both the master cross-connect switch 17 and the backup cross-connect switch 18. Since similar protective switching is required for each fibre connection to the cross-connect arrangement, it would be possible for both the input and the output parts of the protective switching to be multiplied appropriately and to be provided by a suitable array on the chip 25. However this may be prevented by system or geometrical constraints or design philosophy, and instead the input and output parts of the protective switching may be incorporated into separate chips.

Figure 2C shows the input parts of such protective multiple fibre switching arrangements integrated on a SOI chip 26 for connection to n fibres of the ring 1 and have pairs of output waveguides 15 and 16 for connection to respective input connections of the master cross-connect switch 17 and the backup cross-connect switch 18. Furthermore Figure 2D shows the output parts of such multiple fibre protective switching arrangements integrated on a SOI chip 27 for connection to n fibres of the ring 1 and have pairs of input waveguides 19 and 20 for connection to respective output connections of the master cross-connect switch 17 and the backup cross-connect switch 18.

Apart from the above described cross-connect protective switching function, embodiments in accordance with the invention may be used to for ring protection switching, that is to provide protective switching in the event of a line fault in a UPSR or BLSR configuration. Figure 3A diagrammatically shows a protective switching arrangement 30 for a UPSR configuration in accordance with a second embodiment of the invention. Such a protective switching arrangement 30 incorporates an optical source 31, such as a laser diode, a splitter 32 and a 1X2 switch 33 for connection to an output optical fibre by way of an output waveguide 34. The splitter 32 splits the input optical signal from the optical source 31 between a first branch waveguide 35 connected to a first transmission route 37 of the UPSR and a second branch waveguide 36 connected to a second transmission route 38 of the UPSR. The inputs of the 1X2 switch

33 are connected to a third branch waveguide 39 which is in turn connected to the first transmission route 37 of the UPSR and a fourth branch waveguide 39A which is in turn connected to the second transmission route 38 of the UPSR. Couplers 21, 22 and 23 and associated photodiodes are provided to perform the same functions as in the embodiment of Figure 2A.

In use of such a protective switching arrangement 30 in a UPSR configuration, optical signals are simultaneously supplied to both transmission routes 37 and 38 of the UPSR. The 1X2 switch 33 will normally be switched so that the output waveguide 34 receives an optical signal from the first transmission route 37 by way of the third branch conduit 39. However, in the event that the photodiode of the coupler 22 does not sense the presence of an optical signal in the waveguide 39 indicating a fault in the first transmission route 37, an electrical signal is supplied to the 1X2 switch 33 so as to switch the output waveguide 34 to receive an optical signal from the second transmission route 38 by way of the fourth branch waveguide 39A.

Figure 3B shows such a protective switching arrangement integrated on a SOI chip 100 for connection to both transmission routes 37 and 38 of the UPSR. The optical source 31 may be a source of either light of a single wavelength or of light of different wavelengths, and is optionally integrated on the chip 100 where it is required to provide only a single wavelength. Since this protective switching function is required at each node of the network such an arrangement is advantageously provided at each network node.

Figure 4A diagrammatically shows a protective switching arrangement 143 for a BLSR configuration in accordance with a third embodiment of the invention. Such a protective switching arrangement 143 incorporates an optical source 144, such as a laser diode, a 1X2 switch 145 and a further 1X2 switch 146 for connection to an output optical fibre by way of an output waveguide 147. In this case switches 145 and 146 are required at both the source and destination ends, and centralised control circuitry within the network determines the route which the optical signal should take through the network and sets the switches 145 and 146 accordingly. The switch 145 switches the input optical signal from the optical source 144 to either a first branch waveguide 148 connected to a first transmission route 150 of the BLSR or to a second branch waveguide 149 connected to a second transmission route 151 of the BLSR, so that an optical signal is transmitted along only one of these transmission routes 150 and 151 at any one time (only the transmission route 150 being specifically shown in Figure 4A to indicate that the switch 145 is currently switched to cause the optical signal to be transmitted along only that route). The inputs of the 1X2 switch 146 are connected to a third branch waveguide 152 which is in turn connected to the first transmission route 150 of the BLSR and a fourth branch waveguide 153 which is in turn connected to the second transmission route 151 of the BLSR. Couplers 22 and 23 and associated photodiodes are provided to perform the same functions as in the embodiment of Figure 2A, and in addition couplers 154 and 155 and associated photodiodes are provided to monitor the light levels of the optical signal transmitted along one of the first and second branch waveguides 148 and 149 for the purpose of determining the route along which the optical signal is directed.

In use of such a protective switching arrangement 143 in a BLSR configuration, the optical input signal is supplied to a selected one of the transmission routes 150 and 151 of the BLSR depending on the switching position of the 1X2 switch 145. The 1X2 switch 146 will normally be switched to receive an optical signal from the first transmission route 150 by way of the third branch conduit 152. However, in the event that the photodiode of the coupler 22 does not sense the presence of an optical signal in the waveguide 152 indicating a fault in the first transmission route 150, electrical signals are supplied to the switches 145 and 146 so as to switch the optical signal to the second transmission route 151.

Figure 4B shows such a protective switching arrangement integrated on a SOI chip 110 for connection to both transmission routes 150 and 151 of the BLSR. In the case of both the UPSR protective switching arrangement of Figure 3B and the BLSR protective switching arrangement of Figure 4B, the functional elements may be repeated as many times as required to accommodate the required number of inputs or outputs. Since similar protective switching is required for each fibre of a multi-fibre ring, it would be possible for both the input and the output parts of the protective switching to be multiplied appropriately and to be provided by a suitable array on a chip, in a similar manner to the arrangements of Figures 2C and 2D.

Figure 5A is a diagram of a generic integrated protective switching module which may be used either in a UPSR or in a BLSR arrangement. Such a module 40 comprises, on a silicon substrate, two input waveguides 41 and 42 incorporating variable optical amplifiers (VOAs) 43 and 44 and tap-off couplers 45 and 46, and output waveguides 47 and 48 incorporating VOAs 49 and 50 and tap-off couplers 51 and 52. The input and output waveguides are interconnected by a switch or coupler 53 which may be a digital optical switch (DOS), a Mach-Zender switch or a multimode interferometer (MMI) for example.

It will be appreciated that, where such a generic protective switching module is to be used in a BLSR arrangement, two such modules must be used, one at the head end of the line and the other at the tail end of the line. Figure 5B shows the connection of such a module 40 at the head end of such a BLSR arrangement with the input signal being supplied to the switch or coupler 53 by way of the VOA 43, and the switch or coupler 53 supplying a signal to only one of the transmission routes by way of the VOA 49 or 50 in dependence on an electrical control signal determined by whether or not an optical signal is detected in one of the branch waveguides at the tail end of the arrangement.

Figure 5C shows the manner of connection of such a module 40 at the tail end of the BLSR arrangement where the two transmission routes are connected to the switch or coupler 53 by way of the VOAs 43 and 44, and the output signal from the switch or coupler 53 is supplied by way of a further VOA 49 (due to the fact that this VOA is in any case provided in the generic chip). Where a switch 53 is used rather than a coupler, the switch 53 is controlled by an electrical control signal so as to supply a signal from one of the transmission routes to the output, the transmission route being selected on the basis of whether or not an optical signal is detected by a pin photodiode associated with one of the tap-off couplers 45 and 46. Thus the switches/couplers 53 of the two modules may be operated to ensure that the signal transmission occurs along only one of the two transmission routes and, in the event of failure of that route, the switch is used to transfer the transmission to the other route.

Where a coupler 53 is used instead of a switch, signals will be transmitted from the head end to the tail end along both transmission routes, and the VOAs 49 and 50 may be operated to attenuate the signal along one of the channels whilst allowing the signal in the other channel to be transmitted to the outlet with minimum attenuation, such attenuation being controlled by an electrical control signal in dependence on the output of a pin photodiode which determines whether or not a signal is present in one of the channels. In the event of a line failure being detected, the control signal supplied to the VOAs 49 and 50 causes the previously attenuated channel to be substantially unattenuated so as to allow the signal transmission to take place along the other channel. Pin photodiodes may be coupled to each of the tap-off couplers 45, 46, 51 and 52 to monitor the signals outputted by the VOAs 43, 44, 49 and 50 with a view to controlling the power levels of the signals inputted to, or outputted from, the switch or coupler 53.

Even where a switch 53 is provided at the tail end, it may be preferred to control the VOAs so as to ensure that the leakage across the switch is minimised, to thereby provide a 60 dB switch for example. Normally the switch will be adapted to switch to a defined state in the event of the power supply failing. To this end the switch may be Mach-Zender switch or a DOS switch which fails to a preselected state. It would also be possible to integrate both lasers and photodetectors on the chip. In the event of a hybridised photodetector being provided on the chip, it is possible to arrange for two waveguides to be positioned to supply signals to a single photodiode or multimode fibre in order to reduce complexity.

Figure 6 shows a protective switching arrangement 60 for a BLSR configuration having three channels incorporating three waveguides which are spread out to accommodate 1X2 switches 61, 62 and 63, and having a 1XN switch 64 receiving an electrical control signal which is supplied to a selected one of the switches 61, 62 and 63 in order to enable the optical signal transmission to occur along only one of the channels. As in the other embodiments described pin photodiodes (not shown) are provided for detecting the presence of an optical signal in at least one of the channels, and for switching the signal transmission to another channel in the event of a detected line failure.

As previously described, the 1X2 switch 145 used in the embodiment of Figure 4A may be a DOS switch (in which switching is effected either by the thermo-optic effect or by free carrier injection) or a prism switch (in which a heater is used to heat the prism to cause a refractive index change which deflects the beam from its default path). However it is preferred to use a Mach-Zender switch as shown in Figure 7 to perform this function. In this case the switch 70 comprises a splitter 71, a phase shifter 72 and a combiner 73. The phase shifter 72, which may be a pin diode or a heater, can be activated by a electrical control signal to shift the phase of the signal in one arm of the switch relative to the signal in the other arm of the switch so that the signal is directed either to the output 74 or to the output 75 depending on the relative phases of the signals in the two arms and the manner in which they interfere with one another in the combiner 73. In a preferred implementation the splitter 71 is a tapered Y-junction splitter, the phase shifter 72 is a thermo-optic phase shifter and the combiner 73 is an MMI combiner, although other choices of components may be preferred for other applications. It is important that the switch should have a high extinction ratio, and this may be enhanced by the inclusion of absorption VOAs at the switch outputs.

Furthermore the splitter 11 or 32 of the embodiment of Figure 2A or 3A may comprise a tapered Y-junction as shown in Figure 8 in order to minimise the introduction of insertion loss or polarisation dependent loss. In this case the input waveguide 13 has a tapered end 80 which is positioned in relation to adjacent tapered ends 81 and 82 of the branch waveguides 15 and 16 (or 35 and 36) in order to minimise insertion loss.

The above described protection switching modules have a number of advantages in use. They are small in size and have low power losses as compared with known arrangements requiring a number of optical fibre interconnections, as well as being fully solid state so that they are of high reliability. The fact that no fibre interconnections are required greatly reduces the size of the modules and renders manufacture simpler. They also permit faster switching than in known arrangements, thus requiring less system buffering, and can be fabricated in a relatively straightforward manner. The switches may be used singly or in multiple arrays, and the provision of a generic switching module incorporating VOAs enables a wide range of functions to be performed by a single module.

CLAIMS:

1. An optical protective switching module for providing protective switching in the event of a fault within an optical fibre communication system, the module comprising an input waveguide (13) for receiving an input optical signal, an output waveguide (14) for supplying an output optical signal, first and second branch waveguides (15, 16), optical coupling means (11) for supplying the input optical signal to the first and second branch waveguides, first optical connection means for connection of the first and second branch waveguides to two optical transmission paths (17, 18), third and fourth branch waveguides (19, 20), second optical connection means for connection of two optical transmission paths (17, 18) to the third and fourth branch waveguides (19, 20), selection means (12) for supplying the output optical signal from a selected one of the third and fourth branch waveguides (19, 20) to the output waveguide (14), and photodetector means (22, 23) for detecting the presence of the optical signal in at least one of the third and fourth branch waveguides and for supplying an electrical control signal to the selection means (12) for selecting one of the third and fourth branch waveguides for the supply of the output optical signal.

2. A module according to claim 1, for providing protective switching in a unidirectional path switch ring (UPSR) arrangement, wherein the optical coupling means comprises a splitter for splitting the input optical signal between the first and second branch waveguides so as to supply optical signals to the two optical transmission paths at the same time.

3. A module according to claim 1, for providing protective switching in a bidirectional line switch ring (BLSR) arrangement, wherein the optical coupling means comprises an optical switch for directing the input optical signal to a selected one of the first and second branch waveguides so as to supply an optical signal to only one of the optical transmission paths at a time.

4. A module according to claim 1, 2 or 3, for providing protective switching in the event of a switch failure within an optical fibre communication system utilising cross-

connect switches, wherein the optical coupling means comprises a splitter for splitting the input optical signal between the first and second branch waveguides so as to supply optical signals to first and second cross-connect switches at the same time, the selection means serving to select the optical signal supplied by the second cross-connect switch in the event of failure of the first cross-connect switch.

5. A module according to claim 2 or 4, wherein the splitter means comprises a Y-junction.

6. A module according to any preceding claim, wherein the selection means comprises optical switching means.

7. A module according to any one of claims 1 to 5, wherein the selection means comprises optical attenuation means.

8. A module according to any one of claims 1 to 7, wherein the selection means comprises a Mach-Zender switch.

9. A module according to any one of claims 1 to 7, wherein the selection means comprises a digital optical switch (DOS).

10. A module according to any one of claims 1 to 7, wherein the selection means comprises a multimode interferometer (MMI).

11. A module according to any preceding claim, wherein optical attenuation means are provided for attenuating the optical signal supplied along at least one of the branch waveguides.

12. A module according to any preceding claim, wherein the photodetector means comprises a photodetector coupled to receive a proportion of the optical signal from the first optical transmission path and a photodetector coupled to receive a proportion of the optical signal from the second optical transmission path.

13. A module according to any preceding claim, wherein further photodetector means are coupled to receive a proportion of the input optical signal in the input waveguide.

14. A module according to any preceding claim, wherein further photodetector means are coupled to receive a proportion of the optical signal in each of the first and second branch waveguides.

15. A module according to any preceding claim, wherein an array of optical coupling means are provided for supplying a plurality of input signals from a plurality of input waveguides to corresponding pairs of optical transmission paths.

16. A module according to any preceding claim, wherein an array of selection means are provided for supplying a plurality of output signals to a plurality of output waveguides from selected ones of corresponding pairs of optical transmission paths.

17. An optical protective switching module for providing protective switching in the event of a fault within an optical fibre communication system, the module comprising a substrate, two input waveguides on the substrate for receiving at least one input optical signal, two output waveguides on the substrate for supplying at least one output optical signal, selection means on the substrate for supplying an optical signal from one of the input waveguides to one of the output waveguides in dependence on an electrical selection signal supplied to the selection means by control means, and detector means on the substrate for detecting the presence of an optical signal in at least one of the waveguides and for supplying an electrical control signal to the control means, whereby the switching module is adapted to switch an optical signal from a first optical transmission path to a second optical transmission path in response to detection of a fault.

18. An optical protective switching module for providing protective switching in the event of a fault within an optical fibre communication system, the module comprising

an input waveguide (13) for receiving an input optical signal, first and second branch waveguides (15, 16), optical coupling means (11) for supplying the input optical signal to the first and second branch waveguides, optical connection means for connection of the first and second branch waveguides to two optical transmission paths (17, 18) for transmitting the input optical signal, and photodetector means (21) for detecting the presence of the input optical signal and for supplying an electrical output signal to subsequent selection means (12) for selecting one of the optical transmission paths (17, 18) for the supply of an output optical signal.

19. An optical protective switching module for providing protective switching in the event of a fault within an optical fibre communication system, the module comprising an output waveguide (14) for supplying an output optical signal, optical coupling means (11) for supplying the input optical signal to the first and second branch waveguides, two branch waveguides (19, 20) for receiving input optical signals from two alternative optical transmission paths (17, 18), optical connection means for connection of the branch waveguides (19, 20) to the optical transmission paths (17, 18), selection means (12) for supplying the output optical signal from a selected one of the branch waveguides (19, 20) to the output waveguide (14), and photodetector means (22, 23) for detecting the presence of the optical signal in at least one of the branch waveguides and for supplying an electrical control signal to the selection means (12) for selecting one of the branch waveguides for the supply of the output optical signal.

20. A module according to any preceding claim, wherein optical attenuation means are provided for attenuating the optical signal supplied along at least one of the waveguides.

21. A module according to any preceding claim, which is integrally fabricated on the substrate using planar waveguide technology, such as silicon-on-insulator (SOI) technology.

22. An optical protective switching module substantially as hereinbefore described with reference to the accompanying drawings.

23. An optical fibre communication system incorporating at least one module according to any preceding claim.

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Application No: GB 0212500.3
Claims searched: 1-16, 18, 19 & 20-23 (partially)

Examiner: Matthew Nelson
Date of search: 27 December 2002

Patents Act 1977 : Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance	
X	1, 5, 12, 14, 18, 19, 23 at least	EP 0851704 A2	(LUCENT) See col. 3, line 18 - col. 4, line 14; col. 5, line 42 - col. 6, line 4 and figures 2, 4 and 7.
X	1, 18, 19, 23 at least	JP 030126334 A	(NIPPON) See online abstract and figure 1.
A		WO 00/57583 A1	(TELLIUM) See the abstract and figure 2.
A		US 20020034354 A1	(HAYASHI et al) See the abstract and figure 1.
A		US 5559622	(HUBER et al) See whole document, e.g. col. 1, lines 19-32.
A		CA 2295407 A	(NORTEL) See whole document.
A		DE 19946487 A1	(SIEMENS AG) See online abstract.

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The following online and other databases have been used in the preparation of this search report.

WPI, EPODOC, JAPIO, INSPEC