RFL 9506D
Digital Powerline Carrier System

Figure 1. A typical RFL 9506D Digital Powerline Carrier System

The RFL 9506D Digital Powerline Carrier (PLC) system makes it possible to transmit full-duplex digital signals of up to 81 kbit/s over high voltage power lines.

Data stream multiplexing allows a more efficient use of the frequency spectrum so that speech and data can share the transmission frequency band. This band can also be shared with teleprotection signals.

The transmission channel occupies a bandwidth of 16 kHz in each direction, and the channeling is compatible with the standard 4 kHz RF frequency plan. However, a more efficient use of the band can be achieved by means of a built-in echo canceller which allows the transmitted and received signals to coexist in the same 16 kHz bandwidth.

The technology used in the design of this equipment is based on high-speed data transmission techniques combined with digital signal processing.

The RFL 9506D uses algorithms for error detection and correction in order to achieve better performance in the presence of channel noise. Trellis coding improves the signal-to-noise ratio by 4 dB.

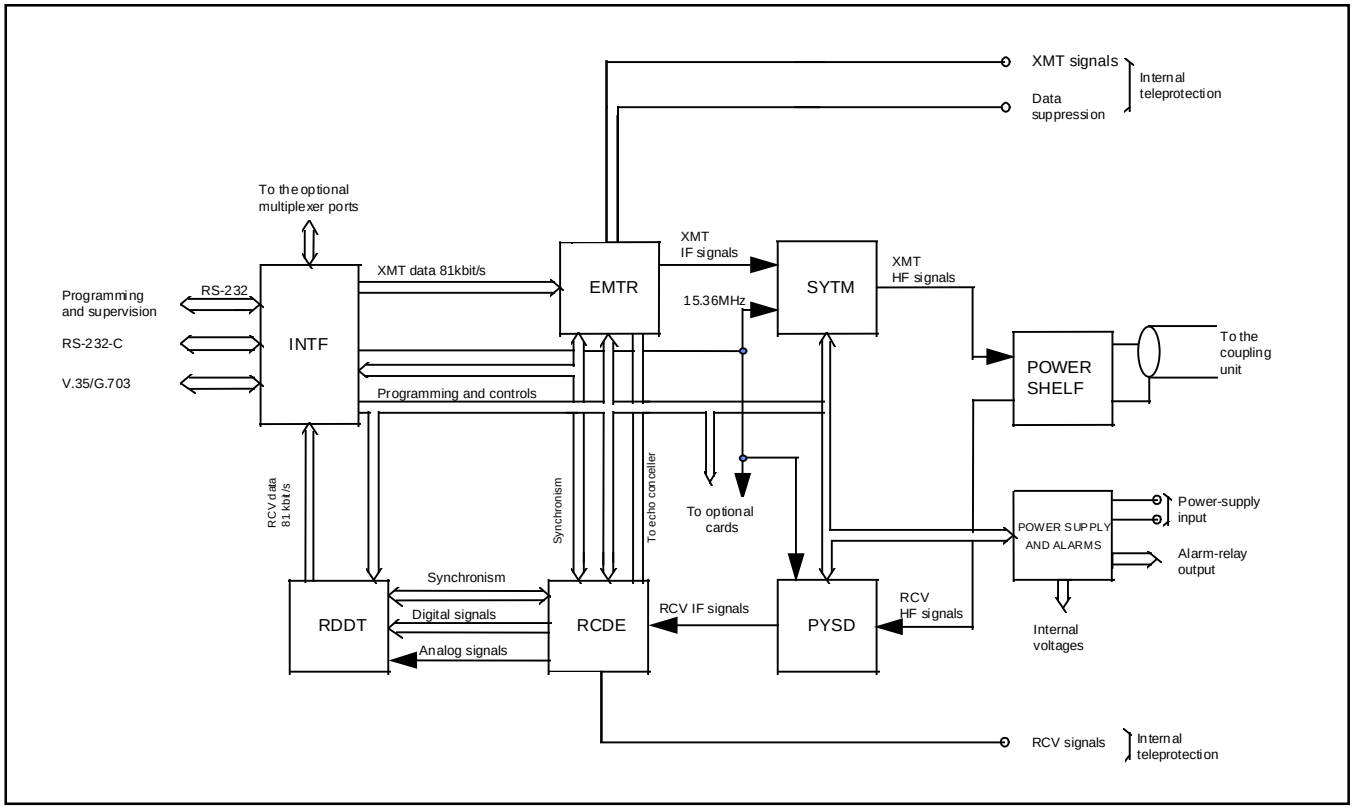

Figure 2. RFL 9506D Simplified Block Diagram

OPERATIONAL DESCRIPTION

Transmission is carried out at a gross bit rate of 81 kbit/s, where 1 kbit/s is used for synchronization, 1 kbit/s for the internal service channel, and 79 kbit/s are available for the user. The RFL 9506D can be programmed to operate at speeds lower than the nominal gross bit rate (40.5 or 27 kbit/s) for cases when there is excessive noise in the PLC link.

The RFL 9506D, as shown in the block diagram above, consists of a user interface (INTF module), a high-speed modem (EMTR, RCDE and RDDT modules), a frequency converter (SYTM and PYSD modules), and a power shelf. In addition, the RFL 9506D can be equipped with up to three optional MMXA multiplexer modules. The RFL 9506D terminal can also be equipped with TPMB and TPCB analog teleprotection modules for the transmission of up to three independent commands.

User Interface

The INTF (user interface card) includes two data ports, one of which is synchronous and the other asynchronous.

The synchronous port has an interface that compiles with ITU-T Recommendation V.35, and supports a data channel of up to 72 kbit/s. The asynchronous port has an interface that complies with ITU-T Recommendation V.24/V.28 (RS-232C), and supports a data channel of up to 14.4 kbit/s.

As an option, the V.35 interface can be replaced with a co-directional or contra-directional G.703 interface.

The 79 kbit/s that are available for user information provides for different input combinations as described on page 4, under the "Optional Multiplexer" heading. The INTF card also includes the circuits for the following:

Programming and supervision of the equipment
The INTF card has a front panel mounted RS-232C interface (with a transmission speed of 300 to 9600 bit/s), a microprocessor, a real time clock, memory to store the programming parameters, and memory to store sequence of events data.

Frame generation and recovery
Data proceeding from the interface circuits, together with bits for synchronization and for the internal service channel is framed in this card and sent to the transmit circuits. Furthermore, frame synchronism is recovered from the received data which is disassembled, decoded, and sent to the output circuits.

Speech service channel
When it is necessary to use the speech service channel, the fact that it occupies 16 kbit/s of the overall frame must be taken into account. If the equipment operates at the maximum capacity, the user must decide, by programming, which services can be suppressed when the speech service channel is used.

Frequency synthesizer
The frequency synthesizer generates the carriers that are necessary for the frequency conversions by means of a highly stable quartz oscillator and frequency division circuits.

Internal process clocks
There are three ways in which the transmit clocks can be generated. These are by means of a master oscillator, by applying an external clock signal to the high-speed synchronous port, or by using the clock recovered from the received signals. The receive circuit synchronism is generated from the clock recovered from the received signals.

Control and management of the multiplexer
The different input channels, according to their rates, are distributed over the frame. In addition, the different ports of the multiplexer are supervised.

High Speed Modem

The high speed modem consists of the EMTR module on the transmit side, and the RDCE/RDDT modules on the receive side.

Transmit Side
The data stream proceeding from the INTF user interface card is encoded into symbol sequences according to a 128 QAM signal space. For this purpose the data is subjected to the following process: scrambling, serial-to-parallel conversion, differential encoding, convolutional encoding (Trellis encoding), symbol mapping, pulse-shape filtering, and QAM modulation.

Digital signals obtained in this way are converted into analog bandpass signals between 28 kHz and 44 kHz. These signals are then sent to the SYTM frequency converter module.

The EMTR module has an output for displaying the signal space constellation by means of an external analog oscilloscope. This module also contains the internal teleprotection signal input circuits.

Receive Side
The analog bandpass signals proceeding from the PYSD frequency converter card enter the RCDE module where they are subjected to an AGC process and then converted to digital signals, which are bandpass filtered for selectivity purposes. Filtered signals are applied to an echo canceller device where the spurious transmit signals that superimpose the incoming receive signals are canceled by means of a processed signal from the transmitter. Signals are then converted back to analog and sent to the RDDT module. When the echo canceller is not used, digital filtered signals are sent directly to the RDDT module.

Teleprotection signals are extracted from the digital signals before echo cancellation, converted to analog, and then sent to the output.

Analog data signals that enter the RDDT module are converted again to digital and then demodulated and decoded in order to be sent to the INTF interface module. Adaptive equalization is carried out in this card.

As with the transmit side, the signals required to display the signal space constellation on an external analog oscilloscope are available.

Frequency Converter and Power Shelf

The bandpass signals supplied by the EMTR module are sent to the SYTM module and are transposed to the desired frequency band by means of a double modulation process. The second modulation carrier frequency is programmable and is generated by means of a Direct Digital Synthesis technique (DDS). The HF signals so obtained are amplified and sent to the line through the transmit filter and HF hybrid (JFLH module).

The transmit and receive bands can be either superimposed or separated. The 16kHz wide transmit filter is fully adjustable over the operating range of 40 to 500 kHz.

The HF hybrid can be disconnected when non-adjacent bands are used for transmission and reception. The receive signals, which can be collected from the output of

the high frequency hybrid or directly from the line, depending on whether superimposed or non-adjacent bands are used, are sent to the PYSD module where they pass through a receive bandpass filter and then are subjected to a double demodulation process before being sent to the RCDE module. The first demodulation carrier frequency is programmable and is generated by means of the DDS. The 16 kHz wide receive filter is also fully adjustable over the operating range of 40 to 500 kHz.

Programming

All parameters involved in the operation of the RFL 9506D terminal, such as carrier frequencies, parameters of speech and data ports, teleprotection parameters, etc., are programmed by an external personal computer. Transmit and receive filters are manually adjusted with the aid of the software provided with the system.

Supervision of the local and remote terminals is also carried out from a personal computer. It allows different parameters of the communication link, such as transmission quality, chronological event and alarm registering, receive signal levels etc., to be made known.

Optional Multiplexer

Flexibility is the main characteristic of the multiplexer which allows different channels, ranging from 50 bit/s to 38.4 kbit/s, to share the system net bit rate of 79, 39.5, or 26.3 kbit/s.

Any multiplexer input combination is possible, as long as the total rate of all the channels does not exceed the net bit rate selected above.

The different channels for speech and/or data transmission can access the high speed modem through a maximum of eleven ports. Two of the eleven ports are data ports which are located on the INTF module. The remaining ports are provided by optional MMXA modules. Since each of these MMXA multiplexer modules controls up to three ports, nine additional ports are available when all three MMXA modules are equipped.

The programming and configuration of the ports of the multiplexer is carried out by means of the programming system of the RFL 9506D terminal.

In order to check the correct operation of the ports of the multiplexer, the program allows a loop to be effected at the input/output level, or allows the service associated with a particular port to be deactivated. The characteristics of each MMXA module port are determined by the type of associated submodule(s).

Three different submodules and a subscriber side adapter are available:

KDMX Data Submodule
This submodule contains a synchronous, asynchronous or anisochronous data port with an interface that complies with ITU-T Recommendation V.24/V.28 (RS-232C). Table 1 below shows the data speed allowed for each type of channel according to the gross bit rate of the system.

	System Capability		
	81 kbit/s	40.5 kbit/s	27 kbit/s
Synchronous Port	600 bit/s to 38.4 kbit/s	600 bit/s to 38.4 kbit/s	600 bit/s to 19.2 kbit/s
Asynchronous Port	50 bit/s to 28.8 kbit/s	50 bit/s to 28.8 kbit/s	50 bit/s to 19.2 kbit/s
Anisochronous Port	up to 1440 bit/s	up to 1440 bit/s	up to 1440 bit/s

Table 1. Speed of the Data Ports

KVMX Voice Submodule
This 16 kbit/s speech submodule can be used for a 2/4-wire termination with E&M signaling, or for a 2-wire exchange side termination for a telephone subscriber circuit.

This submodule contains an ADPCM device that codifies speech signals which come from a telephone or an exchange and generates a 16 kbit/s digital signal.

If E&M signaling is employed, 1 kbit/s of the overall frame is used when operating at a gross bit rate of 81 kbit/s. The use becomes 500 bit/s or 333 bit/s at gross bit rates of 40.5 or 27 kbit/s, respectively.

KAVX Voice Submodule
This programmable speech submodule has a speed of 4800, 6400 or 8000 bit/s for a 2/4-wire termination with E&M signaling, or for a 2-wire exchange side telephone termination. Built-in error correction provides perfectly clear voice reception.

The operation of this submodule is based on MP-MLQ multi-pulse encoding. This termination allows for the transmission of G3 fax signals at a rate of up to 7200 bit/s.

The KAVX submodule can use "in-band" signaling (codified in the speech signal) or "out-of-band" E&M signaling. If E&M signaling is employed, 1kbit/s of the overall frame is used when operating at a gross bit rate of 81kbit/s.

KALT Circuit
This subscriber termination circuit is added to the relevant voice submodule when a 2-wire telephone connection is required. The associated ring generator is included in the corresponding multiplexer module.

Optional Teleprotection Equipment

Built-in teleprotection equipment is available, based on the use of digital signal processing, which can be constituted by either one or two different modules according to the users requirements.

TPMB Basic teleprotection module
This module contains the Digital Signal Processor (DSP), which carries out the generation of the guard and trip tones and the implementation for the filters for the reception of these tones. An auxiliary microcontroller makes a decision upon command reception, takes charge of the logical management of inputs and outputs, supervises the link, and carries out both automatic and manual tests. This module also contains the input and output circuits for the transmission and reception of one command.

TPCB Teleprotection module up to two additional commands
Input and output circuits for the additional commands are contained on this module.

TECHNICAL CHARACTERISTICS

High Frequency Characteristics

Frequency Range: 40 kHz to 500 kHz

Transmission and reception bands: Superimposed or non-adjacent

Bandwidth: Superimposed bands =16 kHz; Non-adjacent bands =16 kHz in each direction.

Center frequency: Programmable in 1 Hz steps

Carrier frequency input/output: Selectable between balanced and unbalanced

Nominal impedance: Selectable at 50, 75, 125, or 140 Ohms

Return loss: Greater than 11 dB

Balance to ground: Greater than 40 dB at power frequency

Tapping loss: In accordance with IEC 495, Fig. A.1 with n=4.

Insulation Withstand Voltages: IEC 870-2-1, class VW3

High frequency disturbance: 2.5kV for common mode, 1.25 kV for differential mode per IEC 870-2-1 level III

Fast Transient: 2kV in accordance with IEC 870-2-1 level III

Transmitter
Maximum output power of the QAM signal over a resistive load:
+40 dBm which corresponds to a PEP of 80W (+49dBm).

Nominal power:
+37 dBm (adjustable from +1 to -6 dB)

Transmit filter bandwidth: 16 kHz, adjustable in 1 Hz steps.

Receiver

Receive filter bandwidth: 16 kHz, adjustable in 1 Hz steps

Maximum power at the input: +40 dBm in the 16 kHz band

Trans-hybrid attenuation: >20 dB

Sensitivity: -10 dBm (average of the QAM signal)

Selectivity: Higher than 65 dB at 300 Hz, and starting from 4 kHz, higher than 80 dB, in accordance with IEC 495 clause 5.3.1.5

AGC range: 50 dB

Minimum S/N ratio at receiver input at 81 kbit/s: 25 dB for an error probability of 10^{-9} with white guassian noise.

General Characteristics of the Modem

Modulation: 128 or 16 QAM with Trellis coding, 4 QAM

Gross bit rate: 81 kbit/s, 40.5 kbit/s, or 27 kbit/s

Max. user data rate: 79 kbit/s, 39.5 kbit/s, or 26.3 kbit/s

Test facilities: HF loop, local and remote port loops. Possibility of displaying the XMT and RCV signal space constellation on an external analog oscilloscope.

User Interfaces

Basic equipment: One synchronous data port up to 72 kbit/s with ITU-T V.35 or G.703 interface. One asynchronous data port up to 14.4 kbit/s with EIA RS-232C interface

Options: Up to a total of nine ports for speech and/or data transmission, mounted on up to three MMXA modules.

Speech ports: At 16 kbit/s (ADPCM). From 4.8 kbit/s to 8 kbit/s (MP-MLQ)

Connection: 2-wire, or 2/4-wire with E and M signaling, or DTMF

Data ports: Synchronous, asynchronous or anisochronous. Programmable from 600 bit/s to 38.4 kbit/s for synchronous channels, from 50 bit/s to 28.8 kbit/s for asynchronous channels, and up to 1440 bit/s for anisochronous channels.

Interface: V.24/V.28

Other Characteristics

Alarms: Power supply failure, power amplifier failure, high RCV level, low RCV level, frequency synthesizer failure, loss of synchronism, card out, BER $>10^{-3}$, BER$> 10^{-6}$, terminal in test condition. Both local and remote alarms are displayed on each terminal. A chronological register of the alarms is maintained.

Alarm display: By means of LEDs

External alarm contacts: Provided by four relays to which the alarms can be assigned from a personal computer.

Contact rating: 250 V/1 A

Interface for the programming and supervision system: EIA RS-232C, Transmission rate: 300, 600, 1200, 2400, 4800 and 9600 bit/s, selectable by the user.

Operating Conditions

Temperature and humidity: From -5° to +45°C and relative humidity not greater than 95% in accordance with IEC 870-2-2, class C1

Maximum temperature: +55 °C for a period not greater than 24 hours (IEC 495 clause 3.1)

Power supply voltage: 48 Vdc ±20% or 125 Vdc ±20% Other voltages on request.

Nominal power consumption: Basic Terminal = 160W, optional MMXA modules = 20W, and optional teleprotection modules = 15 W

Power supply insulation: In accordance with IEC 870-2-1, class VW3

EMI and EMC: In accordance with IEC 870-2-1, class B

Storage conditions: In accordance with IEC 870-2-2, class C3

Mechanical Characteristics

Dimensions: 19” (w) x 15.75” (h) x 12.75” (d) (482 x 400 x 324 mm)

Weight: 57 pounds (26 kg)

Specifications subject to change without notice.

Notes:

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