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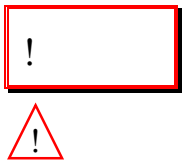
UNIVERSAL POWER-LINE CARRIER SYSTEM

TYPE OPU-1

GENERAL DESCRIPTION

Rev 7 - May 2019

SAFETY SYMBOLS



WARNING OR CAUTION:

This symbol denotes a hazard. Not following the indicated procedure, operation or alike could mean total or partial breakdown of the equipment or even injury to the personnel handling it.

NOTE:

Information or important aspects to take into account in a procedure, operation or alike.

TABLE OF CONTENTS

Page

1 INTRODUCTION

1.1 TRANSMISSION CAPACITY

The OPU-1 Universal Power-Line Carrier (PLC) terminal is outstanding in its high level of modularity, allowing the transmission of all type of services through a high-voltage line.

It can be configured to transmit analog, digital or both analog and digital channels simultaneously, including teleprotection.

When working with analog channels, the OPU-1 terminal can transmit one or two 4 kHz standard channels in each direction. The effective band of each channel, from 300 Hz to 3850 Hz, can be used for the transmission of data at high speed, various VF telegraph channels, teleprotection signals or for a speech-plus service.

When working with a digital channel, the OPU-1 terminal can support two different digital modulation schemes (QAM or OFDM/OQAM). In general terms QAM is more suited for long lines and medium transmission rates, while OFDM/OQAM is more suited for higher transmission rates over short lines.

With the OFDM/OQAM digital modulation scheme, the OPU-1 terminal can support a maximum transmission rate of 324 kbit/s in a bandwidth of 32 kHz, in each direction. A transmission rate of 160 kbit/s in a bandwidth of 16 kHz, of 72 kbit/s in a bandwidth of 8 kHz, and of 32 kbit/s in a bandwidth of 4 kHz, in each direction, is also possible.

When working with a QAM digital channel, the OPU-1 terminal offers a transmission rate of 81 kbit/s, of which 79 kbit/s are available for user information, allowing various speech and data channels to be multiplexed or, alternately, establish a channel of 64 kbit/s plus other additional channels, up to a total of 15 kbit/s for signalling, telecontrol, etc. The multiplexing of the different services, if desired, can be carried out by using an optional TDM internal multiplexer that consists of up to three additional modules (speech and data ports). The high-frequency transmission channel occupies a bandwidth of 16 kHz, in each direction. Thanks to the use of a built-in echo canceller, the transmission and reception bands can be superimposed, resulting in a total bandwidth of 16 kHz.

With a QAM digital channel, transmission at 40.5 kbit/s in an 8 kHz bandwidth and at 20.25 kbit/s over a 4 kHz bandwidth is also possible, over a single frequency slot in superimposed bands or two slots in non-adjacent bands in both cases.

At 40.5 kbit/s, the transmission and reception channels, each of 8 kHz, can be adjacent, resulting in a total bandwidth of 16 kHz. At 20.25 kbit/s, the transmission and reception channels, each of 4 kHz, can be adjacent, resulting in a total bandwidth of 8 kHz.

When working with a QAM digital channel, the OPU-1 can integrate teleprotection signals in the digital operation band.

Examples of transmission possibilities are summarized in FIGURE 1. In case of frequency congestion, the OPU-1 can be equipped with additional filters to use different frequency slots for the analog and the digital channels in the same line or, even, as is represented in FIGURE 2, in independent lines.

The use of additional filters in a twin-channel analog terminal also allows the transmission and reception bands of each channel to be non-adjacent.

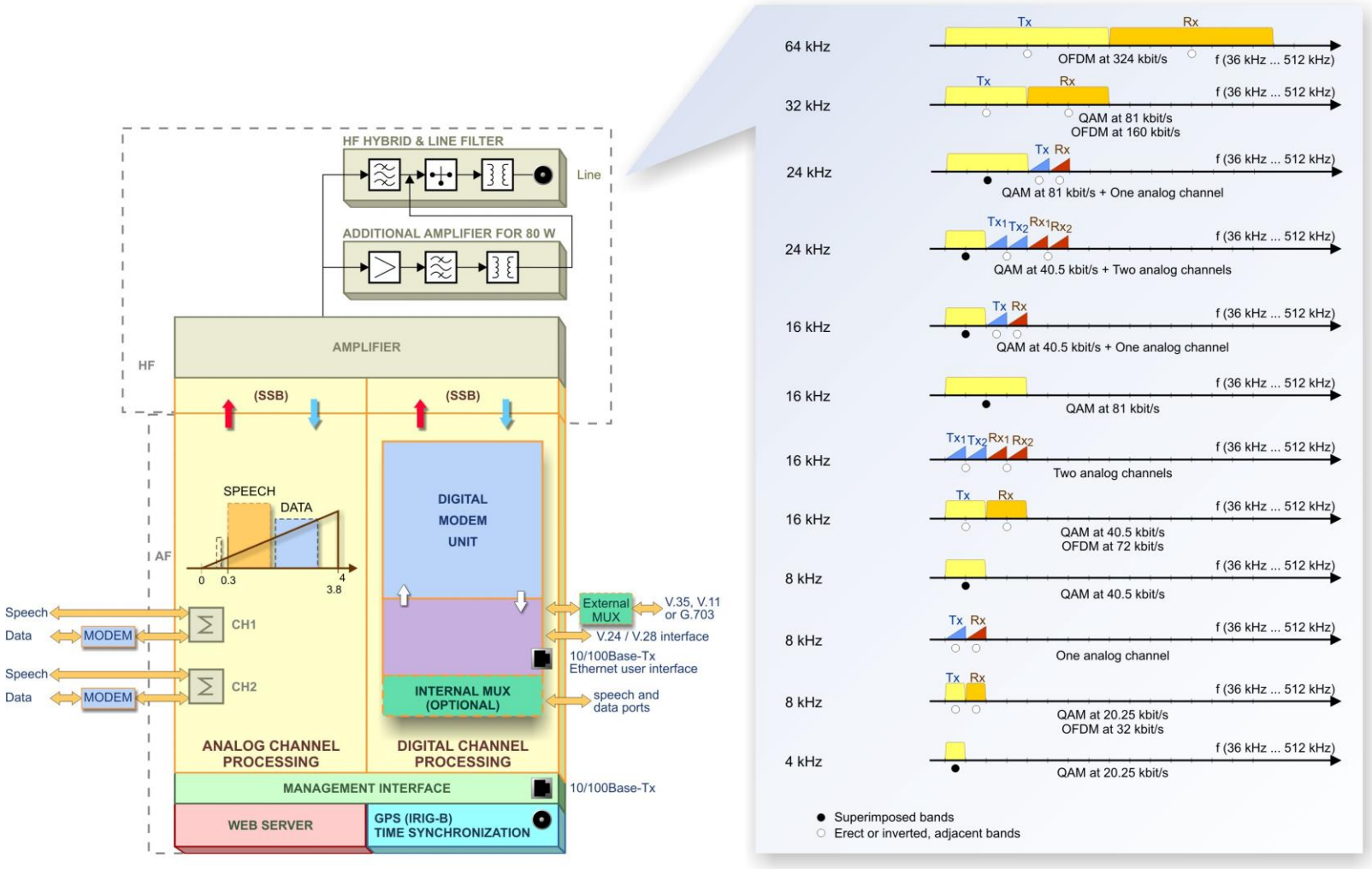
The OPU-1 terminal can work with different line filters, depending on the backplane type.

If desired, as a solution for PLC networks with frequency congestion, the OPU-1 can function as a High-Frequency teleprotection system. This functionality enables electrical power utilities to transmit teleprotection commands between protection relays over high-voltage lines in a single 4 kHz bandwidth, using 2 kHz for transmission and 2 kHz for reception. This functionality implies a specific hardware architecture of the terminal.

OPU-1 terminals comply with the International Recommendation IEC 495, regarding PLC equipment.

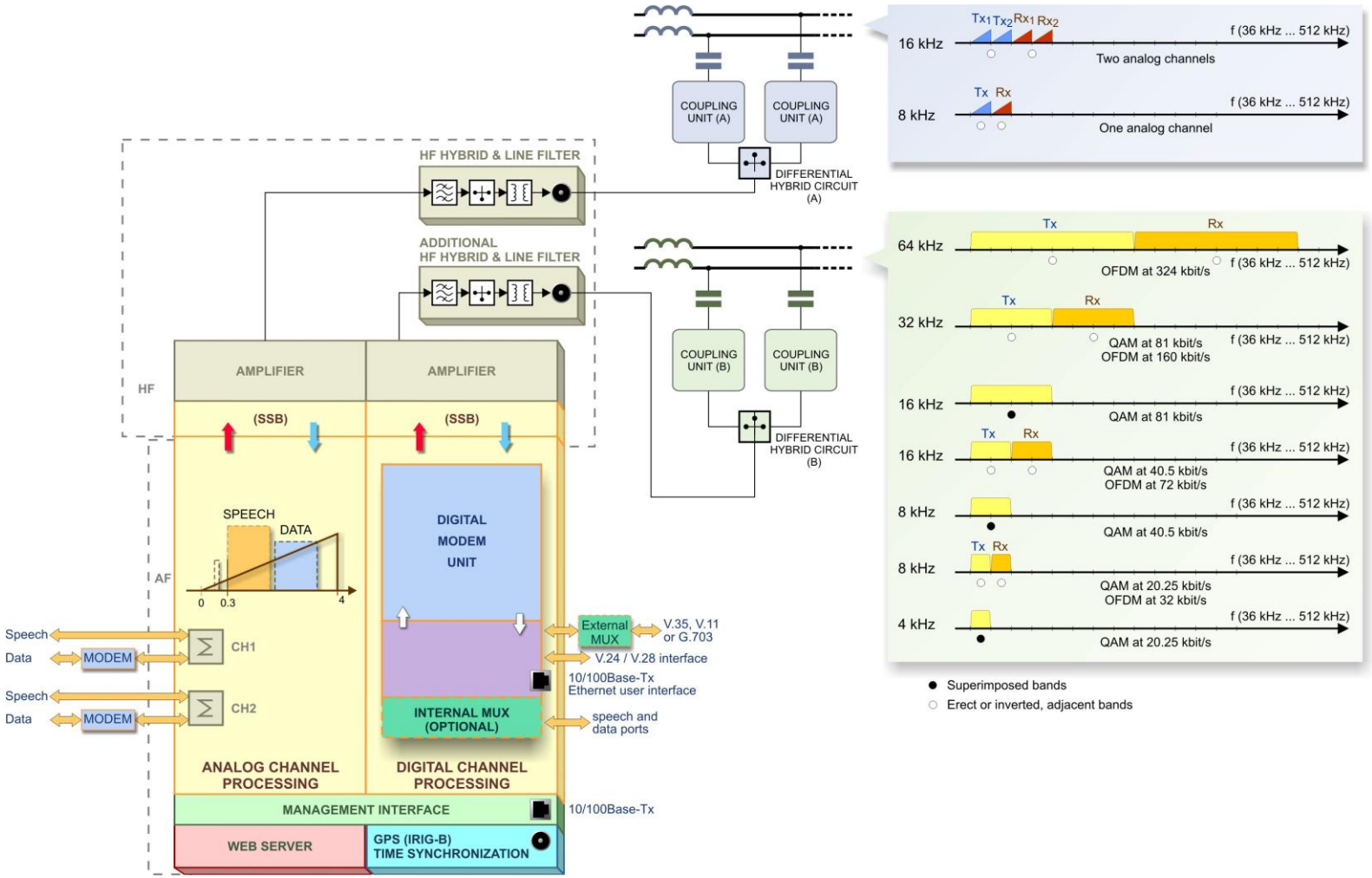
HF Teleprotection functionality meets the security and dependability requirements specified in IEC 60834-1 Recommendation for the three types of teleprotection command schemes: Permissive tripping schemes, Intertripping schemes (Direct or transfer tripping) and Blocking protection schemes.

FIGURE 1 OPU-1 general architecture for 20, 40 and 80 W



NOTE: The OPU-1 can work with different line filters, depending on the backplane type.

FIGURE 2 OPU-1 general architecture for 20 and 40 W with additional filters



NOTE: The OPU-1 can work with different line filters, depending on the backplane type.

1.2 MAIN FEATURES

Some of the most remarkable features of the OPU-1 terminal are the following:

- **Time synchronization.**

  The OPU-1 terminal chronologically registers all the alarms produced in the terminal, as well as the events that refer to the link service. In order to establish the date and time the alarms and/or events are produced, the OPU-1 terminal has a real time clock, which can be synchronized with the GPS system or by means of the SNTP protocol.

- **Two digital modulation schemes**

  The OPU-1 offers two different modulation schemes to better suit all transmission needs in terms of the quality of service required by the applications and the transmission line characteristics. Both QAM and OFDM/OQAM are supported by the OPU-1 and can be selected from the programming software.

  The choice between QAM and OFDM/OQAM depends on the required transmission rate, required BER and internal latency, on the one hand, and S/N ratio and line attenuation on the other hand. QAM can work at lower values of S/N and has a lower transmission latency, whereas OFDM/OQAM increases the transmission rate at the expense of a higher transmission latency and needs higher values of S/N ratio.

- **Automatic fall-back/increase rates.**

  A remarkable feature of the OPU-1 when working with a digital modem unit is the automatic fall-back rate when there is unfavourable line noise and/or signal reflection conditions.

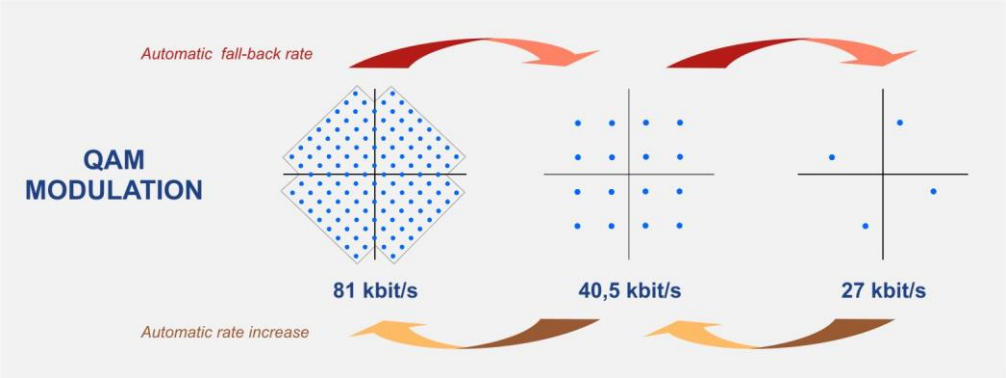
  In the example for QAM, see FIGURE 3, the transmission rate is automatically reduced to half or a third of the maximum value if necessary, that is to say, to 40.5 kbit/s and 27 kbit/s respectively. When the line conditions improve, the transmission rate is automatically re-established.

  In OFDM/OQAM, the channel is constantly evaluated in such a way that the carriers that are affected by noise or interferences can automatically reduce its base modulation or even disappear. Also the turbo code rate can change to make communications more reliable. The two mechanisms combined allow the maximum transmission rate to be dynamically adjusted, ensuring a correct BER in every condition.

  For the QAM, this automatic feature can be disabled from the programming software if necessary.

  The link quality measurement is based on the G.821 standard concepts.

FIGURE 3 Automatic fall-back/increase rates (QAM)



- **Ethernet user interface with built-in bridge functionality.**

  On the front plate of the terminal it is available an Ethernet user interface which is of utility when using the OPU-1 for the interconnection of different line segments. In this case, the built-in Ethernet bridge selects the frames to be transmitted to the remote end, thus making a more efficient use of the communications channel.

  The information is multiplexed with the rest of speech and data channels and transmitted in the QAM signal.

- **SNMP agent.**

  The OPU-1 terminals can include an SNMP agent to make GET and SET operations as well as to send TRAP and INFORM notifications (unsolicited information spontaneously transmitted) about alarms and events of the terminal to the devices specified by the user, and this makes it possible to monitor the OPU-1 terminal from an SNMP management application.

- **Narrow-Band High-Frequency Teleprotection functionality.**

  This functionality is the best solution for PLC networks with frequency congestion. It enables electrical power utilities to transmit teleprotection commands over high-voltage lines, in only one standard 4 kHz channel, using 2 kHz for Tx and 2 kHz for Rx.

  This functionality implies a specific hardware architecture of the terminal.

1.3 MANAGEMENT SYSTEM

The OPU-1 terminals have a built-in web server containing all the pages necessary for the system programming and monitoring, being unnecessary for any software to be supplied with the equipment.

The connection between the computer and the terminal can be direct, or should the necessary networking devices be available, by means of an IP network (LAN). In the last case, all the computers connected to the IP network can manage any OPU-1 terminal connected to the said IP network.

The user can access the home web page of the Management System by entering the IP address of the web server of the OPU-1 terminal, once authorisation is gained by means of the user password.

By default, the system has two created user profiles, one basic and the other administrator, whose user identifications and passwords can be seen in TABLE 1. Each one has different management capacities, whilst the administrator user being able to modify and supervise any parameter of the terminal, the basic user can only retrieve or supervise the parameters of the terminal, and is unable to alter its operation at any time.

TABLE 1 Default user passwords of the system

	User identification	**Password**
Basic User	basic	basic
Administrator User	admin	admin

1.4 EXAMPLES OF APPLICATION

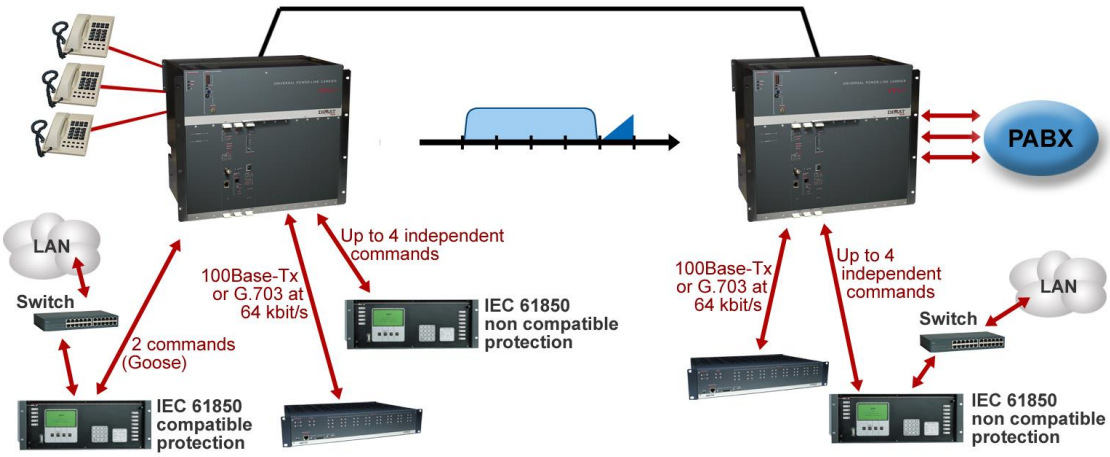
The modularity of the OPU-1, together with its wide range of interfaces, permit most configurations found in different applications to be covered. The following examples clearly show some of the most relevant.

General purpose

Analog channel intended for teleprotection signals, and QAM/OFDM signal for data and speech channels.

For this application the OPU-1 terminal is equipped with a set of 4-command teleprotection system and with the necessary optional multiplexer modules.

FIGURE 4 Transmission of data, speech and teleprotection signals

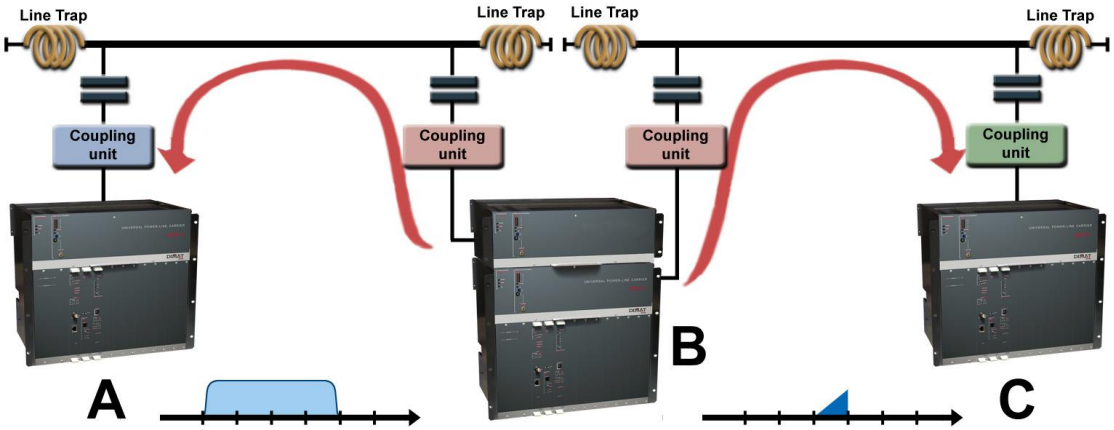


Two independent PLC terminals in a single equipment

QAM/OFDM signal in one direction and analog 4 kHz channels in the other.

For this application it is necessary the additional filters.

FIGURE 5 Two independent PLC terminals in a single equipment

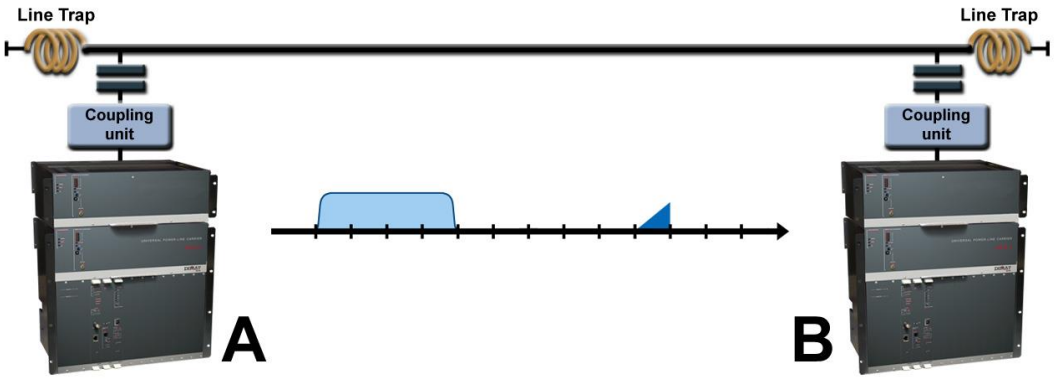


Frequency congestion solution

Different frequency slots in the same high-voltage line (see FIGURE 6) or, even, in different lines (see FIGURE 5).

For this application it is necessary the additional filters.

FIGURE 6 Frequency congestion solution

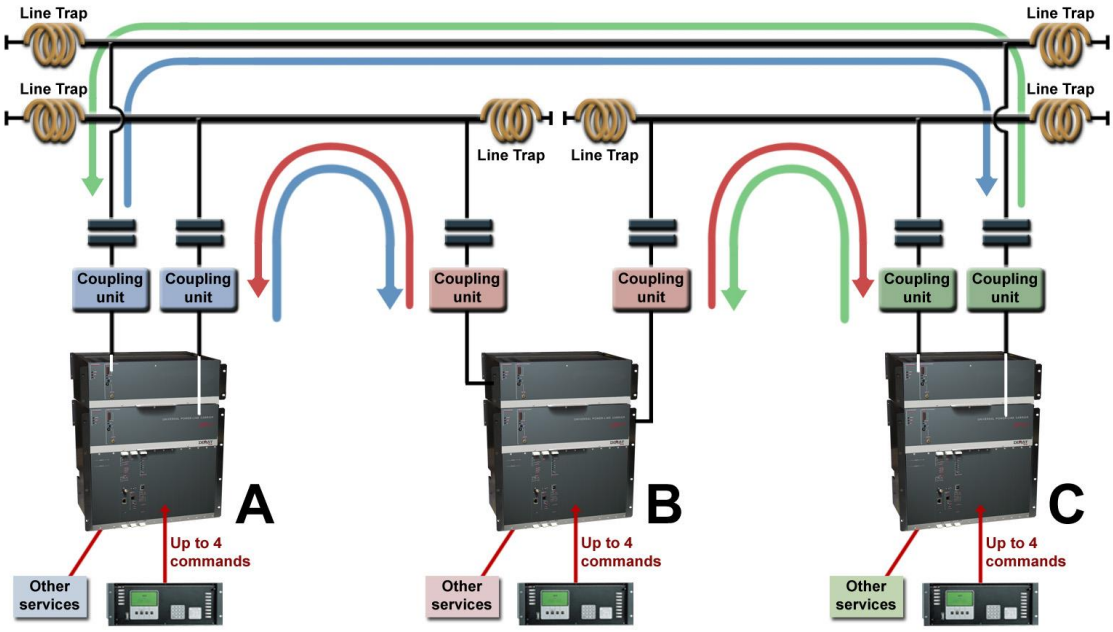


Teleprotection between 3 sites using only three OPU-1 terminals

This application consists in sending the same teleprotection information to two different sites using only three OPU-1 terminals equipped each with two sets of 4-command teleprotection system.

For this application, additional filters are necessary.

FIGURE 7 Teleprotection between 3 sites application



The use of additional filters in a twin-channel analog terminal allows the transmission and reception bands of each channel to be non-adjacent.

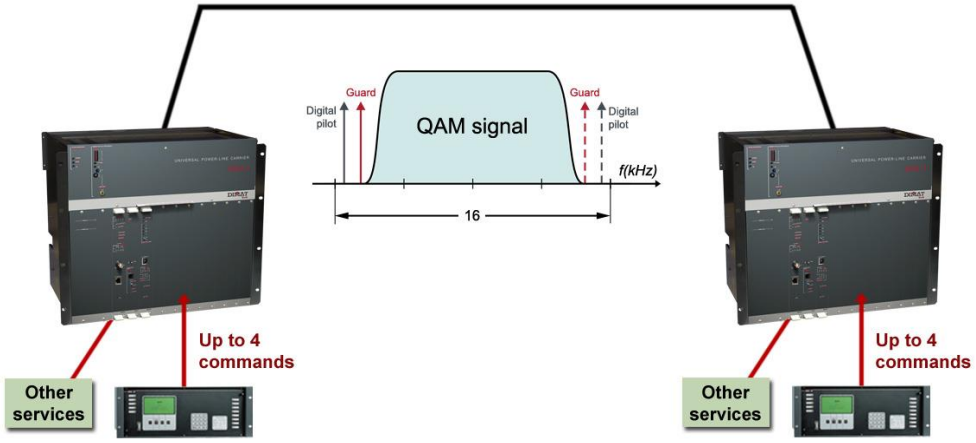
Teleprotection integrated in the digital band

The digital operation band is used for the QAM signal and teleprotection signals.

For this application the OPU-1 terminal is equipped with a specific set of 4-command teleprotection system.

The guard signal is sent to the high-voltage line together with the QAM signal. When the receiver detects the absence of the guard signal, the QAM signal is blocked, for a pre-set period of time, to allow command signal detection.

FIGURE 8 Teleprotection integrated in the digital band (16 kHz)



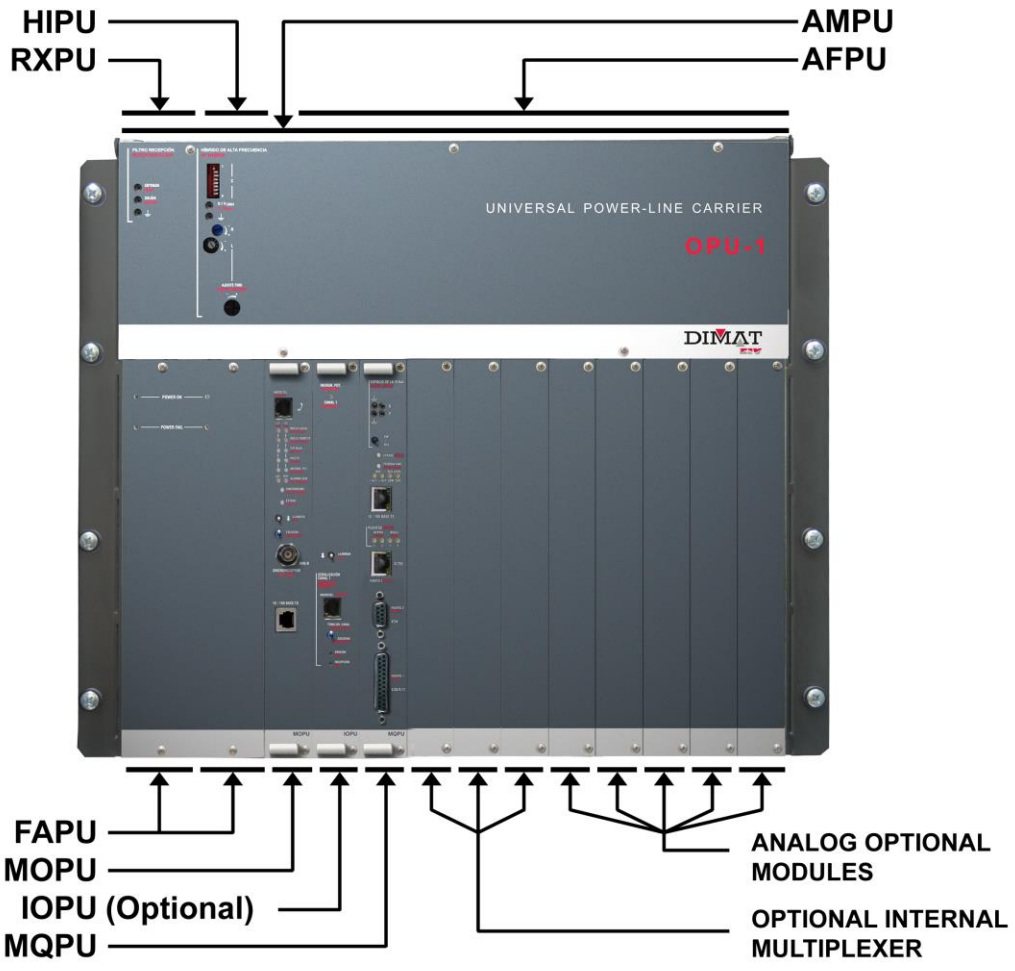
2 MODULE DESCRIPTION

The OPU-1 terminal can have an output power of 20 W, 40 W and 80 W (PEP), measured at the coaxial-connector output, shared between the analog and digital channels.

The OPU-1 basic terminal consists of one shelf of 3 s.u. in height, which contains the power stage modules for 20 W and 40 W, and one shelf of 6 s.u. in height, which contains the power supply, the management, signal processing and control unit, digital modem unit and the optional modules. The module arrangement for 20 and 40 W is shown in FIGURE 9.

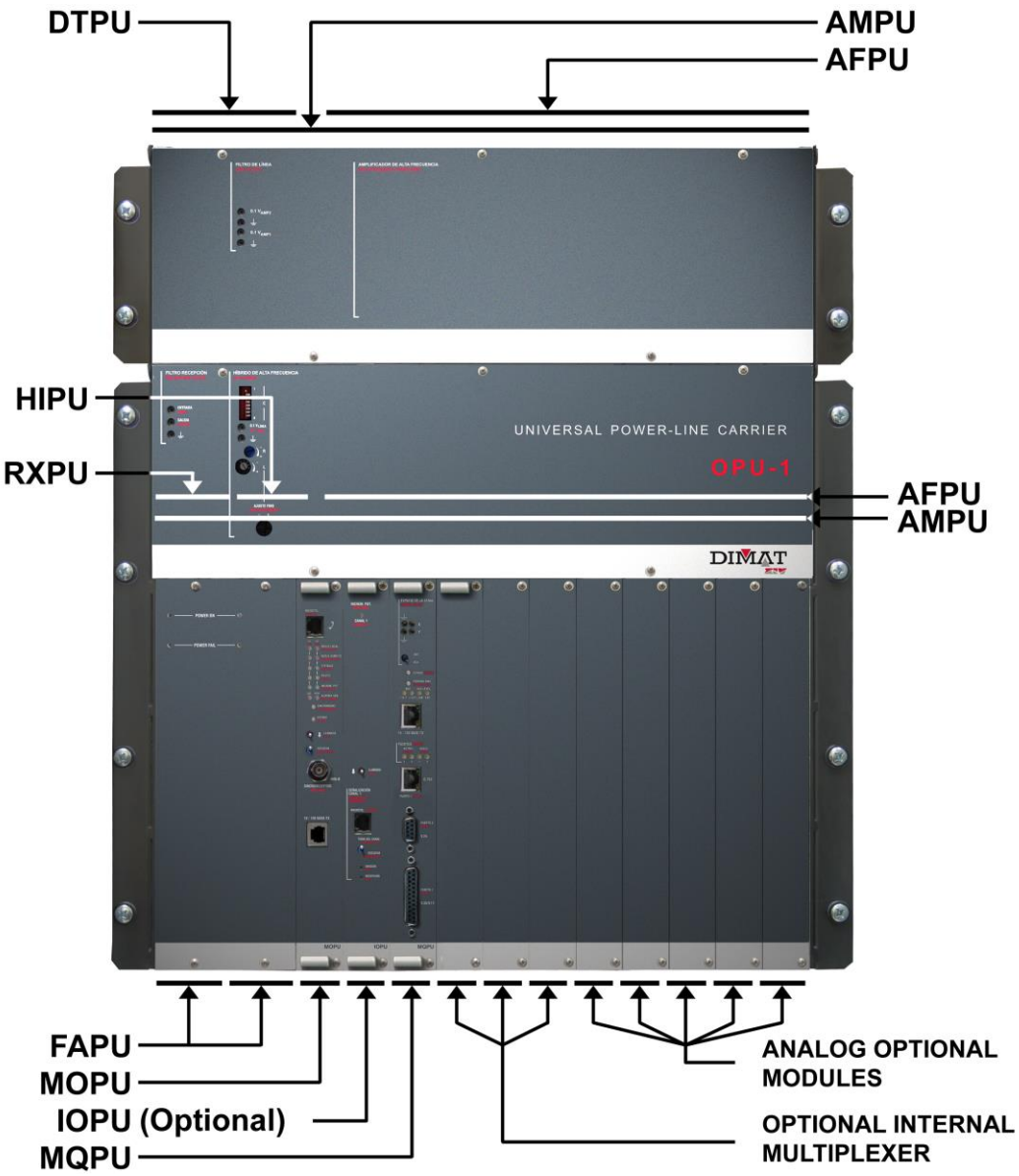
All the shelves are prepared for mounting in a 19" rack.

FIGURE 9 OPU-1 module arrangement for 20 and 40 W



The 80 W terminal is obtained by adding to the 40 W terminal an additional shelf of 3 s.u. in height, containing a second 40 W amplifier and a differential transformer to connect the first in parallel to the second to obtain the 80 W output power. The module arrangement for 80 W is shown in FIGURE 10.

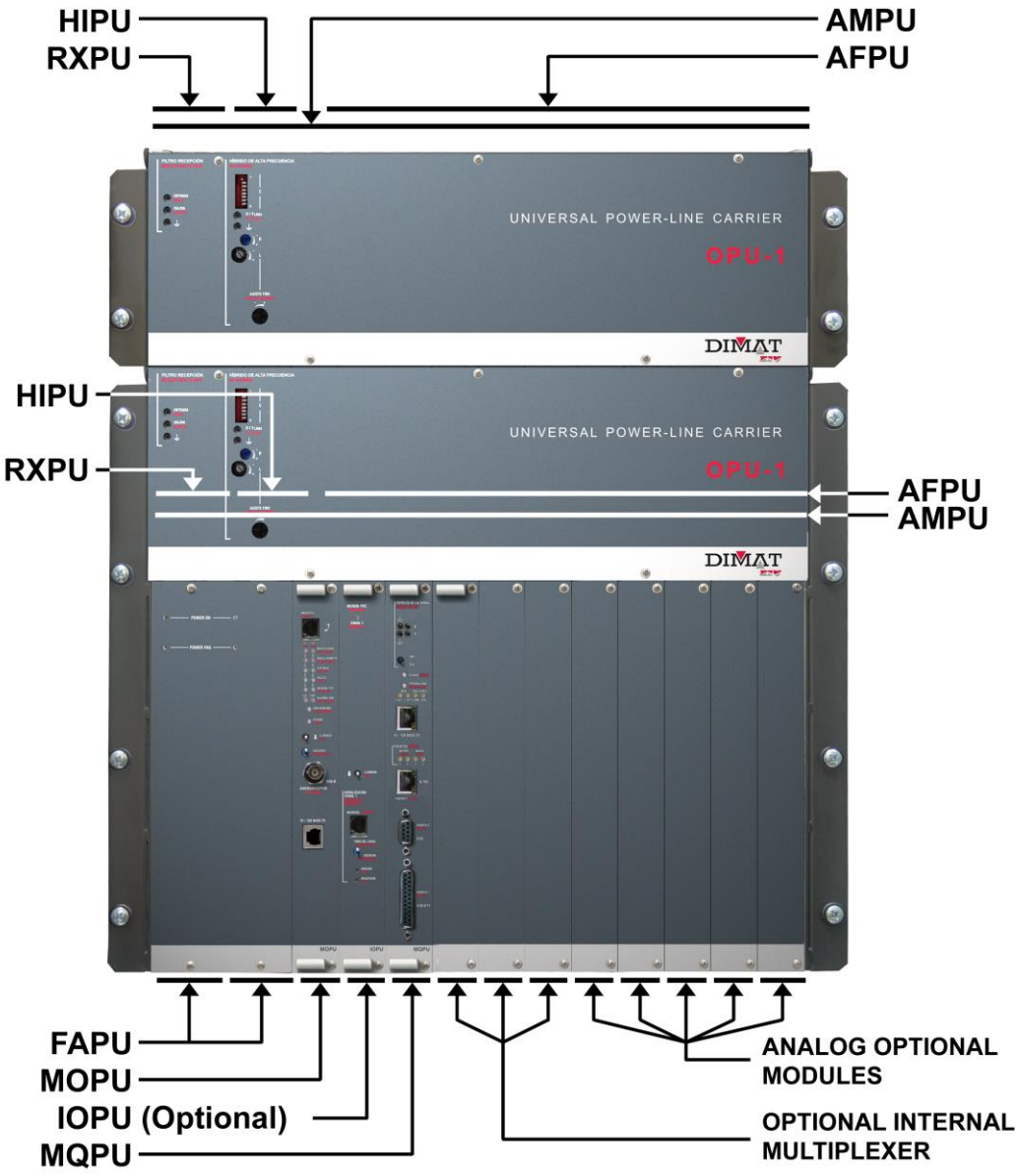
FIGURE 10 OPU-1 module arrangement for 80 W



When working in hybrid mode, it is possible to provide the 20 W or 40 W terminal with additional filters to use different frequency slots for the analog and the digital channels in the same line or, even, in independent lines. The module arrangement for the additional filters is shown in FIGURE 11.

The use of additional filters in a twin-channel analog terminal also allows the transmission and reception bands of each channel to be non-adjacent.

FIGURE 11 OPU-1 module arrangement for 20 and 40 W with additional filters



2.1 BASIC MODULES FOR TERMINALS OF 20 AND 40 W

FAPU **POWER SUPPLY**

This module contains the DC/DC converter that generates the internal power-supply voltages from the input voltage, as well as a filter at the input to suppress disturbance caused by fast transient bursts.

The module also contains the power-supply alarm external signalling relay.

The type of module depends on the nominal input voltage. The following types are available:

FAPU.02 Input voltage of 48 V_{DC}.

FAPU.10 Input voltage of 110 V_{DC}.

FAPU.10/20 Input voltage from 110 to 220 V_{DC} and V_{AC}.

If power-supply redundance is necessary, the OPU-1 terminal must be equipped with two power-supply modules.

The power supply is protected against polarity inversion.

MOPU.1X **MANAGEMENT & ANALOG SIGNAL PROCESSING UNIT**

On the one hand, it contains the central management unit that is made up of: LAN interface (10/100Base-Tx), loop control, a decoder capable of processing according to IRIG-B standard, a web server, an SNMP agent and the associated MIB, and service channel.

On the other hand, for processing the analog signals, it contains a central processing unit that is made up of: the circuits for the mixing of the signals to be transmitted, modulation and demodulation circuits, synchronization circuits, digital signal filtering, signal-to-noise ratio measurement and automatic gain control (AGC) circuits.

It also contains the whole-band service-telephony circuits, which are operational only when the IOPU module is not installed in the equipment.

The type of module depends on whether the terminal is working with one or two analog channels in this way:

MOPU.10 One analog channel (CH1).

MOPU.11 Two analog channels (CH1 and CH2).

MQPU.1X **DIGITAL MODEM UNIT**

This module includes two data ports, one for synchronous data, with interface V.35 or V.11 or G.703, and the other for asynchronous data, with interface V.24/V.28. It also includes an Ethernet user interface.

It contains the frequency conversion and modulation and demodulation circuits, synchronization and automatic gain control (AGC) circuits, and the control circuits of the optional internal multiplexer.

For QAM, it also contains the circuits for link quality measurement according to the G.821 standard, an adaptive equalizer which minimizes the intersymbol interference, and the echo canceller which allows the transmission in superimposed bands to be carried out.

For processing the signals proceeding from the interfaces, this module generates an internal frame and carries out the 128-QAM, 16-QAM or 4-QAM modulation, and the Trellis coding.

In OFDM/OQAM, the bit stream is dynamically assigned to the 244 carriers which can be modulated from a 4-QAM to a 4096-QAM depending on the channel quality and sharing this modulation each group of carriers. The turbo code rate also is dynamically assigned.

The type of module depends on the digital modulation scheme, in this way:

MQPU.10 QAM.

MQPU.11 OFDM/OQAM

RXPU **RECEPTION FILTER**

This module comprises the receive-channel filter. This module is located in the 3 s.u. shelf.

HIPU **HF HYBRID**

This module contains the high-frequency hybrid. This module is located in the 3 s.u. shelf.

AMPU **HIGH-FREQUENCY AMPLIFIER**

This module contains the wideband output amplifier of 20 W or 40 W and the alarm circuits for overload or low transmitted-signal level. This module is located in the 3 s.u. shelf.

The output impedance of the HF amplifier must be consistent with the bandwidth of the line filter, in this way:

AMPU.00 For line filter with bandwidth of 8, 16 or 24 kHz.

AMPU.02 For line filter with bandwidth of 8, 16 or 32 kHz.

AFPU **LINE FILTER**

This module contains the line filter. This module is located in the 3 s.u. shelf.

The bandwidth of the line filter is selected configuring a jumper and two switches in the 3 s.u. backplane.

WOPU **6 s.u. backplane**

It contains three alarm external signalling relays, whose activation condition is established from the Management System, the main power-supply switch, the fuses, the power-supply sockets, and the connectors for external connections.

WPPU **3 s.u. backplane**

It contains the line transformer, the coaxial connector for making the connection to the line, the jumpers for selecting the line impedance, the dummy load, a setting to connect or not the coaxial-cable shield to chassis, and the jumpers and switches for selecting the bandwidth of the line filter.

The type of backplane depends on the line-filter bandwidth in this way:

WPPU.00 The bandwidth of the line filter may be 8, 16 or 24 kHz.

WPPU.01 The bandwidth of the line filter may be 8, 16 or 32 kHz.

2.2 ADDITIONAL MODULES FOR 80 W

DTPU **DIFFERENTIAL TRANSFORMER**

This module contains the differential transformer to obtain the 80 W output power. This module is located in the additional 3 s.u. shelf.

AMPU **HIGH-FREQUENCY AMPLIFIER**

This module contains the second 40 W wideband output amplifier and the alarm circuits for overload or low transmitted-signal level. This module is located in the additional 3 s.u. shelf.

AFPU **LINE FILTER**

This module contains the transmit-line filter for the second 40 W amplifier. This module is located in the additional 3 s.u. shelf.

2.3 ADDITIONAL MODULES FOR AN EXTRA FILTERS FOR 20 AND 40 W

RXPU **ADDITIONAL RECEPTION FILTER**

This module comprises the receive-channel filter. This module is located in the additional 3 s.u. shelf.

HIPU **ADDITIONAL HF HYBRID**

This module contains the high-frequency hybrid. This module is located in the additional 3 s.u. shelf.

AMPU **ADDITIONAL HIGH-FREQUENCY AMPLIFIER**

This module contains the wideband output amplifier of 20 W or 40 W and the alarm circuits for overload or low transmitted-signal level. This module is located in the additional 3 s.u. shelf.

The output impedance of the HF amplifier must be consistent with the bandwidth of the line filter, in this way:

AMPU.00 For line filter with bandwidth of 8, 16 or 24 kHz.

AMPU.02 For line filter with bandwidth of 8, 16 or 32 kHz.

AFPU **ADDITIONAL LINE FILTER**

This module contains the line filter. This module is located in the additional 3 s.u. shelf.

The bandwidth of the line filter is selected configuring a jumper and two switches in the additional 3 s.u. backplane.

WPPU **Additional 3 s.u. backplane**

It contains the line transformer, the coaxial connector for making the connection to the line, the jumpers for selecting the line impedance, the dummy load, a setting to connect or not the coaxial-cable shield to chassis, and the jumpers and switches for selecting the bandwidth of the additional line filter.

The type of backplane depends on the line-filter bandwidth in this way:

WPPU.00 The bandwidth of the line filter may be 8, 16 or 24 kHz.

WPPU.01 The bandwidth of the line filter may be 8, 16 or 32 kHz.

2.4 OPTIONAL INTERNAL MULTIPLEXER

When working with a digital channel, the multiplexing of the different services, if desired, can be carried out by using an optional internal multiplexer.

There are two models of optional internal multiplexer, the description of each one being in the following.

2.4.1 MXPU internal multiplexer

This optional internal multiplexer of the OPU-1 terminal consists of up to three MULTIPLEXER modules (MXPU). Each MXPU module can house up to three ports. The characteristics of a port depends on the type of submodule installed.

MXPU **MULTIPLEXER**

This module conforms the internal multiplexer. It can contain up to three submodules. There are three different types of submodule depending on whether the port has to be data, voice at 16 kbit/s or voice at 4800 bit/s, 6400 bit/s or 8000 bit/s.

KDMX **Data submodule**

Supports a communication channel for synchronous, asynchronous or anisochronous data. It is equipped with an interface (DB25) that complies with Recommendation V.24/V.28 of the ITU-T (RS-232C).

KVMX **Speech submodule at 16 kbit/s**

Submodule for 4-wire or 2-wire telephone termination, with ADPCM speech encoder at 16 kbit/s.

When 2-wire is configured, two operation modes are obtained: 2-wire exchange-side (it includes ring detection and the exchange subscriber-loop management) and 2-wire subscriber side (it includes the subscriber circuits: ring-current generator and pick up detection).

KAVX **Speech submodule at 4800 bit/s, 6400 bit/s or 8000 bit/s**

Submodule for 4-wire or 2-wire telephone termination, with speech encoder at 4800 bit/s, 6400 bit/s or 8000 bit/s based on MP-MLQ multipulse encoding.

When 2-wire is configured, two operation modes are obtained: 2-wire exchange-side (it includes ring detection and the exchange subscriber-loop management) and 2-wire subscriber side (it includes the subscriber circuits: ring-current generator and pick up detection).

This termination also allows the transmission of Group 3 fax signals up to 7200 bit/s in accordance with Recommendations V.21, V.27ter and V.29 of the ITU-T, as well as modem signals at 2400 bit/s and 1200 bit/s in accordance with Recommendation V.22bis.

2.4.2 DMPU/TMPU internal multiplexer

This optional internal multiplexer of the OPU-1 terminal consists of up to three modules type DMPU and/or TMPU.

The characteristics of the DMPU and TMPU modules are described in the following.

DMPU.## Data module.

Each DMPU module can house up to six data ports.

TABLE 2 indicates the interfaces allowed for each port and connector type.

The module can perform drop-insert functionality which allows a more efficient use of the system bandwidth. The drop-insert is particularly suitable for half-duplex communications or polling systems (Central Unit/Remotes).

The type of module depends on the number of ports, in this way:

DMPU.02 2 data communication channels (port 3/9/15 and port 4/10/16).

DMPU.04 4 data communication channels (port 3/9/15, port 4/10/16, port 5/11/17 and port 6/12/18).

DMPU.06 6 data communication channels (port 3/9/15, port 4/10/16, port 5/11/17, port 6/12/18, port 7/13/19 and port 8/14/20).

TABLE 2 Interfaces supported by the DMPU module ports

Port 3/9/15 (DB15) and Port 4/10/16 (DB15)	**Port 5/11/17 (DB9), Port 6/12/18 (DB9), Port 7/13/19 (DB9) and Port 8/14/20 (DB9)**
V.24/V.28 (RS-232C) X.21 RS-422 RS-485 (HD/FD)	V.24 asynchronous RS-422 RS-485 (HD/FD)

TMPU. ## Speech module.

It allows full-duplex transmission and reception with speech encoder at 2100 bit/s, 2450 bit/s or 2800 bit/s based on RALCWI coding algorithm.

The Mean Opinion Score (MOS) of voice quality is about 3.5-3.6.

Supports up to 2 speech communication channels for 4-wire or 2-wire telephone termination. When 2-wire is configured, two operation modes are obtained: FXO (2-wire exchange-side) and FXS (2-wire subscriber side). For FXO, it includes ring detection and the exchange subscriber-loop management. For FXS, it includes the subscriber circuits: ring-current generator and pick up detection.

It allows in-band DTMF transmission and reception.

It allows in-band or out-of-band transmission and reception by E&M wires.

It allows in-band factory pre-set tones transmission and reception.

Possibility of incorporating modem protocols for V.21 (300 bit/s FSK), Bell 103 (300 bit/s FSK), V.23 (1200/75 bit/s FSK) and Bell 202 (1200/75 bit/s FSK) standards.

The TMPU module can contain a data port with an interface (DB15) that complies with Recommendation V.24/V.28 of the ITU-T (RS-232C).

The type of module depends on the number of ports, in this way:

TMPU.11 1 speech communication channel (Port 4/10/16) plus 1 data channel (Port 3/9/15).

TMPU.21 2 speech communication channels (Port 4/10/16 and Port 5/11/17) plus 1 data channel (Port 3/9/15).

2.5 ANALOG OPTIONAL MODULES

When working with analog channels, the OPU-1 terminal can contain up to five optional modules. The following sections detail the large variety of options available.

2.5.1 Speech module

For a speech-plus service (T-type channel), the OPU-1 terminal must have a speech module.

The TDPU.20 speech module is a compact module with all the circuits required to operate as: 4-wire termination, 2-wire termination, exchange-side 2-wire termination, and subscriber termination. **No plug-in submodules are needed**.

The TDPU.20 module is compatible with previous TDPU modules. The external connection is also compatible.

The TDPU.20 module contains the speech-band transmit and receive filters, the upper frequency of which can be defined from the management terminal, the dynamic compressor/expander, a 4-wire configurable termination and a subscriber-side 2-wire telephone termination.

The 4-wire configurable termination can be dynamically switched between 4W/2W operation by means of an external command. This termination can be configured as an exchange-side 2-wire termination, carrying out the required telephone-converter tasks.

The subscriber-side 2-wire telephone termination comprises the telephone hybrid, the subscriber circuits and the ring-current generator. This termination supports up to two telephones in parallel.

The TDPU.20 speech module also contains the circuits needed to receive the external input of the M wire (transmission call) and for signalling the E wire (reception call).

2.5.2 Teleprotection terminals

There are several teleprotection terminals, based on the use of digital signal processing.

2.5.2.1 Teleprotection terminal using single tone

The analog teleprotection terminal using single tone is able to transmit and receive in a 4 kHz analog band up to three independent commands and in any combination or up to four commands according to a certain logic.

Teleprotection system type ABIT-CDIT

The terminal can be constituted by either one or two different modules according to the number of commands. For one or two commands, ABIT.01 module (commands A and B) is only necessary. For three or four commands, in addition to the previous one, CDIT.01 module (commands C and D) is also necessary.

ABIT.01 This module contains the Digital Signal Processor (DSP), which generates the guard and command tones and implements a bank of filters for the reception of commands.

It also has the software necessary for decision making in the transmission and reception of commands, as well as software for input/output management, link supervision and the carrying out of tests.

It contains two command input and output circuits together with five relays for signalling and/or alarm, configurable by the user.

CDIT.01 This module contains two command input and output circuits together with four relays for signalling and/or alarm, configurable by the user.

Teleprotection system type TPPU

The terminal is constituted by a single module.

TPPU.00 This module contains the Digital Signal Processor (DSP), which generates the guard and command tones and implements a bank of filters for the reception of commands.

It also has the software necessary for decision making in the transmission and reception of commands, as well as software for input/output management, link supervision and the carrying out of tests.

Two frequencies are assigned to each command signal, and a single frequency is assigned to the guard signal.

2.5.2.2 Teleprotection terminal using FSK channels

The analog teleprotection terminal using FSK channels is able to transmit and receive up to four independent commands and in any combination in a 4 kHz analog band.

The terminal can be constituted by either one or two different modules according to the number of commands. For one or two commands, ABIT.01 module (commands A and B) is only necessary. For three or four commands, in addition to the previous one, CDIT.01 module (commands C and D) is also necessary.

ABIT.01 This module contains the Digital Signal Processor (DSP), which generates the FSK channels in transmission (at the programmed frequency and shift) and implements for each channel the elements which differentiate between the guard and command signals in reception.

It also has the software necessary for decision making in the transmission and reception of commands, as well as software for input/output management, link supervision and the carrying out of tests.

It contains two command input and output circuits together with five relays for signalling and/or alarm, configurable by the user.

CDIT.01 This module contains two command input and output circuits together with four relays for signalling and/or alarm, configurable by the user.

2.5.2.3 Teleprotection terminal using dual tone

The analog teleprotection terminal using dual tone is able to transmit and receive up to four independent commands and in any combination in a 1 kHz, 2 kHz or 4 kHz analog band.

The terminal is constituted by a single module.

TPPU.00 This module contains the Digital Signal Processor (DSP) that generates the encoded signals and implements the necessary processing circuits for the reception of all the frequencies used.

It also has the software necessary for decision making in the transmission and reception of commands, as well as software for input/output management, link supervision and the carrying out of tests.

Two frequencies are assigned to each command signal, and a single frequency is assigned to the guard signal.

It contains four command input and output circuits together with two relays for signalling and/or alarm, configurable by the user.

2.5.2.4 Teleprotection terminal integrated in the digital band

When only working with a QAM digital channel (of 8 kHz or 16 kHz), the OPU-1 terminal can be equipped with a specific analog teleprotection terminal using single tone or dual tone that will be able to use the digital operation band to transmit teleprotection signals.

The guard signal is sent to the high-voltage line together with the QAM signal generated in the OPU-1 terminal.

When a command needs to be transmitted, the guard signal is replaced by the corresponding command signal (SINGLE TONE or DUAL TONE) and, in order to allow the transmission of the command tone using all the power available, the transmission of the QAM signal is interrupted for a pre-set period of time.

When the receiver detects the absence of the guard signal, the QAM signal generated by the OPU-1 terminal is blocked, for a pre-set period of time, to allow command signal detection.

Teleprotection system type ABIT-CDIT

The teleprotection terminal integrated in the digital band and using single tone is able to transmit and receive up to three independent commands and in any combination or up to four commands according to a certain logic

The terminal can be constituted by either one or two different modules according to the number of commands. For one or two commands, ABIT.01 module (commands A and B) is only necessary. For three or four commands, in addition to the previous one, CDIT.01 module (commands C and D) is also necessary.

ABIT.01 This module contains the Digital Signal Processor (DSP), which generates the guard and command tones and implements a bank of filters for the reception of commands.

It also has the software necessary for decision making in the transmission and reception of commands, as well as software for input/output management, link supervision and the carrying out of tests.

It contains two command input and output circuits together with five relays for signalling and/or alarm, configurable by the user.

CDIT.01 This module contains two command input and output circuits together with four relays for signalling and/or alarm, configurable by the user.

Teleprotection system type TPPU

The teleprotection terminal integrated in the digital band and using dual tone is able to transmit and receive up to four independent commands and in any combination.

The terminal is constituted by a single module.

TPPU.00 This module contains the Digital Signal Processor (DSP) that generates the encoded signals and implements the necessary processing circuits for the reception of all the frequencies used.

It also has the software necessary for decision making in the transmission and reception of commands, as well as software for input/output management, link supervision and the carrying out of tests.

Two frequencies are assigned to each command signal, and a single frequency is assigned to the guard signal.

It contains four command input and output circuits together with two relays for signalling and/or alarm, configurable by the user.

2.5.3 Asynchronous programmable modem type MFPU

The MFPU is an asynchronous narrowband modem with frequency-shift keying (FSK) modulation for the transmission of data at speeds of 50 to 1200 Bd.

The technology used in the MFPU modem is based on digital signal processing and allows the transmission speed and central frequency of each channel to be programmed by the user. The transmission speed can be 50, 100, 200, 600 or 1200 Bd, whilst the central frequency of each channel can be selected from between a wide range of values, including those enumerated in recommendations R.35, R.37, R.38A and R.38B of the ITU-T. The MFPU modem is also compatible with standard V.23 of the ITU-T.

2.5.4 Others

IOPU **BASEBAND INPUT/OUTPUT CIRCUIT**

It contains two 600 Ω balanced inputs and two 600 Ω balanced outputs and the whole-band service-telephony circuits.

It also receives the external input for power-boosting control, the external input of the M wire (transmission call) and the signalling of the E wire (reception call).

The type of module depends on whether the terminal is working with one or two analog channels in this way:

IOPU.01 One analog channel (CH1).

IOPU.02 Two analog channels (CH1 and CH2).

This module is always installed adjacent to MOPU module.

FTPU VFT-TRANSIT FILTER

Audio-frequency signal filter and amplifier with phase equalizer. It is used to select a determinate band and to carry out the transit towards other communication channels.

It includes a transformer-decoupled output with programmable level.

FDPU DIGITAL TRANSIT FILTER

It is used to select a specific band and to carry out the two-way transit towards other communication channels.

It includes a transformer-balanced input and output with programmable level.

The cutoff frequency is selected by means of jumpers.

Filters with other cutoff frequencies can be supplied on request.

EYPU INPUT/OUTPUT COMBINER

The EYPU module has four inputs and four outputs that are all decoupled by transformer, and two inputs and two outputs for signals coming from the low-frequency buses of each of the analog channels of the OPU-1 terminal. It is therefore possible, by programming the module, to effect any combination in the connection of six inputs and four outputs or of four inputs and six outputs. As it is not possible to connect the AF reception and transmission buses of the OPU-1 terminal to each other, the combination of six inputs and six outputs is not permitted.

TPSU 6 s.u. extension card.

3 PARTICULARITIES OF THE SYSTEM

3.1 USE OF THE ANALOG BASE BAND

The available band, extending from 300 Hz to 3850 Hz, can be used for the transmission of data at high speed, various VF telegraph channels, teleprotection signals (D-type channel) or for a speech-plus service (T-type channel).

TABLE 3 indicates the maximum number of standardized channels of 50, 100 and 200 Bd that can be situated in the D-type channel.

TABLE 3 Maximum number of channels for a D-type channel

ITU-T Recommendation	R.35	R.37	R.39	R.38A	R.38B
Transmission rate (Bd)	50	100	100	200	200
Separation (Hz)	120	240	170	480	360
Number of channels	29	14	20	7	9

The number of higher-rate FSK channels that can be transmitted in the same band is three for a transmission rate of 600 Bd (with a separation of 960 Hz) and two for a rate of 1200 Bd.

In the T-type channel, where the available band is shared between speech and data, the speech band is limited by a frequency lower than 300 Hz and by an upper one that is programmable between 2000 Hz and 3400 Hz. The superimposed band extends between 1.06 times the cutoff frequency selected for the speech band and 3850 Hz. The maximum transmission rate that can be obtained in the superimposed band is 1200 Bd when the speech band is limited to 2000 Hz.

3.2 USE OF THE PILOT (ANALOG CHANNEL)

The pilot is situated below the available band, at the virtual frequency of 150 Hz, which makes all of the band between 300 Hz and 3850 Hz available for the transmission of information.

The following information describes the different functions performed by the pilot channel.

Automatic Gain Control (AGC)

The equipment supervises at all times the level of the pilot signal received in each one of the channels. The amplitude of this signal, once digitized, is used to carry out the automatic gain control of each channel. Thanks to the use of digital processing techniques, it is also possible to compensate for a level variation of the receiver outputs, which is caused by the presence of noise in the pilot channel.

Link synchronization

It is possible to work plesiochronously, that is to say, each terminal works with its own master clock or in a synchronized way, that is to say, each terminal uses its internal oscillator as the master transmission clock and synchronizes its reception with the other terminal using the pilot received. This synchronization is completely digital.

Telephone signalling

Modulating the pilot signal by frequency shifting at a maximum rate of 50 Bd, corresponding to 25 impulses a second, permits telephone signalling to be transmitted.

Internal data transmission

The supervision of the system is carried out by transmitting data through the internal communication channel at a rate of 50 Bd. The transmission is interrupted when telephone signalling appears and is resumed when it has no transitions.

Furthermore, data transmission is periodically interrupted in order to carry out the link synchronization.

Noise spectral density

The system estimates the noise spectral density from the measurement of the noise power in the band of the pilot tone. Assuming that this density is constant in the whole 4 kHz channel, the signal-to-noise ratio is independently calculated for each of the channels.

The value thus determined is compared with pre-set thresholds in order to block the previously-programmed audio-frequency outputs and to deliver an excess-noise alarm.

3.3 MODULATIONS AND DEMODULATIONS

The transposition of a 4 kHz channel to a band of frequencies that extends from 36 to 512 kHz is carried out by means of a modulation process that is completely digital. The type of modulation used is single side-band with suppressed carrier.

In this way, the analog signal in base band is digitized and delivered to the MOPU where, by means of digital signal processing, is transposed to the desired channel frequency, with a resolution of 1 Hz. The resulting digital signal is converted to analog and, before being transmitted to the high-voltage line, passes through a power stage.

In reception the transposition is carried out in reverse, that is to say, the received analog signal, after passing through the AGC circuit, is digitized and delivered to the signal processing unit which carries out the transposition of the signal of each channel in base band, and extracts the pilot. The digital signal of each channel is then converted to analog.

For the QAM, the data stream proceeding from the digital user interface is encoded and then modulated at 128-QAM, 16-QAM or 4-QAM according to whether the gross bit rate is of 81 kbit/s, 40.5 kbit/s or 27 kbit/s, respectively. The data is subjected to the following processes: scrambling, serial-to-parallel conversion, differential encoding, convolutional encoding (Trellis encoding), symbol mapping, pulse-shaping filtering and QAM modulation.

The QAM signals obtained in this way are then transposed to the desired frequency band and, before being transmitted to the high-voltage line, passes through a power stage.

In reception the transposition is carried out in reverse, that is to say, the received analog signal enters the MQPU module where, once subjected to an AGC process, it is converted into a digital signal and passes through a band-pass filter which gives the receiver the selectivity characteristics desired.

In the superimposed-band operation mode, the filtered signal is applied to an echo-canceller device where the transmit signal that superimposes the received signal is cancelled, by means of a signal coming from the transmitter and adequately processed. The obtained signal is demodulated and decoded in order to be sent to the user interface.

In the non-adjacent band operation mode, when an echo canceller is not used, the filtered signal is directly demodulated and decoded in order to be sent to the user interface.

The input of the OFDM/OQAM modulator is a complex symbol stream for each of the carriers of the system.

This symbol stream is first processed by a staggering block, which outputs a complex symbol stream at twice the input rate.

This stream is then multiplied by a carrier specific exponential weight and processed by an IFFT block, whose output is filtered by the polyphase components of the prototype pulse followed by a decimate-and-sum network.

At the receiving side, the inverse operations are carried out.

3.4 LINK SYNCHRONIZATION

With the analog channels (MOPU module), it is possible to work plesiochronously, that is to say, each terminal works with its own master clock or in a synchronized way, that is to say, each terminal uses its internal oscillator as the master transmission clock and synchronizes its reception with the other terminal using the pilot received. This synchronization is completely digital.

The MQPU module (QAM digital channel) works with only one clock, which is internal. The programming of the terminal configuration automatically determines a *Master-Slave* operating mode for the recovery of synchronisms. The *Master* terminal generates the transmit synchronisms from the internal oscillator. The *Slave* terminal always uses the clock recovered from the data received from the line to generate the transmit synchronisms. The receive synchronisms are always generated from the clock recovered from the received data.

With respect to synchronism, it is recommended that the customer terminals of a link use the clocks generated in transmission and in reception by the OPU-1 terminals.

3.5 TIME SYNCHRONIZATION

The OPU-1 terminal chronologically registers all the alarms produced in the terminal, as well as the events that refer to the link service. In order to establish the date and time the alarms and/or events are produced, the OPU-1 terminal has a real time clock, which can be synchronized with the GPS system or by means of the SNTP protocol.

When time synchronization is established in the terminal, via GPS or Ethernet, the OPU-1 refers its internal real time clock to the UTC[1] system, estimating in this way the UTC time by which it can calculate the time in other zones of the world. In this case, the UTC time will always remain as a model of the internal clock of the terminal, even against any date and time programming carried out by the user.

3.5.1 GPS synchronization

The OPU-1 terminal can synchronize its real time clock with the time reference given by the GPS system. In order to do so, the time, day, month and year must be programmed in the OPU-1 terminal and it must then be connected to a GPS receiver that has a timing output, which must be an IRIG-B output. The IRIG-B standard establishes the format of signals used to identify specific instants of time.

The standard IRIG-B signals are classified according to the modulation applied to them, their frequency/resolution and codes applied to the words (set of bits) that contain the information. According to this classification, a number is applied to each one of the three parameters mentioned earlier and standards are defined, such as for example, the IRIG-B 120 or the IRIG-B 123.

The OPU-1 terminal is capable of processing standard IRIG-B 123 signals, in which the signal is modulated in amplitude at 1 kHz, and standard IRIG-B 003 signals, in which the signal is modulated by pulses.

3.5.2 Ethernet synchronization

The OPU-1 terminal can also synchronize its real time clock via Ethernet using the SNTP (Simple Network Time Protocol) protocol, which uses UTC as a time base.

It is possible to configure up to 5 possible addresses of SNTP servers from the OPU-1 Management System.

[1] UTC is not really an abbreviation but a variant of universal time (*UT*) and the C of "coordinated" is added to show that it is another variant of UT.

4 MAIN MANAGEMENT MENUS

The home web page of the OPU-1 Management System is as shown in FIGURE 12.

As can be seen, four main menus appear. The first menu, *System*, controls the flow of information entering and leaving the Management System, allows the pages necessary for carrying out off-line Web Management to be downloaded as well as the display of the module software versions, and allows all the parameters relating to the network management to be programmed. The second menu, *Configuration*, allows all the operative parameters of the terminal to be configured and those of its collateral, that is to say, those of the terminal at the other side of the link. The third menu, *Monitoring,* allows supervision of the system to be carried out, whilst the fourth, *Alignment help*, contains guidelines on alignment and maintenance.

These menus are described in more detail in the following sections.

FIGURE 12 OPU-1 Management System home web page

4.1 SYSTEM MENU

This menu contains three options. The first gives access to the reading functions of the disk or terminal and writing functions to disk or in the terminal. The second allows the pages necessary for carrying out off-line Web Management to be downloaded as well as the display of the module software versions. The third gives access to the options which allow the specification of: the web server user passwords, the basic network management parameters (IP address, subnetwork mask and gateway), that must be compatible with those of the management computer.

4.2 CONFIGURATION MENU

This menu allows the programming of the terminals to be defined, that is to say, their identification and configuration, transmission and reception frequency bands, audio-frequency input and output levels, signal-level percentages for each service, digital modulation scheme (QAM or OFDM/OQAM), gross bit rate of the QAM digital modem, digital ports programming as well as the operative parameters of the optional analog modules. It also allows alarms to be assigned to the external signalling relays.

- **Terminal configuration**

  In the OPU-1 terminals it is possible to program a numeric identification and a description of up to 50 characters.

  Before programming the operating parameters it is necessary to configure the terminal. The output power (which can be of 20, 40 or 80 W), the operating mode and the options incorporated in the equipment are defined by means of this configuration.

  For the analog channels, should the reception of the terminals of the link need to be synchronized, synchronization mode must be configured. For the QAM digital channel, to establish whether the terminal should operate as master or slave.

- **Carrier-channel frequencies and bands.**

  The carrier frequency of the analog channel is defined by introducing, from the management terminal, the values of the virtual carrier frequency, for transmission and reception, and the type of band, which can be erect or inverted.

  For the digital channel, the central-frequency values for transmission and reception must also be introduced, and whether the transmission and reception bands are superimposed or non-adjacent. It must be taken into account that when programming superimposed bands for the QAM, the echo canceller is being activated at the same time. In the case of superimposed bands, the frequency values in transmission and reception must be the same.

The only manual adjustment required is that of the line and reception filters. The Management System contains a help menu in which the operations for the adjustment of these filters are indicated for each channel.

- **Modulation levels and percentages (analog channel).**
  The system allows the signal-level percentages assigned to each signal as well as their input and output levels to be defined. This section also defines the power boosting used to send the teleprotection signal, as well as the signals of the analog channel that must be excluded when it is sent.

- **Signal-level percentages (digital channel).**
  The system allows the signal-level percentages assigned to the pilot and QAM/OFDM signals to be defined.

- **Blocking.**
  The audio-frequency outputs can be blocked because of pilot loss or excessive noise. The user can define the signal-to-noise ratio for each output for which blocking must be effected as well as the value of excess noise which causes the external alarm to be activated.

- **Alarms.**
  The terminal has three alarm signalling relays, with a simple contact, to which an alarm or combination of alarms can be assigned from the Management System.

- **Analog optional modules.**
  From the Management System it is possible to program all the parameters of the analog optional modules, such as the transmission speed and central frequency of the modem and speech characteristics, and teleprotection parameters.

- **Multiplexer**
  Allows the operative parameters of the data ports of the MQPU module to be programmed, as well as those of the data and speech ports of the modules of the optional internal multiplexer. It also makes it possible to de-activate the service associated to a port, activating it again when necessary.

4.3 MONITORING MENU

The monitoring menu allows information to be gained about the state of each terminal of the link.

The monitoring of the remote terminal is carried out by transmitting data through the internal communication channel, which can only take place when the channel is not used for link synchronization and when there are no transitions in the signalling channel. If signalling appears while data are being transmitted, this transmission process is interrupted and resumed again once the sending of telephone signalling has finished.

The information provided by the monitoring system relating to each terminal is the following: Terminal alarms, Chronological list of alarms, Chronological list of events, Receive pilot level, S/N ratio, Quality of the received signal (established with regard to Recommendation G.821), and the state of module MQPU ports as well as those of the optional modules of the built-in multiplexer (MXPU or DMPU/TMPU).

❖ **Alarm display**

The alarms of the terminal that can be monitored from the Management System are the following:

- Main and/or secondary power-supply failure.
- Amplifier overload of 3 s.u. shelf.
- Low output level in amplifier of 3 s.u. shelf.
- Loss of synchronism.
- Pilot loss.
- Low Signal/Noise ratio.
- AF limiter operation in analog channel.
- Temperature alarm.
- Terminal configuration error.
- Hardware failure.
- BER>10^{-3} in digital channel.
- BER>10^{-6} in digital channel.
- Low RCV level in digital channel.
- RCV level exceeded in digital channel.
- Failure in G.703 interface input in digital channel.

❖ **Chronological register**

The appearance and disappearance of the alarms is stored in a register together with the indication of the date, with day, month and year, and time, with minute, second and millisecond, they were produced.

Events related to the link service, such as the activation of teleprotection, the switching on of the terminal, the modification of the programming and insertion of the telephone handset in the terminal are also introduced in the same register. The register has a maximum capacity of 1000 alarms and events; when the limit is reached the events or alarms introduced at the beginning of the register are eliminated.

4.4 ALIGNMENT HELP MENU

The Alignment help menu is provided to facilitate commissioning operations and system maintenance. The menu allows the internal clock of the terminal to be set and contains the procedures for carrying out line-filter adjustments and instructions for making the loops necessary to check the operation of the link, etc. The menu also contains an option that shows how to configure a jumper in order to load the IP address by default as well as the default user passwords in the terminal. On the other hand, the menu has the necessary options for the commissioning of the optional modules.

Clocks and synchronism

The Alignment help menu has an option that shows the date and time of the internal real time clock of the terminal and the UTC time allowing, if desired, the date and time values of the internal clock of the terminal to be modified using the UTC clock as a reference.

> The date and time programming of the internal clock of the terminal does not remain when the terminal has an external timing synchronization programmed via GPS or Ethernet.

Initializations

This option allows a reset of the equipment to be carried out without having to use the button on the front, block the Automatic Gain Control (AGC) circuit, and cancel the phase amplitude equalizer (analog channel).

Line-filter adjustment

For each transmission channel the Alignment help menu indicates the jumpers to be made for the programming of the central frequency of the line and receive filters as well as the adjustment of inductances for the setting of the bandwidth of these filters. This adjustment is carried out by means of a signal generated by the OPU-1 terminal's own transmitter.

Control of audio-frequency loops (analog channel)

To control the state of a communication system it is necessary to know the response curve of each link. The Web Management allows the user to obtain this information from one end of the link by establishing two types of loops at the other end. The first, which has signal-level regeneration at the said end, enables the response curve of the return circuit to be made known. This is possible thanks to the measurement of the received signal, for which it is known that the transmission level is constant. The second loop, which does not have signal-level regeneration, allows the response curve of the looped circuit to be obtained and, therefore, allows the response curve of the outward circuit to be calculated. The response curves are obtained by carrying out a channel sweep by means of an external generator. The Alignment help menu indicates how to carry out the operations mentioned.

Port loops

This option allows a data loop to be carried out in the ports associated to the digital channel.

5 TECHNICAL CHARACTERISTICS

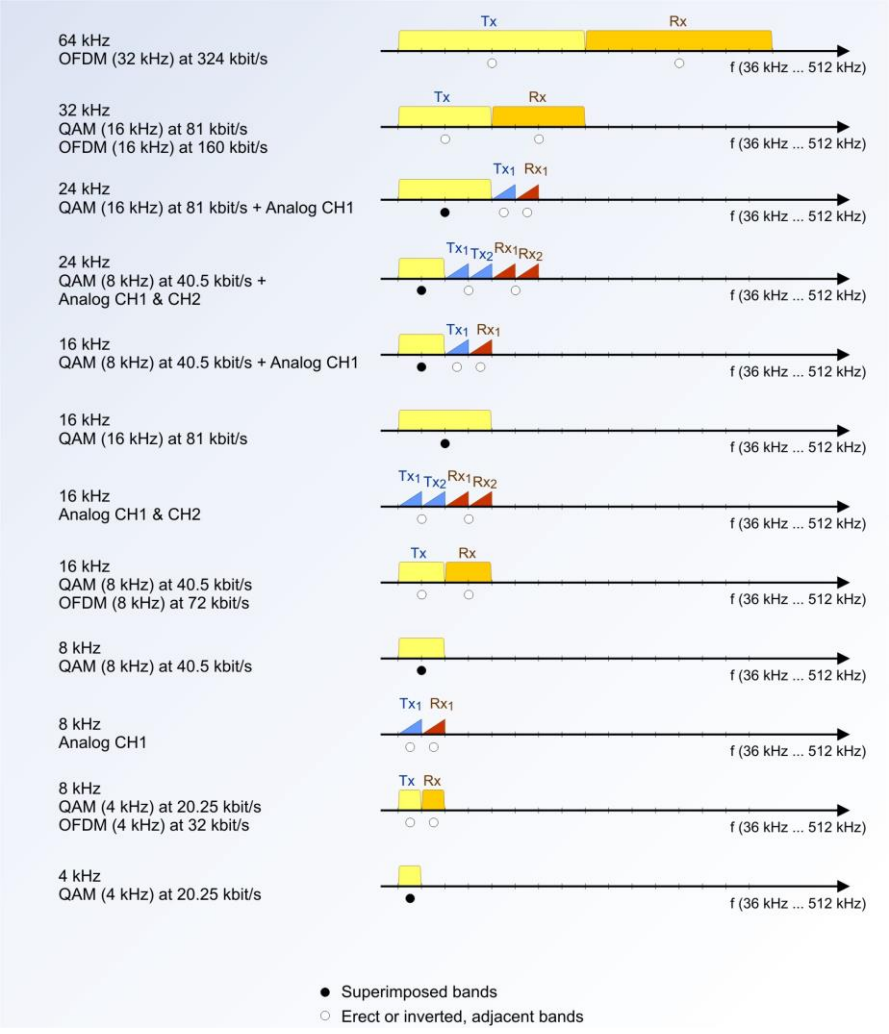
5.1 GENERAL CHARACTERISTICS

Operating mode[2]	Simultaneous transmission of analog and digital channels including teleprotection
Modulation	Analog channel: Single side-band (SSB) with suppressed carrier Digital modem: QAM with Trellis Coding or OFDM/OQAM
Transmission and reception bands	➢ Analog channel: Erect or inverted, adjacent or non-adjacent. ➢ Digital channel (QAM): Superimposed or adjacent or non-adjacent. ➢ Digital channel (OFDM/OQAM): Adjacent or non-adjacent.
Basic bandwidth	➢ Analog channel: 4 kHz per channel in each direction. ➢ Digital channel (QAM): 16 kHz at 81 kbit/s (maximum), single for superimposed bands or in each direction for non-adjacent bands. 8 kHz at 40.5 kbit/s (maximum), single for superimposed bands or in each direction for non-adjacent bands. 16 kHz at 40.5 kbit/s (maximum), for adjacent 8 kHz bands. 8 kHz at 20.25 kbit/s (maximum), for adjacent 4 kHz bands. 4 kHz at 20.25 kbit/s (maximum), single for superimposed bands or in each direction for non-adjacent bands.

[2] If desired, the OPU-1 can function as a High-Frequency teleprotection system. This functionality enables electrical power utilities to transmit teleprotection commands over high-voltage lines, in only one standard 4 kHz channel, using 2 kHz for Tx and 2 kHz for Rx. This functionality implies a specific hardware architecture of the terminal

	➢ Digital channel (OFDM/OQAM): 32 kHz at 324 kbit/s (maximum), in each direction for adjacent bands. 16 kHz at 160 kbit/s, in each direction for adjacent bands. 8 kHz at 72 kbit/s, in each direction for adjacent bands. 4 kHz at 32 kbit/s, in each direction for adjacent bands.
Transmission capacity	See examples in FIGURE 13. The possibilities can be enlarged with the use of the additional filters

FIGURE 13 Transmission capacity examples



NOTE: The OPU-1 can work with different line filters, depending on the backplane type.

Supervision of data link quality	According to the G.821 standard
Pilot tone (analog channel)	
Functions	➢ Automatic Gain Control. ➢ Telephone signalling. ➢ Signal-to-noise ratio measurement. ➢ Link synchronization. ➢ Service channel (data transmission).
Central frequency	150 Hz (virtual frequency)
Modulation	By frequency-shift keying of ±30 Hz
Maximum rate	50 bit/s
Pilot tone (digital channel)	
Functions	Automatic Gain Control
Internal clock (Master)	
Frequency stability within specified temperature and voltage ranges	±1ppm
Ageing	<1ppm/year
Synchronization	➢ Analog channel: Synchronous or Plesiochronous (non-synchronism). ➢ Digital channel (QAM): Master-Slave
Automatic Gain Control (AGC) in analog channel	
Dynamics	≥55 dB with 10% pilot modulation
Efficiency	±20 dB input level variations cause variations of less than ±0.2 dB at the output
Automatic Gain Control (AGC) range in digital channel	47 dB

5.2 HIGH-FREQUENCY CHARACTERISTICS

Frequency range	From 36 to 512 kHz
Operating frequency	Programmable in 1 Hz steps
Nominal impedance	Selectable among 50, 75, 125 and 140 Ω
Return loss	Better than 10 dB in accordance with IEC 495
Tapping loss	In accordance with IEC 495, Fig. A.1 with n=4 (digital channel), figure 5 (analog channel)
Frequency separation for parallel connection on the same line (analog channel)	
Between transmitter and receiver of the same equipment	≥0 kHz
Between transmitters of adjacent equipment	≥8 kHz
Between transmitter and receiver of adjacent equipment	≥4 kHz
Between receivers of adjacent equipment	≥0 kHz
Transmitter	
Peak envelope power over resistive load	20, 40 or 80 W, shared between the analog and digital channels
Spurious emission (analog channel)	In accordance with IEC 495 cls. 5.2.4 and figures 7 and A.2
Receiver sensitivity	➢ Analog channel: -30 dBm (measured in the pilot signal). ➢ Digital channel: -10 dBm
Receiver selectivity	➢ Analog channel: higher than 65 dB at 300 Hz, and higher than 75 dB starting from 4 kHz; in accordance with IEC 495 cls. 5.3.1.5.

	➢ Digital channel: in accordance with IEC 495 cls. 5.3.1.5.

5.3 QAM DIGITAL MODEM CHARACTERISTICS

Crest factor	8 dB
Modulation	
128 QAM	➢ 16 kHz: 81 kbit/s (79 kbit/s). ➢ 8 kHz: 40.5 kbit/s (39.5 kbit/s). ➢ 4 kHz: 20.25 kbit/s (19.75 kbit/s).
16 QAM	➢ 16 kHz: 40.5 kbit/s (39.5 kbit/s). ➢ 8 kHz: 20.25 kbit/s (19.75 kbit/s). ➢ 4 kHz: 10.125 kbit/s (9.87 kbit/s).
4 QAM	➢ 16 kHz: 27 kbit/s (26.3 kbit/s). ➢ 8 kHz: 13.5 kbit/s (13.15 kbit/s). ➢ 4 kHz: 6.75 kbit/s (6.55 kbit/s).
Fall back/increase rate(3)	Automatic. Can be disabled from the programming software. The change of speed presents hysteresis, whose thresholds can be programmed from the programming software. The factory configuration is the following: ➢ **Medium-Upper** step: 23 dB ➢ **Upper-Medium** step: 20.5 dB ➢ **Medium-Lower** step: 11.6 dB ➢ **Lower-Medium** step: 14.4 dB
16 kHz QAM bandwidth	➢ Upper: 81 kbit/s. ➢ Medium: 40.5 kbit/s. ➢ Lower: 27 kbit/s.

(3) The terminal permanently measures the S/N ratio in the digital band to decide the speed increase before retraining (1.5 s).

8 kHz QAM bandwidth	➢ Upper: 40.5 kbit/s. ➢ Medium: 20.25 kbit/s. ➢ Lower: 13.5 kbit/s.
4 kHz QAM bandwidth	➢ Upper: 20.25 kbit/s. ➢ Medium: 10.125 kbit/s. ➢ Lower: 6.75 kbit/s.
Minimum S/N ratio, with white Gaussian noise (AWGN) at receiver input (16 kHz QAM bandwidth)	➢ BER = 10-3: 20 dB at 81 kbit/s. 12 dB at 40.5 kbit/s. 8 dB at 27 kbit/s. ➢ BER = 10-6: 23 dB at 81 kbit/s. 16 dB at 40.5 kbit/s. 12 dB at 27 kbit/s.
Minimum S/N ratio, with white Gaussian noise (AWGN) at receiver input (8 kHz QAM bandwidth)	➢ BER = 10-3: 20 dB at 40.5 kbit/s. 12 dB at 20.25 kbit/s. 8 dB at 13.5 kbit/s. ➢ BER = 10-6: 23 dB at 40.5 kbit/s. 16 dB at 20.25 kbit/s. 12 dB at 13.5 kbit/s.
Minimum S/N ratio, with white Gaussian noise (AWGN) at receiver input (4 kHz QAM bandwidth)	➢ BER = 10-3: 20 dB at 20.25 kbit/s. 12 dB at 10.125 kbit/s. 8 dB at 6.75 kbit/s. ➢ BER = 10-6: 23 dB at 20.25 kbit/s. 16 dB at 10.125 kbit/s. 12 dB at 6.75 kbit/s.
Internal latency	10 ms

5.4 OFDM DIGITAL MODEM CHARACTERISTICS

Modulation	Orthogonal frequency-division multiplexing (OFDM/OQAM)
Fall back/increase rate	Automatic
32 kHz bandwidth	324 kbit/s
16 kHz bandwidth	160 kbit/s
8 kHz bandwidth	72 kbit/s
4 kHz bandwidth	32 kbit/s

5.5 USER INTERFACES

Analog channel (IOPU option)	
Available band	From 300 to 3850 Hz
Interface	Two 4-wire inputs and outputs per channel
Nominal impedance	600 Ω, balanced
Return loss	Better than 14 dB in accordance with IEC 495
Nominal level	Programmable between –20 dBm and +6 dBm
Limiter action in base-band inputs	In accordance with IEC 495 cls. 5.3.1.9
Base-band output blocking	For pilot loss and/or low S/N ratio with an independent threshold value for each output
Link amplitude distortion	In accordance with IEC 495 figure 9. Three terminals connected in cascade also comply with M.1020 figure 1
Link group-delay distortion	In accordance with IEC 495 figure 10. Three terminals connected in cascade also comply with M.1020 figure 2
E and M signalling	
Transmission	By means of optocoupler. Input voltage between 30 V and 150 V
Reception	By means of relay. Contact rating: 1 A/250 V_{AC}
Pulse distortion of telephone signalling	≤10%
External teleprotection input	Any whole-band input can be used for the transmission of a teleprotection signal, and can be programmed with a signal-level percentage of between 10% and 100% in the command signal
Boosting control	By means of optocoupler. Input voltage between 30 V and 150 V

Digital channel	
Synchronous data port	To be chosen between: ➢ Interface in accordance with Rec. V.35 of the ITU-T of 1200, 2400, 3600, 4800, 6400, 7200, 8000, 9600, 14400, 16000, 19200, 28800, 32000, 38400, 64000 and 72000 bit/s. ➢ Interface in accordance with Rec. V.11 of the ITU-T of 1200, 2400, 3600, 4800, 6400, 7200, 8000, 9600, 14400, 16000, 19200, 28800, 32000, 38400, 64000 and 72000 bit/s. ➢ Interface G.703, co-directional, of the ITU-T of 64 kbit/s
Asynchronous data port	200, 600, 1200, 2400, 3600, 4800, 7200, 9600 and 14400 bit/s with interface in accordance with Rec. V.24/V.28 of the ITU-T (EIA RS-232C)
Ethernet data port	10/100Base-Tx with built-in bridge functionality

5.6 OPTIONAL BUILT-IN MULTIPLEXER CHARACTERISTICS

5.6.1 MXPU internal multiplexer

MXPU built-in multiplexer (optional)	Up to nine additional ports, either speech or data, distributed in three MXPU modules (up to three ports per module)
Speech ports	16 kbit/s (ADPCM). 4800 bit/s, 6400 bit/s or 8000 bit/s (MP-MLQ); group 3 fax signals up to 7200 bit/s in accordance with Recommendations V.21, V.27ter and V.29 of the ITU-T; modem signals at 2400 and 1200 bit/s in accordance with Recommendation V.22bis of the ITU-T

Connection	2-wire and 4-wire with E and M signalling or DTMF
Data ports (DCE mode)	➢ Synchronous, of 600, 1200, 2400, 3600, 4800, 6400, 7200, 8000, 9600, 14400, 16000, 19200, 28800, 32000 and 38400 bit/s. (Up to 19200 bit/s at the 27 kbit/s gross bit rate). ➢ Asynchronous, of 200, 600, 1200, 2400, 3600, 4800, 6400, 7200, 8000, 9600, 14400, 19200 and 28800 bit/s. (Up to 19200 bit/s at the 27 kbit/s gross bit rate). ➢ Anisochronous, of 60, 120, 240, 360, 480, 640, 720, 800, 960 and 1440 bit/s
Interface (DB25)	V.24/V.28 of the ITU-T (EIA RS-232C)
Asynchronous data format	1 Start bit. 6 to 8 data bits. 1 or 2 Stop bits

5.6.2 DMPU/TMPU internal multiplexer

DMPU/TMPU built-in multiplexer (optional)	Up to three modules type DMPU and/or TMPU, being available the following. DMPU.02: two data ports DMPU.04: four data ports DMPU.06: six data ports TMPU.11: one speech port plus one data port TMPU.21: two speech ports plus one data port Drop-insert functionality in DMPU module data ports. The drop-insert is particularly suitable for half-duplex communications or polling systems (Central Unit/Remotes

Asynchronous data format	1 Start bit. 6 to 8 data bits. 1 or 2 Stop bits
Data speed	➢ Synchronous, of 600, 1200, 2400, 3600, 4800, 6400, 7200, 8000, 9600, 14400, 16000, 19200, 28800, 32000 and 38400 bit/s. (Up to 19200 bit/s at the 27 kbit/s gross bit rate). ➢ Asynchronous, of 50, 100, 200, 600, 1200, 2400, 3600, 4800, 6400, 7200, 8000, 9600, 14400, 19200 and 28800 bit/s. (Up to 19200 bit/s at the 27 kbit/s gross bit rate). ➢ Anisochronous, of 60, 120, 240, 360, 480, 640, 720, 800, 960 and 1440 bit/s
DMPU data ports (DCE mode)	
Interface	➢ Port 3/9/15 (DB15 female) & Port 4/10/16 (DB15 female): ❖ V.24/V.28 of the ITU-T (EIA RS-232C) ❖ X.21 of the ITU-T ❖ RS-422 of the ITU-T ❖ RS-485 (HD/FD) ➢ Port 5/11/17 (DB9 female), 6/12/18 (DB9 female), 7/13/19 (DB9 female) and 8/14/20 (DB9 female): ❖ V.24 asynchronous ❖ RS-422 of the ITU-T ❖ RS-485 (HD/FD) Implementation of enhanced V.14 in asynchronous mode (allows communication between equipment at speeds of up to 10% difference)

TMPU data port (DCE mode)	
Interface	➢ Port 3/9/15 (DB15 female): ❖ V.24/V.28 of the ITU-T (EIA RS-232C) Implementation of enhanced V.14 in asynchronous mode (allows communication between equipment at speeds of up to 10% difference)
TMPU speech ports	Full-duplex transmission and reception at 2100 bit/s, 2450 bit/s or 2800 bit/s (RALCWI coding algorithm).
Connection	2-wire and 4-wire telephone termination. FXO (exchange side) or FXS (subscriber side) mode for the 2-wire configuration
Signalling	E&M (in-band or out-of-band). DTMF (in-band). Factory pre-set tones (in-band)
Voice quality	Mean Opinion Score (MOS) about 3.5-3.6
Others	Up to three analog transits. Possibility of incorporating modem protocols for V.21 (300 bit/s FSK), Bell 103 (300 bit/s FSK), V.23 (1200/75 bit/s FSK) and Bell 202 (1200/75 bit/s FSK) standards

5.7 OTHER CHARACTERISTICS

Analog built-in optional modules	➢ Speech module. ➢ Asynchronous programmable modem. ➢ 2 or 4-command teleprotection system using single tone in a 4 kHz bandwidth. ➢ 2 or 4-command teleprotection system using FSK channels in a 4 kHz bandwidth.

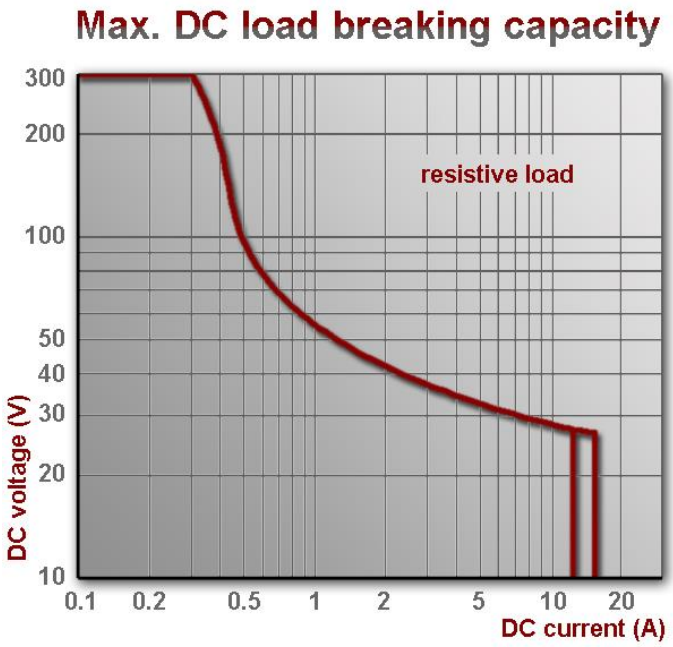
	➢ Teleprotection system of up to four independent commands or in any combination for dual tone in a bandwidth of 1 kHz, 2 kHz or 4 kHz. ➢ 2 or 4-command teleprotection system using single tone or dual tone, which is integrated in the QAM digital band. ➢ Digital transit filter. ➢ Input/output combiner.
Other optional equipment that can be added	External teleprotection unit type TPU-1 or CTP-1
Front-plate indications	
Signalling	➢ Terminal powered. ➢ Terminal status. ➢ Data port state. ➢ Local terminal in loop. ➢ Remote terminal in loop. ➢ Power-boosting command. ➢ Call reception. ➢ Call transmission.
Alarms	• Power-supply failure. • Loss of synchronism. • Pilot loss. • Low Signal/Noise ratio. • Excess or low receive level in digital channel. • BER alarm in digital channel. • General alarm.[4] • Remote alarm.[5]

[4] It lights up when one of the following alarms is produced: Power-supply failure, Amplifier overload, Low output level in amplifier, Loss of synchronism, Pilot loss, Low Signal/Noise ratio, AF limiter operation, Temperature alarm, Terminal configuration error, Hardware failure, BER alarm, Excess or low receive level and Failure in G.703 interface input.

	The terminal has three alarm signalling relays to which an alarm or combination of alarms can be assigned from the Management System
Power-supply alarm external signalling	
Type	By relay. Changeover contact. Contact rating: 1 A/250 V_{AC}, see FIGURE 14 for V_{DC}
Number of relays	One per power supply
State in normal operation conditions	Energized (N.O. and C contacts short-circuited)
Alarm external signalling	
Type	By relay. Changeover contact. Contact rating: 1 A/250 V_{AC}, see FIGURE 14 for V_{DC}
Number of relays	3 relays whose alarm condition can be programmed by the user. Any alarm situation that occurs in the terminal, as well as in the collateral, is shown on the front plate of the terminal by means of the GENERAL ALARM LED and REMOTE ALARM LED, respectively
State in normal operation conditions	Energized (N.O. and C contacts short-circuited)
Timing for relay activation	Programmable between 0 and 60 s
Test elements	➢ Analog channel: ❖ Possibility of carrying out HF and audio-frequency test loops. ➢ Digital channel: ❖ Data loop in local and remote terminals. ❖ High-frequency loop (isolated terminal). ❖ Displaying of the XMT and RCV signal space constellation by means of oscilloscope (QAM).

Capacity of chronological register	1000 alarms and events with 1 ms resolution
Time synchronization of the chronological register	Via GPS (IRIG-B) or via Ethernet (SNTP protocol)
GPS time connector	Type: BNC Standard: IRIG-B 123 and IRIG-B 003

FIGURE 14 DC voltage/DC current



NOTE: 2A is the maximum current

5.8 OPERATING CONDITIONS

Temperature and humidity	From –5 °C to +55 °C and relative humidity not greater than 95%, in accordance with IEC 721-3-3 class 3K5 (climatogram 3K5)
Maximum temperature	+55 °C for a period no longer than 24 hours (IEC 495 cls 3.1)

Power supply	48 V_{DC} ±20%. 110 V_{DC} ±20%. 110 to 220 V_{DC} and V_{AC} ±20%.
Consumption (mixed terminal with QAM/OFDM & analog pilots at 10%)	1.87 A for 48 V_{DC} (90 W)
Protection against overvoltages in DC voltage	By means of fuse of 7 A/250 V for 20 and 40 W terminals
Insulation, voltage withstand and electromagnetic compatibility	In accordance with IEC 495 tables 2 and 3: ➢ IEC 255-4 class II and class III. ➢ IEC 255-5. ➢ IEC 255-22-1 class II and class III. ➢ IEC 801-2 class III. ➢ IEC 801-3. ➢ IEC 801-4 level 3.
Storage conditions	In accordance with IEC 721-3-1, class 1K5

5.9 MECHANICAL CHARACTERISTICS

Dimensions	
Basic terminal	483 x 398 x 355 mm (one 19"/6 s.u. shelf and one 19"/3 s.u. shelf)
80 W or additional filters for 20 and 40 W	483 x 548 x 355 mm (one 19"/6 s.u. shelf and two 19"/3 s.u. shelves)
Weight	20 kg (20/40 W terminal) 23 kg (20/40 W terminal with options) 30 kg (80 W terminal) 33 kg (80 W terminal with options)
Module arrangement	See FIGURE 15

FIGURE 15 Module arrangement

Connections	By means of connectors at the back of the terminal and built-in terminal blocks. If desired, the necessary cables can also be supplied upon request. Cabinet-mounting terminal blocks can be supplied upon request
Power-supply terminals	Terminals that do not have disconnect devices and that are suitable for flexible conductors of up to 4 mm^2 of section or rigid conductors of up to 6 mm^2 of section
Alarm-relay terminals	Terminals that do not have disconnect devices and that are suitable for flexible conductors of up to 2.5 mm^2 of section or rigid conductors of up to 2.5 mm^2 of section

The rest of the terminals	Terminals that do not have disconnect devices and that are suitable for conductors of up to 1.31 mm^2 of section

In disturbed environments it is recommended to use screened cables for the connections. For safety reasons the screen of the connection cables must be grounded, the connection to earth being made at just one end to avoid interference.

5.10 MANAGEMENT SYSTEM

Terminal management interface	
10/100Base-TX LAN interface	
Type of interface	IEEE 802.3 (CSMA/CD)
Connector	8-pin RJ-45 female
Type of cable	UTP-5
Transmission rate	10 or 100 Mbit/s
OPU-1 Management System	Programming and monitoring of the system from a PC running a standard Web browser, without the need for additional software. ❖ Programming: network parameters, terminal identification and configuration, transmission and reception frequency bands, audio-frequency input and output levels, signal-level percentages for each service in normal operation or boosting condition, digital modulation scheme (QAM or OFDM/OQAM), gross bit rate of the QAM digital modem, digital ports, fall back/ increase rate, optional analog modules, external signalling relays, clock and synchronisms and loops. ❖ Monitoring: Chronological list of alarms and events, terminal alarms, receive pilot level, S/N ratio, Quality of the link (established with regard to Recommendation G.821), and state of the digital ports.

SNMP agent	
SNMP protocol	v1, v2c and v3
Functions	➢ Transmission of both unconfirmed and confirmed notifications (traps and informs) of alarms and events of the terminal. INFORM available in v2c and v3 only. ➢ Supervision of certain monitorable parameters of the terminal by means of a GET operation, these being: ❖ Network parameters (IP, subnet mask and gateway). ❖ State of command transmission and reception counters and input and output activation counters (ABIT-CDIT teleprotection option). ❖ State of alarm signals (basic equipment and ABIT-CDIT teleprotection option). ❖ Alarm monitoring. ❖ Event notification. ❖ Signal/Noise ratio (basic equipment and ABIT-CDIT teleprotection option). ❖ Receive level. ➢ Initialization by means of a SET operation of command transmission and reception counters and input and output activation counters (ABIT-CDIT teleprotection option). ➢ Modification of the network parameters (IP, subnet mask and gateway) by means of a SET operation.
Supervision by means of SNMP agent	Possible from an SNMP application. The most of the variables of the OPU-1 that can be monitored are to be found in the MIB of the terminal, which can be integrated into the management platform.

Management computer	
Type	Compatible personal computer (PC)
Model	Pentium III 550 MHz processor or higher
RAM memory	512 MBytes
Graphic adapter	1 Mbyte SVGA
Communication	LAN module with 10/100Base-Tx
Operating system	Microsoft Windows XP Service Pack 2 version, Microsoft Windows 7 or Microsoft Windows 10
Web browser	Microsoft Internet Explorer v 6.0 or higher
JAVA virtual machine (Sun Microsystems)	Version 1.7 and higher

APPENDIX A

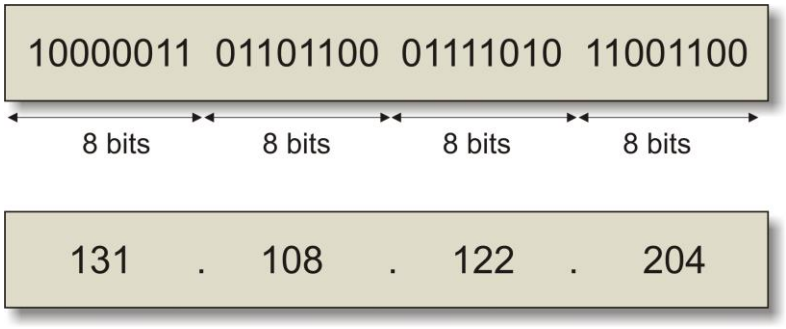
IP ADDRESSING

The Management System of the OPU-1 terminals is based on web technology. This technology is based on a Client/Server model in which the Server (OPU-1 terminal) replies to requests made by the Client (web browser of the management computer) with data that it has stored.

The configuration of the OPU-1 Management System requires the configuration of the Server and the configuration of the Client, so it is necessary to enter an IP address in each one that is compatible with the one of the other.

An IP address has a length of 32 bits and is made up of two main parts, a network number and a host number. The 32 bits of an IP address are grouped into 4 sets of 8 bits represented in a decimal form and separated by dots (*dotted-decimal*), as seen in FIGURE 16.

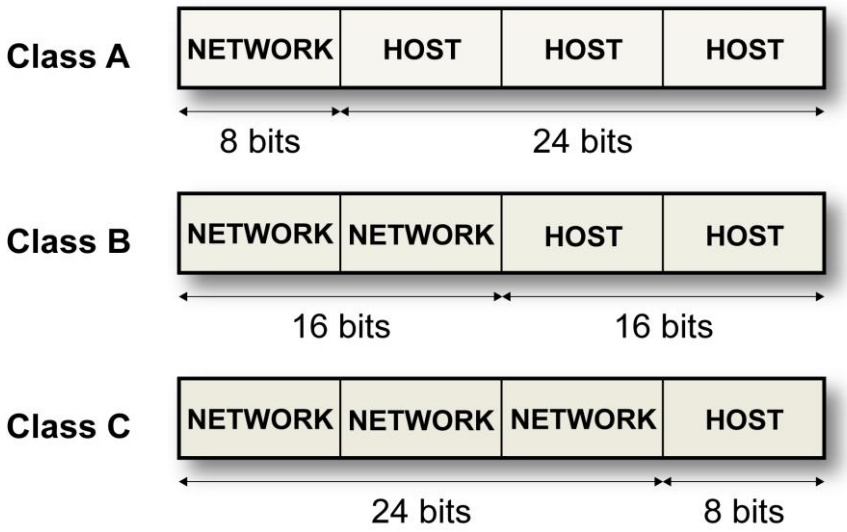
FIGURE 16 Format of an IP address



The network number of an IP address identifies the network to which a device is attached, whilst the host number identifies the specific device on that network. Because IP addresses consist of four octets separated by dots, one, two, or three of these octets may be used to identify the network number or the host number, depending on the class of IP address.

There are three classes of IP addresses, class A addresses, class B addresses and class C addresses. These classes are distinguished by the number of bits devoted to the network number and the host number, as shown in FIGURE 17.

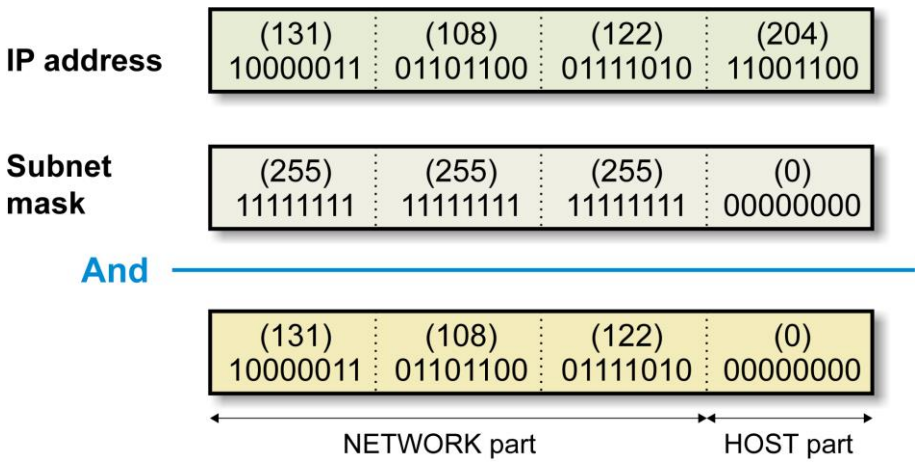
FIGURE 17 Classes of IP addresses



In IP addresses, it is possible to use the bits devoted to the host number to create subnetworks, justifying the existence of subnet masks, which are used to identify the network number and the host number of an IP address and have the same format (32 bits).

Given an IP address and a subnet mask, by performing an AND logical operation between them both, the part of the IP address that corresponds to the network is determined, and also the part that corresponds to the host, as shown in FIGURE 18.

FIGURE 18 IP address and subnet mask



The devices (hosts) of a single local area network are only able to connect directly with devices that have the same network number in their IP address. If they have a different network number they are unable to communicate unless there is another device that allows a connection to be made between the two networks. The IP address of these devices capable of connecting different networks is the one that in the hosts is identified as the default gateway.

In this way, to configure the IP address, the subnet mask and the default gateway of the web server of the OPU-1 terminal and the management computer, it must be considered whether or not they belong to the same network.

If the OPU-1 terminal and the computer are connected directly or through a LAN (they belong to the same network), the IP address of each of them must have the same network number and a different host number, so the subnet mask must be the same for both. The default gateway does not need to be configured.

If the OPU-1 terminal and the management computer belong to different LANs and the connection between them is via WAN, their IP addresses may have a different network number, but both must be connected to some device (default gateway) capable of interconnecting LANs.