JPRS L/9980

14 September 1981

Worldwide Report

TELECOMMUNICATIONS POLICY, RESEARCH AND DEVELOPMENT

(FOUO 13/81)

FBIS FOREIGN BROADCAST INFORMATION SERVICE

NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

JPRS L/9980

14 September 1981

WORLDWIDE REPORT

TELECOMMUNICATIONS POLICY, RESEARCH AND DEVELOPMENT

(FOUO 13/81)

CONTENTS

WORLDWIDE AFFAIRS

Briefs

WEST EUROPE

ITALY

WORLDWIDE AFFAIRS

BRIEFS

JAPAN, LIBYA SATELLITE STATION--Nippon Electric Company (NEC) said Saturday the company has clinched a 7.9 billion yen satellite communication earth station deal with the Libyan Government. The company said the contract awarded by the Libyan Department of Communications and Maritime Transport calls for supplying 14 earth stations for domestic satellite communication on a full turnkey basis. NEC said it is the largest single earth station export deal arranged by the company in recent years. The company has exported earth stations mainly to the United States, Canada and Thailand. Under the contract, two stations will be completed by October this year and the remaining 12 stations by September next year. The company said technical guidance would be provided to the Libyans in operating and maintaining the stations. The deal is on a yen-payment basis, and 15 percent of the price was paid when the contract was concluded with the balance payable at the time of shipment, NEC said. [Text] [Tokyo THE DAILY YOMIURI in English 24 Aug 81 p 4]

CSO: 5500/2296

ITALY

LIGHT POWERED OPTICAL TELEPHONE RECEIVER

Rome ELETTRONICA E TELECOMUNICAZIONI, in Italian Mar-Apr 81 pp 55-64

[Article by Dr of Engineering Alberto Brosio, Mauro Perino and Paolo Solina of the CSELT (Telecommunications Research and Study Center) of Turin: "Optical-Fiber Telephone with Remote Powering of Receiver"]

[Text] Summary--A low-consumption light-powered telephone on optical fiber: Optical fibers utilization is extending to short, medium and long distance links, and their introduction in the loop network is foreseeable. In this view, it will be important to provide the telephone service over the fiber link; however, service continuity, even during power-line failures, should be preserved. At CSELT laboratories, a bidirectional speech-transmission system has been implemented in which the subscriber set has been light-powered through the optical fiber by the local electrically powered exchange. Link length of about 550 m has at present been reached; however, a 2-km link length is considered easily achievable by using ad-hoc components that are at present being investigated.

I. Introduction

The beginning of optical-fiber telecommunications can be seen as going back to 1970, the year in which two fundamental events came to fruition: the obtaining, by Corning Glass Works (United States), of the first optical fibers with attenuation less than 20 dB/km, which was judged the limit for use of the fibers themselves in the field of telecommunications; and the achievement, in the Bell Laboratories, of the first semiconductor laser functioning continuously at ambient temperature. Starting in that year, the laboratories of the most highly industrialized countries, with the CSELT among them, began to work on communications in optical fibers.

Ten years after those events, it can be seen that the progress in this sector has been so rapid as to exceed the most optimistic forecasts. Optical fibers are now becoming a reality in the field of connections between urban exchanges and short-distance interurban connections: worldwide, there are now some dozens of installations in public service, with industrial-type transmission systems, so that it can be said that for this type of connection, we are now in a transition from the research phase to the industrial and operational phase.

The research-laboratory efforts are now being concentrated mainly in two other sectors: large-capacity and long-distance connections, and the connections between exchanges and subscribers.

As regards the long-distance connections, it is essentially a matter of exploiting the possibilities offered by transmission at the wavelengths around 1.3 μm and 1.5 μm, called also the "second window" and "third window" of transmission, which make it possible to obtain regeneration pitches on the order of 50-100 km and even more; in this way it is possible to avoid introducing into the optical cables conductors for remote powering of the regenerators, inasmuch as it is always possible, with such pitches, to design around a local power supply.

For the distribution network, the outlooks are hazier for now, but in the principal laboratories the conviction prevails that optical fibers will be able, in the not too distant future, to offer great advantages in this area also. Indeed, their great band width, low attenuation and insensitivity to interference will make it possible to offer the subscriber a whole series of new services with higher quality at lower costs than those obtainable with the traditional copper cables, in addition to normal telephone service.

On the basis of these considerations, the CSELT has undertaken a feasibility study for development of an "optical telephone"--that is, a system for bidirectional transmission of telephone conversation between exchange and subscriber in a single optical fiber.

The objective set with regard to the sizing of the system was to maintain a fundamental characteristic of the telephone connection--that is, remote powering of the subscriber's set--that guarantees continuity of service even at times when power is not available in the public network. To achieve this, it is necessary for the power for actuation of all the functions of the set (transmission, reception, signaling of microtelephone position, selection and excitation of ringing mechanism) to be provided optically from the exchange through the fiber itself.

The solution approaches so far proposed in the literature follow two main lines. Systems based on direct optoacoustical conversion, by means of nonconventional transducers developed for the purpose, have been proposed by Bell Laboratories (Bibliography 1) and by Siemens AG (Bibliography 2); an experimental development of this type of approach using, on the exchange side, two laser sources at different wavelengths, is reported in Bibliography 3. The indirect (that is, optoelectrical-electroacoustical) conversion technique, which uses a photovoltaic cell, has also been taken under consideration by Bell, which has obtained interesting results by using special optoelectronic components developed for the purpose in its own laboratories (Bibliography 4, 5).

In the experimental prototype developed in the CSELT laboratories, a solution based on indirect conversion has been pursued: this approach, together with work to optimize both the choices for the sizing of the system and the efficiency of the circuit solutions, has made it possible to construct the prototype with the use of optical and optoelectronic components obtainable on the market.

2. Description of the Receivers and Criteria for Sizing

In the sizing of the receivers for a subscriber-connection network based on optical-fiber carrier, two essential requirements were kept under consideration: remote powering, and the possibility of exciting the ringing mechanism from the exchange. In both cases, the difficulties are related to the limited quantity of power that can be transferred from the exchange to the subscriber in a fiber connection, by comparison with what is obtainable with the conventional loop.

The first requirement has conditioned the choice of the optical and optoelectronic components and has necessitated optimization of the subscriber-set's circuits from the point of view of output and dissipation.

For the ringing mechanism, since solutions of conventional type cannot be used, a higher-output transducer of piezoelectric type, developed in the CSELT laboratories, has been employed.

Below are described the various elements that make up the system, with the considerations that have conditioned the design choices. Reference is made to the simplified block diagram of Figure 1.

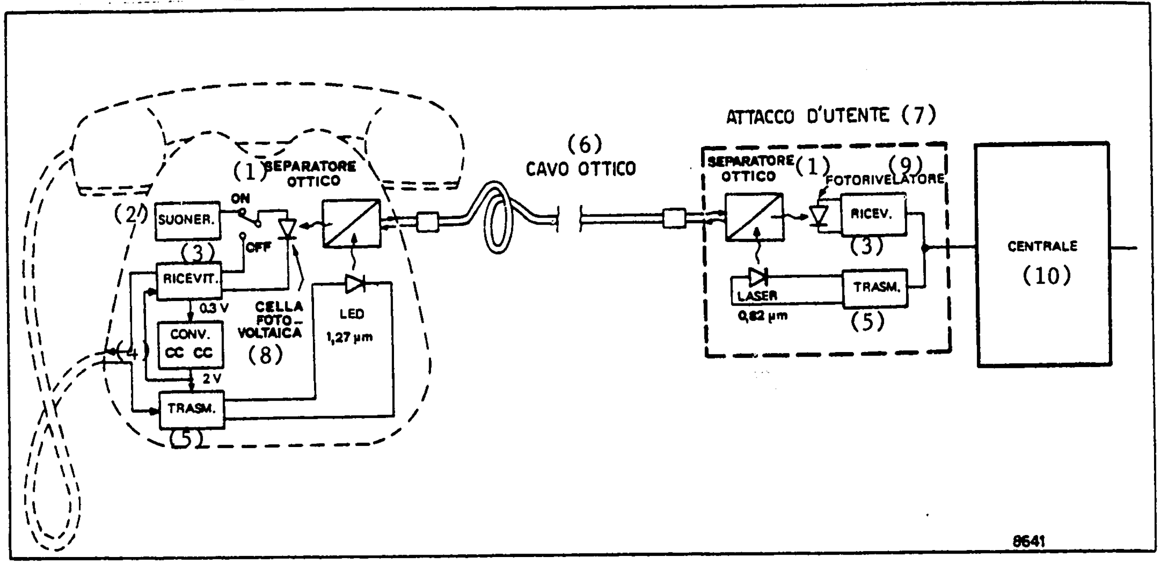

Figure 1 - Simplified block diagram of the optical-fiber telephone system

Key:

1. Optical separator
2. Ringing mechanism
3. Receiver
4. DC-DC converter
5. Transmitter
6. Optical cable
7. Subscriber-set connection
8. Photovoltaic cell
9. Photodetector
10. Exchange

2.1 Optical Sources and Modulation Technique

The optical source on the exchange side is composed of a multiheterostructure (Ga-Al-As) semiconductor laser, with emission peak at a wavelength of 820 nm, selected by the supplier for more than 12 mW of optical power emitted in air.

The source is kept turned on for about 98 percent of the carrier period (50 microseconds), so as to ensure high transfer of mean optical power to the remote-powered set.

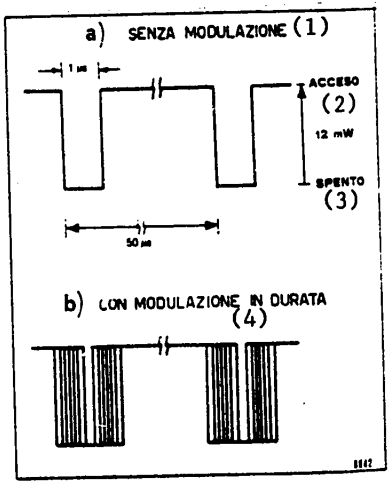

Figure 2 - Laser source in the exchange-end connection: pulse-width-modulation (PWM) technique

Key:

1. without modulation	3. Off
2. On	4. With pulse-width modulation

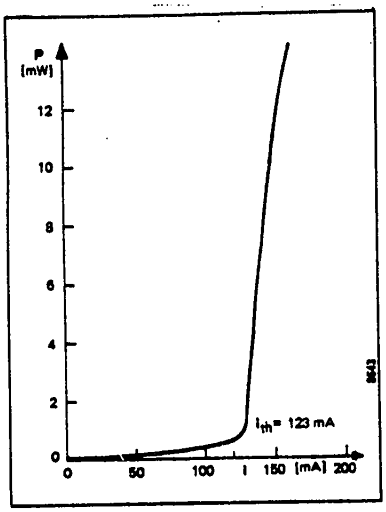

Figure 3 - Laser source in exchange-end connection: current-optical power in air characteristic

The duration of the dark intervals is modulated by the voice signals (Figure 2). The modulation technique used (pulse-width modulation, PWM) proves advantageous in this case inasmuch as it makes it possible to eliminate any eventual nonlinearity effects introduced by the source because of the presence of discontinuity in the optical power P-current I characteristic (Figure 3); this type of modulation also makes it possible to transmit a power with a mean value very close to the peak value.

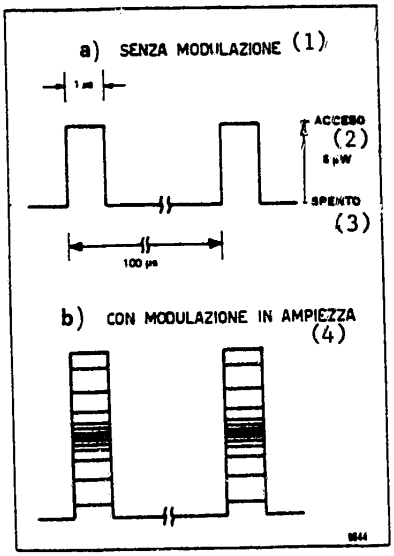

Figure 4 - LED source in the subscriber set: pulse-amplitude-modulation (PAM) technique

Key:

1. Without modulation
2. On
3. Off
4. With pulse-amplitude modulation

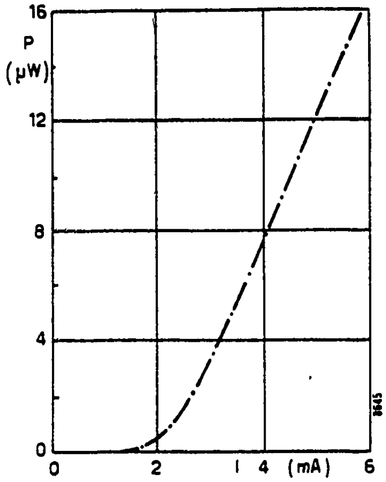

Figure 5 - LED source in the subscriber set: current-optical power in fiber characteristic

Since the frequency of repetition of the pulses (per Figure 2, $f_c = 10^6/50 = 20{,}000$ Hz) is two times greater the sound band, the useful component of the modulated signal is easily separable, at reception, with a low-pass filter [as published].

The question of the optical source to be used at the subscriber end led to the use of a high-radiance light-emitting diode (LED), which makes it possible to have a relatively high value of emitted optical power with low modulation-current values.

The device is activated by a succession of current pulses, furnished by the local oscillator (which is part of the TRASM [expansion unknown] block in the subscriber set shown in Figure 1) and having a repetition frequency f_u of about 10 KHz with a full-vacuum ratio of ~1 percent.

The choice of the transmission technique, consisting in amplitude modulation of the aforesaid pulses (Figure 4) by the voice signal (pulse-amplitude modulation, PAM), makes it possible to use the device in a zone of the optical power-current characteristic (Figure 5) in which the quantic efficiency is higher than at the origin, so that for equal power consumption, a higher output is obtained than is obtainable with baseband analog transmission.

A double-heterosplice (In-Ga-As-P/In-P) LED has been used in the experimental prototype, with light-emission peak at the wavelength of 1.27 μm; the peak power thrown into the fiber, in the absence of a modulating signal, is 8 μW.

The choice of the two different wavelengths is related to the problem of separation of transmission directions in the subscriber-end connection; this will be discussed more fully below.

2.2 Photodetectors

The photodetector used in the development of the exchange-end connection is an APD (Avalanche Photo Diode) of germanium, on the basis of the choice made for the remote-powered terminal source--that is, the 1.27-μm LED.

The choice of the subscriber-side photodetector has to be made on the basis of the double necessity of providing maximum mean optical-power conversion efficiency so as ensure correct power supply to the terminal, and of guaranteeing an appropriate frequency for detection of the voice signal.

In view of the fundamental importance to the system of the problem of remote powering of the subscriber terminal, special attention has been devoted to the search for high-efficiency devices for optical-electrical conversion and to the characterization of them.

In the laboratory tests done, several types of silicon PIN[1] photodetectors available on the market have been considered. The one that provided a higher output was a PIN of the UDT [expansion unknown], which, with an incident optical power of 2 mW, furnished an output equal to 10.7 percent.

Consideration was then given to a photodetector designed by SGS-ATES [expansion unknown] for use as a solar cell and optimized to function in solar-concentration systems (Bibliography 6). This component, illuminated with the same optical power of 2 mW, furnished an output close to 16 percent with a notable advantage for the specific use considered.

---

[1] PIN = p-i-n (donor-doped silicon - intrinsic silicon - acceptor-doped silicon)-silicon detector.

The I - V characteristics of the two components, UDT and SGS, are compared in Figure 6.

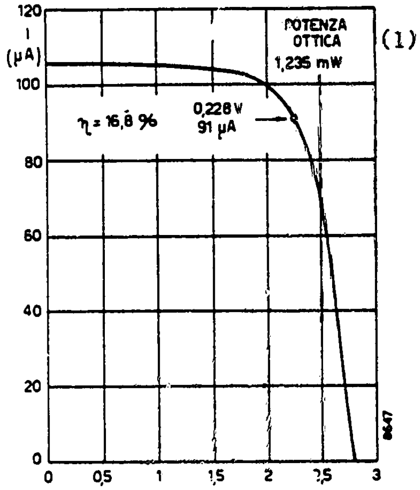

Figure 6 - V - I characteristics of the silicon cells (UDT and SGS-Ates)

Key:
1. Optical power

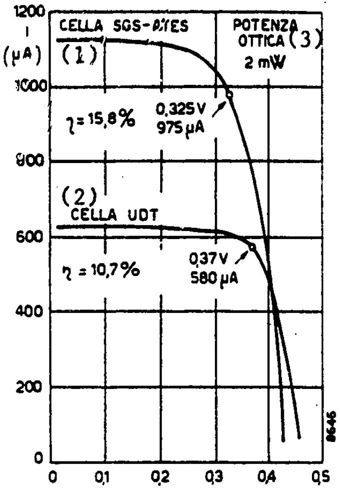

Figure 7 - V - I characteristics of the gallium-arsenide cell (four elements connected in series)

Key:
1. SGS-ATES cell
2. UDT cell
3. Optical power

By optimization of this component for the specific function now considered, its output can be further increased.

From Figure 6 it is seen that the voltage corresponding to maximum output is on the order of 325 mV.

In view of the fact that the circuits present in the telephone terminal in the laboratory experiment a supply voltage of 2V, it would be possible to furnish this voltage directly with the conversion device by the use of several photovoltaic elements in series. But since each of the elements constitutes a current generator whose value is proportionate to the incident optical power, it is necessary, so as not to reduce the output, to ensure that all the photodetectors are illuminated by the same optical power; the resultant problems of alignment, together with the losses due to the inert zones of separation between the elements and to the drop in the output of the individual elements with decrease of the incident power, have led to rejection of the structure with several cells in series when the number of elements is higher than four.

In the terminal built, the 2V voltage for powering the circuits is consequently obtained with a DC-DC current converter (cc-cc in Figure 1) starting from the ~0.3 V available from the photodetector, with a conversion efficiency on the order of 50 percent.

Nonetheless, the testing toward defining of the optimal configuration of this element of fundamental importance for the functioning of the system is being developed. In particular, a solution that uses gallium-arsenide cells connected in series is under examination.

The higher voltage in vacuum, together with the better output of the individual elements, has made it possible to obtain, in the laboratory tests with four elements connected in series, a continuous voltage of 2 V with a conversion efficiency of 16.8 percent (Figure 7), eliminating the problem of intrinsic power loss in the DC-DC converter. Enhanced performance characteristics are anticipated from optimization of the efficiency, form and gridding of the individual elements.

2.3 Choice of Fiber and Coupling Problems

For optimization of the transmission medium, fibers should be chosen that have high core-diameter and numerical-aperture values, so as to facilitate coupling with the sources and therefore inject higher power levels.

The lowest possible fiber-introduced attenuation values will provide for a greater subscriber-connection length, while a relatively high band width will make it possible to expand the auxiliary services planned on the subscriber hookups.

Several things must be considered for correct sizing of the system as regards the coupling between sources and fibers. The parameters related to the source that influence the coupling of it with the fiber are, on the one hand, the geometric dimensions of the emitting surface, and on the other, the form of the radiation patterns relative to the planes parallel and perpendicular to the connection (Figure 8).

For correct laser-to-fiber coupling (exchange side), diameter values for the core of the fiber used that are higher than the maximum image dimension (25.5 μm) are sufficient, as is obvious from Figure 9 and Table 1, which show the attenuations of total power emitted by the source in the optical coupling with a fiber of numerical aperture NA = 0.22 for various numerical-aperture and focal-aperture values of the objective, considering a source having typical dimensions of 0.254 X 12.7 μm.

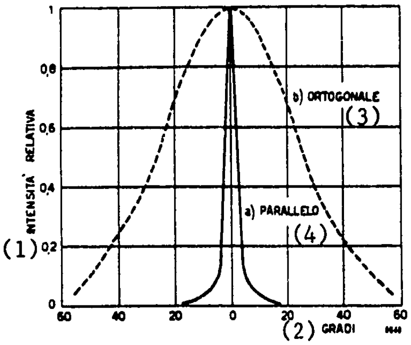

Figure 8 - Laser radiation patters: a) relative to the parallel plane at the connection; b) relative to the orthogonal plane

Key:

1. Relative intensity	3. Orthogonal
2. Degrees	4. Parallel

Table 1 - Optical Coupling between LASER or LED and Optical Fiber

The second objective has the following characteristics: f_2 = 18 mm, magnification 7X, NA = 0.2. For various paramters of the first objective, the dimensions of the source image on the optical fiber and the coupling losses, with both laser and LED, are given. For the fiber, NA = 0.22

First Objective			LASER		LED	
f_1 (mm)	Magnification	NA	Image Dimension (μm)	Attenuation* (dB)	Image dimension diameter (μm)	Attenuation* (dB)
18	7X	0.2	0.254 X 12.7	6.4	50	14
16	10X	0.3	0.286 X 14.3	4.9	56	10.4
10	18X	0.45	0.457 X 22.85	3.7	90	6.8
9	20X	0.5	0.508 X 25.4	3.4	100	5.9

* The losses introduced by the objectives are comprised in the values given.

In the same Table 1 are presented, for various values of the numerical aperture and the focal length of the objectives previously considered for coupling with the laser, the values for attenuation of the total optical power emitted by the source in coupling with a fiber having again a numerical aperture of 0.22, still with reference to the diagram of Figure 9.

The calculations were carried out considering a source radiation pattern of spherical type (Figure 10) and assuming the typical value of 50 μm as the diameter of the emitting area of the LED source.

On the basis of these considerations, use of fibers with core diameter greater than 100 μm proves advisable.

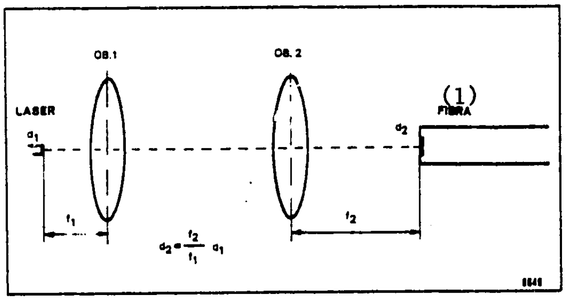

Figure 9 - Diagram of optical coupling between source and fiber

Key: 1. Fiber

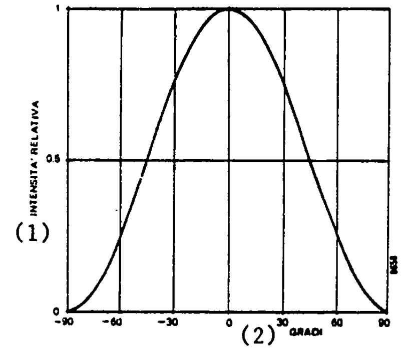

Figure 10 - Radiation pattern of the LED

Key: 1. Relative intensity 2. Degrees

In the system built, a step-index type of fiber was chosen, with NA = 0.22, core of 200 µm, and attenuation of 5 dB/km at 820 nm.

2.4 Optical Couplers

A telephone connection for bidirectional conversation with the use of a single fiber must employ optical couplers that fulfill the function of the traditional telephone forks.

The optical couplers conventionally used are of the beam-splitter type or [as published] obtained with Y-fused fibers. These couplers introduce an insertion attenuation not less than 3 dB in both directions and in addition, if the plane surface of fiber interfacing with the coupler is not suitably treated, it reflects a part of the incident signal, which, besides causing a power loss that can be calculated at 2 to 4 percent of the incident power, can be a cause of disturbance, as will be seen below.

But other techniques can be used, insofar as they permit better output of the couplers used at the phone-set terminal and in the exchange-end connection.

In the subscriber set, the optoelectronic components coupled to the fiber are the LED and the photodetector.

The structure provided for the experimentation is diagrammed in Figure 11.[2]

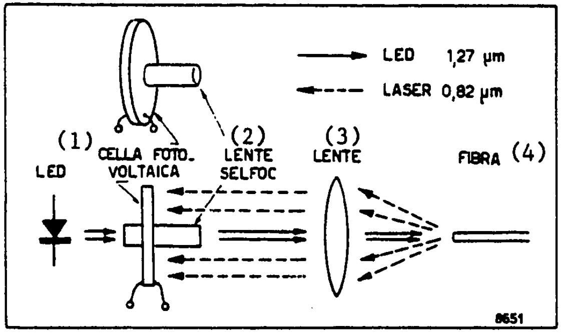

Figure 11 - Optical coupler in the subscriber terminal

Key:
1. Photovoltaic cell
2. Selfoc lens
3. Lens
4. Fiber

At the center of the photodetector is inserted a Selfoc microlens[3] of 2 mm diameter with a numerical aperture of 0.5, so as to permit focusing of the light beam emitted by the LED into the fiber.

In view of the reduced longitudinal dimensions (~10 mm) of the microlens, the attenuation that occurs in the coupling between the LED and the fiber is due exclusively to the insertion of the objective with numerical aperture of 0.3, and corresponds to a value of about 1 dB.

As regards the attenuation that the signal undergoes at the receiving end, in addition to the losses due to the objective there is the further loss due to the diminution of the useful surface of the photodetector.

Assuming for the diameter of the light beam incident on the photodetector a typical value of 7 mm, and 2 mm for the diameter of the microlens, the power loss due to the presence of the latter can be evaluated at about 0.4 dB.

The components to be coupled to the fiber at the subscriber-end connection are the semiconductor laser and the APD photodiode used in detecting the voice signal.

The criterion followed in the designing of this coupler consists in reduction to the minimum of the signal generated by the reflection onto the fiber of the light transmitted by the laser, inasmuch as the laser disturbs the reception; therefore, interferential filters were used, per the structure shown in Figure 12. The attenuations

---

[2] Patent 67939-A/80, filed 17 June 1980.

[3] The Selfoc microlens is composed of a glass cylinder characterized by a refraction-index profile that varies from the axis toward the periphery by a parabolic law.

given in the figure relate to the transmission path (wavelength λ_1), the reception path (wavelength λ_2), and the diaphony associated with the optical power emitted by the laser source and reflected toward the APD photodetector.

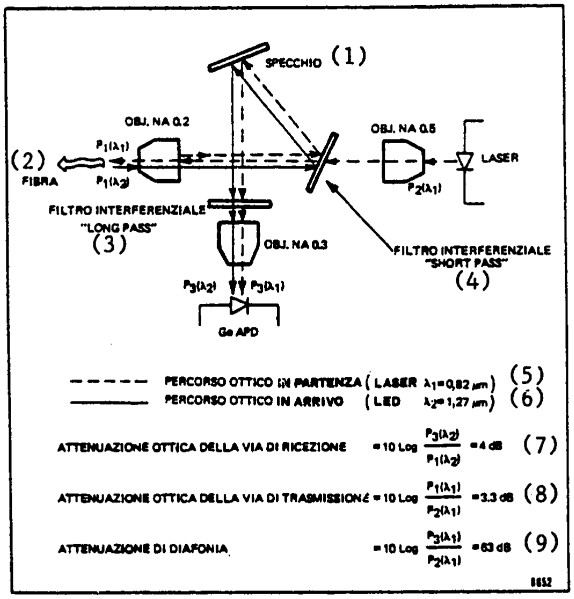

Figure 12 - Coupler at the exchange-end connection

Key:
1. Mirror
2. Fiber
3. "Long pass" interferential filter
4. "Short pass" interferential filter
5. Optical route going
6. Optical route coming
7. Optical attenuation of reception path
8. Optical attenuation of transmission path
9. Diaphony attenuation

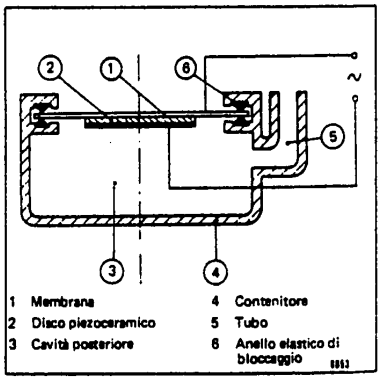

Figure 13 - Structure of electroacoustic transducer

Key:
1. Membrane
2. Piezoceramic disc
3. Rear cavity
4. Case
5. Tube
6. Elastic stop ring

Use of a second-window (1,270 nm) LED as the emitter in the subscriber terminal obviously facilitated solution of the problem of separation of the two paths, with the interferential filters that were available.

The possibility is being considered of using, with the employment of filters chosen ad hoc, two closer wavelengths for the two transmission paths (820 and 900 nm, for example), reserving the longer wavelengths for transmission of auxiliary services.

2.5 Ringing Mechanism

The low available power imposes the use of a ringing-mechanism transducer that has the highest possible efficiency (understood as the ratio between the acoustical power and the electrical power furnished). In addition, the transducer has to be of reduced dimensions so as to fit easily inside the telephone set.

These two kinds of considerations have led to the development of a piezoelectric transducer whose functioning makes use of the resonant technique (Bibliography 7), with resonance frequency in the neighborhood of 1,350 Hz.

The basic diagram of the transducer is presented in Figure 13.

It is composed essentially of the aluminum membrane (1) onto which is soldered a disc of piezoceramic material metalized on its opposite side (2); the cavity (3), which, with the tube (5), constitutes a Helmholtz resonator tuned to the excitation-signal frequency; the case (4); and the elastic stop rings (6).

The specifications presently in force for the ringing signal stipulate that in an anechoic chamber, in a free field at a distance of 1 meter, there be a sound-pressure level equal to 65 dB_{SPL}[4]; the effective value that must be furnished to the transducer in order to meet the specifications is 1 V, at the resonance frequency of 1,350 Hz.

2.6 Microtelephone Units

As has been seen, the high efficiency required has necessitated the development of an ad-hoc ringing-mechanism transducer.

But for the microtelephone transducers, the products available in the market were examined, models of various types and sources being considered.

In this case too, fundamental consideration was given mainly to efficiency criteria calling for a transducer which, in functioning as a microphone, would furnish maximum electrical power at a given acoustical excitation, and in the inverse function, maximum acoustical output at a given level of electrical excitation.

The choice fell to a transducer of electrodynamic type--that is, with movable coil--with plastic membrane and impedances equal to 150 ohm, almost resistive and therefore constant throughout the telephone band (Bibliography 8).

2.7 Circuit Particulars

Remote powering from the exchange by means of a light signal, with the related problems of limited power available at the subscriber end, entails the making of circuits

---

[4] Sound-pressure level, at 20 μPa (in air).

functioning at low voltages so as to keep dissipated power as low as possible. Under these conditions, realization of the various functions required in the subscriber set could lead to development of "custom" circuits using appropriate technology.

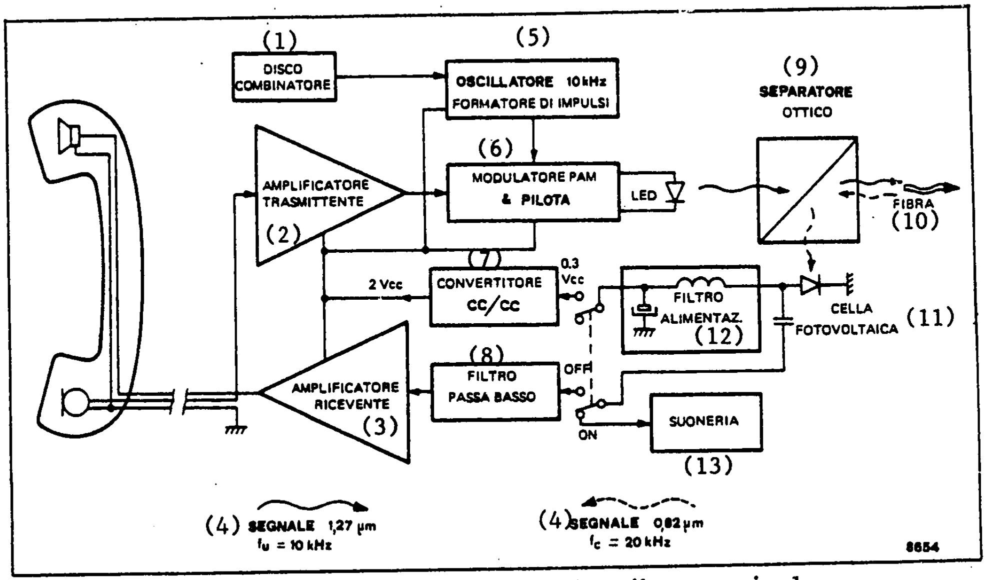

Figure 14 - Block diagram of subscriber terminal

Key:

1. Dial
2. Transmitting amplifier
3. Receiving amplifier
4. Signal
5. 10-kHz oscillator, pulse shaper
6. PAM modulator & pilot
7. DC-DC converter
8. Low-pass filter
9. Optical separator
10. Fiber
11. Photovoltaic cell
12. Power-supply filter
13. Ringing mechanism

In the present phase of experimentation, the circuits in question have been made by traditional separate-component techniques, inasmuch as this type of solution does not preclude the adoption of other, more advanced approaches, it has made greater flexibility possible in the solutions adopted and tested out from time to time, and it has made it possible to carry out, in short time-spans, checks of the system's feasability.

For the subscriber terminal, the block pattern shown in Figure 14 has been adopted.

When the microtelephone is lowered (ON position), the photovoltaic cell is connected, through a transformer, to the ringing mechanism, thus permitting reception of the call signal from the exchange, composed of a square wave of frequency equal to the resonance frequency of the ringing mechanism (1.35 kHz).

In this condition, the subscriber set does not require remote powering, inasmuch as all the blocks related to the various functions are deactivated. It is nevertheless possible for the subscriber to call for the line, and therefore for remote powering from the exchange, by lifting the handset (OFF position).

In this way, the oscillator and the pilot circuit of the LED are connected with the power-supply filter through the DC-DC converter. The energy stored in the filter's condenser is sufficient to activate the pulsed 10-kHz oscillator (Figure 14), whereby the sequence of unmodulated pulses going from the subscriber end to the exchange is identified by the exchange as a request for use of the line. This produces an increase in the power put out by the laser, the polarization of which is automatically varied.

With remote powering thus achieved, the subscriber can make his call, which is done by interrupting the oscillator with the pulses coming from the dial. Alternative approaches, suitable for use with numerical keyboards, are presently under study.

In the block diagram of the subscriber connection in the exchange (Figure 15) there are shown, in addition to the circuits for transmission and reception of the voice signal, those for recognition of switch-hook position and of number called, based on identification of the PAM carrier, and the circuit--already mentioned--for automatic variation of the laser-polarization current.

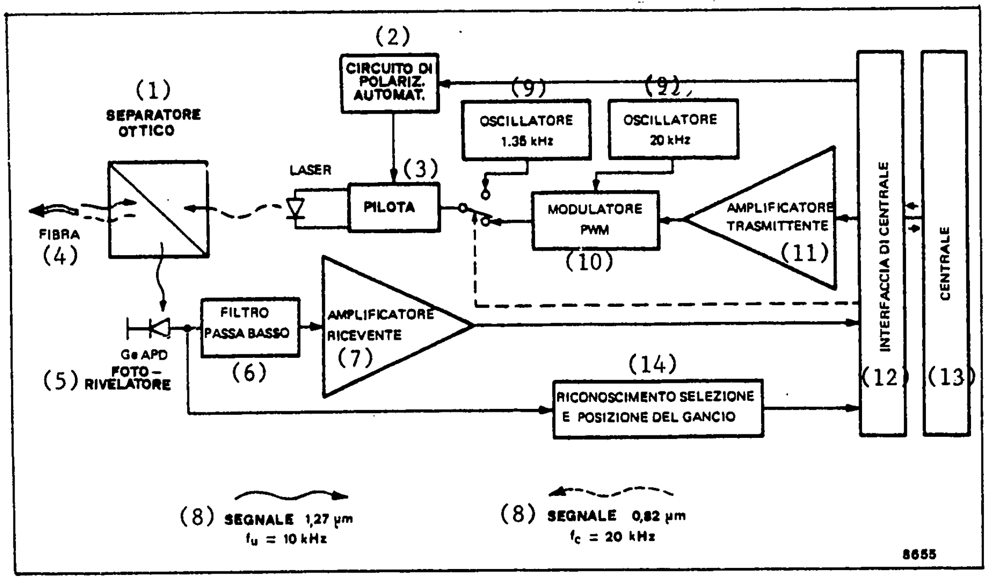

Figure 15 - Block diagram of subscriber connection in the exchange

Key:
1. Optical separator
2. Automatic polarization circuit
3. Pilot
4. Fiber
5. Photodetector
6. Low-pass filter
7. Receiving amplifier
8. Signal
9. Oscillator
10. PWM modulator
11. Transmitting amplifier
12. Exchange interface
13. Exchange
14. Recognition of number called and of switch-hook position

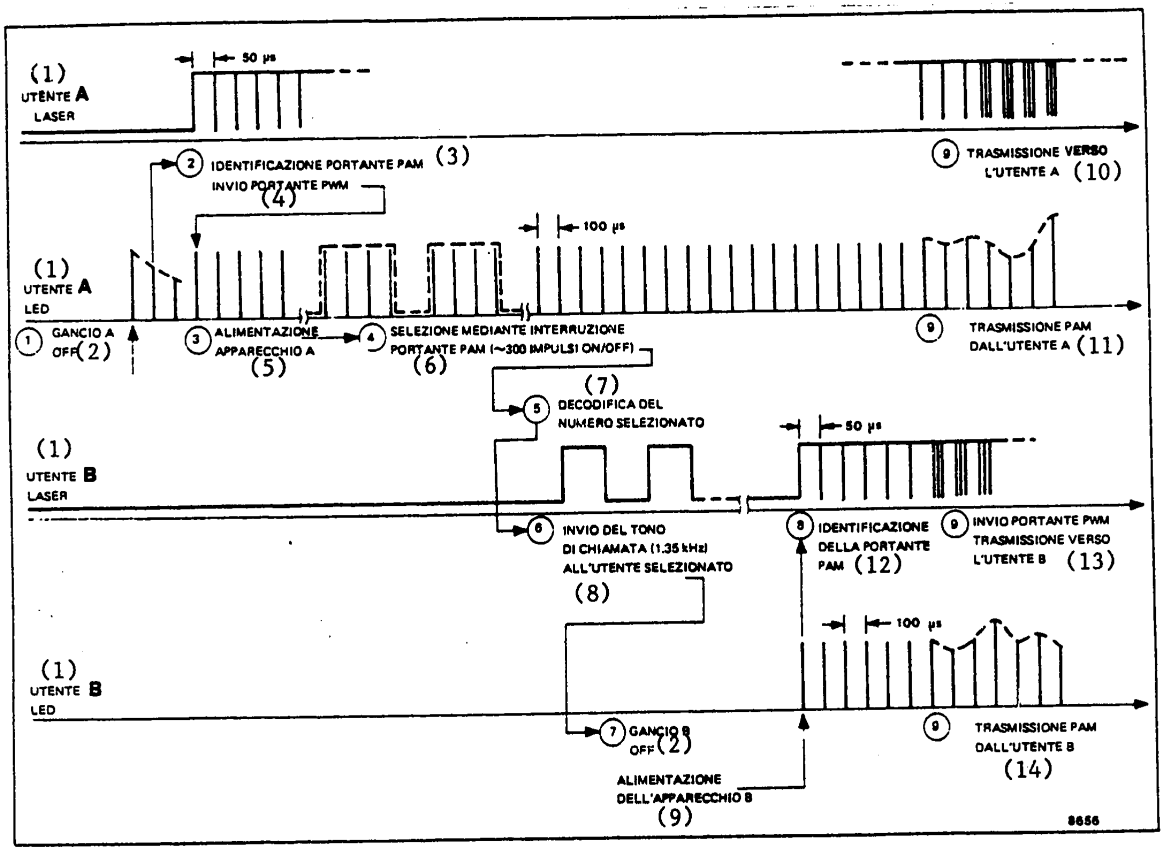

Figure 16 - Functional time diagram (not to scale)

Key:

1. Subscriber
2. Switch hook
3. Identification of PAM carrier
4. Sending of PWM carrier
5. Powering of set A
6. Number-dialing by interruption of PAM carrier (~300 pulses ON/OFF)
7. Decoding of number dialed
8. Sending of call ring to subscriber called
9. Powering of set B
10. Transmission to subscriber A
11. PAM transmission by subscriber A
12. Identification of PAM carrier
13. Sending of PWM transmission carrier to subscriber B
14. PAM transmission by subscriber B

The optical power emitted by the laser source remains reduced until either a sequence of pulses (line-use request) is identified or a call arrives for the subscriber; the useful life of the device is thus considerably increased.

At rest, the laser is polarized at a level slightly above the threshold, so as to avoid discharge of the power-supply filter condenser into the subscriber set, thus recovering its discharge current.

3. Description of the Functioning of the System

To simplify description of the functioning of the system, it is possible to follow a sequence that corresponds to the various phases of a telephone communication; for this purpose, we refer to the functional time diagram of Figure 16.

With the telephone set at rest, the switch hook is in the ON position (Figure 14), and the electronic circuits are without power supply. The output of the photodetector (the photovoltaic cell in Figures 1 and 14) is AC-coupled, through a transformer, to the ringing mechanism, so as to permit reception of any call coming from the exchange.

When calling subscriber A lifts the receiver, the switch-hook contacts go into the OFF position, thus making it possible for the circuits present in the subscriber's terminal set to be powered. In particular, the 10-kHz oscillator is activated that furnishes the carrier to the PAM modulator connected to the pilot circuit of the LED, which send a light signal to the exchange (Figure 16, point 1).

This light signal that arrives in the exchange (Figure 15) is initially constituted by the unmodulated 10-kHz carrier. It is detected by the GeAPD photodiode and arrives both at the number-dialed and switch-hook-position recognition circuit and at the low-pass filter, and therefore at the receiving amplifier.

Through the first channel, by use of the 10-kHz component (Figure 16, point 2), it can take the line by closing the relay positioned in the interface circuit in the direction of the exchange. The automatic exchange-end-connection polarization circuit corresponding to subscriber A causes the laser to work above the threshold, with emitted power of 12 mW. Arriving at the calling subscriber's set, this light flow, constituted by the unmodulated PWM carrier, permits remote powering of the terminal proper (Figure 16, point 3).

At this point, subscriber A dials his number, interrupting the 10-kHz oscillator with the pulses from the dial (point 4).

In the exchange, the number dialed is decoded (point 5), and the subscriber-B exchange-end connection corresponding to that number is activated and sends the call ring (point 6). This signal, composed of a square wave at 1,350 Hz (the resonance frequency of the piezoelectric transducer), excites subscriber B's ringing mechanism, which is connected to the photovoltaic cell through the switch hook (in ON position).

When the receiver of the set called is raised, the switch hook goes into OFF position (point 7) and the LED send into the fiber the 10-kHz carrier, which, as described above, takes the line (point 8). The call ring is thus shut off, while the circuits for sending the PWM carrier toward subscriber B are activated.

Thus is the phonic connection between the two subscribers involved made and maintained for so long as both receivers are off the hook (point 9).

When the receiver is hung up, there is no further transmission of the 10-kHz carrier, and the line-engagement circuit of the subscriber-end connection involved therefore frees the line, reducing the optical power emitted by the laser.

4. Results and Outlooks

The system's present capacity makes it possible to reach sections up to 550 m of "step-index" fiber with core diameter of 200 µm (NA = 0.22; attenuation = 5 dB/km at 820 nm).

Optimization of the circuits in the telephone set from the power-consumption point of view has resulted in reduction of electric-power dissipation in the terminal itself to only 300 µW, including the efficiency of the DC-DC booster that raises the voltage from 0.3 to 2 V (about 50 percent). This means that the photovoltaic cell has to put out, with a voltage of 0.3 V, a current of 1 mA, corresponding to a light power of about 2 mW incident on the surface of the cell. In these conditions, satisfactory bidirectional transmission of conversations and a good ringing level in the phone set have been achieved.

In subjective tests, the quality has been considered good.

The experimental tests in progress are aimed at increasing the connection length obtainable; in particular, as has been mentioned, it is possible, by the use of gallium-arsenide (GaAs) photovoltaic cells, to make connections up to about 2 km.

Table 2 summarizes the characteristics of the system built and the performance characteristics obtained.

Table 2 - Characteristics of the Optical-Fiber Telephone

a) Subscriber connection in exchange

source	GaAlAs MH LASER ($\lambda = 0.82$ µm)
mean optical power emitted	12 mW
frequency of pulses f_c	20 kHz
modulation technique	PWM (full-vacuum ratio of pulses: 98 percent)
photodetector	Ge APD
mean optical power received	15 nW

b) Subscriber telephone set

source	In-Ga-As-P/In-P-DH LED ($\lambda = 1.27$ µm)
peak optical power emitted	8 µW
frequency of pulses f_u	10 kHz
modulation technique	PAM (full-vacuum ratio of pulses: 1 percent)
photodetector	photovoltaic cell (Si)
mean optical power received	2 mW
electric power necessary for remote powering	300 µW
acoustical power put out by ringing mechanism	66 dB_{SPL}

c) Connection length achievable

step-index fiber; core diameter	200 µm; NA: 0.22; attenuation: 5 dB/km at 0.82 µm
with Si photovoltaic cell (version currently made)	500 m
with GaAs photovoltaic cell	~2 km

5. Conclusions

An optical-fiber bidirectional telephone-conversation transmission system has been built in which the subscriber set is remote-powered optically, through the fiber itself, from the exchange. The possibility of optical remote actuation of the ringing mechanism of the subscriber set has been verified. The connection length presently obtainable is 550 m, but developments presently being implemented indicate the possibility of achieving lengths up to 2 km. The achievement of subscriber-terminal circuits with very low dissipation has permitted realization of the system with optical and optoelectronic components available on the market.

Acknowledgements

The authors wish to thank B. Catania for his guidance and G. Modena for having given us the idea for this piece. R. Ceruti and R. Ravaglia developed the piezoelectric ringing mechanism and collaborated notably on the electroacoustical problems. Finally, we mention the assistance lent by E. Vezzoni and B. Sordo in evaluation of the optical coupling techniques.

BIBLIOGRAPHY

1. Kleinman, D.A. et al., "The Photophone--an Optical Telephone Receiver," J ACOUST SOC AM, June 1976.

2. Gosch, J., "Light Powered Phone Operates without an Internal Light Source," ELECTRONICS, May 1979.

3. Fromm, I., "Optophone--an Optical Transmission System for Sound," FREQUENZ, 1978.

4. De Loach, B.C., et al., "Sound Alerter Powered over Optical Fiber," BSTJ, November 1978.

5. Miller, R.C., et al., "Optically Powered Speech Communication over a Fiber Lightguide," BSTJ, September 1979.

6. Conti, M., "Problems Relative to Fabrication of Silicon Cells for Concentrators," Study Days on "Photovoltaic Conversion of Solar Energy," Microelectronics Group, Milan, 18-19 October 1979.

7. Ceruti, R., and others, ""Piezoelectric Transducer for Electronic Telephone Ringing Mechanisms," AIA Annual Conference, Siena, October 1979.

8. Brosio, A., et al., "System Study and Experimental Verification of a Telephonic Connection in Fiber with Optical Remote Powering of the Subscriber Set," unpublished internal document.

11267
CSO: 5500/2244

END