User's Manual Set

V-PLC9000 Series

General Description Manual

Veesta - Universal PLC Communication System 9000 Series Product

Universal Power Line Carrier equipment designated for realization of telecommunication links and services over High Voltage Power Lines

VEESTA WORLD

Author: Veesta World Co., Engineering Department

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1.1 General Information

Secure and cost effective supply of electricity is basis for every country's economy and modern lifestyle. Complex power systems are built for that purpose. Dependable operation and supervision of such complex system is based on dependable and technologically up-to-date subsystems. Reliable information flow between elements of the power system (power plants, substations, control centres, etc.) on the same hierarchical level and between hierarchal levels is of crucial importance for efficient control over power system in order to achieve dependable and stable operation.

Power transmission network consists out of a number of High Voltage Power Lines (HV PL). Almost all sites of power system are interconnected with HV PLs. Primary task of HV PLs is transportation of electric energy and are therefore well maintained. Due to this reason the idea emerged in 1925 to use HV PLs as telecommunication media. This technology kept itself with the progress of telecommunication until present.

Telecommunication technology of transmitting information through HV PLs is known as Power Line Carrier or PLC for short. PLC is not predominant telecommunication technology today but is successfully used in Power Systems Telecommunication network together with other Telecommunication technologies.

PLC is especially technically and/or economically efficient in the following applications:

- Last-mile-access or telecommunication connection of end-point power system installations into telecommunication backbone with relatively low transmission capacity
- Redundant transmission of important information (important data, protection commands, hot dispatcher speech links, etc.) where also redundancy on the transmission media level is achieved

Classic (or analogue) PLC terminal enable building of telecommunication links (PLC links) with low number (1 to 6) of standard analogue telecommunication channels of 4kHz gross bandwidth. In the nineties of last century so-called digital PLC terminals emerged. These enable building of telecommunication links in the form of digital channels. Digital telecommunication channel has two major characteristics: transmission capacity stated in kbps (kilobits-per-second) and bandwidth used stated in kHz. Main reasons for the digital PLC terminal occurrence are:

- Predominate need for transmission of data
- Existence of high quality algorithms for compression of digitised speech
- Integration of PLC links into uniform digital telecommunication transmission network

Existence of digital PLC links only partially reduces the significance of analogue PLC links. Analogue PLC links are much more robust due to its high resistance to adverse operational conditions and are therefore suitable for realization of most important communication services (such as point-to-point dispatcher speech links, transmission of teleprotection commands, redundant transmission of critical information through two different transmission media, etc.). Less resistant digital PLC links on the other hand offer relatively high transmission capacity considering the bandwidth used (n times 4kHz).

Major part of PLC terminal is of the same construction regardless of the channel type (analogue or digital). It is therefore sensible that the structure of the PLC terminal is universal. Universal PLC terminal provides analogue (aPLC) and digital (dPLC) PLC channels or even combination of both.
VP-9UPT PLC terminal is typical **universal PLC terminal** with the following main features:

- **Universal design** provides analogue (aPLC) and/or digital (dPLC) channels.

- **Full programmability** without changing any hardware (modules). Value of most parameters may be set by means of PC locally or remotely.

- **One-step modulation scheme** enables simple production of PLC terminals with different number and type of channels:
  from 1 to 6 aPLC channels or
  1 dPLC channel or
  aPLC channels and 1 dPLC channel

- **Modular design** enables adjusting the PLC terminal structure to specific needs of particular application. User always buys only necessary hardware modules. With adding (or removal) of modules structure of PLC terminal can be adjusted to new requirements: changing of number and type of channels, aPLC channels version (»standard« or »speech-plus«), power supply source and possibility of later integration or removal of TPS (TeleProtection Signalling) function.

- **Wide RF range** of operation from 20kHz to 1.000 kHz (programmability without changing of hardware)

- **Compact design:** Regardless of PLC terminal's output power PEP (10W, 20W, 40W or 80W) and of number of channels, VP-9UPT PLC terminal occupies standard 19-inch rack of 6U (266mm) height and of 295mm depth.

- **Powerful diagnostics** generates lists of diagnostics data (alarms, operational parameters, events) which enable follow up of a device condition locally or remotely.

- **Modern technology:** Intensive use of DSP (Digital Signal Processing) and CPLD (Complex Programmable Logic Device)

- **Compliance with the relevant standards and recommendations:** IEC 495 (1993-09), document »Report on Digital Power Line Carrier« (CIGRE WG 35.09, April 2000) and relevant standards on EMC (ElectroMagnetic Compatibility)

1.2 Veesta World Co

Veesta World Co is a leading company in automation field in Iran and specialized in design and installation of IT Network of wide area and local area, Automation control units, control rooms, DCS design, PLC and SCADA application installation and system integration. The main advantage of Veesta World's products is complying international standards and do customs basic design.

Veesta World Co is a dynamic company located in the Tehran, IRAN, whose main commitment is the customer's satisfaction. Business vision and its future evolution together with the proper combination of new and existing technologies are the main aspects considered in the solutions proposed by Veesta World Co. Owing to this, key issues like Scalability, the Return of Investment or the Total Cost of Ownership are carefully considered. Consequently, the solutions offered by Veesta World Co are able to cope with the requirements of a sustainable growth. Veesta World Co is a service-oriented company and the customer perspective is its action guide. An added value of the offer is the evaluation and Management of the risk. This issue is getting a major relevance in the changing environment in which new technologies have to be applied, particularly when profitability is a major concern.

The objective of Veesta World Co is focused on the creation of value for the customer through the proper business strategy alignment and the right combination of technologies. These principles, developed under the Total Quality Management practice, allow Veesta World Co to offer, in a seamless approach, consultancy, engineering and training services. The founders of Veesta World Co are professionals with a large experience in the Telecommunication and Networking and Industrial fields. Veesta World Co is formed by a balanced team of professionals that gather knowledge in a wide range of technologies and specific know-how on how to apply these technologies in mission-critical control networks.

1.3 Copyrights

Figure 1-1: Veesta World Co Logo and sign

Chapter 2 - V-PLC9000 Terminal Structure

Structure of PLC terminal is dependant on particular request outlined by the application. Structure differs with regard to the number and type of channels, version of each analogue channel, power supply source as well as power supply type (single or doubled (redundant) power supply). Structure of PLC terminal (number of built in hardware (modules)) significantly influences the price of the final PLC terminal.
VP-9UPT Universal PLC terminal structure is indeed modular. With that feature it is possible to fit the terminal structure to the application in best possible mode. Therefore optimal price of the PLC terminal for the customer may be achieved.

2.1 Mechanical design and system modules

VP-9UPT Universal PLC terminal is a part of ***V-PLC9000 Communication System***.

»***V-PLC9000 Communication system***« apart from being a common name for family of terminals and devices also signifies unified technological platform on which all terminals are designed upon. Elements of unified platform are:

- standard 19-inch housing (EMC version)
- power supply system
- parametrising system
- diagnostic system
- technology

All devices within »V-PLC9000 Communication system« are built within the same housing (19-inch rack labelled VP-9RXY; XY determines version of housing) and include same one (single power supply) or two (redundant power supply) power supply modules VP-9PSHY (Y = type of power supply module with regard to supported power supply source). Supervision and control of all devices is performed through the same parametrising and diagnostic system. Significant part of hardware (modules) is unified as well. This feature is important as it lowers cost of spare parts and maintenance personnel training.

VP-9UPT Universal PLC terminal is built into 19-inch standard housing type VP-9R1P (Figure 2-1)

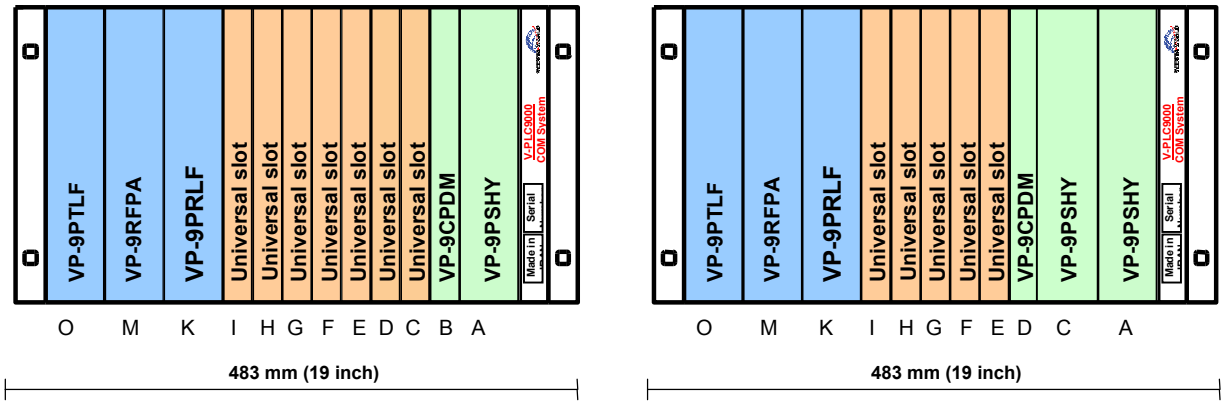

Figure 2-1:19-inch housing VP-9R1P; single or doubled redundant power supply

At least one system power supply module VP-9PSHY is built into every VP-9UPT rack. Five types of power supply module (Y in the abbreviations stands for type) are available:

POWER SOURCE		POWER SUPPLY TYPE (Y)
mains	115 / 230 V **A**C	VP-9PSH**A**
battery	2**4** V DC	VP-9PSH**4**
battery	48 / 60 V **D**C	VP-9PSH**D**
battery	**1**10 V DC	VP-9PSH**1**
battery	**2**20 V DC	VP-9PSH**2**

Power supply system is designed so that redundant mode of power supply is possible. In case of redundant power supply two VP-9PSHY power supply modules are built into the rack. Both power supply modules are operating at all time and share the load. Such operating mode prolongs the life period of modules because they are under lower load. In case of malfunction of one of the power supply modules the second takes over the power supply of the complete equipment.

Modules may be of same or different type.

Modules of the same type are both connected to the same power supply source so that the redundancy is ensured on the level of power supply module only.

Modules of different type are connected to different power supply sources. Such power supply system gives redundancy at the level of power supply source as well.

System module **VP-9CPDM** (see Figure 2-1) is always built into the rack regardless of configuration. It enables parametrising of the terminal and diagnostics (supervision of the terminal operation). This module also enables either local or remote (modem) connection of

the PC to the terminal. With the appropriate software package it is possible to parametrise and supervises the terminal (diagnostics; alarm list, operation parameters and events). Software package is enclosed with each terminal.

General description of the system for parametrising and supervision of operation is described in details in document »V-PLC9000 Communication system: P&D system«.

Parametrising of VP-9UPT Universal PLC terminal is described in document »V-PLC9000 Universal PLC terminal: Putting in to operation«.

Diagnostics of VP-9UPT Universal PLC terminal is described in document »V-PLC9000 Universal PLC terminal: Maintenance«.

2.2 Modules of Universal PLC Terminal VP-9UPT

The base of VP-9UPT universal PLC terminal is housing VP-9R1P with built in VP-9PSHY module (one or two power supply modules) and VP-9CPDM module (system module for parametrising and diagnostic) as described in previous chapter. Slots in the rack described as »dedicated slot« and »universal slot« (see Figure 2-1) are available for placement of VP-9UPT PLC terminal modules.

2.2.1 Line part modules

Modules of the line part are always built into the VP-9UPT universal PLC terminal (Figure 2-2):

- module **VP-9RFPA** RF power amplifier – transmitter; PEP(RFPA)max = 120W
- module **VP-9PTLF** programmable transmit line filter; RF hybrid and line transformer
- module **VP-9PRLF** programmable receive line filter and low noise amplifier

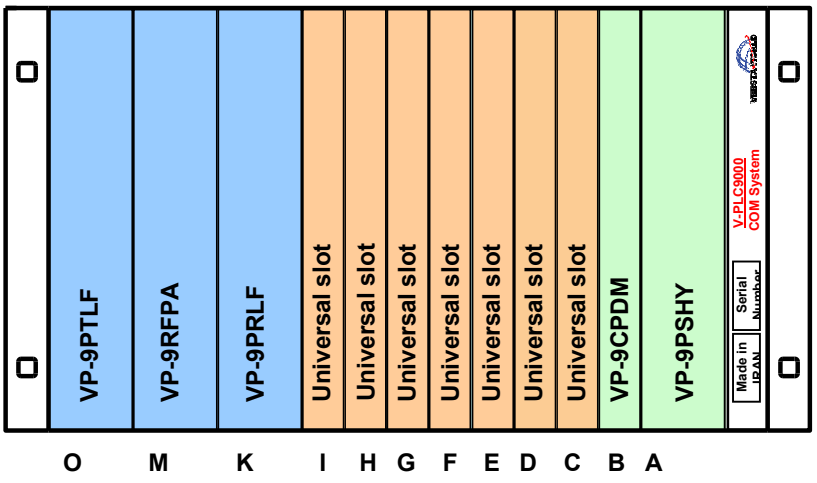

Figure 2-2: Line part modules of VP-9UPT PLC terminal

2.2.2 Channel module

At the slots described as »universal slot« right from the line part adequate number of channel modules **VP-9PXYS** may be build in; Figure 2-3. For each channel of VP-9UPT PLC terminal one channel module is built in.

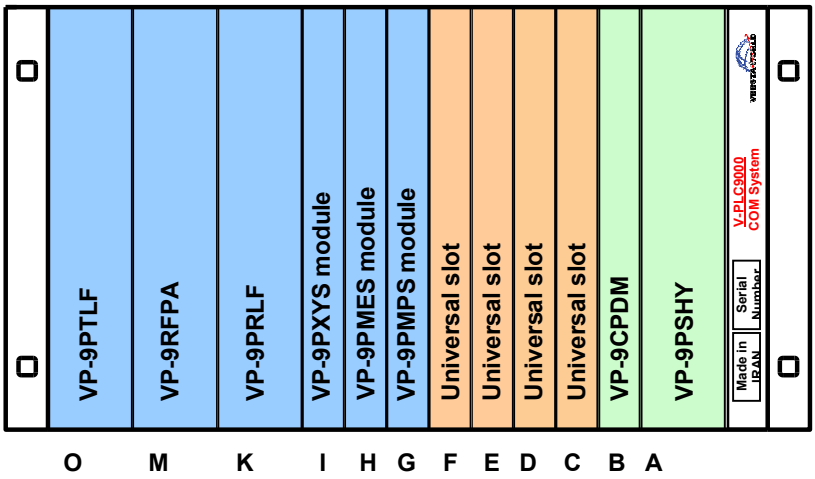

Figure 2-3: Channel modules VP-9PXYS of VP-9UPT PLC terminal; example

Base of the channel module is **VP-9PXYZ** module (Figure 2-4). This module is one of the basic building blocks of V-PLC9000 Communication system and is therefore present in majority of applications (VP-9UPT, VP-9ACT, VP-9PST-A, VP-9PST-D, etc.).

Always mounted on the VP-9PXYZ module is »baby board« module **VP-9DSP**. On VP-9DSP module a powerful DSP (Digital Signal Processor) is placed together with the appropriate periphery (such as memory blocks, interfaces, operation control unit (“watch-dog”)). VP-9DSP »baby board« module provides enough processing power for al necessary digital processing of signals. It also provide all necessary communication resources such as internal communications on the channel module, communicates with other modules of VP-9UPT PLC terminal and communications with system module VP-9CPDM (parametrising and diagnostic).

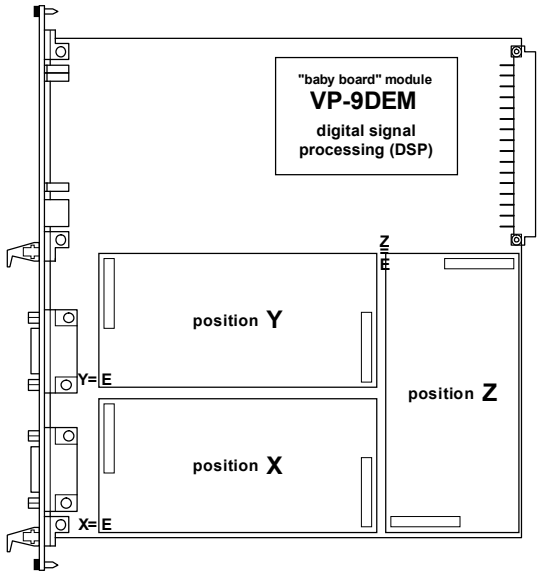

Figure 2-4: VP-9PXYS Module

At the lower part of the VP-9PXYZ module there are 3 positions intended for placing of »baby board« modules: site X (down), site Y (middle) and site Z (right). Within the communication system V-PLC9000 there are a number of functionally different »baby board« modules. Which modules are placed depends on desired functionality of appointed VP-9PXYZ module. So, different versions of VP-9PXYZ module are created and their version is defined in the following way:

Each »baby board« module is marked by three letters mark (VP-9SFC, VP-9MAI, VP-9PTI, VP-9DIA, VP-9DIO, VP-9DIU, etc.). Letters X, Y and Z of the VP-9PXYZ module type mark are replaced with the letter mark of the »baby board« modules that are built on appropriate positions. If position is empty (no »baby board« module is placed) the letter is replaced with mark E (Empty).

Each channel of VP-9UPT universal PLC terminal contains one VP-9PXYZ module. On position Z there »baby board« module VP-9SFC is always placed (Z=S); Figure 2-5.

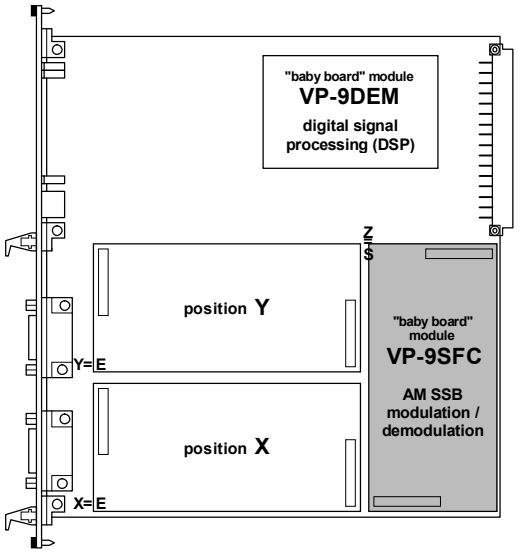

Figure 2-5: VP-9PXYS Channel Module

Structure of each channel module VP-9PXYS depends on: type of channel (analogue or digital channel), version of analogue channel (standard aPLC channel or or speech-plus aPLC channel), and number and type of digital channel interfaces of dPLC channel.

Version of channel module VP-9PXYS of aPLC channel depends on aPLC channel version. aPLC channel may be of standard or speech–plus version. Interface »baby board« module **VP-9MAI** is always placed on position X (it contains triple 4-w AF interface); Figure 2-6. In case of standard aPLC channel position Y is always empty (Y=E) and in case of speech-plus version of aPLC channel interface »baby board« module VP-9PTI (universal telephony interface) is placed on position Y (Y=P); Figure 2-7 :

aPLC CHANNEL VERSION	**VP-9PXYZ MODULE VERSION**
standard	VP-9PMES
speech-plus	VP-9PMPS

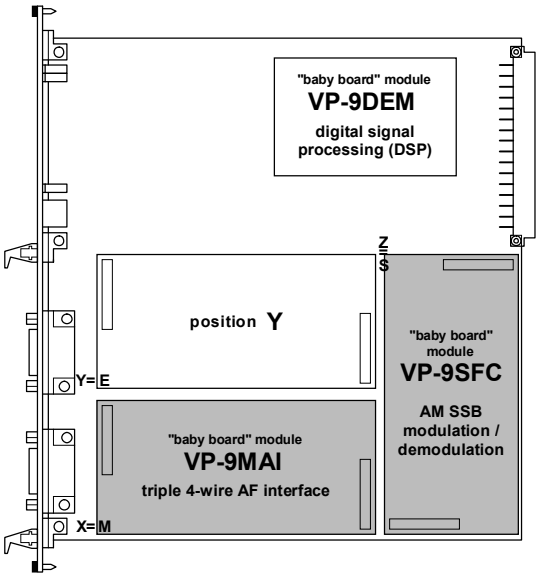

Figure 2-6: VP-9PXYS - VP-9PMES version

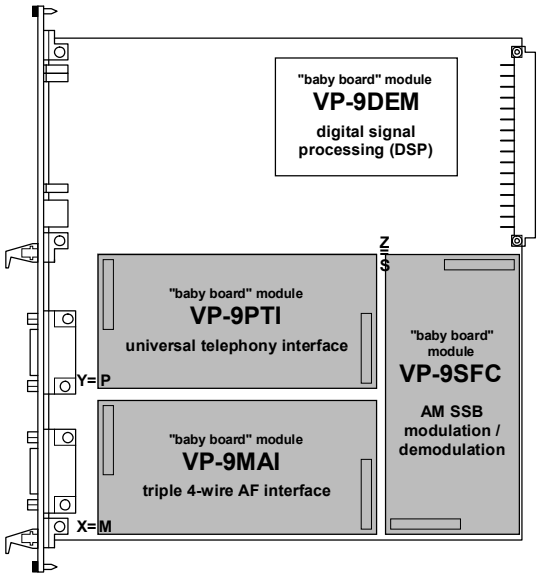

Figure 2-7: VP-9PXYS - VP-9PMPS version

On the VP-9PXYS channel module of dPLC channel position X always contains digital channel interface »baby board« module of appropriate type; Figure 2-8.

In certain applications two digital channel interfaces are required, one on position X and another on position Y; Figure 2-9.

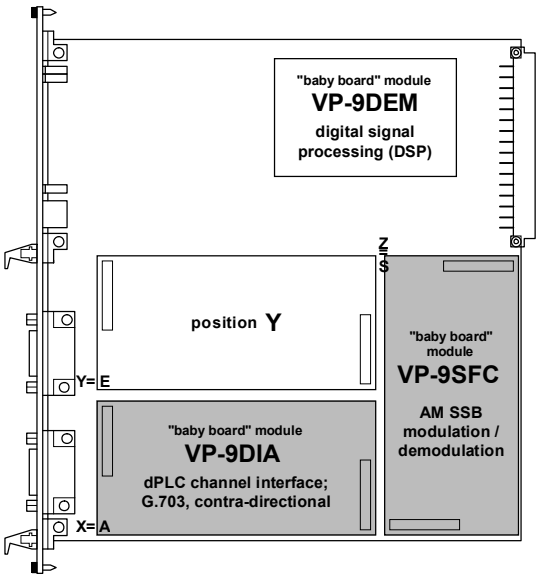

Figure 2-8: VP-9PXYS - VP-9PAES version

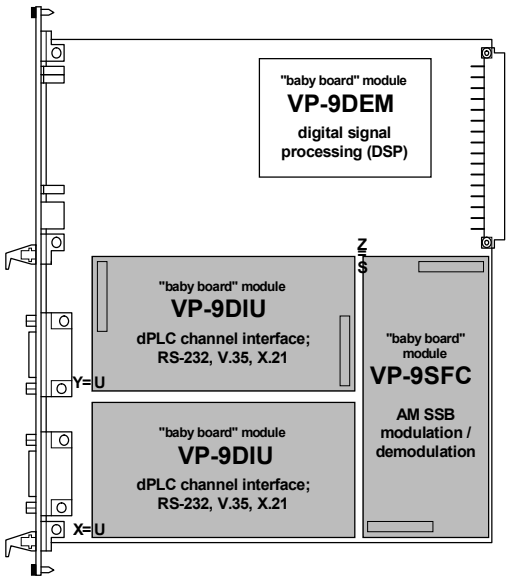

Figure 2-9: VP-9PXYS - VP-9PUUS version

Three (3) different types of digital channel interface »baby board« module are available:

MODULE TYPE	INTERFACE (STANDARD)
VP-9DIU	universal; V.24/V.28 (RS 232), V.35, X.21
VP-9DIA	G.703 contra-directional
VP-9DIO	G.703 co-directional

Version of VP-9PXYZ channel module of dPLC channel (X and Y part of version mark) depends on number (one or two) and type of built in digital channel interfaces (interface »baby board« modules).

If two digital channel interfaces are installed on VP-9PXYZ channel module of dPLC channel then both digital channel interfaces should be of VP-9DIU type; see Figure 2-9.

Example; Figure 2-6: On the module VP-9PXYZ designated for the standard version of analogue PLC channel of VP-UPT universal PLC terminal following »baby board« modules are inserted: on position X there is interface »baby board« module VP-9**M**AI (X = **M**), on position Y there is no »baby board« module (Y = **E**) and on position Z »baby

board« module VP-9**S**FC is inserted (Z = **S**). The marking for such version of VP-9PXYZ module is therefore **VP-9PMES**.

Example; Figure 2-9: On VP-9PXYZ module, designated for dPLC channel of VP-9UPT Universal PLC Terminal, with two digital channel interfaces both installed »baby board« modules are of VP-9DIU type. One VP-9DI**U** »baby board« module is installed on position X (X=**U**) while another one VP-9DI**U** »baby board« module is installed on position Y (Y=**U**). In addition VP-9**S**FC »baby board« module is installed on position Z (Z=**S**). Consequently version mark of such VP-PXYZ module is **VP-9PUUS**.

2.3 Front Panels of Modules

Connectors intended for the connection of the terminal to the application environment, diagnostic elements such as green, yellow and red LED's, switch and main fuse of the terminal are situated at the front panels of the modules. Front panels are shown on Figure 2-10.

2.3.1 Elements on VP-9CPDM module front panel

1. **ALARM OUT:** 26-pole female D-SUB connector; outputs (change-over contacts) of eight (8) alarm relays
2. **ACCESS; LOCAL:** shielded 8-pole RJ45 socket; local access to the terminal by means of PC (RS 232 serial data interface - DCE; parametrising & diagnostic)
3. **ACCESS; REMOTE:** shielded 8-pole RJ45 socket; local access to the terminal by means of PC (RS 232 serial data interface - DCE; parametrising & diagnostic)
4. **RESET:** hole; access to reset button of VP-9CPDM module and complete terminal
5. **ALARM; MAJOR:** red LED; indication of active status of any major alarm
6. **ALARM; MINOR:** yellow LED; indication of active status of any minor alarm
7. **READY:** green LED; indication of consistent operation of VP-9CPDM module
8. **FAIL:** red LED; indication of VP-9CPDM module malfunction
9. **VP-9CPDM:** handle with module type mark

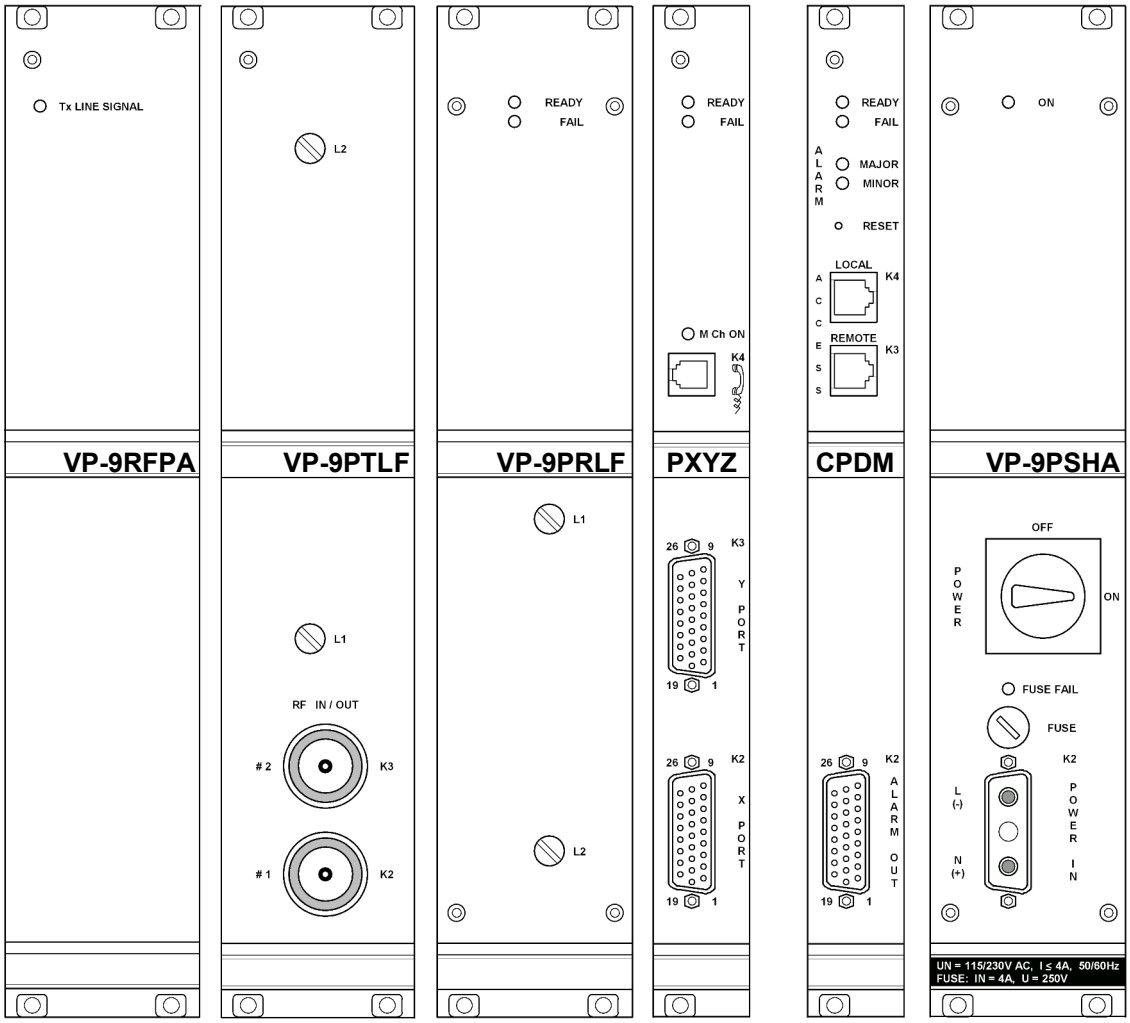

Figure 2-10: Front Panels of Modules

2.3.2 Elements on VP-9PSHY module front panel

1. **POWER IN; L (-), N (+):** 2-pole male D-SUB power connector; terminal power supply connection
2. **FUSE:** housing of terminal main fuse
3. **FUSE FAIL:** yellow LED; indication of main fuse fail
4. **POWER; ON, OFF:** main switch; terminal ON/OFF
5. **ON:** green LED; indication of switch on and properly operation of power supply module
6. **VP-9PSHY:** handle with type mark of power supply module; character Y is replaced with the appropriate character marking the type of the power supply module (see Chapter 2.1)

2.3.3 Elements on VP-9PTLF module front panel

1. **RF IN/OUT; #1, #2:** two paralleled coaxial connectors; connection of PLC terminal to coupling equipment and/or connection of parallel PLC terminal(s)
2. **L1:** hole; access to adjusting axle of inductivity L1 of programmable transmit line filter
3. **L2:** hole; access to adjusting axle of inductivity L2 of programmable transmit line filter
4. **VP-9PTLF:** handle with module type mark

2.3.4 Elements on VP-9RFPA module front panel

1. **Tx LINE SIGNAL:** green LED; indication of presence of transmit (Tx) signal on the output of VP-9RFPA module
2. **VP-9RFPA:** handle with module type mark

2.3.5 Elements on VP-9PRLF module front panel

1. **L1:** hole; access to adjusting axle of inductivity L1 of programmable receive line filter
2. **L2:** hole; access to adjusting axle of inductivity L2 of programmable receive line filter
3. **READY:** green LED; indication of VP-9PRLF module consistent operation
4. **FAIL:** red LED; indication of VP-9PRLF module malfunction
5. **VP-9PRLF:** handle with module type mark

2.3.6 Elements on VP-9PXYZ module front panel

1. **X PORT:** 26-pole female D-SUB connector; connections of interface »baby board« module placed on position X
2. **Y PORT:** 26-pole female D-SUB connector; connections of interface »baby board« module placed on position Y
3. **K4:** shielded 6-pole RJ11 socket; maintenance speech channel handset connector
4. **M Ch ON:** yellow LED; indication of maintenance speech channel signalling and activity
5. **READY:** green LED; indication of consistent operation of VP-9PXYZ module
5. **FAIL:** red LED; indication of VP-9PXYZ module malfunction
5. **VP-9PXYZ:** handle with module type mark

2.4 Connection (input/output terminals)

One of the design features of V-PLC9000 Communication system is that all the connections are situated at the front panel of the housing. Connectors are located at the front panels of the modules. In such way there is no need for extra space in the housing designated for the terminal blocks.

Installation of the VP-9UPT universal PLC terminal requires the following connections to be made:

- Earthing of the terminal housing
- Connection of power supply module(s) to the power supply source(s)
- Connection of alarm relay outputs
- Connection of PLC terminal to coupling equipment
- Connection of channel modules interfaces user terminals (INPUTS/OUTPUTS) to main distribution frame (MDF) or to user terminal equipment directly (Telephone, PABX, Modem, Fax, AMUX, RTU, etc.)

All necessary connectors for installation onto connecting cables are enclosed to the modules.

Detailed description of installation procedure is described in document »V-PLC9000 Universal PLC terminal: Installation«.

2.4.1 Power supply connection and earthing

Connection of the PLC terminal to the power supply source is realized through 2-pole male D-SUB power connector »POWER IN« at the power supply front panel. Connection must be always realized by means of two wires.

Pin L (-) is intended for the connection of the phase conductor or negative (-) battery pole. Pin N (+) is intended for the connection of the neutral conductor or positive (+) battery pole.

In case of redundant power supply both power supply modules must be connected to the power source(s).

Well earthing of PLC terminal housing is very important for the safe use of the equipment and its proper operation (EMC). For that purpose terminal in the form of screw with the cable crimp terminal (cable lug) is situated at the PLC terminal housing. Terminal enables earthing of the PLC terminal housing with the earthing cord of 16 mm2 cross-section. It is situated at the housing side panel (far right down corner) and is marked with standard yellow earthing mark.

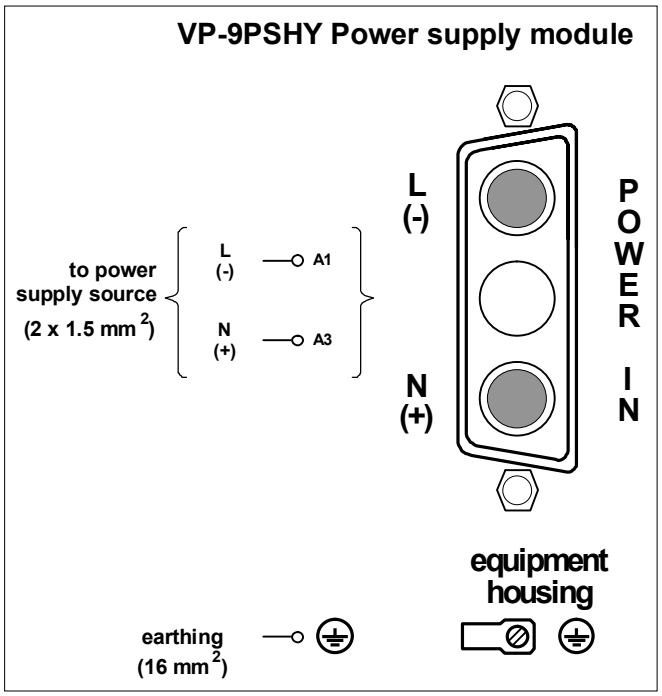

Figure 2-11: Power Supply and earthing

2.4.2 Alarm outputs

There are eight (8) alarm relays built onto VP-9CPDM system module. Alarm relay #1 activates whenever any major (important) alarm is activated. Alarm relay #2 activates whenever any minor (less important) alarm is activated.

The use of the rest six alarm relays is determined in the PLC terminal parametrising phase.

Relay contacts are accessible at 26-pole D-SUB female connector »ALARM OUT« located on VP-9CPDM module front panel; one voltage free switch-over contact of each relay.

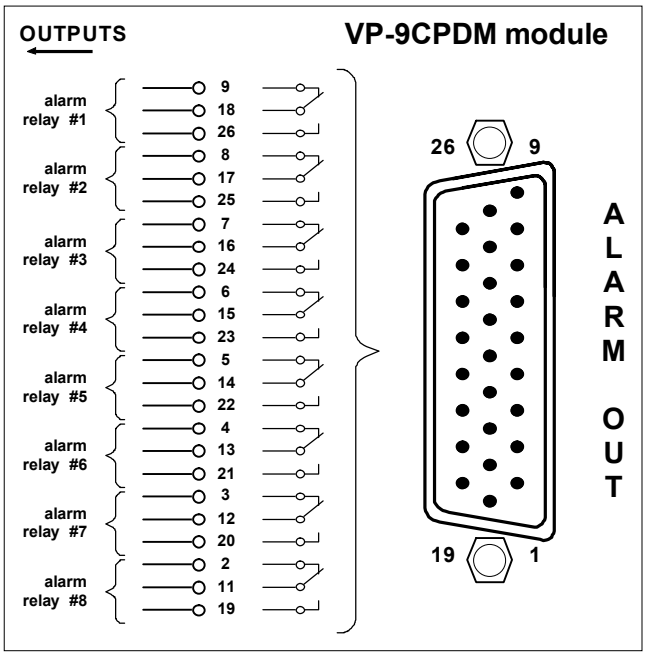

Figure 2-12: Alarm Outputs

2.4.3 RF line port (input/output)

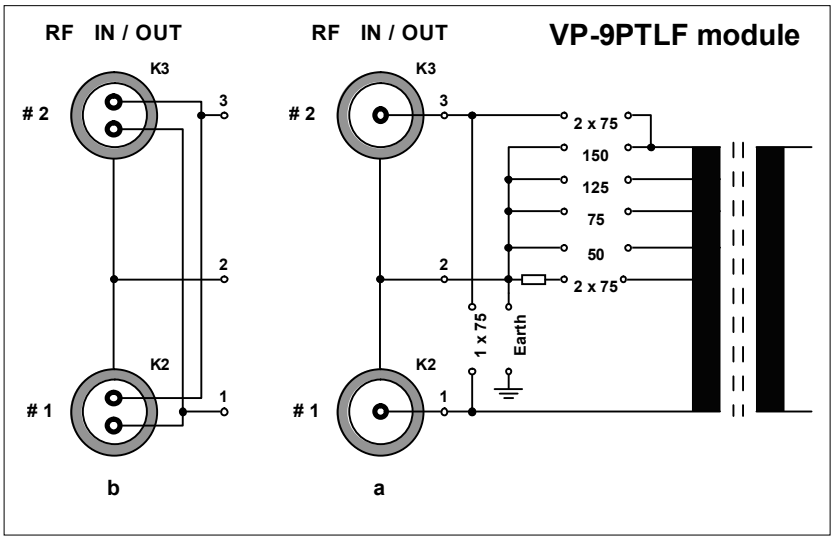

Figure 2-13: RF Line Connection

RF line port »RF IN/OUT« is placed at the VP-9PTLF front panel and is intended for connection of PLC terminal to the coupling equipment. It consists out of two (2) coaxial (asymmetrical) connectors labelled with marks #1 and #2; Figure 2-13a. Based on the customer requirement it is also possible to build in two (2) symmetrical connectors; Figure 2-13b.

In case of asymmetrical connection one pole of the connection is always earthed. If one pole (coat) of the asymmetrical (coaxial) cable is earthed at both ends (at the PLC terminal and at the Coupling Device) problems with strong equalizing currents due to potential difference may arise. Therefore earthing must be completed at one side of the coaxial cable only. Optimal method is to implement earthing at the Coupling Device side. This is the reason why neither pole of the RF line terminal is permanently earthed inside of the PLC terminal. Earthing of one pole of asymmetric terminal is enabled with bridge »EARTH«; Figure 2-13. Same rules are implemented for earthing of the symmetrical cable protection shield.

Different connections of PLC terminals to coupling equipment are implemented in different applications worldwide. To support different methods of connection in the simplest way possible design of VP-9PTLF module is very universal. Possible connection modes of PLC terminal to coupling equipment are shown on Figure 2-14.

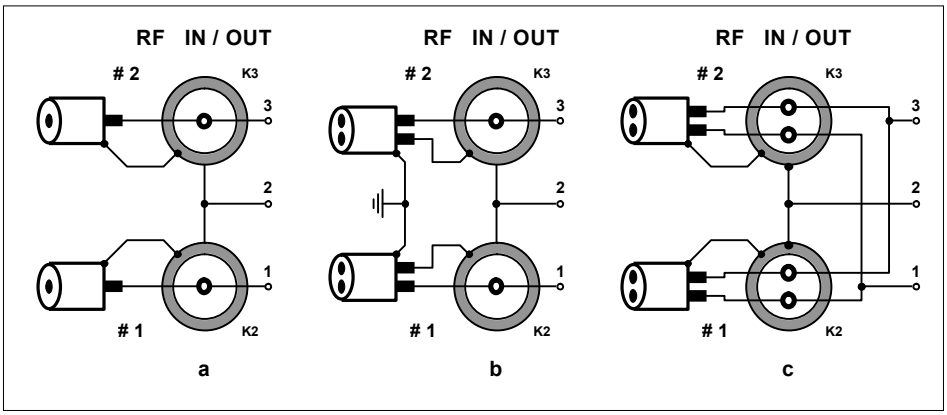

Figure 2-14: Possible connection modes of PLC terminal to coupling equipment

Configuration on Figure 2-14a enables two different connection modes:

- **a1**: asymmetrical connection with possibility of RF line terminal impedance setting (50, 75, 125 or 150 Ohms)
- **a2**: double asymmetrical differential-phase connection with RF line impedance of 75 Ohms

Mode a1 enables asymmetrical connection of PLC terminal to coupling equipment. In this case two coaxial connectors #1 and #2 are connected in parallel. Consequently, simple connection of more paralleled PLC terminals to one Coupling Device is enabled:

connector #1 is used for coupling to the Coupling Device and connector #2 for connecting of the parallel PLC terminal(s). Suitable HW settings on the PTLF module should be established; Figure 2-13. Strap »1 x 75« should be inserted and one of the straps for chosen impedance of RF line terminal should be inserted; »50«, »75«, »125« or »150«.

Mode a2 enables »phase-to-phase« coupling with use of two identical Coupling Devices which are intended for »phase-to-ground« coupling. Line transformer on VP-9PTLF module serves as symmetrical matching transformer (SMU); Figure 2-13. In this mode connectors #1 and #2 are no longer connected in parallel. Impedance of RF line terminal in this mode is not adjustable and is always 75 Ohm (2 x 75 Ohms respectively). Weakness of such connection is quantity of used coaxial cable (two coaxial cables from PLC terminal to the Coupling Devices). At VP-9PTLF module both straps »2 x 75« should be inserted; Figure 2-13.

Configuration on Figure 2-14b is showing symmetrical connection with the use of asymmetrical connectors #1 and #2. With regard to line signal frequency (< 1MHz) this kind of symmetrical connection is acceptable. Configuration is similar to the mode a1 with the difference that none of the connector poles #1 and #2 is ever earthed. At VP-9PTLF module strap »1 x 75« should be inserted as well as one of the straps for RF line terminal impedance setting; »50«, »75«, »125« or »150«.

Configuration on Figure 2-14c is similar to the configuration at Figure 2-14b with the difference of two symmetrical connectors built in instead of asymmetrical (coaxial) connectors. Such arrangement is possible with the prior agreement with the customer only.

2.4.4 User I/O terminals

Following the description of the channel module VP-9PXYS in chapter 2.2 of this document its important characteristic is universality. On positions X and Y several »baby board« modules of different type may be inserted. All »baby board« modules are interface modules meaning that different user terminal equipment should be connected to it. To facilitate that two (2) shielded 26-pole D-SUB female connectors are available at front panel of VP-9PXYS channel module. Connector marked »X PORT« belongs to interface »baby board« module on position X while connector »Y PORT« belongs to interface »baby board« module on position Y. Pin arrangement depends on the »baby board« module type.

2.4.5 VP-9MAI interface module

VP-9MAI interface »baby board« module is always placed onto VP-9PXYS channel module of aPLC channel on position X. Its user terminals are therefore accessible at »X PORT« connector at front panel of PMYS channel module; Figure 2-15.

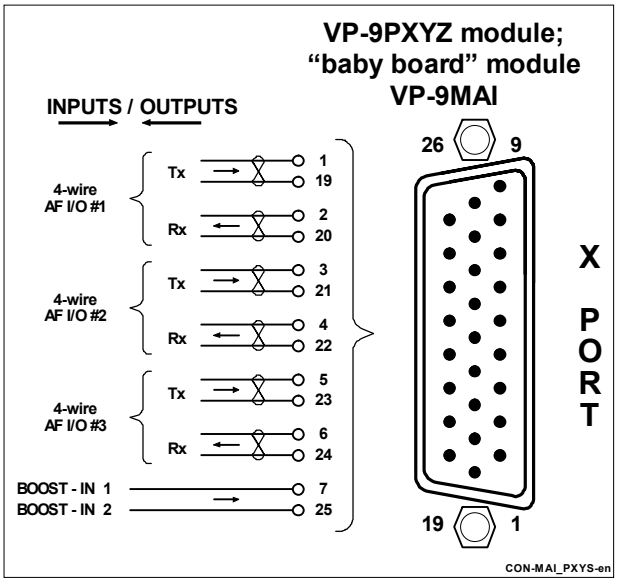

Figure 2-15: VP-9MAI interface module pin-out

Three (3) galvanic separated (transformers) 4-wire AF I/O ports are available at VP-9MAI »baby board« module. They are intended for »wide band« access to aPLC channel in AF band. All three ports have similar characteristics. Additional functions may be activated on ports #1 and #2.

Port #1 offers possibility of activating programmable transit filter separately for transmit and receive path.

Port #2 offers possibility to connect external TeleProtection Signalling terminal (TPS terminal) if required.

Galvanic separated control input BOOST is intended for connection of BOOST control signal generated by external TPS terminal connected to port #2.

2.4.6 VP-9PTI interface module

VP-9PTI interface »baby board« module is universal (programmable) telephony interface of aPLC channel. It is always inserted on position Y of PXYS channel module for »speech-plus« version of aPLC channel. Its user terminals are therefore accessible at »Y PORT« connector situated on front panel of VP-9PXYS channel module; Figure 2-16.

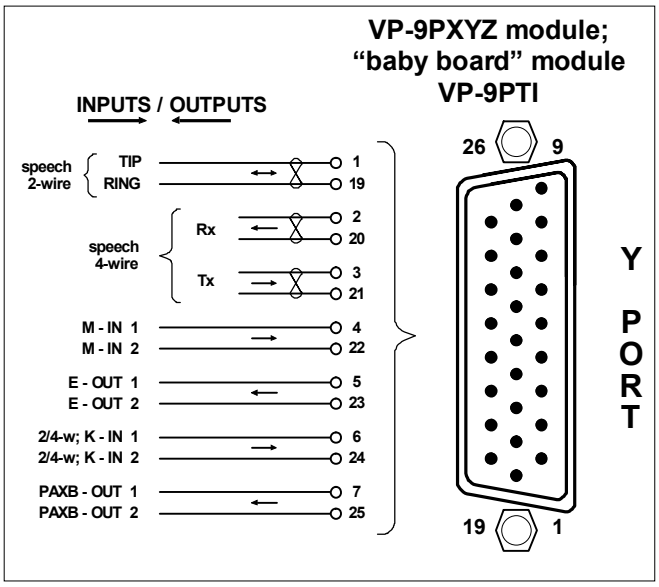

Figure 2-16: VP-9PTI interface module pin-out

VP-9PTI module incorporates 2-wire speech port, 4-wire speech port, signalling input M, signalling output E, control input »2/4–w; K« and control output PAXB. All ports are galvanic separated.

Control output »2/4–w; K« has two different functionalities. Which is in use depends on telephony interface operating mode. When telephony interface is operating in 2-w; E&M mode or in 4-w; E&M mode (TRUNK interconnection between telephone exchanges), it serves to switch between 2-wire and 4-wire speech port. When on the other hand telephony interface operates in FXO mode (subscriber - PAX side) control output »2/4–w; K« serves to switch on/off the compander.

Control output PAXB is intended for blocking of the telephone exchange interface in case of aPLC channel failure.

2.4.6.1 Design of control Inputs/Outputs

All control inputs/outputs (including BOOST control input at »baby board« module MAI) are galvanic separated; Figure 2-17.

Every control input may be activated with voltage free relay contact. Other possible way is to ground pin IN 2. In that case pin IN 1 must be permanently grounded.

Although control outputs are designed by means of semiconductor technology their electrical characteristics are identical to electrical characteristics of voltage free relay contact. Polarity of voltage source connected to control output is not important.

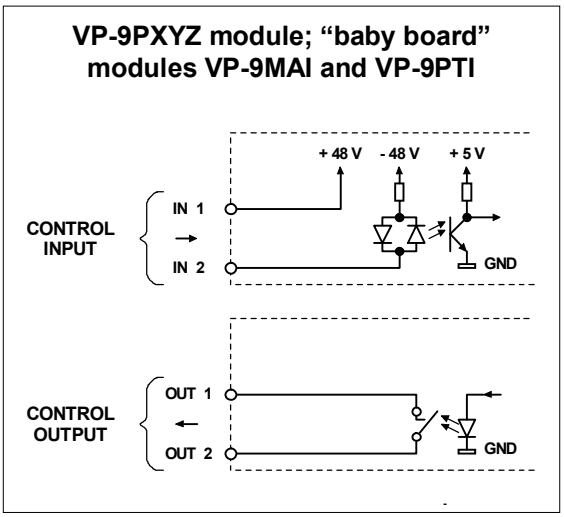

Figure 2-17: Design of control Inputs and Outputs

2.4.7 VP-9DIO interface module

VP-9DIO interface »baby board« module is communication interface of dPLC channel. It corresponds to ITU-T standard G.703; co-directional interface. This module may be placed onto channel module VP-9PXYS of dPLC channel on position X or Y. Its user terminals are accessible at »X PORT« connector if it is inserted on position X or »Y PORT« connector if it is inserted on position Y; Figure 2-18.

Connection is realised via two twisted pairs: one for composite transmit signal Tx and one for composite receive signal Rx.

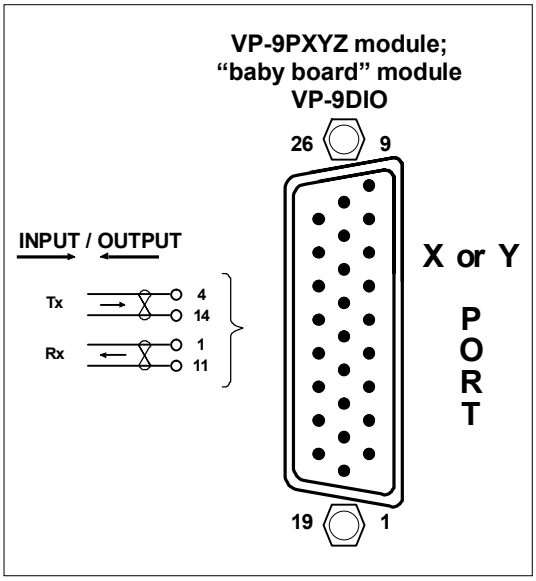

Figure 2-18: VP-9DIO interface module pin-out

2.4.8 VP-9DIA interface module

VP-9DIA interface »baby board« module is communication interface of dPLC channel. It corresponds to ITU-T standard G.703; contra-directional interface. This module may be placed onto channel module VP-9PXYS of dPLC channel on position X or Y. Its user terminals are accessible at »X PORT« connector if it is inserted on position X or »Y PORT« connector if it is inserted on position Y; Figure 2-19.

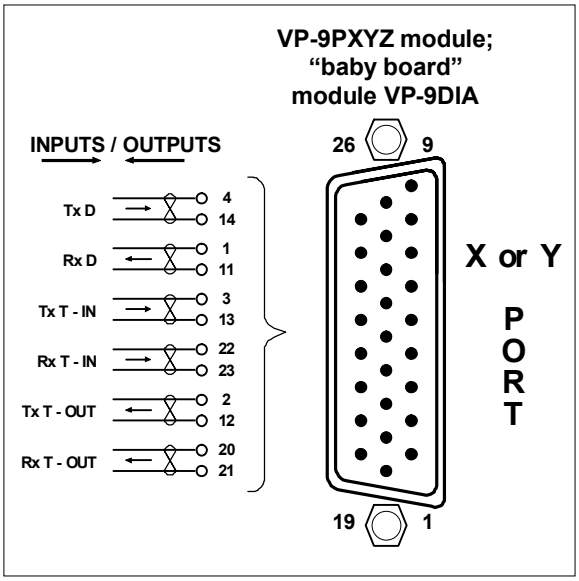

Figure 2-19: VP-9DIA interface module pin-out

Connection is realised via 4 twisted pairs: first for transmit information signal Tx D, second for receive information signal Rx D, third for transmit timing signal Tx T and fourth for receive timing signal Rx T.

Contra-directional communication interface G.703 is generally used to interconnect telecommunication devices. In such configuration one of the devices is of higher hierarchical level (controlling device) and other of lower hierarchical level (subordinate device). Transmit and receive timing signal is always generated by the device of higher hierarchical level.

Design of the VP-9DIA interface »baby board« module enables that the dPLC channel of VP-9UPT universal PLC terminal plays the role of hierarchically higher or lower level device (setting). Transmit and receive timing signal can be interface input signals (dPLC channel is subordinate device) or output signals (dPLC is controlling device). When dPLC has status of subordinate device transmit timing signal is connected to interface input »Tx T – IN« and receive timing signal to »Rx T – IN«. If dPLC channel has a controlling device status VP-9DIA interface »baby board« module generates transmit timing signal at interface output »Tx T – OUT« and receive timing signal at interface output »Rx T – OUT«.

2.4.9 VP-9DIU interface module

VP-9DIU interface »baby board« module is universal data interface of dPLC channel. This module is placed onto channel module VP-9PXYS of dPLC channel on position X or Y. Its user terminals are accessible at »X PORT« connector if it is inserted on position X or »Y PORT« connector if it is inserted on position Y; Figure 2-20.

VP-9DIU interface »baby board« module is universal data interface. It is called universal because it supports three (3) different interface standards. It may operate in accordance with ITU-T standards V.24/V.28 (RS-232), V.35 or X.21. Operating mode is determined at the terminal parametrising phase (setting).

Figure 2-20 shows complete set of VP-9DIU interface module terminals (inputs and outputs).

ITU-T standards V.24/V.28 (RS-232), V.35 and X.21 are different in terms of interface signals set and electrical characteristics of them. Figure 2-21, Figure 2-22 and Figure 2-23 are showing pin-out of VP-9DIU interface module for different operating modes; V.24/V.28 (RS-232), V.35 and X.21.

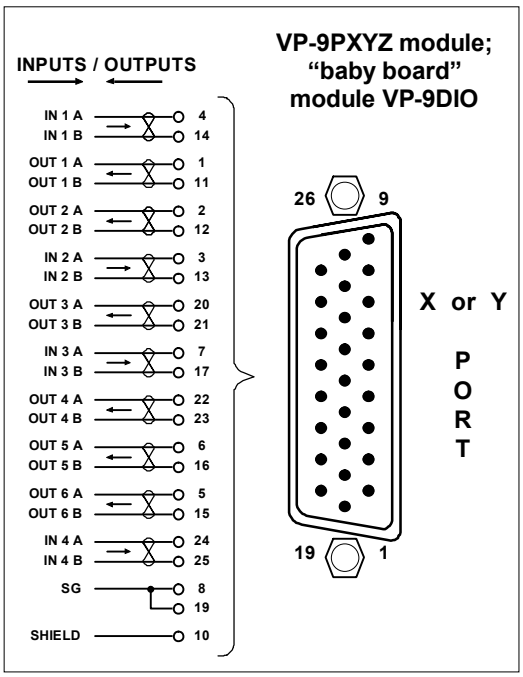

Figure 2-20: VP-9DIU interface module pin-out general

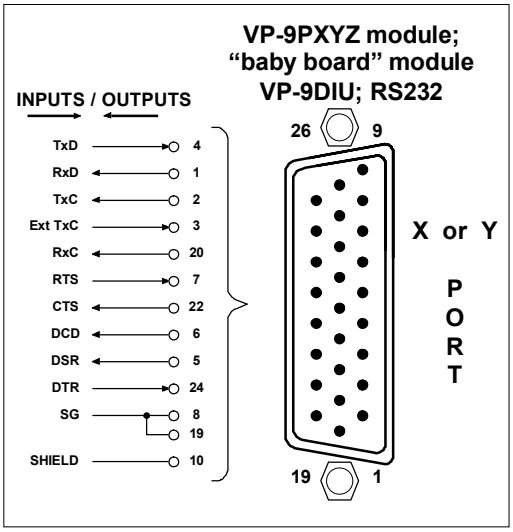

Figure 2-21: VP-9DIU interface module pin-out; V.24/V.28 (RS-232)

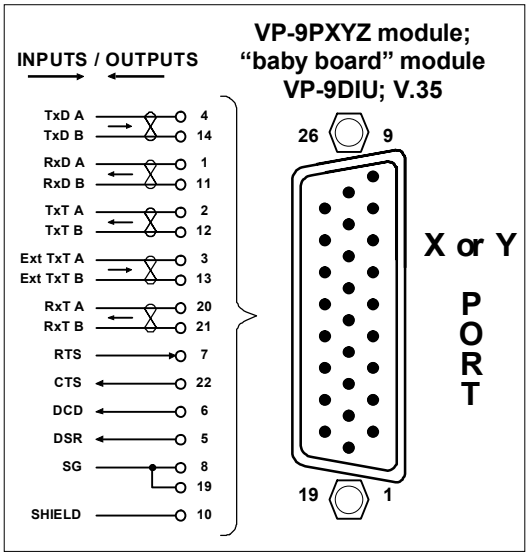

Figure 2-22: VP-9DIU interface module pin-out; V.35

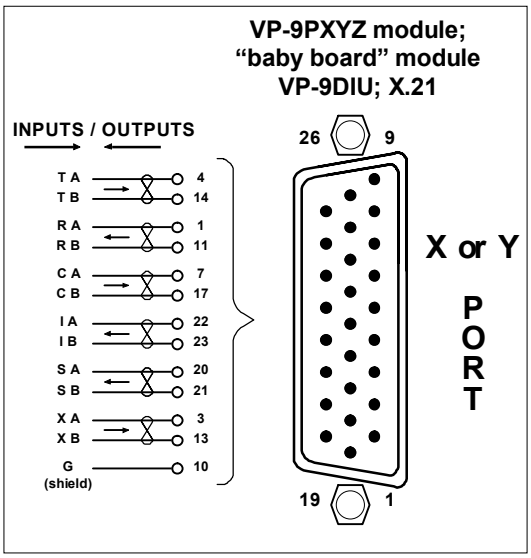

Figure 2-23: VP-9DIU interface module pin-out; X.21

2.5 Installation

VP-9UPT universal PLC terminal is built into standard 19-inch housing of (EMC version) of 6U height (266mm) and of 295mm depth (including front side located connectors). Dimensions of the PLC terminal housing are always the same regardless of PLC terminal transmit peak envelope power PEP and number/type of channels. PLC terminal is suitable for mounting on standard 19-inch self-standing frame or into cabinet with built in 19-inch swing frame. Switch-on and usage of PLC terminal is permitted only when properly installed on standard 19-inch self-standing frame or into cabinet with built in 19-inch swing frame. Correct installation is shown on Figure 2-24.

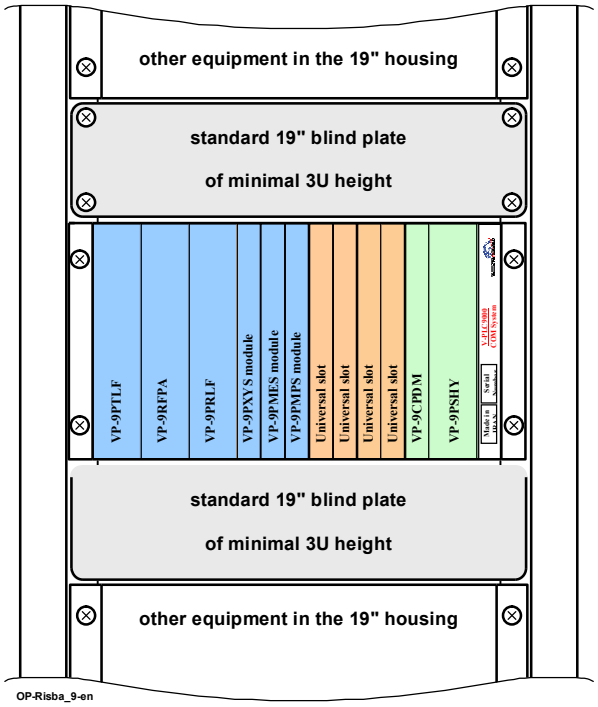

Figure 2-24: Correct installation on the 19-inch self-standing frame or into cabinet

Many devices in standard 19” housing could be installed on one standard 19-inch self-standing frame or in one cabinet with built in 19-inch swing frame. For each PLC terminal free space of minimum 3U (133mm) height should be assured above and below of PLC terminal (see Figure 2-24). Each free space should be covered by standard 19-inch blind plate.

Detailed description of VP-9UPT PLC terminal installation procedure is available in document »V-PLC9000 Universal PLC terminal: Installation«.

Chapter 3 - OPERATION

For understanding of this chapter it is essential to read Chapter 2 - V-PLC9000 Terminal Structure Helpful for understanding of the operation principles is Principal block diagram of VP-9UPT Universal PLC terminal; Figure 3-1.

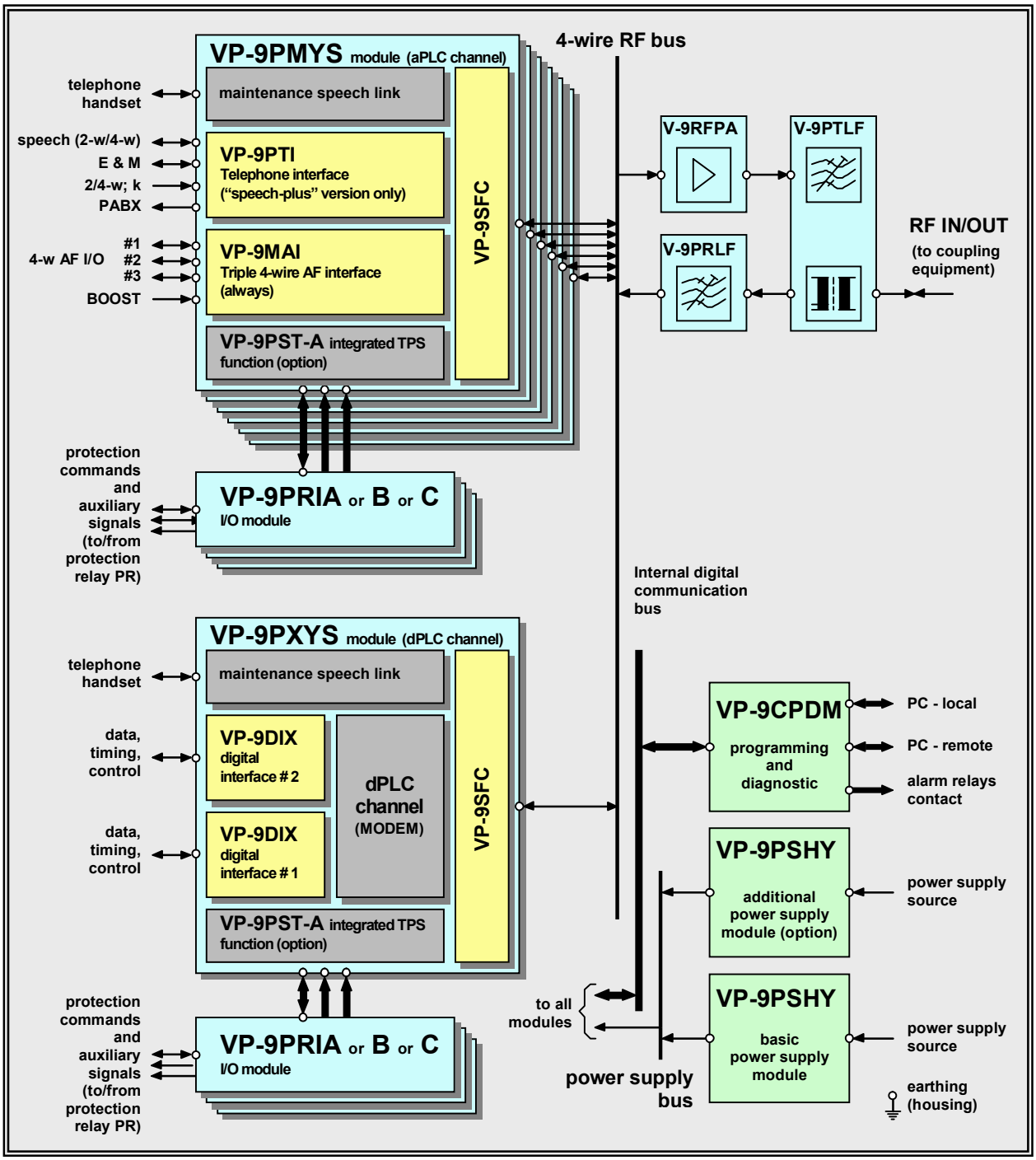

Figure 3-1: VP-9UPT Universal PLC Terminal principal block diagram

3.1 Channel part

Two of main characteristics of the VP-9UPT universal PLC terminal are ***universality*** and ***modularity***. Production of PLC terminals with different number and type of PLC channels is enabled in a simple way: one (1) to six (6) analogue (aPLC) channels and/or one (1) digital (dPLC) channel. The only limitation is overall bandwidth of all channels for one direction of transmission: ***BW (Tx)*** bandwidth of transmitted channels and ***BW (Rx)*** bandwidth of received channels; Figure 3-2:

adjacent Tx/Rx channels: BW (Tx) = BW (Rx) ≤ 12kHz;
BW (Tx + Rx) ≤ 24kHz

non-adjacent Tx/Rx channels: BW (Tx) = BW (Rx) ≤ 24kHz

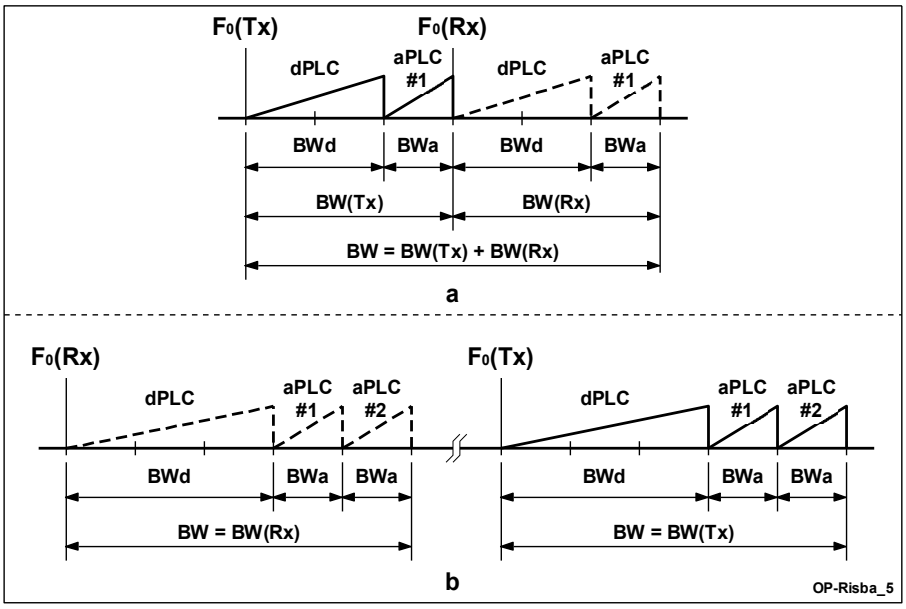

Figure 3-2: RF plan of VP-9UPT universal PLC terminal

Bandwidth of aPLC channel for one direction of transmission BWa is always the same and totals 4 kHz. Bandwidth of dPLC channel for one direction of transmission BWd is one of the most essential parameters of dPLC channel and has strong influence to the »Cd/SNR« characteristics of dPLC channel (where Cd is transmission capacity of dPLC channel). BWd may total 4 kHz, 8 kHz, 12 kHz or 16 kHz. Overall bandwidth of all channels for one direction of transmission equals to:

BW (Tx) = BW (Rx) = (Na x 4 kHz) + BWd; ***Na*** = number of aPLC channels
BWd = 4, 8, 12 or 16 kHz

Example; Figure 3-2a: RF plan of adjacent Tx/Rx channels is shown on Figure 3-2a. It is two (2) channel PLC link: one (1) digital (dPLC) channel (BWd = 8 kHz) and one (1) analogue (aPLC) channel. BW (Tx) and BW (Rx) equal 12kHz while BW (Tx + Rx) consequently equals to 24 kHz.

Example; Figure 3-2b: RF plan of non-adjacent Tx/Rx channels is shown on Figure 3-2b. It is three (3) channel PLC link: one digital (dPLC) channel (BWd = 12 kHz) and two (2) analogue (aPLC) channels. BW (Tx) and BW (Rx) equal to 20 kHz.

Polarisation of channels for both directions of transmission ***is always normal***.

One VP-9PXYS channel module is built into VP-9UPT universal PLC terminal for each channel. One (on position X) or two (on positions X and Y) interface »baby board« modules are placed onto the channel module enabling connection of channel users such as telephone, PABX, modem, RTU, etc. Type of built in interface »baby board« modules depends on type and version of PLC channel. All necessary digital signal processing of Tx (transmit) and Rx (receive) signals within AF (Audio Frequency) band is performed at channel module.

Each channel module performs also AM SSB modulation (frequency up conversion) and demodulation (frequency down conversion). Modulation means translation of channel signals from AF band to the desired position in RF (Radio Frequency) band. Demodulation is opposite process. Modulation and demodulation process is performed on SFC »baby board« module placed on position Z. Modulation / demodulation process is performed for each channel separately.

RF outputs of all channel modules are connected to Tx (transmit) pair of 4-wire RF bus. Transmit signals of all channels already properly allocated in the RF band and suitably polarised are summarized at the Tx pair of RF bus. Composite transmit signal which contains frequency multiplexed transmit signals of all channels in suitable polarisation represents input signal of RF power amplifier VP-9RFPA which input is connected to the Tx pair of 4-wire RF bus to.

Composite receive signal containing frequency multiplexed signals of all channels in suitable polarisation is led from output of VP-9PRLF programmable receive line filter to Rx (receive) pair of 4-wire RF bus. RF inputs of all channel modules are also connected to Rx pair of 4-wire RF bus.

3.1.1 PEP of the PLC terminal and PEP of the channel

Maximal PEP (Peak Envelope Power) of VP-9UPT PLC terminal is 80 W:

PEPmax = 80 W

PEPmax is achieved by one VP-9RFPA RF power amplifier module only. PEP of PLC terminal may be set to any of the following values: 10 W, 20 W, 40 W or 80 W. Regardless of chosen PEP value only one VP-9RFPA module is built into PLC terminal and is always of the same type. This feature enables simple adjustment of PEP value in case of circumstances on HV PL. This is also very helpful when number of channels is to be changed anytime in period of exploitation.

RF range of VP-9UPT PLC terminal is from 20 kHz to 1000 kHz. If it operates at higher frequencies its PEP is reduced as follows:

FREQUENCY BAND	PEPmax
from 20 kHz to 500 kHz	80 W
from 500 kHz to 750 kHz	40 W
from 750 kHz to 1000 kHz	20 W

PEP must be equally distributed to all PLC channels. Division is performed on the basis of bandwidth comparison. Bandwidth of all aPLC channels is always the same and equals 4 kHz, while bandwidth of dPLC channel may vary and equals to 4 kHz, 8 kHz, 12 kHz or 16 kHz e.g. is multiplier of 4 kHz bandwidth:

BWa = 4 kHz
BWd = Nd x 4 kHz; Nd =1, 2, 3 or 4

Part of the PEP of PLC terminal which correspond to 4 kHz bandwidth is:

$$PEP\ (4\ kHz) = PEP / (Na + Nd)^2;$$

Na = number of aPLC channels

Considering that the bandwidth of aPLC channel is always 4 kHz, channel PEP of each aPLC channel is same:

PEPa = PEP (4 kHz)

Channel PEP of dPLC channel depends on dPLC channel bandwidth:

$$PEPd = Nd^2 \times PEP\ (4\ kHz)$$

Example; Figure 3-2b: Na = 2, Nd = 3, PEP = 80 W

$$PEP\ (4kHz) = PEP / (Na + Nd)^2 = 80\ W / (2 + 3)^2 = 3.2\ W$$

PEPa (aPLC #1) = PEPa (aPLC #2) = 3.2 W

$$PEPd = Nd^2 \times PEP\ (4\ kHz) = 3^2 \times 3.2\ W = 28.8\ W$$

Because it is valid that:

BW (Tx) + BW (Rx) ≤ 24kHz (adjacent Tx / Rx channels)
BW (Tx) = BW (Rx) ≤ 24kHz (non adjacent Tx / Rx channels),

it is also valid that: (Na + Nd) = N (4 kHz) = 1, 2, 3, 4, 5 or 6

Values for PEP (4 kHz), which should serve as input data for planning of the PLC links, established using VP-9UPT PLC terminals, are stated in Table 3-1. Parameters are peak envelope power (PEP) of PLC terminal and number of 4 kHz bands N (4 kHz).

		PEP (W / dBm)			
		10 / 40	**20 / 43**	**40 / 46**	**80 / 49**
N (4kHz)	**1**	10 / 40,0	20 / 43,0	40 / 46,0	80 / 49,0
	2	2,50 / 34,0	5,00 / 37,0	10 / 40,0	20 / 43,0
	3	1,11 / 30,5	2,22 / 33,5	4,44 / 36,5	8,89 / 39,5
	4	/	1,25 / 31,0	2,50 / 34,0	5,00 / 37,0
	5	/	0,80 / 29,0	1,60 / 32,0	3,20 / 35,0
	6	/	/	1,11 / 30,5	2,22 / 33,5

Table 3-1: Values for PEP (4 kHz)

3.1.2 Analogue PLC channel (aPLC channel)

Analogue PLC channel is telecommunication resource in the form of usable AF band intended for transmission of base-band analogue signals. Whole aPLC channel may be allocated for the transmission of only one signal (leased line modem or transit of complete aPLC channel) or several narrow band modem signals (Telegraph (TG) channels). Such operation mode is called ***single-purpose use of aPLC channels***. aPLC channel may also be used for simultaneous transmission of band limited speech signal together with associated signalling in the lower part of the usable AF band and the »speech-plus« band is used for transmission of narrow band modem signals. Such operation mode is called ***multi-purpose use of aPLC channels***. aPLC channel which is enabling transmission of speech with associated signalling must have built in telephony interface.

Many applications require transmission of protection commands (TPS terminal). TPS terminal is permanently occupying only a fraction of usable AF band of aPLC channel to transmit so called »GUARD« signal. On the other hand, to transmit protection command(s) TPS terminal uses significant of usable AF band normally allocated for another purpose. Therefore, to transmit the protection command(s), TPS terminal temporarily (for less than 1s) cuts off the transmission of other signals normally transmitted within usable AF band. Every aPLC channel of VP-9UPT universal PLC terminal offers all functionality as described above.

3.1.3 Version of aPLC channel and channel module

One channel module is built into VP-9UPT PLC terminal for each aPLC channel.

There are two different types of VP-9PXYS channel module of aPLC channel. ***VP-9PMES*** type without programmable (universal) telephony interface VP-9PTI and ***VP-9PMPS*** type with built in programmable (universal) telephony interface VP-9PTI. We are talking about channel module of ***standard aPLC*** channel and channel module of ***speech-plus aPLC*** channel.

Channel module of ***standard aPLC*** channel does not enable transmission of speech (single purpose use of aPLC channel). In case of standard version of aPLC channel only triple 4-wire AF interface in the form of VP-9MAI »baby board« module is built onto VP-9PMES channel module. Programmable (universal) telephony interface in the form of VP-9PTI »baby board« module is not a part of VP-9PMES.

Channel module of ***speech-plus aPLC*** channel enables transmission of speech in addition (multi-purpose use of aPLC channel). For that purpose apart from VP-9MAI »baby board« module there is also built in VP-9PTI »baby board« module.

At VP-9PMPS version of channel module (speech-plus aPLC channel) also standard version of aPLC channel may run as application (speech and signalling channel should be switched off).

The difference between channel modules (VP-9PMPS for speech plus and VP-9PMES for standard aPLC channel) is price. In actual applications a lot of aPLC channels are used to transit complete aPLC channel or to transmit signal of standard voice grade leased line modem (together with the transmission of protection commands). In that case there is no need for speech transmission therefore telephony interface VP-9PTI is not necessary. Consequently it is sensible to use cheaper VP-9PMES channel module (without programmable universal telephony interface VP-9PTI).

3.1.3.1 aPLC channel utilization

Usable AF band of aPLC channel is from 300 Hz to 3720 Hz. Possible utilization modes of usable AF band are shown on Figure 3-3.

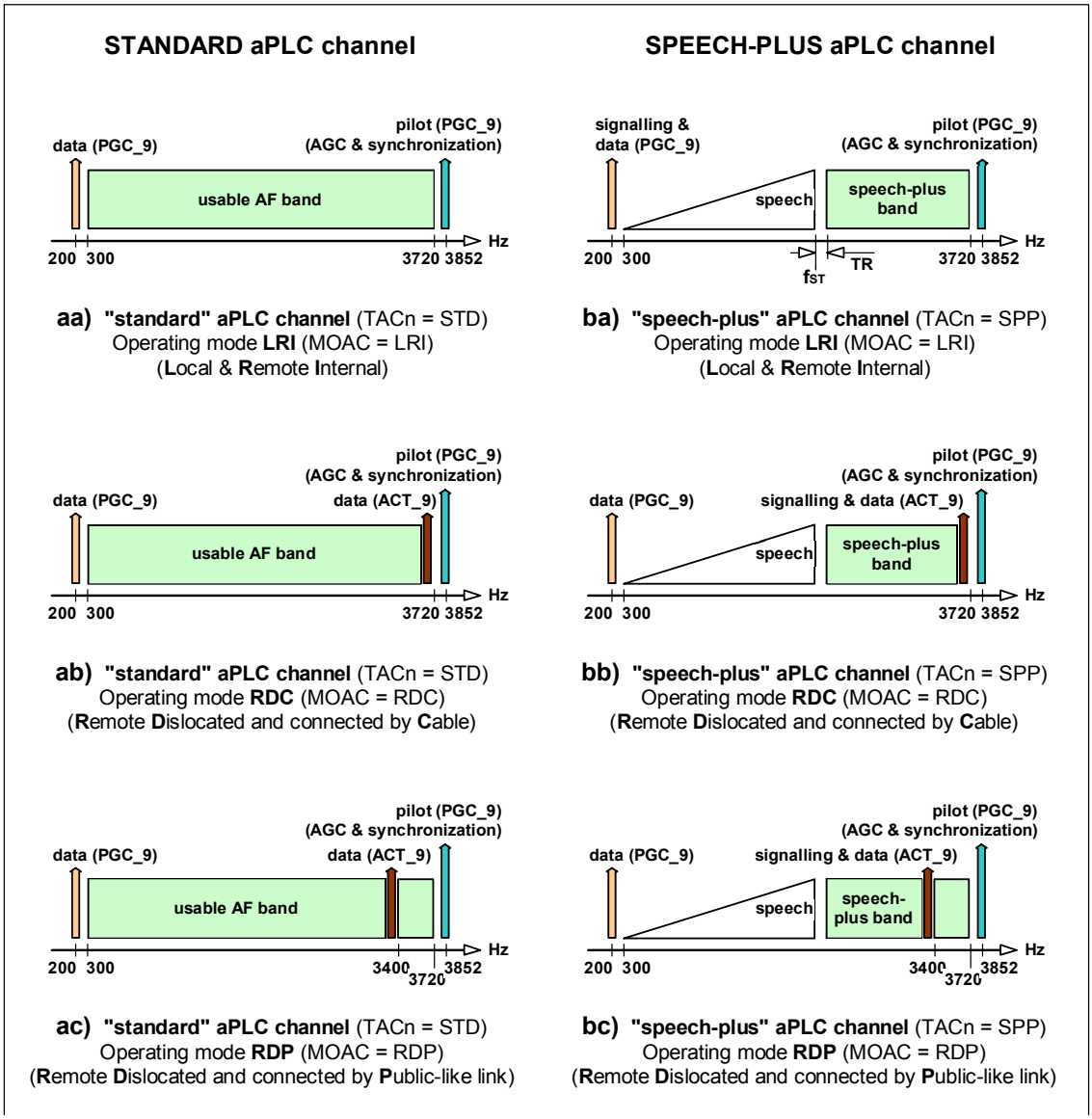

Figure 3-3: aPLC channel usable AF band utilization modes

Left side of Figure 3-3 shows three (3) possible utilization modes of ***standard*** aPLC channel and on the right side there are three (3) utilization modes of ***speech-plus*** aPLC channel.

Upper frequency limit of speech channel f_{ST} can be set to 2.0 kHz (speech channel version 2K0), 2.2 kHz (speech channel version 2K2), 2.4 kHz (speech channel version 2K4) or 3.4 kHz (speech channel version 3K4). Between speech channel and speech-plus band TR transition band exists which is useless. TR is declared as frequency band between upper frequency limit of speech channel (f_{ST}) and frequency where speech filter reaches attenuation of > 60 dB. Width of TR band depends on f_{ST}. If f_{ST} equals 2.0 kHz (2.2 kHz, 2.4 kHz, 3.4 kHz) then width of TR band equals 70 Hz (80 Hz, 90 Hz, 100 Hz).

Frequency band »speech-plus« is used for transmission of narrow band modems signals (TG channels) and/or transmission of TPS terminal signals.

At the frequency 200 Hz there is always located a data channel with the transmission capacity of 100 bps (bits-per-second). It is intended for transmission of diagnostics data between two VP-9UPT PLC terminals which form PLC link and transmission of signalling in case of »speech-plus« version of aPLC channel.

At the frequency 3852 Hz there is always located pilot channel (signal) of aPLC channel. Bandwidth of pilot channel equals to the bandwidth of 50 Baud TG channel. Pilot signal transmitted in the pilot channel is used for Automatic Gain Control (AGC) and for synchronisation of basic oscillators. Both processes are carried out in the receiver of the aPLC channel module. AGC and synchronisation are performed separately for each aPLC channel. For synchronisation the »***master-slave***« principle is implemented; Figure 3-4.

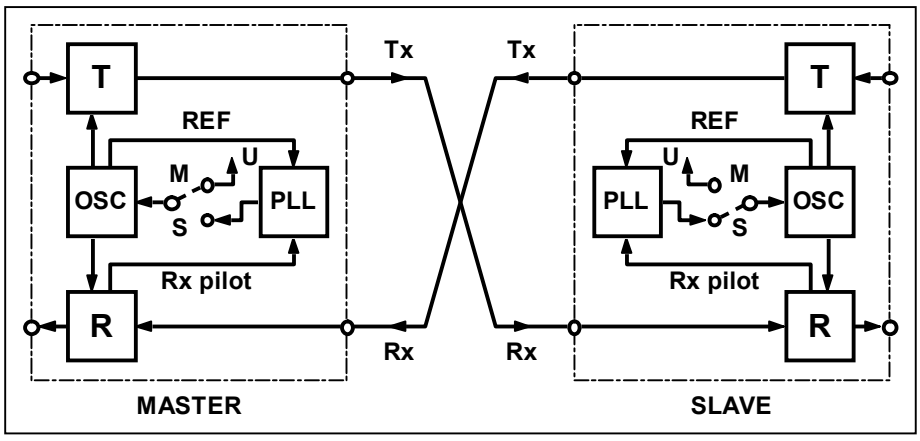

Figure 3-4: »master-slave« principle of synchronization

In certain applications at site there is a need for extending of the complete aPLC channel to the location where aPLC channel user's are situated (modem (RTU), PABX, ...); Figure 3-5. Distance between the location of PLC terminal (location B on Figure 3-5) and location of aPLC channel user's (location C on Figure 3-5) may be from few hundred meters to few ten's of kilometres. To accommodate such application's requirements device **VP-9ACT** called »Analogue channel terminal« exists in the V-PLC9000 Communication system; see documentation of VP-9ACT Analogue Channel Terminal.

aPLC channel may be extended only at one side of the PLC link (case on Figure 3-5) or at both ends of the PLC link.

If aPLC channel is extended at both sides of the PLC link then aPLC channel at both sides operate in operation mode LRI; Figure 3-3aa.

If aPLC channel is extended only at one side of the link (case on Figure 3-5.) then the VP-9ACT Analogue Channel Terminal at location C operates in pair with aPLC channel of PLC terminal at location A. Compatibility of the signals in AF band must be ensured. Therefore aPLC channel of PLC terminal at location A must operate in RDC mode (Figure 3-3ab in Figure 3-3bb) or in RDP mode (Figure 3-3ac in Figure 3-3bc). Operating mode depends on the characteristics of telecommunication link connecting aPLC channel of PLC terminal at location B with the VP-9ACT terminal at location C; Figure 3-5. If telecommunication link is realised with the cable aPLC channel of PLC terminal at site A operates in RDC operation mode. When telecommunication link is realized with the standard analogue telecommunication channel with usable AF band from 300 Hz to 3400 Hz aPLC channel of PLC terminal at site A must operate in RDP mode.

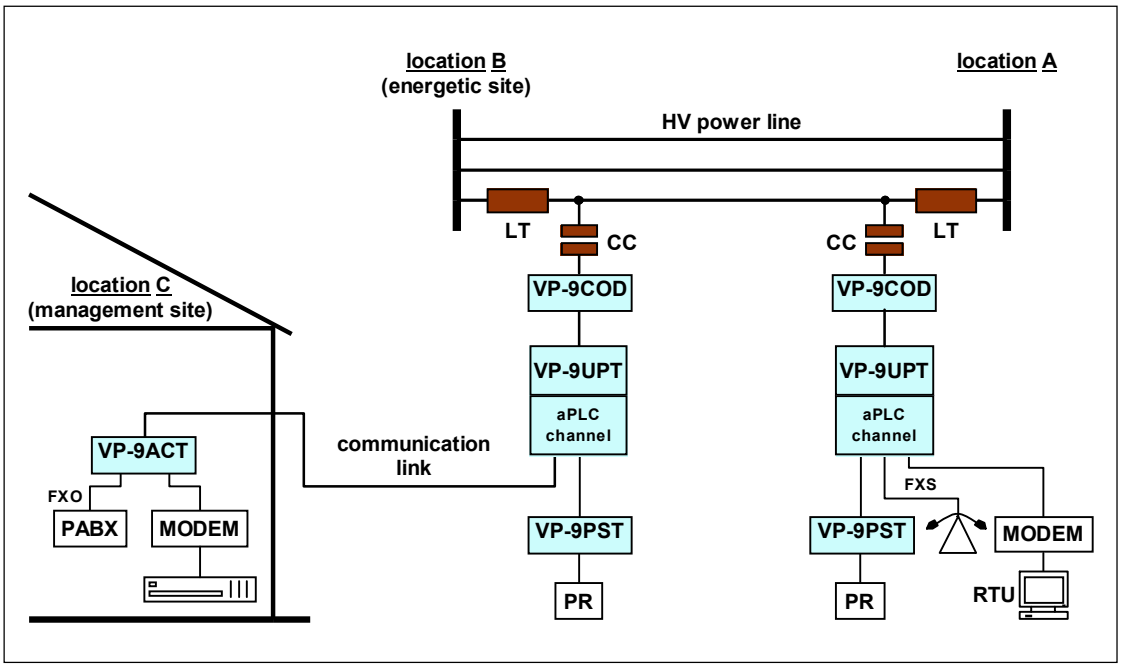

Figure 3-5: Extension of aPLC Channel

aPLC channel of PLC terminal at location B must operate as standard aPLC channel in LRI mode; Figure 3-3aa.

In any case data channel with 50 bps emerges in the usable AF band. It is intended for the transfer of diagnostic information of VP-9ACT terminal (Figure 3-3ab and Figure 3-3ac) and in case of speech-plus aPLC channel also transmission of signalling between aPLC channel of PLC terminal at location A and VP-9ACT terminal at location C (Figure 3-3bb in Figure 3-3bc).

3.1.4 Triple 4-wire AF interface; VP-9MAI interface

Always it is positioned on position X of standard and speech-plus aPLC channel module (Figure 2-6 and Figure 2-7). Three (3) 4-wire AF I/O ports of aPLC channel are available: AF I/O #1, NF I/O #2 in NF I/O #3; Figure 2-15. Each of the ports may be switched off. Port AF I/O #2 may operate in special TPS operation mode. Control input BOOST is also located at interface VP-9MAI. It is used in when external TPS terminal is connected to aPLC channel (to 4-wire port AF I/O #2). BOOST control signal is generated by TPS terminal and is intended to prepare aPLC channel for transmission of protection commands. Active state control signal at control input BOOST results in switching off transmit signals within aPLC channel (optionally it can be set to switch off all transmitted signals or speech only) and raises the level of transmit signal for preset value (boosting).

All three 4-wire AF I/O port are equal. However additional functionality may be switched on.

3.1.4.1 4-wire AF I/O port #1

It may be used as general 4-wire AF I/O port or as transit filter. Enables switching on of two (2) completely independent transit filters: one in the transmit direction (transmit transit filter) and one in the receive direction (receive transit filter). Settings of transmit and receive transit filter are completely independent of each other (switching off of transit filter or setting of the transit frequency band). In general, characteristics of both transit filters are same; Figure 3-6.

Transit filter is combination of high pass (HP) and low pass (LP) filter which characteristics are summarized. Parameters of high and low pass filter may be independently set. Each filter may be switched off or frequency limit of the pass band may be set. Pass band frequency limit of HP filter f_{HP} may be set from 510 Hz to 3630 Hz in 120 Hz steps and of LP filter f_{LP} from 450 Hz to 3570 Hz in 120 Hz steps. Such design enables very flexible selection of transit band: transit bandwidth BW_{TF} and location in usable AF band.

When using the transit filter, bandwidth between pass band and stop bands of transit filter must be considered. Attenuation of transit filter

reach value of 30 dB at 60 Hz from the upper and lower limit of the transit filter pass band BW_{TF}.

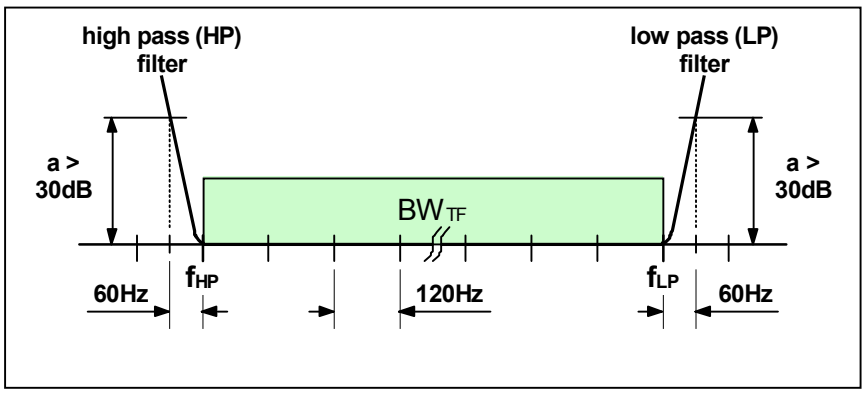

Figure 3-6: aPLC channel transit filter (transmit and receive)

3.1.4.2 4-wire AF I/O port #2 and BOOST control input

4-wire AF I/O #2 may be used as general 4-wire AF I/O port. When external TPS terminal is connected to aPLC channel it is always connected at 4-wire AF I/O port #2. In this case AF I/O #2 port must operate in TPS operation mode. In this mode transmit signal connected to this port even in case of active state of BOOST input does not switch off. In case of switching off all aPLC channel signals (setting) transmit signals on other two 4-wire AF I/O ports (#1 in #3) are switched off for the time necessary to transmit protection command(s). In transmit chain of 4-wire AF I/O port #2 there is a boosting amplifier which raises transmit signal level for the value that is set. Boosting value of the transmit signal may be set from 0d B to 15 dB in 3 dB steps.

BOOST control input active state causes switching off transmit signals. It is possible to choose from two options: switching off all transmitted signals or switching off speech only.

3.1.4.3 4-wire AF I/O port #3

This port's special feature is switching on the equalizer in transmit direction. AF equalizer is intended for compensation of frequency dependence of telecommunication cable transmission characteristics. It is used when any type of terminal equipment is connected to 4-wire AF I/O port #3 with longer telecommunication cable. AF equalizer feature may be either switched off or operates in accordance with the chosen equalizing curve (setting); Figure 3-7.

In case of aPLC channel extension with VP-9ACT terminal interconnection telecommunication link is always connected to 4-wire AF I/O port #3. AF equalizer is most useful when the telecommunication link is realized by means of telecommunication cable.

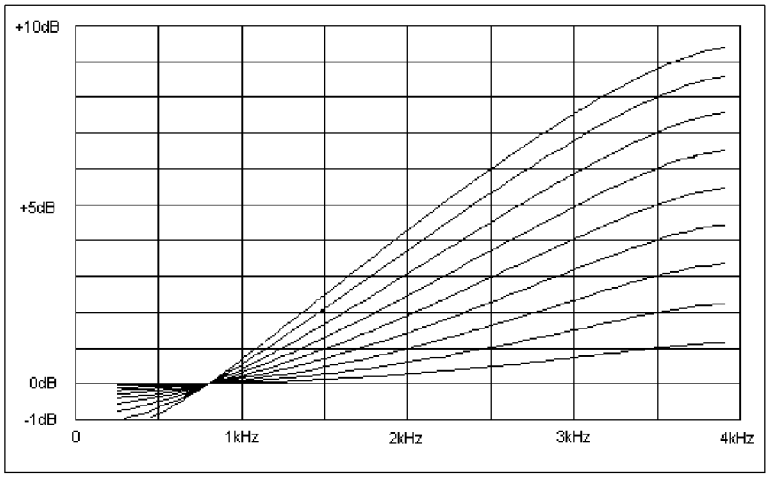

Figure 3-7: AF equalizer compensation curves

3.1.5 Universal telephony interface; VP-9PTI interface

Speech-plus aPLC channel enables transmission of speech and corresponding signalling. Therefore a suitable telephony interface must be available to connect different types of telephony equipment: telephone, telephone exchange subscriber port or telephone exchange port for interconnection between telephone exchanges (TRUNK port). Each of the three different connections requires different functionality of aPLC telephony interface. Universality is therefore very important feature of the aPLC telephony interface. It is very useful to use the same type of telephony interface module for connection of all three different types of telephony equipment. Consequently there is no need to specify user's equipment type at ordering phase and also there is no need to invest if user's requirements are changed during the period of PLC equipment exploitation.

aPLC channel telephony interface of VP-9UPT PLC terminal is designed as ***VP-9PTI*** »baby board« module placed on position Y of the speech-plus version channel module (VP-9PMPS) and is a good example of universal telephony interface; Figure 2-7. It supports connection of all three types of telephony equipment described above.

It is possible to choose from 4 different operating modes of telephony interface:

OPERATING MODE	APPLICATION
FXO	subscriber – exchange side
FXS	subscriber – subscriber side
2E&M	trunk – 2-wire
4E&M	trunk – 4-wire

Direct link between two telephones (without telephone exchange) situated at both ends of PLC link is realized so that telephony interfaces at both ends operate in FXS operating mode. Lifting of the handset at one side induces ringing at another side of the PLC link.

Compander is included into a speech path: compressor in transmitting direction and expander in receive direction. Compander has compression/expansion ratio of 2 and is compliant with ITU-T standard G.162. Compander could be turned on and off (setting).

In case of trunk connection (operating modes 2E&M and 4E&M) compander is always turned off. In operating mode FXS it is recommended that the compander is always turned on. Of course it is possible to turn it off if so desired. In operation mode FXO it is recommended that the compander be turned on if the user (telephone set) is situated immediately at the other end of the PLC link. If there is a speech transit at other end of the PLC link to another PLC link or other telecommunication connection, compander must be turned off. In FXO operating mode there is a possibility that telephone exchange turns compander on and off.

Ports of universal telephony interface VP-9PTI are shown on Figure 2-16, structure of the signalling (E and M) and control input/outputs is shown on Figure 2-17 in Chapter 2 - of this document.

At VP-9PTI telephony interface there are also control input »2/4-w; K« and control output PAXB.

3.1.5.1 Control input »2/4-w; K«

This control input is intended for the control of telephony interface operation performed by telephone exchange. Functionality of “2/4-w; K” control input is not fixed but depends on the operating mode of telephony interface (MOTI parameter), status of compander (SCOM parameter) and on the value of TCIF parameter. The following functionalities of control input are available (settings):

- operating mode of telephony interface is set to “4-wire; E&M” (MOTI = 4E_M) or to “2-wire; E&M” (MOTI = 2E_M), function of control input is set to “switch-over of compander status” (TCIF = CO) and status of compander is set to “switched off” (SCOM = OFF): activation of “2/4-w; K” control input results in switch on of compander
- operating mode of telephony interface is set to “4-wire; E&M” (MOTI = 4E_M) or to “2-wire; E&M” (MOTI = 2E_M), function of control input is set to “switch-over of compander status” (TCIF = CO) and status of compander is set to “switched on” (SCOM = ON): activation of “2/4-w; K” control input results in switch off of compander
- operating mode of telephony interface is set to “4-wire; E&M” (MOTI = 4E_M) and function of control input is set to “2-wire / 4-wire switch-over” (TCIF = 24): activation of “2/4-w; K” control input

results in switch-over of telephony interface operating mode from "4-wire; E&M" to "2-wire; E&M", while status of compander is permanently dictated by setting of SCOM parameter value

- operating mode of telephony interface is set to "2-wire; E&M" (MOTI = 2E_M) and function of control input is set to "2-wire / 4-wire switch-over" (TCIF = 24): activation of "2/4-w; K" control input results in switch-over of telephony interface operating mode from "2-wire; E&M" to "4-wire; E&M", while status of compander is permanently dictated by setting value of SCOM parameter value
- operating mode of telephony interface is set to FXO or to FXS and status of compander is set to "switched off" (SCOM = OFF): function of control input is fixed to "switch-over of compander status" (TCIF = CO; fixed) and activation of "2/4-w; K" control input results in switch on of compander
- operating mode of telephony interface is set to FXO or to FXS and status of compander is set to "switched on" (SCOM = ON): function of control input is fixed to "switch-over of compander status" (TCIF = CO; fixed) and activation of "2/4-w; K" control input results in switch off of compander

3.1.5.2 Control output PAXB

In case of aPLC channel failure control signal at PAXB control output activates. This gives the possibility to signal outage of telecommunication link to telephone exchange.

3.1.6 Distribution of aPLC channel Peak Envelope Power (PEP)

SIGNAL TYPE	RELATIVE TRANSMIT LEVEL (dB); PEPa = 0 dB
SPEECH; 2K0, 2K2 or 2K4	-8
SPEECH; 3K4	-5
DATA & SIGNALLING (VP-9UPT); 100 Baud	-19
DATA & SIGNALLING (VP-9ACT); 50 Baud	-22
PILOT; 50 Baud	-22
TG channel; 50 Baud	-22
TG channel; 100 Baud	-19
TG channel; 200 Baud	-16
Complete usable AF band of aPLC channel	-2
Input signal to MAI = 0 dBm	0

Table 3-2: Relative transmit signal level of typical signals within aPLC channel

Within aPLC channel usually a number of different signals are transmitted. Peak envelope power caused by peak voltages sum of all signals should not exceed PEP of aPLC channel. aPLC channel PEP should be suitably distributed to all signals transmitted within aPLC channel.

Distribution of aPLC PEP is performed on the basis of bandwidths potentially used by the certain signal and not on the basis of number and type of actually transmitted signals. This leads to little less efficient use of aPLC channel PEP. On the other hand this method ensures always the same transmit levels of typical signals regardless of number and type of actually transmitted signals.

Transmit levels of typical signals are listed in Table 3-2. Levels are expressed relatively to channel PEP of aPLC channel (PEPa = 0 dBr).

3.1.7 Connection of external TPS terminal

Transfer of protection commands is one of the basic telecommunication services realized by means of PLC links.

Each VP-9UPT PLC terminal channel may have integrated VP-9PST-A TPS function. In that case there is no wire connections between TPS function and channel module.

External TPS terminal may be also connected to any aPLC channel of VP-9UPT universal PLC terminal. External TPS terminal may be VP-9PST-A type, or a third vendor product.

External TPS terminal is always connected by 4-wire connection to »AF I/O #2« port of triple 4-wire interface module VP-9MAI. 4-wire port »AF I/O #2« must operate in PST operating mode (setting).

External TPS terminal may prepare aPLC channel for the transmission of protection commands through BOOST control input. Activating of the control signal on control input BOOST results in switching off transmit signals that are currently transmitted within aPLC channel and raises the level of transmit signal for the preset value (boosting; setting). For the time interval of the protection command transmission all signals or only speech signal may be temporarily switched off (setting).

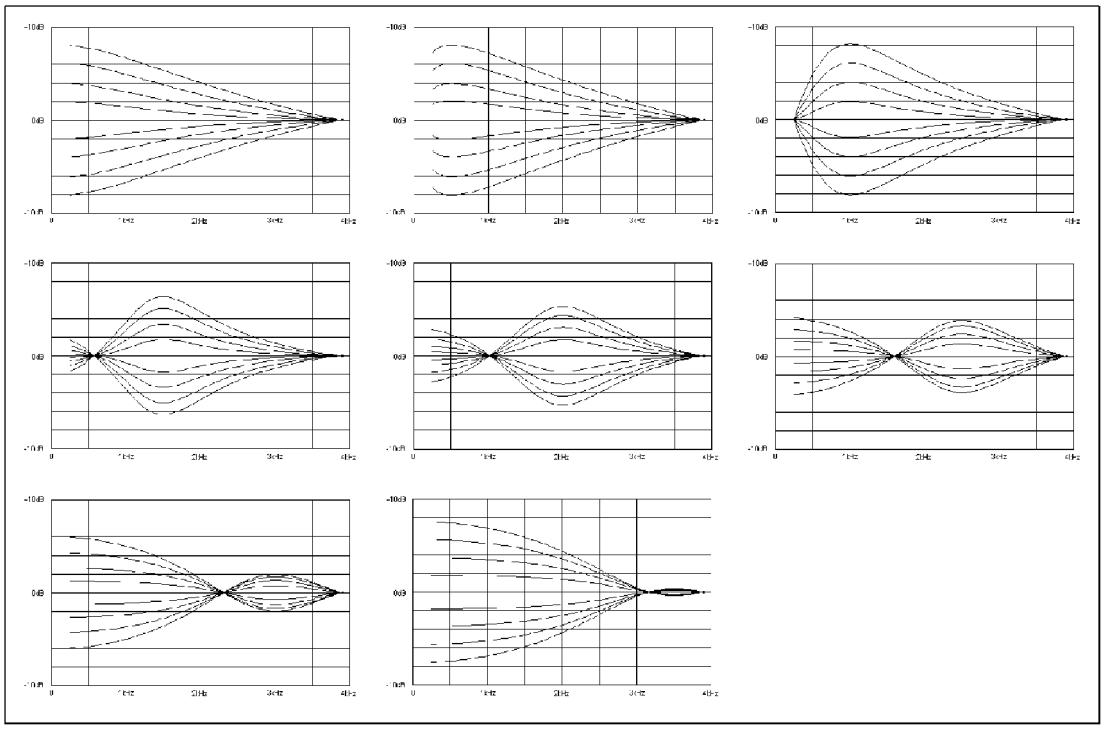

Figure 3-8: RF equalizer compensation curves

3.1.7.1 RF equalizer of aPLC channel

The aPLC channel band is relatively narrow (only 4 kHz). But the attenuation of HV PL in frequency band of one aPLC channel may significantly depend on frequency. To achieve high quality of the aPLC channel it is important to have a possibility to compensate frequency dependency of the HV PL's attenuation. This is the reason for implementation of RF equalizer into each aPLC channel. RF equalizer may be turned off or may operate in accordance with chosen equalization curve (setting); Figure 3-8.

3.1.8 Digital PLC channel (dPLC channel)

Digital PLC channel is telecommunication resource in the form of transmission capacity ***C***, expressed in kbps (**k**ilo**b**its-**p**er-**s**econd), intended for the transmission of information in digital form (speech & signalling and data). Overall transmission capacity of dPLC channel could be used for the transmission of one digital information flow (single purpose use of dPLC channel). In that case user of dPLC channel (telecommunication or terminal equipment) is connected directly to digital channel interface of dPLC channel.

Other possible way of dPLC channel transmission capacity utilization is multi-purpose use. In that case dPLC channel is used for simultaneous transmission of one or more digitized and compressed speech signals with corresponding signalling and one or more

independent digital data signals. In such case "Access Digital Multiplexer" or AMUX for short is added to VP-9UPT PLC terminal. Input signals are time division multiplexed (TDM) into single digital line signal. TDM is performed by AMUX device.

AMUX device has built in corresponding number of access interfaces of application corresponding type. These enable connection of telephony equipment (speech & signalling) and terminal equipment (data). Telephony interfaces perform also the speech signal digitization and compression of digitized speech signal.

Composite digital line signal is available at digital interface of AMUX device link module. dPLC channel of VP-9UPT PLC terminal and AMUX device are interconnected with cable. Cable connects digital channel interface of dPLC channel and digital interface of AMUX link module.

For AMUX in PLC terminal VP-9UPT, Veesta World Company offers AMUX product from **V-MUX9000** for voice & data multiplexer product series and from **V-COM2000** for data purpose usage of multiplexer series which are modular, have quality algorithms for speech compression and high efficiency of multiplexing (low »overhead«) and is on very high technological level.

dPLC channel, as a telecommunication resource, is not suitable for the transmission of protection commands. DPLC also does not provide with analogue 4-wire AF port, which is necessary for the connection of external TPS terminal. However it is possible to integrate VP-9PST-A TPS function into dPLC channel. Integrated TPS function and dPLC channel operate in time multiplex. In majority of time analogue line signal of dPLC channel is transmitted within frequency band BWd of dPLC channel. When request for transmission of protection command appears, line analogue signal of dPLC channel is switched off for a short period of time and the analogue signal of integrated TPS function is transmitted within frequency band of dPLC channel.

3.1.8.1 Channel module of dPLC channel

Channel module of dPLC channel is the same as channel module of aPLC channel: VP-9PXYS module. Of course, different types of interface »baby board« module are built onto channel module for dPLC channel. While interface »baby board« modules VP-9MAI and VP-9PTI are used as access interfaces of aPLC channel, digital interface »baby board« modules are used as access interfaces of dPLC channel.

Three (3) types of digital interface »baby board« module are available and are supporting five (5) different standard interfaces:

TYPE of module	INTERFACE supported
VP-9DIU	RS 232, V.35, X.21
VP-9DIA	G.703 contra-directional
VP-9DIO	G.703 co-directional

Digital interface »baby board« modules are described in detail in Chapter 2 - of this document: figures from Figure 2-18 to Figure 2-23 together with corresponding description. At least one digital channel interface is built onto channel module of dPLC channel. It is built onto position X (VP-9DIX #1). Two digital channel interfaces may also be built onto channel module of dPLC channel; one inserted on position X (VP-9DIX #1), and the other on position Y (VP-9DIX #2); see Figure 2-8 and Figure 2-9 in Chapter 2 - of this document. Any type of digital interface »baby board« module (VP-9DIA, VP-9DIO or VP-9DIU) could be inserted onto any position (X or Y).

3.1.8.2 Digital modulation and efficiency of dPLC channel

Bandwidth of dPLC channel ***BWd*** equals 4 kHz, 8 kHz, 12 kHz or 16 kHz. Transmit digital signal which is entering dPLC channel module through channel interface definitely does not have proper properties for transmission within band limited channel. Therefore it must be suitably transformed. The process of transforming of base band digital signal to base band analogue signal is called ***digital modulation***. Reverse process must be performed in receiver (digital demodulation): transformation of band limited base band analogue signal to receive base band digital signal.

One should be careful not to mix up digital modulation/demodulation with AM SSB modulation because these two are completely different types of transformation. AM SSB modulation is intended for conversion of band limited base band analogue signal of aPLC channel (from 0 to 4 KHz) or dPLC channel (from 0 to 4 kHz, 8 kHz, 12 kHz or 16 kHz) from AF range to desired position in RF range. AM SSB demodulation is reverse process. In case of aPLC channel AM SSB modulation/demodulation in performed only. In case of dPLC channel in transmitter digital modulation is performed first and after that AM SSB modulation. In receiver AM SSB demodulation is performed first and after that digital demodulation is performed.

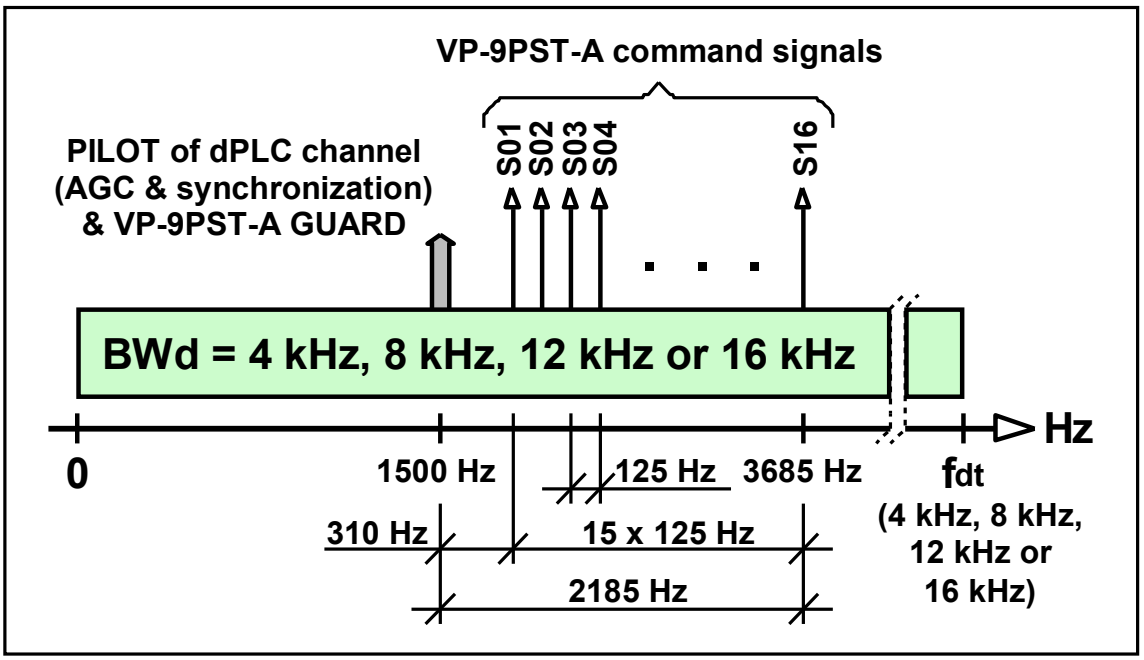

Figure 3-9: Frequency plan of dPLC channel

Digital modulation of ***MC OFDM QAM*** type is implemented for dPLC channel of VP-9UPT PLC terminal. MC (**M**ulti-**C**arrier) means that the bandwidth BWd is divided into several sub-channels where each of the channels is intended for transmission of one carrier. OFDM (**O**rthogonal **F**requency **D**ivision **M**ultiplex) means that the carriers are located at different frequencies (Frequency Division Multiplex; FDM) and are orthogonal. Orthogonal carriers enable performing of the digital demodulation in dPLC channel receiver without prior filtering of each carrier. QAM (**Q**uadrature **A**mplitude **M**odulation) means simultaneous modulation of amplitude and phase of the each carrier; QAM is performed at each carrier separately.

As has been outlined several times in this document already the bandwidth of the dPLC channel BWd is 4 kHz, 8 kHz, 12 kHz or 16 kHz. Logical question arises: What is the transmission capacity of dPLC channel ***Cd***, expressed in kbit/s or kbps (kilobits-per-second) with regard to value of dPLC channel bandwidth BWd.

Transmission capacity is one of the parameters of dPLC channel and may have value from 9.6 kbps to 96 kbit/s (setting; see Technical data). BWd is also a parameter of dPLC channel which value is independent of the chosen value of dPLC channel transmission capacity. With regard to value of these two parameters the efficiency ***Effd*** of dPLC channel is defined, expressed as transmission capacity (bit/s) per 1 Hz of the used frequency band:

$$Effd = Cd / BWd \quad (bit/s/Hz)$$

Example: If necessary transmission capacity of dPLC channel is 64 kbit/s and there is 16 kHz bandwidth available for transmission then dPLC channel will operate with efficiency of 4 bit/s/Hz.

In general, efficiency of dPLC channel will be higher if the transmission capacity is higher and bandwidth used is narrower.

High efficiency of the dPLC channel is absolutely its positive characteristic. But one must be aware that higher efficiency means also higher sensitivity of dPLC channel to all kinds of disturbances (interferences, pulse disturbances and noise). Therefore while planning PLC links with dPLC channels following rule applies: transmission capacity of dPLC channel should be as low as possible and bandwidth used by dPLC channel should be as wide as possible. We should thrive to achieve as low efficiency as possible. Limitation on one hand is minimal transmission capacity still enabling realization of the application and on another hand availability of frequency space in RF range.

Of course there is also design limitation of the maximal efficiency of the dPLC channel expressed as maximal transmission capacity of dPLC channel ***Cdmax*** with regards to dPLC channel bandwidth ***BWd***:

BWd	Cdmax
4 kHz	24 kbit/s
8 kHz	48 kbit/s
12 kHz	72 kbit/s
16 kHz	96 kbit/s

3.1.8.3 Link synchronization, training sequence and adaptive equalizer

At the beginning of the establishing of PLC link with dPLC channel certain procedures are performed to enable quality operation of the dPLC channel.

First the synchronization of the basic oscillator in dPLC channel receiver to receive pilot signal frequency must be ensured. Then the symbol synchronization follows.

After that so called "training sequence" is performed. With this procedure receiver of the dPLC channel finds out what are the characteristics of the transmission path consisting out of coupling equipment and HV PL. In correspondence with the result of this procedure receiver sets the starting value of correction parameters.

Switching to normal operation follows.

A big problem represents permanent changes of the transmission path characteristics (weather, time of year, configuration of transmission path, etc.). In the phase of training sequence receiver of the dPLC channel adapts to current characteristics of the transmission path. Each later change of the transmission path characteristics would possibly disable correct performance of the digital demodulation. Most of the changes on the transmission path arise slowly (weather, year season).

To avoid above mentioned difficulties adaptive equalizer is implemented in dPLC channel receiver. It takes care of permanent adaptation of correction parameters value to changes of transmission path characteristics.

3.1.8.4 Clock sources

At digital channel interface among other signals there are also clock signals. They are necessary in case of synchronous transmission of digital signal. Receive clock (Rx CLOCK) is always generated by dPLC channel. Transmit clock (Tx CLOCK) is usually generated by dPLC channel but there is always possibility that transmit clock is brought from external source. It is generated by device attached to digital channel interface of dPLC channel; Figure 3-10.

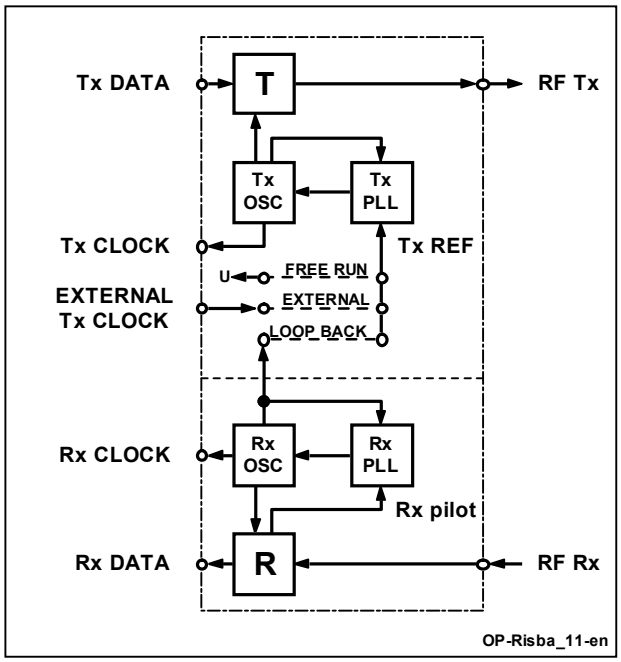

Figure 3-10: Clock signal generation

Receive clock (Rx CLOCK) is always generated by dPLC channel. Source of receive clock is always dPLC channel receiver oscillator

(Rx OSC) which is oscillator always synchronized to the frequency of receive pilot signal (Rx pilot).

Transmit clock may be generated by dPLC channel (Tx CLOCK) or is brought from external source (EXTERNAL Tx CLOCK).

In case when transmit clock is generated by dPLC channel the source of the clock is dPLC channel transmitter oscillator (Tx OSC). Tx oscillator may be free running (setting »FREE RUN«), synchronized to receive clock (setting »LOOP BACK«), or synchronized to external transmit clock (setting »EXTERNAL«). This enables easy integration of PGC_9 PLC terminal dPLC channel into digital telecommunication transmission networks.

3.1.8.5 Single-purpose use of dPLC channel

In case of single-purpose use of dPLC channel complete transmission capacity of dPLC channel is used for transmission of one digital signal. AMUX device is not necessary in such application.

Three typical examples of single-purpose use of dPLC channel are shown on Figure 3-11. In case a) dPLC channel serves as direct communication link between substation PC or substation RTU and control centre.

In b) case dPLC serves as telecommunication resource for connection of smaller Power Utility installation to the backbone of all-digital telecommunication transmission network (last mile access).

In case c) dPLC channel serves as an element of all-digital telecommunication transmission network. This application is used to ensure redundancy of important telecommunication links. In this application dPLC channel serves as backup transmission path.

When dPLC channel is used in single-purpose application digital signal is always connected to digital channel interface DIX #1 (placed on position X (connector »X PORT«) on channel module of dPLC channel). There is nothing wrong if also digital channel interface DIX #2 is built in (on position Y (connector »Y PORT«) on channel module of dPLC channel), but that digital channel interface is not in use.

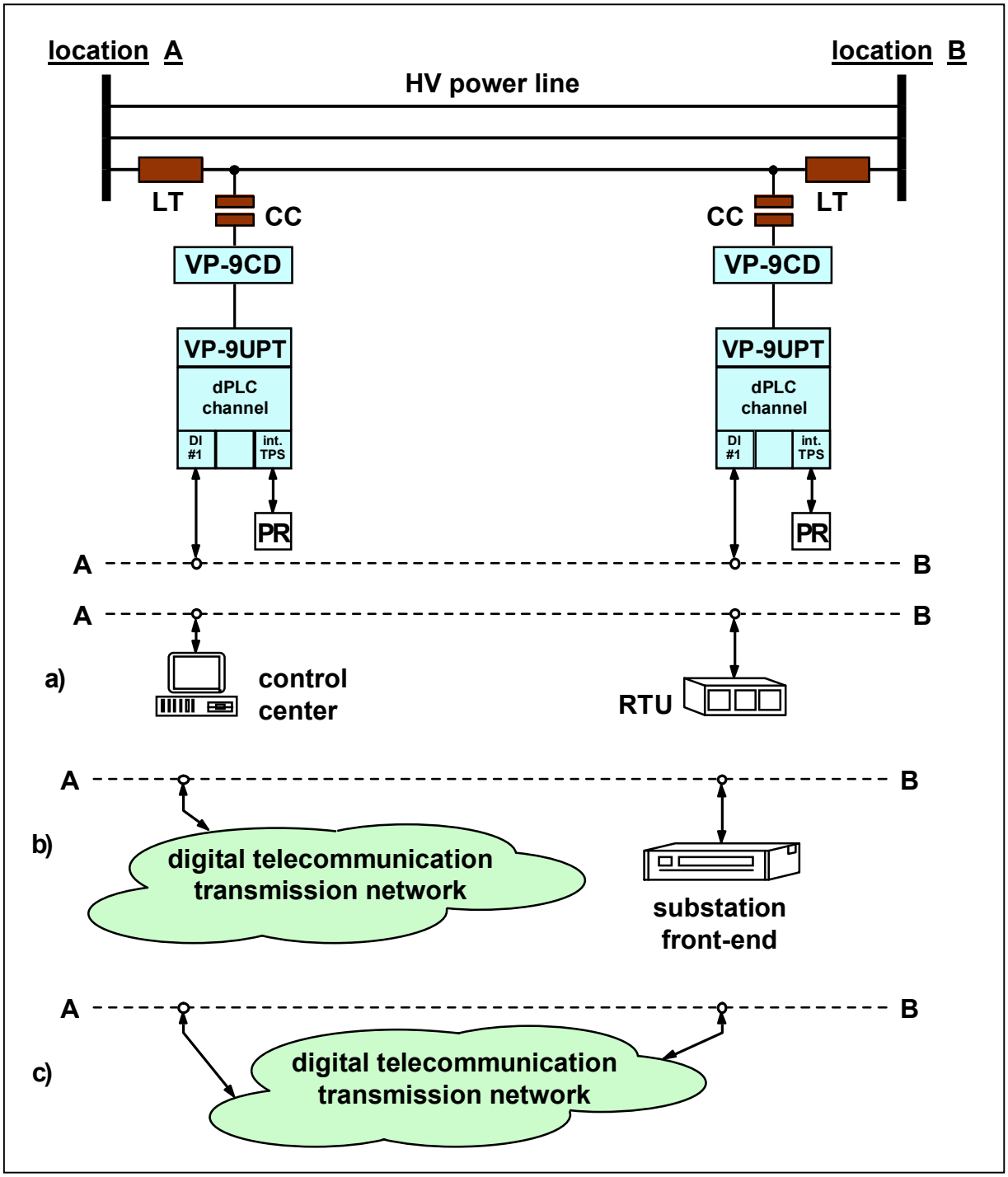

Figure 3-11: Typical examples of dPLC channel single-purpose use

Of course it is always possible to integrate VP-9PST-A TPS function into dPLC channel. In that case at least one interface module VP-9PRIX is built into VP-9UPT PLC terminal to connect TPS function with the protection relay (PR).

3.1.8.6 Multi-purpose use of dPLC channel; access multiplexer AMUX

It is sensible to use relatively high capacity of dPLC channel to transmit more independent information signals. Typical telecommunication link of Power Utility installation must ensure one or more speech channels and transmission of one or more independent digital data signals. dPLC channel together with access multiplex (AMUX) is suitable technology to realize such complex applications; Figure 3-12. This type of use of dPLC channel is called multi-purpose use of dPLC channel. In case of multi-purpose use of dPLC channel X.21 connection is used to connect AMUX device and dPLC channel (digital channel interface DIX #1 of dPLC channel). Therefore VP-9DIU digital channel interface operating in X.21 operating mode is always built in on position X of dPLC channel module.

Of course in case of multi-purpose use of dPLC channel it is possible to integrate VP-9PST-A TPS function into dPLC channel. In that case at least one interface module VP-9PRIX is built into VP-9UPT PLC terminal to connect TPS function with the protection relay (PR).

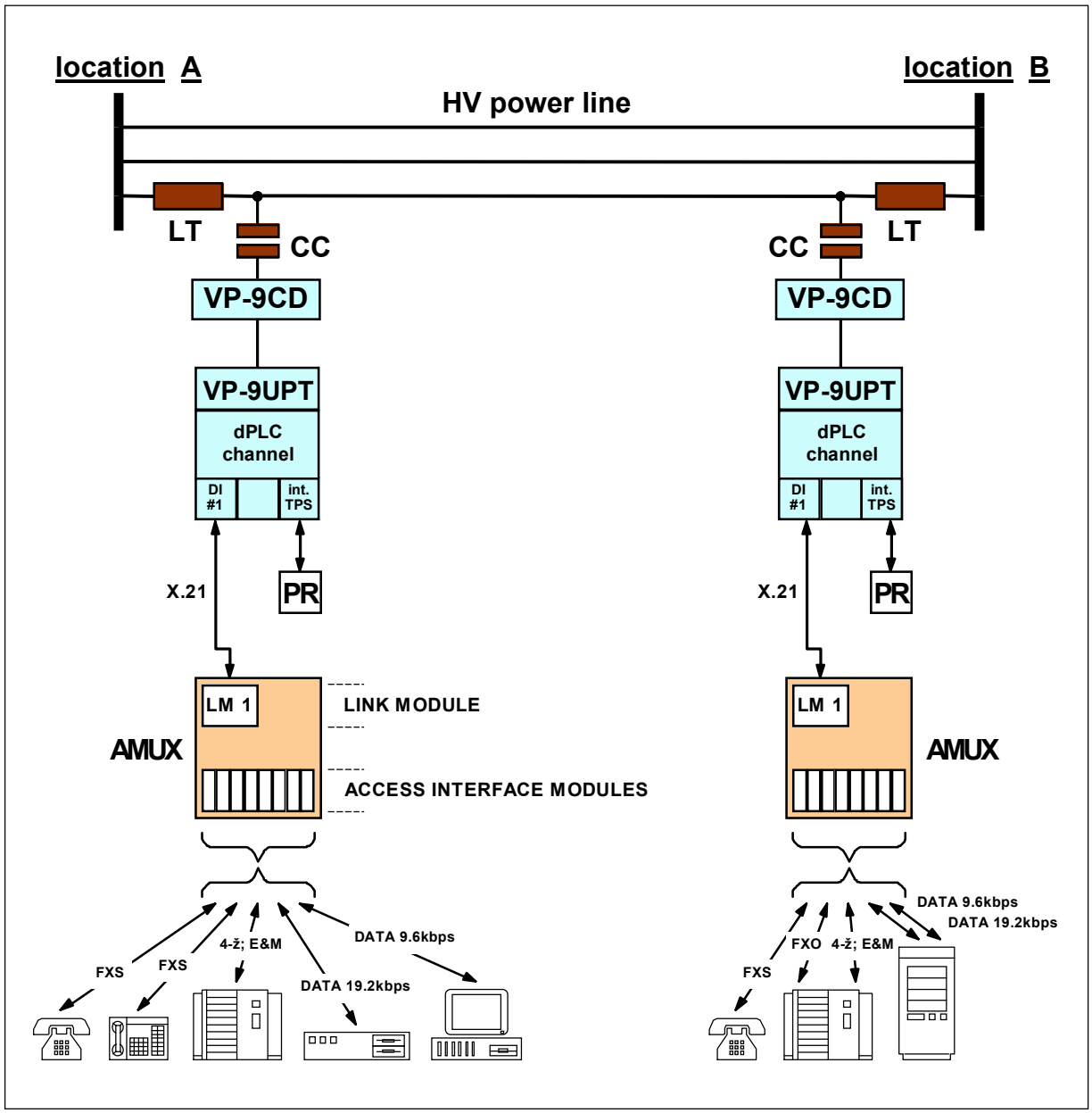

Figure 3-12: Multi-purpose use of dPLC channel

3.1.8.7 Function »FALL BACK – FALL FORWARD«

In case of multi-purpose use of dPLC channel many independent information signals are simultaneously transmitted within one dPLC channel. Some of them are very important for the operation of Power Utility system and some are less important. In case of dPLC channel multi-purpose use usually there is a need for high transmission capacity of dPLC channel. This leads to higher sensitivity of transmission to all kind of disturbances.

dPLC channel of VP-9UPT PLC terminal offers together with AMUX device possibility to realize so called »FALL BACK – FALL FORWARD« function; Figure 3-13. All information signals are transmitted when the operating conditions on the transmission media are favorable. In case of worsening of transmission conditions only the most important information signals are transmitted. When the situation on the transmission media improves, all information signals are transmitted again.

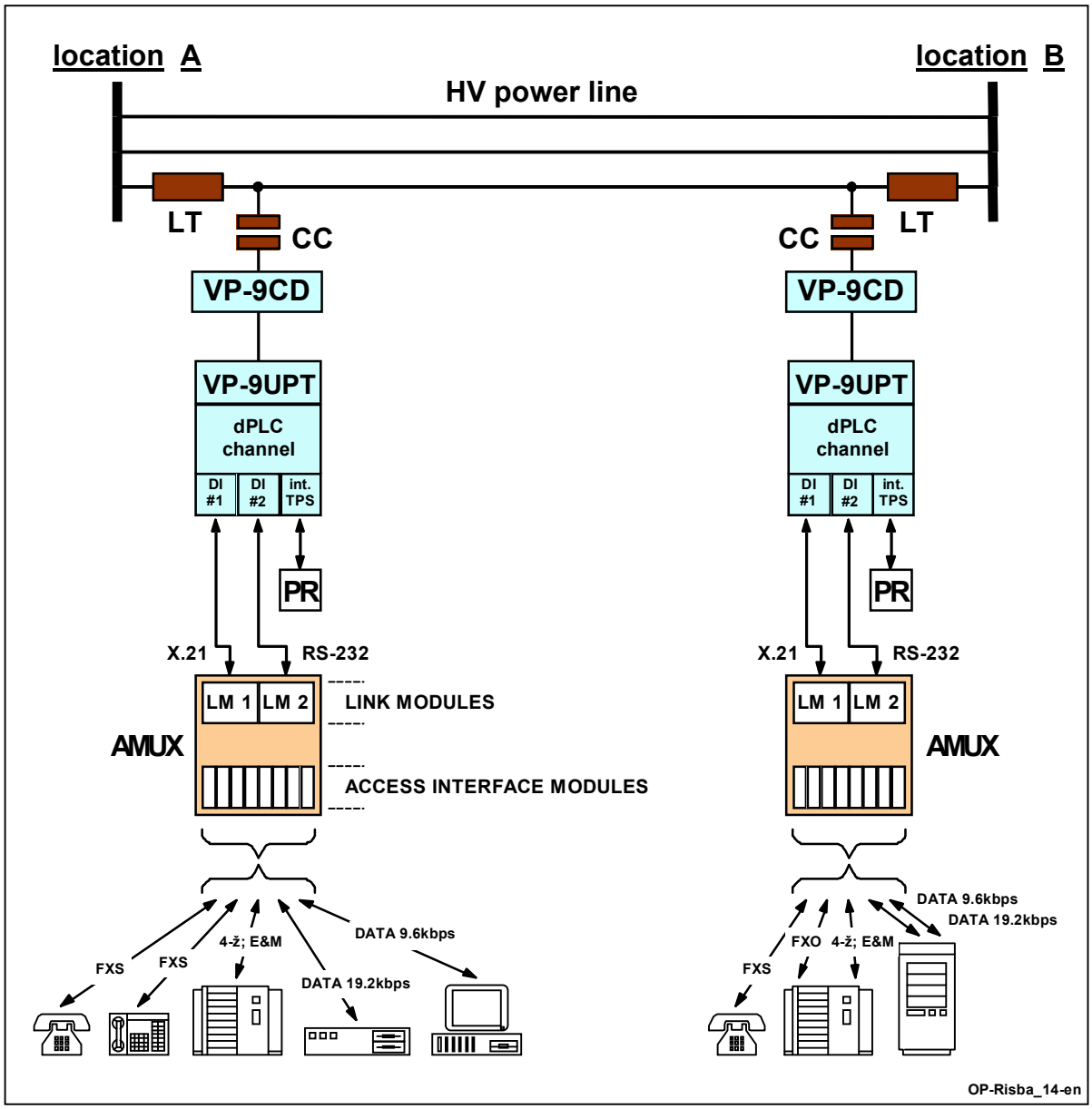

Figure 3-13: »FALL BACK – FALL FORWARD« function realizations

In each AMUX device two different schemes of time division multiplexing are saved. First multiplex scheme enables multiplexing of all connected information signals. Active is link module LM1, which is connected to digital channel interface VP-9DIX #1 of dPLC channel. Second multiplex scheme is enabling multiplexing of most important information signals only. Bit rate of digital link signal decreased. If second multiplex scheme is used, link module LM 2 is active. This module is connected to VP-9DIX #2 digital channel interface of dPLC channel. Until receive digital link signal is present at input of link module LM 1 AMUX uses first multiplex scheme. At fall out of receive digital link signal at line module LM 1 interface, AMUX starts using second multiplex scheme and switches to line module LM 2.

Until dPLC channel operates at high transmission capacity it uses digital channel interface DIX #1. When dPLC channel switches to lower transmission capacity it starts using digital channel interface VP-9DIX #2.

Described functionality of AMUX device and dPLC channel of VP-9UPT PLC terminal enables performing of the »FALL BACK – FALL FORWARD« function. Both digital interface »baby board« modules built onto dPLC channel module are of VP-9DIU type. The one placed on position X (VP-9DIX #1) operates in operating mode X.21 and the other placed on position Y (VP-9DIX #2) in operating mode RS-232.

If »FALL BACK – FALL FORWARD« function is active (setting) then is not possible to perform transit of compressed digitised speech signal as described in further text.

3.1.8.8 Transiting of compressed digitised speech at digital level

Compression of digitised speech signal is one of basic techniques enabling multi-purpose use of dPLC channel. It enables transmission of more speech signals together with digital data signals via one dPLC channel.

Very satisfactory quality of transmitted speech is ensured already at transmission bit rate 4.8 kbit/s. However speech compression has influence on speech intelligibility and introduces rather high delay (up to 200 ms). Influence becomes larger as bit rate of transmission is lower. Quality of transmitted speech (intelligibility and delay) remains on the acceptable level if compression/decompression of speech signal is performed up to maximum two times on established speech connection.

In complex speech network this may be ensured if follow two rules are respected:

- every transiting of speech signal from one PLC link to another PLC link must be performed on digital level (without decompression and repeated compression)
- trunk links between exchanges must not be compressed or compression rate must be low (32 kbit/s ADPCM or in last instance 16 kbit/s ADPCM).

By following the above rules quality of speech connection between any two users in the speech network will remain satisfactory high.

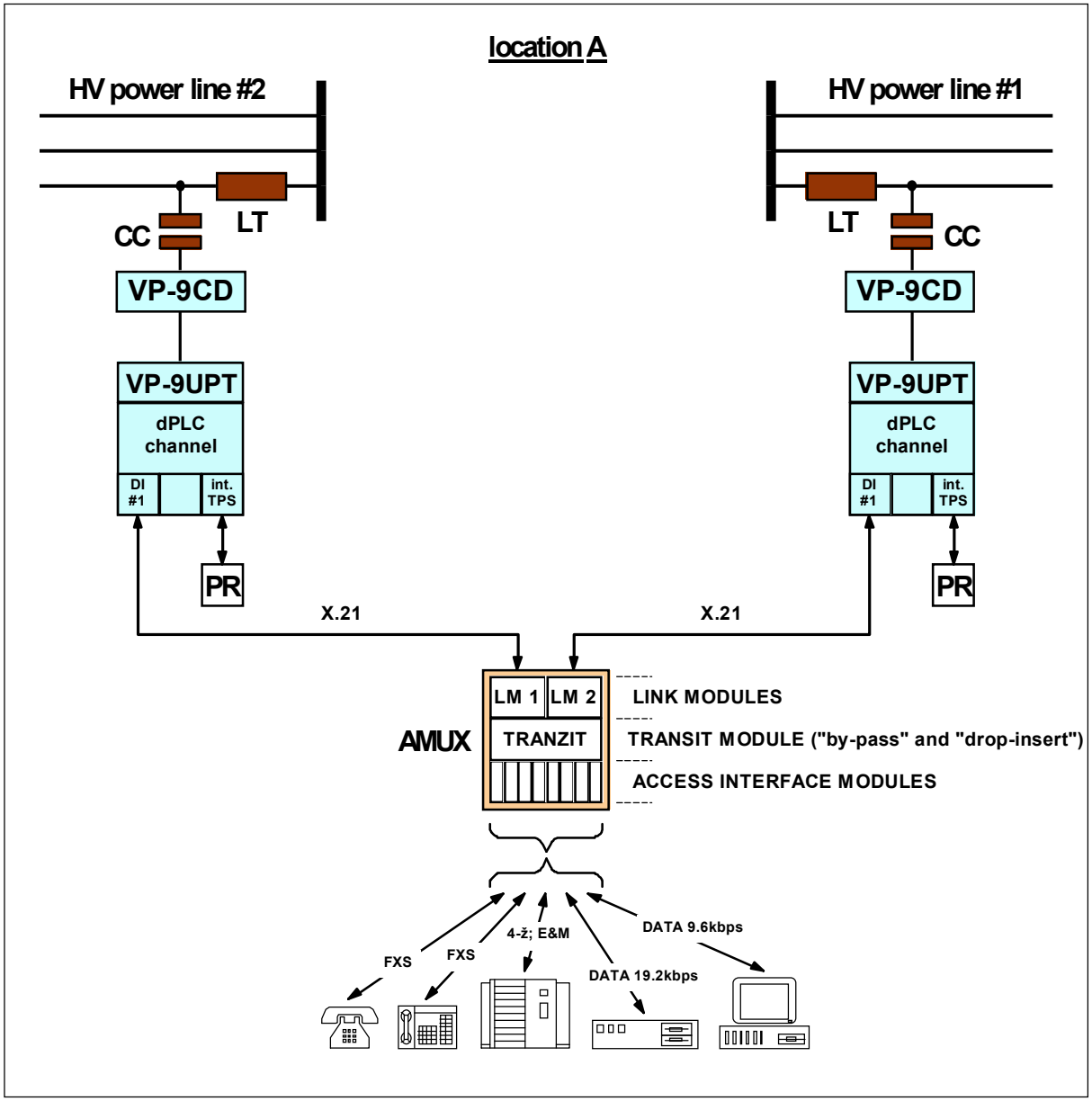

Figure 3-14: Transiting of compressed digitised speech signal at digital level

AMUX device offered by Veesta World Co., enables transiting of compressed speech signal at digital level; Figure 3-14. In that case AMUX device comprises out of two link modules (LM 1 and LM 2) and transit module enabling »BY-PASS« and »DROP - INSERT« functions.

The interesting issue about this configuration is that one AMUX device is connected to dPLC channels of two different VP-9UPT PLC terminals, which belong to two different PLC links. This is clear example why AMUX device must not be an integral part of PLC terminal dPLC channel.

It is clear that in such configuration »FALL BACK – FALL FORWARD« function cannot be used.

3.1.9 Level of dPLC channel transmit signal

Only indirect measurement of dPLC channel transmit signal level is possible by ***selective*** measurement of dPLC channel transmit pilot signal level. The frequency of dPLC channel transmit pilot signal in HF range is always defined as follows:

fp (kHz) = F0(Tx) (kHz) + 1.5 kHz

Relative level of dPLC channel transmit pilot signal regarding to the declared transmit PEP of dPLC channel ***PEPd*** depends on bandwidth of the dPLC channel ***BWd*** and on transmission capacity of dPLC channel ***Cd***. The level of dPLC channel transmit pilot signal also depends on the state of dPLC channel and is different during the TRAINING sequence and during normal OPERATION.

Nominal values of dPLC channel transmit pilot signal relative level during TRAINING sequence (see columns T in Table 3-3) and during normal OPERATION (see columns O in Table 3-3) are given in Table 3-3.

RELATIVE LEVEL of TRANSMIT PILOT SIGNAL (dBr) *PEPd = 0 dBr*								
Cd (kbit/s)	**BWd** (kHz)							
	4		**8**		**12**		**16**	
	T	O	T	O	T	O	T	O
9.6	-11,0	-13,0	-13,5	-14,0				
14.4	-11,5	-12,5	-16,0	-15,0	-16,0	-15,0		
19.2	-11,0	-12,5	-16,0	-15,5	-17,0	-16,0	-16,5	-16,0
24	-11,0	-12,0	-16,0	-15,0	-19,0	-16,5	-18,0	-17,5
28.8			-16,0	-15,5	-19,0	-17,5	-19,0	-18,0
32			-16,0	-15,5	-19,0	-17,0	-19,0	-18,0
48			-16,5	-15,0	-19,0	-16,5	-19,0	-18,5
56					-18,5	-16,0	-19,5	-18,5
64					-19,0	-16,0	-19,0	-18,5
72					-19,0	-15,5	-19,0	-17,5
96							-19,0	-16,5

Table 3-3: Nominal values of dPLC channel transmit pilot signal relative level

3.1.10 Integrated TPS function VP-9PST-A

Within V-PLC9000 Communication system there exist also terminal for transmission of protection commands over analogue transmission paths with type mark VP-9PST-A. It consists out of processing module VP-9PMEE and one (1), two (2) or three (3) interface modules of type VP-9PRIA, VP-9PRIB or VP-9PRIC.

TPS function which characteristic are the same as characteristics of independent (external) VP-9PST-A TPS terminal may be integrated into any channel of VP-9UPT universal PLC terminal: into analogue (aPLC) as well as into digital (dPLC) channel. In case of independent (external) VP-9PST-A terminal DSP software package runs on processing module VP-9PMEE. DSP software package of integrated VP-9PST-A TPS function is running on channel module of the corresponding channel into which TPS function is integrated. For each integrated TPS function corresponding number of VP-9PRIX modules is inserted into the rack. The only limitation for adding number of TPS functions to VP-9UPT PLC terminal channels is available free space in the rack.

For description and technical data of integrated VP-9PST-A TPS function please see documentation of VP-9PST-A Protection Signaling Terminal.

3.1.11 Maintenance speech channel

Commissioning and maintenance of PLC link demand simultaneous activities on both sides of the PLC link. It is therefore essential to have communication link between two crews on both sides of the link. It is comfortable to realize speech communication over one of the channels of PLC link. This is handy especially when performing maintenance works on PLC link.

Every PLC channel of VP-9UPT PLC terminal (aPLC and dPLC) offers possibility of establishing maintenance speech channel. Handset is not enclosed to each VP-9UPT PLC terminal. Handset is part of maintenance kit, available as separate item (VP-9MK2 or VP-9MK1).

Speech connection is established in the following way:

- Caller connects handset to shielded 6-pole RJ11 socket located at the front panel of channel module (see Figure 2-10; module VP-9PXYZ front panel).
- Call for establishing a maintenance speech link is transferred to another side of the PLC link. Call is signalised at the calling side of the link as blinking of yellow LED »M Ch ON«, which is situated above RJ11 handset socket and by sound signal.

- Call is received so, that handset is connected to shielded 6-pole RJ11 socket at receiving side of the call on channel module where yellow LED »M Ch ON« is blinking.
- By completing that maintenance speech link is established and yellow LED is permanently lighting.

Maintenance speech link is cut off immediately after one of the users disconnects the handset from the RJ11 socket.

Speech signal of the maintenance speech link is naturally transmitted within frequency band of PLC channel. The signals, which are normally transmitted within PLC channel, are disconnected for the time of maintenance speech link activity. In case of standard aPLC channel all signals are disconnected. In case of speech-plus aPLC channel only speech signal is disconnected. In dPLC channel transmission of digital signal is inhibited.

Transfer of protection commands has the highest priority. In case there is a request for transfer of protection commands (activation of control signal at control input BOOST in case of external TPS terminal (aPLC channel only) or activation of internal control signal BOOST in case of integrated TPS function) maintenance speech link is cut off immediately.

3.2 Line Part

Line part of VP-9UPT PLC terminal consists out of the following modules; Figure 3-15:

- module **VP-9RFPA** : RF power amplifier– transmitter; PEP(RFPA)max = 120 W
- module **VP-9PTLF**: programmable transmit line filter, RF hybrid and line transformer
- module **VP-9PRLF**: programmable receive line filter and low noise amplifier

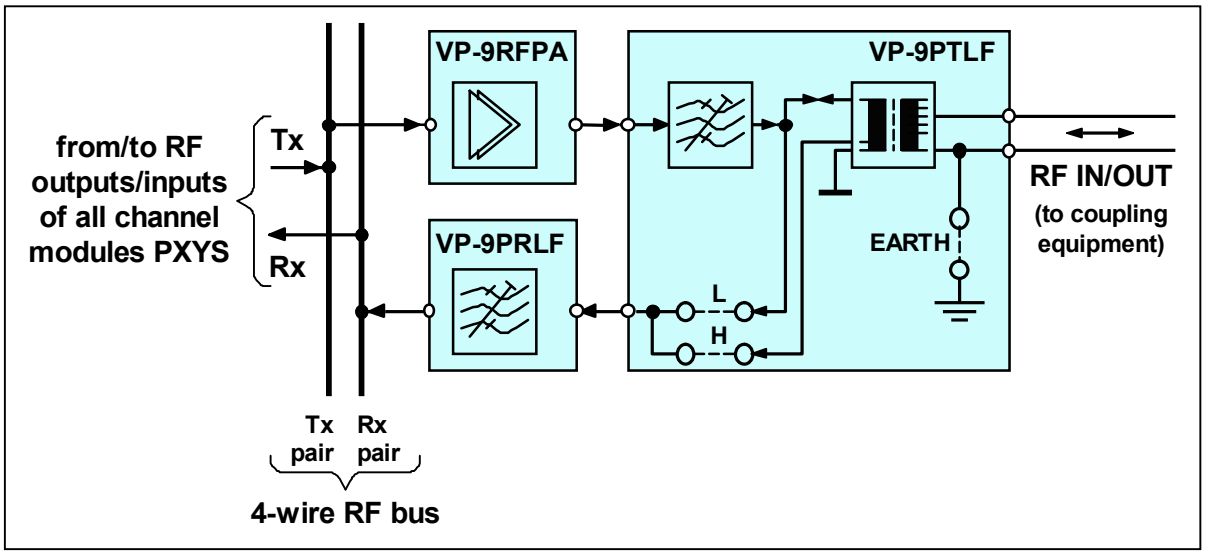

Figure 3-15: Line part of VP-9UPT PLC terminal

At Tx (transmit) pair of 4-wire RF bus composite transmit signal is present which contains frequency multiplexed and suitably polarised transmit signals of all channels. From Tx pair composite transmit signal is led to VP-9RFPA power amplifier module input which is also connected to Tx pair of the 4-wire RF bus.

Peak envelope power PEP(VP-9RFPA)max of the power amplifier equals 120 W (within frequency band from 20 kHz to 500 kHz) ensuring PEPmax of the PLC terminal of 80 W. Regardless of the chosen PEP of the PLC terminal (10 W, 20 W, 40 W or 80 W; setting) only one VP-9RFPA module is built into the PLC terminal and is always of the same type. Such construction enables simple changing of peak envelope power PEP of PLC terminal any time during exploitation period.

Power amplifier suitably amplifies composite transmit signal brought to input of programmable transmit line filter (VP-9PTLF module) which performs the following tasks:

- pass band filtering of composite transmit signal
- ensuring nominal output (non-adjacent Tx/Rx channels) or input/output impedance (adjacent Tx/Rx channels) of PLC terminal ***within*** operating frequency band (return loss)
- ensuring suitably high output (non-adjacent Tx/Rx channel) or input/output impedance (adjacent Tx/Rx channels) of PLC terminal ***out of*** operating frequency band (tapping loss)

Central frequency of transmit line filter is programmable in whole RF range (from 20 kHz to 1000 kHz) as well as its pass bandwidth (4 kHz, 8 kHz, 12 kHz, 16 kHz, 20 kHz or 24 kHz).

From programmable transmit filter composite transmit signal is led to line matching transformer. Main tasks of line transformer are:

- galvanic separation (isolation) of PLC terminal from coupling device
- matching of PLC terminal input/output impedance to actual coupling device impedance (of coupling point actually)
- attenuation of transmit signal incursion to its own receiver in case of adjacent Tx/Rx channels (RF hybrid)
- enabling different configurations of RF line port

Line transformer and possible configurations of RF line port are described in detail in Chapter 2 - of this document (RF line port; Figure 2-13 in Figure 2-14).

Composite receive signal which contains frequency multiplexed and suitably polarised receive signals of all channels is led through line transformer to input of programmable receive line filter (VP-9PRLF module). There are two possible ways to connect composite receive line signal to receive line filter:

- **mode 1:** through RF hybrid (strap H inserted)
- **mode 2:** directly from the output of transmit line filter (strap L inserted)

In case of adjacent Tx/Rx channels mode 1 is always used.
Both modes may be used in case of non-adjacent Tx/Rx channels.

If ***mode 1*** of connection is used ***input impedance*** of PLC terminal is ***high*** within frequency band of Rx channels. Receive line filter does not cause any tapping loss but receive line signal is not optimally terminated. Mode 1 should be used only when there is really a lack of frequency space and if PLC terminal consists of aPLC channels only.

If ***mode 2*** of connection is used ***input impedance*** of PLC terminal within frequency band of Rx channels is same as output impedance of PLC terminal within frequency band of Tx channels (***nominal*** impedance). This mode of connection ensures clear situation in terms of input/output impedance in frequency band of Tx channels as well as of Rx channels.

Central frequency of receive line filter is programmable in whole RF range (from 20 kHz to 1000 kHz) as well as its pass bandwidth (4 kHz, 8 kHz, 12 kHz, 16 kHz, 20 kHz or 24 kHz).

From the output of VP-9PRLF receive line filter module composite receive signal is brought to Rx pair of the 4-wire RF bus to which also RF inputs of all channel modules are connected.

Chapter 4 - Ordering Instructions

VP-9UPT PLC terminal is very complex because of its universality and modularity. It offers wide choice of different configurations. It is rather difficult to find application from the field of PLC telecommunications, which is not possible to be covered with the suitably structured VP-9UPT Universal PLC terminals.

Wide ranges of possibilities demand that the structure of certain VP-9UPT PLC terminal is detailed in the phase of inquiry already. Structure of the PLC terminal influences the price. Only by clearly stated requirements it is possible to determine the price of PLC terminal.

To avoid misunderstandings in phase of enquiry, offering or ordering useful form »*Specification of PLC equipment; Equipment type:* ***VP-9UPT*** *Universal PLC terminal*« has been prepared which we advise to be filled in by customer to acknowledge full PLC terminal structure details. This form is enclosed on next two pages.

Page 1/2 contains essential data, which are necessary to determine optimal price of the PLC terminal. This page may be filled in not just for one piece of PLC terminal but for larger quantity of structurally same PLC terminals (item **23** Quantity).

Page 2/2 contains additional data, which do not influence the price but enable setting of the majority of parameters of PLC terminals in the factory (at production stage) thus simplifying and shortening the procedure of commissioning at site.

We advise that customer fills in the copy of enclosed forms and send it by fax to the manufacturer's fax number.

In case of multi-purpose use of dPLC channel it is necessary to submit the specification of AMUX device as well. AMUX device is also very modular device therefore detailing the structure to determine optimal price. Application is described primarily by demands in terms of type and number of access interfaces for speech & signalling and data. Form »*Specification of PLC equipment; Equipment type:* ***AMUX*** *Digital access multiplexer*« is enclosed further in this document.

Form »*Specification of PLC equipment; Equipment type:* ***VP-9UPT*** *Universal PLC Terminal*« does not include information regarding integrated TPS function. Each TPS terminal type VP-9PST-A (external or integrated) must be specified with the separate form »*Specification of PLC equipment; Equipment type:* ***VP-9PST-A*** *TPS Terminal*« which is enclosed in documentation of VP-9PST-A TPS terminal.

Chapter 5 - Technical Data

5.1 General Characteristics

1. **PLC Terminal type:** VP-9UPT

2. **Modulation type :** Single step AM (amplitude modulation)

3. **Transmission mode :** SSB (single side band) with suppressed carrier

4. **Operating mode :** Duplex

5. **Number of aPLC channel :** From 0 to 6

6. **Number of dPLC channel :** 0 or 1

7. **Basic frequency band of aPLC channel:** 4 kHz

8. **Basic frequency band of aPLC channel:** 4 kHz, 8 kHz, 12 kHz or 16 kHz

9. **Tx and Rx bandwidth:**
   1) adjacent Tx and Rx band: 4 kHz, 8 kHz or 12 kHz
   2) non -adjacent Tx and Rx band: 4 kHz, 8 kHz, 12 kHz, 16 kHz or 24 k

   NOTE: Tx bandwidth and Rx bandwidth are always the same!

10. **RF range:** from 20 kHz to 1000 kHz

11. **Channel positioning in RF range:** programmable in whole RF range in 1 kHz step

12. **Channel polarisation (Tx and Rx) in RF range:** normal (always)

13. **Allocation of Tx and Rx band in RF range:**
    1) configuration with dPLC channel: non-adjacent (always)
       (only dPLC channel)

    2) all other configurations: adjacent or non-adjacent
       (only aPLC channel(s) or mix (aPLC channel(s) + dPLC ch.))

15. Frequency accuracy in RF range:

1) f_{RF} = from 20 kHz to 500 kHz: ≤ +/- 10 Hz
2) f_{RF} = from 500 kHz to 1000 kHz: ≤ +/- 20 Hz

16. Output Peak Envelope Power of PLC terminal - PEP:

1) output power of PLC terminal (PEP): 0 W, 20 W, 40 W or 80 W
2) output power of PLC terminal with regard to Tx band position in RF range:
   f_{RF} = from 20 kHz to 500 kHz: PEP
   f_{RF} = from 500 kHz to 750 kHz: PEP / 2
   f_{RF} = from 750 kHz to 1000 kHz: PEP / 4

17. Spurious emission: in accordance with IEC 60495; clause 5.2.4, figure 7 and figure A.2

18. RF line port:

1) output impedance: 50, 75, 125 or 150 Ohms
2) input impedance: same as output impedance (nominal) or high (applicable in case of non-adjacent Tx/Rx bands only)
3) configuration: balanced, unbalanced or 2 x 75 Ohms unbalanced, differential-phase
4) return loss: > 12 dB
5) balance to ground (balanced configuration only); f = 50Hz (60Hz) > 40 dB
6) RF connector: two (2) unbalanced (coaxial) N type connectors or two (2) balanced (symmetrical) connectors (on request only)

19. Receiver selectivity :

1) tested according to the IEC 60495; clause 5.3.1.5 COMPLY

5.2 Channel Part, Analogue (aPLC) Channel

1. Bandwidth (kHz): 4 (gross)

2. Usable AF band (Hz): 300 – 3,720

3. Channel versions: »standard« or »speech-plus«

4. AF channel interface: 3 x 4-wire port & BOOST

5. Transit filter: YES (in Tx and Rx direction)

6. Telephony interface: Universal; FXS, FXO, 2-/4-wire, E&M (TRUNK)

7. **Receiver sensitivity:** pilot level ≥ -30dB (PEP/channel = 10W: line attenuation ≤ 51dB)

8. **AGC range:** ≥ 40dB

9. **Synchronization:** YES; »master – slave«

10. **Integrated functions:** maintenance speech ch. TPS function VP-9PST-A (option)

5.3 Channel Part, Digital (dPLC) Channel

1. **Digital modulation:** MC OFDM QAM

2. **Adaptive equalizer:** YES

3. **Nominal channel Capacity (kbps):** 9.6, 14.4, 19.2, 24, 28.8, 32, 48, 56, 64, 72 or 96

4. **Bandwidth used (kHz):** 4, 8, 12 or 16

5. **Utilization methods:** single-purpose use or multi-purpose use (AMUX)

5.4 Mechanical Design (Rack VP-9R1P)

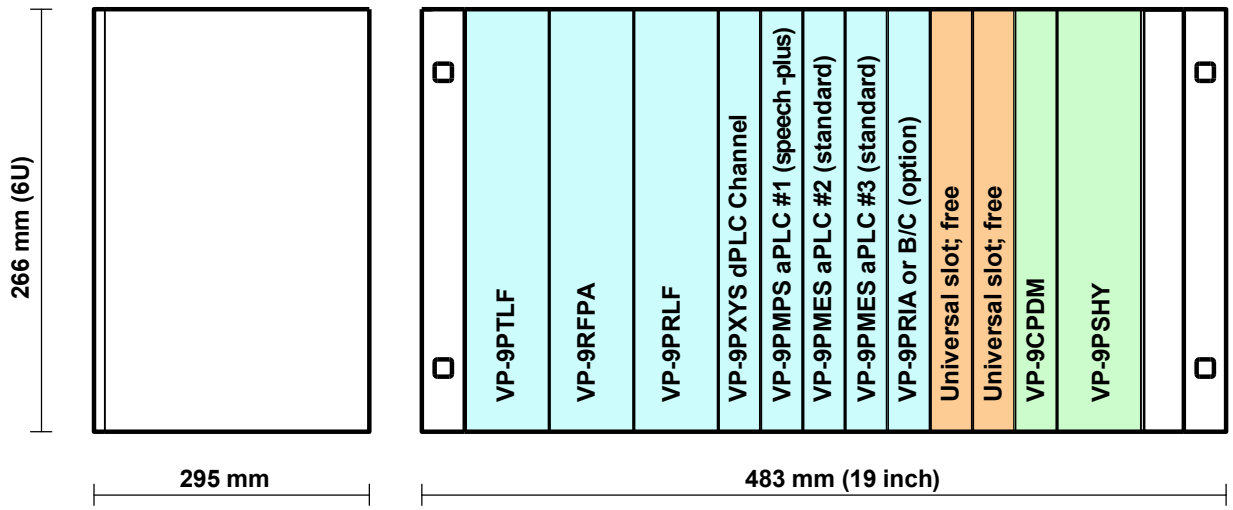

Figure 5-1: V-PLC9000 sub rack design for VP-9UPT

Chapter 6 - VP-9PST, Protection Signaling Terminal

6.1 General

Transmission of information for teleprotection systems is one of the most important telecommunication services that power utility private telecommunication system must provide. Information between Protection Relays (PRs) in teleprotection systems of command type is transmitted in the form of protection commands. Protection relays are located at ends of HV power lines. Commands are used in several applications: direct trip, permissive trip and (de)blocking. Each protection relay can handle the required protection operations also without information from the opposite side of HV power line. However fast, secure and dependable transfer of protection commands between two protection relays ensures *faster and/or more selective operation* of protection system. Important parameters of protection commands transmission are transmission time, security against unwanted commands and dependability of command transmission.

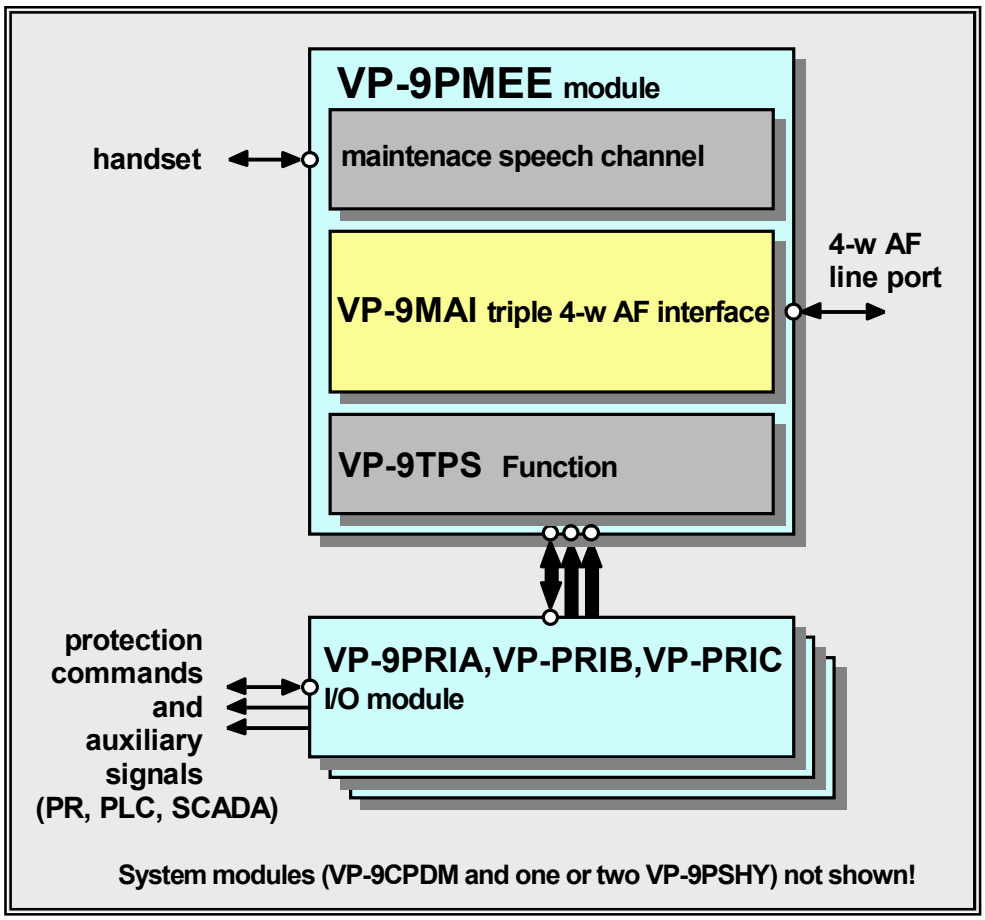

Figure 6-1: VP-9PST principle block diagram

VP-9PST-A TeleProtection Signaling terminal (TPS terminal) is designed for full duplex transmission of protection commands. Transmission of protection commands between two PRs is performed with two VP-9PST-A terminals located at the ends of HV power line together with PRs. Between two VP-9PST-A terminals a telecommunication link must exist. VP-9PST-A TPS terminal enables transmission of protection commands through »analogue« (voice grade) telecommunication channels in point-to-point configuration. »Analogue« means that the telecommunication channel is suitable for transfer of analogue signals within basic frequency band from 0Hz to 4kHz gross. Type of telecommunication technology used has no influence. It is however important that the telecommunication channel provides minimal delay. Considering that, most suitable technologies are copper or fiber optic cables, PLC links and radio links. Satellite or switched links are not suitable for such application.

VP-9PST-A fully programmable TPS terminal enables transmission of up to eight (8) protection commands in different priority schemes. Transmission parameters for each protection command are determined by chosen command application. Allocation of signals in AF band is also programmable.

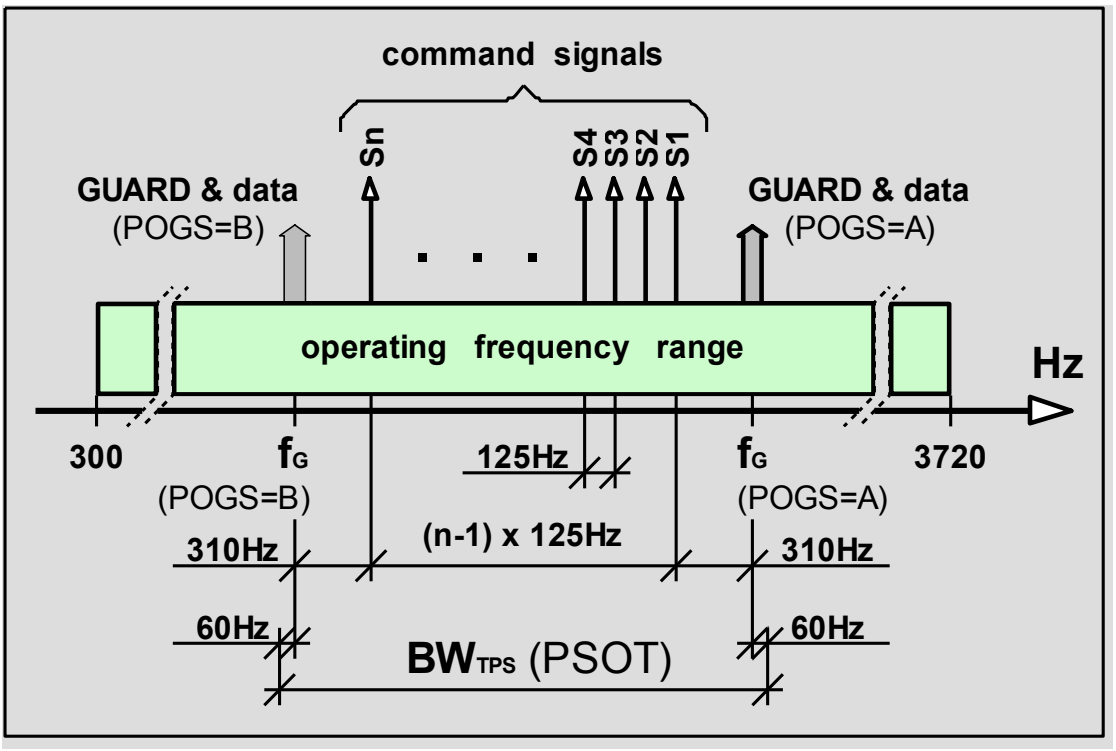

Figure 6-2: VP-9PST programmable Teleprotection Terminal

VP-9PST-A consists of processing DSP module VP-9PMEE and adequate number (1, 2 or 3) of interface modules VP-9PRIA, VP-9PRIB and/or VP-9PRIC. Interface modules provide interconnection between VP-9PST-A terminal and PR, supervision system (SCADA) and PLC terminal (BOOST-OUT). All modules are of the same dimensions: 25,4mm (width; 5HE) x 233,35mm (height;

6U) x 220mm (depth). Two fully independent VP-9PST-A terminals can be installed into one VP-9R22 type 19 inch rack. Each terminal includes necessary system modules: one or two (redundant power supply) power supply modules VP-9PSHY and parametrising/ diagnostic module VP-9CPDM.

TPS function with identical characteristics may be integrated into any aPLC or dPLC channel of VP-9UPT universal PLC terminal and into VP-9ACT analogue channel terminal.

VP-9PST-A fully complies with relevant international standard IEC 60834-1 (1999-10).

6.2 Technical Data

6.2.1 General Characteristics

1.	**AF band:**	0 – 4kHz gross; 300 – 3720 (3400) Hz net		
2.	**Operating mode:**	4-wire, full duplex		
3.	**Number of commands:**	from 1 to 8		
4.	**Transmission mode:**	guard tone/command(s) tone (F6 modulation)		
5.	**Command application:**	direct trip, permissive trip or (de)blocking		
6.	**Priority schemes:**	3I, 4I, 6P (1+1+1+1+1+1), 22 (2+2) in 42 (2+2+2+2)		
7.	**Frequency plan:**	programmable		
8.	**Nominal transmit time (ms):**	**direct.** <20	**permiss.** <15	**block.** <10
9.	**Probability of an unwanted Command P_{uc} (security);** (noise = white noise bursts)	$<10^{-7}$	10^{-5}	10^{-3}
10.	**Probability of a missing com P_{mc} (dependability) / T_{ac} (ms);** (S/N = +6dB)	$<10^{-4}$/40	$<10^{-4}$/20	$<10^{-3}$/15

6.2.2 AF Line interface (4-wire)

1.	**Impedance:**	600Ω; balanced
2.	**Return loss:**	≥ 20dB
3.	**Balance to ground:**	≥ 40dB
4.	**Nominal / max. Tx level:**	0dBm / +9dBm (command)
5.	**Receiver sensitivity:**	-30dBm (command)

6.2.3 Binary Input

1.	**Number of inputs:**	module VP-9PRIA: 2x IN module VP-9PRIB: 4x IN module VP-9PRIC: 6x IN
2.	**Input technology:**	Optocoupler
3.	**Electrical characteristics:**	Uin = from 24V to 250V DC (Iin = const. = 5mA)
4.	**Function (setting):**	transmit (Tx) command or BOOST-IN (from PR)

6.2.4 Binary output

1.	**Number of Outputs:**	module VP-9PRIA: 6x OUT module VP-9PRIB: 4x OUT module VP-9PRIC: 2x OUT
2.	**Output technology (setting):**	MOSFET or relay contact
3.	**Electrical characteristics:**	Umax = 250V Imax = 2A (MOSFET) Imax = 5A (relay contact)
4.	**Function (setting):**	receive (Rx) command, BOOST-OUT (to PLC), ALARM, PR deblocking, Tx command control
5.	**Command counters:**	Each command; Tx and Rx
6.	**Test:**	YES; Manula or Automatic

6.2.5 Other Characteristic

1. **Integrated function:** maintenance speech channel
2. **Power Supply - mains:** 115 / 230 V AC
3. **Power Supply - battery:** 24, 48, 60, 110 or 220 V DC
4. **Temperature range (°C):** 0 - 45 (55)
5. **Compliance:** IEC 60834-1 (1999-10)

6.2.6 Mechanical Design (Rack VP-9R1P)

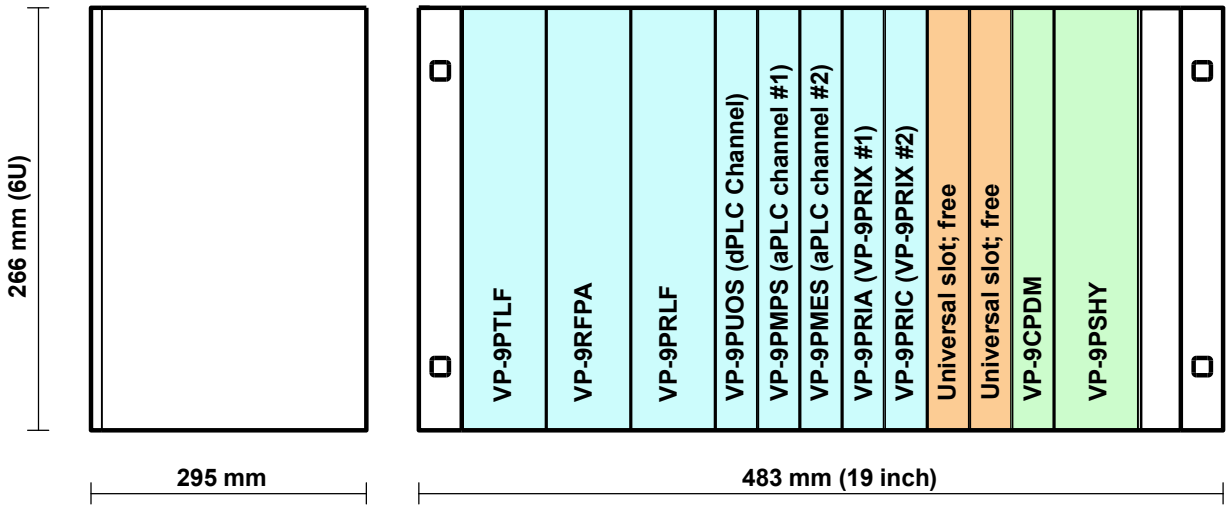

Figure 6-3: V-PLC9000 sub rack design for VP-9PST

Veesta World Co
World Wide Web: http://www.veesta-world.com/
E-Mail: info@veesta-world.com