

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
14 December 2006 (14.12.2006)

PCT

(10) International Publication Number
WO 2006/132927 A2

(51) International Patent Classification:
H04J 14/00 (2006.01)

(74) Agents: **MAYER, Stuart, H.** et al.; **MAYER & WILLIAMS PC**, 251 North Avenue West, 2nd Floor, Westfield, NJ 07090 (US).

(21) International Application Number:
PCT/US2006/021303

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(22) International Filing Date: 2 June 2006 (02.06.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/145,008 3 June 2005 (03.06.2005) US

(71) Applicant (*for all designated States except US*): **RED SKY SUBSEA LIMITED** [GB/GB]; New Saxon House, 1 Winsford Way, Boreham Interchange, Chelmsford, Essex CM2 5PD (GB).

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

(72) Inventors; and

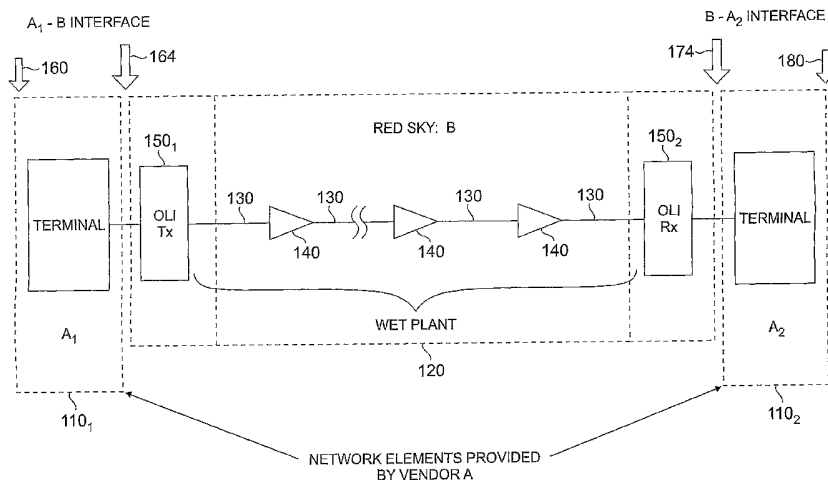
(75) Inventors/Applicants (*for US only*): **WILSON, David, L.** [US/US]; 64 Laurel Drive, Little Silver, NJ 07739 (US). **NAGEL, Jonathan, A.** [US/US]; 416 Clinton Street, Brooklyn, NY 11031 (US). **SUTTORA, Mario** [US/US]; 20 Washington Place, East Rutherford, NJ 07073 (US).

Published:

— *without international search report and to be republished upon receipt of that report*

[Continued on next page]

(54) Title: OPTICAL SUPERVISORY CHANNEL TRANSLATOR



(57) Abstract: An optical line interface is provided for communicating between terrestrial terminal equipment and an undersea optical transmission path a WDM optical signal having a plurality of wavelength components. The optical line interface includes a signal processing unit for transforming WDM optical signals between optical layer transport protocols employed by the terrestrial terminal equipment and undersea optical layer transport protocols employed over the undersea optical transmission path. The optical inter interface also includes an optical supervisory channel translator for transforming an optical service signal received at a first wavelength from the terrestrial terminal equipment to a second wavelength employed by the undersea optical transmission path for communicating service information.

WO 2006/132927 A2



For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

OPTICAL SUPERVISORY CHANNEL TRANSLATOR

Field of the Invention

[0001] The present invention relates generally to optical transmission systems, and more particularly to a method and apparatus for transmitting service channel information over the optical transmission system.

Background of the Invention

[0002] A typical long-range optical transmission system includes a pair of unidirectional optical fibers that support optical signals traveling in opposite directions. An optical signal is attenuated over long distances. Therefore, the optical fibers typically include multiple repeaters that are spaced apart from one another. The repeaters include optical amplifiers that amplify the incoming, attenuated optical signals. The repeaters also include an optical isolator that limits the propagation of the optical signal to a single direction.

[0003] Optical transmission systems generally provide some mechanism for the transmission of service communications. Service communications can include, for example, telemetry signals that provide control or command signals, or status signals for equipment located within the optical fiber communication system. Examples of such signals are those indicating alarms, temperature conditions, equipment failure and the like. Service communications can also include service signals representing voice communication between maintenance personnel located at various sites within the optical fiber communication system.

[0004] One conventional method for providing service signals in optical form involves using wavelengths outside of the wavelength window that is used for carrying customer traffic. That is, the service signals are out-of-band signals. For example, some commercially available equipment uses wavelengths in the range from 1200 to 1400 nm (nanometers) to carry service signals, and wavelengths in the range from 1500 to 1600 nm to carry customer traffic. Such conventional equipment is described in U.S. Pat. No. 5,113,459, which provides for the transmission of telemetry signals at a dedicated, selected wavelength (for example, 1310 nm) in one direction on one fiber and at the same or a different dedicated, selected wavelength to transmit telemetry signals in the opposite

direction using the second fiber. The service signals are typically transformed into a corresponding electrical signal in the repeaters to provide, for example, control to the optical amplifiers located therein. Accordingly, the service signals must be demultiplexed, regenerated and re-multiplexed with the customer data. In other cases the service signals only need to be transmitted between terminals, in which case demultiplexing, regenerating and re-multiplexing is not required.

[0005] One type of highly specialized optical transmission network in which service signals are employed is an undersea or submarine optical transmission system in which a cable containing optical fibers is installed on the ocean floor. The cable contains optical fibers that carry Wavelength Division Multiplexed (WDM) optical signals between land-based terminals. The terminals contain power supplies for powering repeaters located along the undersea cable, transmission equipment to insert and remove WDM signals from the fibers and associated monitoring and control equipment. The design of the land-based terminals (the "dry-plant") and the undersea cable and repeaters (the "wet plant") are typically customized on a system-by-system basis and employ highly specialized terminals to transmit data over the undersea optical transmission path. For this reason the wet and dry plants are typically provided by a single entity that serves as a systems integrator. As a result all the elements of the undersea system can be highly integrated to function together. For example, all the elements can exchange information and commands in order to monitor service quality, detect faults, and locate faulty equipment. In this way the quality of service from end to end (i.e., from one land-based terminal to another) can be guaranteed. Moreover, since there is a single systems integrator involved, the system operator always knows who to contact in the event of a failure.

[0006] Recently, undersea optical transmission systems have been proposed in which the wet plant can be designed independently of the dry plant. Specifically, the wet plant is designed as an independent, stand-alone network element and is transparent to the dry plant. In this way the wet plant can accommodate a wide variety of different land-based terminals. In order to achieve such universal transparency, an optical interface device is provided between the wet plant and the terminals. One problem with this arrangement is that the land-based terminals generating the service signals must still communicate the service channel over the wet plant so that they can provide the same service communications as a conventional system that is provided by a single vendor. This could

present a problem since the service signals employed by the terminals are not necessarily located at the same wavelength or wavelengths employed by the wet plant.

Summary of the Invention

[0007] In accordance with the present invention, an optical line interface is provided for communicating between terrestrial terminal equipment and an undersea optical transmission path a WDM optical signal having a plurality of wavelength components. The optical line interface includes a signal processing unit for transforming WDM optical signals between optical layer transport protocols employed by the terrestrial terminal equipment and undersea optical layer transport protocols employed over the undersea optical transmission path. The optical inter interface also includes an optical supervisory channel translator for transforming an optical service signal received at a first wavelength from the terrestrial terminal equipment to a second wavelength employed by the undersea optical transmission path for communicating service information.

[0008] In accordance with one aspect of the invention, the signal processing unit is configured to perform at least one signal conditioning process selected from the group consisting of gain equalization, bulk dispersion compensation, optical amplification, Raman amplification, dispersion slope compensation, PMD compensation, and performance monitoring.

[0009] In accordance with another aspect of the invention, the second wavelength is an in-band wavelength located within a waveband in which traffic is communicated over the undersea optical transmission path.

[0010] In accordance with another aspect of the invention, the second wavelength is an out-of-band wavelength located outside of a waveband in which traffic is communicated over the undersea optical transmission path.

[0011] In accordance with another aspect of the invention, the optical supervisory channel translator is further configured to transform an optical service signal received at the second wavelength from the undersea optical transmission path to the first wavelength employed by the terrestrial terminal equipment for communicating service information.

[0012] In accordance with another aspect of the invention, the first wavelength is an in-band wavelength located within a waveband in which traffic is communicated by the terrestrial terminal equipment.

[0013] In accordance with another aspect of the invention, the first wavelength is an out-of-band wavelength located outside a waveband in which traffic is communicated by the terrestrial terminal equipment.

[0014] In accordance with another aspect of the invention, the undersea optical transmission path includes at least one repeater and the second wavelength is an in-band wavelength located within a waveband that undergoes optical amplification in the repeater.

[0015] In accordance with another aspect of the invention, the undersea optical transmission path includes at least one repeater and the second wavelength is an out-of-band wavelength located outside of a waveband that undergoes optical amplification in the repeater.

[0016] In accordance with another aspect of the invention, a method is provided for communicating a WDM optical signal having a plurality of wavelength components between terrestrial terminal equipment and an undersea optical transmission path. The method begins by receiving the WDM optical signal from the terrestrial terminal equipment and transforming the WDM optical signal between optical layer transport protocols employed by the terrestrial terminal equipment and undersea optical layer transport protocols employed over the undersea optical transmission path. An optical service signal located at a first wavelength is received from the terrestrial terminal. The optical service signal received at a first wavelength from the terrestrial terminal equipment is transformed to a second wavelength employed by the undersea optical transmission path for communicating service information. The transformed optical service signal is directed over the undersea optical transmission path.

Brief Description of the Drawing

[0017] FIG. 1 shows a simplified block diagram of an exemplary wavelength division multiplexed (WDM) transmission system in accordance with the present invention.

[0018] FIG. 2 is a block diagram showing one example of an optical interface device constructed in accordance with the present invention.

Detailed Description of the Invention

[0019] FIG. 1 shows an example of an undersea optical transmission system that employs an optical interface device to provide transparency between the terminal equipment and the wet plant. The system consists of terminal equipment 110₁ and 110₂ that communicate with one another over a wet plant 120 consisting of optical transmission spans 130 connected by repeaters 140. An optical interface device 150 provides the connectivity between the wet plant 120 and each terminal 110. Specifically, optical interface device 150₁ provides optical-level connectivity to terminal equipment 110₁ and optical interface device 150₂ provides optical-level connectivity to terminal equipment 110₂. The wet plant 120 and the optical interface devices 150 will generally be provided by a single vendor or system integrator while the terminal equipment 110₁ and 110₂ may be provided by a different vendor. In this case, in the event of a failure, the system operator must be able to determine which vendor to contact for repairs to be made.

[0020] The terminal equipment 110 will typically perform any necessary optical-to-electrical conversion, FEC processing, electrical-to-optical conversion, and optical multiplexing. The terminal equipment 110 may also perform optical amplification, optical monitoring that is designed for the terrestrial optical network, and network protection. Examples of terminal equipment that are currently available and which may be used in connection with the present invention include, but are not limited to, the Nortel LH1600 and LH4000, Siemens MTS 2, Cisco 15808 and the Ciena CoreStream long-haul transport products. The terminal equipment may also be a network router in which Internet routing is accomplished as well the requisite optical functionality. Moreover, the terminal equipment that is employed may conform to a variety of different protocol standards, such as SONET/SDH ATM and Gigabit Ethernet, for example.

[0021] The optical interface device 150 provides the signal conditioning and the additional functionality necessary to transmit the traffic over an undersea optical transmission cable. Examples of suitable interface devices are disclosed in U.S. Appl. Serial Nos. 10/621,028 and 10/621,115, which are hereby incorporated by reference in their entirety. As discussed in the aforementioned reference, the optical interface device disclosed therein receives the optical signals from terminal equipment such as a SONET/SDH transmission terminal either as individual wavelengths on separate fibers or as a WDM signal on a single fiber. The interface device provides the optical layer signal

conditioning that is not provided by the SONET/SDH terminals, but which is necessary to transmit the optical signals over the undersea transmission path. The signal conditioning that is provided may include, but is not limited to, gain equalization, bulk dispersion compensation, optical amplification, multiplexing, Raman amplification, dispersion slope compensation, polarization mode dispersion (PMD) compensation, performance monitoring, signal load balancing (e.g., dummy channel insertion), or any combination thereof. The optical interface device may also include line monitoring equipment such as a COTDR arrangement, an autocorrelation arrangement, or other techniques that use in-band or out-of band probe signals to determine the status and health of the transmission path. Additionally, the optical interface device may supply pump power to the transmission path so that Raman amplification can be imparted to the optical signals.

[0022] The undersea transmission system shown in FIG. 1 must provide the same end-to-end quality of service guarantee, including maintenance services, as a conventional system that is provided by a single vendor. This requires the system to be able to communicate service information between the terminal equipment 1101 and 1102. As previously mentioned, optical service signals are often located out-of-band. Since the service signals are out-of-band their wavelengths do not necessarily need to fall precisely on the ITU-T grid that is generally used to specify the wavelengths of the data channels. Moreover, since the repeaters typically transform the optical service signal into a corresponding electrical signal, the optical service signal can even be located at a wavelength outside the gain band of the optical amplifiers employed by the repeaters. Accordingly, relatively inexpensive lasers such as uncooled Fabry-Perot lasers are often used in the terminals to generate the service signals.

[0023] Since the terminal equipment 1101 and 1102 may be provided by a different vendor than the wet plant 120, the wavelength or channel used by the terminal equipment to provide the service signal will not necessarily be the same as the wavelength or channel reserved by the wet plant 120 for transmitting the service signal. Accordingly, in the present invention, an optical service channel translator (OSCT) is employed in the optical interface device 150 to translate the optical service signal provided by the terrestrial terminal equipment to another wavelength that may be reserved by the wet plant to communicate the service information. Moreover, in some embodiments of the invention the wavelength to which the OSCT translates the service signals may even be

located within the waveband of the optical amplifiers used in the repeaters. That is, in some cases the service signals, which are originally out-of-band signals, may be converted to in-band signals by the OSCT. It may be particularly convenient to employ in-band service signals when the service signals do not need to undergo optical to electrical conversion in the repeaters, thus allowing them to be amplified by the optical amplifiers along with the traffic signals. Such optical to electrical conversion may be avoided when active control of the repeaters from the terminal equipment is not necessary. This is often the case in undersea transmission systems, in which the repeaters must be highly reliable and therefore simple in design.

[0024] The OSCT may translate the wavelength at which the service channel is located by any appropriate means available to those of ordinary skill in the art. For example, in some cases the service channel may be converted to an electrical signal and then back into an optical signal at the desired wavelength.

[0025] The service channel that is provided by the system and method of the present invention can be used for the transmission of, for example, data, control and status signals, as well as voice traffic. The voice traffic carried by the service channel is used by maintenance personnel or service personnel who are working on the equipment in the optical fiber communication system. The service channel can be used to carry status information or data that relates to the equipment in the optical fiber communication system. For example, the service channel can carry data that relates to the environmental conditions at the various optical repeater sites 140, such as temperature. Alternatively, the service channel can carry status information with respect to the equipment, such as the power level, current level and signal performance information. The service channel can also carry alarm information, such as component (equipment or optical fiber) failure, or when the system switches from the protection system to the working system or from the working system to the protection system. The service channel can also carry control signals that turn on or off various pieces of equipment in the system, or change the operating mode of one or more pieces of equipment in the communication system. In some cases, such as when control signals are being transmitted, it may be necessary to transform the optical signal into an electrical signal. The data sent over the service channel is typically low speed data with each message being less than two megabits,

typically on the order of 64 kilobits. In contrast, the commercial traffic that is being sent on the optical fiber communication system is on the order of 10-40 gigabits.

[0026] FIG. 2 shows a block diagram of one particular embodiment of the optical interface device 500 similar to that shown in U.S. Appl. Serial Nos. 10/621,028 and 10/883,040. Also seen in FIG. 2 is optical transmission terminal 520 and cable termination box 522. The optical signal received from the terminal 520 is monitored for optical performance by optical performance monitor 502, multiplexed by multiplexer 503 with various signals such as a COTDR monitoring tone from COTDR assembly 502 and idler tones from idler tone generator 530, optically amplified by rare-earth doped amplifier 506, passed through a dispersion compensation device 508 such as a dispersion compensating fiber or a grating-based dispersion compensation device, and optically amplified by Raman amplifier 540, after which the optical signal is ready to traverse the undersea optical transmission path. OSCT 560 receives the optical service channel(s) provided by the transmission terminal 520, converts the service channel(s) to the appropriate wavelength for use over the undersea transmission path, and, via multiplexer 503, multiplexes the translated service channel(s) with the optical signal. Likewise, the optical signal received by the interface device 500 from the undersea optical transmission path is optically amplified by amplifier 510 and passed through a dispersion compensation device 512. The monitoring signals are demultiplexed by demultiplexer 505 and the idler tones are removed by idler tone blocker 532 before the optical signal carrying traffic is directed to the transmission terminal 520. OSCT 560 receives the optical service channel(s) provided by the undersea transmission path via demultiplexer 550, converts the service channel(s) to the appropriate wavelength for use by the transmission terminal 520, and directs the service channel(s) to the transmission terminal 520.

[0027] Although various embodiments are specifically illustrated and described herein, it will be appreciated that modifications and variations of the present invention are covered by the above teachings and are within the purview of the appended claims without departing from the spirit and intended scope of the invention. For example, while the invention has been discussed in terms of an undersea optical transmission system, those of ordinary skill in the art will recognize that the invention is equally applicable to a land-

based optical transmission system in which the transmission path is to be transparent to the terminals that communicate over it.

Claims:

1. An optical line interface for communicating between terrestrial terminal equipment and an undersea optical transmission path a WDM optical signal having a plurality of wavelength components, said optical line interface comprising:

a signal processing unit for transforming WDM optical signals between optical layer transport protocols employed by the terrestrial terminal equipment and undersea optical layer transport protocols employed over the undersea optical transmission path; and

an optical supervisory channel translator for transforming an optical service signal received at a first wavelength from the terrestrial terminal equipment to a second wavelength employed by the undersea optical transmission path for communicating service information.

2. The optical line interface of claim 1 wherein the signal processing unit is configured to perform at least one signal conditioning process selected from the group consisting of gain equalization, bulk dispersion compensation, optical amplification, Raman amplification, dispersion slope compensation, PMD compensation, and performance monitoring.

3. The optical line interface of claim 1 wherein said second wavelength is an in-band wavelength located within a waveband in which traffic is communicated over the undersea optical transmission path.

4. The optical line interface of claim 1 wherein said second wavelength is an out-of-band wavelength located outside of a waveband in which traffic is communicated over the undersea optical transmission path.

5. The optical line interface of claim 1 wherein the optical supervisory channel translator is further configured to transform an optical service signal received at the second wavelength from the undersea optical transmission path to the first wavelength employed by the terrestrial terminal equipment for communicating service information.

6. The optical line interface of claim 1 wherein said first wavelength is an in-band wavelength located within a waveband in which traffic is communicated by the terrestrial terminal equipment.

7. The optical line interface of claim 1 wherein said first wavelength is an out-of-band wavelength located outside a waveband in which traffic is communicated by the terrestrial terminal equipment.

8. The optical line interface of claim 1 wherein the undersea optical transmission path includes at least one repeater, said second wavelength being an in-band wavelength located within a waveband that undergoes optical amplification in the repeater.

9. The optical line interface of claim 1 wherein the undersea optical transmission path includes at least one repeater, said second wavelength being an out-of-band wavelength located outside of a waveband that undergoes optical amplification in the repeater.

10. A method for communicating a WDM optical signal having a plurality of wavelength components between terrestrial terminal equipment and an undersea optical transmission path, comprising:

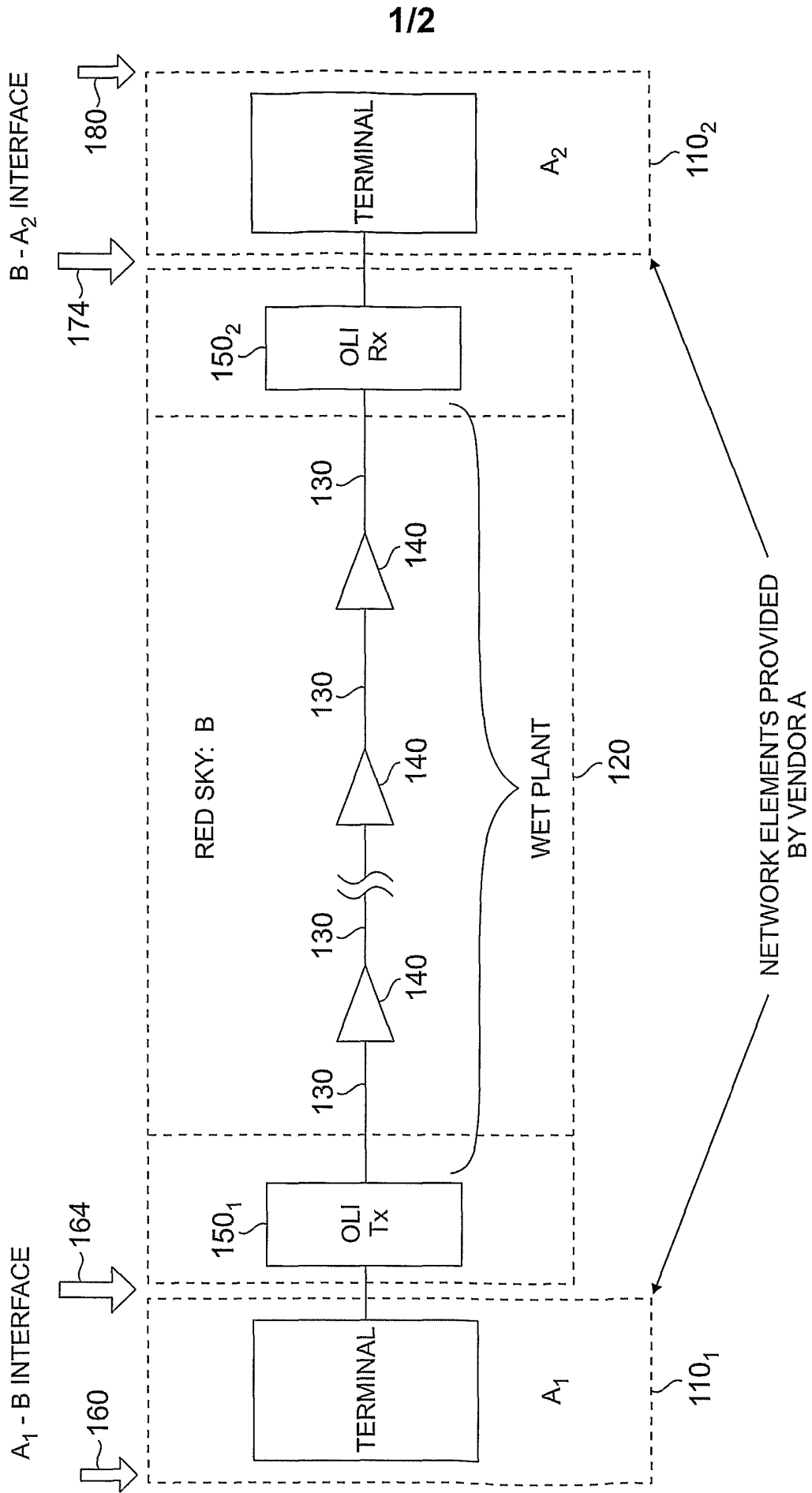
receiving the WDM optical signal from the terrestrial terminal equipment;

transforming the WDM optical signal between optical layer transport protocols employed by the terrestrial terminal equipment and undersea optical layer transport protocols employed over the undersea optical transmission path;

receiving an optical service signal located at a first wavelength from the terrestrial terminal;

transforming the optical service signal received at a first wavelength from the terrestrial terminal equipment to a second wavelength employed by the undersea optical transmission path for communicating service information; and

directing the transformed optical service signal over the undersea optical transmission path.



NETWORK ELEMENTS PROVIDED BY VENDOR A

FIG. 1

