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(54) OPTICAL SIGNAL TRANSMITTING APPARATUS, OPTICAL FREQUENCY DIVISION MULTIPLEX TRANSMISSION SYSTEM, AND OPTICAL SIGNAL COMMUNICATION METHOD

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(57) **ABSTRACT**

An optical signal transmitting apparatus is disposed in an optical frequency division multiplex transmission system that includes plural nodes that are in an optical transmission path and respectively use a unique frequency to frequency-multiplex information with a carrier wave to transmit the information to an optical signal receiving apparatus in the optical transmission path. The optical signal transmitting apparatus outputs the carrier wave and includes a transmitting unit into which information to be delivered to the nodes is input, the transmitting unit transmitting the information using a frequency that does not overlap the unique frequencies used by the nodes; and a multiplexing unit that frequency-multiplexes output of the transmitting unit and the carrier wave, and sends the frequency-multiplexed output to the optical transmission path.

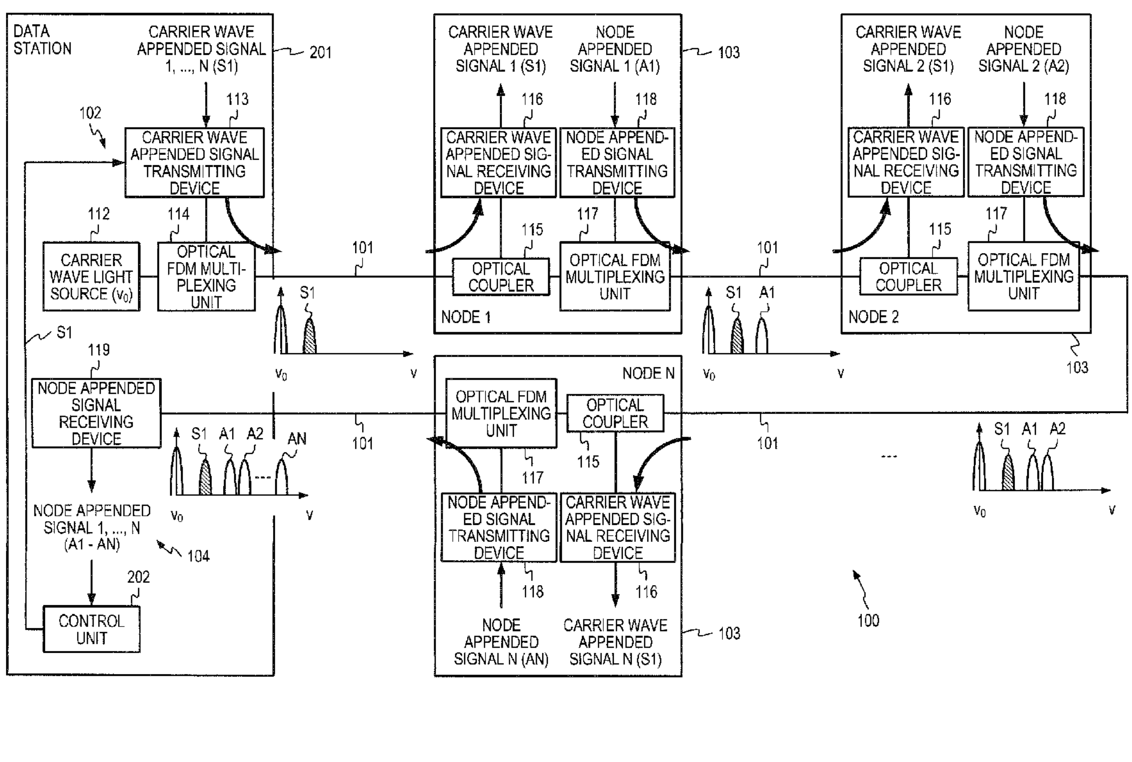


FIG.1

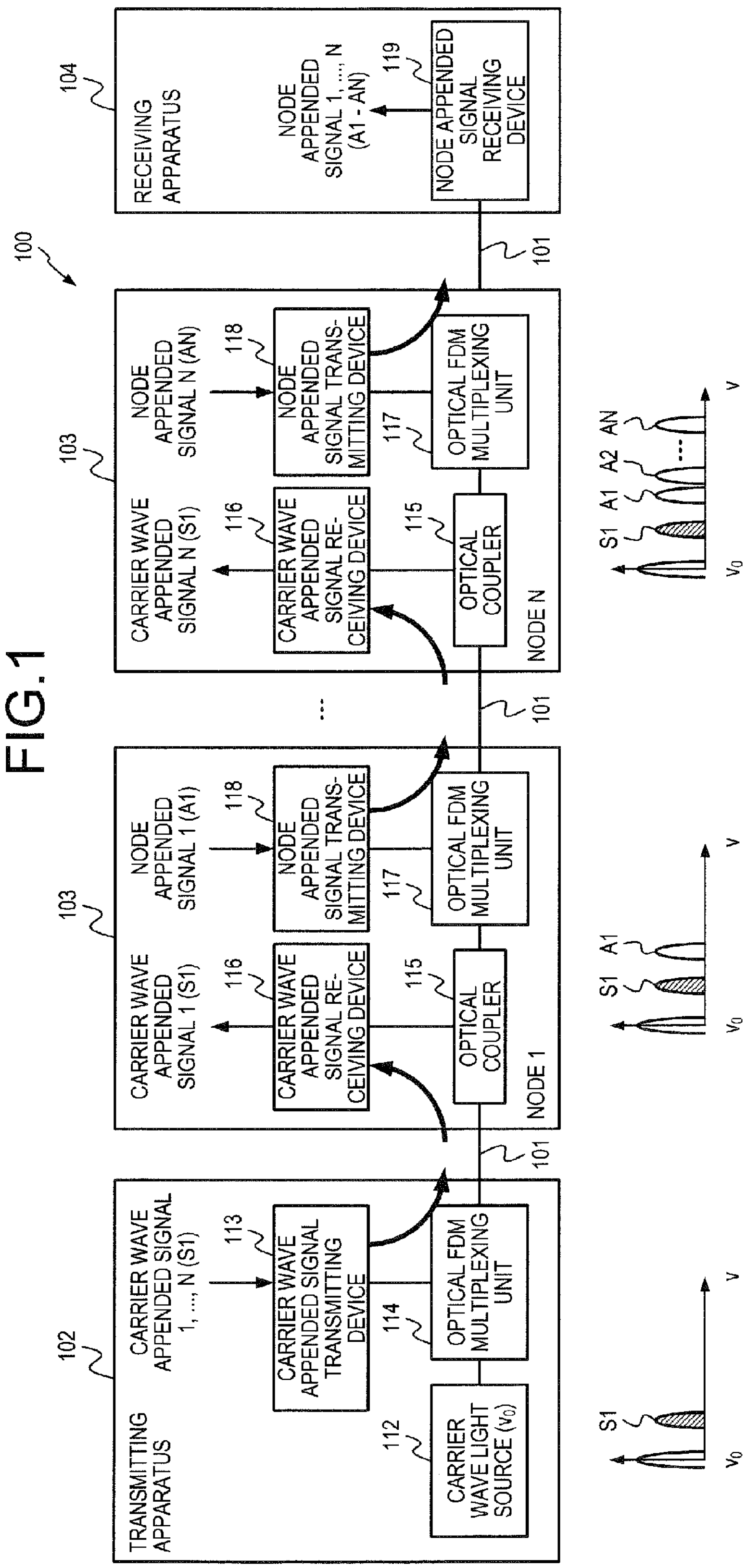

100
TRANSMITTING APPARATUS
102
CARRIER WAVE LIGHT SOURCE (ν_0)
112
CARRIER WAVE APPENDED SIGNAL 1, ..., N (S1)
CARRIER WAVE APPENDED SIGNAL TRANSMITTING DEVICE
113
OPTICAL FDM MULTIPLEXING UNIT
114
101
NODE 1
103
CARRIER WAVE APPENDED SIGNAL 1 (S1)
CARRIER WAVE APPENDED SIGNAL RE-CEIVING DEVICE
116
OPTICAL COUPLER
115
NODE APPENDED SIGNAL 1 (A1)
NODE APPENDED SIGNAL TRANS-MITTING DEVICE
118
OPTICAL FDM MULTIPLEXING UNIT
117
...
NODE N
CARRIER WAVE APPENDED SIGNAL N (S1)
NODE APPENDED SIGNAL N (AN)
RECEIVING APPARATUS
104
NODE APPENDED SIGNAL 1, ..., N (A1 - AN)
NODE APPENDED SIGNAL RECEIVING DEVICE
119
S1
A1
A2
AN
ν_0
ν

FIG.2

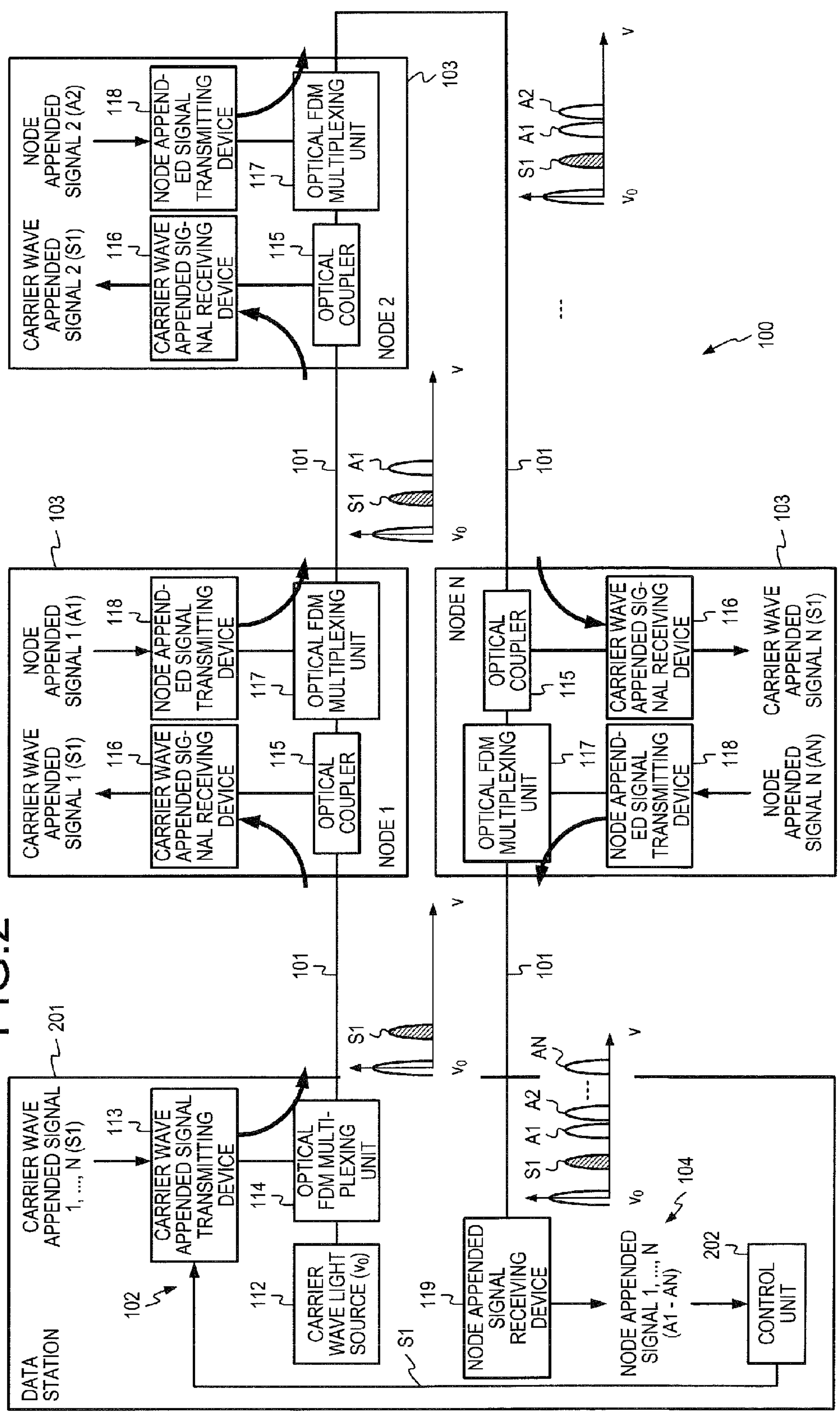
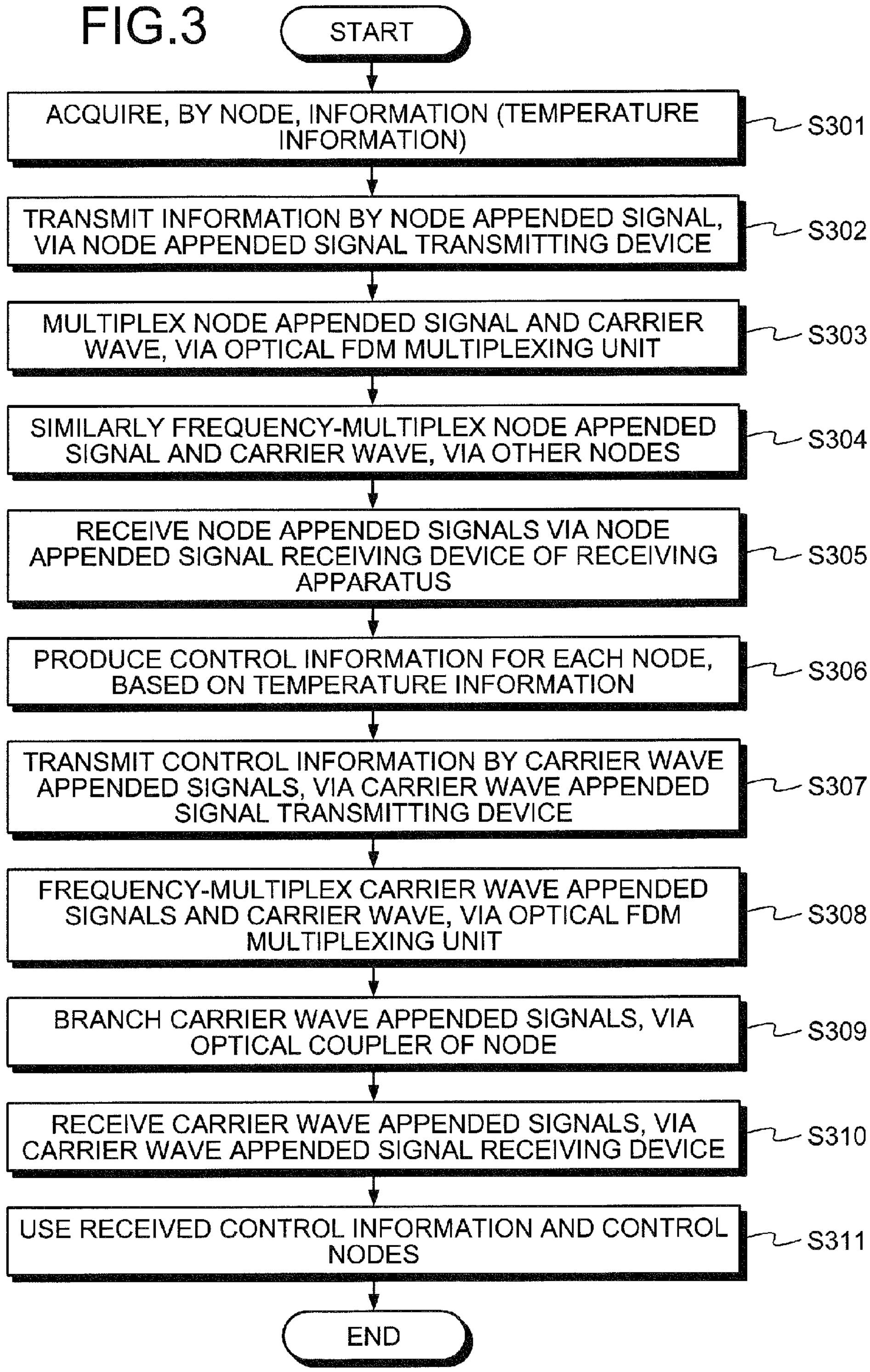

DATA STATION
201
102
CARRIER WAVE APPENDED SIGNAL 1, ..., N (S1)
113
CARRIER WAVE APPENDED SIGNAL TRANSMITTING DEVICE
112
CARRIER WAVE LIGHT SOURCE (ν0)
114
OPTICAL FDM MULTI-PLEXING UNIT
S1
119
NODE APPENDED SIGNAL RECEIVING DEVICE
104
NODE APPENDED SIGNAL 1, ..., N (A1 - AN)
202
CONTROL UNIT
S1 A1 A2 ... AN
ν0
ν
101
NODE 1
CARRIER WAVE APPENDED SIGNAL 1 (S1)
116
CARRIER WAVE APPENDED SIG-NAL RECEIVING DEVICE
115
OPTICAL COUPLER
NODE APPENDED SIGNAL 1 (A1)
118
NODE APPEND-ED SIGNAL TRANSMITTING DEVICE
117
OPTICAL FDM MULTIPLEXING UNIT
103
NODE 2
CARRIER WAVE APPENDED SIGNAL 2 (S1)
NODE APPENDED SIGNAL 2 (A2)
NODE N
CARRIER WAVE APPENDED SIGNAL N (S1)
NODE APPENDED SIGNAL N (AN)
100
...

FIG.3


START
ACQUIRE, BY NODE, INFORMATION (TEMPERATURE INFORMATION)
S301
TRANSMIT INFORMATION BY NODE APPENDED SIGNAL, VIA NODE APPENDED SIGNAL TRANSMITTING DEVICE
S302
MULTIPLEX NODE APPENDED SIGNAL AND CARRIER WAVE, VIA OPTICAL FDM MULTIPLEXING UNIT
S303
SIMILARLY FREQUENCY-MULTIPLEX NODE APPENDED SIGNAL AND CARRIER WAVE, VIA OTHER NODES
S304
RECEIVE NODE APPENDED SIGNALS VIA NODE APPENDED SIGNAL RECEIVING DEVICE OF RECEIVING APPARATUS
S305
PRODUCE CONTROL INFORMATION FOR EACH NODE, BASED ON TEMPERATURE INFORMATION
S306
TRANSMIT CONTROL INFORMATION BY CARRIER WAVE APPENDED SIGNALS, VIA CARRIER WAVE APPENDED SIGNAL TRANSMITTING DEVICE
S307
FREQUENCY-MULTIPLEX CARRIER WAVE APPENDED SIGNALS AND CARRIER WAVE, VIA OPTICAL FDM MULTIPLEXING UNIT
S308
BRANCH CARRIER WAVE APPENDED SIGNALS, VIA OPTICAL COUPLER OF NODE
S309
RECEIVE CARRIER WAVE APPENDED SIGNALS, VIA CARRIER WAVE APPENDED SIGNAL RECEIVING DEVICE
S310
USE RECEIVED CONTROL INFORMATION AND CONTROL NODES
S311
END

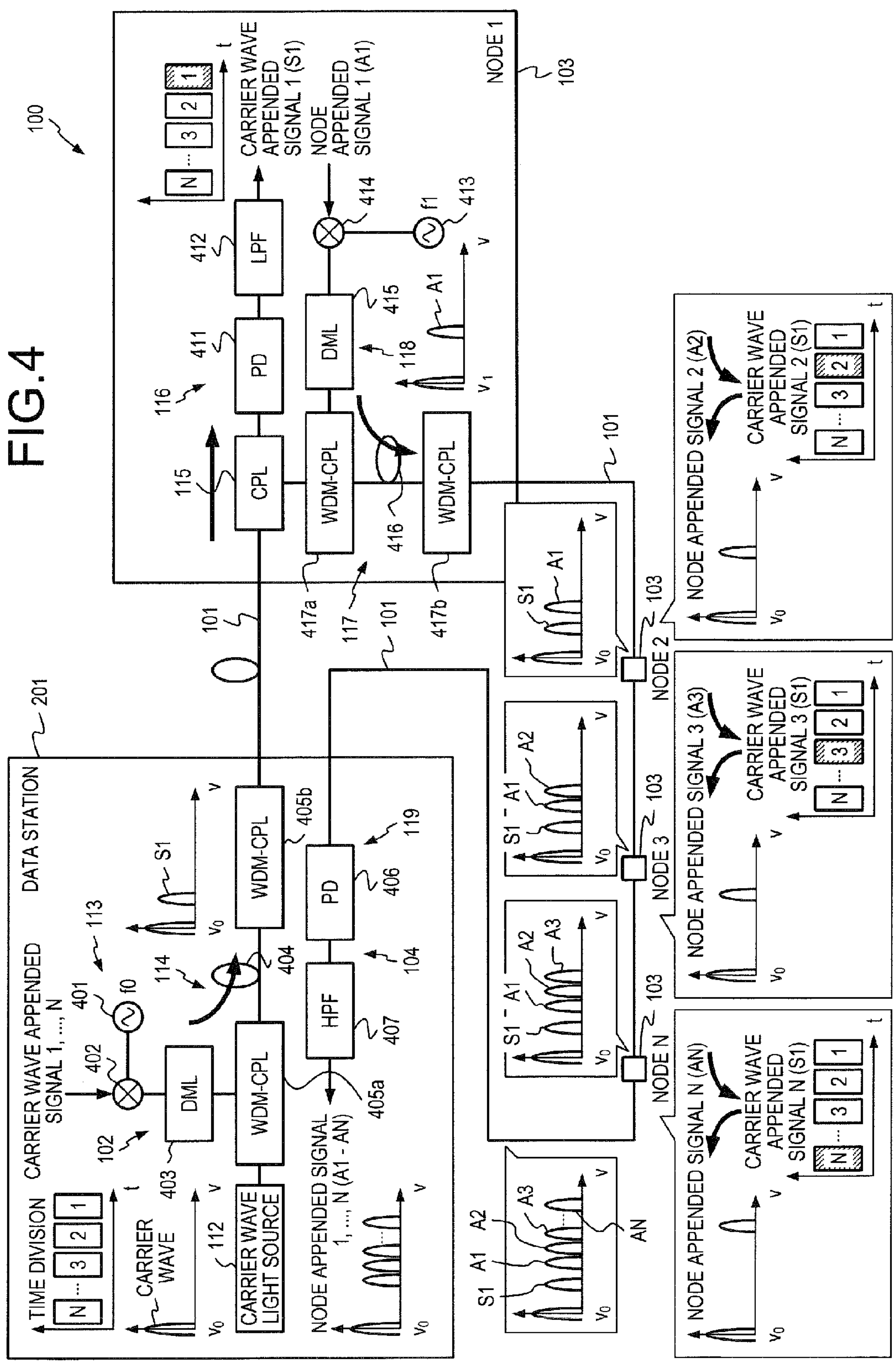

DATA STATION
NODE 1
NODE 2
NODE 3
NODE N
CARRIER WAVE LIGHT SOURCE
DML
WDM-CPL
HPF
PD
CPL
LPF
CARRIER WAVE APPENDED SIGNAL 1, ..., N
NODE APPENDED SIGNAL 1, ..., N (A1 - AN)
TIME DIVISION
CARRIER WAVE
CARRIER WAVE APPENDED SIGNAL 1 (S1)
NODE APPENDED SIGNAL 1 (A1)
NODE APPENDED SIGNAL 2 (A2)
CARRIER WAVE APPENDED SIGNAL 2 (S1)
NODE APPENDED SIGNAL 3 (A3)
CARRIER WAVE APPENDED SIGNAL 3 (S1)
NODE APPENDED SIGNAL N (AN)
CARRIER WAVE APPENDED SIGNAL N (S1)

FIG.4

FIG.5

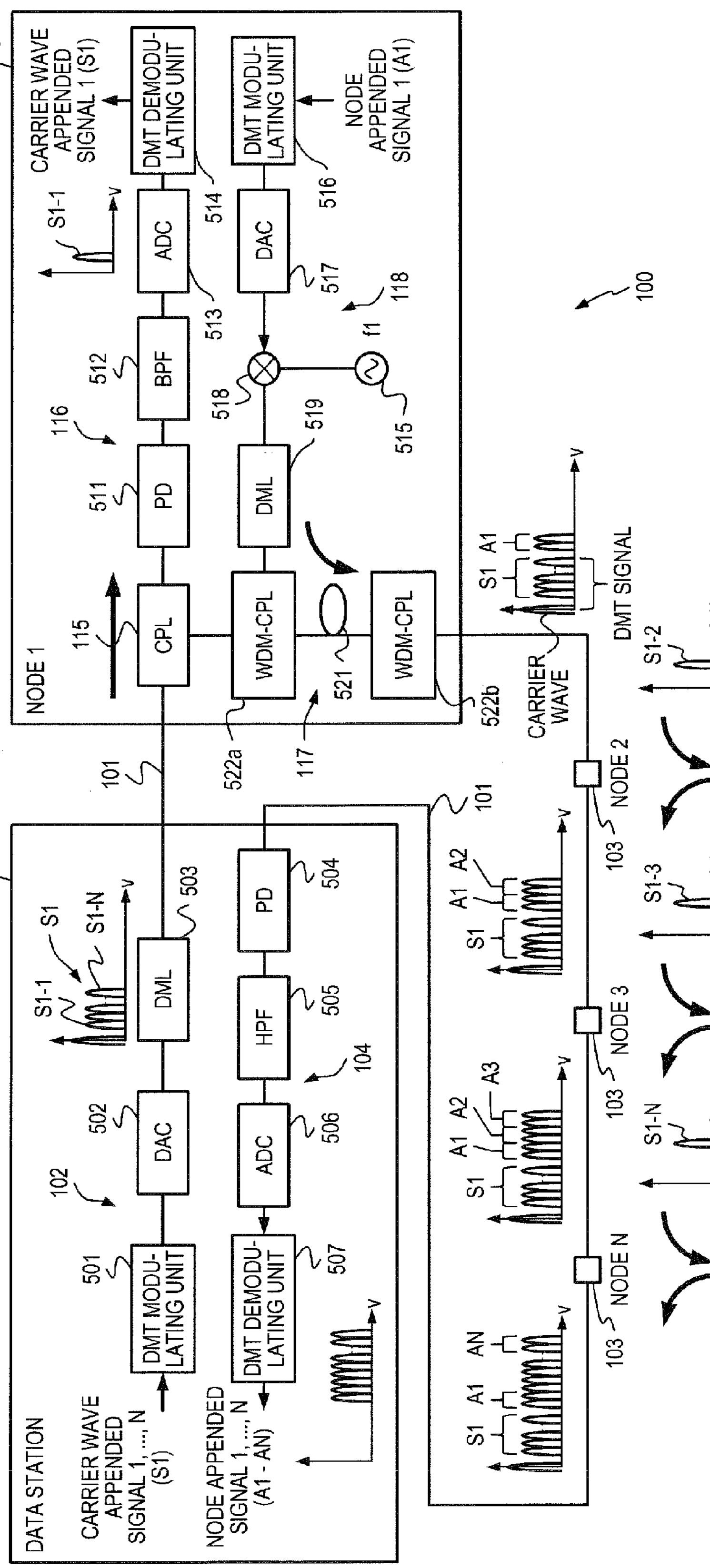
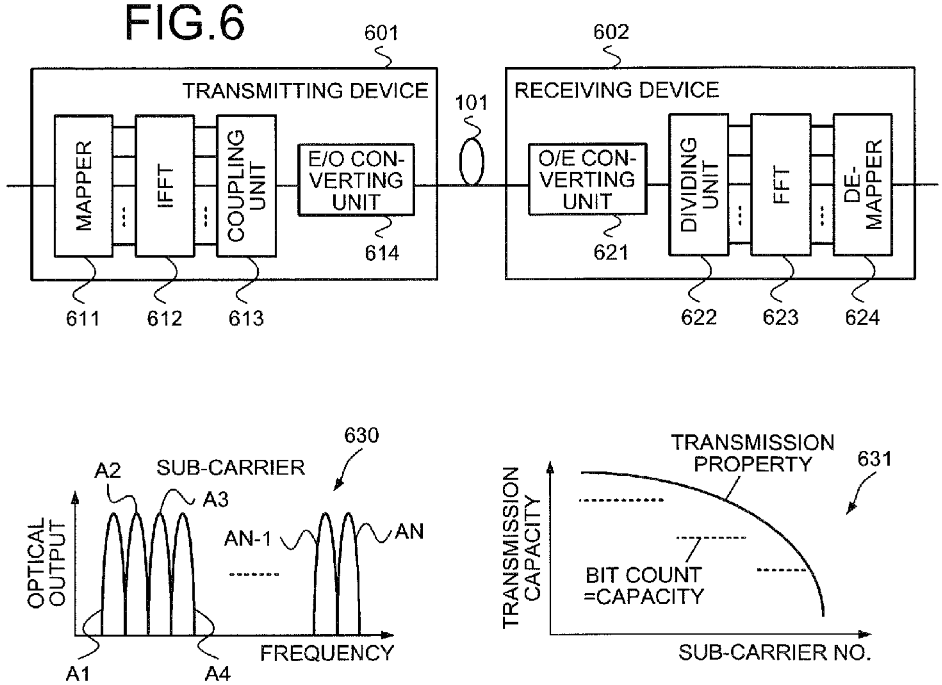

103
NODE 1
CARRIER WAVE APPENDED SIGNAL 1 (S1)
DMT DEMODU-LATING UNIT
NODE APPENDED SIGNAL 1 (A1)
DMT MODU-LATING UNIT
514
516
S1-1
ADC
DAC
513
517
118
BPF
512
f1
518
515
116
PD
511
DML
519
115
CPL
WDM-CPL
WDM-CPL
521
522a
522b
117
S1
A1
DMT SIGNAL
CARRIER WAVE
S1-2
NODE 2
101
201
DATA STATION
CARRIER WAVE APPENDED SIGNAL 1, ..., N (S1)
NODE APPENDED SIGNAL 1, ..., N (A1 - AN)
DMT MODU-LATING UNIT
DMT DEMODU-LATING UNIT
501
507
102
DAC
502
ADC
506
DML
503
HPF
505
104
PD
504
S1-1
S1-N
A2
S1-3
NODE 3
A3
S1-N
NODE N
AN
100
v

FIG.6


601
TRANSMITTING DEVICE
MAPPER
IFFT
COUPLING UNIT
E/O CON-VERTING UNIT
614
611
612
613
101
602
RECEIVING DEVICE
O/E CON-VERTING UNIT
621
DIVIDING UNIT
FFT
DE-MAPPER
622
623
624
630
SUB-CARRIER
A2
A3
A1
A4
AN-1
AN
OPTICAL OUTPUT
FREQUENCY
631
TRANSMISSION PROPERTY
TRANSMISSION CAPACITY
BIT COUNT =CAPACITY
SUB-CARRIER NO.

OPTICAL SIGNAL TRANSMITTING APPARATUS, OPTICAL FREQUENCY DIVISION MULTIPLEX TRANSMISSION SYSTEM, AND OPTICAL SIGNAL COMMUNICATION METHOD

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2012-223875, filed on Oct. 9, 2012, the entire contents of which are incorporated herein by reference.

FIELD

[0002] The embodiments discussed herein are related to an optical signal transmitting apparatus, an optical frequency division multiplex transmission system, and an optical signal communication method that employ a scheme of adding a sub-carrier modulation signal to a carrier wave and transmitting the signal and the wave.

BACKGROUND

[0003] Wavelength division multiplexing (WDM) is a technique of multiplexing optical signals of wavelengths (optical carrier frequencies) that differ from one another. According to WDM, base band modulation is executed for each carrier wave among carrier waves of differing wavelengths and an optical coupling and decoupling device executes multiplexing and de-multiplexing of the carrier waves. To multiplex at narrow wavelength (frequency) intervals, highly precise wavelength control is required of the transmitters and wavelength de-multiplexer. Consequently, multiplexing at narrow wavelength (frequency) intervals is difficult.

[0004] Optical frequency division multiplexing (FDM) may be performed. In a system employing optical FDM, along an optical transmission path such as an optical fiber, plural nodes are disposed and a carrier wave (a carrier light beam) is transmitted from a light source of a transmitting apparatus disposed at the starting point of the optical transmission path. Data signals at different sub-carrier frequencies are multiplexed and transmitted with the carrier wave from the plural nodes. The receiving side (a receiving apparatus) disposed at the end point of the optical transmission path receives information transmitted from the nodes (see, e.g., Japanese Laid-Open Patent Publication No. 2011-215603).

[0005] In the system employing optical FDM, the data signals are multiplexed with one carrier wave in a single optical transmission path and therefore, the receiving side merely has to receive the carrier wave and therefore, can receive the information transmitted by the plural nodes by a simple configuration compared to that of the WDM.

[0006] In a system employing conventional optical FDM, although the information concerning the transmitting apparatus at each of the nodes can be aggregated by the receiving apparatus using the downlink transmission, the designation of nodes along the optical transmission path and the transmission of the information to the designated nodes cannot be performed. Although a single optical transmission path is used for the optical FDM, the receiving apparatus is disposed at the ending point of the optical transmission path. Therefore, no uplink transmission to the nodes can be executed from the receiving apparatus.

[0007] For example, the nodes of the entire optical FDM system can centrally managed when a control signal can be transmitted to each of the nodes. However, the nodes can not be controlled conventionally through the optical transmission path.

SUMMARY

[0008] According to an aspect of an embodiment, an optical signal transmitting apparatus is disposed in an optical frequency division multiplex transmission system that includes plural nodes that are in an optical transmission path and respectively use a unique frequency to frequency-multiplex information with a carrier wave to transmit the information to an optical signal receiving apparatus in the optical transmission path. The optical signal transmitting apparatus outputs the carrier wave and includes a transmitting unit into which information to be delivered to the nodes is input, the transmitting unit transmitting the information using a frequency that does not overlap the unique frequencies used by the nodes; and a multiplexing unit that frequency-multiplexes output of the transmitting unit and the carrier wave, and sends the frequency-multiplexed output to the optical transmission path.

[0009] The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

[0010] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention.

BRIEF DESCRIPTION OF DRAWINGS

[0011] FIG. **1** is a diagram of an optical frequency division multiplex transmission system according to a first embodiment;

[0012] FIG. **2** is a diagram of the optical frequency division multiplex transmission system according to a second embodiment;

[0013] FIG. **3** is a flowchart of an example of the content of control executed by a data station;

[0014] FIG. **4** is a diagram of an example of a configuration of a system to transmit carrier wave appended signals based on time multiplex;

[0015] FIG. **5** is a diagram of an example of a configuration of a system to transmit carrier wave appended signals and node appended signals based on multi-carrier modulation; and

[0016] FIG. **6** is an explanatory diagram of signal production executed based on the multi-carrier modulation.

DESCRIPTION OF EMBODIMENTS

[0017] Preferred embodiments of the disclosed technology will be described in detail with reference to the accompanying drawings. FIG. **1** is a diagram of an optical frequency division multiplex transmission system according to a first embodiment. The network depicted in FIG. **1** is configured by a bus-type optical transmission path. Depiction of the units thereof include signals output from the units (the horizontal axis represents frequency and the vertical axis represents optical power).

[0018] An optical frequency division multiplex (FDM) transmission system **100** includes an optical transmission path **101** such as an optical fiber, and plural communication apparatuses disposed on the optical transmission path **101**.

Roughly classifying by function, the communication apparatuses include an optical signal transmitting apparatus (a transmitting apparatus) **102**, plural nodes **103** in the optical transmission path **101**, and an optical signal receiving apparatus (a receiving apparatus) **104**.

[0019] The transmitting apparatus **102** includes a carrier wave light source **112**, a carrier wave appended signal transmitting device **113**, and an optical FDM multiplexing unit **114**. The carrier wave light source **112** inserts a carrier wave (of a frequency υ0) such as a continuous wave (CW) light beam into the optical transmission path **101**. The carrier wave appended signal transmitting device **113** receives input of common information or individual information 1 to N to be transmitted to the plural nodes **103** as a carrier wave appended signal S**1** and the frequency of the carrier wave appended signal S**1** is set to be a sub-carrier frequency that is different from the frequency of the carrier wave. The carrier wave appended signal S**1** is a signal that is modulated based on a multi-carrier modulation scheme. The optical FDM multiplexing unit **114** sends the carrier wave appended signal S**1** to the optical transmission path **101** and causes the carrier wave appended signal S**1** to be coupled with the carrier wave.

[0020] Each of the nodes 1 to N (**103**) includes an optical coupler **115**, a carrier wave appended signal receiving device **116**, an optical FDM multiplexing unit **117**, and a node appended signal transmitting device **118**. The nodes 1 to N (**103**) have a data transmission function of sending individual node appended signals A (A**1** to AN) to the optical transmission path **101** and cause the individual node appended signals A to be transmitted to the receiving apparatus **104**. The nodes **103** have a data reception function of extracting the carrier wave appended signal S**1** transmitted from the transmitting apparatus **102**.

[0021] The internal configuration of each of the nodes will be described taking node 1 (**103**) as an example. The node appended signal transmitting device **118** assigns the node appended signal A**1** input thereinto to the sub-carrier frequency that is different from the frequency of the carrier wave. In this case, the frequency of the node appended signal A**1** is also different from the sub-carrier frequency of the carrier wave appended signal S**1** used by the other nodes 2 to N (**103**). The optical FDM multiplexing unit **117** couples the node appended signal A**1** to the carrier wave and sends the coupled signal and the carrier wave to the optical transmission path **101**.

[0022] Thus, the N nodes **103** send the node appended signals A**1** to AN to the optical transmission path **101**. The node appended signals A**1** to AN are a group of frequency division multiplexed signals and are transmitted to the receiving apparatus **104** through the optical transmission path **101**.

[0023] The optical coupler **115** of the node 1 (**103**) branches the optical signal (transmission signal) and outputs the resulting optical signal branches to the carrier wave appended signal receiving device **116**. The carrier wave appended signal receiving device **116** separates the sub-carrier frequency of the carrier wave appended signal S**1**, extracts only the carrier wave appended signal S**1**, executes a process for receiving (demodulating) the carrier wave appended signal S**1**, and outputs the carrier wave appended signal S**1** to the node 1 (**103**). The optical coupler **115** of the node 1 (**103**) may be configured to directly branch the carrier wave appended signal S**1** from the optical signal (transmission signal).

[0024] Similarly, each of the nodes 2 to N (**103**) executes the process for receiving the carrier wave appended signal S**1**. The carrier wave appended signal S**1** is a signal that is modulated based on the multi-carrier modulation scheme and includes not only the information common to the nodes 1 to N but also individual information for the nodes 1 to N.

[0025] For example, the carrier wave appended signal S**1** is usable as an individual control signal for the nodes 1 to N (**103**). In this case, the transmitting apparatus **102** uses the carrier wave appended signal S**1** and thereby, can individually control each of the nodes 1 to N through the optical transmission path **101**. For example, the carrier wave appended signal S**1** is usable as a control signal to individually control the presence or absence of a transmission session of each of the node appended signals A**1** to AN transmitted respectively by the nodes 1 to N, and is also usable as a control signal to control for each of the nodes, the setting and change of the sub-carrier frequency of each of the node appended signals A**1** to AN respectively transmitted by the nodes 1 to N. The carrier wave appended signal S**1** is not only used as the control signal but also can transmit the common information or the individual information (data) to the nodes 1 to N from the transmitting apparatus **102**.

[0026] The receiving apparatus **104** includes a node appended signal receiving device **119**. The node appended signal receiving device **119** collectively receives the node appended signals A**1** to AN transmitted from the plural nodes 1 to N in the optical transmission path **101**, separates the sub-carrier frequencies of the nodes 1 to N from each other, extracts and demodulates a data modulation component, and outputs the plural node appended signals A**1** to AN. Thus, the receiving apparatus **104** can receive all of the node appended signals A**1** to AN transmitted from the nodes 1 to N (**103**) and can centrally execute the data processing.

[0027] Details of the multiplexing of the node appended signals A**1** to AN with the carrier wave executed by each of the nodes 1 to N (**103**) and the multiplexing of the carrier wave appended signal S**1** executed by the transmitting apparatus **102**, using the optical FDM technique, will be described later.

[0028] FIG. **2** is a diagram of the optical frequency division multiplex transmission system according to a second embodiment. Although the configuration of each of the units of FIG. **2** is substantially same as that of FIG. **1**, a data station **201** includes the transmitting apparatus **102** and the receiving apparatus **104** of FIG. **1**. The optical transmission path **101** is a loop-back path that is disposed having therein the transmitting apparatus **102** as the starting point and the receiving apparatus **104** as the ending point through the plural nodes **103**. The data station **201** newly includes a function of a control unit **202**.

[0029] The data station **201** only has to have functions of the transmitting apparatus **102**, the receiving apparatus **104**, and the control unit **202**. The transmitting apparatus **102**, the receiving apparatus **104**, and the control unit **202** may each be a separate apparatus and further a portion thereof may be implemented as separate apparatuses. The control unit **202** includes a CPU, memory, etc. The CPU executes a program and thereby, executes a predetermined process.

[0030] In the data station **201**, the transmitting apparatus **102** sends the carrier wave and the carrier wave appended signal S**1** to the optical transmission path **101**; and the receiving apparatus **104** receives the node appended signals A**1** to AN transmitted from the nodes 1 to N (**103**). The data station **201** functions as a control unit that sends the information to the nodes 1 to N and that also centrally processes information of the information (the node appended signals **A1** to AN) transmitted by the nodes 1 to N.

[0031] The control unit **202** executes data processing using the node appended signals **A1** to AN transmitted from the nodes 1 to N (**103**). The control unit **202** may be configured to cause an external processing apparatus thereof to execute the data processing. The control unit **202** controls the information of the carrier wave appended signals 1 to N (**S1**) transmitted by the data station **201** to the nodes 1 to N (**103**). The control of the information of the carrier wave appended signals 1 to N (**S1**) can be executed based on the reception of the node appended signals **A1** to AN (including the data processing) and, in addition, may independently be executed regardless of the received node appended signals **A1** to AN.

[0032] FIG. **3** is a flowchart of an example of the content of the control executed by the data station. In the example, the nodes 1 to N (**103**) each acquire temperature information concerning the node point and transmit the temperature information to the data station **201** (the receiving apparatus **104**) as the node appended signals **A1** to AN; and the data station **201** centrally processes the temperature information concerning the nodes 1 to N (**103**).

[0033] The nodes 1 to N (**103**) first acquire the temperature information (step **S301**). For example, in the node 1 (**103**), a temperature sensor not depicted is disposed and acquires the temperature information detected by the temperature sensor. The node appended signal transmitting device **118** transmits the acquired information (the temperature information) as the node appended signal **A1** (step **S302**). The node appended signal **A1** to be transmitted is frequency-multiplexed with the carrier wave in the optical transmission path **101** by the optical FDM multiplexing unit **117** (step **S303**).

[0034] Similarly, the other nodes 2 to N (**103**) frequency-multiplex the node appended signals **A2** to AN, each including temperature information with the carrier wave (step **S304**). In this case, as depicted in FIGS. **1** and **2**, the frequencies of the node appended signals **A1** to AN to be multiplexed by the nodes 1 to N (**103**) are different from each other.

[0035] The node appended signal receiving device **119** disposed in the receiving apparatus **104** in the data station **201** receives the node appended signals **A1** to AN transmitted from the nodes 1 to N (step **5305**) and outputs the node appended signals **A1** to AN to the control unit **202** of the data station **201**. The control unit **202** extracts the temperature information included in the node appended signals **A1** to AN and centrally processes the temperature information concerning the nodes 1 to N (**103**). In the central processing, processes are executed such as monitoring the state of temperature variation in each of the nodes 1 to N (**103**) setting a threshold value.

[0036] The control unit **202** produces control information for each of the nodes 1 to N (**103**) based on the temperature information concerning the nodes 1 to N (**103**) (step **S306**). For example, the control unit **202** increases the acquisition cycle of the temperature information for the node **103** whose temperature variation is small, and decreases the acquisition cycle of the temperature information for the node **103** whose temperature variation is large. When no temperature information can be acquired or when the detected temperature indicates an abnormal value (that is greater than or equal to, or less than or equal to a threshold value), the control unit **202** can reset, etc., the node appended signal transmitting device **118** to normally acquire the temperature information.

[0037] The control unit **202** produces control information to control the nodes 1 to N (**103**) including the control of suspension of the operation and re-starting of the nodes 1 to N (**103**) and the control of the frequency used (used band) by each of the node appended signals **A1** to AN set in the node appended signal transmitting device **118** of each of the nodes 1 to N (**103**).

[0038] The control unit **202** outputs the produced control information **S1** to the carrier wave appended signal transmitting device **113** disposed in the transmitting apparatus **102** of the data station **201**. The carrier wave appended signal transmitting device **113** includes the control information **S1** with the control information **S1** in each of the carrier wave appended signals 1 to N and transmits the resulting signal (step **S307**). The control information **S1** may include different control content for each of the nodes 1 to N or may include control content that is common to all the nodes 1 to N.

[0039] The optical FDM multiplexing unit **114** of the transmitting apparatus **102** frequency-multiplexes the carrier wave appended signals 1 to N with the carrier wave and sends the signals and the carrier wave to the optical transmission path **101** (step **S308**). In FIGS. **1** and **2**, "**S1**" denotes the frequency of each of the carrier wave appended signals 1 to N.

[0040] In each of the nodes 1 to N (**103**), the optical coupler **115** branches the carrier wave appended signals 1 to N transmitted in the optical transmission path **101** (step **S309**). The carrier wave appended signal receiving device **116** of each of the nodes 1 to N (**103**) extracts the frequency of the carrier wave appended signal (**S1** in FIGS. **1** and **2**) and receives the carrier wave appended signals **1** to N (**S1**) (step **S310**). In each of the nodes 1 to N (**103**), a control unit not depicted controls each of the nodes 1 to N (**103**) independently using the control information **S1** of the node included in the carrier wave appended signals 1 to N (step **S311**). In this case, each of the nodes 1 to N (**103**) extracts the control content for the node indicated by the control information **S1** and controls the node according to the extracted control content.

[0041] According to the above configuration, the receiving apparatus **104** can collectively receive the information concerning the nodes 1 to N (**103**) using the node appended signals **A1** to AN. The transmitting apparatus **102** can send to the optical transmission path **101**, the control information **S1** concerning the nodes 1 to N (**103**) and thereby, the plural nodes 1 to N (**103**) can collectively or individually be controlled through the optical transmission path **101**.

[0042] As depicted in FIG. **2**, the optical transmission path **101** is set to be a loop-back path, and the transmitting apparatus **102**, the receiving apparatus **104**, and the control unit **202** can be disposed in the same data station **201**. The control unit **202** can produce the control information **S1** based on the content (for example, the temperature variation) of the node appended signals **A1** to AN output by the nodes 1 to N (**103**) received by the receiving apparatus **104**. As described, the data station **201** can output the control information to the nodes 1 to N as feedback, based on the information collected from the nodes 1 to N and can remote-control the nodes 1 to N (**103**).

[0043] The frequency multiplexing will be described of the node appended signals **A1** to AN with the carrier signal. The node appended signal transmitting device **118** of each of the nodes 1 to N (**103**) includes, for example, a control light beam producing unit, an optical wave coupling unit, and a non-linear optical medium. The control light beam producing unit produces a control light beam to be a sub-carrier modulation signal at a sub-carrier frequency fj that is a frequency different from and somewhat away from the frequency of the carrier wave. The optical wave coupling device couples the carrier wave (at an optical frequency υ0) and the control light beam produced by the control light beam producing unit. The non-linear optical medium mutually phase-modulates the carrier wave (the carrier light beam) using the control light beam. Thereby, each of the nodes 1 to N (**103**) multiplexes a frequency division multiplex signal υ0±fj with the carrier wave in a wide band.

[0044] The receiving apparatus **104** includes a wavelength dispersion medium having a predetermined amount of dispersion against a wavelength, a photo detector (PD) that converts an optical signal received through the wavelength dispersion medium into an electrical signal, and a multiplexed signal receiving unit that electrically executes a reception process based on the electrical signal output by the PD. The multiplexed signal receiving unit includes a band-pass filter that transmits only a desired modulation signal, and a phase synchronization circuit that causes the electrical signal after passing through the band-pass filter to phase-synchronize and that demodulates the signal.

[0045] The receiving apparatus **104** includes plural wavelength dispersion media whose amounts of wavelength dispersion each differ corresponding to, for example, the frequency of the sub-carrier modulation signal of each of the nodes 1 to N (**103**). Thus, a data modulation component can be extracted and received from the sub-carrier modulation signal transmitted by each of the plural nodes 1 to N (**103**). In this manner, the receiving apparatus **104** adds proper dispersion; collectively receives the carrier light beam on which the plural multiplexed signals are superimposed using the photo detector; thereafter, electrically cuts and demodulates the desired modulation frequency (each of the node appended signal A**1** to AN) using the band-pass filter; and thereby, can receive the light beam as an intensity modulation signal.

[0046] The wavelength dispersion medium as that available in the market can be an ordinary optical fiber (SMF), a dispersion compensation fiber (DCF), a fiber Bragg grating (FBG) whose amount of dispersion is controlled, and a medium formed using an etalon filter.

[0047] The receiving apparatus **104**, using a steep optical filter, may extract only the one-side waveband component that is on one side of the frequency of the carrier wave as a central frequency, in addition to using the wavelength dispersion medium.

[0048] The signal with which the nodes 1 to N (**103**) multiplex is not limited to the single sub-carrier modulation signal and a multiplexed signal is usable that is formed by adding plural sub-carrier modulation signals each independent from each other.

[0049] Optical phase modulation based on phase inter-modulation, optical intensity modulation based on an optical parametric effect, etc. are useable as the optical inter-modulation using the non-linear optical medium in each of the nodes 1 to N (**103**). An optical fiber, cyclic polarization inverted lithium niobate, a semiconductor optical amplifier, and a high refraction-index difference optical waveguide such as a silicon thin-line waveguide, etc., are usable as the non-linear optical medium. For example, in addition to a highly non-linear optical fiber (HNLF), an optical fiber or a waveguide configuration whose core's non-linear refraction index is increased by doping germanium, bismuth, etc., into the core; an optical fiber or a waveguide configuration whose optical power density is increased by reducing the mode field; an optical fiber or a waveguide configuration using chalcogenide glass; a photonic crystal optical fiber or a photonic crystal waveguide configuration; etc., may also be employed as the optical fiber.

[0050] A semiconductor optical amplifier having a quantum well configuration, a quantum dot semiconductor optical amplifier, a silicon photonics waveguide, etc., are also usable as another non-linear optical medium. A device that generates a second-order non-linear optical effect such as three-optical wave mixing, is also usable as yet another non-linear optical medium. In this case, for example, a LiNbO3 waveguide, a GaAlAs element, a second-order non-linear optical crystal, etc., each having a pseudo phase matching structure are also usable as the non-linear optical medium.

[0051] In the description above, the frequency multiplex of the node appended signal A**1** to AN with the carrier wave executed by the nodes 1 to N (**103**) has been described. However, the carrier wave appended signals 1 to N (S**1**) in the transmitting apparatus **102** can also be transmitted to the nodes 1 to N (**103**) by adding the signals 1 to N (S**1**) to the carrier wave based on the same configuration as above. In this case, the carrier wave appended signals 1 to N (S**1**) may be multiplexed using the frequencies that are different from those of the node appended signals A**1** to AN.

[0052] FIG. **4** is a diagram of an example of the configuration of a system to transmit the carrier wave appended signals based on time multiplex. The optical transmission path **101** of the system is basically set to be a loop-back path similarly to that of FIG. **2** and the system includes the data station **201** and the plural nodes 1 to N (**103**). The configurations same as those of FIG. **2** are given the same reference numerals used in FIG. **2**.

[0053] The data station **201** includes the transmitting apparatus **102**, the receiving apparatus **104**, and the control unit **202** not depicted (see FIG. **2**). The transmitting apparatus **102** includes the carrier wave light source **112**, the carrier wave appended signal transmitting device **113**, and the optical FDM multiplexing unit **114**. The carrier wave appended signal transmitting device **113** includes an oscillating device **401**, a multiplying device **402**, and a directly modulated laser (DML) **403**. The frequency of the oscillating device **401** is set to be a predetermined frequency f0. The multiplying device **402** multiplies the carrier wave appended signals 1 to N (S**1**) by the predetermined frequency f0 and outputs the multiplication result to the optical FDM multiplexing unit **114**.

[0054] The optical FDM multiplexing unit **114** includes, for example, an optical fiber **404** as the non-linear optical medium; and a pair of WDM couplers (CPLs) **405***a* and **405***b* at the ends of the optical fiber **404**. The WDM coupler (CPL) **405***a* superimposes the carrier wave appended signals 1 to N (S**1**) at the predetermined frequency f0 on the carrier wave (at the frequency υ0), thereafter, the optical fiber **404** copies the superimposed signals 1 to N at a frequency ("S**1**" in FIG. **4**) that is different from that of the carrier wave (at the frequency υ0). Thereafter, the WDM coupler (CPL) **405***b* cuts the components (the carrier wave appended signals 1 to N (S**1**)) of the control light beam that are superimposed on the carrier wave. Thereby, the data station **201** outputs the carrier wave appended signals 1 to N (S**1**) at the frequency that is different from that of the carrier wave.

[0055] The carrier wave appended signal S**1** is set to include information that differs for each of the nodes 1 to N

(**103**) and, as depicted, transmits information 1 to N respectively concerning the nodes 1 to N (**103**) based on a time division scheme.

[0056] The receiving apparatus **104** includes the node appended signal receiving device **119**. The node appended signal receiving device **119** includes a photo detector (PD) **406** and a high-pass filter (HPF) **407**. The photo detector **406** collectively receives the carrier light beam with which the plural node appended signals A**1** to AN are multiplexed and outputs the received carrier light beam to the high-pass filter **407**. The high-pass filter **407** electrically cuts and demodulates the frequencies of the node appended signals A**1** to AN and outputs the node appended signals A**1** to AN to the control unit **202** (see FIG. **2**).

[0057] Each of the plural nodes 1 to N (**103**) includes the optical coupler **115**, the carrier wave appended signal receiving device **116**, the optical FDM multiplexing unit **117**, and the node appended signal transmitting device **118**. The optical coupler **115** branches and outputs the optical signals to the carrier wave appended signal receiving device **116** on the optical transmission path **101**. The carrier wave appended signal receiving device **116** includes a photo detector (PD) **411** and a low-pass filter (LPF) **412**. The photo detector **411** receives the carrier light beam that includes the carrier wave appended signals 1 to N (S**1**) and outputs the carrier light beam to the low-pass filter **412**. The low-pass filter **412** electrically cuts and demodulates the frequency of the carrier wave appended signals 1 to N (S**1**) and outputs the carrier wave appended signals 1 to N (S**1**).

[0058] The control unit (not depicted) extracts the carrier wave appended signal addressed to the corresponding node **103** of the carrier wave appended signals 1 to N (S**1**). For example, the node 1 (**103**) extracts only the carrier wave appended signal 1 and the node 2 (**103**) extracts only the carrier wave appended signal 2. Thereby, the node 1 (**103**) is enabled to extract the information addressed to the node 1 transmitted by the data station **201**. As described, the control unit can execute the control based on the carrier wave appended signal 1 (S**1**). The carrier wave appended signals 1 to N can each be set to be not only the control information for the node **103** but also the common or the individual information such as data to be delivered to the nodes 1 to N (**103**).

[0059] The node appended signal transmitting device **118** of each of the nodes 1 to N (**103**) includes an oscillating device **413**, a multiplying device **414**, and a directly modulated laser (DML) **415**. The frequency of the oscillating device **413** is set to be a predetermined frequency f1. The frequency f1 is set to be a frequency that is different from those of the carrier wave appended signals and other nodes (2 to N) **103**. The multiplying device **414** of the node 1 (**103**) multiplies the node appended signal A**1** by the predetermined frequency f1 and outputs the multiplication result to the optical FDM multiplexing unit **117**.

[0060] The optical FDM multiplexing unit **117** includes, for example, an optical fiber **416** as the non-linear optical medium; and a pair of WDM couplers (CPLs) **417***a* and **417***b* at the ends of the optical fiber **416**. Thereby, the node 1 (**103**) outputs the node appended signal A**1** at the frequency that is different from that of the carrier wave. Similarly, the nodes 2 to N (**103**) also output the node appended signals A**2** to AN at the frequencies that are each different from that of the carrier wave and those of the other nodes 1 to N (**103**).

[0061] According to the above configuration, the nodes 1 to N (**103**) can respectively extract the information (the carrier wave appended signals 1 to N) addressed to the nodes 1 to N (**103**) transmitted by the data station **201** based on the time division multiplex. Thereby, the data station **201** is enabled to remote-control the nodes 1 to N (**103**) by sending the control information thereto through the optical transmission path **101** and is also enabled to send the data to the nodes 1 to N (**103**) to cause the data to be used in the data processing by the control unit of each of the nodes 1 to N (**103**).

[0062] The data station **201** centrally processes the node appended signals A**1** to AN transmitted by the nodes 1 to N (**103**) and therefore, can transmit to the nodes 1 to N (**103**) the control information and data that correspond to the variation of the node appended signals A**1** to AN. Thereby, the entire system can be configured that includes the data station **201** and the nodes 1 to N (**103**) connected to each other by the optical transmission path **101**. The data station **201** is enabled to control the nodes 1 to N (**103**) by sending thereto the feedback or transmit the information, based on the variation of the information transmitted thereto by the nodes 1 to N (**103**).

[0063] FIG. **5** is a diagram of an example of the configuration of a system to transmit the carrier wave appended signals and the node appended signals based on the multi-carrier modulation. The description will be made with reference to FIG. **5** taking an example of discrete multi tone (DMT) modulation as the multi-carrier modulation.

[0064] The transmitting apparatus **102** of the data station **201** includes a DMT modulating unit **501**, a DAC **502**, and a DML **503**. The DMT modulating unit **501** DMT-modulates the plural carrier wave appended signals 1 to N to be transmitted to the nodes 1 to N. The DAC **502** converts a digital output of the DMT modulating unit **501** into an analog output. The DML **403** executes photo-electric conversion for the output of the DAC **502**. Thereby, the transmitting apparatus **102** outputs the (group of) carrier wave appended signals S**1** (S**1**-**1**, S**1**-**2**, . . . , and S**1**-N) that corresponds to the number of nodes N and that each are at a sub-carrier frequency different from each other, as the carrier wave appended signal S**1**. A DC component of the carrier wave appended signal S**1** is used for the carrier wave by the optical FDM. A predetermined gap (a frequency interval) is provided between each modulated component (carrier wave appended signal S**1**) and the carrier wave (the DC component).

[0065] The receiving apparatus **104** of the data station **201** includes a photo detector (PD) **504**, a high-pass filter (HPF) **505**, an ADC **506**, and a DMT demodulating unit **507**. The photo detector **504** collectively receives the carrier light beam with which the plural node appended signals A**1** to AN are multiplexed and outputs the received carrier light beam to the high-pass filter **505**. The high-pass filter **505** electrically cuts the frequencies of the node appended signals A**1** to AN and the ADC **506** converts the analog signal to a digital signal. The DMT demodulating unit **507** demodulates the node appended signals A**1** to AN transmitted by the nodes 1 to N (**103**), from the output of the ADC **506**.

[0066] Each of the plural nodes 1 to N (**103**) includes the optical coupler **115**, the carrier wave appended signal receiving device **116**, the optical FDM multiplexing unit **117**, and the node appended signal transmitting device **118**. The optical coupler **115** branches the optical signal in the optical transmission path **101** to the carrier wave appended signal receiving device **116**. The carrier wave appended signal receiving device **116** includes a photo detector (PD) **511**, a band-pass filter (BPF) **512**, an ADC **513**, and a DMT demodulating unit **514**. The photo detector **511** receives the carrier light beam that includes the carrier wave appended signals 1 to N (S**1**) and outputs the received carrier light beam to the band-pass filter **512**. The band-pass filter **512** extracts the carrier wave appended signal of the corresponding node of the carrier wave appended signals 1 to N (S**1**) and outputs the received carrier wave appended signal to the ADC **513**. The ADC **513** converts the analog signal into a digital signal and outputs the digital signal to the DMT demodulating unit **514**. The DMT demodulating unit **514** demodulates the carrier wave appended signal 1 (S**1**) addressed to the corresponding node. The band-pass filter may be disposed in the post-stage of the ADC **513**.

[0067] The node appended signal transmitting device **118** of each of the nodes 1 to N (**103**) includes an oscillating device **515**, a DMT modulating unit **516**, a DAC **517**, a multiplying device **518**, and a directly modulated laser (DML) **519**. The frequency of the oscillating device **515** of the node 1 (**103**) is set to be the predetermined frequency f1. The frequency f1 is set to be a frequency that is different from those of the carrier wave appended signals and those of the other nodes (2 to N) **103**.

[0068] The DMT modulating unit **516** of the node 1 (**103**) DMT-modulates the node appended signal A**1** input thereinto and the DAC **517** converts the digital signal into an analog signal and outputs the analog signal to the multiplying device **518**. The multiplying device **518** multiplies the node appended signal A**1** by the predetermined frequency f1 and outputs the multiplication result to the optical FDM multiplexing unit **117**.

[0069] The optical FDM multiplexing unit **117** includes, for example, an optical fiber **521** as the non-linear optical medium; and a pair of WDM couplers (CPLs) **522***a* and **522***b* at the ends of the optical fiber **521**. Thereby, the node 1 (**103**) outputs the node appended signal A**1** at the frequency that is different from that of the carrier wave. Similarly, the nodes 2 to N (**103**) respectively output the node appended signals A**2** to AN at frequencies that each are different from that of the carrier wave and from those of the other nodes 1 to N (**103**). The node appended signals A**2** to AN output respectively from the nodes 1 to N (**103**) are received by the receiving apparatus **104** of the data station **201**.

[0070] In the description above, all of the carrier wave appended signals 1 to N and the node appended signals A**1** to AN are adapted to be DMT-modulated. However, the node appended signals A**1** to AN may be modulated based on not only the DMT modulation scheme but also another scheme that is the multi-carrier modulation scheme.

[0071] FIG. **6** is an explanatory diagram of signal production executed based on the multi-carrier modulation and depicts a configuration where a signal is transmitted from a transmitting device **601** to a receiving device **602** that form a pair. For example, the transmitting device **601** corresponds to the transmitting apparatus **102** that transmits the carrier wave appended signals 1 to N and the receiving device **602** corresponds to the carrier wave appended signal receiving device **116**. The devices are not limited to these and the transmitting device **601** may be applied to the node appended signal transmitting device **118** that transmits the node appended signals A**1** to AN and the receiving device **602** may be applied to the receiving apparatus **104** that receives the node appended signals A**1** to AN.

[0072] The transmitting device **601** includes a mapper **611**, an IFFT **612**, a coupling unit **613**, and an E/O converting unit **614**. The receiving device **602** includes an O/E converting unit **621**, a dividing unit **622**, an FFT **623**, and a de-mapper **624**. The O/E converting unit **621** corresponds to the PD **511** of FIG. **5**. The transmitting device **601** can assign the number of bits that corresponds to the transmission properties such as the S/N of each of the sub-carriers, using the mapper **611**. For example, when sub-carriers (for the example of the node appended signals A**1** to AN) are assigned that are each different from each other on the frequency axis as depicted in a graph **630**, for example, the transmission capacities are each different from each other for each sub-carrier number as depicted in a graph **631**. Corresponding to this, allocation is executed to cause the transmission capacity to differ for each sub-carrier number within the permissible range for the transmission property. Thereby, an increase is enabled of the degree of multiple values of the sub-carriers whose S/N ratios are excellent, and improvement is enabled of the frequency use efficiency. Sub-carriers can be set at arbitrary frequencies.

[0073] According to the embodiment, in the optical FDM transmission system, the plural nodes in the optical transmission path can send the node appended signal information and the receiving apparatus can collectively receive the information. The plural nodes superimpose on the carrier wave, the sub-carrier modulation signals at the sub-carrier frequencies that each are different from each other. In the embodiment, the transmitting apparatus superimposes on the carrier wave, the common or individual carrier wave appended signals and sends the carrier wave appended signals to the nodes through the optical transmission path. Thereby, each of the nodes can receive the carrier wave appended signal transmitted by the transmitting apparatus through the optical transmission path and can not only simply send the information but also externally capture information.

[0074] In the embodiment, the frequencies of the carrier wave appended signals are set in the vicinity of the frequency of the carrier wave. However, the setting of the frequencies is not limited hereto. The frequencies of the carrier wave appended signals only have to avoid overlapping on the frequencies of the node appended signals and therefore, may be set not only in the vicinity of the frequency of the carrier wave but also at, for example, the frequencies each between the frequencies of the node appended signals. When, for example, the control signal is adapted to be sent to each of the nodes as the carrier wave appended signal, the carrier wave appended signal includes a small amount of data compared to that of the node appended signal such as the data transmitted by the node. In this case, the frequency of the carrier wave appended signal may be set to be at the frequency between those of the node appended signals.

[0075] According to an embodiment, in the wavelength division multiplex transmission, the transmission of information to plural nodes can be executed.

[0076] All examples and conditional language provided herein are intended for pedagogical purposes of aiding the reader in understanding the invention and the concepts contributed by the inventor to further the art, and are not to be construed as limitations to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although one or more embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. An optical signal transmitting apparatus that is disposed in an optical frequency division multiplex transmission system that comprises plural nodes that are in an optical transmission path and respectively use a unique frequency to frequency-multiplex information with a carrier wave to transmit the information to an optical signal receiving apparatus in the optical transmission path, the optical signal transmitting apparatus outputting the carrier wave and comprising:

a transmitting unit into which information to be delivered to the nodes is input, the transmitting unit transmitting the information using a frequency that does not overlap the unique frequencies used by the nodes; and

a multiplexing unit that frequency-multiplexes output of the transmitting unit and the carrier wave, and sends the frequency-multiplexed output to the optical transmission path.

2. The optical signal transmitting apparatus according to claim **1**, wherein

the transmitting unit frequency-multiplexes the information to be delivered to the nodes and the carrier wave by applying multi-carrier modulation thereto, and sets a predetermined frequency gap between the frequency for the multiplexed information and a frequency of the carrier wave.

3. The optical signal transmitting apparatus according to claim **1**, wherein

the transmitting unit transmits information that is common to the plural nodes or individual information of the nodes.

4. The optical signal transmitting apparatus according to claim **3**, wherein

the transmitting unit transmits the individual information to the nodes based on time division for each of the nodes.

5. An optical frequency division multiplex transmission system comprising: an optical signal transmitting apparatus that outputs a carrier wave to an optical transmission path; plural nodes that are disposed on the optical transmission path, that each frequency-multiplex information and the carrier wave using a unique frequency, and that each send the information and the carrier wave to the optical transmission path; and an optical signal receiving apparatus that, via the optical transmission path, receives the information sent from each of the nodes, wherein

the optical signal transmitting apparatus comprises:

a transmitting unit into which information to be delivered to the nodes is input, the transmitting unit transmitting the information using a frequency that does not overlap the unique frequencies used by the nodes; and

a multiplexing unit that frequency-multiplexes output of the transmitting unit and the carrier wave, and sends the frequency-multiplexed output to the optical transmission path.

6. The optical frequency division multiplex transmission system according to claim **5**, wherein

the nodes each comprise:

a coupler that extracts information addressed to the node; and

a receiving unit that receives the information.

7. The optical frequency division multiplex transmission system according to claim **5**, wherein

the optical signal transmitting apparatus and the optical signal receiving apparatus are disposed in a vicinity of each other,

the optical transmission path is a loop-back path through the plural nodes, with the optical signal transmitting apparatus as a starting point thereof and the optical signal receiving apparatus as an ending point thereof, and

the optical frequency division multiplex transmission system comprises a control unit that based on information sent by the nodes and received by the optical signal receiving apparatus, produces information to be delivered to the nodes from the optical signal transmitting apparatus.

8. The optical frequency division multiplex transmission system according to claim **7**, wherein

the control unit produces control information to control the nodes, based on the information sent by the nodes.

9. The optical frequency division multiplex transmission system according to claim **5**, wherein

the optical signal transmitting apparatus and the nodes assign for the information to be sent based on multi-carrier modulation, bit counts according to a transmission property of a sub-carrier.

10. The optical frequency division multiplex transmission system according to claim **9**, wherein

the optical signal transmitting apparatus transmits the information to be delivered to the nodes in a discrete multi-tone modulation scheme.

11. An optical signal communication method of an optical frequency division multiplex transmission system comprising an optical signal transmitting apparatus that outputs a carrier wave to an optical transmission path; plural nodes that are disposed on the optical transmission path, that each frequency-multiplex information and the carrier wave using a unique frequency, and that each send the information and the carrier wave to the optical transmission path; and an optical signal receiving apparatus that, via the optical transmission path, receives the information sent from each of the nodes, the optical signal communication method comprising:

receiving by the optical signal transmitting apparatus, input of information that is to be delivered to the nodes and transmitting, via a transmitting unit, the information using a frequency that does not overlap the unique frequencies used by the nodes; and

frequency-multiplexing by the optical signal transmitting apparatus via a multiplexing unit, the carrier wave and the information transmitted by the transmitting unit, and sending the frequency-multiplexed carrier wave and information to the optical transmission path.

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