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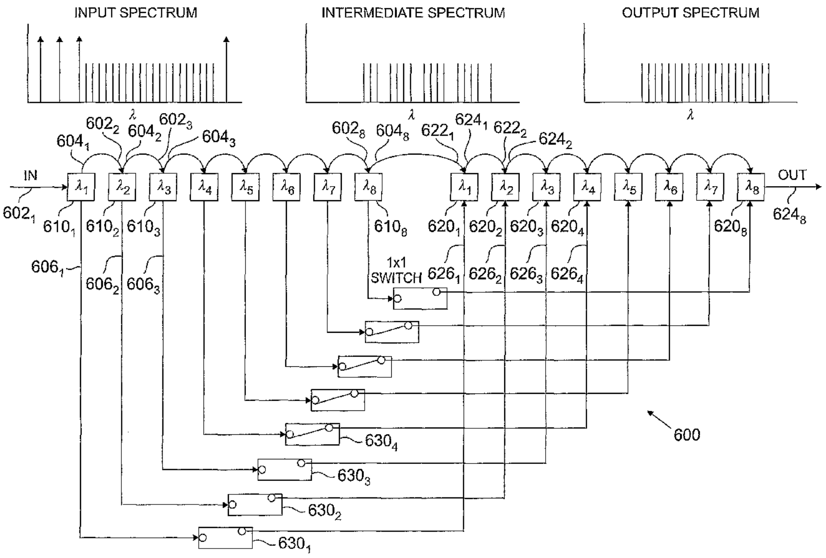
(54) **Title:** IDLER TONE BLOCKER



(57) **Abstract:** An optical line interface is provided for communicating between terrestrial terminal equipment and an undersea optical transmission path a WDM optical signal having a plurality of wavelength components. The optical line interface includes a signal processing unit for transforming WDM optical signals between optical layer transport protocols employed by the terrestrial terminal equipment and undersea optical layer transport protocols employed over the undersea optical transmission path. The optical line interface also includes an idler tone generator for generating idler tones at wavelengths corresponding to selected wavelengths components of the WDM signal that are not information-carrying wavelength components. An idler tone blocker is located within a signal path of the signal processing unit for selectively transmitting and blocking wavelength components of the WDM optical signal corresponding to the idler tones.

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

IDLER TONE BLOCKER

Field of the Invention

[0001] The present invention relates generally to WDM optical transmission systems, and more particularly to an optical interface for providing communication between terrestrial optical terminal equipment and an undersea optical transmission path.

Background of the invention

[0002] Optical wavelength division multiplexing (WDM) and dense wavelength division multiplexing (DWDM) have gradually become the standard backbone networks for fiber optic communication systems. WDM and DWDM systems employ signals consisting of a number of different wavelength optical signals, known as carrier signals or channels, to transmit information on optical fibers. Each carrier signal is modulated by one or more information signals. As a result, a significant number of information signals may be transmitted over a single optical fiber using WDM and DWDM technology. In a WDM system, when the optical signals are transmitted over long distances, periodic amplification of the optical signals is necessary. Currently, amplification is accomplished by using optical amplifiers, e.g. Erbium Doped Fiber Amplifiers (EDFAs) or Raman amplifiers. Optical amplifiers have the advantage of being relatively low in cost while being able to amplify all wavelengths without the need for demultiplexing and optoelectronic regeneration.

[0003] WDM systems currently under development are anticipated to have thirty or more channels, i.e., modulated optical signals with different wavelengths. These WDM systems place stringent demands on the optical amplifiers that are employed, especially when two or much such amplifiers are distributed along the transmission path of the WDM system, resulting in only very limited tolerances in certain parameters. Among these parameters gain flatness and gain tilt are of special importance. Gain tilt arises when there are dynamic changes in operating conditions such as the input power and wavelengths of the transmitted channels. For example, when a channel is added or subtracted, thus changing the input power and spectrum of the optical signal, a gain fluctuation occurs that depends on the channel's wavelength, effectively "tilting" the gain of the amplifier.

[0004] WDM systems are often initially deployed at less than their maximum capacity. That is, a system designed to transmit 30 channels or more, for instance, initially may be more lightly loaded with only 2, 4, or 8 channels. Since the power and wavelength distribution of the optical signal will vary as the system is upgraded to increase its channel capacity, a problem arises when a system designed for a given capacity is operated at less than that capacity. This problem occurs because, as mentioned, the changes in power and wavelength distribution of the optical signal give rise to variations in gain flatness and gain tilt, which are undesirable because the system is generally designed to operate with a specific degree of gain flatness and a particular gain tilt. In order to maintain the same gain flatness and gain tilt of the amplifiers even when the system is operating at less than full capacity, unused or idler channels are sometimes inserted along with the data-carrying channels. The idler channels are often provided as unmodulated or cw tones. As the WDM system is upgraded, idler channels can be removed and replaced with data-carrying channels.

[0005] One type of highly specialized optical WDM system is an undersea or submarine optical transmission system in which a cable containing optical fibers is installed on the ocean floor. The design of such optical transmission systems is generally customized on a system-by-system basis and employ highly specialized terminals to transmit data over the undersea optical transmission path. Since the specialized terminals are produced in small volumes they are relatively expensive in comparison to the optical terminals that are designed to communicate over terrestrial optical layer protocols, which are typically produced in relatively high volume for terrestrial optical transmission networks.

[0006] To overcome the need for such highly specialized equipment, U.S. Appl. Serial No. 10/621,028 discloses an undersea optical WDM system in which the highly specialized terminals are replaced with less expensive, readily available terrestrial optical terminals that communicate with the undersea transmission path, which is often referred to as the "wet plant." An optical line interface (OLI) is provided between each terminal and the wet plant so that the wet plant is transparent to the terminals. The OLI provides high compatibility between the proprietary interface of terrestrial optical terminals available from multiple vendors and the wet plant. That is, the OLI is designed to be terminal independent and serves as an interface between terrestrial optical layer transport protocols and an undersea optical layer transport protocol.

[0007] In the paradigm employed in the aforementioned patent application, the terrestrial optical transmission equipment performs any necessary optical-to-electrical conversion, FEC processing, electrical-to-optical conversion, and optical multiplexing. The terrestrial optical transmission equipment may also perform optical amplification, optical monitoring that is designed for the terrestrial optical network, and network protection. The optical line interface in turn provides the signal conditioning necessary to transmit the traffic over an undersea optical transmission cable. In particular, the optical line interface receives the optical signals from the terrestrial optical transmission equipment either as individual wavelengths on separate fibers or as a WDM signal on a single fiber. The interface device provides the optical layer signal conditioning that is not provided by the terrestrial equipment, but which is necessary to transmit the optical signals over the undersea transmission path. The signal conditioning that is provided may include, but is not limited to, gain equalization, bulk dispersion compensation, optical amplification, multiplexing, Raman amplification, dispersion slope compensation, polarization mode dispersion (PMD) compensation, performance monitoring, signal load balancing (e.g., idler channel insertion), or any combination thereof. The optical line interface may also include line monitoring equipment such as a COTDR arrangement, an autocorrelation arrangement, or other techniques that uses in-band or out-of band probe signals to determine the status and health of the transmission path. Additionally, the optical line interface may supply pump power to the transmission path so that Raman amplification can be imparted to the optical signals.

[0008] To maintain transparency between the terminals and the wet plant, when idler channels are added by the OLI at one end of the system they should be removed by the other OLI before reaching the remotely located terminal.

Summary of the Invention

[0009] In accordance with the present invention, an optical line interface is provided for communicating between terrestrial terminal equipment and an undersea optical transmission path a WDM optical signal having a plurality of wavelength components.

The optical line interface includes a signal processing unit for transforming WDM optical signals between optical layer transport protocols employed by the terrestrial terminal equipment and undersea optical layer transport protocols employed over the undersea optical transmission path. The optical line interface also includes an idler tone generator for generating idler tones at wavelengths corresponding to selected wavelengths components of the WDM signal that are not information-carrying wavelength components. An idler tone blocker is located within a signal path of the signal processing unit for selectively transmitting and blocking wavelength components of the WDM optical signal corresponding to the idler tones.

[0010] In accordance with another aspect of the invention, the idler tone blocker includes a first plurality of narrow band filters each having an input port, a reflection port, and a transmission port. Each filter has a transmission band corresponding to a different one of the wavelength components of the WDM optical signal. The reflection port of a first of the first plurality of filters is optically coupled to the input port of a second of the first plurality of filters. A second plurality of narrow band filters each having an input port, a reflection port, and a transmission port, each have a transmission band corresponding to a different one of the wavelength components of the WDM optical signal. The reflection port of a first of the second plurality of filters is optically coupled to the input port of a second of the second plurality of filters. A plurality of 1x1 optical switches each have an input coupled to a transmission port of a different one of the filters in the first plurality of filters and an output coupled to the transmission port of a filter in the second plurality of filters. The filters in the first and second plurality of filters that have transmission ports optically coupled to one another by one of the switches have the same transmission band.

[0011] In accordance with another aspect of the invention, at least one of the narrow band filters comprises a fiber Bragg grating.

[0012] In accordance with another aspect of the invention, at least one of the narrow band filters comprises a multilayer dielectric thin film.

[0013] In accordance with another aspect of the invention, the idler tone blocker includes a first dispersive element for spatially displacing each of the wavelength components of the WDM signal with respect to one another. The idler tone blocker also includes a spatial modulator for selectively transmitting and blocking each of the spatially displaced wavelength components. A second dispersive element is provided for spatially recombining those wavelength components received from the spatial modulator.

[0014] In accordance with another aspect of the invention, at least one of the first and second dispersive elements is a grating.

[0015] In accordance with another aspect of the invention, the grating is selected from the group consisting of a blazed fiber grating, a ruled grating, a holographic grating, and an arrayed waveguide router.

[0016] In accordance with another aspect of the invention, the spatial modulator is selected from the group consisting of a liquid crystal cell array, a MEMs based shutter arrangement, and a MEMs based mirror arrangement.

[0017] In accordance with another aspect of the invention, the signal processing unit is configured to perform at least one signal conditioning process selected from the group consisting of gain equalization, bulk dispersion compensation, optical amplification, Raman amplification, dispersion slope compensation, PMD compensation, and performance monitoring.

Brief Description of the Drawings

[0018] FIG. 1 shows an undersea optical WDM transmission system that employs conventional terrestrial terminal equipment that operates independently of the wet plant.

[0019] FIG. 2 shows an exemplary spectrum across the bandwidth of the channel wavelengths employed in the WDM system.

[0020] FIGs. 3(a) and 3(b) show the functionality to be provided by an idler tone blocker 300 constructed in accordance with principles of the present invention.

[0021] FIGs. 4 and 5 show the functionality of a narrow band pass filter that may be employed in an idler tone blocker constructed in accordance with the principles of the present invention.

[0022] FIG. 6 shows one embodiment of an idler tone blocker constructed in accordance with the principles of the present invention.

[0023] FIG. 7 shows an alternative embodiment of the inventive idler tone blocker.

[0024] FIG. 8 shows a block diagram of one embodiment of an optical line interface in which the present invention can be employed.

Detailed Description

[0025] FIG. 1 shows an undersea optical WDM transmission system that employs conventional terrestrial terminal equipment that operates independently of the wet plant. Terminal equipment 100_1 and 100_2 communicate with one another over wet plant 140 in a transparent manner via optical line interfaces (OLIs) 130_1 and 130_2, respectively. Optical line interface may be of the type described in U.S. Appl. Serial No. 10/621,028, filed July 16, 2003. Of course, the present invention encompasses other OLIs that provide transparency between the terminal equipment and the wet plant.

[0026] OLIs 130_1 and 130_2 generate idler tones at unused channel wavelengths. As previously mentioned, idler tones serve to increase the total optical power into the amplifiers to that of a fully loaded system in which all channel wavelengths are used to transmit information. FIG. 2 shows an exemplary spectrum across the bandwidth of the channel wavelengths employed in the WDM system. As shown, idler tones are periodically spaced across the bandwidth. In order to maintain transparency between the terminal equipment and the wet plant, the idler tones added by each of the OLIs 130_1 and 130_2 on their transmit sides must remove on their receive sides the idler tones generated by the other OLI so that the idler tones do not reach the terminal equipment 100_1 and 100_2.

[0027] FIGs. 3(a) and 3(b) show the functionality to be provided by an idler tone blocker 300 constructed in accordance with the present invention, which can be incorporated into the OLIs 130_1 and 130_2 shown in FIG. 1. In FIG. 3(a) a WDM signal directed to the input of the idler tone blocker 300 has channel wavelengths λ_1, λ_8, λ_{15}, λ_{22} and λ_{29} that are depicted as idler tones. As shown, the idler tone blocker 300 removes the idler tones so that they do not appear at its output.

[0028] As idler tones are converted to signal channels, the idler tone blocker 300 must transmit those signal channels that it previously blocked. That is, the idler tone blocker 300 must be able to block an idler tone at a given wavelength and then at a later time transmit signals at that same wavelength. In FIG. 3(b), for example, a number of signal channels have been added to the WDM signal shown in FIG. 3(a), including at wavelengths λ_{15} and λ_{22}, which in FIG. 3(a) were idler tone channels. The idler tone blocker 300 allows all signal wavelengths to appear on its output, which now includes wavelengths λ_{15} and λ_{22} that were previously blocked.

[0029] The functionality of idler tone blocker 300 may be achieved in a wide variety of different always. Although the present invention encompasses any such arrangement, a few exemplary embodiments will be presented below for illustrative purposes.

[0030] In one embodiment, the idler tone blocker comprises narrow band filters and a series of 1x1 optical switches. The filters are three port devices designed in accordance with well-known principles to transmit one particular wavelength and reflect all others. As illustrated in FIGs. 4 and 5, each filter can operate in a reciprocal manner so that the transmitted wavelength may be added or dropped from the WDM signal. The narrow band filters may be, for example, filter Bragg gratings or multilayer dielectric thin films.

[0031] FIGs. 4 and 5 show the functionality of such a filter when used in a drop mode (FIG. 4) and an add mode (FIG. 5). In the drop mode of FIG. 4, a WDM signal comprising wavelengths $\lambda_1, \lambda_2, \ldots \lambda_n$ is directed along input port 410 of filter 400. The filter 400 transmits a particular wavelength, in this case λ_1, to the transmission port 430 and reflects the remaining wavelengths to the reflection port 420. That is, the wavelength λ_1 is dropped to the transmission port 430. Similarly, in the add mode of FIG. 5 a WDM signal comprising wavelengths $\lambda_2, \lambda_3, \ldots \lambda_n$ is directed along input port 510 of filter 500. The wavelength λ_1 is added along the transmission port 530 so that the wavelengths λ_1, $\lambda_2, \lambda_3, \ldots \lambda_n$ appear on the reflection port 520. It should be emphasized that the filters 400 and 500 are identical to one another, only the manner in which the wavelengths are directed to them differ.

[0032] Of course, while the filter shown in FIGs. 4 and 5 transmits a wavelength λ_1, other filters may be configured to transmit other wavelengths. In the present invention the idler tone blocker employs a series of filters that each transmit a successive wavelength with respect to one another

[0033] FIG. 6 shows one embodiment of the idler tone blocker 600 that employs the narrow band pass filters shown in FIGs. 4 and 5. The idler tone blocker 600 comprises a first series of filters 610_1, 610_2, 610_3, ... 610_n, where n is equal to the number of channels in the WDM signal. In the particular example depicted in FIG. 6, n is equal to 8. The idler tone blocker 600 also comprises a second series of filters 620_1, 620_2, 620_3, ... 620_n. Each filter 610_i drops a wavelength λ_i on its transmission port. Likewise, each filter 620_i adds a wavelength λ_i on its transmission port. That is, for all the filters, filter 610_i is the same as filter 620_i. and thus the first series of filters are the same as the second series of filters.

[0034] In the first series of filters, the reflection port 604_i of filter 610_i is optically coupled to the input port 602_{i+1} of filter 610_{i+1}. In the case of filter 610_1, its input port 602_1 serves as the input port on which the WDM signal is received. In the case of filter 610_8, its reflection port 604_8 is optically coupled to the input port 622_1 of filter 620_1 in the second series of filters. As shown, the transmission port 606_i of each filter 610_i in the first series of filters is coupled to the input port of a 1x1 optical switch 630_i.

[0035] The filters 620 in the second series of filters are interconnected with one another in the same manner as the filters 610 in the first series of filters. That is, the reflection port 624_i of filter 620_i is optically coupled to the input port 622_{i+1} of filter 620_{i+1}. In the case of the final filter 620_8, its reflection port 624_8 serves as the output port from the idler tone blocker 600. The transmission port 626_i of each filter 620_i in the second series of filters is coupled to the output port of the 1x1 optical switch 630_i.

[0036] In operation, each filter 610_i drops the wavelength λ_i to its transmission port 606_i and transfers the remaining wavelengths from its reflection port 604_1 to the input port 602_i of the filter 610_{i+1}. For example, filter 610_1 drops wavelength λ_1 to its transmission port 606_1 and transfers wavelengths λ_2, λ_3, ... λ_8 from its reflection port 604_1 to the input port 602_2 of filter 610_2. Likewise, filter 610_2 drops wavelength λ_2 to its transmission port 606_2 and transfers wavelengths λ_3, λ_4, ... λ_8 from its reflection port 604_2 to the input port 602_3 of filter 610_3.

[0037] Once the dropped wavelengths are received at the input of their respective switches 630, those dropped wavelengths that are currently being used as idler tones will be blocked by opening their respective switch 630. For example, in FIG. 6, wavelengths λ_1, λ_2, and λ_3 and λ_8 are shown as idler tones. Accordingly, their corresponding switches, switch 630_1, 630_2, 630_3, and 630_8, respectively, are shown in their open positions so that the idler tones are not transferred to the switch outputs. Those wavelengths that are not blocked (i.e., the signal wavelengths) will be directed from the output of the switch 630 to the transmission port of the corresponding filter 620 in the second series of filters by closing the switch. In FIG. 6, for example, signal wavelengths λ_4, λ_5, λ_6, and λ_7 are directed to the transmission port of the filters 620_4, 620_5, 620_6, and 620_7, respectively. The signal wavelengths are then directed by their respective filters from the transmission port to the reflection port, which then communicates the signal wavelengths to the input port of the successive filter. In this way the signal wavelengths propagate through the second series of filters 620 and finally appear on the reflection port 624_8 of the final filter 620_8.

[0038] A number of design considerations should be noted when optimizing the embodiment of the idler tone blocker shown in FIG. 6. For example, since the filters 610 and 620 have some net loss for both the transmitted and reflected signals, the accumulated losses on the dropped wavelengths are balanced by arranging the filters so that the first wavelength dropped in the first series of filters is also the first wavelength added in the second series of filters. Likewise, the second wavelength dropped in the first series of filters should also be the second wavelength added in the second series of filters. Moreover, in some cases it may be desirable to add an optical attenuator between the first and second series of the filters to equalize the loss between the dropped/added wavelengths and those wavelengths that are only reflected (i.e., those wavelengths that are never used as idler channels and thus do not need to be added and dropped). Finally, extra filtering sometimes may be required because even high quality filters can give rise to a reflection of the transmitted wavelength that is attenuated by about 20dB. This attenuated "ghost" signal can cause undesirable signal fluctuations if it is successfully transferred from the first series of filters to the second series of filters, where it can interfere with the transmitted portion of the same signal. This problem can be avoided by providing another series of drop filters after the first series of drop filters (i.e., filters 610). In this second series of drop filters the transmission port is simply terminated.

[0039] FIG. 7 shows one alternative embodiment of the inventive idler tone blocker that employs a free space dispersive arrangement to selectively transmit and block the idler tones. A first dispersive element 710 disperses the spectrum of the incoming WDM signal in free space. The dispersive element 710 may be a grating such as a blazed fiber grating, a ruled grating, a holographic grating, or an arrayed waveguide router, for example. The first dispersive element 710 spatially displaces the different wavelengths. A spatial modulator 730 is located within the beam path of the spatially displaced wavelengths that can selectively transmit or block any desired wavelength or wavelengths. Those wavelength components corresponding to idler tones will be blocked by the spatial modulator 730. The spatial modulator 730 is formed from a series of apertures, one for each wavelength. The spatial modulator can encompass any appropriate arrangement including, but not limited to, a liquid crystal cell array, a MEMs based shutter arrangement, and a MEMs based mirror arrangement. Those wavelengths that traverse the spatial modulator 730 will be reflected off a second dispersive element 720 that spatially recombines the wavelengths so that the resulting signal can be directed to the output port of the idler tone blocker.

[0040] FIG. 8 shows a block diagram of one embodiment of an optical line interface 800 in which the present invention can be employed. The optical signal received from the terminal equipment is monitored for optical performance by optical performance monitor 802, then optically amplified by amplifier 806, and passed through a dispersion compensation device 808 such as a dispersion compensating fiber or a grating-based dispersion compensation device, after which the optical signal is ready to traverse the undersea optical transmission path. Likewise, the optical signal received by the interface device 800 from the undersea optical transmission path is optically amplified by amplifier 810, passed through a dispersion compensation device 812, and monitored for performance by optical performance monitor 818. Optical performance monitors 802 and 818 monitor signal quality between the terminal equipment and the optical line interface 800. In some cases the optical performance monitors 802 and 818 may also monitor the health and status of the wet plant. Idler tone generator 820 generates idler tones that are coupled with the optical signal received from the terminal equipment for transmission along the wet plant. Idler tone blocker 822 is located in the transmission path of the optical line interface 800 that receives optical signals from the wet plant and forwards them to the terminal equipment. In FIG. 8 the idler tone blocker 822 is located between dispersion compensator 812 and the optical performance monitor 818. However, the idler tone blocker 822 may be situated at other points along the path that returns the optical signals to the terminal equipment. For example, idler tone blocker 822 may be located downstream from the optical performance monitor 818.

Claims

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

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

an idler tone generator for generating idler tones at wavelengths corresponding to selected wavelengths components of the WDM signal that are not information-carrying wavelength components; and

an idler tone blocker located within a signal path of the signal processing unit for selectively transmitting and blocking wavelength components of the WDM optical signal corresponding to the idler tones.

2. The optical line interface of claim 1 wherein the idler tone blocker comprises:

a first plurality of narrow band filters each having an input port, a reflection port, and a transmission port each having a transmission band corresponding to a different one of the wavelength components of the WDM optical signal, wherein the reflection port of a first of the first plurality of filters is optically coupled to the input port of a second of the first plurality of filters;

a second plurality of narrow band filters each having an input port, a reflection port, and a transmission port each having a transmission band corresponding to a different one of the wavelength components of the WDM optical signal, wherein the reflection port of a first of the second plurality of filters is optically coupled to the input port of a second of the second plurality of filters; and

a plurality of 1x1 optical switches each having an input coupled to a transmission port of a different one of the filters in the first plurality of filters and an output coupled to the transmission port of a filter in the second plurality of filters such that the filters in the first and second plurality of filters having transmission ports optically coupled by one of the switches have the same transmission band.

3. The optical line interface of claim 2 wherein at least one of the narrow band filters comprises a fiber Bragg grating.

4. The optical line interface of claim 2 wherein at least one of the narrow band filters comprises a multilayer dielectric thin film.

5. The optical line interface of claim 1 wherein the idler tone blocker comprises:

a first dispersive element for spatially displacing each of the wavelength components of the WDM signal with respect to one another;

a spatial modulator for selectively transmitting and blocking each of the spatially displaced wavelength components; and

a second dispersive element for spatially recombining those wavelength components received from the spatial modulator.

6. The optical line interface of claim 5 wherein at least one of the first and second dispersive elements is a grating.

7. The optical line interface of claim 6 wherein said grating is selected from the group consisting of a blazed fiber grating, a ruled grating, a holographic grating, and an arrayed waveguide router.

8. The optical line interface of claim 5 wherein the spatial modulator is selected from the group consisting of a liquid crystal cell array, a MEMs based shutter arrangement, and a MEMs based mirror arrangement.

9. The optical line interface of claim 1 wherein the signal processing unit is configured to perform at least one signal conditioning process selected from the group

consisting of gain equalization, bulk dispersion compensation, optical amplification, Raman amplification, dispersion slope compensation, PMD compensation, and performance monitoring.

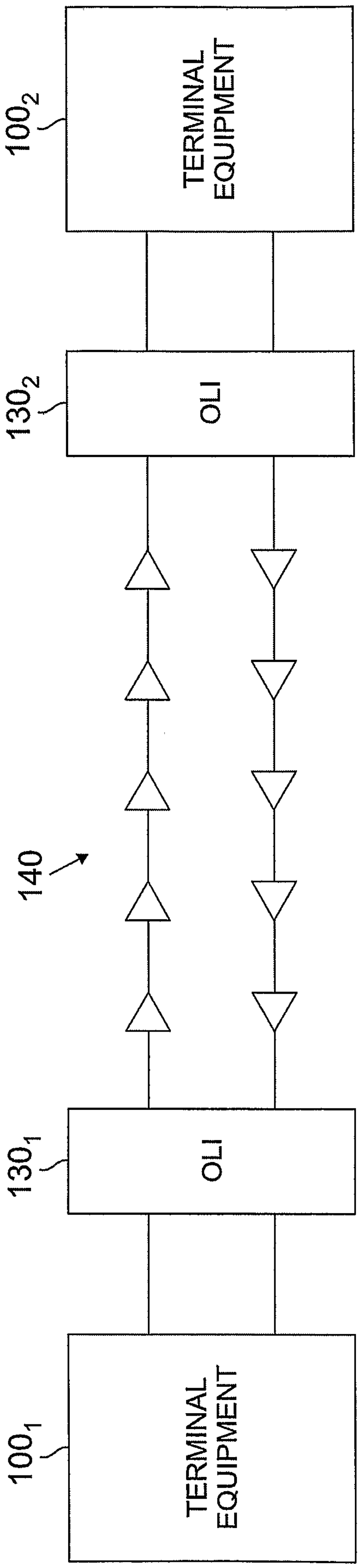

100_2
TERMINAL EQUIPMENT
130_2
OLI
140
130_1
OLI
100_1
TERMINAL EQUIPMENT

FIG. 1

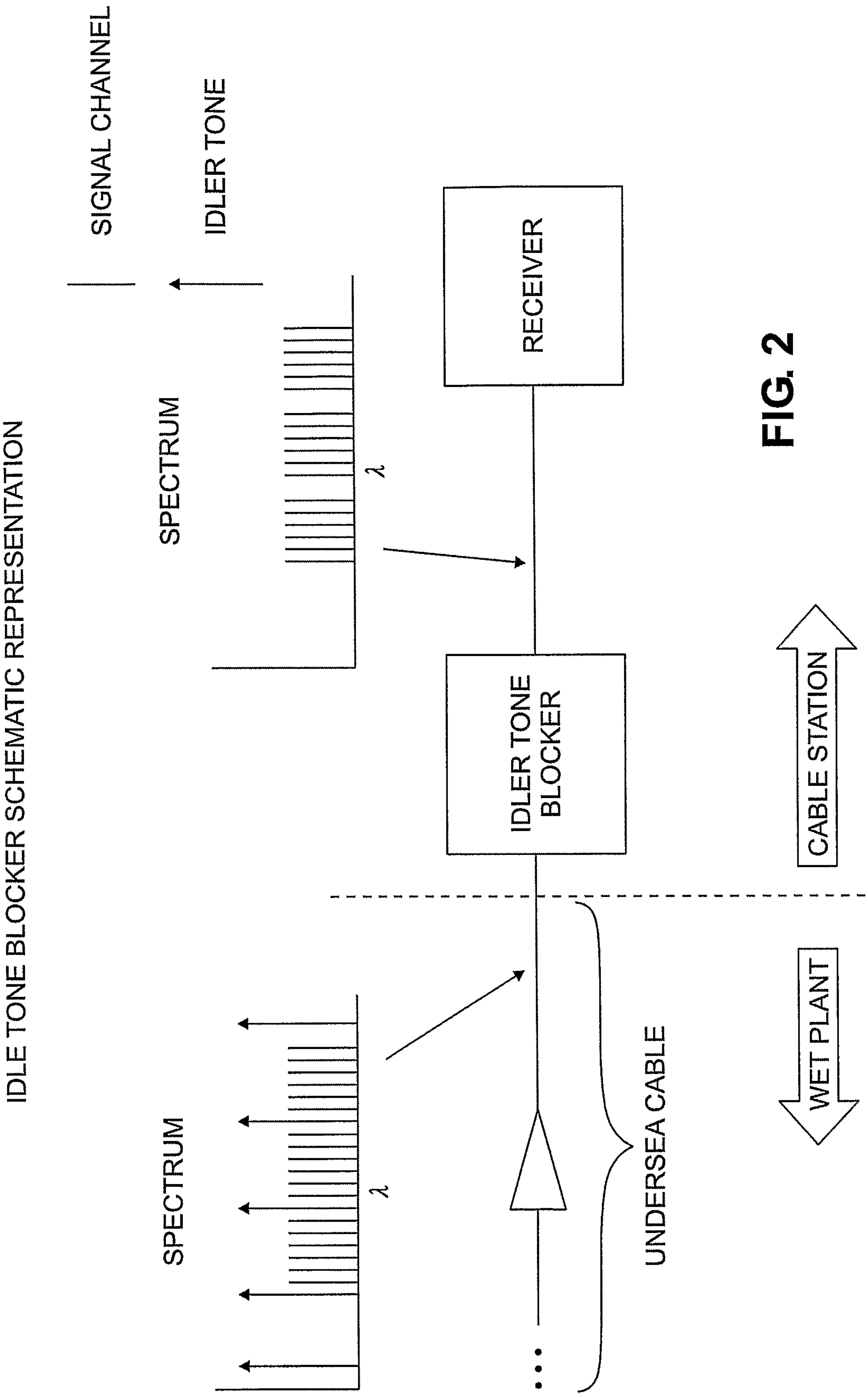

IDLE TONE BLOCKER SCHEMATIC REPRESENTATION
SIGNAL CHANNEL
IDLER TONE
SPECTRUM
λ
RECEIVER
IDLER TONE BLOCKER
CABLE STATION
WET PLANT
UNDERSEA CABLE
SPECTRUM
λ

FIG. 2

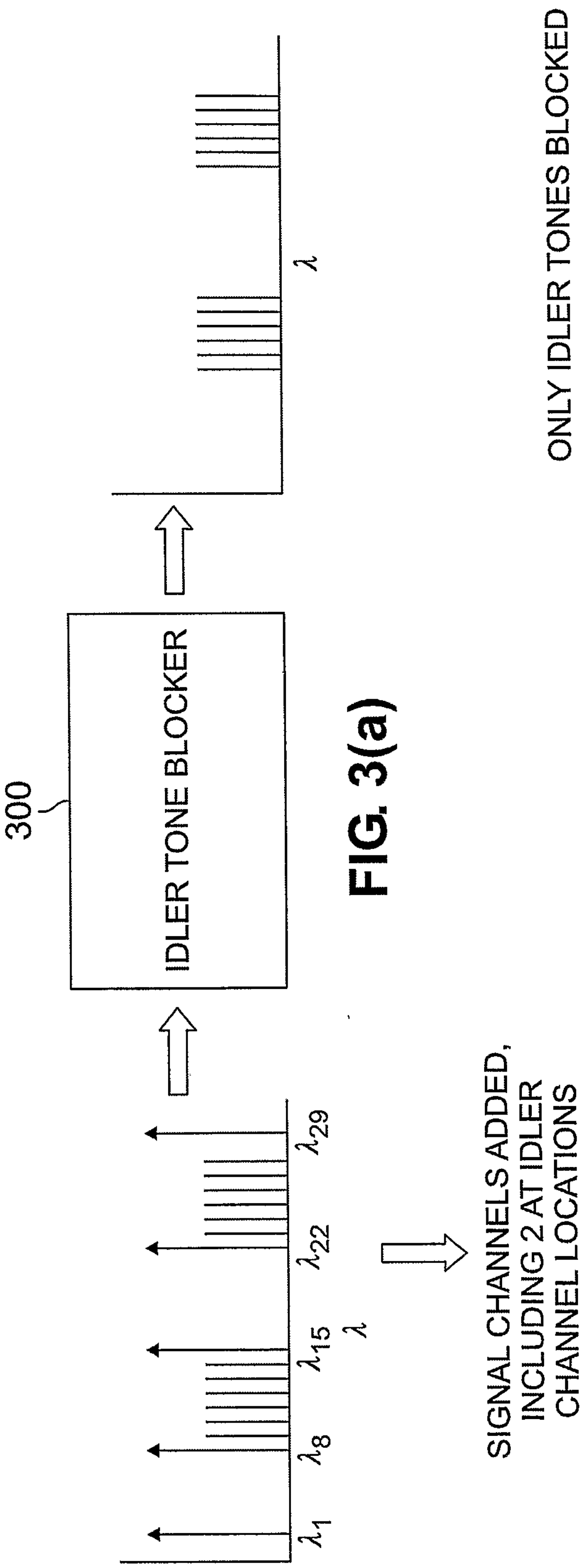

300
IDLER TONE BLOCKER
λ
λ1
λ8
λ15
λ22
λ29
λ
SIGNAL CHANNELS ADDED, INCLUDING 2 AT IDLER CHANNEL LOCATIONS
ONLY IDLER TONES BLOCKED

FIG. 3(a)

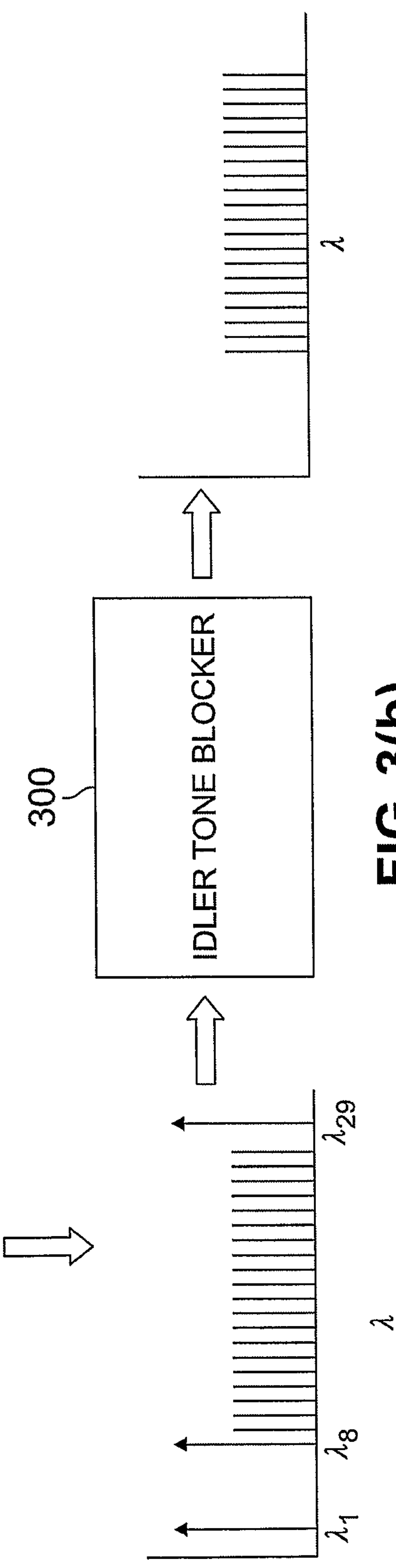

300
IDLER TONE BLOCKER
λ
λ1
λ8
λ29
λ

FIG. 3(b)

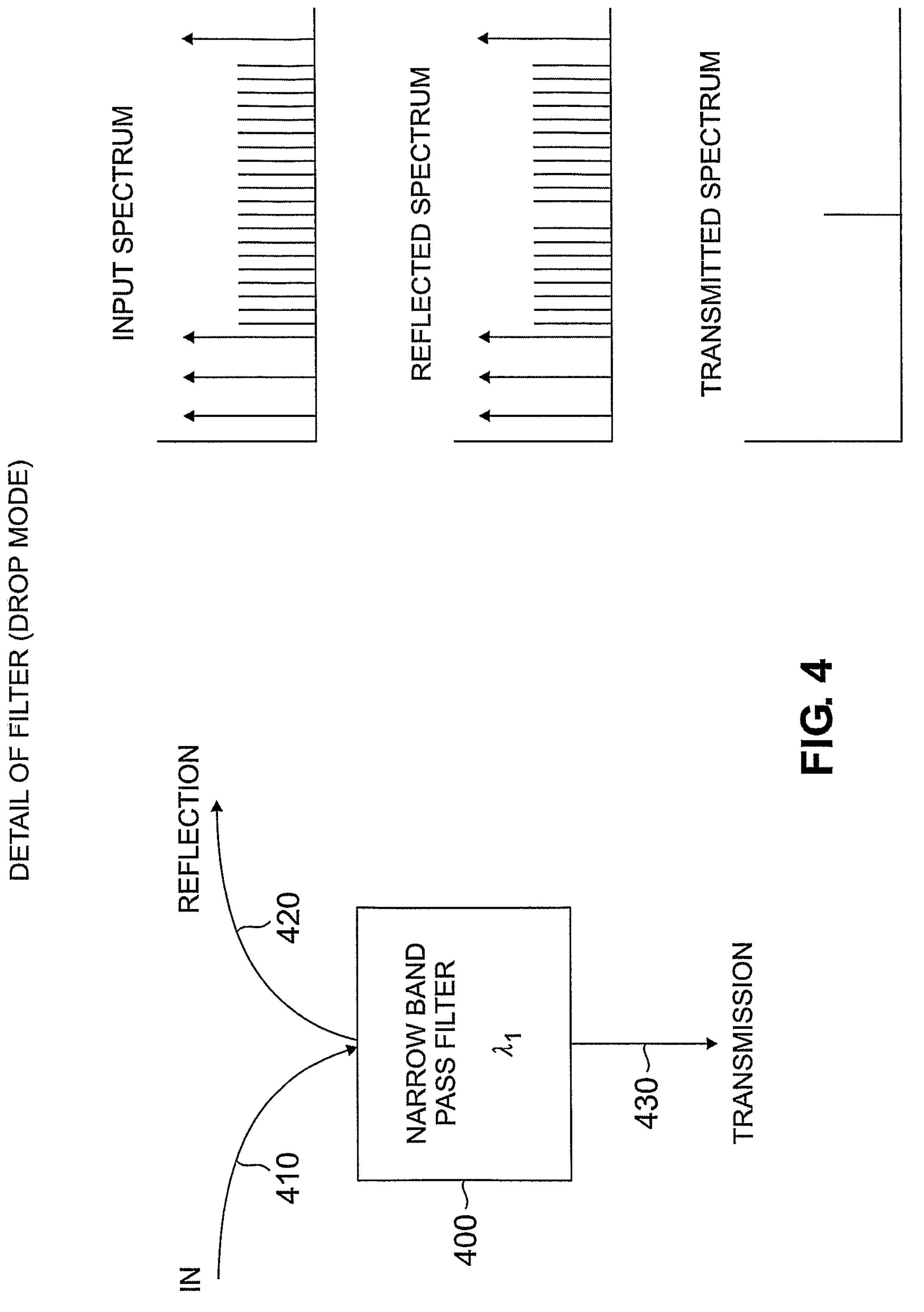

DETAIL OF FILTER (DROP MODE)
INPUT SPECTRUM
REFLECTED SPECTRUM
TRANSMITTED SPECTRUM
REFLECTION
420
NARROW BAND PASS FILTER
λ1
IN
410
400
430
TRANSMISSION
TRANSMISSION

FIG. 4

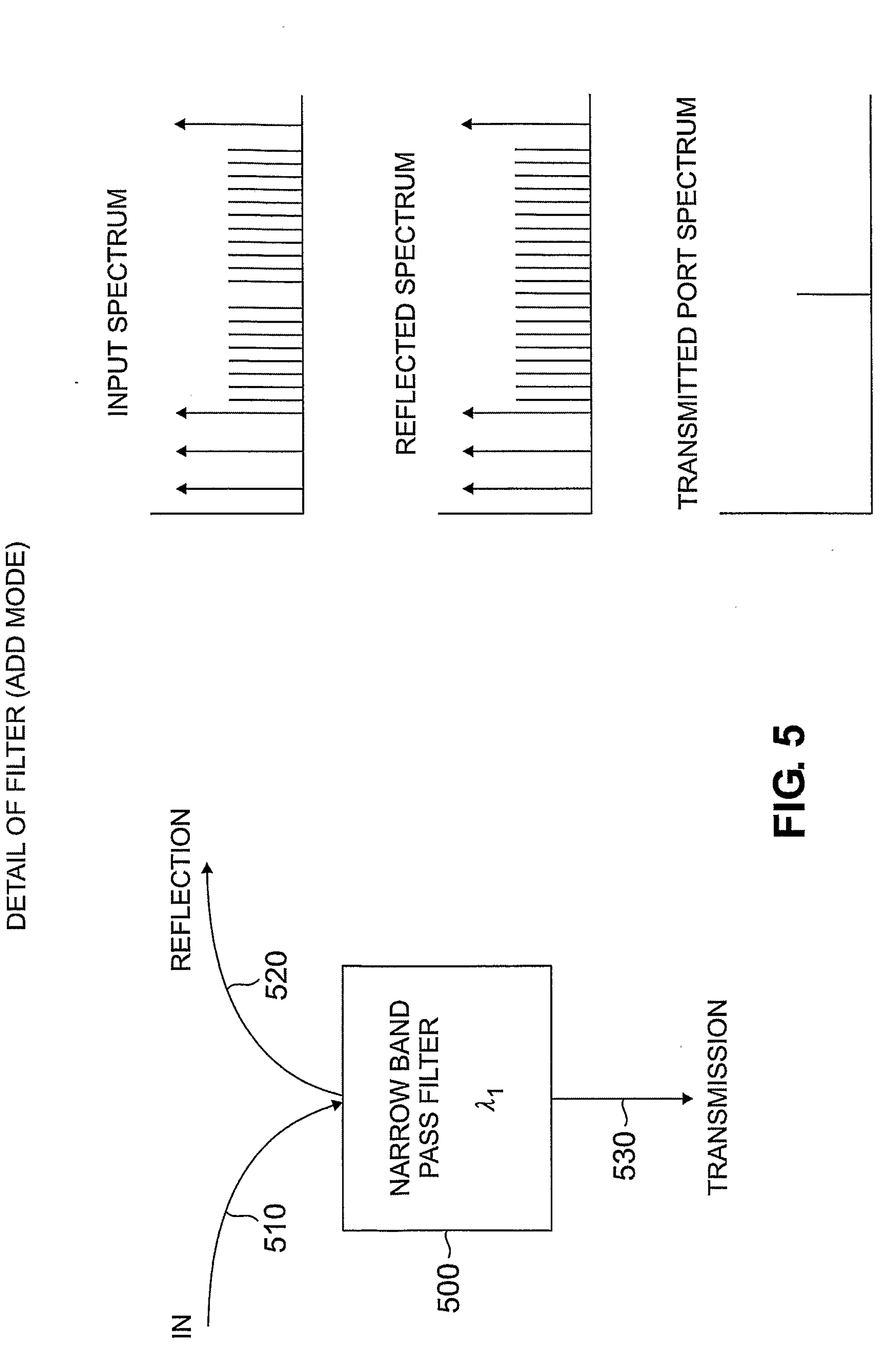
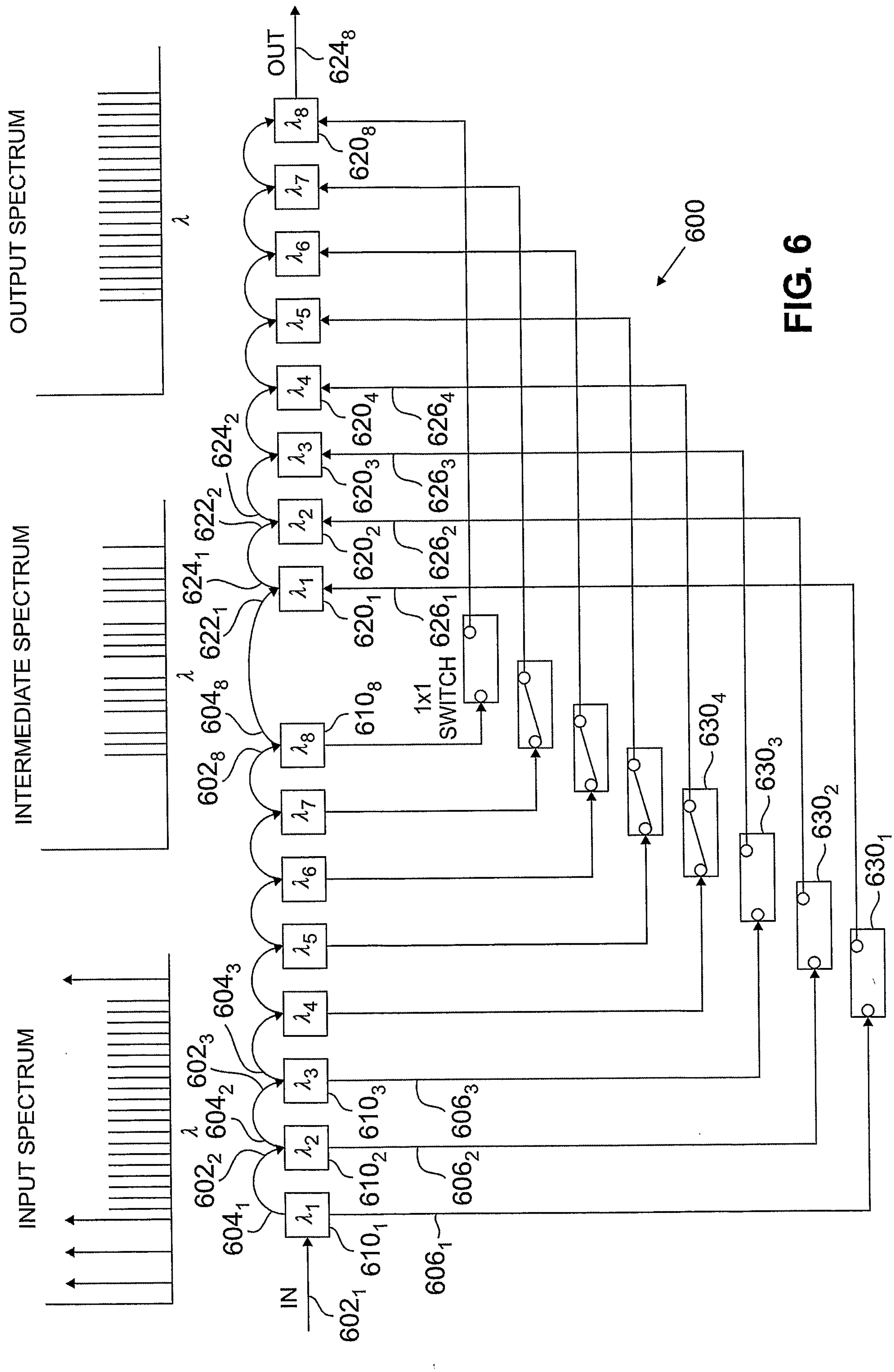

DETAIL OF FILTER (ADD MODE)
INPUT SPECTRUM
REFLECTED SPECTRUM
TRANSMITTED PORT SPECTRUM
IN
510
REFLECTION
520
NARROW BAND PASS FILTER
λ_1
500
530
TRANSMISSION

FIG. 5



INPUT SPECTRUM
INTERMEDIATE SPECTRUM
OUTPUT SPECTRUM
λ
IN
OUT
1x1 SWITCH
600
602_1
602_2
602_3
602_8
604_1
604_2
604_3
604_8
606_1
606_2
606_3
610_1
610_2
610_3
610_8
620_1
620_2
620_3
620_4
620_8
622_1
622_2
624_1
624_2
624_8
626_1
626_2
626_3
626_4
630_1
630_2
630_3
630_4
λ_1 λ_2 λ_3 λ_4 λ_5 λ_6 λ_7 λ_8

FIG. 6

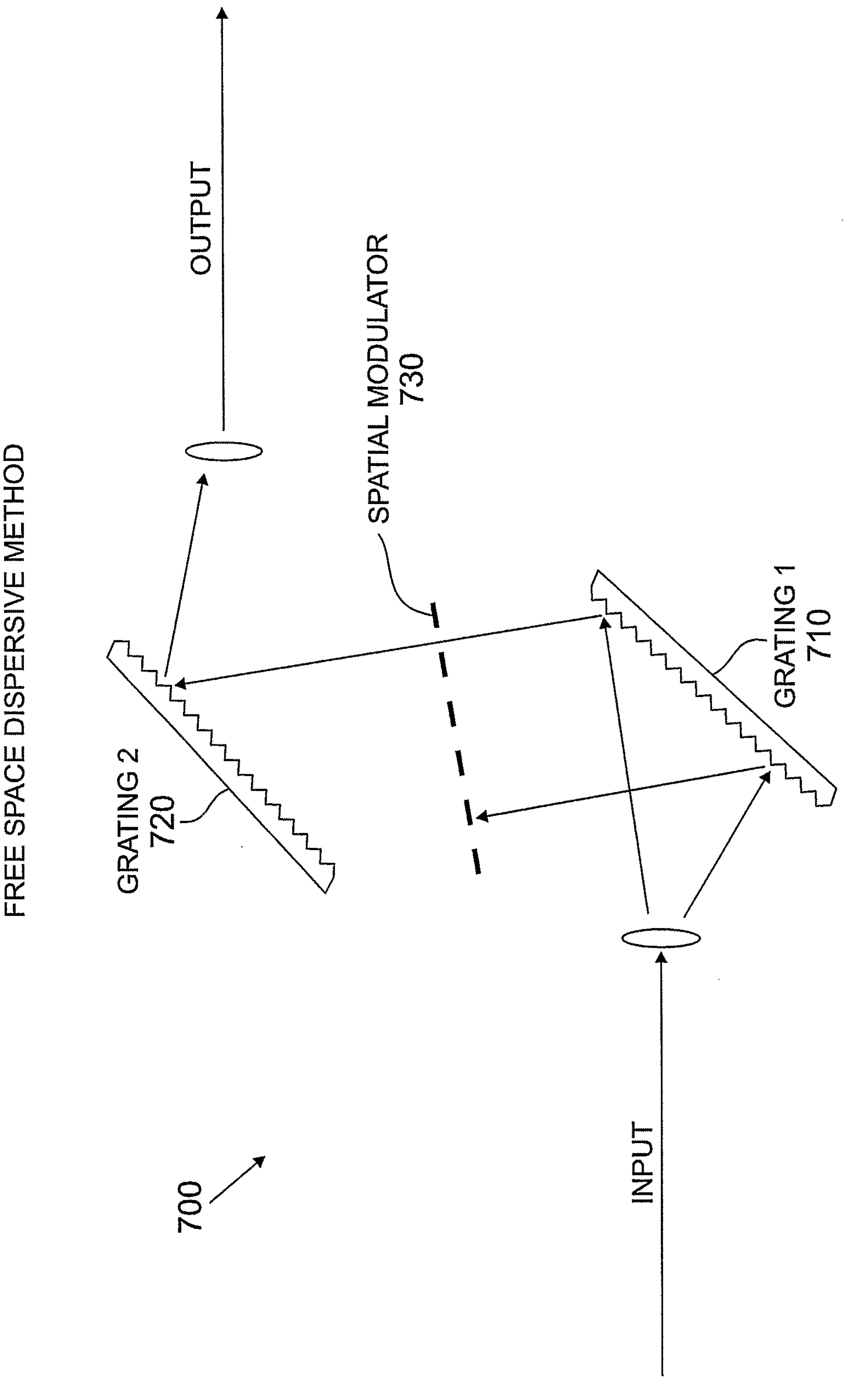

FREE SPACE DISPERSIVE METHOD
OUTPUT
SPATIAL MODULATOR
730
GRATING 2
720
GRATING 1
710
INPUT
700

FIG. 7

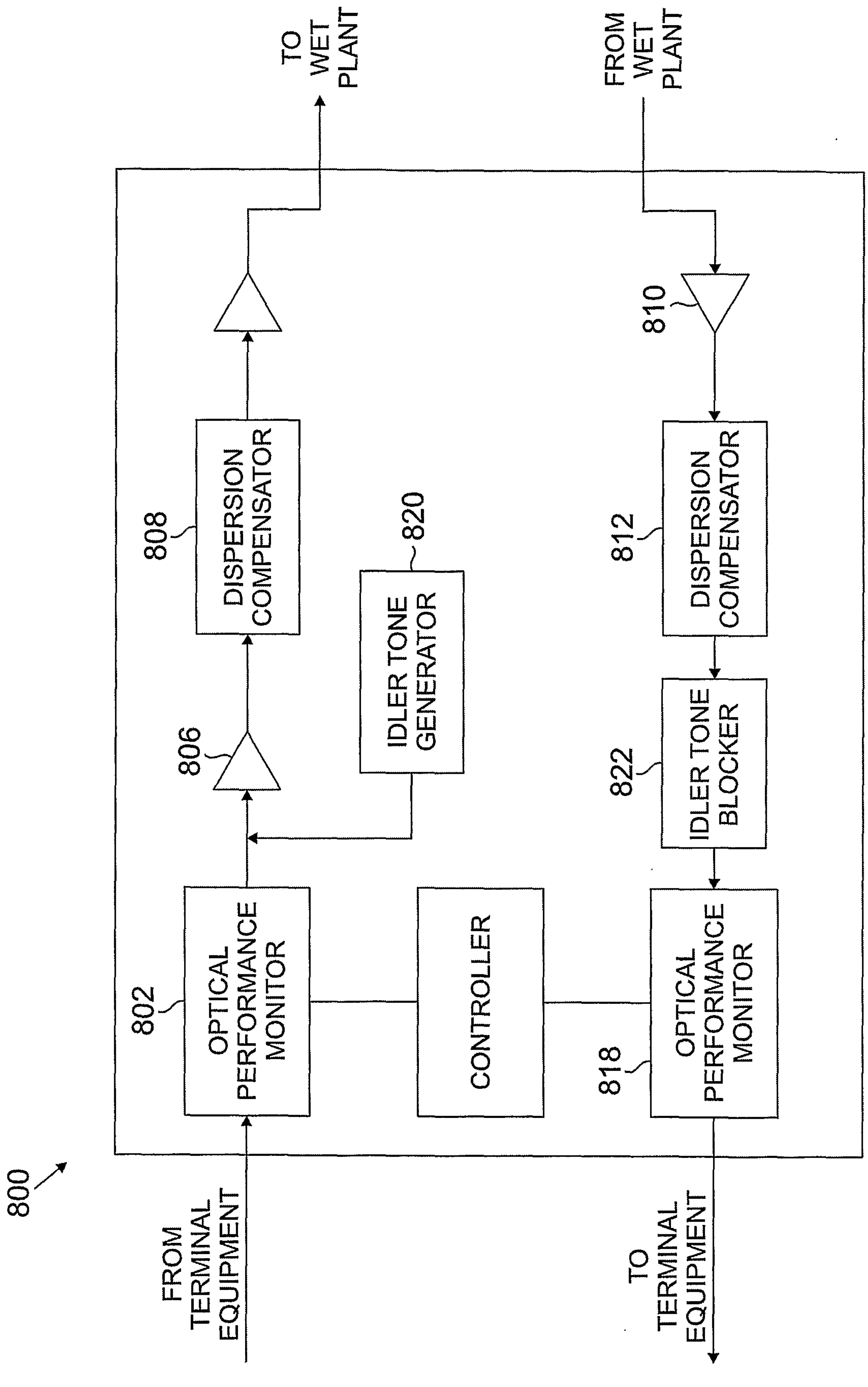

TO WET PLANT
FROM WET PLANT
810
808
DISPERSION COMPENSATOR
820
IDLER TONE GENERATOR
812
DISPERSION COMPENSATOR
806
822
IDLER TONE BLOCKER
802
OPTICAL PERFORMANCE MONITOR
CONTROLLER
818
OPTICAL PERFORMANCE MONITOR
800
FROM TERMINAL EQUIPMENT
TO TERMINAL EQUIPMENT

FIG. 8