

US00RE43403E

(19) **United States**
(12) **Reissued Patent**
Jaggi et al.

(10) **Patent Number:** **US RE43,403 E**
(45) **Date of Reissued Patent:** **May 22, 2012**

(54) **DISTRIBUTED TERMINAL OPTICAL TRANSMISSION SYSTEM**

4,636,859 A * 1/1987 Vernhet et al. 348/468
4,710,022 A * 12/1987 Soeda et al. 356/73.1
5,224,183 A * 6/1993 Dugan 385/24
5,225,922 A * 7/1993 Chraplyvy et al. 398/94

(75) Inventors: **Pawan P. Jaggi**, Plano, TX (US);
Marvin R. Young, Allen, TX (US);
William David Bragg, Plano, TX (US)

(Continued)

FOREIGN PATENT DOCUMENTS

(73) Assignee: **Pivotal Decisions LLC**, Las Vegas, NV (US)

JP 1/115230 * 5/1989

(Continued)

(21) Appl. No.: **13/045,261**

OTHER PUBLICATIONS

(22) Filed: **Mar. 10, 2011**

International Patent Application No. PCT/US2003/09761: International Search Report dated Nov. 5, 2003, 3 pages.

Related U.S. Patent Documents

(Continued)

Reissue of:

(64) Patent No.: **7,502,562**
Issued: **Mar. 10, 2009**
Appl. No.: **11/514,730**
Filed: **Aug. 31, 2006**

Primary Examiner — Leslie Pascal

(74) *Attorney, Agent, or Firm* — Woodcock Washburn LLP

U.S. Applications:

(63) Continuation of application No. 10/402,840, filed on Mar. 27, 2003, now Pat. No. 7,505,687.

(60) Provisional application No. 60/368,545, filed on Mar. 29, 2002.

(51) **Int. Cl.**
H04J 14/02 (2006.01)

(52) **U.S. Cl.** **398/66; 398/83**

(58) **Field of Classification Search** **398/66-72, 398/82-86**

See application file for complete search history.

(57) **ABSTRACT**

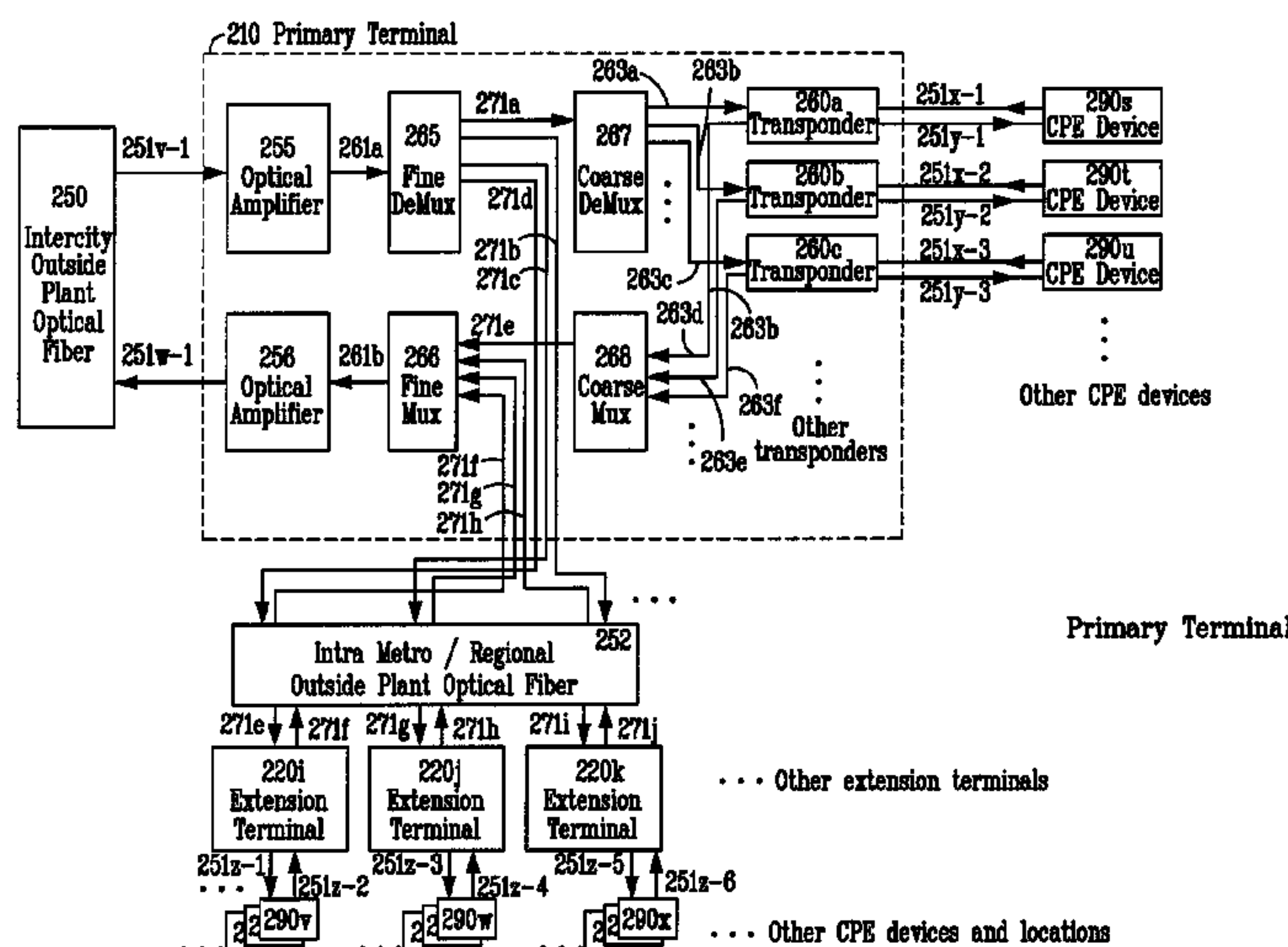
The invention facilitates optical signals generated from customer premise equipment (CPE) at the edges of the metro domain networks. The CPEs are connected to extension terminals that transform the optical signal originating at the CPE into a suitable format for long haul transmission. The optical signal then propagates to a primary terminal where the signal is multiplexed with other optical signals from other extension terminals. The multiplexed signals are then transmitted over LH or ULH network to a second primary terminal where the signal is then demultiplexed from other optical signals and transmitted to the proper extension terminal. At the extension terminal, the demultiplexed optical signal is transformed from its LH format back into a format suitable for interconnection to a CPE. Using this architecture, the signal under goes optical-to-electrical conversion only at the extension terminals or end points. These end points can be located in lessee's facility. The only equipment located in lessor's facility is the primary terminal containing line amplifiers and add/drop nodes.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,109,111 A * 8/1978 Cook 370/268
4,229,831 A * 10/1980 Lacher 398/214
4,301,534 A * 11/1981 Genter 370/510
4,355,384 A * 10/1982 Genter et al. 370/372
4,535,459 A * 8/1985 Hogge, Jr. 375/324

65 Claims, 12 Drawing Sheets



US RE43,403 E

Page 2

U.S. PATENT DOCUMENTS

5,267,071	A *	11/1993	Little et al.	398/162
5,299,048	A *	3/1994	Suyama	398/181
5,321,541	A *	6/1994	Cohen	398/82
5,455,703	A *	10/1995	Duncan et al.	398/136
5,559,625	A *	9/1996	Smith et al.	398/66
5,613,210	A *	3/1997	Van Driel et al.	455/45
5,726,784	A *	3/1998	Alexander et al.	398/91
5,737,118	A *	4/1998	Sugaya et al.	359/341.43
5,778,116	A *	7/1998	Tomich	385/16
5,790,285	A *	8/1998	Mock	398/21
5,812,290	A *	9/1998	Maeno et al.	398/45
5,877,881	A *	3/1999	Miyauchi et al.	398/193
5,903,613	A *	5/1999	Ishida	375/340
5,914,794	A *	6/1999	Fee et al.	398/20
5,914,799	A *	6/1999	Tan	398/92
5,936,753	A *	8/1999	Ishikawa	398/72
5,940,209	A *	8/1999	Nguyen	359/341.1
5,963,350	A *	10/1999	Hill	398/70
5,995,694	A *	11/1999	Akasaka et al.	385/123
6,005,702	A *	12/1999	Suzuki et al.	398/185
6,021,245	A *	2/2000	Berger et al.	385/123
6,038,062	A *	3/2000	Kosaka	359/337
6,075,634	A *	6/2000	Casper et al.	398/139
6,078,414	A *	6/2000	Iwano	398/182
6,081,359	A *	6/2000	Takehana et al.	398/1
6,081,360	A *	6/2000	Ishikawa et al.	398/147
6,084,694	A *	7/2000	Milton et al.	398/83
6,088,152	A *	7/2000	Berger et al.	359/334
6,108,074	A *	8/2000	Bloom	356/73.1
6,122,095	A *	9/2000	Fatehi	359/337
6,151,334	A *	11/2000	Kim et al.	370/468
6,157,477	A *	12/2000	Robinson	398/147
6,160,614	A *	12/2000	Unno	356/73.1
6,163,392	A *	12/2000	Condict et al.	398/1
6,163,636	A *	12/2000	Stentz et al.	385/24
6,173,094	B1 *	1/2001	Bowerman et al.	385/24
6,177,985	B1 *	1/2001	Bloom	356/73.1
6,198,559	B1 *	3/2001	Gehlot	398/161
6,229,599	B1 *	5/2001	Galtarossa	356/73.1
6,236,481	B1 *	5/2001	Laor	398/9
6,236,499	B1 *	5/2001	Berg et al.	359/341.2
6,246,510	B1 *	6/2001	BuAbbud et al.	359/337
6,259,553	B1	7/2001	Kinoshita	
6,259,554	B1 *	7/2001	Shigematsu et al.	359/337
6,259,693	B1 *	7/2001	Ganmukhi et al.	370/366
6,259,845	B1 *	7/2001	Sardesai	385/123
6,272,185	B1 *	8/2001	Brown	375/340
6,275,315	B1 *	8/2001	Park et al.	398/148
6,282,334	B1 *	8/2001	Hodgson et al.	385/12
6,288,811	B1 *	9/2001	Jiang et al.	398/79
6,288,813	B1 *	9/2001	Kirkpatrick et al.	398/136
6,307,656	B2 *	10/2001	Terahara	398/139
6,307,986	B1 *	10/2001	Duerksen et al.	385/24
6,317,231	B1 *	11/2001	Al-Salameh et al.	398/34
6,317,255	B1 *	11/2001	Fatehi et al.	359/341.44
6,323,950	B1 *	11/2001	Kim et al.	356/477
6,327,060	B1 *	12/2001	Otani et al.	398/83
6,327,062	B1 *	12/2001	King et al.	398/9
6,339,663	B1 *	1/2002	Leng et al.	385/24
6,341,186	B1 *	1/2002	Singh et al.	385/27
6,356,384	B1 *	3/2002	Islam	359/334
6,359,729	B1 *	3/2002	Amoruso	359/341.1
6,388,801	B1 *	5/2002	Sugaya et al.	359/334

6,396,853	B1 *	5/2002	Humphrey et al.	370/535
6,480,326	B2 *	11/2002	Papernyi et al.	359/334
6,493,117	B1 *	12/2002	Milton et al.	398/49
6,515,779	B2 *	2/2003	Fee	398/147
6,519,082	B2 *	2/2003	Ghera et al.	359/341.4
6,546,166	B1 *	4/2003	Liu et al.	385/24
6,563,985	B2 *	5/2003	Yin et al.	385/37
6,574,037	B2 *	6/2003	Islam et al.	359/334
6,587,470	B1 *	7/2003	Elliot et al.	370/404
6,690,848	B2 *	2/2004	Graves et al.	385/16
6,694,100	B1 *	2/2004	Fatehi et al.	398/99
6,744,958	B2 *	6/2004	Inagaki et al.	385/123
6,744,988	B2 *	6/2004	Leclerc et al.	398/102
6,807,232	B2 *	10/2004	Nicholson et al.	375/240.26
6,822,943	B1	11/2004	Mantin	
6,826,201	B2 *	11/2004	Hind	370/535
6,868,201	B1	3/2005	Johnson et al.	
6,944,163	B2 *	9/2005	Bottorff et al.	370/395.5
6,950,448	B2 *	9/2005	Tornetta et al.	370/537
7,046,695	B2 *	5/2006	Silvers	370/493
7,054,559	B1	5/2006	Le et al.	
7,139,277	B2 *	11/2006	Ofek et al.	370/401
7,164,861	B2 *	1/2007	Takachio et al.	398/70
7,170,906	B2 *	1/2007	Ofek et al.	370/498
7,254,333	B2 *	8/2007	Shimizu	398/79
7,308,197	B1 *	12/2007	Zhong et al.	398/48
7,502,562	B2	3/2009	Jaggi et al.	
7,505,687	B2	3/2009	Jaggi et al.	
7,796,886	B2	9/2010	Jaggi et al.	
2001/0005271	A1	6/2001	Leclerc et al.	
2001/0007605	A1	7/2001	Inagaki et al.	
2001/0009468	A1	7/2001	Fee	
2001/0014104	A1	8/2001	Bottorff et al.	
2001/0017722	A1	8/2001	Takachio et al.	
2001/0048799	A1 *	12/2001	King et al.	385/125
2002/0008913	A1	1/2002	Yin et al.	
2002/0012152	A1 *	1/2002	Agazzi et al.	359/189
2002/0015220	A1	2/2002	Papernyl et al.	
2002/0034197	A1	3/2002	Tornetta et al.	
2002/0044317	A1 *	4/2002	Gentner et al.	359/124
2002/0044324	A1 *	4/2002	Hoshida et al.	359/179
2002/0048287	A1	4/2002	Silvers	
2002/0051468	A1	5/2002	Ofek et al.	
2002/0063948	A1	5/2002	Islam et al.	
2002/0064181	A1	5/2002	Ofek et al.	
2002/0075903	A1	6/2002	Hind	
2002/0080809	A1	6/2002	Nicholson et al.	
2002/0171897	A1 *	11/2002	Cho et al.	359/172
2003/0067655	A1 *	4/2003	Pedersen et al.	359/152
2006/0114939	A1 *	6/2006	Singh	370/469

FOREIGN PATENT DOCUMENTS

JP	01115230	5/1989
JP	2/238736	* 9/1990
JP	02238736	9/1990
WO	WO 03/084082	10/2003

OTHER PUBLICATIONS

The Cook Report on the Internet, "Netera Offers CWDM Gig E Backbone Supernet to Bring Fiber to Entire Province Focus on Alberta in Assessing Canadian Development in Current Economic Downturn", Jun. 2001, pp. 1-31.

* cited by examiner

FIG. 2

Optical Transport System—Terminal
Prior Art

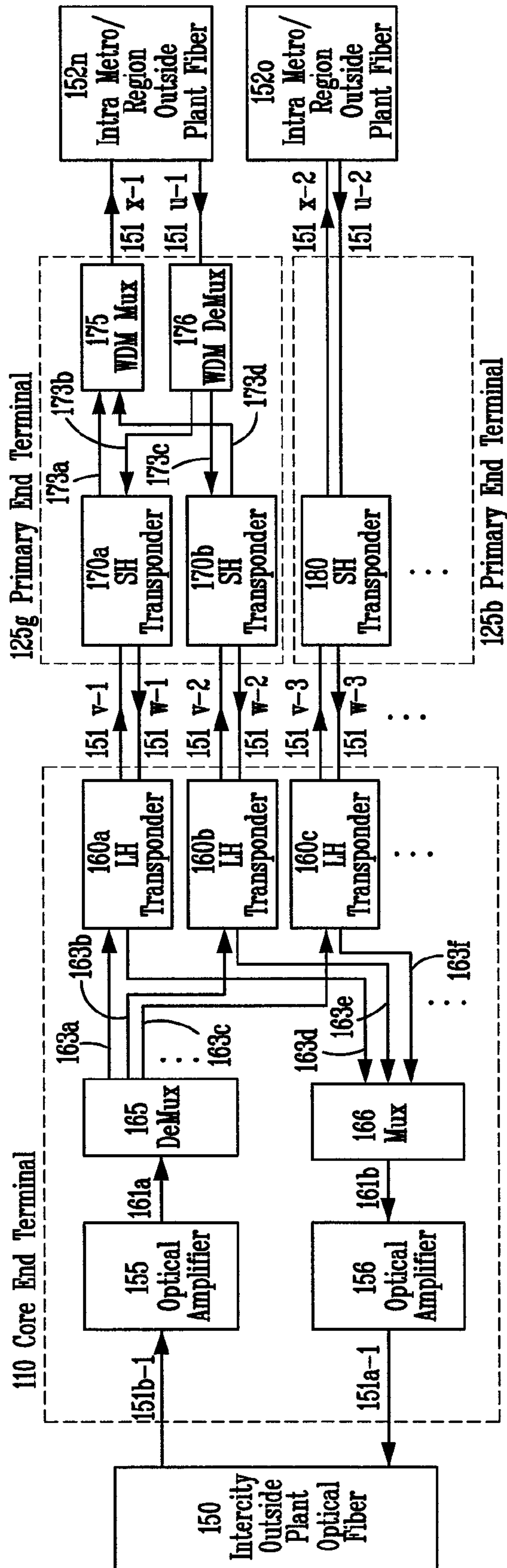
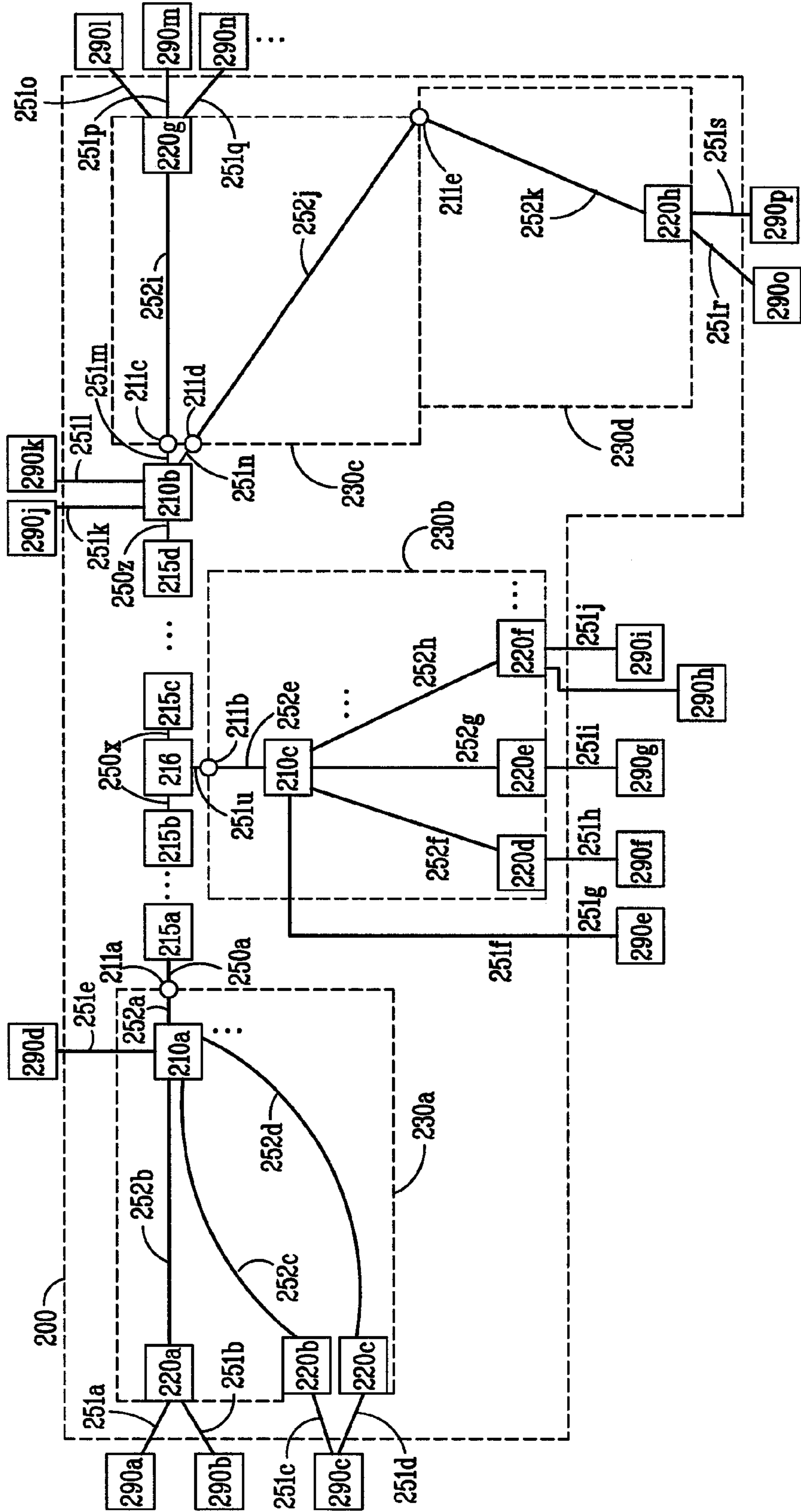


FIG. 3

Interdomain Optical Transport System



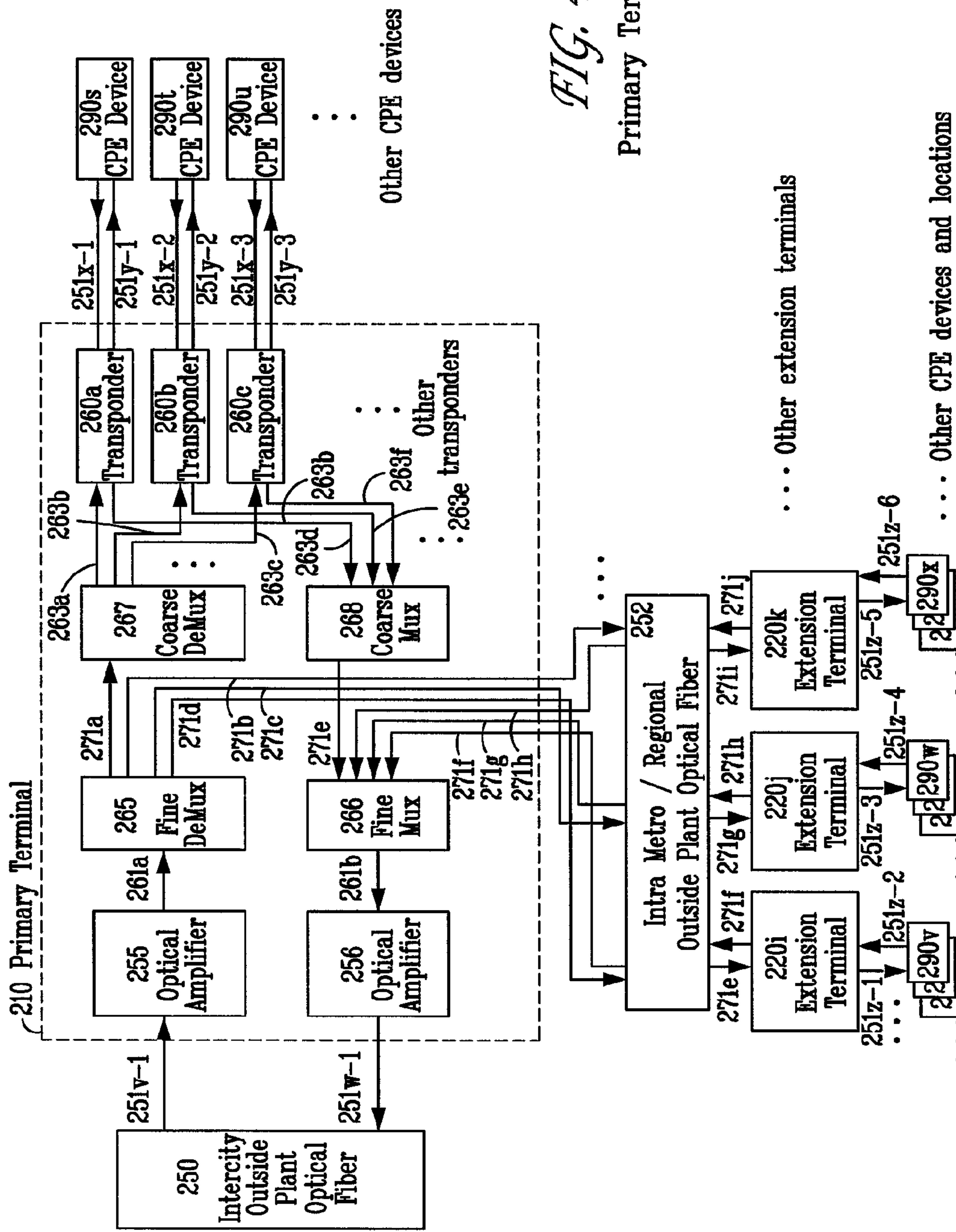


FIG. 4

Primary Terminal

... Other extension terminals

... Other CPE devices and locations

FIG. 5
Type One Extension Terminal

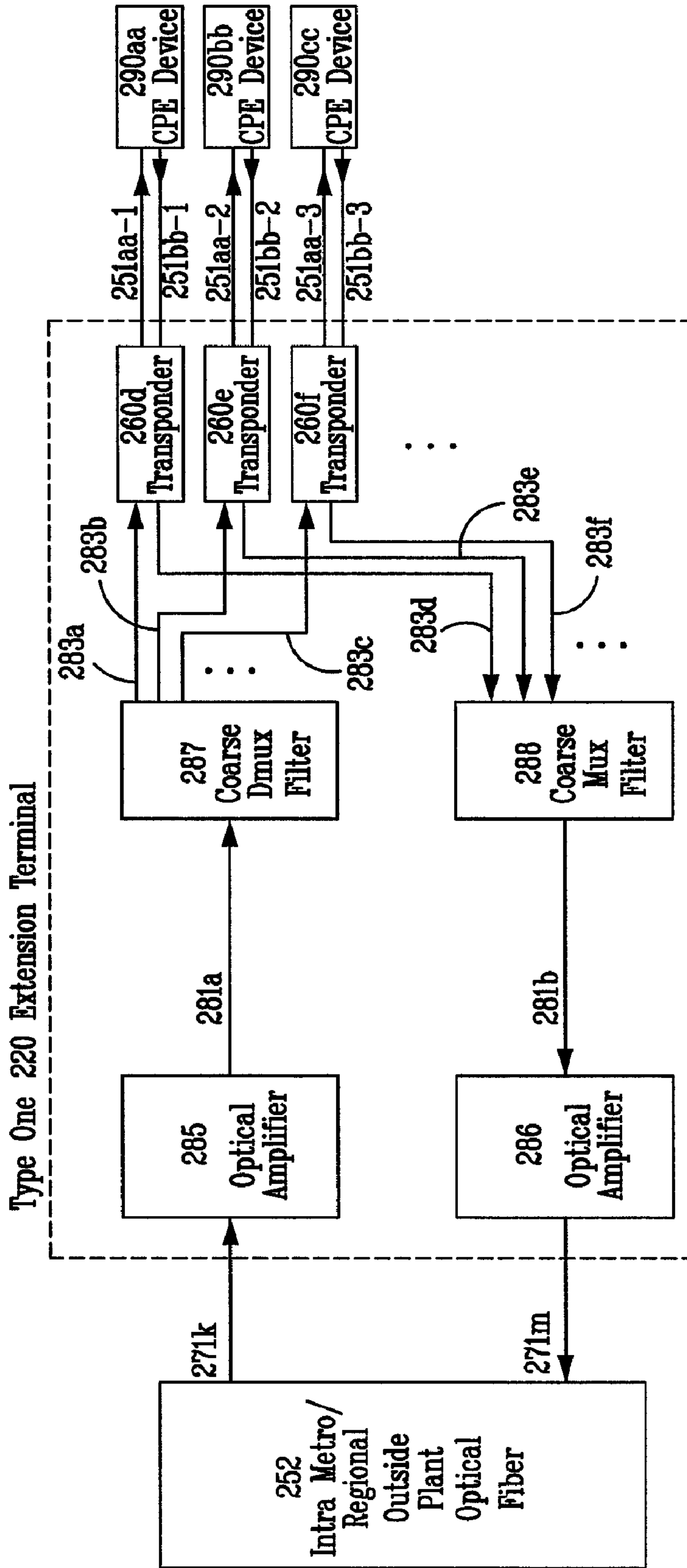


FIG. 6

Type Two Extension Terminal

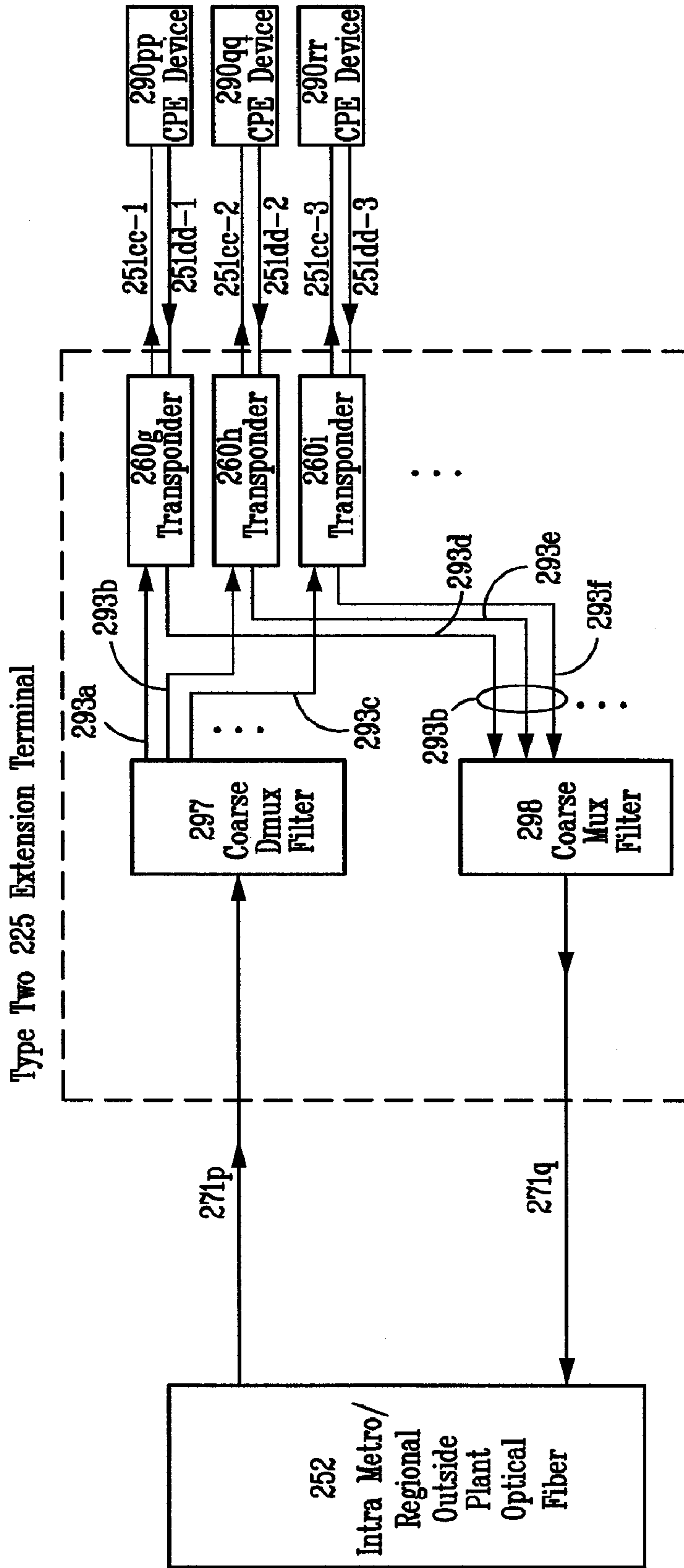


FIG. 7

Mux/Dmux - Interleaver based

500 8xN channels 50 GHz Distributed Optical Multiplexer or Demultiplexer

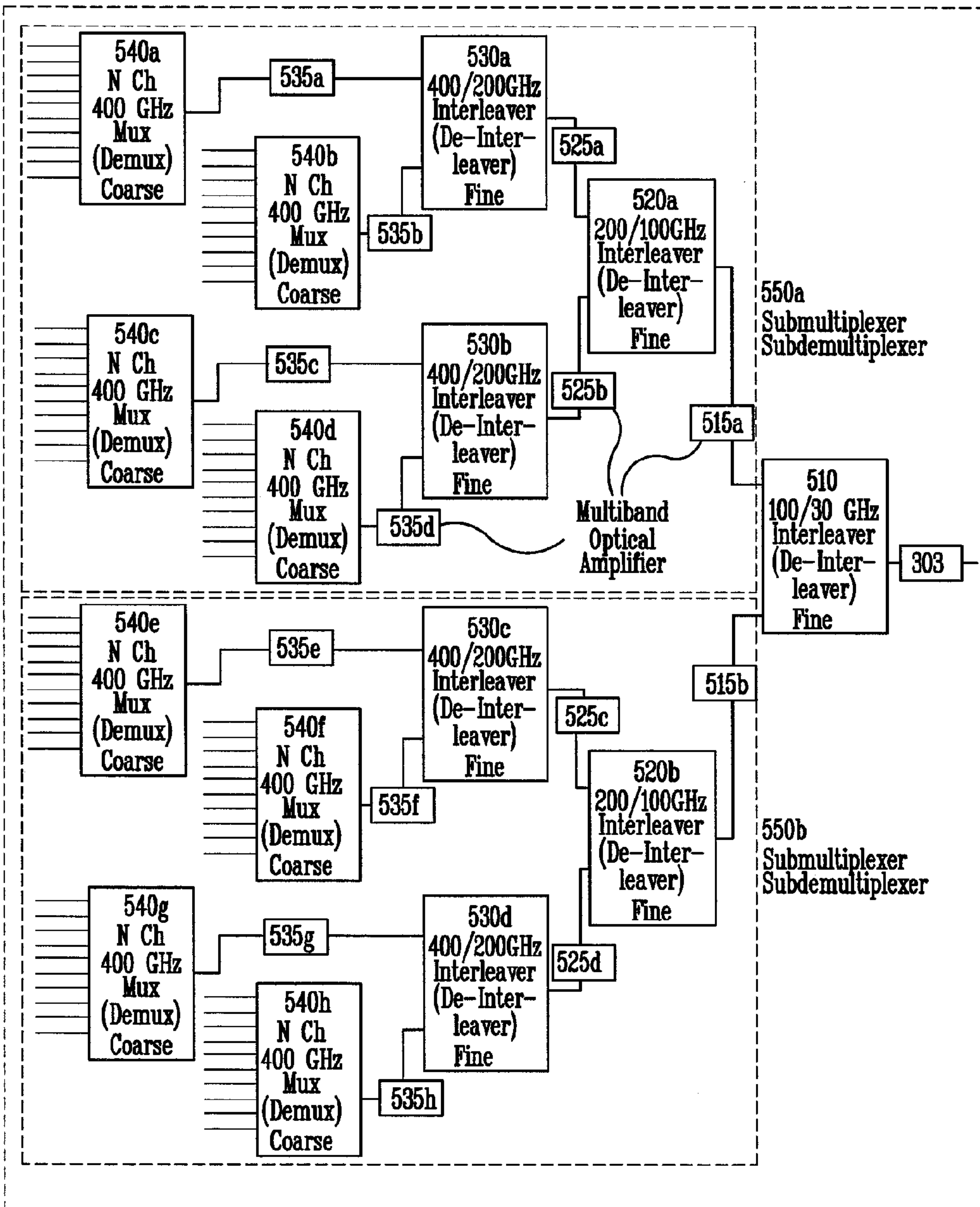


FIG. 8

Mux/Dmux - Banded DWDM Filters

600 8xN channels 50 GHz Distributed Optical Multiplexer or Demultiplexer

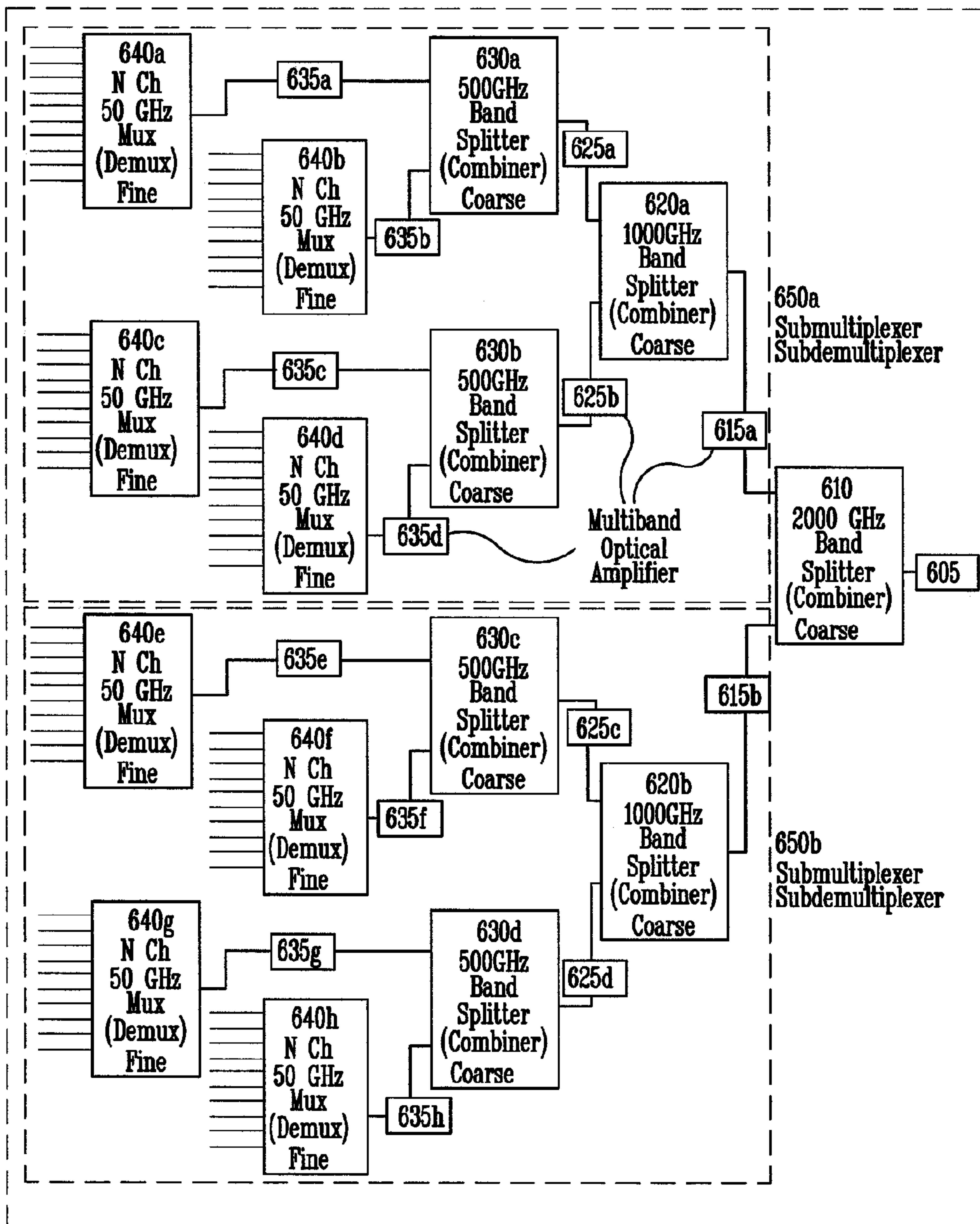


FIG. 9

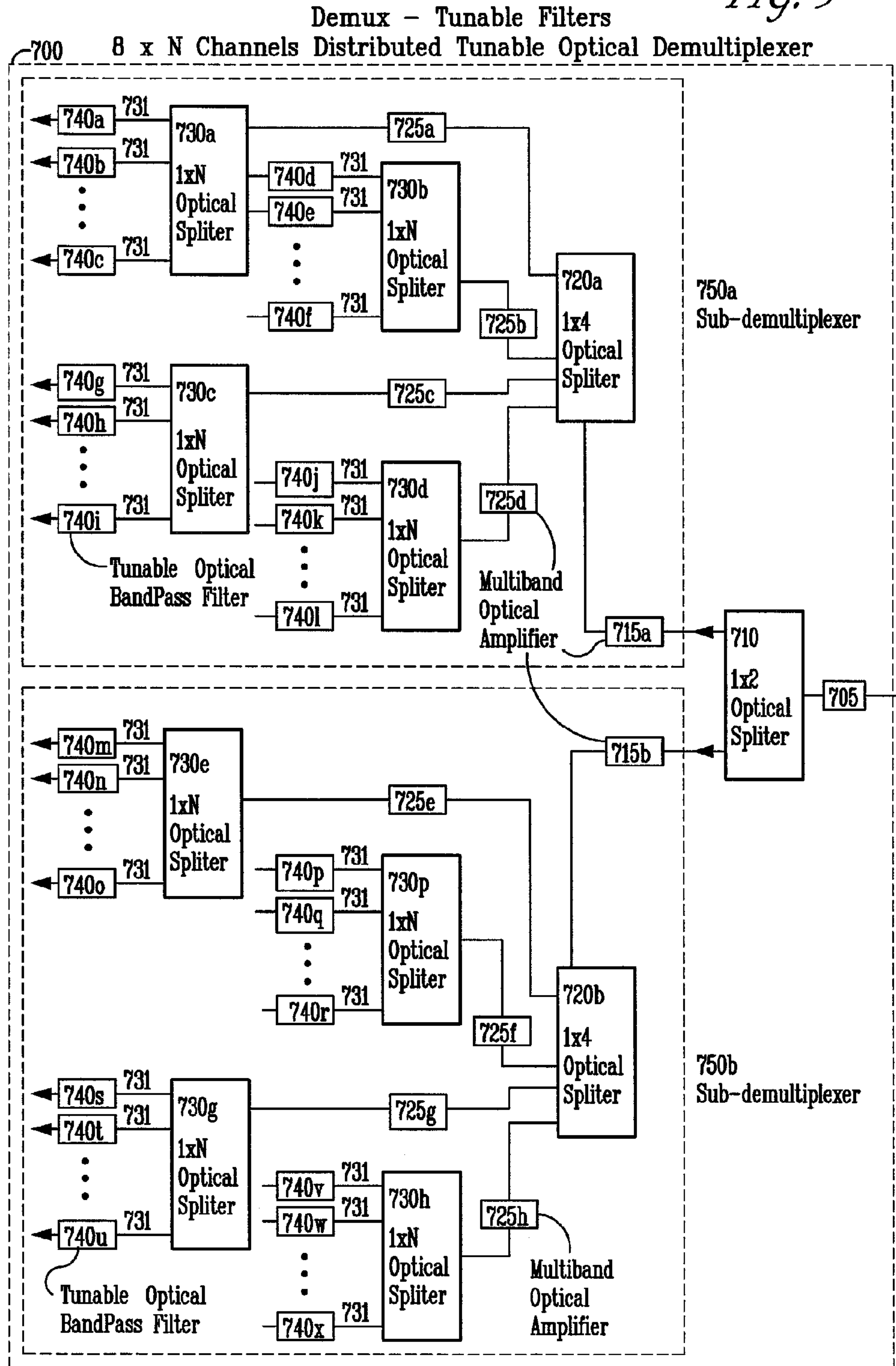
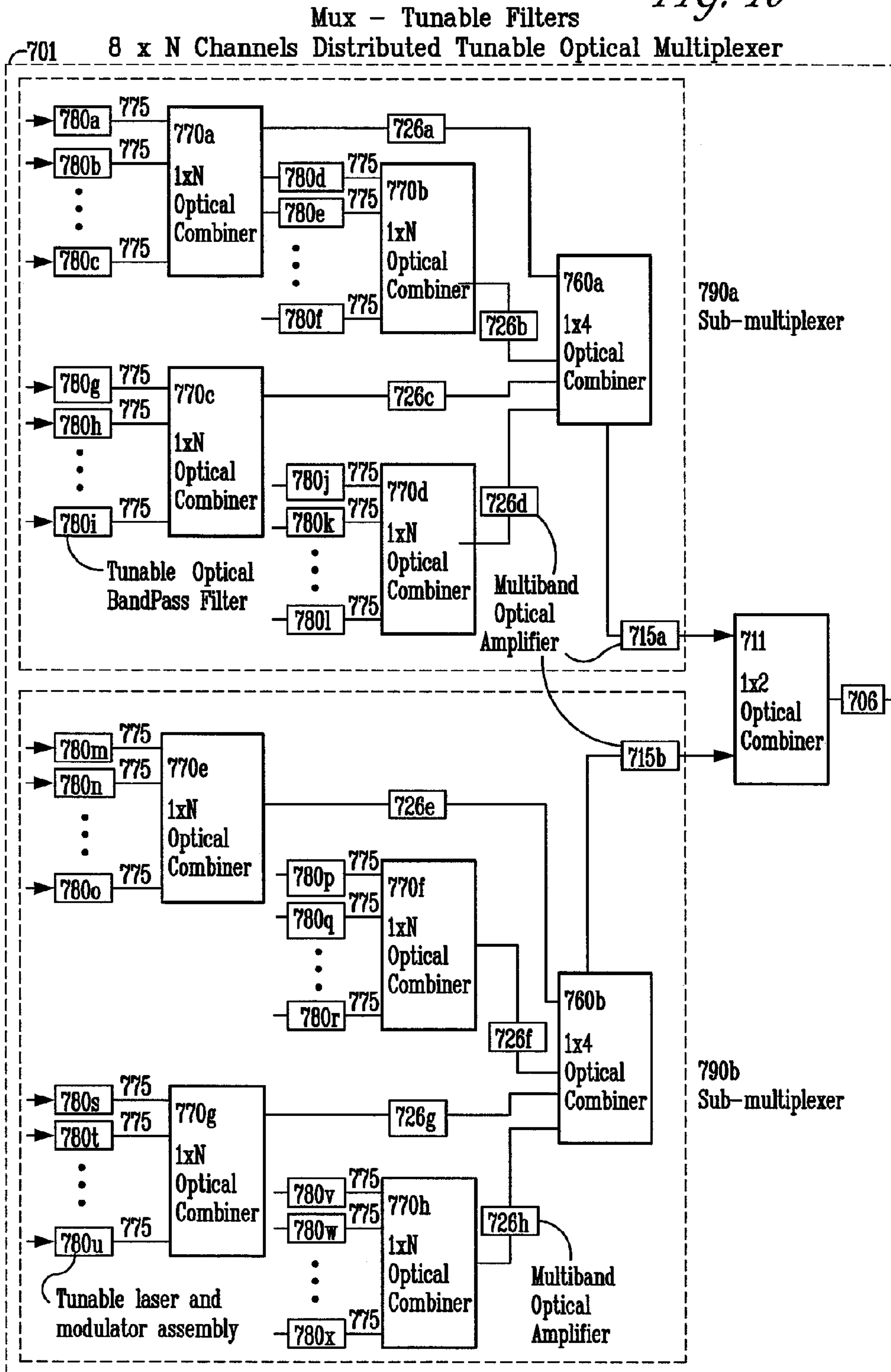


FIG. 10



System Configurations

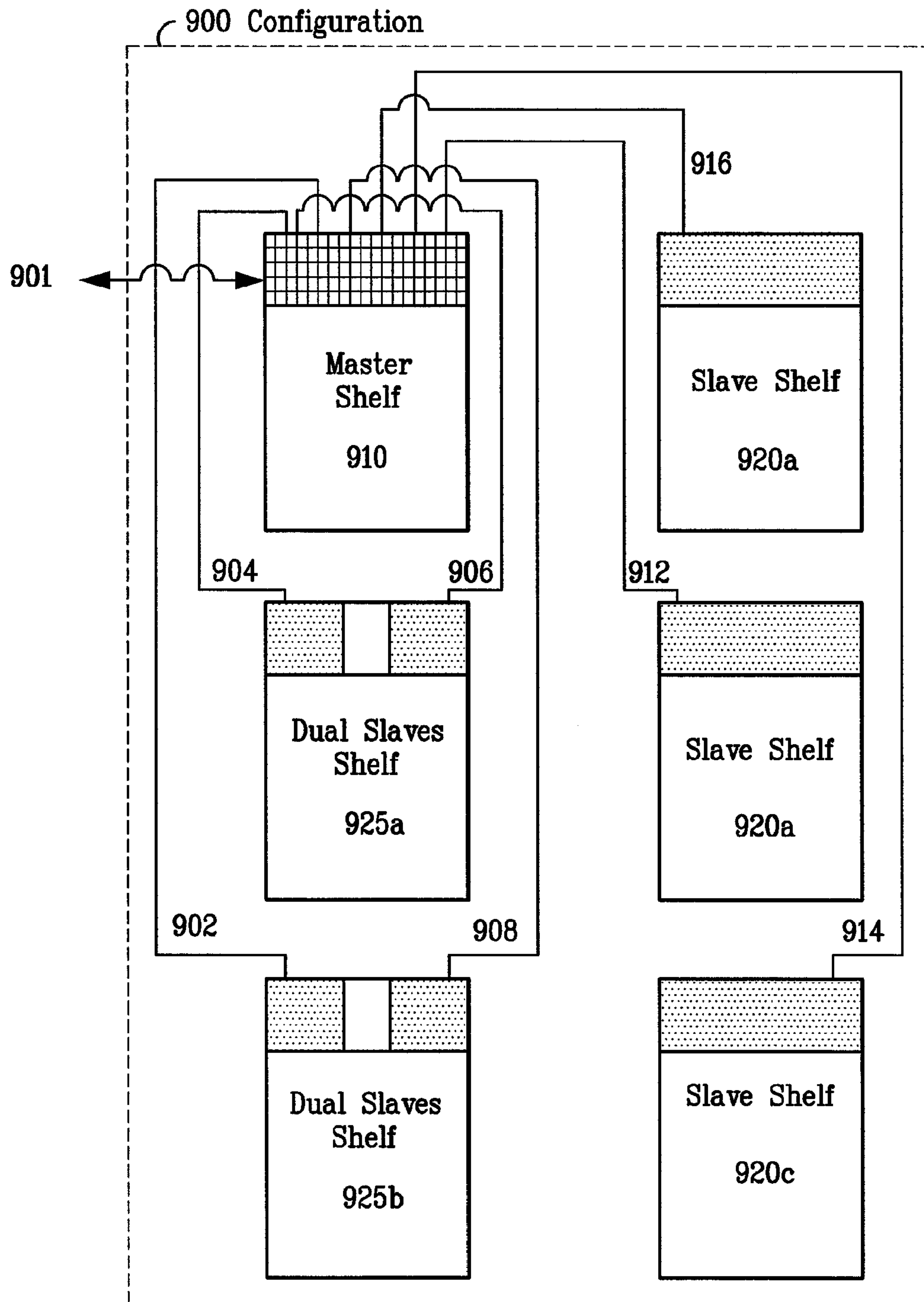
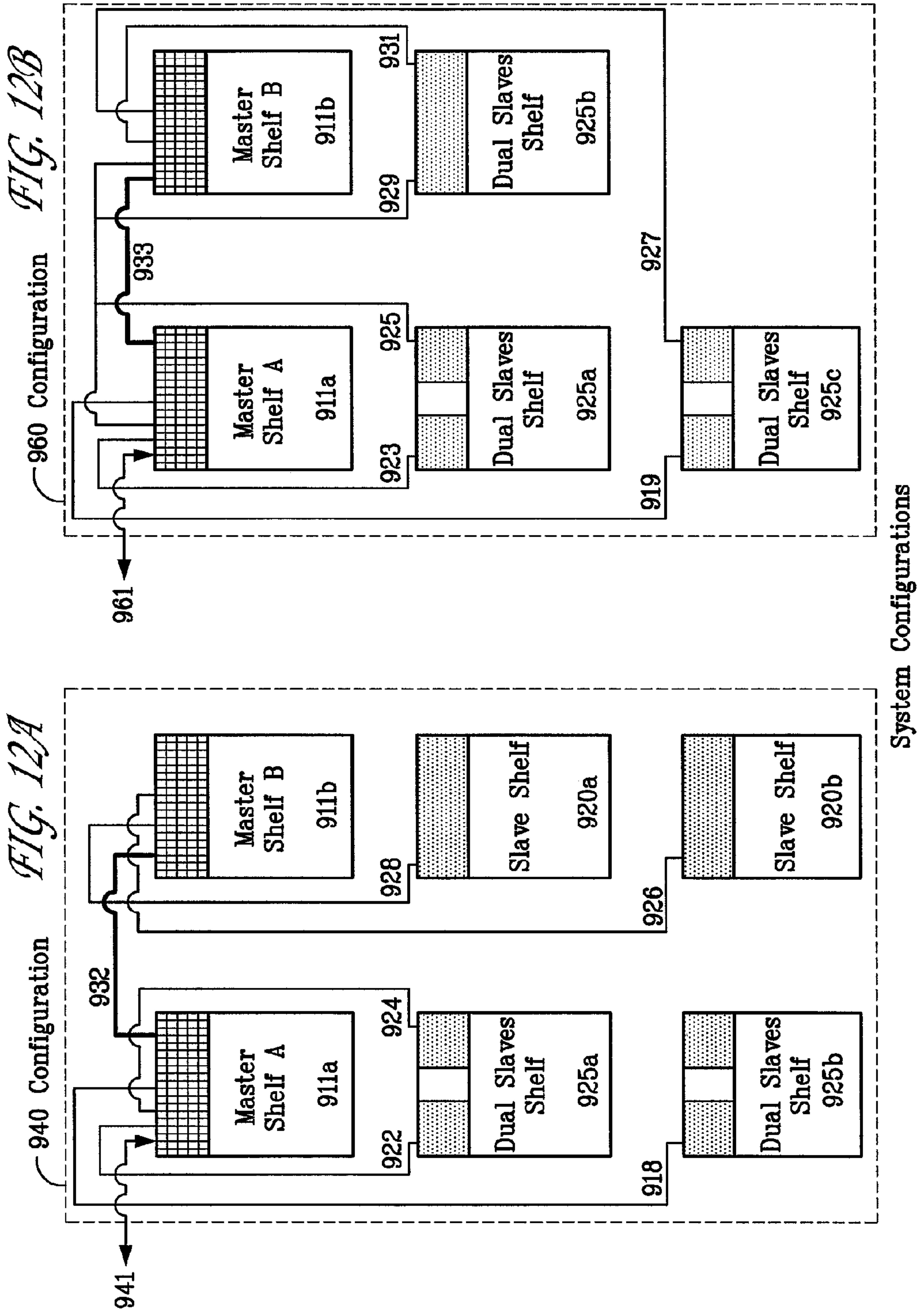


FIG. 11



DISTRIBUTED TERMINAL OPTICAL TRANSMISSION SYSTEM

Matter enclosed in heavy brackets [] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. application Ser. No. 10/402,840 filed Mar. 27, 2003, which claims benefit of U.S. Provisional Application No. 60/368,545, filed Mar. 29, 2002, each of which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

This invention relates to a computer system for transporting optical signals between coupled metro domains using an optical transport networking system and more particularly using a lessor's optical transport networking system to transport a lessee's signal.

BACKGROUND OF THE INVENTION

The transmission, routing and dissemination of information has occurred over computer networks for many years via standard electronic communication lines. These communication lines are effective, but place limits on the amount of information being transmitted and the speed of the transmission. With the advent of light-wave technology, a large amount of information is capable of being transmitted, routed and disseminated across great distances at a high rate over fiber optic communication lines.

In traditional optical networks, long haul (LH) and ultra-long haul (ULH) optical networks typically connect major cities. The LH and ULH optical networks can span local geographical regions, countries, continents and even large bodies of water. The construction and maintenance costs of these long haul and ultra-long haul optical networks are prohibitively large. Because of these prohibitive costs, few communication service providers own their own optical networks. Many communication service providers lease the right to transmit optical signals over another communication service provider's optical network. The communication service providers that construct their national networks through the leasing of the optical networks from other communication service providers incur disadvantages, including increased cost versus those communication service providers that own their own optical networks.

A typical communication service provider leasing "space" on another communication service provider's optical network must provide optical data networking equipment at their own local facilities in a metropolitan area and must also provide optical data networking equipment at the lessor's facility which may be in the same metropolitan area or a short distance away in another metropolitan area. In addition to the cost of maintaining multiple sets of optical data networking equipment, there is an additional penalty from the requirement to use metro transmission systems to connect the lessee communication system provider's facility to the lessor communication service provider's facility and then to use the LH and ULH optical data networking equipment to traverse the LH and ULH optical network. This system results in exces-

sive optical-to-electrical conversions and increases the operational complexity of the overall systems.

What is needed is an optical transmission system that would locate all terminal equipment in the lessee's facility. It would also be beneficial if only line amplifiers and add/drop nodes were in the lessor's facilities. The signal should undergo optical-to-electrical conversion only at the endpoints, preferably in the lessee's facility and at any regeneration points required by physical constraints.

SUMMARY OF THE INVENTION

The present invention provides an architecture and method for transmitting signals over a network which allows for all of lessee's equipment to be located at a extension terminal in lessee's facility. It allows for efficient optical-to-electrical conversions and does not require multiple sets of optical data networking equipment.

Prior art systems suffer from the limitation that a typical communication service provider leasing "space" must provide optical data networking equipment at their own local facilities and must also provide optical data networking equipment at the lessor's facility. In addition to the cost of maintaining multiple sets of optical data networking equipment, there is an additional penalty from the requirement to use metro transmission systems to connect the lessee communication system provider's facility to the lessor communication service provider's facility and then to use the LH and ULH optical data networking equipment to traverse the LH and ULH optical network. This system results in excessive optical-to-electrical conversions and increases the operational complexity of the overall systems. In addition, prior art systems suffer from the requirement to convert customer premise equipment signals into short haul format for transport to a facility, usually a lessor's, and then at the facility, to be converted into a LH format for transport over a LH network. Certain prior art systems have attempted to address these problems with varying success.

U.S. Pat. No. 5,726,784 to Alexander, et al., entitled WDM OPTICAL COMMUNICATION SYSTEM WITH REMODULATORS AND DIVERSE OPTICAL TRANSMITTERS, discloses an invention which is capable of placing information from incoming information-bearing optical signals onto multiple optical signal channels for conveyance over an optical waveguide. A receiving system is configured to receive an information bearing optical signal at a particular reception wavelength and each receiving system must include at least one Bragg grating member for selecting the particular reception wavelength. However, Alexander is intended to provide compatibility with existing systems and does not disclose or suggest a system that allows for efficient optical-to-electrical conversions or one that would locate all terminal equipment in the lessee's facility.

U.S. Pat. No. 5,613,210 to Van Driel, et al., entitled TELECOMMUNICATION NETWORK FOR TRANSMITTING INFORMATION TO A PLURALITY OF STATIONS OVER A SINGLE CHANNEL, discloses an invention which uses a method wherein a signal to be transmitted is modulated on a subcarrier having its own frequency and then modulated on a main carrier in each sub-station. While Van Driel does utilize subcarrier multiplexing, only two wavelengths are involved and the multiplexing is therefore limited. Van Driel does not disclose transmitting the signals over a LH network. Nor does Van Driel disclose or suggest a system that allows for efficient optical-to-electrical conversions or one that would locate all terminal equipment in the lessee's facility.

U.S. Pat. No. 5,559,625 to Smith, et al., entitled DISTRIBUTIVE COMMUNICATIONS NETWORK, discloses a method and system for increasing the amount of re-use of information transmission wavelengths within a network. A distributive communications network includes groups of nodes at different levels. At each level of nodes, wavelength traffic is either passed on to a higher level, or looped back according to the band of wavelengths to which it is assigned. Philip does not disclose or suggest a system that allows for efficient optical-to-electrical conversions or one that would locate all terminal equipment in the lessee's facility.

Other patents such as U.S. Pat. No. 5,778,116 to Tomich, entitled PHOTONIC HOME AREA NETWORK FIBER/POWER INSERTION APPARATUS, and U.S. Pat. No. 5,914,799 to Tan, entitled OPTICAL NETWORK disclose an invention that is limited to signal transfer from a central station to subscriber stations. Neither of the patents disclose a method or apparatus for transmitting signals over a LH network, disclose or suggest a system that allows for efficient optical-to-electrical conversions or one that would locate all terminal equipment in the lessee's facility.

The present invention is an improvement over the prior art because it allows for efficient optical-to-electrical conversions and does not require multiple sets of optical data networking equipment. The present invention provides for coupled metro domain networks which are a part of a larger inter-domain network. The invention facilitates optical signals generated from customer premise equipment (CPE) at the edges of the metro domain networks. The CPEs are connected to extension terminals preferably in lessee's facility. The extension terminals transform the optical signal originating at the CPE into a suitable format for long haul transmission. One or more CPEs may be connected to one or more extension terminals. The optical signal then propagates from an extension terminal to a primary terminal along a metro fiber. At the primary terminal, the optical signal is multiplexed with other optical signals from other extension terminals. The multiplexed signals are then transmitted over LH or ULH network to a second primary terminal via core fiber. The optical signal may propagate along the core fiber with the help of a chain of amplifiers and optical add/drops. The second primary terminal then demuxes the optical signal from other optical signals and transmits the demuxed signal to the proper extension terminal. At the extension terminal, the demuxed optical signal is transformed from its LH format back into a format suitable for inter-connection to a CPE. Using this architecture, the signal under goes optical-to-electrical conversion only at the extension terminals. These extension terminals can be located in lessee's facility. The only equipment located in lessor's facility is the primary terminal containing line amplifiers and add/drop nodes. The transport system meets the networking requirements of intercity connections without the need for complex and costly metro transport gear. Also, the core extension terminals may be physically distributed across several metro network nodes.

The invention will be better understood from the following more detailed description taken in conjunction with the accompanying drawings.

DETAILED DESCRIPTION OF THE DRAWINGS

A better understanding of the invention can be obtained from the following detailed description of one exemplary embodiment as considered in conjunction with the following drawings in which:

FIG. 1 is a block diagram depicting a prior art inter-domain optical networking between core networks and metro/regional networks;

FIG. 2 is a block diagram of the detail of the prior art end-terminals and the interconnections between optical transport systems in FIG. 1;

FIG. 3 is a block diagram depicting an inter-domain optical transport system according to the present invention;

FIG. 4 is a block diagram of the detail of a primary terminal for use in the present invention;

FIG. 5 is a block diagram of a type one extension terminal for use in the present invention;

FIG. 6 is a block diagram of a type two extension terminal for use in the present invention;

FIG. 7 is a block diagram showing a multiplexer-demultiplexer architecture based on optical interleaver and deinterleaver filters for use in the present invention;

FIG. 8 is a block diagram showing a multiplexer-demultiplexer architecture based on banded DWDM filters for use in the present invention;

FIG. 9 is a block diagram showing a tunable demultiplexer architecture for use in the present invention;

FIG. 10 is a block diagram showing a tunable multiplexer for use in the present invention;

FIG. 11 is a block diagram of shelf configurations according to the present invention; and

FIGS. 12a and 12b are block diagrams of alternate shelf configurations according to the present invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

In the descriptions that follow, like parts are marked throughout the specification and drawings with the same numerals, respectively. The drawing figures are not necessarily drawn to scale and certain figures may be shown in exaggerated or generalized form in the interest of clarity and conciseness. Reference of an A-Z signal or direction means from the left side of the drawing to the right side of the drawing while Z-A means from the right side to the left side. The A-Z or Z-A designation is used for illustrative purposes only.

The prior art as it relates to optical transport networking between domains is shown in FIG. 1 and FIG. 2. Referring to FIG. 1, an optical transport network may be composed of several domains: a core network 100 with a geographic extent of typically between 100 km and 1500 km and a plurality of metro network domains 130a-d with geographic extents typically of 3 km to 100 km.

Customer premise equipment (CPE) 190a-h are considered to be outside metro domains 130a, 130b, 130c, and 130d. CPE 190a-h is sometimes referred to as client equipment or end-user equipment. CPE 190a-h are connected to metro domain 130a-d via interoffice fiber, 151c, 151d, 151e, 151j-l, and 151p-s.

Metro domains 130a-d vary widely in extent interconnection, and in the types of systems that are deployed within them. Metro domain 130a shows a plurality of ring-protected systems. Metro domain 130a is composed of primary ring end terminal 135a, extension ring end terminal 136a, primary multi-node terminal 145, and extension multi-node terminals 146a and 146b. Optical signals are propagated to and from primary ring end terminal 135a and extension ring end terminal 136a on metro fibers 152a and 152b. Optical signals may propagate on either or both legs of the ring so that in the event fiber 152a or fiber 152b fails, a connection is continually

maintained between primary ring end terminal **135a** and extension ring end terminal **136a**.

A more complex, multi-node protected ring is indicated by primary multi-node ring end terminal **145** and extension multi-node ring end terminals **146a** and **146b**, whereby, all three nodes are interconnected via metro fiber **152c** and **152d**. Metro fiber **152c** and **152d** may be a single fiber or a plurality of fibers. Methods for ring protection are well known in the art and will not be discussed further.

Metro domain **130b** is different from metro domain **130a** in that metro domain **130b** consist of primary end terminals **125a-c** and extension end terminals **126a-c** being connected by metro fiber **152e-g** in a linear fashion as opposed to a ring protected system as shown in metro domain **130a**. Metro domain **130b** provides a network consisting of a plurality of unprotected linear links where the optical signals are propagated along a single path of fiber in an unprotected way. For example, if metro fiber **152e** is cut or fails, then optical signals terminating at and originating from CPE **190d** will no longer be connected with core end terminal **110c**. By the interconnection of CPE **190e** to extension end terminals **126b** and **126c** and extension end terminals **126b** and **126c** being connected to core end-terminal **110c** via primary end terminal **125b** and **125c** an economical path protection can be realized at the client equipment layer. Path protection at the client equipment layer is realized because if one interconnection of CPE **190e** to either extension end terminal **126b** or **126c** fails, the other interconnection can still transmit signals to **110c**.

Metro domain **130c** indicates a combination of protected and unprotected links. Primary end terminal **125d** is connected to extension end terminal **126d** in a linear fashion via fiber **152h**. Primary end terminal **135b** is connected to extension end terminal **136b** in a ring-protected system via fibers **152i** and **152j**. Primary end terminal **125e** is connected to extension end terminal **126e** via metro fiber **152k**. Core end terminal **110b** is ultimately connected to CPE **190h** by the transiting link of primary end terminal **125f** and extension end terminal **126f** in domain **130d** via fiber **152m** and by the transiting link of primary end terminal **125e** and extension end terminal **126e** in domain **130c** via fiber **152k**. Secondary end terminal **126e** is connected to primary end terminal **125f** via multiple fiber **151r**. Such architecture may occur, for example, because the geographical distance between core end terminal **110b** and CPE **190h** is too large for one domain. More relevant to this invention, the situation may occur because different entities own and manage the two domains **130c** and **130d** and there is no way to connect domain **130d** to core end-terminal **110b** without some type of intermediate equipment and associated fiber.

Metro-systems may multiplex more than one optical signal onto a single fiber using methods that are well known in the art as such as code wave division multiplexing (CWDM), wavelength division multiplexing (WDM), or dense wavelength division multiplexing (DWDM) methods. Starting from core end-terminal **110b** in the core network **100**, a plurality of tributary signals are interconnected and terminated on primary end terminal **125e** via multiple fiber **151o**. Primary end terminal **125e** muxes the plurality of tributary signals together and transmits the muxed signals to extension end terminal **126e** via metro fiber **152k**. Secondary end terminal **126e** demuxes the plural tributary signals and transmits them via multiple pairs of intra-office fibers **151r** to primary end terminal **125f** in domain **130d**. Primary end terminal **125f** muxes the plurality of tributary signals together and transmits the muxed signals to extension end terminal **126h** via metro fiber **152m**. Finally, extension end terminal **126h** demuxes the plural tributary signals and connects them, via multiple intra-

office fibers **151s** to CPE **190h** where the signals terminate. If the signals originated at CPE **190h** the process would be reversed.

Core network **100** is sometimes referred to as a long haul network and may be composed of a plurality of linear DWDM systems or more complex ring structures employing SONET ADMs or a mix of each type. A linear DWDM system is shown in FIG. **1**. Signals are transferred into and out of core network **100** by core end terminals **110a-c** via intra-office fiber **151a**, **151b**, **151f-i**, and **151m-o**. The tributary interfaces will be described in more detail in FIG. **2** as are the methods used to transmit signals through the core end terminals **110a-c**. The transmitted signals from one core end terminal **110a-c** propagate through a set of core optical amplifiers **115a-d** and optical add-drop multiplexing device (OADM) **116** on core fiber **150a**, **150x**, and **150z** before reaching a second core end terminal **110a**, **110b**, and **110c** where the signals are transmitted into a metro network domain **130a-d**.

Core amplifiers **115a-d** perform the function of compensating for loss of optical signal power as the optical signals propagate through core fiber **150a**, **150x**, and **150z**. The amplifiers are spaced typically 60 km to 120 km apart. The ellipsis in the drawing indicates that there could be any number amplifiers between **115a** and **115b** and between **115c** and **115d**. Also, there may be more than one OADM along core fiber **150a**, **150x** and **150z**. OADM **116** performs the function of extracting and inserting optical signals from core fiber **150a**, **150x** and **150z**, and placing or acquiring the signals on or from intra-office fiber **151a**, **151b**, **151f-i**, and **151m-o**.

In FIG. **2**, the details of signals paths from core fiber **150** (shown as a block), core end terminal **110**, primary end terminals **125g** and **125h**, to the metro fiber **152n** and **152o** (shown as blocks) are shown. These signals paths occur between, for example, **110c** and **125a-c** in FIG. **1**. With the exception of core fiber **150** and metro fiber **152n** and **152o**, all the elements of FIG. **2** are physically co-located in a metro central office (CO) or a core network point-of-presence (POP) facility. Moreover, typically all end-terminal components in core end terminal **110** and metro terminal **125g** and **125k** must be co-located in the same facility and within adjacent bays according to prior art.

Continuing in FIG. **2**, intra-office fibers usually consist of a fiber pair, for example intra-office fiber **151t-1** and **151u-1**, whereby the transmit and receive optical signals usually propagate on separate fibers. Optical or WDM signals from core fiber **150** enter core end terminal **110** via intra-office fiber **151t-1**. Intra-office fiber **151t-1** is connected to optical amplifier **155** where the propagating signals are amplified. Optical amplifier **155** is further connected to DWDM demux **165** via core end terminal fiber **161a**. Core end terminal fiber **161a** carries composite optically muxed signals. The composite signals are deconstructed into their constituent and individual optically modulated signals by DWDM demux **165** and appear on fiber interconnects **163a-c**. Optical signals on fiber interconnects **163a-c** are received by Long Haul (LH) transponders **160a-c**. LH transponders **160a-c** electrically process and optically remodulate the signals, and transmit the LH remodulated signals through tributary interfaces **151v-1** and **152v-2** to short haul (SH) transponders **170a** and **170b** or SH transceiver **180** via intra-office fibers **151v-3**.

LH transponders **160a-c** may be varied in their capability and composition. For example, they may employ internal modulation or external modulation using NRZ, RZ, or other formats as known by those skilled in the art. LH transponders **160a-c** have the primary function of converting short and intermediate reach intra-office signals typically generated by directly modulated lasers to long reach signals; long reach

signals (LH format) being compatible with intercity propagation of hundreds or thousands of kilometers.

The SH transponders **170a** and **170b** and SH transceiver **180** may be of different varieties typically found in metro domain systems and known well to those skilled in the art. The distinguishing feature of SH transponder **170a** and **170b** and SH transceiver **180** from LH transponders **160a-c** is in the propagation distance limitation on the SH transponders **170a** and **170b** and SH transceiver **180**. SH transponders **170a** and **170b** and SH transceiver **180** have a propagation distance limited to less than or about 80 km.

The term transponder applies to both the LH and SH applications wherein the input optical signal to the device is narrow band and occurs at a particular input wavelength or frequency and wherein the device converts the input signal to an output optical signal of a different wavelength or frequency and may be narrowband or broadband in nature. In general, a transponder will operate in full-duplex mode. The term transceiver applies to a device that converts input signals at a particular wavelength or frequency to an output signal at the same wavelength or frequency while maintaining similarity between the optical bandwidth and dispersive capacity of the input signal to the optical bandwidth and dispersive capacity of the output signal.

Both LH and SH devices perform the functions of regeneration or amplification and reshaping, and may or may not employ retiming. Further details of the LH or SH receiver technology and transmitter technology, that is the transponders and transceivers, are known in the art and will not be described further.

Continuing the description of FIG. 2, the optical signals on intra-office fibers **151v-1**, **151v-2**, and **151v-3** are received by SH transponders **170a** and **170b** and SH transceiver **180**. The optical signals on **151v-3** are converted by transponder **180** to optical signals that propagate directly on the intra-office fibers **151x-2** to metro fiber **152o**. Alternatively, the optical signals appearing on intra-office fiber **151v-1** and **151v-2** are converted by SH transponders **170a** and **170b**, respectively, to intermediate signals and transmitted to WDM mux **175** via fiber interconnect **173a** and **173d**, respectively. WDM mux **175** muxes the intermediate signals and transmits them to the metro fiber **152n** via intra-office fiber **151x-1** and ultimately to an extension end terminal.

In the Z-A direction, optical signals from metro fiber **152n** propagate along intra-office fiber **151y-1** to WDM demux **176**. WDM demux **176** extracts the optical signals propagated along intra-office fiber **151y-1**, and transmits the extracted signals to SH transponders **170a** and **170b** via interconnects **173b** and **173c**. SH transponders **170a** and **170b** electronically process and optically remodulate the extracted signals for transport over a SH network and transmit the remodulated signals to LH transponders **160a** and **160b** via intra-office fibers **151w-1** and **151w-2**. LH transponders **160a** and **160b** convert the signals for into a format suitable for LH transporting and transmits the prepared signals to DWDM mux **166** via fiber interconnects **163d** and **163e**.

Optical signals from metro fiber **152o** propagate along intra-office fiber **151y-2** to SH transceiver **180**. SH transceiver **180** electronically processes and optically remodulates the extracted signals for transport over a SH network and transmits the remodulated signal to LH transponder **160c** via intra-office fiber **151w-3** and tributary interface **155c**. LH transponder converts the signal into a format suitable for LH transporting and transmits the prepared signal to DWDM mux **166** via fiber interconnect **163f**.

DWDM mux **166** muxes the signals received from fiber interconnects **163d-f** and transmits the muxed signals to

transmitting optical amplifier **156** via core end terminal fiber **161b**. Transmitting optical amplifier **156** amplifies the muxed signals and transmits the amplified signals to core fiber **150** via intra-office fiber **151u-1**.

The preferred and alternate embodiments of the invention are described with reference to FIGS. 3-12. Beginning with FIG. 3, the invention includes a set of coupled metro networks **230a-d** which are a part of a larger inter-domain network **200**. The metro networks **230a-d** are connected by a plurality of linear DWDM systems or more complex ring structures employing SONET ADMs or a mix of each type. A linear DWDM system is shown in FIG. 3, but the invention encompasses other structures. The invention facilitates optical signals generated from CPE **290a-p** at the edges of metro networks **230a-d** to be interconnected directly with each other. CPEs **290a-p** are the same type as CPEs **190a-h** shown in FIG. 1. Those skilled in the art will recognize that the configuration of metro network domains may take many forms and that those depicted are exemplary. Similarly, the invention can be applied to a widely varying arrangement of interconnections of metro optic networks, as will be appreciated by those skilled in the art. CPEs **290a-d**, **290f-i** and **290l-p** are in communication with extension terminals **220a-h** via intra-office fiber **251a-d**, **251g-i** and **251o-s**. Intra-office fibers **251a-s** are the same type of fiber as intra-office fibers **151a-s** shown in FIG. 1. CPE **290d** is connected to primary terminal **210a** via intra-office fiber **251e**. CPE **290e** is connected to primary terminal **210c** via intra-office fiber **251f**. CPEs **290j** and **290k** are connected to primary terminal **210b** via intra-office fibers **251k** and **251l**.

Extension terminals **220a-f** are connected to primary terminals **210a** and **210c** via metro fiber **252b-d** and **252f-h**. Metro fiber **252a-k** is the same type of fiber as metro fiber **152a-m**. Primary terminals **210a** and **210c** are connected to junctions **211a** and **211b** via metro fiber **252a** and **252e**. Extension terminal **220g** is connected to junction **211c** via metro fiber **252i**. Extension terminal **220h** is connected to junction **211e** via metro fiber **252k**. Junction **211e** is connected to junction **211d** via metro fiber **252j**. Junction **211a** is connected to core amplifier **215a** via core fiber **250a**. Amplifiers **215a-d** are the same type of amplifiers as **115a-d**. Core fiber **250a**, **250x** and **250z** is the same type of fiber as core fiber **150a**, **150x** and **150z**.

Junction **211b** is connected to OADM **216** via interoffice fiber **251u**. Junctions **211c** and **211d** are connected to primary terminal **210b** via intra-office fiber **251m** and **251n**. Also connected to primary terminal **210b** are CPE **290j** and **290k** through intra-office fiber **251k** and **251l**.

To accomplish the interconnection of metro networks **230a**, **230b**, **230c**, **230d**, core optical amplifiers **215a-d** are connected to OADM **216** via core fiber **250a**, **250x** and **250z**. The ellipses in the drawing indicate there can be any number of core amplifiers **215a-d** between junction **211a** and OADM **216** and between primary distributed terminal **210b** and OADM **216**. Also, there may be more than one OADM **216** along core fiber **250a**, **250x** and **250z**. Either OADM **216** or core amplifiers **215a-d** are connected to a sub-system of primary terminals **210a-c** and extension terminals **220a-h** composed of terminal shelves. CPE **290a-p** may be interconnected directly to primary terminals **210a-c** or extension terminals **220a-h** to accomplish the transfer of optical signals from a particular CPE to a different CPE that may be in a geographically distinct location. OADM **216** can be fixed or not fixed as in broadcast and select architectures. In the preferred embodiment, OADM **216** includes a broadcast and select architecture as is known in the art. Core optical amplifiers **215** and OADM **216** may or may not contain compo-

nents to perform optical dispersion compensation and other components to perform gain equalization, both of which may employ techniques known in the art.

Referring to FIG. 3, a link between CPE 290a and CPE 290p in the A-Z direction of a full-duplex signal path will now be described as an example. CPE 290a is connected to extension terminal 220a via intra-office fiber 251a. Extension terminal 220a transforms the signal originating at 290a into a suitable format for LH transmission. Extension terminal 220a transmits the transformed signal to primary terminal 210a via metro fiber 252b. At primary terminal 210a, the transformed signal is optically muxed with other signals from extension terminals 220b and 220c and with signals generated at CPE 290d. The multiplexed signals are transmitted to junction 211a via metro fiber 252a. At junction 211a, metro fiber 252a is connected to core fiber 250a and the optical signal propagates along core fiber 250a, 250x and 250z through the chain of core amplifiers 215a-d and OADM 216 to the primary distributed terminal 210b. At primary distributed terminal 210b, the desired signal for CPE 290p is optically demuxed from the other signals and transmitted along intra-office fiber 251n to junction 211d. At junction 211d, intraoffice fiber 251n is coupled to metro fiber 252j. The desired optical signal propagates along metro fiber 252j to junction 211e. At junction 211e, metro fiber 252j is coupled to metro fiber 252k. The desired optical signal continues to propagate on metro fiber 252k to extension terminal 220h. At extension terminal 220h, the desired optical signal is received and transformed from its LH format into a format suitable for interconnection with CPE 290p through intra-office fiber 251s. The optical signal terminates at CPE 290p. In the Z-A direction of the full duplex signal can be described in a similar way, so that signals originating from CPE 290p and terminating at CPE 290a are propagated in a similar manner.

There are many optical links that can be established in the inter-domain network 200. For example, the present invention allows for CPE 290c to be interconnected to any one of the other CPE shown in FIG. 3. Also, more than one CPE may be connected to a single extension terminal or primary terminal. For example, CPE 290a and CPE 290b are both connected to extension terminal 220a. CPE 290a and 290b may be co-located together or geographically separate and neither CPE 290a or 290b need be co-located with extension terminal 220a. Although in practice they are usually co-located and interconnected by intra-office fiber 251a and 251b as shown. Additionally, one CPE may be connected to a plurality of extension terminals or primary terminals. For example, CPE 290c is shown having at least two distinct optical interfaces, one being connected to extension terminal 220b and the other connected to extension terminal 220c. By interconnecting extension terminals 220b and 220c to primary terminal 210a with metro fiber 252c and 252d, a protected connection can be made between CPE 290c and primary terminal 210a. If a fiber failure occurs on either metro fiber 252c or 252d the other metro fiber 252c or 252d may carry the optical signals safely from CPE 290c to other points in inter-domain network 200.

Another link example will illustrate further features of the current invention. Simultaneous multiple interconnections between metro networks 230b and 230c consisting of links between CPE 290e to CPE 290o, CPE 290h to CPE 290k, and CPE 290i to CPE 290p is described. In particular, CPEs 290h and 290i are connected to extension terminal 220f via intra-office fiber 251i and 251j, respectively. Secondary terminal 220f converts the originating signals from CPEs 290h and 290i to a LH format. Secondary terminal 220f optically muxes the converted signals and transmits the muxed signals to primary terminal 210c via metro fiber 252h. Also, CPE

290e is connected to primary terminal 210c via intra-office fiber 251f and transmits an SH signal to primary terminal 210c.

At primary terminal 210c, the optical signal originating from CPE 290e is converted to a LH format and optically muxed with the other optical signals originating from extension terminal 220f. The muxed optical signals from primary terminal 210c propagate on metro fiber 252e to junction 211b. The signals propagate through junction 211b to intra-office fiber 251u and continues on to OADM 216. OADM 216 muxes the signals from intra-office fiber 251u onto core fiber 250x. The optical signals propagate on core fiber 250x and 250z towards primary terminal 210b. Multiple core amplifiers 215c and 215d may be used to boost the signal. Additional OADMs 216 may also be present on core fiber 250x and 250z.

At primary terminal 210b, the optical signals on core fiber 250z are optically demuxed in such a way that optical signals destined for CPE 290e and CPE 290i are transmitted on intra-office fiber 251n while optical signals destined for CPE 290h are transmitted on intra-office fiber 251l. The signal on intra-office fiber 251l terminates at CPE 290k and the signal from CPE 290h has been successfully transmitted to CPE 290k. CPE 290k is considered local to core distributed terminal 210b.

The signals originating from CPE 290e and CPE 290i on intra-office fiber 251n propagate along intra-office fiber 251n through junction 211d and onto metro fiber 252j inside metro network 230c. The LH signals propagate along metro fiber 252j through junction 211e and onto metro fiber 252k inside metro network 230d. The optical signals propagate along metro fiber 252k to extension terminal 220h. At extension terminal 220h, the optical signals are demuxed and converted from a LH format to a format suitable for interconnection to CPEs 290o and 290p. The converted signals are transmitted to CPEs 290o and 290p via intra-office fiber 251r and 251s, respectively, where the signals terminate. The signal from CPE 290e has been successfully transmitted to CPE 290o and the signal from 290i has been successfully transmitted to CPE 290p. In the Z-A direction of the full duplex signal can be described in a similar way so that originating signals from 290k, 290r, and 290q destined for 290h, 290e, and 290i respectively, are propagated in a similar manner to that just described.

The above explains how a signal may propagate through more than one metro network 230 without conversion from an LH format. In the preferred embodiment, the links between primary terminals 210a-c and extension terminals 220a-h may be more than 100 km and may include optical amplifiers with or without dispersion compensators and gain equalizers.

The invention allows for primary terminals 210a-c to be placed outside or within a metro network 230 as required by the location of CPEs 290a-p. Primary terminals 210a and 210c are inside respective metro networks 230a and 230b while primary terminal 210b is outside metro networks 230c and 230d.

The invention also allows for remote interconnections between OADM 216 and primary terminals 210a-c to be of distances greater than those found in most interoffice networks. The distance for the remote interconnection is similar in nature to the long distances between primary terminals 210a-c and extension terminals 220a-p and could be around 100 km. Interconnection between primary terminals 210a-c, extension terminals 220a-h and OADM 216 are accomplished with a single pair of fibers. This feature is further described in relation to FIG. 4.

FIG. 4 depicts the preferred embodiment of a primary terminal. Primary terminal 210 allows for the interconnection

of full duplex signals from core fiber **250** (shown as a block) to various distinct CPEs **290s-x**. CPEs **290s-x** are the same type as CPEs **290a-p** FIG. **3** and CPEs **190a-h** FIG. **1**. CPEs **290s-x** maybe geographically diverse from one another. In the A-Z direction, an LH format optical signal is transmitted from the core fiber plant **250** to receiving amplifier **255** via intra-office fiber **251v-1**. Intra-office fibers **251v-a**, **251x-1**, **251x-2**, **251x-3**, **251y-1**, **251y-2**, **251y-3**, **251z-1**, **251z-2**, **251z-3**, **251z-4**, **251z-5**, **251z-6**, **251w-1** are the same type of fiber as intra-office fibers **251a-s** and **151a-s**. Receiving amplifier **255** performs the function of amplifying the incoming multiplexed WDM or DWDM signals from intra-office fiber **251v-1** to a known level, so the signal has enough optical power to transmit to other components such as extension terminals **220i-k**. The amplified signal is transmitted to fine demux **265** via fiber **261a**. The signal can contain any number of muxed optical signals. In the preferred embodiment, there are twelve optical signals, referred to as M (12) to denote any arbitrary number of twelve signals.

Fine demux **265** demuxes the M (12) muxed signals in such a way as to leave N (4) smaller groups of M/N (3) optical signals. The N (4) smaller groups are muxed onto 4 intra-office fiber interconnections **271a-d**. These smaller groups of approximately M/N (3) optical signals will be called "optical mux groups" or simply "mux groups" hereinafter. One mux group on intra-office fiber interconnection **271a** remains inside the primary terminal **210** for further processing while the other mux groups on intra-office fiber interconnections **271b-d** exit for distribution to distinct locations, such as CPE **290v-x**.

The mux group on fiber interconnection **271a** is transmitted from fine demux **265** to coarse demux **267**. Coarse demux **267** demuxes the approximately M/N (3) optical signals into individual optical signals and transmits the individual signals to transponders **260a-c** via output fiber connections **263a-c**. Transponders **260a-c** convert the individual LH format signals into optical signals for transmission on intra-office optical fibers **251x-1**, **251x-2**, and **251x-3**. The transmitted optical signals are suitable for use by CPEs **290s-u**, and therefore the primary terminal **210** serves as the interface device for the local traffic (optical signals) intended for CPEs **290s-u**. As shown by the ellipsis, there may be a plurality of CPEs **290** connected to any one of the transponders **260a-c**.

For the delivery of remote traffic (optical signals) to remote CPE **290v-x**, fine demux **265** transmits the mux groups on intra-office fiber interconnections **271b-d** to metro fiber **252**. The optical mux groups are transported from metro fiber **252** to extension terminals **220i-k** via geographically distinct fiber interconnections **271e-i**. Secondary terminals **220i-k** demux the optical mux groups into individual optical signals and transmit the individual signals to CPEs **290v-x** via intra-office fibers **251z-1**, **z-3**, and **z-5**. As shown by the ellipsis, there may be a plurality of CPEs connected to any one of the extension terminals **220i-k**.

The optical signals, being in full duplex, also flow in a direction opposite to that just described and in a similar way. Individual optical signals that originate from CPE **290v-x** are transmitted to extension terminals **220i-k** via intra-office optical fibers **251z-2**, **z-4**, **z-6**. Secondary terminals **220i-j** mux the optical signals into optical mux groups and transmit the mux groups to metro fiber **252** via fiber interconnections **271f**, **271h**, and **271j**. The optical mux groups propagating on metro fiber **252** are transmitted to fine mux **266** via fiber interconnections **271f-h**. The optical mux groups are muxed into one mux group by fine mux **266**. Fine mux **266** transmits a signal containing the mux group to output amplifier **256** via

fiber **261b**. Output amplifier **256** then amplifies the signal for transmission on intra-office fiber **251w-1** to core fiber **250**.

Similarly, optical signals originating from CPEs **290s-u** flow in the Z-A direction through transponders **260a-c** via intra-office fiber **151y-1**, **151y-2** and **151y-3**. Transponders **260a-c** convert the individual optical signals to a LH format and send the converted signals to coarse mux **268** via output fiber connection **263d-f**. Coarse mux **268** muxes the converted signals together into an optical mux group and transmits the optical mux group to fine mux **266** via fiber interconnection **271e**. The optical mux groups propagating on fiber interconnections **271e-h** are muxed into one mux group by fine mux **266**. Fine mux **266** transmits the signal containing the mux group to output amplifier **256** via fiber **261b**. Output amplifier **256** then amplifies the signal for transmission on intra-office fibers **251w-1** to core fiber **250**. The combination of primary terminal **210** and extension terminals **220i-k** form a system of distributed terminals, which is a preferred embodiment of the present invention.

In FIG. **5**, the preferred embodiment of a type one extension terminal **220** is shown. A mux group containing approximately M/N, for example 3, optical signals is propagated from metro fiber **252** (shown as a block) to terminal **220** via fiber interconnection **271k**. The mux group traverses terminal **220** receiving amplifier **285** which may be or may not be the same type of amplifier as receiving amplifier **255** in primary terminal **210**, FIG. **4**. Terminal **220** receiving amplifier **285** amplifies the incoming approximately M/N (3) multiplexed optical WDM or DWDM signals from **271k** to a known level so the signals have enough optical power to be transmitted to the other components in type one extension terminal **220** and connecting devices such as CPE **290aa-cc**. The approximately M/N (3) multiplexed optical signals are transmitted from extension terminal receiving amplifier **285** to extension terminal coarse demux **287** via extension terminal interconnection **281a**. Secondary terminal coarse demux **287** demuxes the approximately M/N (3) multiplexed optical signals into individual optical signals for transmission to transponders **260d-f** via extension terminal output fiber connections **283a-c**. Transponders **260d-f** are the same type of transponders as transponders **260a-c** in FIG. **4**.

Transponders **260d-f** convert the LH format optical signals on extension terminal output fiber connections **283a-c** into signals suitable for use by CPEs **290aa-cc**. Transponders **260d-f** are connected to CPE **290aa-cc** via intra-office fibers **251aa-1**, **251aa-2** and **251aa-3**.

Terminal **220** serves as the interface device for the local traffic (optical signals) intended for CPE **290aa-cc**. Intra-office fibers **251aa-1**, **251aa-2** and **251aa-3** are usually physically co-located with terminal **220**, but they may incorporate long reach capability including optical amplifiers to connect to an individual port on a remote CPE **290** via an intra-office fiber.

The full duplex optical signals also flow in the Z-A direction, from CPEs **290aa-cc** through intra-office fibers **251bb-1**, **251bb-2** and **251bb-3** to transponders **260d-f**. Transponders **260d-f** convert the signal formats used by CPEs **290aa-cc** to a LH format. The converted LH format signals are sent to extension coarse mux **288** via extension terminal output fiber connections **283d-f**. Secondary terminal coarse mux **288** combines the optical signals into an optical mux group and transmits the optical mux group to optical amplifier **286** via extension terminal interconnection **281b**. The mux group is amplified by terminal **220** transmitting optical amplifier **286** for propagation along fiber interconnection **271m** to metro fiber **252** and on to a primary terminal **210** (FIG. **4**).

The preferred embodiment of a type one extension terminal **220** is capable of transmitting and receiving signals from primary terminal **210** from distances on the order of but possibly even larger than 100 km For distances much larger than 100 km a stand-alone optical amplifier or chain of such devices can be inserted between the extension terminals and the primary terminal.

A type two extension terminal **225** is depicted in FIG. 6. Terminal **225**, can be used for short distance connections, of the order of 5 km or less, that require a physical separation between the primary terminal **210** and multiple CPEs. The primary difference between a type two extension terminal **225** and type one extension terminal **220** is that receiving optical amplifier **285** and transmitting amplifier **286** are not found in type two terminal **225**. With the exception of the optical amplifiers, the signal propagation is the same to that described for type one extension terminal **220**.

In the A-Z direction, an optical mux group containing approximately M/N optical signals are propagated from metro fiber **252** (shown as a block) to type two extension terminal **225** via fiber interconnection **271p**. The optical mux group propagates to short extension coarse demux **297**. Coarse demux **297** demuxes the approximately M/N (3) optical signals into individual optical signals and transmits the individual signals to transponders **260g-i** via terminal output fiber connections **293a-c**. Transponders **260g-i** are the same type of transponders **260d-f** as shown in FIG. 5.

Transponders **260g-i** convert the LH format optical signals on output fiber connections **293a-c** into signals suitable for use by CPEs **290pp-rr**. Transponders **260g-i** are connected to CPEs **290pp-rr** via intra-office fibers **251cc-1**, **251cc-2** and **251cc-3**.

Terminal **225** can also serve as the interface device for the local traffic (optical signals) intended for CPE **290pp-rr**. Intra-office fibers **251cc-1**, **251cc-2** and **251cc-3** are usually physically co-located with terminal **225**, but they may incorporate long reach capability including optical amplifiers to connect to an individual port on a remote CPE **290** via intra-office fiber **251**.

The full duplex optical signals also flow in the Z-A direction from CPE **290pp-rr** through intra-office fibers **251dd-1**, **251dd-2** and **251dd-3** to transponders **260g-i**. Transponders **260g-i** convert the optical signal formats from that used by CPEs **290pp-rr** to a LH format. The converted LH format signals are sent to terminal coarse mux **297** via terminal output fiber connections **293d-f**. Coarse mux **298** combines the optical signals into an optical mux group for propagation along fiber interconnection **271q** to metro fiber **252** and on to primary terminal **210**.

In both terminal **220** and terminal **225**, coarse demux **287**, terminal coarse demux **297**, coarse mux **288**, and coarse mux **298** may perform the function of attenuating the individual optical signals. In this way, the invention can launch or detect the appropriate optical powers without the need of gain equalization provided by optical amplifiers. Furthermore, the attenuation function in extension terminal coarse demux **287** and extension terminal coarse mux **288** alleviate the need for tightly controlled gain equalization in the extension terminal receiving optical amplifier **285** and transmitting optical amplifier **286** thereby lowering the cost.

FIGS. 7 through 10 depict various embodiments of mux and demux architectures which constitute a part of the invention. In FIG. 7, mux **500** is made up of two submultiplexers **550a** and **550b**. Submuxers **550a** and **550b** are capable of taking four times N optical signals at different wavelengths and combining them onto one output fiber connection **515a** and **515b**. N can be any number, for example, 10 as shown in

FIG. 7. Mux **500** is capable of taking $8 \times N$ (10) optical signals at different wavelengths and combining them onto one output optical connection **505**. Thus, the architecture is scaleable up or down in the number of wavelengths, for example a 50/25 GHz interleaver may be placed in conjunction with two muxs **500** to form a $16 \times N$ multiplexer unit.

The function of an optical interleaver is to combine a "comb" of optical wavelengths consisting of even and odd numbered wavelengths ordered by integers as a monotonically increasing sequence with wavelength or frequency of the optical carrier. The function of an optical de-interleaver is to separate a "comb" of optical wavelengths consisting of even and odd numbered wavelengths ordered as before. Specific interleaver or de-interleaver device implementations are known in the art and will not be described further. Interleavers known in the art and can be obtained from, for example, JDS Uniphase, model number IBC-LW1D00310.

In what follows, the muxing function will be described along with the demuxing function that utilizes the same basic architecture and connectivity. Demuxing is described in parentheses. In the A-Z direction, Z-A in parentheses, signals enter (leave) mux **500** through a set of 400 GHz filters **540a-h**, known in the art as optical thin film filters or layered dielectric optical filters and available from JDS Uniphase as model number DWS-2F3883P20.

Filters **540a** and **540b** mux (demux) the received N (10) optical signals together (apart) into (from) a "comb" of wavelengths separated by 400 GHz and connected to 400/200 GHz interleaver **530a** by fiber connections **535a** and **535b**. Because an interleaver for signals in the A-Z direction is also a deinterleaver for signals in the Z-A direction, the term interleaver will be used to describe both an interleaver and deinterleaver. Similarly, 400 GHz filter pairs **540c** and **540d**, **540e** and **540f**, and **540g** and **540h** mux (demux) together (apart) the received optical signals into (from) a "comb" of wavelengths separated by 400 GHz. The filter pairs **540c** and **540d**, **540e** and **540f**, and **540g** and **540h** are in communication with 400/200 GHz interleavers **530b**, **530c** and **530d**, respectively, via 400/200 GHz fiber connections **535c-h**, respectively. 400/200 GHz interleavers **530a-d** combine (separate) optical signals from (for) filters **540a-h** into (from) a single "comb" of wavelengths separated by 200 GHz. The combined (separated) output (input) is transmitted (received) to (from) 200/100 GHz interleaver **520a** via 200/100 GHz fiber connection **525a** and **525b** where they are combined (separated) into (from) a single "comb" of wavelengths 100 GHz apart. Similarly, output from **530c** and **530d** propagate via fiber connection **525c** and **525d** to (from) interleaver **520b** where they are combined (separated) into (from) a single "comb" of wavelengths 100 GHz apart. Finally, the output (input) "combs" of interleavers **520a** and **520b** are transmitted to (from) 100/50 GHz interleaver **510** via 100/50 fiber connections **515a** and **515b**. 100/50 interleaver **510** combines (separates out) the single comb of wavelengths to form (from) composite optical connection **505** made up of a comb of wavelengths 50 GHz apart.

In reference to FIG. 4, primary terminal **210** is shown to be composed of a coarse mux **268**, a coarse demux **267**, a fine mux **266**, and a fine demux **265**. The fine demux **265** and fine mux **266** coincide with the preferred embodiment in FIG. 7 of the combination of 100/50 GHz interleavers **510**, 200/100 GHz interleavers **520a-b**, and 400/200 GHz interleavers **530a-d**. The coarse demux **267** and coarse mux **268** coincide with the preferred embodiment in FIG. 7 of 400 GHz filters **540a-h**. The coarse mux **288** and coarse demux **287** in the extension terminals of FIG. 5 and coarse mux **298** and coarse demux **297** of FIG. 6 also coincide with 40 GHz filters **540a-h**. Optical connection **505**, 100/50 fiber connections **515a-d**,

200/100 fiber connections **525a-c**, and fiber connections **535a-h** may function as simple fiber jumpers or optical amplifiers or optical attenuators or some combination thereof to achieve required fiber distances between the various stages of a distributed terminal.

FIG. **8** indicates an alternate embodiment of a mux and demux structure. Mux/demux **600** comprises two submuxs **650a** and demuxs **650b**. Because mux/demux **600** comprises two submux **650a** and demux **650b** pairs, mux/demux **600** is capable of taking $8 \times N$ optical signals (10 are shown in FIG. **8**) at different wavelengths and combining them onto one output/input connection **605**. Because submux **650a** and demux **650b** are capable of taking four times N optical signals at different wavelengths and combining them onto one 2000 GHz fiber connection **615a** and **615b**, the architecture is scaleable up or down in the number of wavelengths. For example, a 4000 GHz Band combiner may be placed in conjunction with two mux/demuxes to form a $16 \times N$ (10) multiplexer unit.

The function of an optical band splitter/combiner is to split/combine a specified band of optical wavelengths consisting of tightly spaced optical wavelengths of typical separation 50 GHz or 25 GHz into or out of two coarse bands of such wavelengths. Specific band splitters or band combiner device implementation are well known in the art and not described further. Band filtering devices can be obtained from, for example, Oplink Corporation model number CR000001111.

In the A-Z direction, signals enter mux/demux **600** through a set of fine 50 GHz filters **640a-h**, known in the art. 50 GHz filters **640a-h** may also be 25 GHz filters also known in the art. Two examples of fine 50 GHz filters **640** are the arrayed waveguide filters and layered dielectric optical filters available as, for example, JDS Uniphase model numbers AWG-5NBUC003T and DWM-5F8DSX2, respectively.

Starting with fine 50 Hz filter **640a** and **640b**, the $N(10)$ optical signals are muxed together into a band of wavelengths contained within about 500 GHz and transmitted to 500 GHz band combiner **630a** via 500 GHz fiber connections **635a** and **635b**. Similarly, fine 56 Hz filter pairs **640c** and **640d**, **640e** and **640f** and **640g** and **640h** mux $N(10)$ optical signals together and transmit the muxed signals to 500 GHz band combiners **630b**, **630c** and **630d** respectively via 500 GHz fiber connections **635c-h** respectively. 500 GHz band combiner **630a** combines the optical signals from filters **640a** and **640b** into a single broader band of wavelengths contained within about 1000 GHz. Similarly, 500 GHz band combiners **630b-d** combine received optical signals into a single broader band of wavelengths.

The single broader band of wavelengths from extension band combiners **630a** and **630b** are transmitted to 1000 GHz band combiner **620a** via 1000 GHz fiber connections **625a** and **625b**. 1000 GHz band combiner **620a** combines the signals from 500 GHz band combiners **630a** and **630b** into a single band of wavelengths contained within about 2000 GHz. Similarly, 1000 GHz band combiner **620b** combines the wavelengths transmitted from 500 GHz band combiners **630c** and **630d** via 1000 GHz fiber connection. **625c** and **625d** into a single band of wavelengths. Each 1000 GHz band combiner **620a** and **620b** transmits the single band of wavelengths to 2000 GHz combiner **610** via 2000 GHz fiber connections **615a** and **615b**. 2000 GHz combiner **610** combines the received single band of wavelengths into a composite signal band contained within about 4000 GHz. The composite signal band is transmitted on output/input connection **605**.

In the Z-A direction, 2000 GHz combiner **610** receives a composite signal band contained within about 4000 GHz on

output/input connection **605**. Because a combiner for signals in the A-Z direction can also be a splitter for signals in the Z-A direction, the term combiner will be used to describe both a combiner and a splitter. 2000 GHz combiner **610** splits the composite signal into two single band of wavelengths contained within about 2000 GHz. The bands of wavelengths within 2000 GHz are transmitted to 1000 GHz band combiners **620a** and **620b** via 2000 GHz fiber connections **615a** and **615b**. 1000 GHz combiners **620a** and **620b** each separate the single band of wavelengths within 2000 GHz into two single band of wavelengths within about 1000 GHz. The single band of wavelengths within 1000 GHz is transmitted from 1000 GHz combiners **620a** and **620b** to 500 GHz band combiners **630a-d** via 1000 GHz fiber connections **625a-d**. 500 GHz band combiners **630a-d** each split the single band of wavelengths contained within about 1000 GHz into a single band of wavelengths contained within about 500 GHz. The single band of wavelengths contained within 500 GHz is transmitted from 500 GHz band combiners **630a-d** to fine 50 Hz filters **640a-h** via 500 GHz fiber connections **635a-h**. Fine 50 Hz filters **640a-d** demux the single band of wavelengths within 500 GHz into $N(10)$ bands of wavelengths wherein the $N(10)$ wavelengths are transmitted out of mux/demux **600**.

The fine filter function performed by 50 Hz filters **640a-h** and the coarse filtering functions performed by the combination of 2000 GHz combiner **610**, 1000 GHz combiners **620a** and **620b**, and 500 GHz band combiners **630a-d** can be separated. The coarse and fine filtering functions are reversed in the hierarchy of the interleaver based mux **500**. Also, output/input connection **605**, 2000 GHz fiber connection **615a** and **615b**, 1000 GHz fiber connection **625a-h**, and 500 GHz fiber connection **635a-h** may function as simple fiber jumpers, optical amplifiers, optical attenuators, or some combination thereof to achieve required fiber distances between the various stages of primary terminal **210**.

A second alternative embodiment of the multiplexing and demultiplexing function of the present invention is indicated in FIGS. **9** and **10**. The embodiment depicts a means of implementing a wavelength tunable system with primary terminals. Beginning with FIG. **9** tunable demux **700** is composed primarily of first optical splitter **710**, second optical splitter **720a** and **720b**, and third optical splitter **730a-h**. Third optical splitter **730a-h** is operationally connected to tunable filters **740** via tunable filter fiber connection **731**.

In the Z-A direction, first optical splitter **710** receives a composite signal band contained within about 4000 GHz on tunable input connection **705**. The embodiment shown is one way of constructing a "tree" whereby a single band of wavelengths transmitted on tunable input connection **705** is demuxed so as separate out groups of wavelengths. The exact nature and combining ratio is not essential. First optical splitter **710** splits the composite signal on tunable input connection **705** into two single bands of wavelengths contained within about 2000 GHz. The bands of wavelengths within 2000 GHz are transmitted to second optical splitters **720a** and **720b** via first splitter fiber connections **715a** and **715b**. Second optical splitters **720a** and **720b** each separate the single bands of wavelengths within 2000 GHz into two single band of wavelengths within about 1000 GHz. The single bands of wavelengths within 1000 GHz are transmitted from second optical splitters **720a** and **720b** to third optical splitters **730a-h** via second splitter fiber connection **725a-h**. Third optical splitters **730a-h** each split the single band of wavelengths contained within about 1000 GHz into a single band of wavelengths contained within about 500 GHz. The single band of wavelengths contained within 500 GHz is transmitted from

third optical splitters 730a-h to tunable filters 740a-x via tunable filter fiber connections 731.

While the order could be greater, in the preferred embodiment, tunable filters 740a-x operate as narrow spectral width bandpass filters with a passband in the order of two and one-half to three times the bandwidth of the carrier frequency; for example, 30 GHz or more for a 10 GHz optical signal. Tunable filters 740a-x are tuned to pass any one of the signals appearing at the outputs of third optical splitters 730a-h. Optical splitters are known in the art, an example being JDS Uniphase model number NEM-221003119. Tunable optical filters are also known in the art, examples being JDS Uniphase model number VCF050 or NORTEL model number MT-15-025. Tunable input connection 705, first splitter fiber connections 715a and 715b, and second splitter fiber connection 725a-h may function as simple fiber jumpers or optical amplifiers or optical attenuators or some combination thereof to achieve required fiber distances between the various stages of a distributed terminal.

With reference to FIG. 10 tunable mux 701 is composed of first optical combiner 711, second optical combiner 760a and 760b, and third optical combiner 770a-h. Third optical combiner 770a-h is operationally connected to tunable lasers 780a-x. Tunable lasers 780a-x may be narrowly tunable around 200 GHz or broadly tunable, for example, over the entire C or L band of Erbium-doped fiber amplifiers, the spectral width being of the order of 4000 GHz. The laser components may have an optical output power on the order of 20 mW, wavelength stability on the order of 2.5 GHz or better, side-mode suppression ratio on the order of 35 dB, and relative intensity noise (RIN) on the order of -140 dB. Optical combiners are known in the art, an example being JDS Uniphase model number NEM-221003119. Tunable lasers are known in the art, one example, JDS Uniphase CQF310/208-19365.

In the Z-A direction, tunable lasers 780a-x receives a composite signal. The exact nature and combing ratio is not essential, the embodiment shown is one way of constructing a "tree" whereby one or more optical signals generated by one or more different tunable lasers are wavelength muxed so as to appear at output fiber connection 706 as a single band of wavelengths.

Tunable lasers 780 receive a band of wavelengths. The wavelengths are tuned and transmitted to third optical combiner 770a-h via tunable laser fiber connection 775. Third optical combiner 770a-h muxes the received signal from tunable lasers 780a-x into a single band of wavelengths within 500 GHz. The single band of wavelengths within 500 GHz is transmitted to extension optical combiner 760a and 760b via second optical fiber connections 726a-h. Second optical combiners 760a and 760b mux the received single band of wavelengths within 500 GHz into a single band of wavelengths contained within about 1000 GHz. The single band of wavelengths contained within about 1000 GHz is transmitted to first optical combiner 711 via first fiber connections 716a and 716b. Primary optical combiner 711 muxes the received single band of wavelengths within 1000 GHz into a single band of wavelengths within about 2000 GHz. The single band of wavelengths within about 2000 GHz is transmitted over output fiber connection 706.

Output fiber connections 706, first fiber connections 716a and 716b, second fiber connections 726a-h, and tunable laser fiber connection 775 may function as simple fiber jumpers or optical amplifiers or optical attenuators or some combination thereof to achieve required fiber distances between the various stages of a distributed terminal.

Valid and useful multiplexer and demultiplexer designs can be constructed with combinations of parts shown in FIGS. 7-10. Fine mux/demux 640a-b from FIG. 8 can individually replace blocks 740a-x as shown in FIG. 9 or blocks 780a-x as shown in FIG. 10 to form splitter/combiner based fixed filters. This alternate arrangement is advantageous because the cost of components would scale with the deployed bandwidth. Likewise, tunable components 740a-x from FIG. 9 and 780a-x from FIG. 10 can individually replace the fixed filters 640a-h in FIG. 8 to form banded DWDM based tunable filters. Another advantageous embodiment is that of replacing coarse mux/demux filters 540a-h in FIG. 7 with the tunable filter components 780a-x from FIG. 9 and 740a-x from FIG. 10 to form a mux and demux, respectively.

FIGS. 11 and 12 show different shelf connection configurations of the preferred embodiment that result from integrating the sub-systems of FIGS. 4-7 into a distributed terminal system. Each numbered block in FIGS. 11 and 12 is a self-contained shelf within the optical transmission system: the master terminal shelf 910 embodies the primary terminal 210, the slave shelves 920a-b embody the type one extension terminal 220; and the dual slaves shelf 925a-b embody two type two extension terminals 225 in one unit. In the preferred embodiment, eight optical mux groups are made up of 10 optical signal-carrying wavelengths.

FIG. 11 depicts a star configuration 900, whereby the submuxs are both contained within the master terminal shelf 910 along with one local 400 GHz filter. The shelves 910 and 920a-c are interconnected using fiber jumpers 916, 914 and 912. Dual slave shelves 925a-b are interconnected using fiber jumpers 902, 904, 906 and 908.

FIG. 12a depicts a second configuration 940 whereby two master shelves 911a and 911b are utilized to distribute the optical mux groups. Shelf 911a, is similar in function to primary terminal 210, and a 100/506 Hz interleaver, submux, and a 400 GHz filter. Shelf 911b, which is also similar in function to primary terminal 210, contains submuxs and a 400 GHz filter. The interconnection between master shelves 911a and 911b is accomplished by fiber interconnection 932 which is a 100/50 fiber connection. The configurations 940 and 960 service 8 optical mux groups or up to 80 optical signal wavelengths in six shelves. Line 941 is an optical input/output connection. Slave shelves 920a and 920b and dual slave shelves 925a and 925b contain the same equipment as described in relation to FIG. 11. Dual slave shelves 925a and 925b are coupled to master shelf via dual slave-to-master connections 918, 922 and 924. Slave shelves 920a and 920b are coupled to master shelf 911b via slave-to-master connections 926 and 928. Dual slave-to-master connections 918 and 922 may be as long as about 5 km in the preferred embodiment. Slave-to-master connections 926 and 928 may be as long as about 100 km without additional optical amplifiers.

FIG. 12b depicts a third configuration 960 similar to configuration 940 but utilizing only dual slave shelves 925a-c attached to the master shelves 911a and 911b. Configuration 960 achieves the highest system density of the configurations of the preferred embodiment. Two master shelves, 911a and 911b, and three dual slave shelves 925a-c can be used to service all 8 optical mux groups or up to 80 optical signal wavelengths in less than two standard 19 or 23 inch wide seven foot equipment racks. Master shelf 911a is connected to master shelf 911b by connection 933. Master shelf a and b contain the same components as described in relation to FIG. 12a. Master shelf a is connected to dual slave shelf 925a by jumpers 923 and 925. Master shelf 911a is connected to dual slave shelf 925c by jumper 919. Master shelf 911b is con-

nected to dual slave shelf **925b** by jumpers **929** and **931**. Master shelf **911b** is connected to dual slave shelf **925c** through jumper **927**.

Dual slave shelves **925a**, **b** and **c** contain the same equipment as described in FIG. **12a**. The fiber shelf interconnections **919**, **923**, **927**, **925**, **929** and **931** may be as long as about 5 km in the preferred embodiment while the master-to-master fiber connection **933** may be on the order of 100 km (without additional optical amplifiers).

Although the invention has been described with reference to one or more preferred embodiments, this description is not to be construed in a limiting sense. There is modification of the disclosed embodiments, as well as alternative embodiments of this invention, which will be apparent to persons of ordinary skill in the art, and the invention shall be viewed as limited only by reference to the following claims.

The invention claimed is:

1. A primary terminal of an optical transport system, the primary terminal comprising:

a transponder coupled to a customer premise equipment, wherein the transponder is configured to convert a first optical signal from the customer premise equipment into a first individual long-haul optical signal, and wherein the first optical signal is in a format suitable for use by the customer premise equipment;

a coarse multiplexer coupled to the transponder, wherein the coarse multiplexer is configured to multiplex the first individual long-haul optical signal into a first mux group of long-haul optical signals; and

a fine multiplexer coupled to the coarse multiplexer and to an extension terminal via a metro fiber, wherein the fine multiplexer is configured to receive a second mux group of long-haul optical signals from the extension terminal, wherein the fine multiplexer is configured to multiplex the first mux group from the coarse multiplexer and the second mux group from the extension terminal into a third mux group of long-haul optical signals, and wherein the primary terminal is configured to transmit the third mux group over a long-haul network.

2. The primary terminal of claim **1** further comprising an amplifier coupled to the fine multiplexer, wherein the amplifier is configured to amplify the third mux group from the fine multiplexer.

3. The primary terminal of claim **1**, wherein the coarse multiplexer and the fine multiplexer each include one of an optical interleaver, a banded dense wavelength division multiplexing (DWDM) filter, or a tunable filter.

4. The primary terminal of claim **1** further comprising a first demultiplexer coupled to the long-haul network,

wherein the first demultiplexer is configured to demultiplex a fourth mux group of long-haul optical signals from the long-haul network into a fifth mux group of long-haul optical signals and a sixth mux group of long-haul optical signals, and

wherein the primary terminal is configured to transmit the fifth mux group to the extension terminal via the metro fiber.

5. The primary terminal of claim **4** further comprising an amplifier coupled to the first demultiplexer, wherein the amplifier is configured to amplify the fourth mux group from the long-haul network.

6. The primary terminal of claim **4** further comprising a second demultiplexer coupled to the first demultiplexer and to the transponder, wherein the second demultiplexer is configured to demultiplex the sixth mux group from the first demultiplexer into a second individual long-haul optical signal.

7. The primary terminal of claim **6**, wherein the first demultiplexer comprises a fine demultiplexer and the second demultiplexer comprises a coarse demultiplexer.

8. The primary terminal of claim **6**, wherein the first and second demultiplexers each include one of an optical interleaver, a banded dense wavelength division multiplexing (DWDM) filter, or a tunable filter.

9. The primary terminal of claim **6**, wherein the transponder is further configured to convert the second individual long-haul optical signal from the second demultiplexer into a second optical signal, and

wherein the second optical signal is in the format suitable for use by the customer premise equipment.

10. The primary terminal of claim **9**, wherein the primary terminal is further configured to transmit the second optical signal to the customer premise equipment.

11. A method for transporting optical signals at a primary terminal, the method comprising:

converting a first optical signal from a customer premise equipment into a first individual long-haul optical signal, wherein the first optical signal is in a format suitable for use by the customer premise equipment;

multiplexing, via a coarse multiplexer, the first individual long-haul optical signal into a first mux group of long-haul optical signals,

receiving a second mux group of long-haul optical signals from an extension terminal via a metro fiber;

multiplexing, via a fine multiplexer, the first mux group and the second mux group into a third mux group of long-haul optical signals; and

transmitting the third mux group over a long-haul network.

12. The method of claim **11** further comprising amplifying the third mux group.

13. The method of claim **11** further comprising:

demultiplexing a fourth mux group of long-haul optical signals from the long-haul network into a fifth mux group of long-haul optical signals and a sixth mux group of long-haul optical signals; and

transmitting the fifth mux group to the extension terminal via the metro fiber.

14. The method of claim **13** further comprising amplifying the fourth mux group.

15. The method of claim **13** demultiplexing the sixth mux group into a second individual long-haul optical signal.

16. The method of claim **15** further comprising converting the second individual long-haul optical signal into a second optical signal, wherein the second optical signal is in the format suitable for use by the customer premise equipment.

17. The method of claim **16** further comprising transmitting the second optical signal to the customer premise equipment.

18. An optical transport system for transporting optical signals, the optical transport system comprising:

an extension terminal coupled to a first customer premise equipment; and

a primary terminal coupled to the extension terminal via a metro fiber, wherein the primary terminal comprises a coarse multiplexer and a fine multiplexer,

wherein the extension terminal is configured to receive a first optical signal suitable for use by the first customer premise equipment and to convert the first optical signal into a first individual long-haul optical signal,

wherein the extension terminal is further configured to multiplex the first individual long-haul optical signal into a first mux group of long-haul optical signals and to transmit the first mux group to the fine multiplexer of the primary terminal via the metro fiber.

21

19. The optical transport system of claim 18, wherein the primary terminal is configured to transmit the first mux group over a long-haul network.

20. The optical transport system of claim 18, wherein the primary terminal is coupled to a second customer premise equipment,

wherein is the primary terminal configured to receive a second optical signal suitable for use by the second customer premise equipment and to convert the second optical signal into a second individual long-haul optical signal, and

wherein the primary terminal is further configured to multiplex, via the coarse multiplexer, the second individual long-haul optical signal into a second mux group of long-haul optical signals.

21. The optical transport system of claim 20, wherein the primary terminal is further configured to multiplex, via the fine multiplexer, the first mux group and the second mux group into a third mux group of long-haul optical signals, and

wherein the primary terminal is further configured to transmit the third mux group over a long-haul network.

22. The optical transport system of claim 21, wherein the primary terminal is further configured to amplify the third mux group.

23. The optical transport system of claim 18, wherein the extension terminal is further configured to amplify the first mux group.

24. An optical transport system for transporting optical signals, the optical transport system comprising:

an extension terminal coupled to a first customer premise equipment; and

a primary terminal coupled to the extension terminal via a metro fiber,

wherein the primary terminal comprises a coarse demultiplexer and a fine demultiplexer,

wherein the primary terminal is configured to receive a first mux group of long-haul optical signals from a long-haul network,

wherein the fine demultiplexer configured to demultiplex the first mux group into a second mux group of long-haul optical signals and a third mux group of long-haul optical signals,

wherein the coarse demultiplexer is configured to demultiplex the second mux group,

wherein the primary terminal is further configured to transmit the third mux group to the extension terminal via the metro fiber,

wherein the extension terminal is configured to demultiplex the third mux group into a first individual long-haul signal, and

wherein the extension terminal is further configured to convert the first individual long-haul signal into a first optical signal suitable for use by the first customer premise equipment and to transmit the first optical signal to the first customer premise equipment.

25. The optical transport system of claim 24, wherein the primary terminal is coupled to a second customer premise equipment,

wherein the coarse demultiplexer is configured to demultiplex the second mux group into a second individual long-haul optical signal, and

wherein the primary terminal is further configured to convert the second individual long-haul optical signal into a second optical signal suitable for use by the second customer premise equipment and to transmit the second optical signal to the second customer premise equipment.

22

26. The optical transport system of claim 24, wherein the primary terminal is further configured to amplify the first mux group.

27. The optical transport system of claim 24, wherein the extension terminal is further configured to amplify the second mux group.

28. A primary terminal of an optical transport system, the primary terminal comprising:

a fine demultiplexer coupled to a long-haul network and to an extension terminal, wherein the fine demultiplexer is configured to demultiplex a first mux group of long-haul optical signals from the long-haul network into a second mux group of long-haul optical signals and a third mux group of long-haul optical signals;

a coarse demultiplexer coupled to the fine demultiplexer, wherein the coarse demultiplexer is configured to demultiplex the second mux group into a first individual long-haul optical signal; and

a transponder coupled to the coarse demultiplexer and to a customer premise equipment, wherein the transponder is configured to convert the first individual long-haul optical signal into a first optical signal that is in a format suitable for use by the customer premise equipment, wherein the transponder is configured to transmit the first optical signal to the customer premise equipment, and wherein the primary terminal is configured to transmit the third mux group to the extension terminal over a metro fiber.

29. The primary terminal of claim 28 further comprising an amplifier coupled between the long-haul network and the fine demultiplexer, wherein the amplifier is configured to amplify the first mux group from the long-haul network.

30. The primary terminal of claim 28, wherein the coarse demultiplexer and the fine demultiplexer each include one of an optical interleaver, a banded dense wavelength division multiplexing (DWDM) filter, or a tunable filter.

31. The primary terminal of claim 28, wherein the transponder is further configured to receive a second optical signal from a second customer premise equipment and to convert the second optical signal into a second individual long-haul optical signal.

32. The primary terminal of claim 31 further comprising a coarse multiplexer coupled to the transponder, wherein the coarse multiplexer is configured to multiplex the second individual long-haul optical signal into a fourth mux group of long-haul optical signals.

33. The primary terminal of claim 32 further comprising a fine multiplexer coupled to the coarse multiplexer and the extension terminal, wherein the fine multiplexer is configured to receive a fifth mux group of long-haul optical signals from the extension terminal.

34. The primary terminal of claim 33, wherein the fine multiplexer is configured to multiplex the fourth mux group and the fifth mux group into a sixth mux group of long-haul optical signals.

35. The primary terminal of claim 34 further comprising an amplifier coupled to the fine multiplexer, wherein the amplifier is configured to amplify the sixth mux group from the fine multiplexer.

36. The primary terminal of claim 34, wherein the primary terminal is configured to transmit the sixth mux group over the long-haul network.

37. A primary terminal of an optical transport system, the primary terminal comprising:

a transponder configured to convert a first optical signal from a customer premise equipment into a first individual long-haul optical signal, and wherein the first

23

optical signal is in a format suitable for use by the customer premise equipment;
 a coarse multiplexer coupled to the transponder, wherein the coarse multiplexer is configured to multiplex the first individual long-haul optical signal into a first mux group of long-haul optical signals; and
 a fine multiplexer coupled to the coarse multiplexer, wherein the fine multiplexer is configured to receive a second mux group of long-haul optical signals from an extension terminal via a metro fiber,
 wherein the fine multiplexer is configured to multiplex the first mux group from the coarse multiplexer and the second mux group from the extension terminal into a third mux group of long-haul optical signals, and
 wherein the primary terminal is configured to transmit the third mux group over a long-haul network.

38. The primary terminal of claim 37 further comprising an amplifier coupled to the fine multiplexer, wherein the amplifier is configured to amplify the third mux group from the fine multiplexer.

39. The primary terminal of claim 37, wherein the coarse multiplexer and the fine multiplexer each include one of an optical interleaver, a banded dense wavelength division multiplexing (DWDM) filter, or a tunable filter.

40. The primary terminal of claim 37 further comprising a first demultiplexer,

wherein the first demultiplexer is configured to demultiplex a fourth mux group of long-haul optical signals from the long-haul network into a fifth mux group of long-haul optical signals and a sixth mux group of long-haul optical signals, and

wherein the primary terminal is configured to transmit the fifth mux group to the extension terminal via the metro fiber.

41. The primary terminal of claim 40 further comprising an amplifier coupled to the first demultiplexer, wherein the amplifier is configured to amplify the fourth mux group from the long-haul network.

42. The primary terminal of claim 40 further comprising a second demultiplexer coupled to the first demultiplexer and to the transponder, wherein the second demultiplexer is configured to demultiplex the sixth mux group from the first demultiplexer into a second individual long-haul optical signal.

43. The primary terminal of claim 42, wherein the first demultiplexer comprises a fine demultiplexer and the second demultiplexer comprises a coarse demultiplexer.

44. The primary terminal of claim 42, wherein the first and second demultiplexers each include one of an optical de-interleaver, a banded dense wavelength division multiplexing (DWDM) filter, or a tunable filter.

45. The primary terminal of claim 42, wherein the transponder is further configured to convert the second individual long-haul optical signal from the second demultiplexer into a second optical signal, and

wherein the second optical signal is in the format suitable for use by the customer premise equipment.

46. The primary terminal of claim 45, wherein the primary terminal is further configured to transmit the second optical signal to the customer premise equipment.

47. An optical transport system for transporting optical signals, the optical transport system comprising:

an extension terminal configured to receive a first optical signal from a first customer premise equipment, the first optical signal suitable for use by the first customer premise equipment; and

24

a primary terminal coupled to the extension terminal, wherein the primary terminal comprises a coarse multiplexer and a fine multiplexer,

wherein the extension terminal is configured to convert the first optical signal into a first individual long-haul optical signal,

wherein the extension terminal is further configured to multiplex the first individual long-haul optical signal into a first mux group of long-haul optical signals and to transmit the first mux group to the fine multiplexer of the primary terminal via a metro fiber.

48. The optical transport system of claim 47, wherein the primary terminal is configured to transmit the first mux group over a long-haul network.

49. The optical transport system of claim 47,

wherein the primary terminal is configured to receive a second optical signal from a second customer premise equipment, the second optical signal suitable for use by the second customer premise equipment, and the primary terminal is configured to convert the second optical signal into a second individual long-haul optical signal, and

wherein the primary terminal is further configured to multiplex, via the coarse multiplexer, the second individual long-haul optical signal into a second mux group of long-haul optical signals.

50. The optical transport system of claim 49, wherein the primary terminal is further configured to multiplex, via the fine multiplexer, the first mux group and the second mux group into a third mux group of long-haul optical signals, and

wherein the primary terminal is further configured to transmit the third mux group over a long-haul network.

51. The optical transport system of claim 50, wherein the primary terminal is further configured to amplify the third mux group.

52. The optical transport system of claim 47, wherein the extension terminal is further configured to amplify the first mux group.

53. An optical transport system for transporting optical signals, the optical transport system comprising:

an extension terminal; and

a primary terminal coupled to the extension terminal, wherein the primary terminal comprises a coarse demultiplexer and a fine demultiplexer,

wherein the primary terminal is configured to receive a first mux group of long-haul optical signals from a long-haul network,

wherein the fine demultiplexer is configured to demultiplex the first mux group into a second mux group of long-haul optical signals and a third mux group of long-haul optical signals,

wherein the coarse demultiplexer is configured to demultiplex the second mux group,

wherein the primary terminal is further configured to transmit the third mux group to the extension terminal via a metro fiber,

wherein the extension terminal is configured to demultiplex the third mux group into a first individual long-haul signal, and

wherein the extension terminal is further configured to convert the first individual long-haul signal into a first optical signal suitable for use by a first customer premise equipment and to transmit the first optical signal to the first customer premise equipment.

54. The optical transport system of claim 53, wherein the coarse demultiplexer is configured to demultiplex the second mux group into a second individual long-haul optical signal, and

wherein the primary terminal is further configured to convert the second individual long-haul optical signal into a second optical signal suitable for use by a second customer premise equipment and to transmit the second optical signal to the second customer premise equipment.

55. The optical transport system of claim 53, wherein the primary terminal is further configured to amplify the first mux group.

56. The optical transport system of claim 53, wherein the extension terminal is further configured to amplify the second mux group.

57. A primary terminal of an optical transport system, the primary terminal comprising:

a fine demultiplexer configured to demultiplex a first mux group of long-haul optical signals from a long-haul network into a second mux group of long-haul optical signals and a third mux group of long-haul optical signals;

a coarse demultiplexer coupled to the fine demultiplexer, wherein the coarse demultiplexer is configured to demultiplex the second mux group into a first individual long-haul optical signal; and

a transponder coupled to the coarse demultiplexer, wherein the transponder is configured to convert the first individual long-haul optical signal into a first optical signal that is in a format suitable for use by a customer premise equipment,

wherein the transponder is configured to transmit the first optical signal to the customer premise equipment, and wherein the primary terminal is configured to transmit the third mux group to an extension terminal over a metro fiber.

58. The primary terminal of claim 57 further comprising an amplifier coupled to the fine demultiplexer, wherein the amplifier is configured to amplify the first mux group from the long-haul network.

59. The primary terminal of claim 57, wherein the coarse demultiplexer and the fine demultiplexer each include one of an optical interleaver, a banded dense wavelength division multiplexing (DWDM) filter, or a tunable filter.

60. The primary terminal of claim 57, wherein the transponder is further configured to receive a second optical signal from a second customer premise equipment and to convert the second optical signal into a second individual long-haul optical signal.

61. The primary terminal of claim 60 further comprising a coarse multiplexer coupled to the transponder, wherein the coarse multiplexer is configured to multiplex the second individual long-haul optical signal into a fourth mux group of long-haul optical signals.

62. The primary terminal of claim 61 further comprising a fine multiplexer coupled to the coarse multiplexer, wherein the fine multiplexer is configured to receive a fifth mux group of long-haul optical signals from the extension terminal.

63. The primary terminal of claim 62, wherein the fine multiplexer is configured to multiplex the fourth mux group and the fifth mux group into a sixth mux group of long-haul optical signals.

64. The primary terminal of claim 63 further comprising an amplifier coupled to the fine multiplexer, wherein the amplifier is configured to amplify the sixth mux group from the fine multiplexer.

65. The primary terminal of claim 63, wherein the primary terminal is configured to transmit the sixth mux group over the long-haul network.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : RE43,403 E
APPLICATION NO. : 13/045261
DATED : May 22, 2012
INVENTOR(S) : Jaggi et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Face Page, in Field (57), under “ABSTRACT”, in Column 2, Line 11, delete “transmited” and insert -- transmitted --, therefor.

On Page 2, in Field (56), under “FOREIGN PATENT DOCUMENTS”, in Column 2, Line 3, delete “JP 02238736 9/1990”.

In Column 1, Line 10, delete “RELAYED” and insert -- RELATED --, therefor.

In Column 1, Lines 51-52, delete “increased cost” and insert -- increased cost, --, therefor.

In Column 3, Line 62, delete “DETAILED” and insert -- BRIEF --, therefor.

In Column 4, Line 57, delete “extent” and insert -- extent, --, therefor.

In Column 9, Line 22, delete “intraoffice” and insert -- intra-office --, therefor.

In Column 13, Line 4, delete “100 km” and insert -- 100 km. --, therefor.

In Column 13, Line 46, delete “293d-f” and insert -- 293d-f. --, therefor.

In Column 15, Line 35, delete “DWM-5F8DSX2,” and insert -- DWM-5F8DSXXX2, --, therefor.

In Column 16, Line 43, delete “730a-h” and insert -- 730a-h. --, therefor.

Signed and Sealed this
Twenty-sixth Day of March, 2013



Teresa Stanek Rea
Acting Director of the United States Patent and Trademark Office