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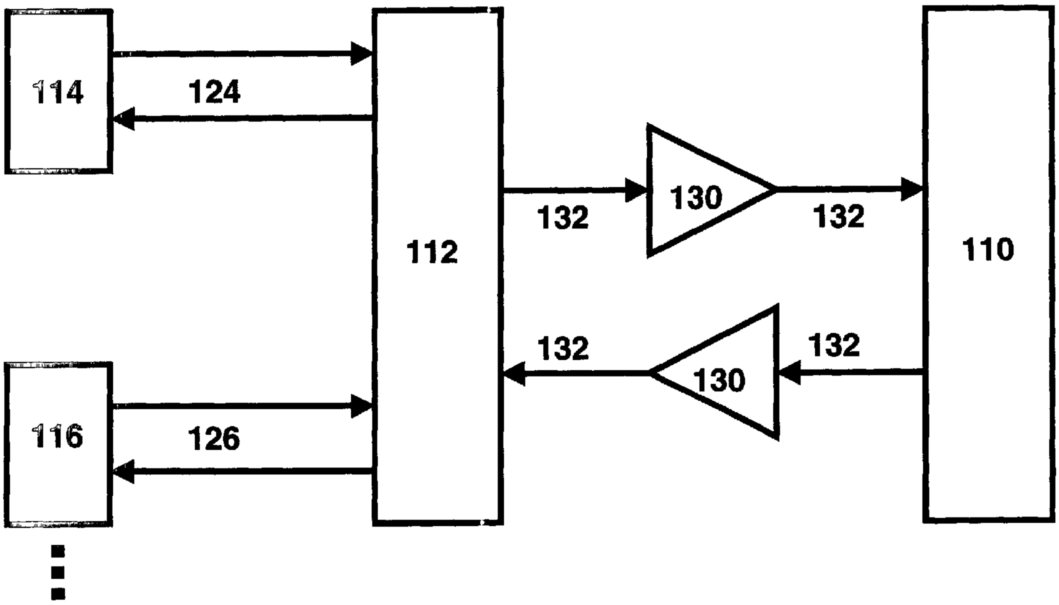

(57) Abstract: The invention pertains to optical fiber transmission systems, and is particularly relevant to transmission of high volume of data and voice traffic among different locations (110, 112, 114, 116). In particular, the improvement teaches the use of a single optical transport system for both metropolitan area transport and long haul transport of data and voice traffic.

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OPTICAL TRANSPORT SYSTEM ARCHITECTURE FOR REMOTE TERMINAL CONNECTIVITY

Cross-Reference to Related Applications

This application claims priority to U.S. Provisional Patent Application Serial No. 60/377,085, entitled "OPTICAL TRANSPORT SYSTEM UTILIZING REMOTE TERMINAL CONNECTIVITY", by Angela Chiu, filed April 30, 2002.

Technical Field of the Invention

The present invention relates, in general, to the field of optical communications, and in particular to, an optical transport system that uses distributed terminals. Characteristics of a distributed terminal architecture are described in co-pending U.S. Patent Application No. 10/402,840 entitled "Distributed Terminal Optical Transmission System" incorporated herein by reference. More specifically, this invention teaches the architecture to provide connectivity between remote terminals.

Background of the Invention

A goal of many modern long-haul optical transport systems is to provide for the efficient transmission of large volumes of voice traffic and data traffic over trans-continental distances at low costs. Various methods of achieving these goals include time-division multiplexing (TDM) and wavelength-division multiplexing (WDM). In time division multiplexed systems, data streams comprised of short pulses of light are interleaved in the time domain to achieve high spectral efficiency, high data rate transport. In wavelength division multiplexed systems, data streams comprised of short pulses of light of different carrier frequencies, or equivalently wavelength, co-propagate in the same fiber to achieve high spectral efficiency, high data rate transport.

The transmission medium of these systems is typically optical fiber. In addition there is a transmitter and a receiver. The transmitter typically includes a semiconductor diode laser, and supporting electronics. The laser is often a DFB laser stabilized to a specified frequency on the ITU frequency grid. The laser may be directly modulated with a data train with an advantage of low cost, and a disadvantage of low reach and capacity performance. In many long-haul systems, the laser is externally modulated using a modulator. A single stage modulator is sufficient for a non-return-zero (NRZ) modulation format. A two-stage modulator is typically used with the higher performance return-to-zero (RZ) modulation format. An example of a modulator technology is the Mach-Zehnder lithium niobate modulator. Alternatively, an electro-absorptive modulator may be used. After binary modulation, a high bit may be transmitted as an optical signal level with more power than the optical signal level in a low bit. Often, the optical signal level in a low bit is engineered to be equal to, or approximately equal to zero. In addition to binary modulation, the data can be transmitted with multiple levels, although in current optical transport systems, a two-level binary modulation scheme is predominantly employed. The receiver is located at the opposite end of the optical fiber, from the transmitter. The receiver is typically comprised of a semiconductor photodetector and accompanying electronics.

Typical long-haul optical transport dense wavelength division multiplexed (DWDM) systems transmit 40 to 80 channels at 10 Gbps (gigabit per second) across distances of 3000 to 6000 km in a single 35-nm spectral band. In a duplex system, traffic is both transmitted and received between parties at opposite end of the link. In a DWDM system, different channels operating at distinct carrier frequencies are multiplexed using a multiplexer. Such multiplexers may be implemented using arrayed waveguide grating (AWG) technology or thin-film technology, or a variety of other technologies. After multiplexing, the optical signals are coupled into the transport fiber for transmission to the receiving end of the link. The total link distance may, in today's optical transport systems, be two different cities separated by continental distances, from 1000 km to 6000 km, for example. To successfully bridge these distances with sufficient optical signal power relative to noise, the signal is periodically amplified using an in-line optical amplifier. Typical span distances between optical amplifiers are 50-100km. Thus, for example, 30 100-km spans would be used to transmit optical signals between points 3000 km apart. Examples of in-line optical amplifiers include erbium doped fiber amplifiers (EDFAs) and semiconductor optical amplifiers (SOAs).

At the receiving end of the link, the optical channels are demultiplexed using a demultiplexer. Such demultiplexers may be implemented using AWG technology or thin-film technology, or a variety of other technologies. Each channel is then optically coupled to separate optical receivers.

Other common variations include the presence of post-amplifiers and pre-amplifiers just before and after the multiplexer and de-multiplexer. Often, there is also included dispersion compensation with the in-line amplifiers. These dispersion compensators adjust the phase information of the optical pulses in order to compensate for the chromatic dispersion in the optical fiber while appreciating the role of optical nonlinearities in the optical fiber. Another variation that may be employed is the optical dropping and adding of channels at cities located in between the two end cities. The invention disclosed applies in any of these variations, as well as others.

Traditionally, optical transport systems are either long haul systems, for traffic between distant cities, or metropolitan ("metro") systems for traffic in and around a city. Typically the terminals of a long-haul optical transport system are located in one location such as a central office, and all the channels in a DWDM system are terminated. The traffic is then sorted by electronic identification of data and routed to different parts of the metropolitan area using metropolitan optical transport systems. In many practical circumstances, there is a space, power and cost inefficiency in terminating the long haul signal and retransmitting over a second metro-system. For this reason, the concept of a distributed terminal architecture was invented, and is disclosed in co-pending United States Patent Application No. 10/402,840, hereafter referred to as Jaggi.

As taught by Jaggi, there was no provision for duplex traffic between distributed terminals in the same metropolitan area. It would be highly desirable for a terminal in one section of a city to exchange traffic with a second terminal in a second section of the city while also providing scalable communication with cities a great distance away.

Summary of the Invention

In the present invention, improvements to an optical transport system with a distributed terminal architecture are disclosed. More specifically, this invention teaches the architecture to provide scalable duplex connectivity between multiple terminals and remote terminals.

In one embodiment of the invention, an overlay for connections in a distributed terminal architecture is taught.

In another embodiment of the invention, an architecture to provide scalable duplex connectivity between multiple terminals at a terminal city overlay is taught.

In another embodiment of the invention, an architecture to provide scalable duplex connectivity between terminals at optical-add-drop multiplexed (OADM) sites is taught.

Brief Description of the Drawings

For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

FIG. 1 is a schematic illustration of a scalable multiplexed optical transport system.

FIG. 2 is a schematic illustration of a scalable multiplexed optical transport system with a distributed terminal architecture having connectivity between remote terminals.

FIG. 3 is a schematic illustration of a scalable optical transport system a distributed terminal architecture having connectivity between remote terminals at a terminal city in accordance with a preferred embodiment.

FIG. 4 is a schematic illustration of a scalable optical transport system with a distributed terminal architecture having connectivity among remote terminals at an intermediate optical add-drop multiplexed (OADM) city in accordance with a preferred embodiment.

FIG. 5 is a flow chart of the method of combining short haul traffic with long haul traffic in accordance with this invention.

Detailed Description of the Invention

While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts which can be embodied in a wide variety of specific contexts. The specific embodiments described herein are merely illustrative of specific ways to make and use the invention and do not delimit the scope of the invention.

In Fig. 1 is shown a block diagram of an optical transport system with a distributed terminal architecture as taught by *Jaggi*. The distributed terminal architecture of one preferred embodiment comprises master terminal **110,** terminal **112** and remote terminals **114** and **116**. A specific advantage of the present invention is scalability that allows additional terminals and remote terminals to be added to the architecture. In Fig. 1, master terminal **110** and terminal **112** comprise terminals separated by long haul distances. In a preferred embodiment, a plurality of spans **132** and in-line amplifiers **130** will enable total link distances that are measured in thousands of kilometers. As an example, master terminal **110** may be located in one metropolitan area, while terminal **112** may be located in a second metropolitan area located 6000 km away. Terminal **112** may function as a remote terminal where it is located. In addition to terminal **112**, there is also remote terminal **114** and second remote terminal **116** located in the second metropolitan area. In this example, terminal **112**, remote terminal **114** and remote terminal **116** comprise distributed terminals in the second metropolitan area. In a preferred embodiment, the fiber link pair **124** between terminal **112** and remote terminal **114** may be a distance of 50 km. In the preferred embodiment, the fiber link pair **126** between terminal **112** and remote terminal **116** may also be 50 km in length. In operation, duplex communication will occur between master terminal **110** and any of terminal **112**, remote terminal **114** or remote terminal **116**. In a preferred embodiment, one set wavelengths in a spectral band from master terminal **110** terminate in terminal **112**, a second set of wavelengths in a spectral band from master terminal **110** terminate in remote terminal **114** and a third set of wavelengths in a spectral band from master terminal **110** terminate in remote terminal **116**. In a preferred embodiment, the spectral band is the L-band, which extends from approximately 1565 nm to 1605 nm.

It should be noted that master terminal **110** may also be replaced with a distributed architecture in the first metropolitan area.

Fig. 1 depicts an optical transport system supporting duplex operation wherein each endpoint can both send and receive voice and data traffic. This is important to achieve a typical conversation. In Fig 1, duplex operation is shown to use two distinct fibers, the both together often referred to as a fiber pair. For example, optical transport systems are sometimes deployed with bidirectional traffic providing duplex service on a single fiber.

In Fig. 2 is shown a schematic illustration of a multiplexed optical transport system with a distributed terminal architecture having duplex connectivity **225** between terminal **112** and remote terminals **114** and **116**. The ellipses below remote terminal **116** indicate that any number of remote terminals can be accommodated. In a preferred embodiment, duplex connectivity **225** is a very high data rate optical link enabled by wavelengths not used in duplex communication with master terminal **110**. For example, if duplex communication with master terminal **110** uses optical signals in the L-band, then duplex connectivity between terminal **112** and remote terminal **114** may use signals in the C-band.

In Fig. 3 is a block diagram of an optical transport system with a distributed terminal architecture having connectivity between remote terminals at a terminal city in accordance with a preferred embodiment. In particular Fig 3 shows multiplexing and de-multiplexing arrangements in terminal **112**, remote terminal **114** and remote terminal **116** to enable duplex connectivity **225**. Shown also is fiber link pair **124** and fiber link pair **126**. The arrangement is shown relative to long haul fiber pair **132**.

The arrangement comprises multiplexers **310, 312, 314, 316, 318, 350** and **351** as shown in Fig. 3. These multiplexers combine individual wavelengths or channels into bands of wavelengths or channels. Each multiplexer can be a nx1 multiplexer to accommodate differing requirements. In addition, the arrangement comprises de-multiplexers **311, 313, 315, 317, 319, 352** and **353**. These de-multiplexers subdivide a band of wavelengths, or channels, into particular wavelengths or channels. Examples of multiplexing and de-multiplexing technologies include thin film filters, array waveguides and interleavers, and combinations thereof.

The arrangement further comprises wavelength selective couplers, **320**, **322**, **324**, **326**, **354** and **357** and wavelength selective de-couplers **321**, **323**, **325**, **327**, **355** and **356**. In a preferred embodiment, wavelength selective couplers may be C/L band couplers, which act to couple together C-band signals from one input port and L-band signals from a second input port, and combine them onto a single output port. One technology known in the art for this C/L band coupler is thin film filter technology. In a preferred embodiment, wavelength selective de-couplers may be C/L band de-couplers, which act to de-couple C-band signals and L-band signals from a single input port into C-band signals on a first output port and L-band signals on a second output port. One technology known in the art for this C/L band de-coupler is thin film filter technology. It is noted that a C/L band coupler using thin film filter technology may be used as a C/L band de-coupler by reversing the input and output designations on the ports.

The arrangement further comprises optical coupler **340**, and optical de-coupler **341**. In a preferred embodiment, optical coupler **340** and optical de-coupler **341** may be splitters and combiners, in particular a 1x4 splitter and a 1x4 combiner. The ellipsis at **340** and **341** indicate that, in general, optical coupler **340** and optical **341** can be 1xn. A 1xn coupler allows for the invention to be easily scalable by adding additional signals from other remote terminals cheaply and effectively. In another preferred embodiment, AWG technology may be used to implement optical coupler **340** and optical de-coupler **341**. In this manner cyclic routing capability is provided. In particular, 4 port AWGs may be used for optical coupler **340** and optical de-coupler **341**. Shown in FIG. 3 is a unidirectional optical amplifier **345** to provide gain to the combined short haul signals. The use of a unidirectional optical amplifier further enhances the scalability of the invention by allowing multiple signals to be amplified without additional equipment or connections. Dispersion compensation may be included as part of the unidirectional optical amplifier to add additional capability as additional remote terminals are added.

In another preferred embodiment wavelength selective de-coupler **321** and wavelength selective coupler **320** may be implemented via a splitter or combiner, in particular, a 1x4 splitter/combiner. Similarly, wavelength selective de-coupler **323** and wavelength selective coupler **322** may be implemented via a splitter or combiner, in particular, a 1x4 splitter/combiner. In general a 1xn splitter or combiner may be used. In this embodiment, optical coupler **340** may be implemented as a spectral band coupler and optical de-coupler **341** may be implemented as a spectral band de-coupler.

The flow of signals through this arrangement may now be understood. Long haul traffic enters and departs the metropolitan area via fiber span **132**. Entering traffic is de-multiplexed in de-multiplexer **311**. The group of channels to be routed to remote terminal **114** proceeds to wavelength selective coupler **320**. At remote terminal **114**, the group of channels proceeds through wavelength selective de-coupler **325**, and are separated into particular channels via de-multiplexer **313**. The group of channels to be routed to remote terminal **116** proceeds from de-multiplexer **311** to wavelength selective coupler **322**. At remote terminal **116**, the group of channels proceeds through wavelength selective de-coupler **327**, and are separated into particular channels via de-multiplexer **317**. The group of channels to be routed to terminal **112** proceeds from demultiplexer **311** to selective coupler **357**. The group of channels proceeds then through wavelength selective decoupler **355** and are separated into particular channels via demultiplexer **352**.

Duplex communication between remote terminal **114** and master terminal **110** is enabled through a signal flow via multiplexer **312**, wavelength selective coupler **324**, wavelength selective de-coupler **321**, and multiplexer **310**. Duplex communication between remote terminal **116** and master terminal **110** is enabled through a signal flow via multiplexer **316**, wavelength selective coupler **326**, wavelength selective de-coupler **323**, and multiplexer **310**. Duplex communication between terminal **112** and master terminal **110** is enabled through a signal flow via multiplexer **350**, wavelength selective coupler **354**, wavelength selective decoupler **356** and multiplexer **310**.

Duplex connectivity between remote terminals is now described through this arrangement. Signal flow from remote terminal **114** to remote terminal **116** proceeds via terminal **112** through multiplexer **314**, wavelength selective coupler **324**, wavelength selective de-coupler **321**, into optical coupler **340**, through unidirectional optical amplifier **345**, and into optical de-coupler **341** and on to wavelength selective coupler **322**. The desired path for signals continues through terminal **112** to remote terminal **116**, proceeds via wavelength selective coupler **322**, wavelength selective de-coupler **327**, and through de-multiplexer **319**. Depending on the implementation of optical de-coupler **341** there may also be a return path of signals from remote terminal **114**, back to remote terminal **114**. This return path proceeds via wavelength selective coupler **320**, and wavelength selective de-coupler **325**. If necessary, these signals are blocked in de-multiplexer **315**. Signal flow from remote terminal **116** to remote terminal **114** proceeds through multiplexer **318**, wavelength selective coupler **326**, wavelength selective de-coupler **323**, into optical coupler **340**, through unidirectional optical amplifier **345**, and into optical de-coupler **341** and on to wavelength selective coupler **320**. The desired path for signals to remote terminal **114** then proceeds via wavelength selective coupler **320**, wavelength selective de-coupler **325**, and through de-multiplexer **315**. Depending on the implementation of optical de-coupler **341** there may also be a return path of signals from remote terminal **116**, back to remote terminal **116**. This return path proceeds via wavelength selective coupler **322**, and wavelength selective de-coupler **327**. If necessary, these signals are blocked in de-multiplexer **319**. Duplex connectivity from terminal **112** to remote terminal **114** and from remote terminal **114** to terminal **112**, and from terminal **112** to remote terminal **116** and from remote terminal **116** to terminal **112** is provided in a similar matter. Also, similarly, there may be a return path of signals from terminal **112** back to terminal **112**. The invention provides scalability easily with the addition of optical coupler **340**, unidirectional amplifier **345** and optical decoupler **341** because additional remote terminals may be added without the need for duplicate amplification.

Additionally, connectivity to other remote terminals can be added in a similar manner. The ellipses near couplers **340** and **341**, and demultiplexer **311** and multiplexer **310**, show where additional connections to these terminals may be made.

FIG. 4 is a schematic illustration of an optical transport system with a distributed terminal architecture with connectivity among remote terminals at an intermediate optical add-drop multiplexed (OADM) city in accordance with a preferred embodiment. The arrangement is shown relative to long haul fiber pair **132**, and in particular, at an optical add-drop multiplexing (OADM) site which deploys optical coupler **401** and optical de-coupler **402**. In a preferred embodiment, optical coupler **401** and optical de-coupler **402** are 50:50 or 3dB splitters, and the OADM is configured in a broadcast and select mode.

The architecture of the present invention comprises distributed terminals **403**, **404** and **405**, and enables duplex connectivity among all distributed terminals, or between any two pairs of distributed terminals. Any or all of distributed terminals **403**, **404** or **405** may also be remote terminals placed apart from the OADM site, potentially at different locations within a metropolitan area. In a preferred embodiment, short haul fiber pairs **406**, **407** and **408** may be approximately 50 km from the OADM site. In will be understood by one skilled in the art, that the distances of short haul fiber pairs **406**, **407** and **408** may be unequal, shorter, and, with appropriate optical amplification and dispersion compensation, much longer than 50 km from the OADM site.

The arrangement further comprises wavelength selective coupler **410** and wavelength selective de-coupler **411**. In a preferred embodiment, wavelength selective coupler **410** may be C/L band couplers, which act to couple together C-band signals from one input port and L-band signals from a second input port, and combine them onto a single output port. One technology known in the art for this C/L band coupler is thin film filter technology. In a preferred embodiment, wavelength selective de-coupler **411** may be C/L band de-couplers, which act to de-couple C-band signals and L-band signals from a single input port into C-band signals on a first output port and L-band signals on a second output port. One technology known in the art for this C/L band de-coupler is thin film filter technology. It is noted that a C/L band coupler using thin film filter technology may be used as a C/L band de-coupler by reversing the input and output designations on the ports. The arrangement may also comprise optical amplifier **415**. As is well known in the art, this optical amplifier may be an erbium doped optical amplifier, or a semiconductor optical amplifier.

The arrangement further comprises optical coupler **416** and optical de-coupler **417**. In a preferred embodiment, optical coupler **416** may be a 1xN combiner, and optical de-coupler **417** may be a 1xN splitter. The ellipses indicate that additional remote terminals may be included in other embodiments.

The arrangement further comprises wavelength selective couplers, **420**, **422** and **424**, and wavelength selective de-couplers **421**, **423**, and **425**. In a preferred embodiment, wavelength selective couplers may be C/L band couplers, which act to couple together C-band signals from one input port and L-band signals from a second input port, and combine them onto a single output port. One technology known in the art for this C/L band coupler is thin film filter technology. In a preferred embodiment, wavelength selective de-couplers may be C/L band de-couplers, which act to de-couple C-band signals and L-band signals from a single input port into C-band signals on a first output port and L-band signals on a second output port. One technology known in the art for this C/L band de-coupler is thin film filter technology. It is noted that a C/L band coupler using thin film filter technology may be used as a C/L band de-coupler by reversing the input and output designations on the ports.

The arrangement comprises multiplexers **430**, **432**, **434**, **436**, **438** and **440**. These multiplexers combine individual wavelengths or channels into bands of wavelengths or channels. In addition, the arrangement comprises de-multiplexers **431**, **433**, **435**, **437**, **439** and **441**. These de-multiplexers subdivide a band of wavelengths, or channels, into particular wavelengths or channels. Examples of multiplexing and de-multiplexing technologies include thin-film filters, AWGs and inter-leavers, and combinations thereof.

The flow of signals through this arrangement may now be understood. Long haul traffic enters and departs the OADM via fiber span **132**. Entering traffic is split using optical de-coupler **402** and propagates through wavelength selective optical coupler **410**. Optical de-coupler **417** broadcasts the entering traffic to remote terminals **403**, **404** and **405**. At remote terminals **403**, **404** and **405**, the entering traffic proceeds through wavelength selective de-coupler **421**, **423** and **425**, and is separated into particular channels via de-multiplexers **431**, **435** and **439**.

Traffic from distributed terminal **403** intended for transmission on fiber span **132** proceeds from multiplexer **430** to wavelength selective optical coupler **420** and optical coupler **416**. The signal proceeds to wavelength selective decoupler **411** to optical coupler **401** onto fiber span **132**. Traffic from distributed terminal **404** intended for transmission on fiber span **132** proceeds from multiplexer **434** to wavelength selective optical coupler **422** and optical coupler **416**. The signal proceeds to wavelength selective decoupler **411** to optical coupler **401** onto fiber span **132**. Traffic from distributed terminal **405** intended for transmission on fiber span **132** proceeds from multiplexer **438** to wavelength selective optical coupler **424** and optical coupler **416**. The signal proceeds to wavelength selective decoupler **411** to optical coupler **401** onto fiber span **132**.

Connectivity among the distributed terminals is now described through this arrangement. Signals destined for remote terminals **404** and **405** that originates from remote terminal **403** proceeds via multiplexer **432**, wavelength selective optical coupler **420**, optical coupler **416**. From wavelength selective optical coupler **420** until wavelength selective optical de-coupler **411**, long haul traffic and short haul traffic propagates together. Wavelength selective optical de-coupler **411** decouples the long haul traffic from the short haul traffic. The short haul signal may proceed through optical amplifier **415**, and then into wavelength selective optical coupler **410** and optical de-coupler **417**. Optical de-coupler **417** routes the traffic to remote terminals **404** and **405**. Depending on the implementation, there may also be a return path to remote terminal **403**. Such traffic is blocked or otherwise sorted via de-multiplexer **433**. In remote terminal **404**, the traffic is routed via wavelength selective optical de-coupler **423** and optical de-multiplexer **437**. In remote terminal **405**, the traffic is routed via wavelength selective optical de-coupler **425** and optical de-multiplexer **441**.

Signals destined for remote terminals **403** and **405** that originate from remote terminal **404** proceed via multiplexer **436**, wavelength selective optical coupler **422**, optical coupler **416**. From wavelength selective optical coupler **422** until wavelength selective optical de-coupler **411**, long haul traffic and short haul traffic propagates together. Wavelength selective optical de-coupler **411** decouples the long haul traffic from the short haul traffic. The short haul signal may proceed through optical amplifier

415, and then into wavelength selective optical coupler **410**. Optical de-coupler **417** routes the traffic to remote terminals **403** and **405**. Depending on the implementation, there may also be a return path to remote terminal **404**. Such traffic is blocked or otherwise sorted via de-multiplexer **437**. In remote terminal **403**, the traffic is routed via wavelength selective optical de-coupler **421** and optical de-multiplexer **433**. In remote terminal **405**, the traffic is routed via wavelength selective optical de-coupler **425** and optical de-multiplexer **441**.

Signals destined for distributed terminals **403** and **404** that originate from remote terminal **405** proceed via multiplexer **440**, wavelength selective optical coupler **424**, optical coupler **416**. From wavelength selective optical coupler **424** until wavelength selective optical de-coupler **411**, long haul traffic and short haul traffic propagates together. Wavelength selective optical de-coupler **411** decouples the long haul traffic from the short haul traffic. The short haul signal may proceed through optical amplifier **415**, and then into wavelength selective optical coupler **410**. Optical de-coupler **417** routes the traffic to remote terminals **403** and **404**. Depending on the implementation, there may also be a return path to remote terminal **405**. Such traffic is blocked or otherwise sorted via de-multiplexer **441**. In remote terminal **403**, the traffic is routed via wavelength selective optical de-coupler **421** and optical de-multiplexer **433**. In remote terminal **404**, the traffic is routed via wavelength selective optical de-coupler **423** and optical de-multiplexer **437**.

Additional distributed terminals may be connected and traffic between terminals will flow in a similar manner to the above descriptions for terminals **403**, **404** and **405**. The ellipses in Fig. 4 indicate additional distributed terminals and additional ports of coupler **416** and decoupler **417**.

In Fig. 5 is shown a flow chart of the method of combining short haul traffic with long haul traffic in order to provide connectivity between distributed terminals which is a subject of this invention. In step **510**, short haul traffic is generated on a first spectral band. In a preferred embodiment, this first spectral band is the C-band. In step **512**, long haul traffic is generated on a second spectral band. In a preferred embodiment, this first spectral band is the L-band. In step **514**, the first spectral band and second spectral band are over-layed. In a preferred embodiment this step is accomplished using a wavelength selective optical coupler. A wavelength selective optical coupler may be a C/L band coupler. A thin film filter may be used to realize a C/L band coupler. In step **516** the combined traffic is propagated along a metropolitan fiber span. In step **518**, the short haul traffic is separated from the long haul traffic. In a preferred embodiment this step is accomplished using a wavelength selective optical de-coupler. A wavelength selective optical de-coupler may be a C/L band de-coupler. A thin film filter may be used to realize a C/L band de-coupler. At step **518**, the short haul and long haul traffic is also split into two directions. Long haul traffic is multiplexed at step **520,** followed by transmission on long haul optical fiber **522**. Short haul traffic is combined with other short haul traffic from other terminals in step **524**. It is amplified in unidirectional amplifier at **526** and then is separated into specific short haul traffic at step **528**. When separated, the short haul traffic is distributed at step **530**. In a preferred embodiment, this method provides half-duplex connectivity between two distributed terminals, and may be repeated in the opposite traffic flow direction to achieve duplex connectivity between the two distributed terminals.

In an alternate embodiment, this method may be used to provide connectivity between a distributed terminal and a central location such as a master terminal or an OADM site. Additional routing from the central location is employed to further propagate the short haul traffic to a second distributed terminal. In a preferred embodiment, this additional routing may be achieved using an optical de-coupler. An optical splitter may be used to realize the optical de-coupler. In a preferred embodiment, this method provides half-duplex connectivity between two distributed terminals, and may be repeated in the opposite traffic flow direction to achieve duplex connectivity between the two distributed terminals.

While this invention has been described in reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments, as well as other embodiments of the invention, will be apparent to persons skilled in the art upon reference to the description. It is therefore intended that the appended claims encompass any such modifications or embodiments.

CLAIMS:

1. A distributed terminal architecture for transmitting duplex optical traffic comprising:

a long haul optical transmitter connected to a transport system for transmitting long haul traffic;

a short haul optical transmitter connected to the transport system for transmitting short haul traffic;

at least one wavelength selective optical coupler connected to the long haul transmitter and the short haul transmitter for combining the short haul traffic and the long haul traffic;

a long haul optical receiver, connected to the transport system, for receiving the long haul traffic;

a short haul optical receiver, connected to the transport system, for receiving and optically distributing the short haul traffic; and

at least one wavelength selective optical de-coupler, connected to the long haul optical receiver and the short haul optical receiver, for optically separating and distributing the short haul traffic from the long haul traffic.

2. The architecture of claim 1 wherein the wavelength selective optical coupler is a C/L band coupler.

3. The architecture of claim 2 wherein the C/L band coupler is a thin film de-coupler.

4. The architecture of claim 1 wherein the long haul traffic is transmitted on the L-band.

5. The architecture of claim 1 wherein the short haul traffic is transmitted on the C-band.

6. The architecture of claim 1 further comprising:

an optical combiner for receiving the short haul traffic;

a unidirectional amplifier connected to the optical combiner to amplify the short haul traffic; and

an optical splitter connected to the unidirectional amplifier for routing the short haul traffic to at least one additional short haul terminal.

7. The architecture of claim 1 wherein the optical combiner is a spectral band coupler.

8. The architecture of claim 1 wherein the optical splitter is a spectral band decoupler.

9. The architecture of claim 6 wherein the wavelength selective optical decoupler is a C/L band decoupler.

10. The architecture of claim 9 wherein the C/L band de-coupler is a thin film de-coupler.

11. The architecture of claim 6 wherein the long haul traffic is transmitted on the L-band.

12. The architecture of claim 6 wherein the short haul traffic is transmitted on the C-band.

13. A method of overlaying short haul traffic and long haul traffic comprising the steps of:

carrying the long haul traffic on a first spectral band;

carrying the short haul traffic on a second spectral band;

coupling the short haul traffic and long haul traffic at a first distributed terminal using a first wavelength selective optical coupler; and,

decoupling the short haul traffic from the long haul traffic at a second distributed terminal using a wavelength selective optical decoupler.

14. The method of claim 13 including a second short haul signal and comprising the further steps of:

coupling the first short haul signal and the second short haul signal into a combined short haul signal;

amplifying the combined short haul signal with a unidirectional amplifier;

decoupling the combined short haul signal into the first and second short haul signals.

15. The method of claim 13 wherein the first spectral band is the L-band.

16. The method of claim 13 wherein the second spectral band is the C-band.

17. The method of claim 13 wherein the first wavelength selective optical coupler is a C/L band coupler.

18. The method of claim 17 wherein the C/L band coupler is a thin film coupler.

19. The method of claim 13 wherein the wavelength selective optical decoupler is a C/L band coupler.

20. The method of claim 19 wherein the C/L band coupler is a thin film coupler.

21. An architecture for transporting a first long haul optical signal, a second long haul optical signal and a first short haul optical signal comprising:

a first remote terminal receiving the first long haul signal and the first short haul signal into a first optical coupler and transmitting a first combined optical signal on a first optical pathway;

a first distributed terminal connected to the first optical pathway receiving the first combined optical signal into a first optical de-coupler and transmitting the first short haul signal to a second optical coupler and the first long haul signal on a second optical pathway;

the second optical coupler connected to a second optical decoupler for receiving the first short haul signal;

the first distributed terminal receiving a second long haul optical signal and combining it with the first short haul signal from the second optical decoupler in a third optical coupler and transmitting a second combined optical signal on a third optical pathway; and

a second remote terminal connected to the third optical pathway receiving the second combined optical signal into a third optical de-coupler and transmitting the short haul signal on a fourth optical pathway and the second long haul signal on a fifth optical pathway.

22. The architecture of claim 21 wherein a second distributed terminal is connected to the second optical pathway.

23. The architecture of claim 22 wherein the second distributed terminal transmits the second long haul signal.

24. The architecture of claim 22 wherein the second optical pathway includes an amplifier.

25. The architecture of claim 21 wherein the long haul optical signals are L band.

26. The architecture of claim 21 wherein the short haul optical signal is C band.

27. The architecture of claim 21 wherein the optical couplers are C/L band couplers.

28. The architecture of claim 21 wherein the optical de-couplers are C/L band de-couplers.

29. The architecture of claim 21 wherein the first short haul signal is comprised of a plurality of sub-short haul signals.

30. The architecture of claim 29 wherein the plurality is combined in a multiplexer.

31. The architecture of claim 30 wherein the multiplexer includes a thin film filter.

32. The architecture of claim 21 wherein the first long haul signal is comprised of a plurality of sub-long haul signals.

33. The architecture of claim 32 wherein the plurality is combined in a multiplexer.

34. The architecture of claim 33 wherein the multiplexer includes a thin film filter.

35. The architecture of claim 21 including an architecture for transporting a third long haul optical signal, a fourth long haul optical signal and a second short haul optical signal comprising:

the second remote terminal receiving the third long haul optical signal and the second short haul signal into a fourth optical coupler and transmitting a third combined optical signal on a sixth optical pathway;

the first distributed terminal connected to the sixth optical pathway receiving the third combined optical signal into a fourth optical de-coupler and transmitting the second short haul optical signal to the second optical coupler and the third long haul signal on a seventh optical pathway;

the second optical decoupler receiving the second short haul optical signal;

the first distributed terminal receiving a fourth long haul optical signal and combining it with the second short haul optical signal from the second optical decoupler into a fifth optical coupler and transmitting a fourth combined optical signal on an eighth optical pathway; and, the first remote terminal connected to the eighth optical pathway receiving the fourth combined optical signal into a fifth optical de-coupler and transmitting the second short haul optical signal on a ninth optical pathway and the fourth long haul optical signal on a tenth optical pathway.

36. The architecture of claim 35 wherein a second distributed terminal is connected to the seventh optical pathway.

37. The architecture of claim 36 wherein the seventh optical pathway includes an amplifier.

38. The architecture of claim 36 wherein the second distributed terminal transmits the fourth long haul signal.

39. The architecture of claim 35 wherein the first distributed terminal further comprises a multiplexer to combine the first long haul optical signal and the third long haul optical signal.

40. The architecture of claim 39 wherein the multiplexer includes a thin film filter.

41. The architecture of claim 35 wherein the second short haul signal is comprised of a plurality of sub-short haul signals.

42. The architecture of claim 41 wherein the plurality is combined in a multiplexer.

43. The architecture of claim 42 wherein the multiplexer includes a thin film filter.

44. The architecture of claim 35 wherein the third long haul signal is comprised of a plurality of sub-long haul signals.

45. The architecture of claim 44 wherein the plurality is combined in a multiplexer.

46. The architecture of claim 45 wherein the multiplexer includes a thin film filter.

47. The architecture of claim 35 wherein the second long haul signal and the fourth long haul signal arrive at the first distributed terminal as a combined long haul signal and are separated by a multiplexer.

48. The architecture of claim 47 wherein the multiplexer includes a thin film filter.

49. The architecture of claim 35 wherein the second optical pathway and the seventh optical pathway are combined by a multiplexer.

50. The architecture of claim 49 wherein the multiplexer includes a thin film filter.

51. The architecture of claim 35 wherein the first distributed terminal transmits the first short haul signal and the second short haul signal through at least one amplifier.

52. An architecture for distributing short haul signals and long haul signals comprising:

at least one incoming short haul signal and incoming long haul signal;

an optical combiner receiving the incoming short haul and long haul signal, combining the incoming combined short haul and long haul signals into a first meta signal and routing the first meta signal to a selective de-coupler;

the selective de-coupler de-coupling the short haul signal and the long haul signal from the first meta signal and routing an outgoing long haul signal to a transport system and the short haul signal to a selective coupler;

the selective coupler receiving at least one incoming long haul signal from the transport system, combining the incoming long haul signal with the short haul signal to generate a second meta signal and transmitting the second meta signal to an optical de-coupler; and,

the optical de-coupler separating the second meta signal into at least one outgoing combined short haul signal and long haul signal.

53. The architecture of claim 52 wherein the incoming combined short haul signal and long haul signal includes a plurality of short haul and long haul signals.

54. The architecture of claim 52 wherein each of the incoming combined short haul and long haul signals is created by at least one remote terminal.

55. The architecture of claim 52 wherein the short haul signal is C band.

56. The architecture of claim 52 wherein the long haul signal is L band.

57. The architecture of claim 52 wherein the selective de-coupler is a wavelength selective filter.

58. The architecture of claim 57 wherein the wavelength selective filter is a C/L band de-coupler.

59. The architecture of claim 52 wherein the selective coupler is a wavelength selective filter.

60. The architecture of claim 59 wherein the wavelength selective filter is a C/L band coupler.

61. The architecture of claim 54 wherein each remote terminal combines the short haul signals and the long haul signals with a wavelength selective coupler.

62. The architecture of claim 52 wherein each long haul signal is comprised of a plurality of sub-long haul signals.

63. The architecture of claim 62 wherein the remote terminal combines the plurality of sub-long haul signals with a multiplexer.

64. The architecture of claim 52 wherein each short haul signal is comprised of a plurality of sub-short haul signals.

65. The architecture of claim 64 wherein the remote terminal combines the sub-short haul signals with a multiplexer.

66. The architecture of claim 52 wherein each of the plurality of outgoing combined short haul and long haul signals is received by a remote terminal.

67. The architecture of claim 66 wherein each distributed terminal splits the short haul signals and the long haul signals with a wavelength selective de-coupler.

68. The architecture of claim 66 wherein each long haul signal is comprised of a plurality of sub-long haul signals.

69. The architecture of claim 68 wherein the distributed terminal splits the plurality of sub-long haul signals with a de-multiplexer.

70. The architecture of claim 52 wherein each short haul signal is comprised of a plurality of sub-short haul signals.

71. The architecture of claim 70 wherein the distributed terminal splits the sub-short haul terminals with a de-multiplexer.

72. An apparatus to transmit optical signals comprising:

a remote transmitter transmitting a first overlayed signal;

a selective decoupler receiving the first overlayed signal and decomposing it into a first short haul signal and a first long haul signal;

a transport system receiving the first long haul signal;

a selective coupler receiving a second long haul signal from the transport system and the first short haul signal and creating a second overlayed signal; and

a remote receiver receiving the second overlayed signal.

73. The apparatus of claim 72 wherein the remote transmitter and remote receiver are collocated.

74. The apparatus of claim 72 wherein the transmitter is a transceiver.

75. The apparatus of claim 72 wherein the receiver is a transceiver.

76. The apparatus of claim 72 wherein the overlayed signal includes a C band and L band signals.

Figure 1

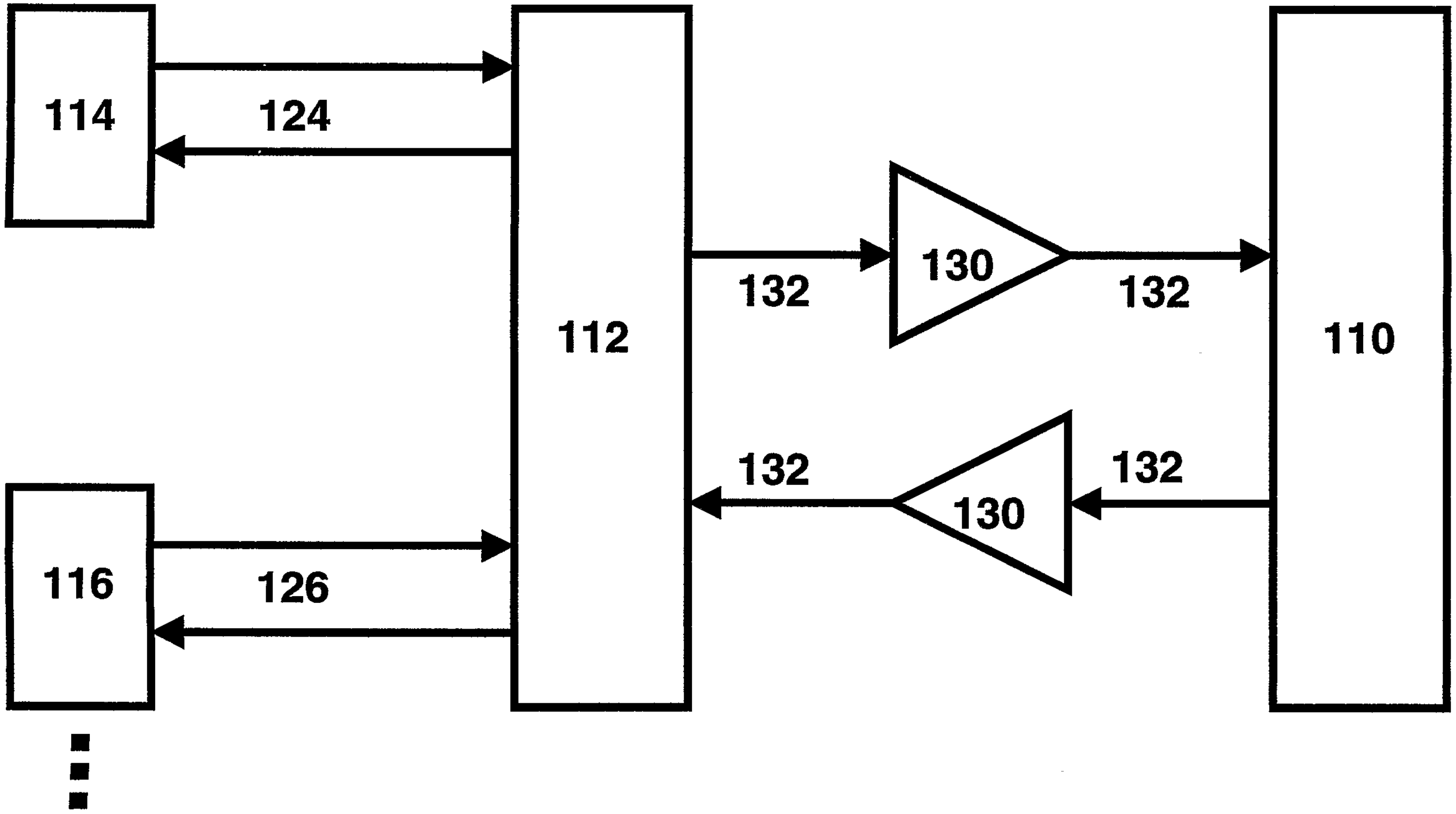


Figure 2

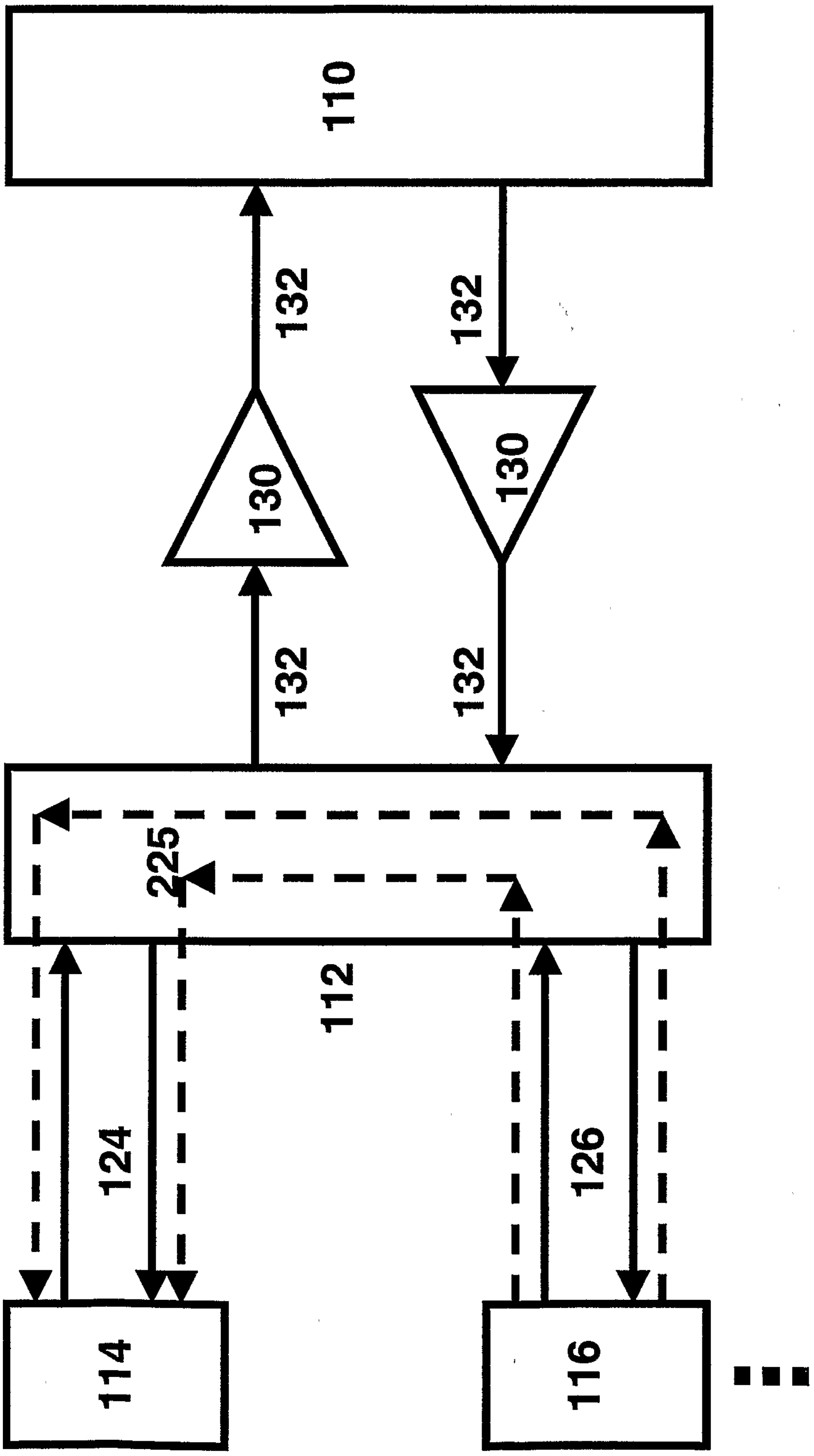
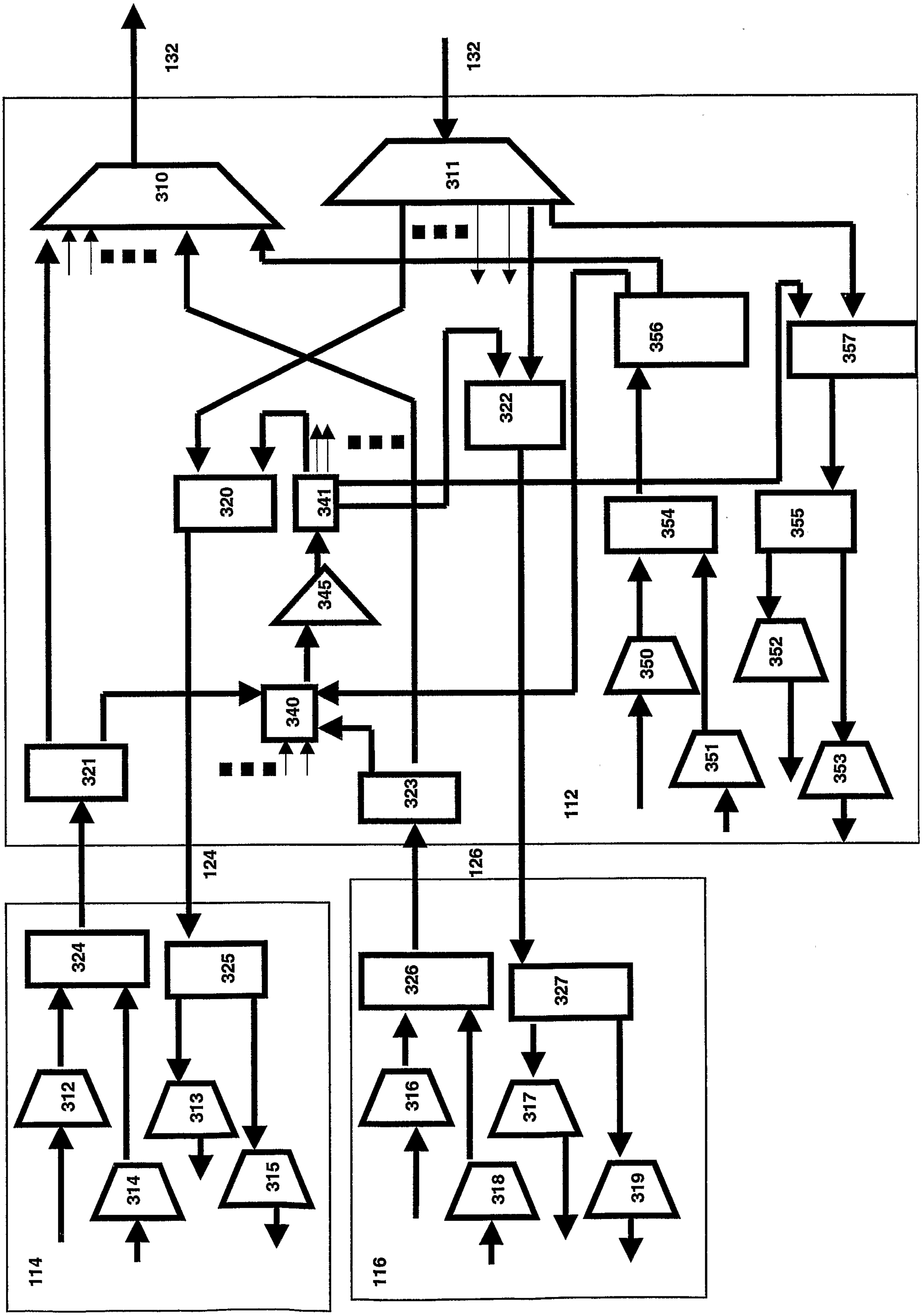


Figure 3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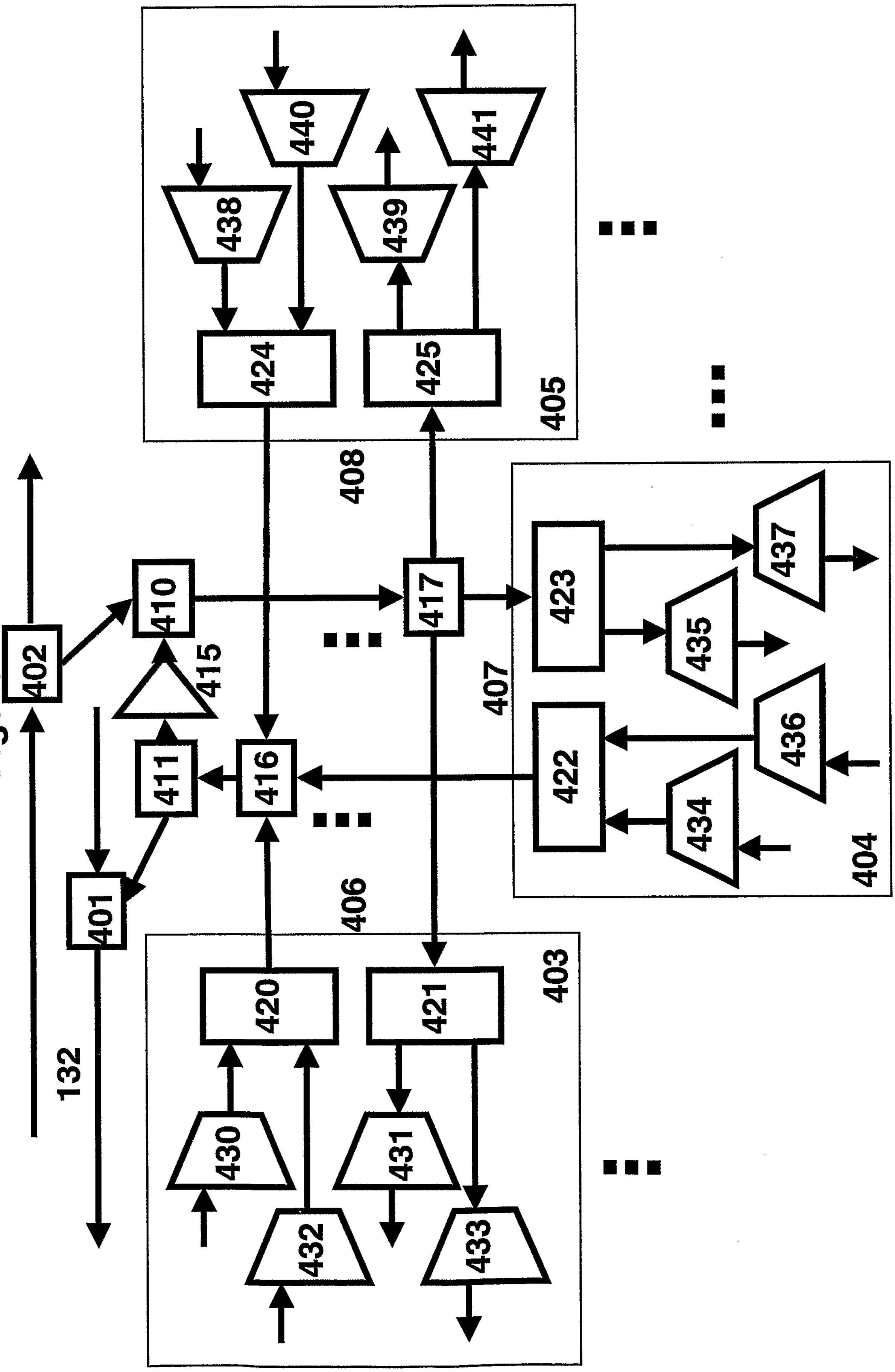
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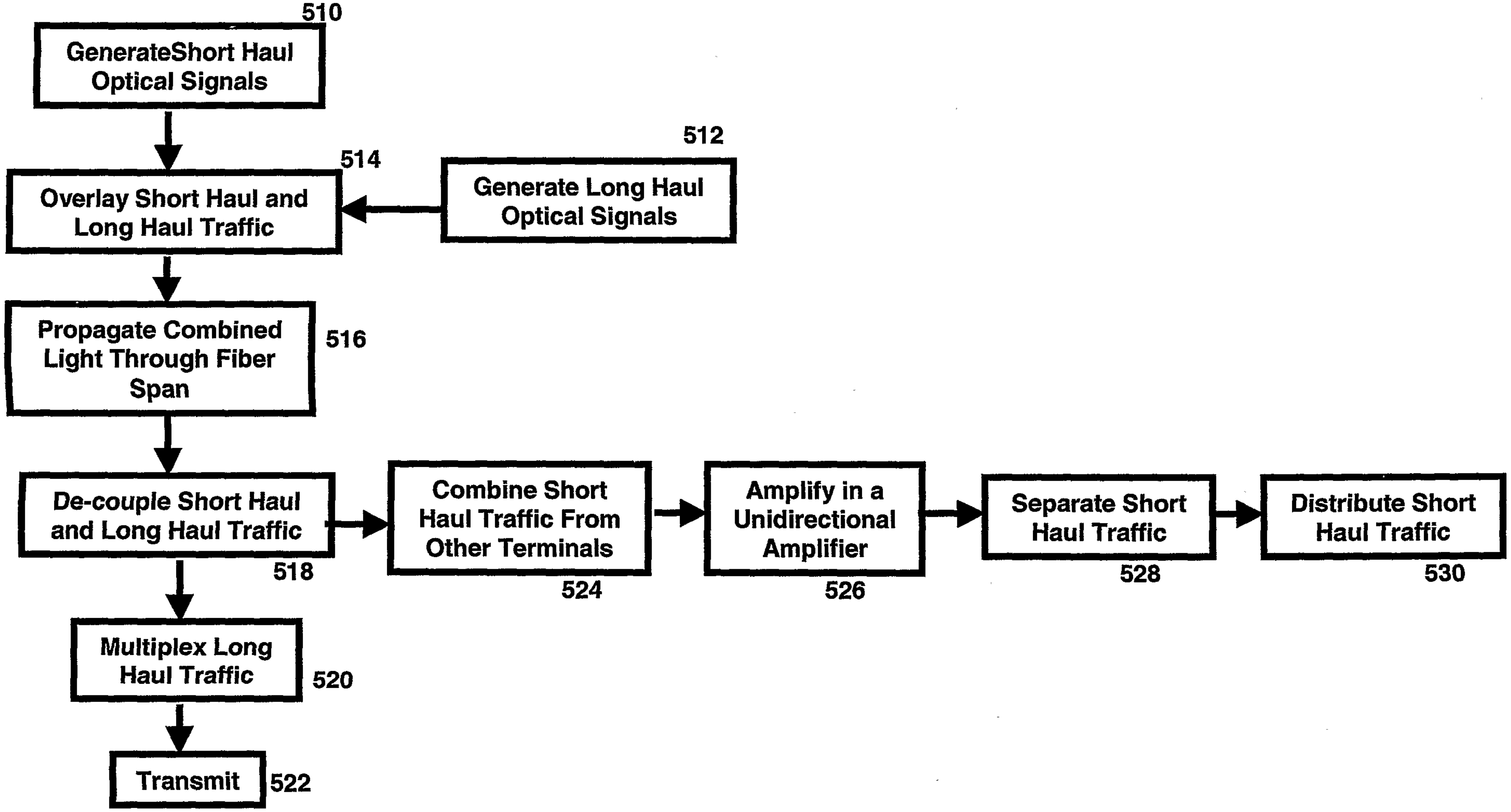
Figure 4

Figure 5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GenerateShort Haul Optical Signals
512
Generate Long Haul Optical Signals
514
Overlay Short Haul and Long Haul Traffic
516
Propagate Combined Light Through Fiber Span
518
De-couple Short Haul and Long Haul Traffic
520
Multiplex Long Haul Traffic
522
Transmit
524
Combine Short Haul Traffic From Other Terminals
526
Amplify in a Unidirectional Amplifier
528
Separate Short Haul Traffic
530
Distribute Short Haul Traffic

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US03/13314

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : H04J 4/00; H04B 10/00, 10/12
US CL : 398/70, 71, 72, 142, 145, 149, 165
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 398/70, 71, 72, 142, 145, 149, 165

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,075,634 A (CASPER et al) 13 June 2000 (13.06.2000), figure 4, col. 2, line 3 to col. 5, line 64.	1-76
Y	US 5,351,146 A (CHAN et al) 27 September 1994 (27.09.1994), figures 2, 3, col. 4, ,line 1 to col. 6, line 49.	1-76
Y	US 6,236,499 B1 (BERG et al) 22 May 2001 (22.05.2001), figures 2a, 2b, 3, 4a, 4b, 5a, 5b, 9a, 9b, 9c, 10a, 10b, col. 2, line 23 to col.10, line 65.	1-76
Y,P	US 6,519,060 B1 (LIU) 11 February 2003 (11.02.2003), see entire document.	1-76
Y,P	US 6,438,286 B1 (DUERKSEN et al) 20 August 2002 (20.08.2002), see entire document.	1-76
Y,P	US 6,608,709 B2 (DUERKSEN) 19 August 2003 (19.08.2003), see entire document.	1-76

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E"	earlier application or patent published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

04 September 2003 (04.09.2003)

Date of mailing of the international search report

03 OCT 2003

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