Fiber Optic Time and Frequency Transfer Modem

VCH-608

Operating Manual

Table of Contents

1 List of Abbreviations

AC – Alternating current;

ADEV – Allan deviation;

AGC – Automatic gain control system;

FC/APC– Fiber connector / angled physical contact;

FOCL – Fiber optic communication line;

FTS – Frequency and time standard;

ITU-T – The ITU Telecommunication Standardization Sector of the International Telecommunication Union (ITU);

LD – Laser diode module containing a laser diode and feedback photodiode;

OM – Operating manual;

ORL – Optical return loss;

ORTM – Optical receiving and transmitting module;

PM – Paired modems: transmitter modem and receiver modem.

PD – Photodiode module containing a photodiode, a transimpedance amplifier, and an automatic gain control system;

TCPS – Temperature coefficient of phase shift of the modem electrical sinusoidal signal due to changes in the temperature of the air surrounding the modem.

2 Safety requirements

Carefully read the operating manual before working with the device and note the safety information.

Attention! BEFORE TURNING ON THE MODEM POWER, MAKE SURE THAT A PROTECTIVE PLUG OR A CONNECTED OPTICAL CABLE IS INSTALLED ON THE MODEM OPTICAL CONNECTORS!

Accessible conductive parts of the device are protected by basic insulation and electrically connected to the protective grounding.

The device is grounded via the protective conductor in the power cable and/or the protective earth terminal  marked on the rear panel.

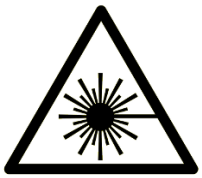
When using the rear panel terminal, the protective grounding must be connected before the modem is connected to AC power. When using the modem with other devices, all devices must be grounded.

Attention! DO NOT OPERATE THE MODEM WITHOUT PROTECTIVE GROUNDING!

The device is connected to AC power via the three-wire power cable (two poles and ground) included in the delivery set.

Do not touch current-carrying elements during repair or when checking component operating modes, since the modem contains AC voltage of 220 V. Repair and operation of the modem must be carried out by qualified personnel authorized to work with high voltage (up to 1000 V).

Warning! PARTS MAY BE REPLACED ONLY WHEN THE MODEM IS POWERED OFF!



CLASS 1 LASER EQUIPMENT
INVISIBLE LASER RADIATION
. DO NOT LOOK INTO THE ENDS OF THE OPTICAL CONNECTORS

Do not look into the ends of the fiber optic cable, optical cable connectors, or optical modem connectors.

Do not use optical equipment (microscopes, lenses, etc.) that is not designed for work with optical fiber.

Using these instruments near active optical fibers can focus the light beam on the retina and cause irreversible damage to vision.

Avoid getting optical fiber fragments on clothing or skin if the optical fiber is mechanically damaged.

The resulting fragments should be collected in tightly closed containers or on adhesive tape and disposed of only after being packaged.

3 Device description and operating principles

The external view of the device is shown in Figure 1.

Figure 1 – External view

3.1 Application and operating conditions

The VCH-608 fiber-optic time and frequency transfer modem is designed to receive and transmit atomic clock signals (FTS) through a fiber optic communication line (FOCL). The signals are:

- 1 PPS with delay compensation;
- sinusoidal 5 MHz, 10 MHz, or 100 MHz signals with phase instability compensation.

In addition, the VCH-608 generates sinusoidal signals with nominal frequencies of 5 and 10 MHz at the remote end of the FOCL, coherent with the input signal.

Reception and transmission of high-precision FTS signals via the FOCL is provided using a pair of modems: one is configured as a Transmitter and installed at the FOCL end where the FTS signal source is located; the other is configured as a Receiver and installed at the opposite end of the FOCL.

Key applications

- time scale comparison and synchronization systems;
- production and testing of high-precision oscillators and devices based on them;
- tasks related to ensuring measurement uniformity when determining the metrological parameters of atomic clocks;
- distributed signal processing systems that require coherent synchronization, e. g. antenna arrays;
- scientific research.

Operating conditions

Normal operating conditions:

— Air temperature: (20 ± 5) °C;
— Relative humidity: from 30 to 80 %;
— Atmospheric pressure: from 84 to 106 kPa (from 630 to 795 mm Hg);
— Power supply: (220 ± 4.4) V.

Working operating conditions:

— Air temperature: from +5 to +40 °C;
— Relative humidity: up to 90 % at +25 °C;
— Atmospheric pressure: from 70 to 106.7 kPa (from 537 to 800 mm Hg);
— Power supply: (220 ± 22) V;
— Power supply frequency: (50 ± 2) Hz.

Extreme operating conditions:

— Air temperature: from -40 to +50 °C;
— Relative humidity: up to 95 % at +25 °C.

The modem retains its technical characteristics within specification limits after exposure to extreme climatic conditions, followed by exposure to normal (working) operating conditions for 24 hours.

Modem designation for ordering or reference in external documentation:

Fiber optic time and frequency transfer modem VCH-608 (modification).

Modification code interpretation – **VCH-608**.X_1X_2 (all modifications are for rack mounting with cables connected to the rear panel of the device), where X_1 and X_2 mean:

X_1 – additional modem modules:

$X_1 = 0$ – no additional modules;

$X_1 = 1$ - frequency multiplier 5/10-100 MHz (hereinafter referred to as the *multiplier*);

$X_1 = 2$ – frequency synthesizer (*synthesizer*);

X_2 – optical radiation wavelengths (for transmission of 100 MHz and 1 PPS signals, respectively):

$X_2 = 0$ – 1550; 1530 nm;

$X_2 = 1$ – 1310; 1330 nm;

$X_2 = 2$ – 1310; 1550 nm;

$X_2 = 3$ – 1550; 1310 nm;

$X_2 = 4$ – 1310; 1310 nm;

$X_2 = 5$ – 1550; 1550 nm.

Note - The trailing zeros in the modification designation may be omitted; that is, the designation VCH-608.10 is identical to the designation of modification VCH-608.1; VCH-608.20 is identical to the designation of modification VCH-608.2; VCH-608 is identical to the designation of modification VCH-608.00.

Designation examples:

Fiber optic time and frequency transfer modem VCH-608 mod. VCH-608.00

This entry means: the modem is designed for rack installation with cables connected to the rear panel of the device, contains no additional modules, uses an optical radiation wavelength of 1550 nm to transmit 100 MHz signals, and uses an optical radiation wavelength of 1530 nm to transmit 1 PPS signals.

Fiber optic time and frequency transfer modem VCH-608 mod. VCH-608.12

This entry means: the modem is designed for rack installation with cables connected to the rear panel of the device, contains a multiplier, uses an optical radiation wavelength of 1310 nm to transmit 100 MHz signals, and uses an optical radiation wavelength of 1550 nm to transmit 1 PPS signals.

Fiber optic time and frequency transfer modem VCH-608 mod. VCH-608.22

This entry means: the modem is designed for rack installation with cables connected to the rear panel of the device, contains a synthesizer, uses an optical radiation wavelength of 1310 nm to transmit 100 MHz signals, and uses an optical radiation wavelength of 1550 nm to transmit 1 PPS signals.

3.2 Product specifications

Modem configuration

The modem is configured using the supplied cable kit as a Transmitter (transmitting modem) or Receiver (receiving modem).

Optical characteristics

The total optical output power of any optical port for each of the 1310 nm (O-band) and 1550 nm (C-band) telecommunication windows is not more than 10 mW (+10 dBm), while all wavelengths emitted by the modem are only in the O-band and C-band.

The permissible loss of optical power between modems:

– direct: at least 15 dB;

– return loss (ORL): must exceed the direct loss by at least 20 dB.

Input harmonic signal (to be transmitted via the FOCL), «⊖ 100 MHz-Ref» connector of the Compensator module:

– nominal frequency value of 100 MHz;

–root-mean-square (RMS) voltage value: (1.0 ± 0.2) V.

Additional input harmonic signals (to be transmitted via the FOCL) for the VCH-608.1X_2 modification, «⊖ 5/10 MHz» connector of the Multiplier module:

– nominal frequency value of 5 or 10 MHz (according to the modification);

– root-mean-square (RMS) voltage value: (1.0 ± 0.2) V.

Output harmonic signals:

«⊖ **100 MHz»** connector of the Compensator module (100 MHz output signal of the receiving modem):

- nominal frequency - 100 MHz;
- RMS voltage value: (1.0 ± 0.2) V at a load resistance of (50 ± 1) Ω.

«⊖ Synthesis 1», «⊖ Synthesis 2» connectors of the Synthesizer module (additional output signals of the receiving modem):

- permissible nominal frequency: 5 or 10 MHz (or other frequencies on request);
- RMS voltage value: (1.0 ± 0.2) V at a load resistance of (50 ± 1) Ω.

Frequency instability of the electrical sinusoidal signal added by paired modems

Since reception and transmission of atomic clock signals via a FOCL is provided using a pair of modems, the added frequency instability is also measured for a pair of modems: transmitting and receiving. Then the receiving and transmitting modems switch roles. The worst result is taken as the characteristic value.

The added frequency instability for a 100 MHz harmonic signal is measured between the input of the transmitting modem («⊖ 100 MHz-Ref» connector of the Compensator) and the output of the receiving modem («⊖ 100 MHz» connector of the Compensator).

Frequency instability values (ADEV) not exceeding those specified in Table 3.1 are guaranteed when the air temperature changes by no more than ± 0.3 °C per hour

(within the operating temperature range) while meeting the optical loss requirements specified in clause 3.2.3 of this OM.

Table 3.1 - Frequency instability (ADEV) of the electrical sinusoidal signal

Averaging time (τ), s	ADEV added by paired modems
1 s	$1.0 \cdot 10^{-13}$
10 s	$1.5 \cdot 10^{-14}$
100 s	$4.5 \cdot 10^{-15}$
1000 s	$5.0 \cdot 10^{-16}$

Frequency instability of the electrical sinusoidal signal added by the multiplier

The frequency instability added by the multiplier included in the VCH-608.1X_2 modem modifications is measured between the «⊖ **5/10 MHz**» input and the «⊖ **100** MHz» output of the Frequency Multiplier.

Frequency instability values (ADEV) of not more than $4.0 \cdot 10^{-14}$ measured over a time interval of 1 s are guaranteed when the air temperature changes by no more than ± 0.3 °C per hour (within the operating temperature range).

Frequency instability of the electrical sinusoidal signal added by the synthesizer

The frequency instability added by paired modems for additional harmonic signals of 5 MHz, 10 MHz, or other frequencies fo_r VCH-608.2X_2 modifications is measured between the «⊖ **100 MHz**» input and the « ⊖**Synthesis 1»** and «⊖ **Synthesis 2**» outputs of the Synthesizer.

Frequency instability values (ADEV) of not more than $8.0 \cdot 10^{-14}$ measured over a time interval of 1 s are guaranteed when the air temperature changes by no more than ± 0.3 °C per hour (within the operating temperature range).

Temperature coefficient of phase shift (TCPS) of the modem

TCPS is the phase shift of a 100 MHz electrical harmonic signal transmitted by paired modems when the temperature of the air surrounding the device changes:

– for the device operating in the "Reception" mode, not more than $5.0 \cdot 10^{-12}$ s/°C;

– for the device operating in the "Transmission" mode, not more than $5.0 \cdot 10^{-12}$ s/°C.

Input pulse signals of 1 Hz

(the signal to be transmitted through the FOCL is applied to the «⊖ ⎍⎍⎌» connector of the ORTM):

–pulse polarity: positive;

–pulse amplitude: from 2.5 to 5.0 V;

–pulse duration: from 10 to 20 microseconds;

- duration of the pulse rise/fall time: not more than 3 ns.

Output pulse signals of 1 Hz

(the output signal of the receiving modem, output from the « ⊖→»⎍⎍⎌ connector of the ORTM):

– pulse polarity: positive;

– pulse amplitude: from 2.5 to 5.0 V at a load resistance of 50 Ω;

– pulse duration: from 10 to 20 microseconds;

– duration of the pulse rise/fall time: not more than 3 ns.

Synchronization error during 1 PPS time signal transmission

The synchronization error when transmitting a 1 PPS time signal is not more than 300 ps. It is measured between the «⊖ ⎍⎍⎌» ORTM connector of the transmitting modem and «⊖→ ⎍⎍⎌» ORTM connector of the receiving modem. Then the receiving and transmitting modems switch roles. The worst result is taken as the characteristic value (not more than 300 ps).

Note - The synchronization error values are guaranteed when the air temperature changes by no more than ± 0.3 °C per hour (within the working operating conditions) while meeting the optical loss requirements specified in clause 3.2.3 of this OM.

Warm-up time: no more than 2 hours.

The device meets its specifications under working operating conditions after a 2-hour warm-up time.

Note – Input signals must be supplied to the modem inputs during the warm-up time.

Modem reliability characteristics

3.2.1.1 Mean time between failures: at least 20.000 hours.

3.2.1.2 Gamma-percentage resource with confidence probability γ=0.95: at least 100.000 hours.

3.2.1.3 Gamma-percentage lifetime with confidence probability $\gamma = 0.95$: at least 12 years.

3.2.1.4 Gamma-percentage storage life of the modem with confidence probability $\gamma = 0.95$:

- at least 15 years for heated storage facilities;
- at least 3 years for unheated storage facilities.

The device provides continuous, uninterrupted operation under working conditions with all specifications preserved.

The device retains its specifications when powered by (220 ± 22) V, (50 ± 2) Hz AC.

Power consumption is not more than 30 V·A (220 V AC).

Weight: not more than 8 kg. In the packing case: not more than 25 kg.

Dimensions (H×W×D): 140 × 483 × 328 mm.

3.3 Product composition

The delivery set is given in Table 3.2.

Table 3.2 – Delivery set

Name, type	Designation	Quantity	Note
1 Fiber-optic modem VCH-608	ЯКУР.411145.021	1	mod. _____ according to the delivery contract
2 Fuse holder ВП2Б-1В 2А	ОЮО.481.005 ТУ-Р	2	
3 HF connecting cable	ЯКУР.685670.372	1	
4 HF connecting cable	ЯКУР.685670.693	2	
5 HF connecting cable	ЯКУР.685670.795	3	
6 Power cable	SCZ-1	1	
7 Interface cable	USB2.0 AM/BM - 1.8 m	1	
8 Optical attenuator	Att-FM FC/APC-SM 2 dB	1	*4)
	Att-FM FC/APC-SM 15 dB	1	*1)
9 Optical cord	ШОС-3.0-FC/APC-FC/APC-SM-2m-G657A1	1	*4)
	ШОС-breakout-4x2.0-4FC/APC-4FC/APC-SM-2m-LSZH	1	*5)
	ШОС-breakout-4x2.0-4FC/APC-4FC/APC-SM-80m-LSZH	1	*1)
10 HF connecting cable	ЯКУР.685670.796	3	*2)
		2	*3)
11 Set of operating documentation			
11.1 Operating manual	ЯКУР.411145.021РЭ	1	
11.2 Verification procedure	ЯКУР.411145.021МП	1	
11.3 Device form	ЯКУР.411145.021ФО	1	
12 Packing and transportation case	ЯКУР.411915.135	1	
Notes *: *1) under a separate agreement; *2) for modems mod. VCH-608.1X_2, VCH-608.2X_2, with X_2 from 0 to 5; *3) for modems mod. VCH-608.0X_2; *4) for modems mod. VCH-608. X_1X_2, with X_2 from 0 to 3; *5) for modems mod. VCH-608. X_1X_2, with X_2 from 4 to 5;			

3.4 Basic configuration and operation

To receive and transmit sinusoidal 100 MHz and pulsed 1 PPS signals of atomic clocks via the FOCL, paired modems are used: transmitting and receiving. The operating mode of each modem - transmitting or receiving - is set using an HF (high-frequency) jumper cable. This allows the transmitting and receiving modems to switch roles without physically moving them. To compensate for phase instability of the 100 MHz sinusoidal signal, as well as instability of the 1 PPS pulse delay, pre-distortion is introduced into the transmitted signals. To determine the necessary phase changes of the transmitted signals, the 100 MHz and 1 PPS signals received by the receiving modem are re-emitted back to the transmitting modem side; therefore, the FOCL used must be bidirectional, i.e. able to transmit signals in both directions. This can be implemented using four fibers of a single cable for the VCH-608.$X_1$4 and VCH-608.$X_1$5, or using a single fiber and optical circulators (OCs) for the remaining modems.

The method for connecting the modems' optical ports to the FOCL depends on the modem modification (Figure 3.1).

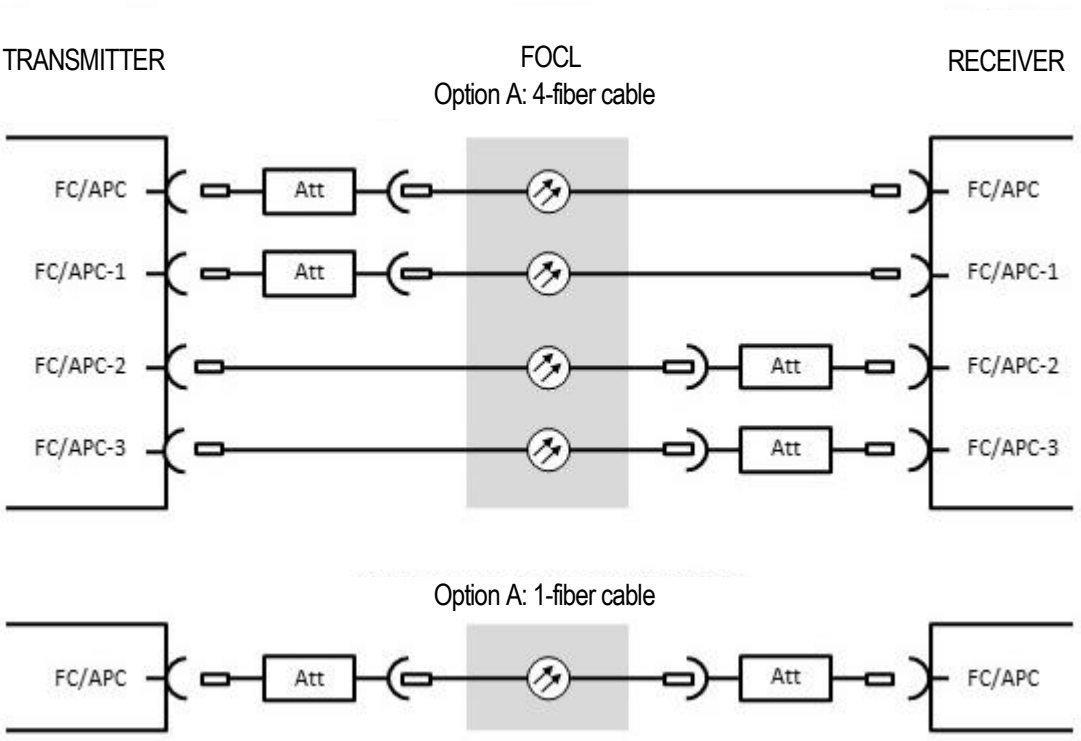


Figure 3.1 – Modem connection options via optical ports

To connect modems VCH-608.$X_1$4 and VCH-608.$X_1$5, use option A; for other modem modifications, use option B.

All device units are implemented as modules with input and output connectors.

All modules are inserted into the modem case from the rear panel along specific rails and are connected by a common cross-board.

The top and bottom of the modem are covered with easily removable covers with ventilation holes.

The device consists of the following modules:

A1 – Voltage converter ~220\±12, +5, +3.3 V;

A2 – Optical receiving and transmitting module ЯКУР.433784.004 (A2-1) or ЯКУР.433784.003 (A2-2). ЯКУР.433784.004 is installed in modem modifications VCH-608.$X_1$4 and VCH-608.$X_1$5; ЯКУР.433784.003 is installed in other modem modifications;

A3 – 100 MHz 2-channel Amplifier;

A4 – Compensator;

A5 – Synthesizer (A5-1: for VCH-608.2X_2 modem modification only) or Frequency multiplier 5/10-100 MHz (A5-2: for VCH-608.1X_2 modem modification);

A6 – Cross-board.

A1) Voltage converter ~220\±12, +5, +3.3 V

Powered from a 220 V AC supply, the Voltage Converter generates stabilized voltages (±12 V, +5 V, +3.3 V) to power the device modules. The Voltage Converter indicators "+5 V", "+12 V", and "-12 V" show the presence of the corresponding stabilized output voltages.

A2-1) Optical receiving and transmitting module (ORTM) ЯКУР.433784.003

The block diagram of the ORTM is shown in Figure 3.2.

The ORTM is implemented using an LD, which converts input electrical signals into intensity-modulated optical signals, and a PD, which converts optical signals into voltage-modulated electrical signals. The PD contains a transimpedance amplifier with AGC. The PD has a low-frequency cutoff from 15 to 25 kHz; therefore, to transmit a 1 PPS signal, the signal must be converted into a synchronized pulse sequence containing a 1 PPS timestamp and having a pulse repetition frequency exceeding the

cutoff frequency. The conversion is carried out by an FPGA-based pulse signal generator.

A sinusoidal electrical signal from the «⊖ **100 MHz**» input connector is sent to the inputs of buffer amplifiers BA1 and BA2. The CLK signal taken from BA1 is used as the FPGA clock signal, and the signal taken from BA2 is used as the modulating voltage for LD1.

The 1 PPS electrical signal is sent to the pulse signal generator from the input connector «⊖⎍», where it is converted into a signal that is then sent to LD2.

The operating modes of both LDs (the operating point on the power-current characteristic in the absence of modulation) are set using precision adjustable current sources. Thus, the total emitted LD power consists of constant bias power (operating point) and modulating signal power.

The precision adjustable current source includes a digital potentiometer controlled by a digital control unit. The current value is set by programming via the JTAG and SPI interfaces during ORTM adjustment.

Optical signal TX1 from the LD1 output via the first and second ports of CO1 and TX2 via the first and second ports of CO2 have different wavelengths and are combined into one fiber using an optical multiplexer. The combined optical signal is sent to the FOCL through the "FC/APC" optical port for transmission to the paired modem.

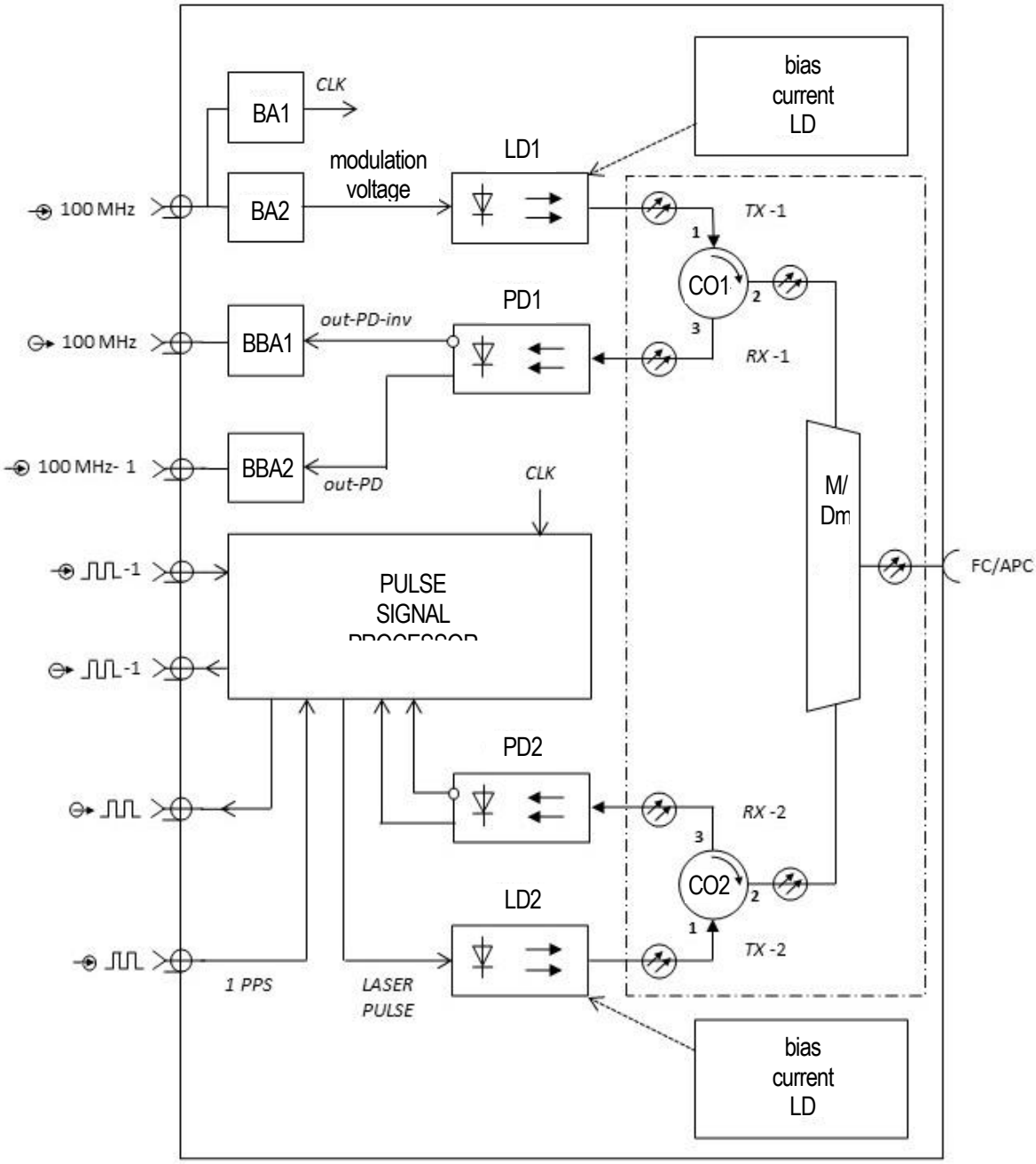


Figure 3.2 – Block diagram of ЯКУР.433784.003 ORTM

From the inverse output of PD1, the "out-PD-inv" signal is sent to broadband amplifier BBA1, where it is amplified and output via the «⊖→ **100 MHz**» connector to adjacent modem modules:

– input «–⊖ **100 MHz–Ref**» of the Compensator, if you need to receive 100 MHz signals;

– input «–⊖ **100 MHz**» of the Synthesizer, if you need to receive 5 and/or 10 MHz signals;

– inputs of both the Compensator and the Synthesizer through an external signal splitter if the receiving side simultaneously requires 100 MHz signals and at least one of the 5 or 10 MHz signals. From the direct output of PD1, the "out-PD" signal is sent to BBA2, where it is amplified and output through the «**100 MHz-1**» connector, which must be connected by an external jumper cable to the «**100 MHz**» connector to modulate LD1 and as a CLK signal for the modem when operating in receiver mode, thereby reflecting the received optical signal to the transmitting modem.

The differential signal from the non-inverting and inverting outputs of PD2 is supplied to the pulse signal generator, which then outputs a 1 PPS pulse signal from the « » connector to the consumer's equipment; for pulse modulation of LD2 of the receiving modem, a LASER PULSE signal is generated containing a 1 PPS timestamp and having a pulse repetition frequency exceeding the cutoff frequency of the PD used in the modem.

A2-2) Optical receiving and transmitting module ЯКУР.433784.004

The block diagram of the ORTM is shown in Figure 3.3.

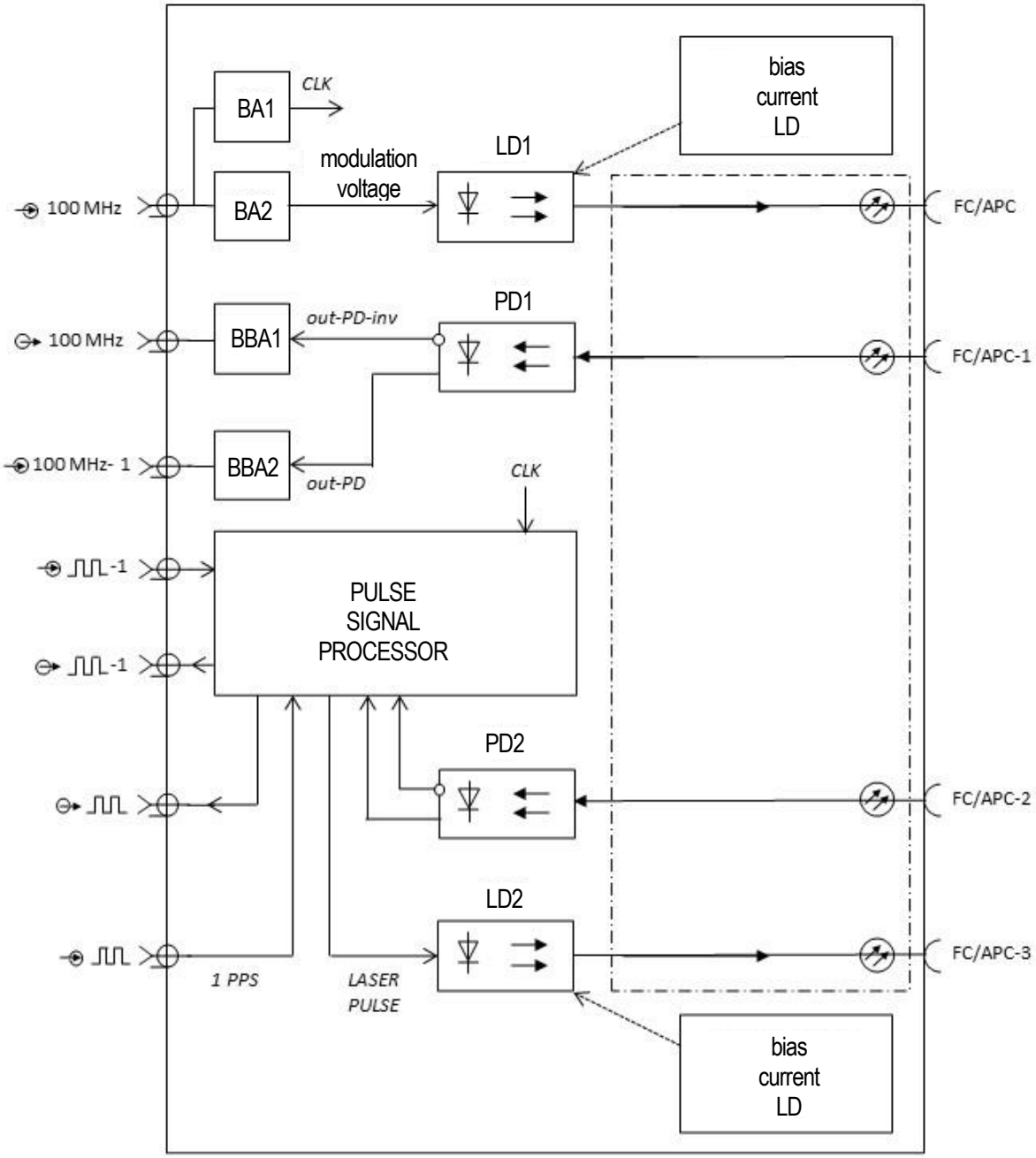


Figure 3.3 – Block diagram of ЯКУР.433784.004 ORTM

Unlike ORTM ЯКУР.433784.003, it does not contain circulators (CO1 and CO2) or the multiplexer/demultiplexer "M/Dm" (Figure 3.2). Optical ports LD1, PD1, LD2, and PD2 are connected to four optical fibers through FC/APC, FC/APC-1, FC/APC-2, and FC/APC-3 feedthrough adapters, respectively. This prevents reflections from the FOCL to PD1 and PD2, increasing the signal transmission distance.

A3) 100 MHz 2-channel Amplifier

It is used on long-distance FOCLs with large direct optical losses. It increases the FOCL optical budget by 5 dB through fuller use of the dynamic range of the photodetector modules used in the modem. The voltage gain is set by the manufacturer to 10 dB by default, or at the customer's request (to maximize compliance with FOCL optical losses) within 10 dB.

A4) Compensator

The block diagram of the compensator is shown in Figure 3.4.

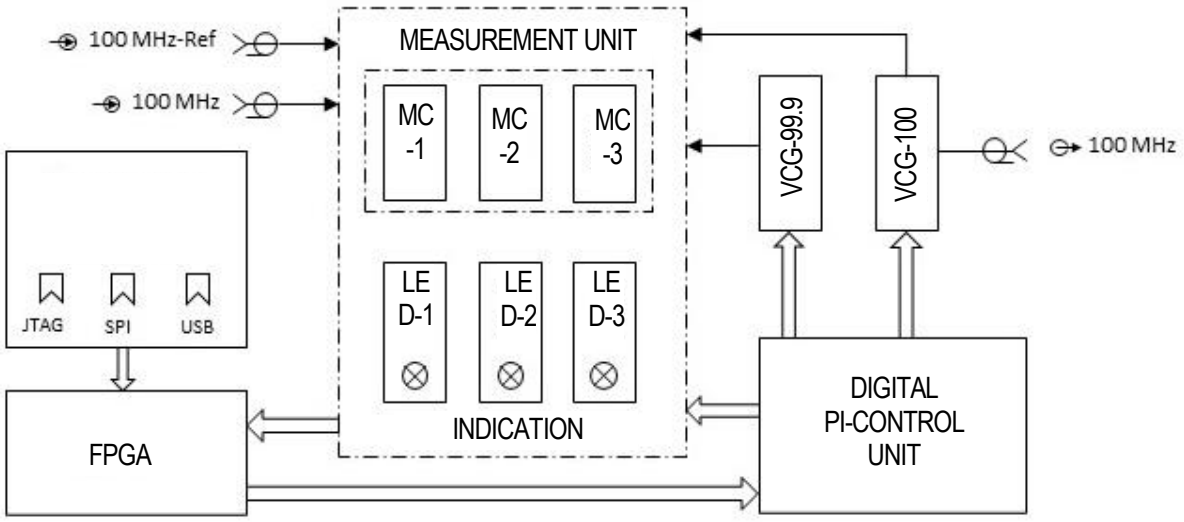


Figure 3.4 – Block diagram of the Compensator.
MC - measuring channel; VCG - voltage-controlled generator; LED - light-emitting diode

A4-1. *Module operation when the modem is configured as a transmitter.*

In this mode, the compensator introduces pre-distortion into the transmitted 100 MHz signal to compensate for phase instability.

The following electrical signals are supplied to the input connectors:

«100 MHz-Ref» – sinusoidal electrical signal of 100 MHz from a reference source;

«100 MHz» – sinusoidal electrical signal of 100 MHz returned from the remote end of the FOCL (that is, from the **«100 MHz»** connector of the ORTM).

The following electrical signals are output from the output connectors:

«100 MHz» – electrical signal of 100 MHz for LD modulation (must be connected by a jumper cable to the "100 MHz" connector of the ORTM).

A4-2. *Module operation when the modem is configured as a receiver.*

In this mode, the compensator is used to restore the 100 MHz sinusoidal waveform after transmission through the FOCL.

The following electrical signal is supplied to the input connector «⊖ **100 MHz-Ref**»:

«⊖ **100 MHz**» – electrical signal of 100 MHz from the ORTM photodiode.

The following electrical signals are emitted from the output connectors:

«⊖ **100 MHz**» - sinusoidal electrical signal of 100 MHz: a signal from a photodiode (see above), "reconstructed" using the PLL module of the Compensator.

The measurement unit that generates the pre-distortion signals consists of three identical measuring channels based on phase detectors that monitor the digital PI control of the PLL loops. If the loops are successfully locked, all three indicator LEDs located on the printed circuit board of the Compensator should light continuously.

The digital PI control unit is based on an FPGA.

The FPGA firmware contains the following algorithms:

– determining the modem mode ("transmitting" – if there is a signal returned from the remote end of the FOCL at the input «⊖ **100 MHz**»; otherwise – "receiving");

– phase compensation of the 100 MHz signal.

A5-1) Synthesizer

The block diagram of the synthesizer is shown in Figure 3.5.

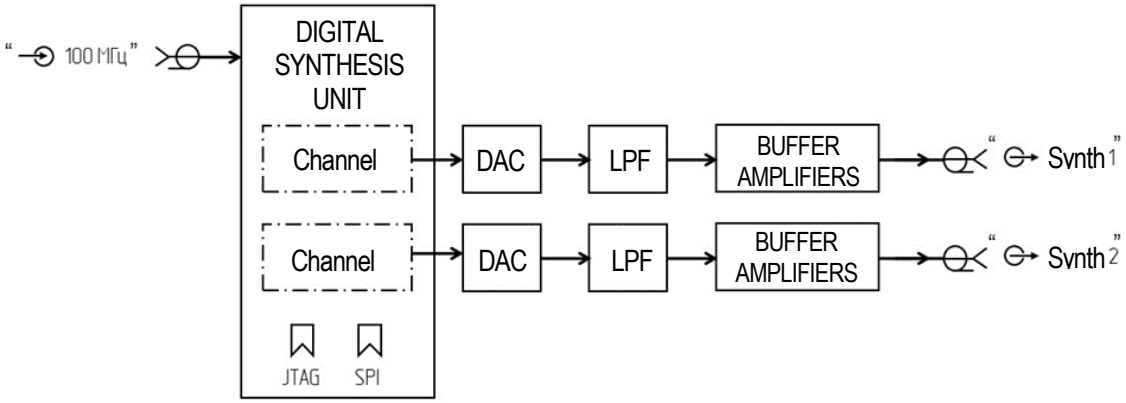


Figure 3.5 – Block diagram of the Synthesizer.
DAC – digital-to-analog converter; LPF – low-pass filter

The electrical signal from the «⊖ **100 MHz**» input connector is supplied to the input of the digital synthesis unit (DSU). There are two channels in the DSU; each generates signals by direct digital synthesis. The signals are up to 10 MHz and synchronized with the 100 MHz input signal. By default, the manufacturer sets the nominal frequency values of the Synthesizer output signals to 5 and 10 MHz.

The synthesized signals from the DSU channel outputs are sent to a digita l-to-analog converter, a low-pass filter, and a buffer amplifier. Buffer amplifiers are required to form a sinusoidal signal of the appropriate amplitude at a 50 Ω load.

From the outputs of the buffer amplifiers, sinusoidal electrical signals are routed to the «⊖→ **Synthesis 1**», «⊖→ **Synthesis 2**» output connectors.

The structure of each DSU channel and the nominal frequency of the synthesized signal are set by programming via the JTAG and SPI interfaces during Synthesizer adjustment.

A5-2) Frequency multiplier 5/10-100 MHz

The block diagram of the frequency multiplier is shown in Figure 3.6.

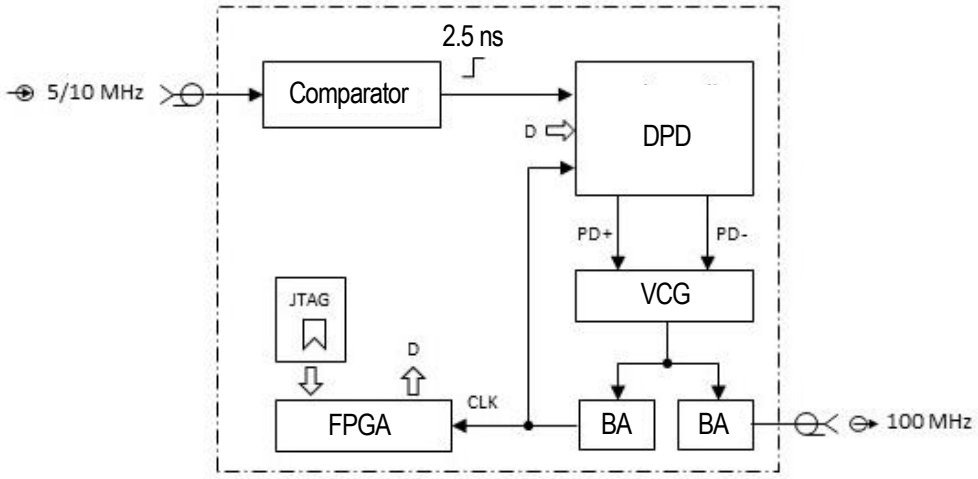


Figure 3.6 – Block diagram of frequency multiplier
VCG – voltage-controlled generator; BA – broadband amplifier

The 5/10-100 MHz frequency multiplier is based on a PLL.

The PLL loop consists of:

- digital phase detector (DPD) based on a flip-flop. In the DPD, the input and output signals of the multiplier are compared and PD+ and PD- signals are generated, forming the control voltage;

- voltage-controlled generator (VCG) based on a crystal oscillator with a nominal frequency of 100 MHz. Part of the signal from the VCG output goes through a BA to the frequency multiplier **«⊖→ 100 MHz»** output. The other part of the signal goes through another BA to the FPGA as a CLK clock signal and to the input of the DPD, closing the feedback loop. A pulse signal with an edge duration of about 2.5 ns, generated by the Comparator from the **«→⊖ 5/10 MHz»** input connector, is supplied to the other input of the DPD through the Comparator unit.

The FPGA also applies a signal (D) to the DPD, allowing selection of the Multiplier input frequency: 5 or 10 MHz. The nominal input frequency of the Multiplier is set by programming via the JTAG interface during Multiplier adjustment.

A6) Cross-board

The cross-board is designed to provide stable supply voltages (±12 V, +5 V, +3.3 V) from the Voltage Converter ~220\±12, +5, +3.3 V to the Compensator, Synthesizer, and ORTM modules.

3.5 Device operating modes

General information

Depending on the connection diagram (cables connected to connectors), the modem can operate in one of two modes: "Transmission" or "Reception".

Use the shortest possible cables to connect the consumer's equipment. Cable jumpers pos. 6 and pos. 7 in Figure 3.7 are included in the delivery package.

"Transmission" mode (Figure 3.7)

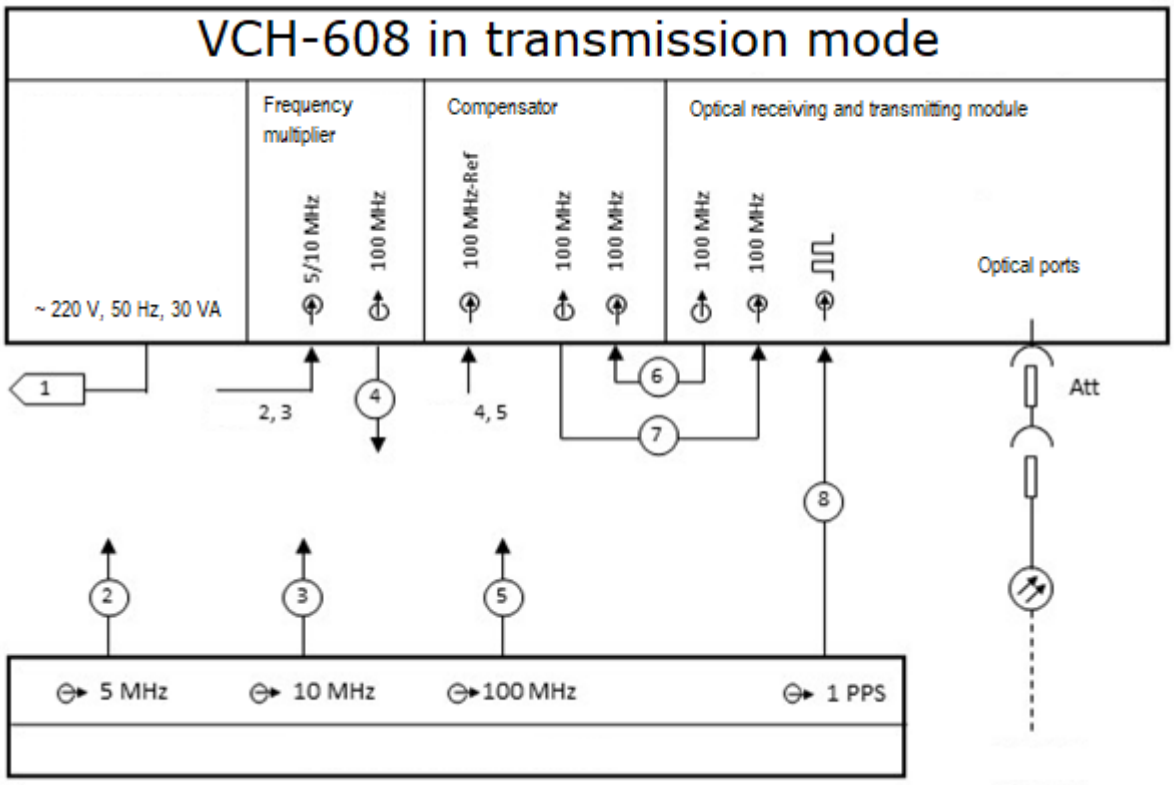


Figure 3.7 – Modem operation in the "Transmission" mode

Depending on the task, different sets of input electrical harmonic signals can be applied to the modem.

3.5.1.1 In all "Transmission" mode configurations:

Connect the «⊖ ⎍⎍» ORTM connector to the 1 Hz signal source using an HF connecting cable (in Figure 3.7, cable item 6, connector «⊖ 1 PPS» of the signal

source). The signal characteristics must comply with those specified in clause 3.2.11 of this OM.

Connect the «⊸ **100 MHz**» connector of the compensator to the «⊶ **100 MHz**» ORTM connector using HF jumper cable pos. 6.

Connect the «⊶ **100 MHz**» connector of the compensator to the «⊸ **100 MHz**» ORTM connector using HF jumper cable pos. 7.

3.5.1.2 Case 1. 100 MHz signal is applied.

In addition to clause 3.5.3.1:

Connect the «⊸ **100 MHz-Ref**» connector of the compensator to the 100 MHz signal source using an HF connecting cable (in Figure 3.7, cable item 5, connector «⊶ **100 MHz**» of the signal source). The signal characteristics must comply with those specified in clause 3.2.4 of this OM.

3.5.1.3 Case 2. 5 or 10 MHz (frequencies at the customer's request) is applied.

In addition to clause 3.5.3.1:

Connect the «⊸ **5/10 MHz**» connector of the frequency multiplier using HF jumper cable pos. 2 to the «⊶ **5 MHz**» connector, or pos. 3 to the «⊶ **10 MHz**» connector of the signal source, depending on the selected frequency multiplier setting.

Connect the «⊸ **100 MHz-Ref**» connector of the compensator to the 100 MHz output of the frequency multiplier using an HF connecting cable (in Figure 3.7, cable item 4, connector «⊶ **100 MHz**» of the frequency multiplier).

"Reception" mode (Figure 3.8)

Depending on the task, the user can obtain different sets of electrical harmonic signals from the modem.

3.5.1.4 In all "Reception" mode configurations:

Connect the 1 Hz output signal (ORTM connector «⊶ ⎍⎍⎌») to the user's equipment using HF cable pos. 7.

Connect the «⊖→ ⎍⎍-1» ORTM connector to the «→⊕ ⎍⎍-1» ORTM connector using HF jumper cable pos. 8.

Connect the «⊖→**100 MHz-1**» ORTM connector to the «→⊕ **100 MHz**» ORTM connector using HF jumper cable pos. 6.

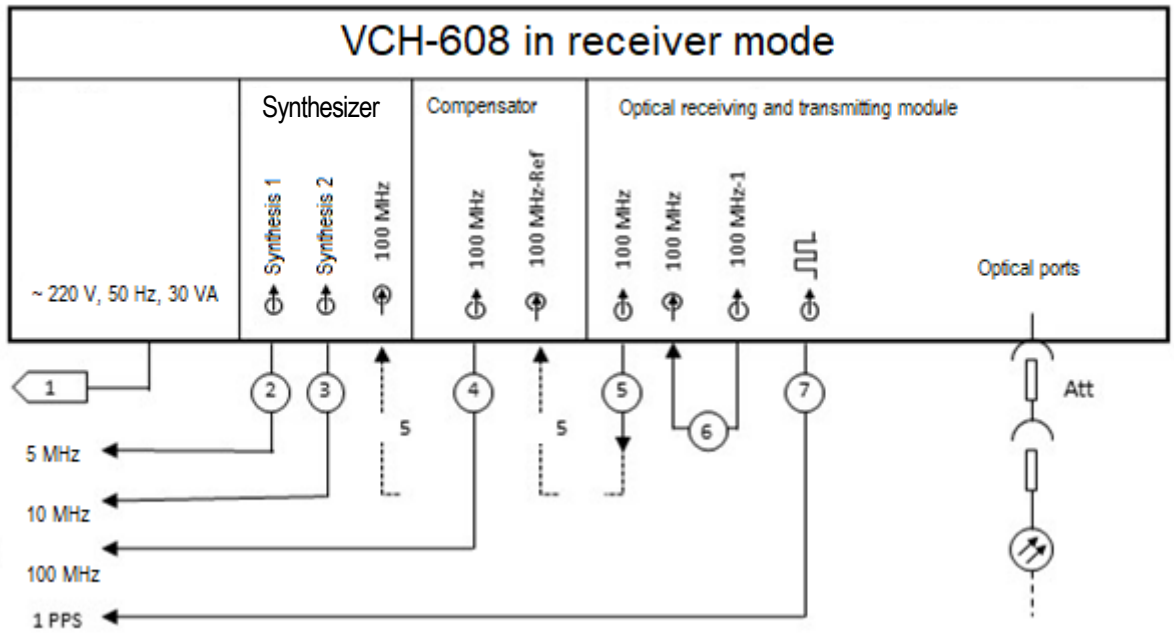


Figure 3.8 – Modem operation in the "Reception" mode

3.5.1.5 Case 1. The 100 MHz signal is not required. Signals of other frequencies (5 MHz, 10 MHz, or another frequency at the consumer's request) are required from the synthesizer outputs.

In addition to clause 3.5.3.1:

Connect the «⊖→ **100 MHz**» ORTM connector to the «→⊕ **100 MHz**» synthesizer connector using HF jumper cable pos. 5.

Connect the output signals of the required frequencies (connectors «⊖→ **Synthesis 1**» and «⊖→ **Synthesis 2**» of the synthesizer) to the consumer's equipment using HF connecting cables pos. 2 and pos. 3.

3.5.1.6 Case 2. Only the 100 MHz signal is required. Signals from the synthesizer outputs are not needed.

In addition to clause 3.5.3.1:

Connect the «⊖→ **100 MHz**» ORTM connector to the «–⊖ **100 MHz-Ref**» compensator connector using HF jumper cable pos. 5.

Connect the 100 MHz output signal (connector «⊖→ **100 MHz**» of the compensator) to the user's equipment using HF cable pos. 4.

Note – If all signals are required (100 MHz and 5 MHz, 10 MHz), the «⊖→ **100 MHz**» output signal of the ORTM must be applied to both the Synthesizer module and the Compensator module. External equipment should be used in this case, for example a signal amplifier/multiplier such as VCH-605.

4 Preparing the device for use

4.1 Operational limitations

It is recommended to install the modem in a closed, temperature-stabilized room with limited personnel access.

Attention! DO NOT INSTALL THE MODEM NEAR ENGINES, GENERATORS, TRANSFORMERS AND OTHER EQUIPMENT THAT CAN PRODUCE MAGNETIC FIELDS AND ACOUSTIC VIBRATIONS!

Installation near such equipment may disrupt modem operation.

Working operating conditions:

— Air temperature: from +10 to +40 °C;
— Air temperature change: no more than ±1 °C within one hour;
— Relative humidity: up to 80 % at +25 ˚C;
— Power supply: (220 ± 22) V, AC;
— Power supply frequency: (50 ± 2) Hz.

Transportation conditions:

— Air temperature: from -40 to +50 °C;
— Relative humidity: up to 95 % at +25 ˚C.

Warm-up time.

The device meets its specifications under working operating conditions after a 2-hour warm-up time.

Note – Input signals must be supplied to the modem inputs during the warm-up time.

The connectors of unconnected optical ports of the modem should be covered with green plugs to protect against aerosols and dust.

Note - The green protective plugs are designed for FC/APC optical ports.

Smoking is prohibited in the rooms where the modem is located.

Smoke particles and tobacco tar settle on the glass end faces of the modem optical connectors, thereby contaminating them.

4.2 Unpacking and repacking

Unpacking

The packaging drawing is shown in Figure 10.1.

Unpacking is performed as follows:

– open the top cover of the packing/transport box and remove the packing list;

– remove the cardboard box in a plastic bag containing the modem;

– remove the set of cables, fuse links, and operating documentation in plastic bags;

– open the plastic bag, open the cardboard box, and remove the set of operating documentation and foam inserts from it;

– remove the modem from the cardboard box;

– remove the plastic covers from the modem, cable set, fuse links, and operating documentation;

– put the foam inserts, cardboard box, and other packaging materials back into the packing box;

– perform a visual inspection of the modem delivery set in accordance with clause 4.2.2 of this OM.

Visual inspection

Visual inspection includes checks for:

– integrity of seals;

– completeness of the delivery set according to Table 3.2;

– absence of mechanical damage;

– presence and secure fastening of controls and fuses in their positions in the device;

– cleanliness of connectors and grounding terminal;

– the presence of green protective plugs on the optical connectors;

– the appearance of the power and optical cables;

– condition of the silica gel indicator.

Repacking

Place the modem in a plastic cover. Seal the flap of the cover with adhesive tape.

Fuses should be placed in plastic bags. HF and power cables should be coiled, fixed at two points with wire, and placed in plastic bags. Place the optical cable carefully in a plastic bag: its bending radius should be at least 40 mm.

Packages with fuses and cables should be placed in a plastic cover, sealed with adhesive tape, and placed in a packing box.

Put a foam insert on the bottom of the cardboard box. Put the modem in a plastic cover in the cardboard box and fill the sides with foam inserts. Cover the modem with foam inserts from above.

Operating documents should be placed in a plastic cover, sealed with adhesive tape, and placed on the packed modem.

The cardboard box should be closed and sealed with adhesive tape.

The bags with silica gel and silica gel indicator should be evenly laid and fixed with adhesive tape on top of the cardboard box.

The cardboard box with bags of silica gel should be placed in a plastic cover. Pump the air out of the cover and heat-seal the cover.

The packing list should be placed in a plastic cover, heat-sealed, laid on the packed modem, and fixed with adhesive tape.

The cardboard box should be placed in a packing box. The packing box should be closed and sealed.

The following labels should be on two adjacent side surfaces of the packing box: "**Fragile**", "**Keep away from moisture**", "**Top**".

4.3 Installation

Safety requirements

The modem must be operated according to the safety requirements described in section 3 of this OM.

Visual inspection steps

Unpack the modem in accordance with clause 4.2.1 of this OM.

Check the delivery set of the modem.

Perform an external inspection of the modem in accordance with clause 4.2.2 of this OM.

Installation location

The location for the device should be chosen taking into account the device dimensions, 140 x 483 x 328 mm, and the need for free air convection through the ventilation openings of the device casing.

Do not install the modem near engines, generators, transformers and other equipment that can produce magnetic fields and acoustic vibrations. In such conditions, the modem's compliance with the technical specifications is not guaranteed.

Avoid accidental human exposure to laser radiation if there are no protective plugs on the modem optical connectors, if the optical cable connector is disconnected from the modem optical port, or if the active optical cable is broken.

Note – When safety requirements are met, optical radiation from the modem is completely blocked.

Access to the modem optical connectors should be restricted to maintenance personnel.

4.4 Preparing the device for use

Perform a visual inspection of the modem as described in section 4.2.2 of this OM.

The workplace must be provided with AC power supply of 220 V, 50 Hz.

The workplace must be provided with a FOCL for communication with the paired modem. The FOCL losses must meet the requirements of clause 3.2.3:

- total (direct) - at least 15 dB;
- ORL (optical return loss) - must exceed the direct loss by at least 20 dB.

To estimate direct losses in the FOCL, it is recommended to use two mutually calibrated testers (TOPAZ-7325-AL series or similar): one as an optical source and the other as a power meter with a preset power reference value.

The tester used as an optical source should be connected to the FOCL only with an optical cord (OC) with FC/UPC-FC/APC connectors (Figure 4.1), so as not to mechanically damage the polishing of the corresponding connectors of the tester and the FOCL.

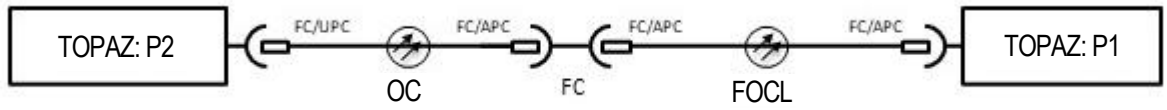


Figure 4.1 – Measuring direct loss in one fiber of the FOCL cable

When the FOCL optical loss is less than 3 dB, it is recommended, for optical matching of paired modems, to install optical attenuators on a fixed optical attenuator

Att-FM FC/APC-SM-2 or similar with 2 dB attenuation, as shown in Figure 3.3. If the FOCL optical loss between paired modems is more than 3 dB, do not install attenuators.

When measuring return loss, use the P2 connector of the tester in RL mode - "Optical Return Loss (ORL)" (Figure 4.2).

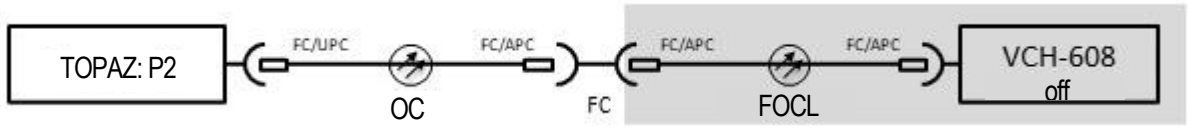


Figure 4.2 – Measuring return loss in one fiber of the FOCL cable

On one side of the test line, connect the tester via the OC, and on the other side, connect the modem while it is turned off. Thus, the return loss will include reflection loss from the internal structures of the modem, for example from the photodiode module.

Measure the direct and return loss values of the FOCL separately for each operating wavelength of the modems.

The FOCL optical connectors used for connection to a modem must be FC/APC type.

During operation, the ventilation openings on the modem case must not be covered with foreign objects.

Before turning on the modem, read section 3 of this OM.

Make a startup entry in the operating log.

5 Operating procedure

5.1 Location of controls and connectors

All device units are implemented as modules, which are inserted into the modem case from the rear panel along specific rails (Figures 5.1-5.6).

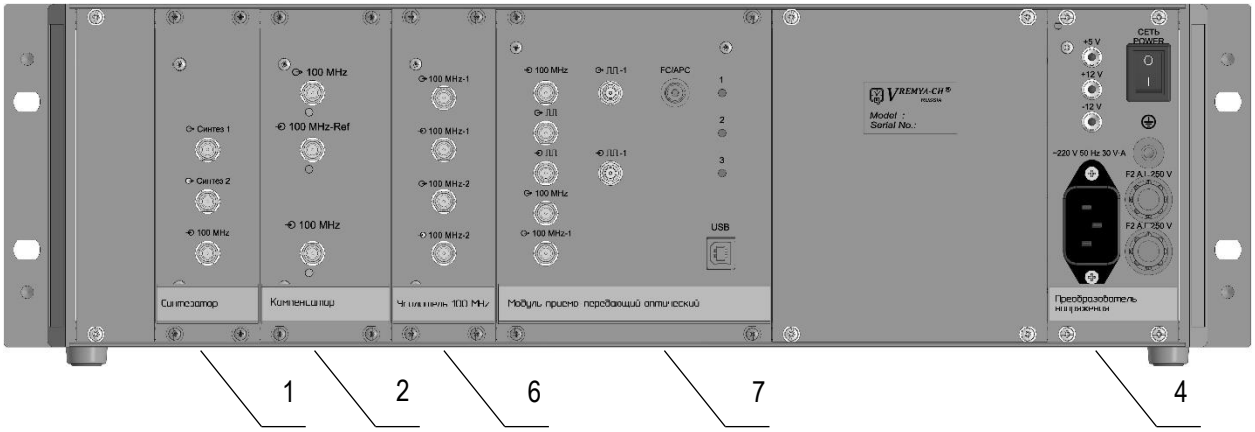


Figure 5.1 – Module locations inside the modem case (mod. VCH-608.2X_2, where $X_2 \leq 3$)

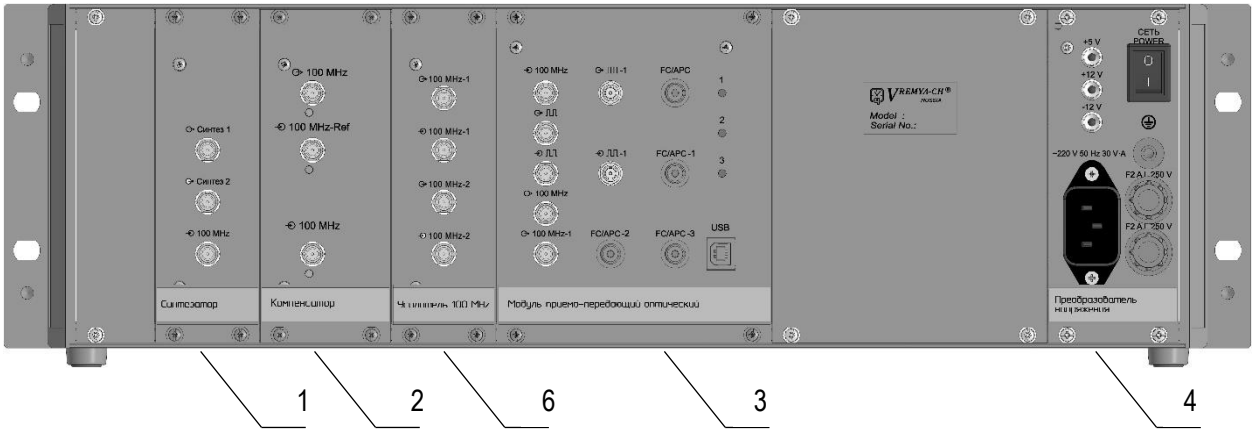


Figure 5.2 – Module locations inside the modem case (mod. VCH-608.2X_2, where $X_2 \geq 4$)

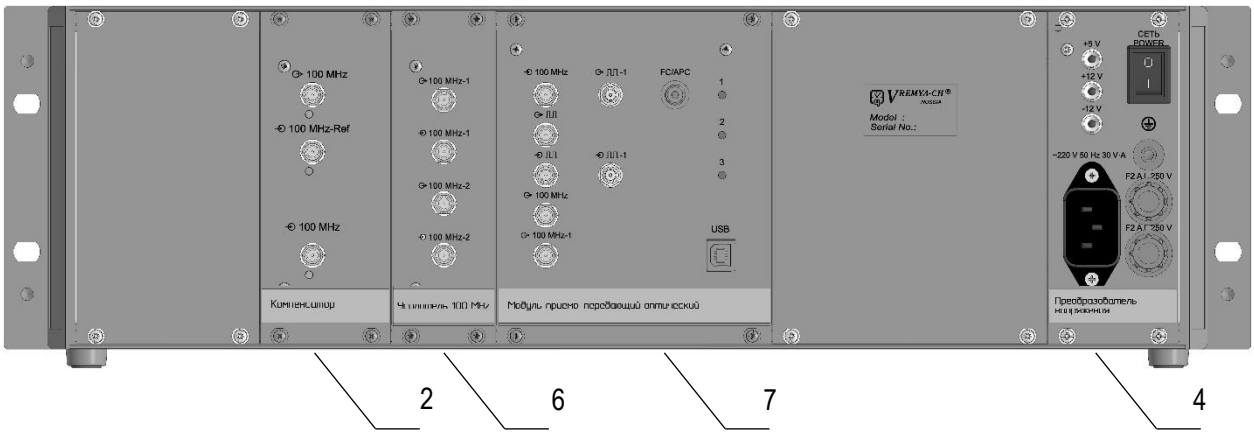


Figure 5.3 – Module locations inside the modem case
(mod. VCH-608.0X_2, where $X_2 \leq 3$)

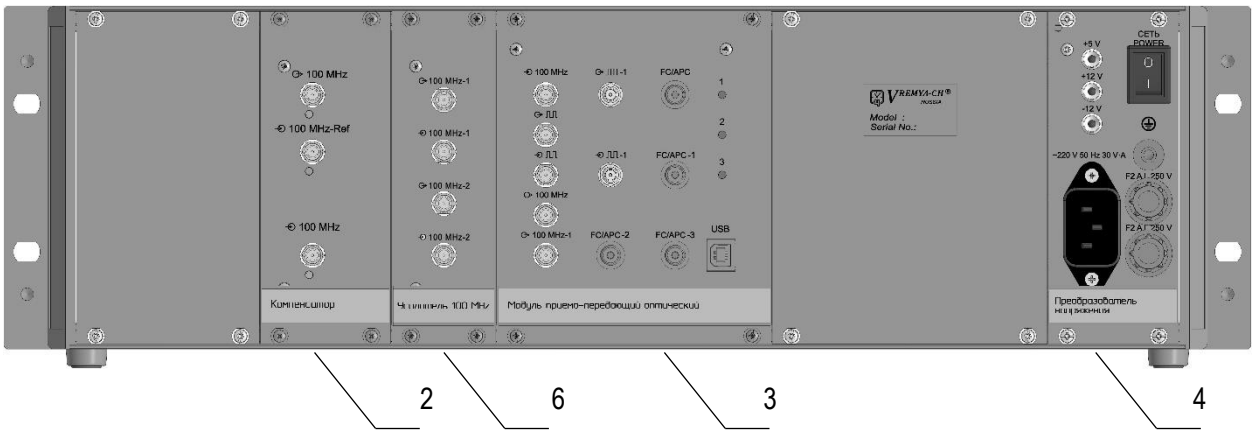


Figure 5.4 – Module locations inside the modem case
(mod. VCH-608.0X_2, where $X_2 \geq 4$)

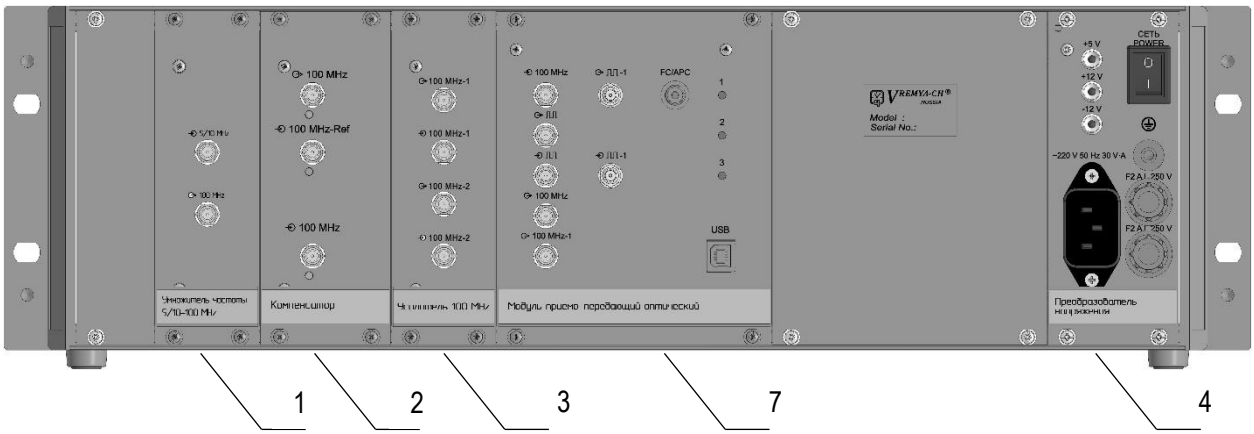


Figure 5.5 – Module locations inside the modem case
(mod. VCH-608.1X_2, where $X_2 \leq 3$)

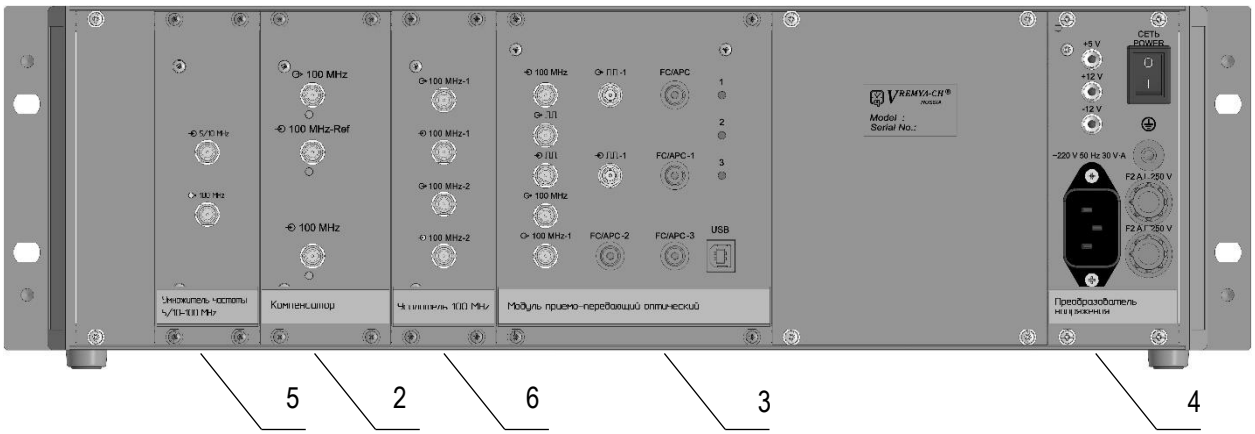


Figure 5.6 – Module locations inside the modem case
(mod. VCH-608.1X_2, where $X_2 \geq 4$)

All controls, connectors, and indicators are located on the rear panel (Figure 5.7), which is assembled from the rear panels of the inserted modules.

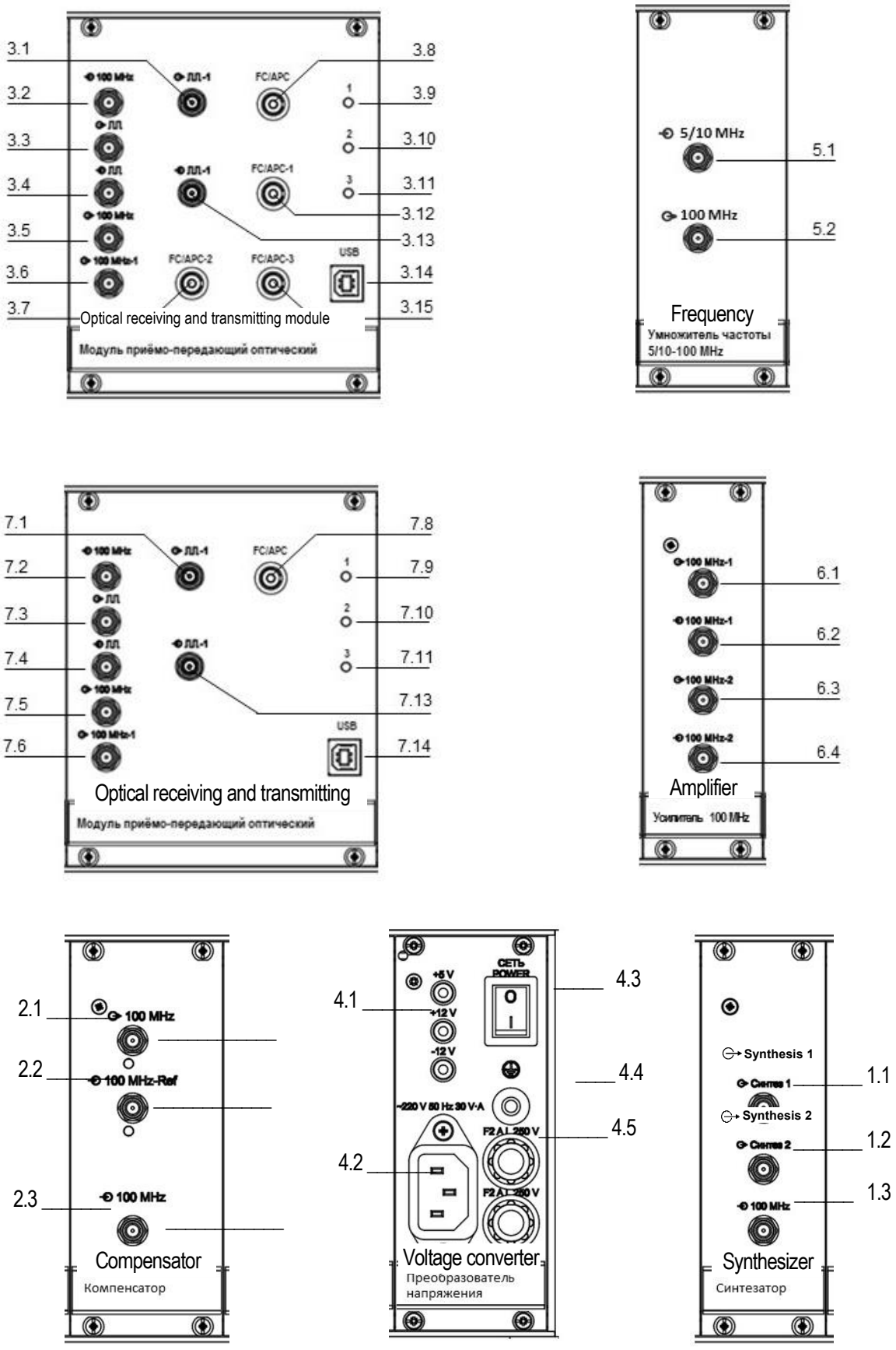


Figure 5.7 – Location of control, connection, and indication systems on the rear panel

The control and connection systems and modules of the device are described in Table 5.1.

Table 5.1 – Controls and connectors

No. (Figure 5.7)	Name	Designation
1	**Synthesizer**	Direct digital synthesis of 5 and 10 MHz signals synchronized with the input 100 MHz signal
1.1	«⊖→ **Synthesis 1**»	SMA connector; output electrical signal with a nominal frequency of 5 and 10 MHz, respectively (or as agreed) (clause 3.2.6)
1.2	«⊖→ **Synthesis 2**»	SMA connector; output electrical signal with a nominal frequency of 5 and 10 MHz, respectively (or as agreed) (clause 3.2.6)
1.3	→⊖ **100 MHz**	SMA connector; input electrical signal with a nominal frequency of 100 MHz
2	**Compensator**	Compensation of phase instability of the 100 MHz electrical signal
2.1	⊖→ **100 MHz**	SMA connector; output electrical signal with a nominal frequency of 100 MHz (p. 3.2.6)
2.2	→⊖ **100 MHz-Ref**	SMA connector; input electrical signal from a 100 MHz reference sinusoidal signal source (frequency standard) (clause 3.2.4)
2.3	→⊖ **100 MHz**	SMA connector; electrical signal from ORTM 100 MHz (see line 3.5 of this table)
2.4 – 2.6	–	Compensator tuning loop lock indicators (LEDs located near the input and output signal connectors)
3	**ORTM, mod. A**	Conversion of signals from optical to electrical form and vice versa
3.1	⊖→ ⎍-1	SMA connector; output electrical signal 1 Hz (p. 3.2.12)
3.2	→⊖ **100 MHz**	SMA connector; input electrical signal 100 MHz
3.3	⊖→ ⎍	SMA connector; output electrical signal 1 Hz (p. 3.2.12)
3.4	→⊖ ⎍	SMA connector; input electrical signal 1 Hz (p. 3.2.12)
3.5	⊖→ **100 MHz**	SMA connector; output electrical signal with a nominal frequency of 100 MHz (p. 3.2.6)
3.6	⊖→ **100 MHz-1**	SMA connector; output electrical signal with a nominal frequency of 100 MHz for connection to the synthesizer, identical to the ⊖→ **100 MHz** signal
3.7	**FC/APC-2**	Optical input 100 MHz
3.8	**FC/APC**	Optical output 100 MHz
3.9	**1**	1 Hz input signal presence indicator
3.10	**2**	1 Hz output signal presence indicator
3.11	**3**	1 Hz returned from FOCL signal presence indicator
3.12	**FC/APC-1**	Optical output 1 Hz
3.13	→⊖ ⎍-1	SMA connector; 1 PPS electrical signal used for compensation; connect to No. 3.7

No. (Figure 5.7)	Name	Designation
3.14	**USB**	USB connector for connection to a PC
3.15	**FC/APC-3**	Optical input 1 Hz
4	**Voltage Converter**	Powered by AC with a rated voltage of 220 V. Generates stabilized voltages (± 12 V, +5 V, +3.3 V) to power the modem modules.
4.1	+5V, +12V, –12V	Voltage presence indicators
4.2	220 V 50 Hz 30 V·A	220 V AC power input connector
4.3	**POWER**	Toggle switch for turning the 220 V AC power supply ON/OFF
4.4	⏚	Protective grounding terminal
4.5	F 2 A L 250 V	Fuse holders
5	**Frequency Multiplier 5/10-100 MHz**	Conversion of 5 or 10 MHz harmonic input signals to a 100 MHz signal
5.1	**5/10 MHz**	SMA connector; 5 or 10 MHz electrical signal input
5.2	**100 MHz**	SMA connector; 100 MHz electrical signal output
6	**Amplifier 100 MHz**	Gain of 100 MHz harmonic output signals – 2 identical channels
6.1	**100 MHz-1**	SMA connector; 100 MHz electrical signal input channel 1
6.2	**100 MHz-1**	SMA connector; 100 MHz electrical signal output channel 1
6.3	**100 MHz-2**	SMA connector; 100 MHz electrical signal input channel 2
6.4	**100 MHz-2**	SMA connector; 100 MHz electrical signal output channel 2
7	**ORTM, mod. B**	Conversion of signals from optical to electrical form and vice versa
7.1	-1	SMA connector; output electrical signal 1 Hz (p. 3.2.12)
7.2	**100 MHz**	SMA connector; input electrical signal 100 MHz
7.3		SMA connector; output electrical signal 1 Hz (p. 3.2.12)
7.4		SMA connector; input electrical signal 1 Hz (p. 3.2.12)
7.5	**100 MHz**	SMA connector; output electrical signal with a nominal frequency of 100 MHz (p. 3.2.6)
7.6	**100 MHz-1**	SMA connector; output electrical signal with a nominal frequency of 100 MHz for connection to the synthesizer, identical to the 100 MHz signal
7.8	**FC/APC**	**FC/APC connector;** optical port for connection to an external FOCL
7.9	**1**	1 Hz input signal presence indicator
7.10	**2**	1 Hz output signal presence indicator
7.11	**3**	1 Hz returned from FOCL signal presence indicator
7.13	-1	SMA connector; 1 PPS electrical signal used for compensation; connect to No. 3.7
7.14	**USB**	USB connector for connection to a PC

5.2 Preparing the device for use

Carefully read this OM before working with the device. Study the location of plug-in modules in the modem case, as well as the modem controls and connectors (Figure 5.7) and their assignment (Table 5.1).

Read the instructions for connecting and operating electrical cables in section 5.2.1.1 and optical cables in section 5.2.1.2.

5.2.1.1 Instructions for connecting and operating electrical cables

The SCZ-1 power cable must be connected to the modem according to the safety requirements described in section 2.3.1 of this OM.

HF connecting cables must have SMA connectors and be made of coaxial cable with a characteristic impedance of 50 Ω. The tightening torque of SMA-type connectors should be from 0.8 to 1.1 N·m.

5.2.1.2 Instructions for connecting and operating optical cables

Optical cables must be connected to the modem according to the safety requirements described in section 3 of this OM.

Optical cables connected to the modem optical connectors must be made of single-mode optical fiber of type G.652 or G.657, as defined by ITU-T recommendations, and terminated with FC/APC connectors.

WARNING! Using other types of connectors will damage the optical connectors!

The bending radius of the cable during laying (installation) must be at least twenty nominal outer diameters of the cable. The permissible static bending radius is 40 mm for standard optical fiber and 20 mm for bend-insensitive fiber. The permissible bending radius for bend-insensitive fiber during installation is 3 mm (for a time interval of not more than 10 minutes).

When laying the cable, do not exceed the permissible tensile, compressive, or other loads specified for the particular fiber.

WARNING! Never look into fiber ends or optical connectors!

Connecting electrical and optical cables to the modem

Follow the diagrams for connecting cables to the modems (Figure 3.7; Figure 3.8) and the instructions in section 3.5.

Ensure that the modem is securely grounded before starting work. Protective grounding is carried out through the protective conductor of the power cable and the grounding contact of the power cord plug, or through the protective grounding clamp. The protective earth terminal must be connected to the ground bus before other connections. The grounding terminal «» fasteners and conductor⏚s must be securely fixed.

Connect an external FOCL to the "**FC/APC**" connector. Use the optical cord supplied with the modem if the external FOCL is terminated with a feedthrough optical adapter.

ATTENTION! If the external FOCL has a connector of a type other than FC/APC, optical adapters should be used.

Connect the modem to external equipment

Use clause 3.5.2 of this OM if the modem is used in the “Transmission” mode. If the modem is used in the “Reception” mode, use clause 3.5.3 of this OM.

Connect the AC power supply (220 V, 50 Hz) using the power cable.

Turn on the modem by setting the **"**POWER" switch to position **"I"** (on).

The modem will provide the guaranteed Allan deviation noise floor indicated in Table 3.1 after the warm-up period has elapsed (2 hours).

ATTENTION! Optical cables may be connected to and disconnected from modem connectors without turning off modem power, but only if laser radiation is prevented from entering the eyes!

To turn off the modem, set the **"POWER" s**witch to position **"O" (**off).

ATTENTION! Disconnected optical connectors should always be covered with green protective plugs!

6 Modem verification

6.1 The modem is verified in accordance with the procedure set out in Appendix A "Fiber optic time and frequency transfer modem VCH-608. Verification procedure".

6.2 The interval between verifications is 24 months.

7 Maintenance

7.1 When carrying out maintenance work on the modem, the safety requirements set out in clause 2 of this OM must be fulfilled.

7.2 The types of technical condition monitoring and maintenance, as well as the frequency and scope of work performed during their implementation, are determined by this OM.

7.3 The main type of technical condition monitoring is a routine inspection of the modem during operation.

7.4 Routine inspection is carried out by the person operating the modem when preparing the modem for its intended use.

The routine inspection of the modem includes:

– visual inspection to check for the absence of mechanical damage, mounting quality of controls and connectors, integrity of insulation and paint coatings, and serviceability of cables;

– checking the cleanliness of the HF connectors of the modem;

– checking the cleanliness of cable connectors (HF and power divider cables from the modem package);

– the presence of green protective plugs on the optical connectors;

– checking the markings.

7.5 Maintenance includes the following types:

– daily maintenance;
– Maintenance No. 1 (M-1);
– Maintenance No. 2 (M-2).

7.6 Daily maintenance is carried out when preparing the modem for its intended use, is combined with routine inspection, and includes:

– correcting issues discovered during routine inspection;
– removal of dust and moisture from external surfaces.

Daily maintenance is performed by the personnel operating the modem, without opening it.

7.7 Maintenance No. 1 is carried out before preparing the modem for use and when placing the modem for short-term storage.

M-1 includes:

- correcting issues discovered during routine inspection;
– removal of dust and moisture from external surfaces;
– other operations specified in operational documentation;
– checking the condition and completeness of the modem;
– verification that operating documentation is maintained;
– correcting issues discovered during M-1.

M-1 is performed by the personnel operating the modem, without opening it.

7.8 Maintenance No. 2 is carried out at the same interval as modem verification and is combined with it, and also when placing the modem in long-term storage (more than two years); it includes:

– M-1 procedure;
– verification to ensure the required metrological characteristics;

– modem preservation (performed when the modem is placed in long-term storage).

M-2 is performed by the personnel operating the modem, except for verification, which is carried out by the metrology service or by the technical control department.

7.9 Before running any type of maintenance, operating documentation should be prepared and rectified technical ethyl alcohol and bleached cotton cloth should be obtained for cleaning the HF connectors of the modem and cable connectors (HF and power divider cables from the modem package).

Material consumption rates for modem maintenance for 1 year are:

– rectified technical ethyl alcohol – 150 g;

– bleached cotton cloth – 0.5 $m^{2.}$

8 Repair

8.1 If the modem does not meet the required technical characteristics, or for other reasons that make continued use impossible, the modem is subject to repair.

8.2 Repair of the modem and its components requires complex special equipment and therefore can only be carried out by the manufacturer.

9 Transportation and storage

9.1 The modem may be transported by all types of transport in its packaging, provided that it is protected from direct exposure to precipitation.

9.2 The climatic conditions during transportation must remain within the following limits:

- ambient temperature: from -40 to +50 °C;

- relative humidity: up to 95 % at +25 °C.

9.3 When transported by plane, the modem must be placed in a heated sealed compartment.

9.4 After exposure to extreme conditions, the exposure time in normal (working) conditions is at least 24 hours.

9.5 If the modem is exposed to subzero temperatures, it should be kept in a warm room for at least 24 hours without opening the packaging to prevent condensation inside the modem.

9.6 Ship holds and vehicle bodies used to transport the modem must be free of cement, coal, chemicals, etc.

9.7 When placing the modem in storage, it should be repacked (clause 4.2.3 of this OM).

9.8 When the modem is placed in storage (or removed from storage), a dated entry should be made in the operating documentation.

9.9 Before commissioning, the modem should be stored in a warehouse in the original packaging at an ambient temperature from 0 to +40 °C and a relative humidity of up to 80 % at +35 °C.

9.10 When not packaged, the modem should be stored at an ambient temperature from +5 to +40 °C and a relative humidity of up to 80 % at +25 °C.

9.11 In storage rooms, levels of dust, acid and alkali vapors, aggressive gases, and other harmful impurities that cause corrosion must not exceed regulatory limits.

10 Packaging

10.1 The packaging drawing with dimensions is shown in Figure 10.1.

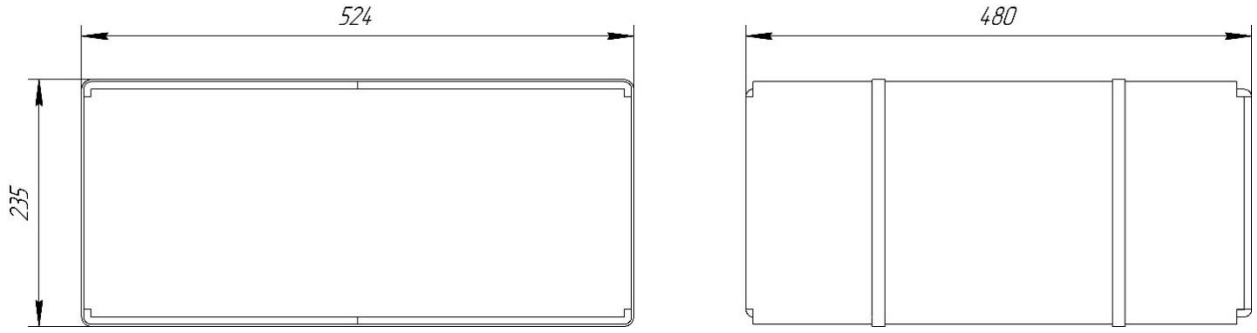


Figure 10.1 – Modem Packaging

10.2 The packaging provides temporary anti-corrosion protection.

10.3 Technical and shipping documents should be placed in a plastic cover.

10.4 The packaging is marked in accordance with design documentation.

The following labels should appear on two adjacent side surfaces of the packing box: **"Fragile", "Keep away from moisture", "Top"**.

11 Marking and sealing

11.1 The name and designation of the modem and the company trademark are printed on the front panel.

11.2 The serial number and year of manufacture are printed on the rear panel and on the left side panel, respectively.

11.3 The modem accepted by the technical control department is sealed with mastic seals installed in the screw cups securing the front panel and plug-in modules.

12 Recycling

12.1 A modem does not pose an environmental hazard when disposed of. The disposal procedure is determined by the consumer.