

FORM 1
COMMONWEALTH OF AUSTRALIA
PATENTS ACT 1952

623498

Application for a Standard Patent or
A Standard Patent of Addition

We, ALCATEL N.V. of Strawinskylaan 341
1077 XX Amsterdam, The Netherlands,
, hereby apply for the grant of a standard patent/~~patent of addition~~
for an invention entitled

"OPTICAL SUBSCRIBER LOOP SYSTEM"

which is described in the accompanying ~~provisional~~/complete specification.

Details of basic application(s) —

Number of basic application P 39 07 497.8

Name of Convention country in which basic application was

filed Federal Republic of Germany

Date of basic application 8 March 1989

Our address for service is:

PATENT DEPARTMENT,
STANDARD TELEPHONES AND CABLES PTY. LIMITED,
252-280 BOTANY ROAD,
ALEXANDRIA, N.S.W. 2015.
AUSTRALIA.

Dated this Twentysixth day of February 1990.

ALCATEL N.V.

FO14792 28/02/90

BY: 
Signature of Applicant
B. O'Connor

To: The Commissioner of Patents

FORM 8

COMMONWEALTH OF AUSTRALIA
PATENTS ACT 1952 - 1969

DECLARATION IN SUPPORT OF A CONVENTION APPLICATION
FOR A PATENT OR A PATENT OF ADDITION

In support of the Convention application made
for a patent ~~of addition~~ for an invention entitled
"OPTICAL SUBSCRIBER LOOP SYSTEM"

I, BRIAN PATRICK O'CONNOR
of STANDARD TELEPHONES AND CABLES PTY. LIMITED, 252-280
Botany Road, Alexandria, 2015, N.S.W., Australia
do solemnly and sincerely declare as follows:-

1. I am authorised by ALCATEL N.V.
the applicant for the patent ~~of addition~~ to make
this declaration on its behalf.
2. The basic application as defined by Section 141
of the Act was ~~was~~ made in Federal Republic of Germany
on 8 March 1989
by STANDARD ELEKTRIK LORENZ AG
3. DR. HANS JURGEN MATT, a German citizen, of Schumannstr.
6, 7148 Remseck 1, Federal Republic of Germany

is ~~was~~ the actual inventor of the invention, and
the facts upon which the applicant is entitled to
make the application are as follows:-

ALCATEL N.V. is the Assignee of STANDARD ELEKTRIK LORENZ AG
who is the Assignee of the SAID INVENTOR.

4. The basic application referred to in paragraph 2
of this Declaration was ~~was~~ the first application
in a Convention country in respect of the invention
the subject of the application.

Declared at Sydney this 26th day of February 1990

ALCATEL N.V.

.....
Signature of Declarant

B. O'Connor

To: The Commissioner of Patents.

(12) PATENT ABRIDGMENT (11) Document No. AU-B-50180/90
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 623498

- (54) Title
OPTICAL SUBSCRIBER LOOP SYSTEM
- International Patent Classification(s)
(51)⁵ **H04J 014/02 H04B 010/20 H04J 013/00 H04J 014/08**
- (21) Application No. : **50180/90** (22) Application Date : **28.02.90**
- (30) Priority Data
- (31) Number (32) Date (33) Country
3907497 08.03.89 DE FEDERAL REPUBLIC OF GERMANY
- (43) Publication Date : **13.09.90**
- (44) Publication Date of Accepted Application : **14.05.92**
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- (56) Prior Art Documents
AU 602553 10814/88 H04B 009/00
AU 529470 80658/82 H04B 009/00
- (57) Claim

1. An optical communication system for transmitting information signals in both directions between a centre and subscribers, wherein the subscribers are arranged in groups and subscriber-assigned signals to be transmitted from the centre to a group of subscribers are combined into an electric multiplex signal at the centre and transmitted as an optical signal having a first wavelength to the vicinity of the subscribers of said group over an optical waveguide common to said group, said optical signal being distributed to the subscribers by optical means and over individual optical waveguides, and at each subscriber means are provided for converting the received optical signal into an electric signal and for extracting from the subscriber-assigned signals the signal intended for said subscriber, said optical waveguides being also used to transmit information signals from the subscribers to the centre using wavelength-division multiplexing , wherein said signals to be transmitted from the centre to a group of subscribers are combined at the centre into a frequency-division multiplex signal having subscriber-assigned carrier frequencies for subscriber-assigned signals, the signals to be transmitted from the subscribers of said group to the centre modulate carriers having subscriber-assigned carrier frequencies, said modulated carriers being con-

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verted into optical signals having a second wavelength common to all subscribers of a group, which optical signals are transmitted over the individual optical waveguides to the common optical waveguide and over the latter to the centre, said the centre including means for converting the received composite optical signal into a composite electric signal and for demodulating the latter.

623498

ORIGINAL

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952-1969

COMPLETE SPECIFICATION FOR THE INVENTION ENTITLED

"OPTICAL SUBSCRIBER LOOP SYSTEM"

The following statement is a full description of
this invention, including the best method of
performing it known to us:-

This invention relates to an optical communication system for transmitting information signals in both directions between a centre and subscribers, wherein the subscribers are arranged in groups and subscriber-assigned signals to be transmitted from the centre to a group of subscribers are combined into an electric multiplex signal at the centre and transmitted as an optical signal having a first wavelength to the vicinity of the subscribers of said group over an optical waveguide common to said group. The optical signal is distributed to the subscribers by optical means and over individual optical waveguides, and at each subscriber means are provided for converting the received optical signal into an electric signal and for extracting from the subscriber-assigned signals the signal intended for said subscriber. Optical waveguides are also used to transmit information signals from the subscribers to the centre using wavelength-division multiplexing.

Such a system is already known in which the signals to be transmitted from an exchange to a group of subscribers are sent as digital signals, and they are grouped at the exchange into a TDM multiplex signal. In the opposite direction (i.e. from the group of subscribers to the exchange), the signals are transmitted over individual optical waveguides using subscriber-specific wavelengths, to the common optical waveguide and then over this to the exchange. Different wavelengths are used for the different directions, so that the optical waveguides used for transmission in one direction are also used for transmission in the opposite direction, the separation resulting from wavelength multiplexing.

With this known system, the multiplex/demultiplex equipment at the exchange and at the subscribers, which is required to produce the TDM signal and separate it again, represents a significant circuit cost, thus preventing a cost effective realisation of the known system.

It is therefore the task of the invention to find a cheaper system of the type mentioned.

According to the present invention there is provided an optical communication system of the aforementioned type, wherein the signals to be transmit-



ted from the centre to a group of subscribers are combined at the centre into a frequency-division multiplex signal having subscriber-assigned carrier frequencies for subscriber-assigned signals, and wherein the signals to be transmitted from the subscribers of said group to the centre modulate carriers having subscriber-assigned carrier frequencies, and wherein said modulated carriers are converted into optical signals having a second wavelength common to all subscribers of a group, which optical signals are transmitted over the individual optical waveguides to the common optical waveguide and over the latter to the centre, and wherein the centre includes means for converting the
10 received composite optical signal into a composite electric signal and for demodulating the latter.

In order that the invention may be readily understood, embodiments thereof will now be described with reference to the accompanying drawings, in which:

Figure 1 shows the fundamental design of the system according to the invention;

Figure 2 shows modulation and multiplex equipment to produce the frequency multiplex signal containing the telephone and data signals to be transmitted to the group of subscribers;

20 Figure 3 shows the demodulation and modulation equipment at the subscriber for telephone and data signals;

Figure 4 shows the demodulation equipment at the exchange per subscriber for telephone and data signals;

Figure 5 shows schematically how the frequency multiplex signal is made up of separate frequency bands;

Figure 6 shows an arrangement of several electro-optic converters to change the separate frequency bands into optical signals;

Figure 7 shows a first protection arrangement for establishing the existence of a break in the optical fibre;

Figure 8 shows a second, alternative, protection arrangement for establishing the existence of a break in the optical fibre.

In Figure 1, the left hand side shows the equipment provided at the exchange for a group of subscribers, while the right hand side shows the equipment provided for one subscriber in this group. The exchange, drawn as a building, is given the reference 100, and the equipment at the subscriber, shown as installed in a single house, is referenced together as 111. An optical fibre 112 which is common to a group of subscribers leads to a star coupler SK, and from there individual fibres L_1 to L_k lead to the individual 10 subscribers in the group.

This optical fibre 112 carries both the subscriber-specific signals from the exchange to the subscriber group (the so-called forward direction), as well as the subscriber-specific signals from the subscriber group to the exchange (the backward direction); a first wavelength λ_0 (e.g. 1300 nm) is used for the forward direction, and a second wavelength λ_1 (e.g. 800 nm) for the backward direction. The optical fibre 112 and the optical fibres L_1 to L_k are thus used in wavelength multiplex mode to transmit signals in both directions. The details are described later.

The system serves for the transmission of communication signals of any 20 type - analogue or digital, broadband or narrow band, broadcast services (eg. television) or two-way services (eg. telephone or data) in which typically subscriber-specific signals must be transmitted in both directions.

It is advantageous to use the system for two-way services such as telephone or data transmission, separately from broadcast services, in those applications where either there is no requirement for broadcast services, or where these are to be introduced later as separate systems.

The invention will be described using the example of transmission of subscriber-specific signals in both directions (two-way service). The subscriber signals will also be referred to as telephone and data signals, these 30 terms being taken to include: analogue signals from a conventional telephone

set, 64 kbit/s digital signals from a digital telephone set, 144 kbit/s signals from an ISDN terminal and digital data signals of 2 to 34 Mbit/s.

The telephone and data signals to be transmitted to the subscriber group originate at a local exchange 118, and are applied to modulation/demodulation equipment 119 which preferably produces a frequency division multiplex signal, as will be explained later. This multiplex signal is changed into an optical signal in electro-optical converter 120, using intensity modulation of the wavelength λ_0 . By means of coupler 125, the optical signal is coupled into the optical fibre 112 and transmitted to the star coupler SK in the vicinity

10 of the subscribers; from there it is distributed to the optical fibres L_1 to L_K and transmitted over these to the subscribers. In the diagram the optical fibre marked L_3 is connected to Subscriber 111.

At the subscriber, the received optical signal is coupled out by coupler 126 and applied to the opto-electric converter 121 which transforms it to an electrical signal.

The demodulator of model 123 selects the desired signal from the frequency division multiplex signal which includes both telephone and data signals, and transforms it into the appropriate standard form for the terminal involved (telephone set, data terminal or ISDN subscriber terminal). This ensures that the terminals of subscriber 111 only receive the telephone or data signals intended for them. In the simplest case, the subscriber has only one terminal, e.g. a telephone 127. If several terminals are involved, and therefore several signals need to be selected, then the appropriate number of modems must be provided.

The concept of a subscriber with several terminals can include either a single subscriber or a local group of subscribers whose members share living or business space in a building.

If several terminals are involved, it is always best to instal equipment 121 and 123 in some central position (eg. basement) and to connect the termi-

nals to this over the internal cabling that is generally already provided in the building.

Telephone or data signals to be sent from a subscriber terminal to the exchange are modulated onto a subscriber-specific carrier by the modulator or modem 123. If the subscriber (or local subscriber group) has several terminals, eg. several telephones, then a number of modulators modulate different carriers and a multiplexer (not shown) groups these into a frequency band. Either a single modulated carrier, or a frequency band comprising several mod-

10 verter 122 and coupled by means of coupler 126 into the subscriber's

individual optical fibre, eg. L_3 , which leads to the star coupler SK.

Subscribers belonging to a local group use an individual carrier frequency for every terminal of the group. Provision has been made for 64 such carrier frequencies. However, some other number of frequencies, say 'm', can be provided instead. Therefore, a total number of up to m telephones or data terminals can be connected for the subscribers in a local group. The allocation of these to individual subscribers then depends on their individual requirements and the available bandwidth of the system.

The electro-optic converters 122 provided for the different subscribers all operate with the same wavelength λ_1 , so that star coupler SK receives 64 optical signals with the same wavelength λ_1 , but modulated by different carrier frequencies (or band of frequencies).

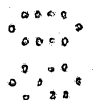
This system for transmitting several different signals over a single optical fibre is known.

In the exchange 100, the opto-electric converter 129 transforms the received composite optical signal, with wavelength as coupled out of fibre 112 by coupler 125, into a composite electrical signal with different carrier frequencies, which is then applied to modulator/demodulator 119. This separates the composite signal into its individual components, demodulates them and
30 makes them available at its output terminals (eg. 64 terminals) to the local

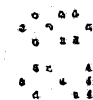
exchange 118, in the form of standard telephone or data signals. The telephone or data signals are provided at the input terminals to the local exchange 118 in the same form and with the same quality as is prescribed for the transmission of telephone or ISDN or data signals.

The couplers 125 and 126 are wavelength-selective and separate the two signals with wavelengths λ_0 and λ_1 without large losses and with very low crosstalk.

With the aid of Figure 2, the type of modulation and multiplexing will now be described that is carried out by the modulation and multiplex sections 10 of the equipment 119.

 Figure 2 shows the modulator/multiplex section of the equipment 119 for telephone and data signals, as provided in the exchange.

 The signals coming from the local exchange (118 in Figure 1) over a normal 2-wire line 201 are transformed in a so-called adapter 202 into a form suited to transmission via a 4-wire system with frequency modulation. The adapter 202 basically fulfills the function of a converter, eg. for 2-wire/4-wire conversion, for dialling signals, ringing signals, etc. The signal resulting from this conversion is applied to the signal input of a modulator 203 and there is frequency modulated into a carrier with frequency f_1 . This carrier frequency f_1 is individually allocated to a telephone connection of one of the subscribers in the group of subscribers shown in Figure 1.

 As outlined above, the subscribers in this group can also have other connections than to the telephone system, eg. access to a digital network such as ISDN (Integrated Services Digital Network). In that case, the digital ISDN signals are applied via a further 2-wire line 204 to an adapter 211 for ISDN signals; the digital output signals from this are sent to the signal input of a modulator 205 suitable for digital signals, where it is modulated onto a carrier with frequency f_{32} which is individually allocated to this ISDN sub-

scriber; either phase shift keying (PSK) or frequency shift keying (FSK) may be used.

In the example just described, a first group of 32 carriers is formed with different frequencies in the range 20 to 30 MHz, which are either frequency modulated with analogue telephone signals, or phase or frequency modulated with digital (eg. ISDN) signals. The example shows one group in which a carrier with frequency f_1 is frequency modulated by telephone signals and a second group in which a carrier with frequency f_{32} is phase modulated by ISDN signals. Any arbitrary combination is possible.

10 In the example shown, a first combiner 206 groups 32 modulated carriers with frequencies f_1 to f_{32} into a frequency band from 20 to 30 MHz, and a second combiner 207 similarly groups 32 modulated carriers with frequencies f_1 to f_{32} into the frequency band from 20 to 30 MHz. By means of converter 208 and filter 209, one of these frequency bands is then shifted to the frequency band from 30 to 40 MHz and both these frequency bands are then combined into the band 20 to 40 MHz which can accommodate 64 telephone and data signals. This frequency band is then the output signal of the equipment referenced as 119 in Figure 1.

From "Electronics Letters", 22 October 1987, Vol. 23, No. 22, p.1196 to 1197, a method is known of transmitting a multiplicity of signals by frequency modulating different carriers and using the composite signal to intensity modulate a single optical transmitter. There the signals are television signals and no mention is made of telephone or ISDN signals (two-way services).

With the aid of Figure 3, the processing of the telephone and data signals at the subscriber end will now be described. The frequency band 20 to 40 MHz containing these signals is pre-filtered by filter 500 which is set to the individual frequency allocated to the subscriber being considered; the desired carrier is thus selected from the composite signal, but only to an inadequate degree, i.e. the other carriers are still present but at low level.

30 In frequency converter 501 this signal is mixed with local carrier HT, this

frequency being so chosen that the desired carrier is converted to the same standard intermediate frequency for all carriers, preferably 10.7 MHz. The subsequent IF filter 502, set to this intermediate frequency, then isolates the desired signal adequately from all the other interfering carriers. After demodulation by demodulator 503 the telephone or data signal is finally made available in its original baseband form.

In the case of telephone access the demodulator is an FM demodulator, while an ISDN connection uses a PSK or FSK demodulator.

The conversion to an intermediate frequency of 10.7 MHz and subsequent
10 filtering and FM-demodulation corresponds to the signal processing in today's conventional short-wave broadcast receivers; it therefore has the advantage of being able to use proven, low-cost equipment. A further advantage lies in the fact that all subscriber connections can use standard demodulators and IF filters and, apart from the local carrier frequency, standard frequency converters.

The telephone or ISDN signal appearing at the output of demodulator 503 is finally so transformed in adapter 504 (whose function was already described
in connection with Figure 2) that signals meeting the normal standards are applied to the subscriber's equipment (telephone set or ISDN terminal).

20 The signals being transmitted to the exchange from this subscriber are so transformed in adapter 504 and the modulator 505 that a modulated carrier is formed that has a frequency f_1 allocated specifically to that subscriber in that local group; the modulator is either an FM modulator (for telephone signals) or a phase shift keying or frequency shift keying modulator (for data signals). This modulated carrier is then in the simplest case applied directly to the electro-optic converter 122 of this subscriber; if the subscriber has several terminals, the signals are combined in a multiplexer (not shown), so that in this case the laser in the converter 122 is intensity modulated by a composite signal comprising several modulated carriers.

The modulators and demodulators shown in Figure 2 and Figure 3 can be switchable so that they can process either telephone signals by frequency modulation, or data signals by frequency or phase shift modulation.

Figure 4 shows the demodulator section of the equipment 119 of Figure 1. The optical signal received over the optical fibre 112, after conversion to an electrical signal in the opto-electric converter 129, is distributed to m separate lines (eg. $m=64$), since it may contain up to 64 telephone or data signals. This composite signal is applied to several demodulation circuits, of which only one is shown. Demodulation takes place using pre-filter 600, IF converter 601, IF filter 602 and demodulator 603, as already explained in connection with correspondingly-named circuits in Figure 3. The telephone or data signal at the output of demodulator 603 is finally transformed in adapter 202 (already described in connection with Figure 2), in such a way that it may be sent over the 2-wire line leading to the local exchange.

In the example of the invention described above, a star coupler is shown as the optical component for splitting the optical signal in the forward direction, and for coupling into the optical fibre 112 the signals sent from the subscribers to the exchange in the backward direction.

Naturally, separately arranged couplers can also be used for these components, as is known.

Also, these optical components do not have to be passive devices; at suitable places optical amplifiers or electrical amplifiers can be inserted, together with the appropriate opto-electric or electro-optic converters.

In the following a few modifications and developments of the system described in Figure 1 are discussed. One variation concerns the choice of the frequencies for the transmission of the telephone or data signals, both in the forward and backward direction. Included in the term "telephone or data signal" are all the signals specified above. As mentioned above, the carriers for the transmission of these signals lie, for example, in the frequency range 20 to 40 MHz. The carrier frequencies used for the transmission of both the

analogue telephone signals and the digital signals with bitrates from 64 to 144 kbit/s should preferably have a uniform spacing, i.e. the carrier frequency spacing should be 300 kHz. In this way, the proven circuits from ultra-short-wave systems can be used for the transmission of the analogue signals by frequency modulation. The carrier frequencies for transmitting digital data with 2 Mbit/s are preferably placed in the upper part of the frequency band from 20 to 40 MHz - for example, at 38 MHz; the modulation for transmitting a 2 Mbit/s digital signal requires a bandwidth of 1 to 2 MHz and therefore a separation from adjacent carriers of 1 to 2 MHz.

10 A further variation concerns the electro-optic converters used in the system. If their characteristics are not sufficiently linear, they produce intermodulation products at frequencies in the transmission band, causing problems thereby. These problems become more serious the wider the frequency spectrum of the input signal. In order to improve the linearity of the electro-optic converters, each of the converters is equipped with a linearising circuit in which the linearising results from negative feedback of the optical signal, such as is known from e.g. US-PS 3 996 526.

A further modification concerns the transmission of the optical signal which contains a number of modulated carriers. In the above discussion of the example of equipment 119, it is assumed that a single electro-optic converter 120 receives at its input a frequency division multiplex signal containing a number of modulated carriers.

A problem with this method of transmission is the noise of the system, i.e. with many carriers being transmitted simultaneously over an optical transmitter, the signal-to-noise ratio can become too low in each channel. This is partly due to the fact that the large number of carriers in the composite signal results in a low modulation factor for each carrier, if overloading of the laser in the electro-optic converter is to be avoided. If the modulation factor is increased, the input signal to the laser has large amplitude peaks, leading to overloading. Interaction between the desired signals

then causes interference products which seriously degrade the quality of the signals.

According to one advantageous version of the invention, provision is therefore made to divide the total frequency band being transmitted into several sub-bands, each of which only contains a part of all the modulated carriers to be transmitted; each sub-band is then converted to an optical signal in its own electro-optic converter, with the same wavelength being used for all optical signals, and these optical signals are then coupled into the optical fibre 112 (Figure 1) connecting the group of subscribers to the exchange.

Figure 5 shows how the frequency band being transmitted is subdivided into the sub-bands. A frequency band containing a number of carriers is so divided into n sub-bands that each sub-band contains a group of m carriers and that thereby the total number of $m \times n$ carriers in the original frequency band is distributed to the sub-bands as shown in Figure 5. The sub-bands can therefore have the same width as the original transmission band. However, they contain a much smaller number of carriers than the original frequency band.

Figure 6 shows that each of the n sub-bands is applied to its own electro-optic converter W_1 to W_n and that their output signals are combined into a composite optical signal by means of star coupler SK1 and then coupled into the optical fibre 112 (Figure 1) leading to the group of subscribers. In this way each electro-optic converter, or more precisely the laser therein, can be driven in an optimal manner with respect to intermodulation and noise effects. Because of the smaller number of carriers, the modulation factor is now significantly higher for each carrier, so that the signal-to-noise ratio is significantly better. The wavelength of the converters W_1 to W_n is preferably chosen to be the same, eg. 1300 nm. As shown in Figure 1, at the receiving end the transmitted composite optical signal is converted to an electrical signal, using a single converter 121; this signal contains all the original

carriers, but with a far better signal quality than in the case of transmission by a single optical transmitter.

In connection with this transmission method it should be noted that the separation into sub-bands of a broadband frequency division multiplex signal and the separate conversion of the sub-bands into optical signals, is known. However, in this type of conversion optical signals with different wavelengths are produced and transmitted over a single optical fibre. On the other hand, in the system for transmitting several different signals over a single optical fibre previously mentioned, several non-overlapping frequency bands are converted, each by its own electro-optic converter, into an optical signal with the same frequency; these signals are then combined using a star coupler and transmitted over a single optical fibre.

An additional advantage of using several lasers in parallel, as described above, is a higher power level at the output of the star coupler SK; this allows larger optical attenuations to be overcome and simplifies the distribution of optical signals to several subscribers by means of a star coupler.

In the following, an additional variation is described that concerns the safety of system users in the event of a break in the optical fibre. Since lasers are preferably used as optical transmitters in the system, they must be switched off in the event of interruptions, eg. if the cable is broken by earth-moving equipment, in order to avoid the risk of eye injury and consequent damages claims.

With the optical communication system according to this invention it may be necessary to work with a high transmitter power (more than -6 dBm) in order to achieve certain system requirements, such as for example the spanning of a minimum distance between exchange and subscribers, or the achievement of a given signal-to-noise ratio. It is not feasible to use a backward channel to send an alarm signal from the subscriber to the exchange to switch off the laser, since sending back an alarm signal is impossible if the cable is defec-

tive (each subscriber is only connected to the exchange by one cable or one fibre).

According to the invention, one of the protective circuits described below can be used.

Figure 7 shows a protection circuit which provides an electrical or optical loop for the supervision of a length of optical fibre. To detect a break in a fibre between two points A and B (eg. between exchange 100 and coupler SK as shown in Figure 7), an optical or electrical loop 181 is placed in the immediate vicinity of the fibre. For example, from the supervisory equipment 180 a copper wire can be run alongside the fibre 112 to the coupler SK and back to the supervisory equipment. The latter sends a steady current around this loop in the normal operating state. If the cable is broken, this loop is also broken and the supervisory equipment switches off the laser in the electro-optic converter 120.

It is also possible to use the power feeding conductors in this way to detect cable breaks. The copper conductors can either be placed in the core of the cable, or a thin copper cable can be placed in parallel to the optical fibre cable.

Instead of copper wire, optical fibres can also be used which form part of the cable containing the transmission fibre. In that case, the auxiliary fibres are spliced together near the coupler and a fibre break is detected by the break in the optical loop from the exchange to the coupler and back.

If a copper wire loop is used and there are optical connectors in the transmission path, then they can be so constructed that the electrical loop is closed when the connectors are mated.

Figure 8 shows a protection circuit which has an optical coupler 184 spliced between the electro-optic converter 120 and the optical fibre cable; the optical signal being transmitted is coupled into the transmission fibre 112 by means of this coupler. The signals reflected and scattered back from this are detected at one end of the coupler 184 by means of opto-electric con-

verter 182. A supervisory circuit 183 processes the electrical output signal from the converter 182 and switches off the laser in the electro-optic converter 120 as soon as the detected light exceeds a given threshold. The basis of this is that an excessive level of reflected light points to a break in the optical fibre.

According to a further development of the protective circuit of Figure 8, it is possible to connect an opto-electric converter to the unused end of coupler 184. This then detects a part of the light sent out from the electro-optic converter and provides an electrical output signal that can be used as
10 negative feedback to the laser, in order to linearise its characteristic; also the low-frequency component can be used to set the laser operating point.

It should be pointed out that the protective circuits just described are not only usable with the system according to the invention, but can be independently considered as solutions whenever it is necessary to guard against breaks in an optical transmission line between two points A and B.

Finally, one other modification will be described which concerns the two-way transmission of telephone and data signals between the exchange and the
subscribers. The transmission of these signals has been described above as
taking place by a frequency division multiplex method, using carrier frequencies specific to each subscriber.
20

However, the signals can instead also be transmitted by time division or code multiplex methods.

If a time division multiplex system is used for transmitting from the exchange to subscribers, the signals to be transmitted to the subscribers are grouped together at the exchange into a digital time division multiplex signal with a bitrate of eg. 8 Mbit/s; this is then transmitted, possibly being modulated onto a carrier and/or limited to a suitable frequency band by means of a transmission code. Analogue telephone signals are converted to digital signals before the formation of the time division multiplex signal. Every

subscriber has appropriate demultiplexers which select the signals intended for him.

If code multiplexing is used to transmit the telephone and data signals from exchange to subscribers, the digital (or digitised) signals for each group are multiplied by an address code, grouped into a composite code multiplex signal by means of an adder, and then transmitted. Every subscriber has appropriate demultiplexers which select the signal intended for him.

Code multiplex or time division multiplex can also be used for the transmission of the telephone and data signals in the opposite direction. The sub-

10 subscribers' multiplexers then ensure that the telephone or data signals to be sent from a local group of subscribers are either assigned to a subscriber-specific time slot in a TDM frame, or multiplied by a subscriber-specific address code, and converted into an optical signal with wavelength λ_1 . A group of optical signals is then transmitted to the exchange which differ, not in their wavelength, but in the time slots allocated to the telephone or data signals, r in the codes of the signal (or signals) modulating the relevant electro-optic converter 122 (Figure 1). The exchange contains appropriate demultiplexers to separate the composite electrical output signal from the opto-electric converter 129 (Figure 1) into its individual components.

20 The preferred combination uses time division multiplex for the forward direction (ie. from the exchange) and code multiplex for the backward direction.

The claims defining the invention are as follows:

1. An optical communication system for transmitting information signals in both directions between a centre and subscribers, wherein the subscribers are arranged in groups and subscriber-assigned signals to be transmitted from the centre to a group of subscribers are combined into an electric multiplex signal at the centre and transmitted as an optical signal having a first wavelength to the vicinity of the subscribers of said group over an optical waveguide common to said group, said optical signal being distributed to the subscribers by optical means and over individual optical waveguides, and at each subscriber means are provided for converting the received optical signal into an electric signal and for extracting from the subscriber-assigned signals the signal intended for said subscriber, said optical waveguides being also used to transmit information signals from the subscribers to the centre using wavelength-division multiplexing, wherein said signals to be transmitted from the centre to a group of subscribers are combined at the centre into a frequency-division multiplex signal having subscriber-assigned carrier frequencies for subscriber-assigned signals, the signals to be transmitted from the subscribers of said group to the centre modulate carriers having subscriber-assigned carrier frequencies, said modulated carriers being converted into optical signals having a second wavelength common to all subscribers of a group, which optical signals are transmitted over the individual optical waveguides to the common optical waveguide and over the latter to the centre, said the centre including means for converting the received composite optical signal into a composite electric signal and for demodulating the latter.

2. A system as claimed in claim 1 including modulator means for modulating the subscriber-assigned information signals to be transmitted to the subscribers onto different carriers having subscriber-assigned carrier frequencies, and multiplexer means for combining the modulated carriers into the frequency-division multiplex signal; electric-to-optical transducer which

converts the frequency-division multiplex signal into an optical signal by intensity-modulating of the light produced by it, and demodulators and converters means for recovering from the frequency-division multiplex signal the subscriber-assigned information signals intended for said subscriber and for converting the recovered information signals into the original form.

5

3. A system as claimed in any one of the preceding claims wherein the electro-optic converters contain circuits to improve their linearity.

4. A system as claimed in any one of the preceding claims wherein the frequency division multiplex signal is divided into several sub-bands, and wherein for each of

10 the sub-bands an electro-optic converter is provided which converts it to an optical signal, the resulting optical signals being coupled into an optical fibre and transmitted thereby.

5. A system as claimed in any one of the preceding claims, including an optical or electrical loop in parallel with an optical fibre carrying a high-level optical signal, a supervisory circuit for one of the electro-optic converters connected to the optical fibre, the supervisory circuit sending light or an electric current around this loop and

15 switching off the electro-optic converter in the event of an interruption of the light or current path.

6. A system as claimed in any one of the claims 1 to 4, wherein a coupler is inserted between an electro-optic converter transmitting light into an optical fibre and the optical fibre, which coupler couples out reflected light from the optical fibre, and wherein a detector and a supervisory circuit is provided which switch off the electro-optic converter when the level of the coupled-out reflected light exceeds a given

20 threshold.

7. A system as claimed in claim 6, wherein the coupler also couples out a part of the light transmitted by the electro-optic converter, and wherein a detector is provided which transforms the coupled-out light into an electrical signal, and wherein circuits are provided which use the electrical signal for negative feedback in the electro-optic converter, and the low frequency part -

25



of the electrical signal to set the operating point of the electro-optic converter.

8. A system as claimed in any one of the preceding claims, wherein the multiplex signal formed at the centre is a time-division multiplex signal having subscriber-assigned time slots for the subscriber-assigned signals instead of a frequency-division multiplex signal having subscriber-assigned carrier frequencies for the subscriber-assigned signals.

9. A system as claimed in any one of claims 1 to 8, wherein the multiplex signal formed at the centre is a code multiplex signal having subscriber-assigned codes for the subscriber-assigned signals.

10. A system as claimed in any one of the preceding claims, wherein the signals to be transmitted from said group of subscribers to the centre are converted into digital signals having subscriber-assigned codes which are converted into optical signals and transmitted to the centre.

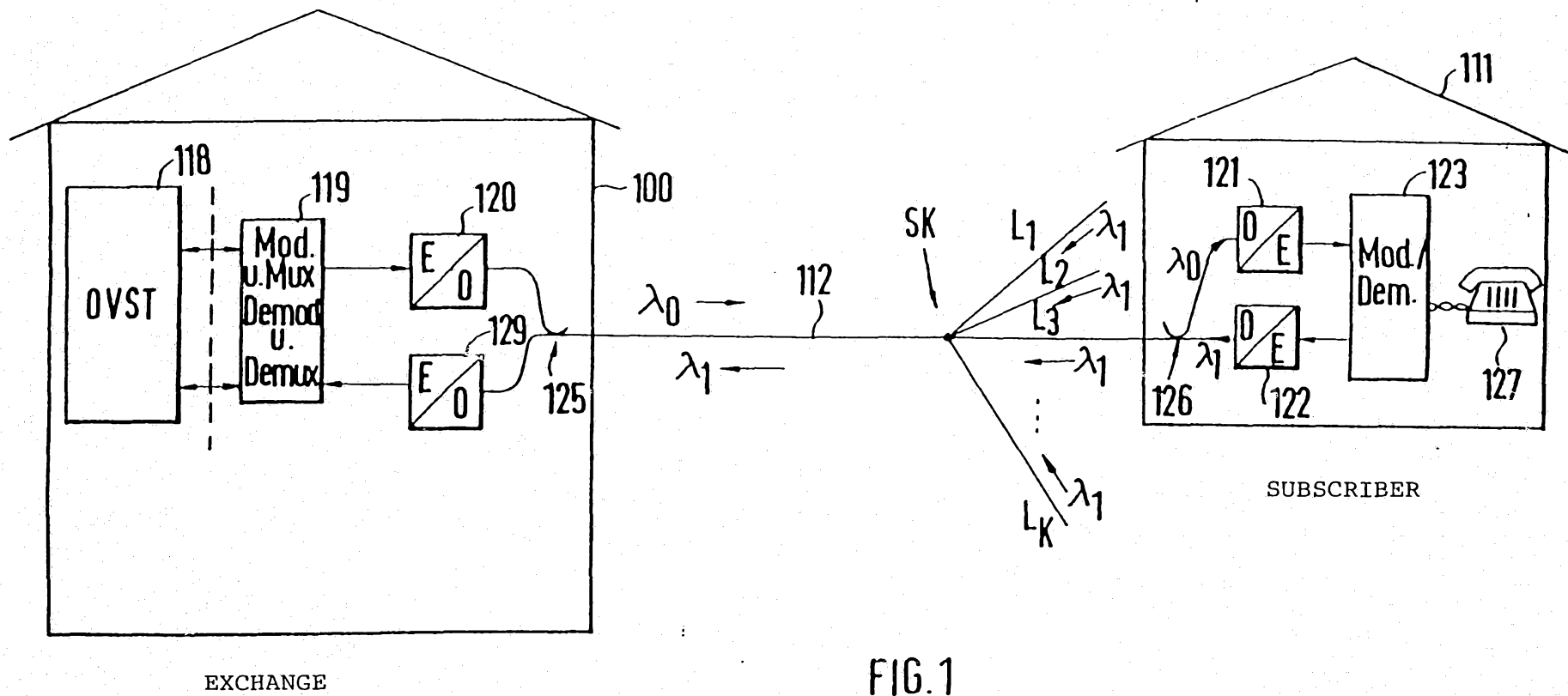
11. A system as claimed in any one of claims 1 to 9, wherein the signals to be transmitted from said group of subscribers to the centre are converted into digital signals having subscriber-assigned active time periods relative to a frame which are converted into optical signals and transmitted to the centre.

12. An optical communication system substantially as herein described with reference to Figures 1 - 8 of the accompanying drawings.

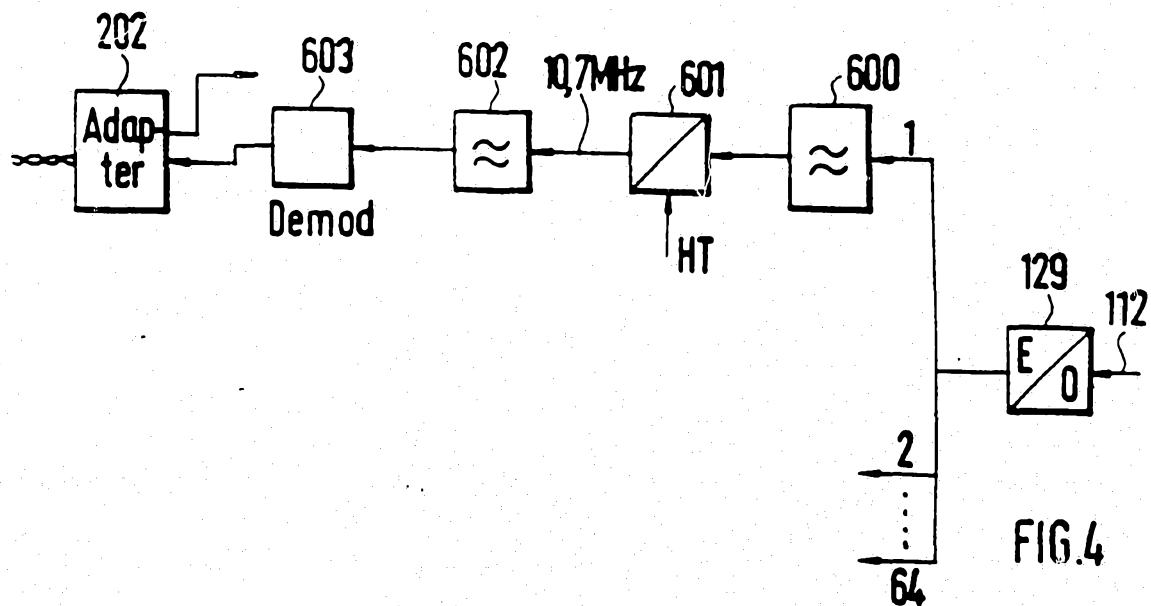
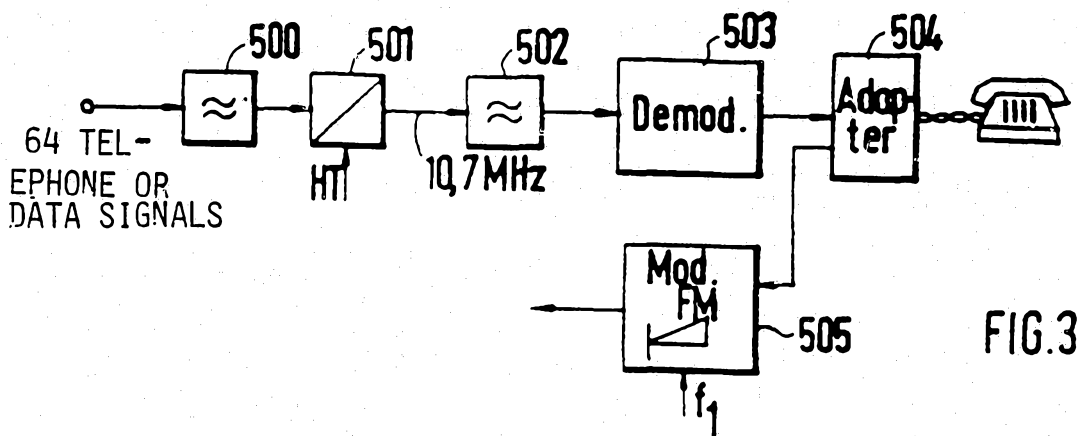
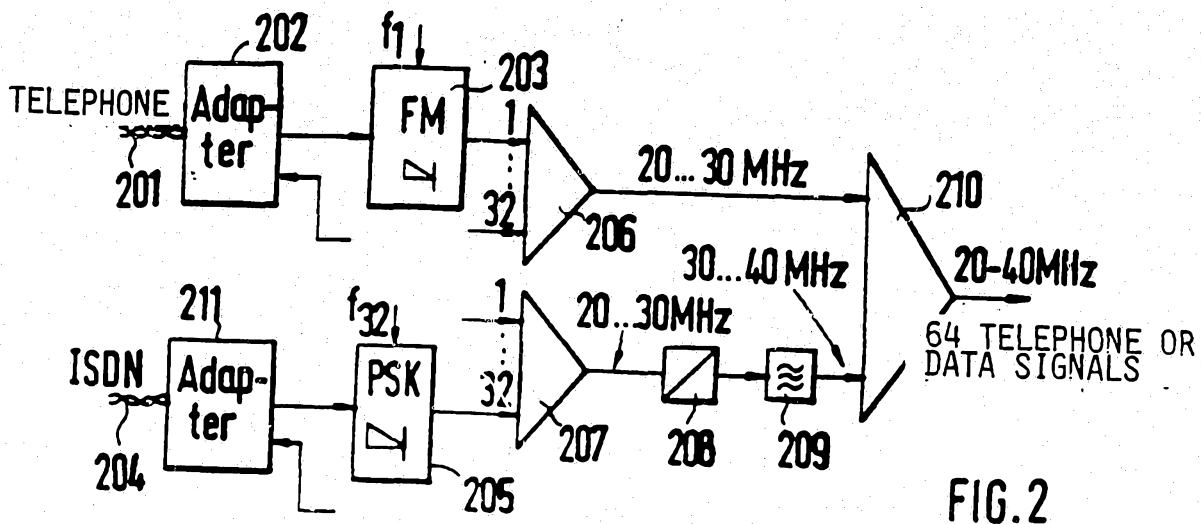
DATED THIS TENTH DAY OF FEBRUARY 1990

ALCATEL N.V.

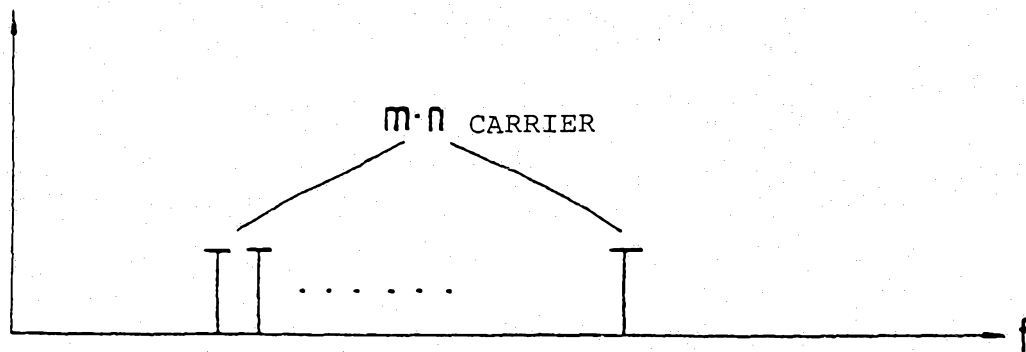
31 192 50180



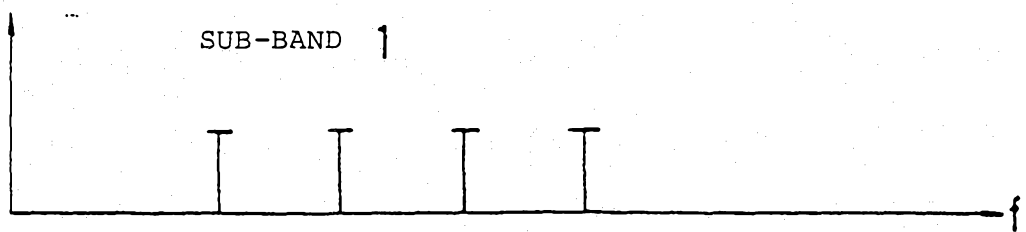
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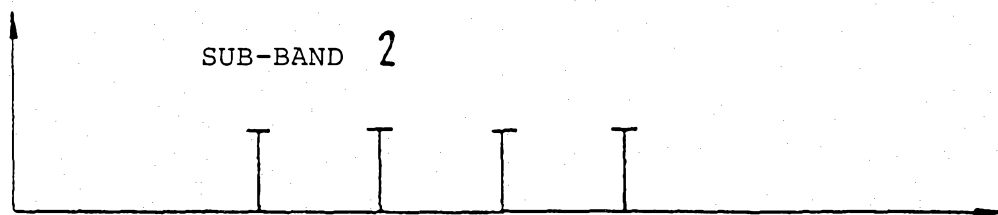
FREQUENCY BAND



SUB-BAND 1



SUB-BAND 2



SUB-BAND n

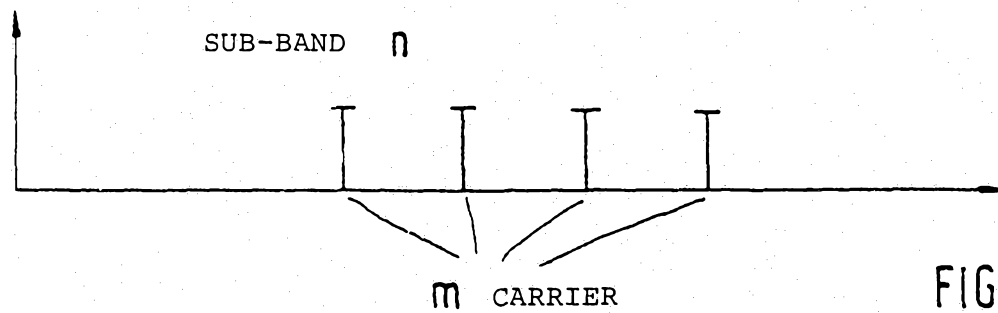


FIG.5

