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— *With international search report.*

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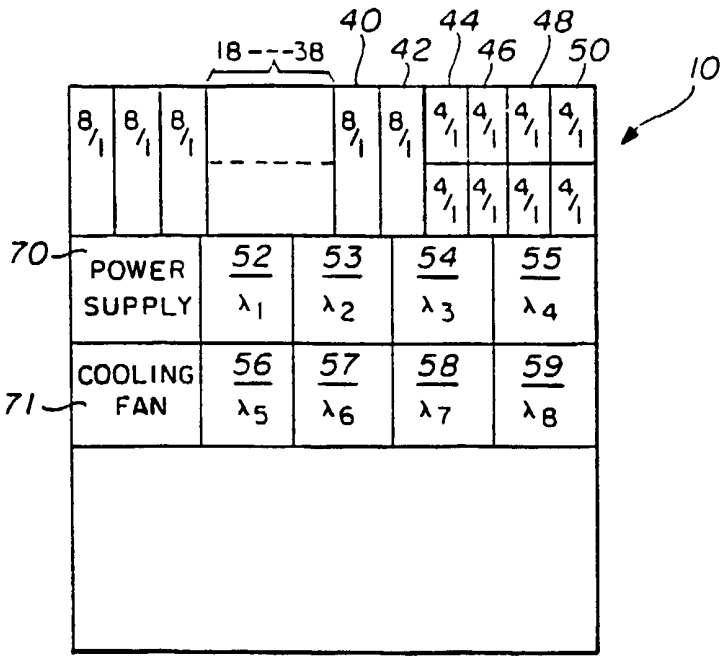
(54) Title: APPARATUS AND METHODS FOR MAINTAINING BALANCED COMMUNICATION CHANNELS WITH INCREASING SERVICE DEMANDS



(57) Abstract: The present invention relates to methods and apparatus for use in a distribution cabinet of an optical communication system, and more specifically to distribution apparatus which allows the addition on demand of substantially a maximum number of electrical RF (radio frequency) user channels onto a wavelength carrier at a specific wavelength before being required to add another light generator for generating a carrier at a different wavelength. That is, the addition of an optical generator for generating a specific wavelength may be substantially delayed until the optical wavelength carrier in use is almost to saturation. This is done without substantial downtime by making simple terminal connections between the existing panels.

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APPARATUS AND METHODS FOR MAINTAINING BALANCED COMMUNICATION CHANNELS WITH INCREASING SERVICE DEMANDS

CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims priority from the following application:
U.S. Application No.: 60/135,624, filed May 24, 1999.

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to methods and apparatus for use in a distribution cabinet of an optical communication system, and more specifically to distribution apparatus which allows the addition on demand of substantially a maximum number of electrical RF (radio frequency) user channels onto a wavelength carrier at a specific wavelength before being required to add another optical transmitter for generating a carrier at a different wavelength. That is, the addition of an optical generator for generating a specific wavelength may be substantially delayed until the optical wavelength carrier in use is almost to saturation. This is done without substantial downtime by making simple terminal connections between the existing panels.

2. DESCRIPTION OF RELATED ART INCLUDING INFORMATION DISCLOSED UNDER 37 CFR 1.97 AND 1.98

The communications industry is using more and more optical or light fibers in lieu of copper wire. Optical fibers have an extremely high bandwidth thereby allowing significantly more information than can be carried by a

copper wire transmission line such as twisted pairs or coaxial cable. However, because of the different usage of cable modem transmissions in various neighborhoods (commonly referred to as penetration), there may be some areas either business or residential where the penetration is almost one hundred percent. That is, almost every household path (HHP) will require the use of a cable modem transmission whereas other neighborhoods may be at substantially zero penetration.

However, just because an area may be at zero penetration at one point in time suggests that the growth rate in that area may be very rapid, and a need exists so that such rapid grown can be handled quickly and inexpensively without the major addition of new equipment and without significant downtime to the customer.

SUMMARY OF THE INVENTION

The above objects and advantages are achieved in the present invention by distribution apparatus in an optical communication system which allows the addition on demand of substantially a maximum number of cable modem transmission user channels with minimum downtime and at no expense. In areas of low usage or low penetration, an optical fiber may carry a single wavelength of light which is modulated by RF signals around a center wavelength of light of about 1550 nanometers. The same optical fiber carrying the 1550 nanometers of light will typically also be capable of carrying other wavelengths of lights which have center wavelengths close to the 1550 nanometers but somewhat displaced so as to have good isolation between the signals. For example, if it were desirable to carry three different wavelengths of light, the center frequencies might be selected to be 1545 nanometers, 1550 nanometers, and 1555 nanometers. The use of three different wavelengths of light as discussed will provide ample separation such that there is no cross talk or interference between the different wavelengths of

light. In fact, up to eight different and specific wavelengths of light may be selected around the base wavelength referred to as 1550. Each of these different eight wavelengths may be referred to as λ such as λ1, λ2, λ3, λ4, λ5, λ6, λ7, and λ8. The 1550 nanometers of light which is considered a base wavelength is selected to minimize the transmission loss of the optical fibers. Certain ones of the most used optical fibers will typically have transmission characteristics such that certain wavelengths are highly desirable as center wavelengths such as, for example, 1550 nanometers, 1310 nanometers, and 960 nanometers of light. However, to understand how eight different wavelengths of light around the 1550 nanometer length can exist at the same time may best be understood by thinking of the 1550 nanometers being one of the best possible wavelengths for transmission over the optical fiber, yet 1545 and 1555 nanometers also are very efficient transmissions. Therefore, so long as there is sufficient separation between the various wavelengths of light such that there is no cross talk or interference from each of the various wavelength transmissions, there is sufficient bandwidth to readily handle a large number of customers such as, for example, 768 cable modem customers. The novel apparatus of this invention which allows such flexibility, comprises a first group of combining circuits each of which has a plurality of inputs and a single output. Each of the combining circuit inputs is capable of receiving an input signal on each one of the plurality of input terminals. The plurality of input signals which may be of different frequencies are then directly combined by the combining circuits and provided as an output signal made up of these combined received input signals on the single output terminal. In a preferred embodiment, the plurality of inputs and the single output terminate in an SMB-type coax connector. Further, each one of the inputs may itself be carrying signals from up to at least 24 HHP's (household paths) or cable modem customers. The inputs to the input terminals are provided by a multiplicity of input cables each of which may be carrying, as mentioned above, up to at least 24 different channels or signals from 16 different cable

modem customers. Each one of the input cables will also terminate with an SMB connector suitable for mating with the SMB connectors on the first group of combining circuits. There is also a second group of combining circuits similar to the first group in that they also have a plurality of inputs and a single output. Each one of the second group of combining circuits receives one of the outputs from one of the first group of combining circuits and then, as in the same manner as with respect to the first group of combining circuits, combines these inputs to produce a combined output signal which is made up of all of the output signals received from the first group of combining circuits. The inputs of this second group of combining circuits is also a first type of connector, such as an SMB connector as discussed above.

Then, depending upon the level of penetration, the output of the second group of combining circuits may go directly to an optical transmitter which generates light over a frequency band at a very select center wavelength around 1550 nanometers of light. Alternately, the output from the second group of combining circuits goes to a third or final combining circuit. The final combining circuit, in the same manner as the first and second groups of combining circuits, receives the output from the second group of combining circuits as input signals and combines these signals into a final or modulation output signal which is used to modulate the wavelength of light generated by the optical transmitter.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the present invention will be more fully disclosed when taken in conjunction with the following Detailed Description of the Invention in which like numerals represent like elements and in which:

FIG. 1 is a distribution cabinet or other support structure showing apparatus as used in the present invention;

FIG. 2 shows the densely aligned panels or combining circuits of the present invention;

FIGS. 3A and 3B show the side and front views of a type of combining circuit having eight similar input connectors and a single output connector;

FIGS. 4A and 4B show another type of panel similar to FIG. 3A and 3B except that it has two independent combining circuits each of which has four inputs and a single output;

FIGS. 5A, 5B, and 5C show still another type of combining circuit which produces a final or modulating output going to the light generator for modulating the specific wavelength of light. According to one embodiment, each of these combining circuits has four inputs of one type connector and a single output of a different type connector;

FIGS. 6A and 6B show a typical type arrangement and connections for the apparatus of this invention for a distribution area with low penetration or user demand;

FIG. 7 is a simplified schematic showing the HHP (household path) inputs (individual modem user) through the distribution apparatus of this invention to the light generation and modulation circuit which produces the light having a specific wavelength such as 1545 nanometers and referred to in this example as $\lambda 1$. This figure is representative of the low penetration of FIGS. 6A and 6B;

FIGS. 8A and 8B show the apparatus of this invention connected in a manner suitable for an average amount of cable modem users or medium penetration;

FIGS. 9A and 9B show the apparatus of the present invention arranged for use in an area of high penetration; and

FIG. 10 shows a block diagram schematic of portions of the apparatus of this invention as it may be arranged for medium or high penetration.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 1, there is shown a distribution cabinet or other support structure 10 supporting the distribution apparatus of the present invention. According to the embodiment shown, there are sixteen distribution panels 12-42 having eight inputs and a single output. In addition, there are four dual distribution panels 44 through 50 making eight total distribution circuits each of which has four inputs and a single output. Also shown are eight optical transmitters for generating eight different and specific wavelengths of light $\lambda 1$-$\lambda 8$ having reference numerals 52-66. Also shown is a power supply 70 for providing power to the optical transmitters. It will also be appreciated that a fan 71 could be included for keeping the rack and the equipment cool.

Referring now to FIG. 2, there is shown a larger and more detailed view of the twenty different panels 12-50 shown in FIG. 1 and which contain the various types of combining circuits.

As shown, each of the panels or combining circuits 12-42 include eight input terminals or connectors 12A-12H and a single output connector 12. Since each of the panels 12-42 is identical, only one will be discussed. Also as shown, each of the panels 12-42 as well as each of the dual panels 44-50 according to the present embodiment include a securing bolt 72 which secures the densely arranged panels 12-50 to the rack area or pocket 73. Also shown attached to the rack area or pocket 73 are mounting brackets 74 and 76 for mounting the rack area to the support structure.

Referring now to FIG. 3A, there is shown a side view and a front view of panel 12. As was discussed above, the purpose of the panel containing the combining circuit is to receive signals on the input connectors 12A-12H and provide an output on the output connector 12. Thus, there is a copper path from the connector 12A to 12. It will also be appreciated, by those skilled in the art, that since the electrical paths from the input connectors 12A-12H as

well as the output path going to connector 12 are all carrying signals having a frequency in the megahertz range, the conductive path should maintain a constant impedance such that there will not be an impedance mismatch with the resulting signal attenuation and reflection. In the embodiment shown, the conductive paths maintain a 75-ohm impedance between the inputs 12A-12H and the output 12 such as commonly required by coaxial cable. In the embodiment shown in FIGS. 3A and 3B, the input connectors 12A-12H are SMB connectors as is the output connector 12. It will also be appreciated that if necessary the paths could be made to have a different constant impedance path.

Referring now to FIGS. 4A and 4B, there is shown a side view and a front view of another combining circuit similar to that of FIGS. 3A and 3B except the combining circuit of this Figure is a dual combining circuit. According to this embodiment, each one of the dual circuits includes four inputs 78, 80, 82, and 84 and a single output 86. The panels shown in FIGS. 4A and 4B are typically used in areas of low penetration where these panels represent the second combining circuits which go to a third and final combining circuit. According to this embodiment, all the input connectors are SMB as are the output connectors, although it will be appreciated that other types of connectors are still within the scope of this invention.

Referring now to FIGS. 5A, 5B, and 5C, there is shown a side view of a panel with two different front views. Panels 5A and 5B are substantially the same as that discussed with respect to FIGS. 4A and 4B except the output connectors 98 and 100 are of the larger, sturdier type "F" type coax connector. The face plate or front view of FIG. 3 shows an alternate embodiment wherein only one of the combining circuits on the panel is used since that there are only four inputs and a single output 100.

Referring now to FIGS. 6A and 6B, there is shown a simplified block diagram of the electrical cable connections between the panels containing the combining circuits of the present invention. In this particular embodiment, the

8-input/1-output panels are divided into four groups of four panels each, these groups are referred to as 102, 104, 106, and 108. Referring again to FIG. 2, it can be seen that each one of the panels 12-42 can receive eight inputs to provide one output. In the embodiment shown, the connections are for a low penetration area and as shown the first group 102 of panels has no inputs that is, these panels are not being used. However, in the second group, there are 20 inputs from 20 separate distribution panels coming into the four panels. As an example only, panel 20 is shown as receiving eight inputs, panel 22 six inputs, panel 24 four inputs, and panel 26 two inputs. Since each one of the panels 20-26 does receive at least two inputs and up to eight inputs, each one of these panel outputs provides an input to the panel 44B. It should be noted, of course, that with respect to panels 12-18, which receive no inputs, there is no need to make connections between these panels and the 4-input/1-output panel 44A as is indicated by the "X" 107. In a similar manner, groups 106 and 108 receive 32 inputs for the four panels or eight inputs per panel. Thus also as was the case with the group 104, each one of the panels 28-34 and 36-42 provides a single output to the four inputs of the 4-to-1 combining panel 46A and 46B. Thus, as was discussed, since each one of the panels 44A, 44B, 46A, and 46B may receive up to four inputs each, they will each be capable of providing a single output to the 4-to-1 combining panel 48A, which will in turn combine the inputs and provide a single output to the optical transmitter 52 to modulate the specific wavelength of light $\lambda 1$.

To better illustrate the connections, FIG. 7 shows an overall schematic diagram of an input from a single ONU (optical network unit) to the light generator 52. The light generated by generator 52 is modulated with all of the signals on that path. As shown, the HHP's (household paths) or user inputs are provided to a distribution panel referred to as ONU No. 1 and provides one of the inputs to the 8-to-1 distribution on combining circuit 20. In a similar manner, although not shown, there are six ONU's 9-18 providing inputs to six of the inputs on combining circuit 22. The outputs of each of the combining

circuits 20 and 22 are then provided to one portion of the dual 4-to-1 combining circuits 44A and 44B. The output of this circuit 44B is then provided to one of the inputs of the circuit 48A as are inputs from the other 4-to-1 combining circuits 44A, 46A, and 46B. As shown, the output of the combining circuit 48A is provided to the light generator 52 for modulating the wavelength of light $\lambda 1$. Most arrangements assume about 96 users or different modems can be handled by any one of the single wavelengths of light λ-$\lambda 8$. Consequently, a single rack of 20 different panels such as shown in FIG. 2 can handle up to approximately 768 customers by using eight different wavelengths of light $\lambda 1$ through $\lambda 8$. However, the rack may actually be able to receive a higher number of HHP's such as, for example 2016.

Referring now to FIGS. 8A and 8B, there is shown a block diagram schematic for a medium penetration arrangement. As shown in this embodiment, the 8-to-1 combining circuits 16, 18, 24, 26 are not used as indicated by the "X" through these panels. Thus as shown in FIG. 8A, the two panels 12 and 14 of group 102 provide outputs to two of the inputs to a final combining circuit 44. It will be recalled that the 8-to-1 combining circuits 16, 18, 24, and 26 are not being used in the illustrated embodiment. Likewise, half of each of the circuits 44, 46, 48, and 50 are shown as not being used by means of the "X" through these circuits. Thus, the outputs from panels 12 or 14 are provided as two inputs to the final combining circuit 44 which output is then provided as an input to light generator 52 which produces a specific wavelength $\lambda 1$ modulated by the output of combining circuit 44. Similarly, the two outputs from panels 20 and 22 are provided to two of the four inputs of the 4-to-1 combining circuit 46 which in turn provides a modulating output to light generator 54 which produces a wavelength of light $\lambda 2$. Also, each of the four panels in group 106 provides an input to panel 48 which then provides its single output to light generator 56 which produces a wavelength of light $\lambda 3$. Finally, panels 36-42 provide four single outputs to the inputs of 4-to-1

combining circuit 50 which in turn provides a single modulating output to light generator 58 which generates a wavelength of light $\lambda 4$.

For a high penetration area, and as shown in FIGS. 9A and 9B, each one of the 8-to-1 combining circuits produces one output such that each of the final combining circuits 44A, 44B, 46A, 46B, 48A, 48B, 50A, and 50B each receive two inputs and provide one output to their respective light generators 52-56 to modulate wavelengths of light $\lambda 1$-$\lambda 8$.

Referring now to FIG. 10, there is shown a schematic connection of the panels 16-34 as used in the mid-penetration arrangement earlier shown in FIGS. 8A and 8B. It will also be appreciated that the connections shown for panels 16 and 18 of the 8-to-1 combining circuits and the panel 46 of the 4-to-1 combining circuits providing a single output to light generator 52. This arrangement is the same as used in the high penetration arrangement for these panels shown in FIGS. 9A and 9B.

The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed.

CLAIMS:

1. Distribution apparatus in an optical communication system to allow the addition on demand of substantially a maximum number of electrical RF (radio frequency) user channels onto a specific optical wavelength carrier before being required to add an optical carrier at a different wavelength comprising:

a first group of combining circuits, each combining circuit having a plurality of inputs and an output, each combining circuit suitable for receiving an input signal on each one of said plurality of inputs and for providing an output signal comprised of said received input signals on said output, said plurality of inputs and said output terminating with a first type of connector;

a multiplicity of input cables, each one of said input cables carrying an input signal and terminating with a connector suitable for connecting with one of said first type of connectors on said first group of combining circuits;

a second group of combining circuits, each one of said second group of combining circuits having a plurality of inputs and an output, and each one of said plurality of inputs of said second group suitable for receiving one of said output signals from one of said first group of combining circuits and each one of said second group of combining circuits providing a combined output signal at its output comprised of said output signals received from said first group of combining circuits, said plurality of inputs on each of said second group of combining circuits terminating with one of said first type of connectors; and

a first group of connecting cables terminated at each end with a connector suitable for connecting with one of said first type of connectors, each of said first group of connecting cables connecting an output from one of

said first group of combining circuits to one of said inputs on one of said second group of combining circuits.

2. The apparatus of claim 1 and further comprising a light-emitting device and wherein said combined output signal from one of said second group of combining circuits modulates the light from said light-emitting device.

3. The apparatus of claim 1 wherein said output on said second group of combining circuits terminate with one of said first type of connectors and further comprising:

a final combining circuit, said final combining circuit having a plurality of inputs and an output, at each one of said plurality of inputs of said final combining circuits suitable for receiving one of said combined output signals from one of said second group of combining circuits and said final combining circuit providing a modulation output signal at its output comprised of said combined output signals received from said second group of combining circuits, said plurality of inputs on said final combining circuit terminating with one of said first type of connectors; and

a light-emitting device connected to said output of said final combining circuit such that said modulation signal modulates the light from said light-emitting device.

4. The apparatus of claim 1 wherein each one of said first group of combining circuits are located in a readily releasable panel installed in a support structure.

5. The apparatus of claim 1 wherein at least two of said second group of combining circuits are located in a single, readily releasable panel installed in a support structure.

6. The system of claim 1 wherein said first type of connector is an SMB connector.

7. The apparatus of claim 1 wherein said first group of combining circuits combine up to eight input signals for each output.

8. The apparatus of claim 2 wherein said first group of combining circuits combine up to eight input signals for each output and said second group of combining circuits combine up to four input signals for each output.

9. The apparatus of claim 3 where said first group of combining circuits combines up to eight input signals for each output and said second group of combining circuits and said final circuit combine up to four input signals for each output.

10. A method for allowing on demand the addition of substantially a maximum number of user channels onto a specific optical wavelength carrier before adding an optical carrier of a different wavelength comprising the steps of:

receiving one each of a multiplicity of input signals at a plurality of inputs on a first group of combining circuits;

combining said input signal at each of said first group of combining circuits and providing an output signal from said each one of said first combining circuits, said output signal comprised of said combined input signals;

receiving output signals from at least two combining circuits of said first group at two inputs of a plurality of inputs on one of a second group of combining circuits; and

combining said received output signals by one of said second group of combining circuits and providing a combined output signal from each

one of said second combining circuits, said combined output signal comprised of said received output signals.

11. The method of claim 10 and further comprising the step of modulating light from a light-emitting device with said combined output signal.

12. The method of claim 10 and further comprising the steps of:

receiving combined output signals from at least two combining circuits of said second group at two inputs of a plurality of inputs on a final combining circuit; and

combining said received multi-combination output signals at said final combining circuit and providing a modulation output signal from said final combining circuit, said modulation output signal comprised of said combined output signals.

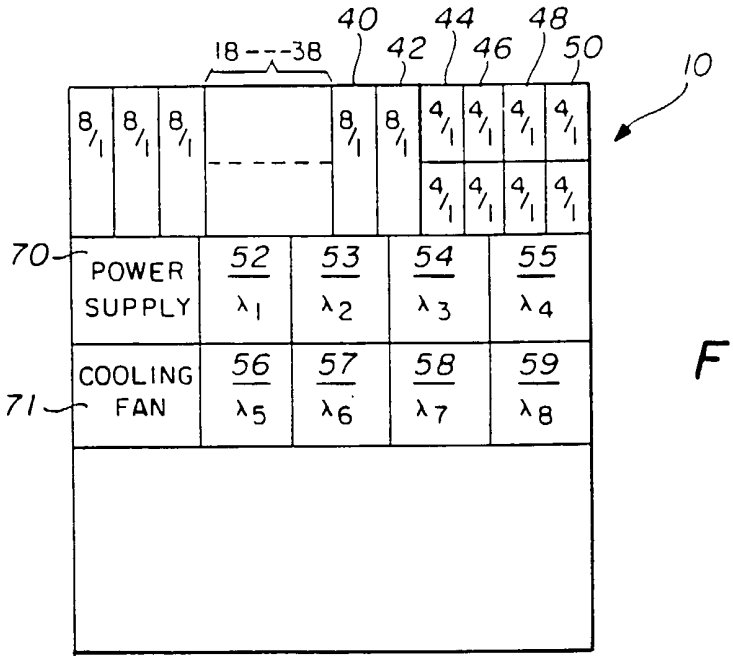

FIG. 1

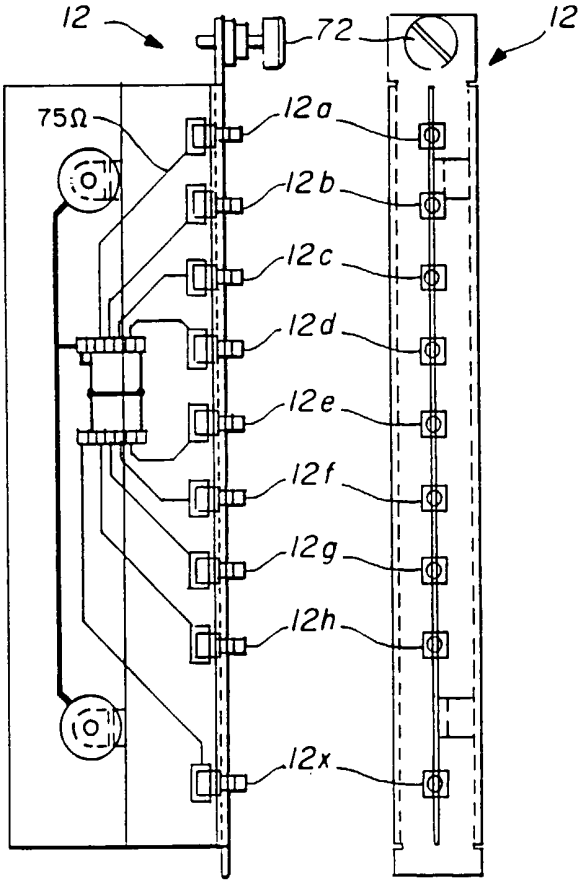

FIG. 3A FIG. 3B

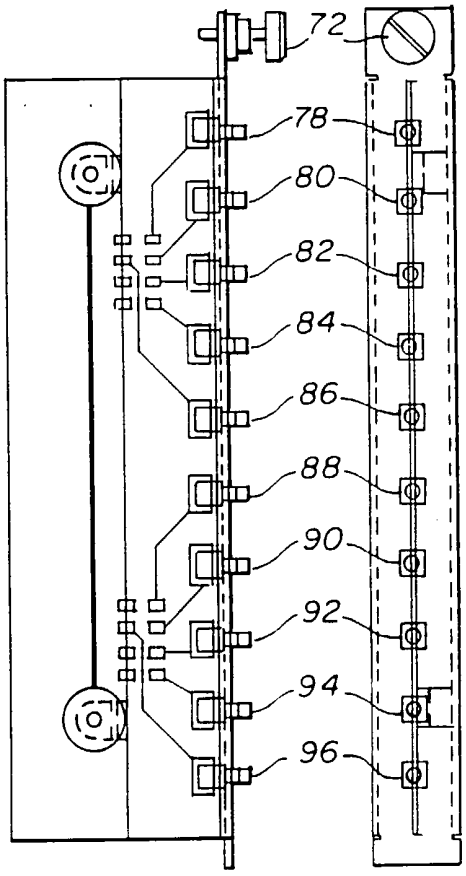

FIG. 4A FIG. 4B

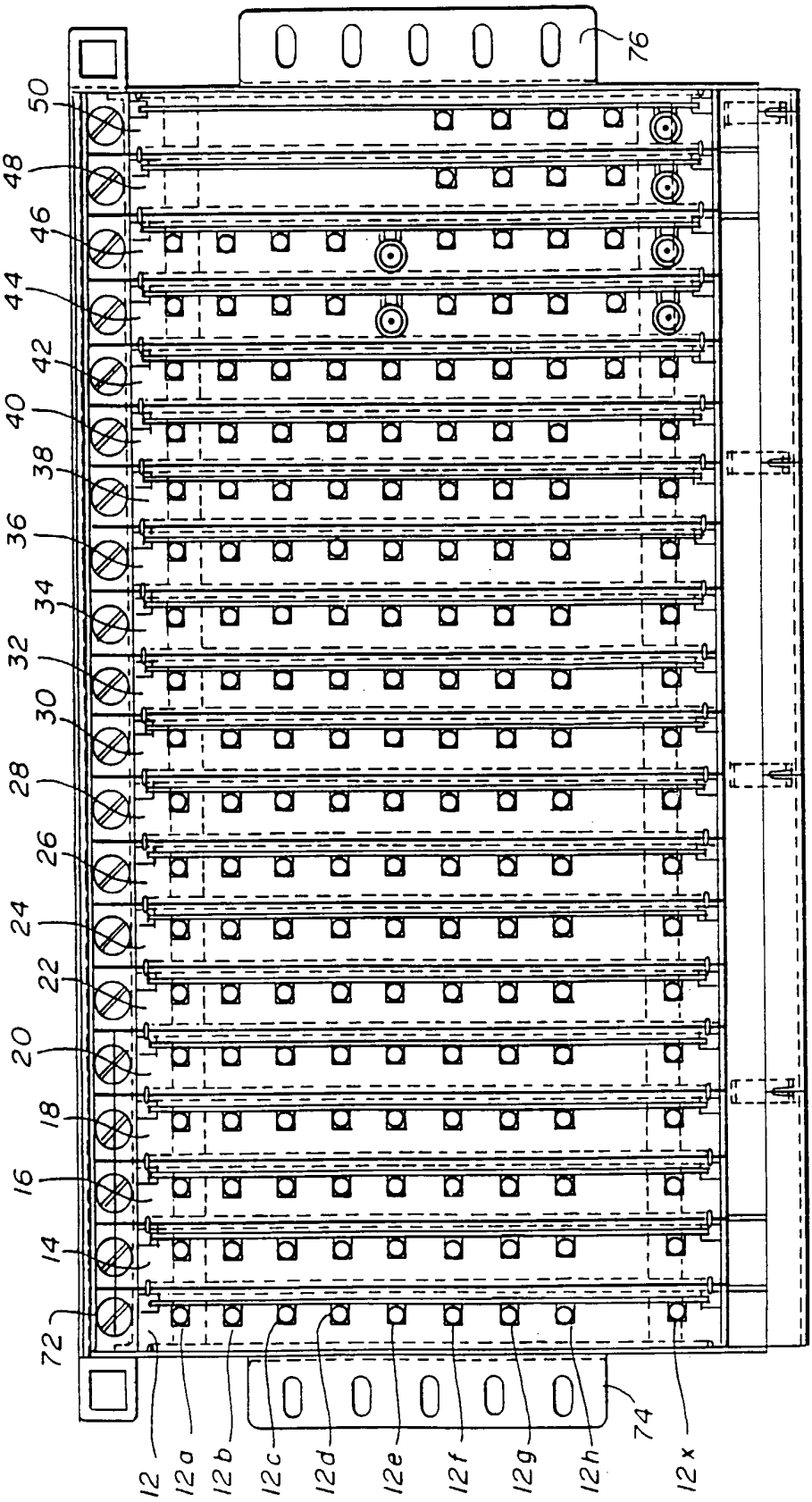
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FIG. 2

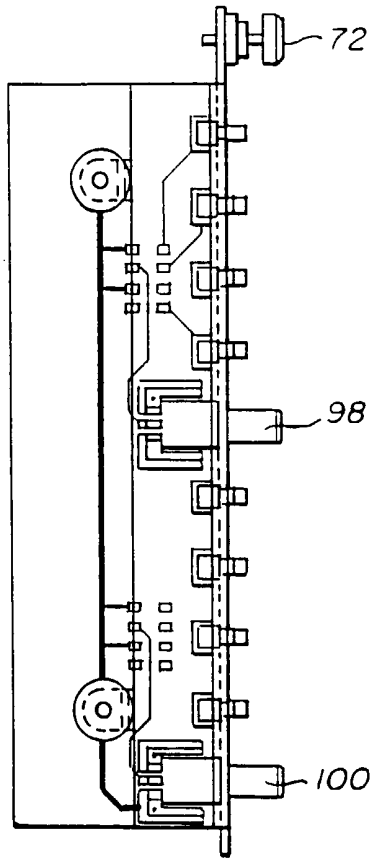


FIG. 5A

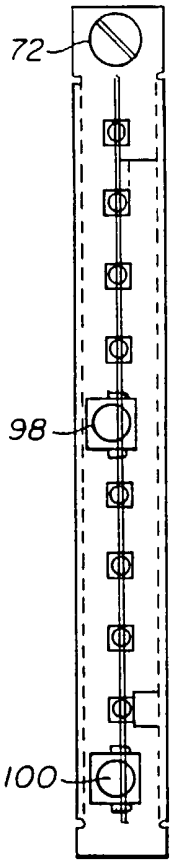


FIG. 5B

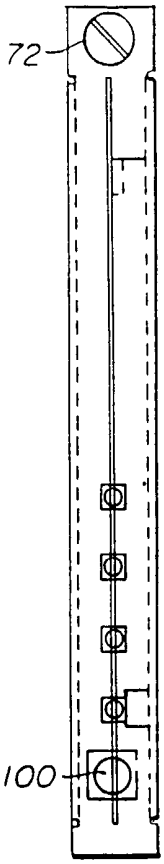


FIG. 5C

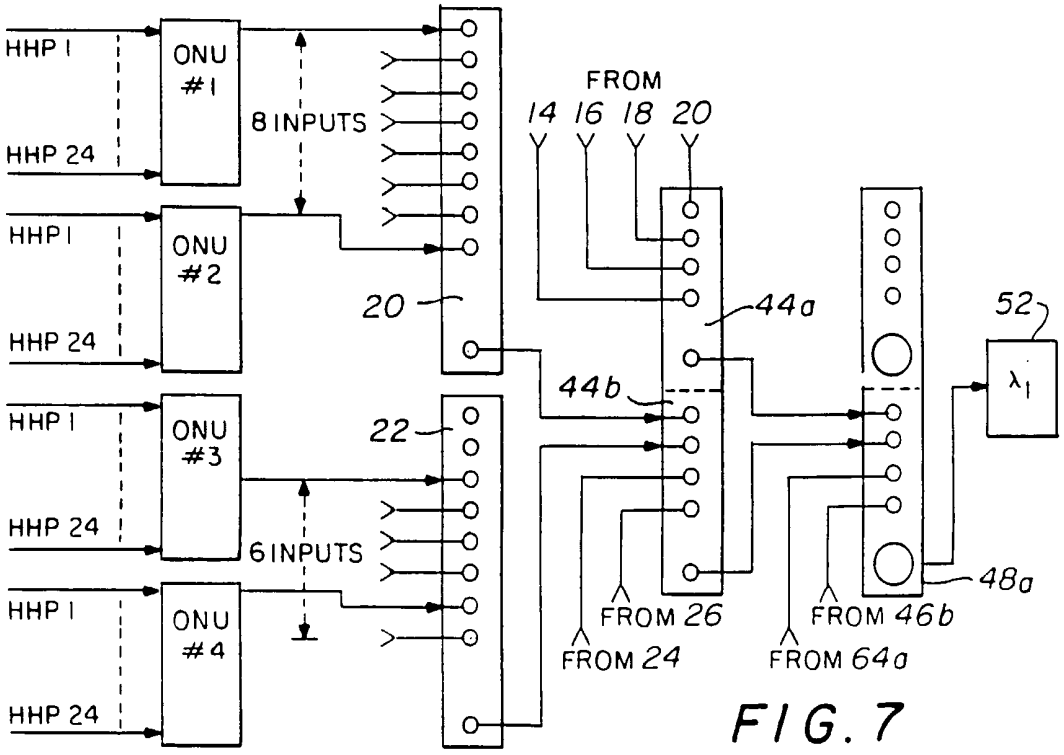
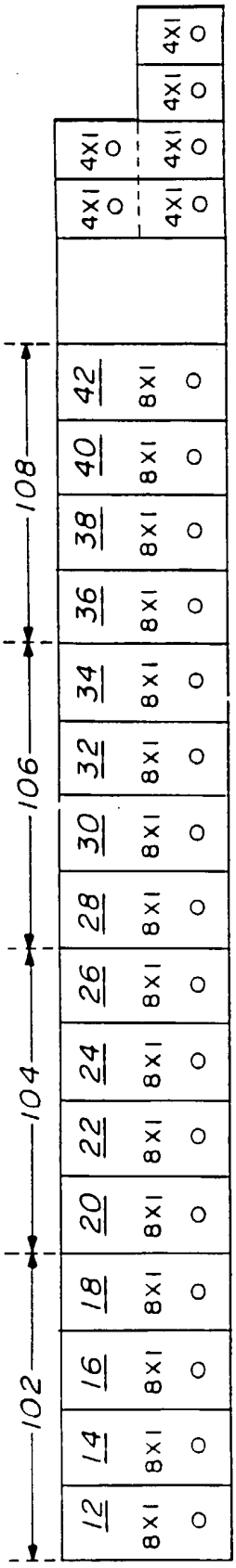


FIG. 7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106
108

FIG. 6B

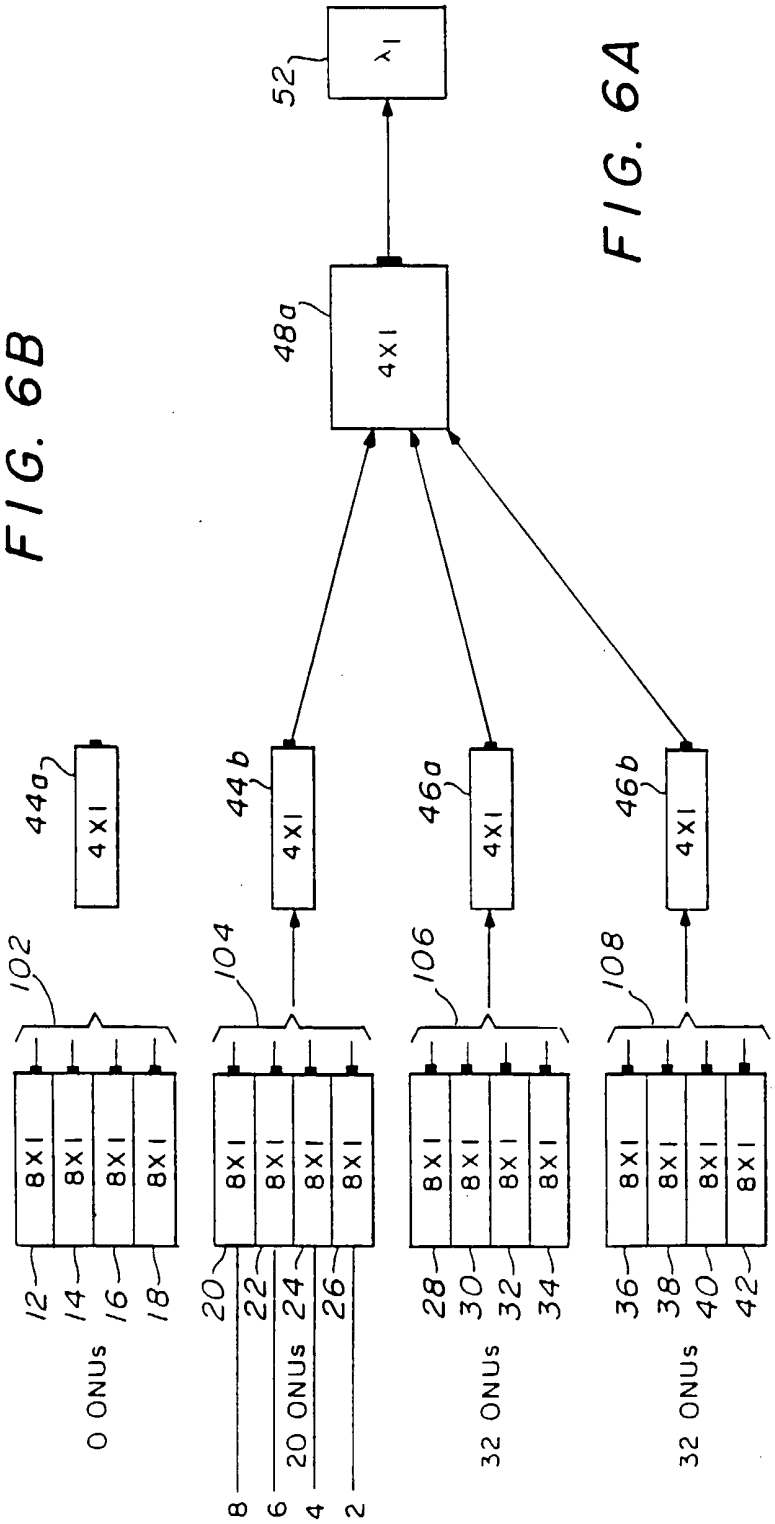
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FIG. 6A

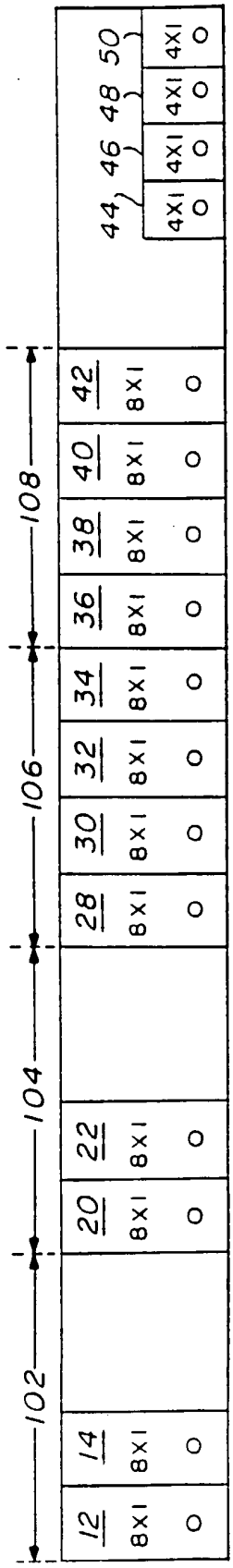
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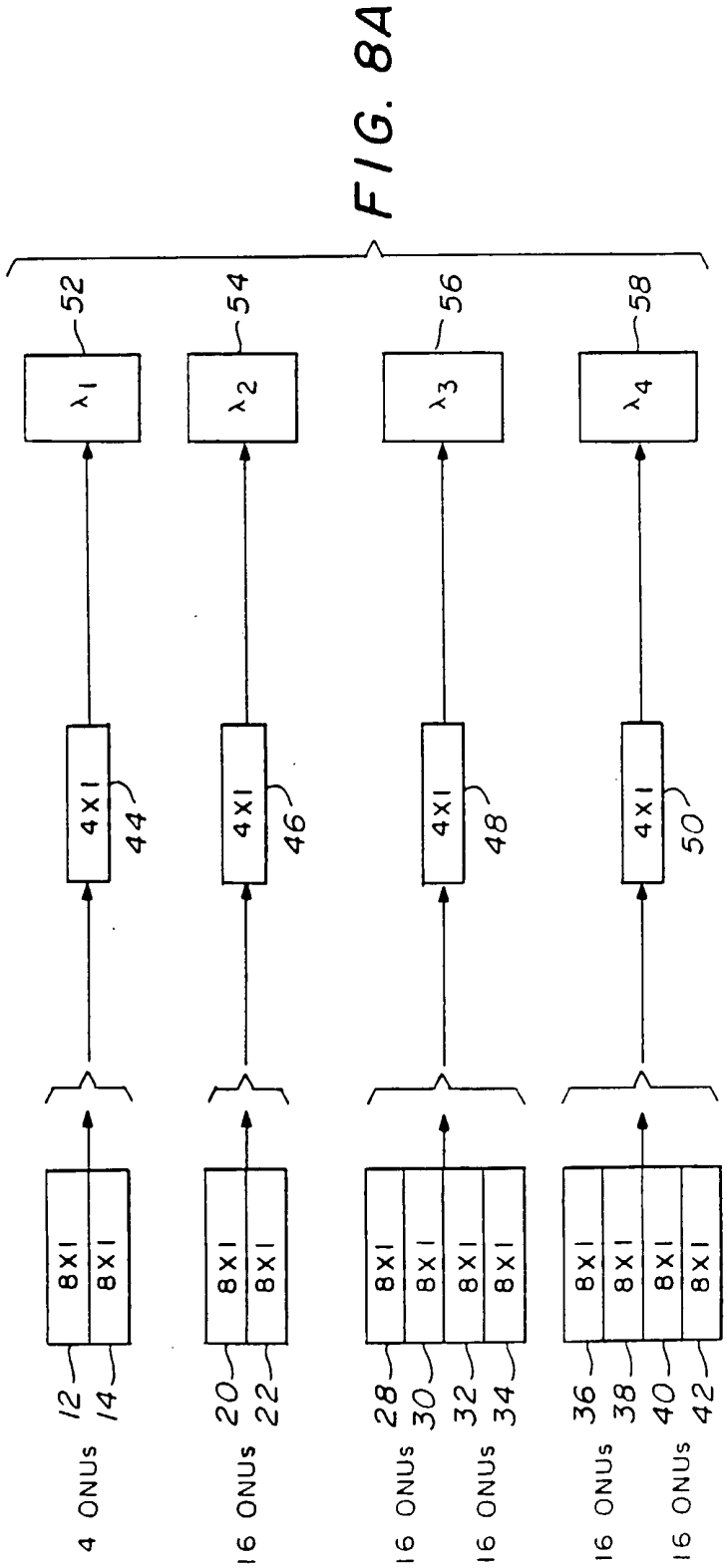
FIG. 8B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20 22 16 ONUs
28 30 16 ONUs
32 34 16 ONUs
36 38 16 ONUs
40 42 16 ONUs

FIG. 8A

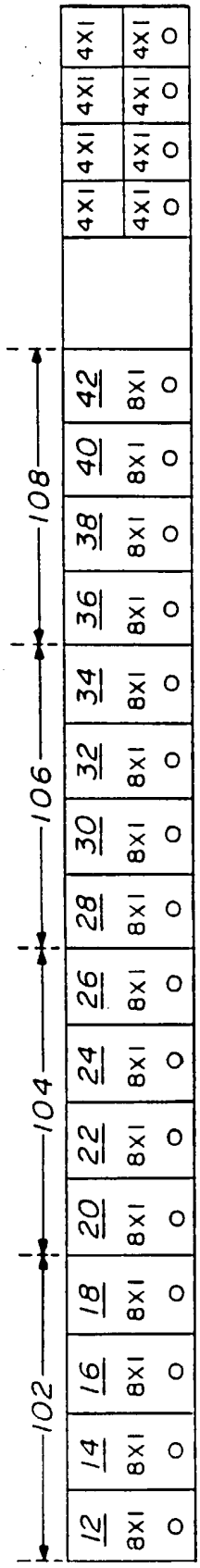
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
8X1
0
102
104
106
108

FIG. 9A

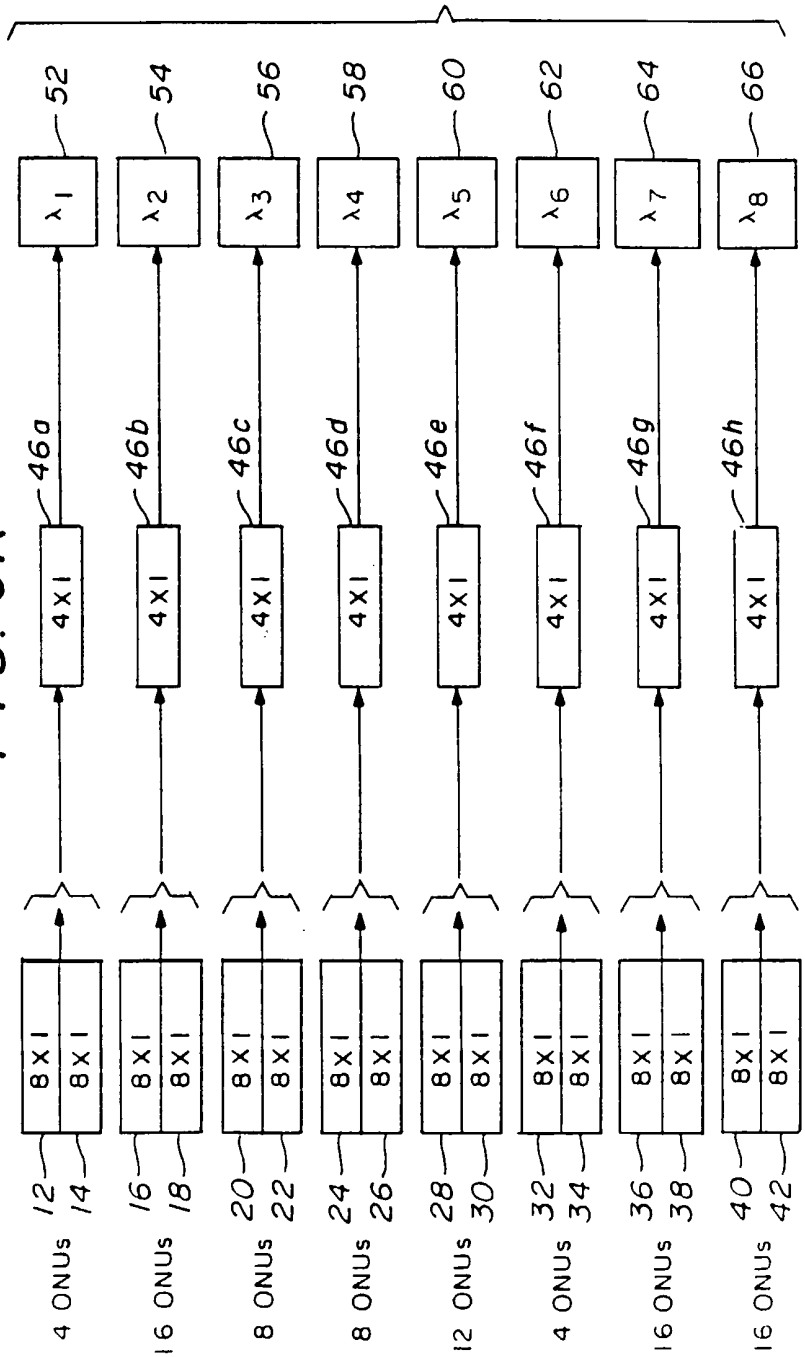
52
54
56
58
60
62
64
66
λ1
λ2
λ3
λ4
λ5
λ6
λ7
λ8
46a
46b
46c
46d
46e
46f
46g
46h
4X1
8X1
4 ONUs
16 ONUs
8 ONUs
8 ONUs
12 ONUs
4 ONUs
16 ONUs
16 ONUs

FIG. 9B

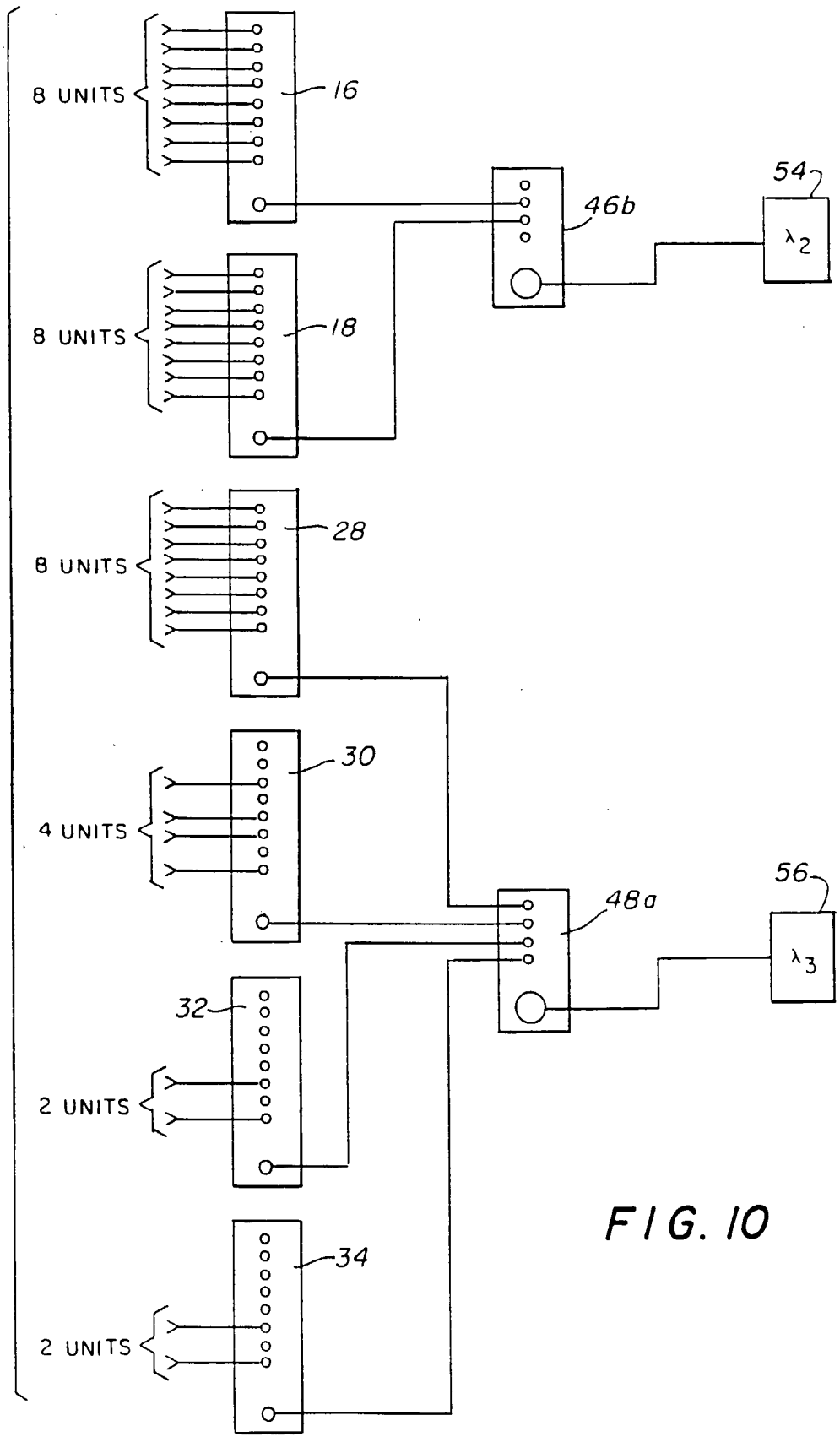
8 UNITS
16
8 UNITS
18
8 UNITS
28
4 UNITS
30
2 UNITS
32
2 UNITS
34
46b
54
λ_2
48a
56
λ_3

FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/13816

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04J14/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04J H04Q

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 768 186 A (BODELL DONALD H) 30 August 1988 (1988-08-30) column 1, line 5 - line 10 column 1, line 25 - line 46 column 2, line 4 - line 42 column 3, line 3 -column 4, line 21; figure 1	1-12

X	US 4 061 577 A (BELL CHARLES H) 6 December 1977 (1977-12-06)	1,2, 10-12
A	column 1, line 13 - line 18 column 1, line 38 - line 53 column 2, line 40 -column 3, line 36; figure 1 column 3, line 49 -column 5, line 5; figure 2	3,7-9

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
6 September 2000	13/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Roldán Andrade, J

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/13816

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 247 (P-1365), 5 June 1992 (1992-06-05) & JP 04 056829 A (NIPPON TELEGR & TELEPH CORP), 24 February 1992 (1992-02-24) abstract	1-3,7-12
A	EP 0 724 366 A (EL GAD PHONE LTD) 31 July 1996 (1996-07-31) column 1, line 10 -column 2, line 51 column 3, line 12 -column 4, line 29; figures 1A,1B,2,3	4-6

INTERNATIONAL SEARCH REPORT

Information on patent family members

Intern[redacted]al Application No
PCT/US 00/13816

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4768186 A	30-08-1988	BR 8700735 A CA 1260164 A	15-12-1987 26-09-1989
US 4061577 A	06-12-1977	NONE	
JP 04056829 A	24-02-1992	NONE	
EP 0724366 A	31-07-1996	IL 112451 A	23-07-1996