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(54) **CORRECTION TABLE FOR INTERFEROMETRIC OPTICAL SIGNAL-TO-NOISE RATIO MONITOR**

(71) Applicant: **Fujitsu Limited**, Kawasaki-shi, Kanagawa (JP)

(72) Inventors: **Jeng-Yuan Yang**, Garland, TX (US); **Youichi Akasaka**, Allen, TX (US); **Motoyoshi Sekiya**, Richardson, TX (US); **Takuji Maeda**, Kawasaki (JP); **Hiroki Ooi**, Kawasaki (JP); **Kentaro Nakamura**, Tokyo (JP); **Satoru Okano**, Yokohama (JP)

(73) Assignee: **Fujitsu Limited**, Kawasaki-shi (JP)

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H04B 17/00	(2015.01)

(52) **U.S. Cl.**

CPC ***H04B 10/07953*** (2013.01); ***H04B 17/0062*** (2013.01)

(58) **Field of Classification Search**

CPC H04B 10/07953; H04B 10/07955; H04B 17/0062

USPC 398/26

See application file for complete search history.

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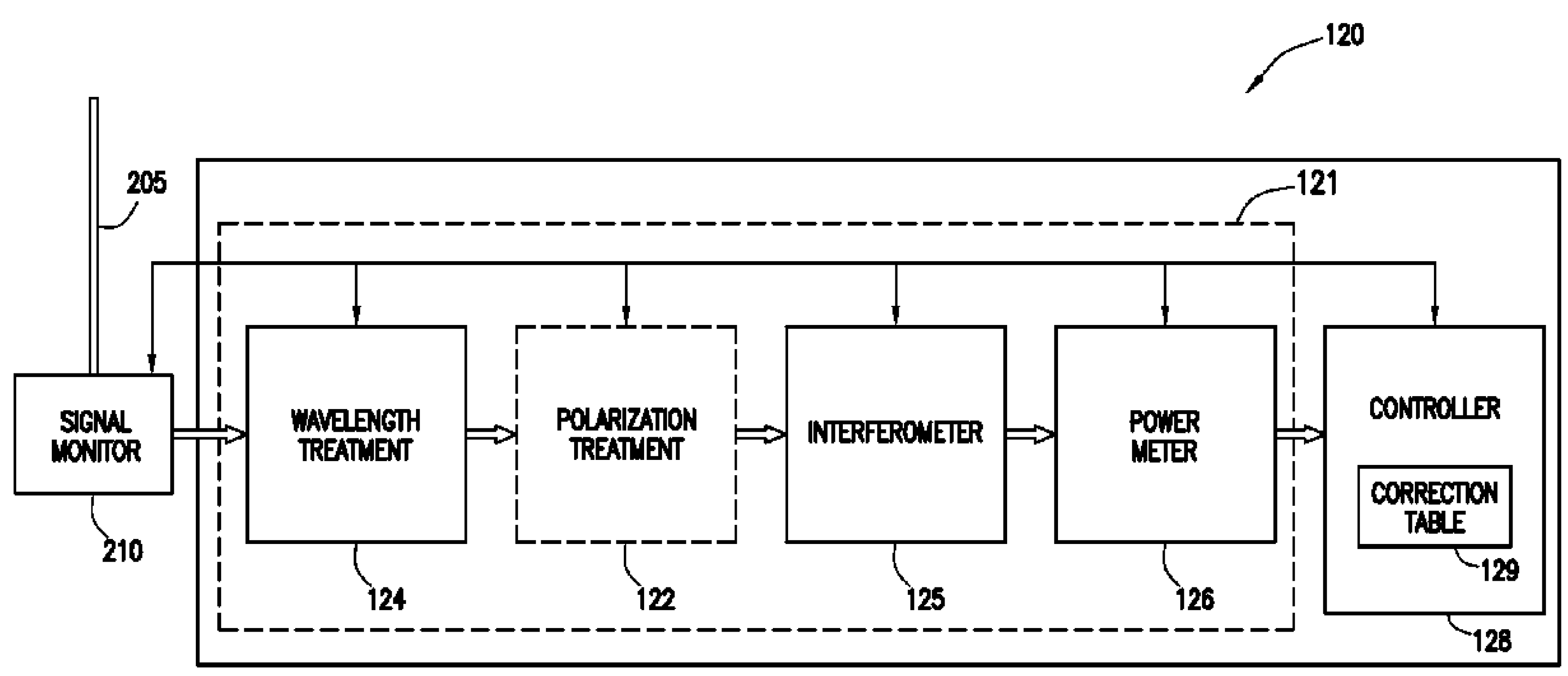
Primary Examiner — M. R. Sedighian

(74) *Attorney, Agent, or Firm* — Baker Botts L.L.P.

(57) **ABSTRACT**

The present disclosure includes a computer-implemented method of correcting a measured optical signal-to-noise ratio (OSNR) comprising receiving an optical signal and measuring OSNR of the optical signal using an interferometric OSNR monitor device. The method also includes applying a correction table to the measured OSNR to generate a corrected OSNR using a controller, the correction table comprising a correction function to counteract an artifact in the measured OSNR. The method also includes storing the corrected OSNR in a non-transitory computer-readable medium. The present disclosure also includes associated devices applying the correction table and methods of generating the correction table.

26 Claims, 12 Drawing Sheets



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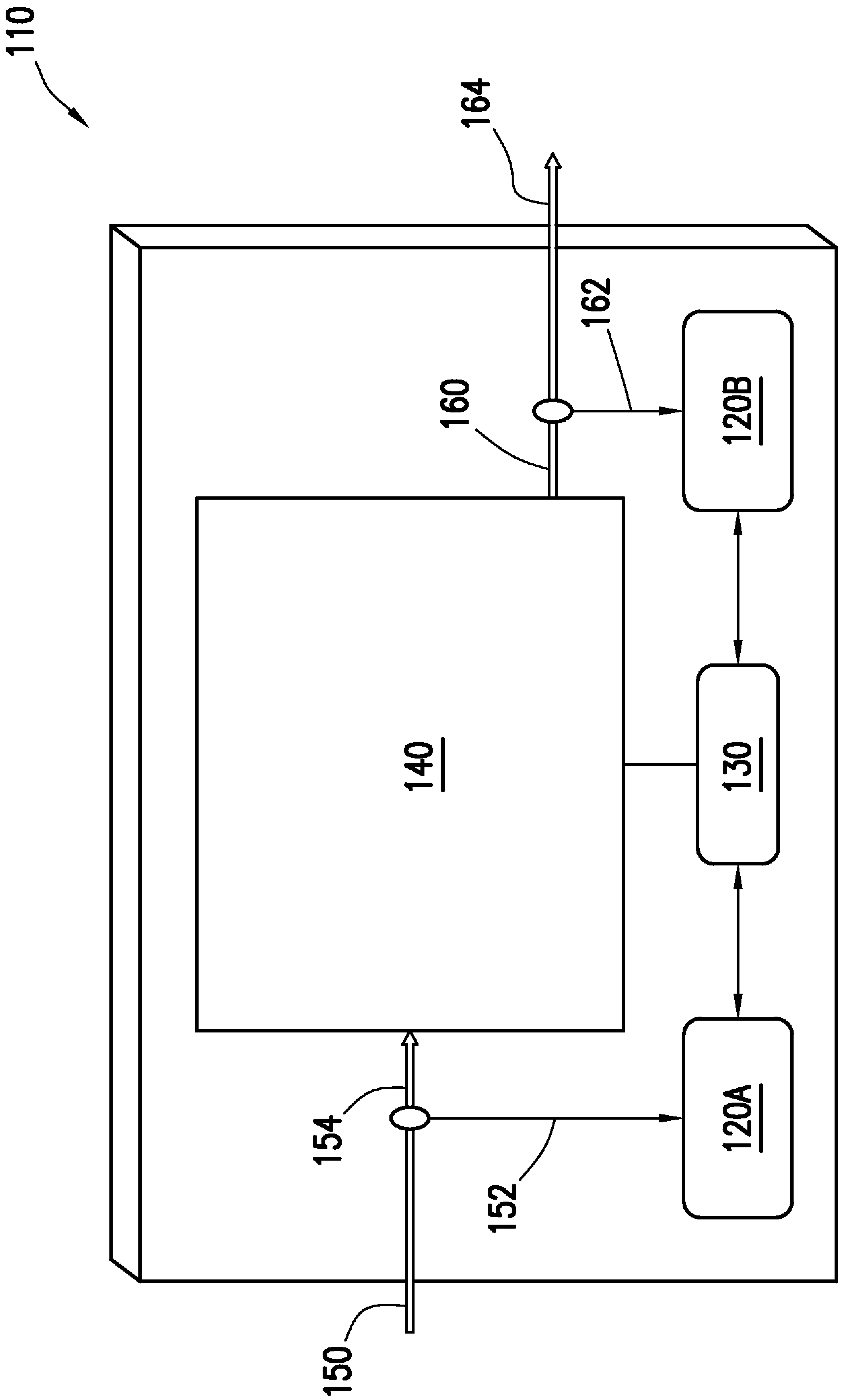
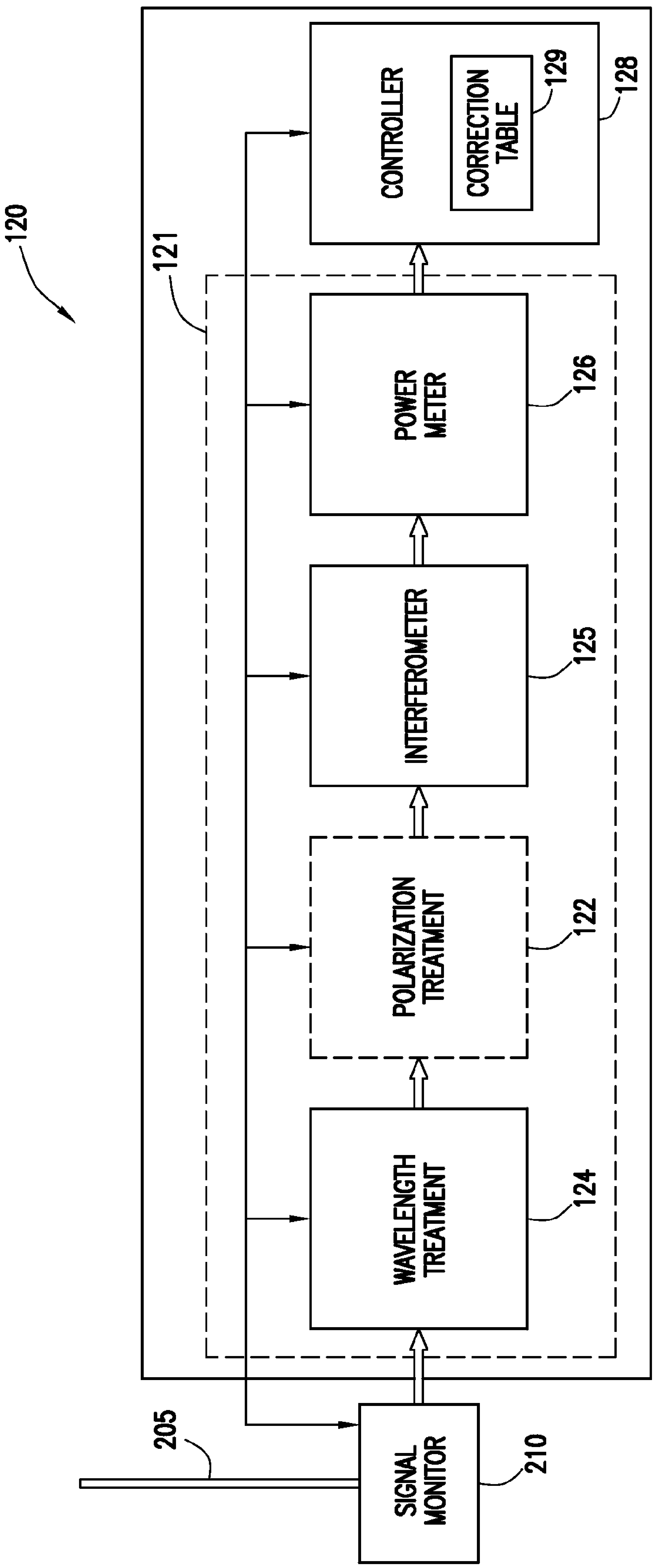


FIG. 1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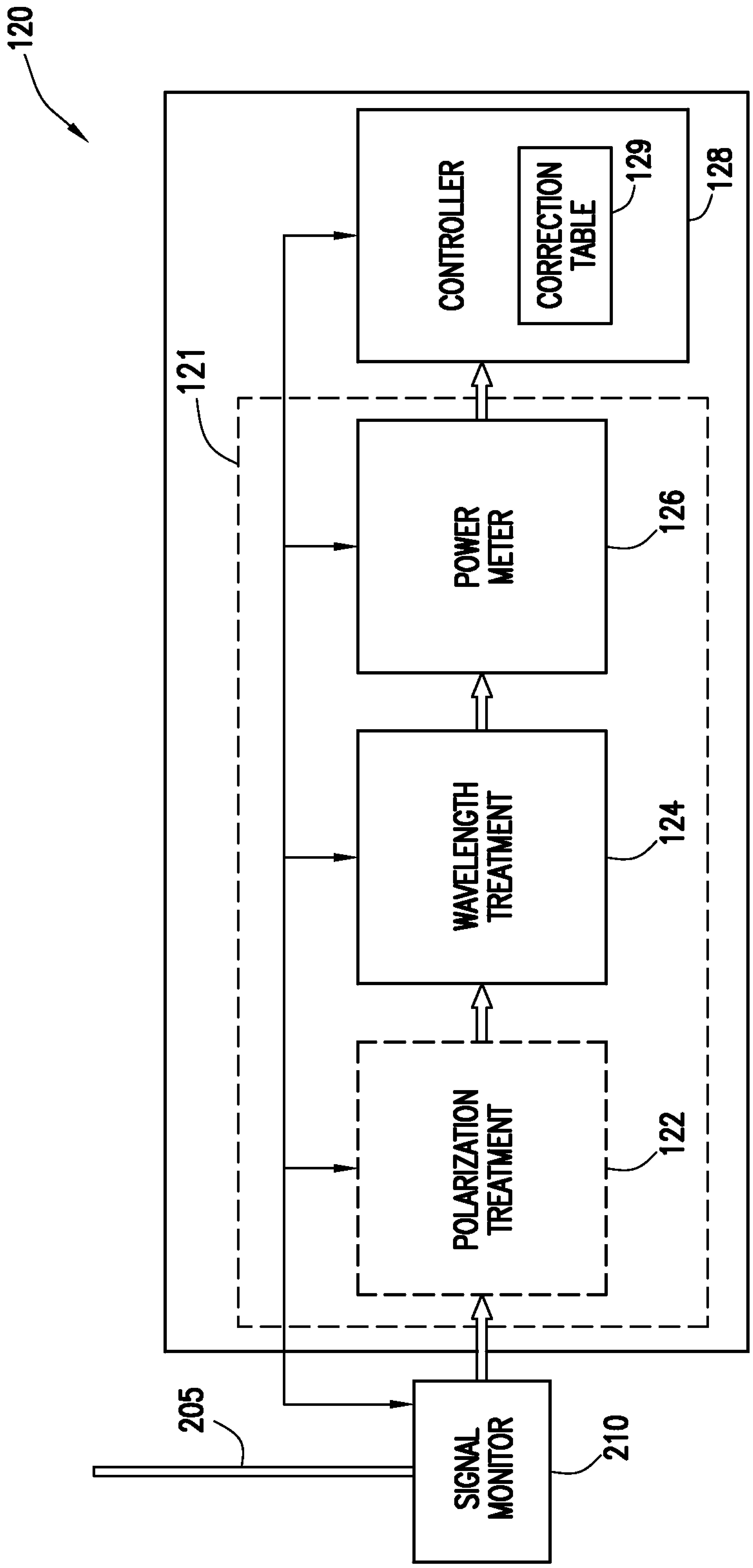
121
CONTROLLER
CORRECTION TABLE
129
128
POWER METER
126
INTERFEROMETER
125
POLARIZATION TREATMENT
122
WAVELENGTH TREATMENT
124
205
SIGNAL MONITOR
210

FIG. 2A


120
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CORRECTION TABLE
129
128
121
POWER METER
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WAVELENGTH TREATMENT
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POLARIZATION TREATMENT
122
205
SIGNAL MONITOR
210

FIG. 2B

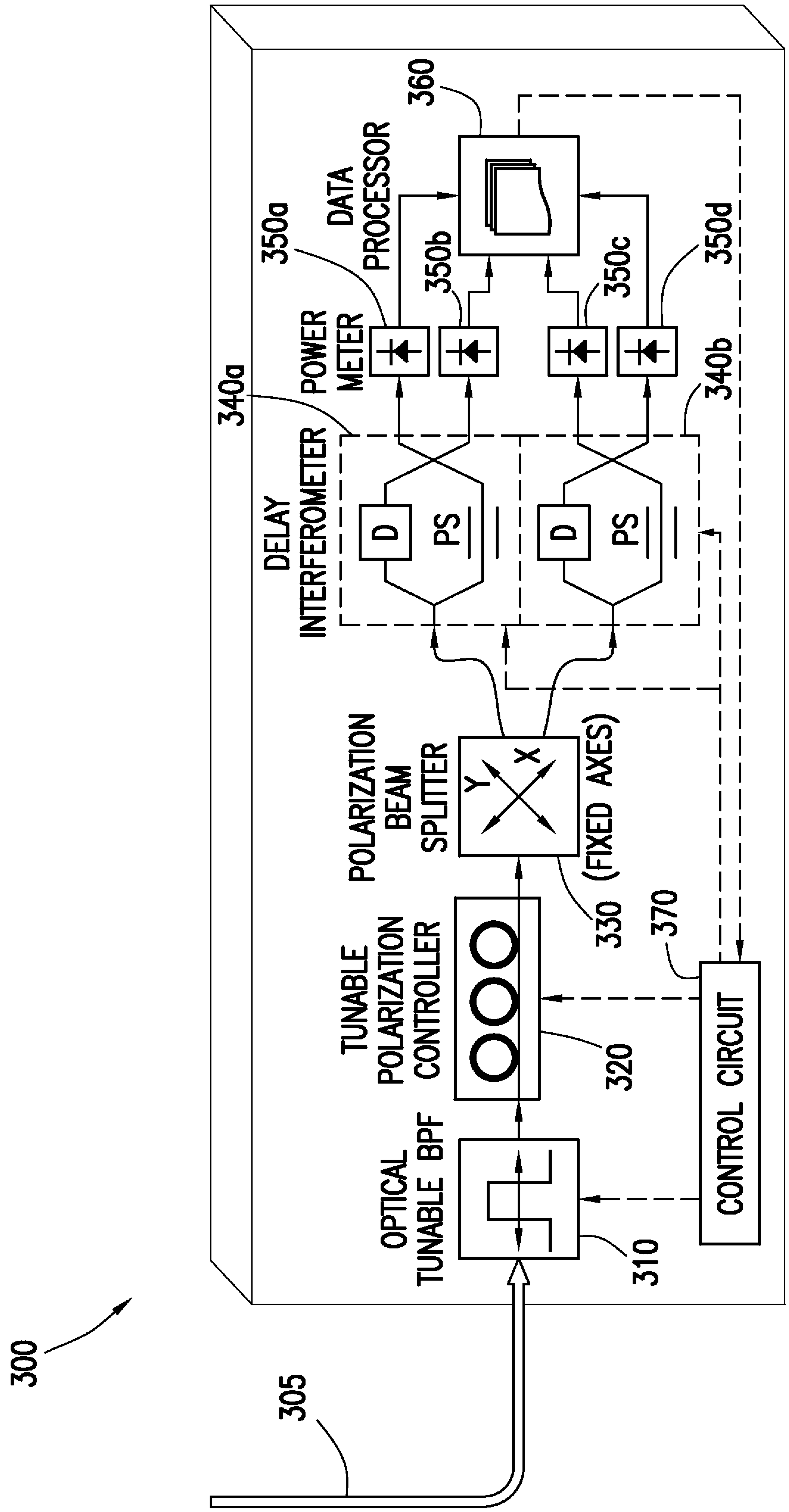
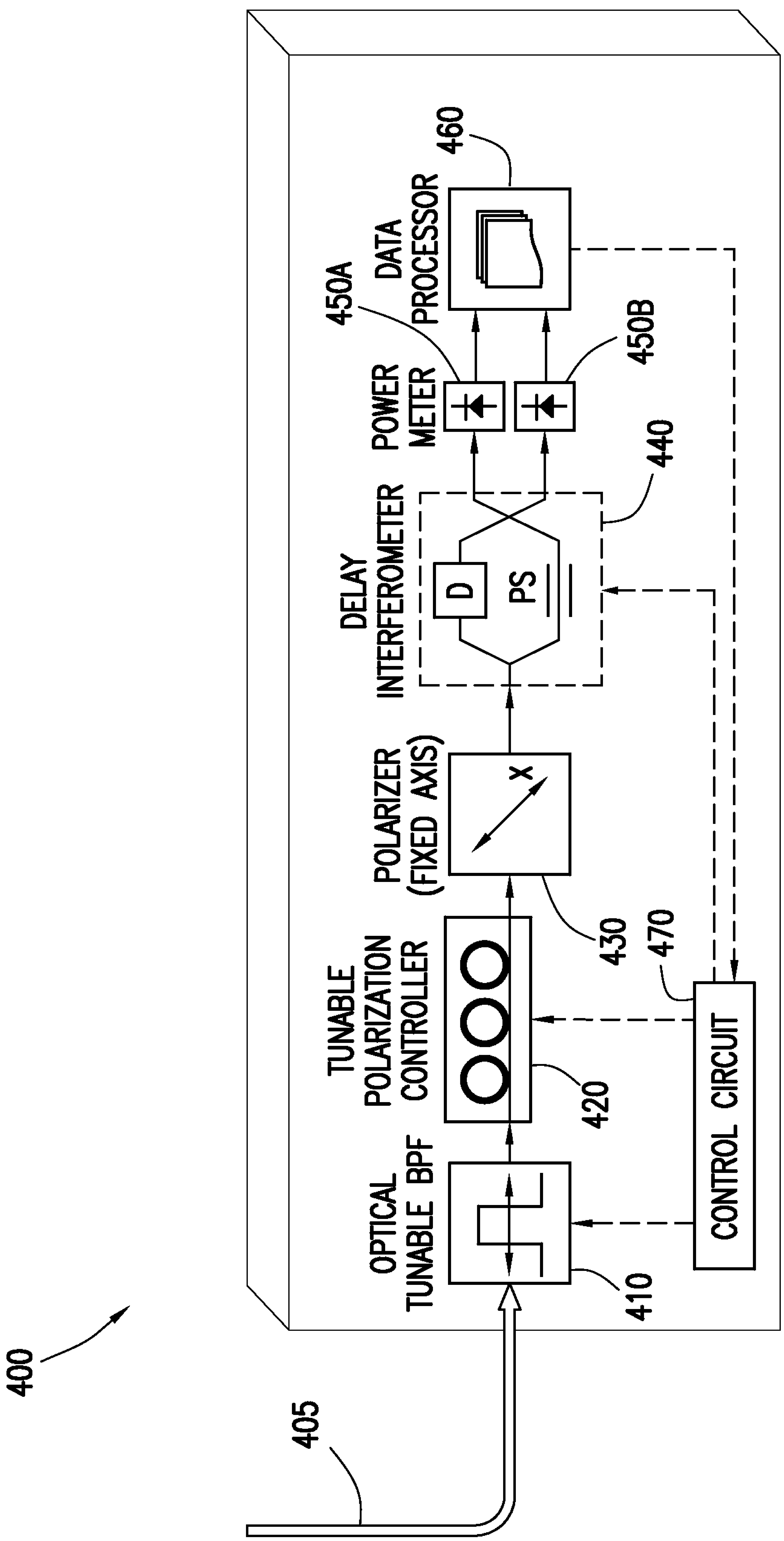

300
305
310
OPTICAL TUNABLE BPF
320
TUNABLE POLARIZATION CONTROLLER
330
POLARIZATION BEAM SPLITTER
Y
X
(FIXED AXES)
370
CONTROL CIRCUIT
340a
340b
DELAY INTERFEROMETER
D
PS
POWER METER
350a
350b
350c
350d
DATA PROCESSOR
360

FIG. 3



400
405
OPTICAL TUNABLE BPF
410
TUNABLE POLARIZATION CONTROLLER
420
POLARIZER (FIXED AXIS)
X
430
DELAY INTERFEROMETER
D
PS
440
POWER METER
450A
450B
DATA PROCESSOR
460
CONTROL CIRCUIT
470

FIG. 4

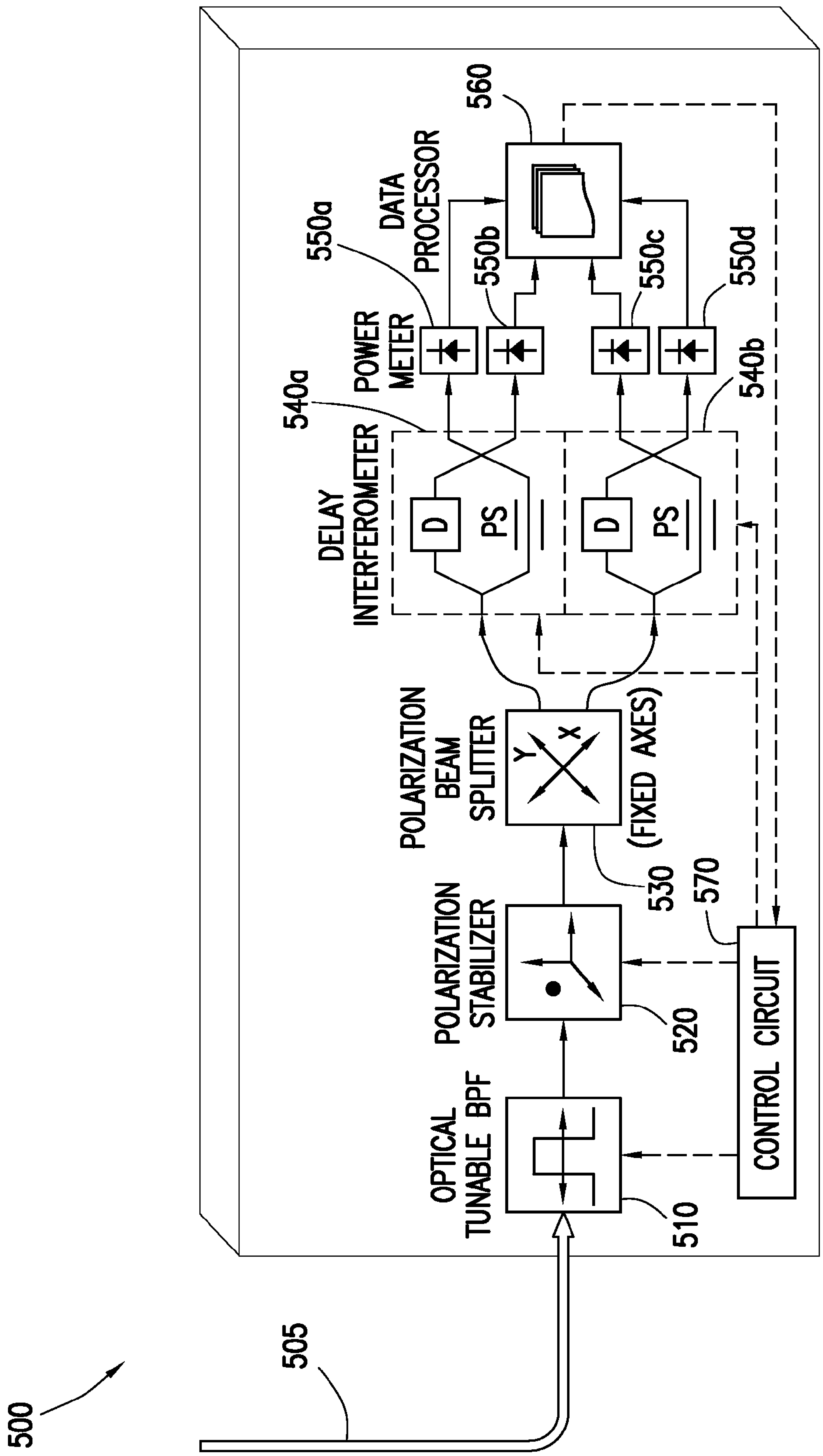

500
505
OPTICAL TUNABLE BPF
510
POLARIZATION STABILIZER
520
POLARIZATION BEAM SPLITTER
Y
X
(FIXED AXES)
530
570
CONTROL CIRCUIT
DELAY INTERFEROMETER
D
PS
540a
540b
POWER METER
550a
550b
550c
550d
DATA PROCESSOR
560

FIG. 5

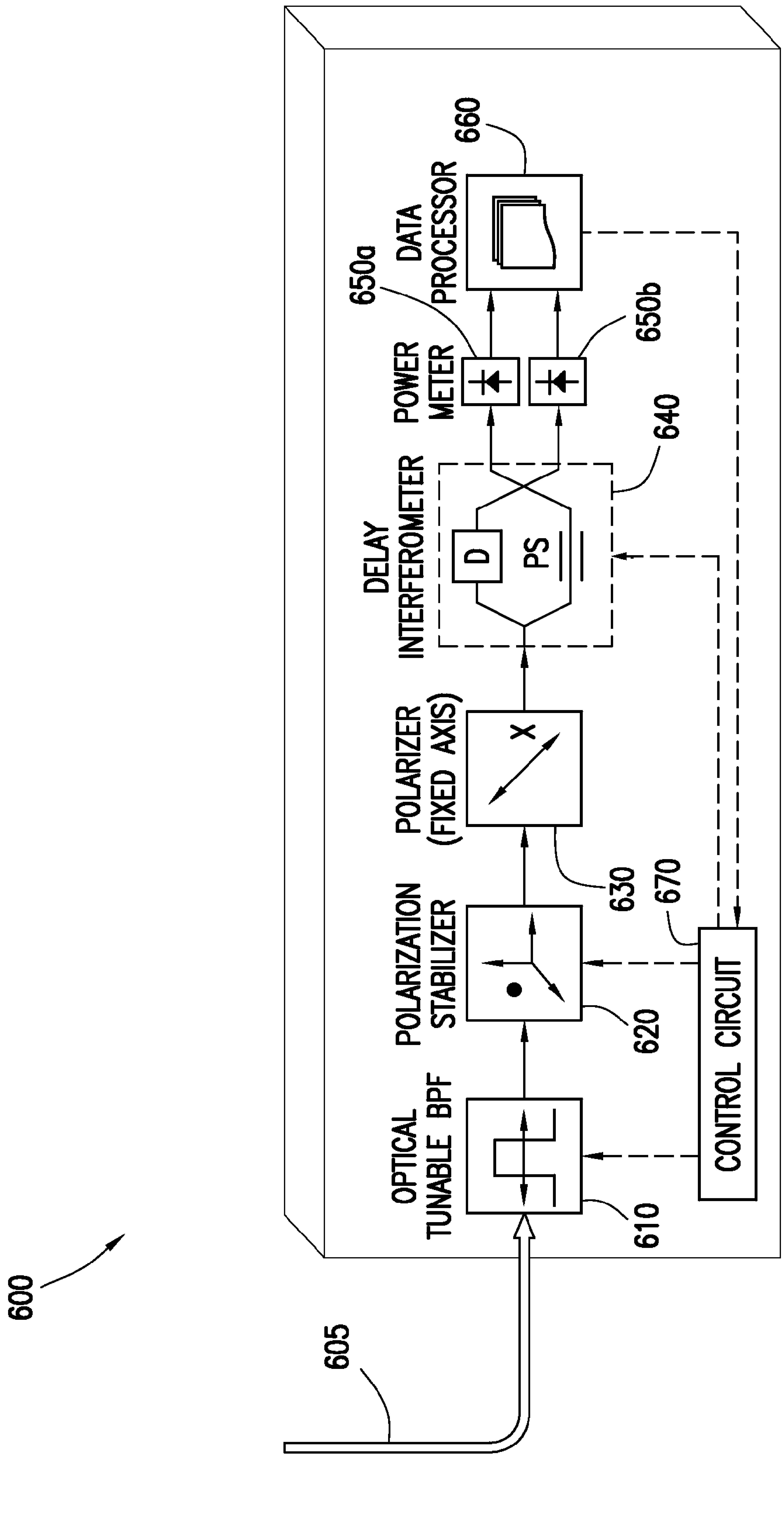

600
605
OPTICAL TUNABLE BPF
610
POLARIZATION STABILIZER
620
POLARIZER (FIXED AXIS)
X
630
DELAY INTERFEROMETER
D
PS
640
POWER METER
650a
650b
DATA PROCESSOR
660
CONTROL CIRCUIT
670

FIG. 6

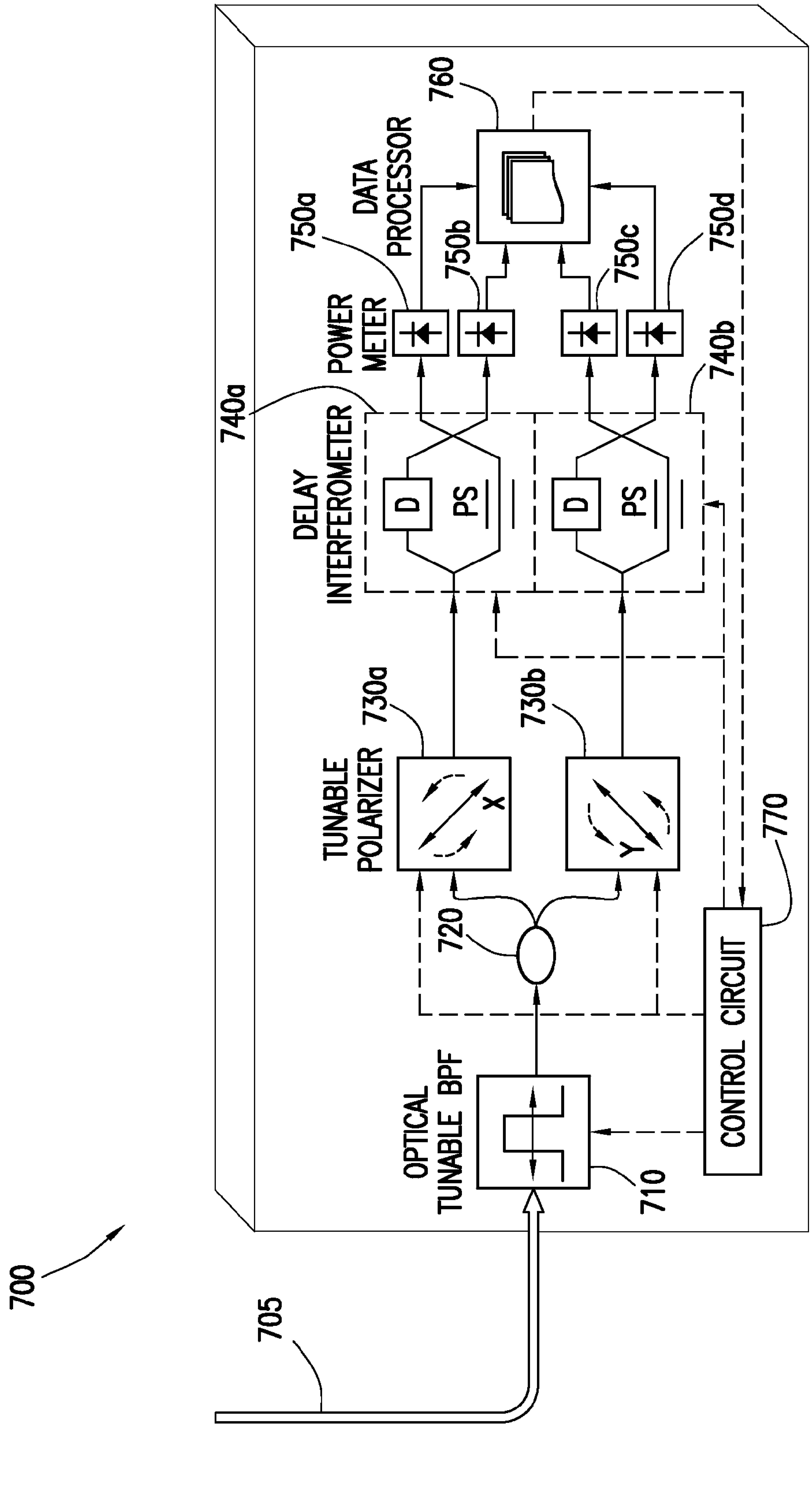

700
705
OPTICAL TUNABLE BPF
710
720
TUNABLE POLARIZER
730a
730b
X
Y
DELAY INTERFEROMETER
740a
740b
D
PS
POWER METER
750a
750b
750c
750d
DATA PROCESSOR
760
CONTROL CIRCUIT
770

FIG. 7

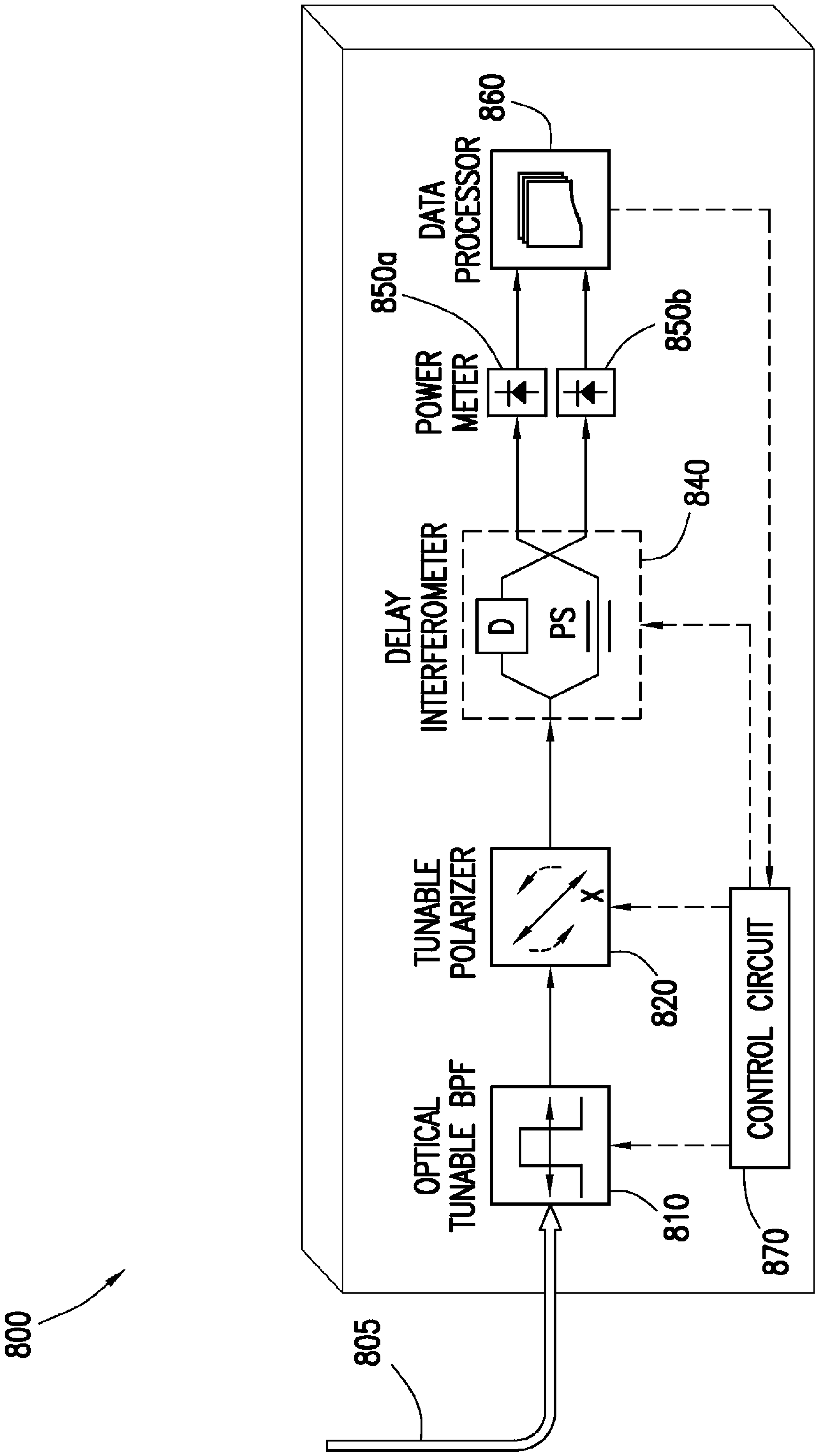

800
805
OPTICAL TUNABLE BPF
810
TUNABLE POLARIZER
820
DELAY INTERFEROMETER
D
PS
840
POWER METER
850a
850b
DATA PROCESSOR
860
CONTROL CIRCUIT
870

FIG. 8

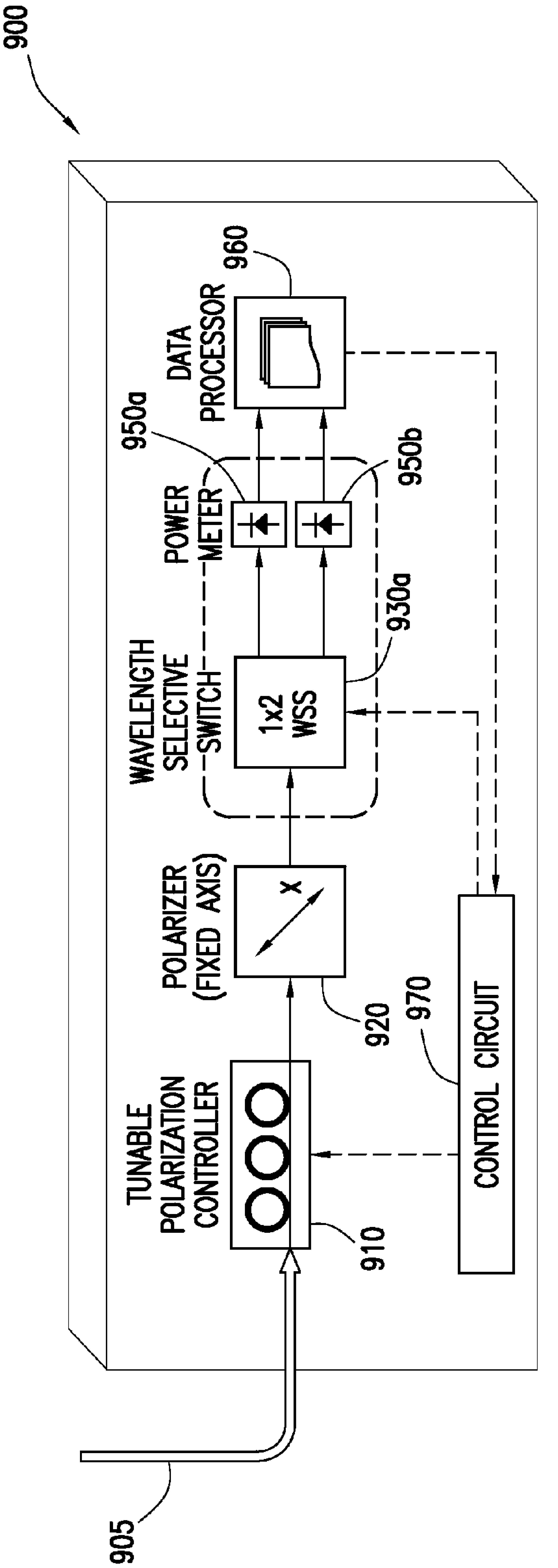

900
TUNABLE POLARIZATION CONTROLLER
POLARIZER (FIXED AXIS)
X
WAVELENGTH SELECTIVE SWITCH
1x2 WSS
POWER METER
DATA PROCESSOR
CONTROL CIRCUIT
905
910
920
930a
950a
950b
960
970

FIG. 9A

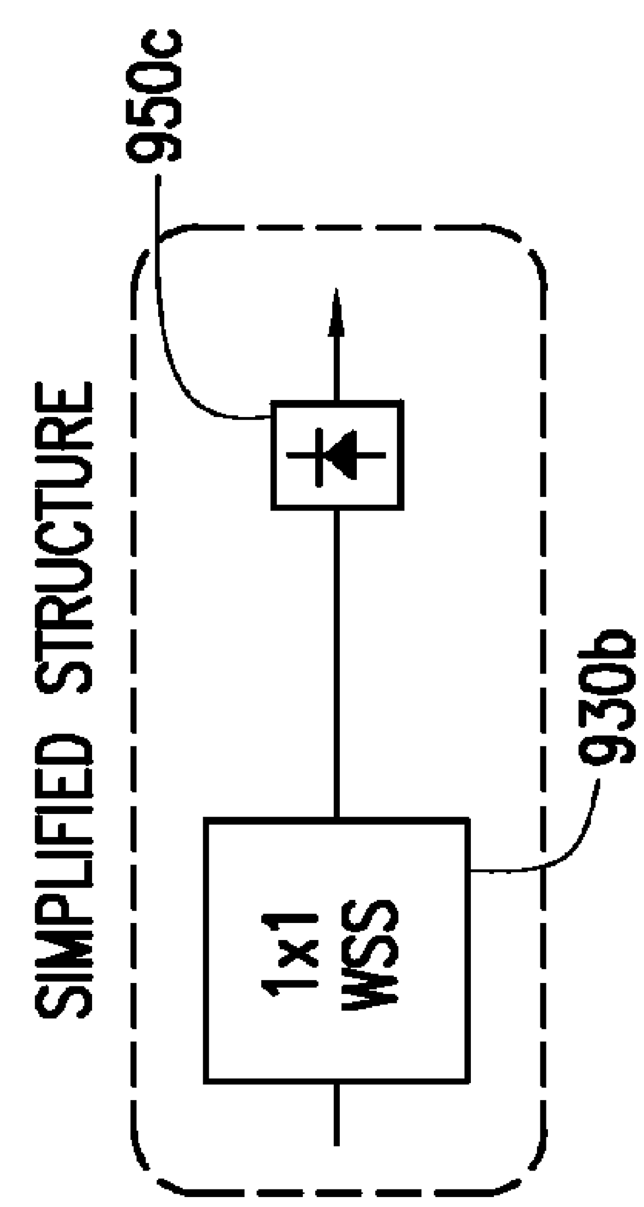

SIMPLIFIED STRUCTURE
1x1 WSS
930b
950c

FIG. 9B

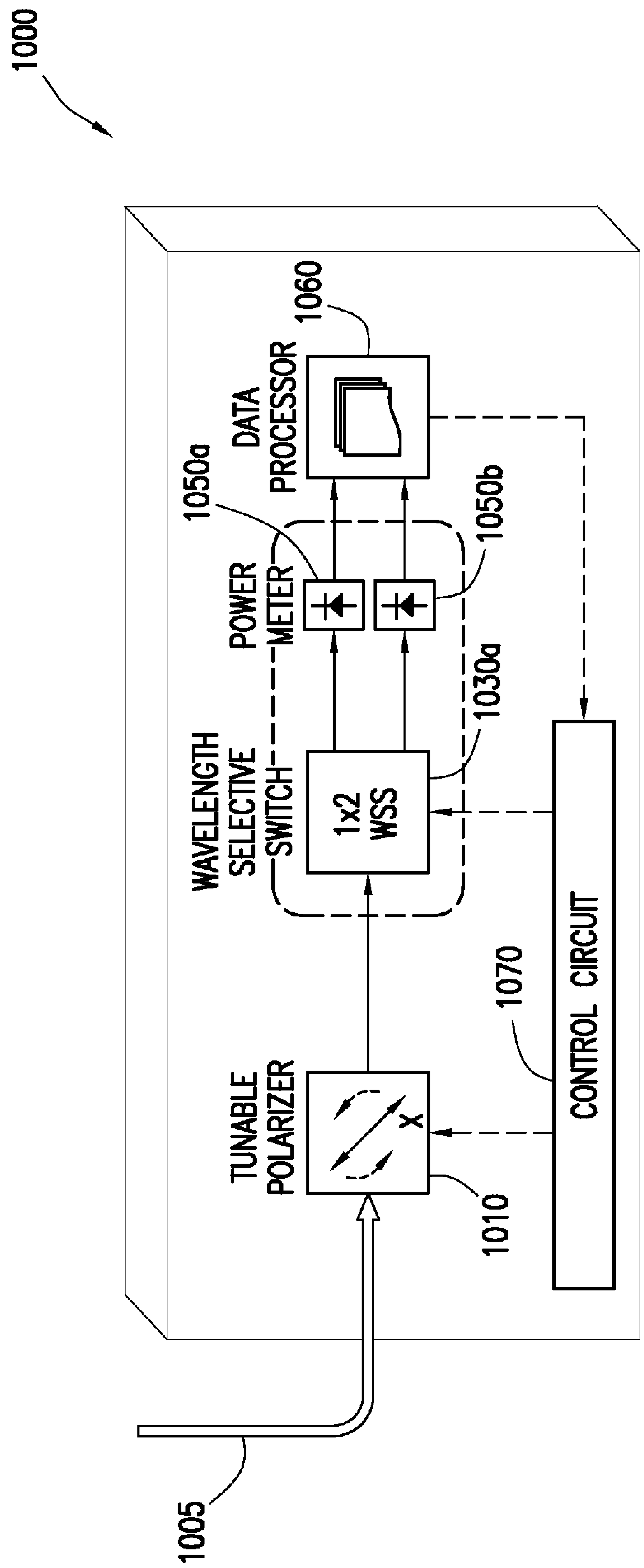


FIG. 10A

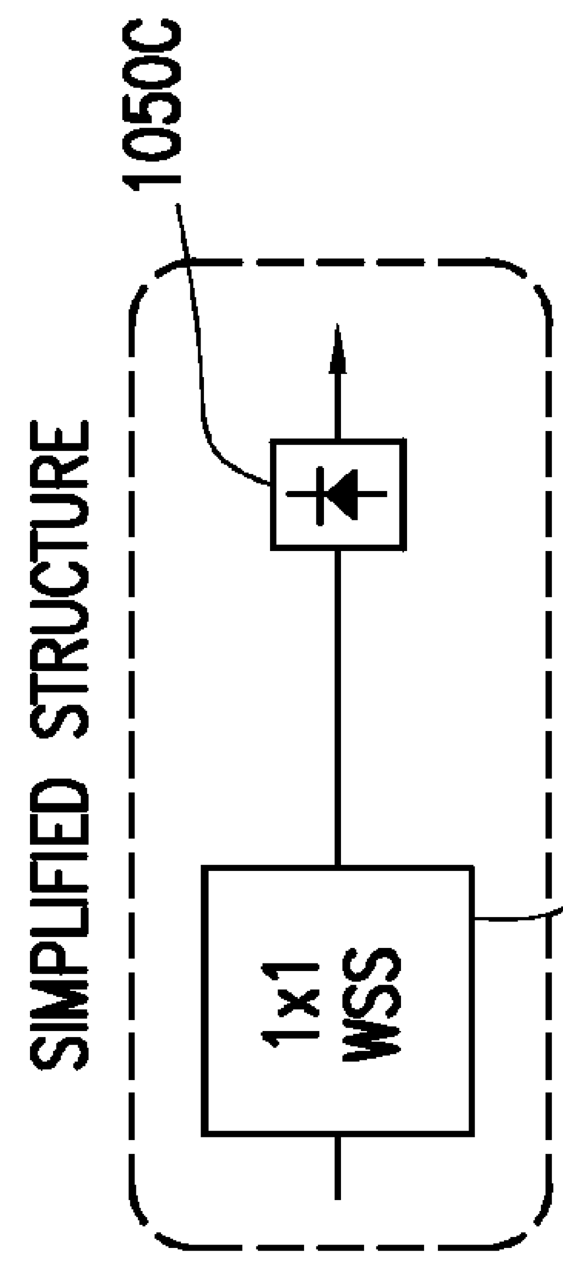


FIG. 10B

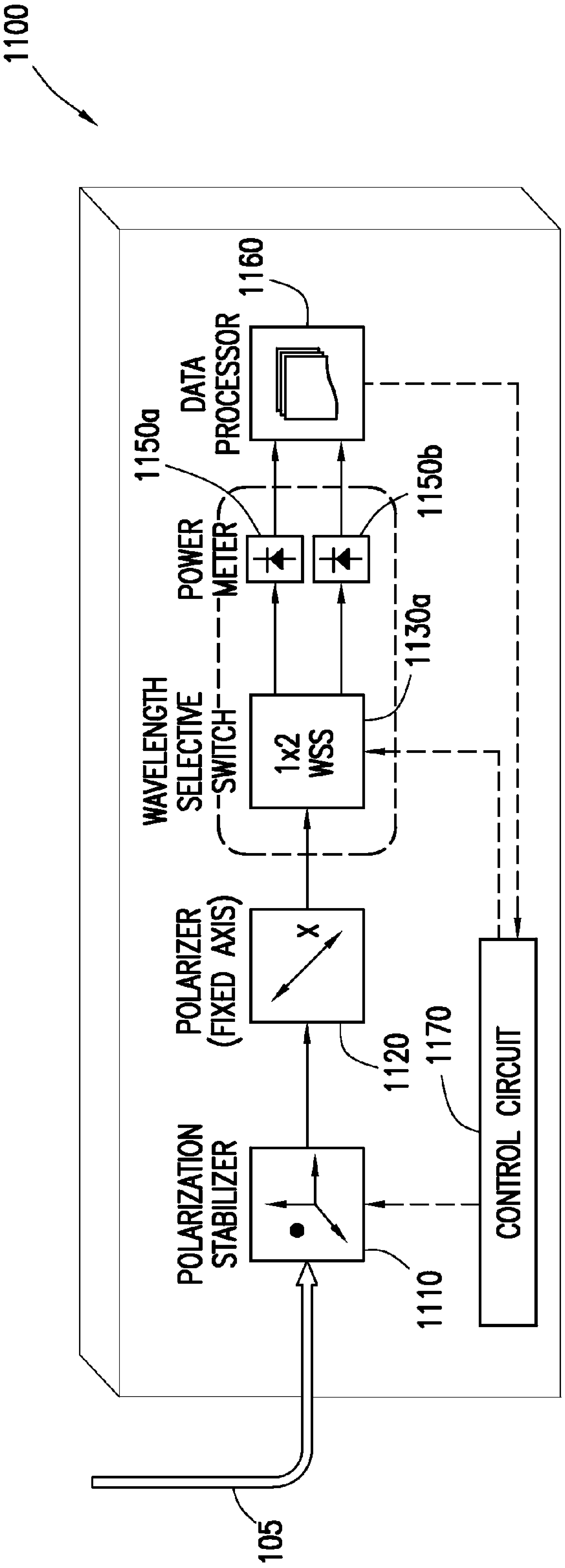


FIG. 11A

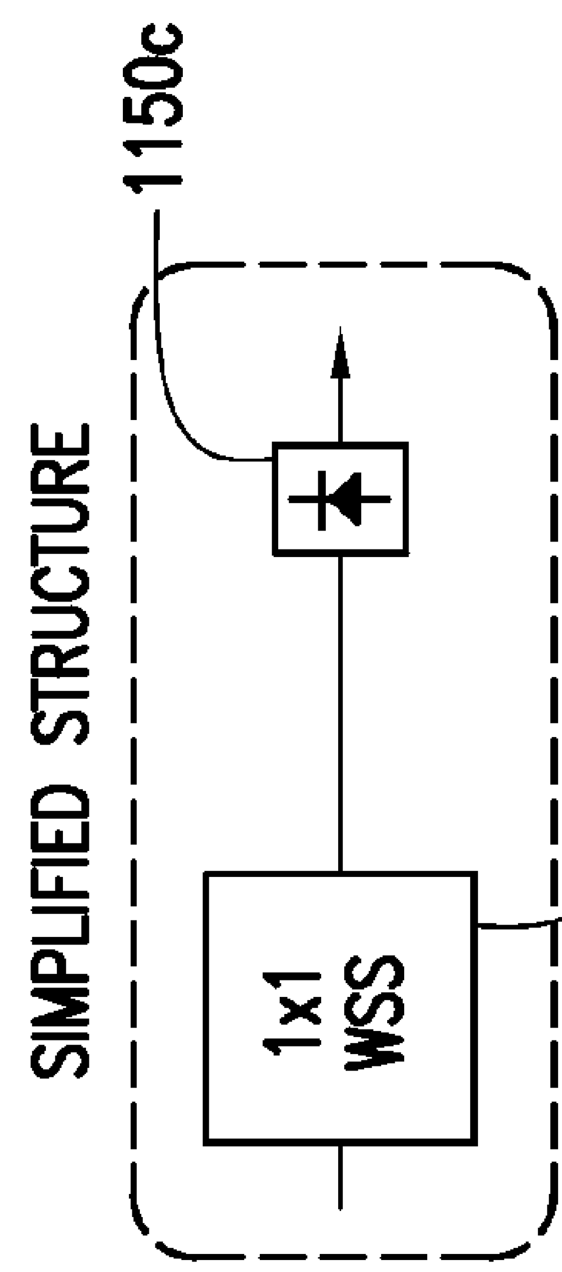


FIG. 11B

CORRECTION TABLE FOR INTERFEROMETRIC OPTICAL SIGNAL-TO-NOISE RATIO MONITOR

TECHNICAL FIELD OF THE DISCLOSURE

The present disclosure relates generally to optical communication networks and, more particularly, to a correction table for an interferometric optical signal-to-noise ratio (OSNR) monitor.

BACKGROUND

Telecommunications systems, cable television systems and data communication networks may use optical networks to rapidly convey large amounts of information between remote points. In an optical network, information may be conveyed in the form of optical signals through optical fibers. Optical fibers may comprise thin strands of glass capable of communicating the signals over long distances with very low loss.

One consideration in analyzing the effectiveness of communicating a signal is the optical signal-to-noise ratio (OSNR). This value may indicate the instantaneous quality of a signal. As a signal passes through a network, it may lose signal strength or may increase in noise, resulting in a decrease of the overall OSNR. If OSNR drops below a certain point, the signal may be unreadable at a desired destination. Thus, it may be desirable to measure OSNR.

OSNR may be represented by the relationship in Equation (1).

$$OSNR[\mathrm{dB}] = 10 \times \log\left(\frac{P_{sig}}{P_{noise}}\right) \tag{1}$$

where P_{sig} represents the power of the signal to be measured (for example, the magnitude of signal strength), and P_{noise} represents the power of the noise. For example, for optical signals, this may represent the intensity of light.

Optical networks often carry different signals at different wavelengths of light as optical signals, which may be referred to as data-carrying wavelengths. When measuring for OSNR, the noise may be monitored only at a specific bandwidth that may or may not correspond to a data-carrying wavelength. Such noise may be referred to as "out-of-band" noise. In contrast, "in-band" noise is the noise that is present at the bandwidth band for the optical signal that is actually being monitored, for example, at the data-carrying wavelength. The value of OSNR may be different for different data-carrying wavelengths within an optical signal as the "in-band" noise may be different at those different wavelengths.

Optical networks often employ modulation schemes to convey information in the optical signals over optical fibers. Such modulation schemes may include phase-shift keying ("PSK"), frequency-shift keying ("FSK"), amplitude-shift keying ("ASK"), and quadrature amplitude modulation ("QAM").

In PSK, the information carried by the optical signal may be conveyed by modulating the phase of a reference signal, also known as a carrier wave. The information may be conveyed by modulating the phase of the signal itself using differential phase-shift keying ("DPSK").

In QAM, the information carried by the optical signal may be conveyed by modulating both the amplitude and phase of the carrier wave. PSK may be considered a subset of QAM, wherein the amplitude of the carrier waves is maintained as a constant.

PSK and QAM signals may be represented using a complex plane with real and imaginary axes on a constellation diagram. The points on the constellation diagram representing symbols carrying information may be positioned with uniform angular spacing around the origin of the diagram. The number of symbols to be modulated using PSK and QAM may be increased and thus increase the information that can be carried. The number of signals may be given in multiples of two. As additional symbols are added, they may be arranged in uniform fashion around the origin. PSK signals may include such an arrangement in a circle on the constellation diagram, meaning that PSK signals have constant power for all symbols. QAM signals may have the same angular arrangement as that of PSK signals, but include different amplitude arrangements. QAM signals may have their symbols arranged around multiple circles, meaning that the QAM signals include different power for different symbols. This arrangement may decrease the risk of noise as the symbols are separated by as much distance as possible. A number of symbols "m" may thus be used and denoted "m-PSK" or "m-QAM."

Examples of PSK and QAM with a different number of symbols can include binary PSK ("BPSK" or "2-PSK") using two phases at 0° and 180° (or 0 and π) on the constellation diagram; or quadrature PSK ("QPSK", "4-PSK", or "4-QAM") using four phases at 0°, 90°, 180°, and 270° (or 0, $\pi/2$, π, and $3\pi/2$). Phases in such signals may be offset. This may be extended, for example, up to 16-QAM, using sixteen phases. These various signals (for example, 2-PSK or 16-QAM) may be arranged in one circle on the constellation diagram.

M-PSK signals may also be polarized using techniques such as dual-polarization QPSK ("DP-QPSK"), wherein separate m-PSK signals are multiplexed by orthogonally polarizing the signals. Additionally, M-QAM signals may be polarized using techniques such as dual-polarization M-QAM ("DP-M-QAM"), wherein separate M-QAM signals are multiplexed by orthogonally polarizing the signals.

SUMMARY

In one embodiment, the present disclosure includes a computing processor-implemented method for generating a correction table for correcting measured optical signal-to-noise ratio (OSNR) comprising receiving an optical signal and detecting, by a controller, an artifact associated with a measured OSNR of the optical signal. The method also includes calculating, by the controller, a correction function to counteract the artifact, the correction function varying over the measured OSNR, and storing the correction function in the correction table in a non-transitory computer readable medium.

In another embodiment, the present disclosure includes a computing processor-implemented method of correcting a measured optical signal-to-noise ratio (OSNR) comprising receiving an optical signal and measuring OSNR of the optical signal using an interferometric OSNR monitor device. The method also includes applying a correction table to the measured OSNR to generate a corrected OSNR using a controller, the correction table comprising a correction function to counteract an artifact in the measured OSNR. The method additionally includes storing the corrected OSNR in a non-transitory computer-readable medium.

In a further embodiment, the present disclosure includes a device for correcting a measured optical signal-to-noise ratio (OSNR) of an optical signal, the device comprising a monitor device configured to generate values from which OSNR of the optical signal may be measured and a controller configured to measure the OSNR of the optical signal using the values generated by the monitor device and apply a correction table to the measured OSNR to generate a corrected OSNR, the correction table comprising a correction function to counteract an artifact in the measured OSNR. The device also includes a non-transitory computer readable medium to receive the corrected OSNR from the controller and store the corrected OSNR.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and its features and advantages, reference is now made to the following description, taken in conjunction with the accompanying drawings, in which:

FIG. **1** illustrates an example embodiment of a system for measuring and correcting optical signal-to-noise ratio (OSNR), in accordance with the present disclosure;

FIGS. **2**A and **2**B illustrate example devices for generating and applying a correction table for correcting OSNR, in accordance with the present disclosure; and

FIGS. **3**-**11**B illustrate various alternative embodiments of a device for measuring and correcting OSNR when an optical signal has a plurality of polarization components, in accordance with the present disclosure.

DETAILED DESCRIPTION

The present disclosure relates to correcting a measured optical signal-to-noise ratio (OSNR) using an interferometric monitor. When measuring for OSNR, artifacts may be present in the measured value for the OSNR. These artifacts may be introduced by the hardware used in transmitting the optical signal, receiving the optical signal, or even monitoring the OSNR. Such artifacts may cause an incorrect measurement of OSNR, particularly in instances of high or low OSNR. By introducing a correction table to be applied to the measured OSNR, the artifacts may be counteracted and the correct OSNR may be reported or recorded.

FIG. **1** illustrates an example embodiment of a network where it may be desirable to measure OSNR, and have a corrected measurement thereof. The network may include a node **110** that may comprise an OSNR monitor device, for example, OSNR monitor devices **120**A and **120**B for measuring in-band noise, a node controller **130**, and a switching device **140**. Node **110** may receive an incoming signal **150**, and may include a signal splitter to split incoming signal **150** into a major component **154** and a minor component **152**. Node **110** may also include a signal splitter to split an outgoing signal **160** into a minor component **162** and a major component **164**. The OSNR monitor devices **120**A and **120**B may be configured both to measure OSNR and to apply a correction table to the measured OSNR.

The network may include one or more transmission media operable to transport one or more signals communicated by components of the network. The components of the network, coupled together by transmission media, may include a plurality of network elements or nodes **110**. In the network, each node **110** may be coupled to one or more other nodes **110**. However, any suitable configuration of any suitable number of nodes **110** may create the network. The network may be configured as a shared mesh network, ring network, a point-to-point network, or any other suitable network or combination of networks. The network may be used in a short-haul metropolitan network, a long-haul inter-city network, or any other suitable network or combination of networks. The network may represent all or a portion of a short-haul metropolitan network, a long-haul inter-city network, and/or any other suitable network or combination of networks.

Each transmission medium may include any system, device, or apparatus configured to communicatively couple nodes **110** to each other and communicate information between corresponding nodes **110**. For example, a transmission medium may include an optical fiber, an Ethernet cable, a T1 cable, copper cable, a WiFi signal, a Bluetooth signal, or other suitable medium. In embodiments of the present disclosure, optical fibers may include thin strands of glass capable of communicating signals over long distances with very low loss. Optical fibers may include any suitable type of fiber, such as a Single-Mode Fiber (SMF), Enhanced Large Effective Area Fiber (ELEAF), or a TrueWave® Reduced Slope (TW-RS) fiber. The capacity of network **100** may include, for example, 40 Gbit/s, 100 Gbit/s, 400 Gbit/s, or 1 Tbit/s. Information may be transmitted and received through the network by modulation of one or more wavelengths of light to encode the information on the wavelength. Additionally, information may be transmitted and received by modulation of one or more polarizations of light to encode the information in various polarization components, for example x-polarization and y-polarization components. In optical networking, a wavelength of light may also be referred to as a channel. Each channel may be configured to carry a certain amount of information through the network.

The network may communicate information or "traffic" over transmission media. Traffic may include information transmitted, stored, or sorted in the network. Such traffic may comprise optical or electrical signals configured to encode audio, video, textual, and/or any other suitable data. The data may be real-time or non-real-time. Traffic may be communicated via any suitable communications protocol, including, without limitation, the Open Systems Interconnection (OSI) standard and Internet Protocol (IP). Additionally, the traffic communicated in network **100** may be structured in any appropriate manner including, but not limited to, being structured in frames, packets, or an unstructured bit stream.

Node **110** may include any suitable system operable to transmit and receive traffic. In the illustrated embodiment, node **110** may be operable to transmit traffic directly to one or more other nodes and receive traffic directly from one or more other nodes. Node **110** may include any suitable arrangement of components operable to perform the operations of node **110**. As an example, node **110** may include logic such as hardware, software, other logic, and/or any other suitable combination of the preceding. Logic may include any suitable device operable to execute instructions and manipulate data to perform operations, for example, a processor, microprocessor, field-programmable gate array (FPGA), or application specific integrated circuit (ASIC). Node controller **130** may be the implementation of the logic for node **110**. Node **110** may include an interface operable to receive input, send output, process the input and/or output, or any combination of the preceding. An interface may include ports, conversion software, or both. Node **110** may include memory, such as, logic operable to store and facilitate retrieval of information. Memory may include Random Access Memory (RAM), Read Only Memory (ROM), a magnetic drive, a disk drive, a Compact Disk (CD) drive, a Digital Video Disk (DVD) drive, removable media storage, any other suitable data storage medium, or a combination of any of the preceding, and/or any other suitable components. Node **110** may be implemented as an electronic device.

While node **110** may be illustrated as receiving input signal **150** from the left and outputting signal **160** to the right, it will be appreciated that this is merely for convenience and node **110** may likewise communicate from right to left, or in any number of degrees or directions.

In certain embodiments of the present disclosure, node **110** may be configured to transmit optical signals through the network in specific wavelengths or channels, as well as specific polarizations. For example, the optical signals may include dual-polarization components, x-polarization and y-polarization components orthogonal to each other. These axes may be rotated or shifted to varying degrees. Node **110** may include any system, apparatus or device configured to convert an electrical signal into an optical signal and transmit the optical signal. For example, node **110** may comprise a laser and a modulator configured to receive electrical signals and modulate the information contained in the electrical signals onto a beam of light produced by the laser at a particular wavelength and/or polarization and transmit the beam carrying the signal throughout the network. Node **110** may include client cards, switches, such as, wavelength selective switches, optical transport network (OTN) switches, line cards, one or more multiplexers, one or more amplifiers, one or more reconfigurable optical add/drop multiplexers (ROADM), and/or one or more receivers. For example, node **110** may include switching device **140** that may be any system or device configured to route major component **154** of incoming signal **150** to other nodes in the network. Node controller **130** may comprise logic to direct and control switching device **140**.

As shown in FIG. **1**, node **110** may receive an input signal **150**. Node **110** may include a signal splitter configured to split input signal **150** into a major component **154** and a minor component **152**. In some embodiments, major component **154** may include 90-95% of the power of the optical signal, and minor component **152** may include 5-10% of the power of the optical signal. In other embodiments, major component **154** may include 95-99% of the power of the optical signal, and minor component **152** may include 1-5% of the power of the optical signal. Major component **154** may be routed within node **110** to switching device **140**, and may then be routed out of node **110** to other areas of network **100**. Minor component **152** may be routed within node **110** to OSNR monitor device **120**A.

In like manner, node **110** may include a signal splitter configured to split output signal **160** into a major component **164** and a minor component **162**. In some embodiments, major component **164** may include 90-95% of the power of the optical signal, and minor component **162** may include 5-10% of the power of the optical signal. In other embodiments, major component **164** may include 95-99% of the power of the optical signal, and minor component **162** may include 1-5% of the power of the optical signal. Major component **164** may be routed external to node **110**, for example, to another node of the network. Minor component **162** may be routed within node **110** to OSNR monitor device **120**B. While OSNR monitor devices **120**A and **120**B are shown as separate components, it will be appreciated that the same physical components may be used. For example, both minor components **152** and **162** may be routed to the same components. In some embodiments, only one of OSNR monitor devices **120**A and **120**B may be present. For example, node **110** may only measure and correct OSNR on incoming signals **150** or outgoing signals **160**. Further, while two OSNR monitor devices **120**A and **120**B may be illustrated, it will be appreciated that many more OSNR monitor devices may be included within node **110**. Additionally, while the remainder of examples may refer to minor component **152**, it will be appreciated that minor component **162** may also be used, or any other of a variety of optical signals.

While OSNR monitor devices **120**A and **120**B may be illustrated as part of node **110**, it will be appreciated that an OSNR monitor device may be implemented in any of a variety of locations or devices throughout network **100**. For example, and in no way limiting, an OSNR monitor device may be incorporated in one or more line cards, as a sub-component to a switching device, as sub-component to an add-drop multiplexer, or any combinations thereof.

FIG. **2**A illustrates an example embodiment of a device for monitoring and correcting optical signal-to-noise ratio (OSNR). As shown in FIG. **2**A, an OSNR monitor device **120** may receive an optical signal **205**. Optical signal **205** may be monitored by signal monitor device **210** prior to receiving optical signal **205** at OSNR monitor device **120**. OSNR monitor device **120** may include a monitoring device **121** and a controller **128**. Monitoring device **121** may detect and measure various optical signal values, which may be used to determine OSNR as described below. These optical signal values may be passed to controller **128** to measure OSNR. Once OSNR has been measured, controller **128** may apply a correction table to the value of OSNR to more accurately measure the OSNR by counteracting artifacts in the optical signal. OSNR monitor device **120** may measure in-band noise in determining OSNR.

Monitoring device **121** may include a wavelength treatment device **124**, a polarization treatment component **122**, an interferometer **125**, and a power meter **126**. Each of the components of monitoring device **121** may be in communication with each other and with controller **128**, and each of these components may pass optical signal **205** among or between any other components, either with or without any treatment, filtering, or other handling of optical signal **205**. For example, wavelength treatment device **124** may filter out a particular wavelength of optical signal **205**, and then pass the filtered wavelength to polarization treatment device **122**. Polarization treatment device **122** may filter or otherwise separate out one polarization component of optical signal **205** and then pass the filtered portion of optical signal **205** to interferometer **125**. Interferometer **125** may perform delaying or phase-shifting of optical signal **205** to arrive at the constructive or destructive interference with a copy of the optical signal. Optical signal **205** may then be passed to power meter **126**. Power meter may measure the strength of the outputs of interferometer **125** and may pass that information to controller **128**. The various components of monitoring device **121** will be described in more detail below.

Polarization treatment device **122** may be any system, device, circuitry, or combination thereof operable to separate polarization components and/or tune polarization of an optical signal, for example, selecting a single polarization component from a plurality of polarization components within an optical signal. In some embodiments, polarization treatment device **122** may be configured to rotate, align, or fix the polarization of an optical signal. Polarization treatment device **122** may be configured to split optical signal **205** into two separate pieces, modify one piece a certain way, and modify the other piece another. For example, polarization treatment device **122** may split optical signal **205** into x-polarization and y-polarization components that may be individually tuned, analyzed, and monitored for OSNR. Polarization treatment device **122** may be implemented as a variety of sub-components that perform any of the desired tasks. For example, polarization treatment device **122** may comprise any of a tunable polarization controller, a polarization beam splitter (for example a fixed axes beam splitter), a polarizer (for example a fixed-axis polarizer), a polarization stabilizer (for example a fixed axes stabilizer), a tunable polarizer, or any combination thereof, including combinations of more than one of the same above-mentioned components (for example two tunable polarizers). In some embodiments, monitoring device **121** may not include a polarization treatment device **122** (indicated by the dashed lines of polarization treatment device **122**). In such an embodiment, the optical signal may not include polarization components. Alternatively, OSNR monitor device **120** may average the signal-to-noise ratio for the different polarization components within the optical signal.

Wavelength treatment device **124** may be any system, device, circuitry, or combination thereof operable to perform at least one of selecting a single wavelength from a plurality of wavelengths within an optical signal, delaying an optical signal, or shifting the phase of an optical signal. In some embodiments, wavelength treatment device **124** may split an incoming optical signal, for example, optical signal **205**, into two paths for separate handling, for example, for delaying and phase shifting. Wavelength treatment device **124** may be implemented as a variety of sub-components that perform any of the desired tasks. For example, wavelength treatment device **124** may comprise any of an optical tunable band pass filter, a delay interferometer, a 1×2 wavelength selective switch (i.e. a wavelength selective switch with one input and two outputs), a 1×1 wavelength selective switch (i.e. a wavelength selective switch with one input and one output), or any combination thereof, including combinations of more than one of the same above-mentioned components (for example two delay interferometers).

Interferometer **125** may be any system, device, circuitry, or combination thereof operable to delay an optical signal, shift the phase of an optical signal, and cause optical signals to interfere with each other. In some embodiments, interferometer **125** may split an incoming optical signal, for example, optical signal **205**, into two paths for separate handling, for example, for delaying and phase shifting. Interferometer **125** may be implemented as a variety of sub-components that perform any of the desired tasks. In some embodiments, interferometer may have a portion that is variable for both phase-shifting and for delay. Such a variable portion may be under the direction of controller **128**. A first portion of an optical signal input to interferometer **125** may be delayed and phase-shifted by a first amount and caused to interfere with a copy of the optical signal to cause constructive interference. The constructive interference may be an output of interferometer **125**. A second portion of an optical signal input to interferometer **125** may be delayed and phase-shifted, but phase-shifted by the first amount an additional π radians, and caused to interfere with a copy of the optical signal to cause destructive interference. The destructive interference may be an output of interferometer **125**. The amount of delay and/or phase-shifting may be determined by the controller based on a variety of factors, including modulation format, bandwidth (for example, the speed of the network), wavelength to be analyzed, or wavelength drift.

Power meter **126** may be any system, device, circuitry, or combination thereof operable to measure the magnitude of a given signal. For example, power meter **126** may be a photodiode that generates current in accordance with reception-light power of an optical signal being passed to power meter **126**. OSNR monitor device **120** may include multiple power meters **126**. For example, OSNR monitor device **120** may have two power meters for each delay interferometer.

Controller **128** may be any system, device, circuitry, or combination thereof operable to calculate, determine, measure, or correct OSNR based on received inputs from any of polarization treatment device **122**, wavelength treatment device **124**, power meter **126**, signal monitor device **210**, or combinations thereof. Controller **128** may include a processor, microprocessor, microcontroller, DSP, ASIC, or any other digital or analog circuitry for executing the instructions resident upon a computer-readable medium. Controller **128** may also include computer-readable medium for storage of instructions to facilitate controller **128** performing its functions, for storage of a correction table to be applied to a measured OSNR, for storage of a determined or corrected OSNR or inputs received from other components of node **110** and/or OSNR monitor device **120** to facilitate operation of OSNR monitor device **120**.

Controller **128** may calculate OSNR according to equation (2):

$$OSNR[\mathrm{dB}] = 10\times\log\left[\left(\frac{(a+1)\cdot(s-a)}{\left(\frac{P2}{P1}-a\right)\cdot(s+1)} - \frac{a+1}{s+1}\right)^{-1}\cdot\frac{B}{R}\right] \tag{2}$$

in which OSNR is the value of the optical signal-to-noise ratio, measured in decibels (dB), the set (s, a) are the power distribution and calibration factors associated with signal (s) and noise (a), P2 is the power measured from constructive interference, P1 is the power measured from destructive interference, B is the bandwidth of the optical signal being measured, and R is the measurement resolution. The values of the set (s, a) may be constants dependent on the modulation scheme used for the optical signal, and may be determined beforehand for an OSNR monitor device.

In some embodiments, controller **128** may provide direction or instructions to other components of OSNR monitor device **120**. For example and in no way limiting, controller **128** may direct polarization treatment device **122** to rotate the polarization of optical signal **205** in a certain way and then select out the x-polarization component of optical signal **205**. As an alternative illustrative example, controller **128** may direct wavelength treatment device **124** to filter out all of optical signal **205** besides a particular wavelength. As a further example, controller **128** may direct interferometer **125** with respect to the amount of delay to be used and an amount of phase shifting to occur. As an additional example, controller **128** may apply a correction table **129** to a measured OSNR to counteract an artifact in the optical signal.

An artifact may be any variation, error, or change introduced in the handling, processing, or filtering of an optical signal, which may cause an erroneous measurement of the OSNR. For example, an artifact may include a pass-band narrowing effect, an optical filter's frequency offset, and a transmitter's frequency offset. A pass-band narrowing effect may be experienced when an optical signal is passed through multiple spans or sections of a network. At various hardware components at nodes between spans or sections of the network (for example, a wavelength selective switch), filtering and processing may be performed on the optical signal. There may be a narrowing of the signal band over time as various portions are clipped off the edges in the filtering and processing at the hardware before the optical signal is passed along. This may result in an erroneous measurement of the OSNR.

As described above, a tunable optical filter may be used in some embodiments. Such a filter may be imprecise or may experience drift up or down when filtering an optical signal, for example by plus or minus one gigahertz (GHz). This may be because of the hardware used, limitations of the network, or other causes. This may result in portions of the signal being clipped during measuring of OSNR, while the signal is actually present in the optical signal. This is referred to as the optical filter's frequency offset and may result in an erroneous measurement of the OSNR.

In addition to the optical filter's frequency offset, the transmitter sending the optical signal may also experience some imprecision or drift. For example, a transmitting laser may drift in wavelength by plus or minus one GHz. This may be referred to as the transmitter's frequency offset and may also result in an erroneous measurement of the OSNR.

Correction table **129** may be generated to be used to counteract artifacts in the optical signal. Controller **128** may be configured to generate correction table **129**. Correction table **129** may include one or more correction functions of error introduced by artifacts in the measured OSNR. For example, an optical signal with a known OSNR may be introduced into an OSNR monitor known to experience a particular artifact or artifacts. The difference between the known OSNR and the measured value may be used to generate the correction function at the given OSNR value. This may be repeated for multiple values of OSNR and any intermediate points may be interpolated to generate a correction function of the error introduced by a particular artifact or artifacts. In some circumstances, an artifact may cause a non-linear error to a measured OSNR. For example, some artifacts may cause a larger error at low (for example, below fifteen dB) and/or high (for example, above twenty-five dB) values of OSNR. By generating a correction function of the error introduced by the artifact, this non-linearity may still be addressed and any error introduced by the artifact may be counteracted. Additionally, this may allow the accurate measurement of OSNR for a broad range of values, for example, from between five and thirty-five dB. The two extremes of this range may have increased artifact effects because at low values, the signal and noise are more closely related, and at high values, the signal dominates the noise, making accurate measurements difficult.

After it has been generated, the correction function may be stored as part of correction table **129** in a computer readable medium that is accessible by controller **128**. In some embodiments, correction table **129** may be generated and then disseminated to various other OSNR monitors throughout the network. In some embodiments, the OSNR monitor used to generate correction table **129** may not be attached to an actively used network, and may be generated in a lab or otherwise controlled environment.

Correction table **129** may counteract errors in the measured OSNR such that the measured OSNR value is within a certain accuracy range of the actual OSNR value. For example, any artifact-induced error may be counteracted such that the measured OSNR is within one dB of the actual OSNR, within 0.5 dB of the actual OSNR, within 0.25 dB of the actual OSNR, or may be counteracted such that there is a negligible or undetectable difference between the measured OSNR and the actual OSNR value.

Signal monitor device **210** may be any system, device, circuitry, or combination thereof operable to monitor an optical signal being monitored at OSNR monitor device **120**. For example, signal monitor device **210** may be operable to monitor modulation format, bandwidth (for example, the speed of the network traffic), wavelength to be analyzed, number of sections of network that the optical signal has passed through, and optical or wavelength drift (for example, that caused by temperature variations or laser errors). Signal monitor device **210** may be in communication with controller **128** to provide any or all of the information obtained by signal monitor device **210**. This information may assist controller **128** in controlling the various components of OSNR monitor device **120**, in determining OSNR for an optical signal, or in correcting the measured OSNR. For example, controller **128** may modify the phase-shift of interferometer **125** based on the modulation format of the signal, or may modify the amount of delay based on the speed of the network.

While signal monitor device **210** may be shown as being a passive monitor to an incoming signal that simply passes through the signal, it will be appreciated that signal monitor device **210** may include a splitter (for example, a 3 dB splitter) that takes a portion of an optical signal to measure or monitor a desired characteristic, which may terminate that portion of the optical signal, and may pass the other portion of the signal along to OSNR monitor device **120**. Alternatively, it will be appreciated that such monitoring may be done elsewhere within node **110** or elsewhere within the network, and any desired information regarding a desired characteristic (for example, bandwidth) may be sent to OSNR monitor device **120**. Additionally, while shown as being located before OSNR monitor device **120**, signal monitor device **210** may be an integral part of OSNR monitor device **120**. For example, signal monitor device **210** may be located between wavelength treatment device **124** and polarization treatment device **122**.

The information gathered by signal monitor device **210** may be beneficial in correcting the measured OSNR. For example, monitor device **210** may detect certain types of artifacts, the bandwidth of the optical signal to be monitored, the power of the signal to be monitored, the number of spans of the network the signal has traversed, the frequency drift of the transmitter, or the modulation scheme. Controller **128** may utilize a different correction function for any of the different parameters detected by signal monitor device **210**.

In some embodiments, the correction function may be suited to a particular type of artifact. For example, a correction function associated with pass-band narrowing may be generated; a correction function associated with an optical filter's frequency offset may be generated; a correction function associated with a transmitter's frequency offset may be generated; and a correction function associated with any combination of the foregoing may be generated. If signal monitor device **210** detects a certain artifact or combination of artifacts, a particular correction function of correction table **129** may be used that counteracts the detected artifact.

In addition to a particular correction function of correction table **129** corresponding to a parameter detected by signal monitor device **210**, more than one possible value of the power distribution and calibration factors (s, a) may be included in correction table **129**. The values of (s, a) may be determined for each modulation scheme (for example, QPSK, DP-QPSK, m-PSK, etc.) and may be included as part of correction table **129**. The values of (s, a) may be selected to more accurately detect the OSNR. In some embodiments, after using a modulation-specific (s, a), an artifact-specific correction function may be used. In addition to artifact-specific correction functions, it will be appreciated that the modulation-specific (s, a) values may be coupled with other parameter-specific correction functions of correction table **129**, for example, correction functions based off of number of network spans traversed, bandwidth, power of the signal, etc.

While FIG. **2**A illustrates polarization treatment device **122**, wavelength treatment device **124**, interferometer **125**, power meter **126**, and controller **128** in a particular order, it will be appreciated that this order may be changed and modified, or sub-components of the various elements may be rearranged. For example, a sub-component of wavelength treatment **124** may be located before polarization treatment device **122**, and further sub-components of wavelength treatment device **124** may then be located after polarization treatment device **122**.

By using an OSNR monitor device **120** as shown in FIG. **2**A, real time calculation of OSNR may be achieved. For example, as signal **150** enters node **110** and is handled by switching device **140**, OSNR monitor device **120** may be determining OSNR for the optical signal being routed and handled by switching device **140**. While there may be minor variations in timing of handling vs. determination of OSNR by virtue of processing and calculating times as opposed to handling and routing times, the determination may occur essentially in real time.

FIG. **2**B illustrates an alternative embodiment of OSNR monitor device **120**. As shown in FIG. **2**B, rather than utilizing interferometer **125**, OSNR monitor device **120** may utilize a particular form of wavelength treatment device **124** that also performs the functions of interferometer **125** of FIG. **2**A. For example, in some embodiments, as described above, wavelength treatment device **124** may include a wavelength selective switch that may be configured to perform wavelength filtering, delaying, phase-shifting, or causing signals to interfere with each other, or any combinations thereof.

OSNR monitor device **120** shown in FIG. **2**B may utilize correction table **129** the same way as OSNR monitor device **120** shown in FIG. **2**A. For example, controller **128** may measure the OSNR using values output by power meter **126** and may then apply correction table **129** to counteract an artifact in the optical signal. The only difference may be in how the OSNR is measured, which may change which artifacts may be introduced.

In some embodiments, OSNR monitor device **120** may operate on principles of interferometric monitoring. A description of such principles may be found in U.S. patent application Ser. No. 12/181,613, which is incorporated by reference herein in its entirety. By way of illustrative example, and in no way limiting, the following discussion may describe one embodiment of operation of a delay interferometer. As described below, a delay interferometer may be implemented as at least part of wavelength treatment device **124**.

A delay interferometer may divide a received optical signal into two optical paths. Then, the delay interferometer may cause the divided optical signals to be supplied through the different optical paths and cause the signals to interfere with each other using a difference between the two optical paths. The signals may then be output and measured at one or more power meters **126**. An example of a delay interferometer includes a Mach-Zehnder (MZ) interferometer.

Power meters **126** may be implemented as photodiodes, which generate current in accordance with reception-light power of the input optical signal. For example, two power meters **126** may generate a current in accordance with the reception-light power of the optical signals supplied from the delay interferometer so as to determine presence or absence of the optical signal and intensity of the optical signal and obtain the optical signal. In other words, a component of the data-modulation optical signal which is coherent light or a component of an optical signal which has not been subjected to phase modulation may be mainly output to one of the power meters **126**, and a noise component which is noncoherent light is output to both of the power meters **126**. Note that, in some embodiments, the component of the signal light is mainly received by a second power meter **126** and the noise component is received by both a first and the second power meters **126**. That is, the reception-light power of the second power meter **126** is larger than the reception-light power of the first power meter **126**. Specifically, the power meters **126** may output current in accordance with the optical powers of the two optical signals output from the delay interferometer. These measured optical powers may be represented by "P1 (mW) and P2 (mW)" of optical signals received by the two power meters **126**. In some embodiments, these values may be achieved by averaging the reading at the power meters **126**. These values may be passed to controller **128** to facilitate calculating or determining the OSNR of the signal.

A portion of wavelength treatment device **124** may select a particular bandwidth of wavelength to be analyzed. In some embodiments, this portion of wavelength treatment device **124** may occur before polarization treatment device **122**. For example, a particular channel in the optical signal may be selected and the remainder of the optical signal may be filtered out. This bandwidth "B (nm)" which has been set in wavelength treatment device **124** may be passed to controller **128** to facilitate calculating or determining the OSNR of the signal at that bandwidth. While the term "Bandwidth" may be used, it will be appreciated that this may refer to a particular range of wavelengths within a broader range of wavelengths of an optical signal. For example, "Bandwidth" may refer to a 0.1 nm band of wavelengths within the full optical spectrum. Alternatively, rather than the term "bandwidth," the term wavelength may be used to refer to a particular band of wavelength to be analyzed. While the term wavelength may be used, it will be appreciated that this may refer to a range of wavelengths around or near the specified wavelength. In addition to units of nm, B may also be referenced in corresponding units of GHz. In some embodiments, the value of B is smaller than the channel spacing of the optical signal. For example, if the channel spacing is limited to fifty GHz, the value of B may be less than fifty GHz.

Controller **128** may utilize the bandwidth "B (nm)" from wavelength treatment device **124** and the optical powers "P1 (mW) and P2 (mW)" from power meters **126** in Equation (3) for a 0.1 nm band to calculate OSNR.

$$OSNR[\text{dB}] = 10\times\log(P2-P1) - 10\log\left(2\times P1\times\frac{0.1}{B}\right) \tag{3}$$

Alternatively, by way of another illustrative example, and in no way limiting, the following discussion may describe another embodiment of operation of a delay interferometer.

A controller **128** may control a delay time of a delay circuit included in a delay interferometer. For example, a user may input a delay time, and the input delay time may be sent to the delay circuit.

The delay interferometer may divide a signal into two signals and cause one of the signals that has been delayed by a predetermined time amount to interfere with the other of the signals that has not been delayed, and output the signals to power meters **126** that output current based on intensity of received light. For example, the delay interferometer may divide an optical signal into two signals to be supplied to two optical paths. Then, the delay interferometer may delay the optical signal of the first optical path by "τ" seconds, and may then cause the optical signals of the optical paths to interfere with each other, and then output the optical signals to the power meters **126**. The delay interferometer may operate such that a first current is supplied to the first power meter **126** when a difference between optical phases of the two optical paths corresponds to "π" radian whereas a second current may be supplied to the second power meter **126** when the difference corresponds to "0" radian.

When the value "τ" is equal to "0 (second)," a current is substantially supplied only to the second power meter **126** since the optical phase difference is not generated between the two optical paths. When the value of "τ" is increased, a rate at which the optical phase difference corresponds to "π" relative to a preceding bit may be increased, and accordingly, the current supplied to the first power meter **126** may be increased. On the other hand, when the value "τ" may be equal to "1 bit (second)," that is, at a time of delay of 100%, the currents supplied to the first and second power meters **126** may be substantially equal to each other.

When a delay amount "τ" between the two optical paths corresponds to "1 bit (second)" and when an optical phase difference between the two optical paths corresponds to "π", the same amounts of current may be supplied to the power meters **126**. That is, when an output phase of the first optical path and an output phase of the second optical path are shifted from each other by "1 bit (second)", the same amounts of currents may be supplied to the two power meters **126**. On the other hand, when the delay amount "τ" between the two optical paths is larger than "0" and smaller than "1," e.g., when the delay amount "τ" is "0.75 bits (seconds)", that is, when an inter-symbol phase difference "τ" between the two optical paths is "0.75 bits (seconds)", the amount of the current supplied to the second power meter **126** may be larger than the amount of current supplied to the first power meter **126**. That is, when an output symbol phase of the first optical path is shifted relative to an output symbol phase of the second optical path by "0.75 bits (seconds)", the amount of the current supplied to the second power meter **126** may be larger than the amount of the current supplied to the first power meter **126**.

That is, as the delay amount "τ" between the two optical paths may be shifted from "1 bit (second)" to "0 bit (second)", the amount of the current supplied to the second power meter **126** may become larger than the amount of the current supplied to the first power meter **126**, and when the delay amount "τ" between the two optical paths becomes "0 bit (second)", the current may be supplied only to the second power meter **126** since the optical phase difference between the two optical paths is not generated. Accordingly, in the signal light, the amounts of the currents supplied to the two power meters **126** may depend on the delay amount "τ" and the optical phase difference between the two optical paths. In some embodiments, phase shifting may be done along at least one of the paths in the delay interferometer.

The delay time of the delay interferometer may be set so that a delay time difference may be obtained such that interference of the noise does not occur. That is, the optical signals of the two optical paths interfere with each other in the delay interferometer since the optical signal has coherency, and therefore, a difference between optical levels of the two power meters **126** may be generated in accordance with a state of the interference. However, since the noise does not have coherency, the two power meters **126** receive noise with substantially the same optical levels. In other words, noise light may have substantially the same optical levels at both power meters **126**, and signal light may have different levels detected by the two power meters **126** in accordance with the interference state of the delay interferometer.

As described above, the power measured at the two power meters **126** may depend on the delay amount "τ" between the two optical paths A and B (i.e., a rate of a delay time for one bit time) and the optical phase difference. On the other hand, since the noise light does not have phase information and coherency, the noise light may not depend on the delay amount "r," and the currents supplied to the two optical paths may be equal to each other. Accordingly, characteristics of the differential phase shift keying method representing that "amounts of the currents supplied to the two power meters may be different from each other when the delay amount 'τ' is equal to or smaller than 1 bit (second)" and "the noise does not depend on the delay amount 'τ' and amounts of the currents supplied to the two power meters are equal to each other" are used for the OSNR calculation (measurement).

For example, the noise received by the optical detectors two power meters **126** may be fixed to "0.5" irrespective of the delay time except for a case where the rate "t" of the delay time for one bit time is equal to "0." On the other hand, as for phase modulation signal light beams received by the two power meters **126**, as the rate "t" of the delay time relative to one bit time is increased from "0" to "1", a reception-light power of the second power meter **126** may become smaller (the current supplied to the power meter **126** is reduced) and a reception-light power of the first power meter **126** becomes larger (the current supplied to the second power meter **126** is increased). As a result, when the rate "t" corresponds to "1", the reception-light powers of the two power meters **126** are equal to each other, that is, "0.5". Accordingly, when the optical powers received by the two power meters **126** are denoted by "P1 (mW) and P2 (mW)," an optical signal power may be denoted by "P_{sig} (mW)," and noise total power may be denoted by "P_{noise} (mW)," Equations (4) and (5) below may be satisfied.

$$P1=0.5\times t\times P_{sig}+0.5\times P_{noise} \tag{4}$$

$$P2=(1-0.5\times t)\times P_{sig}+0.5\times P_{noise} \tag{5}$$

Note that, "t" denotes the rate of the delay time for one bit time, and accordingly, when the optical signal power P_{sig} is calculated using Equations (4) and (5), Equation (6) is satisfied. Furthermore, according to Equation (7), the noise power P_{noise} is represented by Expression (8).

$$P_{sig}=\frac{P2-P1}{1-t} \tag{6}$$

$$P1+P2=P_{sig}+P_{noise} \tag{7}$$

$$P_{noise}=P1+P2-P_{sig}=P1+P2-\frac{P2-P1}{1-t} \tag{8}$$

When a band of the noise included in Equation (8) is set to "B (nm)" and a noise power of "0.1 nm" band is calculated ("$P_{noise,\,0.1\,nm}$"), Equation (9) may be obtained. Furthermore, according to Equations (1), (6), and (9), OSNR may be calculated using Equation (10).

$$P_{noise,0.1\,nm}=\left(P1+P2-\frac{P2-P1}{1-t}\right)\times\frac{0.1}{B} \tag{9}$$

$$OSNR[\mathrm{dB}]=10\times\log\left(\frac{P2-P1}{1-t}\right)-10\times\log\left[\left(P1+P2-\frac{P2-P1}{1-t}\right)\times\frac{0.1}{B}\right] \tag{10}$$

Wavelength treatment module **124** may determine the bandwidth band "B" that may be analyzed, and may supply this value to controller **128** to facilitate determination of OSNR. The delay interferometer may divide an optical signal into two signals to be supplied to the two optical paths, and may delay the signal supplied to the first optical path by the predetermined delay time amount. In some embodiments, this time may be determined by controller **128**. Then, the delay interferometer may cause the signals output from the two optical paths to interfere with each other, and outputs the signals to the two power meters **126**. Then, the delay time "τ (second)" may be sent to controller **128** to facilitate calculating OSNR.

Controller **128** may use a stored symbol rate "F (bps)" to facilitate calculation of the rate "t" using the delay time "τ (second)," for example, by Equation (11).

$$t = \frac{\tau}{1/F} = \tau \times F \tag{11}$$

The power monitors **126** may determine "P1" and "P2" as described above, and may supply these values to controller **128**. Controller **128** may utilize the bandwidth "B (nm)", the delay time amount "τ (second)", the optical powers "P1 (mW) and P2 (mW)", and the rate "t" of the delay time for one bit time received as described above to Equation (10) to thereby measure the OSNR. Thereafter, controller **128** may store the calculated OSNR or may output the measured OSNR to a management device or the like.

FIGS. **3**-**11**B illustrate various alternative embodiments of a device for measuring OSNR and applying a correction table in circumstances in which the optical signal contains a plurality of polarization components. As abbreviated on some of the figures, BPF may refer to a band-pass filter, D may refer to delay, and PS may refer to a sub-component of a delay interferometer that may cause phase shifting to occur. The function of controller **128** of FIGS. **2**A and **2**B may be distributed between data processors and control circuits of FIGS. **3**-**11**B, or may be performed by a single centralized component, for example, controller **128** of FIGS. **2**A and **2**B.

FIG. **3** illustrates an OSNR monitor device **300**. OSNR monitor device **300** may comprise an optical tunable band-pass filter **310** as the wavelength treatment device. OSNR monitor device **300** may also comprise a tunable polarization controller **320** and polarization beam splitter **330** as the polarization treatment component. OSNR monitor device **300** may also comprise delay interferometers **340***a* and **340***b* as interferometer **125**. OSNR monitor device **300** may additionally comprise power meters **350***a*-**350***d*. OSNR monitor device **300** may also comprise data processor **360** and control circuit **370** as the controller.

Optical tunable band-pass filter (BPF) **310** may be any device, system, or circuitry configured to separate a particular wavelength from a plurality of wavelengths. For example, optical tunable BPF **310** may be configured to allow only a particular range of wavelength of an optical signal to pass through optical tunable BPF **310**. This range may be a 0.1 nm band of the optical signal. In some embodiments, optical tunable BPF **310** may be communicatively coupled with control circuit **370**, and may receive instructions from control circuit **370** with respect to a desired range of wavelength to allow to pass through optical tunable BPF **310**. Optical tunable BPF **310** may receive an incoming optical signal, for example, optical signal **305**. Optical tunable BPF **310** may then separate out a particular wavelength from optical signal **305**, and may then pass that filtered optical signal on to tunable polarization controller **320**.

Tunable polarization controller **320** may be configured to adjust the x-polarization and y-polarization components of a received optical signal. Such adjustments may include polarization shifting of the x-polarization and y-polarization components. Furthermore, tunable polarization controller **320** may be configured to adjust such components to align with the orientation of polarization beam splitter **330**. Tunable polarization controller **320** may be implemented in any suitable manner to perform such adjustments, for example, by any device, system, or circuitry. Tunable polarization controller **320** may be communicatively coupled to control circuit **370**. Control circuit **370** may be configured to adjust the operation of tunable polarization controller **320**. Such adjustments may be based upon, for example, the nature or kind of input signal, detected output of tunable polarization controller **320**, or orientation of polarization beam splitter **330**.

Polarization beam splitter **330** may be configured to split an input signal according to two fixed axes. For example, optical signal **305** may include an x-polarization component and a y-polarization component, and if these components are aligned with the fixed axes of polarization beam splitter **330**, they may be separated. Thus, polarization beam splitter **330** may be configured to output the x-polarization component of optical signal **305** and to output the y-polarization component of optical signal **305**. Polarization beam splitter **330** may be configured to output each polarization along an independent path or channel. For example, the x-polarization component may be provided to delay interferometer **340***a* and the y-polarization component may be provided to delay interferometer **340***b*. Polarization beam splitter **330** may be implemented in any suitable manner for splitting its input signal into x-polarization and y-polarization components. Polarization beam splitter **330** may be configured such that the outputs have fixed axes with respect to x-polarization and y-polarization. Thus, tunable polarization controller **320** may align the polarization of the received optical signal such that the fixed axes of polarization beam splitter **330** may appropriately separate out the x-polarization and y-polarization components.

Delay interferometer **340** may be implemented as any system or device configured to cause differences in two paths of a separated optical signal such that OSNR may be determined. For example, delay interferometers **340***a* and **340***b* may cause one or both paths to be one of delayed or phase shifted. Delay interferometers **340***a* and **340***b* may operate as described above with respect to calculating or determining OSNR. Delay interferometers **340***a* and **340***b* may be communicatively coupled with control circuit **370**. Control circuit **370** may provide instructions or direction to delay interferometers **340***a* and **340***b*. For example, control circuit **370** may instruct delay interferometers **340***a* and **340***b* regarding duration of delay time "τ" or a desired amount of phase shifting. Delay interferometers **340***a* and **340***b* may provide their outputs to power meters **350***a*-**350***d* as described above.

In some embodiments, power meters **350***b* and **350***d* may be omitted. In such an embodiment, power meter **350***a* may first measure P1 (for example, the constructive interference) of a certain wavelength and polarization component of an optical signal. The phase-shifting component of delay interferometer **340***a* may then be detuned, and then returned to include the phase-shift plus π such that P2 (for example, the destructive interference) may be measured. By measuring them separately, only one power meter **350***a* may be required for interferometer **340***a*. In like manner, interferometer **340***b*, which may be handling an alternative polarization component of the optical signal, may only require one power meter **350***c*.

Data processor **360** may be configured to calculate or determine OSNR based on inputs received at least from power meters **350***a* and **350***b* for delay interferometer **340***a*, and determine OSNR based on inputs received at least from power meters **350***c* and **350***d* for delay interferometer **340***b*. In some embodiments, data processor **360** may also receive inputs from control circuit **370**, optical tunable BPF **310**, delay interferometer **340***a* and/or **340***b*, power meters **350***a*-**350***b*, or any combinations thereof. For example, data processor **360** may receive information regarding "B," "t," "P1," and "P2" for each of the pair of outputs for delay interferometers **340***a* and **340***b*. In this way, data processor **360** may calculate OSNR for both outputs of polarization beam splitter **330** simultaneously, or essentially simultaneously. Data processor **360** may be implemented as any system, device, circuitry, or component to allow data processor **360** to determine OSNR. For example, data processor **360** may be implemented as a processor, microprocessor, microcontroller, ASIC, or FPGA. Data processor **360** may also comprise associated computer-readable media. In some embodiments, data processor **360** may provide the calculated OSNRs to control circuit **370**. In some embodiments, control circuit **370** and data processor **360** may be implemented as the same physical component.

Once data processor **360** has calculated a measured OSNR, data processor **360** may then read a correction table from a computer-readable medium associated with data processor **360** (for example, a computer-readable medium that is part of control circuit **370**, or a computer-readable medium that is dedicated to data processor **360**), and apply the correction table to the measured OSNR to counteract an artifact. By counteracting the artifact in the OSNR, data processor **360** may then arrive at a corrected value of OSNR. For example, for a measured OSNR with a given artifact, a particular value in the correction table may be applied to the measured OSNR to arrive at the corrected OSNR. This may be a factor by which the measured value of OSNR will be multiplied, or a function to which the measured OSNR value will be applied. Data processor **360** may then report the corrected OSNR value to control circuit **370** and control circuit **370** and/or data processor **360** may store the corrected OSNR value.

Control circuit **370** may be configured to provide instructions to at least one of optical tunable BPF **310**, tunable polarization controller **320**, and delay interferometers **340***a* and **340***b*. Control circuit **370** may be implemented as a processor, microprocessor, microcontroller, ASIC, or FPGA. In some embodiments, control circuit **370** may also comprise associated computer readable media.

Using the embodiment shown in FIG. **3**, OSNR may be determined separately and independently for the x-polarization and the y-polarization components of an optical signal. Additionally, they may be determined essentially simultaneously and essentially in real time. Also, an initial measured OSNR value may be corrected to counteract an artifact, resulting in a more precise reporting of OSNR.

FIG. **4** illustrates an alternative embodiment of an OSNR monitor device **400**. OSNR monitor device **400** may comprise an optical tunable BPF **410** as the wavelength treatment device. OSNR monitor device **400** may comprise a tunable polarization controller **420** and a polarizer **430** as the polarization treatment component. OSNR monitor device **400** may also comprise delay interferometer **440** as interferometer **125**. OSNR monitor device **400** may comprise a data processor **460** and a control circuit **470** as the controller. OSNR monitor device **400** may also include power meters **450***a* and **450***b*.

OSNR monitor device **400** may receive an incoming signal, for example, optical signal **405**. Optical tunable BPF **410** may handle the incoming signal as described above with respect to optical tunable BPF **310**. The signal may then be passed to tunable polarization controller **420**. Tunable polarization controller **420** may operate in a similar fashion to tunable polarization **320** described above. However, tunable polarization controller **420** may initially tune its output such that the x-polarization component of the optical signal is first aligned with polarizer **430**, and then be tuned such that they y-polarization component of the optical signal is aligned with polarizer **430**.

Polarizer **430** may be configured to filter out any polarized signal besides a particular axis of polarization. For example, optical signal **405** may include an x-polarization component and a y-polarization component. When optical signal **405** is oriented one way, polarizer **430** may output the x-polarization component of optical signal **405**. When optical signal **405** is oriented another way (for example, rotated ninety degrees), polarizer **430** may output the y-polarization component of optical signal **405**. Polarizer **430** may be configured to output the filtered optical signal to delay interferometer **440**. Polarizer **430** may be implemented in any suitable manner for filtering out any polarized light besides the particular axis of polarizer **430**. In this way, polarizer **430** may be referred to as having a fixed axis. In some embodiments, tunable polarization controller **420** may orient the optical signal such that the x-polarization component may be selected at polarizer **430**. Tunable polarization controller **420** may then be modified to orient the optical signal such that the y-polarization component may be selected at polarizer **430**.

Delay interferometer **440** may be implemented as described above with respect to delay interferometer **340***a* and **340***b*. Power meters **450***a* and **450***b* may be implemented as described above with respect to power meters **350***a*-**350***d*.

Data processor **460** may be implemented as described above with respect to data processor **360**, including the application of the correction table to the measured OSNR. Control circuit **470** may be implemented as described above with respect to control circuit **370**. However, control circuit **470** may be configured to cause tunable polarization controller **420** to re-orient the optical signal after OSNR for one polarization component has been determined such that OSNR may be determined for another polarization component. For example, control circuit **470** may direct tunable polarization controller **420** to orient the optical signal such that polarizer **430** will separate out the x-polarization component so its OSNR may be determined. Once control circuit **470** receives the OSNR for the x-polarization component from data processor **460**, control circuit **470** may direct tunable polarization controller **420** to re-orient the optical signal such that the y-polarization component of the optical signal may be selected at polarizer **430**. The OSNR for the x-polarization and the y-polarization components may be independently corrected by data processor **460**.

As described above, in some embodiments, the number of power meters may be reduced be half by first measuring P1 (for example, the constructive interference) of a certain wavelength and polarization component of an optical signal and then retuning a phase-shifting component such that the signal is phase-shift plus π and then measuring P2 (for example, the destructive interference).

Using the embodiment shown in FIG. **4**, OSNR may be determined separately and independently for the x-polarization and the y-polarization components of an optical signal. The OSNR for these polarizations may be determined successively, for example, by first determining OSNR for the x-polarization component, and then re-orienting the tunable polarization controller **420** to select and determine OSNR for the y-polarization component.

FIG. **5** illustrates an alternative embodiment of an OSNR monitor device **500**. OSNR monitor device **500** may comprise an optical tunable BPF **510** as the wavelength treatment device. OSNR monitor device **500** may comprise a polarization stabilizer **520** and a polarization beam splitter **530** as the polarization treatment component. OSNR monitor device **500** may also comprise delay interferometers **540***a* and **540***b* as interferometer **125**. OSNR monitor device **500** may comprise a data processor **560** and a control circuit **570** as the controller. OSNR monitor device **500** may also include power meters **550***a*-**550***d*.

OSNR monitor device **500** may receive an incoming signal, for example, optical signal **505**. Optical tunable BPF **510** may handle the incoming signal as described above with respect to optical tunable BPF **310**. The signal may then be passed to polarization stabilizer **520**.

Polarization stabilizer **520** may be configured to stabilize the orientation of polarization of an optical signal to a particular set of fixed axes. Such stabilization may include a polarization shifting of the x-polarization and y-polarization components. Furthermore, polarization stabilizer **520** may be oriented such that the output of polarization stabilizer is aligned with the fixed axes of polarization beam splitter **530** such that the x-polarization and y-polarization components of the optical signal may be appropriately separated at polarization beam splitter **530**. Polarization stabilizer **520** may be implemented in any suitable manner to perform such adjustments, for example, by any device, system, or analog or digital circuitry. Polarization stabilizer **520** may also include logic or other processing capability to facilitate the stabilization of the polarization of the optical signal. Polarization stabilizer **520** may be communicatively coupled to control circuit **570**. Control circuit **570** may be configured to inform polarization stabilizer **520** as to a desired orientation of polarization stabilizer **520**'s fixed axes. The desired orientation may be based upon, for example, the nature or kind of input signal, the detected output of polarization stabilizer **520**, or orientation of polarization beam splitter **530**.

Once stabilized to fixed axes, the optical signal may be passed from polarization stabilizer **520** to polarization beam splitter **530**. Polarization beam splitter may operate and be implemented similar to polarization beam splitter **330** as described above. In like manner, delay interferometers **540***a* and **540***b* may function similarly to delay interferometers **340***a* and **340***b* as described above; power meters **550***a*-**550***d* may function similarly to power meters **350***a*-**350***d* as described above; and data processor **560** and control circuit **570** may function similarly to data processor **360** and control circuit **370**, including in the application of the correction table to counteract an artifact in the measured OSNR.

As described above, in some embodiments, the number of power meters may be reduced by half by first measuring P1 (for example, the constructive interference) of a certain wavelength and polarization component of an optical signal and then retuning a phase-shifting component such that the signal is phase-shift plus π and then measuring P2 (for example, the destructive interference).

Using the embodiment shown in FIG. **5**, OSNR may be determined separately and independently for the x-polarization and the y-polarization components of an optical signal. Additionally, they may be determined essentially simultaneously and essentially in real time.

FIG. **6** illustrates an alternative embodiment of an OSNR monitor device **600**. OSNR monitor device **600** may comprise an optical tunable BPF **610** as the wavelength treatment device. OSNR monitor device **600** may comprise a polarization stabilizer **620** and a polarizer **630** as the polarization treatment component. OSNR monitor device **600** may also comprise delay interferometer **640** as interferometer **125**. OSNR monitor device **600** may comprise a data processor **660** and a control circuit **670** as the controller. OSNR monitor device **600** may also include power meters **650***a* and **650***b*.

OSNR monitor device **600** may receive an optical signal, for example, optical signal **605**. The optical signal may first have a particular wavelength selected by optical tunable BPF **610**. Optical tunable BPF **610** may operate and be implemented in a similar fashion to optical tunable BPF **310** as described above. Optical tunable BPF **610** may then pass the optical signal to polarization stabilizer **620** to orient and stabilize the optical signal according to its fixed axes. Polarization stabilizer **620** may function and be implemented in a similar fashion to polarization stabilizer **520** described above. The axes of polarization stabilizer **620** may be aligned with polarizer **630** such that when the optical signal is sent through the fixed axis of polarizer **630**, one polarization component of a plurality of polarization components of the optical signal may be passed on to delay interferometer **640**, for example, only one of the x-polarization or the y-polarization components. Delay interferometer **640** and power meters **650***a* and **650***b* may function and be implemented in a similar fashion to delay interferometer **340** and power meters **350***a*-**350***d*, as described above. Power meters **650***a* and **650***b* may pass along their readings to data processor **660** to facilitate calculation of OSNR for the selected wavelength and polarization component. Data processor **660** and control circuit **670** may function and be implemented in a similar fashion to data processor **360** and control circuit **370** as described above, including in the application of the correction table to the measured OSNR to counteract an artifact in the measured OSNR to arrive at a corrected OSNR.

Control circuit **670** may provide instructions and or directions to polarization stabilizer **620**. For example, as shown in FIG. **6**, after a first polarization component has had the OSNR determined, control circuit **670** may direct polarization stabilizer **620** to re-orient which polarization component is along its fixed axes. For example, if polarizer **630** was oriented to handle x-polarization component received from polarization stabilizer **620**, after OSNR for the x-polarization component was determined, control circuit **670** may direct polarization stabilizer **620** to re-orient the optical signal such that the y-polarization component may be oriented to the axis previously occupied by the x-polarization component such that polarizer **630** may then filter for the y-polarization component. In this way, polarization stabilizer **620** may operate in a similar fashion to tunable polarization controller **420**. However, where a tunable polarization controller may be configured to rotate an optical signal through any degree of rotation, causing the polarization to be oriented in any direction, a polarization stabilizer may be configured to orient the optical signal to a fixed set of axes, although how the optical signal is oriented to conform to those axes may be altered (for example, the x-polarization component may be along the x-axis, the y-axis, or the z-axis).

Control circuit **670** may facilitate successive determination of OSNR for a plurality of polarization components of an optical signal. For example, control circuit **670** may direct polarization stabilizer **620** to orient the optical signal such that polarizer **630** will separate out the x-polarization component so its OSNR may be determined. Once control circuit **670** receives the OSNR for the x-polarization component from data processor **660**, control circuit **670** may direct polarization stabilizer **620** to re-orient the optical signal such that the y-polarization component of the optical signal may be selected at polarizer **630** so that it may also have its OSNR determined.

As described above, in some embodiments, the number of power meters may be reduced by half by first measuring P1 (for example, the constructive interference) of a certain wavelength and polarization component of an optical signal and then retuning a phase-shifting component such that the signal is phase-shift plus π and then measuring P2 (for example, the destructive interference).

Using the embodiment shown in FIG. **6**, OSNR may be determined separately and independently for the x-polarization and the y-polarization components of an optical signal. The OSNR for these polarizations may be determined successively, for example, by first determining the x-polarization, and then re-orienting polarization stabilizer **620** to select and determine OSNR for the y-polarization.

FIG. **7** illustrates an alternative embodiment of an OSNR monitor device **700**. OSNR monitor device **700** may comprise an optical tunable BPF **710** as the wavelength treatment device. OSNR monitor device **700** may comprise tunable polarizers **730***a* and **730***b* as the polarization treatment component. OSNR monitor device **700** may also comprise delay interferometers **740***a* and **740***b* as interferometer **125**. OSNR monitor device **700** may comprise a data processor **760** and a control circuit **770** as the controller. OSNR monitor device **700** may also include power meters **750***a*-**750***d*. OSNR monitor device **700** may additionally comprise a signal splitter **720**.

OSNR monitor device **700** may receive an optical signal, for example, optical signal **705**. The optical signal may first have a particular wavelength selected by optical tunable BPF **710**. Optical tunable BPF **710** may operate and be implemented in a similar fashion to optical tunable BPF **310** as described above. Optical tunable BPF **710** may then pass the optical signal to signal splitter **720**. Signal splitter **720** may be any system, device, circuitry, or combination thereof configured to divide an incoming signal into multiple paths. Signal splitter **720** may have an associated loss with splitting the signal, for example, three decibels (dB). Signal splitter **720** may be configured such that each of the split signals may have the same information and/or format as the unsplit signal, but at reduced amplitude. For example, if the signal were a sine wave, the same function of sine wave may still be observed in the split signals, and only the amplitude may be reduced.

As shown in FIG. **7**, each of the paths from signal splitter **720** may carry the optical signals to tunable polarizers **730***a* and **730***b*. Tunable polarizers **730***a* and **730***b* may be configured to operate in a similar manner to polarizer **430**. However, rather than having a fixed axis that is filtered for, tunable polarizers **730***a* and **730***b* may be modified and adjusted to vary the orientation of the axis that is selected. For example, if an optical signal had the x-polarization component of the signal shifted fifteen degrees, tunable polarizer **730***a* may be tuned by fifteen degrees such that the x-polarization component may be selected through tunable polarizer **730***a*. To further the example, tunable polarizer **730***b* may be tuned to select for the y-polarization component of the optical signal. Tunable polarizers **730***a* and **730***b* may be implemented in any suitable manner to perform such adjustments, for example, by any device, system, or analog or digital circuitry. Tunable polarizers **730***a* and **730***b* may be communicatively coupled to control circuit **770**. Control circuit **770** may be configured to adjust the operation of tunable polarizers **730***a* and **730***b*. Such adjustments may be based upon, for example, the nature or kind of input signal or detected output of tunable polarizers **730***a* or **730***b*. In some embodiments, control circuit **770** may only determine the degree of tuning needed for one of the x-polarization or y-polarization components, and then may determine the other by shifting it by ninety degrees. Using the example above, if control circuit **770** determined that the x-polarization were shifted by fifteen degrees, control circuit **770** may instruct tunable polarizer **730***a* to be tuned by fifteen degrees and may instruct tunable polarizer **730***b* to be tuned by fifteen degrees plus ninety degrees, or one-hundred and five degrees.

The signals output from tunable polarizers **730***a* and **730***b* may be passed on to delay interferometers **740***a* and **740***b*. Delay interferometers **740***a* and **740***b* and power meters **750***a*-**750***d* may function and be implemented in a similar fashion to delay interferometers **340***a* and **340***b* and power meters **350***a*-**350***d*, as described above. Power meters **750***a*-**750***d* may pass along their readings to data processor **760** to facilitate calculation of OSNR for the selected wavelength and polarization component. Data processor **760** and control circuit **770** may function and be implemented in a similar fashion to data processor **360** and control circuit **370** as described above, including in the application of the correction table to the measured OSNR to counteract an artifact in the measured OSNR to arrive at a corrected OSNR.

As described above, in some embodiments, the number of power meters may be reduced by half by first measuring P1 (for example, the constructive interference) of a certain wavelength and polarization component of an optical signal and then retuning a phase-shifting component such that the signal is phase-shift plus π and then measuring P2 (for example, the destructive interference).

Using the embodiment shown in FIG. **7**, OSNR may be determined separately and independently for the x-polarization and the y-polarization components of an optical signal. Additionally, they may be determined essentially simultaneously and essentially in real time.

FIG. **8** illustrates an alternative embodiment of an OSNR monitor device **800**. OSNR monitor device **800** may comprise an optical tunable BPF **810**. OSNR monitor device **800** may comprise tunable polarizer **820** as the polarization treatment component. OSNR monitor device **800** may also comprise delay interferometer **840** as interferometer **125**. OSNR monitor device **800** may comprise a data processor **860** and a control circuit **870** as the controller. OSNR monitor device **800** may also include power meters **850***a* and **850***b*.

OSNR monitor device **800** may receive an optical signal, for example, optical signal **805**. The optical signal may first have a particular wavelength selected by optical tunable BPF **810**. Optical tunable BPF **810** may operate and be implemented in a similar fashion to optical tunable BPF **310** as described above. Optical tunable BPF **810** may then pass the optical signal to tunable polarizer **820**. Tunable polarizer **820** may operate and be implemented in a similar fashion to tunable polarizers **730***a* and **730***b*. However, once OSNR has been determined for a first polarization component of the optical signal, control circuit **870** may direct tunable polarizer to re-orient the axis that it is selecting to select a second polarization component of the optical signal, to facilitate determination of the OSNR for the second polarization component. For example, tunable polarizer **820** may be initially oriented to select out the x-polarization component of an optical signal. Once control circuit **870** recognizes that OSNR for the x-polarization component has been determined, control circuit **870** may direct tunable polarizer **820** to tune itself such that tunable polarizer selects out the y-polarization component of the optical signal, rather than the x-polarization component. This may facilitate the successive independent determination of OSNR for a plurality of polarizations of an optical signal.

The signal output from tunable polarizer **820** may be passed on to delay interferometer **840**. Delay interferometer **840** and power meters **850***a* and **850***b* may function and be implemented in a similar fashion to delay interferometers **340***a* and **340***b* and power meters **350***a*-**350***d*, as described above. Power meters **850***a* and **850***b* may pass along their readings to data processor **860** to facilitate calculation of OSNR for the selected wavelength and polarization component. Data processor **860** and control circuit **870** may function and be implemented in a similar fashion to data processor **360** and control circuit **370** as described above, including in the application of the correction table to the measured OSNR to counteract an artifact in the measured OSNR to arrive at a corrected OSNR.

As described above, in some embodiments, the number of power meters may be reduced by half by first measuring P1 (for example, the constructive interference) of a certain wavelength and polarization component of an optical signal and then retuning a phase-shifting component such that the signal is phase-shift plus π and then measuring P2 (for example, the destructive interference).

Using the embodiment shown in FIG. **8**, OSNR may be determined separately and independently for the x-polarization and the y-polarization components of an optical signal. The OSNR for these polarizations may be determined successively, for example, by first determining the x-polarization, and then re-orienting tunable polarizer **820** to select and determine OSNR for the y-polarization.

FIGS. **9**A and **9**B illustrate alternative embodiments of an OSNR monitor device **900**. As shown in FIG. **9**A, OSNR monitor device **900** may comprise a wavelength selective switch (WSS) **930***a* as the wavelength treatment device. OSNR monitor device **900** may comprise tunable polarization controller **910** and polarizer **920** as the polarization treatment component. OSNR monitor device **900** may comprise a data processor **960** and a control circuit **970** as the controller. OSNR monitor device **900** may also include power meters **950***a* and **950***b*.

OSNR monitor device **900** may receive an optical signal, for example, optical signal **905**. Tunable polarization controller **910** and polarizer **920** may function and be implemented in similar fashion to tunable polarization controller **420** and polarizer **430**. For example, tunable polarization controller **910** may orient the optical signal to align one of the polarizations of the optical signal with the axis of polarizer **920**. Once the OSNR for that polarization component has been determined, control circuit **970** may instruct tunable polarizer to tune the optical signal such that a second polarization component is aligned with the axis of polarizer **920** (for example, by first aligning the x-polarization and then the y-polarization). The output of polarizer **920** may be passed to WSS **930***a*.

WSS **930***a* may be configured to intelligently perform various wavelength treatments on the optical signal, including, for example, filtering, delaying, phase shifting, or any combinations thereof. WSS **930***a* may thus be configured to select a desired channel of the optical signal to have its OSNR determined, for example, on a per-wavelength basis. WSS **930***a* may be implemented in any suitable manner, such as by a device, system, circuitry, or combinations thereof to facilitate performance of these functions. For example, WSS **930***a* may include fibers, active or passive configurable filters, array waveguides, electromechanical devices, crystals, or any combinations thereof. WSS **930***a* may be communicatively coupled to control circuit **970**. Control circuit **970** may be configured to adjust the operation of WSS **930***a* to, for example, filter, delay, or phase shift the input signal. Such adjustments may be based upon, for example, the nature or kind of input optical signal, detected output of WSS **930***a*, or detected output of polarizer **920**. In some embodiments, WSS **930** may be implemented as having one input and two outputs (e.g. a 1×2 WSS like WSS **930***a*) or may be implemented as having one input and one output (e.g. a 1×WSS like WSS **930***b* shown in FIG. **9**B).

WSS **930***a* may comprise a processor, microprocessor, microcontroller, FPGA, ASIC or some other logic device to facilitate WSS **930***a* performing any of the filtering, delaying, or phase shifting of the optical signal. For example, WSS **930***a* may include modules, circuitry, or software configured to delay, adjust phase, filter or adjust power levels of components of signals. For example, the phases of the input signal may be adjusted to facilitate determination of OSNR. In addition, WSS **930***a* may include software configured to control the operation of WSS **930***a*. The software may include instructions resident upon a computer-readable medium for execution by a processor.

WSS **930***a* may be configured to operate in a similar manner and upon similar principles to delay interferometers **340***a* and **340***b*. For example, WSS **930***a* may cause the outputs to be delayed and/or phase shifted such that a comparison of the two outputs of WSS **930***a* may be used to determine OSNR. In some embodiments, an optical signal may be split into two parts for each output (thus, for a 1×2 WSS, an optical signal may be split into four parts) and each part may be individually handled. For example, a first part may remain unchanged and a second part may be delayed and phase-shifted, the first two parts caused to interfere with each other as the constructive interference and be output on one of the outputs. A third part may remain unchanged and a fourth part may be delayed and phase-shifted as before but also plus π radians. The third and fourth parts may be caused to interfere with each other as destructive interference and be output as the other of the outputs. The outputs of WSS **930***a* may be passed to power meters **950***a* and **950***b*. Power meters **950***a* and **950***b* may function and may be implemented in similar fashion to power meters **350***a*-**350***d*. Power meters **950***a* and **950***b* may pass along their readings to data processor **960** to facilitate calculation of OSNR for the selected wavelength and polarization component. Data processor **960** and control circuit **970** may function and be implemented in a similar fashion to data processor **360** and control circuit **370** as described above, including in the application of the correction table to the measured OSNR to counteract an artifact in the measured OSNR to arrive at a corrected OSNR.

With reference to FIG. **9**B, rather than using a 1×2 WSS (e.g. WSS **930***a*), in some embodiments a 1×1 WSS (e.g. WSS **930***b*) may be used. For example, the dashed portion of FIG. **9**A may be swapped for the dashed portion of FIG. **9**B. In such an embodiment, OSNR monitor device **900** may include power meter **950***c* to receive the one output of WSS **930***b*. While a delay interferometer may output two signals and have their powers compared, WSS **930***b* may output one of those signals first, and have that power stored, for example at one of data processor **960** or control circuit **970**, and then WSS **930***b* may output the other signal such that the OSNR may be determined using both output signals. For example, rather than simultaneously determining "P1" and "P2" as described above, "P1" and "P2" may be determined successively using WSS **930***b* and power meter **950***c*.

Using the embodiments shown in FIGS. **9**A and **9**B, OSNR may be determined separately and independently for the x-polarization and the y-polarization components of an optical signal. The OSNR for these polarizations may be determined successively, for example, by first determining the x-polarization, and then re-orienting tunable polarization controller **910** so that OSNR for the y-polarization component may be determined. Using the embodiment shown in FIG. **9**B, each of the two signals used to determine OSNR for one of the polarization components may be measured successively, rather than simultaneously.

FIGS. **10**A and **10**B illustrate alternative embodiments of an OSNR monitor device **1000**. As shown in FIG. **10**A, OSNR monitor device **1000** may comprise a wavelength selective switch (WSS) **1030***a* as the wavelength treatment device. OSNR monitor device **1000** may comprise tunable polarizer **1010** as the polarization treatment component. OSNR monitor device **1000** may comprise a data processor **1060** and a control circuit **1070** as the controller. OSNR monitor device **1000** may also include power meters **1050***a* and **1050***b*.

OSNR monitor device **1000** may receive an optical signal, for example, optical signal **1005**. Tunable polarizer **1010** may function and be implemented in similar fashion to tunable polarizer **820**. For example, tunable polarizer **1010** may orient its fixed axis to align with one of the polarizations of the optical signal. Once the OSNR for that polarization component has been determined, control circuit **1070** may instruct tunable polarizer **1010** to tune tunable polarizer **1010** such that a second polarization component is aligned with the axis of tunable polarizer **1010** (for example, by first aligning the x-polarization and then the y-polarization). The output of tunable polarizer **1010** may be passed to WSS **1030***a*. WSS **1030***a* may function and be implemented in a similar fashion to WSS **930***a*.

The outputs of WSS **1030***a* may be passed to power meters **1050***a* and **1050***b*. Power meters **1050***a* and **1050***b* may function and may be implemented in similar fashion to power meters **350***a*-**350***d*. Power meters **1050***a* and **1050***b* may pass along their readings to data processor **1060** to facilitate calculation of OSNR for the selected wavelength and polarization component. Data processor **1060** and control circuit **1070** may function and be implemented in a similar fashion to data processor **360** and control circuit **370** as described above, including in the application of the correction table to the measured OSNR to counteract an artifact in the measured OSNR to arrive at a corrected OSNR.

With reference to FIG. **10**B, rather than using a 1×2 WSS (e.g. WSS **1030***a*), in some embodiments a 1×1 WSS (e.g. WSS **1030***b*) may be used. For example, the dashed portion of FIG. **10**A may be swapped for the dashed portion of FIG. **10**B. In such an embodiment, OSNR monitor device **1000** may include power meter **1050***c* to receive the one output of WSS **1030***b*. WSS **1030***b* may function and be implemented in a similar manner to WSS **930***b*.

Using the embodiments shown in FIGS. **10**A and **10**B, OSNR may be determined separately and independently for the x-polarization and the y-polarization components of an optical signal. The OSNR for these polarizations may be determined successively, for example, by first determining the x-polarization, and then re-orienting tunable polarizer **1010** so that OSNR for the y-polarization component may be determined. Using the embodiment shown in FIG. **10**B, each of the two signals used to determine OSNR for one of the polarization components may be measured successively, rather than simultaneously.

FIGS. **11**A and **11**B illustrate alternative embodiments of an OSNR monitor device **1100**. As shown in FIG. **11**A, OSNR monitor device **1100** may comprise a WSS **1130***a* as the wavelength treatment device. OSNR monitor device **1100** may comprise polarization stabilizer **1110** and polarizer **1120** as the polarization treatment component. OSNR monitor device **1100** may comprise a data processor **1160** and a control circuit **1170** as the controller. OSNR monitor device **1100** may also include power meters **1150***a* and **1150***b*.

OSNR monitor device **1100** may receive an optical signal, for example, optical signal **1105**. Polarization stabilizer **1110** and polarizer **1120** may function and be implemented in similar fashion to polarization stabilizer **620** and polarizer **630**. For example, polarization stabilizer **1110** may stabilize the polarization component of the received optical signal to align with the fixed axis of polarizer **1120**. Once the OSNR for that polarization component has been determined, control circuit **1170** may instruct polarization stabilizer **1110** to re-orient which polarization component is along which of its fixed axes such that a second polarization component is aligned with the axis of polarizer **1120**. For example, polarization stabilizer **1110** may first stabilize the x-polarization along an axis of polarization stabilizer **1110** that is aligned with the fixed axis of polarizer **1120** and then may stabilize the y-polarization along the axis aligned with the fixed axis of polarizer **1120**. The output of polarizer **1120** may be passed to WSS **1130***a*. WSS **1130***a* may function and be implemented in a similar fashion to WSS **930***a*.

The outputs of WSS **1130***a* may be passed to power meters **1150***a* and **1150***b*. Power meters **1150***a* and **1150***b* may function and may be implemented in similar fashion to power meters **350***a*-**350***d*. Power meters **1150***a* and **1150***b* may pass along their readings to data processor **1160** to facilitate calculation of OSNR for the selected wavelength and polarization component. Data processor **1160** and control circuit **1170** may function and be implemented in a similar fashion to data processor **360** and control circuit **370** as described above, including in the application of the correction table to the measured OSNR to counteract an artifact in the measured OSNR to arrive at a corrected OSNR.

With reference to FIG. **11**B, rather than using a 1×2 WSS (e.g. WSS **1130***a*), in some embodiments a 1×1 WSS (e.g. WSS **1130***b*) may be used. For example, the dashed portion of FIG. **11**A may be swapped for the dashed portion of FIG. **11**B. In such an embodiment, OSNR monitor device **1100** may include power meter **1150***c* to receive the one output of WSS **1130***b*. WSS **1130***b* may function and be implemented in a similar manner to WSS **930***b*.

Using the embodiments shown in FIGS. **11**A and **11**B, OSNR may be determined separately and independently for the x-polarization and the y-polarization components of an optical signal. The OSNR for these polarizations may be determined successively, for example, by first determining the x-polarization, and then re-orienting the optical signal using polarization stabilizer **1110** so that OSNR for the y-polarization component may be determined. Using the embodiment shown in FIG. **11**B, each of the two signals used to determine OSNR for one of the polarization components may be measured successively, rather than simultaneously.

Herein, "or" is inclusive and not exclusive, unless expressly indicated otherwise or indicated otherwise or indicated otherwise by context. Therefore, herein, "A or B" means "A, B, or both," unless expressly indicated otherwise or indicated otherwise by context. Moreover, "and" is both joint and several, unless expressly indicated otherwise or indicated otherwise by context. Therefore, "A and B" means "A and B, jointly or severally," unless expressly indicated otherwise or indicated otherwise by context.

Particular embodiments may be implemented as hardware, software, or a combination of hardware and software. As an example and not by way of limitation, one or more computer systems may execute particular logic or software to perform one or more steps of one or more processes described or illustrated herein. Software implementing particular embodiments may be written in any suitable programming language (which may be procedural or object oriented) or combination of programming languages, where appropriate. In various embodiments, software may be stored in computer-readable storage media. Any suitable type of computer system (such as a single-or multiple-processor computer system) or systems may execute software implementing particular embodiments, where appropriate. A general-purpose computer system may execute software implementing particular embodiments, where appropriate. In certain embodiments, portions of logic may be transmitted and or received by a component during the implementation of one or more functions.

Herein, reference to a computer-readable storage medium encompasses one or more non-transitory, tangible, computer-readable storage medium possessing structures. As an example and not by way of limitation, a computer-readable storage medium may include a semiconductor-based or other integrated circuit (IC) (such as, for example, an FPGA or an application-specific IC (ASIC)), a hard disk, an HDD, a hybrid hard drive (HHD), an optical disc, an optical disc drive (ODD), a magneto-optical disc, a magneto-medium, a solid-state drive (SSD), a RAM-drive, or another suitable computer-readable storage medium or a combination of two or more of these, where appropriate. A computer-readable non-transitory storage medium may be volatile, non-volatile, or a combination of volatile and non-volatile, where appropriate.

This disclosure contemplates one or more computer-readable storage media implementing any suitable storage. In particular embodiments, a computer-readable storage medium implements one or more portions of a processor, one or more portions of a memory, or a combination of these, where appropriate. In particular embodiments, a computer-readable storage medium implements RAM or ROM. In particular embodiments, a computer-readable storage medium implements volatile or persistent memory.

This disclosure encompasses all changes, substitutions, variations, alterations, and modifications to the example embodiments herein that a person having ordinary skill in the art would comprehend. Similarly, where appropriate, the appended claims encompass all changes, substitutions, variations, alterations, and modifications to the example embodiments herein that a person having ordinary skill in the art would comprehend. Moreover, reference in the appended claims to an apparatus or system or a component of an apparatus or system being adapted to, arranged to, capable of, configured to, enabled to, operable to, or operative to perform a particular function encompasses that apparatus, system, component, whether or not it or that particular function is activated, turned on, or unlocked, as long as that apparatus, system, or component is so adapted, arranged, capable, configured, enabled, operable, or operative. For example, various embodiments may perform all, some, or none of the steps described above. Various embodiments may also perform the functions described in various orders.

Although the present disclosure has been described above in connection with several embodiments; changes, substitutions, variations, alterations, transformations, and modifications may be suggested to one skilled in the art, and it is intended that the present disclosure encompass such changes, substitutions, variations, alterations, transformations, and modifications as fall within the spirit and scope of the appended claims.

What is claimed is:

1. A computing processor-implemented method for generating a correction table for correcting measured optical signal-to-noise ratio (OSNR), comprising:

receiving an optical signal;

detecting, by a controller, an artifact associated with a measured OSNR of the optical signal;

calculating, by the controller, a correction function to counteract the artifact, the correction function varying over the measured OSNR; and

storing the correction function in the correction table in a non-transitory computer readable medium;

wherein OSNR can be calculated and measured based on a set of parameters (s, a) related to the power distribution and calibration factors that can have different values for different optical signal modulation schemes.

2. The method of claim **1**, further comprising:

measuring a first OSNR with a first known value; and

measuring a second OSNR with a second known value;

wherein calculating a correction function of the artifact comprises:

determining a first difference caused by the artifact between the first OSNR and the first known value; and

determining a second difference caused by the artifact between the second OSNR and the second known value.

3. The method of claim **1**, wherein the artifact comprises one of a pass-band narrowing effect, an optical filter's frequency offset, and a transmitter's frequency offset.

4. The method of claim **3**, wherein a different correction function of the correction table is generated if the artifact comprises a pass-band narrowing effect, an optical filter's frequency offset, or a transmitter's frequency offset.

5. The method of claim **1**, wherein a different correction function is generated for different bandwidths, different powers of the optical signal, and different numbers of spans of a network traversed by the optical signal.

6. The method of claim **1**, wherein the OSNR is measured using the equation:

$$OSNR[\text{dB}] = 10 \times \log\left[\left(\frac{(a+1)\cdot(s-a)}{\left(\frac{P2}{P1}-a\right)\cdot(s+1)} - \frac{a+1}{s+1}\right)^{-1}\cdot\frac{B}{R}\right].$$

7. The method of claim **1**, wherein the correction table includes corrections for OSNR from five dB to thirty-five dB.

8. The method of claim **1**, wherein the correction table corrects the measured OSNR to within 0.5 dB of an actual OSNR.

9. A computing processor-implemented method of correcting a measured optical signal-to-noise ratio (OSNR), comprising:

receiving an optical signal;

measuring OSNR of the optical signal using an interferometric OSNR monitor device; applying a correction table to the measured OSNR to generate a corrected OSNR using a controller, the correction table comprising a correction function to counteract an artifact in the measured OSNR; and

storing the corrected OSNR in a non-transitory computer-readable medium;

wherein OSNR can be calculated and measured based on a set of parameters (s, α) related to the power distribution and calibration factors that can have different values for different optical signal modulation schemes.

10. The method of claim 9, wherein the optical signal comprises a plurality of data-carrying wavelengths, further comprising:

separating out a first data-carrying wavelength from the optical signal;

wherein the measured OSNR is measured for the first data-carrying wavelength and associated in-band noise.

11. The method of claim 10, wherein the optical signal comprises a plurality of data-carrying polarities, further comprising:

separating out a first polarity of the first data-carrying wavelength;

wherein the measured OSNR is measured for the first polarity of the first data-carrying wavelength and associated in-band noise.

12. The method of claim 9, wherein the artifact comprises one of a pass-band narrowing effect, an optical filter's frequency offset, and a transmitter's frequency offset.

13. The method of claim 12, wherein a different correction function is applied if the artifact is a pass-band narrowing effect, an optical filter's frequency offset, or a transmitter's frequency offset.

14. The method of claim 9, wherein a different correction function is applied for different bandwidths, different powers of the optical signal, and different numbers of spans of a network traversed by the optical signal.

15. The method of claim 9, wherein the OSNR is measured using the equation:

$$OSNR[\mathrm{dB}] = 10 \times \log\left[\left(\frac{(a+1)\cdot(s-a)}{\left(\frac{P2}{P1}-a\right)\cdot(s+1)} - \frac{a+1}{s+1}\right)^{-1} \cdot \frac{B}{R}\right].$$

16. The method of claim 9, wherein the correction table includes corrections for OSNR from five dB to thirty-five dB.

17. The method of claim 9, wherein the correction table corrects the measured OSNR to within 0.5 dB of an actual OSNR.

18. A device for correcting a measured optical signal-to-noise ratio (OSNR) of an optical signal, the device comprising: a monitor device configured to generate values from which OSNR of the optical signal may be measured; a controller configured to measure the OSNR of the optical signal using the values generated by the monitor device and apply a correction table to the measure OSNR to generate a corrected OSNR, the correction table comprising a correction function to counteract an artifact in the measured OSNR; and non-transitory computer readable medium to receive the corrected OSNR from the controller and store the corrected OSNR; wherein OSNR can be calculated and measured based on a set of parameters (s, a) related to the power distribution and calibration factors that can have different values for different optical signal modulation schemes.

19. The device of claim 18, wherein the monitor device is further configured to separate out a first data-carrying wavelength from a plurality of data-carrying wavelengths in the optical signal, and the measured OSNR is measured for the first data-carrying wavelength and associated in-band noise.

20. The device of claim 19, wherein the monitor device is further configured to separate out a first polarity from a plurality of polarities in the optical signal, and the measured OSNR is measured for the first polarity of the first data-carrying wavelength and associated in-band noise.

21. The device of claim 18, wherein the artifact comprises one of a pass-band narrowing effect, an optical filter's frequency offset, and a transmitter's frequency offset.

22. The device of claim 21, wherein a different correction function is applied if the artifact is a pass-band narrowing effect, an optical filter's frequency offset, or a transmitter's frequency offset.

23. The device of claim 18, wherein a different correction function is applied for different bandwidths, different powers of the optical signal, and different numbers of spans of a network traversed by the optical signal.

24. The device of claim 18, wherein the OSNR is measured using the equation:

$$OSNR[\mathrm{dB}] = 10 \times \log\left[\left(\frac{(a+1)\cdot(s-a)}{\left(\frac{P2}{P1}-a\right)\cdot(s+1)} - \frac{a+1}{s+1}\right)^{-1} \cdot \frac{B}{R}\right].$$

25. The device of claim 18, wherein the correction table includes corrections for OSNR from five dB to thirty-five dB.

26. The device of claim 18, wherein the correction table corrects the measured OSNR to within 0.5 dB of an actual OSNR.

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